C.D. 0896 L

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H_2S EQUIPMENT

MARK IIc (A.R.I. 5590)
MARK IIIA (A.R.I. 5583)

INCLUDING TEST EQUIPMENT

PREPARED BY DIRECTION OF THE MINISTER OF AIRCRAFT PRODUCTION

Harold Scott

PROMULGATED BY ORDER OF THE AIR COUNCIL

AIR MINISTRY

JULY 1944

H_2S Equipment

Mark IIC (A.R.I.5590) and Mark IIIA (A.R.I.5583)
together with all associated test equipment

AMENDMENT RECORD SHEET

Incorporation of an Amendment List in this publication is to be recorded by inserting the Amendment List number, signing in the appropriate column, and inserting the date of making the amendments.

A.L. No.	Amendments made by	Date

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CHAPTER 1 - OUTLINE OF THE H.2.S. SYSTEM

The Functions of H.2.S.

1. H.2.S. is a Radar device carried in aircraft to produce on a cathode ray tube a picture of the area over which the aircraft is flying. By comparing this cathode ray tube display with target maps the H.2.S. operator can identify coast-lines, lakes, large rivers, built-up areas and large man-made structures. The centre of the display will always represent the point on the earth's surface directly below the aircraft. From his identification of indications on the display with points on his target map and by using the appropriate controls and markers, the H.2.S. operator can do the following:-

(a) Fix his position.
(b) Determine range and bearing of built-up areas.
(c) Home onto targets for blind bombing.

2. By means of a second cathode ray tube and an associated marker and control the height of the aircraft above the earth's surface can be determined.

3. When the appropriate adjustments have been made the ground speed of the aircraft can easily be determined from the movement of indications across the main H.2.S. display.

4. If an additional unit comprising a 1.5 metre transmitter and suitable receiving stages is incorporated in the H.2.S. installation the equipment can be used for homing on long range beacons and blind approach runway beacons. This additional unit is called Lucero.

5. Another indicating unit can be incorporated in the H.2.S. installation to show the range and azimuth bearing of aircraft appearing in a hemisphere below the aircraft. The centre of this hemisphere will be at the aircraft and the radius of the hemisphere will be equal to the aircraft height. From the movement of an aircraft indication on this display it can be ascertained whether the aircraft is friendly or hostile. This indicating unit is called Fishpond.

6. It follows from our preceding paragraphs that the H.2.S. installation including Lucero and Fishpond is simultaneously:-

(a) An extremely versatile navigational aid.
(b) A blind bombing aid.
(c) A warning device which can reduce the danger of collisions with friendly aircraft and give warning of attack from enemy aircraft provided the attack is not made from above.

Aside from Lucero applications the equipment is self-contained in the aircraft and is therefore not subject to the range limitations inherent in equipments dependent on ground transmissions.

The Nature of the H.2.S. System

7. Before proceeding to study the essentials of the H.2.S. system we may profitably consider an analogy from the field of optics. We may imagine a revolving lighthouse sending out its narrow, intense beam. If the lighthouse stands still this beam will illuminate a sector on the ground or the sea. If a ship, a building or an aircraft appears in the beam some of the light will be reflected. If an operator is standing behind the light he will be able to see these objects because light is reflected from them to his eyes. If the light is allowed to rotate through 360° the beam will, in the course of one revolution, illuminate a circular area of the earth's surface with the lighthouse at the centre of the circle. Any objects causing reflection as the beam crosses them will then be observed once in every revolution for the duration of the interval of illumination. This interval will depend on the width of the beam and the rate of rotation.

8. The H.2.S. installation in an aircraft is very similar to the lighthouse. A suitable modulator pulses a magnetron transmitting valve at a recurrence frequency of 670 c/s. The magnetron develops bursts of R.F. of 1 microsecond duration once every 1500 microseconds. For Mark II H.2.S. a magnetron is used

that develops a wavelength of about 9 cms. For Mark III H.2.S. a different magnetron is used which develops a wavelength of approximately 3 cms. The 1 microsecond bursts of radio frequency energy are radiated from the flared mouth of a waveguide into a paraboloid scanning mirror, or scanner. The mirror concentrates the energy into a narrow beam which is radiated out into space. This beam "flashing" at 670 c/s. serves to "illuminate" a narrow sector of the earth's crust with invisible radiation. This invisible radio frequency radiation differs from visible light only in the wavelength employed. Like visible light it travels at a speed of 186,000 miles per second in space. This is equivalent to a speed of 5.35 microseconds per mile. Hence if the transmitter radiates a 1 microsecond burst of energy into space an electromagnetic wave travels outward at a speed of 5.35 microseconds per mile.

9. When this burst of energy strikes a horizontal surface most of the energy is reflected away from the aircraft. Hence, quiet water will give negligible reflection back to the aircraft. If the radiation strikes rolling country some energy is reflected back from slopes, farm buildings, etc. In the same way, when the sea is rough some energy is reflected back from the sides of the waves. We thus get returns which we call general sea returns or general ground returns. If the beam strikes steep cliffs, the vertical surfaces of large buildings, or a large number of vertical surfaces in heavily built-up areas, an appreciable amount of energy may be reflected back to the aircraft. If an aircraft flies through the H.2.S. beam it will reflect back a quantity of energy depending on its size and orientation with respect to the H.2.S. beam. Hence, we may summarise by saying that the H.2.S. beam will experience:-

(a) Very little reflection from quiet water or flat open country.
(b) Limited amount of reflection froun rough water or rolling country.
(c) Somewhat heavier reflection from surburban areas.
(d) Appreciable reflection from steep cliffs, large structures and heavily built-up areas.

10. Since the speed of the electromagnetic waves is 5.35 microseconds per mile the 'echo time' is 10.7 microseconds per mile. Hence the time interval that will elapse between the instant the transmitter fires and the instant the echo returns will always be given in microseconds by multiplying the slant range of the reflecting object by 10.7. An echo from a target at a slant range of 40 miles would then return in 40 x 10.7 or 428 microseconds. Obviously, all echo times must be proportional to the slant range of the reflecting surface. This is the fundamental principle employed in Radar to measure the range of reflecting surfaces.

The Height Tube Display

11. Range indications are normally displayed on some form of time-base. Every Radar Mechanic is familiar with the usual deflection type of display. An electr stream emitted from the cathode of a cathode ray tube passes between deflecting plates. When both plates are at the same potential the electron stream passes down the centre of the tube. If the stream is sufficiently intense it will cause the fluorescent screen to glow with a colour characteristic of the screen material. By means of a focussing adjustment the electron stream can be made to converge to a fine point so as to cause only a bright dot at the centre of the screen. If one deflecting plate is given a suitable D.C. potential the beam can be deflected to cause a spot at the side, top, or bottom of the tube screen. If now a sawtooth voltage is applied to the deflecting plates to drive the one plate positive and the other negative the electron stream is deflected and the bright spot will sweep across the screen to develop a timebase. If the spot travels across the screen at a constant velocity we say the timebase is linear. If the velocity varies the timebase is non-linear. If we convert radio frequency echoes into video pulses by means of a suitable receiver and app these video pulses to a pair of deflecting plates at right angles to the timebase plates, these pulses will deflect the electron stream for the pulse duration to give the familiar deflection presentation. In order that the resultant deflections or "blips" may remain stationary they must appear at the same point in the timebase sweep for each transmitter pulse. Hence it is always necessary to

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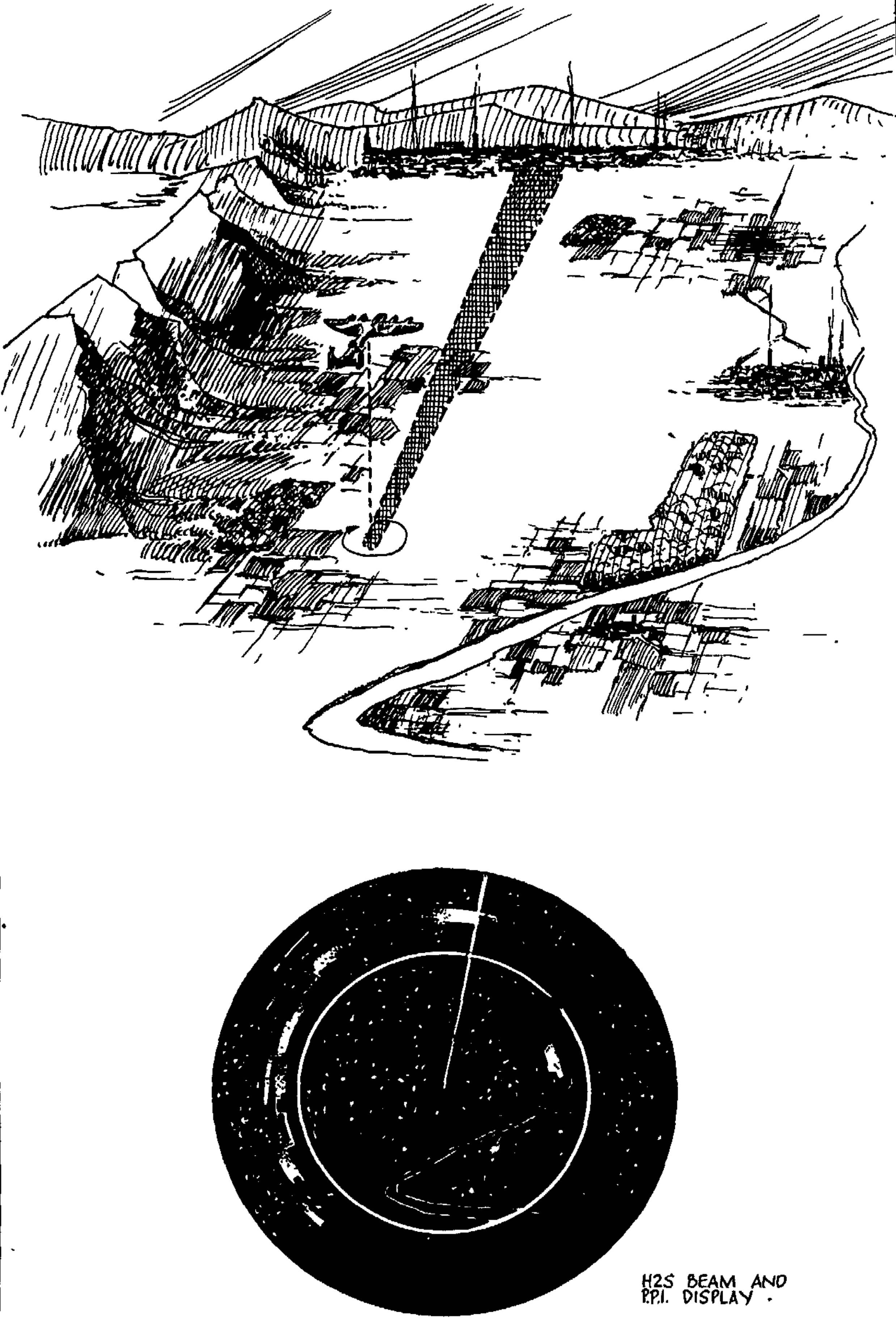

H2S BEAM AND
P.P.I. DISPLAY .

FIG.1

synchronise the transmitter and the timebase. If the timebase sweep begins when the transmitter fires the first blip to appear on it must be the echo from the nearest reflecting surface. This will be the ground echo from the point on the earth's surface directly below the aircraft (if we neglect echoes other aircraft). If the timebase is linear, i.e. the cathode ray tube spot is travelling at a uniform velocity, all blips will appear at distances along the scan which are proportional to their echo time, and hence proportional to their slant range. Such a display is used on the H.2.S. height tube, which uses a vertical scan running from the bottom to the top. Echoes appear as deflections to the right. Since the transmitter fires 670 times per second there must be 670 sweeps of the timebase per second.

12. We have stated that the H.2.S. beam is narrow so as to illuminate only a small sector of the earth's crust at one time. Hence, if the scanner is stationary the height tube timebase can only show deflections due to targets lying in the illuminated sector. In operation the scanner will normally be rotating at 40 - 60 r.p.m. If we assume the speed to be 60 r.p.m. or 1 r.p.s. the H.2.S. beam turns through 360° in one second and in this time the timebase will make 670 sweeps and the transmitter will have sent out 670 bursts of radio-frequency energy, each of 1 microsecond duration. As the scanner turns the narrow H.2.S. beam illuminates different sets of targets or different parts of large targets on successive pulses. Hence the height tube display will not be steady but will show deflections rising and falling at different points along the timebases as targets at different ranges pass in and out of the beam. Such a display, obviously, is not suitable for target identification purposes.

Measurement of Height

13. There will, however, be one echo that remains steady as long as the aircraft height remains constant. This is the ground echo from directly below the aircraft which comes in on each transmitted pulse. Its distance up the trace will be proportional to the aircraft height. To prevent over-loading on strong transmitter breakthrough signals the I.F. amplifier of the H.2.S. receiver is suppressed for 20 microseconds in every 1500 microseconds, the suppression period terminating at the end of the transmitter pulse. Hence the timebase shows a 20 microsecond blank section. At the end of this suppression break the scan may show a deflection to the right which is the tail of the transmitter pulse. Beyond this signal there will be only valve noise until the ground echo appears as a bulge to the right. A height marker pulse is generated in the H.2.S. set which appears on the height tube display as a deflection to the left. This height marker blip can be moved up and down the timebase by means of a height control on a second unit at the Navigator's table, termed a switch unit. If the height marker blip is set to the beginning of the ground echo bulge, the aircraft height above ground can be read from a calibrated scale under an index line. If the aircraft height changes the echo time for the ground echo changes and the ground echo bulge on the height tube display moves accordingly.

Requirements of Display suitable for Target Identification

14. We have seen how the height tube display can be used to give the H.2.S. Operator the height of the aircraft above the earth's surface but we have concluded that the deflection type of presentation is not suitable for target identification. Obviously, the type of display required is one which can be most readily compared with a target map. Suppose that we can arrange to have the height marker trigger a timebase circuit which causes the electron stream to travel from the centre of the tube to the circumference. If the height marker is set to the ground echo then the height marker triggers the timebase at the instant the ground echo reaches the aircraft. The centre of the display will then represent the point directly below the aircraft. This means that the scan will not commence when the transmitter fires but after a time interval equal to the echo time of the ground echo. Let us suppose first that our radial timebase sweep was linear. Echoes from targets would return at time intervals after the transmitter firing which would be found by dividing their slant range by 10.7, the echo time in microseconds per mile return.

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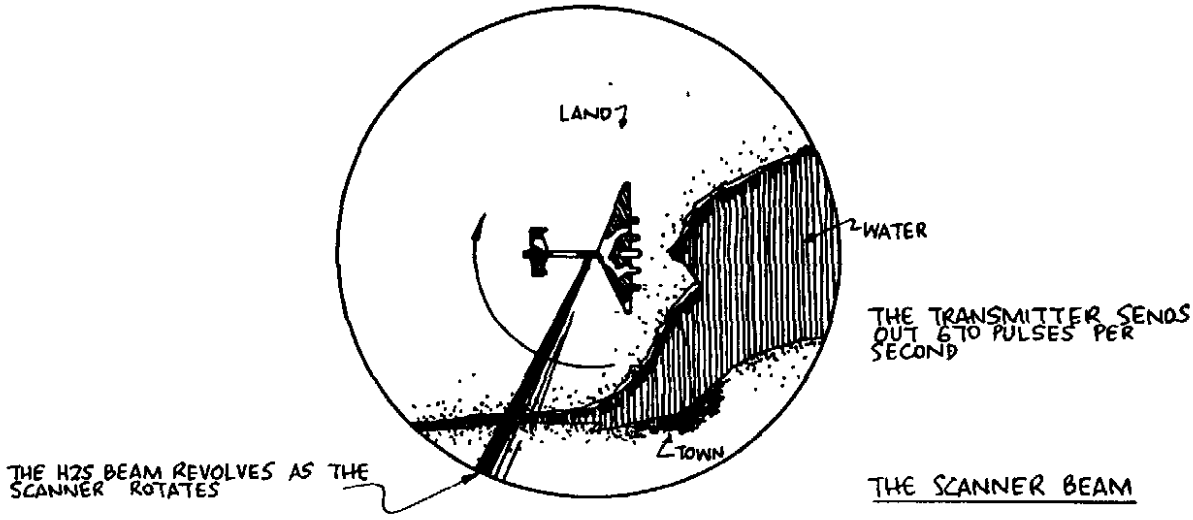


FIG. 2a

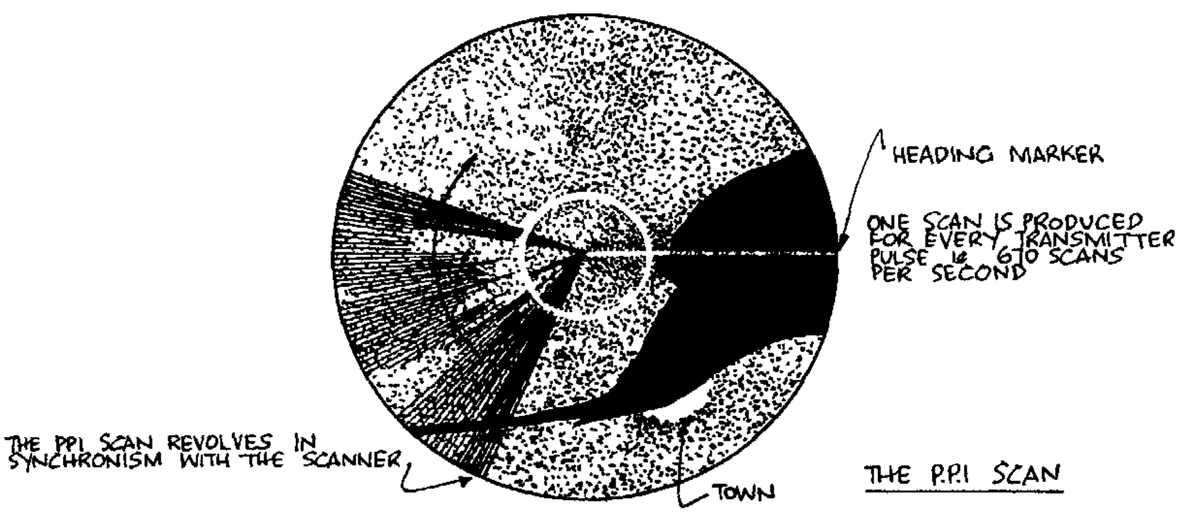


FIG. 2b

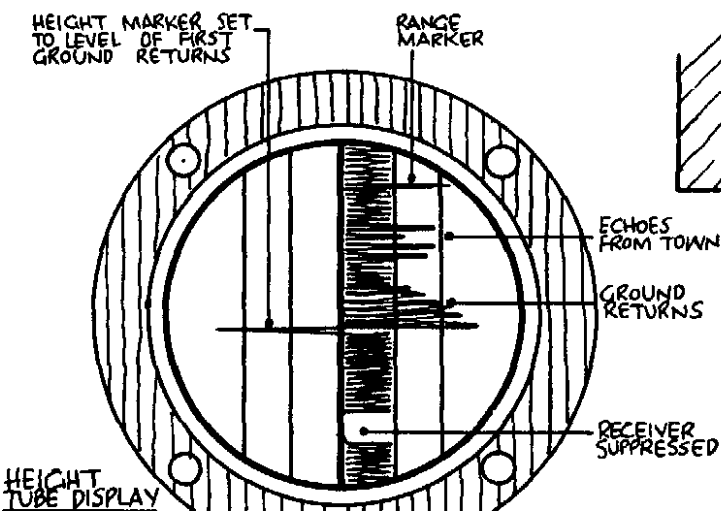


FIG. 3a

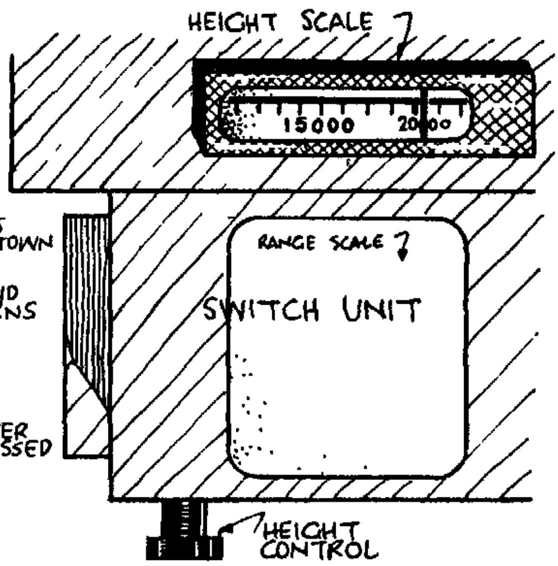


FIG. 3b

The distance from the tube centre at which the indications would appear would be proportional to the time of travel of the cathode ray tube spot, i.e. to the difference between the target echo time and the ground echo time. Since the ground echo time is proportional to the aircraft height and the target echo time is proportional to the slant range, the difference between these times will be proportional to slant range minus height. For ease of target identification by comparison with a target map, target indications should appear at distances from the tube centre which are proportional to their ground range. Since a linear timebase does not fulfil this condition it is necessary to develop a special type of non-linear timebase which does fulfil this condition.

15. What we want is a non-linear radial timebase that begins at the tube centre when the ground echo reaches the aircraft and which will be non-linear in such a way as to show target indications at distances from the centre proportional to their ground range. Moreover, these indications should give the best possible substitute for actual visibility. A display which resembles a relief map suggests itself. If we can make water, with very weak returns, show up as black, general ground returns as faint luminosity, and cliffs, heavily built-up areas, etc. as bright patches, we have something akin to a relief map.

16. In order that such a display can be compared with a target map the H.2.S. operator must know where North appears on his display. He also wants the target indications to have the same relative bearings on the display as on the target map. Hence, H.2.S. should provide a display which fulfils the following conditions:-

(a) The top represents true North.
(b) Target indications appear as luminous patches for strong returns, general ground returns give faint background luminosity, and rivers, lakes and sea can be kept almost blank.
(c) These indications appear at distances from the centre proportional to their ground range and show relative bearings on a target map.
(d) The centre of the display always represents the point directly beneath the aircraft and target indications appear at the correct bearing from the tube centre.

Development of Display for Target Indications

17. To produce the type of display we have described the radio frequency echo pulses after conversion into positive-going video pulses, are applied to the cathode ray tube grid. By adjusting the bias on the cathode ray tube it can be arranged that the intensity of the electron stream emitted from the cathode is not sufficient to cause any glow on the screen unless a positive pulse is acting on the grid. Hence, as the non-linear timebase voltage deflects the stream from the centre to the circumference of the tube, the screen remains blank when there is no signal on the cathode ray tube grid. If the receiver gain is turned up valve noise peaks plus general ground return echoes will cause a faint flashing or "scintillating" background while stronger echoes will cause the screen to brighten up along the sweep at distances from the centre proportional to their ground range. If the top of the map is to represent true North the radial timebase must be sweeping from the centre to the top when the scanner is looking toward the North. If echoes from other directions are to appear as bright patches at their correct bearings on the display the radial timebase must move around the tube in synchronism with the scanner. We have stated that there are 670 sweeps of the timebase per second. Hence if the scanner revolves once per second and the radial timebase moves in synchronism with it, we can think of our timebase as resembling a wheel with 670 spokes, i.e. we have timebase sweeps at angular intervals on the tube of $\frac{360}{670}$ or slightly more than a half degree.

Resolution of Indications

18. Any target will cause a brightening up of the number of sweeps that occur while the H.2.S. beam moves across the target. Hence the angular width of a target indication will be equal to the angle subtended at the aircraft by the target plus the beam width. This follows since returns will come from the target as soon as the leading edge of the beam reaches the target and the returns will continue until the trailing edge of the beam leaves the target. As a consequence of this fact adjacent targets will only give separate indications if their angular separation exceeds the beam width. Hence, the resolution obtainable with H.2.S. depends on the beam width. H.2.S. Mark IIC gives a beam width of about $8\frac{1}{2}$ degrees while the width of the beam developed by H.2.S. Mark IIA is about $3\frac{1}{2}$ degrees. As a consequence of this difference in beam width somewhat better resolution of targets is obtainable with H.2.S. Mark IIIA.

Reason for Using Centimetre Wavelengths

19. The whole reason for using centimetre wavelengths in H.2.S. has been the necessity of developing narrow beams in order to get resolution of targets. The development of narrow beams at longer wavelengths requires elaborate aerial arrays which are much too large for airborne work. As the wavelength is reduced the size of the aerial array required to produce a beam of a specified width diminishes. In the centimetre band narrow beams can be produced by means of mirror arrays which can be carried in aircraft without impairing speed or seriously reducing bomb load.

How Target Indications vary with Changing Range

20. For targets at long ranges the H.2.S. beam strikes the vertical surface of the buildings on the leading edge of the target at a comparatively low angle. Hence, these leading edge buildings will largely screen the greater part of the target. The returns will then cause only a brief brightening of each scan, i.e. only a dot on each scan. These dots will then join together to form a thin arc. As the aircraft approaches the target the beam strikes it at steeper angles and the screening effect decreases. The target indication therefore increases in depth. When the aircraft is close to the target the beam will illuminate the greater part of the target area and an indication will be produced which roughly resembles the outlines of the strongly reflecting regions of the target.

How the Target Display gets its Name

21. Since the main H.2.S. display is essentially a form of relief map showing a plan view of the country under the aircraft, we speak of it as a P.P.I. (plan position indication) display. The cathode ray tube used to develop this display is called the P.P.I. tube. Both the P.P.I. and height tube are incorporated in an indicator at the Navigator's table.

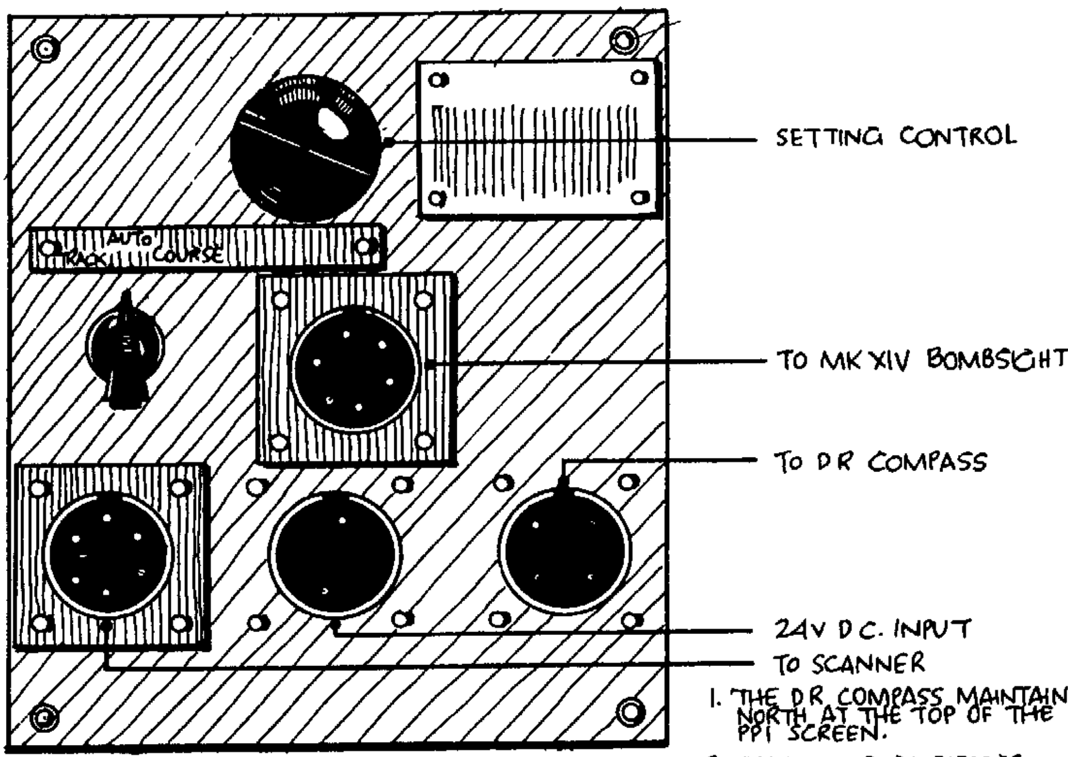
H.2.S. Map Scales

22. As the P.P.I. display is to be compared with a target map it is necessary to know the scale of the H.2.S. map. Three different maps are available. One provides a ground range coverage of around 40 statute miles on a tube of $2\frac{1}{2}$" radius, or a map with a scale of about 16 miles to the inch. The second map provides a ground range coverage of about 20 statute miles or a scale of about 8 miles to the inch. The third gives a ground range coverage of 10 statute miles or a scale of 4 miles to the inch. These correspond to the 1:1,000,000, 1 : 500,000 and 1 : 250,000 scale maps.

The Heading for Course Marker

23. It has been stated previously that it is possible to set the H.2.S. map so that the top represents true North. The control used for making this adjustment is located on a heading control unit which is also mounted at the Navigator's table along with the indicator and switch unit. When this adjustment has been made target indications will appear at the same bearing from a line drawn from the tube centre to the top of the tube as the actual targets appear from a North-South line drawn through the aircraft position on the target map. What the H.2.S. Operator is frequently interested in is the

FIG.4



HEADING CONTROL UNIT 446

1. THE D R COMPASS MAINTAINS NORTH AT THE TOP OF THE PPI SCREEN.
2. TRACK MARKER DIFFERS FROM COURSE MARKER BY THE ANGLE OF DRIFT. THIS INFORMATION IS FED FROM THE BOMBSIGHT.

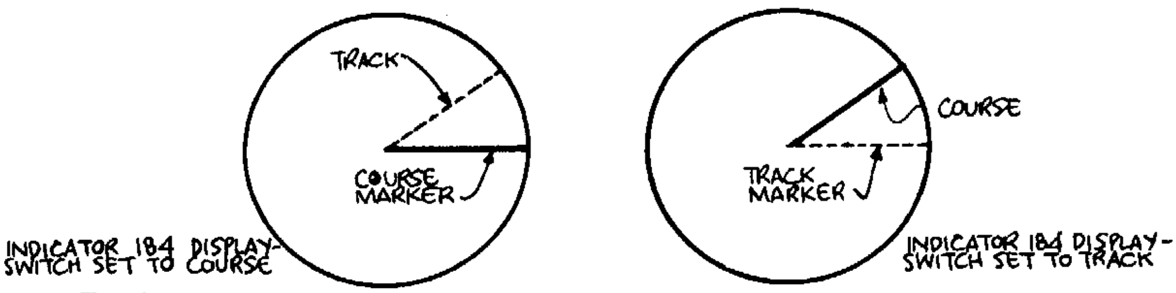
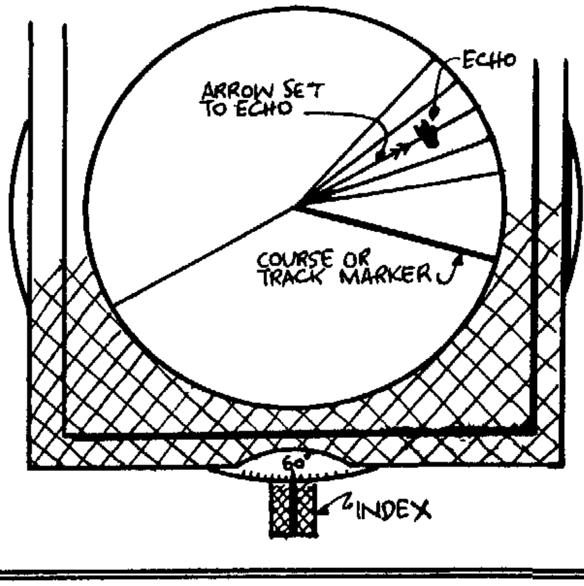


FIG.5a TRACK AND COURSE MARKERS FIG.5b



BEARING RING

FIG.6

bearing of targets with respect to the aircraft heading. To present this information visually a heading marker is provided. We have noted previously that when the scanner is looking in any particular direction the timebase sweep then occurring will travel out from the tube centre at a bearing equal to the bearing of the direction in which the scanner is looking provided the map has been correctly set. It is arranged that at the instant the scanner goes through the dead-ahead position two contacts close to develop a positive pulse on the P.P.I. grid which lasts for the duration of about two sweeps of the timebase. This positive pulse serves to brighten up the two consecutive radial scans that occur as the scanner is passing through the dead-ahead position. Hence, for every revolution of the scanner a bright radial line, formed by the fusion of these two consecutive brightened-up sweeps, flashes up at the bearing of the aircraft heading. Due to the after-glow properties of the screen this marker will be apparent all the time if the Navigator's compartment is in darkness. The position of target indications on the display relative to the heading marker will give an immediate picture of the position of targets relative to the aircraft course. A switch on the switch unit enables the H.2.S. Operator to switch off the heading marker when he does not wish to use it.

The Track Marker

24. In the H.2.S. Mark IIC and Mark IIIA installations facilities are available for converting the heading marker to a track marker in order to facilitate homing on a target during a bombing run. When a switch on the indicator is switched from the "Course" to the "Track" position a second set of moveable contacts is brought into operation in the scanner. This pair is offset from the first fixed pair by the drift angle when this angle has been set on the Mark 14 bombsight. The positive pulse applied to the P.P.I. grid will now occur earlier or later than previously depending on the sense of the drift, and the marker will flash up on a bearing that shows the actual aircraft track as opposed to the heading or course.

The Bearing Ring and Map Setting

25. To permit the H.2.S. Operator to make bearing measurements a bearing ring is provided on the front of the P.P.I. tube. This rotatable ring is graduated in degrees. A pointer is engraved on a perspex screen attached to the ring. When this pointer is set to a target the bearing can be read directly opposite an index at the bottom of the tube. This pointer is used to set up the H.2.S. map so as to have North at the top. When the pilot has set course the H.2.S. Operator sets switches on the heading control unit and indicator to "Course" and sets the bearing ring to read the course opposite the index. He then adjusts his setting knob on the heading control unit until the heading marker flashes along the pointer on the perspex scale. The heading marker now shows the correct aircraft heading and the map is therefore correctly set. The heading control switch is now set to "Auto" and the D.R. compass keeps the setting of the map correct as the aircraft alters course. When a change in course occurs the heading marker moves accordingly.

Range Measurements

26. Although target indications appear at distances from the tube centre which are proportional to their ground range the H.2.S. Operator requires some means of measuring ranges. For this purpose he is provided with a range marker. This range marker is a positive pulse generated in the H.2.S. set on every sweep of the timebase. It is applied to the P.P.I. grid so will cause a bright dot on each of the 670 sweeps. The distance from the tube centre at which these dots appear can be varied by means of a range control on the switch unit. For any setting of this control the distance from the centre at which these dots occur is fixed. Hence the range marker dots on the 670 radial sweeps join up to form a luminous circle. When the H.2.S. Operator wishes to measure a range he adjusts his range control until the marker ring coincides with the target. He can then read the target range directly opposite an index on a calibrated scale. The range marker is also mixed with the signals and applied to the height tube to appear as a blip to the right of the trace.

LUCERO

FIG. 7a

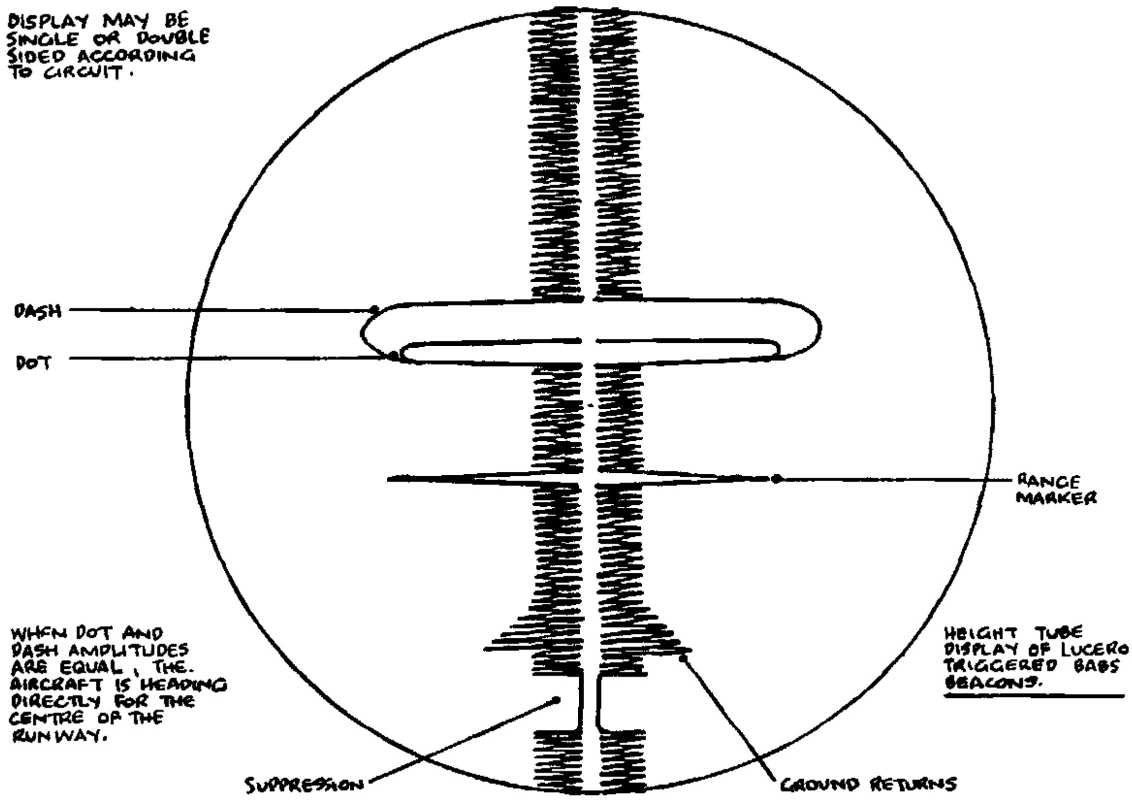
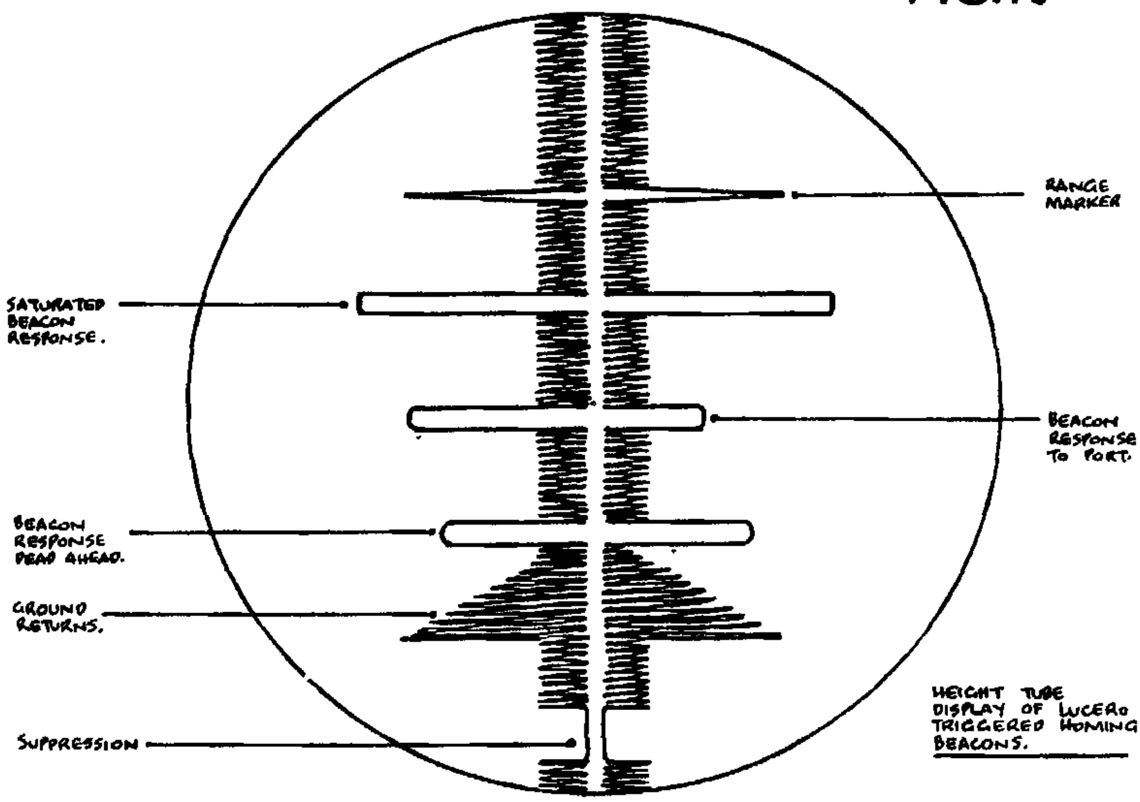


FIG. 7b



The 30 Mile and 100 Mile Range Scales

27. Three different range scales are provided, all located on a range drum which turns as the range control is operated. One scale provides slant range measurements from 0 to 100 statute miles. The first part of this scale is used when the 40 mile timebase is in use. The 40 - 80 mile portion of the scale is not used on the P.P.I. display. This 100 mile scale appears along the outer edge of the range drum. On the inner edge of the range drum is a second scale which is calibrated to read slant ranges from 0 - 30 miles. This scale is used in conjunction with the 20 mile timebase. In each case the range is read from the graduation that appears opposite a little index. It has been stated that the range measured is actually slant range although target indications appear at distances from the centre which are proportional to their ground range. This anomaly arises from the fact that we are actually measuring echo times which are proportional to slant range.

The 10 Mile Range Scale

28. The central part of the range drum shows a set of curves and a metal pointer that tracks across these curves when the height control is operated. These curves serve to convert slant range to ground range and permit measurements of ground ranges between 0 - 10 statute miles. To use this 10 mile scale the height marker must first be set to the beginning of the ground echo on the height tube. As this is done the pointer mentioned above tracks across the range drum and the range marker moves on both the height tube and the P.P.I. This happens because the height marker circuit is triggering the range marker circuit when the 10 mile range scale is in use. This is not the case when the 30 or 100 mile range scales are in use as the height and range marker circuits then operate independently. When the height marker has been set to the ground echo the range control is used to set the range marker ring to the indication on the P.P.I. display. As this is done the curves on the range drum move across the tip of the pointer. The curve opposite the pointer tip when the adjustment has been made gives the ground range of the target.

The Bombing Scales

29. On the range drum two sets of bombing scales are shown in addition to the range scales already mentioned. One of these appears in dotted red lines and the other set in solid red lines. These lines are bombing scales. The dotted lines are 30 second lines, while the solid ones are direct release lines. Both sets are labelled in ground speeds. Suppose that a bombing run is in progress, and the 10 mile timebase and range marker circuits are in operation. Suppose the range control is set to 8 miles and a stop watch started as the target touches the marker ring. The range control is then set to 7 miles and the marker moves in. When the target reaches the marker ring the watch is stopped. This gives the time to travel a mile ground range from which the ground speed is known. The range control is then set to bring the 30 second line which gives the appropriate ground speed opposite the tip of the pointer. If the aircraft flies straight and level at the same height until the target reaches the new position of the marker ring the target touches the marker ring 30 seconds before an ideal bomb should be released. For different types of bombs suitable corrections have to be made to this 30 second value. In any case the number of seconds before the bombs should be released will be known. In this way H.2.S. can be used for blind bombing. If the direct release lines were used instead of the 30 second lines any ideal bomb should be released at the instant the target reaches the marker ring.

The Scan-Marker Switch

30. We have spoken of the different timebases and range scales. Obviously the development of these different scan and marker ranges is achieved by switching components in the appropriate H.2.S. units. This switching is done by means of a 6-position scan-marker switch on the switch unit. The pointer of this switch moves across an engraved scale with two sets of numbers on it. The one set is labelled "Scan", and the other set "Marker". The six positions provide the following combinations of timebases and markers:-

Position	Scanning Range	Markers Range
10/10	10 mi. (ground)	10 mi. (ground)
10/20	20 mi. (ground)	10 mi. (ground)
30/20	20 mi. (ground)	30 mi. (slant)
100/20	20 mi. (ground)	100 mi. (slant)
100/40	40 mi. (ground)	100 mi. (slant)
100/40-80	Not useable on P.P.I.	100 mi. (slant)

From the above table it can be seen that the second or 10/20 position of the scan-marker switch permits the use of the 10 mile range scale, and hence of the bombing scales, on the 20 mile scan. This enables the H.2.S. Operator to use the bombing scales when attacking targets which are so large that they cannot be handled on the 10 mile map.

The Beacon Switch and Lucero

31. A beacon switch is also provided on the switch unit. This switch can be set to "OFF", B+H, B, or BA. When set to "Off" Lucero is inoperative. This is the position that is used in Bomber Command when Lucero is not installed. When set to "B+H" both Lucero and H.2.S. are operating. Signals from homing beacons triggered by the Lucero transmitter will then be fed to the H.2.S. displays along with the H.2.S. signals. The height tube display now becomes double-sided and the height marker no longer appears on the height tube. If set to the position "B" the H.2.S. signals are eliminated and only the homing beacon signals are received. These will appear as two-sided blips on the height tube, flashing a Morse letter to identify the beacon. By altering course until the two sides of the blip are of equal amplitude the aircraft can home onto the beacon. When the "BA" position is used a second local oscillator is switched into the circuit in the Lucero unit. This enables the receiving part of the Lucero unit to amplify signals from BABS runway beacons. These signals take the form of a narrow blip or "dot" inside a wide blip or "dash". If the two blips are of equal amplitude the aircraft is making its approach in a direction coincident with a line down the centre of the runway. If there is no drift the equal amplitude blips will be symmetric with respect to the trace. If drift is present this symmetry will not be obtained when the amplitudes are equal. If certain circuit modifications are introduced displays of Lucero signals will be single sided.

32. When Lucero Mark II is used a push-button tuning unit is included in the installation. This unit permits switching of the tuned circuit components in the Lucero transmitter and local oscillator circuits to operate on different channels in the band 214 to 234 Mc/s. This multiple-frequency design permits different aircraft to trigger different Eureka beacons without causing interference.

The Gain Control

33. The H.2.S. Operator's gain control is also mounted on the switch unit at his table.

The Tuning Control in H.2.S. Mark IIC.

34. In aircraft fitted with an H.2.S. Mark IIC installation a tuning unit containing the local oscillator of the H.2.S. receiver appears at the Navigator's table. The frequency of the magnetron transmitter valve may vary and since it cannot be tuned it is necessary to tune the local oscillator to keep the difference between the signal frequency and local oscillator frequency equal to the fixed frequency to which the I.F. amplifier responds. The local oscillator tuning control appears on the tuning unit where it is readily accessible to the H.2.S. Operator.

The Tuning Controls in H.2.S. Mark IIIA

35. In an H.2.S. Mark IIIA installation the local oscillator is incorporated in the same unit as the transmitter valve. This unit is called the H.F. box in

C.D. 0896L

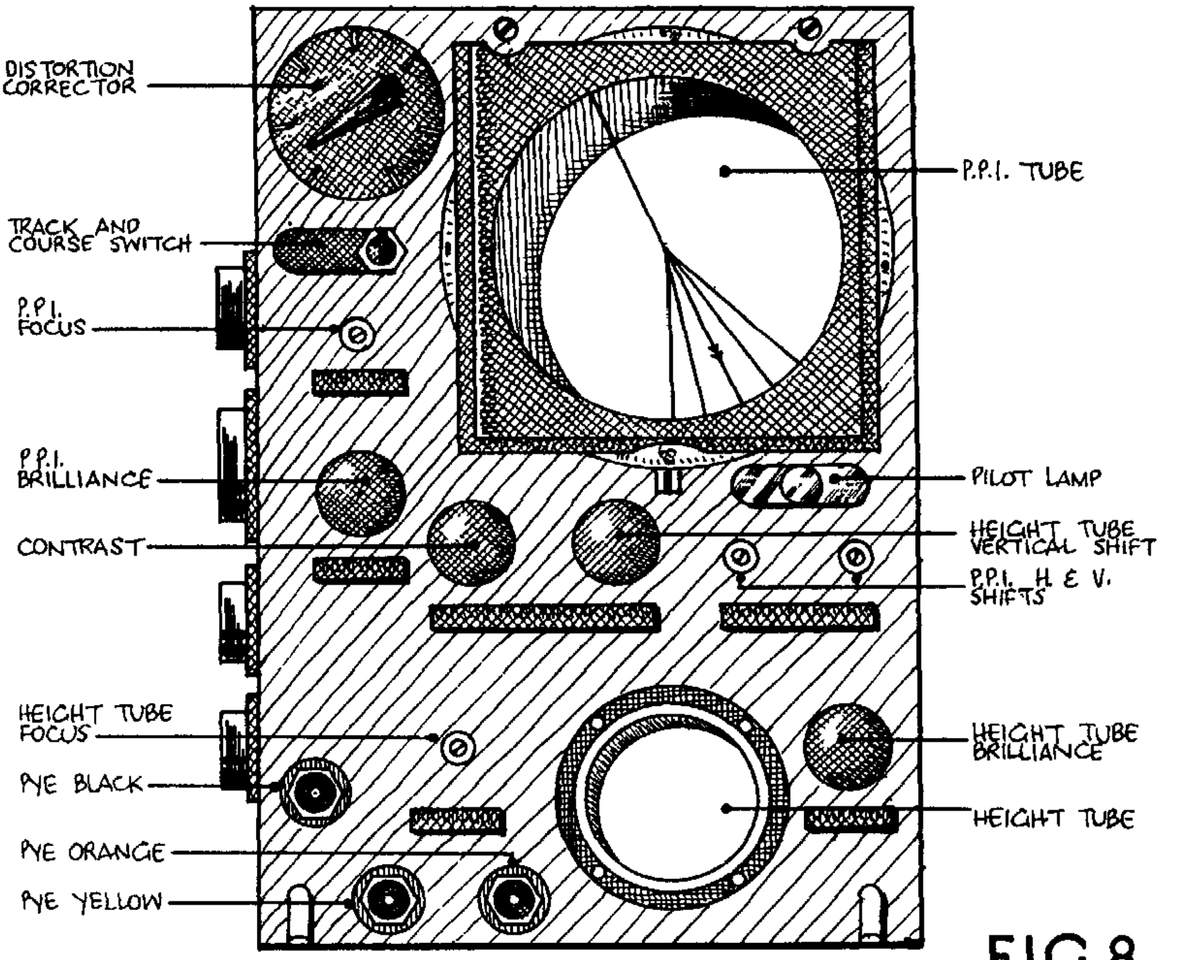


FIG.8

INDICATOR 184

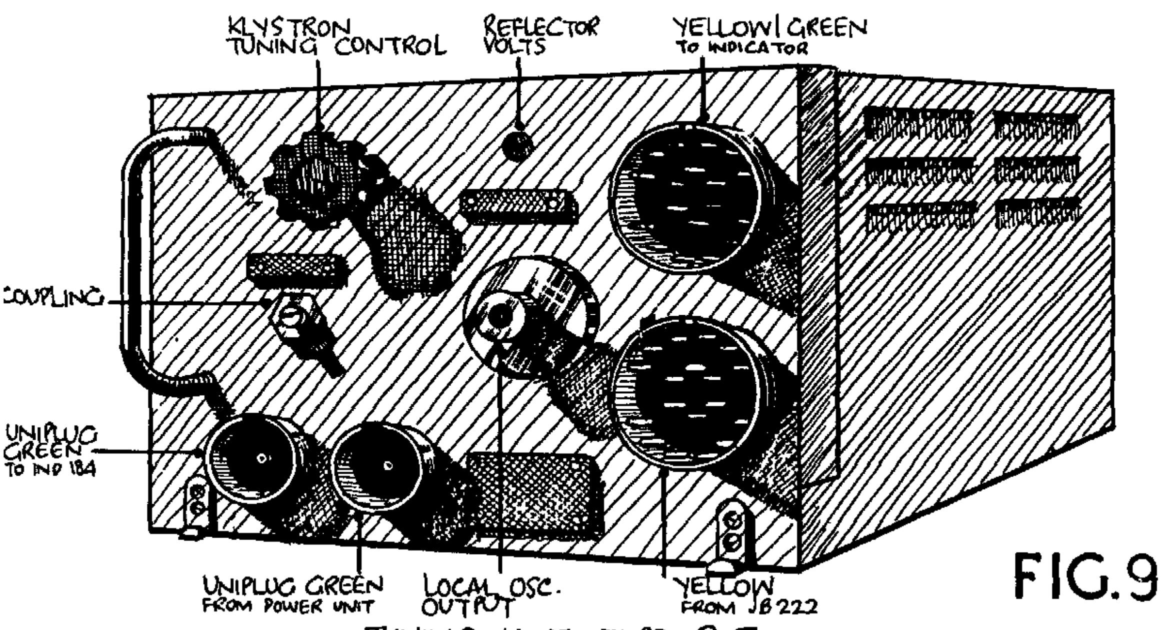


FIG.9

TUNING UNIT TYPE 207

C.D. 0896 L.

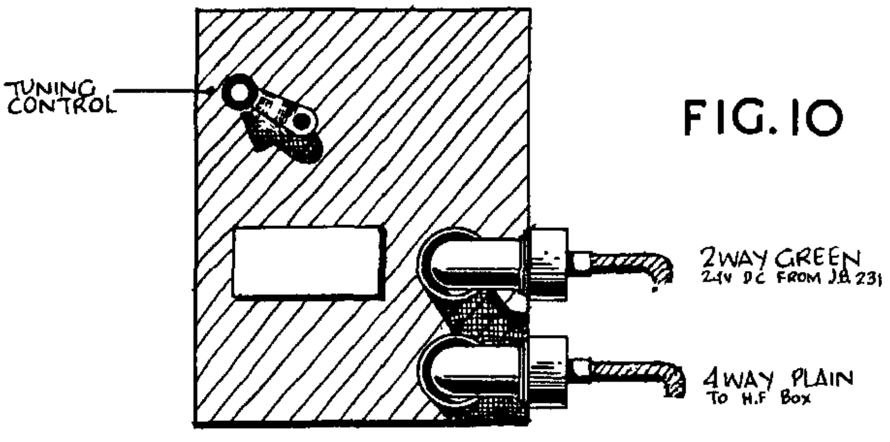


FIG. 10

TUNING UNIT TYPE 444

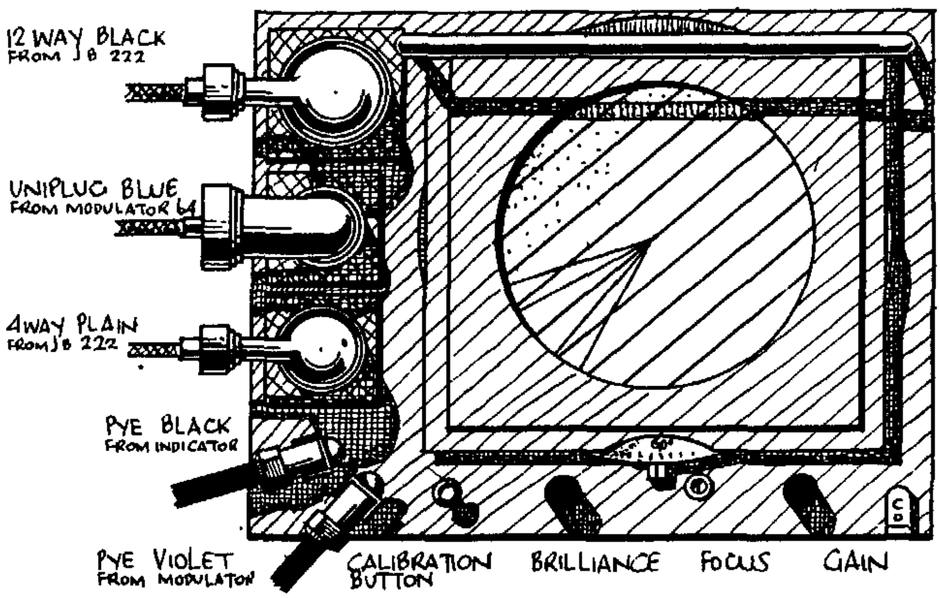
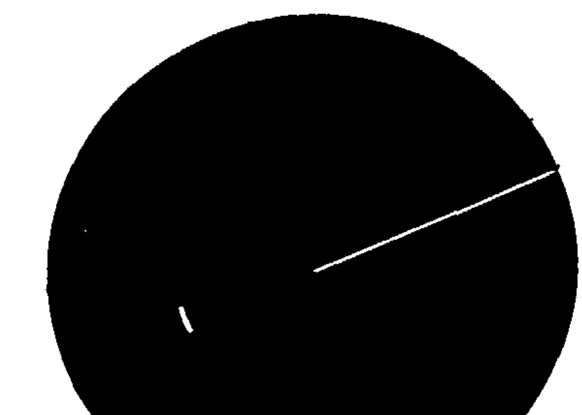


FIG. 11

FISHPOND INDICATOR TYPE 182A



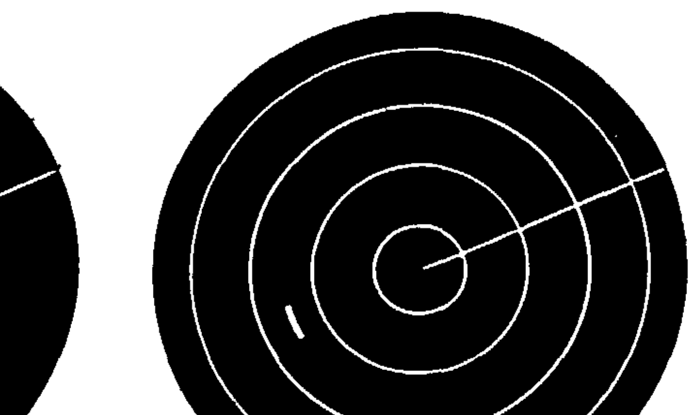


FIG. 12a

FISHPOND DISPLAY

FIG. 12b

Mark III H.2.S. installation. A local oscillator tuning control is provided on the H.F. box for use by the Radar Mechanics. Since the H.2.S. Operator must also be able to tune the local oscillator a tuning unit with a remote tuning control is fitted at the Navigator's table.

Origin of the Term "T^2R"

36. The transmitter unit used in Mark II H.2.S. installations is usually called the T2R. This nomenclature arose in Mark VIII A.I. where the transmitter unit contained both the 9 cm. transmitter and an I.F.F. interrogating transmitter as well as a crystal mixer and the I.F. stage. The term "T2R" indicated the presence of two transmitters as well as receiver stages. The term is really not applicable in H.2.S. since only one transmitter is included in the transmitter unit.

The Distortion Corrector Control

37. Another control of interest to the H.2.S. Operator, the distortion corrector control, appears on the indicator panel. This control must be set to the aircraft height (found by setting the height marker to the ground return) if target indications are to appear at distances from the centre which are proportional to ground range.

Brilliance Control

38. The brilliance controls for the height tube and P.P.I. appear as variable controls on the indicator panel to permit adjustment by the H.2.S. Operator.

Presets

39. Numerous preset controls are included in the equipment but these are primarily the concern of the Radar Mechanic and are more conveniently discussed when dealing with the associated circuits.

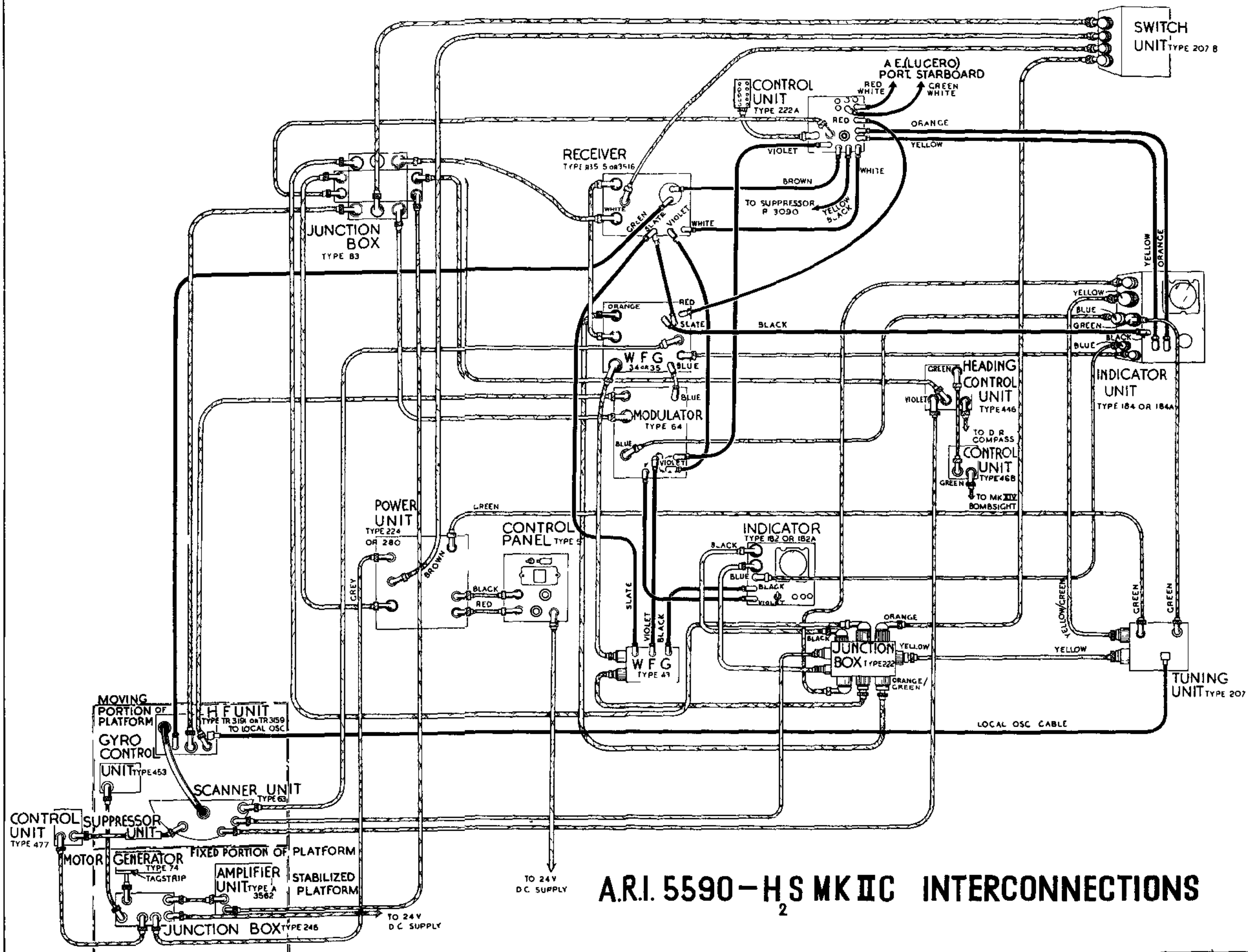
Fishpond

40. The Fishpond indicator unit is used by the Wireless Operator. It provides a P.P.I. display with a timebase which is synchronised to that of the H.2.S. displays. It differs from the H.2.S. P.P.I. display in that the scan is essentially linear and gives a range coverage of 4 - 5 miles independent of the scan in use on the H.2.S. indicator. The effective scan begins when the transmitter fires instead of when the height marker forms. The heading marker appears on this display at the same bearing as on the H.2.S. P.P.I. The tube is provided with a bearing ring similar to that on the H.2.S. indicator. The effective Fishpond scan begins about a half inch from the tube centre when the transmitter fires and the coverage is only 4 - 5 miles, i.e. just over the normal aircraft height. Hence, the only indications from points on the ground that will appear at operational heights will be a ground echo ring around the outside of the tube. The only indications that can appear inside this ground echo ring will be due to reflections from aircraft which may be present in a hemishpere below the aircraft with centre at the aircraft and radius equal to the aircraft height. The position of any such aircraft indications with respect to the heading marker will indicate whether the reflecting aircraft is astern, ahead, on the beam, or on any quarter. There is, however, no definite indication as to its position in elevation. Some idea of elevation may be obtained by banking. If banking causes the indication to cross the heading marker the reflecting aircraft must be well below the receiving aircraft. If banking causes very little displacement relative to the heading marker the reflecting aircraft must be at much the same height as the receiving aircraft. Indications produced by hostile aircraft can be identified by noting whether they alter course to follow the receiving aircraft when it takes evasive action.

41. To get a quick estimate of range a set of marker rings representing 0, 1, 2, 3, 4, 5 miles can be put on the display by means of a push-button switch. A variable gain and brilliance control are provided on the panel.

Power Switches

42. The power switches for the complete installation are located on the switch unit. When the push-button switch labelled "L.T. ON" is pressed a green pilot lamp lights. After about 40 seconds a relay in the power unit closes. If the next push-button labelled "H.T. ON" is now pressed a yellow pilot light lights up. If this button is pressed before the relay in the power unit has closed the yellow pilot lamp will not light up, indicating that the button has been pressed too soon. After a further delay of about the same interval a red pilot lamp lights up and the transmitter starts operating provided a toggle switch on the modulator unit is in the "Down" position. The entire equipment is switched off if the push-button labelled "L.T. OFF" is pressed. If the button "L.T. ON" is pressed when the equipment is running the transmitter becomes inoperative but the rest of the equipment remains operative. The transmitter can be brought on again after the usual delay by again pressing the "H.T. ON" button. A toggle switch on the switch unit labelled "MOTOR" is used to switch the scanner motor on and off. A similar switch adjacent to the scanner switch labelled "LINE OF FLIGHT" is used to switch the heading marker on and off.

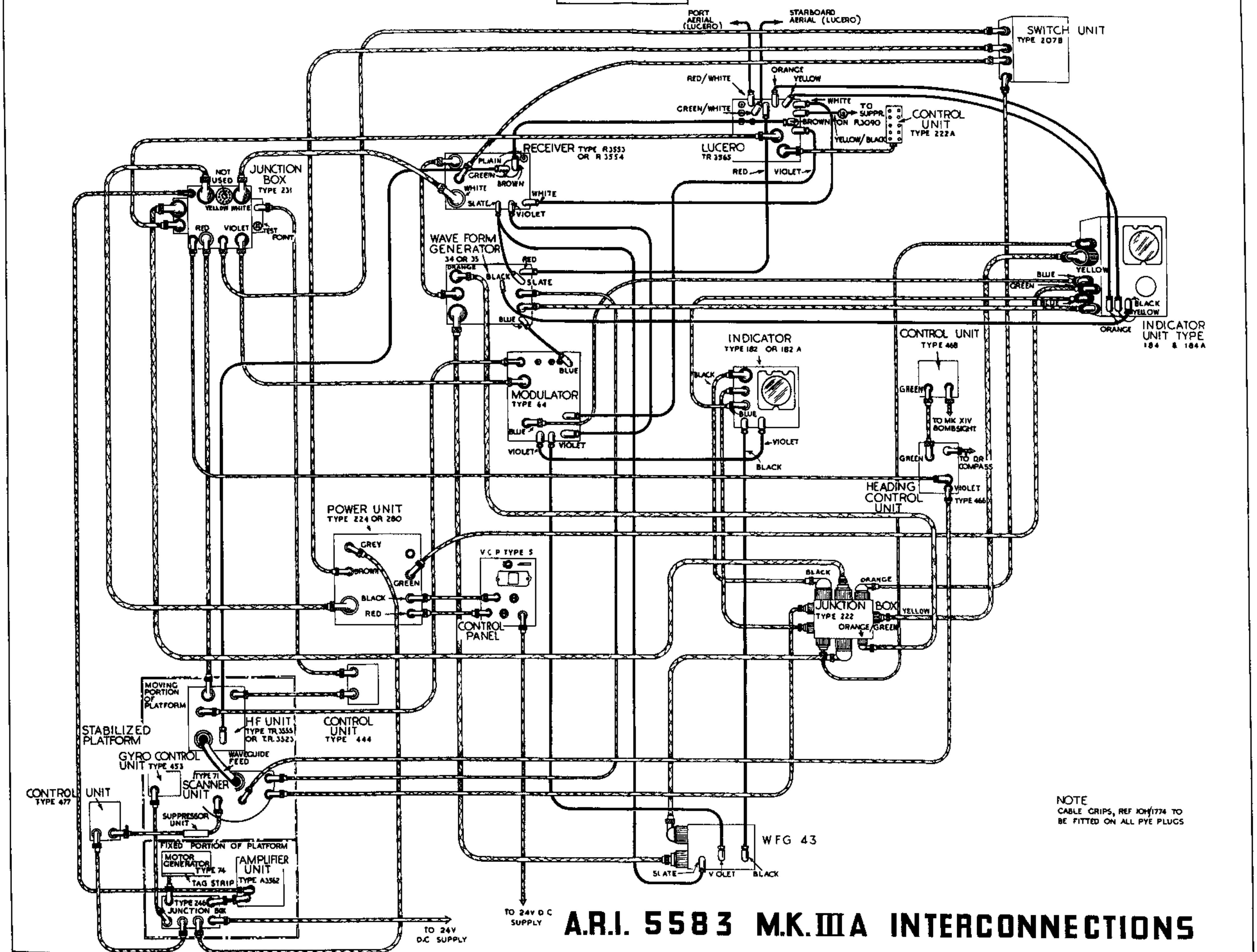


A.R.I. 5590—H$_2$S MK IIC INTERCONNECTIONS

FIG. 13

FIG. 13

CD 0896 L



A.R.I. 5583 M.K. IIIA INTERCONNECTIONS

FIG.14

FIG.14

CHAPTER 2 - WHAT THE H.2.S. INSTALLATION COMPRISES

Introduction

43. In Chapter 1 we discussed H.2.S. from the standpoint of the nature of the system and the facilities it provides operationally. We must now consider the equipment more specifically from the radar mechanic's point of view and note the basic functional sub-divisions of the installation and the way these functional sub-divisions are distributed in units.

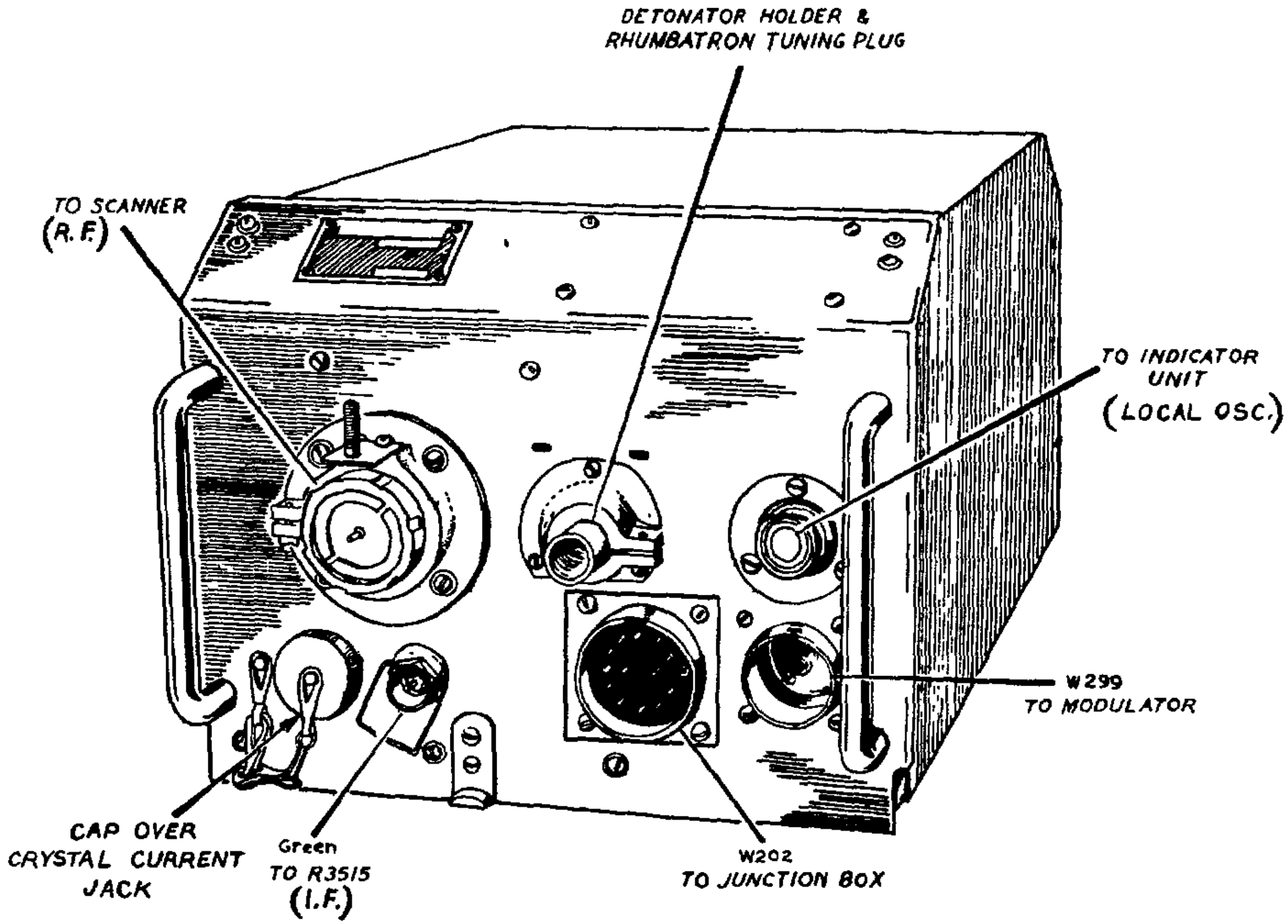
Functional Sub-Divisions

44. From a functional point of view we may regard the H.2.S. installation as comprising the following:-

(a) Power supplies and safety circuits.
(b) H.2.S. timebase circuits for both the P.P.I. and height tube presentations.
(c) A transmitter chain which will include:-
  (i) Synchronising and timing circuits.
  (ii) Circuits to develop the modulating pulse.
  (iii) The transmitter proper.
  (iv) The output system.
(d) A receiver chain which will comprise
  (i) A TR. switch.
  (ii) Crystal mixer.
  (iii) Klystron local oscillator.
  (iv) Head amplifier.
  (v) I.F. strip.
  (vi) Second detector.
  (vii) Output stage.
  (viii) Suppression circuit.
(e) Marker circuits which will comprise
  (i) Heading or track marker circuits, and their automatic and manual controlling stages.
  (ii) Height marker circuits.
  (iii) Range marker circuits.
(f) Bright-up, mixing, output and display circuits.
(g) The roll-stabilisation circuits for the scanner.
(h) Fishpond.
(i) Lucero.

45. With the exception of Lucero and Fishpond these functional sequences are not arranged in units but have sub-divisions and controls scattered in different units. This arises partly from the necessity of having such controls as will be required by the H.2.S. operator at his table, while at the same time arranging a suitable weight distribution of units in the aircraft. The sub-division of the H.2.S. installation into units is, therefore, quite different from its partition into functional sequences. Since the radar mechanic must work with units, although he must think in terms of functional sub-divisions scattered throughout those units, it is proposed to state at this point what units are used and then to proceed in the following chapters to study the functional sequences and the distribution of their subsections in these units. How these units are linked up in the aircraft installations is shown in the cabling diagrams, fig.13, Mark IIC, and fig. 14, Mark IIIA.

FIG.15



TRANSMITTER-RECEIVER TYPE TR3191

C.D. 0896 L

FIG.15

46. The Mark IIC installation, ARI.5590, comprises the following items:-

Item	Type	Ref.No.	Width	Length	Depth	Weight
Transmitter Unit (T^2R)	TR.3191	10DB/1003	9.5"	15.75"	7"	42 lbs.
	or TR3159	10DB/ 867	9.5"	15.75"	7"	42 lbs.
Modulator	Type 64	10DB/ 956	8.5"	21"	12"	47 lbs.
Power Unit	Type 280 or	10KB/ 747	11.5"	18"	12"	30 lbs.
	Type 224	10KB/ 512	11.5"	18"	12"	30 lbs.
Waveform Generator	Type 34 or	10VB/6056	11.5"	10"	8"	15 lbs.
	Type 35	10VB/6057	11.5"	10"	8"	15 lbs.
Switch Unit	Type 207B	10FB/6115	12"	6"	8"	14 lbs.
Receiver-timing Unit	R.3515	10DB/6060	11.5"	18"	8"	30 lbs.
	or R.3516	10DB/6061	11.5"	18"	8"	30 lbs.
Indicator	Type 184	10QB/6035	8.5"	18"	12"	44 lbs.
	or 184A	10QB/6181	8.5"	18"	12"	44 lbs.
Tuning Unit	Type 207	10DB/6499	8.5"	9"	5.75"	13 lbs.
Heading Control Unit	Type 446	10LB/6053	6.5"	3.5"	5.5"	4 lbs.
Junction Box	Type 247	10MB/6499	4.5"	5.5"	3.5"	2 lbs.
Scanner	Type 63	10AB/6343				60 lbs.
Amplifier Unit (RPU)	Type A3562	10UB/6041	8.5"	12.5"	7.5"	21.5 lbs.
Amplifier Unit (Gramco)	or A3562A	10UB/6078	8.5"	12.5"	7.5"	21.5 lbs.
Track Marker Control Unit	Type 468	10LB/6091				2 lbs.
Scanner Speed " Unit	Type 477	10LB/6102	4.75"	4.3"	2.5"	1 lb.
Gyro Control Unit	Type 453	10LB/6074	6.135 di.	7.175		4 lbs. 2 oz
Motor Generator	Type 74	10KB/ 954				
Junction Box	Type 246	10AB/2497	6.5"	6"	2"	118 lbs.
Stabilised Platform	Type 26	10AB/6522				
Main Junction Box	Type 83	10AB/2212	8.5"	5.8"	3"	6 lbs.
Fishpond Indicator	Type 182	10QB/6031	8.5"	18"	8"	26 lbs.
	or 182A	10QB/6037	8.5"	18"	8"	26 lbs.
Fishpond Junction Box	Type 222	10AB/6331	7.1"	3.7"	2.75"	3 lbs.
Fishpond Bright up WFG	Type 43	10VB/6155	8.5"	6.5"	4.75"	
Lucero Mark II	TR.3160	10DB/ 868	8.5"	18"	8"	36 lbs.
Lucero Control Unit	Type 2224	10LB/6010	6.13"	6.02"	3.2"	1½ lbs.
Lucero Aerials	Type 184	10DB/2171				
Adapter Frame for Stab. Platform	Lancaster	10AB/6524				14 lbs.
	Halifax	10AB/6523				14 lbs.
Scanner Heater Connector Set	Lancaster	No ref.no. for complete set				
"	Halifax					
Voltage Control Panel	Type 5	5U/363	8.5"	10.75"	7.875"	18 lbs.
Alternator	Type U	5U/349				38 lbs.

47. The Mark IIIA installation, ARI.5583, comprises the following items:-

Item	Type	Ref.No.	Width	Length	Depth	Weight
Transmitter unit (HF box)	TR.3555B	10DB/6916	10"	11.875"	21"	83 lbs.
	or 3555C	10DB/6917	10"	11.875"	27"	83 lbs.
	or 3523A	10DB/6647	10"	11.875"	27"	52.5 lbs.
Modulator	Type 64	10DB/ 956	8.5"	21"	12"	47 lbs.
Power Unit	Type 280	10KB/ 747	11.5"	18"	12"	30 lbs.
	or 224	10KB/ 512	11.5"	18"	12"	30 lbs.
Waveform Generator	Type 34	10VB/6056	11.5"	10"	8"	15 lbs.
	or 35	10VB/6057	11.5"	10"	8"	15 lbs.
Switch Unit	Type 207B	10FB/6115	12"	6"	8"	14 lbs.
Receiver-timing Unit	Type R.3553	10DB/6305	11.5"	18"	8"	32 lbs.
	or R.3554	10DB/6306	11.5"	18"	8"	32 lbs.
Indicator	Type 184	10QB/6035	8.5"	18"	12"	44 lbs.
	or 184A	10QB/6181	8.5"	18"	12"	44 lbs.
Tuning Unit	Type 444	10LB/6051	6.5"	3.5"	6"	3 lbs.
	or 499	10LB/6185				
Heading Control Unit	Type 446	10LB/6053	6.5"	3.5"	5.5"	4 lbs.
Junction Box	Type 247	10AB/6499	4.5"	5.5"	3.5"	2 lbs.
Scanner	Type 71	10AB/6454				60 lbs.
Amplifier Unit (EPU)	Type A.3562	10UB/6041	8.5"	12.5"	7.5"	21.5 lbs.
" " (Gramco)	or A.3562A	10UB/6078	8.5"	12.5"	7.5"	21.5 lbs.
Track Marker Control Unit	Type 468	10LB/6091	6.5"	3.5"	6"	2 lbs.
Scanner Speed " "	Type 477	10LB/6102	4.75"	4.3"	2.5"	1 lb.
Gyro Control Unit	Type 453	10LB/6074	6.135 di.	7.175"		4 lb. 2 ozs.
Motor Generator	Type 74	10KB/ 954				
Junction Box	Type 246	10AB/2497	6.5"	6"	2"	118 lbs.
Stabilised Platform	Type 26	10AB/6522				
Main Junction Box	Type 231	10AB/6370	9.5"	5.75"	3.25"	4.75 lbs
Fishpond Indicator	Type 182	10QB/6031	8.5"	18"	8"	26 lbs.
	or 182A	10QB/6037	8.5"	18"	8"	26 lbs.
Fishpond Junction Box	Type 222	10AB/6331	7.1"	3.7"	2.75"	3 lbs.
Fishpond Bright Up WFG	Type 43	10VB/6155	8.5"	6.5"	4.75"	
Lucero Mark II	TR.3160	10DB/ 868	8.5"	18"	8"	36 lbs.
Lucero Control Unit	Type 222A	10LB/6010	6.13"	6.02"	3.2"	1.5 lbs.
Lucero Aerials	Type 184	10BB/2171				
Adaptor frame for	Lancaster	10AB/6524				14 lbs.
Stab. Platform	Halifax	10AB/6523				14 lbs.
Scanner Heater						
Connector Set	Lancaster Halifax	No ref.no. for complete set.				
Voltage Control Panel	Type 5	5U/ 363	8.5"	10.75"	7.875"	18 lbs.
Alternator	Type U	5U/ 349				38 lbs.

Component Numbering

48. To reduce confusion which might arise from identical numbering of components in different units, a system of blocks of numbers was allotted to the respective units in the first H.2.S. installation. As a consequence of the introduction of units or sub-units common to other equipments there is now some duplication of component numbering. The present nomenclature is as follows:-

Unit	Number Block
1 - 99	Rx. section of Rx. - T. unit.
100 - 149	Mk. IIC Transmitter Unit.
150 - 199	Switch Unit.
200 - 299	Modulator 65 (obsolete).
300 - 399	Power Unit
400 - 499	Timing Section of Rx. - T. unit.
500 - 599	Waveform Generator.
650 - 749	Indicator 162 (obsolete).
800 - 899	Indicator 184A (Gramco).
1 - 99	Indicator 184 (R.P.U.).
1 - 99	Indicator 182 or 182A (Fishpond).
1 - 99	Modulator 64 (Universal Unit).
1 - 99	T.R. 3160 (Lucero Mark II) in each sub-unit.

<u>Location of Units in the Aircraft</u>

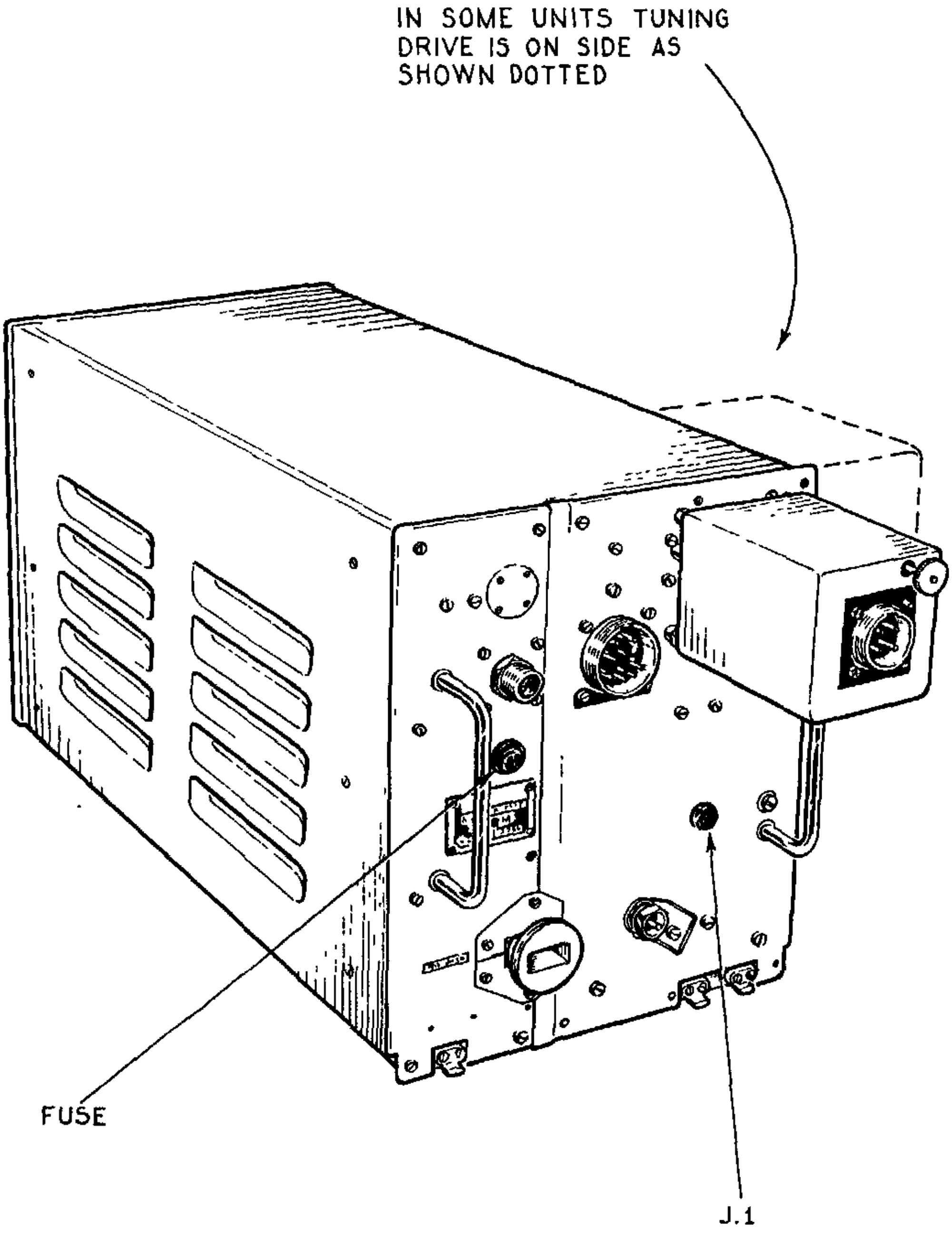
49. (a) The following units will be located at the navigator's table:-
    - (i) Indicator 184 or 184A.
    - (ii) Tuning Unit 207 (Mark IIC) or 444 (Mark IIIA with TR.3555 series) or 499 (Mark IIIA with TR.3523 series).
    - (iii) Heading Control Unit Type 446.
    - (iv) Switch Unit 207B.
    - (v) Lucero Control Unit Type 222A.
    - (vi) Scanner Speed Control Unit Type 477.

(b) The Fishpond indicator (and its bright-up generator, WFG Type 43) will be at the wireless operator's position.

(c) The following will form part of the stabilised scanner installation at or near the perspex cupola:-
    - (i) Adaptor frame for the stabilised platform.
    - (ii) Platform and scanner.
    - (iii) Transmitter unit.
    - (iv) Amplifier unit A.3562.
    - (v) Gyro Control Unit Type 453.
    - (vi) Motor generator Type 74.
    - (vii) Junction boxes 246 and 247.

(d) The track marker control unit type 468 is mounted at the Mark 14 bombsight position.

(e) The remaining units are mainly located in suitable racks amidships. The details will vary somewhat from one aircraft to another and may be modified as required to provide for other radar installations.

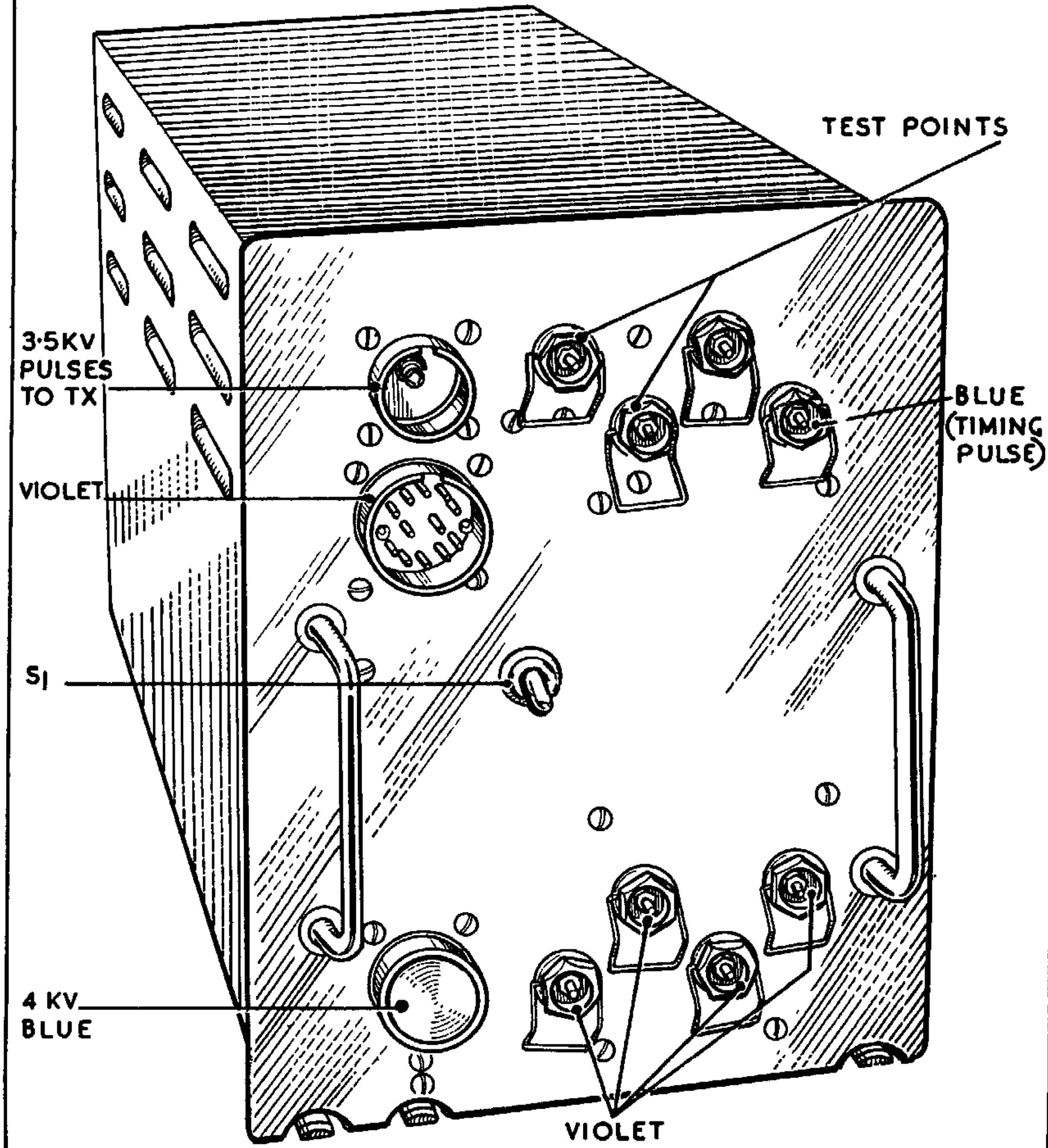


T.R. 3555 – PANEL VIEW

FIG. 16

FIG. 16

C.D. 0896 L

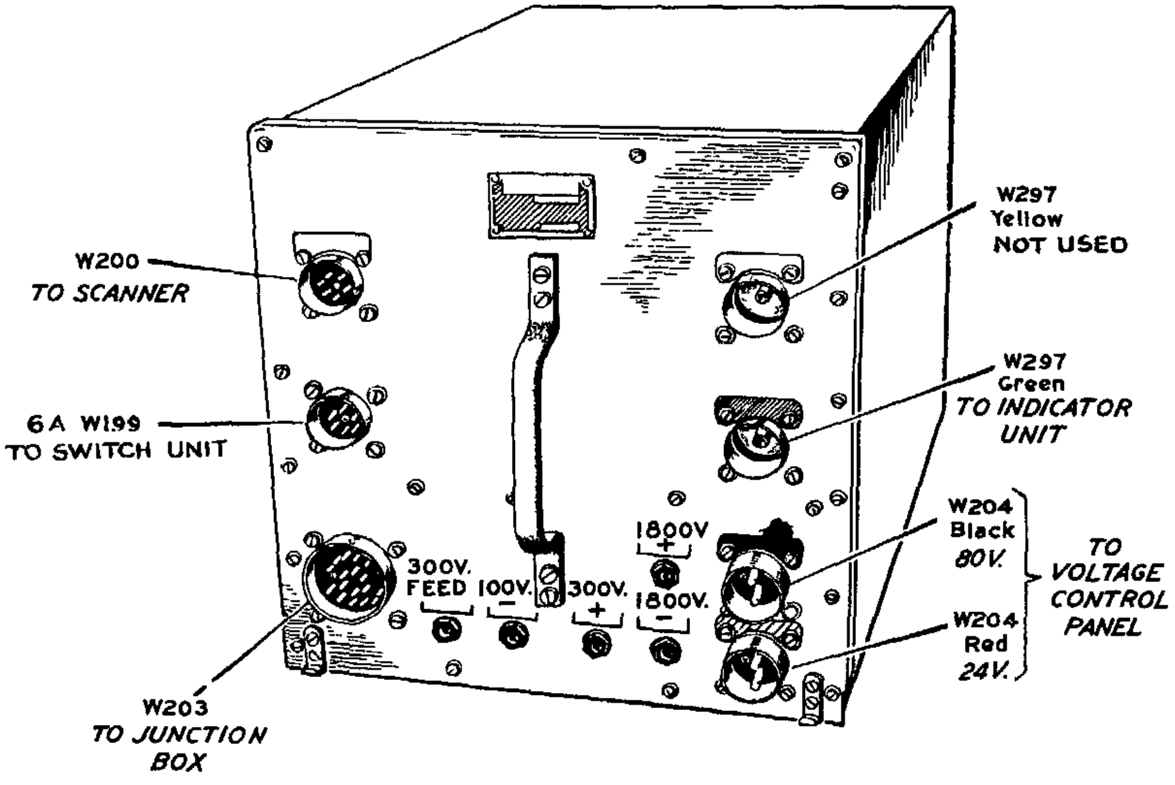


PANEL VIEW

MODULATOR TYPE 64

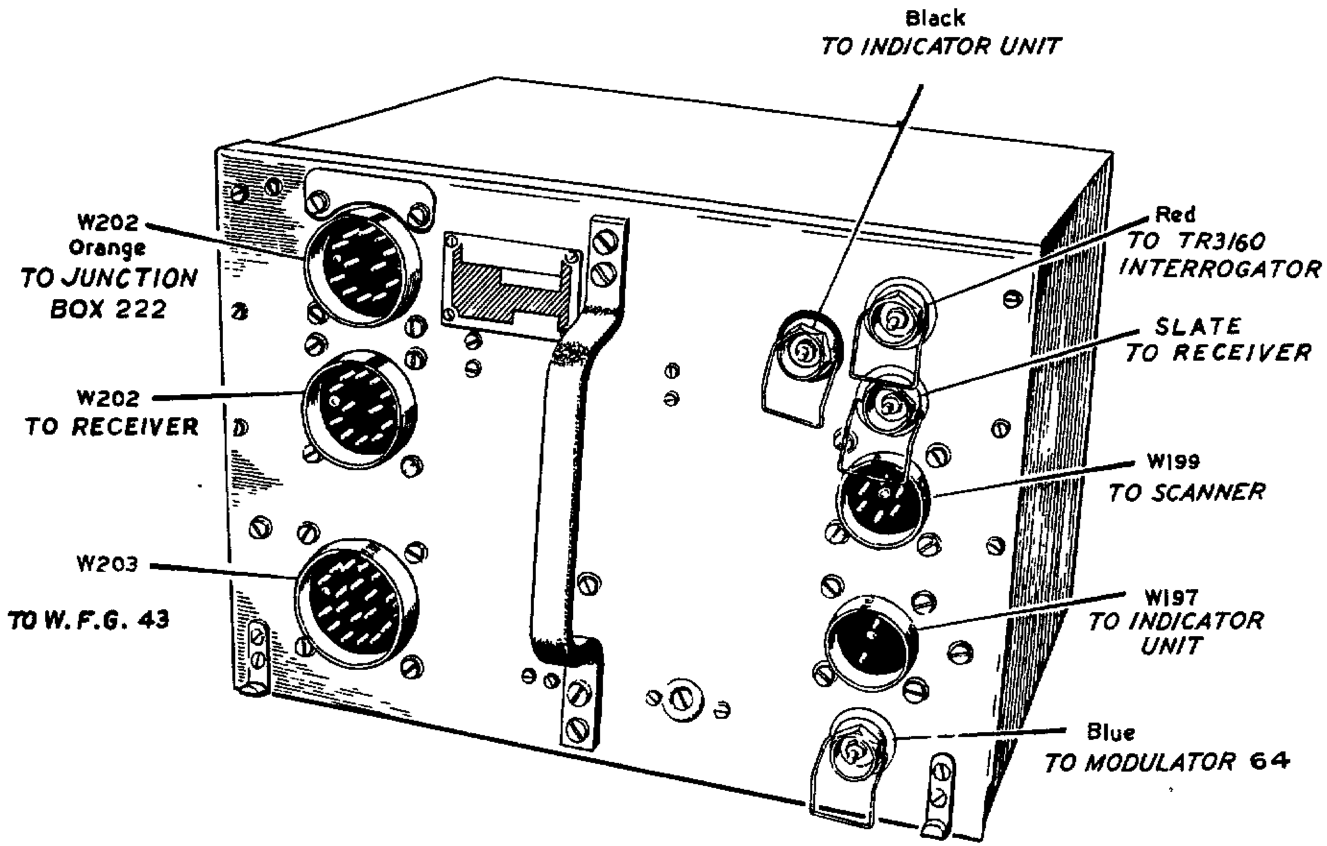
FIG. 17

FIG. 17



POWER UNIT TYPE 280

FIG. 18 FIG. 18



WAVEFORM GENERATOR TYPE 34

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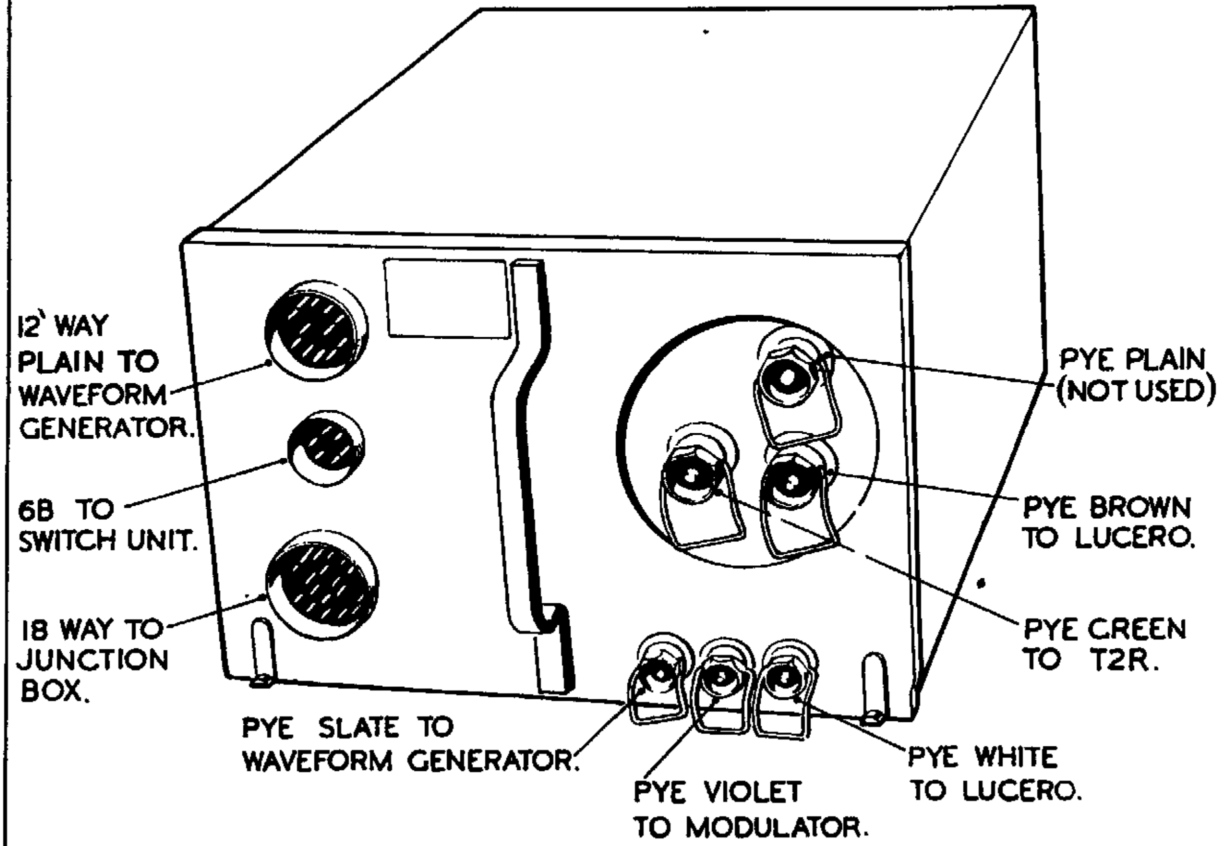


FIG. 21 - RECEIVER UNIT TYPE 3553

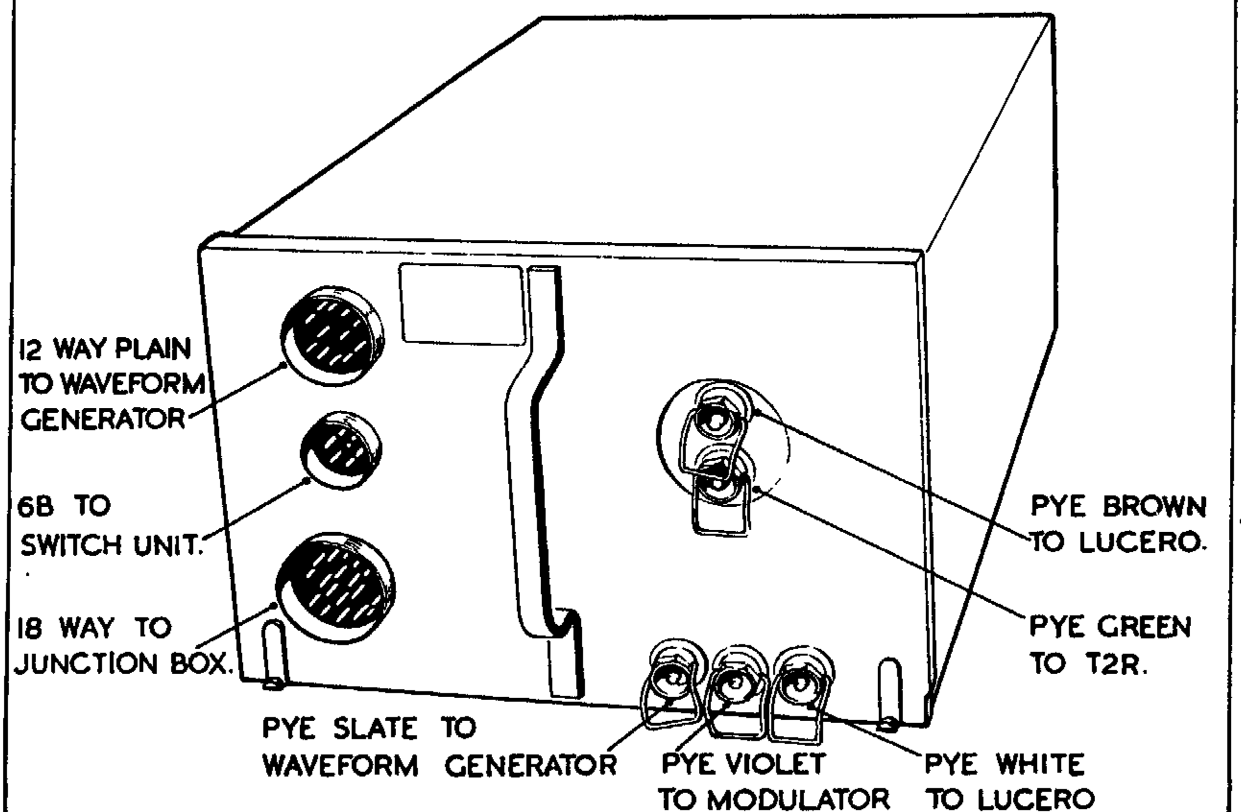
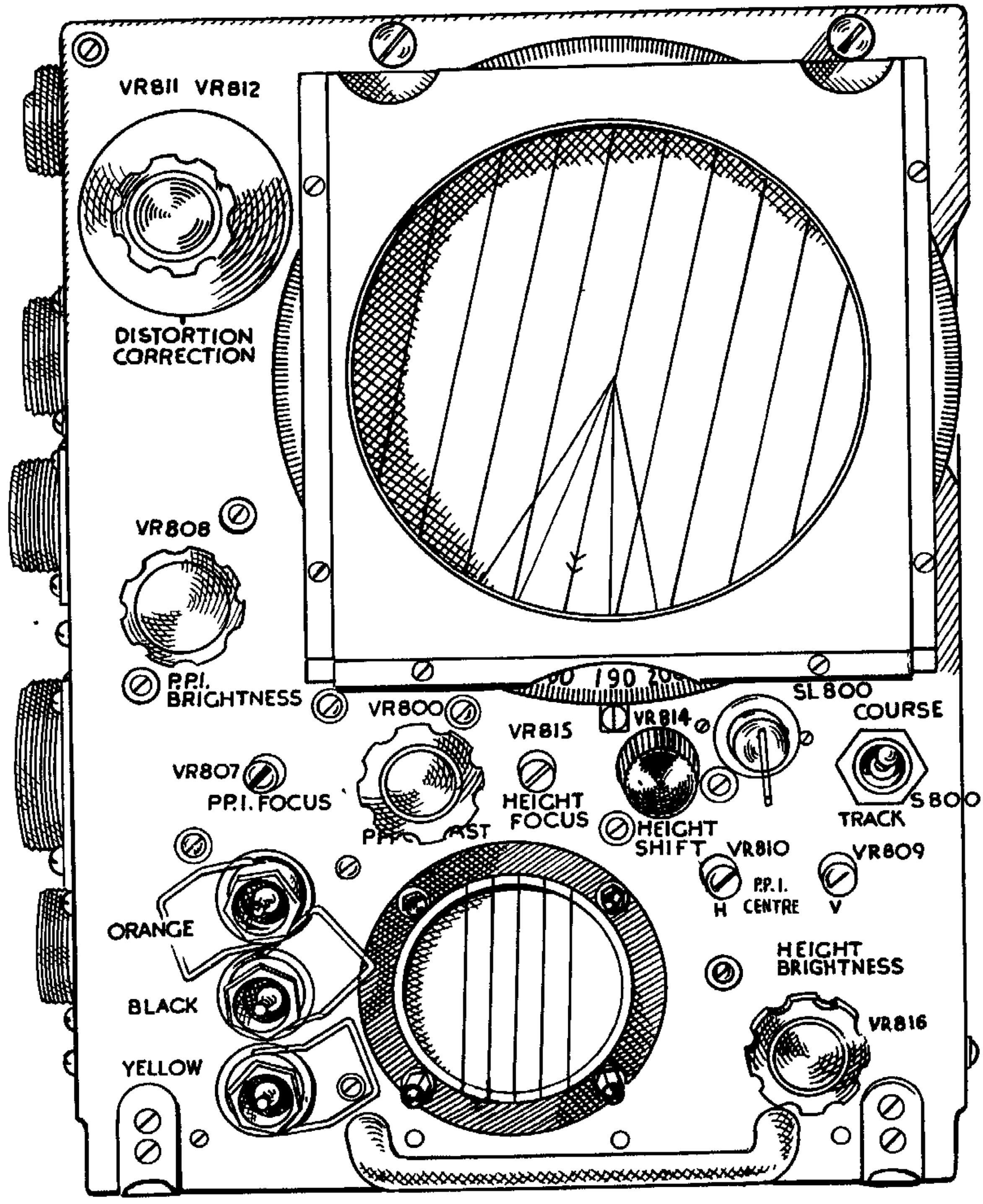


FIG. 20 RECEIVER UNIT TYPE 3515

FIG. 20 & 21

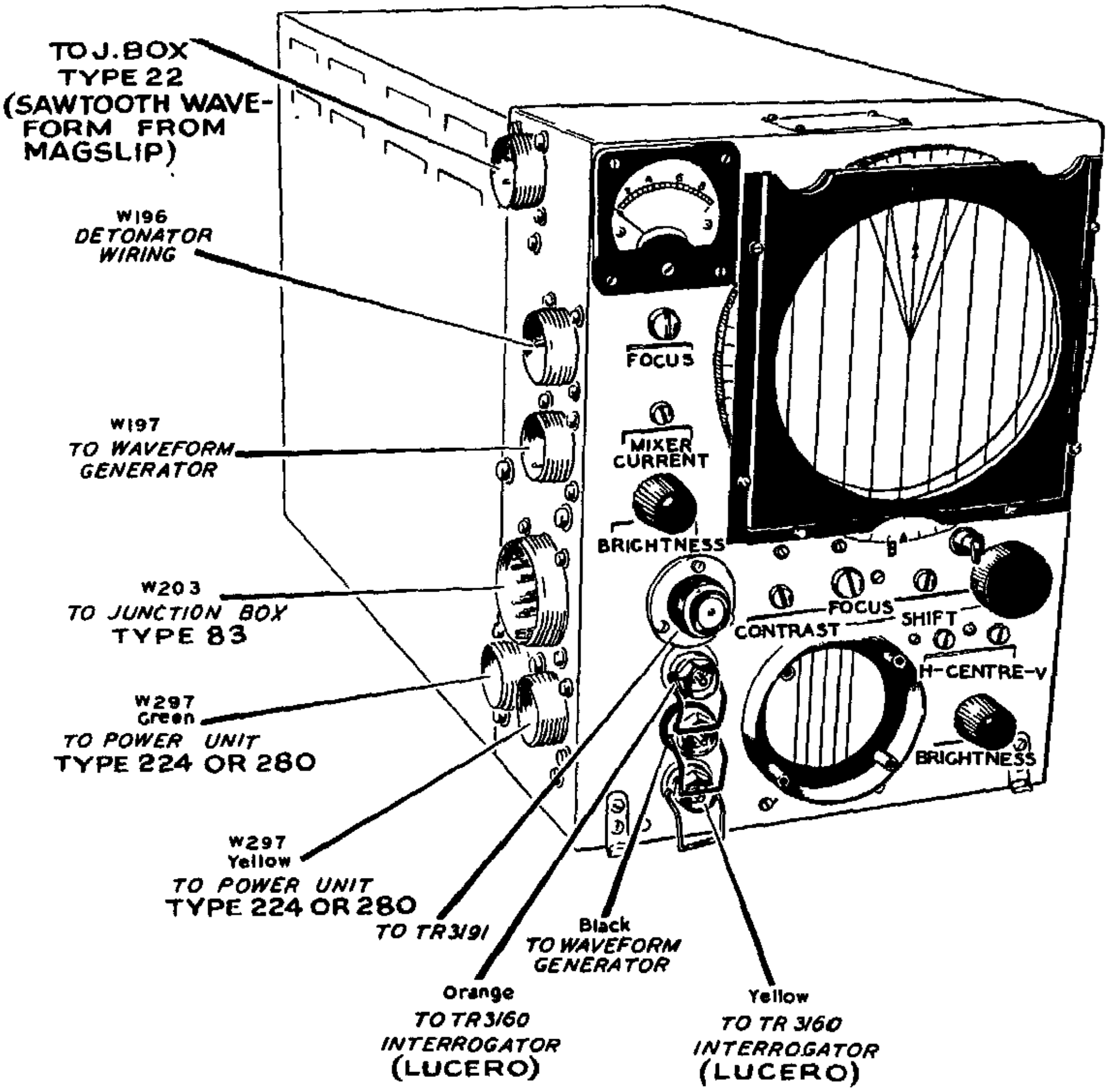


PANEL VIEW

INDICATOR UNIT TYPE 184A

FIG. 22

FIG. 22

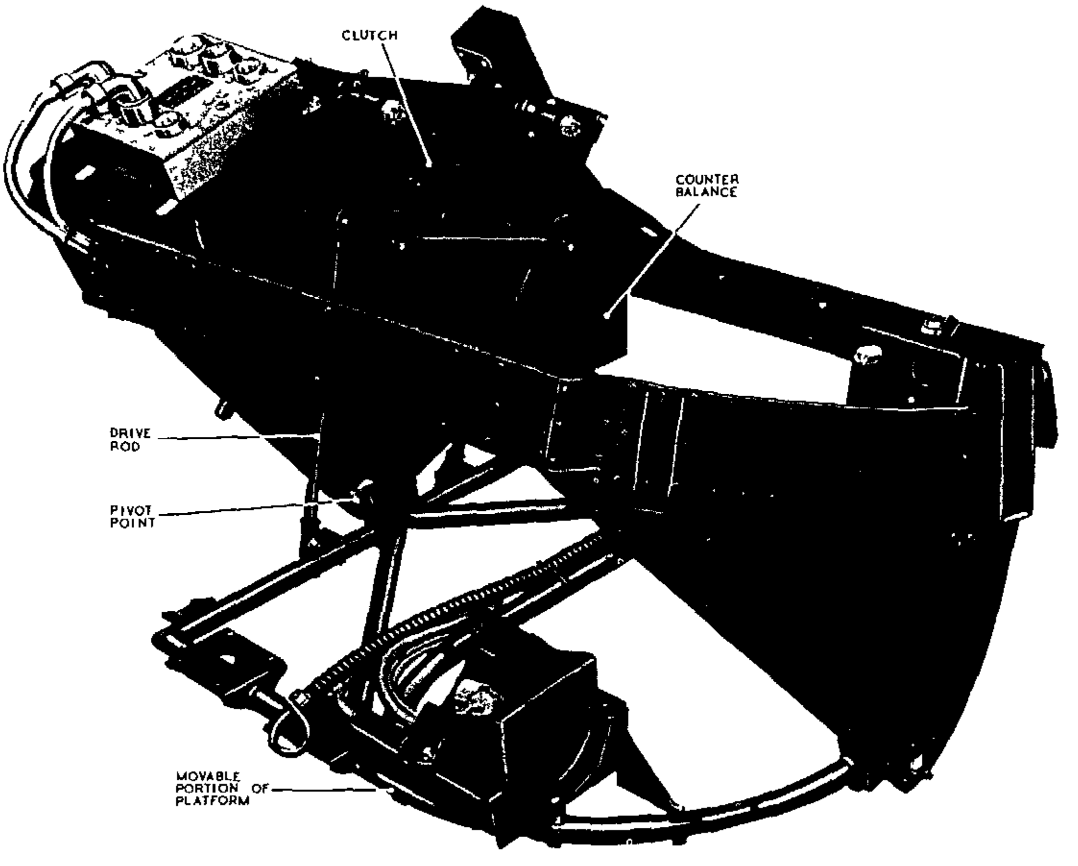


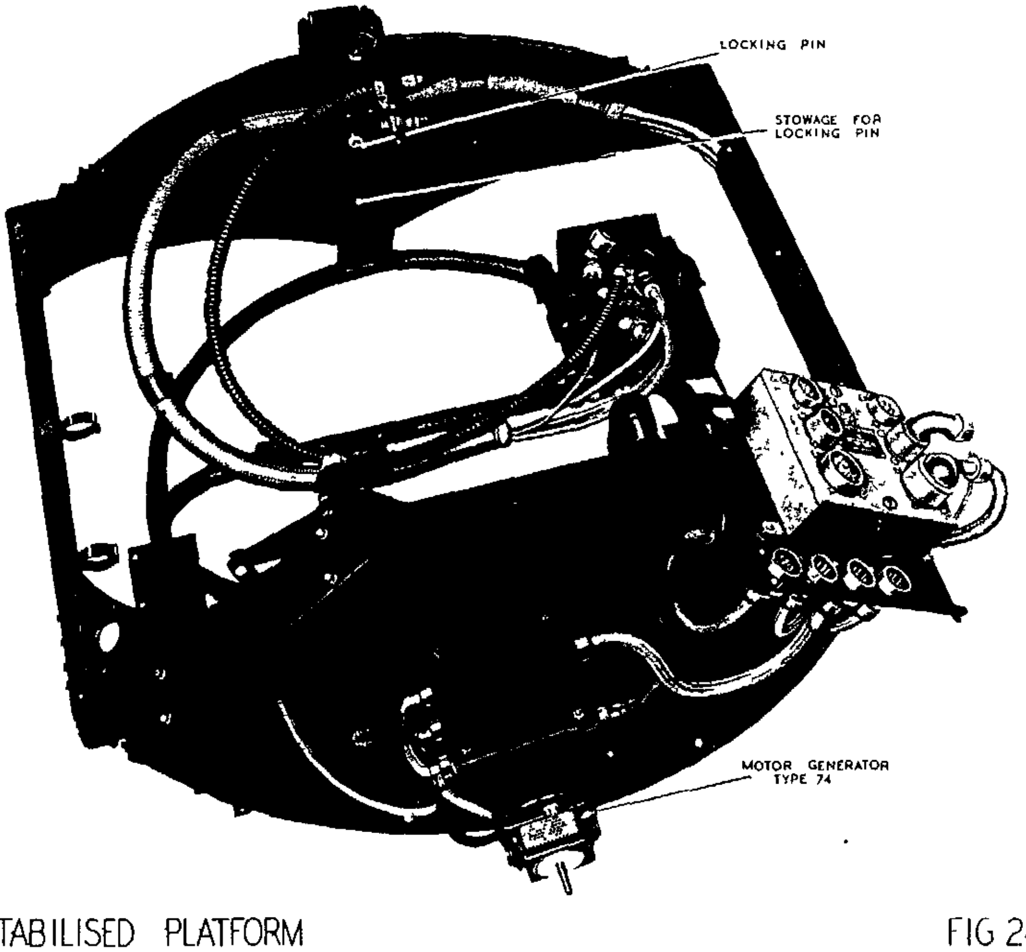
INDICATOR UNIT

TYPE 162

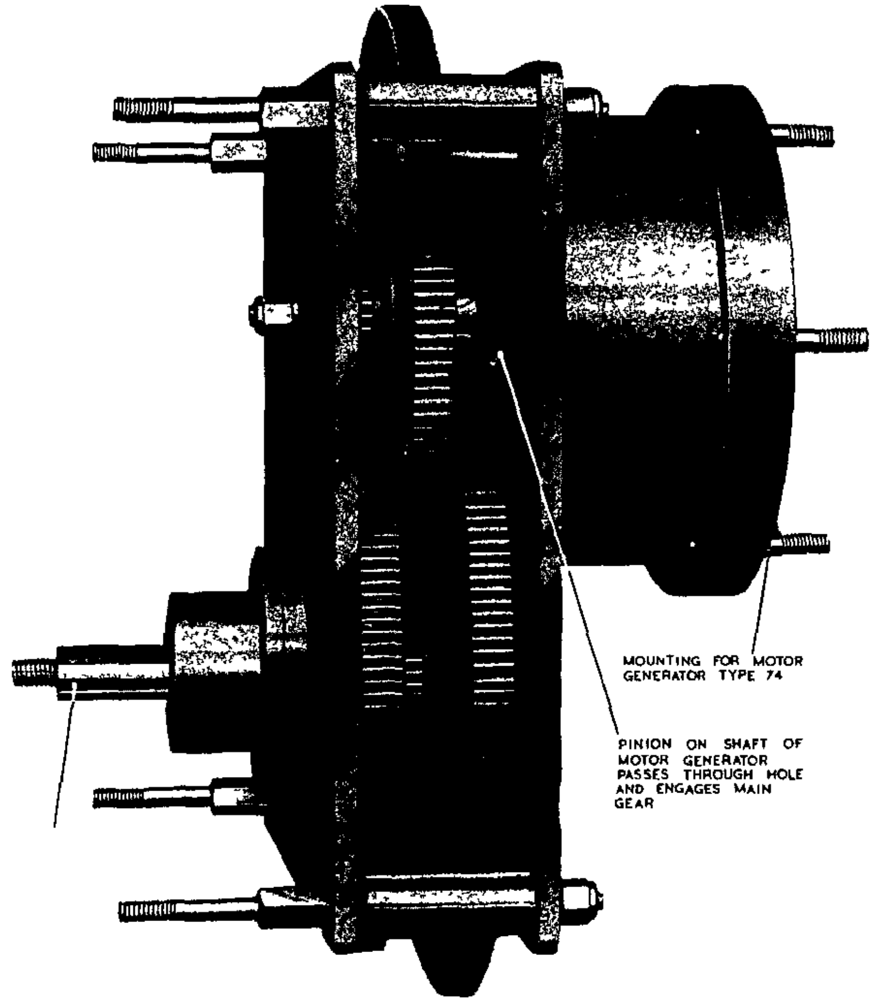
FIG. 23

FIG.23

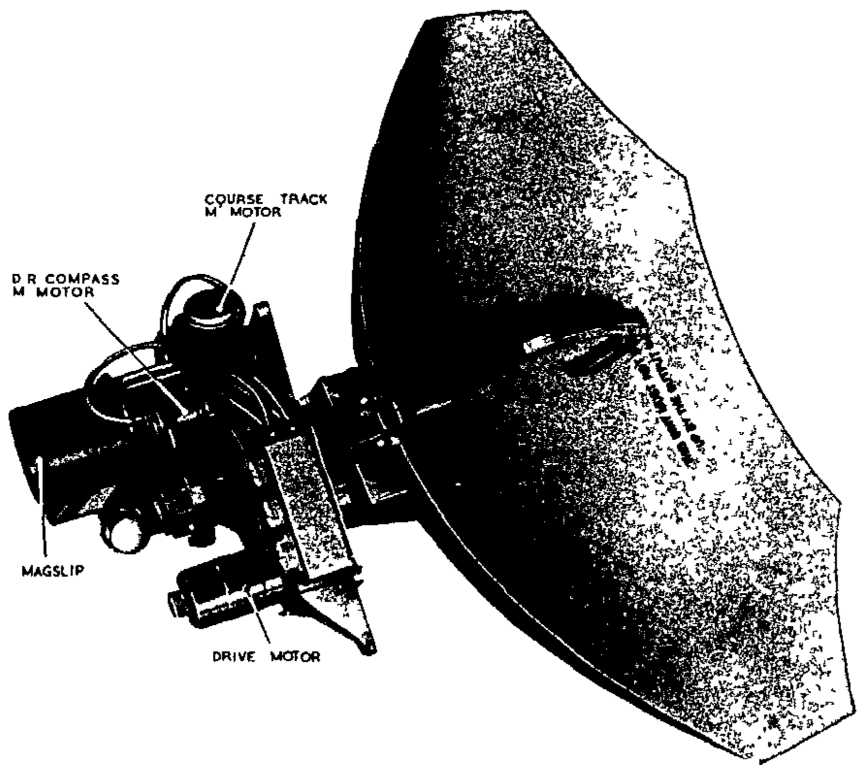




STABILISED PLATFORM FIG 24

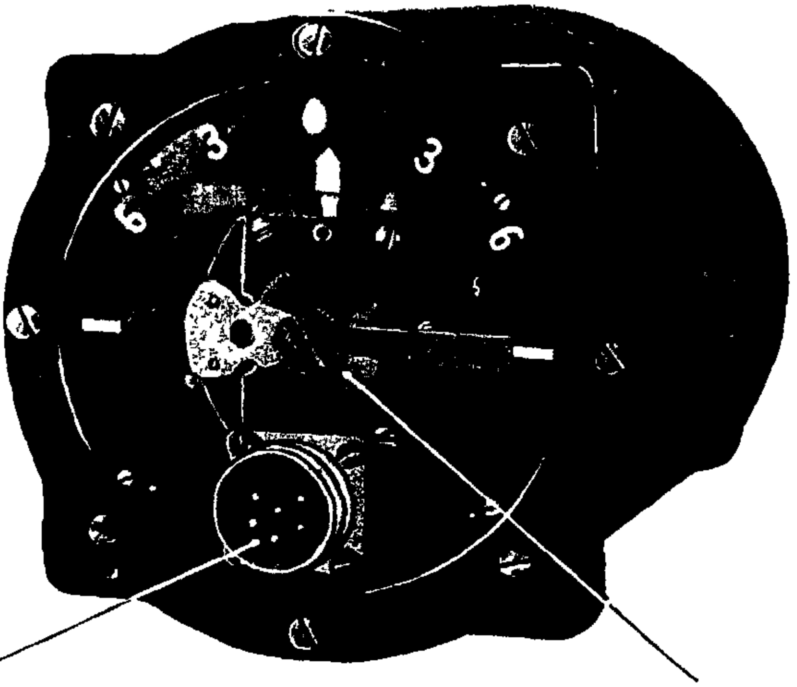


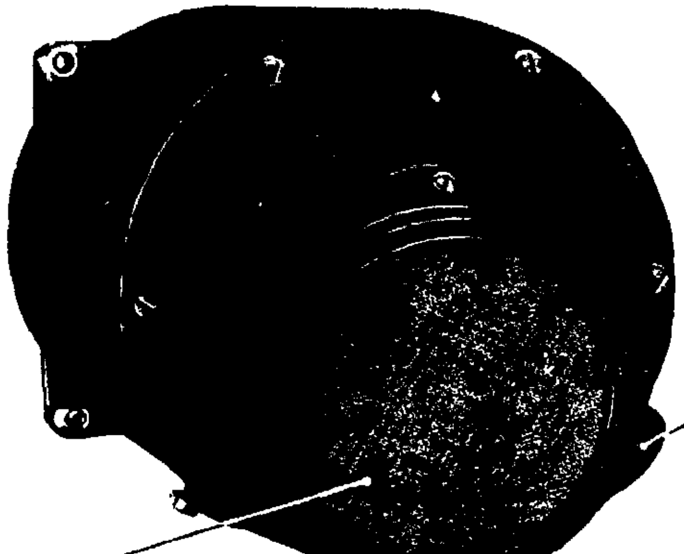
REDUCTION GEARING TO PLATFORM



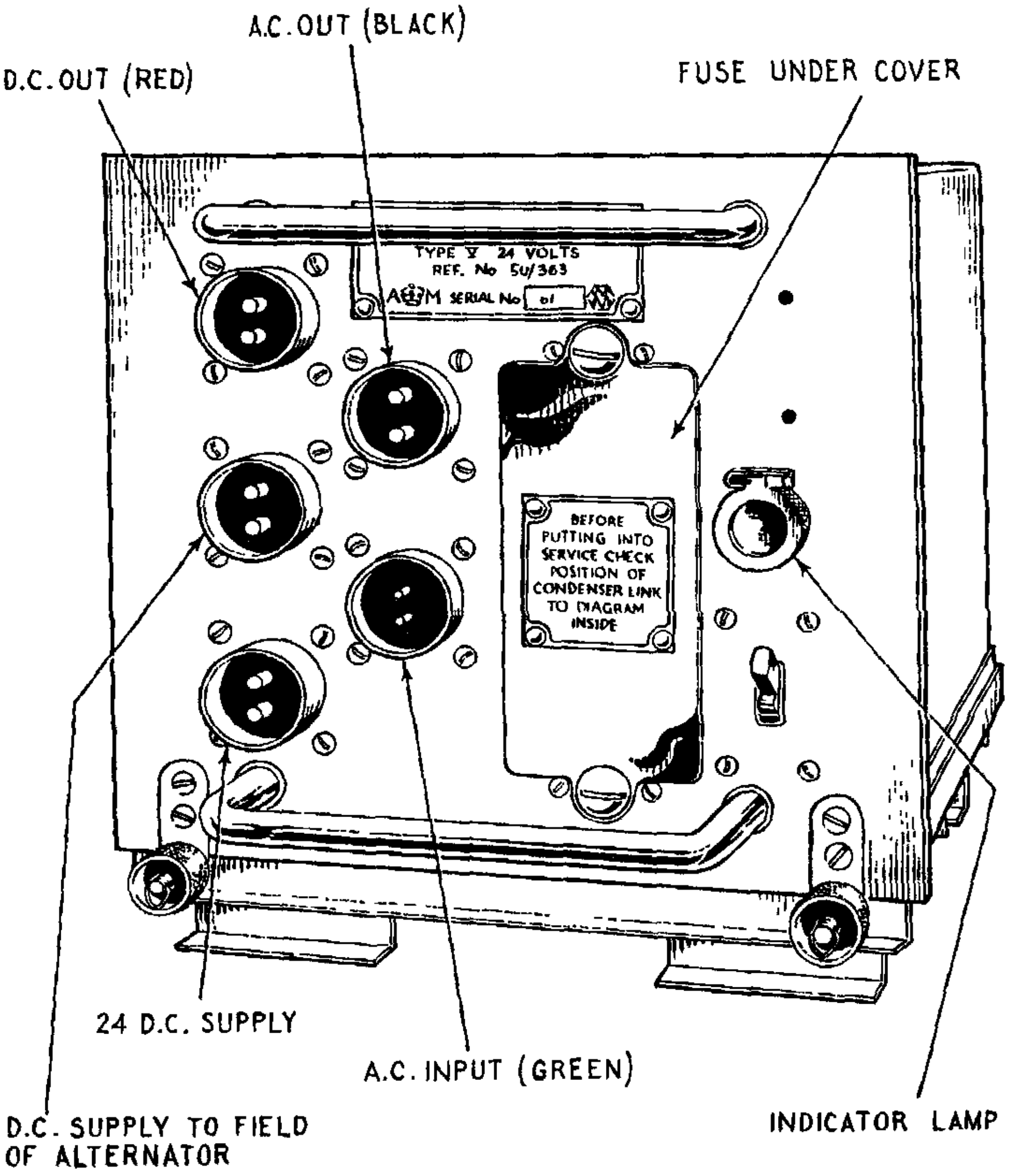
SCANNER UNIT TYPE 71

FIG 25





GYRO UNIT TYPE 453 . FIG. 26



CONTROL PANEL TYPE 5

FIG 27

C.D 0896 L

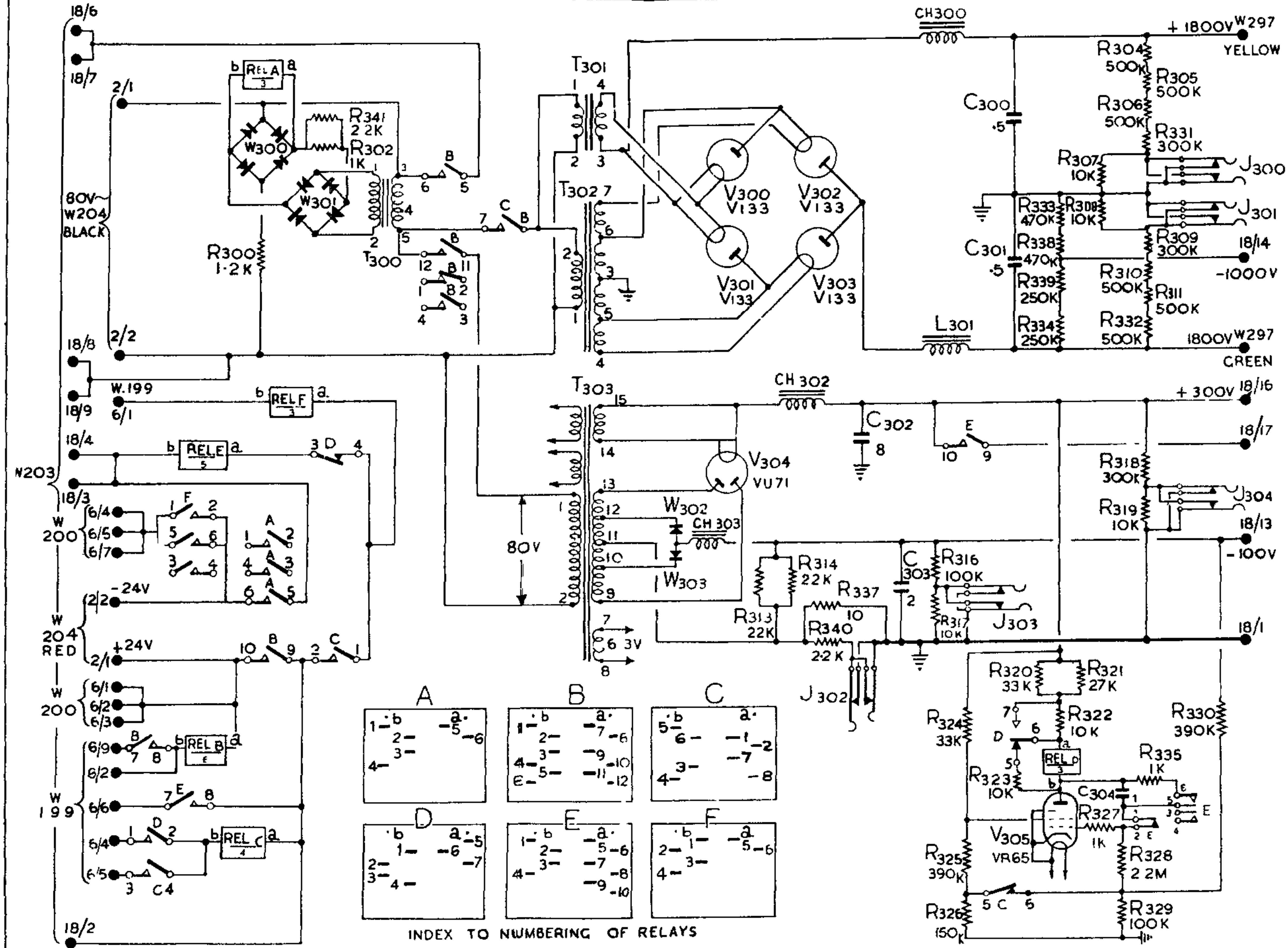
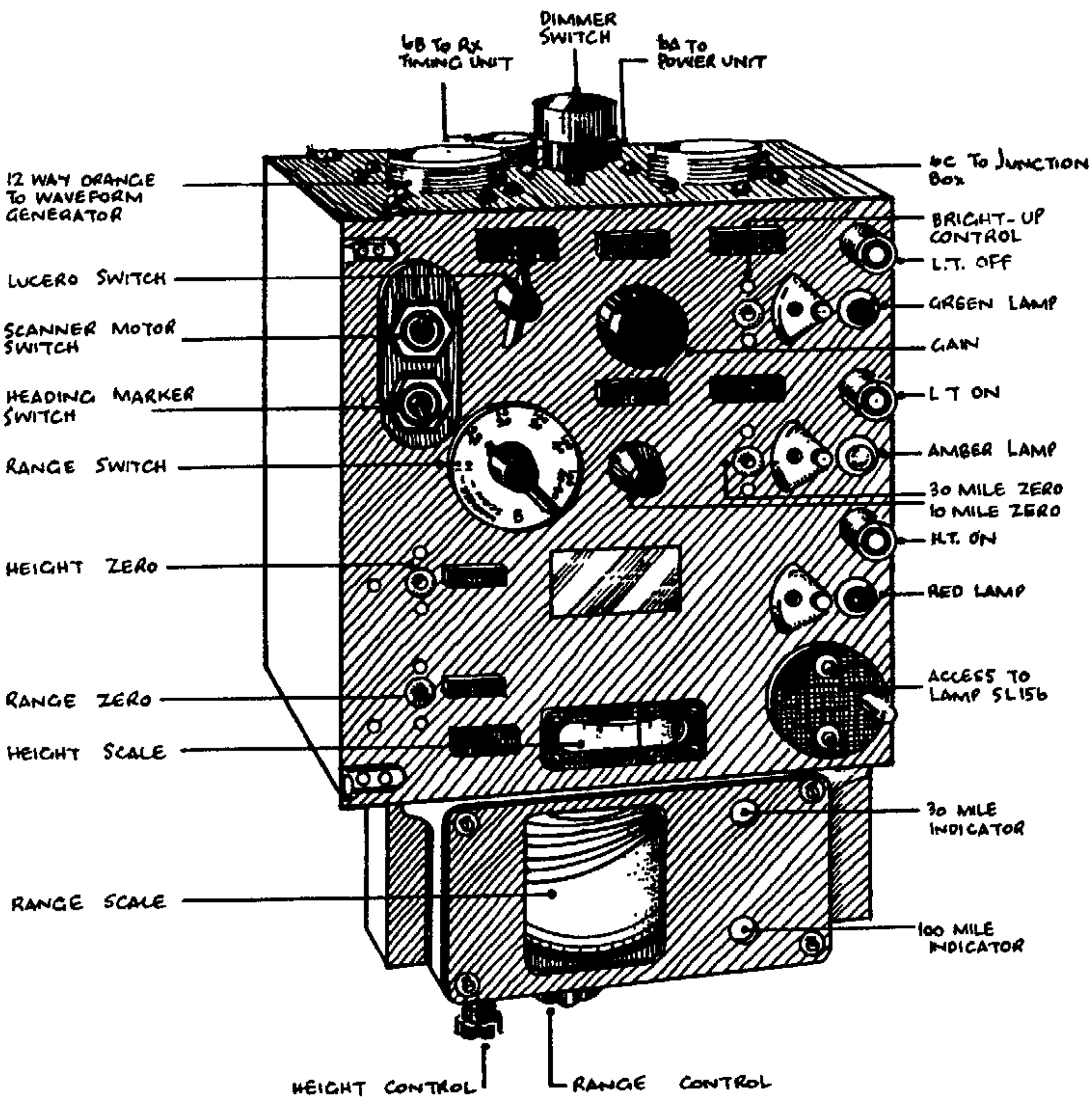


FIG.28

POWER UNIT TYPE 280, CIRCUIT

FIG.28



SWITCH UNIT TYPE 207B

FIG.29

CHAPTER 3 - POWER SUPPLIES

Outline

50. The H.2.S. power supplies are derived from the aircraft 24V. D.C. supply and a Type U 1200 watt engine-driven alternator. The 24V. D.C. supply is taken to a control unit, Type 5, which regulates the D.C. field current to the alternator so as to maintain the A.C. output voltage from the alternator at a constant value of 80V. in spite of fluctuations in engine speed. For engine speeds varying between 1500 and 2600 r.p.m., the maximum variation of the output voltage from the alternator should not exceed ± 2V.

51. The 24V. D.C. supply and the 80V. A.C. supply are taken to the H.2.S. power unit from which they are distributed to the other units via a junction box. The Mark IIC installation uses a junction box type 83 and the Mark IIIA installation a junction box type 231. The 24V. supply is used for operating various motors and relays. Details of the distribution channel are shown in figs.210 and 211. The 80V. supply is distributed for the development of heater supplies, biasses and H.T. supplies.

52. The power unit proper develops the following supplies:-

(a) +300V. from a 5U4G full-wave rectifier stage.
(b) + and - 1800V. from two VU.133, full-wave rectifier stages balanced about earth potential.
(c) -100V. developed from a bridge metal rectifier.
(d) The -1800V. supply is tapped down on a bleeder to provide a -1000V. output.

The +300V. and -1000V. supplies are distributed via the main junction box. The -18000V. supply is transferred directly via a uniplug cable. The +1800V. supply is not used.

53. The modulator type 64 develops the following supplies:-

(a) -4KV. from a single-ended voltage doubler stage. This supply is used to develop the modulating pulse for the transmitter. An output is also tapped off which is used to provide the bleeder supply for the indicator 184 and Fishpond P.P.I. tubes.
(b) -100V. bias supply from a metal rectifier used only inside the modulator.

54. The tuning unit 207 used in the Mark IIC installation contains a +300V. 5U4G double half-wave rectifier which is used to supply the H.T. for the indicator 184.

55. The receiver-timing unit used in the Mark IIIA installation contains an independent power pack which includes:-

(a) A +300V. 5U4G full-wave rectifier stage which supplies the H.T. for the receiver-timing unit, the H.T. and screen voltage for the I.F. strip, and the variable screen voltage for the second head amplifier stage.
(b) A -100V. neon-stabilised metal rectifier for bias voltages.

56. The indicator 184 has a -300V. metal rectifier supply used as a negative rail for the timebase valves. This supply is also used for biasses in the TR.3523.

57. The TR.3555 series transmitter unit has a -2KV. VU.111 half-wave rectifier pack with special stabilisation arrangements. This pack provides the supply voltages for the CV.129 klystron local oscillator and the CV.114 soft rhumbatron TR. switch.

58. The TR.3523 transmitter unit has a power pack which develops the following supplies:-

(a) A 5U4G +300V. full-wave pack with a CV.173 stabiliser stage swinging positive from a level of around 300V. fixed by the 300V. pack in the power unit.
(b) A VU.111 - 1000V. half-wave rectifier pack with a tapped down -300V. neon-stabilised output. The -1000V. supply is used for the CV.221 soft rhumbatron TR. switch.

Both the +300 and -300V. supplies are used on the 723A local oscillators.

59. Fishpond has a 5Y4G 400V. full-wave rectifier supply for the Fishpond valves.

60. The Amplifier Unit, Type A.3562, used in the roll stabilised scanner has its own power pack which develops the following outputs:-

(a) A 5U4G full-wave rectifier develops a +300V. supply for the amplifier valves.
(b) A selenium rectifier develops a 60V. supply fed to the slab-wound potentiometer in the Gyro control unit.

61. The Lucero Mark II unit contains its own power unit which develops:-

(a) -2.5KV. VU.120 half-wave rectifier supply for the Lucero transmitter.
(b) 250V. 5Z4G full-wave rectifier supply for the other Lucero stages.

62. The W.F.G.34 has a VR.116 voltage stabiliser which drops the 300V. supply to provide a stabilised 200V. supply for the master multivibrator stages, first three sawtooth stages and the transmitter-timing valve.

63. The receiver-timing unit has a VR.65 voltage stabiliser stage which provides a stabilised H.T. supply of around 290V. for the height and range marker timing and flip-flop stages and for the heading or track marker circuits.

64. The power unit has a safety circuit stage which operates relays to switch the equipment off if an overload develops.

65. The modulator type 64 also has a safety circuit valve stage which operates relays to switch off the Modulator HT if an overload is applied to the modulator -4KV. pack.

The Power Unit Supplies

General

66. (a) The power unit circuit is shown in fig.28.
(b) The distribution channels are shown in the interconnection diagrams, figs. 210 and 211.

The + and - 1800V. Pack

67. The essentials of this stage are shown in fig.30. 80V. A.C. is fed to the primary of the high voltage transformer, T.302. V.300 and V.301 together form a full-wave rectifier which develops an output of +1800V. smoothed by CK.300 and C.300 and applied to the yellow W uniplug. V.302 and V.303 form a second full-wave rectifier which develops a -1800V. output.

This output is smoothed by CK.301 and C.301 and applied to the green W uniplug.

68. Across the -1800V. output is a bleeder network consisting of R.333, R.338, R.339 and R.334. About -1000V. is tapped off at the junction of R.338 and R.339 and taken to pin 14 of the 18-way plug.

The +300V. Pack

69. The full-wave rectifier, V.304 is fed from the tapped secondary of T.303. The 300V. output, smoothed by CK.302 and C.302, is applied to pin 16 of the 18-way plug.

The -100V. Supply

70. The metal rectifiers, MR.302 and MR.303, are also fed from the tapped secondary of T.303. The -100V. output, smoothed by CK.303 and C.303, is applied to pin 13 of the 18-way plug.

Summary

71. Power Unit inputs are:-

(a) 24V. D.C. at red 2C supplied from aircraft supply via the V.C.P. Type 5.
(b) 80V. A.C. at the black 2C from the engine-driven 1.2KW. alternator, regulated by the V.C.P. Type 5.

72. Power Unit outputs are:-

(a) -1800V. at green W uniplug.
(b) +1800V. at yellow W uniplug (not used).
(c) -1000V. at pin 14 of the 18-way plug.
(d) +300V. at pin 16 of the 18-way plug.
(e) -100V. at pin 13 of the 18-way plug.
(f) -24V. D.C. (switched) to pin 2 of 18-way.
+24V. D.C. (unswitched) to pin 3 of 18-way.
-24V. D.C. (unswitched) to pin 2 of 6A.
-24V. D.C. (switched) to pins 1, 3, 4, 5, 6 of 6A.
(g) 80V. A.C. to pins 6 and 7 (strapped) and to pins 8 and 9 (strapped) on the 18-way when B relay is energised.

The Power Unit Jack Points

73. On the front panel of the power unit are 4 jack points for checking the +1800V., -1800V., +300V. and -100V. supplies. A fifth jack marked "300V. Feed" gives an indication of the total current drain from the 300V. rectifier. Any meter having suitable current ranges may be used for checking. The meter positive should go to the jack tip and the negative to the ring for all the jack points. Normal readings of the voltage jack points are as follows:-

Jack	Normal Reading		Tolerance
	PU 280	PU 224	
+1800V.	1 ma.	1.8 ma.	± 10%
-1800V.	1 ma.	1.8 ma.	± 10%
-100V.	1 ma.	1.0 ma.	± 10%
+300V.	1 ma.	0.3 ma.	± 10%

74. The 300V. feed jack point reading with the H.2.S. Mark II installation used to be 1.2 - 1.6 ma. In the Mark IIC and Mark IIIA installations the value is of the order of 0.8 - 1.0 ma. as the Mark IIIA installation has an added 300V. pack for the receiver while the Mark IIC installation uses an added -300V. pack for the indicator 184.

The Power Unit Relays and the Switching ON Sequence

75. The alternator switch at the navigator's table is in series with the

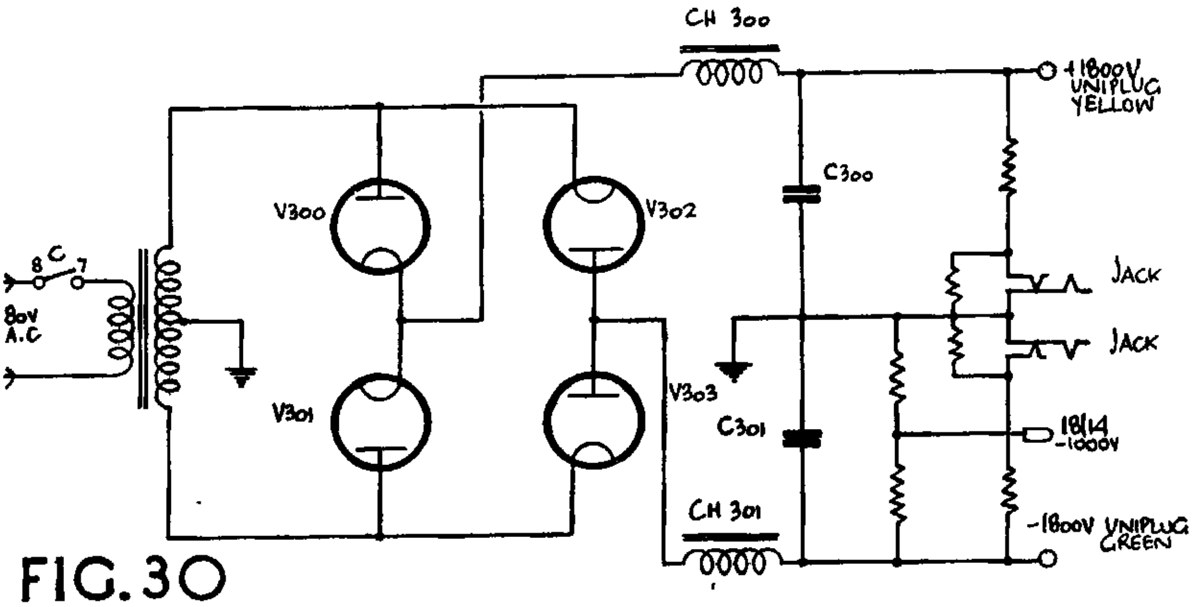


FIG. 30

EQUIVALENT CIRCUIT OF HIGH VOLTAGE RECTIFIER IN POWER UNIT

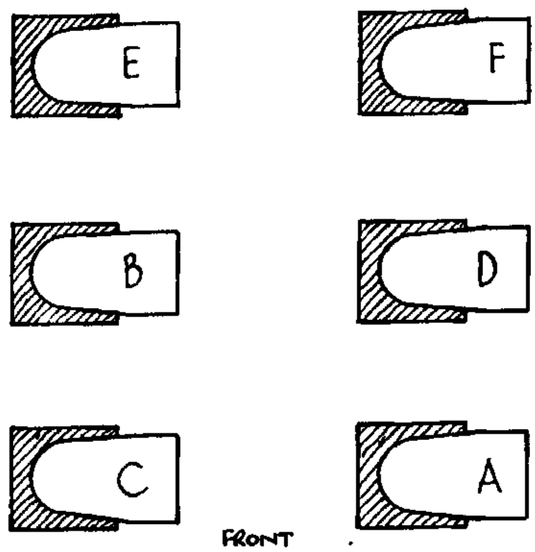
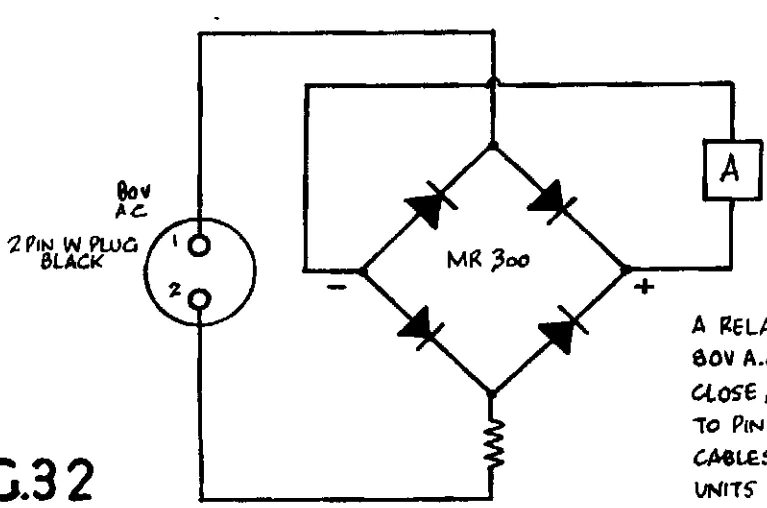


FIG. 31

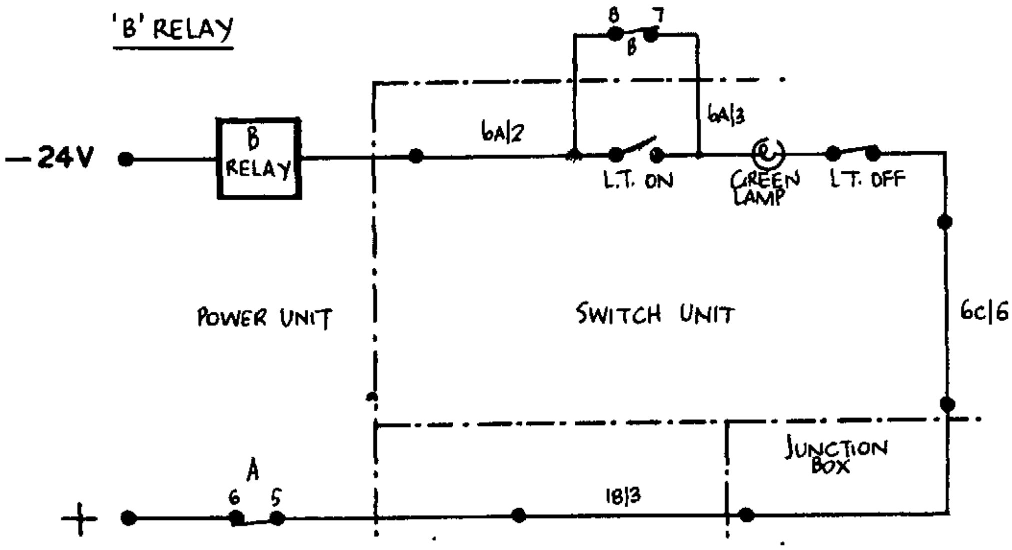
POWER UNIT RELAYS



A RELAY ENERGISED BY 80V A.C. CONTACTS A 5/6 CLOSE, CONNECTING -24V TO PIN 3 OF ALL 18 WAY CABLES, ALSO TO SOME OTHER UNITS E.G. T2R

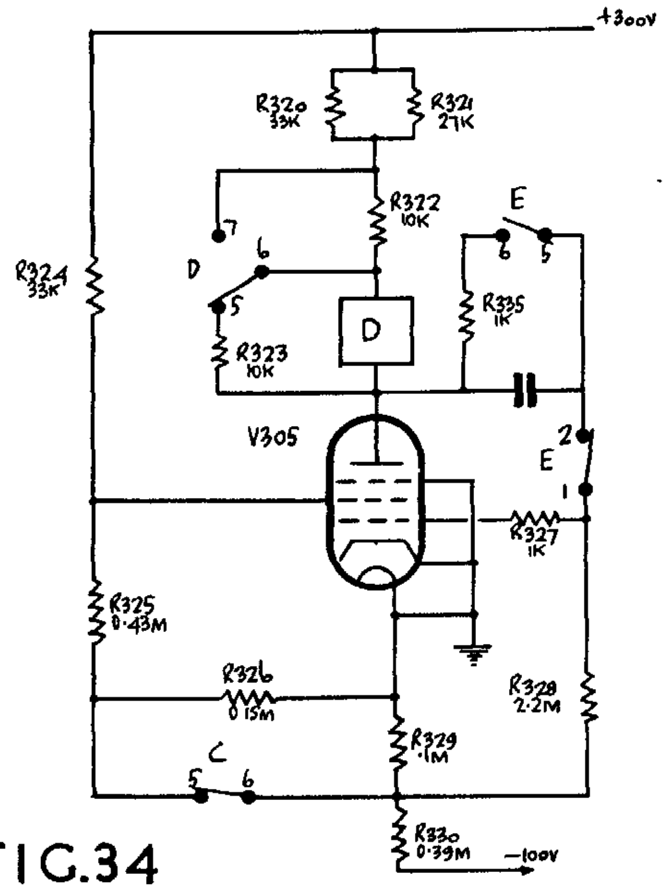
FIG. 32

'A' RELAY



'B' RELAY IS ENERGISED WHEN "L.T ON" IS PRESSED. CONTACTS B7/8 SHORT "L.T. ON" SWITCH. B RELAY CONNECTS 80V TO PIN 7 OF ALL 18 WAY CABLES, +24V TO PIN 2 OF ALL 18 WAY CABLES, AND 80V FROM OVERLOAD TRANSFORMER TO T303 PRIMARY (300V RECTIFIER)

FIG.33



ABOUT 30 SECONDS AFTER PRESSING "L.T. ON", V305 ANODE CURRENT BUILDS UP SUFFICIENTLY TO ENERGISE D RELAY. D15 MOVES TO D17, INCREASING ANODE CURRENT AND STRENGTHENING HOLD OF D RELAY. D RELAY PREPARES OPERATING CIRCUIT OF C RELAY. WHEN "H.T. ON" IS PRESSED C RELAY ENERGISES. AFTER A DELAY D RELAY DE-ENERGISES AND COMPLETES E RELAY ENERGISING CIRCUIT.

D RELAY AND THE DELAY VALVE

FIG.34

V.C.P. switch which will normally be left on. When the alternator switch is closed the field supply to the alternator is completed and the 80V. supply will be developed and fed to the power unit. Closing the alternator switch also completes the 24V. D.C. supply to the power unit. The 80V. input is rectified by MR.300 and energised relay A. Contacts 5 and 6 close and complete the +24V. D.C. line to the switch unit via 18/3 and 6C/6.

76. Pressing the "L.T. ON" button on the switch unit completes the D.C. circuit through the green lamp (SL.150) and 6A/2 to energise B relay whose contacts make the following connections:-

(a) B7/8 complete the 24V. circuit via 6A/3 and the green switch lamp so that B relay remains energised when the pressure is released on the "L.T. ON" button.
(b) B5/6 connect 80V. A.C. to the junction box via pins 6 and 7 of the 18-way. Pins 8 and 9 of the 18-way were connected to the other side of the 80V. A.C. when the alternator was switched on.
(c) B9/10 connect the -24V. D.C. to the junction box via 18/2 to complete the circuit for the blower motor in the transmitter unit. -24V. D.C. is also connected to relay C, relays in the RX, WFG, Fishpond and Lucero, and to the scanner motor and repeater motors.
(d) B11/12 complete the 80V. A.C. supply to the primary of T.303. V.304 comes into operation to develop the +300V. output. The metal rectifiers MR.302, MR.303 now develop the -100V. bias supply. The delay valve, V.305, starts to pass current since its filament is supplied from a winding on T.303.

77. With relay C unenergised, the contacts C5/6 in the grid circuit are closed. Before V.305 commences to pass current its electrodes are at the following potentials:-

(a)	Anode	+300V.
(b)	Screen	+280V.
(c)	Grid	+ 15V.
(d)	Suppressor and cathode	0V.

Within a few seconds of pressing the "L.T. ON" button V.305 starts to pass current and there is a fall in the anode potential. This fall is fed back to the grid via C.304 and contacts 1/2 of relay E. This tendency of the fall in anode potential to carry the grid down retards the build-up of anode current sufficiently to make a delay of 30-40 seconds before sufficient anode current flows to energise relay D (RY.303).

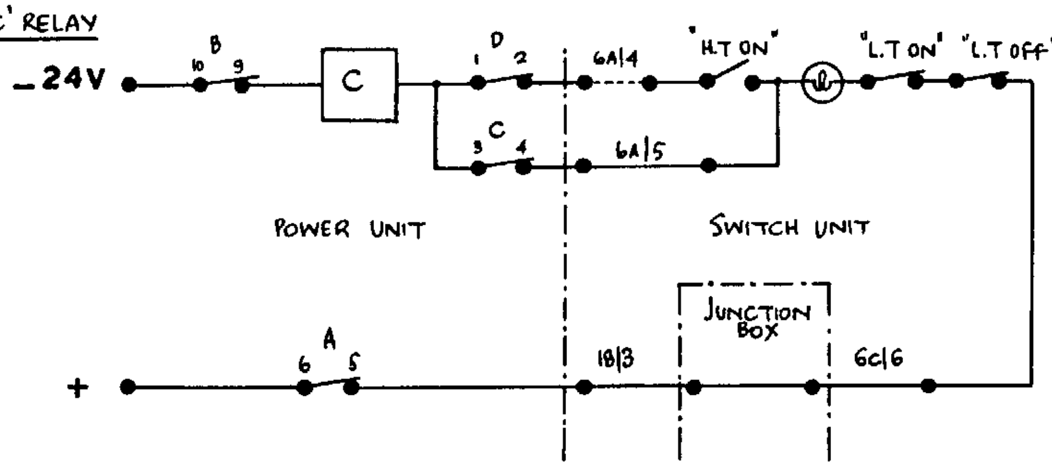
78. When relay D is energised the following circuit changes occur:-

(a) Contact 6 breaks from contact 5 and closes to contact 7 to remove the shunting resistor R.323 and short out R.322. This increases the current through the relay and so holds the relay well energised.
(b) Contacts D1/2 connect relay C to the "H.T. ON" button on the switch unit via pin 4 of the 6A W-plug.
(c) Contacts D3/4, which were closed when the relay was unenergised, now open and break the -24V. supply to relay E. This has no effect at this stage since relay E was not energised.

79. If the "H.T. ON" button is now pressed on the switch unit, the 24V. D.C. circuit to relay C is completed via the amber pilot lamp (SL.151) and 6A/4. The following circuit changes occur with the energising of relay C:-

(a) Contacts C3/4 close to complete the 24V. supply through the solenoid via the amber pilot lamp and 6A/5 when pressure is released from the "H.T. ON" button.

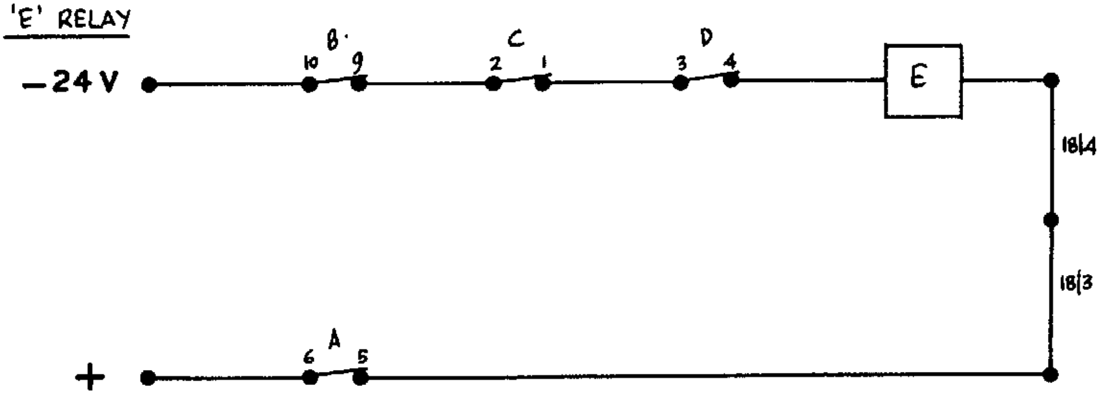
'C' RELAY



'C' RELAY IS ENERGISED BY "H T ON" BUTTON C 3|4 HOLD RELAY ENERGISED. C5|6 REMOVE THE BIAS FROM V305. AFTER ABOUT 30 SECS. V305 ANODE CURRENT FALLS SUFFICIENTLY FOR D RELAY TO DE-ENERGISE. CONTACTS D3|4 CLOSE WHEN D DE-ENERGISES AND COMPLETE ENERGISING CIRCUIT FOR E RELAY

FIG.35

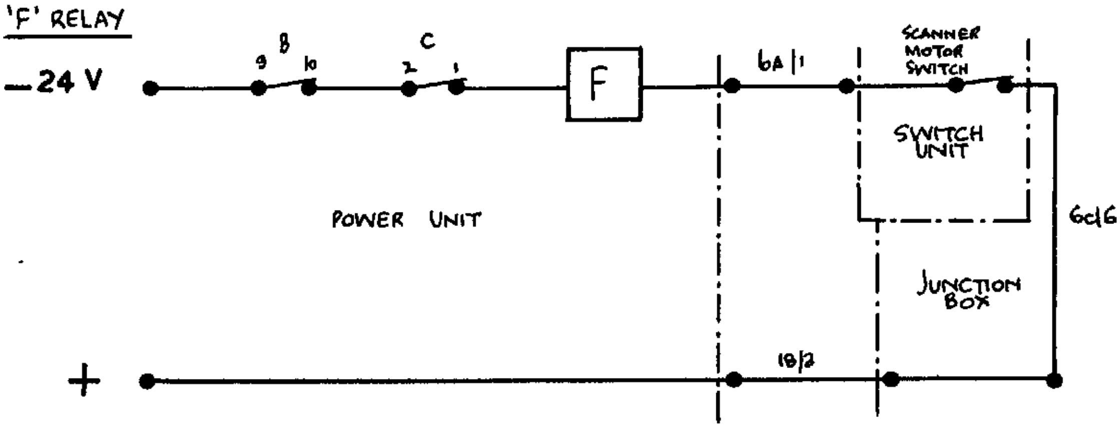
'E' RELAY



'E' RELAY IS ENERGISED WHEN 'D' DE-ENERGISES, CLOSING CONTACTS D 3|4. CONTACTS E 7|8 CONNECT L.T.+ TO RED LAMP.

FIG.36

'F' RELAY



'F' RELAY IS ENERGISED WHEN 'C' RELAY ENERGISES. IF MOTOR SWITCH IS "ON", CONTACTS ON 'F' RELAY COMPLETE 24V D.C. SUPPLY TO SCANNER MOTOR

FIG.37

(b) C1/2 close and complete the -24V. line to relay F and contact 3 of relay D.
(c) C7/8 close and complete the 80V. A.C. supply to the primaries of T.301 and T.302. This makes the EHT circuits operative and the +1800V. -1800V. and -1000V. supplies are developed.
(d) C5/6 open and remove the positive bias from the grid of the delay valve, V.305, which is now left with a negative bias of about -20V. on its grid. The anode current commences to fall but because of the anode-grid feedback this fall is gradual. About 30 seconds elapses before the fall in anode current is sufficient to de-energise relay D.

80. When relay D becomes de-energised the following actions take place:-

(a) D1/2 open and the D.C. circuit between relay C and 6A/4 is broken. This has no effect since relay C is energised through 6A/5.
(b) Contact 6 of relay D breaks from 7 and closes to 5 to put R.322 back in V.305 anode load and shunt R.323 across D relay. V.305 is now back in the condition which existed when its filament was first heated with the exception that the grid now has a negative instead of a positive bias.
(c) D3/4 closes now and completes the 24V supply through the solenoid of relay E which now becomes energised.

81. The energising of E relay brings about the following changes:-

(a) E9/10 close to connect +300V. to the modulator via 18/17. This is the +300V. switched supply to the modulator.
(b) E1/2 break and E5/6 close to disconnect the feedback condenser, C.304 from V.305 grid. This leaves V.305 cut off on the grid.
(c) E7/8 close and complete the 24V supply through the red pilot lamp (SL.152) and pin 6A/6.

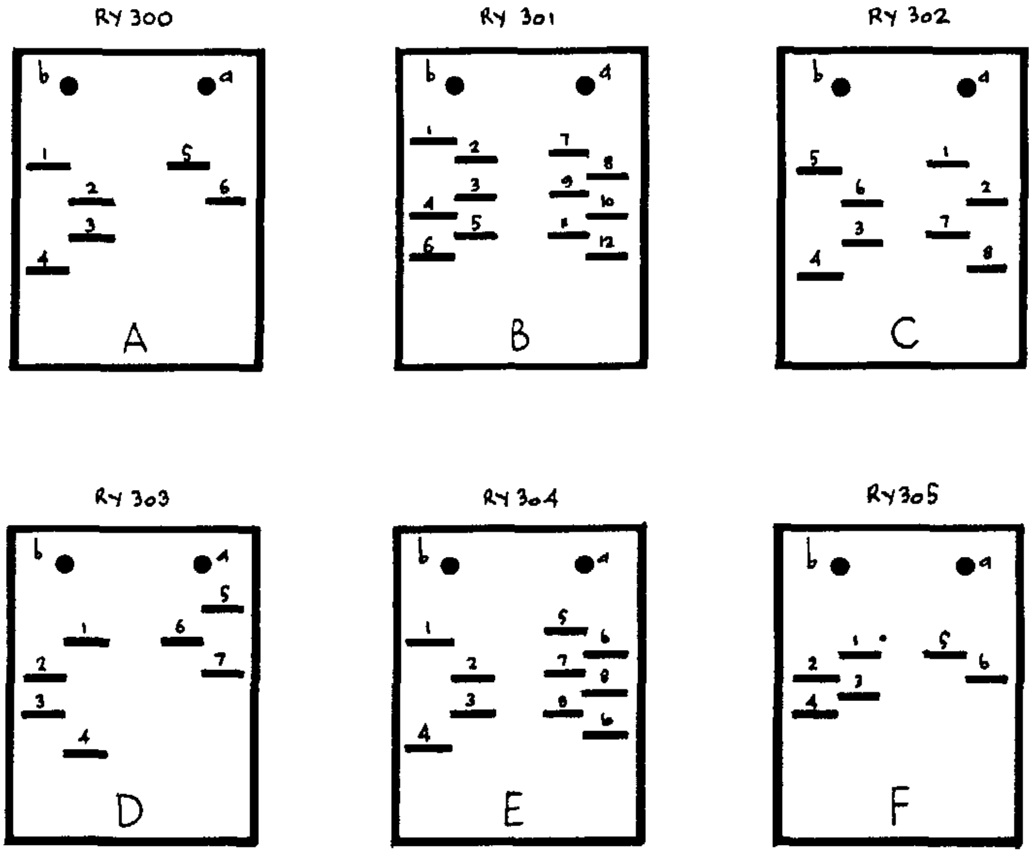
Since the energising of relay E puts the 300V. switched supply into the modulator which enables the trigger gap, spark gap and modulating line to go into operation, the coming up of the red light means that the whole set should be operational. In order to have the transmitter come on with the red light the switch on the panel of the modulator 64 must be down. This switch completes the 80V. A.C. supply to the primary of the transformer which supplies the -4KV. pack in the modulator. This pack, in turn, charges the artificial line which is used to develop the modulating pulse that operates the magnetron transmitting valve.

82. When relay C is energised contacts C1/2 connect -24V. to one side of relay F. The other side of the winding is connected via 6A/1 to the scanner motor switch on the switch unit. The other side of this switch is connected to +24V. When the switch is closed any time after the amber light comes on relay F is energised. Contacts 1/2 and 5/6 then close to supply 24V. to the scanner motor via the 6B plug.

<u>Summary of the Relay Sequence</u>

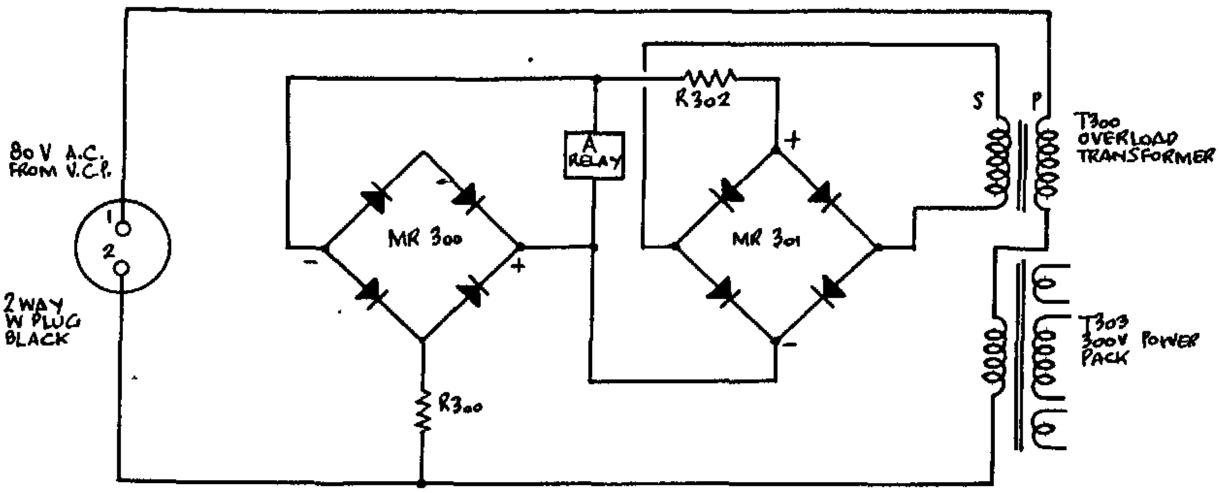
83. (a) A is energised when the 80V. supply is switched on.
(b) B is energised when the "L.T. ON" button is pressed and the green light comes on.
(c) D is energised after a delay of some 30 seconds while the current in the delay valve, V.305, is building up.
(d) C is energised when the "H.T. ON" button is pressed and the amber light comes on.
(e) D is de-energised some 30 seconds after C is energised, the delay being due to the slow decay of the current in V.305.
(f) E is energised immediately after D is de-energised. This completes the 300V. supply to the trigger valve in the modulator and brings on the red light.
(g) When C is energised -24V. is connected to one side of the solenoid of F. When the scanner motor switch on the switch unit is closed +24V. is connected to the other side of the solenoid and the relay is energised to complete the supply to the scanner motor.

C.D. 0896L



LAYOUT OF POWER UNIT RELAY CONTACTS

FIG. 38



ANY OVERLOAD ON T303 (300V RECTIFIER) WILL INCREASE VOLTAGE INDUCED IN T300 (OVERLOAD TRANSFORMER) WHICH WHEN RECTIFIED IS APPLIED TO THE 'A' RELAY IN OPPOSITE POLARITY TO THAT FROM MR 300. THIS WILL DE-ENERGISE 'A' RELAY CUTTING OFF THE 80V A C SUPPLY.

FIG. 39

THE OVERLOAD TRANSFORMER (T300)

Switching Off the H.2.S. Equipment

84. Pressing the "L.T. OFF" button on the switch unit breaks the D.C. supply to relays B and C to cut off the entire power unit and hence all other units. All relays return to their initial condition except relay A which remains energised as long as the 80V. A.C. supply is switched on.

85. If the "L.T. ON" button is pressed when the equipment is running the H.T. and E.H.T. supplies are switched off but the L.T. is left on to keep the filaments warm. The actual sequence of events is as follows:-

(a) The +24V. D.C. connection to 6A/5 is broken thus breaking the supply through the solenoid of C relay to de-energise the relay.
(b) C7/8 open to cut off the 80V. A.C. supply to the primaries of T.302 and T.303. There is then no E.H.T. supply.
(c) C1/2 open to break the 24V. D.C. supply to relays E and F.
(d) Relay F is de-energised and breaks the supply to the scanner motor.
(e) When relay E is de-energised E9/10 open to cut off the +300V. supply to 18/17 and the modulator. This means there is no H.T. to the trigger valve and no further operation of the transmitter.
(f) E5/6 open to disconnect R.335 from C.304. E1/2 close to connect C.304 between anode and grid of the delay valve, V.305. C5/6 close because C relay is de-energised. V.305 conducts at once since C.304 is completely discharged when it is re-connected between anode and grid by E1/2. The grid is therefore pulled very positive and E relay is energised at once. The relays are now in the same condition as they were after the initial delay while the current in V.305 built up sufficiently to energise relay D. The "H.T. ON" button can now be pressed to initiate the sequence outlined in paras. 79-81.

The Power Unit Safety Circuits

86. If the 80V. A.C. supply fails relay A is de-energised since this relay is energised by rectified A.C. Contacts A5/6 then open to break the 24V. D.C. supply for the other relays. The whole equipment is then switched off. A short circuit on the 80V. line will reduce the voltage across MR.300 and so will cause the same result.

87. If the 24V. D.C. supply fails relays B, C, D, E and F are de-energised and the equipment is switched off. A short circuit on the 24V. supply will burn the contacts 5/6 on A relay or reduce the energising current through relays B, C, D, E and F to switch the equipment off.

88. T.300, the overload transformer, provides protection against overloads on the rectifiers. If some fault develops which results an an excessive load on any of the rectifiers, and hence on the 80V. A.C. supply, the current through the primary of T.300 is increased. This increases the output from the metal rectifier, MR.301, which is applied to the winding of relay A in opposite polarity to the output from MR.300. During an overload the increased output from MR.301 cancels out the output from MR.300 to a sufficient extent to de-energise relay A. The 24V. supply is therefore cut-off and the equipment is switched off.

The Modulator Power Pack

89. Circuit details appear in figs. 55, 212 and 213.

90. 80V. A.C. is fed through an interference suppressor to the primary of T.2 which supplies the heater voltage for the VU.133 voltage doubler rectifiers, V.1, V.2. T.1 primary is also fed with 80V. A.C. The secondary provides heater supplies for the other valves in the modulator. A separate winding

provides the input to a half-wave metal rectifier which develops a -100V. bias supply for the CV.73 trigger valve. This -100V. supply is also tapped down on a bleeder to secure the bias for the modulator safety valve, V.4.

91. T.3 is the E.H.T. transformer. The 80V. A.C. supply to the primary is switched on by the modulator C relay in the anode of the trigger valve. When the power unit E relay is energised +300V. is supplied via 18/17 to the CV.73 trigger valve anode. The flow of current results in the energising of the modulator C relay and C/1 closes. If the switch, S.1, on the modulator panel is down the 80V. A.C. input to T.3 primary is completed when the red light comes up on the switch unit. The voltage doubler circuit develops a -4KV. output which is fed to the blue W-uniplug on the modulator panel. From this plug a cable is taken to the indicator 184 to supply the P.P.I. bleeder. A parallel plug is available on the indicator to tap off an output for the Fishpond P.P.I. bleeder. Within the modulator the -4KV. supply is connected through the 64H. choke, L.1, to the artificial line. It is this -4KV. pack which supplies the energy to the modulating pulse which is used to operate the magnetron transmitter valve.

92. Since C relay must be energised in the modulator before the 80V. supply to the -4KV. pack can be completed, and C relay current is the current passed by the trigger valve, V.7, it follows that V.7 must be operating if the -4KV. pack is to operate. It has been pointed out that V.7 grid is biassed back by the -100V. supply. It is necessary, therefore, that V.7 grid be pulsed if C. relay is to be energised. This pulsing is provided by a positive-going 20 microsecond pulse. The pulse is obtained by phase reversing the negative-going 20 microsecond modulator priming pulse developed by the VT.60A V.6. V.5 and V.6 actually form a multivibrator that develops the pulsing waveform for V.7 grid. This multivibrator must then be operating in order that the -4KV. pack may operate.

The Modulator Safety Circuits

93. Circuit details are shown in fig.62.

94. V.4 provides a safety circuit similar in principle to the delay valve, V.305, in the power unit. V.4 is brought into operation whenever the modulator overload relay, A relay, is energised as the result of an overload on the -4KV. pack. The full sequence is discussed in Chapter 5, paras. 256 - 257.

95. The safety valve will also come into operation if a fault in the TR.3555 causes the thermal relay to close. The sequence of events is discussed in Chapter 5, paras. 285 - 286.

The Tuning Unit 207 and Indicator 184 Power Supplies

96. These supplies are discussed in Chapter 4, paras. 203 - 207.

The Mark IIIA Receiver Power Pack

97. This power pack is discussed in Chapter 6, paras. 417 - 418.

The TR.3555 Series Power Pack

98. The local oscillator power pack is dealt with in Chap.6, paras. 389-398.

The TR.3523 Power Pack

99. Full details of this pack are not yet available.

The Fishpond Power Pack

100. Details of the Fishpond power pack are given in Chap.10, paras.711-712.

Amplifier Unit, A.3562, Power Pack

101. This pack is discussed in Chapter 9, paras. 583 - 585.

Lucero Power Pack

102. Details of the power pack are given in Chapter 14, paras. 1298-1301.

W.F.G. Voltage Stabiliser

103. This stage is discussed in Chapter 4, para.188.

Receiver-timing Unit Voltage Stabiliser

104. Details of this stage are discussed in Chapter 7, para. 487.

Voltage Control Panels

Types in Use in Bomber Command

105. (a) V.C.P. Type 3 (5U/1269) fitted with E_1 regulator (5U/1304)
(b) V.C.P. Type 3 (5U/1269) fitted with E_1 regulator (5U/1304T).

The 5U/1304T regulator is a later model than the 5U/1304 and differs only in being fitted with a 50 ohm trimming resistance.

106. (a) V.C.P. Type 5 (5U/363) fitted with E_3 regulator (5U/364)
(b) V.C.P. Type 5 (5U/363) fitted with E_3 regulator (5U/364T).

The 5U/364T differs from the earlier 5U/364 in having a 50 ohm trimming resistance fitted. The type E_3 regulator is the one originally fitted to the V.C.P. Type 5.

107. V.C.P. Type 5 (5U/363) fitted with EU regulator (5U/2544).

The EU regulator should be fitted to all V.C.P.'s Type 5 used in H.2.S. installations. It is a modified type E_3 and is being used pending full production of the Type E_5.

108. V.C.P. Type 5 (5U/363) fitted with E_5 regulator (5U/2274).

The E_5 regulator is to supersede the EU when available.

The Type EU and E5 Regulators

109. The circuit is shown in fig.40.

110. The type EU and E5 regulators are improved versions of the type E3. embodying a stabilising circuit. The E5 employs a visual presetting device not incorporated in the EU. The stabilising effect is obtained by connecting a high resistance winding across the alternator field. This winding is enclosed with the main operating winding and a series winding. The interaction of the high resistance shunt winding with the main operating winding prevents hunting of the regulator over reasonably wide limits of compression. The low resistance series winding is in series with the pile element. Its function is to compensate for the ampere turns of the shunt winding.

111. Six terminals are provided instead of the normal four. In the EU this is achieved by adding a terminal block on the end of the regulator. In the E5 a new 6-way terminal strip is used.

112. A 100 ohm trimming resistance is fitted to facilitate final adjustment of the regulator. This permits variations in the output voltage of about + or - 10V.

113. These regulators can work as anti-hunting devices only if the feedback between the main coil and the shunt stabilising coil is always negative. The current flowing through the main coil is fixed in direction by the sense of the rectified output from the A.C. applied to the metal rectifier. The direction of the current through the shunt winding is fixed by the polarity of the D.C. input to the V.C.P. If this is changed over the sense of the feedback is reversed from negative to positive. The result will be persistent

oscillation of the carbon pile. The manufacturer's wiring of the V.C.P. and regulators is such that Pin 1 should always be connected to the negative side and Pin 2 to the positive side of the D.C. supply. Pin 1 should be connected to the GREEN terminal of the regulator.

114. To eliminate difficulty due to positive feedback and resultant carbon pile oscillation it is essential that all aircraft, bench and P.E. set installations be kept with Pin 1 negative.

Voltage Measurements

115. Measurement of the A.C. voltage output in a way that will give an indication of the D.C. output that will be obtained from the various power packs in radar equipments has always been a difficult problem. Thermal meters give the R.M.S. voltage value regardless of the waveshape, but the same R.M.S. value for different waveshapes will not necessarily result in the same D.C. output from the same power pack. A further difficulty of thermal meters is their tendency to become inaccurate. They become a reasonably safe measuring instrument only if regularly checked against a thermal meter which is well taken care of and kept as a substandard meter.

116. The rectifier type meter will show a reading that depends on the waveshape of the alternator output and the rectifier in the meter. The waveshape of the alternator output will depend on the alternator and the nature of the load. A load containing a reactive component will result in a different waveshape than a purely resistive load. Furthermore, the waveshape may be modified by the V.C.P. condenser. The D.C. voltage output from power packs will only be the same for a given rectifier meter reading on different waveshape alternator outputs if the power pack rectifiers are affected in the same way as the meter rectifier by the change in waveshape.

117. The following table has been compiled from average readings as a guide and must not be assumed to hold invariably for a given combination of units and meter.

V.C.P.	Alternator	Thermal Meter	AVO
Type 3	R	80	83.5
Type 5	U	80	77

This refers to the AVO Model D, 75V. range x 2.

Minor Voltage Adjustments

118. Before making any voltage adjustments, allow time for any moisture on the pile to be dried out by leaving the regulator in operation.

119. After approximately 120 hours use the voltage may rise slightly due to pile wear or shrinkage.

120. For minor voltage adjustments use trimmers whenever these are fitted. Where no trimmer is fitted the core adjustment must be used.

121. If after making trimmer adjustments the regulation is poor, the compression and core adjustment will have to be set up as outlined below.

Setting Up a Regulator (All Types Except E5)

122. (a) Connect the V.C.P. to its dummy load to avoid damage to equipment.
(b) Set the core adjustment flush with the face plate. A fine adjustment is obtained by lining up the punch marks of the core and the face plate.

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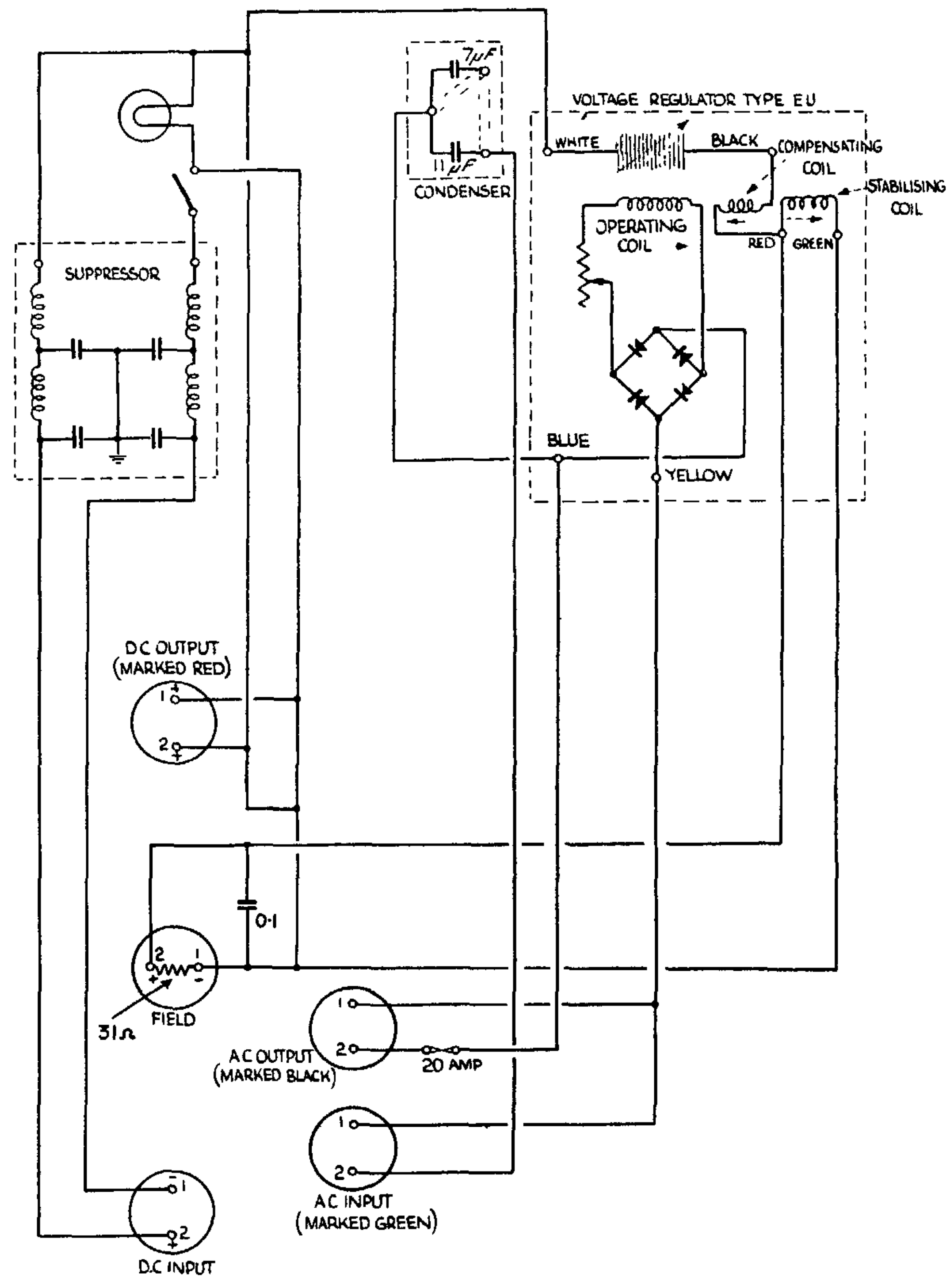

VOLTAGE CONTROL PANEL TYPE V

FIG.40

FIG.40

(c) Set the trimmer in a midway position.
(d) Slack off the compression adjustment.
(e) Connect a voltmeter across the A.C. output. With the compression screw completely slackened off the alternator field circuit is broken. A small A.C. voltage of about 10V. will be observed due to the residual magnetism of the field.
(f) If the compression adjustment is now advanced, the voltage should vary as shown in fig.40a. The voltage rises rapidly to a peak in the region of 110V. Further rotation will result in a fall to a level where oscillation occurs, then a slow fall to some minimum. The oscillation will not appear when the EU regulator is used due to the negative feedback arrangements. The minimum will vary with different settings of the core and should be in the region of 75V. Further rotation from the minimum point will result in a fairly rapid rise. The compression adjustment should be set on the slowly falling side about 5V. from the minimum. If oscillation occurs during adjustment it should not be allowed to continue if damage to the carbon discs is to be avoided.

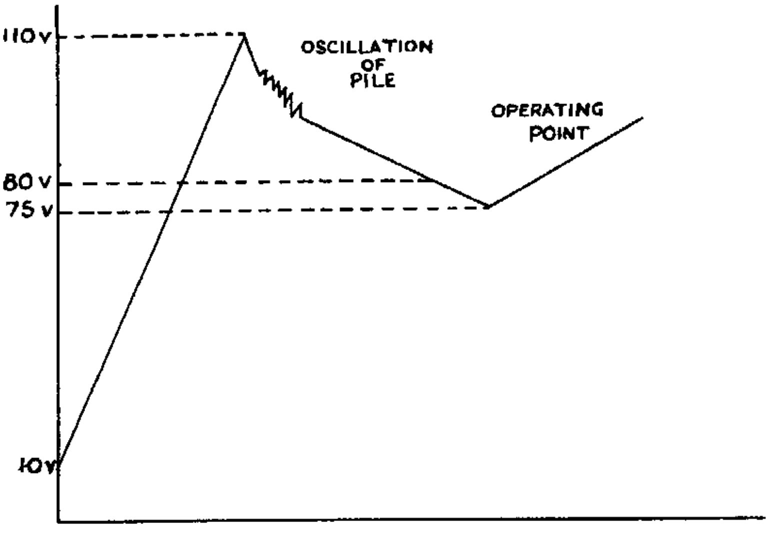

Fig.40(a) - Clockwise Movement of Compression Adjustment

(g) Check the A.C. voltage and make any required fine adjustment on the trimmer or on the core adjustment if no trimmer is fitted. If large core adjustments are necessary the position of the compression adjustment must be rechecked as outlined above.

Regulation Check

123. Switch off the V.C.P. and alternator. Restart and check regulation under varying speeds between 3000 and 6000 r.p.m. Vary the load by means of dummy or equipment loads. Voltage variations should not exceed + or - 3V.

Setting-Up the Type E5 Regulator

124. The voltage output of these regulators is adjusted by the trimmer. If a correct voltage cannot be thus obtained it must be assumed that the regulator is out of adjustment. The following adjustments should be made using a visual presetting device.

125. A spring-loaded movable arm, situated on the flange but insulated from it, makes contact with a flat disc fixed to the armature spring assembly.

It is arranged that the movable arm breaks contact with the disc at the point of correct compression. To obtain a visual indication a low voltage lamp and leads are used. One lead is connected to the terminal of the movable arm on the flange and the other to a convenient point on the frame. If the lamp lights the carbon pile is under-compressed. The locking screw should be slackened off and the compression screw turned till the light is just extinguished. The compression is then back to the manufacturer's setting. The locking screw is then tightened.

126. Should the regulator still prove unstable it must be returned to the M.U. for repair. The core must not be touched.

127. These regulators are carefully adjusted by the manufacturer and sealed. It should be possible to compensate for all normal wear due to "pile shrinkage" by use of the trimmer.

128. The current through the main operating coil should be about 140 ma.

V.C.P. Changeover Panel in Lancaster Aircraft

129. Several cases of V.C.P. damage have occurred through the use of incorrect changeover procedure in the air. The navigator's alternator field switch must be in the "OFF" position before moving any of the plugs on the panel. If this is not done, it may result in having the field of one alternator connected to one V.C.P. and the armature of the same alternator connected to the other V.C.P. There is then no regulation of the alternator output. The resulting voltage increase may destroy the rectifier and coils in the second V.C.P.

The Alternator Type R

130. (a) At speeds between 3000 and 6000 r.p.m, this alternator, when used in conjunction with a V.C.P. Type 3, should give a full output of 6.25 amperes at 80V. R.M.S. to a non-inductive load.
(b) The frequency range over these speeds is 1300 - 2000 c/s.
(c) The normal field current should not exceed 2 amperes at 28V.

Maintenance

131. (a) At intervals of 120 flying hours the outer bearing caps should be removed and the felt lubrication pads soaked in oil (34A/60). A little oil should be applied to the bearing itself.
(b) The bearing caps are secured by 6 small hexagonal nuts at the driving end and 3 similar nuts at the outer end.

Alternator Type U

132. As for the type R, except that a current of 12 amps. can be supplied.

Modification to V.C.P. Type 5

133. When the radar load is removed from the V.C.P., there is a tendency for the A.C. voltage to rise. To counteract this the carbon pile goes out to its extreme limits. This may result in damage to the carbon pile. To reduce the risk of such damage a 31 ohm resistor is fitted in parallel with the alternator field.

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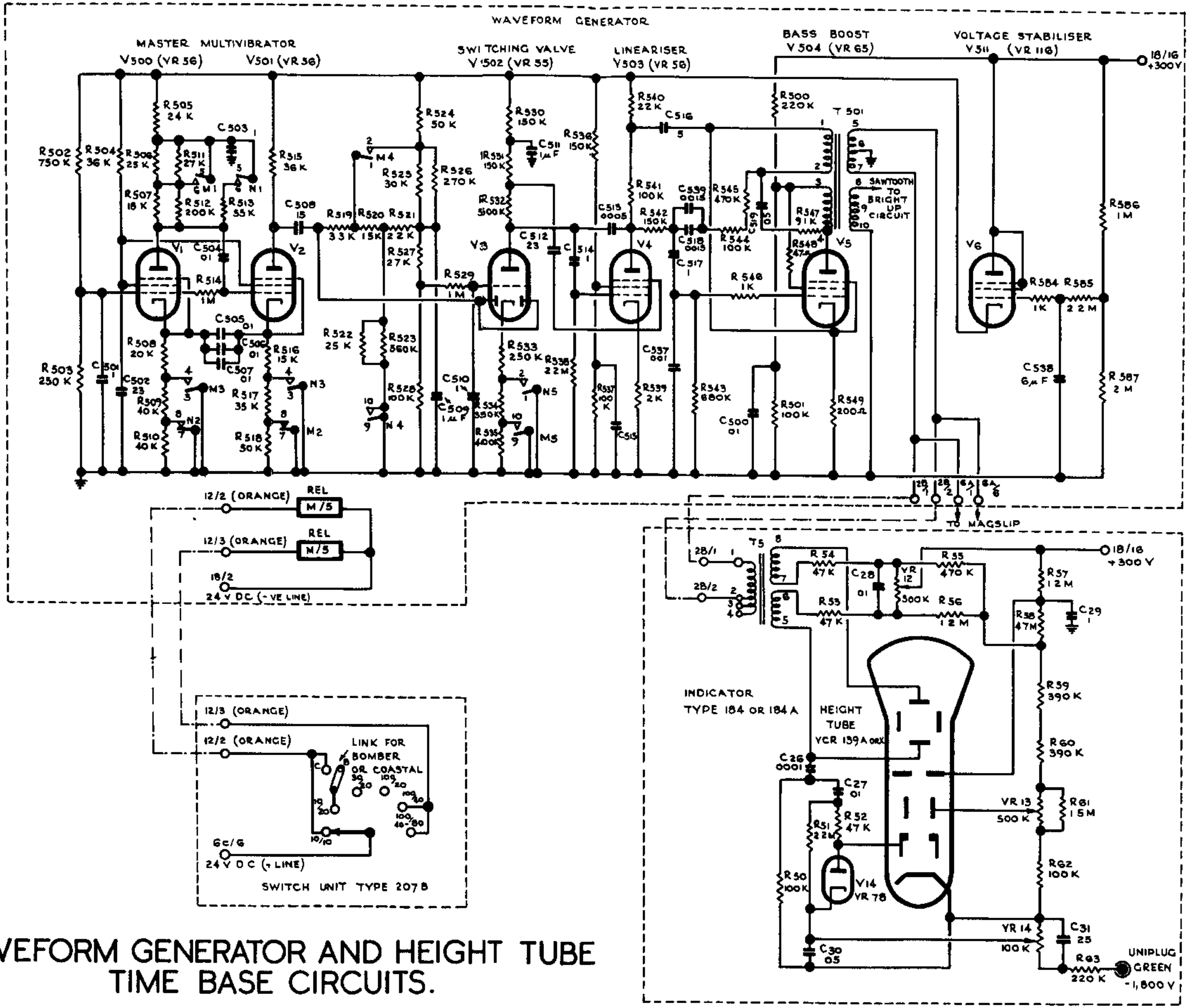

WAVEFORM GENERATOR AND HEIGHT TUBE TIME BASE CIRCUITS.

FIG. 41

CHAPTER 4 - THE H.2.S. TIMEBASE CIRCUITS

Introduction

134. In Chapter 1 it was pointed out that two displays were used in H.2.S. proper. The first one discussed was the height tube display which employs a vertical scan running from the bottom to the top with a deflection type of presentation. This display is used for measurement of height by setting the height marker to the beginning of the ground echo, for homing on beacons, and for setting-up purposes. It is also very useful as a monitor tube for fault finding.

135. It was also pointed out in Chapter 1 that the main display uses a P.P.I. presentation to show target indications in the form of a relief map where strong returns from rugged coastlines and heavily built-up areas show as bright patches, while water shows up nearly black against the background luminosity produced by the general ground returns. The following features of this display were pointed out:-

(a) In order that the centre of the display may represent the point on the earth's surface directly below the aircraft for all aircraft heights, the timebase circuit must be triggered by the height marker which must have been set to the beginning of the ground echo. The scan will then start at the tube centre when the ground echo reaches the aircraft.

(b) The timebase must be synchronised with the transmitter and therefore gives one sweep for every transmission, i.e. 670 sweeps per second or sweeps at 1500 microsecond intervals.

(c) The timebase must be non-linear in order to obtain a distortion-free display, i.e. a display in which target indications appear at distances from the centre which are proportional to their ground range.

(d) In order that this freedom from distortion may be obtained at all aircraft heights it is necessary to make a correction for height. This is done by means of a distortion corrector control on the indicator panel.

(e) The radial timebase sweeps move around the face of the tube in synchronism with the rotation of the scanner. If the scanner rotates at 1 r.p.s. the timebase makes 670 radial sweeps per revolution. These sweeps must then occur at intervals of $\frac{360}{670}$ or slightly more than $\frac{1}{2}$ degree. For faster scanner speeds the interval will be greater which may tend to give the display a pleated effect.

(f) A scan-marker switch on the switch unit can be set to give three different velocity scans and, hence, different ground range coverages. The available ground range coverages are approximately 10, 20 and 40 statute miles.

(g) By setting switches on the indicator and heading control unit to "Course" and using a setting knob, the brightened-up timebase sweeps occurring at the instant the scanner goes through the dead-ahead position can be made to appear at any bearing on the display. By setting the bearing ring to the aircraft course and adjusting the setting knob until the brightened-up timebase sweeps (or heading marker) coincide with the bearing pointer, it is arranged that the bearing along which any sweep takes place is the bearing of the direction in which the scanner is then looking, referred to the top of the display as North. Target indications will then appear at the correct bearing on the display and the H.2.S. map is correctly set.

(h) If the heading control unit switch is set to "Auto" the D.R. compass is linked into the installation to keep the map correctly set as the aircraft alters course.

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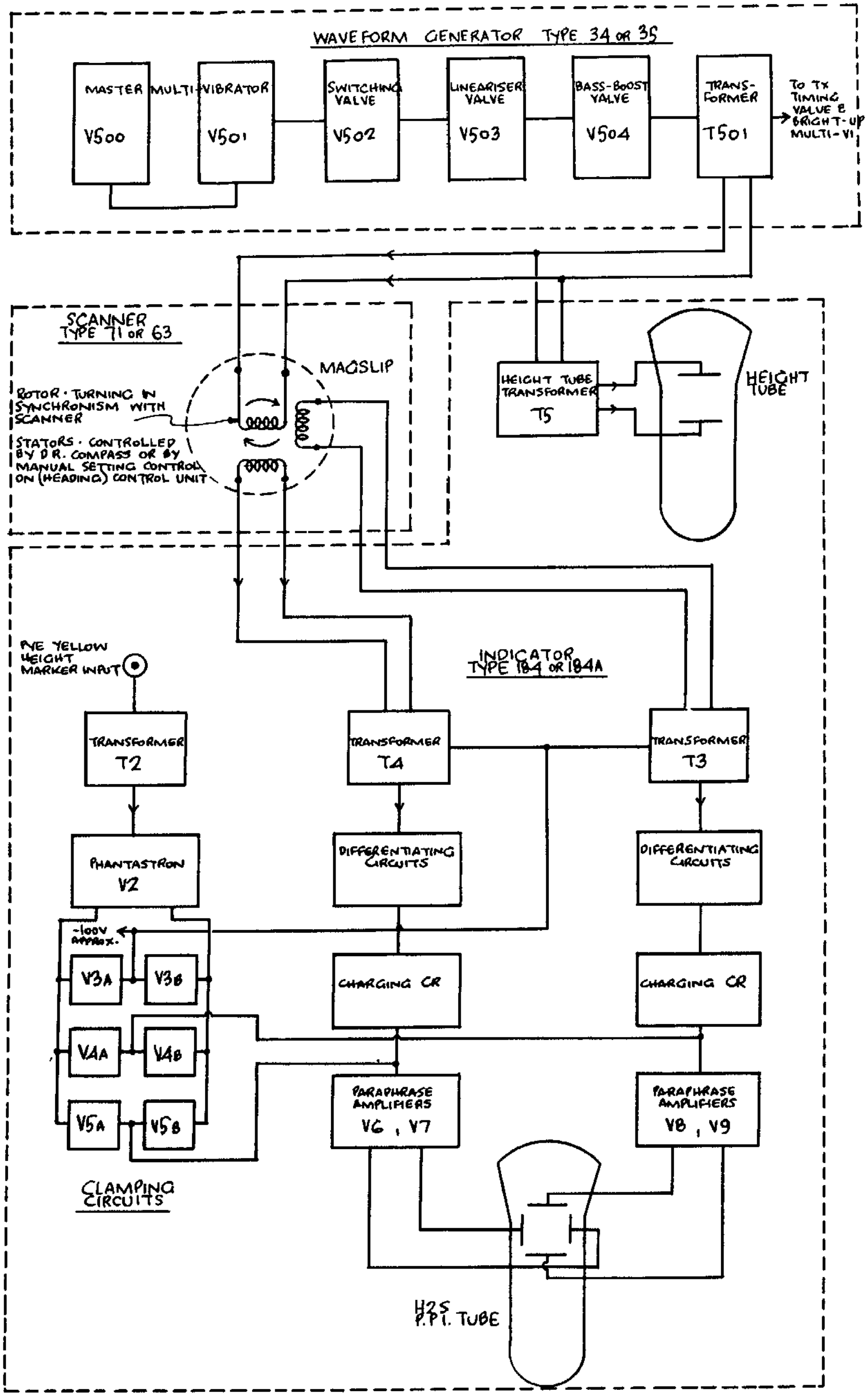


FIG. 42

H2S TIMEBASE CIRCUITS
BLOCK SCHEMATIC

Outline of the Timebase Circuits

136. (a) Fig. 42 gives the major sub-sections in the development of the timebases in block schematic form.
(b) Figs. 41 and 46 give the major circuit details.
(c) Figs. 43, 49, 50 and 54 display the primary waveforms.
(d) Fig. 44 shows the principle of the magslip.
(e) Fig. 45 shows the type of non-linear timebase velocities used for the P.P.I. timebase.

The Master Multivibrator

137. V500 and V501 in the waveform generator form a cathode-coupled master multivibrator free-running at approximately 670 c/s. When the scan-marker switch on the switch unit is operated one of the results is a switching of circuit components in this stage. When this switch is set for scans of 10, 20 and 40 miles, respectively, the multivibrator delivers a square wave at the anode of V501 with proportions as follows:-

Scan	Negative	Positive	Period
10 mile	240 µs	1250 µs	1500 µs
20 mile	720 µs	780 µs	1500 µs
40 mile	1200 µs	300 µs	1500 µs

An antiphase square wave appears at the anode of V500.

The switching Valve, V502

138. The master square wave from V501 anode is applied to V502 diode anodes and serves to cut the triode section of V502 on and off. During the negative part of the master square wave input the triode conducts and the anode of V502 tends to fall exponentially. During the positive part of the master square wave the triode part of V502 is cut-off and the anode tends to rise exponentially.

The Lineariser, V503

139. If V503 is removed a large amplitude exponential rise and fall can be observed at V502 anode but when V503 is inserted only a small waveform is observed.

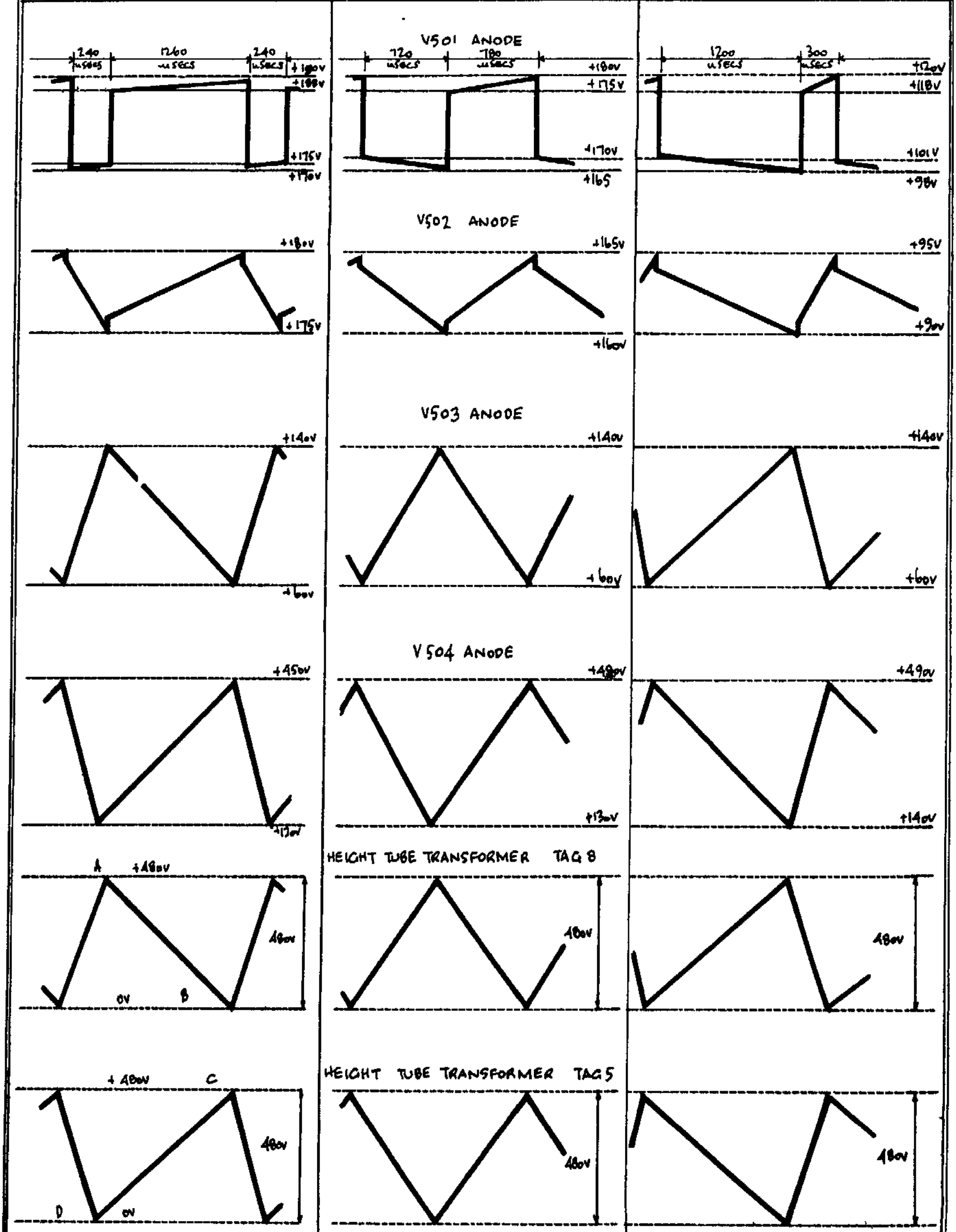
140. Outputs from V502 anode are applied to both grid and cathode of V503. The cathode input serves as a form of negative feedback. Additional negative feedback is applied to the grid of V503 from its anode. These negative feedback arrangements are employed to produce a linear sawtooth at V503 anode.

The Bass Boost Valve, V504

141. The output inpedance of V503 is so high that the sawtooth cannot be applied to a low inpedance cable from V503 anode. V504 is used as a negative feedback amplifier to provide a low inpedance output that can be matched to a low impedance cable. To allow for the fact that low frequency losses are experienced in subsequent stages a discriminating negative feedback is employed. This is achieved by feeding back from anode to grid through two .0015 condensers in parallel. The sawtooth with a recurrence frequency of 670 c/s. can be regarded as being synthesised from a 670 c/s. sinewave with harmonics of suitable amplitudes and phases. A capacity of .003 microfarads will offer low impedance to the high frequency components but high impedance to the low frequency components. The impedance at 1000 c/s. is greater than 50K. Hence, the negative feedback in the low frequency range of the sawtooth components is less than at the higher frequencies. V504 will therefore tend

DEVELOPMENT OF HEIGHT TUBE TIME BASE

SETTING OF MARKER SCAN SWITCH		
10/10	10/20 30/20 100/20	100/40 100/40-80
RANGE COVERAGE OF HEIGHT TUBE DISPLAY		
0-10 MILES	0-30 MILES	0-50 MILES 0-90 MILES



D.C LEVELS A, B, C, D VARIABLE BY SHIFT CONTROL.

FIG. 43

to give greater amplification to the low-frequency components than to the high frequency components. The subsequent low frequency losses are thus provided for before they occur. The stage comprising V504 and the transformer T501 therefore performs two functions:-

(a) Anticipates low frequency losses by providing excess low frequency amplification or "bass boost".
(b) Serves as an impedance transformer by means of which a push-pull sawtooth of about 50 volts amplitude from a centre-tapped secondary can be applied to a low impedance (20 ohm) cable for transfer to the magslip in the scanner.

Synchronisation

142. The transformer T501 also provides another sawtooth output, which swings between about -150 v. and earth, from another secondary winding earthed at the high end. This output is used to develop a bright-up square wave and the transmitter-timing pulse. The locking of the bright-up waveform and signals to the timebase is accomplished by using the master multivibrator to develop both the sawtooth which produces the timebase, and also the sawtooth which is used in the development of the bright-up and transmitter-timing waveforms. The transmitter-timing pulse is also used to develop the waveform which is used to trigger the height and range markers so these also are locked to the timebase.

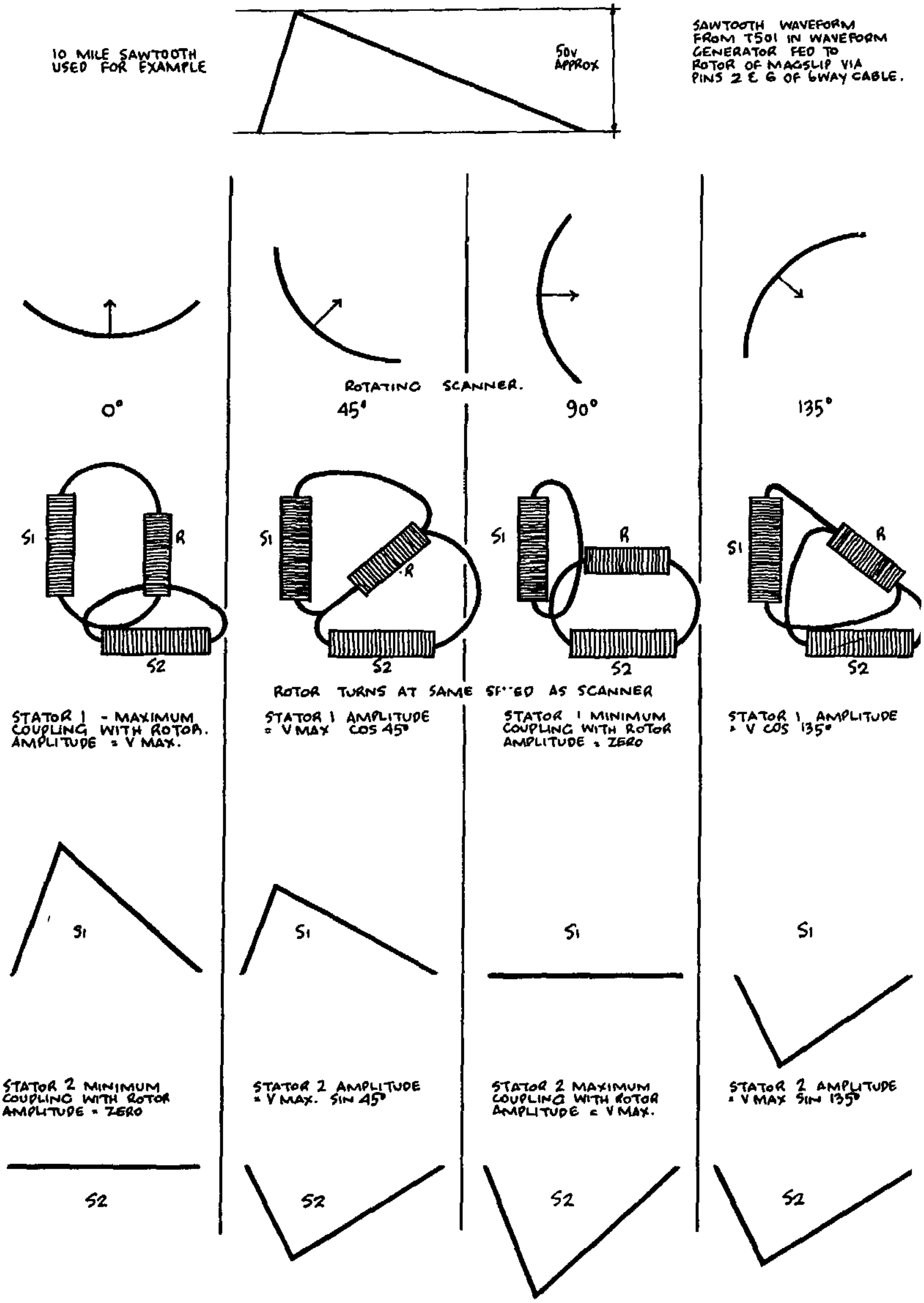
The Height Tube Timebase

143. The timebase sawtooth output from T501 divides at the waveform generator panel. One output is taken from a two-pin plug to the Indicator 184 where it is applied to the primary of a sawtooth transformer. This transformer amplifies the sawtooth about six times to give approximately 300 volts push-pull across the Y-plates of the height tube for the linear height tube time-base.

144. As the transmitter fires at approximately the centre of the sawtooth the first half of the height tube scan is of no particular interest. A vertical shift control is provided by means of which the useful part of the scan can be made to commence near the bottom of the height tube. As was pointed out earlier, the I.F. amplifier is suppressed for a 20 microsecond period, terminating approximately at the end of the main transmitter pulse. This 20 microsecond quiescent period shows as a noise-free break on the height tube display. The position on the scan of this suppression break can be varied over a limited range by means of a screw-driver preset on the front of the receiver-timing unit. If this suppression control is correctly adjusted the height tube display will show just the "tail" of the transmitter pulse as a small blip to the right at the end of the suppression break. This "tail" indicates the approximate position of the time zero on the sawtooth, i.e. when the transmitter fires. When the height tube vertical shift control is adjusted to bring the suppression break as nearly as possible to the bottom of the tube the maximum useful range coverage will be provided. The approximate coverages available for the different settings of the scan-marker switch are as follows:-

Position	Duration of Sawtooth	Range Coverage Statute Miles
10/10	240 microseconds	8 miles (ground)
10/20	720 "	30 miles (slant)
30/20	720 "	30 miles (slant)
100/20	720 "	30 miles (slant)
100/40	1200 "	50 miles (slant)
100/40-80	1200 "	40-90 miles (slant)

MAGSLIP OPERATION



NOTE: THE ABOVE EXAMPLES REPRESENT 45° INTERVALS IN THE ROTATION OF THE SCANNER. AS THE SCANNER ROTATES THE AMPLITUDE AND THE SENSE OF THE SAWTOOTH WAVEFORMS INDUCED IN THE STATORS IS CONTINUOUSLY CHANGING WITH 90° PHASE DIFFERENCE BETWEEN THE TWO STATORS.

FIG. 44

145. When the scan-marker switch is in the 100/40-80 position the transmitter fires approximately 500 microseconds ahead of the centre of the sawtooth. The suppression break will then be off the tube and the first signals that can be displayed will be from about 40 miles away. This position of the scan-marker switch is used when Lucero is being used with homing beacons.

The Magslip

146. A second sawtooth output in parallel with that taken to the indicator for the height tube is taken to the scanner via Pins 2 and 6 on the 6A plug. This sawtooth is applied to the rotor of a magslip or rotary transformer. The magslip has two stators in which the rotor induces sawtooth voltages which are 90° out of phase and whose amplitudes are always such that the resultant of these two components, when they are added vectorially, will be a sawtooth of the same amplitude as that applied to the rotor. When the rotor is making full coupling with Stator 1 it makes zero coupling with the Stator 2. The output from Stator 1 is then equal to the input voltage and the output from Stator 2 is zero. If the magslip rotor now turns through 90° the output from Stator 1 drops to zero while that from Stator 2 rises to a maximum equal to the input voltage. During the next quarter turn the output from Stator 2 drops to zero while that from Stator 1 rises from zero to a maximum in the sense opposite to that at the commencement of the turn. During the third quarter turn the output from Stator 1 falls to zero while that of Stator 2 builds up from zero to a maximum in the reverse sense to that which it had at the end of the first quarter turn. During the final quarter turn the output from Stator 2 falls to zero again while that of Stator 1 builds up from zero to a maximum in the same sense as when the turn commenced. The magslip rotor is geared to the scanner shaft and rotates in synchronism with the scanner at all times. Hence, as the scanner turns, the magslip stators are developing sawtooth outputs which fulfil the following conditions:-

(a) Each goes through the following cycle for one turn of the rotor:
   (i) Zero to maximum in one direction.
   (ii) Maximum to zero.
   (iii) Zero to maximum in reverse direction.
   (iv) Maximum to zero.

(b) The two outputs are always 90° out of phase.
(c) The maximum amplitudes are equal to the rotor input voltage.
(d) The vector sum of the outputs is always equal to the rotor input voltage.

147. The sawtooth outputs from the magslip stators are taken from the scanner direct to the Indicator 184 if Fishpond is not used, and to the Junction Box Type 222 if Fishpond is included in the installation. In the latter case parallel outputs are taken from the Junction Box Type 222 to the Fishpond Indicator and the H.2.S. indicator. It is the use of this sawtooth output to develop the timebases for both the H.2.S. P.P.I. display and the Fishpond P.P.I. display that serves to synchronise these displays.

Timebase Working Strokes

148. In para.137 the durations of the positive and negative-going phases of the master square wave were listed. In para.138 it was noted that the master square wave was used to cut V502 triode on and off to produce a falling exponential at V502 anode during the negative phase of the master square wave and a rising exponential during the positive phase. In para.140 it was pointed out that V503 served to linearise these exponentials and develop the actual sawtooth. The working stroke of the sawtooth, i.e. the part used for the development of timebases, is the part corresponding to the negative part of the master square wave. The stroke occurring during the positive part of the master square wave produces the flyback in all the timebases. From the data in para.138 it follows then that the available working strobe durations are 240, 720 and 1200 microseconds. The reason for these time values arises out of the design of the indicators used in earlier Marks of H.2.S. In these earlier

indicators 10, 30 and 50 mile linear scans were used which carried the cathode ray tube electron beam across a tube diameter on the working stroke of the sawtooth. The first half of this stroke was blacked out to leave only the second half of the sweep effective, i.e. an effective radial timebase was employed. The echo times for 10, 30 and 50 miles would be 107, 321 and 535 microseconds respectively. It is apparent then that working strokes of 240, 720 and 1200 microseconds duration would be, when halved, of ample duration to carry the spot from centre to circumference in these echo times without employing the peaks of the sawtooth voltages which tend to be rounded off.

Shaping of the P.P.I. Timebase

149. The varying amplitude linear sawtooth voltages from the magslip stators are used to develop the non-linear radial scans used on the H.2.S. P.P.I. The 10, 20 and 40 mile scans are developed from the 240, 720 and 1200 microseconds working strokes, recpectively. Before proceeding to study how these linear sawtooth voltages are used to develop non-linear timebase voltages it may be profitable to consider what type of waveform is required. We know that the scans are to meet the following conditions:-

(a) Commence when the height marker forms which involves some form of triggering by the height marker.
(b) Have such velocities that target indications will appear at distances from the centre proportional to their ground range for all aircraft heights.
(c) Provide ground range coverage of approximately 10, 20 and 40 statute miles.

Suppose we consider an aircraft at a height of 4 miles using an indicator that provides the desired type of scans on a tube of 2½" radius. Curves 1, 2 and 3 in Fig.45 show the type of velocity curves that would be required. The data used for constructing these curves is shown in the accompanying table. Column 1 lists target ground ranges from 0 - 40 miles; columns 2, 3, and 4 list the distance from the centre at which indications from targets at these ranges should appear to make distance from centre proportional to ground range. Column 5 gives the slant range corresponding to a height of 4 miles and the ground range in column 1. Since the speed of radio waves is 10.7 microseconds per mile return we can determine the corresponding echo times by multiplying the slant range by 10.7. These echo times, representing the time interval between the instant the transmitter fires and the instant the echo returns to the aircraft, are shown in column 6. Since the electron beam must not leave the tube centre until the height marker forms, i.e. when the ground echo returns, the time of travel of the cathode ray tube spot is found by deducting from the echo time the echo time for the ground echo. For a height of 4 miles the echo time for the ground echo is 4 x 10.7 = 42.8 microseconds. Deducting this value from each figure in column 6 we obtain the figures in column 7. If we now plot the values in columns 2, 3 and 4 as ordinates, against those in column 7 as abscissae, we obtain curves 1, 2 and 3. These curves show how the cathode ray tube spot must move on each of the three scans, to be at such a distance from the centre when any echo arrives to brighten up the sweep, that the indication is at the desired distance from the centre. The steepness of the curves at the beginning of the sweep indicate that the spot must move very rapidly at first. The spot then gradually slows down to a nearly constant speed since the curves become nearly straight lines, indicating an almost constant velocity. The development of waveforms of this shape is achieved by amplifying the linear sawtooth outputs from the magslip stators by means of transformers, then differentiating these amplified sawtooth waveforms to produce square waves which are applied to two charging C.R. combinations. The timebase developments are indicated in the block schematic, Fig. 42. The actual components can be seen in the circuit diagram Fig.46. The differentiation of the sawtooth from the secondary is done by C4, R4, and C3, R3 performs the same function for the sawtooth on the secondary of T3. The square wave appearing at the top of R4 serves as a charging voltage for the network formed by C10, C12, C13, VR4, VR5, R4. Similarly, the square wave appearing at the top of R3 serves as a charging voltage for the network formed by C17, C18, C19, VR6, VR7, R3.

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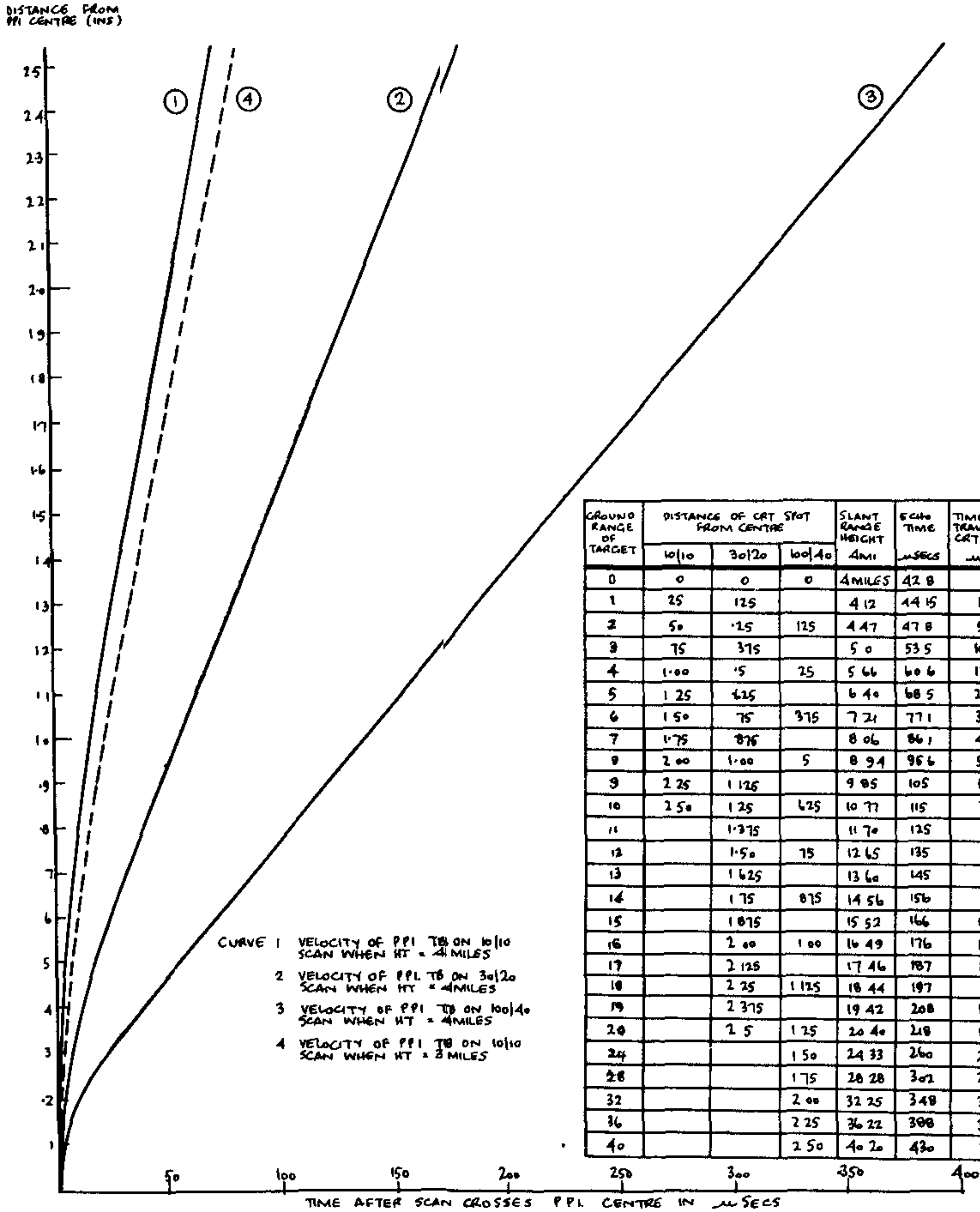

GROUND RANGE OF TARGET	DISTANCE OF CRT SPOT FROM CENTRE			SLANT RANGE HEIGHT	ECHO TIME	TIME OF TRAVEL OF CRT SPOT	SLANT RANGE HEIGHT	ECHO TIME	TIME OF TRAVEL OF CRT SPOT
	10/10	30/20	100/40	4 MI	μSECS	μSECS	3 MI	μSECS	μSECS
0	0	0	0	4 MILES	42 8	0	3	32 1	0
1	25	125		4 12	44 15	1 35	3 16	33 8	1·7
2	50	·25	125	4 47	47 8	5 00	3 61	39 6	7 5
3	75	375		5 0	53 5	10·7	4 24	45 4	13 3
4	1·00	·5	25	5 66	60 6	17 8	5 00	53 5	21 4
5	1 25	625		6 40	68 5	25·7	5 83	62 4	30 3
6	1 50	75	375	7 21	77 1	34 3	6 71	71 9	39 8
7	1·75	875		8 06	86 1	43 3	7 62	81 5	49 4
8	2 00	1·00	5	8 94	95 6	52 8	8 54	91·4	59 3
9	2 25	1 125		9 85	105	62	9 49	101 5	69 4
10	2 50	1 25	625	10 77	115	72	10 44	111·8	79 7
11		1·375		11 70	125	82			
12		1·50	75	12 65	135	92			
13		1 625		13 60	145	102			
14		1 75	875	14 56	156	113			
15		1 875		15 52	166	123			
16		2 00	1 00	16 49	176	133			
17		2 125		17 46	187	144			
18		2 25	1 125	18 44	197	154			
19		2 375		19 42	208	165			
20		2 5	1 25	20 40	218	175			
24			1 50	24 33	260	217			
28			1 75	28 28	302	259			
32			2 00	32 25	348	305			
36			2 25	36 22	388	345			
40			2 50	40 20	430	387			

FIG. 45

VELOCITY CURVES FOR TIME BASE IND. UNIT TYPE 184

INDICATOR TYPE 184

TIME BASE CIRCUITS

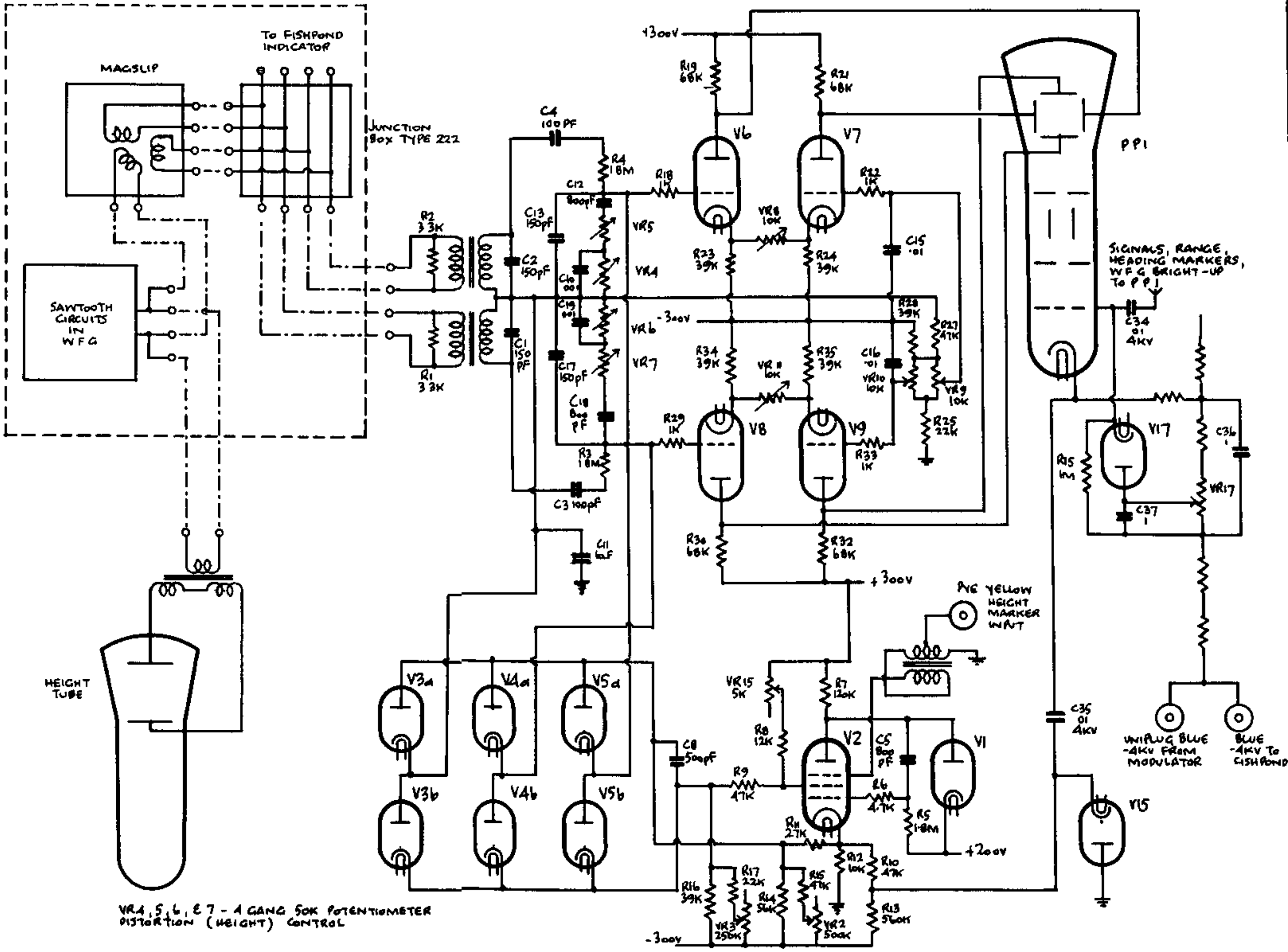

FIG. 46

Differentiation of a Sawtooth

150. The development of a square wave by differentiation of a sawtooth may seem puzzling to the Radar Mechanic who is accustomed to the differentiation of rectangular waveforms to produce pips. The subject may perhaps be most simply approached by recalling the nature of both square and sawtooth waveforms. Any such waveform may be synthesised from a fundamental sinewave of frequency equal to the p.r.f. of the waveform, plus harmonics of this fundamental sinewave of correct amplitudes and relative phases. The steeper the edges of a waveform, the greater the proportion of high frequency components. A square wave, therefore, has a higher proportion of high frequency components than a sawtooth of the same p.r.f. When any waveform is applied to a differentiating circuit consisting of a small condenser and large resistor, the resistor offers equal impedance to all frequencies but the condenser offers an impedance which decreases as frequency rises. The voltage developed across the resistor will then be a higher proportion of the applied voltage for the high frequencies than for the low frequencies. The voltage appearing across the resistor (and anything else in series with it) will thus tend to be squared (fig.48). The amplitude will be reduced, due to the loss of the greater amplitude low frequency components across the small condenser. We thus obtain from the sawtooth input to C3 a squared wave whose voltage appears across R3 and the C.R. network in series with it. The same result is produced across R4 and its series C.R. network by the sawtooth applied to C4.

Action of the Distortion Corrector Control

151. Curve 4 has been included to show how a change in aircraft height influences the shape of the timebase waveform that is required to maintain a display with constant ground range coverage, i.e. which keeps the target indications of a given ground range at the same distance from the tube centre as slant range changes. Column 8 tabulates slant ranges for an aircraft height of 3 miles and column 9 tabulates the corresponding echo times. For a height of 3 miles the ground echo time is 3 x 10.7 or 32.1 microseconds. The times of travel for the cathode ray tube spot are found by deducting 32.1 microseconds from the echo times. These values are shown in column 10. Plotting the values in column 2 against those in column 10, gives curve 4. It can be seen from the curve and from the figures in column 10, that the spot has longer time intervals in which to travel the same distance than when the height is 4 miles. Hence, as the aircraft height decreases the velocity must be decreased. These changes are achieved by varying the setting of the potentiometers in the two charging C.R's by means of the distortion corrector control. The pointer of this control tracks across a scale which is calibrated in intervals of 5,000 feet of height. When set to the aircraft height the potentiometers in the charging C.R's are set to the value which will give a charging waveform of the required shape. The potentiometers VR4, VR5, VR6, VR7 are ganged and move together when the distortion corrector control is operated.

Developing the P.P.I. Timebase

152. The method of employing the charging curves developed when the square waves obtained by differentiating the linear sawtooth waveforms are used as charging voltages on our two charging C.R. networks, is implied in the block schematic. The details are shown in the circuit diagram Fig.46 and waveforms in Figs. 50 and 54. The charging waveforms, correctly shaped by the design of the charging C.R. network, are applied to the grids of V6 and V8. V6 and V7 form a cathode-coupled paraphase amplifier which develops amplified antiphase versions of the charging waveform applied to V6 grid, at the anodes of V6 and V7. These antiphase outputs provide the push-pull timebase waveform applied to the X-plates of the P.P.I. VR8 controls the gain of this stage so serves as an X-amplitude control. V8 and V9 form a similar paraphase amplifier which feeds antiphase waveforms of the requisite shape to the Y-plates and VR11 serves as a Y-amplitude control.

153. Since the outputs of the magslip stators are always 90° out of phase the charging square waves obtained by differentiating the sawtooth wave forms are likewise 90° out of phase. Hence the charging waveforms on the grids of V6 and V8 are 90° out of phase. This means that the push-pull voltage applied across the X-plates is always 90° out of phase with the voltage simultaneously appearing across the Y-plates. Suppose that at some instant the magslip rotor

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TIME BASE ROTATION PRINCIPLE

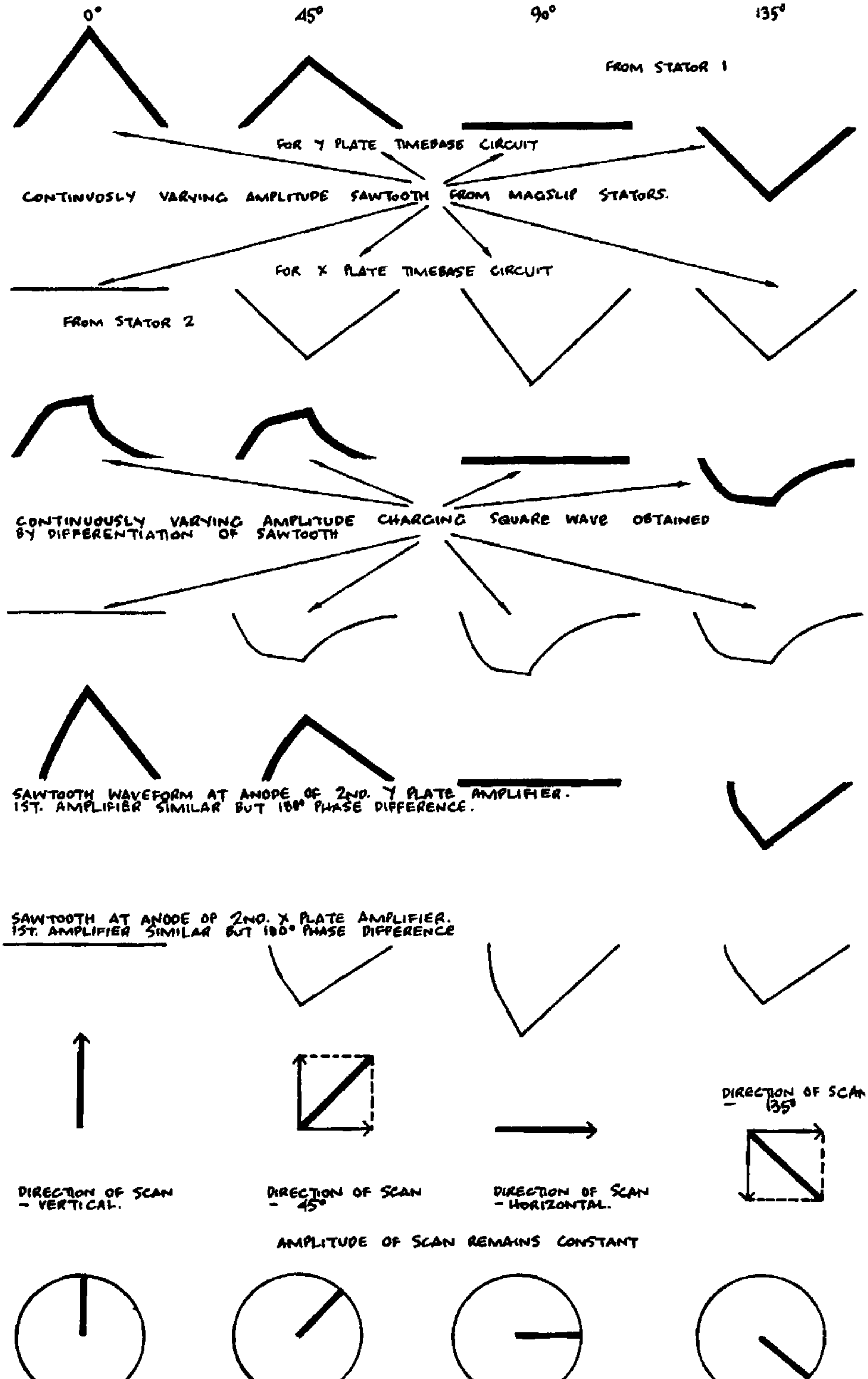

FIG.47

makes full coupling with the stator that feeds T4. It will then be making zero coupling with the stator that feeds T3. Hence we have the maximum amplitude sawtooth on T4 primary, and hence the maximum charging square wave applied to the charging C.R. at V6 grid. We will then have *maximum amplitude* antiphase waveforms at the anodes of V6 and V7. Since the rotor is now making zero coupling with the stator that feeds T3 the sawtooth applied to T3 primary has zero amplitude. Hence there is no charging square wave to operate on the charging C.R. at V8 grid and no output from the anodes of V8 and V9. The cathode ray spot is then subject only to a timebase voltage across the X-plates. Let us assume that the sense of this deflection is such as to cause a horizontal sweep from the centre to the right. During the next quarter turn of the magslip rotor the sawtooth input to T4 drops to zero while the input to T3 rises to a maximum. We will now only have a charging square wave on V8 grid and a deflecting voltage only across the Y-plates. This will be of such a sense as to carry the spot from the tube centre downward. A quarter turn later there will be zero amplitude charging square wave for V8 and a maximum amplitude square wave for V6 but in the reverse sense. The spot will therefore travel horizontally from the centre to the left. At the end of another quarter turn it will be travelling vertically upward from the centre. When the magslip stator is making a partial coupling with both stators there will be charging square waves for both charging C.R's. These will be 90° out of phase since the sawtooth voltages from which they are produced are 90° out of phase. The amplitudes of these square waves are such as to produce charging waveforms on the grids of V6 and V8 whose vector sum is equal to the maximum amplitude appearing at either grid. The vector sum of the outputs from both paraphase amplifiers will therefore always be equal to the maximum amplitude applied across either set of plates. Hence, the amplitude of the radial scan should remain constant as the scanner and magslip turn and cause constantly varying amplitudes across the X and Y plates whose vector sum gives a resultant scan that rotates in synchronism with the scanner. This is not quite true because the X and Y plates have different sensitivities.

Development of the Different Scans

154. The next point to consider is how altering the setting of the scan-marker switch, and hence the proportions of the master square wave and sawtooth output from the magslip stators, serves to develop different velocity timebases on the P.P.I. To deal with this question we must first consider what determines the rate at which the grids of V6 and V8 rise or fall when a charging square wave acts on the charging C.R's. As in a simple C.R., the charging rate depends on the charging voltage. Hence the greater the charging voltage provided by the charging square wave at the instant the height marker forms, the greater will be the rate at which the grid potential changes due to the charging of the C.R. If the square waves resulting from sawtooth differentiation are examined at the junction of C3, R3 or C4, R4 for any position of the scanner it will be observed that the square wave amplitude developed by the 240 microsecond sawtooth is greatest, that developed by the 1200 microsecond sawtooth comes next and that from the 720 microsecond sawtooth is smallest. On the face of things this seems rather contradictory to what we might intuitively have expected. We must remember that as the scan-marker switch setting is varied to produce different scans, relays in the waveform generator switch circuit components in the master multivibrator and switching valve stages. The effect of these changes gives us sawtooth waveforms with different working strokes but constant p.r.f's and nearly constant amplitudes. We may, therefore, regard our sawtooth waveforms as being made up by the synthesis of the same fundamental 670 c/s. sinewave and its harmonics. The differences consist in different amplitude and phase relations between these harmonics. It was pointed out earlier that the steeper the edges of a waveform the greater the proportion of high frequency components present. The 240 microsecond sawtooth has a working stroke of 240 microseconds and the 1200 microsecond sawtooth has a flyback of 300 microseconds. These waveforms have, therefore, a higher proportion of high frequency components than the 720 microsecond sawtooth which has a 720 microsecond working stroke and 780 microsecond flyback. Since the condensers C3 and C4 cause low frequency losses, the 720 microsecond waveform is affected more than the other two as it has the greatest proportion of low frequency components. Hence, we get the maximum amplitude square wave from

the 240 microsecond sawtooth which has the lowest proportion of low frequency components and the next greatest amplitude from the 1200 microsecond sawtooth with the 300 microsecond flyback, since it has the next lowest proportion of low frequency components.

155. We have accounted for the unexpected relationship between the amplitudes of the charging square waves, but we must still account for the fact that the smaller square wave from the 720 microsecond sawtooth provides a greater charging voltage and develops a higher velocity scan than the greater amplitude square wave from the 1200 microsecond sawtooth. The Radar Mechanic knows that when a waveform is passed through a condenser it centres itself about the D.C. level to which the condenser leak is returned. For C3 and C4 the leaks, R3 and R4, are effectively returned through the clamping diodes to about -100V. The square waves will then be centred about this level, i.e. the part of the waveform area above this level must be equal to the portion below it. For the narrow charging square wave developed from the 240 microsecond sawtooth the major part of the square wave amplitude will be above the -100v. level so we have a high effective charging voltage, since the charging voltage is fixed by the potential difference between the mean and peak levels. The mean level of the square wave from the 1200 microsecond sawtooth will be well up on the waveform because the charging square wave has a width of about 4/5 of the waveform. Hence, the actual charging voltage is relatively low, although the square wave amplitude is great. The square wave developed from the 720 microsecond sawtooth is roughly symmetric hence its mean level is near the centre and the charging voltage is roughly equal to half the amplitude. This provides a considerably greater charging voltage than that furnished by the 1200 microsecond sawtooth.

156. When the scan-marker switch is set to the different scan positions we then apply such charging voltages to the charging networks that our 240 microsecond sawtooth develops a non-linear scan whose velocity is such as to give approximately 10 miles ground range coverage, the 720 microsecond sawtooth develops a 20 mile coverage, and 1200 microsecond sawtooth develops a 40 mile coverage.

The Diode Clamping circuit

157. The next problem we must consider is how it is arranged that the height marker should start the radial sweep of the timebase from the tube centre. This is accomplished by means of the phantastron stage, V2, and the diode clamping circuits of V3, V4 and V5. The common point of the secondaries of T3 and T4 and the common point of the diodes V3a and V3b are tied to a point which is held at about -100 volts by means of a bleeder network between -300 volts and earth and decoupled by C11 + C14. The components in this bleeder are R28 and VR9, VR10 and R25. The anodes of the diodes V3a, V4a and V5a are strapped, as are the cathodes of V3b, V4b and V5b. The controls, VR2 and VR3, can be used to adjust these strapped lines to approximately -100 volts. Since the grid of V8 is tied to the common point of V4a and V4b, and the grid of V6 is tied to the common point of V5a and V5b, these grids cannot shift from the -100 volt level as diode conduction will occur in one diode section if the grids try to rise, and in the other section if the grids try to fall. Hence the charging square waves applied to the C.R's on the grids of V6 and V8 will not cause any movement of these grids while the diodes are able to conduct. We say, therefore, that the diodes are clamping the grids.

The Phantastron

158. V2 is a phantastron stage. A phantastron is essentially a one-valve flip-flop which develops antiphase square waves at the screen and cathode. In its stable state the cathode current raises the cathode potential sufficiently high to cut off the anode current by means of suppressor bias since the suppressor is returned to earth through the transformer, T2. All the cathode current is then passing to the screen which is at its minimum potential to the cathode is at its maximum potential. The diode V1 limits the potential to which the anode can rise to the value at the junction of R64 and R65. When V2 is in this stable state, the strapped diodes anodes and cathodes should both be at about -100 volts. If the height marker (amplified by T2 to about 20 volts) is now applied to the suppressor, it over-rides the suppressor bias sufficiently to cause a sharp flow of current to the anode. The screen

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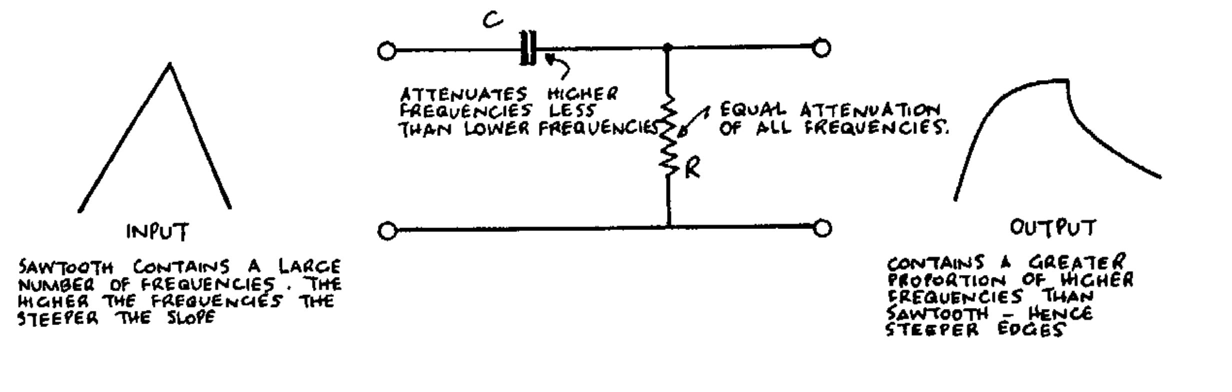
DIFFERENT VELOCITIES



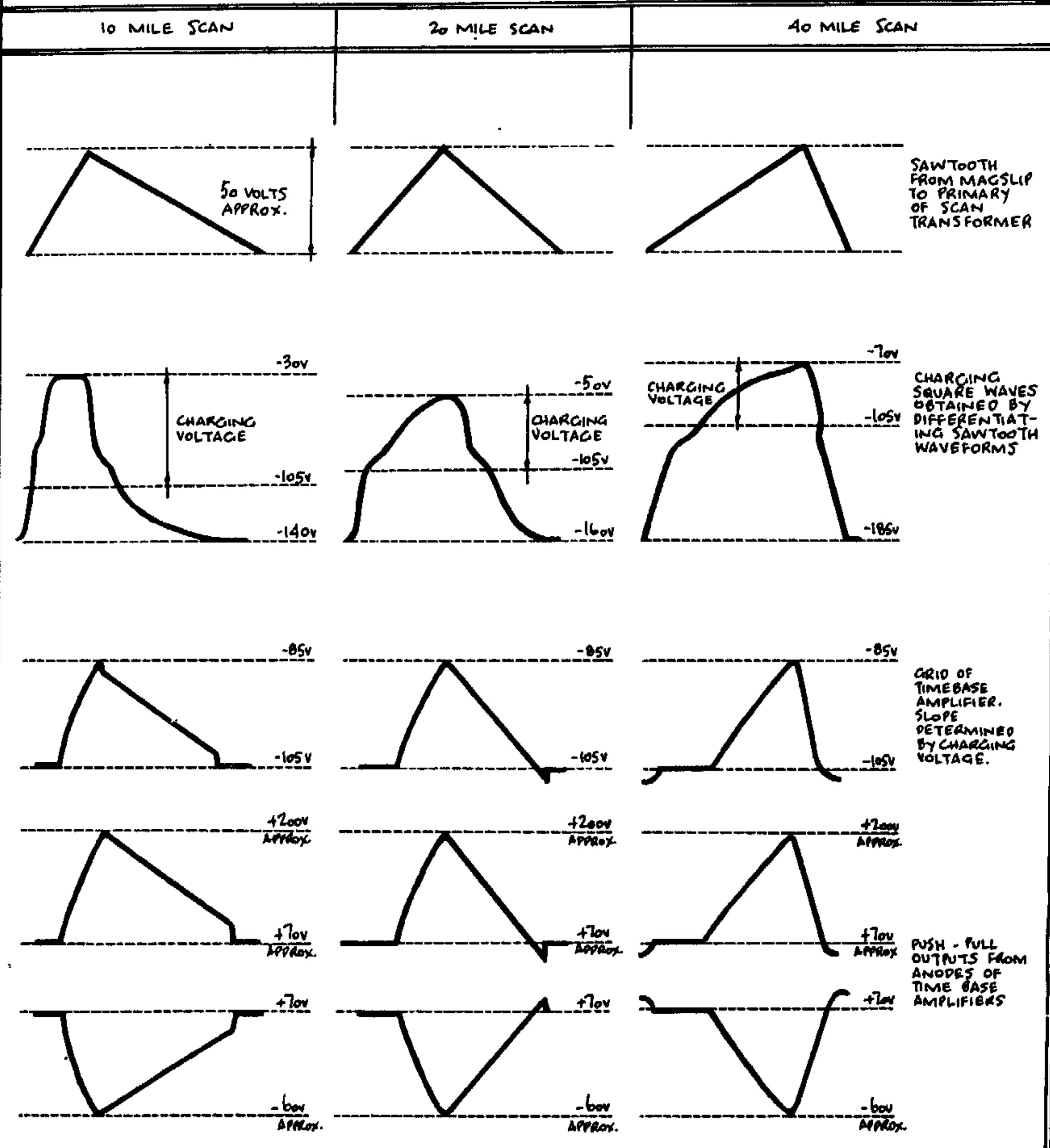


FIG.48

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INDICATOR TYPE 184 PHANTASTRON WAVEFORMS

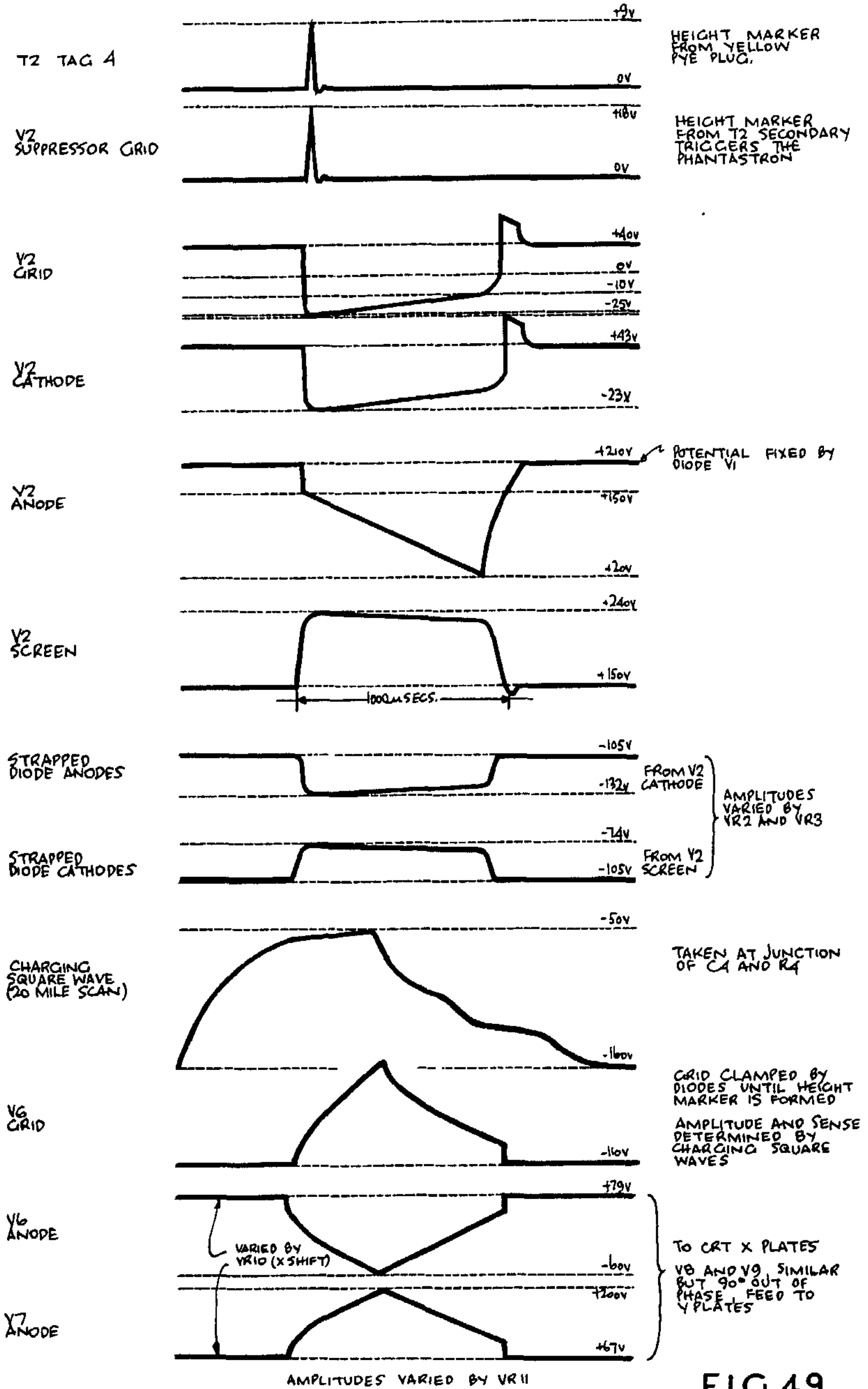

FIG. 49

potential then rises sharply and carries up the strapped diode cathodes. At the same time the fall at the anode is transmitted via C.5 to the grid and the cathode current diminishes. The cathode potential now falls sufficiently to remove the suppressor bias after the height marker ends. This sharp fall at the cathode, which is coincident with the rise at the screen, pulls down the strapped diode cathodes. The six diode sections are thus cut off simultaneously when the height marker forms. Since the grids of V6 and V8 are now unclamped, the charging square waves are now able to act on the charging C.R's and develop waveforms on the grids of V6 and V8 of the required non-linear type. These, as discussed previously, are amplidied by the paraphase amplifiers to develop the push-pull voltages applied to the deflecting plates which produce the radial timebase sweeps. The radial timebase therefore commences its sweep when the height marker forms. If the height marker has previously been set to the beginning of the ground echo the sweep begins when the ground echo reaches the aircraft. The centre of the display now represents the point on the earth's surface directly beneath the aircraft.

159. The height marker which is used totrigger the phantastron is developed in the receiver-timing unit. It is brought out from the receiver-timing unit at the white Pye plug. If Lucero is not included in the H.2.S. installation a Pye cable takes the height marker directly from the white Pye plug on the receiver-timing unit to the yellow Pye plug at the indicator. If Lucero is used one cable goes from the white Pye plug on the receiver-timing unit to the white Pye plug on Lucero. A second cable from the yellow Pye plug on Lucero to the yellow Pye plug on the indicator then completes the channel.

160. The grid of V2 is returned through R5 + R6 to the junction of R64 + R65. When V2 is in its stable state the grid will rise until its potential is just above that of the cathode. Grid current will then flow until the voltage drop developed across R5 + R6 holds the grid just slightly above the cathode. When the arrival of the height marker on V2 suppressor switches part of the screen current to the anode, the fall at the anode carries the grid down until an equilibrium point is reached where a further fall at the grid results in a reduction of anode current which tends to make the anode rise. The reason why the grid can fall considerably and the anode current increase simultaneously, is the fact that the reduction of the cathode current by a falling grid potential drops the cathode potential and so removes the suppressor bias. This causes the anode current to increase at the expense of the screen current. Hence, although the cathode current has dropped the anode current has increased. When the equilibrium point is reached, electrons leak away from the lower plate of C5 through R5 + R6 thus causing the grid potential to rise. The cathode current therefore rises and the cathode follows up with the grid. The anode current then tends to rise and cause a further flow of electrons to the top plate of C5. Since this flow is slower than the leak-away from the lower plate of C5 the grid and cathode potentials rise slowly in accordance with the net rate of discharge of C5 through R5 + R6. The anode meanwhile continues to fall because of the slow rise in anode current as the grid potential rises.

161. This stage continues until the cathode potential has risen sufficiently to again bring suppressor bias into operation and cause a reduction of anode current. This reduction causes the anode to rise and carry the grid and cathode up together to increase the suppressor bias still further. The cycle is cumulative so the anode current is quickly cut off by suppressor bias; the cathode and grid rise to their stable state levels, and the screen falls to its stable state level. The diodes are now again conducting so the grids of V6 and V8 are quickly returned to their clamped level. The paraphase amplifiers are now passing a steady current since the grids are stationary, and the anode potentials are therefore stationary. Since the anodes of the paraphase amplifiers are directly coupled to the P.P.I. deflecting plates the cathode ray tube spot will return to a position determined by the static potentials at the amplifier anodes. By suitably adjusting the grid potentials of V7 and V9 by means of the controls VR9 and VR10, these anode potentials can be adjusted to centre the spot, i.e. to have the radial scans start at the tube centre. VR9 is therefore the X-shift and VR10 the Y-shift.

162. The grids of V6 and V8 are unclamped for the period that V2 passes anode current, i.e. until the leak-away at V2 grid has increased the cathode current sufficiently to bring suppressor bias into operation again. This period is determined by the C.R. of C5 R5 and lasts about 1000 microseconds, allowing ample time for the completion of even the slowest scan. Since the height marker p.r.f. is the same as that of the master multivibrator it occurs at 1500 microsecond intervals. As the grids of V6 and V8 are unclamped for 1000 microseconds they must be clamped for a 500 microsecond period before the height marker forms.

Effects of VR2 and VR3

163. So far the only mention made of the controls VR2 and VR3 has been to state that they can be used to set the D.C. levels at which the strapped diode anode and cathode lines sit to about -100 volts. From Fig.46 it can be seen that we have a bleeder network between +300 volts and -300 volts formed by VR15, R8, R9, R16, R17, VR3. Altering VR3 will then vary the total resistance in the bleeder and hence the bleeder current. This change in bleeder current will cause a variation in the D.C. potential at the junction of R9 and R16, i.e. the potential to which the strapped diode cathodes are tied. At the same time there will be a variation in the D.C. potential applied to V2 screen. VR2 appears in a bleeder network between -300v. and earth, made up of R12, R27, R14, R15, VR2, R10, R13. Altering VR2 alters the equivalent resistance and hence the bleeder current. Hence, by varying VR2 the D.C. potential to which the strapped diode anodes are returned can be varied. Simultaneously the D.C. potential to which V2 cathode is returned will be altered. Hence VR2 and VR3 appear to do two things simultaneously:-

(a) Vary the operating conditions of the phantastron, V2.
(b) Vary the potentials to which the strapped diode anode and cathode lines are returned.

Action of V3

164. Let us suppose that the common point of V3a and V3b is returned to approximately -100v. and the D.C. potential of the strapped cathodes is more negative than this value. V3b will then pass current until the diode current flowing through the bleeder network raises the potential at the junction of R9 and R17 to just below -100v. Similarly, if the potential to which the strapped diode anodes are returned is positive to -100v. V3a will pass current through the other bleeder until the potential at the junction of R11 and R14 is just above -100v. Hence V3b will pull the diode cathode line to approximately -100v. provided the D.C. potential to which this line is tied is not too far negative to this value. Similarly, V3a will pull the diode anode line to approximately -100v. provided the D.C. potential to which this line is returned is not too positive to this value. It follows then that VR3 can have a limited range of settings that return the diode cathode line to a value negative to the decoupled potential at the common point of V3a and V3b without appreciably altering the D.C. level at the junction of R9 and R16. Similarly, VR2 can have a limited range of settings that return the diode anode line to a value positive to the decoupled potential at the common point of V3a and V3b without materially altering the D.C. level at the junction of R11 and R14. Hence, as long as VR2 and VR3 are within these limits the strapped diode anode and diode cathode lines will be very nearly at the same potential as the decoupled potential at the junction of V3a and V3b. Since the sections of V4 and V5 are in parallel with those of V3 and have essentially the same impedance, they will pass the same currents. The D.C. potential at the common point of V4a and V4b and the common point of V5a and V5b, will then be essentially the same as the decoupled potential at the junction of V3a and V3b while the settings of VR2 and VR3 are within this range. Since the grids of V6 and V8 are respectively tied to the common points of V5a, V5b and V4a, V4b, these grids will then also be at the decoupled potential of the junction of V3a, V3b. V3 thus serves to fix the clamped levels of V6 and V8 grids to a steady value for a limited range of settings of VR2 and VR3. Obviously V3 cannot perform these functions if VR3 is so set as to return the strapped diode cathodes to a potential positive to that at the junction of V3a, V3b or VR2 is so set as to return the strapped diode anodes to a potential negative to that at the junction of V3a, V3b.

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DEVELOPMENT OF PPI TIME BASE
10 MILE SCAN

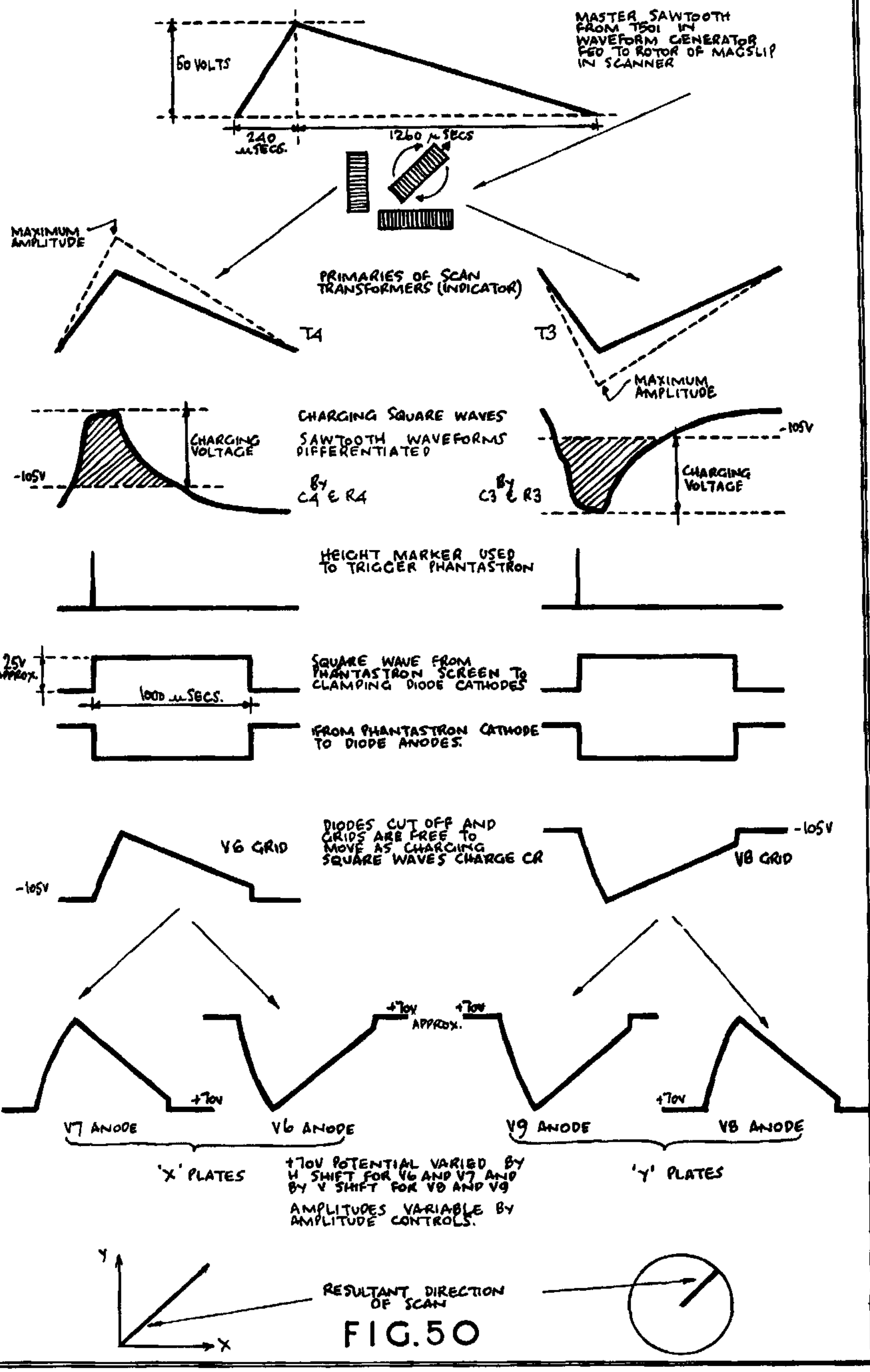


FIG.50

Phantastron Stability

165. It would appear, then, that as long as the settings of VR2 and VR3 remained within the limits discussed, these controls would influence neither the potentials of the strapped diode lines nor the operating conditions of the phantastron. This is not, however, quite the case. Although V3 tends to return the junctions of R9, R16 and R11, R14 to a constant value by superimposing a suitable diode current on top of the bleeder currents, the bleeder currents are still different. Hence, altering VR3 alters the bleeder current through R9 and hence the potential of V2 screen. Similarly, altering VR2 alters the bleeder current through R27 and hence V2 cathode potential. These controls can, therefore, influence V2 operating conditions without altering the potentials to which V6 and V8 grids are clamped. VR15 provides an additional means of altering the operating point of V2 screen. For V2 to operate reliably the following conditions should be fulfilled:-

(a) In the stable state the cathode, anode and screen potentials should be such that the suppressor bias is able to cut off anode current completely. If this condition is not fulfilled changes in supply voltages and pick-up voltages may cause increased anode current which will cause the grid to fall and initiate spurious triggering.

(b) When triggered, the reduction in cathode current due to grid fall must drop the cathode potential sufficiently to remove the suppressor bias by the time the trigger waveform is terminated.

Since both these conditions are contingent on suitable operating potentials for the screen and cathode, the permissible settings of VR2, VR3, and VR15 for phantastron stability must be such as to fulfil these conditions in addition to those which enable V3 to fulfil its functions.

166. V2 will be giving stable phantastron operation if the screen waveform shows a steady constant amplitude square wave with a p.r.f. of 670 c/s. and positive and negative portions of approximately 1000 and 500 microseconds duration respectively. This square wave must move along the height tube trace as the height control is operated and must disappear if the height marker triggering is removed from V2 suppressor by disconnecting the yellow Pye lead at the indicator.

Phantastron Square Wave Amplitude and "Squaring" Effects

167. VR2 and VR3 have a further effect which we have not so far considered. We have pointed out that V2 develops at its screen a square wave with a positive portion of 1000 microseconds and negative portion of 500 microseconds, and an antiphase waveform at the cathode. We have pointed out that these waveforms are used to unclamp the grids of V6 and V8 for 1000 microseconds after the height marker forms, and to clamp them for the 500 microsecond period before the next height marker forms. Obviously, the amplitudes of these waveforms must be in excess of the maximum swings occurring at the grids of V6 and V8 in the scanning periods. If the amplitudes fall below this value either section of V4 or V5 may be opened before the completion of the scan. This will happen if, say, V5a cathode swings negative with V6 grid until the cathode potential has fallen more than the drop impressed on V5a anode by the negative-going square wave. Similarly V5b would open if the anode were carried positive with V6 grid by more than the rise impressed on the strapped cathode line by the positive-going square wave. If the diodes open in this way before the scans are completed, the radial scan will develop a squarish pattern on the P.P.I. This squaring results from the fact that the grid swings at V6 and V8 are a maximum when the scan is nearing the horizontal and vertical positions respectively, since the one charging square wave is then of large amplitude and the other small. In the intermediate positions the charging square waves are more nearly equal and the grid swings are more nearly equal and well below their maximum value. It follows then that the square waves applied to the strapped diode anodes and cathodes must have an amplitude that does not fall below some minimum value. Since the amplitude of the square wave applied to the strapped diode cathodes

is determined by the potential divider formed by R9, R16, R17 and VR3, the setting of VR3 influences this amplitude as well as the operating potential of V2 screen. Similarly, VR2 influences the amplitude of the square wave applied to the strapped diode cathodes as well as the operating potential of V2 cathode. VR2 and VR3, therefore, have three simultaneous conditions to fulfil:-

(a) May not fix the potentials to which the strapped diode anodes and cathodes are returned at values repectively negative and positive to the decoupled potential at the V3a, V3b junction in order to permit V3 to clamp the grids of V6 and V8 to this decoupled potential.
(b) Must not drop the amplitudes of the square waves on the strapped diode lines below the amplitude of the maximum swing on the grids of V6 and V8.
(c) Must be so adjusted as to permit stable phantastron operation.

The inclusion of the control, VR15, makes it possible to obtain condition (c) at the same time and as conditions (a) and (b). It is therefore called the sync. control. VR2 and VR3 may be termed phantastron cathode and screen volts controls, for lack of more appropriate names.

168. "Squaring" may also occur if the timebase amplifiers "bottom" before the scan is completed. That is, while passing minimum current the anode potential drops so nearly to the cathode potential that a further grid rise or cathode fall does not cause a further anode fall.

Unstable Timebase Centre Effects

169. We may now consider what the effects will be if condition (a) in para.167 is not fulfilled. Suppose the diode cathode line is somewhat positive to the decoupled potential at the junction of V3a, V3b. V3b will then be cut off during the 500 microsecond clamping period and the strapped cathode line will not be pulled in to the decoupled potential, but will sit at a higher level. The common point of the secondaries of T3 and T4 is still returned to the lower decoupled potential. For a positive-going flyback, i.e. when the charging square wave is negative-going, the grids of V6 and V8 can rise until they reach the level of the strapped diode cathode line, i.e. to a value more positive than the decoupled potential. For a negative-going flyback, i.e. when the charging square wave is negative-going, the grids of V6 and V8 can fall until they reach the level of the strapped diode anodes, which is essentially equal to the decoupled potential. Hence V6 and V8 grids return to different D.C. levels when the sense of the charging square wave changes. This means that the D.C. levels of the paraphase amplifier anodes will shift. Hence the C.R.T. spot will not come to rest at the same point on the tube at the end of every flyback. If the scanner is rotating the radial scan will therefore commence at different points and give the effect of an unstable centre. Obviously, the same type of effect will be produced if the strapped diode anodes are returned to a potential below that of the decoupled potential. The amount of instability at the tube centre will depend on whether or not both the diode lines are simultaneously maladjusted and the amount of maladjustment.

Summary of P.P.I. Timebase Controls

170. From the preceding paragraphs it follows that setting up the P.P.I. timebase controls involves the following major points:-

(a) Adjustment of VR2, VR3 and VR15 to give the simultaneous requirements of:-
  (i) phantastron stability.
  (ii) stable centre.
  (iii) no "squaring".
(b) Adjusting the scanning centre to coincide with the tube centre with the shift controls VR8 and VR11.
(c) Adjust the gain of the paraphase amplifiers with VR9 and VR10 to obtain a radial scan of constant amplitude which is such as to provide the desired ground range coverages.

Further details will be discussed when dealing with setting up procedures. It might, however, be noted at this point that there will be some interaction between the shift and amplitude controls on each paraphase amplifier since both controls the affect overall push-pull output and the D.C. currents passed by the valves.

Setting-up the P.P.I. Map

171. We have traced the development of the timebases and the part played by the various controls which enter into the development of the scanning waveform. We have not, as yet, considered the part played by the setting control on the heading control unit. It was pointed out that this control can be used to make the heading marker flash up at any desired bearing on the P.P.I. The mechanical details of what goes on when this control is operated will be discussed in para. 420. The effect of the control may profitably be considered now. The bearing at which the radial scan sweeps out from the tube centre at any instant in the rotation of the scanner is determined by the relative amplitudes of the instantaneous deflecting voltages across the X and Y-plates of the P.P.I. This follows since the path along which the spot moves is the direction of the resultant obtained when the X and Y voltages are added vectorially. But the amplitude of the instantaneous X and Y voltages are determined by the amplitude of the instantaneous swings at the grids of V6 and V8. These grid swings, in turn, are determined by the charging voltage developed by the charging square waves. The amplitudes of these square waves is determined by the instantaneous amplitudes of the sawtooth outputs from the magslip stators. The instantaneous value of these sawtooth amplitudes is governed by the coupling between the rotor and each of the two stators. When the rotor makes full coupling with the stator that feeds T4, only V6 and V7 are operating and the scan is vertical. If we want the scan to travel vertically upward when the scanner looks due North, we must arrange that at that instant the rotor shall make full coupling in the appropriate sense with the stator that feeds T3 and the Y-amplifier, V8, V9. Since the rotor is geared to the scanner shaft no adjustment can be made to the rotor. Hence the adjustment can only be made by moving the stators relative to the rotor until this condition is fulfilled. Operating the setting knob on the heading control unit when the switch is set to the "Course" position brings a repeater motor into play in the scanner. This repeater motor rotates the magslip stators. They can thus be set to make any desired coupling with the rotor at any point in the scanner rotation. If the bearing ring has been set to 090°, say, and the setting knob is operated until the heading marker flashes along the bearing ring pointer, the coupling between the rotors and stators must be such as to make full coupling with the stator that feeds T4 at the instant the scanner goes through the dead-ahead position. A quarter turn earlier in the rotation of the scanner and rotor, the rotor will have made full coupling with the stator feeding T3 and the scan will have been travelling straight up. Hence, if the magslip stators have once been set to bring the heading marker up at the bearing on which the aircraft is heading, the bearing of the scan at any instant will be identical with the bearing of the direction in which the scanner is looking at that instant. This will, however, only be true as long as the aircraft continues on the same course or heading.

Need for D.R. Compass Control

172. Suppose the map is set when an aircraft is heading due East. The heading marker then flashes horizontally to the right every time the scanner goes through the dead-ahead position. The magslip rotor is then making full coupling with the stator that feeds T4 and the X-amplifier, at the instant the scanner looks dead-ahead and due East. If the aircraft now turns 90° in a clockwise direction and heads due South, the magslip rotor is still making full coupling with the stator that feeds T4 when the scanner goes through the dead-ahead position, since turning the aircraft in no way affects the scanner or magslip. The heading marker will therefore continue to flash horizontally to the right when the scanner looks dead-ahead, i.e. due South. Hence target indications from the South will now appear at the right of the tube, i.e. the P.P.I. map has slipped back 90°. Hence when the aircraft turns the heading marker remains stationary and the map rotates through the same angle as the aircraft but in the opposite direction. Such a state of affairs may be confusing to an Operator who wants

the top of the map to be North at all times and also wants the heading marker to move as the aircraft turns. Such a result can only be achieved by suitably turning the magslip stators as the aircraft turns. The D.R. compass is utilised to effect this rotation of the magslip stators when the switch on the heading control unit is set to the "Auto" position after once correctly setting the map.

Type of Control Required

173. The question now arises as to which way the magslip stators should turn when the aircraft turns. We noted that when the aircraft turns clockwise that the picture slips counterclockwise through the same angle. What we really want to happen by the time the aircraft completes its turn from East to South, is to have the magslip stators turn in such a way that the rotor makes full coupling with the stator that feeds T3 when the scanner goes through the new dead-ahead position. The coupling must be in such a sense that the sweep of the scan is then vertically downward. Suppose the aircraft took a minute to make the quarter turn, and assume the scanner turns at 60 r.p.m. The timebase will then make 60 x 670 sweeps in the turning interval. If the magslip stators were stationary the scans would be travelling horizontally to that right at the end of the minute since the rotor is at the same position with respect to the stators after 60 complete turns as it was when the first turn began. In order to have the timebase sweeping vertically downward the 60 x 670 sweeps should have carried the scan around the tube face not 60 times, but 60¼ times. That is, the rotor should have made 60¼ turns with respect to the stators. This result would be achieved if the stators moved ¼ turn counterclockwise while the rotor made 60 turns clockwise, i.e. while the aircraft made a quarter turn clockwise. Hence, we want the magslip stators to move through the same angle as the aircraft but in the opposite direction. The map will then appear stationary and the heading marker will rotate through the same angle as the aircraft turns.

Method of Obtaining the Required Control

174. When the aircraft turns the compass mounting turns with it while the compass needle tends to retain the same position, i.e. along the lines of force of the earth's magnetic field. Hence, whenever an aircraft turns there is relative motion between the compass mounting and the needle. This motion is utilised to operate the repeater motor in the scanner instead of using the setting knob and operating it by hand. If the wiring is correct in the heading control unit and D.R. compass box the relative movement between the compass mounting and needle will cause the repeater motor in the scanner to impress the correct rotation on the magslip stators. Should the wiring be incorrect the impressed rotation may be in the reverse sense and the heading marker will then go around the wrong way. A turn from East to South would then cause the heading marker to go from East to North on the H.2.S. display.

Blackout of Flyback

175. The blacking out of the flyback on the height tube is discussed in paras. 562 - 564. Blackout of the flyback on the P.P.I. is wrapped up with bright-up waveforms so cannot be dealt with until the development of these bright-up waveforms has been studied.

VALVE FUNDAMENTALS

Introduction

176. The Radar Mechanic who is interested in a detailed analysis of circuit action may feel that the master multivibrator, switching valve, lineariser, bass boost valve and the indicator paraphase amplifiers, have received scant attention. This temporary neglect has been deemed desirable because these circuits cannot be discussed in detail without elaborating on ideals of cathode coupling and negative feedback. To introduce these digressions while pursuing our study of the way the timebases are developed would tend to distract attention from our primary theme to side issues. Hence we have traced the development of the timebases by focussing our attention on the stages where major

adjustments are involved. We shall now go back to gather up the side issue.

Action of the Control Grid

177. Before going into the subject of cathode coupling it may be well to form a clear mental picture of some valve fundamentals. The Radar Mechanic is so accustomed to the standard practice of applying signals to grids and obtaining antiphase signals at anodes that he tends to assume that a valve will always phase invert, regardless of how the signal is applied. Since many stages in the H.2.S. installation do not invert, such habits of thinking can only result in hopeless confusion. Let us begin by recalling that when the cathode of a valve is heated, electrons are emitted. If a positive potential is applied to the anode these electrons, since they are negatively charged particles, are attracted to the anode. If the grid is held at the same potential as the cathode it exerts no appreciable effect on the flow of electrons from cathode to anode. If the grid is held at a potential that is more negative that that of the cathode it will repel the electrons back towards the cathode and thus reduce the flow to the anode. There will then be an accumulation of electrons between the grid and cathode which will repel electrons trying to leave the cathode. The total emission from the cathode will therefore diminish because of the 'space charge' that accumulates in the grid-cathode space. If the grid is held sufficiently negative to the cathode the force of repulsion will be so great as to stop the flow through the grid mesh completely. We say the grid is then "cut off on the grid". The number of volts by which the grid must be negative to the cathode to cause this cut-off is called the grid base of the valve. If the grid is held at a potential above that of the cathode it will attract electrons to itself. Hence part of the cathode emission will flow to the grid and part to the anode. If the grid is made so highly positive that a heavy flow of electrons passes to the grid the actual flow to the anode may diminish due to this "robbing" although the cathode emission is higher than it was when the anode current had a higher value. Hence for a fixed anode potential we may trace the following changes in anode current as the grid potential is varied:-

(i) For a grid potential negative to that of the cathode by an amount greater than some value called the grid base, no electrons reach the anode.

(ii) For grid potentials that are negative to cathode but inside the grid base, anode current increases as the grid potential rises. This increase is non-uniform at first, i.e. we have a lower bend on the grid volts-anode current characteristic then increase proportionately with the rise in grid voltage along the linear part of the characteristic.

When the grid swings positive to the cathode grid current starts to flow, and for a highly positive grid voltage this flow may be so great as to cause an actual reduction in the flow to the anode.

Valve Amplification

178. If we have an anode load in circuit but no cathode load the cathode remains at the potential to which it is returned but the anode potential falls below the H.T. voltage by the number of volts in the I.R. drop across the anode load. Hence, if a signal swings the grid above cut-off, current flows through the anode load and the anode potential falls to produce a negative-going signal at the anode for a positive-going signal at the grid. The voltage change at the anode for a given swing on the grid is given by the product of the anode load and the change in anode current. Since this product may be many times as great as the signal applied to the grid, we say the valve amplifies. If the grid is above cut-off and swings negative, the electron flow to the anode is reduced. Hence, the voltage drop across the anode load diminishes and the anode potential rises by the product of the anode load and the decrease of anode current. We thus obtain the familiar amplification and phase inversion when signals are applied to the grid.

The Cathode Follower

179. Suppose that we now consider a valve with only a cathode load and no anode load. Assume the grid is tied to earth through a grid leak. The hot cathode will emit electrons which will be attracted to the anode when H.T. is applied. Electrons will flow from earth through the cathode load to replace the emitted electrons. This flow will cause an I.R. drop across the cathode load and the cathode potential will rise. The grid, meanwhile, is returned to earth potential. As the cathode rises above earth potential while the grid is held, we progressively make the cathode more positive with respect to the grid as the cathode warms up and the emission increases. But saying the cathode is becoming increasingly positive to the grid is equivalent to saying that the grid is becoming increasingly negative to the cathode, even though the grid potential is stationary. Hence, an equilibrium point is reached when the cathode current reaches such a value that any further increase will result in such a repulsion from the grid that no more electrons will pass through the grid mesh to the anode.

180. Suppose that we now apply a positive-going signal to the grid. The repulsion of the grid will be reduced, and the cathode can now emit more strongly. Hence the cathode current increases and the cathode potential follows up as the grid rises. If the grid is swung negative by a signal the force of repulsion on the electrons increases and the accumulation of space charge causes reduced emission. The cathode current then falls and the cathode potential falls. This is the familiar cathode follower action which does not result in amplification, but delivers nearly the same output as input without phase inversion and at a low out-put impedance. This low output impedance is frequently utilised to match to low impedance cables.

181. Suppose that we consider next a stage utilising both anode and cathode loads. Let us assume the control grid is returned to earth through a grid leak. When H.T. is applied the hot cathode will emit electrons which will flow to the anode. The I.R. drop across the anode load will result in a fall at the anode. The flow through the cathode load will result in a rise of the cathode potential. Equilibrium will again be reached when the cathode current reaches such a value that the grid is so negative to the cathode that its repulsion prevents a further increase in the flow to the anode. If we now apply a positive signal to the grid the force of repulsion is reduced and the emission increases. Hence the anode potential falls and the cathode potential rises. We thus obtain from a positive signal on the grid a positive signal at the cathode and a negative signal at the anode. This gives us a phase-splitter circuit with antiphase outputs from a single stage. The relative amplitudes of the two outputs will depend on the relative magnitudes of the anode and cathode loads.

Degenerative or Negative Feedback

182. We stated previously that the output at the anode in a simple amplifier with the cathode returned to earth, was equal to the product of the anode load and the change in anode current produced by the change in grid voltage. To get a large output we must get a large change in anode current. But the change in anode current is determined by the swing of the grid relative to the cathode. If there is no cathode load the cathode remains stationary as the grid moves. If, however, there is a cathode load we have seen that the cathode follows the voltage changes at the grid. If a 6 volt change at a grid causes a current change of 3 ma. in a value using an anode load of 40 K. and no cathode load, the output is 120 volts and we have an amplification of 20. If we have a cathode load of 1 K. and again apply a 6 volt signal to the grid, the cathode voltage will rise with the grid as the emission tends to increase. But this following-up by the cathode means that the swing of the grid relative to the cathode is much reduced. <u>Hence, the actual increase in anode current, which depends on how much the grid swings up relative to the cathode, and not on the grid swing relative to earth, will be much less than before</u>. The output at the anode will therefore be materially reduced. We say, therefore, that an undecoupled cathode load introduces degenerative or negative feedback since its action is to reduce amplification.

183. Negative feedback can also occur in other ways. Any circuit arrangement which serves to reduce the swing of the grid relative to the cathode achieves the same result of reduced amplification. Three methods are used in the lineariser stage. In-phase signals are applied to V503 grid and cathode from V502 anode which serve to carry the cathode and grid up and down together and thus reduce the swing of the grid relative to the cathode. The cathode load is undecoupled to begin with, so the cathode would follow up even if no in-phase signal were applied to the cathode. Finally, the anode is coupled back to the grid so that as the grid tries to move in any direction the anode feeds back an antiphase voltage that opposes the grid movement.

Cathode Drive

184. So far we have discussed only grid drive, i.e. the application of signals to the control grid. We have, however, emphasised the fact that the change in anode current due to a signal on the grid, is determined by the swing of the grid relative to the cathode. Suppose that now we consider an amplifier whose grid is tied to some decoupled positive potential and whose cathode is returned to earth through a resistor. If H.T. is applied the hot cathode emits electrons which flow to the anode. The anode potential falls and the cathode potential rises. The cathode rise will continue until the cathode potential is sufficiently above that of the grid that the repulsion exercised by the grid prevents any further increase in emission. Note that both cathode and grid are positive to earth but the cathode is more positive than the grid. Hence the grid is negative to the cathode and we have a negative bias. Suppose we now apply a positive going signal to the cathode. This makes the cathode still more positive so that the grid, though stationary, is becoming more negative with respect to the cathode. The repulsion exerted on the electrons emitted by the cathode increases. Hence, the flow through the grid mesh to the anode is decreased and the anode potential rises. A positive signal on the cathode thus produces a positive signal at the anode. Had the cathode been driven negative the result would be to make the grid less negative with respect to the anode. It would therefore exert less repulsion on the electrons and the flow through the grid mesh to the anode would increase. Hence, the anode potential would fall. It follows then that cathode drive can be used when we desire amplification without phase inversion. It should be borne in mind that with cathode drive it may be necessary to centre tap heaters to a potential in the neighbourhood of the mean cathode potential. If this is not done trouble may arise due to leakage or insulation breakdown between heater and cathode. It may be noted that cathode drive will provide a low input impedance so will match a low impedance source.

The Timebase Paraphase Amplifiers

185. We are now ready to study the operation of the timebase paraphase amplifiers in more detail. Let us assume that V6 grid is being carried positive by the action of a positive-going charging square wave. As the grid rises V6 passes more current. V6 anode falls and V6 cathode rises so we have negative feedback which reduces the gain of V6. Suppose the grid rise is 22 volts and the cathode follows up 12 volts to leave an effective swing of grid with respect to cathode of 10 volts. The cathode rise also appears across VR8 + R24, in parallel with R23. If the ratio $\frac{R24}{VR8 + R24}$ is $\frac{5}{6}$, the rise impressed on V7 cathode is $\frac{5}{6} \times 12$ or 10 volts. But V7 grid is returned to the potential of VR9 slider which is decoupled by C15. Hence we have V7 cathode swinging 10 volts positive with respect to V7 grid. This is equivalent to swinging V7 grid 10 volts negative with respect to its cathode. Hence the signal applied to V6 grid serves effectively to drive V6 and V7 in antiphase to develop a push-pull output from the pair. V8 and V9 operate in the same fashion. Cathode-coupled amplifier circuits of this type are commonly known as long-tailed pairs.

The Amplitude Controls

186. VR8 determines what part of the change at V6 cathode is transferred to V7 cathode. Hence varying the setting of VR8 varies the output at the anode of V7. Since the effective cathode load of V6 is R23 in parallel with VR8 + R24, this cathode load is increased as VR8 is increased. Hence the negative feedback in V8 is increased at the same time as the input to V7 is reduced. Increaseing VR8 then simultaneously reduces the outputs of both

V7 and V8 but affects V7 output most. Decreasing VR8 will reduce the negative feedback operating on V6 and increase V6 output. At the same time, although the total voltage impressed across VR8 + R24 has decreased, the actual voltage impressed on V7 cathode may be increased, as a greater proportion of the change at V6 cathode is applied to V7 cathode. Hence, as VR8 is decreased the amplitudes of both V7 and V8 outputs will increase until a point is reached where they will fall sharply if the maximum negative input is applied to V6 grid. This unexpected development occurs when V7 cathode is driven so far negative that V7 runs into grid current. This grid current biasses back V7 grid and so reduces the gain of V7. Since part of this current is drawn through R23 the D.C. potential of V6 cathode is raised, thus increasing the bias on V6 and also reducing V6 gain.

The Shift Controls

187. As was pointed out earlier, VR9 and VR10 are used to adjust the D.C. potentials at V7 and V9 anodes during the 500 microsecond clamped period, to such a value that the cathode ray tube spot is returned to the tube centre by the flyback. If the electrode alignment of the P.P.I. is not distorted in any way the anode potentials of the valves in each amplifier pair must then be identical. Since there is a fairly wide tolerance in the values of the anode loads this equality of potential may call for rather different currents through the two valves in a pair. Hence, the operating point set for V7 with VR9 may not be the same as that fixed by V3 for V6. Hence, when the scan is centred with the shift controls the gain of V7 and V9 may be altered slightly, resulting in some change in scan amplitude. Also, since altering the amplitude controls alters the effective cathode loads of the amplifiers, an appreciable alteration in the settings of VR8 and VR11 may necessitate a slight adjustment to the shift controls.

The Waveform Generator Voltage Stabiliser

188. Before embarking on a further study of the master multivibrator and waveform generator sawtooth stages, we should consider the voltage stabiliser that provides 200 volts stabilised H.T. for V500, V501, V502, V503 and the transmitter-timing valve V505. This is V511, a VR116 connected as a triode cathode follower. The cathode load is that provided by the valve stages which it supplies. R586 (1M) and R587 (2M) form a voltage divider across the unstalilised 300 v. line. V511 grid is tied to the junction of R586 and R587, i.e. the 200 volt point, through the 2.2M leak, R585. C538, (6 mf.) provides decoupling. With the grid thus returned to 200 v. the valve will pass current until the cathode potential rises to the equilibrium point where the grid bias is such that no further increase in cathode emission is possible without increasing the grid or anode potential. The cathode will then sit close to the 200 volt level since the grid base of a VR116 is short. Should a transient change in the 300 volt supply cause the potential at the junction of R586 and R587 to change, the change would only appear at V511 grid after a time governed by the C.R. of R586 and C538. As the C.R. is 13.2 seconds, brief transients will not affect the potential at V511 cathode. Similarly, any small amount of 1000 c/s. ripple will not have any effect. Hence, provided the V.C.P. is set up correctly and functioning normally, and the 300 v. power pack in the power unit is not faulty, V511 will furnish a very stable H.T. supply at approximately 200 volts to V500, V501, V502, V503 and V505.

The Master Multivibrator

189. This stage, which controls the timebases, transmitter and height and range markers, is another application of cathode coupling. The following details should be noted:-

(a) The grid of V500 is returned to a decoupled potential of about 50 volts.
(b) V500 anode is tied to V501 grid through C504.
(c) C504 leak is R514 returned to the decoupled 50 volt point.
(d) The anode load of V500 and cathode loads of V500 and V501 are switched by relays M and N when the scan-marker switch is operated at the switch unit.
(e) The cathodes of V500 and V501 are coupled capacitively by .03 mf. (C505, 506 and 507 in parallel).

(f) The anode load of V501 is 35K. while V500 will always have more resistance than this between the anode and H.T. line.

190. When we switch on, both valves will pass current and both cathodes will rise. But as V500 anode falls it carries V501 grid down and so reduces the current passed by V501. The cathode potential of V501 then tends to fall and pull down V500 cathode through the coupling capacity. This is equivalent to a positive signal on V500 grid so V500 passes more current and its anode drops still further. We may, therefore, expect that V500 comes into full conduction and carries V501 grid down so far that cut-off occurs. With V500 in full conduction the current passed will be such that the cathode sits above the grid by several volts. Since V501 is cut off the other side of the cathode coupling capacity will be leaking away toward earth potential through the cathode load of V501. At the same time the grid of V501 will be climbing slowly as C504 leaks away through the 1M leak, R514. Since this C.R. is 10,000 microseconds the rise of V501 grid will be much slower than the fall at the cathode. When the cathode has fallen to a point where it is positive to the grid by less than the grid base V501 will again pass current. This will cause the cathode potential to rise and carry up the cathode of V500 via the coupling capacity. This positive drive on V500 cathode is equivalent to a negative signal on the grid. Hence, V500 passes less current and its anode rises. This serves to pull up V501 grid and increase the current passed by V501. The cycle is cumulative, and quickly cuts off V500 and brings V501 on hard. The cathode of V500 will have been carried up by an amount equal to the rise at V501 cathode so the cathode is at a potential well above that of the grid. We shall then have the cathode coupling capacity leaking away through the cathode load of V500 until the cathode potential has fallen to a level above the grid potential by less than the grid base. When this occurs V500 again starts to pass current. The anode then falls and carries down V501 grid. This reduces the current through V501 and its cathode potential so it conducts more heavily. The cycle is cumulative and quickly cuts V501 off and brings V500 on hard to complete one full cycle.

191. The time that V501 is cut off depends on how long it takes the cathode coupling capacity to leak away through the cathode load of V501 to a level where V501 can again conduct. This will depend partly on how far V501 grid was carried down when V500 came into conduction. This, in turn, will depend on the ratio of V500 anode load to its cathode load. How long it takes the coupling capacity to leak away through any specific number of volts depends on the value of V501 cathode load. Hence V501 cut-off time, which fixes the sawtooth flyback period, depends on:

(a) V501 cathode load.
(b) Ratio of V500 anode and cathode loads.

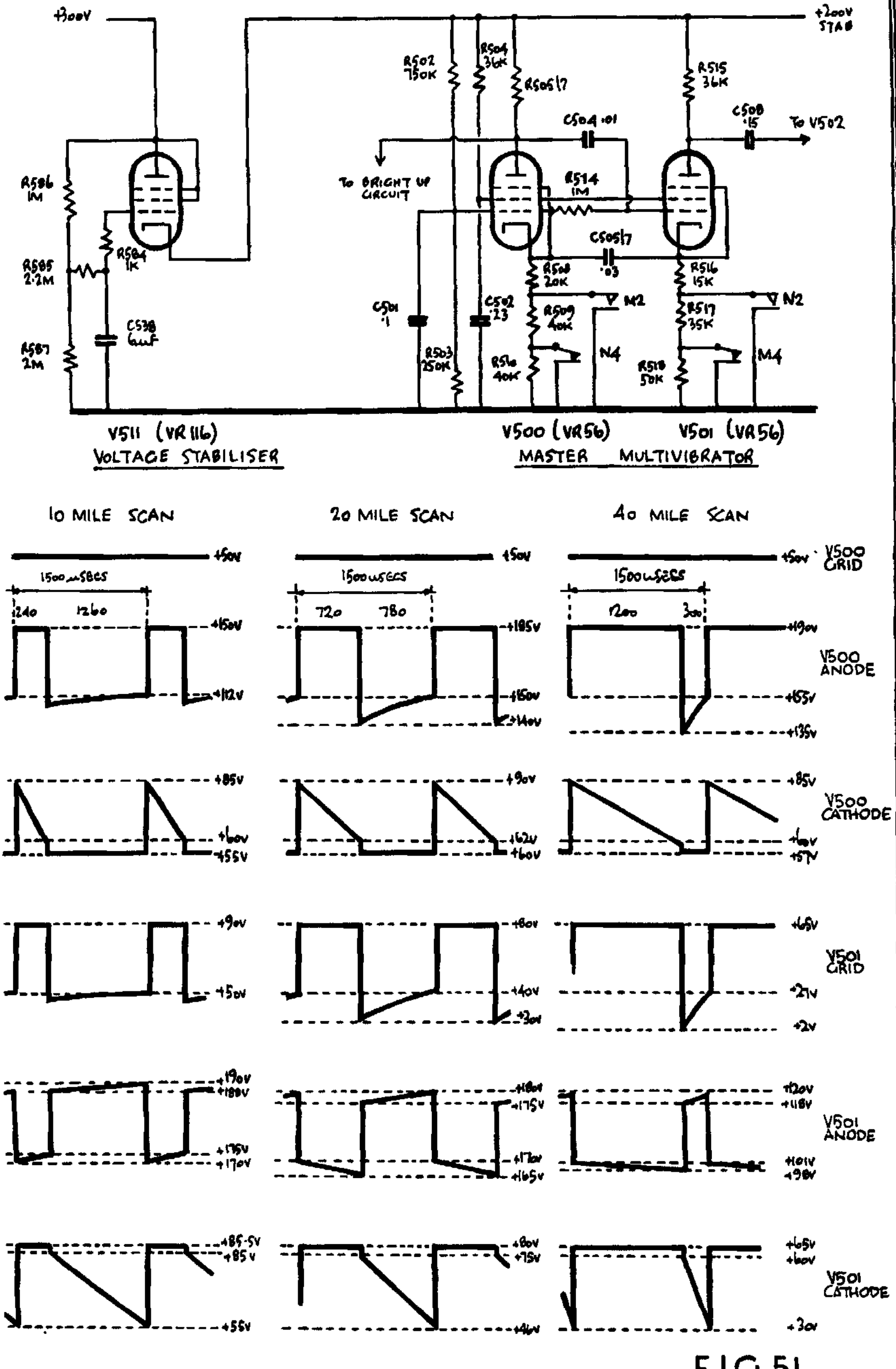
192. The time that V500 is cut off depends on how long it takes V501 cathode to fall from the level to which it is carried by the rise at V501 cathode to within its grid base of the decoupled grid potential. This depends mainly on the cathode load of V500. Hence, the V501 conducting period, which fixes the working stroke of the sawtooth, depends mainly on V500 cathode load.

193. To obtain the required working strokes we therefore switch V500 cathode load. This alters the current passed by V500 in its conducting period and hence the drop applied to V501 grid. In order to keep this drop constant, we then switch V500 anode load. To keep the p.r.f. constant at 670 c/s. we must then vary the cut-off time of V501 so that the sum of this cut-off time and the V500 cut-off time remains at 1500 microseconds. Hence, we switch V501 cathode load to achieve this result.

M and N Relay Contacts

194. When the scan-marker switch is set for the different scans the positions of the M and N relay contacts are as follows:-

C.D. 0896 L



MASTER MULTIVIBRATOR WAVEFORMS

FIG.51

C.D. 0896 L

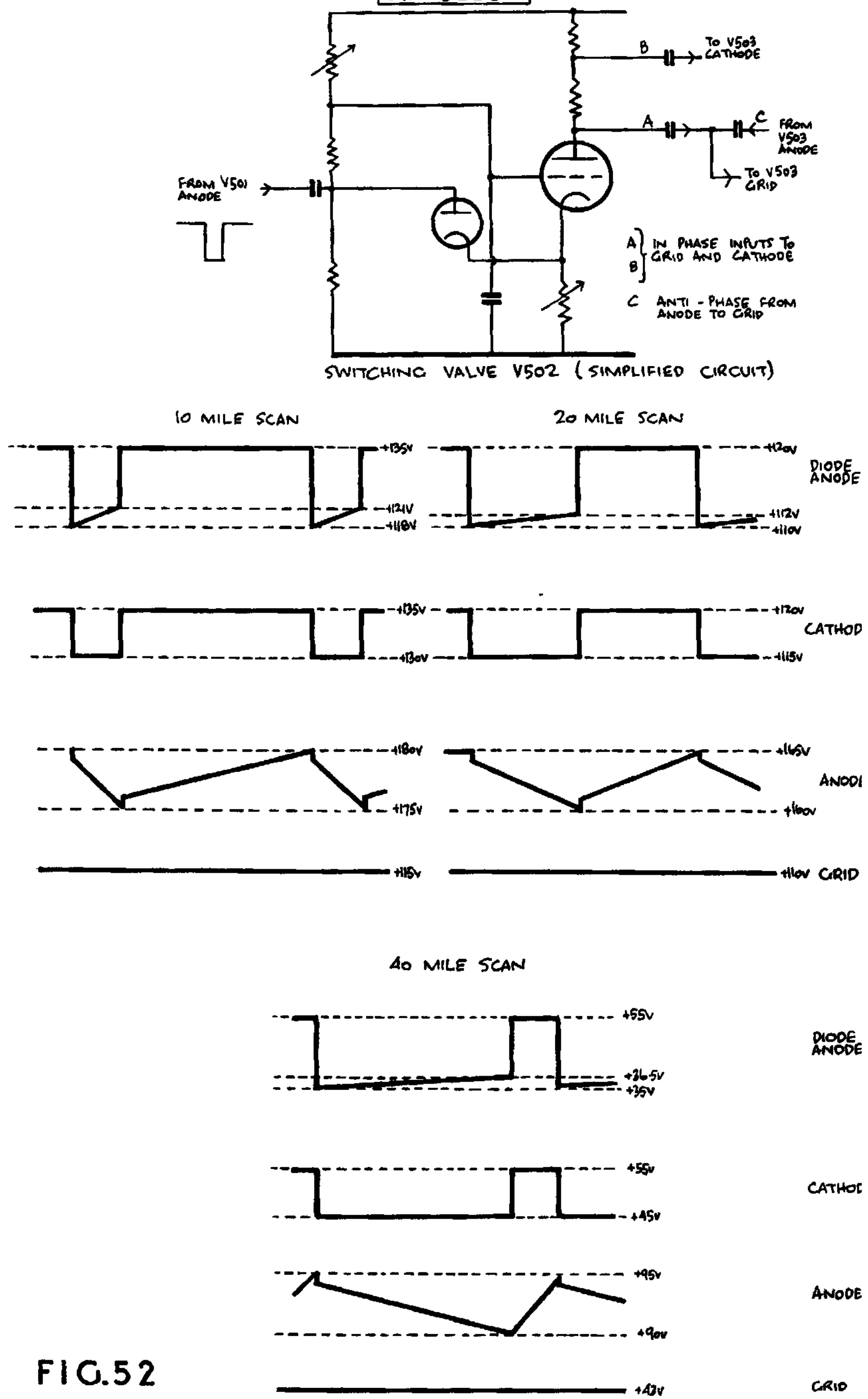


FIG.52

Setting	M1(5/6)	M2(7/8)	M3(3/4)	M4(1/2)	M5(9/10)	N1(5/6)	N2(7/8)	N3(3/4)	N4(9/10)	N5(½)
10/10	Closed	Open	Closed	Closed	Closed	Open	Closed	Open	Open	Open
10/20	Open	Closed	Open	Open	Open	Open	Closed	Open	Open	Open
30/20	Open	Closed	Open	Open	Open	Open	Closed	Open	Open	Open
100/20	Open	Closed	Open	Open	Open	Open	Closed	Open	Open	Open
100/40	Open	Closed	Open	Open	Open	Closed	Open	Closed	Closed	Closed
100/40-80	Open	Closed	Open	Open	Open	Closed	Open	Closed	Closed	Closed

The Switching Valve, V502

195. It was pointed out earlier that the negative part of the master square wave switched on the triode part of V502 while the positive part switched it off. These results are obtained through an indirect form of cathode drive. The following points should be noted:-

(a) The grid of V502 is returned to different decoupled potentials by switching components in a bleeder network as the scan-marker switch is operated.
(b) The cathode load of V502 is switched at the same time.
(c) The master square wave is applied to the strapped diode anodes of V502.
(d) The anode of V502 is tied to earth through C514 (.1) in series with R538 (2.2M.).
(e) The anode of V502 is coupled to V503 grid at the junction of C514 and R538.
(f) The output developed across R531 is applied to V503 cathode via C512, R539.

196. When the positive part of the master square appears on the strapped diode anodes the diode current rises and carries V502 cathode potential above the decoupled grid potential and cuts off the triode section. The anode then tends to rise exponentially as C514 charges exponentially through R531, R532 and R538 and C512 charges through R531 and R539. If V509 is removed, a large positive-going exponential appears at V502 anode. When the negative part of the master square wave is applied to the diode anodes the diode current falls and V502 cathode potential falls sufficiently to permit the triode to conduct. C514 can then discharge through the series impedance of the valve and R538. C512 can discharge through R532, the valve impedance and R539. With V503 removed we then obtain a large amplitude falling exponential at V502 anode.

197. If V503 is inserted we drive V503 grid and cathode with the outputs from V502. If we merely applied a signal to V503 grid we should have an amplified antiphase signal at the anode. Degenerative feedback due to the undercoupled cathode would reduce stage gain. By feeding in-phase signals to grid and cathode this gain is still further reduced. A further reduction is obtained by feeding back from V503 anode to grid through C513 and C514. It is this antiphase signal that results in only a small signal at V502 anode when V503 is inserted. Driving both grid and cathode with exponential waveforms of the same phase but different amplitudes tends to linearise the output of V503. The antiphase feedback from anode to grid furthers this linearisation by tending to counteract the curvature of the grid waveform by applying a curvature in the opposite sense. We thus obtain at V503 anode a reasonably linear sawtooth which is positive-going when V502 anode is negative-going, i.e. during the period that the negative part of the master square wave holds down V502 diode anodes. It is this positive-going sweep that is the working stroke of the sawtooth.

198. The different sawtooth slopes are obtained by altering the current passed by V503 during the triode conducting period. This is achieved by suitably switching the bleeder components to vary the decoupled potentials to which the grid is returned and by simultaneously switching V503 cathode load. The relay positions are shown in para. 194.

The Bass Boost Valve, V504

199. It has previously been pointed out that this stage fulfils two functions:-

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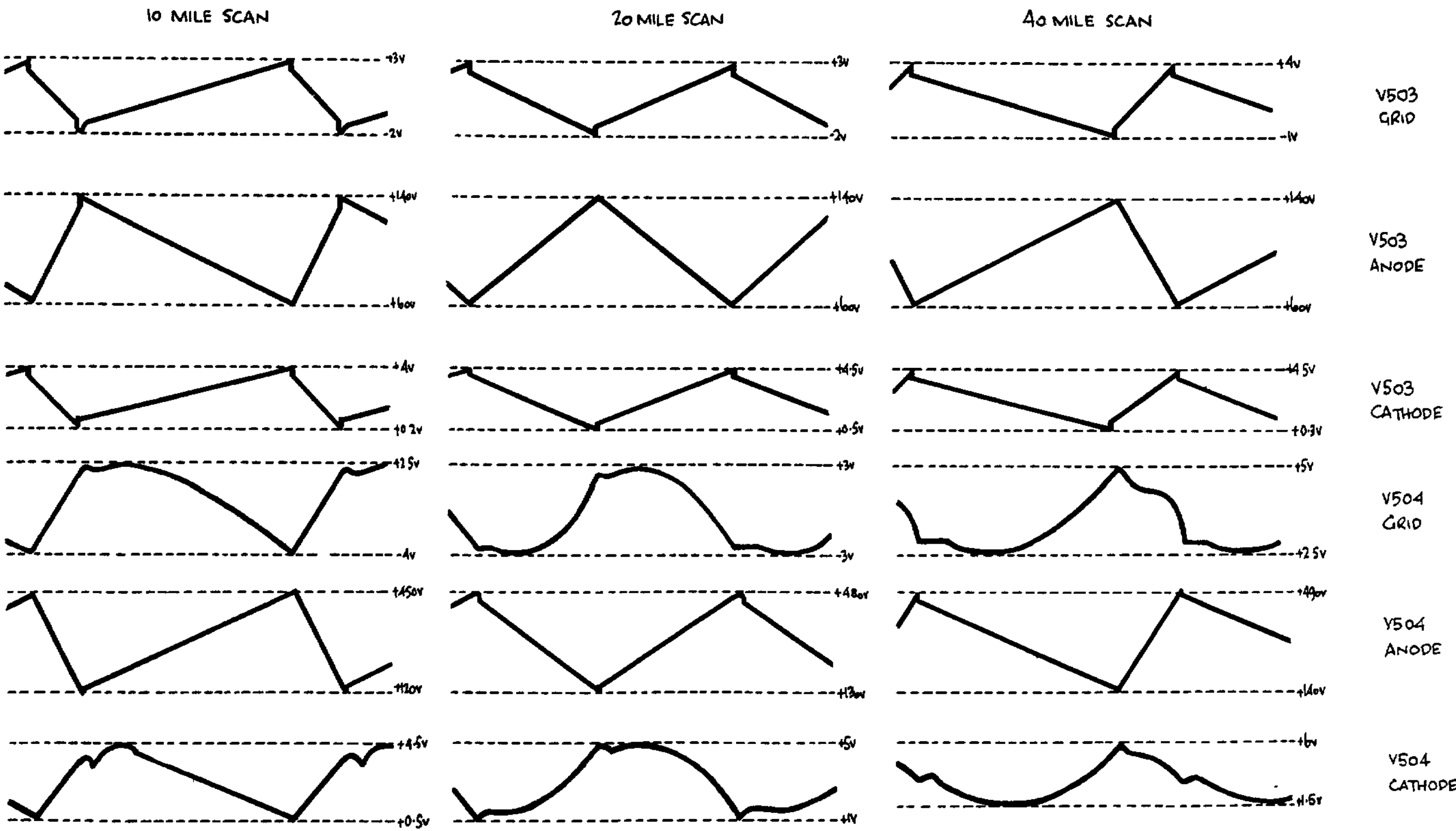

LINEARISER AND BASS BOOST VALVE WAVEFORMS

FIG. 53

(a) Provides discriminating negative feedback to deliberately introduce distortion by giving excess low frequency amplification. This is done in anticipation of subsequent low frequency losses which will balance out this deliberate distortion.

(b) Provides a sawtooth output at a sufficiently low output impedance to match into the low impedance cable.

R542 and R543 form a voltage divider which applies about 4/5 of the output from V503 anode to V504 grid. A feedback winding on the transformer T501 has one end tied to V504 cathode and the other end feeds back to the grid a signal in antiphase to the input. All frequency components are equally attenuated in the resistors R545 + R544. C539 + C518 (.003) provides the discriminating feedback. The low frequency components are considerably attenuated but the high frequency components are offered only a low impedance. Hence the net input on V504 grid has a greater proportion of low frequency components than is required for a linear sawtooth. The output sawtooth therefore has an excess of low frequency components which allows for later losses.

200. The amplitude at V504 anode is around 300 v. and the amplitude at V503 anode is around 75 volts. The gain of V504 is thus obviously low because of the negative feedback. The centre-tapped output winding provides a step-down of about 1 : 6 to apply about a 50 volts push-pull output which is taken to the magslip rotor and the height tube sawtooth transformer.

201. C519 and R547 are included to counteract a tendency for the phase of the feedback to become positive at the high frequency end. Such an effect would tend to cause instability and must therefore be prevented.

202. C537 serves to bypass to earth any R.F. voltages that may be picked up at V504 grid.

Power Supplies for the Indicator 184

203. As the +300V. power pack in the power unit is not capable of supplying the added stages in the indicator 184 which were not included in older indicators, it has been necessary to introduce another +300V supply. In the case of Mark IIC, this power pack is in the tuning unit 207 which also houses the klystron local oscillator. Circuit details are shown in fig. 228. A 5Z4G double half-wave rectifier is employed. 80V A.C. is brought to the transformer primary on pins 6, 7 (strapped) and 8, 9 (strapped) of the 18-way yellow. The smoothed output is taken to pin 16 of the yellow-green 18-way whence it is carried by cable to the 18-way yellow on the indicator 184.

204. In the Mark IIIA installation, the +300V supply for the indicator 184 is drawn from the +300V. pack in the power unit via 18/16. To relieve the added drain imposed on this pack by the indicator 184, an independent +300V supply is provided in the Mark IIIA receiver-timing unit.

205. The -300V negative rail supply used in the indicator 184 is developed from a bridge metal rectifier in the indicator itself. Circuit details are shown in fig. 228. 80V A.C. is brought to the indicator on 18/6,7 and 18/8,9 and applied to T.1 primary. One secondary feeds the bridge metal rectifier whose -300V output is smoothed by the choke L.1 and condenser C.25.

206. Other secondary windings on T.1 supply the various heater voltages. R.85 (680K.) and R.84 (330K.) provide a bridge between -300V and earth whose junction is at about -100V. The heaters for the valves V.3 to V.9 are held at this D.C. level since their cathodes are operating at a voltage in the vicinity of -100V.

207. In the earlier 184 indicators, which are not fitted with a centre-tapped heater system, trouble arises due to 1000 c/s pick-up from the heater line. To minimise the effect of this pick-up 300 ohm balancing potentiometer across the heater line was fitted retrospectively.

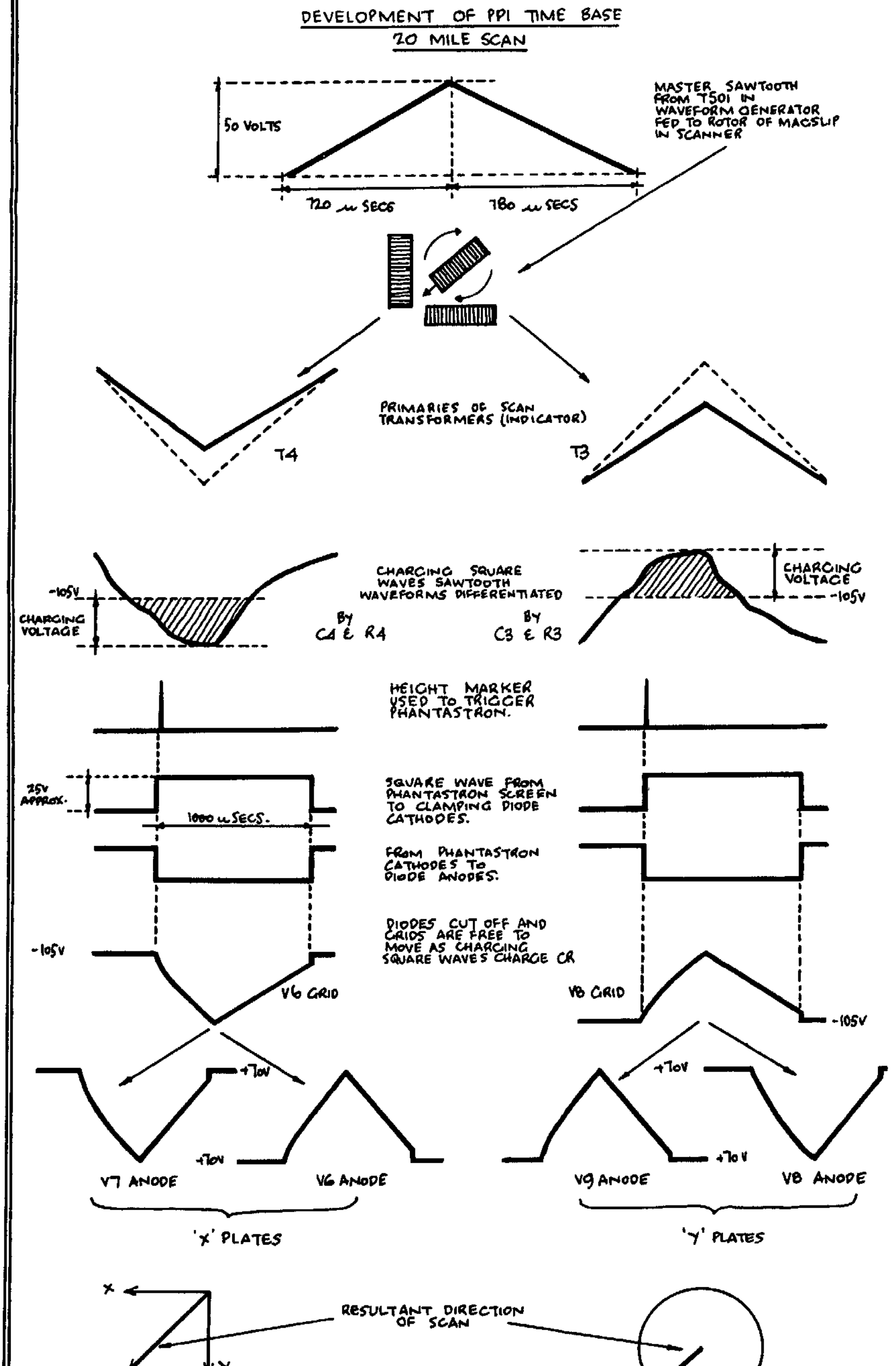
DEVELOPMENT OF PPI TIME BASE
20 MILE SCAN
50 VOLTS
720 μ SECS
780 μ SECS
MASTER SAWTOOTH FROM T501 IN WAVEFORM GENERATOR FED TO ROTOR OF MAGSLIP IN SCANNER
PRIMARIES OF SCAN TRANSFORMERS (INDICATOR)
T4
T3
-105V
CHARGING VOLTAGE
CHARGING SQUARE WAVES SAWTOOTH WAVEFORMS DIFFERENTIATED
BY C4 & R4
BY C3 & R3
HEIGHT MARKER USED TO TRIGGER PHANTASTRON.
25V APPROX.
1000 μ SECS.
SQUARE WAVE FROM PHANTASTRON SCREEN TO CLAMPING DIODE CATHODES.
FROM PHANTASTRON CATHODES TO DIODE ANODES.
DIODES CUT OFF AND GRIDS ARE FREE TO MOVE AS CHARGING SQUARE WAVES CHARGE CR
V6 GRID
V8 GRID
+70V
V7 ANODE
V6 ANODE
V9 ANODE
V8 ANODE
'X' PLATES
'Y' PLATES
X
Y
RESULTANT DIRECTION OF SCAN

FIG. 54

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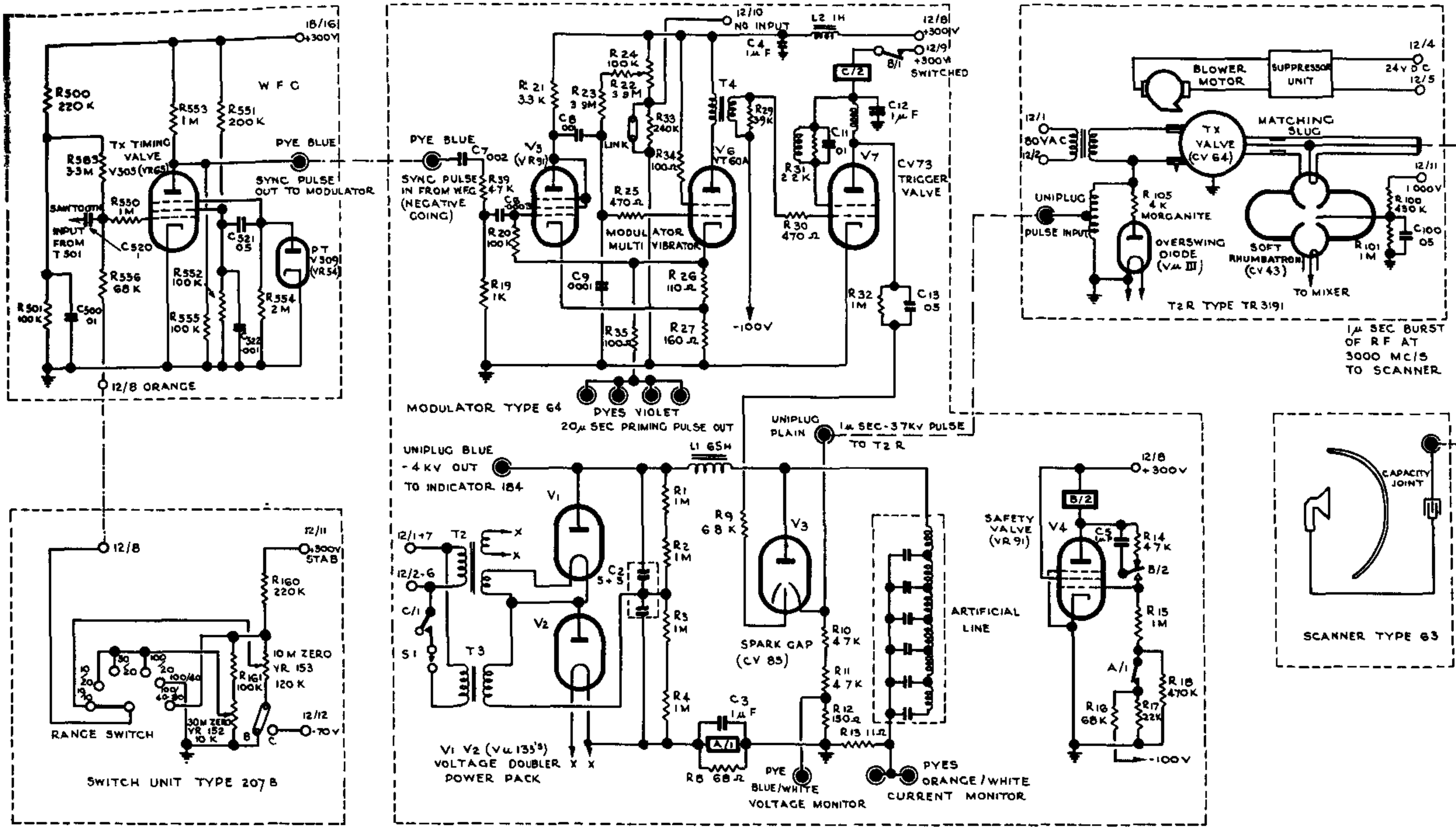

TRANSMITTER CHAIN.
MARK II C

FIG.55

FIG.55

CHAPTER 5 - THE H.2.S. TRANSMITTER CHAIN

Summary

208. It has previously been pointed out that the H.2.S. transmitter has a pulse width of 1 microsecond and à p.r.f. of 670 c/s. In the H.2.S. Mark IIC installation a wave length of about 9.1 cms. is employed, while in H.2.S. Mark IIIA, a wavelength of about 3 cms. is utilised. Magnetron transmitter valves are employed in both installations. The Mark IIC transmitter has a peak power of roughly 30 - 55 K.W. and an efficiency of 20 - 40%. In the Mark IIIA transmitter the peak power is about 18 - 40 K.W., and the efficiency about 13 - 30% when the T.R.3555 series transmitter units are used. In the transmitter chain the following functions are involved:-

(a) Synchronisation of the transmitter pulse to the timebase and control of timing of the transmitter pulse, i.e., of the point on the sawtooth where the transmitter fires.

(b) Development and shaping of the modulation waveform.

(c) Development of the actual R.F. transmitted pulse.

(d) Transferring the transmitter pulse from the magnetron transmitter valve to a suitable radiating array where it is launched into space. This involves suitable feeder arrangements and matching adjustments, a wave-guide mirror feed and the scanning mirror.

(e) Isolation of the transmitter pulse from the receiver chain by a suitable T.R. switch.

Stages (a) and (b) are essentially identical in the two installations. Stages (c), (d) and (e) differ in mechanical details but not in principle.

209. (a) A block schematic of the H.2.S. transmitter is given in fig.56.
(b) Circuit details for Mark IIC are given in fig.55.
(c) Circuit details for Mark IIIA are given in fig.64.
(d) Mark IIC transmitter unit details are shown in fig. 217-218.
(e) Mark IIIA transmitter unit details (T.R.3555 series) are shown in fig. 219 - 222.
(f) Relevant waveform generator 34 details are given in figs.223-225.
(g) Modulator type 64 details are given in fig.212-214.
(h) Relevant switch unit type 207B details are given in figs.226-227.

Outline of the Transmitter Synchronisation and Timing

210. The stages in the development and radiation of the transmitter output can be traced most readily on fig.55 for H.2.S. Mark IIC and in fig.64 for H.2.S. Mark IIIA. The chain commences with the synchronising and timing stages. These include V505 in the W.F.G., its controls in the switch unit, and V.5, V.6 and V.7 in the modulator type 64. V505 is the transmitter-timing valve. It is switched on and off by the sawtooth output from the single-ended secondary in T501. This sawtooth swings between approximately -150V and earth. It will centre itself on the grid side of C520 at the D.C. level to which V505 grid is returned. It can be seen that V505 grid is tied to the moving arm of a switch in the switch unit by means of which it can be returned to different positive potentials. Suppose that V505 were tied to a potential of +40V. The sawtooth would then have its mid-point at +40V. and would try to swing V505 grid up 75V and down 75V from this level. That is, V505 grid would try to swing between -35V and +115V. The cathode of V505 is returned to earth. Assuming the grid base to be 2 volts, V505 will remain cut off until the working stroke of the sawtooth carries the grid up from -35V. to -2V., i.e., through 27V. This means that V505 grid comes into conduction 33/150 ths. or about .22 of the way up the sawtooth. Obviously, if V505 grid is returned to a different potential the valve will be brought into conduction at a different point on the sawtooth. We see then that the switch unit portion of our circuit is devised to permit a variation in the point on the sawtooth at which V505 comes into conduction.

211. It is arranged that when V505 comes into conduction it develops a negative-going pip at its anode. This pip will then have a p.r.f. equal to that of the sawtooth and hence of the master multivibrator. The point on the sawtooth at which it occurs is governed by the switch unit components of our circuit. This pip is taken from V505 anode to the blue Pye plug on the W.F.G. panel and by cable to the blue Pye plug on the modulator type 64. V.5, V.6 in the modulator type 64 form a free-running multivibrator whose p.r.f. can be varied by means of the potentiometer, R24. This is a ratchet type preset at the back of the modulator chassis. It varies the positive potential to which V.6 grid is returned and therefore varies the length of time it takes V.6 to come back into conduction. We shall call this preset the modulator multivibrator P.R.F. control. This is set so that a free-running p.r.f. of about 600 c/s. is obtained. The circuit is so designed that V.6 only conducts for 20 microseconds, i.e., V.5 is conducting most of the period and V.6 grid has a long exponential rise. The negative-going pip from V505 anode is applied to V.5 grid while V.5 is conducting and V.6 grid is rising exponentially toward cut off. The pip carries V.5 grid down thus causing V.5 anode to rise sharply. This sharp rise carries V.6 grid above cut-off and initiates V.6's 20 microsecond conducting period. That is, the negative-going pip from V505 anode is synchronising the modulator multivibrator to run at the same p.r.f. as the master multivibrator and causes a negative-going 20 microsecond pulse to appear at V.6 anode every time the sawtooth carries V505 grid above cut-off.

212. The transformer, T.4, in V.6 anode phase reverses the 20 microsecond pulse and amplifies it to around 140V. The circuit shows V.7 grid returned to -100V. and V.7 cathode returned to earth. Hence, V.7 will be cut off at all times, except for the 20 microsecond period that the positive pulse is applied to its grid. That is, the 20 microsecond pulse cuts V.7 on and off. In the anode of V.7 we have the choke L.4. Its stray capacity tunes this choke to resonate at about 400 kc/s. When the back edge of the 20 microsecond pulse cuts V.7 off, a positive ring of about 10KV. amplitude is developed at the resonant frequency. This ring is applied to the trigger electrode of the spark gap switch, V.3. The first swing of the ring will be positive-going as V.7 is cutting off and the anode potential is rising. As the potential of the trigger electrode swings up towards a 10KV. peak amplitude, the potential difference between the trigger and the earthed ring electrode rises to about 3KV. when flash-over occurs. This flash-over initiates the formation of the 1 microsecond modulating pulse which fires the transmitter. The ringing at V.7 anode is, of course, quickly damped out when flash-over occurs so the undamped amplitude of the 10KV will not be obtained if V.3 is operating.

213. Summarising, we have the following chain of events:-

(a) The sawtooth on V505 grid carries V505 above cut-off at a point on the sawtooth which depends on the potential to which V505 grid is returned in the switch unit.

(b) When V505 crosses cut-off a negative-going pip appears at V505 anode.

(c) This negative-going pip synchronises the 600 c/s free-running modulator multivibrator to run at the master multivibrator p.r.f.

(d) The appearance of the negative-going pip on V.5 grid brings V.6 into conduction for its 20 microsecond conducting period to develop a negative-going 20 microsecond pulse at V.6 anode which is phase reversed by a transformer and applied to V.7 grid.

(e) This 20 microsecond pulse brings V.7 on for 20 microseconds. On the back edge of the pulse V.7 cuts off and the choke in its anode rings at 400 kc/s, the first ring being positive-going and of about 10KV amplitude if not damped by conduction in V.3.

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TIMING OF Tx PULSE AND MARKERS

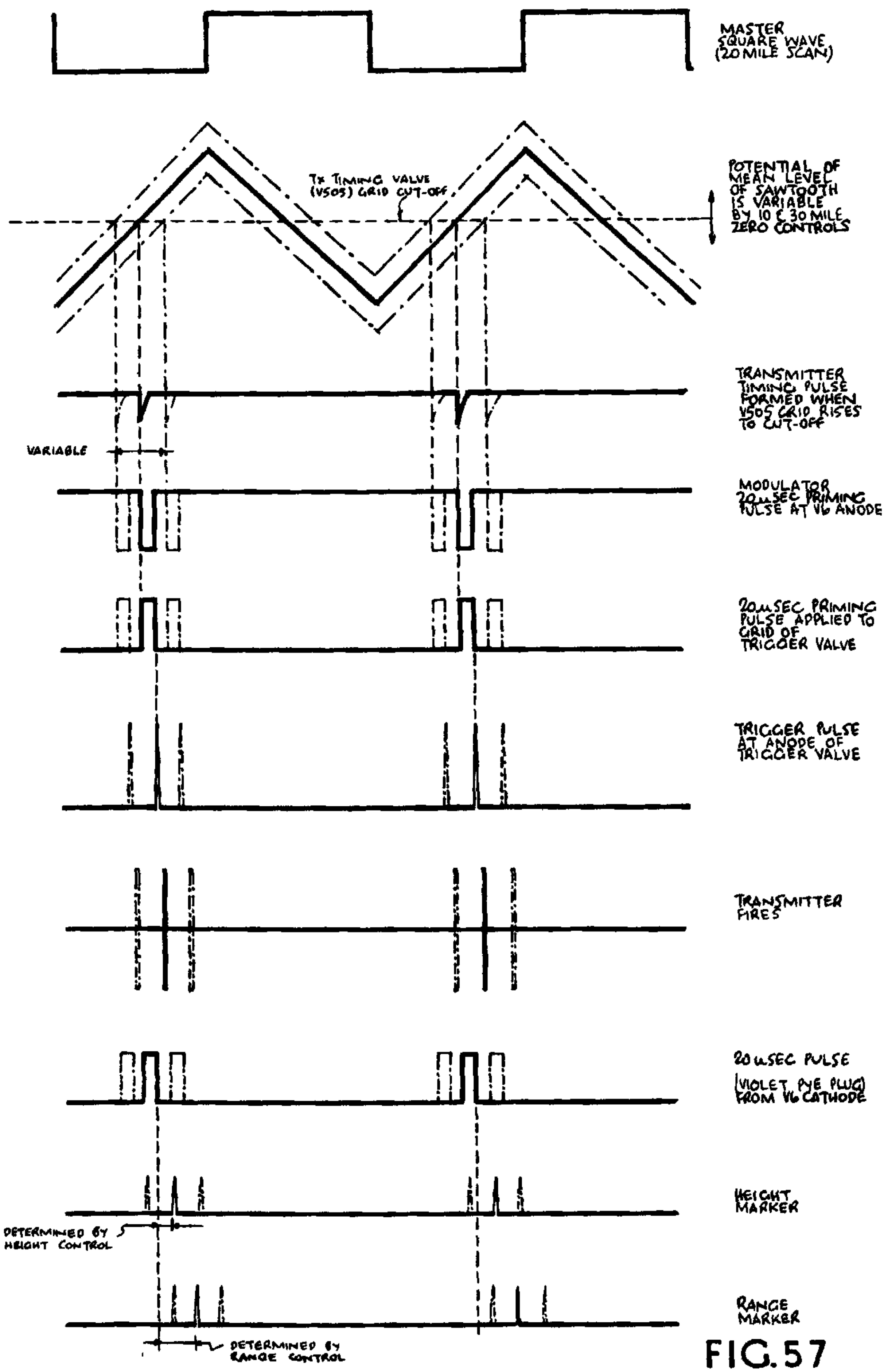

FIG. 57

(f) This 10KV ring is applied to the trigger electrode of the spark gap switch, V.3 and causes flash-over between the trigger and the ring electrode through which the trigger passes.

(g) This flash-over initiates the formation of the 1 microsecond modulating pulse which fires the transmitter to produce a 1 microsecond burst of R.F.

214. Since the pip at V505 anode thus determines the point on the sawtooth at which the transmitter fires we call this pip the transmitter-timing pulse and V505 the transmitter-timing valve.

215. The 20 microsecond pulse applied to V.7 grid is termed the modulator priming pulse.

216. The 10KV ring developed at V.7 anode is called the trigger pulse, and V.7 is called the trigger valve.

217. We may now restate our summary as follows:-

(a) The transmitter-timing pulse determines the start of the 20 microsecond modulator priming pulse.
(b) The trigger pulse is formed on the back edge of the priming pulse.
(c) The 1 microsecond modulating pulse forms just after the trigger pulse. There is actually a slight delay between the back edge of the 20 microsecond priming pulse and the beginning of the modulating pulse. This is the combined effect of the time of rise of the trigger pulse and a delay in the action of the spark-gap switch, V.8.
(d) The modulating pulse fires the transmitter to develop a 1 microsecond burst of R.F. The wavelength will be 9.1 cms. for H.2.S. Mark IIC and about 3.2 cms. for H.2.S. Mk.IIIA.

Synchronisation of Signals and Markers to the Timebase

218. Focussing our attention on the subject of synchronisation of the transmitter pulse (and hence of signals) to the timebase, we note the following points:-

(a) The timebase is developed from the sawtooth taken from the centre-tapped secondary on T501 in V504 anode.
(b) The transmitter-timing pulse, and hence also the actual transmitter pulse, are controlled by the single-ended secondary output from T501.
(c) There is therefore one transmitter pulse for each timebase sweep.
(d) As long as the potential to which V505 grid is returned in the switch unit is kept constant the transmitter-timing pulse will occur at a fixed point in the timebase sweep.
(e) The actual transmitter pulse will occur after this timing pulse by a fixed interval of about 22 microseconds determined by:-

(i) The duration of the modulator priming pulse.
(ii) The amplitude to which the trigger pulse has to rise before the trigger gap flashes over.
(iii) The further delay before the spark gap switch becomes fully conducting.

Since this interval will remain fixed in a serviceable set, the transmitter pulse must occur at a fixed point in the timebase sweep if the amplitude of the sawtooth from V504 remains constant, and the amplitude of the timebase paraphase amplifier output remains constant. Signals must then appear at a fixed point in the timebase sweep, and therefore at a fixed distance from the P.P.I. centre or a fixed distance up the height tube trace. This is equivalent to saying that the transmitter pulse and the signals are locked to the timebase.

219. The height and range marker circuits commence their measurement of time at the back edge of the 20 microsecond priming pulse. These markers are therefore also locked to the timebase.

220. It was pointed out earlier that the modulator multivibrator will free-run at about 600 c/s. Should the transmitting-timing pulse not be applied to V.5 anode, or be ineffective for any reason, the modulator priming pulse will still be developed but at a p.r.f. of about 600 c/s. The transmitter pulse, signals, and the height and range markers will then be developed at a p.r.f. of 600 c/s. The timebase will, however, have a p.r.f. of 670 c/s. There will, therefore, be no synchronisation of the signals and markers to the timebase and the signals and markers will drift. It is apparent then that the transmitter timing pulse is the actual synchronising or locking agent.

Control of Transmitter Timing

221. We shall next consider how the transmitter timing can be varied and what effect such variation will have on the display. We have seen that the point at which V505 goes into conduction to form the transmitter-timing pulse is governed by the D.C. potential to which V505 grid is tied. We can, therefore, vary the point on the sawtooth at which the transmitter pulse is formed by varying this D.C. potential. Examination of our circuit diagram, fig.55, shows V505 grid returned to the moving contact of a switch. This moving contact is one of the three moving contacts on the scan-marker switch. We have already dealt with one contact which serves to operate the relays that switch the circuit components in the master multivibrator and timebase switching valve stages. The third contact is used for operating relays to switch components in the height and range marker circuits in the receiver-timing unit. Returning to the moving contact in which we are interested at present, we note that when we set the scan-marker switch to its respective settings, we have V505 grid returned to the following points if the various links are in the B (Bomber Command) positions:-

Position	Scan	V505 grid returned to	Name of Control	Range of Variation
10/10	10 mi.	VR.153 slider	10 Mi. Zero	0 to +60 V.
10/20	20 mi.	VR.152 slider	30 Mi. Zero	0 to + 5. V.
30/20	20 mi.	VR.152 slider	30 Mi. Zero	0 to + 5. V.
100/20	20 mi.	VR.152 slider	30 Mi. Zero	0 " "
100/40	40 mi.	Earth	None	None
100/40-80	40-80 mi.	+62V.	None	None

From our table it appears that V505 grid can be returned to a potential variable between 0 and +60V. by means of the switch unit control labelled the 10-mile zero. In the next three positions it can be varied between 0 to +5. V. by a control called the 30-mile zero. These presets on the switch unit can be used to alter the point on the sawtooth at which the transmitter-timing pulse forms. The result will be a variation in the point on the sawtooth where the back edge of the 20 microsecond priming pulse forms and the point where the transmitter pulse forms just slightly later. As the height and range marker circuits commence their measurement of time from the back edge of the 20 microsecond priming pulse the markers will form at different points on the sawtooth and hence will move on the displays as the setting of the 10 or 30 mile zero is altered. Since the point at which the transmitted pulse occurs is being varied the point at which the signals appear is also varied. The distance from the centre of the P.P.I. at which signals appear and their distance up the height tube trace will therefore change as the settings of these controls are altered. As V505 grid is made more positive (clockwise rotation of controls), the valve goes into conduction earlier and signals and markers form earlier on the sawtooth so more towards the P.P.I. centre and down the height tube trace, If the controls are turned counterclockwise to make V505 grid less positive the signals and markers form later on the sawtooth and therefore move away from the P.P.I. centre and up the height tube trace.

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CONTROL OF TRANSMITTER FIRING

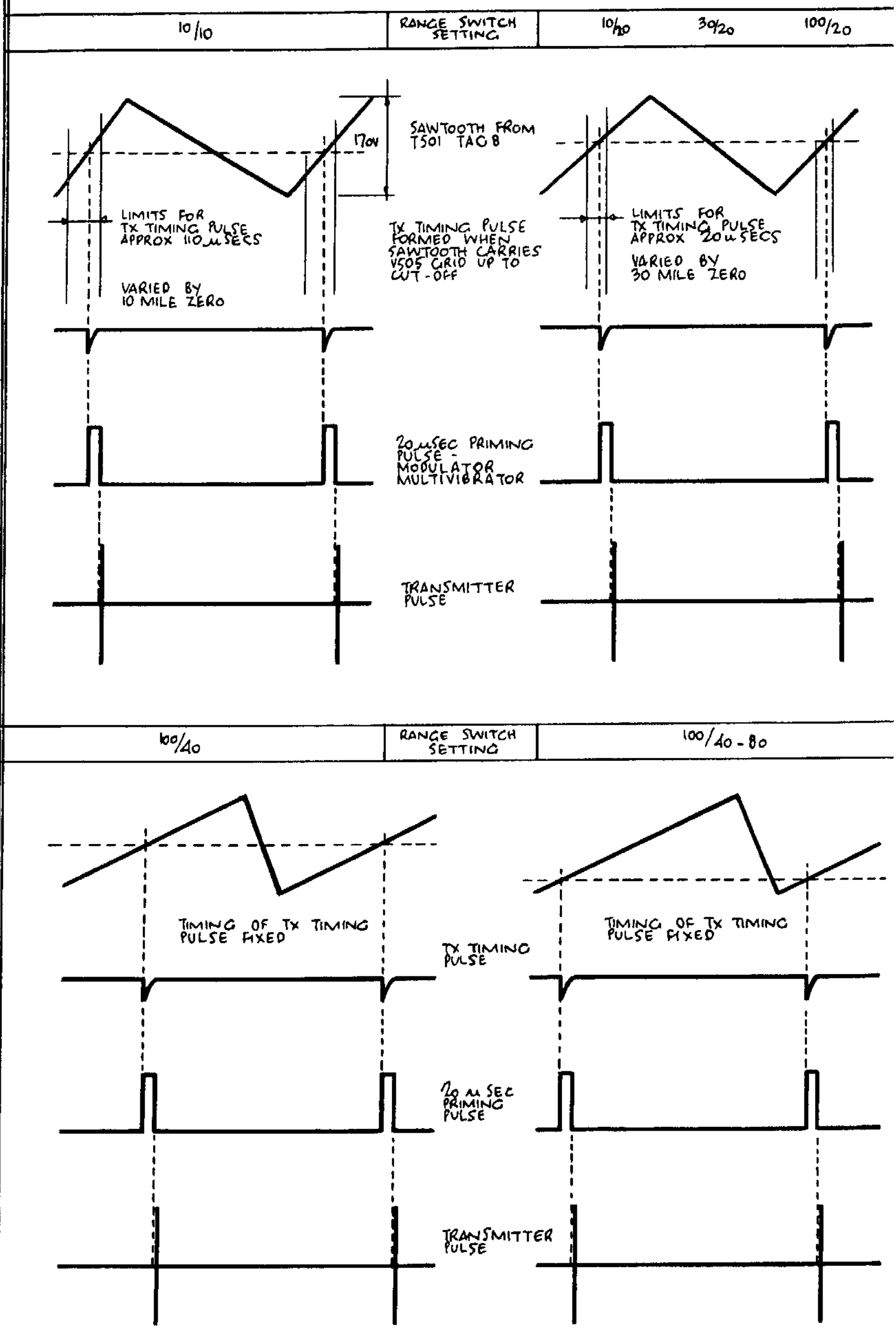

FIG.58

222. The table above shows that V505 grid is returned to earth potential in the switch unit when the scan-marker switch is in the 100/40 position. The points on the sawtooth at which the 20 microsecond priming pulse and the transmitter pulse are formed are then fixed. Assuming a grid base of 2V in V505 and a 150V. sawtooth centred at earth potential, we shall have the sawtooth trying to carry V505 grid between +75V and -75V. V505 will come into conduction when the grid reaches -2V., i.e. after the sawtooth has swung up 73V. Hence, the Tx-timing pulse begins about 73/150ths. of the way up the sawtooth which has a 1200 microsecond working stroke. The transmitter-timing pulse will then form about 73/150ths x 1200 = 584 microseconds from the beginning of the sawtooth. The 20 odd microsecond priming pulse will then bring the transmitter pulse shortly beyond the mid-point of the sawtooth. This result is of interest in Fishpond. The Fishpond zero marker is formed on the back edge of the 20 microsecond priming pulse. When the scan-marker switch is set to the 100/40 position the Fishpond scan is developed from the 1200 microsecond sawtooth. Since the back edge of the 20 microsecond priming pulse and the zero marker are occurring beyond the centre of the sawtooth, the zero marker will appear about ½" from the tube centre.

223. Since the 10-mile zero and 30-mile zero vary the point on the sawtooth at which the 20 microsecond priming pulse forms, they will also shift the markers on the Fishpond display. These controls can therefore be used to shift the point at which the 20 microsecond priming pulse forms on the sawtooth to keep the diameter of the Fishpond zero marker essentially constant as the settings of the scan-marker switch are varied.

224. When the scan-marker switch is in the 100/40-80 position, the grid of V505 is returned to +60V. The 150V sawtooth then tries to swing V505 grid between -15V and +135V. Since V505 will go into conduction at -2V the sawtooth will only swing through 13 volts of its 150V swing before V.505 conducts. Hence, the transmitter-timing pulse occurs 13/150ths x 1200 = 100 microseconds after the sawtooth begins, i.e., almost 500 microseconds before the mid-point of the sawtooth. We have seen that on the 100/40 position the transmitter fires just after the centre of the sawtooth. For the first 4 positions of the scan-marker switch, the transmitter pulse will normally also be forming very nearly at the centre of the sawtooth. Now we noted in Chapter 3 that the height tube shift is set to bring the suppression break at the bottom of the height tube. But this 20 microsecond suppression break is caused by a second output from the modulator multivibrator. Hence, it represents approximately the middle of the sawtooth. If this break appears at the bottom of the height tube on the first 5 positions of the scan-marker switch most of the first half of the timebase sweep is off the tube. Hence, when the scan-marker switch is set to the 100/40-80 position and this suppression break occurs 500 microseconds earlier, it disappears off the bottom of the tube. The first signals that can then appear on the height tube will be those arriving just short of the middle of the sawtooth. These will be from 40 to 50 miles away. We thus obtain a range coverage on the height tube of around 40 to 90 miles. The 100/40-80 position of the scan-marker switch is therefore used when it is desired to pick up homing beacons triggered by the Lucero transmitter. Since the method of developing the P.P.I. scan is not designed for use with this position of the scan-marker switch, there is no point in discussing the P.P.I. display obtained with the 100/40-80 position of the scan-marker switch.

225. It may seem strange that the control which alters the transmitter-timing on the 20 mile scan is called a 30 mile zero. This anomaly arises out of the fact that older indicators provided 10, 30 and 50 mile scans, and that Coastal Command still uses such indicators with the present switch unit. As the control originally operated on a 30 mile scan and still does so in Coastal Command installations the name has not been altered on the switch unit.

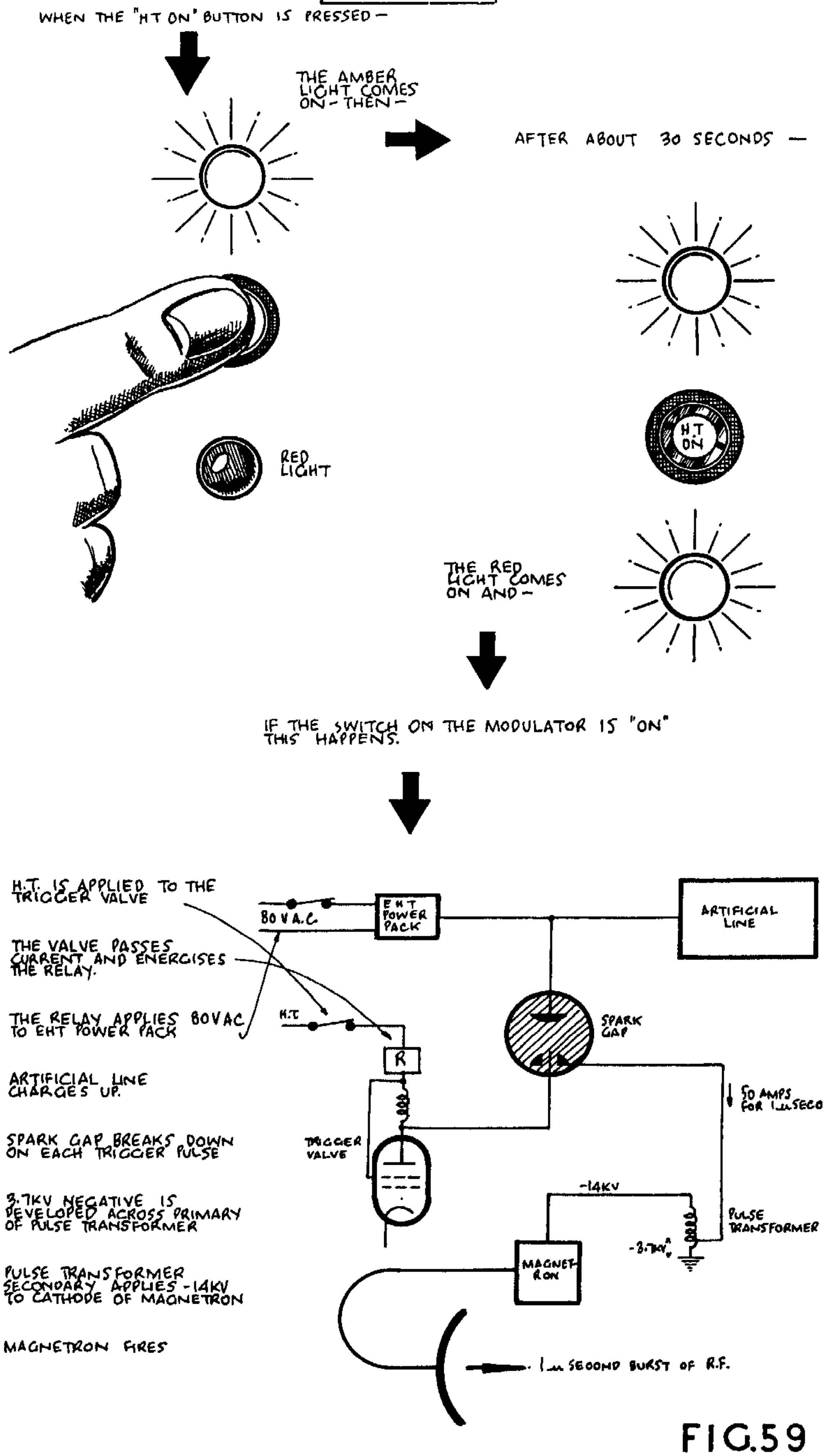
WHEN THE "H.T ON" BUTTON IS PRESSED —
THE AMBER LIGHT COMES ON — THEN —
AFTER ABOUT 30 SECONDS —
RED LIGHT
H.T ON
THE RED LIGHT COMES ON AND —
IF THE SWITCH ON THE MODULATOR IS "ON" THIS HAPPENS.
H.T. IS APPLIED TO THE TRIGGER VALVE
THE VALVE PASSES CURRENT AND ENERGISES THE RELAY.
THE RELAY APPLIES 80VAC TO EHT POWER PACK
ARTIFICIAL LINE CHARGES UP.
SPARK GAP BREAKS DOWN ON EACH TRIGGER PULSE
3.7KV NEGATIVE IS DEVELOPED ACROSS PRIMARY OF PULSE TRANSFORMER
PULSE TRANSFORMER SECONDARY APPLIES -14KV TO CATHODE OF MAGNETRON
MAGNETRON FIRES
80 V.A.C.
E.H.T POWER PACK
ARTIFICIAL LINE
H.T
R
SPARK GAP
TRIGGER VALVE
50 AMPS FOR 1 μSECO
-14KV
PULSE TRANSFORMER
-3.7KV
MAGNETRON
1 μ SECOND BURST OF R.F.

FIG. 59

Outline of Development of the Modulating Pulse

226. It has been pointed out that the 1 microsecond modulating pulse occurs just after the trigger pulse from V7 grid causes the trigger gap of the spark-gap switch, V.3 to flash-over. We shall now consider the development of this modulating pulse. From the circuit diagram, fig.55 we note the following points:-

(a) We have a -4KV supply (developed by a power pack in the modulator) connected in series with a 64 henry choke, a six stage L.C. network and a 1.1 ohm monitor resistor, R.13.

(b) We have the spark-gap switch V.3, and the resistors R10, R11, R12 in parallel with the L.C. network and R13.

(c) In parallel with R10, R11, R12 we have a uniplug pulse-cable to the transmitter unit and the primary of a pulse transformer of the auto-transformer type.

(d) The secondary end of this pulse transformer is connected to the leg of the magnetron transmitting valve heater to which the magnetron cathode is strapped.

(e) A high current diode, V.U.111, in series with suitable resistance, is connected across the pulse transformer with the diode anode linked to the secondary end of the pulse transformer. In the Mark IIC transmitter unit a 4K resistor is used in series with the diode anode. In the Mark IIIA transmitter a 325 ohm resistor is placed in series with the anode, and a 27 ohm resistor in series with a thermal-relay is placed across the diode and its cathode resistor in the Mk.IIIA transmitter unit.

227. When the "H.T. ON" push-button is pressed on the switch-unit the amber light comes on. After a delay the red light comes up and the main gap, i.e. the gap between the main electrodes of V.3, starts flashing provided the switch on the front panel of the modulator 64 is down. If this switch is up V.3 will only show flashing at the trigger gap which will cause a bluish glow only in the lower part of V.3 and will cause a weak 670 c/s. note. When the main gap is flashing a strong bluish glow fills the middle of the valve and a pronounced 670 c/s. note is heard. When the red light comes up on the switch unit the H.T. supply to the trigger valve is completed and the trigger pulse developed at V.7 anode causes the trigger gap of V.3 to flash over at a p.r.f. of 670 c/s. Hence we obtain the glow at the bottom of the valve and the weak 670 c/s. note.

228. To understand the cause of the flashing across the main gap when the modulator switch is down as the red light comes up on the switch unit, we must study the role of the L.C. network across V.3 and the -4KV modulator power pack.

229. The transformer for this power pack is T3. The heater transformer is T2. When the "L.T. ON" button is pressed on the switch unit the heater supply comes on. When, following the usual delay after pressing the "H.T. ON" button, H.T. is applied to V.7 and the trigger gap of V.3 goes into operation, the current passed by V.7 energises the C relay in the modulator and the contact C.1 closes. If now the modulator switch, S.1, is flicked down, the 80V supply to the primary of T.3 is completed and the -4KV supply is developed. Since the L.C. network is in series with this -4KV supply, the condensers of the network charge through the 64 henry choke. The network is called an artificial line since it exhibits the same characteristics with regard to storing energy and to charging and discharging time as a 500" length of ideal coaxial line of suitable dimensions. As the condensers charge up the p.d. developed across them is applied across the electrodes forming the main gap of V.3. The voltage developed is not, however, sufficiently great to break down the main gap unless a spark is first produced at the trigger gap. If we have the trigger gap flashing over and then close S.1, the voltage across the main gap will cause flash-over each time the trigger gap flashes over. We then obtain the glow in the middle part of V.3 and the load 670 c/s. note when S.1 is closed.

230. When the main gap breaks down, its resistance drops to a few ohms and we have the charged artificial line in series with the conducting resistance of the spark-gap, the pulse cable to the transmitter unit, and the primary

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DEVELOPMENT OF MODULATING & RF PULSE

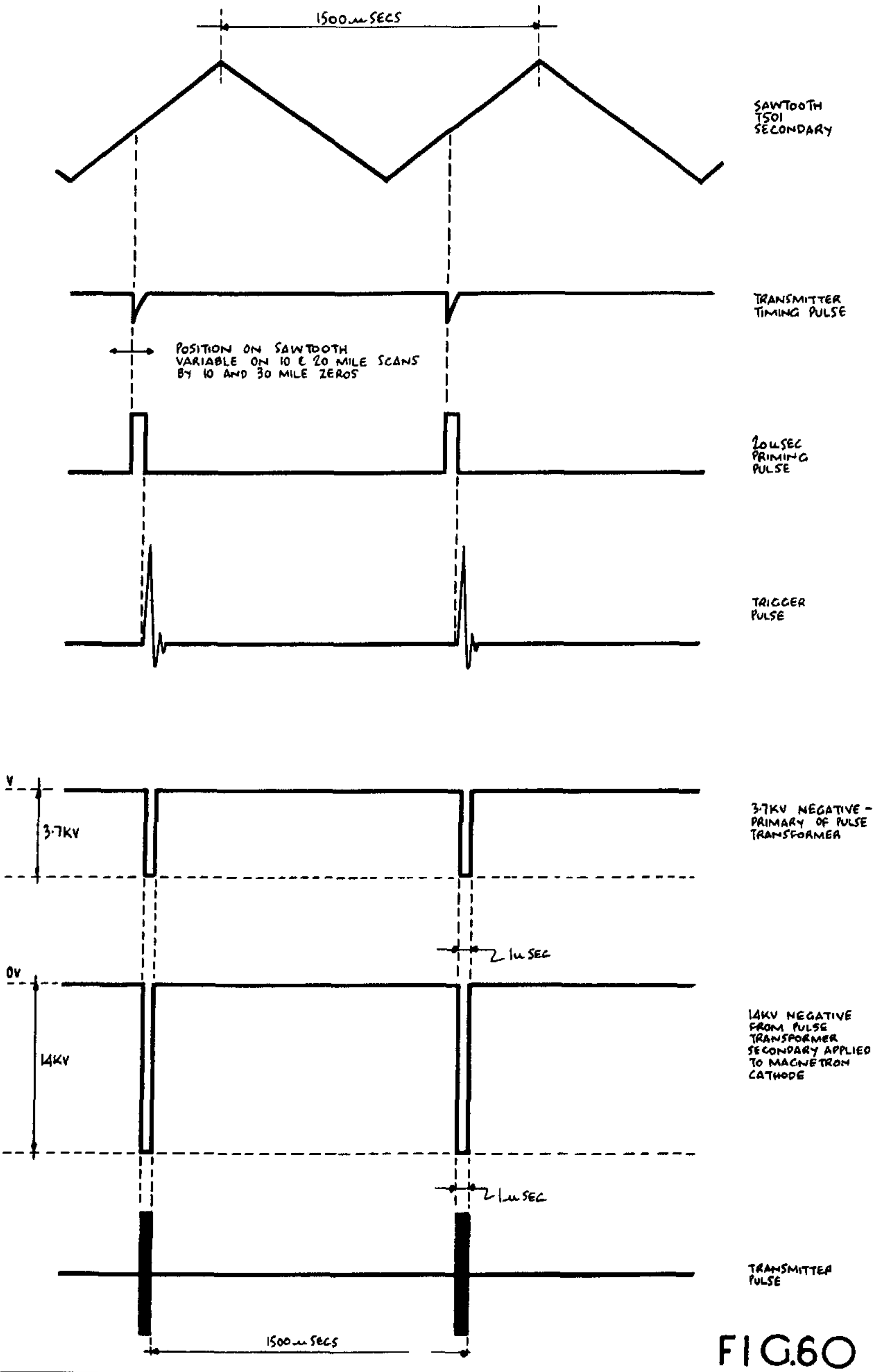

FIG.60

of the pulse transformer. The line, which has stored up energy in the condenser, now discharges its energy in a 1 microsecond burst. There is then a current flow of 40 - 50 amps. through the pulse transformer primary for 1 microsecond. The magnetron transmitter valve applies a resistive load of around 1,500 ohms across the secondary, i.e., the whole winding. The turn ratio is such that this resistance looks like about 74 ohms on the primary side. Hence the artificial line discharges a 1 microsecond burst of about 40 - 50 amps. through a useful load of about 74 ohms. The voltage appearing across the pulse transformer primary is then of the order of 74 x 50 = 3.7KV. The sense of the current flow is such as to make the earthy end of the transformer the high potential side. The tapping point is then taken up to a potential of up to -3.7KV. The turn ratio is such as to step this up to about 14KV across the secondary. The magnetron cathode is therefore taken suddenly from earth potential to about -14KV when the trigger pulse from V.7 anode breaks down the trigger gap. At the end of 1 microsecond the artificial line has completed its discharge and the magnetron cathode returns to earth potential. We thus hold the magnetron cathode about 14KV negative to earth for 1 microsecond every time the trigger pulse from V.7 anode appears on V.3 trigger electrode. This gives us our 1 microsecond modulating pulse just after the back edge of the 20 microsecond modulator primary pulse developed by the modulator multivibrator. If the modulator multivibrator is synchronised by the transmitter-timing pulse, the modulator pulse will have a p.r.f. of 670 c/s. i.e., the same p.r.f. as the timebase. If the modulator is free-running the modulating pulse will have the same p.r.f. as the modulator multivibrator and will not be locked to the timebase.

231. If the blue Pye lead carrying the transmitter-timing pulse is disconnected the spark-gap will continue to operate but the p.r.f. note of the gap will drop indicating that it is now operating at the lower, free-running p.r.f. If the p.r.f. control setting is now varied the changing p.r.f. can be detected by listening to the change in the p.r.f. note of V.3. Whether or not a normal transmitter-timing pulse will synchronise the modulator multivibrator depends on the setting of the p.r.f. control. If this is set for a p.r.f. above that of the master multivibrator synchronisation is obviously impossible.

232. The control shows red, yellow and blue dots. Synchronisation should be obtainable in a normal set when the ratchet is set within + or - 3 notches of the red dot but this will not always be the case. If the control is set for a high p.r.f. and high note from V.3 and then adjusted to lower the pitch, the point at which stable locking is obtained can readily be observed as the pitch of the note then changes noticeably. The control should be set back 3 notches beyond the locking point.

Development of the Transmitter Pulse and Behaviour of Magnetrons

233. Transferring our attention now to the actual transmitter valve stage, we note the following points:-

(a) The magnetron transmitter valve is actually a diode with its anode earthed and its cathode strapped directly to one side of a heater. This heater has its own heater transformer.

(b) No tuned circuit is apparent.

(c) Examination of an actual transmitter unit will show that the magnetron is placed between the poles of a powerful permanent magnet.

(d) The magnetic field appears to be along the axis of the cylindrical anode of the magnetron.

(e) The magnetron is provided with cooling flanges and a blower motor.

(f) The output from the magnetron in a Mark IIC installation is taken from the internal cavity by means of a probe projecting into a coaxial line.

(g) The output from the magnetron in a Mark IIIA (TR.3555) transmitter unit is taken from the internal cavity by means of a probe extending into a waveguide.

(h) The feed to the scanner is by coaxial feeder in the H.2.S. Mark IIC installation and by waveguide in the Mark IIIA installation.

(i) The feed through the scanner is by a coaxial feeder with a capacity joint in Mark IIC and by waveguide with a rotating joint in Mark IIIA.

(j) The actual radiator is a waveguide terminating in a horn in both installations.

234. The magnetron as used in these installations is essentially a form of cavity resonator. When the 1 microsecond -14KV pulse is applied to the cathode we have 14KV. between the cathode and earthed anode. There is then intense emission from the cathode but the presence of the magnetic field forces the emitted electrons to traverse complicated paths in the honeycomb structure that forms the interior of the cavity. We may regard these oscillating electrons as exciting the cavity and causing the development of an intense electro-magnetic field inside it. A loop projecting into this field, but insulated from the earthed cylindrical anode along its output lead, will have induced on it a voltage at the frequency of the oscillations in the cavity. If this loop is linked to the inner of a coaxial line whose outer is earthed the R.F. output will be transmitted along the coaxial line. If the loop terminates in a probe projecting into a waveguide the probe will act as an aerial and launch a wave into the guide.

235. Since we have an oscillating electromagnetic field developed inside the magnetron, the magnetron combines the functions of a transmitter valve and oscillatory circuit. Obviously, the first consideration will be the power output obtainable from the magnetron. We could specify efficiency instead of power output since we supply only a fixed amount of power in the 1 microsecond modulating pulse. How much R.F. power is developed by the magnetron depends on its efficiency. The actual power supplied to the magnetron in the modulating pulse is 125 - 140 K.W., i.e., about 9 - 10 amps. at around 14 KV. How much power appears at the aerial will depend on the conversion efficiency of the magnetron and the matching of the magnetron to its output circuits.

236. The maximum R.F. power output is not, however, the sole consideration. Depending on its internal structure and operating conditions a magnetron may show:-

(a) Moding.
(b) Frequency splitting.
(c) Frequency pulling.

By "moding" we mean operating at random on two different frequencies. That is, some bursts may be at one frequency, and others at an appreciably different frequency. If the local oscillator is tuned to beat with one of these so as to develop the frequency to which the I.F. amplifier responds, the other frequency may develop a beat which will be outside the pass-band of the I.F. amplifier. "Frequency splitting" involves the simultaneous development of two different frequencies. The I.F. amplifier may only be able to amplify the beat note developed by one of these. "Frequency pulling" means that the frequency developed by the magnetron when the installation is lined up may vary with any variation in the impedance presented to the magnetron by its output system. What the radar mechanic must aim to achieve is the maximum output that can be obtained under operating conditions that will produce a single stable frequency.

237. We shall now consider that factors influence the frequency developed by magnetrons, their frequency stability, and the power radiated from the scanner into space. The chief factors which have a bearing on these points are:-

(a) The physical dimensions and structure of the cavity.

(b) The strength of the magnetic field.
(c) The amplitude and shape of the modulating pulse applied to the cathode.
(d) The load presented to the magnetron by its output circuits, i.e., the feeder, waveguide and scanner.
(e) The emission of the magnetron.
(f) The leakage resistance of the magnetron.
(g) The inner surface of the waveguide feed.
(h) The cleanliness of the perspex cupola.

238. The physical dimensions of the cavity determine what range of frequencies any particular magnetron will be able to develop under all possible operating conditions and fixes the frequency band for which any particular magnetron is suitable. The dimensions of the CV.64 used in H.2.S. Mark IIC are such as to give a wavelength in the vicinity of 9.1 cms. The dimensions of the CV.108, CV.208 and 725A used in H.2.S. Mark IIIA are designed to develop a wavelength in the 3.2 cm. region. The design of the internal cavity has a significant bearing on the frequency stability and efficiency of the magnetron. The CV.64 will provide outputs of 35 - 55KW. at around 9.1 cms. The CV.108 will develop about 18 KW. and the CV.208 about 25 KW. at around 3.2 cms. The CV.208 may show frequency pulling and sometimes frequency-splitting. The CV.64 and CV.108 may show both moding and frequency pulling.

239. Magnet field strength appears to affect the particular frequency range over which any particular magnetron will operate with reasonable efficiency and also the frequency stability, i.e., the tendency for the frequency to remain fixed under a range of loading conditions. When magnets fall below a certain minimum value the efficiency and hence the output will fall sharply and the frequency may be unstable. For H.2.S. Mark IIC the strength of the magnet should not be less than about 1250 gauss, measured with the magnet in position on the chassis and the cover on the transmitted unit. For H.2.S. Mark IIIA the strength of the magnet should be at least 2500 gauss with the magnet on the chassis and the cover on in the TR.3555 series transmitter units. In the TR.3523 transmitter units the strength should be at least gauss.

240. When we come to the modulating pulse we must consider the effects of both amplitude and pulse shape. The amplitude will effect the efficiency considerably and may also influence the frequency developed. Changing the modulator used with a given transmitter unit calls, therefore, for a check of the R.F. alignment of the transmitter unit. The shape of the modulating pulse will have an appreciable bearing on frequency stability and hence on the conversion efficiency at any particular frequency. For frequency stability it is essential that the modulating pulse have a very steep edge and a flat top. The rise to maximum should occur in 0.1 microseconds. The maximum amplitude should be maintained constant within ±5% for the pulse duration. Decay to zero should occur in not more than 0.4 microseconds.

241. The load presented to a magnetron by its output circuits effects frequency, frequency stability, and conversion efficiency. We know that any oscillatory system will oscillate at a frequency which makes its reactance zero. This reactance will be the resultant value obtained by combining the reactance of the oscillatory circuit proper and the reactance coupled into it when the output circuit is attached. The frequency at which the magnetron oscillates will then vary if for any reason the output circuits present a changing reactance to the magnetron. In this way frequency pulling becomes possible. If the dimensions of the cavity and the elements in the output coaxial or waveguide feeder system are sufficiently modified by temperature changes there may be a progressive frequency shift. If the perspex cupola is assymetric, there may be changes in the reactance coupled back into the magnetron at different points in the rotation of the scanner. This reactance change may result in frequency pulling during part of each revolution of the scanner. Since the beat frequency resulting from the mixing of the L.O. signal and R.F. signal is then not equal to the I.F., radial gaps will appear on the P.P.I. display. These will coincide with those points on the scanner rotation where frequency pulling occurs.

242. When an oscillator tank circuit is coupled to an aerial circuit the resonant frequency of the entire system may show zero reactance for two tuning positions of the aerial circuit. The transmitter may then show the phenomenon of frequency jump, i.e., the aerial may radiate on either of two frequencies. The difficulty can be avoided by using a light coupling which will, of course, reduce the energy transferred from the transmitter to the aerial. To achieve a frequency response curve that has only a single peak, i.e., frequency stability, it is necessary to reduce coupling and sacrifice output, i.e., efficiency. This same conflict may appear in the H.2.S. transmitter. We have already spoken of the double frequency problems of moding and frequency splitting. These problems are most likely to appear when a magnetron has been matched to its output circuit, i.e., when the power output is at maximum. In lining up an H.2.S. transmitter it may, therefore, be necessary to depart from the setting of the matching adjustments which gives maximum power output in order to obtain a greater measure of frequency stability.

243. The gain in frequency stability at the expense of output power applies to the problem of frequency pulling as well as those of moding and frequency splitting.

244. The magnetron emission, i.e., the magnetron current for a given modulating voltage, also plays a part in the efficiency and frequency stability of the H.2.S. transmitter. As the emission falls the frequency stability diminishes and the efficiency falls.

245. When a magnetron starts to go "soft", i.e., the insulation from either side of the heater to the anode (earth) starts to go down, the resistance it presents to the pulse transformer secondary alters. The turn ratio is then no longer correct for the transformation of the magnetron hot impedance to a value that matches the characteristic impedance of the pulse cable. Part of the energy from the artificial line will then be reflected and only part applied to the magnetron. The power output therefore falls. A succession of reflected pulses will then travel along the pulse cable causing a series of weak magnetron pulses. These pulses may be seen as a block of constant amplitude pulses in the height tube immediately after the suppression break when a magnetron is going soft. If the pulse transformer or filament transformer insulation is going down a similar indication may be observed since these defects also cause a mismatch and result in similar reflections on the pulse cable. The pulses will continue until the voltage developed across the spark-gap by the artificial line is not sufficiently great to keep the gap in an ionised or conducting state.

246. If the magnetron emission goes down its effective resistance increases and mismatch. Conditions arise which will cause the reduced efficiency mentioned above.

247. If dirt or moisture appears on the surface of the waveguide and horn radiator in the Mark IIC scanner, or the inner surface of the waveguide feed a radiating system in the Mark IIIA scanner, considerable attenuation will take place. The power output will therefore fall off. These effects become more serious as the wavelength becomes shorter.

248. Oil, dirt, etc. on the perspex cupola can likewise cause heavy attenuation of the R.F. beam during its passage from the mirror out into space. Due to the reduction in power actually going out in the beam the returns will then be weak.

Shaping of the Modulating Pulse

249. So far we have not discussed the function of the diode and resistance connected in series across the pulse transformer. The function of these components is to prevent spurious triggering of the magnetron after the modulating pulse has been completed. To appreciate how such triggering could occur we must consider the pulse transformer at the instant the current pulse delivered by the artificial line is starting to decay. A certain amount of energy will be stored in the magnetic field surrounding the primary. As the current from the artificial line decays the collapse of the magnetic field will cause ringing at a frequency determined by the inductance and self-capacity of the transformer. The first positive overswing cannot cause magnetron triggering as the cathode of

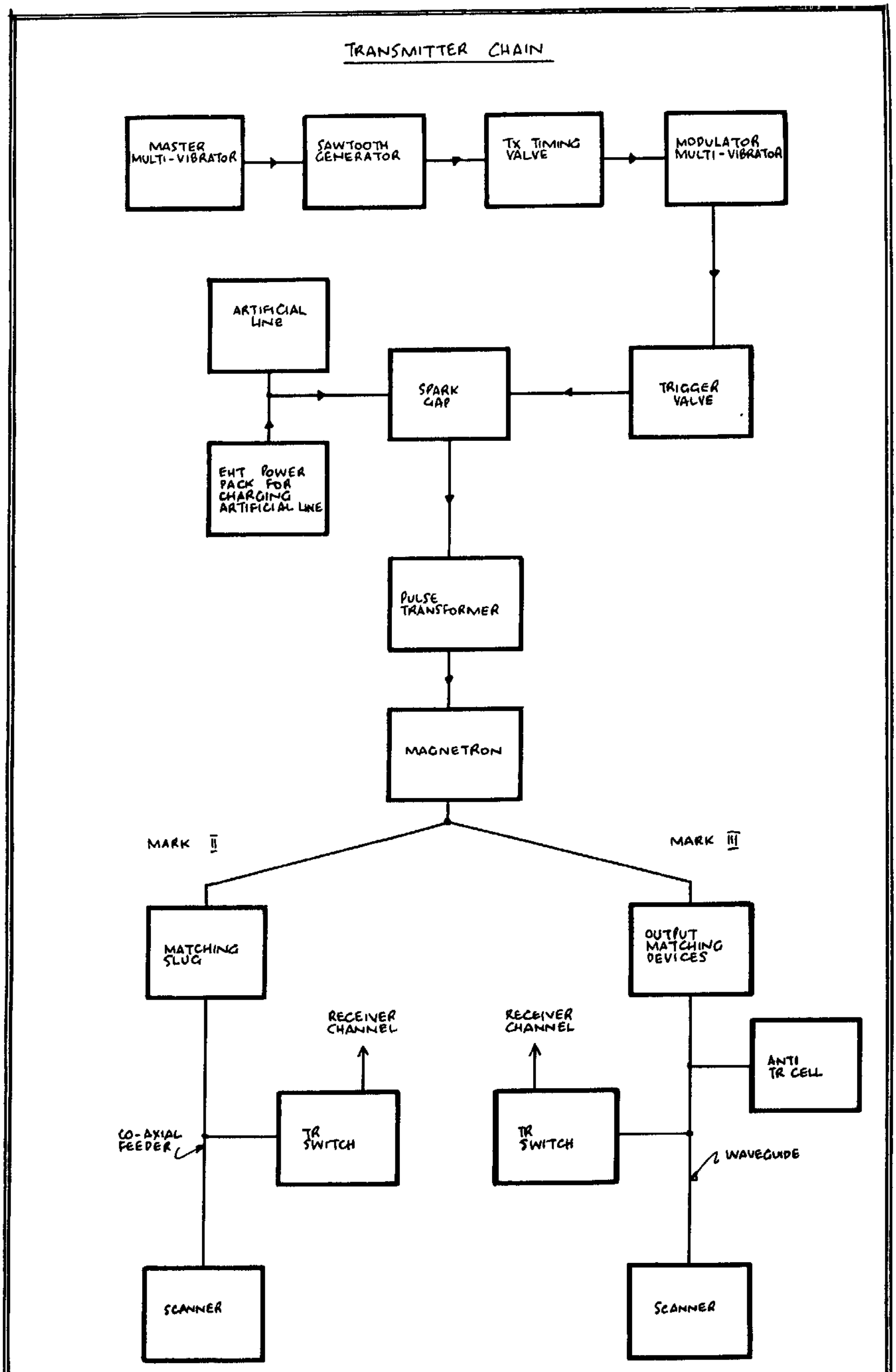
TRANSMITTER CHAIN
MASTER MULTI-VIBRATOR
SAWTOOTH GENERATOR
TX TIMING VALVE
MODULATOR MULTI-VIBRATOR
ARTIFICIAL LINE
SPARK GAP
TRIGGER VALVE
EHT POWER PACK FOR CHARGING ARTIFICIAL LINE
PULSE TRANSFORMER
MAGNETRON
MARK II
MARK III
MATCHING SLUG
OUTPUT MATCHING DEVICES
RECEIVER CHANNEL
RECEIVER CHANNEL
ANTI TR CELL
CO-AXIAL FEEDER
TR SWITCH
TR SWITCH
WAVEGUIDE
SCANNER
SCANNER

FIG. 56

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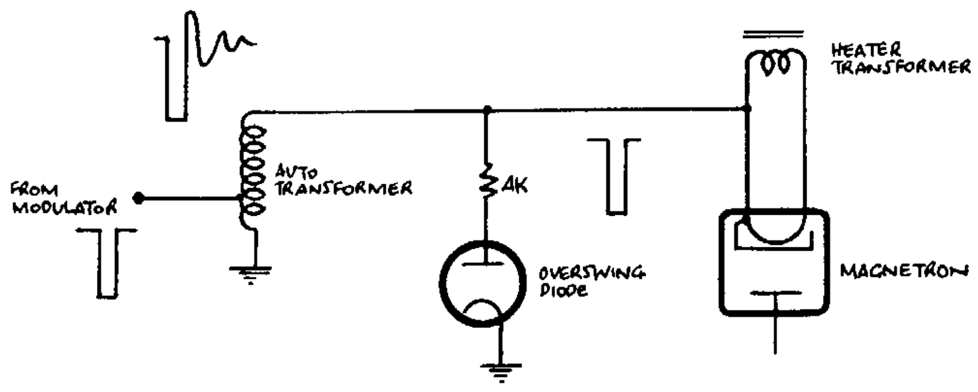
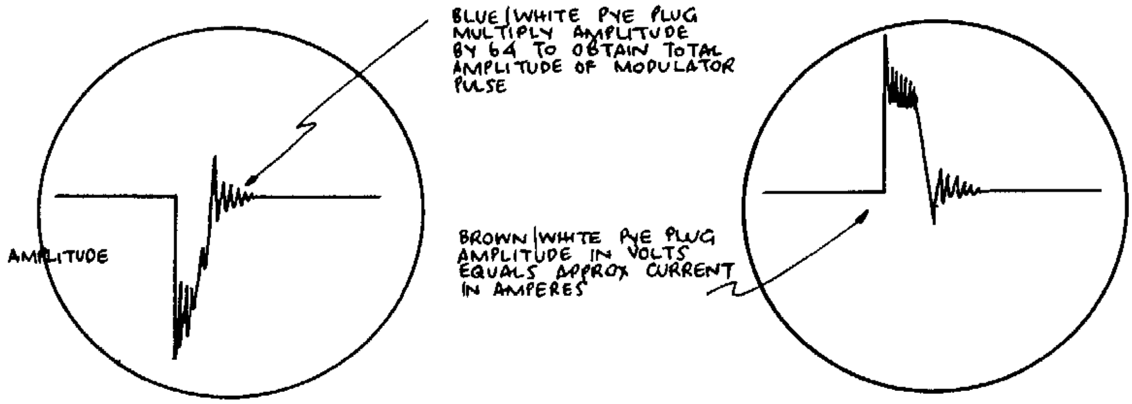
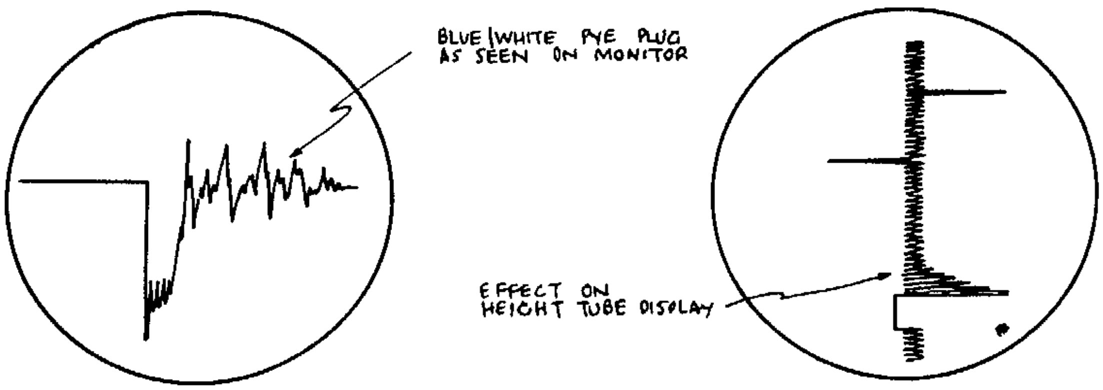
THE OVERSWING ELIMINATOR DIODE CIRCUIT



MONITOR TEST POINTS ON MODULATOR



NORMAL WAVEFORMS AS SEEN ON MONITOR 28



OVERSWING DIODE NOT FUNCTIONING

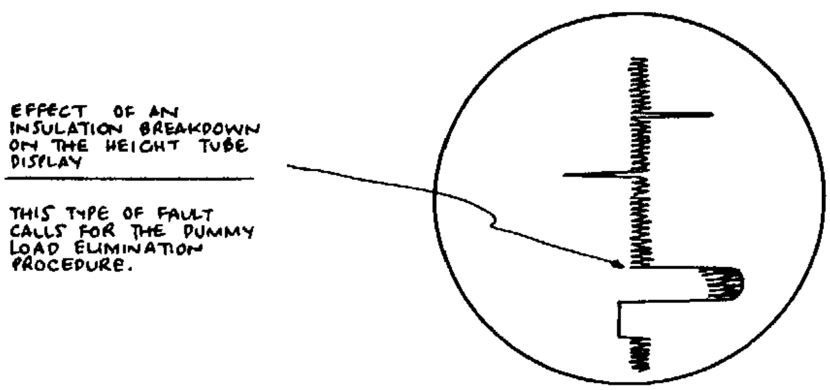


FIG.61

the magnetron is being carried positive to the earthed anode. The following negative overswing will, however, tend to cause the magnetron to radiate a second burst shortly after the first. Further negative overswings may cause additional radiation. These spurious pulses will tend to result in a main echo with feeble echoes tagging along behind it. The effect on the P.P.I. display will be to swamp the receiver by means of transmitter break through after the suppression ends and thus greatly reduce minimum range. These spurious pulses will appear on the height tube as a series of pulses of diminishing amplitude directly after the suppression break if the diode or the series resistance is faulty. This indication should not be confused with that produced by a "soft" magnetron or a faulty pulse or filament transformer which appears as a series of constant amplitude pulses.

250. If the diode and series resistance are functioning, the positive overswing carries the diode into heavy current and puts the low conducting resistance of the diode in series with the relatively low associated resistance across the transformer. This serves to damp the ringing so heavily that it dies out without developing an amplitude capable of causing any material pulsing of the magnetron. The first negative overswing cannot, however, be fully damped out, and receiver suppression must be adjusted to continue through this period if breakthrough is to be prevented entirely.

251. If the emission of a magnetron is falling and the resistance it impresses across the pulse transformer is high, the voltage across the secondary may be so high as to cause arcing in the diode. This arcing may also appear before the magnetron emission has reached its full value when a cold set is first switched on. Such arcing in a set which has had time to warm up should put the magnetron immediately under suspicion. The diode itself may, of course, be faulty. This can be checked by first changing diodes.

252. If the aluminium spray on the ends of the 4K. resistor (used in Mark IIC) flakes off and a high resistance contact develops between the resistor and the metal grip, the effective resistance goes up to such a high value that damping of the pulse transformer ringing becomes negligible and the series of spurious pulses with diminishing amplitude shows up on the height tube.

The Modulating Pulse Current Monitor Point

253. On the front of the modulator 64 panel are two brown and white Pye plugs. Examination of the circuit diagram, fig.55, shows that these plugs are strapped and tapped in between the artificial line and the 1.1 ohm monitor resistor. Scoping at either of these plugs will show the waveform developed across the resistor by the current discharged from the artificial line during the modulating pulse. The amplitude of this waveform can be measured in volts by means of the calibrated Y-shift on the Monitor 28. Since $E = IR$, $I = \frac{E}{R} = \frac{E}{1.1}$ would give the current which flows out of the line. Treating the 1.1 ohm resistor as 1 ohm we can say that the current in amperes is given approximately by the amplitude measured on the Monitor 28 in volts.

The Modulating Pulse Voltage Monitor Point

254. The modulator 64 panel also shows a blue and white monitor point. From a circuit diagram it is apparent that this plug is tapped between R.11 and R.12 in the resistance chain between the spark gap and earth. But R.10, R.11 and R.12 are in parallel with the pulse cable and the pulse transformer primary. Hence the voltage across R.10, R.11, R.12 must be equal to that across the pulse transformer primary while the artificial line is discharging. The voltage developed across R.12 will be 150/9550ths. or about 1/64th of the total. Hence, by measuring the voltage developed across R.12 at the blue and white monitor plug on the Monitor 28 and multiplying by 64 we have the approximate amplitude of the voltage output from the modulating line. This will be of the order of 3.5KV. The normal pulse will show as a negative-going pulse with a slight heavily damped positive overswing and a smaller negative overswing.

255. Since the pulse transformer is an auto-transformer and does not, therefore, cause a phase inversion, the waveform at the voltage monitor point will be in the same phase as that at the magnetron cathode. Any ringing due to a faulty diode or 4K. resistor will then appear at this point as a series of rings following the initial negative-going pulse. If a faulty magnetron, pulse

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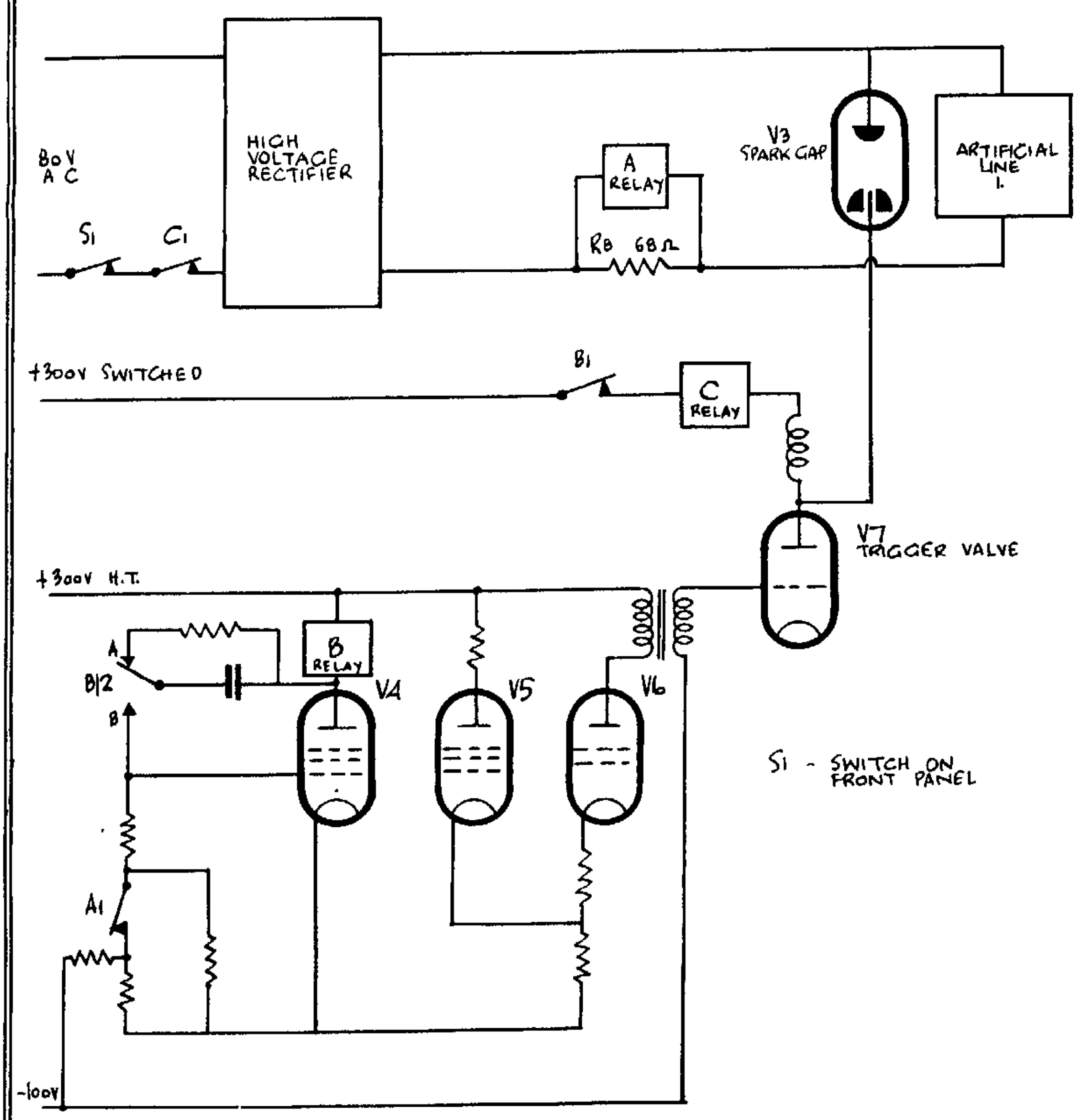
MODULATOR SAFETY CIRCUIT



'A' RELAY - NORMALLY NOT ENERGISED (A1 CONTACT CLOSED)

'B' RELAY - " " . (B1 AND B/2A CONTACTS CLOSED)

'C' RELAY - NORMALLY ENERGISED (C1 CONTACT CLOSED)

'C' RELAY BECOMES ENERGISED WHEN POWER UNIT 'E' RELAY ENERGISES AND SWITCHES +300V TO ANODE OF TRIGGER VALVE (V7) I.E. WHEN RED LIGHT COMES ON C RELAY COMPLETES 80V A.C. TO PRIMARY OF E.H.T. TRANSFORMER

FIG.62

transformer of filament transformer is resulting in a mismatch to the pulse cable and consequent reflections, the reflected pulses can also be seen in their appropriate phase at this point. Scoping at this point on daily inspection will therefore give a convenient check as to whether or not all is well in the overswing diode, pulse transformer, filament transformer and magnetron. Scoping at the current monitor point will serve the same purpose but will show phase-reversed waveforms.

The Modulator Overload Trip Safety Circuit

256. To prevent damage to the modulator power pack due to any form of overload resulting from a fault in the modulator or transmitter unit, an overload relay is included in the modulator. This is relay A in the modulator 64. The associated safety circuit is shown in fig.62. R.8, across the relay solenoid, is in series with the earth line, and the power pack. The voltage developed across the solenoid by the normal mean current is not sufficient to energise the relay. The appearance of any fault which results in any appreciable increase in this mean current will raise the voltage across R.8 sufficiently to energise the relay. The safety valve, V.4, in the modulator, is then brought into operation and relay B is energised. This results in cutting off the H.T. supply to the trigger valve. Relay C is then de-energised and the 80V A.C. input to T.3 is broken and the rectifier taken out of operation. When the safety valve has completed its cycle the trigger valve comes back on and the supply to T.2 is again completed. If the fault has disappeared the equipment will now operate normally. If the fault persists the overload relay will again be energised and the cycle will be repeated.

257. The details of the sequence of events are tabulated below:-

(a) When an overload energises A relay, contact A/1 in the grid circuit of V.4 opens. This removes the negative bias from the grid and the valve passes current. Relay B in its anode circuit is then energised.

(b) When relay B is energised the contacts B/1 and B/2 are operated

(i) B/1 breaks the +300V supply to the trigger valve V.7. This results in a cessation of spark-gap operation and hence of transmitter operation. Also, since V.7 is not passing current, C relay is de-energised.

(ii) B/2 connects the feedback condenser, C.5, between the anode and grid of V.4.

(c) When C relay is de-energised C/1 opens and the 80V input to T.3 primary is broken so the -4KV power pack ceases to operate. This, of course, removes the current through A relay solenoid which caused the original tripping and A relay is de-energised.

(d) When A relay is de-energised A/1 closes and reconnects the negative bias to V.4 grid which tends to cut the valve off. Due to the presence of C.5 between anode and grid the attempt of the anode potential to rise tends to carry the grid with it and thus delays cut-off and makes the decay of anode current gradual. In about 10 seconds the decay will have proceeded far enough to make B relay de-energise.

(e) When B relay is de-energised B/2 switches C.5 out to restore the safety valve circuit to its normal state and B/1 reconnects the 300V supply to V.7.

(f) The renewed flow of current in V.7 again energises C relay and C/1 closes.

(g) The closing of C/1 restores the 80V A.C. input to T.3 primary and the -4KV pack goes back into operation.

(h) The circuit is now fully operational again. If the fault has been cleared normal operation is resumed. If it still persists A relay will trip again and the same cycle will repeat.

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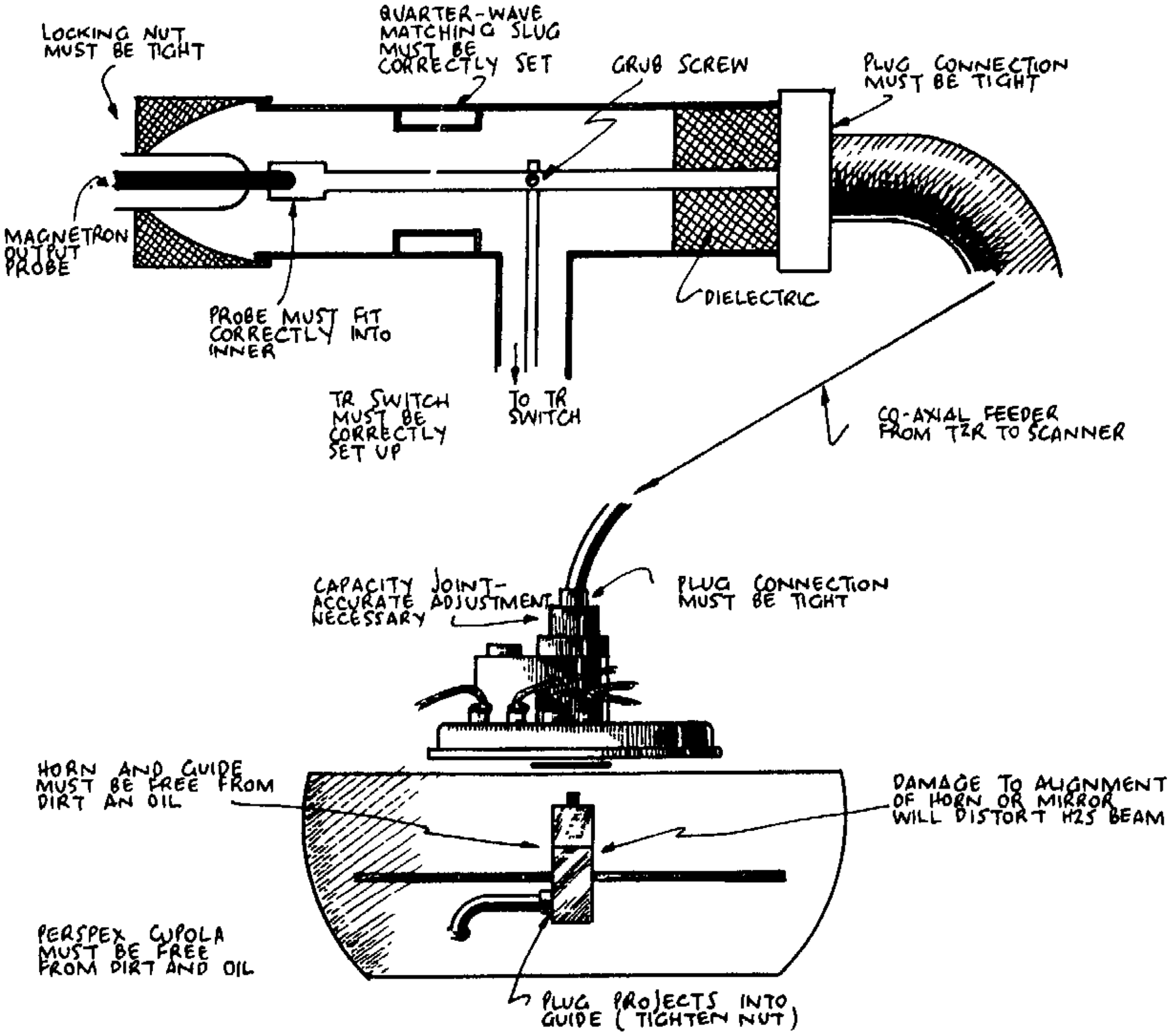
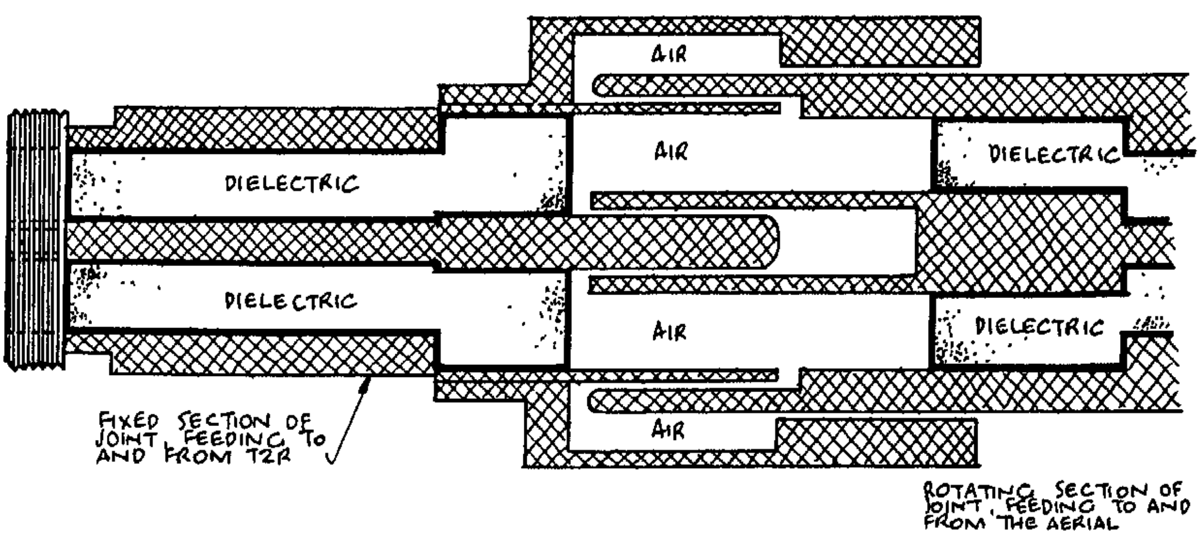
MK II FEEDER SYSTEM

PRECAUTIONS NECESSARY FOR MINIMUM POWER LOSSES ARE INDICATED





ROTATING CAPACITY JOINT

FIG. 63

The Mark IIC Feeder System

258. Examination of a Mark IIC installation will reveal the following points:-

(a) Projecting from a glass seal passing into the cylindrical cavity of the CV.64 magnetron is a metal probe. The other end of this probe terminates in a loop whose end is tied to the earthed anode. The oscillating R.F. field that appears in the cavity during the 1 microsecond modulation period induces a voltage on the loop. The potential of the output end of the loop, i.e., the probe coming through the glass seal, then rises and falls sinusoidally with respect to earth at the radio frequency of the cavity oscillations. This probe fits into a flexible section of the inner of a coaxial line whose outer is earthed. The R.F. voltage then appears between the inner and outer of the coaxial line which terminates at an output plug on the panel of the transmitter unit.

(b) In this section of coaxial line is an adjustable quarter-wave matching slug which is merely a section of metal cylinder sliding on the inside of the outer of the coaxial line.

(c) Passing from the output plug to the scanner Type 63 is a dielectric-filled high power feeder which terminates in a plug at the scanner.

(d) If the scanner is stripped down it will show a further section of coaxial feeder clamped rigidly where it enters the scanner by means of a suitable clamping band. This feeder section terminates in the fixed part of a capacity joint shown in fig.63.

(e) Fitting into this fixed section of the capacity joint is another suitably designed section of the coaxial feeder. At the high frequencies involved the narrow air gaps are as effective as an actual metallic contact but provide relative movement between the two sections which are coupled capacitively across the air gaps. We thus obtain electrical continuity at the radio frequency in a rotating capacity joint.

(f) The rotating member of the joint passes up through a tube which is attached to the rotating member of the scanner main bearing. The free end of the tube is segmented into six tapered sections. A tapered locking nut screws up over this end. As this nut is tightened up the feeder section passing up through the tube is gripped firmly and held properly control with respect to the fixed section of the capacity joint. The feeder section thus gripped rotates with the motor-driven mirror.

(g) The rotating section of the feeder passes through the back of the mirror and terminates at a plug on the side of a section of rectangular waveguide. The inner of the line, embedded in polystrene, projects part way across the narrow dimension of the guide. This projection serves to launch the R.F. energy into the waveguide in much the same way as an aerial launches R.F. energy into free space. An electromagnetic wave guided by the walls of the guide, travels towards the mouth of the guide. To avoid heavy reflections at the guide mouth where the wave must pass from its guided form into the free space form, it is necessary to have the guide mouth suitably flared.

(h) The flaring at the end of the waveguide is called a sectoral horn. The shape and dimensions of this horn and its position with respect to the focus of the paraboloid mirror play a large part in the polar diagram of the transmitted beam. Any damage to the horn or to its supports may therefore be expected to upset the shape of the H.2.S. beam.

(i) The wave radiated from the horn mouth will have the E vector across the narrow dimension of the horn, i.e., in the horizontal plane. The H.2.S. beam is therefore horizontally polarised. The azimuth beam width of the main lobe for the type 63 scanner is about $8\frac{1}{2}^{\circ}$.

(j) Returning to the transmitter unit we note that between the slug and the output plug a branch line comes off at right angles to the coaxial output line. This line passes to a CV.43 T.R. switch which flashes over when the magnetron pulses. When the CV.43 flashes over the result is to practically short the branch line an odd number of quarter wavelengths from the junction. The branch line then presents a high impedance at the junction when the transmitter pulses and there is no appreciable flow of energy down the branch line. This branch line is actually the receiver channel through which received signals pass to the crystal mixer chamber through the CV.43 T.R. switch.

259. Having noted the channel along which the R.F. pulses developed by the CV.64 must travel, we must now consider the functions of the matching slug. For the maximum transfer of energy from the magnetron cavity out into space we must arrange that:-

(a) Resistive losses in the feeder system are kept to a minimum.
(b) The magnetron is matched to the feeder and the feeder to the array.
(c) The flow of R.F. energy down the branch line is kept down to a minimum.

260. To minimise losses the following simple precautions are necessary:-

(a) Ensuring that the output probe of the CV.64 is properly fitted into the flexible inner section of the coaxial output line and has not pushed the flexible line to one side.
(b) Ensuring that the plug connections are tight at both the scanner and the transmitter unit.
(c) That there is no accumulation of dirt or moisture in the waveguide radiator to cause attenuation.
(d) That the perspex cupola is free from dirt and oil films.
(e) That standing waves be kept down to the minimum throughout the feeder system.

Should sparking be occurring in the plugs due to poor contacts, or at a faulty contact between the CV.64 output probe and the flexible inner link, the effect will be, not only to reduce output due to losses, but to greatly increase noise. On the P.P.I. display this will appear as flashing or spoking, that is when the gain is high enough to bring up signals the high noise level will brighten up the full timebase sweeps.

261. The problem of minimising standing waves in the feeder system involves some form of matching wherever a discontinuity occurs. Most of these points are taken care of in the actual design and do not call for any adjustment by the radar mechanic.

The Mark IIC R.F. Output Matching

262. Complete presetting of the magnetron matching arrangements is not, however, possible as magnetrons differ in the impedance they present to the feeder system. We may then regard the problem as a matter of transforming the impedance of the high power feeder at the transmitter unit output plug to a value at the magnetron that matches the output impedance of the magnetron. If we assume that the feeder offers a purely resistive impedance, the length of coaxial between the plug and the quarter-wave slug transforms the characteristic resistance to a new value depending on the length of line. The quarter-wave slug has itself some characteristic impedance determined by its diameter and the diameter of the common inner. Let us assume the value is Z_0 and the impedance presented to the plug side of the plug is Z_1. This impedance will be transformed to some value given by $Z_2 = Z_0^2/Z_1$ if the frequency of the signal is such as to make the slug a quarter wavelength. This impedance value is again transformed by the line section beyond the slug to a value determined by the length of this section. The position and range of movement of the slug have been so chosen that by moving it through its travel a point can be found where the resistive component of the impedance presented to the normal magnetron matches the hot impedance of the magnetron. If the impedance presented to the magnetron also includes reactance the effective reactance of the oscillatory system is not the same as it would be if the impedance presented were purely resistive. The frequency of the oscillations is therefore modified to a value where the net reactance of the system is zero. As the position of the matching slug is varied the power output from the horn radiator will increase as the resistive match is improved. At the same time frequency changes may appear due to changes in the reactance coupled

back into the magnetron oscillatory circuit. For certain slug positions a small change in position may result in appreciable frequency changes. This position may, in some cases, coincides with the position for maximum power output and maximum signal amplitude.

263. If, with such a setting of the slug, the standing wave in the cupola due to reflections from the perspex and parts of the fuselage differs at different points in the scanner rotation the reactance coupled back into the magnetron may vary appreciably during the scanner rotation. The result will be frequency pulling which will result in signals returning on different frequencies during different parts of the scanner rotation. This, in turn, will result in radial fades or gaps as the I.F. developed in the mixer will not be constant and may swing in and out of the pass-band of the I.F. amplifier. Altering the L.C. tuning may then alter the portions of the scanner rotation where the I.F. output from the mixer is within the I.F. amplifier pass-band. The radial gaps will then shift. If the pulled frequency is outside the pass-band of the CV.43 this gap shifting by the L.O. tuning will not occur.

264. The tendency for small changes in the reactance at the scanner end to be transformed into appreciable reactance changes (and hence frequency changes) at the magnetron, depends very largely on the position of the matching slug. During portions of its travel the result will be mainly to alter the resistive match without coupling back much reactance. In this range the power output will change without any appreciable frequency change occurring. The best position of the matching slug is therefore a position where the slug can be moved ¼ inch either way without altering frequency much while at the same time not sacrificing power output by more than is necessary to ensure reasonable frequency stability. With a good magnetron, good magnet, and satisfactory modulating pulse, it should be possible to find a matching slug position that permits displacement of the slug by + or - ¼ inch without causing frequency changes of more than + or - 4 Mc/s. and without reducing power output by more than 10 - 20% of the maximum value. If the L.C. is not returned and the amplitude of signals does not drop by more than 50% as the slug is moved + and - ¼ inch, the magnetron frequency change is less than 4 Mc/s. With such a setting gapping should not occur. If the magnetron emission falls, magnet strength goes below about 1250 gauss, or modulating pulse has inadequate amplitude or poor shape, the occurrence of radial gaps or fades will be much more likely.

265. Although more clearly allied with the receiver chain it may be instructive to consider at this point the relation of the matching slug to returned signals. These signals pass down the waveguide, through the capacity joint, and along the high power coaxial feeder to the transmitter unit. From the R.F. plug they pass to the coaxial line in the unit. At the junction of the branch line the incoming signal has the choice of two paths. The first of these is straight ahead toward the magnetron and the second is down the branch line. As the impedance of the cold magnetron is almost wholly reactive, the flow to the magnetron is reflected and this reflected wave may interfere with the wave flowing directly into the receiver branch line. Such interference will be minimised if the position of the matching slug so modifies the phase of the reflected wave as to bring it into phase with the direct wave. We say the slug has then transformed the cold magnetron impedance to a high value at the branch line junction since the effect is the same as if there had been no flow to the magnetron due to a high opposing impedance. As the setting of the slug is varied to match the hot impedance of the magnetron to the output system, the cold impedance presented at the branch line junction will also vary. It may be found that maximum output will occur at a slug setting that will permit an appreciable interference between the wave flowing directly into the branch line and the wave reflected from the magnetron. Practice in the past in Bomber Command has therefore been to adjust the slug on the ground for maximum permanent echo signal output from the receiver as observed on the Monitor 28. This method is open to the objection that such a method of setting may leave the slug in a position where small changes in the reactance coupled back into the magnetron may cause an appreciable change in the magnetron frequency. Alternatively, small changes in supply voltage causing changes in the magnetron emission or in the modulating pulse amplitude, may also cause unstable frequency conditions. What constitutes the most reliable way of obtaining the best compromise between frequency stability and strength of returned signals remains one of the uncertainties in the use of the transmitter unit employed in the various H.2.S. installations.

266. To ensure that the flow of R.F. energy down the receiver branch line is kept to a minimum during transmittion it is only necessary to ensure that the CV.43 T.R. switch is functioning properly. Fuller details of this valve will be given when dealing with its functions in the receiver chain. Its functions in the transmitter chain is to flash-over when the transmitter pulse commences and thus make the branch line appear effectively a shorted quarter-wave stub at the junction with the main line, thus reducing to a trickle the energy flow down the branch line while the transmitter pulses. This flash-over will occur earlier in the transmitter pulse rise and will develop a more effective short when the CV.43 resonant cavity is tuned to the same frequency as the magnetron. Hence, CV.43 tuning has a bearing on the transmitter output radiated from the scanner. The losses down the branch line are, however, more significant from the standpoint of damage to the crystal than from the standpoint of reduced range due to reduced power output.

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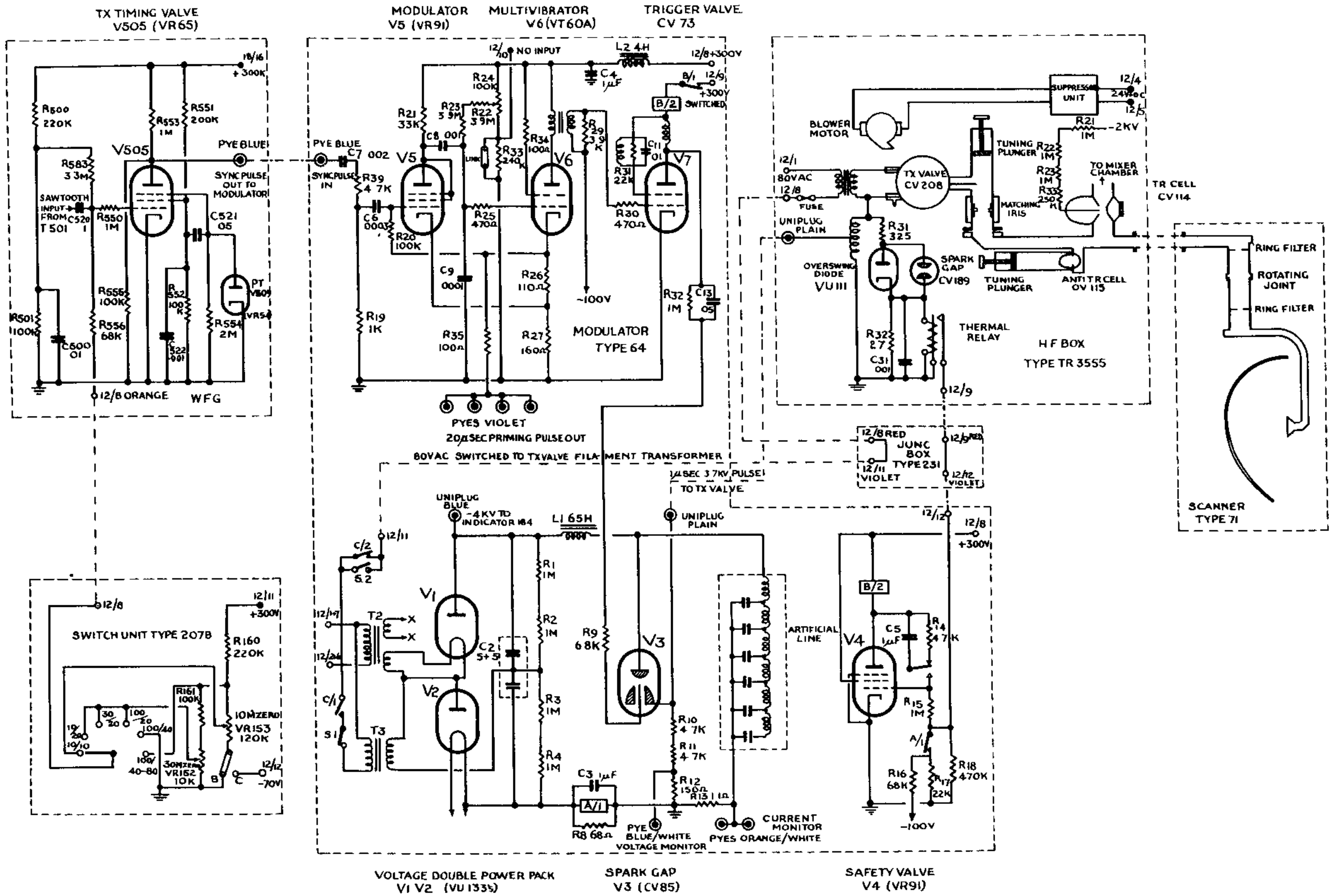

TRANSMITTER CHAIN MARK IIIA.

FIG. 64

FIG. 64

The Mark IIIA Feeder System

267. The Mark IIIA feeder system is much more elaborate than that used in Mark IIC for the following reasons:-

(a) In the 3 cm. band dielectric losses in coaxial feeders become so great that it becomes necessary to devise some form of transmission channel to the scanner that introduces a much lower attenuation. The only form of transmission channel capable of meeting this requirement is a waveguide system.

(b) Propagation in waveguides can take place by means of different modes, i.e., different electromagnetic field patterns, which will behave differently at discontinuities, bends, etc. with regard to the introduction of standing waves. Standing waves may result in voltage maxima of such amplitudes that corona discharges may develop across the guide. Such discharges will cause large energy losses and will develop noise. It becomes necessary, therefore, to use mode filters at various points to cut out unwanted modes which will introduce unwanted standing waves and unwanted losses.

(c) To prevent the appearance of unwanted modes as much as possible and at the same time carry the energy around bends, across a vibrating joint, and across a rotating joint, it is necessary to use both circular and rectangular guide sections. The transitions from one to the other call for suitable matching adjustments.

(d) To operate with a common T and R array we require:-
    (i) Matching adjustments to match the magnetron to its output system.
    (ii) Adjustments to match the common array to the receiver channel.
    (iii) To transform the cold impedance of the magnetron to a high value at the receiver branch line junction.

It is these matching adjustments with which the radar mechanic will be primarily concerned. The various mode filters and fixed matching adjustments are of interest to the scientifically-minded mechanic but are not a major concern.

268. Examination of an H.2.S. Mark IIIA installation fitted with a transmitter unit of the T.R.3555 series will reveal the following points:-

(a) The oscillatory voltage developed in the magnetron cavity is induced on a loop inside the cavity. One end of the loop is tied to the earthed anode and the other comes out as a probe inside a glass seal.

(b) The probe of the CV.108 terminates in a rounded knob which projects into a circular guide section. The rounded knob is used to prevent sparking across to the guide wall. The CV.208 probe differs from that of the CV.108 in that it is not rounded at the end. As an alternative method of preventing sparking or corona discharge the glass seal is extended to enclose the entire probe. For both valve types the guide is held stationary with respect to the magnetron by means of a suitable locking ring arrangement. The R.F. energy is launched into the circular guide section from the end of the probe in somewhat the same way as energy is launched from an aerial into space.

(c) In the earlier units in the T.R.3555 series the two output matching adjustments provided consisted of an adjustable shorting piston in the end of the circular guide, and an adjustable iris between the probe and the junction of the circular guide and the rectangular guide section into which it feeds. In some units of the TR.3555 series, instead of the piston and the adjustable iris two silica tuning probes on an adjustable carriage are fitted to a square section inserted in the circular guide. The distance that these probes project into the guide can be varied. The two adjustments then consist in moving the carriage and the position of the matching probes and in varying the distance the probes project into the guide.

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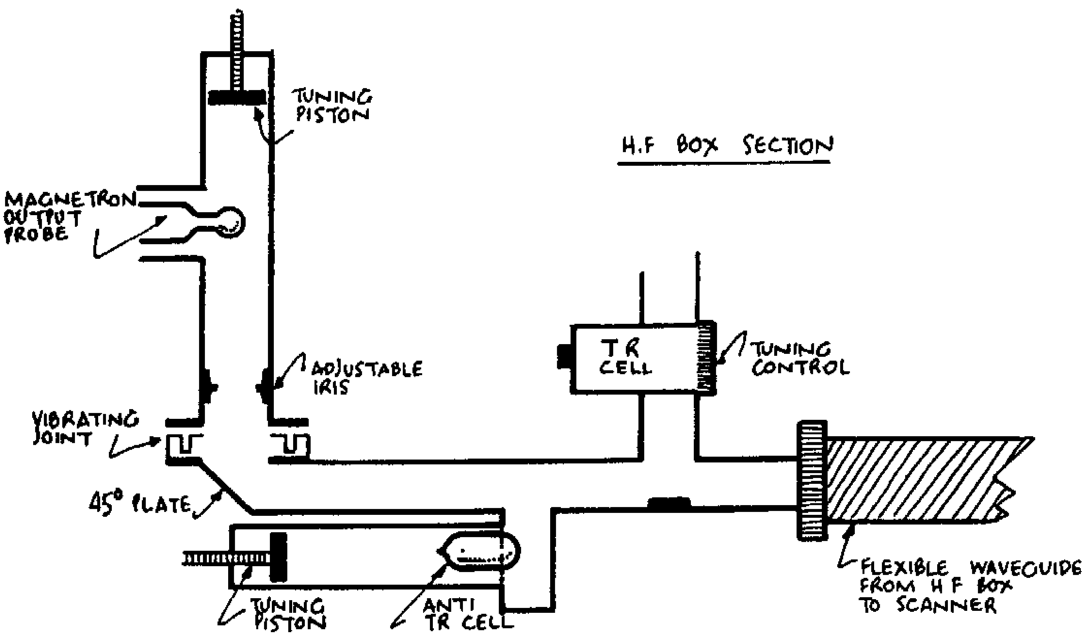
MARK III FEEDER SYSTEM



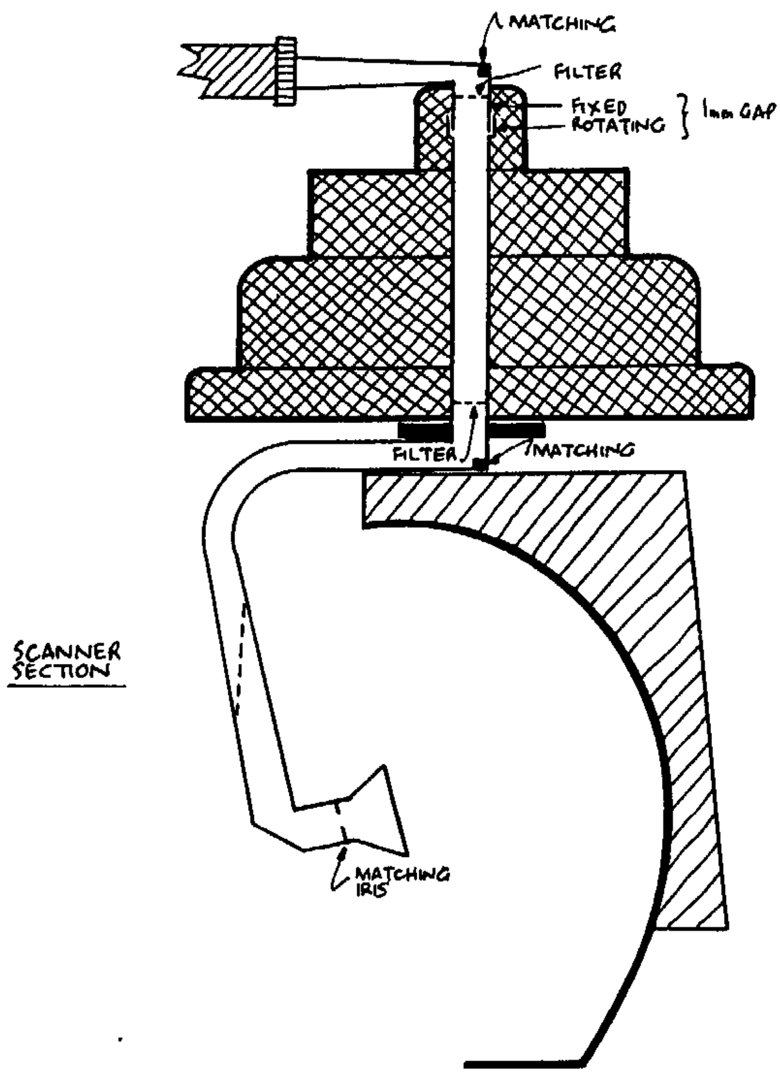


FIG.65

(d) The circular guide, instead of being mechanically connected to the rectangular guide, is terminated in a circular flange. A short circular section is fitted to the rectangular guide. This short section likewise terminates in a circular flange separated from that on the main circular guide by a narrow air gap. The primary purpose of this gap is to allow for tolerances in the dimensions of the magnetrons. To prevent escape of R.F. energy through this gap it must appear to the wave in the guide as if no gap were present. To assist in achieving this result, ditches, a quarter-wave deep and a quarter-wave out from the inner guide surface, are cut in the lower flange. These serve effectively as R.F. chokes.

(e) The end of the rectangular guide is fitted with a 45° inclined plate. The purpose of this plate is to take the R.F. energy around the right angle bend without introducing appreciable reflections back up the circular guide.

(f) Proceeding along the rectangular guide we note a short rectangular branch at the bottom of the guide. The base of this branch is shorted. Into the side is fitted a circular section with an adjustable tuning piston. A little gas-filled valve, CV.115, with a copper diaphragm sealed into the envelope, is fitted at the junction of these circular and rectangular sections.

(g) A little farther along the guide is the receiver branch line. This line includes the T.R. switch, CV.114, the crystal mixer, and another section of circular guide fitted with a shorted tuning piston. This piston and the one mentioned in (f) are the R.F. input matching adjustments.

(h) The rectangular guide, with its narrow dimension vertical, terminates at the panel of the H.F. box. Connection to the scanner type 71 waveguide system is made by means of a circular section of flexible rubber guide.

(i) The rubber guide section feeds into a further rectangular section that feeds into a circular section at right angles to it. A perspex seal is inserted at the entrance to this rectangular section. This seal, together with another near the waveguide horn, forms an airtight system which breathes through a drying agent bottle. It also prevents any dirt, etc. in the cupola from working back into the H.F. box waveguide sections. The perspex is essentially transparent to the R.F. pulses and signals.

(j) The circular section into which the rectangular section in (i) feeds forms the fixed member of a rotating waveguide joint.

(k) A further section of circular guide, separated by 1 mm. from that in (j), forms the rotating member of the joint. This section moves with the mirror as it turns.

(l) Circular mode filter rings, mounted on trolitul supports, appear in each of the circular sections that form the rotating joint.

(m) The rotating circular section feeds at right angles into a rectangular section with the long dimension of its cross-section in the horizontal plane. This section is taken around a gradual bend and terminates in a waveguide union which couples to a further section of rectangular guide. This section continues the bend but is also twisted through 90° to finish up with the guide mouth facing the paraboloid mirror with the long dimension of its cross-section in the vertical plane and the narrow one in the horizontal plane.

(n) The guide is terminated in a sectoral horn, i.e., the narrow cross-section dimension is kept constant but the long one is increased. The wave emerging from the guide has the E vector in the horizontal plane, i.e., the radiation is horizontally polarised. The main lobe of the radiated beam has an azimuth width of about 3½° in the scanner type 71.

(o) Another matching iris is fitted at the back of the horn.

269. Transmission line and waveguide principles are discussed in Chap.13.

The Output Controls of the TR.3555 Series H.F. System

270. We have discussed the mechanical details of the waveguide feeder system. We shall now consider the functions to be fulfilled by controls and the controls provided to fulfil these functions. In order to obtain the maximum flow of energy from the magnetron output probe along the feeder system and out into space, we must arrange:-

(a) That the maximum energy flow leaves the probe and passes into the guide. This requires that the output system present to the probe a resistive impedance component equal to that of the probe.
(b) That the maximum fraction of the energy launched into the guide be radiated into space. This means that we must:-
    (i) Minimise standing waves in the guide since these represent energy reflecting back and forth in the guide system thus introducing losses by heating the inner guide surface and by causing corona discharges at points where the standing waves show voltage maxima.
    (ii) Effectively prevent the flow of energy through gaps and down parallel branches instead of along the main feeder.

To minimise standing waves it is necessary to arrange that the reactance presented to the probe by the output system be equal in magnitude and opposite in sense to the reactive component of the probe output impedance. To effectively prevent the flow of energy into the branch lines and gaps during the duration of the transmitter pulse it is necessary to arrange that these appear to present electrical continuity, i.e., as if there were no gap in the surface.

271. In considering the controls which are adjusted to obtain a good R.F. output it may be helpful to consider the transmission line analogy. Suppose we have an ordinary transmitter which is coupled to an aerial by means of a feeder. To get the maximum energy transfer from the tank circuit to the feeder the feeder and tank circuit must be matched. This is normally done by some form of transformer coupling. The feeder may be tapped in directly on the coil which then serves as an auto-transformer. Alternatively, depending on the type of feed used at the aerial, it may be preferable to use a second coil coupled to the tank coil to give a mutual transformer arrangement. In either case the turn ratio of the primary and secondary windings must be given by

$$\frac{\text{Secondary Turns}}{\text{Primary Turns}} - \frac{\text{Z Tank Circuit}}{\text{Z feeder}}$$

where Z Tank Circuit is the dynamic resistance of the tank circuit and Z feeder is the characteristic resistance of the line.

272. Matching the tank circuit to the feeder serves to get the maximum output on the feeder but does not guarantee that this output is radiated from the aerial. To get the maximum energy radiated the feeder must be matched to the aerial. The aerial will present a certain impedance to the feeder at any specific frequency. This impedance depends on the aerial dimensions and design. If the aerial is resonant this impedance will be pure resistance. For a non-resonant aerial the impedance will contain both resistive and reactive components. To have the R.F. energy travel down the feeder to the aerial without reflection, i.e., without causing a standing wave on the feeder, the resistive component of the aerial impedance must be matched to the characteristic resistance of the line and the net reactance of the system must be brought to zero. These two results are often achieved by some form of stub-matching. A tapping point is located at which the resistive component of the aerial impedance has been transformed to a value equal to the characteristic resistance of the feeder The impedance transformer is, of course, the length of feeder between the tapping point and the aerial. The reactive component appearing at the tapping point is then cancelled out by putting a short-circuited or open-circuited stub of suitable length across the line at the tapping point. When the two condition of resistive match and zero net reactance have been fulfilled the energy will flow from transmitter to aerial in the form of a travelling wave. The standing wave which is produced when reflections occur as the result of a mismatch will then be absent and there will be no voltage maxima and minima along the main feeder.

273. Returning to our H.F. box feeder system we are faced with a similar type of problem. There is a difference, however, since the introduction of the output probe of the magnetron into the waveguide results in the appearance of both reactive and resistive components in the output impedance of the magnetron. To get the maximum flow of energy into the guide we must meet the same conditions that are necessary to get the maximum energy radiated from an aerial. In the first place we must match the resistive component of the probe's output impedance to the wave impedance of the guide. The second condition to be met is to match out the reactive component of the probe's output impedance. The first condition calls for some form of impedance transformation and the second for the introduction of a reactance which is equal in magnitude and opposite in sense to that of the probe.

274. To pursue these points further without going into a detailed study of waveguides at this point it will be necessary to accept the following points:-

(a) The term wave impedance is the waveguide term that corresponds to characteristic impedance of a feeder. The value of the wave impedance depends on dimensions, shape, frequency and the type of wave.
(b) Reactances introduced in feeders cause reflections and standing waves but cannot absorb power since current and voltage are 90° out of phase. In the same way reactances in a guide cause reflections and standing waves but do not absorb power. Hence when a standing wave appears due to an unbalanced reactive component we can effectively eliminate it by introducing some form of reflector that causes a standing wave of the same amplitude but exactly in antiphase. The two will then cancel out and we may say that the net reactance is zero.
(c) In transmission line matching the quarter-wave transformer is often employed. This matching device is essentially a section of transmission line of a different characteristic impedance from the main feeder. In guides, quarter-wave irises, i.e., sections with different dimensions or a different dielectric are often employed. Instead of a different guide section two projections into the guide separated by a quarter wavelength may be used. If the distance that such a pair of projections extend into a guide is made variable, they can serve simultaneously as a quarter wave transformer to obtain resistive matching and a variable reactance to match out an unwanted reactive component.
(d) Guide dimensions must be of a certain minimum size before a wave can be propagated inside them for any appreciable distance. These minimum dimensions are called the cut-off dimensions.
(e) The wavelength in a guide depends on the wave type or mode. For a wave that has a free-space wavelength of 3.2 cms., the wavelength in the rectangular guide is 4.14 cms. and the wavelength in the circular guide is 5.95 cms.

275. Let us consider now the actual matching adjustments used in the earlier H.F. boxes in the TR.3555 series. Principles are discussed in paras. 1227-1229. Details are shown in figs.65, 180 and 220. The piston can be adjusted to a position where the resistive component presented by the probe is transformed to a value that matches the wave impedance of the guide. There will, however, be a standing wave in the guide section between the probe side of the iris and the piston. By moving the iris the phase of the reflection from the iris can be adjusted to be opposite to that from the probe. It is not likely that complete cancellation will occur due to amplitude differences. A readjustment of the piston will now give an improved cancellation of the iris reflection. Thus, by alternately varying the two adjustments, a combination of settings can be found which results in the maximum flow of energy down the guide system.

276. What happens to this energy depends on:-

(a) Whether the guide is correctly matched at its output end.
(b) Whether there are losses in gaps and branch lines.
(c) Whether the successive sections are matched to each other.

The radar mechanic is not in a position to do anything about these points in so far as adjustments are concerned, but should be aware of the provisions made and how their failure may result in low output from a good magnetron.

277. Matching the waveguide proper to its output stage is done by properly locating the guide with respect to the mirror and by suitably flaring the guide mouth. Any damage to the guide that alters its position or distorts the horn termination will result in a reduced output and probably in polar diagram distortion.

278. Matching of the guide sections to one another is done by suitably choosing the dimensions used and by introducing fixed adjustments. Suitable filter ring are inserted to prevent the passage of unwanted wave types or modes which may appear at discontinuities. These rings serve the same purpose as wavetraps an filters in the more familiar types of R.F. circuits. Care must be exercised in scanner and H.F. box maintenance to avoid any distortion or derangement of the waveguide feeder system if the fixed matching and filtering devices are to function properly. Care must also be exercised to prevent oil, dust, or moist from getting into the guide system and causing heavy attenuation of the output.

279. To prevent R.F. energy from flowing into the receiver branch line when the transmitter fires we have a T.R. cell, CV.114, an electrical wavelength up the receiver branch line. This cell has a low pressure water-vapour filling which flashes over when the cavity is shocked into violent oscillation by the energy flowing down the branch line during the first cycles of the transmitter pulse. There is then an effective short circuit a wavelength from the junction of the branch line, and the output line. When the wave reaches the shorted end it is reflected and travels back towards the main line. Since it has travelled two full wavelengths it is in phase with the wave travelling down the main line so the effect is the same as if there were electrical continuity straight acros the mouth of the branch line. There is then no appreciable loss down the receiver branch line and no interference at the junction. Should the CV.114 be faulty and fail to flash over the transmitter output will obviously be reduced, but what is more significant, the crystal will be ruined.

280. The purpose of the second branch line may not be immediately apparent. Its function is wrapped up with reception of signals rather than transmission. Suffice it to say at this point that tuning piston 2 is included so that incoming signals arriving at the branch line will see a high impedance in the direction the magnetron so will travel down the receiver branch line. Since this branch line has been included some provision is necessary to effectively prevent the flow of transmitter output into it. The rectangular section of the branch is a wavelength long and is shorted at the end. Fitted in the side is an anti-T.R. cell, CV.115. This valve is argon-filled. A copper diaphragm with a resonant slot appears half-way down the wall of the wavelength of rectangular guide. The CV.115 must be inserted to have the slot horizontal. When the transmitter fires the resonant slot arcs over to effectively give the wavelength of rectangular guide two continuous sidewalls. The wave then travels to the shorted bottom, reflects, and travels back. As the path traversed down the branch line and back is two wavelengths the reflected wave will be in phase with the wave continuing down the main guide. The result is then again the same as if the main guide wall were continuous and there were no branch line present. Should the CV.115 be left out, faulty, or fitted with the slot vertical, energy will flow through the slot and reflect back to arrive in the main line with a phase that will depend on the setting of the piston. If there is a large phase displacement, the reflected and direct waves and the output will interfere with fall. Tuning pistons 2 and 3 are receiver adjustments so will be dealt with in the receiver chain.

281. The loss of energy at the vibrating joint is prevented by means of the quarter-wave ditches at right angles to the E-vector. As the R.F. currents flow in the guide walls the wave travelling through the gaps will produce a certain current distribution in the upper flange. On the lower flange the currents must travel down the one side of the quarter-wave slot and up the other so are out of phase by half a wavelength or 180^{o} when they reach the flange surface. The fields set up in the upper and lower flanges beyond the ditch are then in antiphase so cancel out. Hence there is no flow of energy out through the joint. The ditches thus serve as R.F. chokes.

282. To prevent sparking between the pistons and guide walls across the gap that must obviously be left to permit piston movement, the piston faces are arranged as shown in fig.180. The energy travelling down that side, into the ditch and back again, will have travelled a full wavelength so will be in phase with the wave reflecting from the piston face. The effect is then the same as if the piston face were actually making metallic contact with the guide wall and there were no gap at all.

283. In the latter H.F. boxes of the T.R.3555 series the iris and tuning piston 1 are replaced by a moveable carriage carrying two adjustable silica tuning probes separated by a quarter wavelength. As the two probes are discontinuities a quarter-wavelength apart, we may regard them as forming a quarter-wave matching transformer with a characteristic impedance dependent on the distance they project into the guide. If we start with the probes projecting in about $\frac{1}{4}$ inch and slide the carriage we can find the point that gives the best output down the guide. There will probably still be some unbalanced reactance, i.e., a standing wave between the control and the top of the guide. By increasing the distance the probes project into the guide by $\frac{1}{4}$ inch and again adjusting the carriage, a better setting may be found with a smaller standing wave. By increasing the distance the probe projects into the guide in $\frac{1}{4}$ inch steps and finding the best carriage position it is possible to find the position for maximum power output.

284. So far we have assumed that the guide is correctly terminated so that there will be no standing wave along its length. When setting up with a Test Set 205 this will be the case. Actual scanners may not, however, provide this correct match. The guide may then show a fairly pronounced standing wave. This is equivalent to coupling additional reactance into the magnetron which may cause frequency pulling, frequency splitting or moding. In the case of the CV.108 moding is the more common result and in the CV.208 frequency pulling is the more usual effect. These effects will be most pronounced when the heaviest loading is applied to the magnetron, i.e., when the matching adjustments are set for maximum output. The effect will be unstable returned signals in the case of moding, and falling off signals with frequency pulling. The unstable signal strength results from the fact that the one mode of oscillation may give a signal which comes within the I.F. pass-band after beating with the L.O. signal while the other mode results in an I.F. signal near the edge or outside the I.F. pass-band. To prevent frequency pulling or moding it is necessary to reduce the loading on the magnetron by introducing a deliberate mismatch at the magnetron. This process is analagous to loose coupling in short wave transmitters in order to secure a higher frequency stability. A suitable mismatch unit which introduces a standing wave with an amplitude of the same order as that caused by the worst scanner is used to ascertain what settings of the two H.F. output controls will sustain a stable frequency as the phase of standing wave is varied throughout its full range. When this setting of the control is found it is reasonable to assume that the magnetron can be relied on to give a sufficiently stable frequency for operational purposes when the H.F. box is installed in an aircraft.

How the Magnetron is protected in the T.R.3555 Series

285. Details of the protective circuit are shown in fig.66. Provision is made to ensure that:-

(a) Magnetron heater voltage is always applied when there is no modulating pulse on the magnetron cathode.
(b) As soon as the modulating pulse is applied the heater voltage is cut off.

These precautions are taken to protect the magnetron. Once the cathode has been heated until its steady emission is taking place the application of a modulating pulse will result in sufficient bombardment of the cathode by oscillating electrons to sustain the correct emitting temperature. Should the heater voltage be continued the emission would continue to rise until the cathode was destroyed. If the modulating voltage is applied without previously applying heater voltage to warm the cathode the magnetron current will be low. The magnetron will then present an abnormally high impedance to the pulse transformer and the resultant mismatch will apply such a heavy voltage across the thermal relay shown in fig.64 that the neon, CV.189, ionises and energises the

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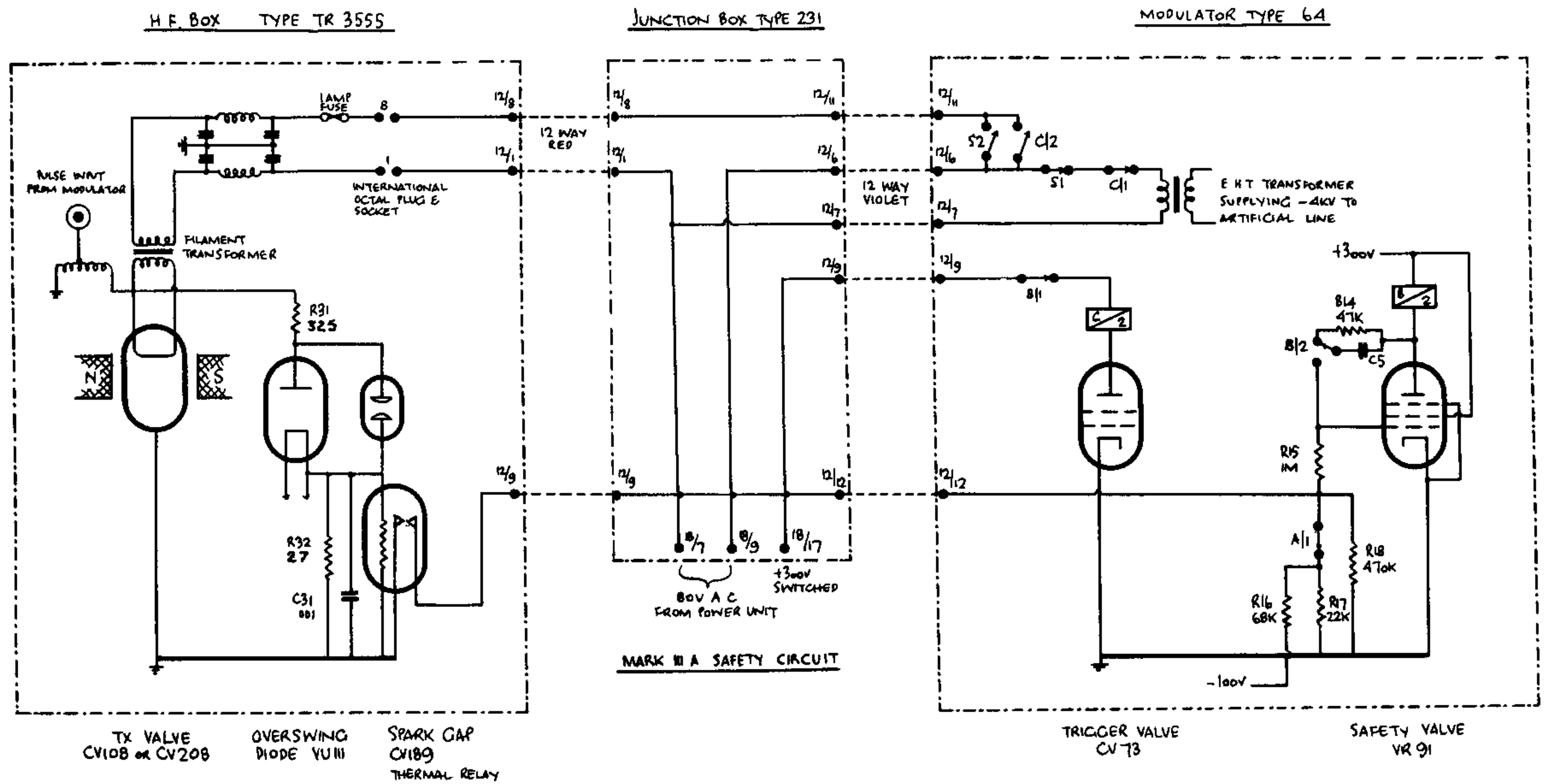


MARK III A SAFETY CIRCUIT

RELAY CONTACTS ARE SHOWN AS FOR NORMAL RUNNING CONDITIONS, ie 'A' + 'B' RELAYS DE-ENERGISED AND 'C' RELAY ENERGISED

SWITCHES S1 AND S2, COMPRISE 'ON/OFF' SWITCH ON FRONT PANEL OF MODULATOR SHOWN IN 'ON' POSITION - S1 CLOSED BUT S2 OPEN

'C' RELAY IS ENERGISED WHEN +300V 'SWITCHED FROM POWER PACK IS APPLIED TO THE MODULATOR TRIGGER VALVE CV73

WHEN THE EQUIPMENT IS SWITCHED ON, 300V IS NOT APPLIED TO THE MODULATOR TRIGGER VALVE UNTIL THE RED PILOT LAMP ON THE SWITCH UNIT IS ALIGHT, SO THAT 'C' RELAY IS NOT ENERGISED, CONTACTS C/2 WILL BE CLOSED, COMPLETING THE 80V A C CIRCUIT TO THE PRIMARY OF THE FILAMENT TRANSFORMER, AND CONTACTS C/1 WILL BE OPEN, RESULTING IN NO EHT BEING SUPPLIED TO THE ARTIFICIAL LINE

WHEN 300V IS APPLIED TO THE TRIGGER VALVE, 'C' RELAY IS ENERGISED CONTACTS C/2 WILL OPEN, BREAKING 80V A C LINE TO FILAMENT TRANSFORMER AND HENCE REMOVING HEATER SUPPLY FROM TX VALVE CONTACTS C/1 WILL CLOSE, COMPLETING 80V AC LINE TO EHT TRANSFORMER, AND -4KV WILL BE SUPPLIED TO ARTIFICIAL LINE, RESULTING IN PULSE BEING APPLIED TO THE CATHODE OF THE TX VALVE

IF MODULATOR IS SWITCHED OFF BY SWITCH ON FRONT PANEL BREAKING THE 80V A C SUPPLY TO THE EHT TRANSFORMER BY OPENING CONTACTS S1, CONTACTS S2 WILL BE CLOSED, THEREBY COMPLETING THE 80V A C LINE TO THE FILAMENT TRANSFORMER AND REAPPLYING HEATER VOLTS TO THE TX VALVE.

IF THE TX VALVE SHOULD BREAK DOWN, THE SPARK GAP CV189 WILL ARC OVER, RESULTING IN THE THERMAL RELAY BEING ENERGISED THEREBY CONNECTING THE JUNCTION OF R15 AND R18 TO EARTH AND REMOVING THE NEGATIVE BIAS FROM THE GRID OF THE SAFETY VALVE THIS VALVE WILL THEN CONDUCT 'B' RELAY WILL BE ENERGISED, RESULTING IN CONTACTS B/1 OPENING, BREAKING THE 300V LINE TO THE TRIGGER VALVE 'C' RELAY WILL NO LONGER BE ENERGISED, THEREFORE CONTACTS C/1 WILL OPEN, HENCE CUTTING OFF THE EHT SUPPLY

CONTACTS A/1 ARE BROKEN WHEN 'A' RELAY IS ENERGISED THIS RELAY IS IN THE CATHODE CIRCUIT OF THE EHT RECTIFIERS AND IS ENERGISED WHEN THE RECTIFIERS DRAW EXCESSIVE CURRENT

FIG.66

thermal relay. The safety valve in the modulator then goes into operation to produce the following results:-

(a) 300V supply to the trigger valve, V.7, is broken and the spark-gap switch, V.3, no longer operates to discharge the artificial line and produce a modulating pulse.
(b) The 80V A.C. input to the primary of the transformer, T.4, whose secondary feeds the -4KV rectifier stage is broken. This means there is no longer any E.H.T. to charge the modulating line.
(c) The heater supply to the magnetron is again completed.

The CV.189 will arc over when the voltage across the secondary of the pulse transformer reaches about 16KV.

286. The cycle of events is as follows:-

(a) When the CV.189 arcs over the thermal relay (bi-metallic strip type) closes and earths the junction of R.15, R.18 in the grid circuit of the modulator safety valve, V.4.
(b) Due to the removal of the negative bias the valve conducts and B relay is energised.
(c) Contact B/1 is then opened and the 300V supply to the trigger valve is broken and the spark-gap ceases to operate, and there is no further application of the modulation pulse to the magnetron cathode.
(d) Due to the cessation of current in V.7, C relay is de-energised.
(e) C/1 then opens and breaks the 80V A.C. input to T.3 primary so the -4KV pack ceases to operate.
(f) C/2 closes and reconnects the heater voltage input to the primary of the magnetron filament transformer.

287. If any other fault develops which causes the rectifiers in the -4KV pack to pass excessive current the overload relay trips and puts the safety valve into operation to produce the same results as outlined in para.256-257. When C relay is energised contact C/2 reconnects the 80V input to the primary of the magnetron filament transformer.

288. The cycle of events when the equipment is switched on is as follows:-

(a) When the "L.T. ON" button is pressed relay C in the modulator is still in an unenergised state. The contact C/2 is closed, so the 80V A.C. supply to the filament transformer of the magnetron is completed. C/1 is open so there is no 80V input to T.3.
(b) After the "H.T.ON" button is pressed there is a delay of about 30 seconds after which the red light comes on. The appearance of the red light coincides with the energising of E relay in the power unit to switch on the +300V supply to the trigger valve in the modulator.
(c) The anode current taken by the trigger valve energises C relay in modulator. Contact C/1 now closes to complete the 80V supply to the primary of T.3 and bring the -4KV power pack and the artificial line into operation. As the trigger valve and the spark-gap are operating the modulating pulse is now applied to the magnetron cathode. Contact C/2 meanwhile has opened and broken the 80V input to the magnetron filament transformer. Hence, as the red light comes up the modulating pulse is applied to the magnetron and the filament supply is simultaneously broken by C relay.

289. If the modulating pulse is removed from the magnetron cathode by operating the switch on the modulator panel, the contact, S.1, breaks the 80V input to T.3 and the contact, S.2, completes the 80V supply to the primary of the filament transformer.

The T.R.3523

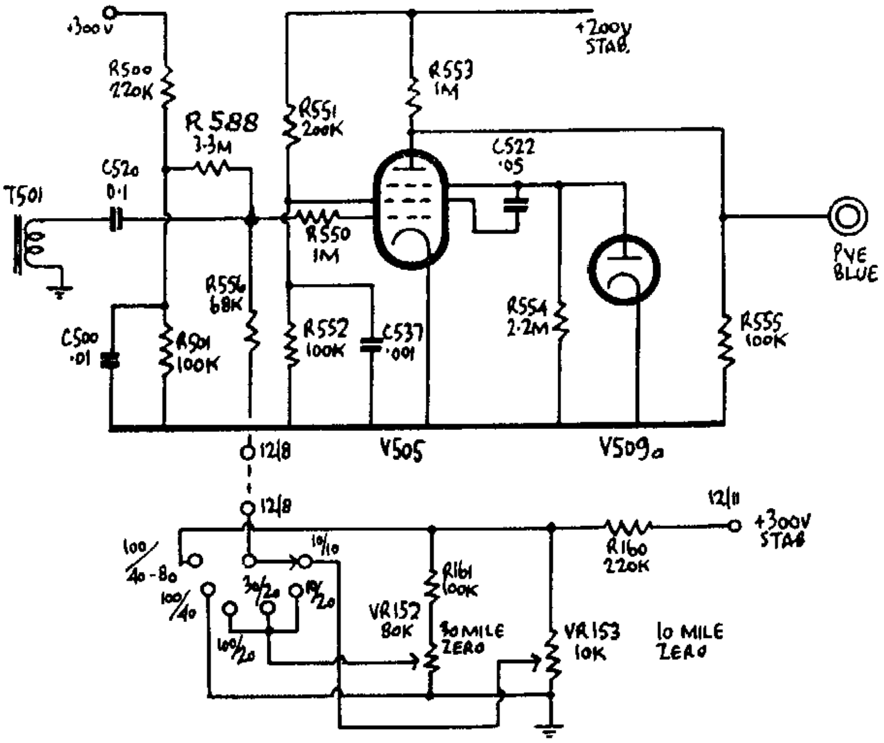
290. The TR.3523 is the transmitter unit which is intended to supersede the TR.3555 series. It offers the following advantages:-

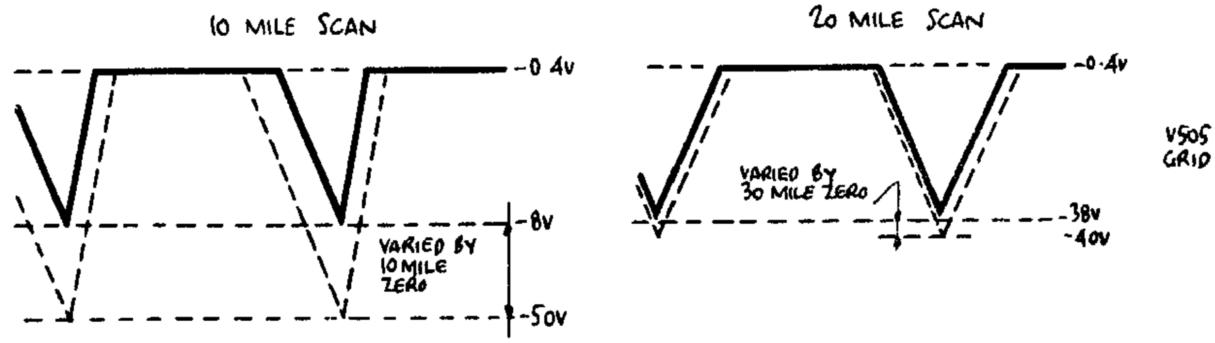
(a) Much greater power than is obtainable from the CV.108 and CV.208. This power is obtained by using an American 725A type magnetron feeding into a pressurised waveguide section which is intended to sustain atmospheric pressure at all operational heights and so prevent flashover at the higher power.
(b) An automatic frequency control system by means of which the difference between the frequency of the klystron L.O. and the magnetron is automatically held at 45 Mc/s.
(c) The power available from the magnetron is sufficiently great to permit pre-plumbing. That is, it is not necessary for the radar mechanic to make any R.F. output matching adjustments.
(d) In the main production models, two klystron local oscillators with independent mixers will be incorporated. The second of these local oscillators will be suitably detuned from the first for operation on 3 cm. ground beacons. This facility cannot be used without the incorporation of a new modulator which can provide a 2 microsecond modulating pulse for beacon triggering in addition to the normal 1 microsecond pulse as used at present.
(e) Both head amplifier stages will have their screen voltage regulated by the gain control.
(f) An improved pulse and filament transformer arrangement is incorporated in which there is no direct connection between the primary of the pulse transformer and its own secondary and the secondary of the filament transformer. This eliminates the application of the single-ended modulating pulse to the filament transformer. The pulse transformer is of the mutual type with a split secondary whose two halves are in the two heater legs to give a symmetric system which is effectively centre-tapped to earth in so far as the heater and filament transformer secondary are concerned. The pulse transformer windings are in an oil-filled container. In so far as the modulating pulse is concerned, the two halves of the split secondary are effectively in parallel and the sense is such as to drive the magnetron cathode down on the usual modulator 64 pulse.

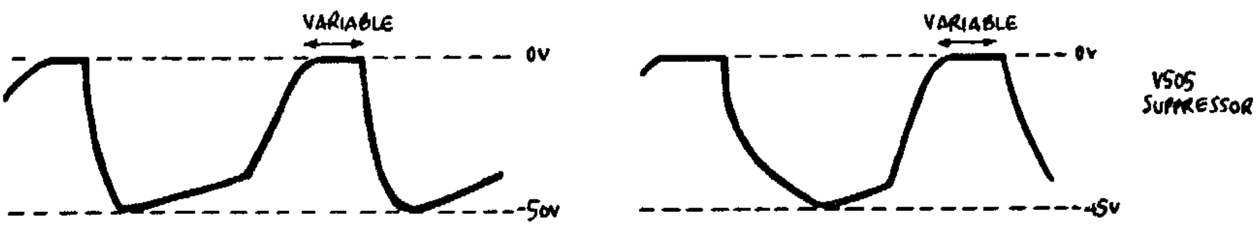
291. Details of the circuit operation and maintenance of the new unit will be issued when it becomes available.

TRANSMITTER TIMING VALVE

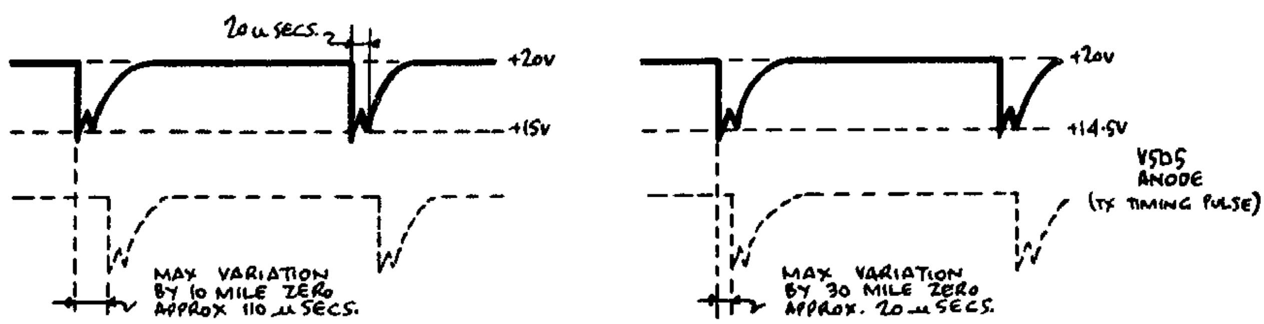
C.D. 0896L







SCREEN SIMILAR TO SUPPRESSOR BUT VOLTAGE RANGE +65 TO +20V



ON 40 MILE SCAN, POSITION OF TX TIMING PULSE IS FIXED AT ALMOST HALF WAY UP WORKING STROKE OF SAWTOOTH
ON 40/80 MILE SCAN, POSITION IS FIXED NEAR BOTTOM OF SAWTOOTH

FIG.67

Further Details on Individual Stages

292. So far we have concentrated our attention on the development and control of the transmitter pulse and have given rather scant attention to the operation of the controlling stages. We shall now examine more carefully the operation of some of the stages whose function we have merely stated without going into a study of how the function is performed.

The Transmitter Timing Valve, V.505

293. We have stressed that V.505 develops a negative pip at the anode when the sawtooth input on the grid carries the valve into conduction. To see why this pip is developed it is necessary to note the design of the stage which may be regarded as a delayed-action transitron. We note the following points about the circuit:-

(a) The anode is returned to a D.C. potential determined by the bleeder, R.553 (1M.) and R.555 (.1M.) across the stabilised 200V line. The static D.C. potential is therefore about +18V.
(b) The screen is returned to the potential determined by the bleeder R.551 (.2M.) and R.552 (.1M.), again across the stabilised 200V. line. The static D.C. potential will then be about 67V.
(c) The screen is lightly decoupled to earth by C.521 (.002).
(d) The screen is tied to the suppressor through C.522 (.05). R.554 (2.2M.) serves as suppressor leak and half of V.509 serves to prevent V.505 suppressor from swinging positive.
(e) As discussed previously, V.505 grid is returned via R.556 (68K.) and pin 8 on the orange 12-way to a variable potential in the switch unit.
(f) R.500 (.22M) and R.501 (.1M.) form a bleeder across the unstabilised 300V. line with a potential of about 90V. at the junction. R.558 (3.3M.) and R.556 (68K.) form a bleeder between this point and the potential to which R.556 is returned in the switch unit. This bleeder will tend to raise the effective D.C. level to which V.505 grid is tied above the potential to which R.556 is tied in the switch unit by 68/3368ths or about 1/50th of the difference between 90V. and the potential to which R.556 is returned. When R.556 is returned to 0V. the effect will be to return V.505 grid to about +2V. When R.556 is returned to +60V. the effect will be to return V.505 grid to about 60.2V.
(g) V.505 cathode is returned to earth.
(h) The input to V.505 grid is a rising sawtooth of about 150V. amplitude which will be centred at the effective D.C. level of V.505 grid.

294. Let us assume for the moment that R.556 is returned to earth potential in the switch unit and V.505 grid is at about +2V. The sawtooth then swings between -73V and +77V. With the anode at +18V. and the screen at +67V, V.505 has a grid base of only a few volts. Hence the valve will conduct when the grid reaches -2 to -4V. The anode potential will then drop to nearly 0V. The screen potential will not drop instantly because of C.521 which must charge negatively through the cathode-screen impedance of the valve. The drop at the screen is therefore exponential. This drop is impressed on the suppressor through C.522 (.05). As the suppressor falls exponentially with the screen the anode current is quickly cut off and the anode potential rises at a rate determined by the capacity of the cable from the anode output point (Pye blue) to the modulator and the 1M. anode load. The anode waveform will then be a negative pip with an exponential tail.

295. When the sawtooth carries the grid up to about the -2V point grid current flows through the 1M. stopper, R.550, into C.520. The leak-away of this grid current through R.556 will develop a negative auto-bias that will reduce the mean D.C. level of V.505 grid. This is essentially counteracted by the arrangement discussed in para.293(f). The flow of grid current will, of course, cut off the balance of the sawtooth.

296. When the scan-marker switch is in the 100/40 - 80 position, and when it is in the 10/10 position and the 10-mile zero is fully clockwise, V.505

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MODULATOR MULTIVIBRATOR

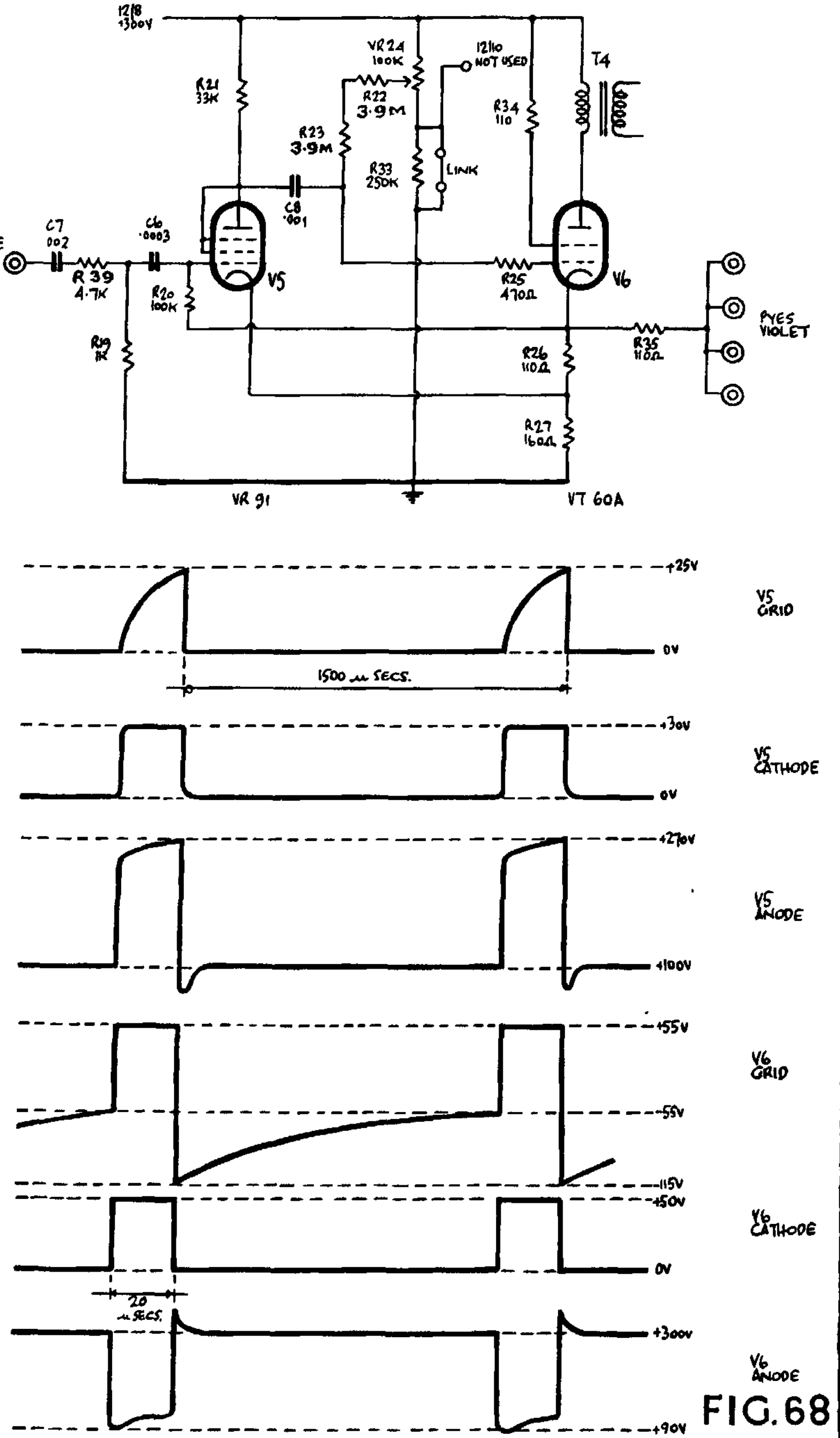

FIG. 68

grid is returned to about +60V. (assuming that autobias due to grid current is cancelled out). The sawtooth will then swing up from a level below +60V. by half the sawtooth amplitude. We have assumed this amplitude is 150V. In this case the sawtooth would carry V.505 grid down to -15V. If the sawtooth amplitude is low, V.505 grid may not reach cut-off and consequently will never cut-off under these operating conditions. In this case there will be no timing pip at V.505 anode, and hence no locking of modulator multivibrator. A check should therefore be made when a new set is being lined up and on main inspections that the sawtooth amplitude is sufficiently great to prevent this fault occurring. The check can be made by scoping the waveform on V.505 grid with the scan-marker switch in the 100/40 position then switching to the 100/40 - 80 position. If the sawtooth is of normal amplitude a small-sawtooth will remain on V.505 grid in the latter position. If the sawtooth amplitude is low the waveform at V.505 grid may show merely an unstable kink or no displacement at all. Under these conditions the modulator will probably unlock or only lock erratically. An increase in sawtooth amplitude can be obtained by increasing R.544 in 25K steps until the trouble is cleared. This assumes, of course, that the fault is due to a sawtooth amplitude well below the 150V. value with a normal valve in V.504 position. Since increasing R.544 reduces the negative feedback from V.504 anode to V.504 grid the gain of V.504 is increased and an increased sawtooth amplitude therefore obtained.

The Modulator Multivibrator, V.5, V.6

297. We have pointed out previously that:-

(a) This stage is a free-running multivibrator which is set for a free-running p.r.f. of about 600 c/s.
(b) The output at V.6 anode is a rectangular wave with a negative phase of 20 microseconds.
(c) When the transmitter-timing pip is applied to V.5 grid the multivibrator is synchronised to run at the master multivibrator p.r.f. of about 670 c/s.
(d) The height and range marker circuits are triggered on the back edge of the 20 microseconds priming pulse developed by this stage.

We shall now examine this stage in more detail to discover the principles employed.

298. The following circuit details are worth noting:-

(a) V.5 anode coupled to V.6 grid via C.8.
(b) Grid leak of V.6 is R.23 + R.22 (3.9 Megs. each) returned to a variable positive potential (For use in Bomber Command R.33 is shorted out by means of the link shown).
(c) Cathode load of V.6 is R.26 (110 ohms) + R.27 (160 ohms).
(d) Cathode load of V.5 is R.27 (160 ohms).
(e) Grid leak of V.5 is R.20 (100K) returned to V.6 cathode.
(f) V.5 grid can only rise as fast as C.6 can charge positively by having electrons leak away through R.20.

299. The valves used in this stage are a VR.91 (V.5) and VT.60A (V.6). The VR.91 is a high slope R.F. pentode. The VT.60A is a power tetrode. It is capable of passing 50-60 ma. steady current and has a long grid base of -60V. When switched on the heavy current passed by V.6 will carry V.5 cathode up to about +30V. and V.5 cathode up to about +50V. V.5 grid tries to follow V.6 cathode up but would take a time determined by the C.R. of C.6, R.20, to reach V.6 cathode potential while V.5 cathode rises instantly. Since this C.R. is 300 x .1 or 30 microseconds V.5 is therefore cut off until the grid can come within the grid base of +30V. This time is about 20 microseconds hence we have V.6 coming on and V.5 cutting off for 20 microseconds. V.5 anode rises towards H.T. but the 20 microseconds interval is not long enough to let sufficient electrons from C.8 leak away through R.21 to bring V.5 anode up more than part of the way. At the end of the 20 microseconds interval V.5 grid crosses cut-off and anode current flows. V.6 then passes less current so the flow through R.26 + R.27 diminishes. This decrease drops V.5 cathode potential instantly. There is also a tendency for V.5 grid potential to fall but C.6, R.20 prevent any instantaneous response. The drop at V.5 cathode

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TRIGGER VALVE

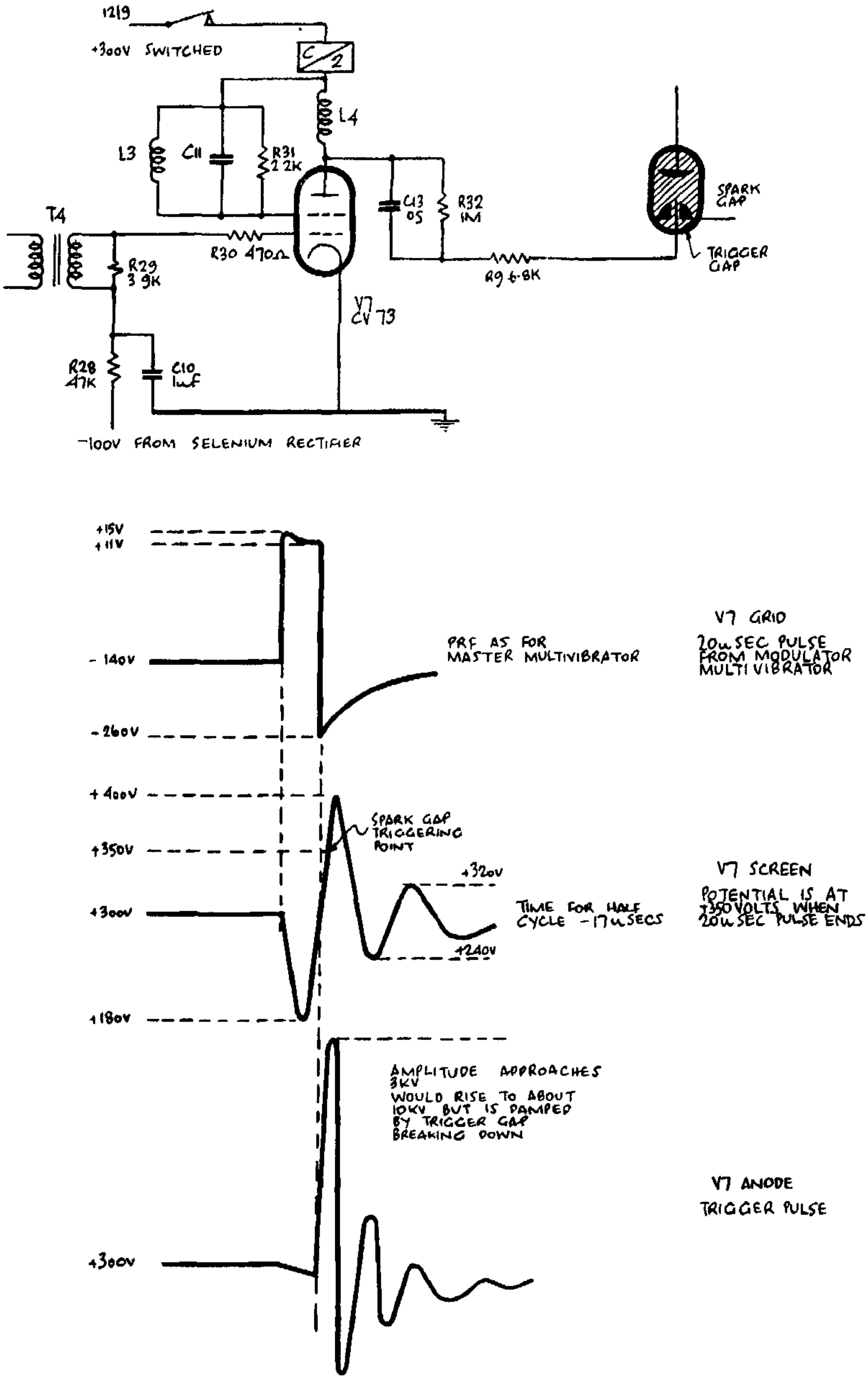

FIG.69

is actually sufficient to cause V.5 to pass grid current which flows into C.6 and the leak away develops a voltage across R.20 that helps carry V.5 grid down. This flow of grid current causes V.5 anode to drop to a low level from which it rises to a steady level in accordance with the current passed by V.5 after grid current has ceased to flow. As the fall at V.5 anode carries V.6 grid below cut-off, V.6 anode swings up. The effective anode load of V.6 is partly resistive and partly inductive. The resistive component is the resistance reflected into the primary circuit by R.29 (3.9K.) on the secondary side of T.4. The inductive component is due to the fact that some of the primary flux does not thread the secondary of T.4. As a result of this inductive component, the potential at V.6 anode overshoots the H.T. voltage and then decays to the H.T. level because of the heavy damping introduced by R.29.

300. How long V.6 remains cut off depends on the time taken for the grid potential to rise to cut-off. This, in turn, is determined by the setting of the p.r.f. control, R.24. This control, as was mentioned earlier, is a ratchet control located at the back of the modulator chassis. For a normal modulator with R.33 shorted out and the p.r.f. control within ± 3 notches of the red dot, the time of rise of V.6 grid will be so slow as to give a p.r.f. of about 600 c/s. When V.6 grid crosses cut-off the rush of current through R.27 again carries V.5 cathode up and cuts V.5 off on the grid for 20 microseconds while V.5 grid climbs exponentially to cut off. The cut-off period of V.5 and conducting period of V.6 is always 20 microseconds regardless of the setting of the p.r.f. control which determines only how far apart these 20 microsecond periods occur.

301. The negative-going 20 microsecond pulse from V.6 anode is the modulator priming pulse which is used to develop the trigger pulse for firing the transmitter. A positive-going 20 microsecond pulse is taken from V.6 cathode through the 100 ohm matching resistor to 4 parallel Pye plugs coded violet on the modulator panel. An output from one of these Pye plugs triggers the height and range marker circuits in the receiver-timing unit. An output from another provides triggering for the Lucero transmitter when Lucero is included in the installation. A third output provides suppression for I.F.F. The fourth output is used in aircraft fitted with Fishpond to trigger the Fishpond marker circuit. An output from one of these Pye plugs is used on the work bench or in the aircraft to trigger the monitor 28 when a triggered timebase is required.

302. Synchronisation of the modulator has been dealt with previously. For the sake of completeness we recall that the transmitter timing pip from V.505 anode is applied to V.5 grid via the blue Pye cable. The arrival of this pip in the V.5 conducting period will drive V.5 grid down and the anode up. The rise at V.5 anode carries V.6 grid above cut-off and brings V.6 into conduction earlier to obtain a synchronised p.r.f. equal to that of the master multivibrator.

<u>The Trigger Valve, V.7</u>

303. In tracing the development of the modulating waveform it was stated that V.7 was switched on and off by the modulator priming pulse and that the positive ring appearing at the anode on the back edge of the priming pulse was used to trigger the spark-gap, V.3. To study this stage in more detail it is necessary to note the following points:-

(a) The grid is returned through R.29 to a decoupled negative potential of -100V. from a metal rectifier in the modulator.
(b) The cathode is returned to earth.
(c) The anode load is a 4 mh. choke tuned by its self-capacity to about 400 Kc/s.
(d) The screen is fed through a tuned circuit L3,C11 damped by R.31 (2.2K.). The resonant frequency of L3,C11 is about 25Kc/s. giving a half-period of about 20 microseconds.
(e) V.7 is a CV.73 beam tetrode, capable of passing a heavy current.

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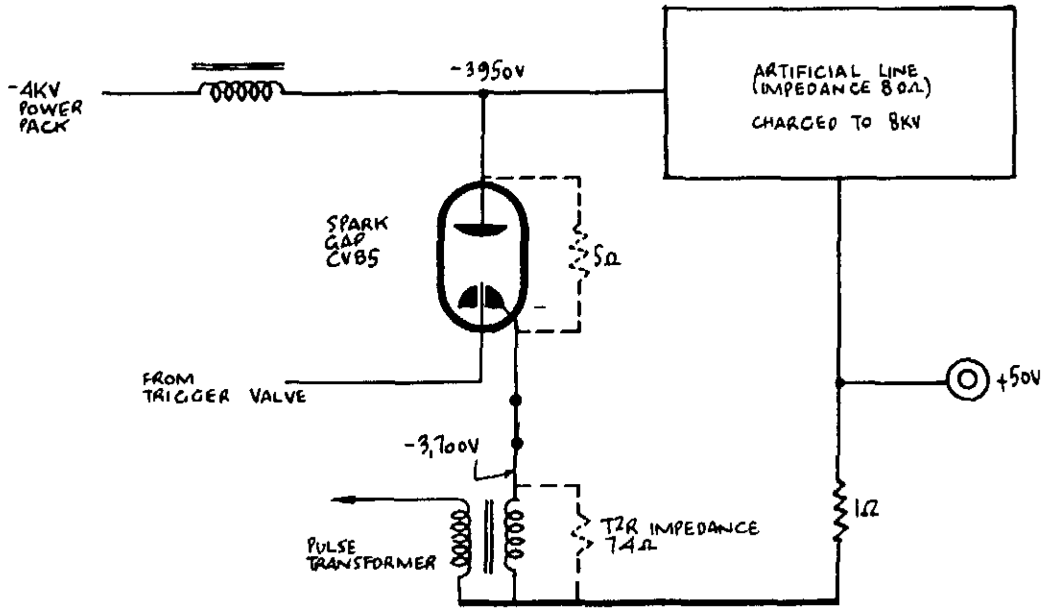
EQUIVALENT CIRCUIT DURING DISCHARGE OF ARTIFICIAL LINE



TOTAL IMPEDANCE = 160Ω ∴ CURRENT = $\frac{8000}{100}$ = 50 AMPS.

VOLTS DROP ACROSS	PULSE LINE	=	80 × 50	= 4000 V
" " "	SPARK GAP	=	5 × 50	= 250 V
" " "	MONITOR RESISTOR	=	1 × 50	= 50 V
"	IMPEDANCE OF T2R PULSE TRANSFORMER	=	74 × 50	= 3700 V
			TOTAL	= 8000 V

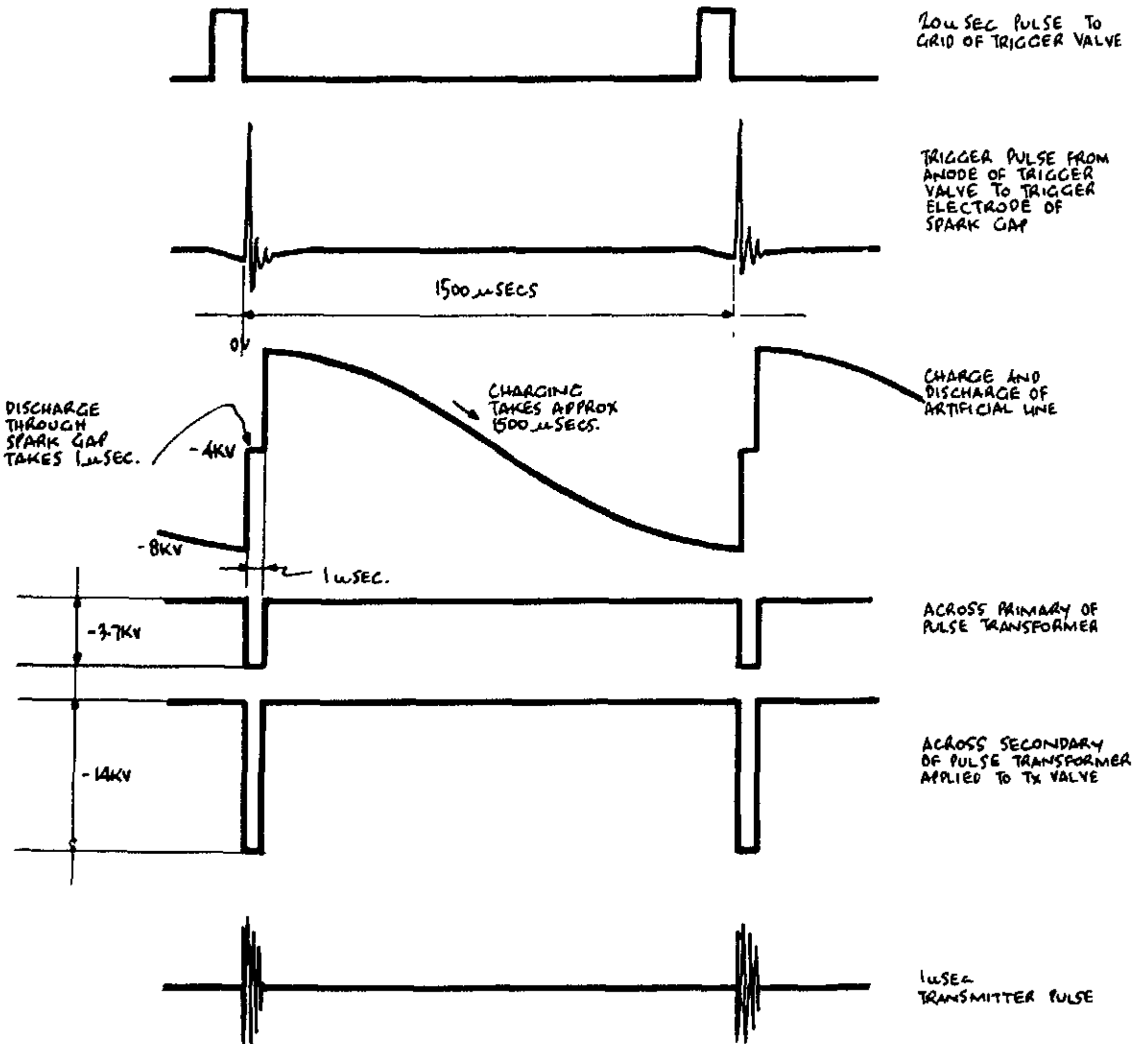


FIG.70

304. The -100V. bias on V.7 grid will hold the valve cut off during the interval between the 20 microsecond positive pulses on the grid. On the leading edge of the priming pulse, V.7 grid is carried up to around +40V. so a very heavy current is passed. If only R.31 were in the screen supply the screen would fall to a steady level. Due to the presence of the ringing circuit in the screen the screen voltage will show a 25 Kc/s damped ring. The initial swing will be negative due to the flow of screen current. As the period is about 40 microseconds the first half cycle will be completed by the time the priming pulse terminates. As the screen is back to the H.T. level the valve will then be passing a very heavy anode current of about 500 ma. There will then be considerable energy stored in the magnetic field of the inductance L4 at the instant that anode current is cut off when the grid is carried down on the back edge of the 20 microsecond priming pulse. Hence, as the anode current is cut off the collapsing field develops a terrific overswing at V.7 anode. If undamped, this ring would have an amplitude of about 10KV. on its first upward swing. As the resonant frequency of the choke is about 400 Kc/s the first half cycle would take 1.25 microseconds. In practice this positive swing causes the trigger gap of V.3 to break down when the amplitude reaches a value of around 3KV. The current flow to the trigger electrode then damps the ring so that there is no further increase in amplitude. The heavy current passed by the valve when it runs into grid current on the leading edge of the priming pulse serves to provide sufficient damping to eliminate any consequent anode ringing.

The Spark Gap Switch, V.3

305. V.3 is filled with argon +3% oxygen at a pressure of 3 atmospheres or about 45 pounds per square inch. To minimise danger from flying glass in case of explosion of the envelope the glass envelope is enclosed in a shellacked net arrangement. The main gap consists of two saucer shaped molybdenum electrodes. The lower one has a hole drilled through it to permit the insertion of the tungsten trigger electrode with only a small clearance. This small clearance provides the trigger gap which ionises when the trigger is carried positive by the ring at V.7 anode on the back edge of the modulator priming pulse. The ring electrode is held at D.C. earth potential through the monitor chain R.10, R.11, R.12 and the parallel path through the uniplug pulse cable to the transmitter unit and the pulse transformer primary. When the potential difference across the trigger gap reaches about 3KV. the trigger gap breaks down to give free electrons that will flow to the positive trigger-electrode and positive ions that will flow to the negative electrode of the main gap. If a sufficiently high voltage exists across the wide main gap these positive ions will travel with a sufficiently great velocity to knock electrons off the neutral molecules in the main gap. These molecules will be under considerable electrical strain due to the voltage impressed across the main gap by the charged modulating line. This strain is not sufficiently great to cause breakdown by itself but collision of high speed positive ions with the strained molecules will cause breakdown and produce more positive ions to collide with more strained neutral molecules. There is thus a progressive ionisation once the trigger gap flashes over. It is the lag due to this progressive ionisation together with the finite time of rise of the trigger pulse that causes the transmitter pulse to occur slightly after the back edge of the modulator priming pulse.

306. After the artificial line has completed its discharge through the spark gap the voltage across the main gap is zero and the positive ions tend to gravitate to the trigger which will exhibit a negative charge due to the electrons that flowed into C.13 when the trigger gap flashed over. The positive ions are then neutralised at the trigger to again become neutral molecules and the gap returns to its non-conducting state.

307. A small percentage of oxygen is included in the filling to start the flash-over as oxygen is much more readily ionised than argon. When the oxygen is largely used up in the formation of oxides of tungsten and molybdenum during the flash-over intervals the gap will become erratic and unserviceable.

The Modulating Line and Charging Choke

308. We may regard the inductance of the charging choke and the elements of the artificial line as combining to form a resonant circuit that tends to ring

when the -4KV. supply is connected in series with it. The mean level of the ring will be the -4KV. level. The crests will be OV. and the troughs -8KV. We may imagine some such sequence as follows. Suppose the line has just completed its discharge through the spark gap and the condensers are completely discharged. The spark gap de-ionises and the -4KV. supply is connected in series with the 64 henry choke, the discharged line, and the resistor R.8 (in parallel with the solenoid of the overload relay). The charging current will be approximately sinusoidal. When the condensers are charged to -4KV. we might expect the flow of electrons into the condensers to cease. But as the rising back e.m.f. developed by the charging condensers tends to reduce the current flowing through the choke, the collapsing magnetic field keeps the electron flow going in the same direction in accordance with Lenz's Law. Putting it differently, the energy stored in the magnetic field of the choke is used up to complete the storage of energy in the condensers of the line. When the choke has lost all its energy, i.e., the magnetic field has collapsed completely and the charging current is zero, the condensers are charged to -8KV. There is then 8KV. across the main gap of V.3, but no current flowing. When the trigger gap is now fired and the main gap breaks down as a result of the collision between ions formed in the trigger gap and strained neutral molecules in the man gap, the resistance of the gap drops to a few ohms. We now have the line with its stored energy connected in series with the low gap resistance, the pulse cable, the resistance reflected into the pulse transformer primary by the magnetron, and the 1.1 monitor resistor. We shall assume the artificial line has a characteristic impedance of about 80 ohms, the gap has a resistance of about 5 ohms, and that the resistance reflected into the pulse transformer primary is about 74 ohms. We may then regard the 80 ohm line as matched to a total load of about 80 ohms if we count in the monitor resistor. We may regard this arrangement as a battery charged to -8KV. with an internal resistance of 80 ohms connected to an 80 ohm load. The current will then be $\frac{8000}{160}$ = 50 amps.

The drop across the line will be 80 x 50 = 4KV. and the drop across the pulse transformer primary will be 50 x 74 = 3.7KV. Since the secondary of the transformer is the full winding and the fixed end is at earth potential, the tapping point goes to -3.7KV. and the output end gives the stepped up voltage of about -14KV for the magnetron cathode. The components in the line are so chosen that the energy stored is discharged in a 1 microsecond burst if the line is matched to its load. The current discharged should build up to its 50 amp. value in about 0.1 microseconds. The inductances in the line serve to maintain the current reasonably constant during the discharge period. The decay of the current involves a collapse of the magnetic field around the pulse transformer winding which will be in the form of the first quarter cycle of a ring whose frequency is fixed by the inductance and self-capacitance of the pulse transformer. This decay will take a little longer than the build-up. As the pulse duration is determined by the amount of energy stored in the line, it depends on the value of the line components and the number of sections.

309. Suppose that the load were 720 ohms instead of 80 ohms. The current would then be $\frac{8000}{800}$ or 10 amps. instead of 50 amps. The drop across the line would be only 80 x 10 or 800 volts and the drop across the load would be 10 x 720 or 7,200 volts. The voltage across the pulse transformer secondary would then be so high that arcing would probably occur in the transmitter unit, to put an effective short across the pulse transformer secondary. In the Mark IIIA H.F. box the CV.189 arcs over and the thermal relay operates as discussed in paras. 285-286. The resultant reflections on the pulse cable will tend to keep the spark gap ionised so long that the current flowing through the gap, the choke and R.8 and the overload relay solenoid will build up to a mean value that causes the overload relay to trip. This then operates the safety valve V.4 to break the input to the -4KV. pack and the H.T. to V.7. Details are given in paras. 256-257. The same effect will be produced by any other fault that puts a short across the pulse transformer output. In general any fault that permits the current flowing through the gap from the -4KV. supply to build up due to prolonged ionisation will cause the overload relay to trip. It will also trip if the p.r.f. is raised to such a high value that the mean current through the solenoid of the overload relay becomes sufficiently great to energise it.

Dummy Loads

310. Since overload relay tripping or failure to switch on can be caused by a number of faults in either the modulator or transmitter units some form of systematic elimination procedure is called for. For this purpose a dummy load is provided to replace the transmitter unit and provide an approximate match to the artificial line in the modulator when it is connected across the pulse output plug. This is the 80 ohm dummy load resistance unit type 228. If the trouble persists the fault may logically be expected to be in the modulator. If the fault disappears either the pulse cable or the transmitter unit must be at fault. The pulse cable can be checked by placing the dummy load across the output end of the cable. If the fault is localised to the transmitter unit, the pulse transformer, magnetron filament transformer, magnetron and overswing diode circuits fall under suspicion, so some form of elimination procedure is called for. A 1.5K. dummy load, resistance unit type 230, is provided for this purpose. This dummy load is intended as an approximate equivalent for the magnetron so is placed across the secondary of the pulse transformer. If the fault disappears the magnetron was faulty. If the fault continues, the pulse and filament transformers are the main suspects. Disconnecting the filament transformer makes it possible to tell whether the pulse transformer is faulty. If not, the filament transformer is the logical suspect. If the pulse transformer is faulty it must be replaced. If the fault is still cleared when the filament transformer is reconnected the filament transformer is all right. If not, replacement must be made. In the Mark IIIA H.F. box the two transformers are in one unit so replacement is necessary as soon as the fault continues after the dummy load is used to replace the magnetron. A fuller outline of trouble-shooting on insulation breakdown faults is given in Chapter 12, paras.1085-1088.

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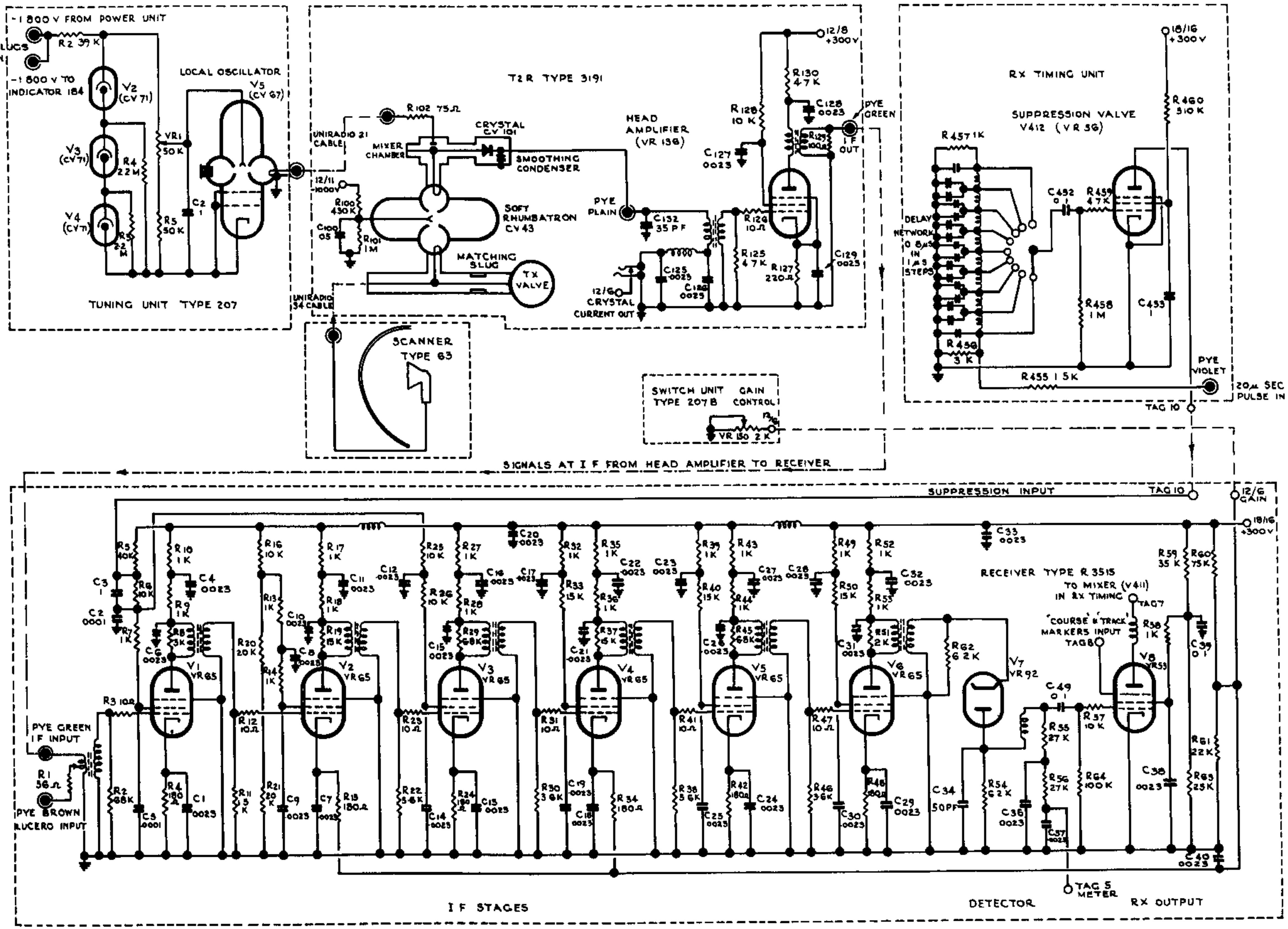

RECEIVER CHAIN – MARK II C.

FIG. 72

FIG. 72

CHAPTER 6 - THE RECEIVER CHAIN

General Considerations

311. Before commencing a study of the H.2.S. receiver chain it may be profitable to recall some relevant facts that must have a bearing on its design and on the way the stages are distributed in the installation.

(a) It is a cm. receiver. In the Mark IIIA installation signals are received on a wavelength of about 3.2 cms. and in the Mark IIC installation the wavelength is about 9.1 cms. R.F. amplification is impossible at these frequencies so the first stage must be a frequency changing stage.

(b) As received signals will be weak signal to noise ratio becomes a major consideration and the frequency changing stage must be designed with a view to obtaining the best possible signal to noise ratio. This consideration has required the use of a crystal mixer.

(c) Since dielectric losses in feeders reach very high values at 3.2 cms. the Mark IIIA R.F. system must use waveguides. The crystal mixer is therefore mounted in a waveguide. In the Mark IIC installation the crystal mixer is mounted in a section of coaxial line. In both cases the shielding thus provided prevents the superimposition of large quantities of external noise on the noise generated by the crystal itself.

(d) Since the first stage is a frequency changer the local oscillator must be capable of generating a C.W. output in the same wavelength band as the magnetron transmitting valve wavelength. This calls for a local oscillator of the resonant cavity type.

(e) To achieve the maximum simplicity in I.F. amplifier design it is necessary to use preset I.F. tuning. As the magnetron frequency is certain to vary and cannot readily be controlled the local oscillator must be tunable. The requirement of a local oscillator which is capable of generating a C.W. output in the appropriate cm. band and which can also be easily tuned makes it preferable to use a resonant cavity oscillator of the reflector klystron type.

(f) Since the H.2.S. operator must be able to tune the local oscillator from his position on the aircraft the tuning control must be at his table. This means that either the oscillator itself must be there or some form of remote tuning is necessary. In the Mark IIC installation the local oscillator is in a tuning unit at the H.2.S. operator's table. In the Mark IIIA installation using the TR.3555 series transmitter unit the local oscillator is incorporated in the transmitter unit and a remote tuning control is provided at the H.2.S. operator's table.

(g) To minmise R.F. losses in both transmitter output and in returned signals it is necessary to keep the R.F. paths as short as possible. The transmitter unit is therefore mounted as near to the scanner as possible and the crystal mixer is located in the transmitter unit. This means that the L.O. signal must either be generated in the transmitter unit or brought to the transmitter unit. In the 3 cm. band feeder losses make it imperative to put the local oscillator in the transmitter unit. Hence we have the remote control tuning unit at the H.2.S. operator's table. In the Mark IIC installation the power obtainable from the local oscillator is ample to allow for feeder losses and the klystron is therefore located in a tuning unit at the H.2.S. operator's table.

(h) Since the receiver is a pulse receiver it must have a bandwidth sufficiently wide to pass the pulses without undue distortion. The bandwidth of the I.F. amplifier is therefore about 4 Mc/s. in H.2.S. Mark IIIA. In H.2.S. Mark IIC, the bandwidth is about 6 Mc/s.

(i) The I.F. chosen is 13.5 Mc/s. in H.2.S. Mark IIC and 45 Mc/s. in H.2.S. Mark IIIA.
(j) Since it is not feasible to incorporate the I.F. amplifier in the transmitter unit it would appear to be necessary to transfer the weak I.F. mixer output via cable from the transmitter unit to another unit housing the I.F. amplifier. Any additional noise picked up en route would then receive the full amplification of the I.F. amplifier. Since the mixer output signals have had no amplification whatever any appreciable addition of noise before amplification occurred would seriously impair the signal to noise ratio. In an attempt to overcome this problem a measure of I.F. amplification is introduced in the transmitter unit. In the Mark IIC transmitter unit only one stage is used while the Mark IIIA transmitter unit two stages are employed. This section of the receiver is termed the head amplifier.
(k) The I.F. amplifier proper is housed in the receiver-timing unit for convenience in mixing signals and markers. Variable gain is required. The gain control must, of course, be located at the H.2.S. operator's table.
(l) Since H.2.S. is a common T. and R. system a TR switch must be incorporated to seal off the receiver branch line in the transmitter unit as much as possible for the duration of the transmitter pulse. The valves used for this purpose are called soft rhumbatrons. They are resonant cavities filled with water vapour at a low pressure. They flash over when the resonant cavity goes into violent oscillation during the transmitter pulse period.
(m) Although the soft rhumbatron TR switch flashes over on the leading edge of the transmitter pulse it does not completely isolate the receiver during the transmitter pulse period. Sufficient R.F. energy will reach the crystal and then pass into the I.F. amplifier to cause overloading of the I.F. amplifier if it remains in a fully sensitive condition while the transmitter is pulsing. To overcome this problem the sensitivity must be reduced during the pulse period. This is accomplished by applying a suppression pulse to some of the stages in the I.F. amplifier which reduces the sensitivity of these stages very nearly to zero.
(n) Since a common T. and R. system is employed suitable provisions must be made to prevent signals travelling down the transmitter and reflecting back in such a phase as to interfere with the signals passing directly into the receiver branch line.

312. Summing up, we may now visualise the H.2.S. receiver as consisting of the following primary sub-divisions:-

(a) Input matching devices to avoid interference from received signals travelling down the transmitter line and reflecting.
(b) TR. switch of the soft rhumbatron type to isolate the receiver as much as possible during the transmitter pulse period.
(c) A suitable crystal mixer stage.
(d) A reflector klystron local oscillator with suitable tuning arrangements at the H.2.S. operator's table. Automatic adjustment of the klystron frequency to follow the changes in magnetron frequency would be desirable.
(e) A head amplifier in the transmitter unit.
(f) An I.F. strip with second detector and a suitable output stage. Variable gain facilities will be incorporated. The control itself must be remote in order to permit its location at the H.2.S. operator's table.
(g) A suppression generator synchronised with the transmitter to prevent the transmitter break-through that gets past the soft rhumbatron TR. switch from overloading the I.F. amplifier and preventing its response to short range signals.

The Mark IIC Receiver

313. The main details of the Mark IIC Receiver are shown in fig. 72.

Input Matching

314. It has been pointed out in Chapter 5 that the matching slug in the Mark IIC transmitter unit is required to perform two functions simultaneously. The first of these functions is to arrange that the coaxial high power feeder is matched to the magnetron. If a thermo-couple is used to measure the R.F. output the matching slug can be set to a position which gives the maximum R.F. output indication. The second condition the matching slug should fulfil at the same time is the transformation of the cold impedance of the magnetron to show a very high value in the diraction of the magnetron at the junction of the receiver branch line with the main one. What we really mean by saying that the magnetron cold impedance is transformed to a high value is that the phase of the wave reflected by the reactive load presented by the cold magnetron is so modified by the slug that it continues down the branch line in phase with the incoming wave. The effect is then the same as if no energy were penetrating past the receiver branch line. Now the matching slug may not fulfil both conditions perfectly with the same setting. The usual procedure in Bomber Command has been to monitor the receiver output and adjust the matching slug for the maximum signal amplitude. This adjustment assumes that if the adjustment gives the maximum signal amplitude for returns from one particular echo it will do so for all other echoes. While this assumption may be true in the majority of cases it is not necessarily always true. The frequency of the magnetron is dependent to some extent on the matching slug setting. The interference pattern produced by waves travelling directly to the target and back and waves reflecting off the ground to the target and back, may result in reinforcement and abnormally strong signals at one particular frequency for some particular echo. If the set is taken into the air and these interference effects no longer appear poor signals may be obtained

315. The method of setting the matching slug for maximum signals is also open to the danger that the slug setting so obtained is sometimes such as to leave the magnetron very susceptible to moding or frequency pulling with the resultant development of gapping or unstable signals. The radar mechanic is therefore warned that, while setting the matching slug for maximum signals on a particular permanent echo will give a satisfactory performance in the majority of cases, there may be exceptions. The only alternative method available at present is to find a position of the matching slug where the power output as noted on a thermo-couple meter is not reduced by more than 10 - 20% from the normal figure given by good sets, and where a variation of + or - $\frac{1}{4}$ inch in the slug position does not result in a frequency shift of more than 4 Mc/s. This frequency shift may be measured with an echo box wavemeter by adjusting the echo box for maximum signal on the height tube trace for the selected slug position and each of the displaced positions. The frequency change in the magnetron will be the change read on the calibrated scale of the wavemeter, if the local oscillator tuning is not varied. A simpler test is observation of the change in the amplitude of permanent echo signals. If the L.O. is not returned and the amplitude does not drop by more than 50% as the slug is moved + or - $\frac{1}{4}$ inch, the frequency shift is less than 4 Mc/s.

The Soft Rhumbatron TR. switch, CV.43

316. The construction of this valve and its electrical equivalent are shown in fig. 73(a) and (b). When the transmitter pulses, an electromagnetic wave travels along the output line, part going to the scanner and part travelling down the branch line. When this wave reaches the coupling loop that extends into the CV.43 resonant cavity, the cavity oscillates violently and develops a high voltage across the lips. This R.F. voltage causes the water vapour to ionise and develop a conducting patch across the lips. The position of the CV.43 in the branch line is so chosen that the short appears an odd number of quarter wavelengths from the branch line junction. The effect is then to produce a shorted quarter wave stub. In such a shorted coaxial stub a phase change of 180° occurs on reflection. The reflected wave, after travelling down and back, i.e., an odd number of half wavelengths, will be back in phase with the wave going down the main line when it reaches the junction. This follows since

it has made a detour of an odd number of half wavelengths plus a phase change of 180° (equivalent to a half wavelength), the sum of which is equivalent to a detour of an integral number of wavelengths. The effect is then the same as if no detour had been made so we say the stub offers a high impedance at the junction with the main line and the effect, in so far as R.F. output is concerned, is essentially the same as if there were no branch line. This statement is not quite correct as the CV.43 does not present a perfect short and some energy does pass through it to the crystal mixers. It is this leakage or transmitter break-through that makes it necessary to have a suppression circuit to suppress the I.F. amplifier while the transmitter pulses.

317. We may think of this leakage or break-through in the following way. When flash-over occurs a low resistance is effectively placed across the resonant cavity. This has the same effect of damping the oscillation in the cavity as a low resistance across an ordinary tuned circuit. Since it is not quite a dead short the oscillation is not, however, completely damped out. Hence the output loop has some voltage induced on it which is fed to the mixer cavity.

318. When the transmitter pulse ends the voltage on the input loop into the CV.43 dies out and there is no further excitation of the cavity. The oscillations are then soon damped out. The positive and negative ions now recombine to form neutral molecules and the short across the lips is removed and our stub becomes an open instead of a short-circuited stub. Such a stub offers a low impedance at the junction with the main line. If the matching slug has been adjusted to make the cold magnetron offer a high impedance the bulk of the incoming signal energy flows down the branch line. When a signal wave reaches the input loop the resonant cavity is again excited but the R.F. voltage developed across the lips is not sufficiently great to cause the water vapour to ionise. Hence, there is no shorted stub to cause reflection and no heavy damping of the resonant cavity. The cavity therefore continues to oscillate while signals come in. The oscillating field induces a voltage on the output loop so the energy is fed into the mixer chamber. While signals are coming in we may regard the resonant cavity as a 1.1 transformer or a half wavelength of transmission line.

The CV.43 Probe

319. To protect the crystal it is essential that the CV.43 flash over on the early cycles of the transmitter pulse before it reaches its full amplitude. To speed up the flash-over a trigger probe is introduced. This probe is connected to a potential of around -700V., obtained by tapping in at the junction of R.100 (430K.) and R.101 (1M.) placed across the -1000V. line coming in from the power unit on pin 11 of the 12-way. The CV.43 cavity is at earth potential. Hence, there is a steady potential difference of about 700V. between the end of the trigger probe and the earthed cavity. This voltage is sufficient to keep a small amount of ionisation in this gap, independent of whether or not the transmitter is operating. This continual ionisation can be observed by connecting an AVO between the probe and the lead to the -700V. tapping point. The positive terminal of the AVO must, of course, be connected to the probe and the negative one to the lead. There will be a steady ionising current depending on the design of the CV.43. Cross-section and ionising currents are shown in fig.73(d). The different types can be recognised by removing the tuning plunger which comes out through the transmitter unit panel and looking at the design of the lips. When the cavity is thrown into violent oscillation by the arrival of the leading edge of the transmitter pulse, the positive ions in the gap surge across the lips as the far side swings to a high negative value. Their collisions with the neutral molecules between the lips will cause these to break down at a lower voltage across the lips than would be the case if the ions were not present. Hence, flash-over occurs earlier than it would if no probe were employed. Consequently less R.F. energy hits the crystal. The incorporation of the probe is thus a means of speeding up ionisation in order to give added protection to the crystal.

320. The presence of the probe assists rapid de-ionisation as well as rapid

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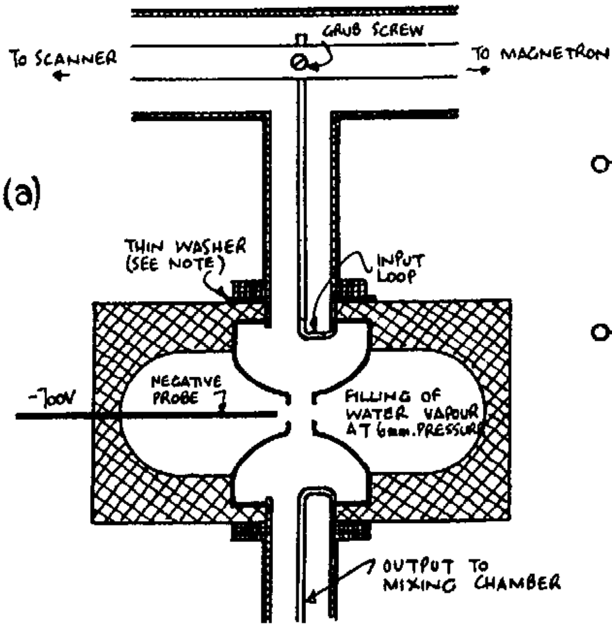
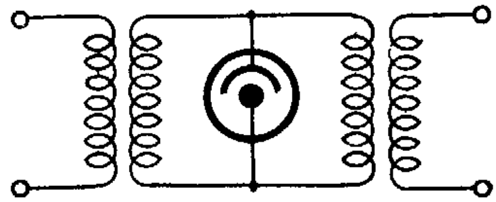
THE CV43 - SOFT RHUMBATRON

FIG. 73



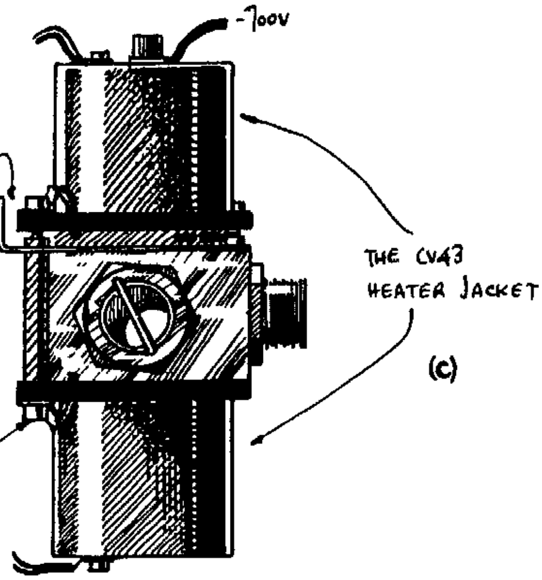


EQUIVALENT CIRCUIT OF CV43

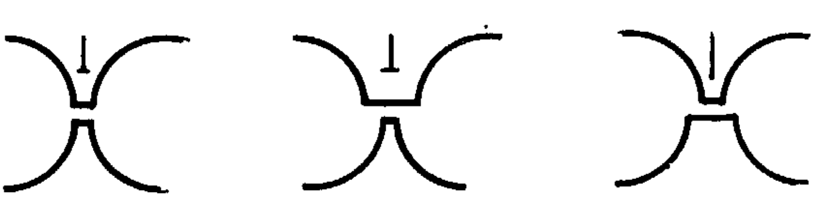
(b)

WITH NORMAL IONISATION, GLOW IS CONFINED TO LIPS. EXCESSIVE IONISATION INDICATED BY DIFFUSED GLOW THROUGHOUT CAVITY IS CAUSED BY OVERCOUPLING. TO REMEDY THIS, SLIGHTLY WITHDRAW INPUT LOOP FROM CAVITY BY INSERTING THIN WASHER BEHIND LOCKING NUT. SLACKEN GRUB SCREW WHEN DOING THIS

NOTE THAT CONNECTION BETWEEN TWO HALVES OF HEATER JACKET IS MADE THROUGH SCREW.



(c)



IONISING CURRENT 1mA | IONISING CURRENT ·75mA. | IONISING CURRENT ·5mA.

THESE ARE AVERAGE CURRENT READINGS. CV43 SHOULD BE CHANGED IF CURRENT FALLS BELOW 75% OF THESE FIGURES.

THREE TYPES OF CV43 IDENTIFIED BY DESIGN OF LIPS (d) ionisation. When the transmitter pulse ends the positive ions in the gap will be attracted to the negative probe where they can speedily become neutralised to form neutral molecules. If no probe were used ionisation could only occur by collision between positive ions and electrons detached when flash-over occurred, or by contact between positive ions and the earthed cavity wall. The completion of the probe supply and the presence of the correct probe voltage are therefore necessary if the CV.43 is to afford the maximum protection to the crystal and is to show speedy de-ionisation.

CV.43 Tuning

321. In order that the oscillations developed in the CV.43 cavity may have the maximum amplitude when signals are being received the cavity must be resonant at the magnetron frequency. Should the resonant frequency be different the oscillations will be of the same nature as the oscillations developed in a ringing circuit by shock excitation. Their frequency will be the natural frequency of the cavity. Since the input will be at a different frequency it will not tend to build up the amplitude so the output will be low. Hence it is necessary to tune the CV.43 cavity to the magnetron frequency to get the maximum signal amplitude into the crystal and hence out of the receiver. This tuning is done by varying the volume of the cavity. To raise frequency, the volume must be decreased. To decrease frequency the volume must be increased. These changes in frequency are made by means of a tuning plunger which projects through the panel of the transmitter unit. There are also two fixed plungers which must be preset to give a bandspread on the tuning plunger that suitably covers the normal range of magnetron frequencies. These plungers should be so set that signal amplitude can be dropped to 50% of maximum by not more than two turns of the tuning plunger in either direction.

CV.43 Overcoupling

322. It may be found when lining up a transmitter unit that the CV.43 tunes very flatly and that the sensitivity of the set is poor. If this is the case the tuning plunger should be completely removed and the cavity viewed through the aperture thus provided. It is very likely that a diffused purple glow will fill the whole centre of the cavity. Such an indication points to overcoupling of the transmitter pulse into the cavity by having the input loop projecting too far into the cavity. The effect is to set up such violent oscillation when the transmitter pulses that ionisation is not restricted to the region between the lips but extends throughout much of the cavity. This widespread ionisation results in such a long de-ionisation period that the cavity is damped considerably for a long time after the transmitter pulse ends. This prolonged damping results, of course, in feeble oscillation when signals are received and hence low input to the mixer and therefore low signal output. The only cure is to reduce coupling until the normal ionisation across the lips only is obtained.

323. To make this adjustment it is necessary to loosen the grub-screw in the main output line which holds the inner of the branch line, the pinch-collar, and the knurled locking ring holding the branch line at the CV.43. The branch line can then be worked away slightly from the CV.43 and towards the main line thus withdrawing the coupling loop. Displacements of the order of 1/32" to 1/16 " are normally sufficient. Obviously, care must be taken not to remove the coupling loop too far or undercoupling will result and the signal amplitude will again suffer. The loop should be withdrawn until the ionisation glow appears across the lips only and the plunger then replaced and a check made on sharpness of tuning and signal amplitude. Checks should then be made to see whether the signal amplitude can be improved by further slight increases or decreases in coupling. When the optimum position has thus been found a washer of the appropriate thickness will have to be fitted between the bush which screws into the cavity and the cavity proper. Otherwise the knurled locking ring will pull the loop back into its original position when the reassembling is done. Care must then be taken to tighten the grub-screw, pinch-collar and knurled locking ring to prevent any further displacement due to vibration.

RECEIVER CHAIN BLOCK SCHEMATIC

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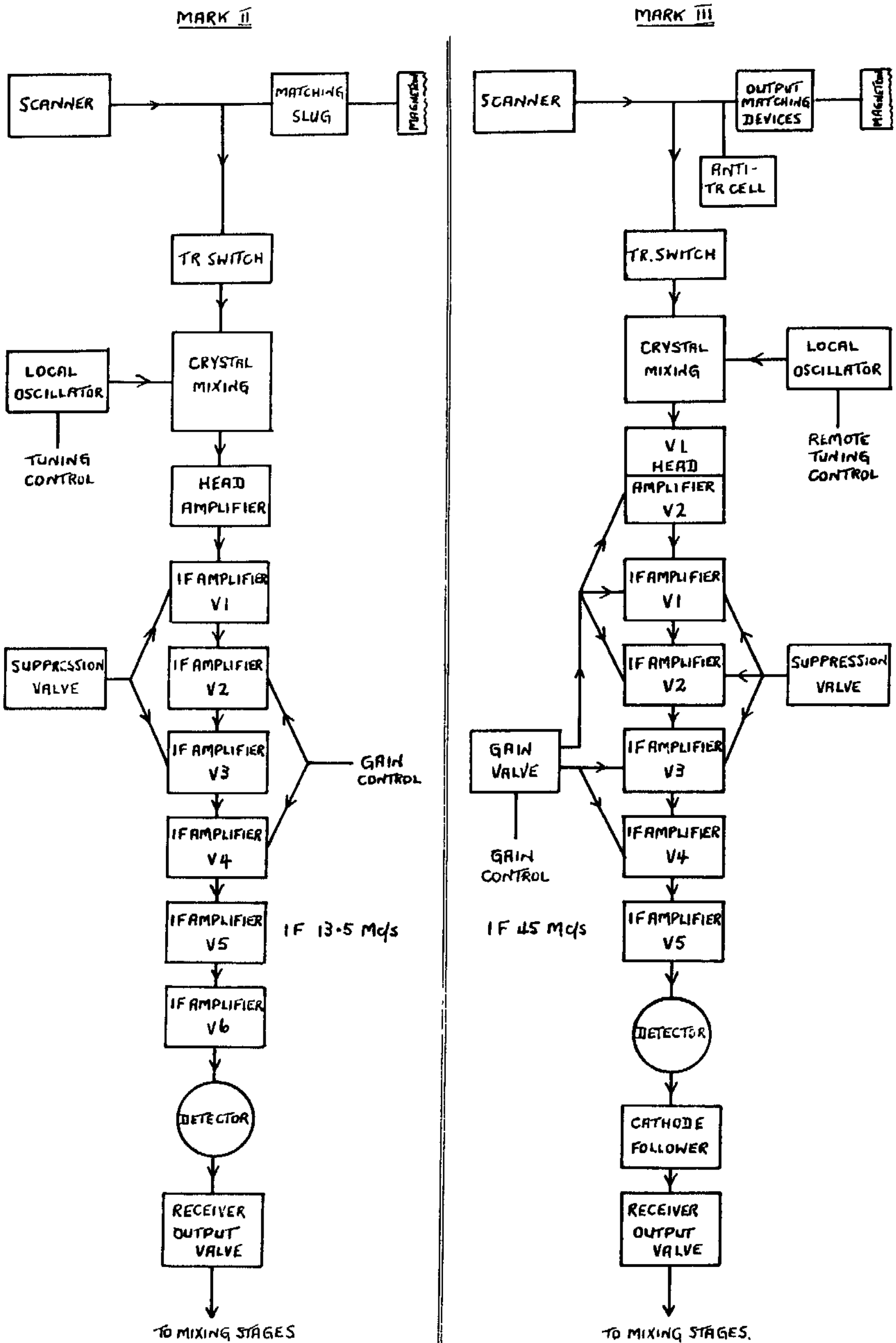

FIG.71

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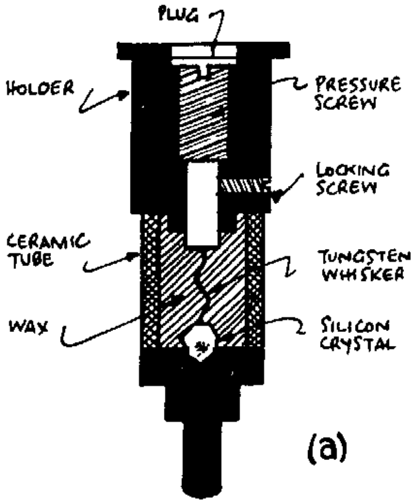
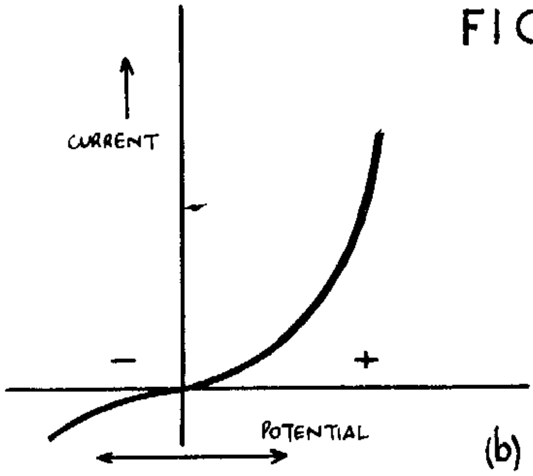
FIG.74



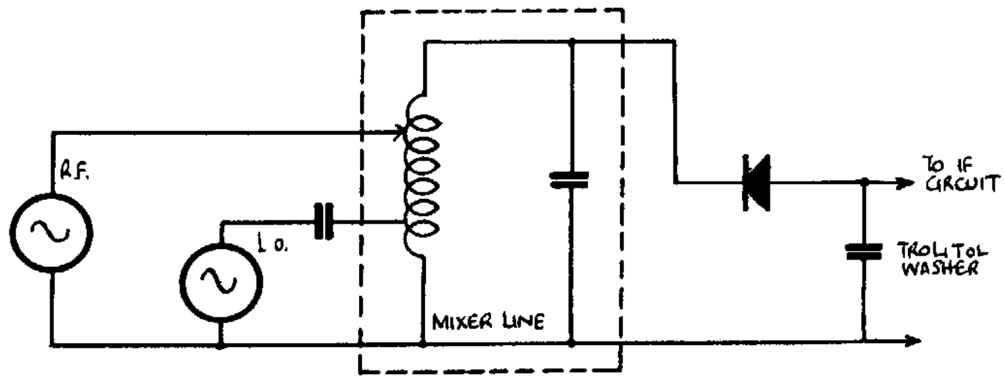
(a)

CONSTRUCTION OF CRYSTAL



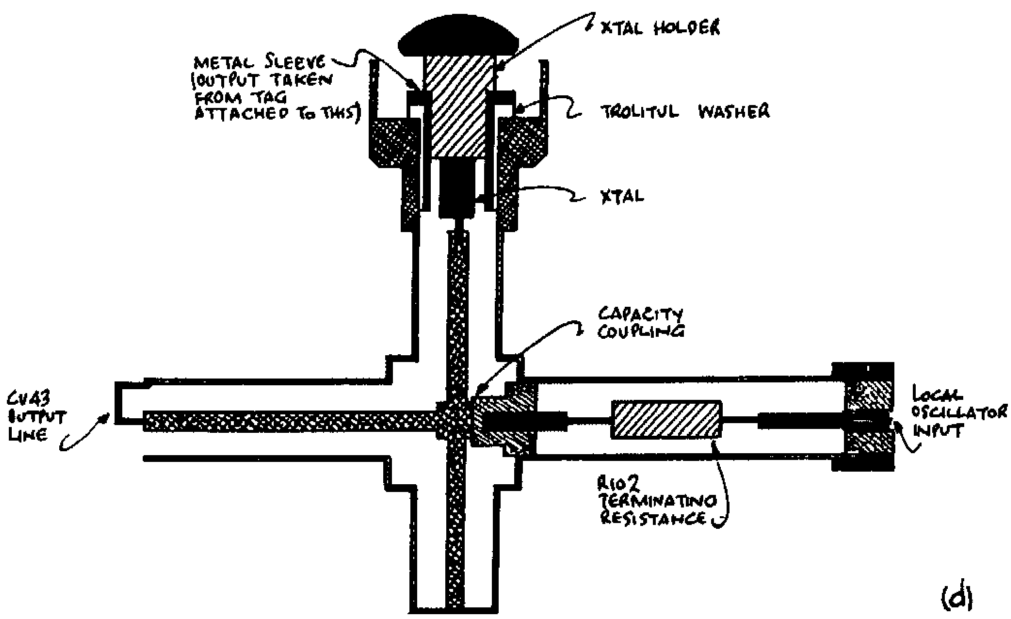
(b)

CHARACTERISTIC OF CRYSTAL RECTIFIER



EQUIVALENT CIRCUIT OF CRYSTAL MIXER

(c)



(d)

DIAGRAM OF MIXER LINE

CV.43 Faults

324. Should crystals be continually burning out, it may logically be expected that the CV.43 is not functioning. This can be checked by looking for the ionisation across the lips. If this is absent and the normal voltage is on the probe the CV.43 must be replaced. The vacuum has probably been lost due to a cracked glass or broken copper-glass seals.

325. Should crystal life be short it is reasonable to suspect too much transmitter break-through is reaching the crystal because the flash-over is not sufficiently rapid. This may be due to a poorly shaped magnetron pulse which rises too slowly or to a faulty CV.43. The only available CV.43 check is on the ionising current. Should this value fall below 75% of the values quoted in fig.73(d) a check should be made that the correct voltage is in the probe. If this is present, the CV.43 should then be replaced.

326. If recurrence of the trouble is experienced along with low sensitivity generally it is probable that the magnet is below the required value of 1250 gauss, measured with the magnet on the chassis and the cover on. This measurement should be made with a flux-meter using a cover with a suitable hole cut in the side to permit insertion of the search coil. Further details are given in Chapter 11, para.842. A faulty magnetron might also be responsible for a poorly shaped pulse. A further rather remote possibility is that the modulator is supplying a poor modulating pulse. This can be checked by running the modulator into the 80 ohm dummy load and noting the pulse shape at the voltage monitor point. A check on the magnetron can be made by noting the pulse shape at the same point when the magnetron is used and when it is replaced by the 1500 ohm dummy load.

CV.43 Heater Jacket

327. The CV.43 is provided with a 24V heater jacket to keep the cavity temperature constant to prevent changes in gas pressure with falling temperature and consequent delayed ionisation. Care must be taken in assembling this jacket to join the + and - 24V supply leads by one of the bolts holding the two sections together. If the circuit is not thus completed the heater jacket is inoperative.

The Crystal Mixer Stage

328. (a) The structure of the crystal itself is shown in fig.74(a).
(b) Mechanical details of the mixer line are shown in fig.74(d).
(c) The major details of the circuit arrangements are shown in fig.72.
(d) The electrical equivalent is shown in fig.74(c).
(e) The theoretical waveforms are shown in fig.75.
(f) The voltage - current characteristic is shown in fig.74(b).

The Crystal

329. The rectifying crystals used commonly as cm. mixers employ a tungsten whisker embedded in a silicon crystal. Structural details are shown in fig.74(a). When a D.C. voltage is connected with the positive side to the silicon and the negative to the tungsten whisker electrons will flow from the whisker to the crystal and the contact will present a resistance of the order 120-200 ohms. When the supply is reversed the current flow is greatly reduced and the apparent resistance is of the order of 1000 to 10,000 ohms. Hence if an A.C. voltage is applied the current passed on the half-cycles that carry the silicon positive will be much greater than the current passed on the half-cycles that carry the silicon negative. The crystal will therefore operate as a rectifier since the current passed is predominantly in one direction.

The Mixing Circuit

330. The crystal is inserted in a section of coaxial line shorted at one end as shown in fig.74(d). The crystal and the smoothing condenser formed by the trolitul washer between the two metal flanges linked to the inner and outer are effectively in series between the inner and outer of the coaxial line. The length of the coaxial line is chosen to make it a resonant cavity at the mean frequency to be expected from magnetrons. The R.F. signals are coupled into

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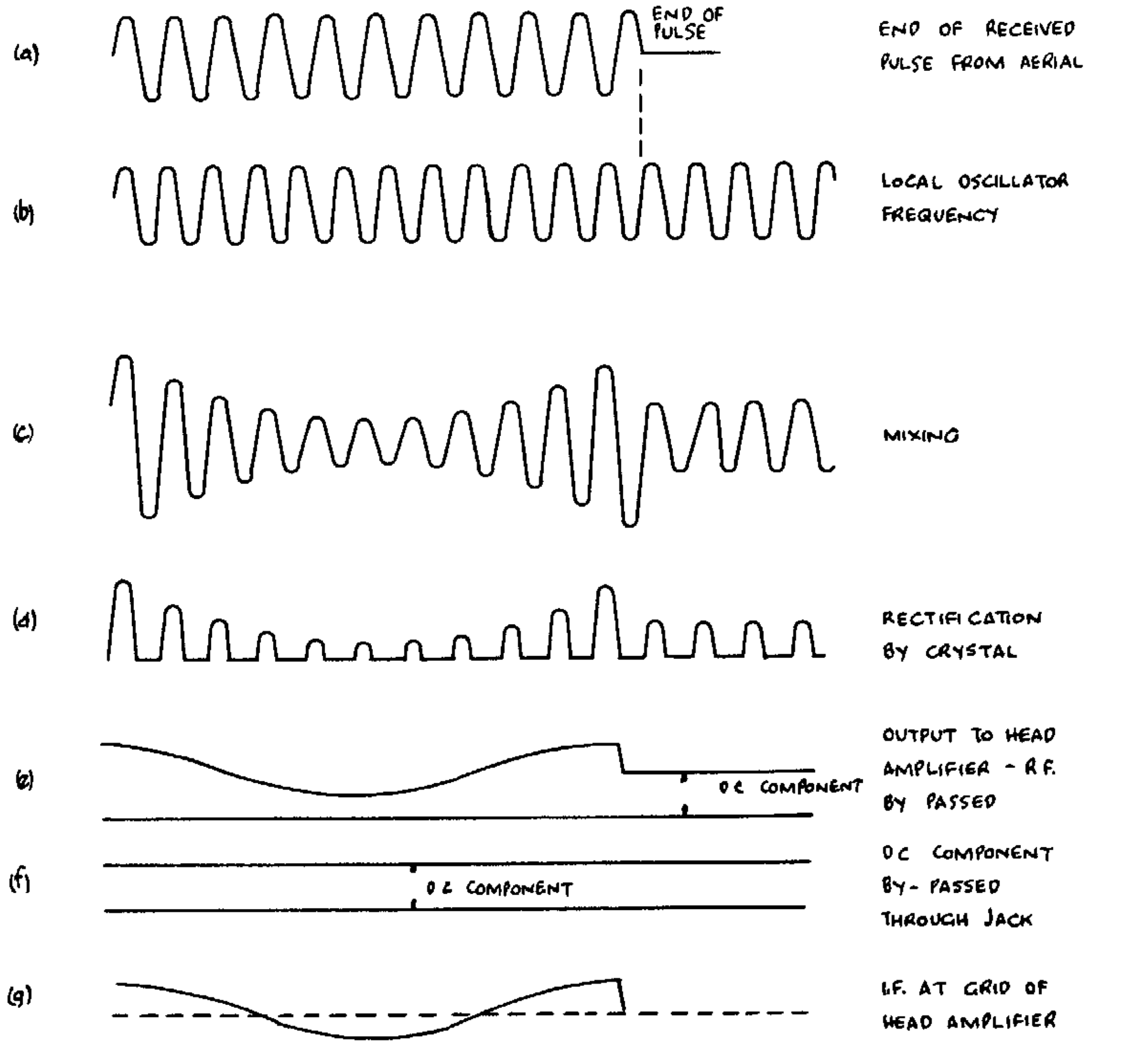
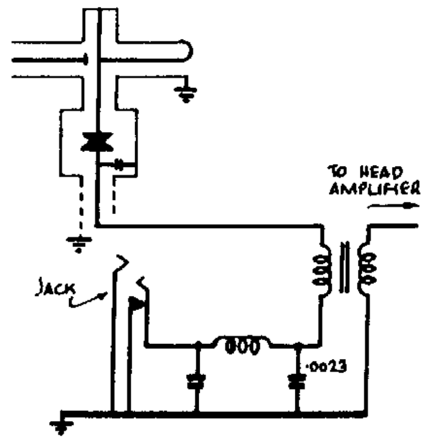
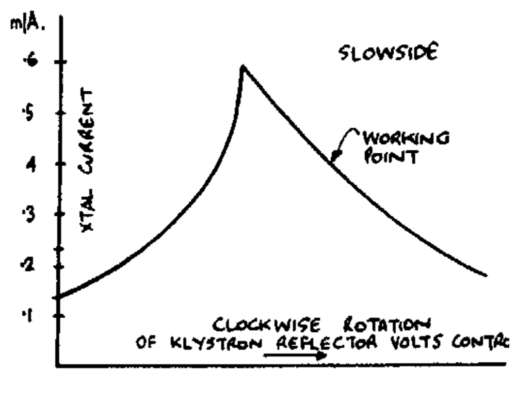
CRYSTAL MIXING

FIG.75







CRYSTAL CURRENT CIRCUIT

FORWARD RESISTANCE OF CRYSTAL APPROX 120 TO 200 OHMS

BACKWARD RESISTANCE OF CRYSTAL APPROX. 1000 TO 10,000 OHMS.

CRYSTAL CURRENT CHARACTERISTIC

MINIMUM CRYSTAL CURRENT NOT TO EXCEED 0·6 m/A.

NORMAL OPERATING CURRENT 0·4 m/A. (MARK II)

FIG.76a

FIG.76b

this cavity from the CV.43 cavity by connecting the inner of the CV.43 output line directly into the inner of the mixer line. Hence, when an echo is being received the R.F. voltage passed to the mixer line excites the cavity. The C.W. output from the klystron local oscillator is also coupled into the mixer cavity by means of a capacity attenuator. The 75 ohm terminating resistor in the probe which terminates the local oscillator feeder is connected to a thick piece of wire which fits into a little trolitul disc. When the probe is pressed in all the way this trolitul disc rests against the inner of the mixer cavity. The maximum voltage is then transferred from the feeder to the cavity if the only attenuation is that due to the voltage drop across the capacity between the two inners. If the probe is pulled out an air gap appears and the dielectric of the input condenser consists of the trolitul and the air gap. This input condenser will now have a lower capacity and a higher impedance. Hence the C.W. input applied to the mixer cavity is reduced, i.e. attenuated. The setting of this probe can thus be used to regulate the C.W. input applied to the mixer cavity. When the local oscillator is correctly tuned the frequency of the C.W. input to the mixer will differ from the R.F. input by the I.F. of 13.5 Mc/s. As the R.F. is of the order of 3300 Mc/s, the two signals will differ in frequency by 0.4%. This difference is so small that the mixer cavity will resonate both. The two signals therefore beat whenever an echo is received and the R.F. voltage applied to the crystal and its series condenser has a frequency equal to the mean of the beating frequencies and an amplitude varying at their difference frequency, i.e., at the I.F. In a single microsecond echo pulse there will be about 3300 cycles of R.F. as the frequency is about 3300 Mc/s. or 3300 cycles per microsecond. Since the I.F. is 13.5 Mc/s or 13.5 cycles per microsecond the modulation envelope of the pulse will show 13.5 cycles. The crystal only passes appreciable electrons from the whisker to the silicon. Hence the condenser must charge positively. Its function is to smooth the R.F. and impress on the Pye output cable the resultant I.F. envelope.

The Crystal Current

331. The waveform impressed on the Pye output cable will include both a D.C. component and a 13.5 Mc/s A.C. component. The D.C. component is the mean voltage developed across the condenser by smoothing the rectified C.W. input in the intervals between echo signals. Since the C.W. is coming in all the time but echoes only for 1 microsecond in every 1500 microseconds, the contribution of signals to the D.C. level is negligible. Hence, the D.C. component is a means of checking the amplitude of the C.W. input to the mixer since the magnitude of the smoothed D.C. voltage developed is determined by the amplitude of the C.W. signal applied and the rectification efficiency of the crystal. To see how measurements can be made we must trace out the path taken by the mixer output, shown in fig.76(a). The inner goes to a Pye plug and thence to the primary of the input transformer of the head amplifier. The other end of this primary is kept at R.F. earth by means of the condenser C.126 (.0023 µF). This condenser blocks off the D.C. component but serves to apply the full A.C. component to the transformer. From the top of C.126 a 13.5 Mc/s. choke passes to one side of a jack-point. The other side is tied to earth. Now the mixer output voltage is between the inner and outer of the Pye cable to the head amplifier. The inner is connected to the one side of the jack. The outer is earthed and hence effectively connected to the other side of the jack. The I.F. choke blocks the A.C. component from the jack-point but the D.C. component is applied across it. Hence, by jacking in a meter, the current developed in the meter by this D.C. component of the mixer output voltage can be read. This reading is called the "crystal current". In the indicator 162 a meter was fitted on the panel which connected to one side of a back contact on this jack-point. The crystal current could then be read at the indicator. This facility is not available in the indicator 184 and crystal current can only be checked at the transmitter unit jack-point in the H.2.S. Mark IIC installation.

Crystal Checks and Tests

332. The "crystal current" reading obtained by jacking in a meter at the transmitter unit is dependent on:-

(a) What C.W. input is applied to the crystal.
(b) How efficiently this input is rectified.

Hence, a comparison of the current values obtained from different crystals with the same C.W. input is a means of comparing the rectification efficiency of different crystals. By simultaneously noting noise level on the height tube for a given gain setting a comparison can be made of the noise developed by different crystals. The higher the current reading obtained and the lower the noise level generated the better the crystal. Conversely, the lower the current passed and the higher the noise level the poorer the crystal.

333. By plugging in the meter on the ohmmeter range with the set switched off, we can apply the cell voltage across the crystal. This follows since the tungsten whisker is connected to the one side of the jack-point and the silicon crystal is earthed at the shorted end of the mixer line. Hence by switching the jack connections both the "back" and "forward" resistance of the crystal can be measured. By "back" resistance we mean the D.C. resistance offered when the positive side of the supply goes to the tungsten whisker and the negative side of the supply goes to the silicon crystal. Since electrons only tend to flow readily in the opposite direction the observed resistance will be reasonably high, anywhere from 1K. to 10K. in a good crystal. When the jack connections are reversed we apply the cell voltage in the direction of normal flow and the observed resistance is low, of the order of 120-200 ohms. These indications are used as crystal checks but they are not fool-proof checks as the D.C. characteristics of a crystal are not necessarily a check of its R.F. rectification properties. The following procedure for crystal checks on D.I.'s is recommended:-

(a) Measure both back and forward resistance and note that forward resistance does not exceed 180 to 200 ohms and that the back resistance is not less than 1000 ohms.
(b) Log the back resistance on a card kept with the T^2R.
(c) Should the back resistance have dropped to less than half the value logged on the previous day, it should be rejected, although the value may still exceed 1000 ohms.
(d) If a crystal is rejected and replaced by a new one it should be checked as in (a) and the modulator then switched on and off 5 or 6 times and the values again checked to test the resistance of the crystal to surges. If the values of the back and forward resistance are still satisfactory the back resistance should be logged and an indication made to show that a new crystal has been fitted. It must be stressed that these crystal checks may be passed and a crystal still give poor R.F. rectification efficiency. Conversely, the tests may not be passed and the crystal may be giving a satisfactory performance. Such cases are, however, the exception. The final test is always receiver sensitivity. If good signal amplitude and a good signal to noise ratio are obtained when the received output is observed on the monitor 28 (or on the height tube) the crystal must be operating satisfactorily. From experience the mechanic will learn what amplitude and signal to noise ratio may normally be expected at each dispersal point from any particular permanent echo. If sensitivity seems to be low the first check is to substitute a known good crystal and note whether any improvement is obtained. The checking of back and forward resistance serves mainly to check whether crystals have deteriorated since the previous check and gives an indication of probable reliability that can be counted on in the majority of cases but not in all cases.

Crystals for H.2.S. Mark IIC

334. The crystal normally used in H.2.S. Mark IIC is the CV.101, a yellow spot crystal which should not be called on to pass a steady current that will give a reading in excess of 0.6 ma. If a subsidiary orange spot appears in addition to the yellow spot it is a CV.102 which will stand a rather higher voltage. If a subsidiary red spot is used the crystal is a CV.103 which will stand still higher voltages.

The Local Oscillator

335. (a) The structure of the CV.67 type of reflector klystron is shown in fig.78.
(b) The major circuit details are shown in fig.77.

Requirements of Cm. Local Oscillator Circuit

336. Since R.F. amplification is impracticable in the cm. band we use a frequency changer as the first stage. Hence, the local oscillator must be capable of providing sufficient C.W. output in the cm. band to secure adequate heterodyning. To fulfil these requirements a resonant cavity type of oscillator is used. Before studying this cm. oscillator in detail we shall recall the requirements it must meet:-

(a) Adequate C.W. output to give efficient heterodyning.
(b) Tunable from the H.2.S. operator's position to allow for variations in the frequency of both the magnetron and the klystron.
(c) As high a frequency stability as is reasonably obtainable.
(d) Adjustable feedback to permit control of amplitude for oscillation.
(e) As high an output stability as is reasonably obtainable.
(f) Adjustable loading to set the amplitude of oscillation to a point where the current drain is not sufficiently high to endanger the valve when frequency and output are stable.
(g) Control of input to mixer to get optimum heterodyning without modifying the loading.

These requirements call for a stabilised power supply, and Tuning, feedback, loading, and output controls.

Details of the Circuit

337. Before attempting to study the action of the local oscillator, we note the following items in the local oscillator circuit in fig.77.

(a) A resonant cavity of the toroidal or rhumbatron type which corresponds to the LC. tank circuit of the normal oscillator.
(b) An electron gun which is used to excite the cavity and which plays the part of the valve in a normal oscillator.
(c) A three section glass envelope sealed to the rhumbatron by means of copper glass seals.
(d) A reflector electrode whose voltage can be varied with respect to the cathode by means of a potentiometer. This serves as the feedback control.
(e) Three preset and one variable plunger. These are the tuning controls.
(f) A rotatable coupling loop. This is the loading or coupling control.
(g) An adjustable capacity probe into the mixer cavity on the end of the L.O. feeder. This probe has already been mentioned as providing a mixer input control.
(h) A neon stabilised power supply to obtain a stable frequency and amplitude.

Principles

338. We shall commence our study of the operation of this microwave C.W. oscillator by recalling the essentials of any form of regenerative oscillator. The first requirement is a ringing circuit which, if excited, will develop sinusoidal oscillations whose amplitude decays exponentially. The lower the circuit losses, i.e., the higher its Q, the more slowly these oscillations would decay. The second essential is a suitable agency for exciting the ringing circuit. The third requirement is some method of supplying positive feedback to make up the losses in the ringing circuit and thus keep the amplitude of the oscillations constant. We may then regard the regenerative oscillator as consisting essentially of a ringing circuit which develops the R.F. energy, and a maintaining circuit which excites it and provides the

requisite amount of energy in the correct phase to overcome losses. D.C. energy must be supplied to the maintaining circuit while R.F. energy can be obtained by loading the ringing circuit. In the familiar L.C. valve oscillator the L.C. circuit provides the ringing circuit. The moving magnetic field associated with the initial current flow provides the excitation that starts oscillation. Some of the R.F. energy of the oscillatory circuit is impressed on the grid in such a phase that the amplified output is returned to the oscillatory circuit to make up the energy supplied to the grid, the ohmic losses in the oscillatory circuit, and the output supplied to the aerial. The oscillations are kept at that constant amplitude where the input returned to the grid just makes up all these losses after amplification in the valve. The valve is purely a convenient maintaining circuit which takes the energy from the H.T. supply and passes it to the oscillatory circuit for conversion into R.F. energy.

339. When the current is building up in the inductance of an L.C. circuit energy is stored in the magnetic field. When the current reaches a steady value the magnetic field collapses and the current overshoots to charge up the condenser to a value above the mean anode potential and the energy of the magnetic field is stored in the electric field of the condenser. When the magnetic field has completely collapsed there is no further charging e.m.f. across the condenser which then discharges through the coil in the reverse direction to again store the energy in the field of the coil. It is only because the coil and condenser are not completely resistanceless that this oscillation will not go on indefinitely without any positive feedback arrangements.

340. Just as any length of wire exhibits inductance, so does the metal of the resonant cavity or rhumbatron of the klystron. What is less apparent is how the two sections of the rhumbatron can exhibit capacitance although they are connected through the outer casing. This phenomenon arises out of the fact that at very high frequencies the distribution of R.F. currents in conductors makes it possible for different parts of the same conductor to have a different R.F. potential. If these parts are separated by a dielectric we have an electric field in which R.F. energy can be stored which is just another way of saying that we have capacitance. The rhumbatron is then just a microwave equivalent of the familiar L.C. circuit.

Excitation

341. The CV.67 operates with the rhumbatron at D.C. earth, the cathode at about -1200 volts and the reflector at around -1500 volts. There is therefore a potential difference of about 1200 volts between the cathode and rhumbatron. Hence, when the cathode starts to emit, the electrons travel at high speed toward the rhumbatron. The grid and screen, although tied to the cathode, by virtue of the fields induced in them by the electrons serve to shape the emitted electrons into a fairly sharp beam which is directed through the orifice in the lip structure.

342. When the electron beam passes through the rhumbatron orifice it has a magnetic field around it since it is just as much an electric current as the electron flow in a wire. This field cuts the metal of the rhumbatron cavity and starts electron displacements in the metal. These electron displacements cause the cavity to start ringing just as the initial current flow in the coil started the ringing of the L.C. circuit. The effect of this ringing is to make the two halves of the rhumbatron swing alternately positive and negative at a frequency determined by the cavity volume. This results in the appearance of an electromagnetic field in the cavity which has its electric vector perpendicular to the two copper plates forming the toroidal cavity. This field is most intense across the lips where the plates are close together. The mutual repulsion of the lines of force cause them to bulge out into the orifice. This field rises and falls sinusoidally at a frequency of around 3300 Mc/s.

Velocity Modulation

343. As the constant velocity electron stream from the gun enters the orifice the velocity of the electrons is modified in accordance with the instantaneous

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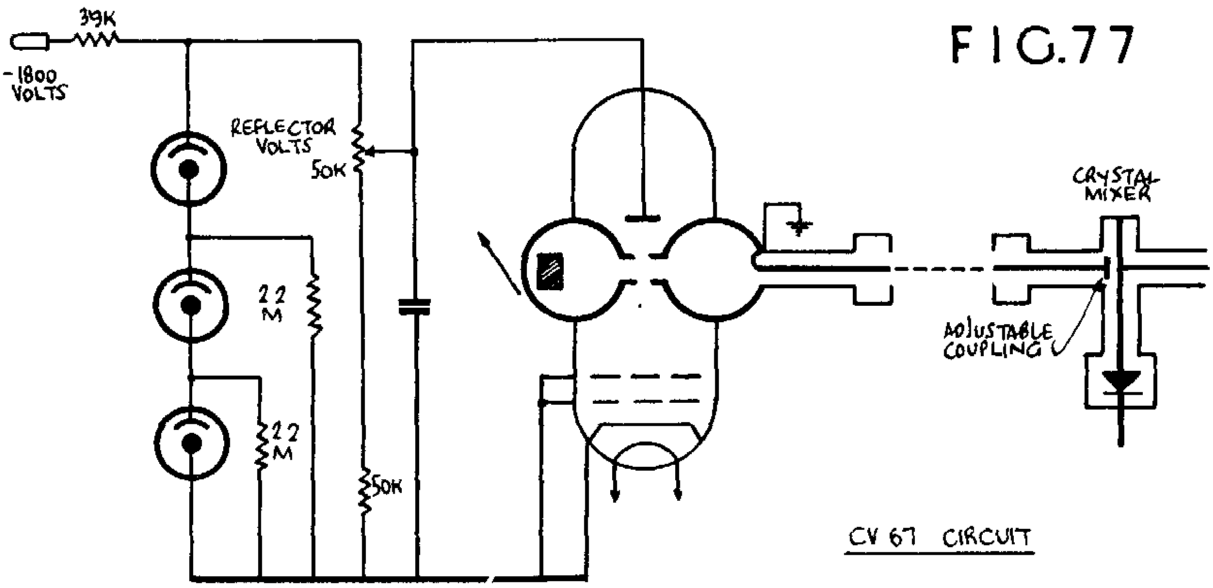
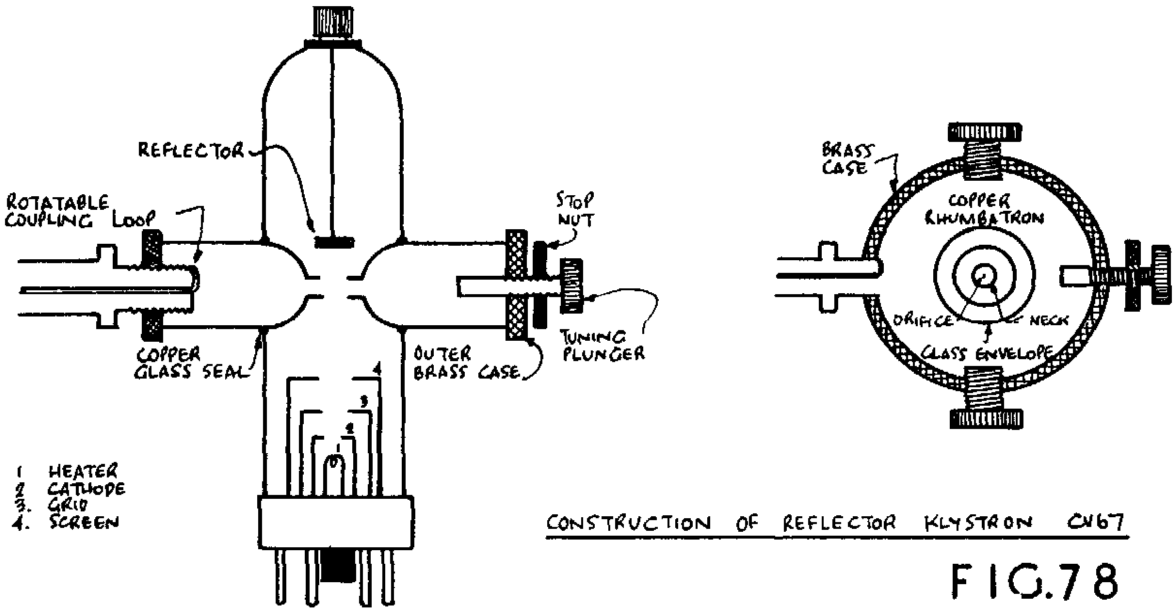
FIG. 77

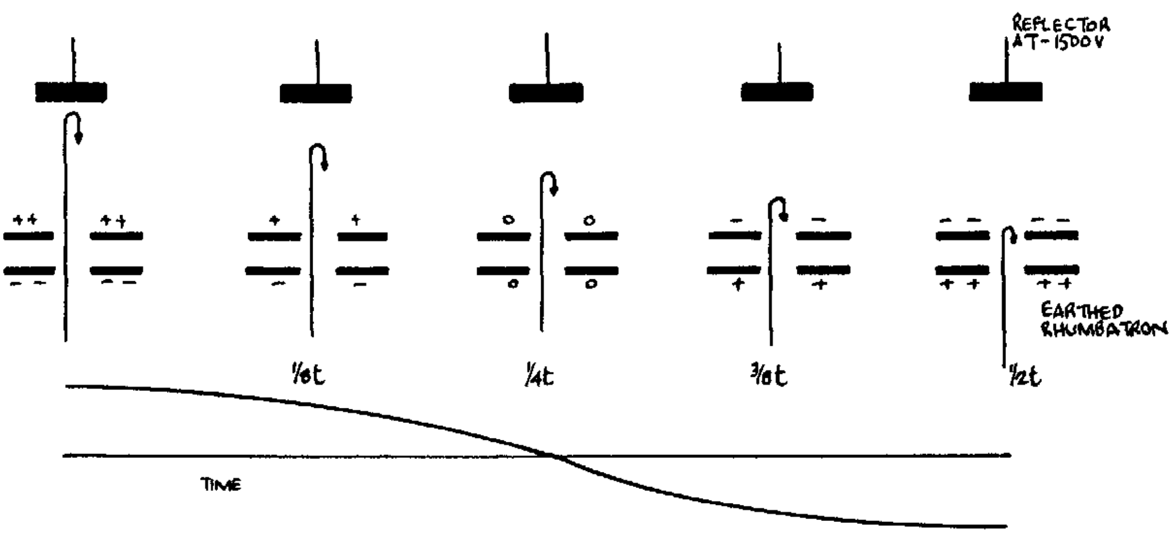


CV 67 CIRCUIT



CONSTRUCTION OF REFLECTOR KLYSTRON CV67

FIG. 78



VELOCITY & DENSITY MODULATION

FIG. 79

sense and magnitude of the electric field bulging into the orifice. Let us assume that the field is at a maximum with the upper plate positive and the lower plate negative. An electron entering the field is then accelerated and travels at an increased rate after getting through the orifice. A quarter cycle later the field will be zero as both plates will be back to R.F. earth as well as D.C. earth potential. An electron passing through at that instant will then travel at the same speed after emerging as it did before entering the space between the lips. After another quarter cycle has occurred the field will be a maximum in the opposite sense, i.e. the top plate will be negative and the lower plate will be positive. An electron now entering the field will be slowed down or decelerated. We see then that the ringing of the cavity is modifying the velocity of the electrons passing through the orifice. That is, the ringing cavity is causing a velocity modulation of the electron stream.

344. To appreciate the significance of this velocity modulation we must now transfer our attention to the space between the earthed rhumbatron and the reflector which is at about -1500 volts. In this space there is a steady D.C. field that will urge electrons away from the highly negative reflector towards the relatively positive rhumbatron. Shooting through the orifice into this field we have the velocity-modulated electron stream. The opposing field will bring them all to a halt and turn them around to shoot back into the orifice since the D.C. field between the reflector and rhumbatron is 1500 volts, while the D.C. field between the cathode and rhumbatron is only 1200 volts. But since the electron stream has been velocity modulated while passing through the orifice the first time there will be differences in how close the electrons come to the reflector before they turn around. The accelerated electrons will penetrate farthest. Electrons coming later which met the zero field will be travelling less rapidly. These will turn around earlier and will tend to fall in step with the accelerated ones that had travelled farther but spent the quarter period in travelling and returning the extra distance. The decelerated electrons coming along a further quarter cycle later will turn around still earlier so will tend to fall in step with both the preceding lots. The combined effect of the reflector and the velocity modulator is therefore a tendency of the electron stream to show bunching, i.e., heavy concentrations of electrons separated by more trickles. We say the stream has been density modulated. If the reflector voltage is correctly adjusted with respect to the cathode voltage and the distance between the reflector and the orifice, we can arrange that the bunches in the reversed stream meet an opposing field when entering the space between the lips on their return journey. The trickles between the bunches meet the accelerating field a half-cycle later.

Density Modulation and Positive Feedback

345. If the dense parts of the reversed stream met an opposing field while the sparse parts meet the accelerating field we will have the majority of the electrons slowed down on their second passage through the field and only a small proportion will be speeded up. In their first passage as many will be speeded up on the average as will be slowed down. The result of suitably adjusting the reflector voltage is then to slow down far more electrons than are accelerated. Now if electrons are speeded up they have taken energy from the oscillating electromagnetic field, i.e., they have damped the ringing. But when they are slowed down they have given up energy to the field and have provided positive feedback. Hence, by correctly adjusting the reflector voltage we obtain positive feedback and sustained oscillations in the resonant cavity. As long as the energy returned to the cavity exceeds the energy taken from it by ohmic losses, in heating the inner surface, by accelerated electrons, and by output circuits, the klystron will oscillate. The amplitude of oscillation will set itself at the level where the total losses balance the energy taken from the electron stream. How much energy is taken from the electron stream depends on the number of electrons meeting an opposing field. It is the opposing field strength which determines the amount of deceleration and hence the amount of kinetic energy taken from the slowed-up electrons. Both the number decelerated and amount of deceleration are altered by varying the reflector voltage since this quantity determines the spacing between the bunches. If the bunches are spaced so that their centre meets the opposing field when it has its maximum value the maximum energy is taken from the electron stream and the amplitude of the oscillations reaches its maximum value. If the bunches meet the opposing field when it has a low intensity the amplitude of oscillation falls since less energy is taken from the electron stream. Altering the

reflector voltage then serves primarily to alter the spacing and phasing of the bunches with respect to the oscillating R.F. field between the rhumbatron lips and thus performs as a feedback or amplitude control. The oscillating field may have different modes, i.e., different electric and magnetic field patterns which correspond to different frequencies. These modes may change as the reflector voltage is varied. Hence although the reflector volts control serves as a feedback control in the CV.67, it may have secondary effects on frequency.

Operating Conditions

346. The actual spacing between bunches can only remain constant if the cathode and reflector potentials remain constant. Hence, for stability of output provision must be made to keep these potentials as steady as possible. To fulfil this requirement, the neon stabiliser circuit is provided across the -1800V. supply brought into the tuning unit 207 from the power unit.

347. The reflector volts potentiometer permits a variation in the reflector potential of around -1400 to -1600V. when the klystron is oscillating. The normal cathode potential is about -1200V. Should this potential fall to the vicinity of -1000V., the klystron operation will become critical. An electrostatic voltmeter must be used to measure the klystron voltages.

348. The normal operating current of the klystron is about 8 ma. This can be measured by connecting a meter between the -1800V. input plug and the 39K. resistor, R.2. The electron flow path is through R.2, the stabilising network, emission from the klystron cathode, and an ultimate flow to the earthed rhumbatron and through the earth line to power unit. Since this is a series circuit, all the current passed flows through the klystron. As the reflector is more negative than the cathode, there is no electron flow to the reflector.

Frequency Control

349. The frequency of the oscillations in the CV.67 is primarily controlled by means of a knob on the front of the tuning unit 207. This knob alters the distance a variable tuning plunger projects into the rhumbatron cavity. The range available on this control should be such as to permit tuning the klystron through 13.5 Mc/s. either above or below the magnetron frequency with some leeway at each end. If these conditions cannot be fulfilled, the two preset plungers require adjustment until this condition is fulfilled. It must be remembered that screwing these plungers in shifts the band covered toward a higher frequency, while screwing them out, shifts the band covered to a lower frequency. The desirability of being able to tune the CV.67 above or below the magnetron by the I.F. of 13.5 Mc/s. arises out of the fact that the mixer line is cut to a fixed length. If the magnetron frequency happens to be near the end of the band to which the mixer cavity responds, say near the low end, then the response to a L.O. signal tuned 13.5 Mc/s. lower will be much poorer than the response to a L.O. signal tuned 13.5 Mc/s. above the magnetron frequency. Hence two-point tuning on the klystron permits selection of the klystron frequency that gives the best response in the mixer cavity and hence the best signal to noise ratio.

350. As pointed out above, the reflector voltage may have a secondary effect on frequency.

Output Control

351. It was pointed out earlier that the electric vector of the oscillating field in the klystron cavity is always directed so as to be perpendicular to the two rhumbatron plates. The magnetic vector will take the form of closed loops in a plane at right angles to the E lines which they circle. If a section of coaxial line with the inner terminated in a loop (whose end is soldered to the outer) is threaded into the cavity, any of the magnetic lines of force threading the loop will induce an R.F. voltage between the inner and outer of the coaxial line. The outer of the line will be in contact with the rhumbatron casing and therefore at earth potential. How large an R.F. voltage is developed between the inner and outer of the coaxial line will depend on how

many magnetic lines of force thread the terminating loop. This will be a maximum when the plane of the loop is perpendicular to the magnetic vector in the cavity. Hence, by altering the angle of the coupling loop the R.F. voltage applied to the line may be varied. This coupling line is brought to the L.O. output plug on the tuning unit 207 panel. A uniradio 21 feeder is connected at the plug and picks up the output voltage for transfer to the mixer cavity. Since the angle of the coupling loop determines how much energy is taken from the cavity by the feeder, i.e., the klystron loading, a variable coupling loop angle provides an output or loading control. A screw-driver preset labelled "coupling" appears on the tuning unit panel. This control varies the coupling loop by means of a suitable lever arrangement. If the coupling is very light and the reflector voltage is set to give a heavy positive feedback the klystron will oscillate very violently and will take a current which may be sufficiently heavy to damage the valve. If the coupling is at maximum to provide a heavy loading, far more energy is transferred to the cable than can possibly be used at the mixer cavity for efficient heterodyning. It is therefore usual to set the coupling loop at about 30° - 45° to the H vector (or maximum coupling) to get an intermediate coupling. Radar mechanics familiar with the indicator 162 must bear in mind that in the tuning unit 207 the klystron is mounted horizontally instead of vertically as was the case in the indicator 162. The coupling indication is given by the position of the slot in the coupling preset. A full range of coupling from minimum to maximum is obtainable by varying the slot between the horizontal and vertical positions.

Setting of Coupling Loop and Capacity Probe

352. As was mentioned in discussing the mixer the L.O. input to the mixer is introduced by means of a capacity probe. This capacity probe with its 75 ohm matching resistor is the termination of the uniradio 21 feeder from the tuning unit 207 to the mixer in the transmitter unit. This capacity probe provides a means of attenuating the local oscillator signal to a suitable value for efficient heterodyning of the R.F. signal. From experience it has been found that a crystal current reading of about 0.4 ma. gives the optimum operating conditions. It is customary to set the coupling to an intermediate value with the loop at 30° - 45° to the maximum coupling position and the capacity probe to a setting such that the maximum crystal current reading obtainable by varying the reflector voltage does not exceed 0.6 ma. This precaution is taken to prevent damage to the crystal. The reflector voltage is finally adjusted to give a current reading of 0.4 ma.

Setting-Up the Reflector Voltage and Crystal Current

353. A point to be watched for is the possibility of getting 0.4 ma. crystal current for two different settings of the reflector voltage. A full crystal current characteristic will show two sides, a "steep" side, and a "slow" side. By the term "steep" side, we mean that over part of the movement range available on the reflector voltage preset the crystal current will rise sharply to a peak (which may in some cases be unstable) for a small rotation of the preset. This means that if the reflector voltage is set to a point within this range a small variation in supply voltages due to changing engine speed, etc., will cause appreciable changes in crystal current. This means that the klystron operation is likely to be erratic and probably noisy as well. Should the reflector voltage be set up in this "steep" or unreliable side of the crystal characteristic on the ground airborne operation will in all probability be unsatisfactory. By the term "slow" side, we mean that over an appreciable part of the movement range available on the reflector volts preset the crystal current will vary very gradually. The more usual performance will be a sharp rise to a peak as the control is turned clockwise and then a slow fall away. Occasionally a slow fall may come first and then the sharp rise. The important considerations are:-

(a) That the current should never exceed 0.6 ma. as the reflector voltage is varied through its full range.
(b) That the final operating point be set for about 0.4 ma. on the slow or reliable part of the crystal characteristic.

A crystal current characteristic is shown in fig.76(b).

Interaction between Tuning and Crystal Control

354. Since altering klystron tuning varies the frequency of the oscillating field, it is varying the period in which the electric field across the lips

is completing a cycle. Now the reflector voltage setting fixes the spacing between bunches. When these bunches meet an opposing field, we have klystron oscillation and crystal current from the rectified C.W. How much crystal current is produced depends on the amplitude of the C.W. input to the mixer, which depends on the amount of positive feedback. But the amount of positive feedback depends on the strength of the opposing field met by the bunches. If the tuning is altered, the bunches will meet the opposing field at a different point in its cycle. Hence the positive feedback may vary and the result may be to vary the amplitude of oscillation and therefore the crystal current. It follows then that when a set is being lined up on the bench or in an aircraft, the crystal current value should be checked if the klystron tuning is altered after the crystal current was set up.

The Crystal Adaptor Check of Klystron

355. When the common fault of low crystal current is encountered the fault is usually in the crystal. It is, however, desirable to have some ready method of checking that the klystron is actually producing a C.W. output at the output plug on the tuning unit 207. This can be done by means of a crystal adaptor which can be connected directly to the output plug. This adaptor is just a crystal rectifier in a suitable mounting. When an AVO is connected to the adaptor the rectifier output current can be measured. Values of about 8-12 ma. are normal. Since this value is well above the value that the crystal can safely carry for any appreciable time interval the adaptor should just be touched to the output plug long enough to see whether or not a satisfactory output is being developed. The actual crystal current value obtained will depend a great deal on the condition of the crystal used. The presence of a reasonable current is sufficient to indicate that the klystron is oscillating.

Klystron Faults

356. The only common klystron faults are as follows:-

(a) Coupling loop so long that it pushes against the glass envelope and either breaks the loop or bends it back on itself so that it is effectively shorted out.

(b) Loss of vacuum due to cracks or breakage of copper-glass seals.

(c) Wear in the output plug and socket resulting in poor contact and poor output and noise when airborne.

(d) Loss of emission due to life factor.

(e) Damage due to passage of excessive current due to undercoupling and heavy positive feedback.

(f) Change in component values resulting in incorrect cathode and reflector voltages.

The Head Amplifier

357. It was pointed out in para.311 (j) that the head amplifier is included in the transmitter unit to give some amplification (gain of about 4) of the mixer output before applying it to the cable passing to the I.F. amplifier in the receiver-timing unit. Whether or not the inclusion of the head amplifier results in a better signal to noise ratio in the receiver output depends entirely on whether the signal to noise ratio of the input to the I.F. strip is better when the head amplifier is included than when it is omitted. This, in turn, will depend on whether the signal amplification in the head amplifier stage exceeds the combined effects of noise picked up and noise developed in the stage. It follows then that the head amplifier stage may become a liability rather than an asset if the stage becomes very noisy. The chief causes of noise are bad earthing connections anywhere in the stage. A low emission VR.136 will also be noisy. A check on the stage can be made by by-passing the head amplifier and feeding directly from the mixer into the I.F. strip. If the signal to noise ratio shows considerable improvement the head amplifier stage is obviously a hindrance rather than a help.

Miscellaneous Transmitter Unit Faults

358. To avoid confusing noise from noisy blower motors which is getting into the head amplifier with noise due to a faulty head amplifier stage or R.F. noise

pick up, the noise level in the receiver output under normal operating conditions should be compared with the value observed when the blower motor is made inoperative.

359. A check can be made on the noise contribution of a particular transmitter unit by comparing the noise level in the receiver output when the transmitter is operating with the level when the modulator is switched off. By substituting a transmitter unit known to be satisfactory for the suspected one and fitting the crystal from the suspected unit in the good one, a check can be made for abnormally high transmitter unit noise from causes other than the crystal.

360. Other causes of noise, intermittent signals, weak signals, no signals, etc., may be:-

(a) Burning of, or bad contacts by, the pin on the CV.64 output line which connects to the aerial feeder inner.
(b) Binding of the nut connecting the outer of the aerial feeder and resulting in a poor contact.
(c) Loose inner contact at pulse input plug socket.
(d) Absence of earth on screening of pulse lead from the input plug to the pulse transformer.
(e) Insufficient clearance between the leads to the magnetron legs and the 4K. morganite rod. Short circuits and sparking may then occur under conditions of vibration, high altitudes and low pressures.
(f) Straps for clamping the capacity probe may be broken or missing.
(g) Faulty joints between 75 ohm resistor in capacity probe and the inner of the feeder.
(h) Rotation of trolitul sleeve in the capacity probe permitting contact between these joints and the outer to short out the C.W. input intermittently or continuously.
(i) The inner of local oscillator input plug may push into the polystyrene and fail to make proper contact or break connection inside the probe to the mixer.
(j) The thread on the outer of the local oscillator input plug may bind so that the lead from the indicator does not make rigid connection to the plug.
(k) Inner of the mixer line failing to make good contact with the pin on the end of the crystal. The split end of this inner may require pinching by careful manipulation of two long-shafted screw-drivers.
(l) The black cap of the crystal holder failing to screw in far enough to clamp the crystal firmly in the holder.
(m) Absence of spring clamp to hold domed cap of mixer line.
(n) Dry joints or broken wires at the I.F. connection to the outer of the crystal at the top of the metal sleeve.
(o) Loose or missing grub-screws in the Pye plug on the I.F. input to the head amplifier.
(p) Loose nuts on the Pye sockets on the input and output of the head amplifier permitting the sockets to rotate when the plugs are handled with resultant breakage of the leads inside.
(q) Bad contacts in the VR.136 holder in the head amplifier stage.
(r) Bad contacts in the crystal current jack.
(s) Insulation breakdown in the crabtree supply plug to the head amplifier unit between the 300V. input pin (1) and the earth pin (2).
(t) Dust cores in head amplifier input or output transformers displaced or dropped out due to faulty sealing.
(u) Faulty suppressor unit on blower motor or scanner motor.
(v) Blower motor running rough due to faulty lubrication and causing excessive vibration.
(w) Faulty brushes on blower motor.
(x) Faulty sealing between chassis and rubber mounting of blower motor.
(y) Beacon switch in the B or BA positions so that HT supply to the head amplifier is cut off.

The I.F. Amplifier

361. The six-stage (VR.65) I.F. amplifier, the diode detector (VR.92) and the receiver output valve (VR.53) are mounted on a sub-chassis in the receiver-timing unit. The tuned anode transformer in the head amplifier is suitably damped on the secondary side to match the Pye cable carrying the head amplifier output from the green Pye plug on the transmitter unit to the corresponding plug on the receiver-timing unit. The input from the green Pye plug on the receiver is applied to the grid of the first I.F. stage via a tuned dust-core transformer, suitably damped on the secondary side to match the Pye cable. A second lead taps into this input transformer from a brown Pye plug on the receiver panel. This plug is used to feed the output of the Lucero unit into the I.F. amplifier. The beacon returns from the receiver section of the Lucero unit are passed into the I.F. amplifier when the beacon switch on the switch unit is in the B + H, B or BA position. In the B + H position, the H.T. supply to the head amplifier is completed and inputs are fed into the I.F. strip at both the green and brown Pye plugs. When the switch is on the B position only Lucero signals from the long range beacons reach the I.F. amplifier. In the BA position a different local oscillator is switched in at the Lucero unit and the input to the I.F. amplifier consists of signals from the Lucero blind approach beacon. In both the B and BA positions the H.T. supply to the head amplifier is broken so that there is no H.2.S. signal input at the green Pye plug. In the OFF position, the Lucero unit is inoperative and only H.2.S. signals are applied to the I.F. amplifier. The taps on the input transformer are chosen to give suitable matching and signal to noise ratio for both input channels.

Gain Control

362. The coupling between the six stages is by dust-core transformers suitably damped on both sides. The overall band width is 13.5 ± 3 Mc/s. The gain is controlled by varying the cathode bias applied to stages 2 and 4. The 2K gain control potentiometer on the switch unit is in parallel with R.61 (22K) in the receiver. This parallel combination is connected in series with R.60 (75K.) between the 300V H.T. line and earth. When the gain control is fully counter-clockwise the whole 2K is in circuit and a bias voltage of about -8V. is tapped off which is sufficient to cut the valves off. When the control is fully clockwise the bias line is returned to earth and stages 2 and 4 operate with the same normal auto-bias as is used in the remaining stages. The amplifier then has its maximum gain.

Suppression

363. It has been pointed out that the CV.43 cannot ionise instantly and always permits the passage of some transmitter pulse energy to the crystal. The mixer output from this breakthrough is of such amplitude that it can overload the I.F. amplifier and cause temporary paralysis of the receiver after each transmitter pulse. To overcome this difficulty the I.F. amplifier must be suppressed until the main transmitter pulse is completed. It has also been pointed out that the back edge of the 20 microsecond modulator priming pulse fires the trigger valve and spark gap to initiate the 1 microsecond transmitter pulse. The positive-going 20 microsecond pulse taken from the cathode of the VT.60A in the modulator multivibrator is therefore a convenient waveform to generate the required suppression pulse since it is always locked to the transmitter pulse.

364. Details of the suppression generator are shown in fig.80. The positive-going 20 microsecond pulse from the VT.60A cathode is applied to the four parallel violet Pye plugs on the modulator panel through the 110 ohm terminating resistor, R.35. From one of these violet plugs, the pulse is taken to the violet plug on the receiver-timing unit. As the transmitter fires 1 to 2 microseconds after the back edge of the modulator priming pulse it is necessary to delay the input to the suppression generator in order to get a suppression waveform that continues until the transmitter pulse is completed. For this reason a delay network with a switch that can be set to provide a delay that is variable between 0 and 8 microseconds is inserted in the input to the suppression generator, V.412. The positive-going 20 microsecond pulse will normally have an amplitude of 40 - 50 volts at the violet input plug. This

amplitude is dropped by the bleeder R.455 (1.5K.) and R.456 (3K.). The effective input impedance is that of R.456 shunted by the characteristic impedance of the network. This results in an input amplitude of 12 - 15 volts. The 1K terminating resistance prevents reflections from the output end of the network. The network therefore applies to V.412 grid a 20 microsecond positive-going pulse delayed relative to the input by 0 - 8 microseconds according to the setting of the switch which is operated by an unlabelled screwdriver preset on the receiver-timing unit panel. The amplitude on V.412 grid is about 13 volts. The effect of this positive pulse is to carry V.412 into grid current for the pulse duration. This grid current flows into C.452 (0.1) and charges it negatively. When the positive pulse collapses the leak-away of the electrons through R.458 (1M.) develops sufficient self-bias to keep V.412 cut-off on the grid until the next positive pulse appears. V.412 anode therefore falls for 20 microseconds in every 1500 microseconds. The anode load of V.412 is R.5 (40K.) in the screen supply line to the 1st and 3rd I.F. stages. The normal screen current to these valves through R.5 makes the cut-off potential of V.412 about +150V. When V.412 goes into grid current the current passed by V.412 results in a drop at the junction of R.5 and R.6 of about 140V. This fall carries the screens of the 1st and 3rd I.F. stages so low that the valves are effectively cut off. When V.412 cuts off again the screens of V.1 and V.3 will return to a sensitive state at a rate determined by their associated time constants. The position of the suppression period can be varied by means of the suppression preset until only a wisp of the breakthrough tail shows on the height tube trace. Due to the first negative overswing on the pulse transformer resulting in a measure of oscillation in the magnetron, it may be necessary to set the suppression control to cover both the primary magnetron pulse and this spurious overswing pulse if breakthrough is to be completely eliminated. This problem has been the factor which limits the minimum range of Fishpond.

The Second Detector

365. The output of the last I.F. stage is applied to the cathode of the VR.92 second detector. The rectified voltage is developed across R.54 (6.2K.) as negative-going 13.5 Mc/s. pulses. C.34 (5 pf.) smooths these to give the envelope of the echo signal. L.5 is an I.F. choke. C.49 (.1) and R.64 (100K.) provide A.C. coupling to the receiver output valve. A.C. coupling is used in preference to D.C. coupling to minimise the possibility of C.W. jamming on the I.F. frequency. With D.C. coupling the back-biassing of the detector anode by a C.W. signal could carry the grid of the output valve to cut-off.

The Monitor Network

366. R.55, R.56, C.36, C.37 provide a monitor network. By connecting a 0 - 500 microammeter between tag 5 and earth the rectified current produced by C.W. input to the I.F. amplifier can be measured. 10V. D.C. output on V.7 anode gives a current of 185 microamps. between tag 5 and earth. By applying a C.W. input from the signal generator type 52A or its equivalent type 106, the overall handwidth can be checked. As the frequency of the input is varied the meter reading will rise sharply as the pass-band is entered. On going out of the pass-band the reading will fall sharply. Normal band width is 13.5 ± 3 Mc/s. If the input frequency is set to mid-band an input setting can be found that will be well short of saturation on a normal set and the meter reading noted. If the same input is applied to a suspected I.F. amplifier the output reading can be compared with that obtained from the good set. In this way a comparative check can be made on suspected insensitive I.F. strips. Conversely, the input required to produce a given output short of saturation may be compared instead.

The Receiver Output Stage

367. The receiver output valve is a variable-mu pentode (VR.53) with the cathode returned to earth and a 10K. grid stopper. Since the pulse input on the grid is negative-going the valve passes the maximum current for zero signal input and its anode potential will then be at its lowest level. As signals are applied to drive the grid negative the anode potential will rise to give a positive-going output. A -8V. signal on the grid will cut the valve off. Hence grid cut-off introduces limiting on any signal input in excess of this value. The effective anode load is R.451 (1K.) in the timing unit section.

R.452 is effectively decoupled by C.440 (1 µf.). The anode of the receiver output valve is taken to tag 7 on the numbered receiver tapboard through the I.F. choke, L.6. From the tagboard a lead completes the connection to R.451 on the timing unit chassis.

368. The suppressor of the receiver output valve is normally returned to earth through one half of the double diode, V.410. Provided the heading marker switch on the switch unit is closed, circuits in the timing unit section apply a negative pulse to the suppressor and cut anode current off on the suppressor for around 2000 - 3000 microseconds once for every revolution of the scanner. The output of the valve will then consist of signals and noise for all timebase sweeps except those occurring whilst the valve is cut-off on the suppressor. If a timebase making 1 sweep per second were available to observe the anode waveform it would show the following details:-

- (a) A suppression break of around 20 microseconds duration at 1500 microsecond intervals.
- (b) A positive-going transmitter pulse tail after each suppression break.
- (c) Noise during the non-suppressed portions of each 1500 microsecond interval.
- (d) Positive-going echo pulses recurring in each 1500 microsecond interval at intervals after the transmitter pulse tail governed by the range of the targets.
- (e) The amplitude of the echo pulses will vary with the strength of the reflected signals for a given setting of the gain control.
- (f) The amplitude of the signals and noise will be a maximum when the gain control is fully clockwise and minimum when the gain control is fully counterclockwise.
- (g) Any signals developing a swing of more than -8V. at the grid will be limited by grid cut-off so will show the same output amplitude.
- (h) Once for every revolution of the scanner, i.e, once per second for a speed of 60 r.p.m., a maximum amplitude positive-going pulse of about 2000 - 3000 microseconds duration will appear when anode current is cut-off on the suppressor by the negative pulse from the heading marker circuit in the timing unit.

369. If the switch on the indicator 184 panel is set to "Course" the heading marker pulse is formed when the scanner goes through the dead-ahead position. If this switch is set to the "Track" position the pulse forms earlier or later depending on the drift angle. Since the receiver output is ultimately applied to the P.P.I. grid as a positive-going signal, this pulse brightens up one full scan and all or part of another onee in every scanner revolution. If the P.P.I. map is correctly set up by means of the setting knob on the heading control unit, this brightened up scan appears at the bearing of the aircraft heading when the indicator 184 switch is set to "Course". If the switch is set to "Track", and the Admiralty transmitter in the control unit 468 has been correctly set up by means of the setting knob on the heading control unit, the positive pulse at the anode of V.8 is so displaced as to make the brightened-up scans on the P.P.I. appear at the bearing of the actual aircraft track. The heading (course) marker or the alternative track marker are then a part of the receiver output that appear only once in every scanner revolution while all other signals appear once for every transmitter pulse.

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FIG.80

RECEIVER SUPPRESSION GENERATOR CIRCUIT AND WAVEFORMS

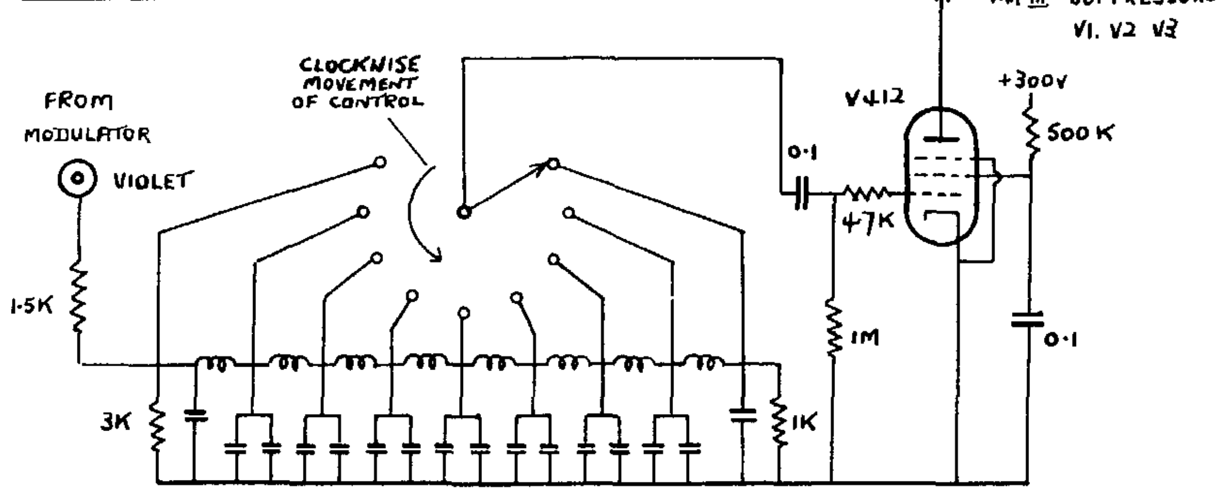
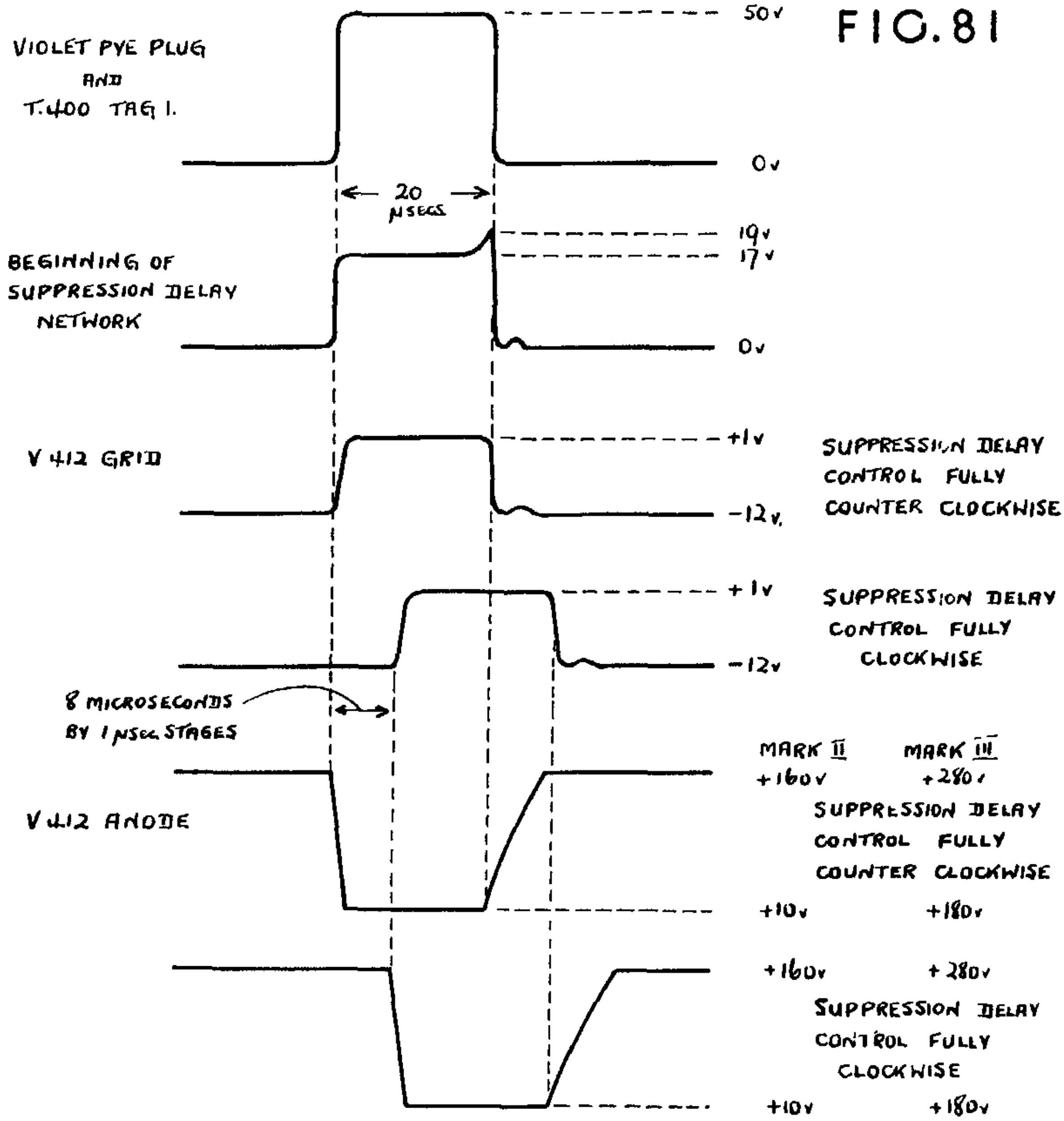


FIG.81



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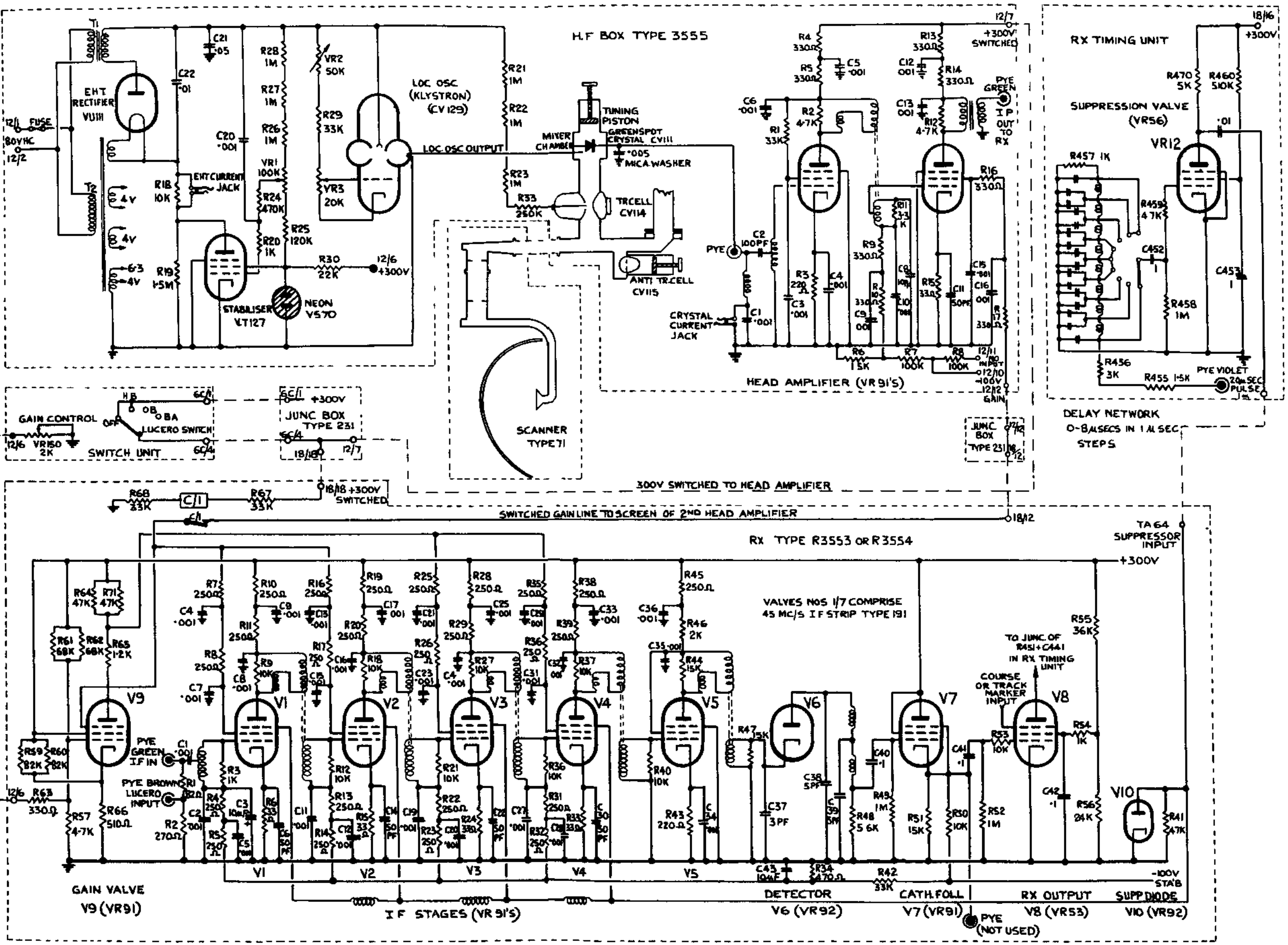


RECEIVER CHAIN MARK III A.

FIG.82

FIG.82

The Mark IIIA Receiver Using T.R. 3555 Series

Outline

370. The differences between the Mark IIC and Mark IIIA receivers are primarily consequences of the fact that a wavelength of about 3.2 cms. is used instead of 9.1 cms. The chief differences are as follows:-

(a) More elaborate input matching arrangements to prevent interference due to passage of received signals down the transmitter line which reflect and partly cancel direct incoming signals.
(b) The T.R. switch, CV.114, has a much smaller cavity, uses pressure tuning, and is mounted in a waveguide.
(c) A different crystal, CV.111, instead of CV.101 is used. This crystal has a higher current capacity and smaller stray capacity. Adjustable matching is provided for the mixer cavity which is a section of waveguide.
(d) The local oscillator stage employs a CV.129 reflector klystron, also with a much smaller cavity and pressure tuning. The local oscillator with its independent power pack is housed in the transmitter unit. A remote tuning control unit is provided at the H.2.S. operator's table.
(e) A two-stage 45 Mc/s. head amplifier unit is used. This is a universal unit employing VR.91's instead of the VR.136.
(f) The I.F. strip is another universal unit. It comprises a 5 stage (VR.91) I.F. amplifier instead of six VR.65 stages. A cathode follower (VR.91) is interposed between the detector and the output valve (VR.53). A gain control valve is used to vary the screen voltage of the second head amplifier valve and the first four I.F. stages. Fixed negative grid biasses are also used. These are derived from a -100V. negative rail.
(g) Suppression is applied to the suppressors of the first three I.F. stages as opposed to the screens of the 2nd and 4th in the Mark II I.F. strip. The same suppression generator circuit is employed.

Diagrams

371. (a) The major essentials of the Mark IIIA (TR.3555) receiver circuit are shown in fig.82.
(b) Mechanical details of the waveguide adjustments are shown in fig.83.
(c) The gain control and Lucero switch circuit details are shown in fig.89.

Input Matching

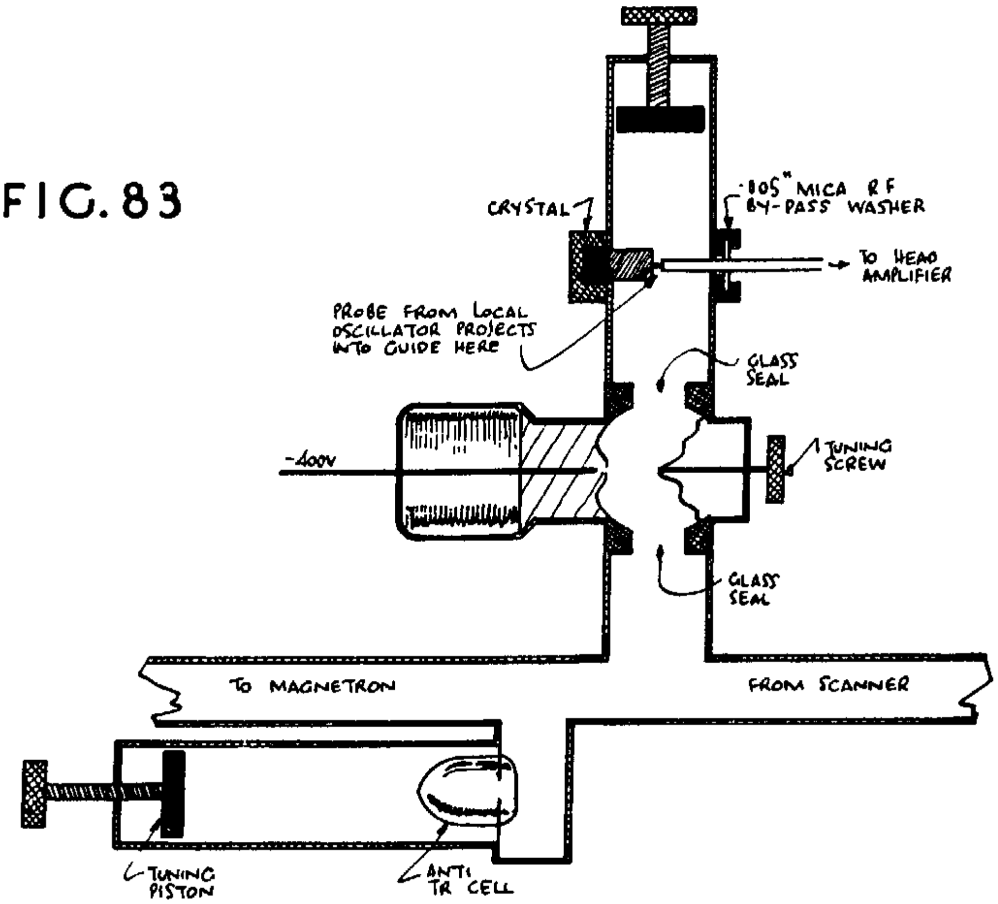
372. As a result of the short wavelength employed input matching is much more critical than in the Mark IIC receiver. When the reflected echo pulses come into the transmitter unit they have optional paths:-

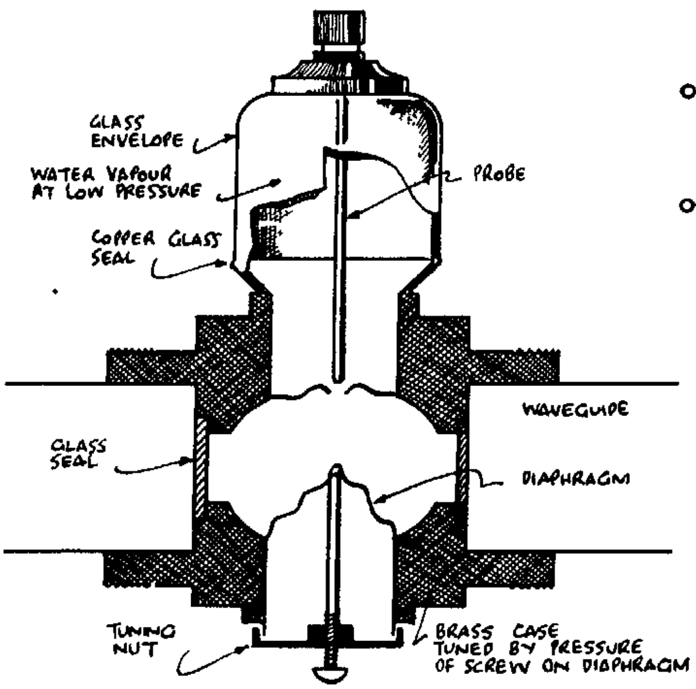
(a) Along the main output line back toward the magnetron.
(b) Down the branch line housing the anti-TR. cell (CV.115) and tuning piston 2.
(c) Down the receiver branch line, through the CV.114 TR. switch, and into the mixer chamber.

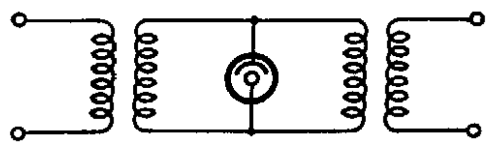
Obviously, what we want to happen is that all the energy of the reflected pulses flows into the mixer cavity for conversion into I.F. pulses. We must set our output controls with only output considerations in mind. Hence, we have no control over the phase of the reflected wave that comes back to the receiver branch line junction from the magnetron waveguide chamber. In some cases the phase may be such that it is correct to reinforce the incoming wave going directly into the receiver branch line. In this case the two waves do not interfere and the effect is the same as if all the energy had gone directly into the receiver branch line. This case is the exception rather than the rule. Some form of correcting adjustment is therefore required.

MARK IIIA RECEIVER WAVEGUIDE

FIG. 83







EQUIVALENT CIRCUIT

FIG.84

CONSTRUCTION OF CV114 TR SWITCH

373. This adjustment is tuning piston 2. The chamber is sealed off during the transmitter pulse period by the flash-over in the CV.115 which effectively makes the end wall continuous. When echo signals come in, the excitation of the resonant slot in the CV.115 is not sufficiently intense to cause flash-over. Energy then flows through the slot, reflects at the piston and comes back again. If the reflections from the magnetron are so phased as to interfere with the wave going directly down the branch line, we can adjust tuning piston 2 to cause a second reflected wave whose phase is such as to cancel out the wave reflection from the cold magnetron. Once the optimum position of the piston is found, there is least interference between the reflected waves and the direct wave into the receiver branch line. In transmission line terminology, we say that the piston is adjusted to introduce an impedance, which, when added vectorially to the magnetron impedance causes the incoming wave to see a high impedance along the main output line when it reaches the receiver branch line junction. The wave is then pictured as flowing mainly into the receiver line. To adjust the piston some form of observation of receiver output is necessary. The piston is then adjusted for maximum output.

374. Cases may occur where altering the piston setting appears to have negligible effect on the receiver output. When this happens, the reflections from the magnetron chamber are already coming back in the approximately correct phase and no appreciable correction is called for.

The soft Rhumbatron, CV.114, TR. Switch

375. The function of the CV.114 is the same as that of the CV.43 in the Mark IIC installation, i.e., to isolate the receiver from the transmitter when the transmitter fires. This isolation is necessary to get the maximum energy into the radiated beam and to protect the crystal. Details of the construction of the CV.114 are shown in fig.84. The cavity is designed to be resonant in the 3 cm. band. Pressure tuning is used to vary the resonant frequency by varying the cavity volume by means of a slight distortion of the cavity.

376. The cavity is filled with water vapour at a few mms. pressure. When the cavity is excited by the flow of energy into the branch line as the transmitter pulse begins, the voltage across the lips causes flash-over and introduces an effective short across the guide. The wave then reflects back into the main guide. The CV.114 is situated a wavelength from the junction. The reflected wave has then travelled an additional two wavelengths when it gets back to the main channel. Hence it is in phase with the outgoing wave and does not cause interference and an effective loss of output. As in the CV.43, a probe is provided to speed up both ionisation and de-ionisation. Details of the probe action in soft rhumbatron TR. switches are discussed in paras. 319-320. The negative voltage for the CV.114 probe is obtained by connecting the probe to the output line of the L.O. power pack through a resistance network, R.21, R.22, R.23 (each 1 M.) and R.33 (250K.). The CV.114 ionising current is about 0.5 ma. This current can be measured by connecting an AVO in series with the probe cap on the CV.114 and R.33. The probe must be connected to the positive and the lead to the negative terminal of the meter. Unless this ionising current is present the valve is faulty and the crystal will suffer. The most probable cause of recurring crystal failure is a faulty CV.114. The voltage at the CV.114 probe will be of the order of -400V. This voltage can be measured with an electrostatic voltmeter. The thickness of the two glass windows is different to permit matching of the cavity to the guide sections on the sides adjacent to the windows. The side towards the mixing chamber has two holes 90° apart drilled in the threaded section. The side towards the main guide has only one hole. These holes are about 1/32 in. in diameter.

377. When the transmitter pulse ends a normal CV.114 will deionise quickly and incoming signal waves will not excite the cavity sufficiently to cause flash-over. The wave will therefore continue into the mixer chamber.

The Crystal Mixer

378. Mechanical details of the mixer assembly are shown in fig.85(a) and the equivalent circuit in fig.85(b). The E vector in the wave-front advancing along the guide will be diametrical. The crystal is inserted into the guide along a diameter so as to be parallel to the E vector and thus have the

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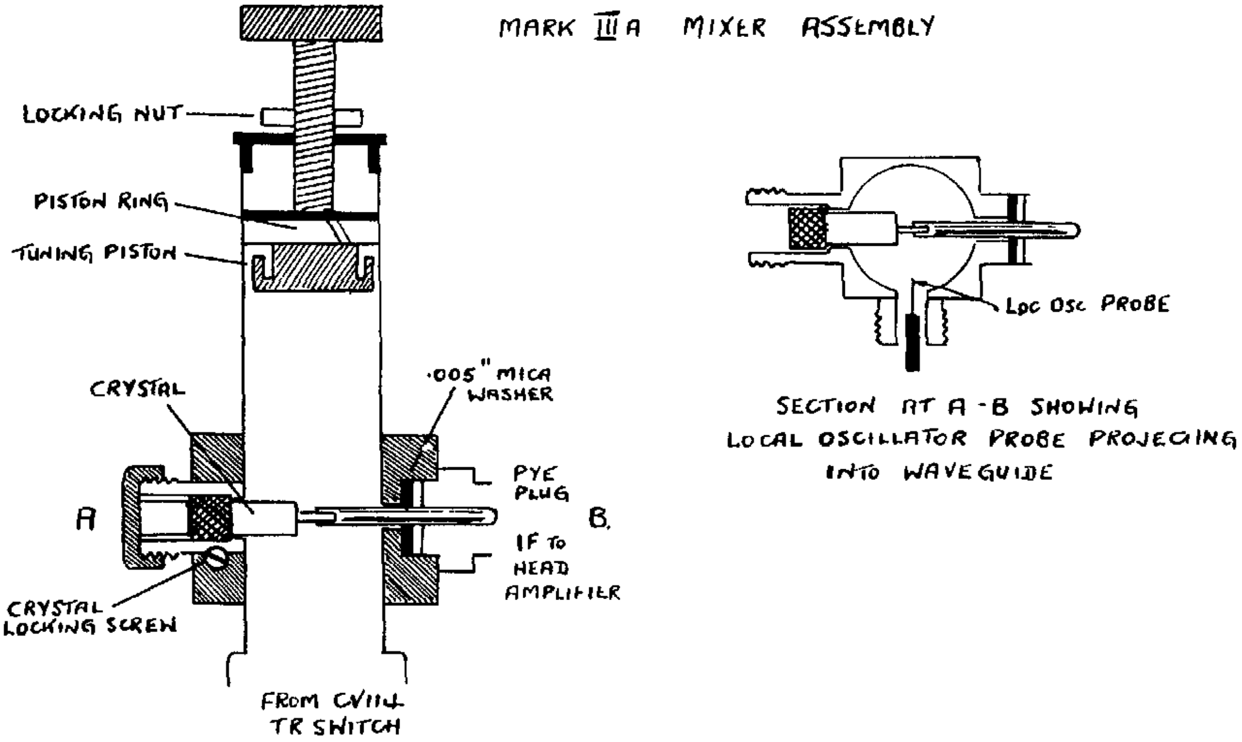
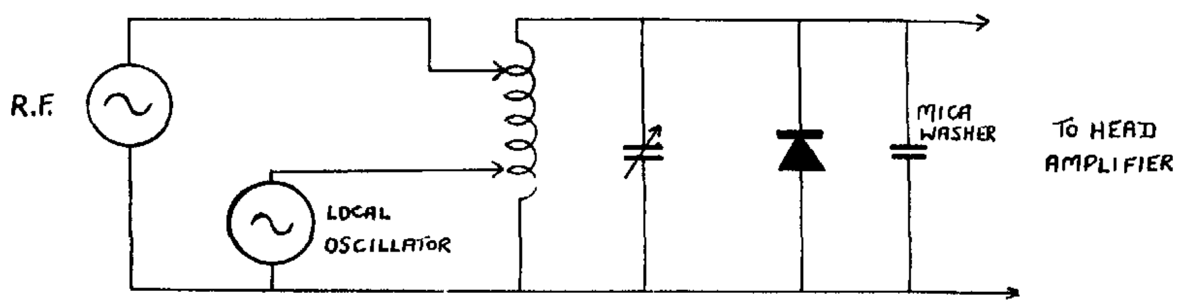
(a)

MARK IIIA MIXER ASSEMBLY

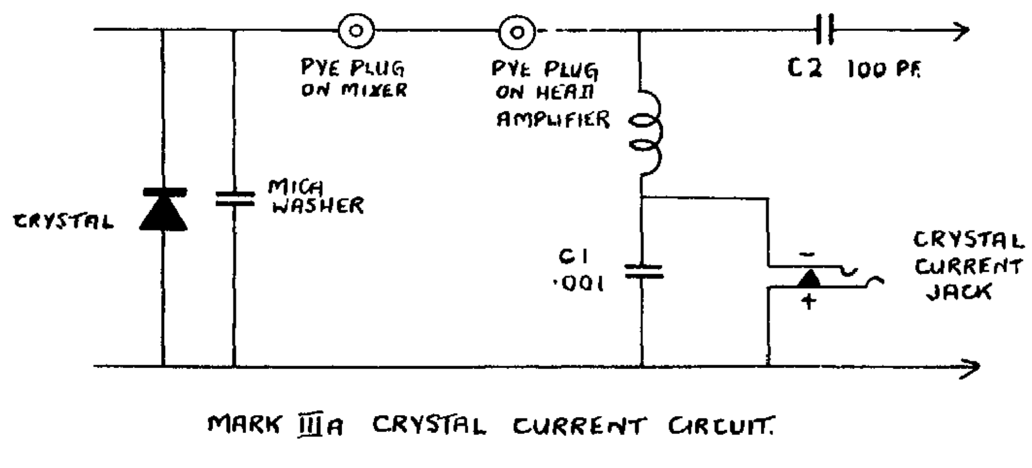


(b).



CRYSTAL MIXING EQUIVALENT CIRCUIT

(c)



MARK IIIA CRYSTAL CURRENT CIRCUIT.

FIG.85

maximum R.F. voltage applied to it. The end of the guide must be closed to prevent the wave travelling on past the crystal and out into space again. But when the guide is closed with a metallic short the part of the wave which is not dissipated in developing a voltage across the crystal travels on to the short and reflects. If the component of the reflected wave appearing across the crystal is not in phase with the direct wave there will be interference and partial cancellation. By closing the end of the guide with an adjustable piston the phase of the reflected wave can be adjusted to be in phase with the direct wave at the crystal. We then abstract the maximum energy from the wave in the crystal. In the transmission line terms, this is described as matching the crystal to the guide.

379. The probe from the silicon crystal in the crystal capsule makes contact with a connector pin coming in from a Pye socket mounted on the guide, diametrically opposite the crystal mounting. This connector pin contacts the inner of the Pye socket inner. The connector pin is insulated from the guide wall by a mica washer through which it enters the guide. The tungsten whisker of the crystal makes metallic connection with a metallic crystal holder which threads into the guide wall. As the outer of the Pye socket and the guide wall are at earth potential, the mica washer is effectively in parallel with the crystal and across the elements of the Pye socket. The mica washer therefore serves as a smoothing condenser for the rectified half-cycles of R.F. passed by the crystal. As the electron flow is from the tungsten whisker to the silicon crystal, the condenser charges negatively and the output from the Pye socket will always be negative-going.

380. The C.W. output from the CV.129 L.O. is brought to the mixing chambers by a short section of coaxial line. The inner of this coaxial projects radially into the guide at right angles to the diameter linking the crystal and the Pye mixer output socket. This projecting inner serves to capacitatively couple the L.O. output to the crystal. That is, there is a steady C.W. wave in the guide with a diametrical E vector, and also an R.F. voltage which only appears intermittently when signals come in. The voltage applied to the crystal at any instant is the result of the two voltages across it. As the two voltages have different frequencies, and hence different wavelengths, they will keep going in and out of step. When they are in phase at the crystal their amplitudes add. When in antiphase, the amplitudes subtract. The voltage across the crystal therefore fluctuates between these two limits. That is, whenever an echo signal appears in the guide, the two signals beat to apply a voltage across the crystal that varies in amplitude at the difference frequency. If the klystron is correctly tuned this difference frequency is 45 Mc/s., the I.F. frequency.

381. While echo waves are in the guide the voltage at the Pye mixer output socket will be the smoothed modulation envelope of the rectified crystal output. That is, bursts of 45 Mc/s. sinewave will appear with a p.r.f. of 670 c/s. Assuming an echo to be of 1 microsecond duration, one such echo burst will contain 45 cycles of 45 Mc/s. sinewaves.

382. In the intervals between echo waves only the steady C.W. wave from the L.O. will be in the guide. The crystal output will then be passing a steady sequence of half-cycles of the L.O. sinewave. These will be smoothed by the mica washer smoothing condenser to provide a standing D.C. voltage at the Pye socket. The amplitude of this D.C. voltage will depend on the C.W. input applied to the guide and the rectification efficiency of the crystal. For a good crystal the voltage will be a measure of the C.W. input and hence of the klystron output.

383. We see then that there are two components in the signal appearing at the Pye mixer output socket. The one is a D.C. component obtained by smoothing the rectified L.O. signal. The other is an A.C. component consisting of 1 microsecond bursts of 45 Mc/s. sinewaves at a p.r.f. of 670 c/s. These components are taken by a short length of Pye cable to the grid of the first head amplifier stage.

The Crystal Current Jack

384. Between the input to the head amplifier and earth we have an I.F. choke and a .001 condenser, C.1. This condenser offers negligible impedance at

45 Mc/s. so the whole A.C. component of the mixer output appears across the I.F. choke and is applied via C.2 (100 pf.) to the input coil. The D.C. component is blocked from earth by C.1 so this voltage appears across C.1 and charges it negatively. By jacking in a meter this D.C. component of the mixer output can be read as a current indication. The tip of the jack will have to go to the negative side of the meter and the sleeve to the positive side. The normal value of crystal current is about 1.5 ma. The value should not exceed 6 ma. or the crystal will be damaged. The unconventional jack polarity arises because the head amplifier was designed for use with a crystal mixer having the silison crystal earthed instead of the tungsten wire as in the present case.

Crystal for H.2.S. Mark IIIA

385. The crystals used in the H.2.S. Mark III equipments are CV.111's indicated by a green spot instead of the yellow spot used on the CV.101's for H.2.S. Mark II. The CV.111 has a higher current rating than the CV.101 and smaller strays. Subsidiary spot markings are used to indicate the order of the voltage to which the crystal should stand up. These markings are orange and red spots. A crystal with only a green spot is capable of passing the required current for Mark III H.2.S. gear but will not stand a very high voltage. If a subsidiary orange spot is added to the green spot a medium voltage can be handled and if a subsidiary red spot is added the crystal has a high voltage breakdown. The green spot crystal with a subsidiary orange spot is called a CV.112. If a green spot crystal bears the subsidiary red spot it is called a CV.113.

The CV.129 Local Oscillator

386. The H.2.S. Mark IIIA local oscillator is a CV.129 type of reflector klystron. To overcome the problem of feeder losses, the CV.129 and its associated power pack and stabilising circuits are located in the transmitter unit. Tuning is done by varying the cavity volume by means of a pressure ring. The pressure exerted on the flexible cavity by this pressure ring is varied by means of a differential thread tuning control. A crank and gear drive arrangement for manual tuning is provided as a gear box attachment mounted external to the transmitter unit case. In the TR.3555 series transmitter units designed for use with the roll-stabilised scanner Type 71 this gear box is on the side of the unit. In the older TR.3555 series units the gear box was mounted on the front. A remote control unit, tuning unit type 444, is provided at the H.2.S. operator's table. This unit has a crank and gear arrangement which operates an Admiralty transmitter that switches the D.C. supply connections to a repeater motor mounted in the transmitter unit gear box. The repeater motor armature rotation is used to operate the klystron tuning shaft through a suitable gear train to give sufficiently slow frequency variation.

(a) Mechanical details of the CV.129 are shown in fig.86.
(b) Circuit details are shown in fig.87.

Operating Conditions

387. The principles underlying the operation of the reflector klystron are discussed in detail in paras.338-354. These principles also apply in the case of the CV.129. The essential differences between the CV.129 and CV.67 are in size, method of tuning, voltages required and power pack design. The CV.67 is operated with the cathode at about -1200V and the reflector at about -1500V. The CV.129 is operated with the cathode not more than 1600V negative to earth. The reflector voltage is 350 - 550V. negative to the cathode. The normal operating current of the CV.129 is around 6 ma. and the coupling into the mixer is adjusted for a crystal current reading at the crystal jack of about 1.5 ma.

The Local Oscillator Power Pack

388. In view of the small dimensions involved in the CV.129 and the short wavelength employed, it is obvious that any appreciable fluctuation in the voltages applied to the reflector and cathode will result in sufficient change in the spacing of the bunches to radically upset the feedback phasing. Shifts

C.D. 0896 L

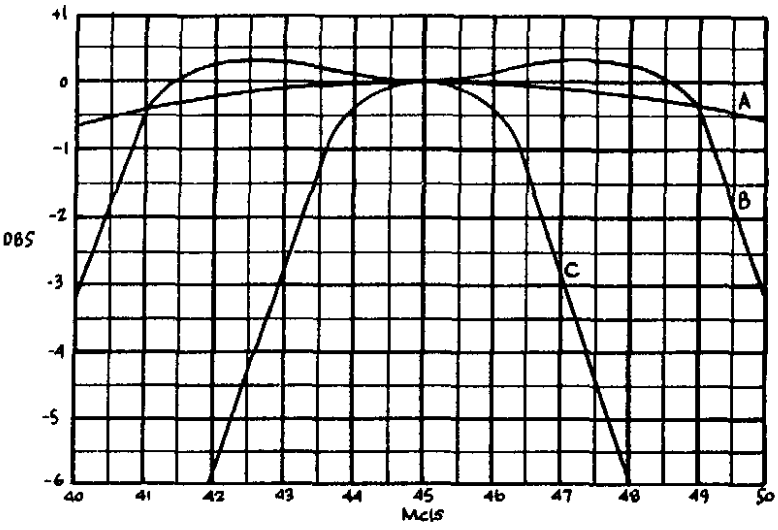
HEAD AMPLIFIER

AMPLIFYING UNIT
TYPE 208A

A OUPUT STAGE RESPONSE

B · INTERSTAGE + OUTPUT RESPONSE

C · OVERALL RESPONSE

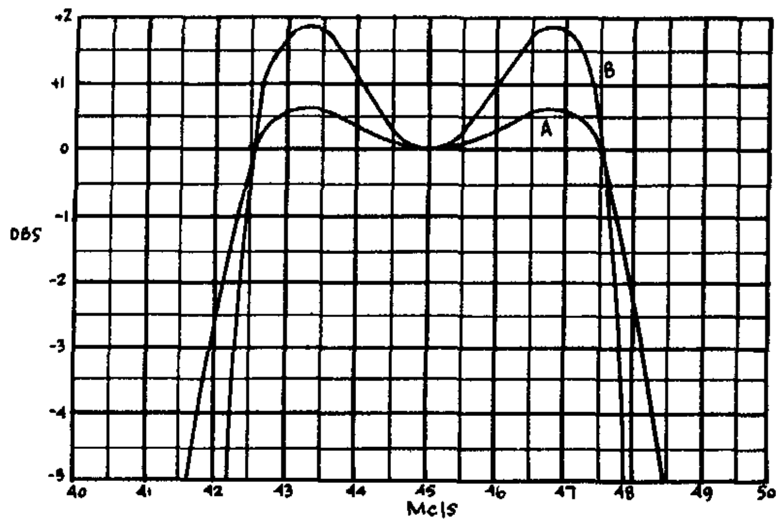


I.F STRIP

RECEIVING UNIT
TYPE 153

A RESPONSE OF ONE OF FIRST THREE STAGES

B RESPONSE OF FIRST THREE STAGES TOGETHER



C RESPONSE OF FOURTH STAGE

D · RESPONSE OF FIFTH STAGE

E OVERALL RESPONSE

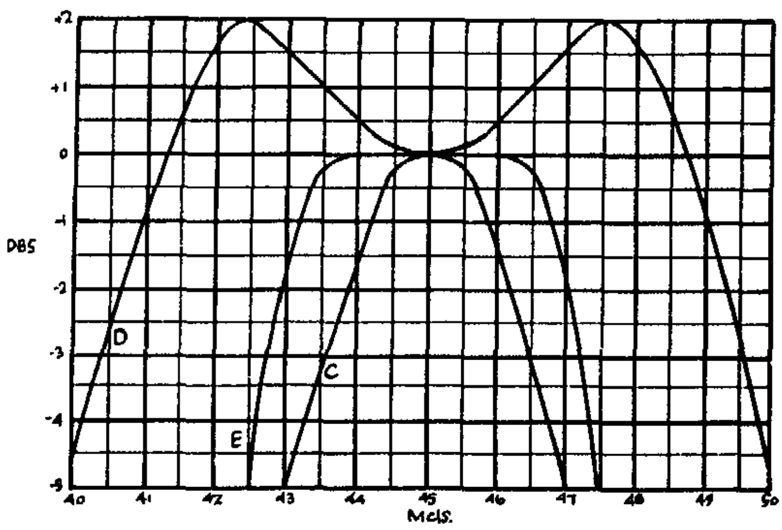
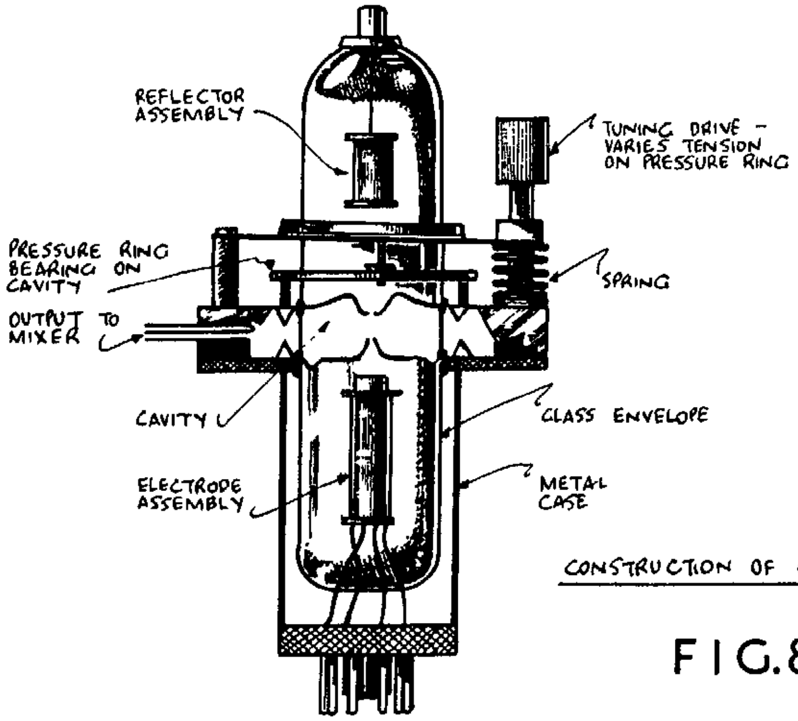


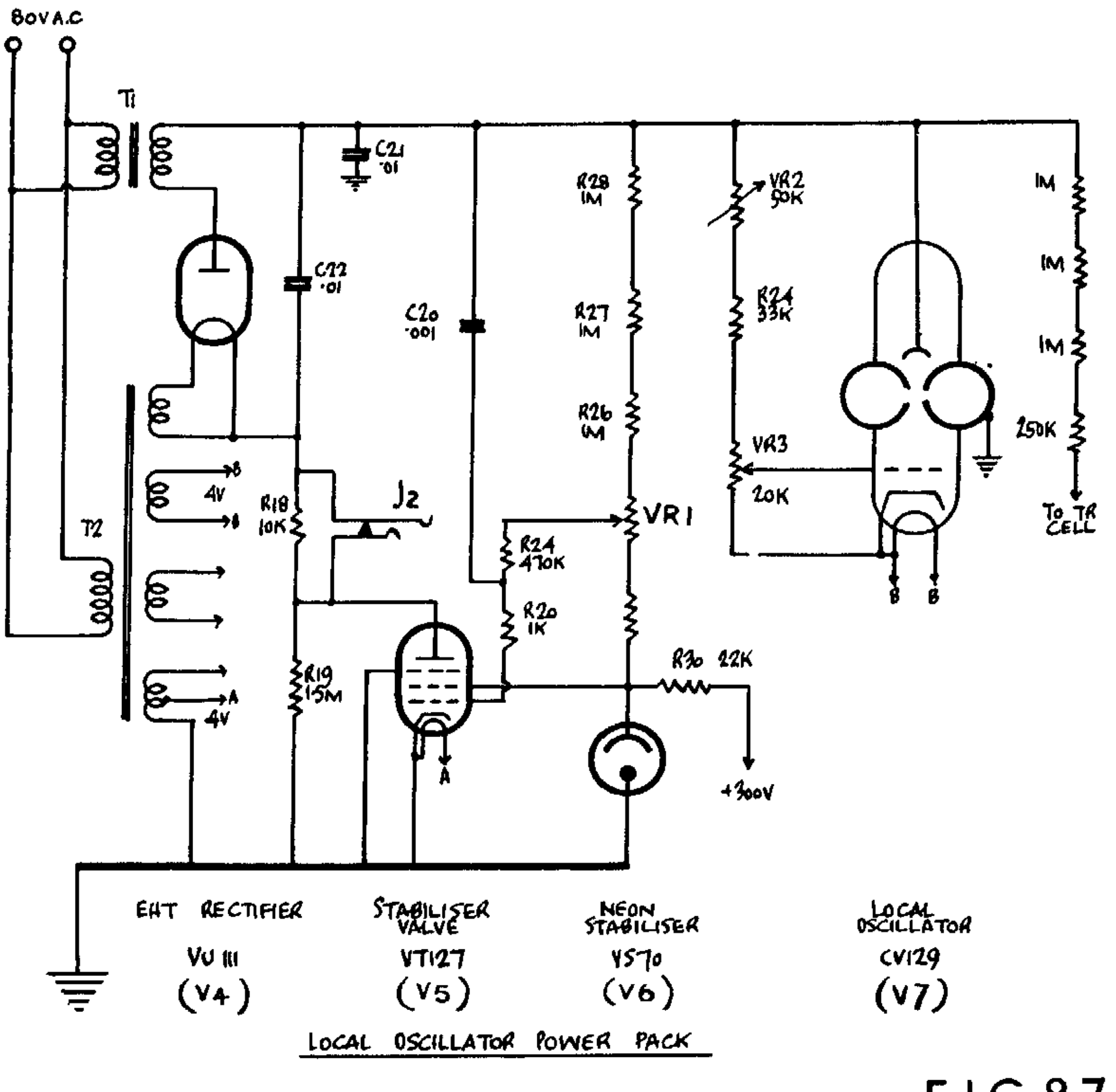
FIG. 88

C.D. 0896 L



CONSTRUCTION OF CV129 KLYSTRON

FIG. 86



LOCAL OSCILLATOR POWER PACK

FIG. 87

in these potentials must therefore incorporate elaborate stabilising arrangements.

389. Circuit details of the L.O. power pack are shown in fig.87. Examination of the circuit shows the following points.

(a) T.1 provides the stepped up 1000 c/s output which is brought in through a suitable noise filter.
(b) V.4, a VU.111, is the actual half-wave rectifier.
(c) The effective cathode load of V.4 is the beam tetrode stabiliser V.5, a VT.127.
(d) The screen voltage for the stabiliser, V.5, is obtained by bridging the screen in on a bleeder between +300V. and earth, formed by R.30 (22K.) and the VS.70 neon stabiliser, V.5. The +300V. line is supplied from the +300V. pack in the power unit. The VS.70 serves to stabilise the screen voltage of V.5 to +100V.
(e) V.5 grid is tapped in at a variable point on the bleeder between the stabilised screen and the power pack output line.
(f) V.5 is shunted by the 1.5 M. resistor, R.19.
(g) The current passed by V.4 can be measured at the jackpoint, J.2.

390. To appreciate how the output voltage is being stabilised we must consider V.5 as a cathode load whose impedance is varied in such a way that when the input to T.1 fluctuates the variations in the impedance of V.5 will serve to keep the output D.C. voltage constant within very small limits. This variation in the impedance of V.5 is achieved by feeding back a fraction of any change in the output voltage to V.5 grid. The tapping point to which V.5 grid is returned must provide a suitable operating potential for V.5 grid. This potential should be about -20V. as the cathode is returned to earth. Let us assume the output voltage is of the order of -2KV. If the grid were to be tapped in on a bleeder between -2KV. and earth at a -20V. point, the tapping point would be only 1/100th of the way up the bleeder. The output voltage would then have to change by 100 volts. to cause a 1 volt change at V.5 grid. The control obtainable would not be satisfactory with such an arrangement. By connecting the bleeder from the -2KV. output line to the stabilised +100V. point, we have 2100V. across the bleeder. Tapping at -20V will be 120V up the bleeder, i.e., about 1/18 th of the way up. Hence, a change of less than 20V (i.e. of 1%) in the output voltage will cause a change of 1 volt at V.5 grid. The control exercised by V.5 therefore becomes much more effective.

391. Let us assume that the 80V input to T.1 primary from the V.C.P. shows a transient increase due to increased engine speed. The -2KV output line will then tend to swing more negative. Approximately 5% of the increase is applied to V.5 grid to carry it more negative. Hence V.5 passes less current, i.e., in impedance rises. There is then a reduced flow of electrons into the reservoir condensers, C.21 and C.22. By correctly adjusting VR.1, the variation in V.5 impedance can be made to counterbalance the normal variations that may be expected in the 80V supply to T.1 primary. The -2KV output is then effectively stabilised.

392. Not only must the klystron supply voltage be stable, but it must be correct or the CV.129 will not operate reliably and efficiently. The circuit design must therefore be such that the selected setting of VR.1 for stability also gives V.5 such an impedance that the output voltage is correct. Since the operating conditions necessary for satisfactory klystron operation are extremely critical the major requirement is actually a correct output voltage. We may, therefore, say that the design must be such as to give adequate stabilisation when the correct output is obtained by suitable adjustment of VR1.

393. The leak, R.19, serves to prevent flash-over in V.5 when the equipment is switched on. The 80V input to T.1 and T.2 will be applied when the "L.T. ON" button is pressed on the switch unit. When V.5 is cold its impedance will be high and the proportion of the T.1 secondary voltage appearing between V.5 anode and earth might well cause flash-over. By providing R.19 in parallel with V.5 this danger is avoided. R.19 also serves as a discharge path for C.22 when the gear is switched off.

394. C.20 prevents R.F. pick-up from influencing the potential of V.5 grid.

The Klystron Circuit

395. Examination of fig.87 gives us the following information about the klystron circuit:-

(a) The reflector potential is that of the output line of the L.O. power pack.

(b) The cathode potential of the CV.129 is determined by the output line voltage and the potential drop across VR.2, R.29 and VR.3. But this potential drop is determined by the klystron current. The klystron current will depend on the klystron impedance which will be modified by the setting of VR.3 since this varies the grid voltage. We may actually regard VR.2, R.29, VR.3 and the klystron impedance as forming a bleeder between the output line and earth. As variation of VR.2 and VR.3 vary the effective resistance of this bleeder, both controls vary the cathode potential of the klystron and the klystron current.

(c) The current taken from the L.O. power pack flows in three channels:-
  (i) Through the klystron network and the klystron to the earthed rhumbacron.
  (ii) Through the bleeder formed by R.25, VR.1, R.26, R.27, R.28.
  (iii) Through the CV.114 network to the probe and thence to the earthed rhumbatron via the ionisation leakage from the probe to the rhumbatron.

396. The voltage of the power pack output line will obviously depend on the current drain imposed on it. It follows then that we cannot set up VR.1 to some arbitrary voltage level and then adjust the klystron controls to get a suitable operating point for the klystron, since adjustment of the klystron controls alters the current drain and hence the reflector voltage. Setting up the klystron controls, VR.2 and VR.3, and the power pack control, VR.1 are therefore not independent operations. Setting up actually calls for consecutive adjustment of the controls in a series of successive approximations which must terminate with stable klystron operation at a suitable amplitude level. From operational experience it has been found that the final conditions called for are:-

(a) Klystron cathode not negative to earth by more than 1600V.
(b) Total E.H.T. current drain not greater than 7.5 ma. (about 6 ma. to klystron).
(c) Crystal current at the crystal jack of 1.5 ma.

The crystal current value is dependent on adequate oscillation in the klystron so is essentially a consequence of the first two conditions rather than an additional condition.

397. The 7.5 ma. current drain is a figure found from experience. It represents about 6 ma. klystron current, 0.5 ma. soft rhumbatron current (CV.114), and 1 ma. bleeder current. To have a constant visual indication of this current drain a meter is jacked in at the jackpoint, J.2. The tip of the jack must go to the meter positive and the sleeve of the jack to the meter negative terminal. The jack tip will be at a potential of about -1000V. with respect to earth. The resistor, R.18 (10K.), serves to avoid the danger of a faulty jack point disconnecting V.5 and leaving V.4 without its stabilising cathode load.

398. To permit observation of the klystron cathode potential while setting up VR.1, VR.2 and VR.3, an electrostatic voltmeter must be connected between the klystron cathode and earth.

Klystron Output Controls

399. The principle of picking up an R.F. voltage from the resonant cavity of a klystron is discussed in para.351. In the case of the CV.129, a very tiny coupling loop is used to pick up the klystron output and impress it on a short length of coaxial feeder. The voltage impressed on this feeder can, of course, be varied by varying the plane of the coupling loop. The other end

of this coaxial line has its inner projecting radially into the mixing chamber to serve as a capacity probe. The intensity of the current set up in the crystal chamber by the L.O. input depends on the distance between the end of the probe and the crystal. This distance is adjustable so serves as an input control. In practice, the klystron coupling loop is set for maximum coupling to put the maximum R.F. voltage on the coaxial line. The distance that the launching probe projects into the mixing chamber is then adjusted to give a crystal current reading of 1.5 ma. on a meter jacked in at the crystal jack-point. The reason for this arrangement is to prevent the loss of signal power via the coaxial line to the L.O. Obviously, such losses are minimised by reducing the distance that the coaxial probe extends into the mixing chamber as much as possible. This arrangement calls for maximum coupling at the klystron to get sufficient C.W. into the mixing chamber with the minimum input coupling and hence the minimum reverse coupling.

The Head Amplifier

400. Circuit details of the two stage VR.91 head amplifier are shown in fig.82. The overall gain of the two stages is about 17 for a screen potential of about 170 volts. The voltage applied to the screen of the second stage is varied by means of the gain control on the switch unit. The H.T. supply and screen supply to both valves should be broken when the Lucero switch is set for either B or BA. Details of the channels are shown in fig.89.

401. A grid bias of -1.5V. is applied to the second stage. R.6(1.5K.) and R.7 (100K.) form a bleeder between -100V. and earth and the grid is tapped in at the junction. The -100V. supply is obtained from the -100V. neon stabilised negative rail in the receiver-timing unit.

402. When a valve has been replaced it is desirable that circuits immediately before and after the particular valve should be realigned. The tune frequencies for the various circuits are as follows:-

Input circuit 45 Mc/s.
Coupling between stages 47.5 Mc/s (two tuning adjustments)
Output Circuit 45 Mc/s.

For the purpose of tuning up a C.W. output from a signal generator should be fed into the unit through a suitable resistance to bring the effective generator output impedance up to 250 ohms. To represent the mixer and cable capacities a 3 pf. condenser should be connected across the Pye elbow socket used for connecting to the input plug. The output should be connected by the normal cable to the I.F. amplifier in the receiver. A suitable meter across the diode detector cathode load should be used to observe the response. With this arrangement the circuits are tuned to give a maximum with an input signal of frequency corresponding to the particular circuit as tabulated above. The trimmers should be sealed after tuning. For the first circuit Durofix should be used. Paraffin wax is used for the interstage coupling and the output.

403. When putting in new valves care must be exercised to ensure that the valve pins and spigot are correctly aligned with respect to the valve holder before attempting to force the valve into position. Failure to observe these precautions will invariably result in breakage of the pin seals in the valve base or damage to the holder.

404. The output is at an impedance of 95 ohms suitable for feeding a terminated cable of this impedance. For this purpose a uniradio 31 cable is used to link the green Pye output plug on the transmitter unit and the green pye input plug on the receiver-timing unit. The performance of the head amplifier is independent of the cable length when operating into this type of cable and the universal type 153 I.F. strip.

The I.F. Amplifier

405. Full circuit details are shown in fig.82.

406. Official response curves are shown in fig.88.

407. The 5-stage, VR.91 I.F. amplifier is part of a universal I.F. strip known as receiving unit type 153. This universal unit is made as a sub-assembly suitable for building into standard airborne boxes. The overall bandwidth is about 45 ± 2 Mc/s. The overall gain at 45 Mc/s. is of the order of 30,000. Gain by stages is as follows:-

(a) First 3 stages - Each about 8 at 45 Mc/s. The mutual coupling is adjusted to give a slightly overcoupled response with slight double peaking at 43 Mc/s. and 47 Mc/s.
(b) Fourth stage - About 7 at 45 Mc/s. Coupling is such as to give a single-peaked response at this frequency.
(c) Fifth stage - About 9 at 45 Mc/s. Arranged to give a double-peaked response.

The overall response should be reasonably flat over the range 43 - 47 Mc/s. The gains quoted above assume a screen voltage of 170 for the first four variable gain stages which is above that actually used.

408. The first 4 stages are run with a fixed negative bias of about 1.5 volts on the grids. This voltage is obtained by tapping in at the junction of R.34 (470 ohms) and R.42 (33K.) placed between the stabilised -100V. rail and earth. The fifth stage operates with auto-bias.

The Gain Control Valve, V.9

409. V.9 serves as a gain control valve. Details of the gain control circuit are shown in fig.89. R.61 and R.62 in parallel are connected in series with R.57 across the 300V. line. The series combination of R.63 in the receiver and the gain control potentiometer in the switch unit, is in parallel with R.57. Varying the gain setting then varies the D.C. potential to which V.9 grid is tied and hence the current passed by V.9 which is strapped as a tetrode. The cathode is bridged in on the bleeder formed by paralleling R.61 and R.62 in series with R.66 to enable V.9 to be cut off. The range of variation on the gain control is as follows:-

	Max. Gain	Half Gain	Min. Gain
(a) Grid	2.7 V.	10 V.	15 V.
(b) Cathode	7 V.	12 V.	16 V.
(c) Anode	130 V.	70 V.	30 V.
(d) Junction of R.64 and R.65	140 V.	80 V.	45 V.

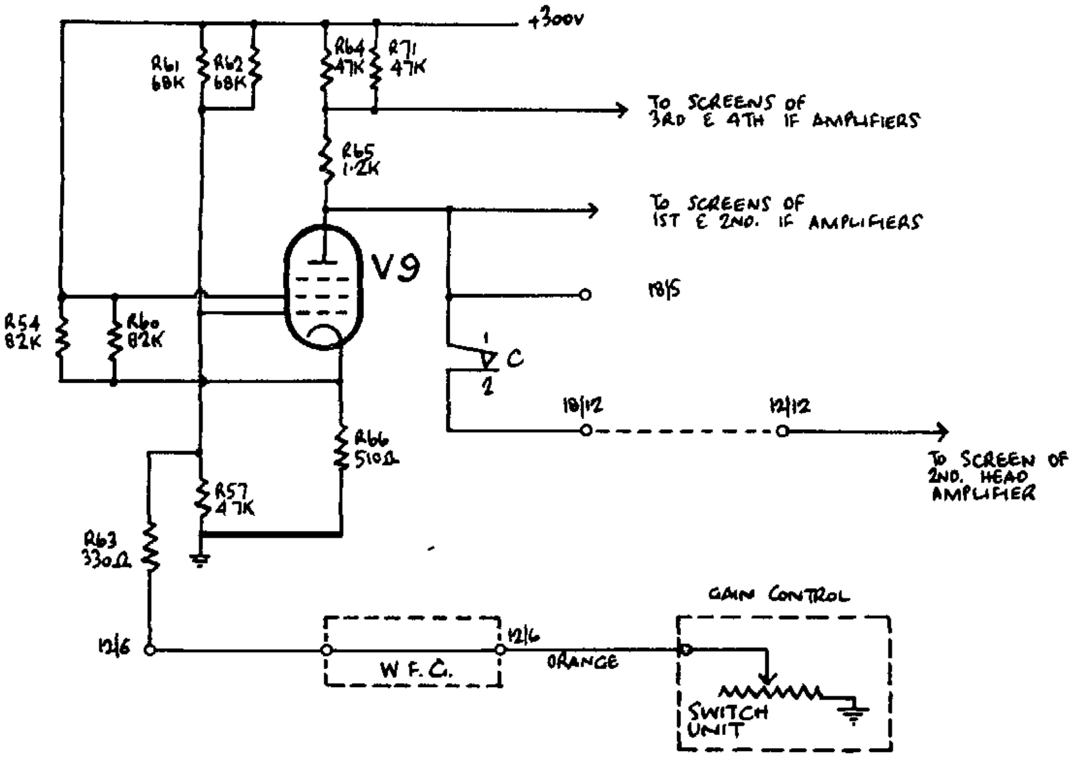
These readings were obtained on a D.C. scope with H.T. at 290V. and the negative rail at -95V. For a higher H.T. level the readings would vary accordingly.

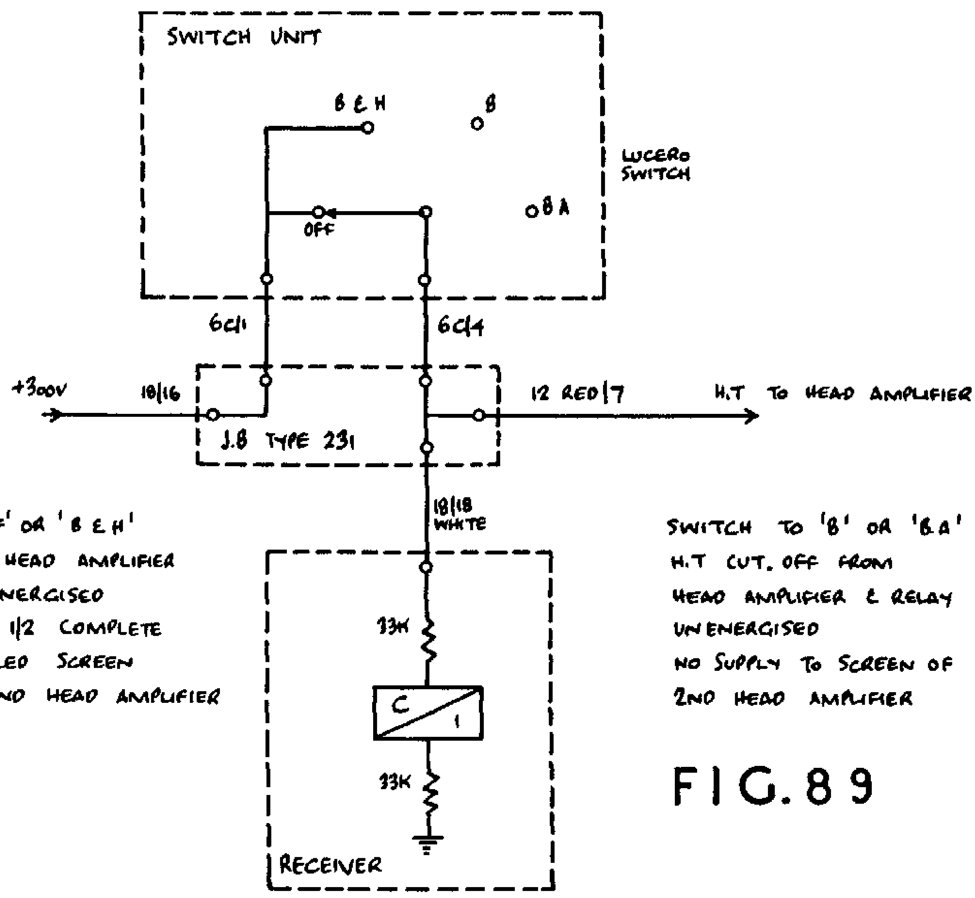
Effect of the Lucero Switch

410. Relay C is used to switch the controlled screen voltage to the second head amplifier stage. If the Lucero switch is set to "OFF" or "B + H", the supply (coming originally from the +300V. pack in the power unit) is completed to the solenoid. The head amplifier screen supply is then completed via 18/12. If the Lucero switch is set to either B or BA the supply to the relay solenoid is broken at the same time as the H.T. to both valves and the screen supply of the first valve are broken. There is then no screen supply to the second head amplifier valve when its H.T. supply is cut off. This is done to help push up the maximum gain of the I.F. amplitude proper for the Lucero signals. If the screen supply were left completed when the H.T. is cut off, the second head amplifier valve would draw an increased current from the gain control valve and would thus lower the controlled voltage to the I.F. amplifier screens. Breaking the screen supply reduces the loading on V.9 and thus raises the I.F. screen voltages, and hence the I.F. amplifier gain. This is desirable since the Lucero input is applied through the attenuating pad formed by R.1 and R.2. The gain measured from the brown Lucero input is cut by half as compared with the gain measured from the green H.2.S. input.

C.D. 0896L

GAIN CONTROL & LUCERO SWITCHING





SWITCH TO 'OFF' OR 'B & H'
300V HT TO HEAD AMPLIFIER
& RELAY C ENERGISED
CONTACTS C 1/2 COMPLETE
GAIN CONTROLLED SCREEN
SUPPLY TO 2ND HEAD AMPLIFIER

SWITCH TO 'B' OR 'B A'
H.T CUT. OFF FROM
HEAD AMPLIFIER & RELAY
UNENERGISED
NO SUPPLY TO SCREEN OF
2ND HEAD AMPLIFIER

FIG. 89

Tuning of the I.F. Stages

411. When a valve has been replaced it is desirable that the circuits immediately before and after the particular valve should be realigned. The tune frequencies for the various circuits are as follows:-

(a)	Input circuit	Preset	
(b)	Coupling between V.1 and V.2	47.0 Mc/s.	(two adjustments)
(c)	Coupling between V.2 and V.3	47.0 Mc/s.	(" ")
(d)	Coupling between V.3 and V.4	47.0 Mc/s.	(" ")
(e)	Coupling between V.4 and V.5	45.0 Mc/s.	(" ")
(f)	Coupling between V.5 and V.6	47.3 Mc/s.	(" ")

A C.W. output from a signal generator with an output impedance of 95 ohms should be fed into one of the input plugs and the output observed on a high resistance voltmeter connected across R.48 (5.6K.), the load of the diode detector. Alternatively, a milliammeter may be connected in series with this load. In either case, to prevent feedback a filter should be used in the meter lead. A .001 condenser connected to ground followed by 220 ohms in series and another .001 to ground will provide a suitable filter. The circuits are then tuned to give a peak with an input signal of frequency corresponding to the particular circuit as tabulated above. The Durofix used to seal the threads of the tuners will peal off easily if the screws is turned gently at first. When tuning is completed the screws should be resealed with a small quantity of Durofix.

412. The cautions outlined in para.403 with regard to changing valves obviously apply equally well to the I.F. amplifier.

Suppression

413. As the CV.114 TR switch will not flash-over instantaneously when the transmitter fires and does not provide perfect receiver isolation after flash-over has occurred, there is always some transmitter breakthrough into the mixing chamber. This breakthrough is amplified by the head amplifier stages and applied to the first I.F. stage. The strength of this signal will be sufficiently great to cause paralysis of the receiver if no provision is made for rendering the receiver insensitive while the transmitter is pulsing. To overcome this problem a suppression pulse is applied to the suppressors of the first three I.F. stages. V.412 serves as the suppression generator. Details of the operation of V.412 are given in para.364. The suppression pulse is developed across the anode load (R.470, 5K.). The diode, V.10, connected between the suppression line and earth, serves to keep the suppressors from swinging positive at the termination of the suppression pulse. The position of the suppression waveform with respect to the transmitter pulse is adjusted by means of the suppression preset on the panel on the receiver-timing unit until only the tail of the transmitter breakthrough shows on the height tube (or monitor 28) when the receiver output is scoped). For operation with Fishpond this setting may require modification.

The Diode Detector

414. The output of the final I.F. stage is applied to the cathode of V.6 (VR.92) which develops a negative-going output. C.38, L.17, C.39, L.18 form an I.F. filter which smooths the detector output to develop the video pulse envelope across the detector load, R.48 (5.6K.). C.40, R.49 form a 0.1 sec. A.C. coupling to the cathode follower, V.7. This A.C. coupling prevents the possibility of jamming by means of C.W. signal in the I.F. band-pass which might bias back the detector, and hence the cathode follower grid, if D.C. coupling were used.

The Cathode Follower

415. V.7 has its cathode bridged in at the junction of R.50 (10K.) and

R.51 (15K.). These resistors serve as a bleeder between -100V. and earth. If V.7 had no heater voltage its cathode potential would be -60V. As the valve warms up and cathode current flows the electron flow from the -100V. line is mainly through the valve. Under normal operating conditions, V.7 cathode potential is then about +3.5V. This bridging arrangement permits operating conditions for V.7 which prevent limiting on V.7 grid on strong signals without recourse to special arrangements for a positive grid bias. As the grid swings down the cathode potential can swing negative to earth instead of stopping at earth potential which would occur if the cathode load of V.7 were returned to earth. R.50 (10K.) is the effective cathode load. The cathode follower output waveform can be scoped at the spare Pye plug on the receiver panel which is not used.

The Receiver Output Valve

416. V.8 (VR.53) serves as the receiver output valve with R.451 (1K.) serving as the effective anode load as R.452 is effectively decoupled by C.440. Paras. 368 and 369 outline briefly the way the course and track marker are introduced at V.8 suppressor and the details of V.8 output.

The Receiver Power Pack

417. As the 300V. power pack on the power unit is incapable of supplying the necessary current for all the valves running off a 300V. supply, a second 300V. pack is included in the receiver-timing unit. Circuit details are shown in fig.82. V.13 is a 5U4G full-wave (double half-wave) rectifier which develops a nominal 300V. output for the receiver-timing unit and the head amplifier stages on the transmitter unit. L.22 and C.43 provide the necessary smoothing.

418. The metal rectifiers, V.11 and V.12 provide a second full-wave (double half-wave) rectifier stage which develops a -100V. output. L.23 and C.44 provide the necessary smoothing and the neon, V.14, provides stabilisations. This stabilisation is necessary in order to obtain a steady grid bias for the first four I.F. stages and the second head amplifier stage. Any ripple on this supply will tend to cause spoking.

CHAPTER 7 - THE MARKER CIRCUITS

General

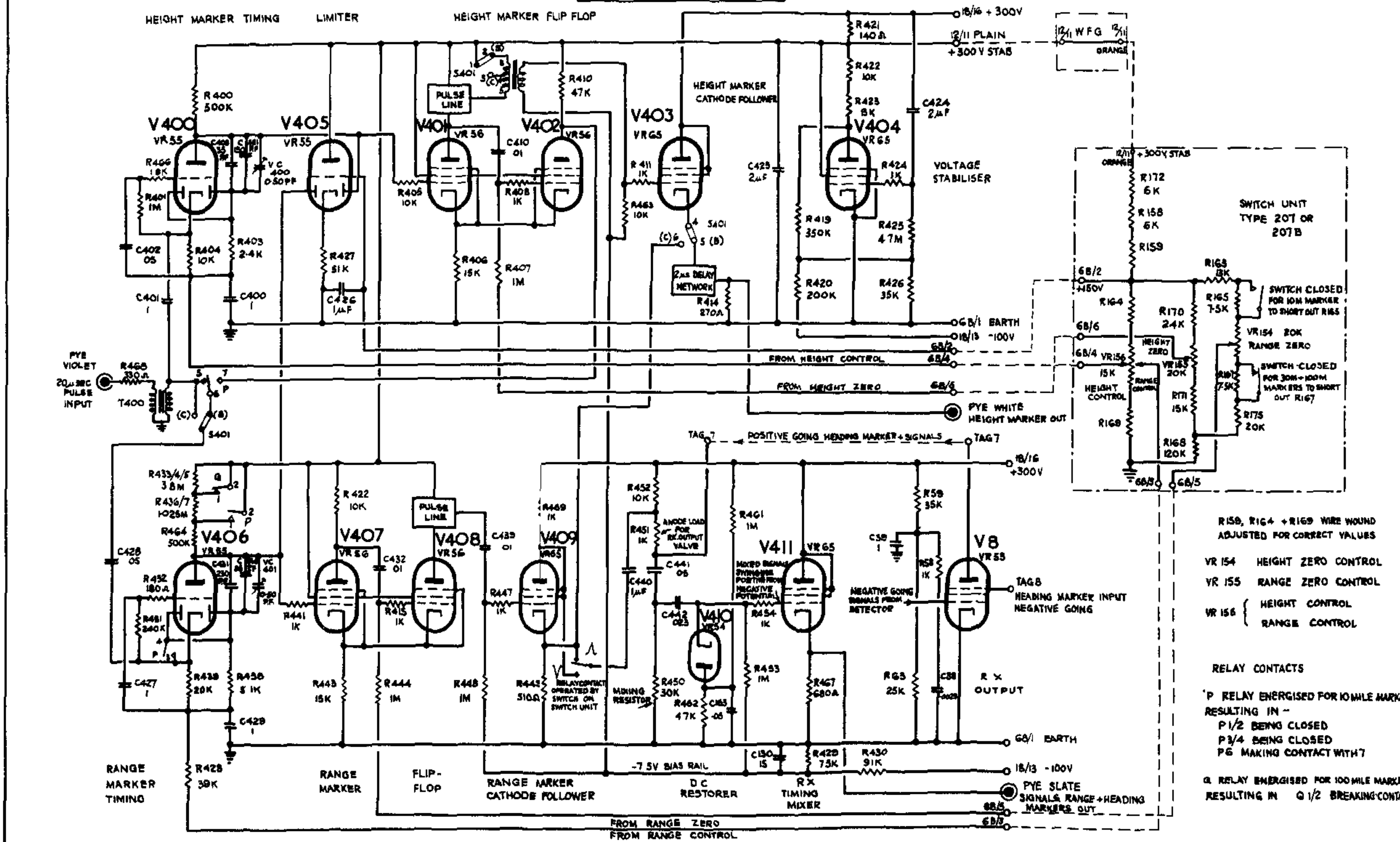
419. Three different markers are used in the H.2.S. Mark IIC and Mark IIIA displays. The range marker appears as a ring on the P.P.I. display and a blip to the right on the height tube display. The height marker appears as a blip to the left on the height tube. The heading (course) marker appears as a radial line on the P.P.I. display. When a switch on the indicator 184 is set to the "Track" position the radial marker serves to indicate the aircraft track. The next phase of our study of H.2.S. will deal with the way these markers are developed.

The Heading Marker

420. The heading marker circuit is the same in the H.2.S. Mark IIC and Mark IIIA installations. Details of the circuit used to develop the heading and track markers are shown in fig.93. The circuit used in setting up the marker is shown in fig.111. Before making a study of these circuits it may be helpful to tabulate the following outline:-

(a) The actual marker pulse is a positive-going signal applied to the P.P.I. grid once in every revolution of the scanner.
(b) The effect of this marker pulse is to increase the P.P.I. emission sufficiently to enable the electron beam to cause the screen to fluoresce as the beam moves from the tube centre to the circumference.
(c) The pulse duration is long enough to brighten up one full scan and all or part of the next.
(d) The marker pulse proper is taken off at the anode of the receiver output valve. It is developed by driving the suppressor down by means of a negative-going pulse of suitable amplitude and duration.
(e) The pulse applied to the suppressor of the receiver output valve is initiated by a contact arrangement in the scanner which must operate automatically to earth the pulse-forming circuits in the receiver-timing unit.
(f) To enable the H.2.S. operator to take the marker off the P.P.I. display without stopping the scanner a switch must be provided at the operator's position. This switch is on the switch unit and is labelled "Line of Flight". The incorporation of such a switch considerably complicates the circuit design as the switch must be introduced in voltage supply channels that originate in other units.
(g) When a bombing run is being made it is desirable to have a track marker instead of a heading marker. Hence it is necessary to incorporate another contact in the scanner which can be suitably offset from the heading marker contact.
(h) In order that the H.2.S. operator may choose the heading or track marker at will it is necessary to provide a switch at his position that will enable him to introduce the appropriate scanner contact into the circuit. This switch is fitted on the indicator panel and is labelled with the two positions "Course" and "Track". Obviously, the incorporation of this control again complicates the wiring channels required.
(i) To set up the scanner "Course" and "Track" contacts the H.2.S. operator must have a remote control at his position. This control is located in the heading control unit type 446. It is essentially a setting knob which operates a set of cams or "transmitter" that switches the D.C. connections to "Course" or "Track" repeater motors in the scanner. A switch is provided on

C.D. 0896 L



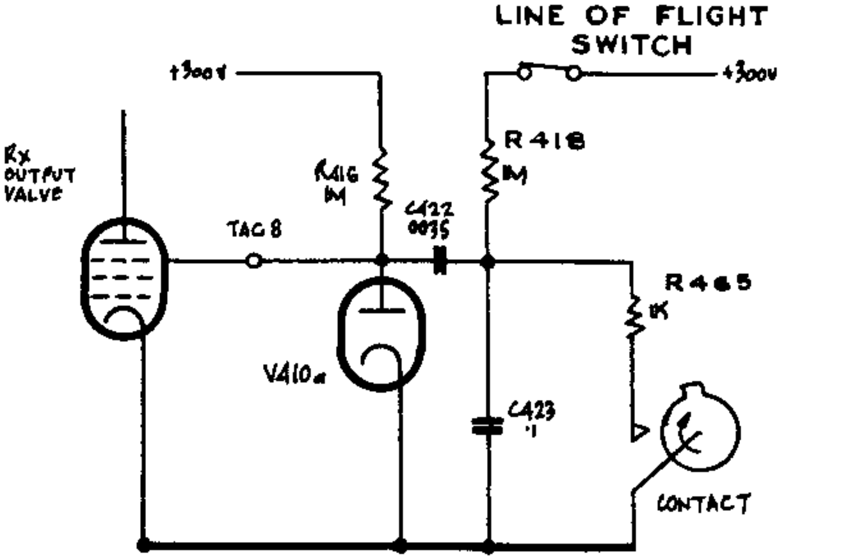
HEIGHT RANGE AND MARKER CIRCUITS.

FIG. 90

FIG. 90

C.D.0896L

"COURSE" AND "TRACK" MARKERS CIRCUIT



BASIC CIRCUIT FOR COURSE & TRACK MARKERS

FIG.91

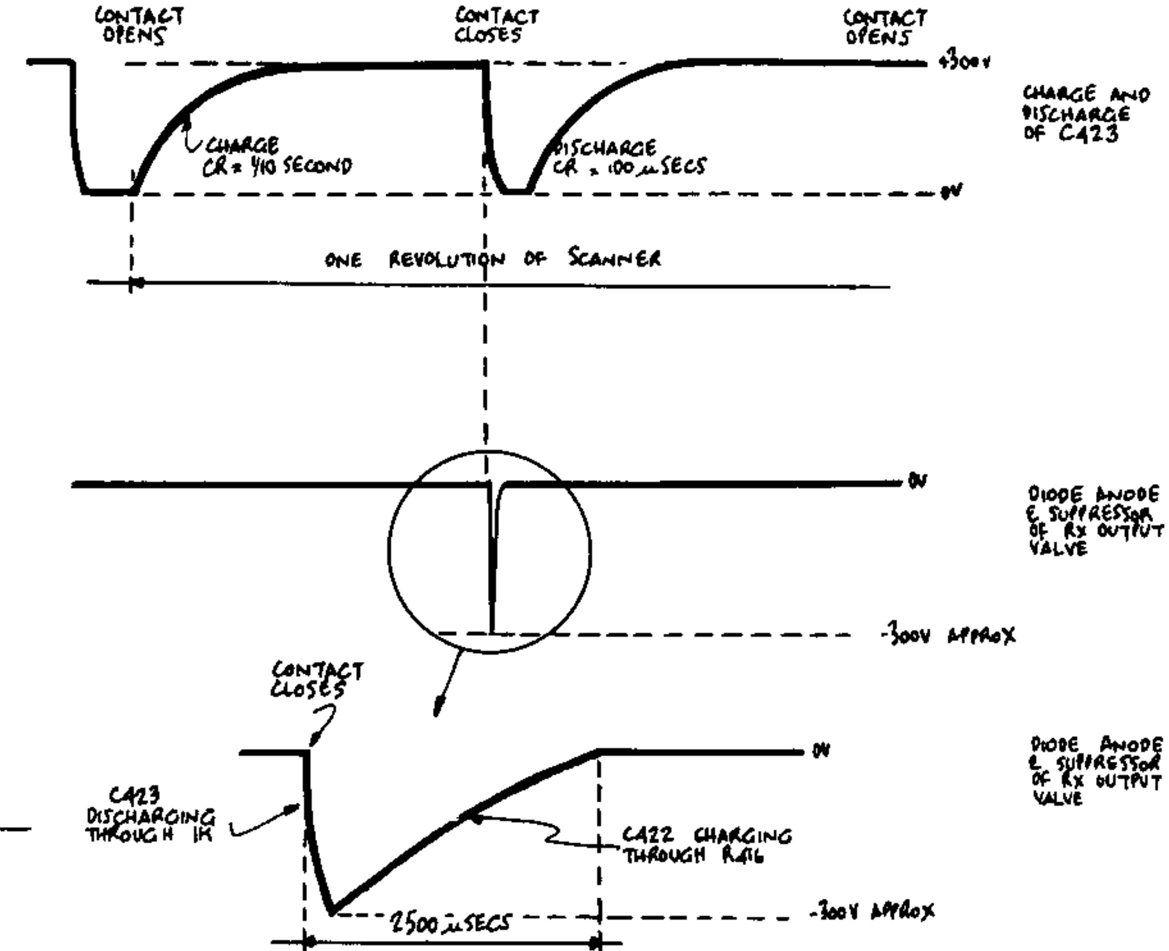
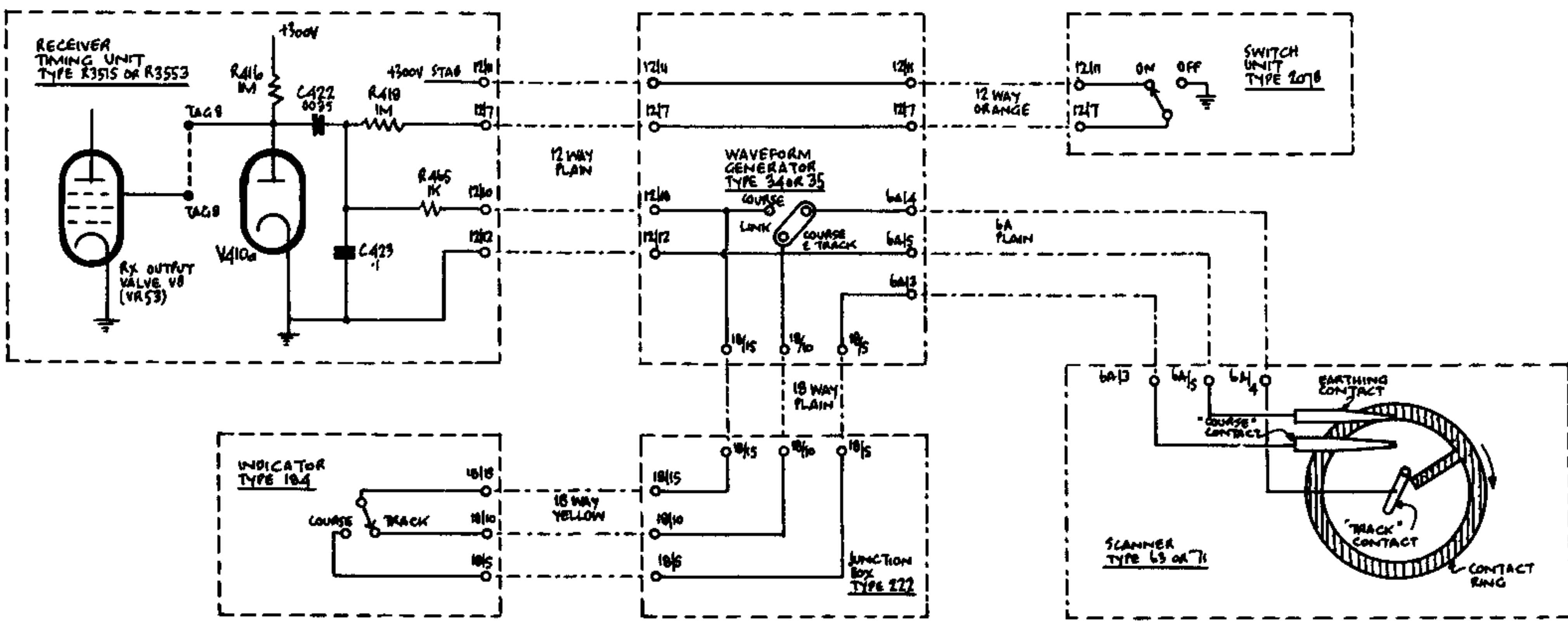


FIG.92



The heading control unit which must be set to "Course" when the setting control is used to operate the "course" repeater motor and to "Track" when the control is being used to operate the "track" repeater motor. This switch must be set to "Auto" once the setting up has been done.

(j) Since the heading marker must move as the aircraft alters course, provision must be made to use the aircraft rotation to move the heading marker through the same angle as the aircraft turns. This is achieved by having the D.R. compass operate a transmitter similar to the one on the heading control unit. This transmitter switches the D.C. connections to a "course" repeater motor in the scanner. The motor armature then drives the magslip stators through a suitable gear train. The gearing used in the D.R. compass drive and in the scanner is such that the magslip stators are displaced through an angle equal and opposite to the aircraft rotation. The P.P.I. map then remains stationary and the marker turns through the same angle as the aircraft as discussed in Chap.4, paras. 171, 172, 173, 174.

(k) Since the D.R. compass transmitter must be disconnected from the "course" repeater motor and the hand-operated transmitter in the heading control unit connected in its place when the heading marker is being set up, the control channel from the D.R. compass to the scanner must be routed through the heading control unit.

(l) Once the track marker contact has been set up an automatic adjustment must be made when the drift setting is altered. This drift setting is made on the Mark 14 bombsight. In order that the bombsight adjustment may result in the correct displacement of the "track" contact in the scanner a flexible drive cable from the bombsight head operates another transmitter in a control unit type 468. The transmitter contacts then switch the D.C. connections to a "track" repeater motor in the scanner. The motor armature then displaces the "track" contact through the appropriate angle by means of a suitable mechanical link.

(m) Since the bombsight transmitter must be disconnected from the "track" repeater motor armature and the hand-operated transmitter in the heading control unit connected in its place when the track marker contact is being adjusted, the control channel from the control unit type 468 to the scanner must also be routed through the heading control unit.

(n) When the heading control unit switch is set to "Course" the control channel from the D.R. compass to the scanner is broken in the heading control unit. A 24V. supply, brought into the heading control unit on a 2-pin cable from the power unit, is then connected to the "course" repeater motor via the hand-operated transmitter in the control unit. Operating the setting knob then operates the "course" repeater motor armature and the magslip stators can be adjusted to bring the heading marker up on the bearing of the aircraft heading. The indicator 184 switch must be set to "Course".

(o) If the heading control unit switch is set to "Track" the control channel from the control unit 468 to the "track" repeater motor in the scanner is broken. The transmitter in the heading control unit is then connected to the "track" repeater motor. If the switch on the indicator 184 is now set to "Track" the marker on the indicator is a track marker. If the bombsight head is set for zero drift the track marker should coincide with the heading marker and the aircraft heading. Hence, to set up the track marker contact zero drift is set on the bombsight head. The heading control unit and indicator 184 switches are set to "Track". The setting knob is then used to bring the track marker up on the aircraft heading. The "track" contact is now correctly adjusted.

(p) The heading control unit switch is now set to "Auto". The D.R. compass transmitter control channel to the "Course" repeater motor is then completed through the heading control unit. Similarly, the bombsight control channel from the transmitter in the control unit type 468 to the "Track" repeater motor is completed through the heading control unit. Any alterations in aircraft heading now automatically cause the magslip stators to turn through the appropriate angle. Any change in the drift setting will now displace the "Track" contact through the appropriate angle.

(q) Which marker appears on the P.P.I. display is determined by the setting of the switch on the indicator 184. The switch unit "Line of Flight" switch must, of course, be closed to get either marker. The indicator switch merely connects the appropriate scanner contact to the circuits in the receiver-timing unit which generate the pulse that is applied to the suppressor of the receiver output valve.

(r) The switch on the switch unit decides whether or not the 300V supply to the circuits in the receiver-timing unit are completed.

421. Summarising, we may gather up the functions of the various controls as follows:-

(a) The "Line of Flight" switch on the switch unit completes the 300V supply to the circuits which form the pulse applied to receive output valve suppressor.

(b) The indicator 184 switch decides whether the "course" or "track" contact in the scanner is connected to the pulse-forming circuits.

(c) The pulse formation is determined automatically by the scanner rotation by earthing the pulse-forming circuits via the contact selected by the indicator 184 switch.

(d) The pulse formation will only produce a marker at the correct position on the P.P.I. display if the magslip stators have beer correctly set up and the "track" contact has been correctly set up.

(e) The magslip stators are set up by setting the indicator switch anc heading control unit switch to "Course" and operating the setting control on the heading control unit.

(f) The "track" contact is set up by setting the indicator switch and heading control unit switch to "Track" and operating the setting control on the heading control unit.

(g) Automatic correction of the magslip stator setting by the D.R. compass, and of the track contact setting by the drift setting placed on the bombsight head, is only introduced when the heading control unit switch is set to the "Auto" position.

Mechanical Details

422. The essentials of the mechanical arrangements in the scanner are shown in fig.93. The contact ring is in a flat metal annular ring mounted on top of the fibre gear wheel which drives the magslip rotor from the scanner shaft The shorting contact is a projection towards the centre, about ½" long and ¼" wide. Mounted above the contact ring by means of a bracket are two metal spring contacts. The outer of this pair is in continuous metallic contact with the contact ring. This spring contact we shall call the earthing conta as it is earthed in the receiver-timing unit. The inner of the pair is returned to the "Course" side of the indicator 184 switch. Every time the scanner rotation brings the shorting contact against the spring tip of the "course" contact the "course" contact will be earthed. R.465 in the receiver timing unit is then earthed until the two contacts separate. The two contact should meet as the scanner goes through the dead-ahead position. The "track" contact, returned to the "Track" side of the indicator 184 switch is mounted above the fibre gear wheel to which the contact ring is attached. It is swivelled on a bearing which coincides with the centre of the gear wheel and ring. This "track" contact has an arm extending back from its bearing which engages in a slotted bush. The bush tracks up and down a worm driving rod. The rod is geared to the "track" repeater motor which is operated by the

transmitter in the control unit type 468 when a drift setting is made on the bombsight head. If the "track" contact is correctly set up the shorting contact earths it when the scanner looks into the direction of the aircraft track.

How the Heading Marker Pulse is Developed

423. The generation of the marker can most readily be understood by studying the basic circuit and waveforms in figs. 91 and 92. When the "Line of Flight" switch is closed on the switch unit the following circuit actions occur:-

(a) 300V. is connected in series with R.418 (1 M.) and C.423 (.1). C.423 then charges up through R.418 towards 300V. The time constant is 100,000 microseconds so the condenser will charge to about 200V. in 1/10 second.

(b) The 300V. supply is also connected in series with R.418 and C.422 (.0035). The other side of C.422 and the suppressor of the receiver output valve will be effectively at earth. R.416 (1 M.) and half of the double diode V.410 form a bleeder across the 300V. line in the receiver-timing unit. As the conducting impedance of the diode is small in comparison with 1 M. the suppressor of the output valve will be only a fraction of a volt above earth potential. C.422 will then also charge up to 300V. through R.418. The time constant is 3500 microseconds. We shall thus have C.422 and C.423 charged up to 300V. in under a half-second.

424. Suppose the indicator 184 switch is set to "Course". When the scanner goes through the dead-ahead position, the shorting contact earths R.465 (1 K.) through the contact ring and earthing contact. C.423, charged to 300V, is now earthed through R.465 (1 K.). The condenser will discharge rapidly as the time constant is only 100 microseconds. The potential at the junction of C.422 and C.423 falls very rapidly from +300V. towards earth potential. At the instant R.465 was earthed the right plate of C.422 was at +300V. and the left plate at nearly OV. That is, the potential difference between the plates was 300V. While C.422 was charging electrons flowed away from the right plate to H.T. leaving the plate positive. Electrons in the dielectric then moved towards this plate and left the opposite side of the dielectric with a deficit of electrons which attracted the electrons from the left plate and left it positive. Electrons from the H.T. supply then flowed to the left plate until it was back at earth potential. When R.465 is earthed electrons flow from earth to the right plate of C.422 until it falls to earth potential. There is then no longer any attraction on the electrons in the dielectric which surge back to their neutral positions. The dielectric then is no longer positive at the left plate and the electrons previously held now swing back into the metal. This leaves the outer surface with an excess of electrons which drives it negative. The result of earthing R.465 is then to drop the right plate of C.422 from +300V towards OV and the left plate from OV towards -300V. The detail above has been given to help the radar mechanic who feels that C.422 should discharge through R.465 without exerting any effect on the suppressor of the receiver output valve.

425. As the left plate of C.422 falls from OV towards -300V., the suppressor of the receiver output valve goes down with it and anode current is cut off on the suppressor. The anode potential then rises sharply to give the leading edge of the heading marker pulse which is ultimately applied to the P.P.I. grid. Since the time constant of C.423 and R.465 is only 100 microseconds the suppressor of the output valve will be carried down quite rapidly. When the fall ceases electrons will flow from the left-hand plate of C.422 through R.416 to H.T. The time constant is 3500 microseconds so we may expect the suppressor of the output valve to have risen to cut-off in something like 2000 - 2500 microseconds. In the meantime anode current is cut off. Hence, the positive pulse at the anode continues for the 2000 - 2500 microsecond period that elapses between the instant that R.465 is earthed via the "course" contact in the scanner and the instant when the suppressor gets up to cut-off again. The P.P.I. grid is then raised by the heading marker pulse for a sufficiently long period to ensure the brightening up of at least one full scan since one scan must occur every 1500 microseconds.

426. As soon as the shorting contact is carried clear of the "course" contact by the scanner rotation, R.465 is again floating. The 300V. supply is then again connected across C.423 and R.419 so C.423 again charges up to +300V. At the same time the right plate of C.422 will be charging towards +300V. through R.419. Both condencers have ample time to complete their charging before the scanner has completed another turn to repeat the earthing of R.435. C.423 provides an effective earth for pick-up which might otherwise be applied to the suppressor of V.8 and thus be mixed with the signals and markers.

Development of the Track Marker Pulse

427. If the indicator switch is set to "Track", the only difference is that R.465 is now earthed when the shorting contact meets the "track" contact. If there is zero drift this should occur when the scanner goes through to dead-ahead position, just as before. If there is drift, R.465 may be earthed either before or after the instant the scanner passes through the dead-ahead position, depending on the wind direction. If the "track" contact has been correctly aligned, the track marker will appear at the bearing on the P.P.I. which gives the aircraft track.

The Action of the Repeater Motors

428. The repeater motor operates on the principle that if a piece of soft iron is free to move in a magnetic field it will experience a torque which tries to bring the cross-section of the iron at right angles to the field. The magnetic lines of force emerge from the north pole of the magnet or electromagnet and pass across the intervening gap to the south pole. If it is an air gap the lines of force will pass straight across in the centre and will bulge outside on both sides due to mutual repulsion between themselves. That is, the lines will be as short as mutual repulsion between themselves will permit. If a piece of magnetic metal like soft iron is now introduced into the field the lines of force will all try to crowd into the iron as it offers a higher permeability than air. Unless the iron is perpendicular to the field the lines will be distorted. In the attempt to shorten as much as possible they exert a turning force or torque on the iron. If the iron is suitably suspended it will turn until the total path in the iron is as long as possible but the total line length is as short as possible.

429. In the repeater motor we have a cylindrical armature with a rectangular soft-iron central section. This armature is mounted in suitable end bearings. The field is developed by means of current from a 24V. supply passed through a suitable field winding arrangement. This field winding actually comprises three windings with one point common. If +24V. is connected to one free end and -24V. to another free end electrons will flow through the two windings thus connected in series. If +24V. is connected simultaneously to two free ends and -24V. to the other free end, electrons will flow through the one winding to the common point and then divide equally the two windings leading to the +24V. ends. If -24V. is connected simultaneously to two free ends and +24V. to the third one electrons will flow from both -24V. ends through the associated windings to the common point. There the two streams will converge and flow through the third winding to the +24V. end. Each winding may be regarded as an electromagnet developing a field across its pole faces. The poles thus developed produce fields across the gap in which the armature is pivoted. The separate fields will add vectorially to produce a resultant field. This resultant field will then decide the position in which the armature comes to rest so as to provide the maximum path length through the soft iron and the shortest total path. As the D.C. connections to the free ends of the windings are switched the polarity of the separate fields is varied. The direction of the resultant field is then varied and the armature is pulled into a new position. If a suitable mechanical link is provided the torque developed by the resultant field will not only pull the armature through the rotation angle of the resultant field but will also provide the motive power for displacing some other mechanism.

Control Action of the D.R. Compass

430. A 24V. supply from the aircraft D.C. supply is taken to the D.R. compass box where it is applied to the transmitters used to operate the various repeater compasses and the "course" repeater motor. The connections from the transmitter cams are brought ultimately to the free ends of the respective repeater

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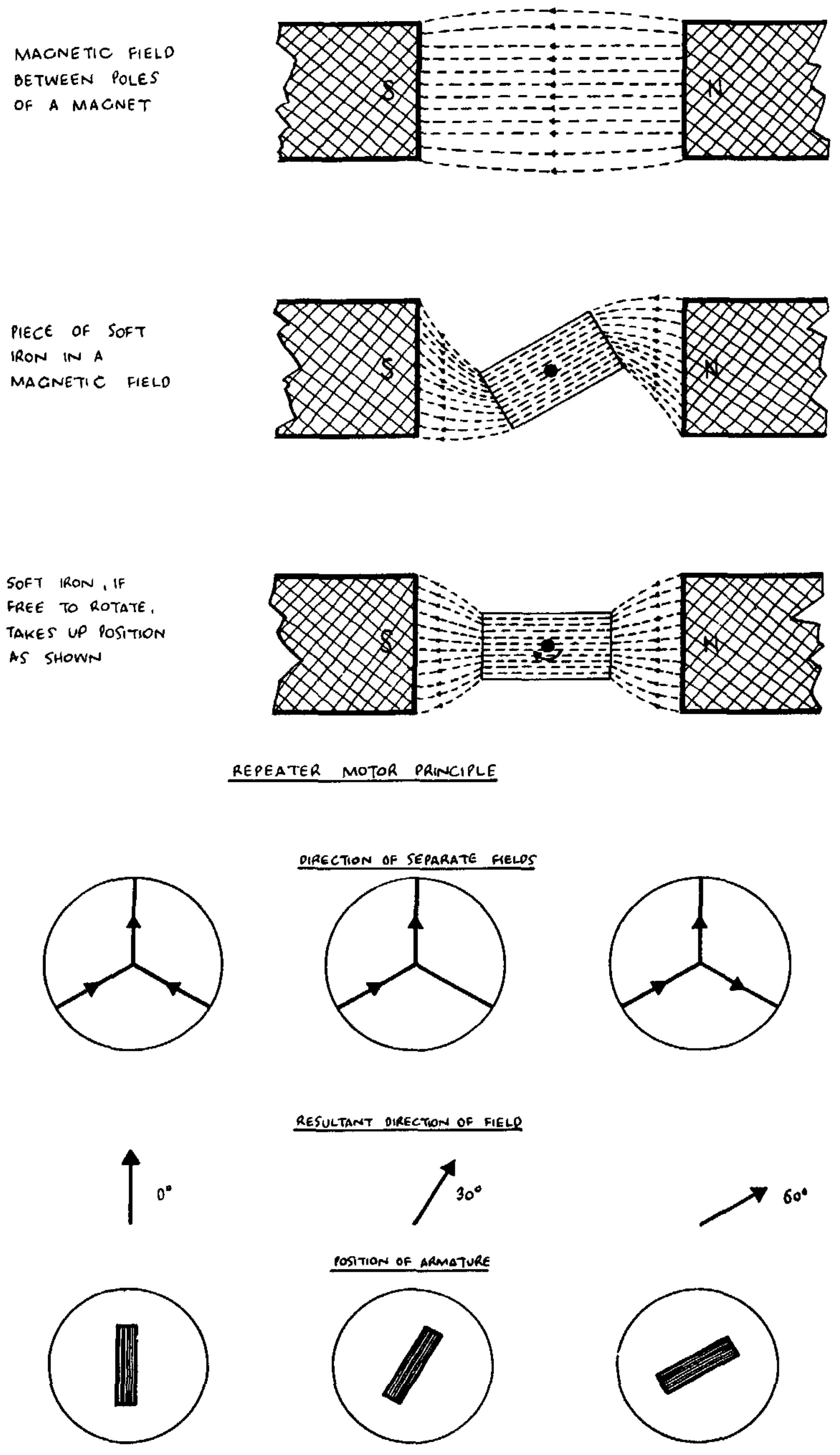

FIG. 94

motor armature windings. In the case of the "course" repeater motor the connections are brought to the heading control unit (see fig.111) on a 4-pin plain from the D.R. compass terminal block. Inside the heading control unit connections are made via the switch to pins 1, 2 and 3 of the 6A violet to the scanner. If the switch is in the "Auto" position the connections to these pins are completed. At the scanner end of the cable these pins are connected to the three free ends of the "course" repeater motor field winding.

431. If the aircraft turns the relative movement between the compass bowl and the needle is used to operate the various transmitters. The connections to the red, green and blue terminals of the windings then go through the following sequence:

Terminal	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5
Red	+	+	+	+	+		-	-	-	-	-		+	+	+	+	+
Black or Blue	+		-	-	-	-	-		+	+	+	+	+	-	-	-	-
Green	-	-	-		+	+	+	+	+		-	-	-	-	-		+

+ indicates connection to + 24V.
- indicates connection to - 24V.
Blank indicates that terminal is floating.

It will be noted from the above table that the sequence consists of 12 different combinations which then repeat themselves. A turn of $\frac{1}{2}^{\circ}$ by the aircraft causes the transmitter to change from its position when the turn commenced to the next one on the table. The whole sequence will then occur for a turn of 6°.

432. As the transmitter cams switch from any one of the above positions to the next in the series the resultant field operating on the repeater motor armature turns through 30°. The armature is then pulled through 30° by the resultant torque. This movement is applied to the magslip stators through a 60:1 all metal gear train. A $\frac{1}{2}^{\circ}$ aircraft turn results in shift of one position on the transmitter. This turns the repeater motor armature through 30°. The 60:1 reduction gear then displaces the magslip stators and the timebase through $\frac{1}{2}^{\circ}$. The timebase is then displaced through the same angle as the aircraft turn and the map therefore remains stationary. As the rotation of the magslip stators has displaced the scan occurring as the scanner goes through the dead-ahead position by an angle equal to the aircraft turn, the heading marker is rotated through the aircraft turn. The new position of the marker will then indicate the new aircraft heading provided it had been correctly set up initially.

Setting Up the Heading Marker

433. When the heading control unit switch is set to "Course" the D.R. compass transmitter connections to the switch are left floating. The + and - 24V. connections coming from the power unit to the heading control unit via the 2B plain and thence to the switch are connected to the transmitter in the unit and its cams are connected to pins 1, 2 and 3 on the 6A violet to the scanner. The field windings of the "course" repeater motor are now connected to these cams. Turning the setting knob switches the supply connections through the same sequence of 12 combinations as we obtain from the D.R. compass transmitter. The setting control thus enables a manual rotation of the magslip stators through 360°. By means of this control the timebase sweep appearing when the scanner goes through the dead-ahead position may be made to appear anywhere on the P.P.I. Setting up the heading marker and H.2.S. map then merely involves the following routine:-

(a) Set bearing ring on P.P.I. to aircraft heading as given by master compass.
(b) Set scanner turning with scanner motor switch on switch unit.
(c) Set "Line of Flight" switch on switch unit to "ON".
(d) Set indicator 184 switch to "Course".
(e) Set heading control switch to "Course".
(f) Operate setting knob on heading control unit till the heading marker flashes up along the bearing ring pointer.

The track marker can then be set up as outlined in para.436.

Bombsight Control of the "Track" Contact

434. It was pointed out in para.422 that the track contact is swivelled on a bearing coinciding with the centre of rotation of the contact ring and that an arm extending back from this bearing engages a slotted bush. This bush tracks up and down a worm driving rod which is geared to the "track" repeater motor. Rotation of the motor armature then results in a rotation of the "track" contact about its bearing. In order that the track marker may give the correct aircraft track this contact must be so placed that the shorting contact meets it when the scanner is looking in the direction of the aircraft track. This means that contact must be made when the scanner is off the dead-ahead position by the drift angle. If there is no cross wind the drift is zero and heading and track are coincident. Under these conditions the shorting contact must meet the "track" and "course" contacts simultaneously. If there is a cross wind it must be allowed for in both bombing and navigation.

435. The drift is found by means of the bombsight computor and is set on the sighting head by means of a flexible drive from the computor. This flexible drive is intercepted and used to operate a transmitter in the control unit type 468. This control unit is mounted at the bottom right hand of the bombsight. The + and - 24V. D.C. connections to the transmitter in the control unit type 468 are taken through the heading control unit via the switch. When the switch is set to "Auto" connections are made from the 2B plain to pins 5 and 6 of the 6B green from the heading control unit to control unit type 468. The cams on the transmitter are connected to pins 1, 3 and 4 on the 6B green. In the heading control unit cross-connections are made to pins 4, 5 and 6 of the 6A violet to the scanner. At the scanner end these pins are connected to the three free ends of the "track" repeater motor field windings. If the switch is set to "Auto" and any drift adjustment is made at the bombsight, the transmitter in the control unit 468 is operated and the D.C. connections to the "track" repeater motor are switched in accordance with the sequence outlined in para.431. The armature rotation drives the linkage to the "track" contact and causes it to rotate about its bearing through the drift angle setting made at the computor.

Setting Up the Track Contact

436. When the heading control switch is set to "Track" the + and - 24V. connections to the transmitter in the control unit type 468 are broken. The "track" repeater motor field winding terminals are now connected to the cams of the transmitter in the heading control unit. Operation of the setting control will now operate the track repeater motor through the range of movement permitted by the worm drive arrangement in the scanner. The following routine will serve to set up the track contact in the air after the heading marker has been aligned. These steps could logically follow after step (f) in para.433.

(g) Set indicator 184 switch to "Track".
(h) Set heading control unit switch to "Auto".
(i) Set zero drift at bombsight computor. If track marker coincides with bearing ring pointer no further adjustment is required. Heading control unit switch can then be left at "Auto" and the P.P.I. radial marker should indicate correct track or heading depending on selection made with switch on indicator 184.
(j) In practice the track marker will not coincide with the bearing ring pointer in (i). Set the heading control unit switch to "Track". Operate the setting knob until the track marker does coincide with the bearing ring pointer.
(k) Switch back to "Auto".
(l) When the correct drift is set at the bombsight computor the track marker should be displaced from the bearing ring pointer (i.e., the heading) by the correct drift angle.
(m) The H.2.S. operator can now use either the track or heading marker by setting the indicator 184 switch to the desired marker.

It should be possible to move the track marker + or - 60° with respect to the heading marker in step (j).

Marker Difficulties

437. If any two of the three field connections of a repeater motor are interchanged, the direction of marker displacement will be the reverse of what it should be. If only two of three connections are made it may operate when the + and - 24V. is connected to the two terminals. If one of the three is connected in error to the blank pin 2 on the 4-way plain or the blank pin 2 repeated on the 6B green, this difficulty will arise. Dry joints have also been a source of trouble.

438. Inadequate lubrication, wear, etc., may cause sticking of the repeater motor armature at some point or points in its rotation. Checks must always be on installation, inspections, and after scanner changes that the heading marker follows without slipping or binding throughout 360°. A similar check should be made that the track marker can be displaced + or - 60° from the heading marker with the setting control. Details of scanner checks for direction of rotation and following are given in Chapter 12, paras. 962 - 965.

439. Another difficulty which may be experienced is a heading marker flashing up when the scanner is passing through a position other than the dead-ahead position. This difficulty can be cleared by loosening the three bolts that hold the washer which clamps the paxolin disc on which the contact ring is mounted. When these bolts are loosened the paxolin disc and the contact ring which is rivetted to it can be moved relative to the gear wheel below. By setting the stationary scanner in the dead-ahead position and rotating the disc and ring until the shorting contact meets the earthing contact on the leading edge, the correct clamping position is located. The bolts can then be tightened to fix the position of the contact ring relative to the driving gear beneath it. With the heading marker coming up as the scanner goes through the dead-ahead position the normal setting up procedure can be carried out in the air.

440. Failure of markers to form or very faint markers may often be caused by leakage in cables due to moisture. Reference to fig.93 will show that continuity and insulation tests can be made very readily by disconnecting the 12-way plain at the receiver-timing unit. A check across pins 7 and 11 with the "Line of Flight" switch on the switch unit closed will establish continuity of the +300V. channel. Meggering with the switch open will provide a leakage test. A check across pins 10 and 12 will serve to establish continuity in the earthing channel. One mechanic should rotate the scanner by hand while the other uses the meter on the cable. Continuity should be established one per revolution regardless of whether the indicator switch is on "Track" or on "Course". By using the megger with the scanner set to break continuity a leakage test can be made.

441. No marker will be formed if pin 12 is not earthed in the receiver-timing unit as R.465 will then always be floating. A check should be made that pin 12 is earthed if trouble is experienced.

The Course-Track Link in the W.F.G.34

442. This link must be in the "Course and Track" position when the W.F.G.34 is used in either a Mark IIC or Mark IIIA installation. Tracing out the circuit in fig.93 will show that the appropriate scanner contact will then be used to earth R.465 when the indicator 184 is on either position.

443. Should the link be left on the "Course" position, R.465 is connected through to the "Track" contact in the scanner at all times regardless of the indicator switch position. When the switch is set to "Track", the usual track marker will appear. If set to "Course", R.465 is also connected to the "Course" contact in the scanner via the switch. Hence, for large drift angles, the P.P.I. display may show both a track marker and a heading marker.

444. If the W.F.G.34 and Indicator 184 are used with scanner type 65 or type 3, the link should be in the "Course" position and the indicator switch in the "Track" position to obtain a normal course marker. Should the link be in the "Course and Track" position, the marker will still appear provided the indicator switch is on "Track". If the indicator switch is on "Course", no marker will appear in "Course" or "Course and Track" positions of the link. This is because

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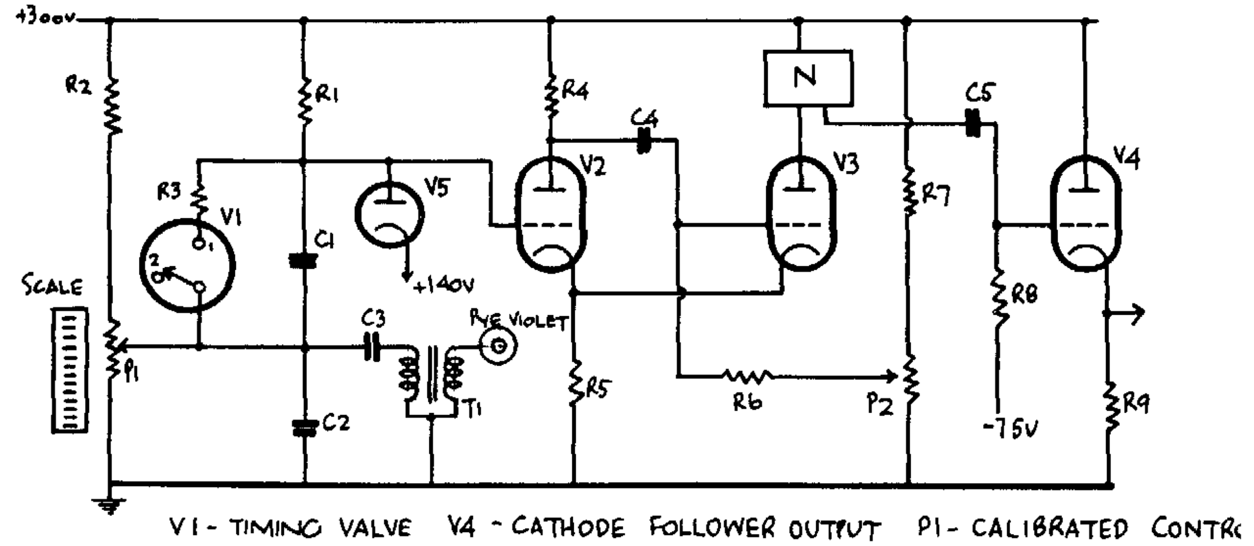
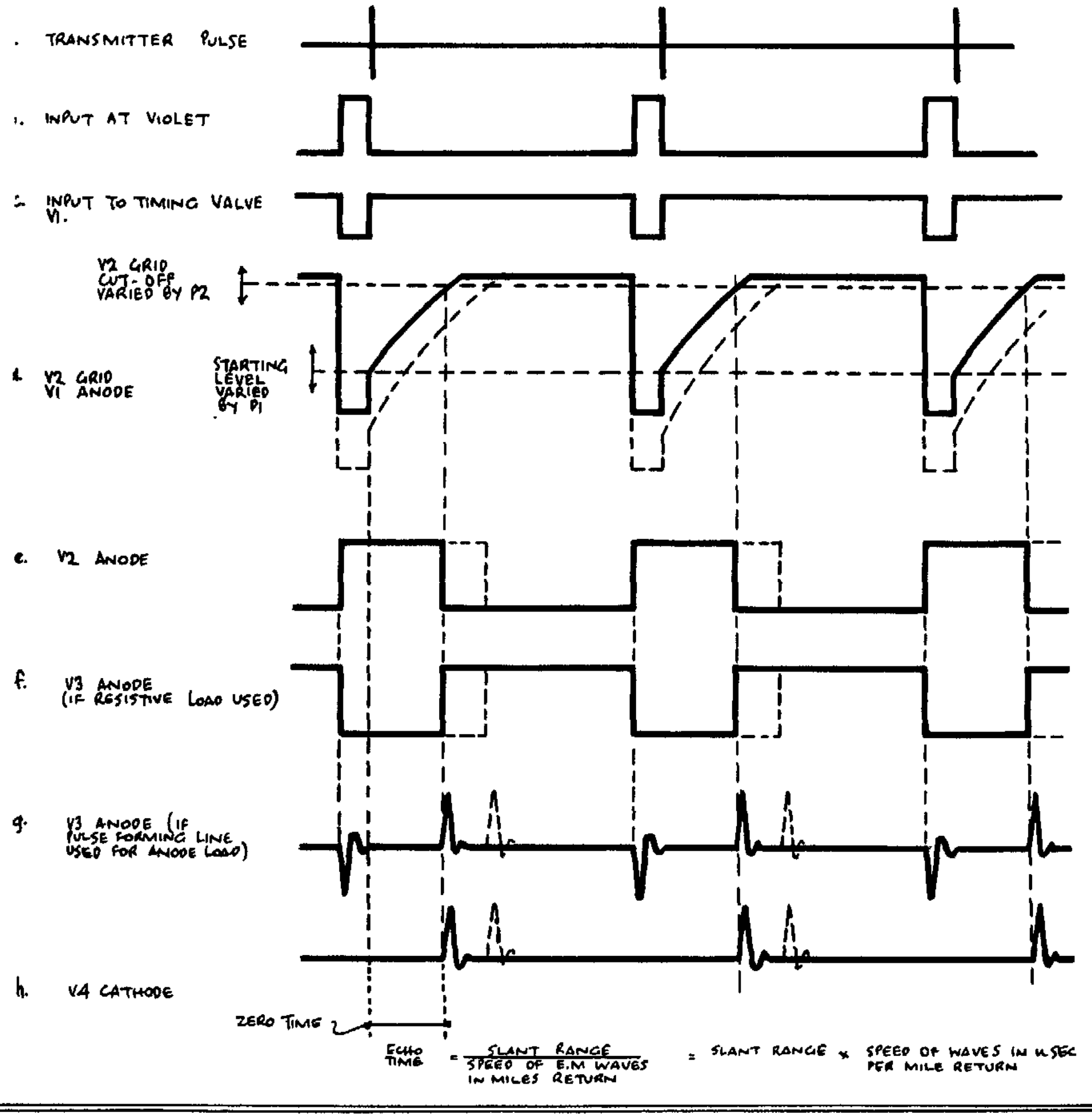
FIG 95

FUNDAMENTALS OF H_2S HEIGHT AND RANGE MARKERS



V1 - TIMING VALVE
V2, V3 - FLIP - FLOP
V4 - CATHODE FOLLOWER OUTPUT
V5 - LIMITER
N - PULSE FORMING NETWORK
P1 - CALIBRATED CONTR[illegible]
P2 - ZERO ADJUSTMENT
C1, R1 - TIMING CR



the indicator switch short circuits the scanner contact with the link to "Course", and leaves it floating with the link to "Course and Track". Hence to obtain a course marker with a Scanner Type 65 and W.F.G. Type 34 and Indicator 184, place the indicator switch to "Track".

The Basic Height and Range Marker Circuit

445. To understand the method used to measure range and height with H.2.S. it is essential that the radar mechanic understand the principle of the timing circuits employed. A basic circuit with descriptive waveforms is shown in fig.95. As a prelude to a study of this basic circuit it may be helpful to gather up what is involved in measuring height or range with a calibrated marker control. We know that echo time is always given by range in miles $\div$ speed of e.m. waves. If we express range in miles and echo time in micro-seconds we must express speed in miles return per microsecond. If we express speed in microseconds per mile return, i.e., 10.7 microseconds per mile return, we may write echo time from the formula

$$t(\text{microseconds}) = \text{range (miles)} \times 10.7$$

We may rewrite this formula to solve for range

$$\text{Range (miles)} = \frac{t\ (\text{microseconds})}{10.7}$$

Range will obviously be target distance, i.e., slant range. In the case of height measurement we can simply substitute height for range. From this formula it follows that if we can measure echo time we can readily determine range or height from the above formula. The H.2.S. method of measuring range and height actually measures echo time but calibrates the scales to read range by dividing the corresponding time values by 10.7.

446. Since we are measuring time we must have a time zero. This zero must be the instant when the transmitter fires. Any time measuring circuit must then start to measure from that time. This suggests the need for some form of electronic switch which closes the time measuring circuit when the transmitter fires. In our basic diagram we have shown this switch, V.1, as an actual switch since its function is only to determine the start of our time measurement by opening the discharge path across the timing condenser, C.1. R.3 represents the conducting resistance of V.1 when in grid current. As C.1 is connected between the anode and cathode of V.1 the valve acts as a discharge path when conducting and as an open circuit when cut off. Obviously, we must have some electrical impulse that will open our switch at zero time by cutting V.1 off. For this purpose we use the positive-going 20 microsecond pulse taken from the cathode of the VT.60A in the modulator multivibrator. The back edge of this pulse coincides with the back edge of the modulator priming pulse which fires the trigger valve, and hence, indirectly the transmitter. We actually cut V.1 off on the cathode to open our switch so require a pulse with the back edge positive-going. We therefore invert the positive input at the violet Pye plug on the receiver-timing unit with T.1. The amplitude is stepped down from about 40V. to about 16V. On the leading edge of the pulse the cathode is taken down which is equivalent to driving the grid up. The 16 volt swing is sufficient to take the valve into grid current. C.1 can then discharge completely through the valve. At the end of the 20 microsecond pulse the cathode comes back up and cuts the valve off, i.e. the switch opens.

447. When the switch opens C.1 is completely discharged with both plates at the decoupled potential of the slider of P.1. We now have applied to the time constant formed by C.1 R.1 a charging voltage of 300V. - slider potential. C.1 will charge exponentially through R.1 towards a terminal voltage of +300V. As the charging proceeds the upper plate of C.1 becomes increasingly positive and the grid of V.2 rises exponentially with it. We may note at this point that the terminal voltage of 300V. can never be reached. V.5 and R.1 form a network between +140V. and +300V. The conducting impedance of V.5 will be so low in proportion with R.1 as soon as the top plate of C.1 reaches +140V. that V.5 and R.1 will form a bleeder which fixes the maximum potential reached by the top plate of C.1 at about 140V. Hence, C.1 charges towards +300V. but is prevented from going above about +140V. by the limiter, V.5.

448. We must now examine the cathode coupled flip-flop circuits of V.2 and V.3. We note that V.3 grid is returned to a variable positive potential. This potential will decide how much current V.3 passes through the common cathode load, R.5. Transferring our attention now to V.2 grid we note that it must rise and fall with the top plate of C.1. Hence, when the leading edge of the 20 micro-second pulse brings V.1 into conduction to short circuit C.1, V.2 grid falls. This fall will carry V.2 grid down. The anode potential then rises and carries up V.3 grid with it to bring V.3 into conduction. The current passed by V.3 through R.5 raises the common cathode potential to about 130 - 140V. which is well positive to V.2 grid potential. V.2 is then cut off on the grid every time V.1 is opened on the leading edge of the 20 microsecond pulse applied to V.1 cathode. V.3, on the other hand, is always brought into conduction at the same time.

449. When the back edge of the 20 microsecond pulse cuts V.1 off to open the short circuit across C.1, V.2 grid starts to rise from the level at which the upper plate of C.1 begins its exponential climb. This starting level is the decoupled slider potential of P.1. Suppose this value is +40V. Now if the common cathode potential of V.2 and V.3 is 142V., V.2 grid will have to climb to about 134V. before the valve can start to conduct. When this level is reached V.2 will start to pass current and the anode will fall. This fall will be impressed on V.3 grid so V.3 will pass less current through R.5. This reduces the bias on V.2 so it conducts more heavily and drives V.3 grid down still more. The cycle is cumulative and quickly cuts V.3 off and brings V.2 on. <u>Note that this change-over occurs when V.2 grid crosses cut-off and that this cut-off potential is fixed by P.2 since V.3 grid potential fixes the current passed through R.5 by V.3.</u> Before noting the effect of this change-over at V.3 anode we may recall that V.2 grid can continue to rise to the limiting level set by V.5. The actual circuit design is such that V.2 cut-off is a few volts below the limiting level.

450. When V.2 grid crosses cut-off and the fall at V.2 anode cuts V.3 off on the grid V.3 anode rises. If V.3 had a resistor for its anode load the anode waveform would obviously be a square wave. The positive-going phase would begin when V.2 grid crossed cut-off. It would terminate on the leading edge of the 20 microsecond pulse when V.2 grid was carried down with the discharge of C.1. Instead of only a resistor we have a pulse-forming network. This network achieves a result very similar to the effect of a short CR. When V.3 anode falls on the leading edge of the 20 microsecond pulse the negative-going edge of When V.2 crosses cut-off and cuts off V.3 the rising edge of the square wave at V.3 anode is converted into a positive pip. We note then that we get a positive pip at V.3 anode every time the rising exponential carries V.2 grid above cut-off.

451. If we had put our pulse-forming line in V.2 anode instead of V.3 anode we should have a negative pip every time V.2 grid is carried above cut-off. phase inverting with a transformer we could convert the negative pip into a positive one. In the actual range marker circuit we use the arrangement shown in our basic circuit. In the height marker circuit the pulse-forming line is in V.2 anode and a transformer is used to invert the negative marker pip.

452. Looking next at V.4 we note that it is a cathode follower with the grid returned to a negative bias of about -7.5V which is sufficient to hold the valve cut off unless a positive-going signal is applied. Hence, when the negative pip is applied there is no output at the cathode. When the positive pip appears the valve passes current and the cathode potential rises to provide a positive-going marker at the cathode. In the case of the actual height marker circuit with the pulse-forming line in V.2 anode the result is the same since the pips at the anode are in opposite phase but these are inverted with a transformer before applying them to V.4 grid. In each circuit we then obtain a positive <u>pip at V.4 cathode every time V.2 grid crosses cut-off. This positive pip is our marker pulse.</u>

453. In the case of the range marker it is mixed with the signals and applied to the P.P.I. grid as a positive-going pulse. As we have one marker pip for every 20 microsecond pulse we have one on every timebase sweep. These positive

pips will appear at the same point in the timebase sweep as long as we do not vary the settings of P.1 and P.2. As each pip forms a bright dot on the scan at some constant distance from the centre the 670 dots so formed will merge to form a range marker ring. This is the P.P.I. range marker ring.

454. The range marker is also applied with the signals to the height tube deflecting plates where it appears as a blip to the right.

455. The height marker is applied to the opposite deflecting plate in the height tube so appears as a blip to the left.

Calibration of the Marker Scales

456. We have seen that we can start C.1 charging at zero time, i.e., on the back edge of the modulator priming pulse, and can produce a positive-going marker pip after a time delay equal to the time taken by the upper plate of C.1 to rise exponentially from P.1 slider potential to V.2 cut-off potential. We might restate the delay time as the interval in which C.1 charges to a potential difference given by V.2 cut-off - P.1 slider potential. How long this time delay will be depends on the following factors:-

(a) The number of volts potential difference that must be developed across C.1.
(b) The time-constant of C.1 and R.1.
(c) The charging voltage applied.

Factor (a) is governed by both the starting level, i.e., P.1 slider potential, and the value of V.2 cut-off potential which depends on the setting of P.2. Hence the settings of P.1 and P.2 determine factor (a). Factor (b) can be predetermined by the components selected. Factor (c) is given by H.T. voltage P.1 slider potential. If we use a stabilised H.T. supply to give a fixed H.T. voltage we may say that factor (c) depends entirely on the setting of P.1. It follows then that if we use a stabilised H.T. supply, a fixed time constant and a preset value of P.2., the delay between the back edge of the modulator priming pulse and the appearance of a marker pip on V.4 cathode will depend entirely on the setting of P.1.

457. Since this time delay depends entirely on P.1 when P.2 is preset it is possible to calibrate the movement of P.1 in terms of time. By dividing the corresponding time intervals by 10.7 we can substitute height or slant range in miles. Let us assume that we have a signal generator triggered on the back edge of the modulator priming pulse which provides a pip after a known variable delay which is calibrated in either thousands of feet or miles. Suppose we had a range of 0 - 30 miles on the control calibrated in mile intervals. This would really mean time delays calibrated in 10.7 microsecond intervals. If we fed the output into the H.2.S. set we could then put rings on the P.P.I. which represented slant ranges of 1, 2, 3 ....30 miles. Since we are discussing the range marker P.1 really represents the range potentiometer on the switch unit. This control is a large wire wound potentiometer. Its wiper and a drum carrying a scale move as the range control is operated. The scale moves past a fixed index. Suppose we started with a blank scale on this range drum. If we set the signal generator control for a 1 mile delay a ring would appear on the H.2.S. P.P.I. If we now adjusted the range control until our range marker ring coincided with it we could put a line on the blank scale opposite the fixed index and label it 1 mile. We could then continue until the whole scale was calibrated from 1 - 30 miles.

458. If we arranged to have R.1 switched we could put in a larger value so that the same settings of P.1 gave longer delays. This is done in the H.2.S. range marker circuit to obtain a range of delays up to 1070 microseconds or 100 miles. This scale could be calibrated in the same way.

459. If we think in terms of the height market P.1 becomes the height control. Actually, we use the same wire-wound potentiometer again but the height control knob rotates another wiper and another scale. The scale moves behind a window with an index line across it. If we set the signal generator control for a 1000 ft. delay and fed the output to the height tube, we would get a blip on the scale. We could then adjust the height control until the height marker

coincided with the signal generator blip. A line could then be drawn on the blank drum under the index line and labelled 1000 ft. In the same way the scale could be calibrated in 1000 ft. intervals from 1000 - 40,000 ft.

460. We have seen how we could calibrate range scales of 0 - 30 miles and 0 - 100 miles, and a height scale of 0 - 40,000 ft. It must be remembered that these calibrations will only hold so long as all the other factors affecting the time taken by C.1 to charge through the potential difference between P.1 slider volts and V.2 grid cut-off volts remain constant. Scales prepared for one switch unit would only be applicable to other switch units if the following conditions were fulfilled:-

(a) H.T. voltage was always the same.
(b) Timing CR. for any range had the same value in all sets.
(c) V.2 grid cut-off was the same in all sets.

Condition (a) can be fulfilled by using a voltage stabiliser stage. Condition (b) can be fulfilled by providing a small trimmer for C.1 in both height and range timing CR's. Condition (c) cannot be preset readily as valves show appreciable tolerance. Hence, we have the need for the second adjustment, P.2. In the range marker circuit this control is called the range zero. It appears as a screw-driver preset on the switch unit labelled "Beacon Zero". In the height marker circuit we have a similar preset which also appears as a screw-driver preset on the switch unit, this time labelled "Altitude Zero". These controls must not in any sense be regarded as fine adjustments. They have only one possible correct setting. That setting is the one which makes V.2 grid cut-off equal to the value used in the standard set on which the prototypes of the mass-produced scales were prepared. Calibrating a scale assumes a specific value for V.2 grid cut-off. Scales will only read perfectly true if V.2 grid cut-off has that value. The height and range zero are provided to permit a limited range of adjustment on V.2 cut-off potential. There can, however, only be one setting for each of these controls for which the scales will be perfectly true. These settings are the ones which cause V.3 to pass such a current that the voltage drop across the common cathode load brings V.2 cut-off to the value used in calibrating the original scales. Obviously, it will be necessary to check these adjustments from time to time. How these checks may be carried out will be discussed in para.481 - 486.

461. It may occur to the radar mechanic that the scales will only remain correct as long as the value of the timing CR's remain fixed. This calls for accurate values, i.e., very narrow tolerances, and freedom from change due to ageing and due to variations in temperature. The resistors used have tolerances of ± 1% and ± 2%. The condensers have tolerances of ± 2%. As has been previously pointed out a trimmer is provided for each timing capacity. These trimmers are of the variable air tuning condenser type and are preset by the manufacturer. Three condensers are actually employed in each CR, two fixed and the one adjustable. By suitably balancing positive and negative temperature co-efficients it is possible to get a reasonable independence of temperature.

462. Before examining in more detail the actual height and range marker circuits shown in fig.90, we shall gather up the following major points with regard to the operation of the range marker circuit on the 30 and 100 mile marker ranges:-

(a) The fundamental principle is a calibrated time delay control.
(b) The variable time factor is the time taken by a timing capacity to charge from a variable starting-point to a preset terminal voltage.
(c) The preset terminal voltage is the grid cut-off voltage of the first valve in a flip-flop.
(d) This terminal voltage is adjustable over a range of 7 - 8 volts by means of a zero control.
(e) The effect of the zero control is to vary the potential to which the grid of the second flip-flop valve is tied, thereby varying the cathode current passed by the valve. This current through the common cathode load fixes the cathode potential of the first flip-flop valve during its cut-off state. The terminal voltage which the grid must reach is the cathode potential - the grid base.

(f) The need for the zero control is to permit adjustment of the terminal voltage to the value used in calibrating the prototype scales. Unless the terminal voltage is set to this value the scale will not track perfectly.

(g) For a preset terminal voltage the delay time is determined by
  (i) Charging voltage = H.T. - starting level.
  (ii) Time constant of timing CR.

(h) In order that the same scale may apply to different sets the timing CR's used on any particular range must have the same value in all sets. This is covered by providing a trimmer condenser which is preset by the manufacturer.

(i) The same H.T. level must also be used if identical scales are going to apply to different sets. This requires a stabilised H.T. supply.

(j) With H.T. level, timing CR. value and terminal voltage, all at the values used in the standard set used for initial scale calibration, the delays for a given value of the starting level must be the same in all sets and must be equal to the value in the standard set. This value is shown where the scale crosses a suitable index.

(k) The actual time delay thus measured can be expressed as slant range or height since echo time is proportional to distance between aircraft and reflecting surface.

(l) Actual measurements are made by varying the starting level with the calibrated delay control until the marker forming at the end of the delay coincides with the echo whose distance is to be measured. If the marker and the echo coincide the variable delay must have the same value as the echo time since the condenser charge began when the transmitter fired. Since the delay is expressed in distance the height or range can be read directly from the calibrated delay control.

(m) The marker itself is a positive-going pulse taken off from a cathode follower output valve. The input to the cathode follower has a negative-going pip coincident with the leading edge of the 20 microsecond triggering pulse, and a positive-going pip coincident with the instant the first flip-flop grid is carried above cut-off by the timing exponential. The negative pip is eliminated by applying 7.5V. negative bias to the grid of the cathode follower.

(n) The pips are formed by using a pulse-forming line in the anode of the second flip-flop for the range marker and in the anode of the first flip-flop for the height marker. The pulse line serves to convert a square wave to pips. It gives a shape to the pips which can be passed through numerous succeeding circuits without appreciable rounding off and widening. Had a short CR been used instead, the sharp leading edge and exponential trailing edge would cause gradually rounding off and widening as the pip went through the later stages. In the height marker circuit a pulse transformer is used to invert the pips formed at the first flip-flop anode to get the correct phase on the cathode follower grid. This change is made in the height marker circuit as a square wave output has to be taken from the anode of the second flip-flop. This square wave is required in the development of a 10 mile range marker which measures ground range instead of slant range.

(o) Since we want to have three different delay scales for range measurement while using the same delay control (range control), we must arrange that the same position of the control, i.e., the same starting-level, gives three different delays. This is accomplished by altering the CR of the timing circuit by switching the value of the resistor used. Since the delays for any setting of the control must be in the proportion of 10:30:100 the value of the resistor is least on the 10, greater on the 30, and greatest on the 100 mile range. The changes are made by a relay which is operated by the scan-marker switch on the switch unit. It switches the anode load of the range marker timing valve, V.406.

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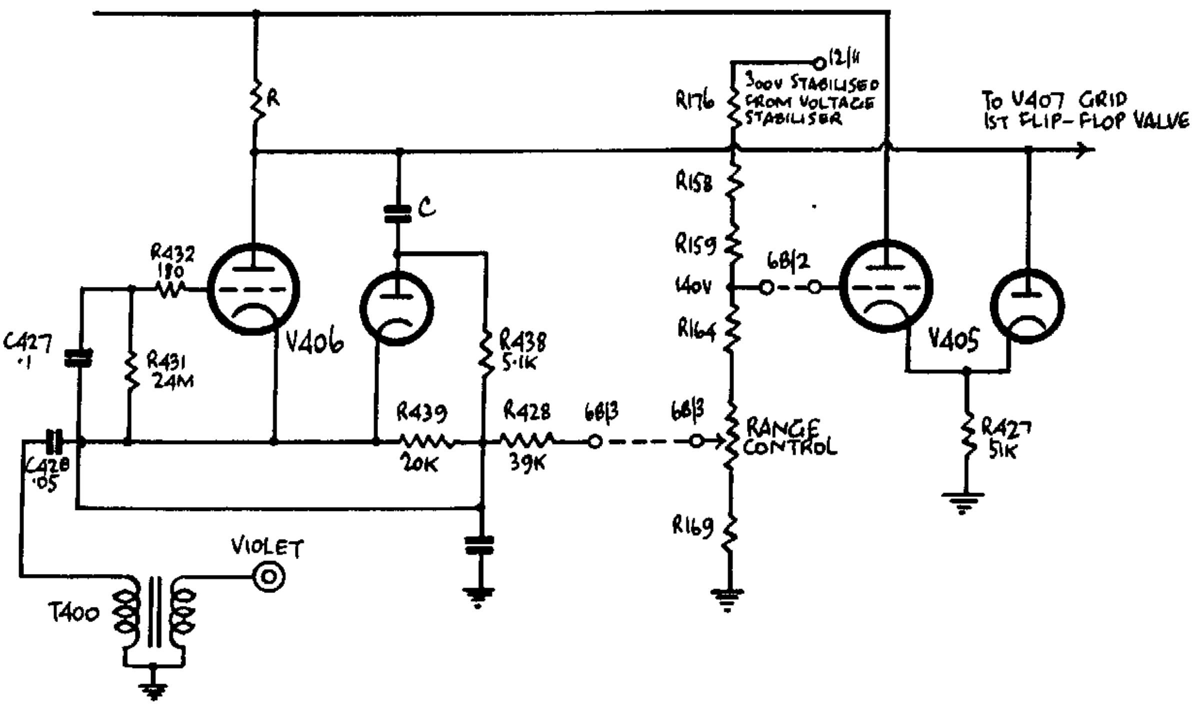
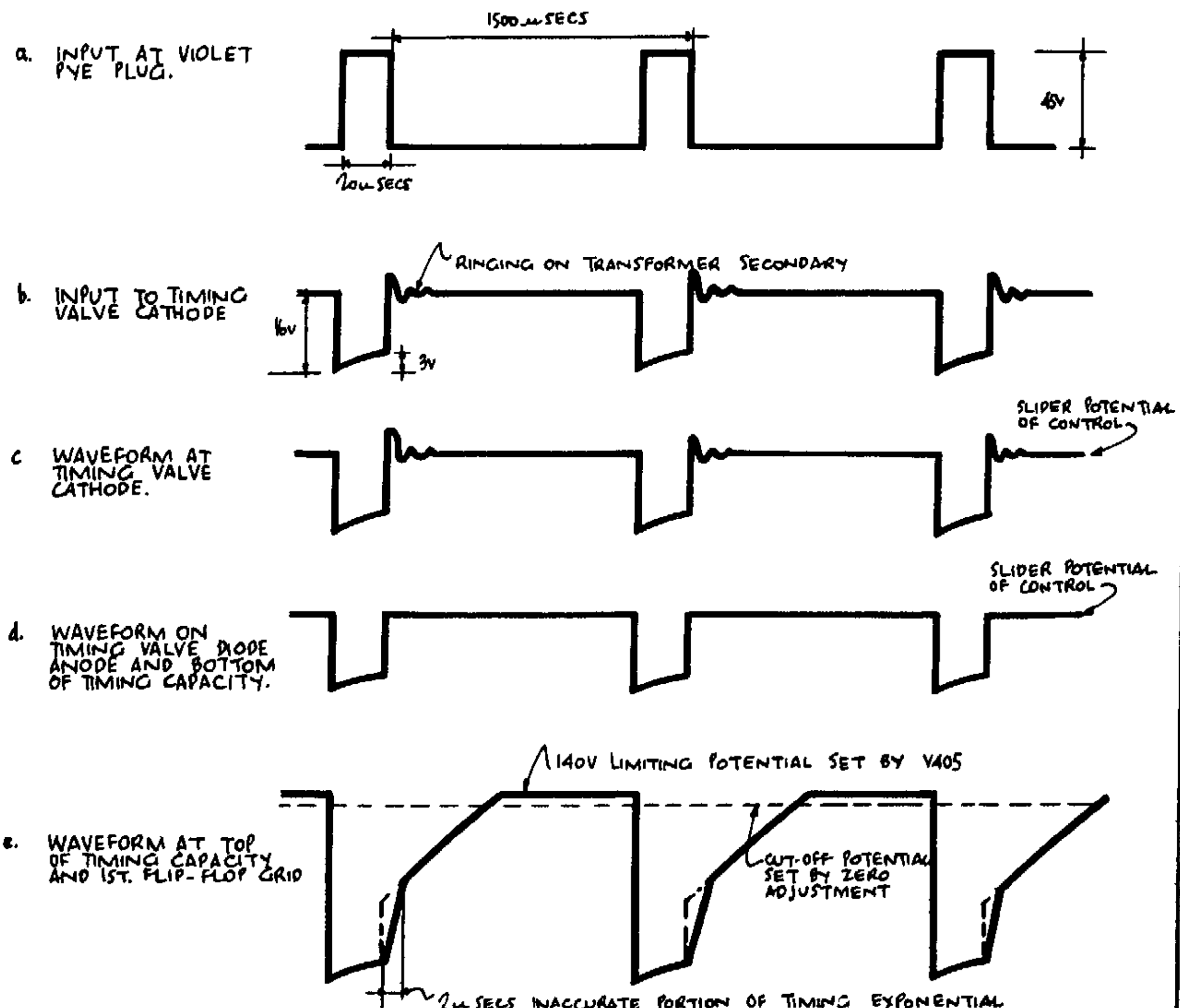
TIMING AND LIMITER VALVE CIRCUITS

FIG. 96



TIMING VALVE WAVEFORMS



(p) To avoid running the first flip-flop valves into excessive current by a continued rise of the timing exponential towards +300V. after the marker has been found when the valve went into conduction, a limiter valve is introduced. This limiter valve prevents the grids from rising above about +140V.

(q) The first valve in each marker circuit is essentially an electronic switch or timing valve. The positive-going 20 microsecond pulse from the modulator violet Pye plug is applied to the cathode after phase inversion in a transformer. The negative-going leading edge takes the valve into grid current and discharges the timing capacity which is effectively between anode and cathode. The rising edge of the trigger pulse cuts the valve off and starts the timing exponential, at the same time the trigger valve fires the spark gap and the transmitter.

The Timing Valve Circuit

463. Examination of the circuit diagram of the receiver-timing unit will show very complex looking circuits for the two timing valves, V.400 for the height marker circuit, and V.406 for the range marker circuit. The use of double-diode triodes in these stages adds to the difficulty of understanding the action of the stage from the standard circuit. Since the diode sections are strapped we may regard them as a single diode. As the cathode of the diode and triode are common we may redraw the actual range marker timing valve stage as it appears in fig.96.

464. In our basic circuit we showed the timing valve as a switch which could be connected across the timing capacity. Fig.96 shows that the timing capacity and the diode section of the timing valve are actually in series between the anode and cathode of the timing valve. We also note that the grid and cathode of the timing valve are tied to the same decoupled D.C. level which is fixed by the control on the switch unit. When the negative pulse from T.400 secondary is applied to the cathode the cathode is driven down. The grid would also follow down if it were not for C.427 which will not permit the grid to fall more rapidly than C.427 can charge negatively through R.431. As this time constant is long (24,000 microseconds) the grid potential will not fall perceptibly during the pulse duration. As the cathode is taken about 16 volts negative to the grid the valve then passes grid current into C.427. At the end of the 20 microsecond pulse the cathode rises again but the discharge of grid-current from C.427 through R.431 develops sufficient bias across R.431 to keep the valve cut off between successive 20 microsecond pulses on the cathode

465. Let us suppose that the decoupled slider potential is 50V. and that we are considering the situation just before the 20 microsecond pulse is applied. The cathode line will then be at +50V. The diode anode and lower plate of the timing capacity must also be at this level as R.438 returns them to the decoupled point. The top plate of the timing capacity and the triode anode will be at the limiting value of +140V. As the diode anode and cathode are at the same potential it will be just conducting. The triode is, of course, cut off by grid current bias.

466. On the leading edge of the 20 microsecond pulse the common cathode is carried down about 16V. +34V. The triode passes grid current and a heavy anode current. Electrons then flow through the timing resistance to H.T. and into the timing capacity. The potential of the top plate then falls to practically cathode potential, i.e. +34V., since the impedance of the triode when in grid current is negligible compared with the anode load. As the cathode is common to the diode and triode the diode passes current so electrons flow to the lower plate of the timing capacity and through R.438 to the decoupled slider level of +50V until the lower plate is almost down at +34V. It will remain slightly higher as the drop across the diode will be a matter of about 2V. and the drop across R.348 will be abour 14V. We thus get both plates of the timing capacity down to very nearly +34V.

467. During the 20 microsecond pulse period the pulse will decay somewhat as the pulse transformer, T.400, will not be able to sustain the flat bottom for the 20 microseconds. There will therefore be a rise of 2 - 3 volts at the cathode line during the pulse period to, say, +37V.

468. At the end of the pulse period the full pulse amplitude of 16V will be applied to the cathode line to take it up to +53V. The triode is immediately cut off by the grid current bias. The diode will be cut off as the cathode is now at +53V. and the anode at say 34V. + 2V drop in diode +3V climb or +39V. We now have the lower plate of the timing capacity at +39V. tied through R.438 (5.1K.) to +50V. Electrons will then flow to the +50V. point and the lower plate will rise quickly, but not instantly, to +50V. At the same time electrons will be flowing from the top plate through the anode load to H.T. Hence the potential of both plates is changing until the lower plate has reached its steady +50V. level. This means that the timing waveform is not a pure exponential for about 2 microseconds after the back edge of the 20 microsecond pulse. This portion of the curve is therefore inaccurate and cannot be calibrated. R.164 limits the maximum potential that can be applied to the slider of the control from reaching such a high value that the flip-flop grid can be carried into conduction by this inaccurate part of the timing curve. The timing exponential can never be shorter than 2 microseconds because of the presence of R.164. This applies to both timing valves (V.400 and V.406).

469. So far there has been no apparent reason why we want the diode section in the circuit as precisely the same results could have been obtained by connecting the timing capacity directly between the anode and cathode of the triode. The reason for the diode is the ring appearing on the cathode line on the back edge of the trigger pulse, due to the pulse transformer. This ringing will continue for several microseconds and would appear on the flip-flop grid if C were tied directly to the cathode. Now we have noted that the common cathode line came up to about +53V on the back edge of the pulse. The diode anode, however, can only rise to the +50V. decoupled potential, so the diode could only be brought into conduction by a negative swing of 3 volts or more due to the ring. As the amplitude is not sufficiently great the diode remains cut off until the ringing has ceased. The ring is thus prevented from reaching the timing capacity and the flip-flop grid. Had the ring been permitted to reach the grid it might cause a jittery marker by triggering the flip-flop at different times. This effect could only occur, of course, for short timing exponentials.

The Limiter Valve

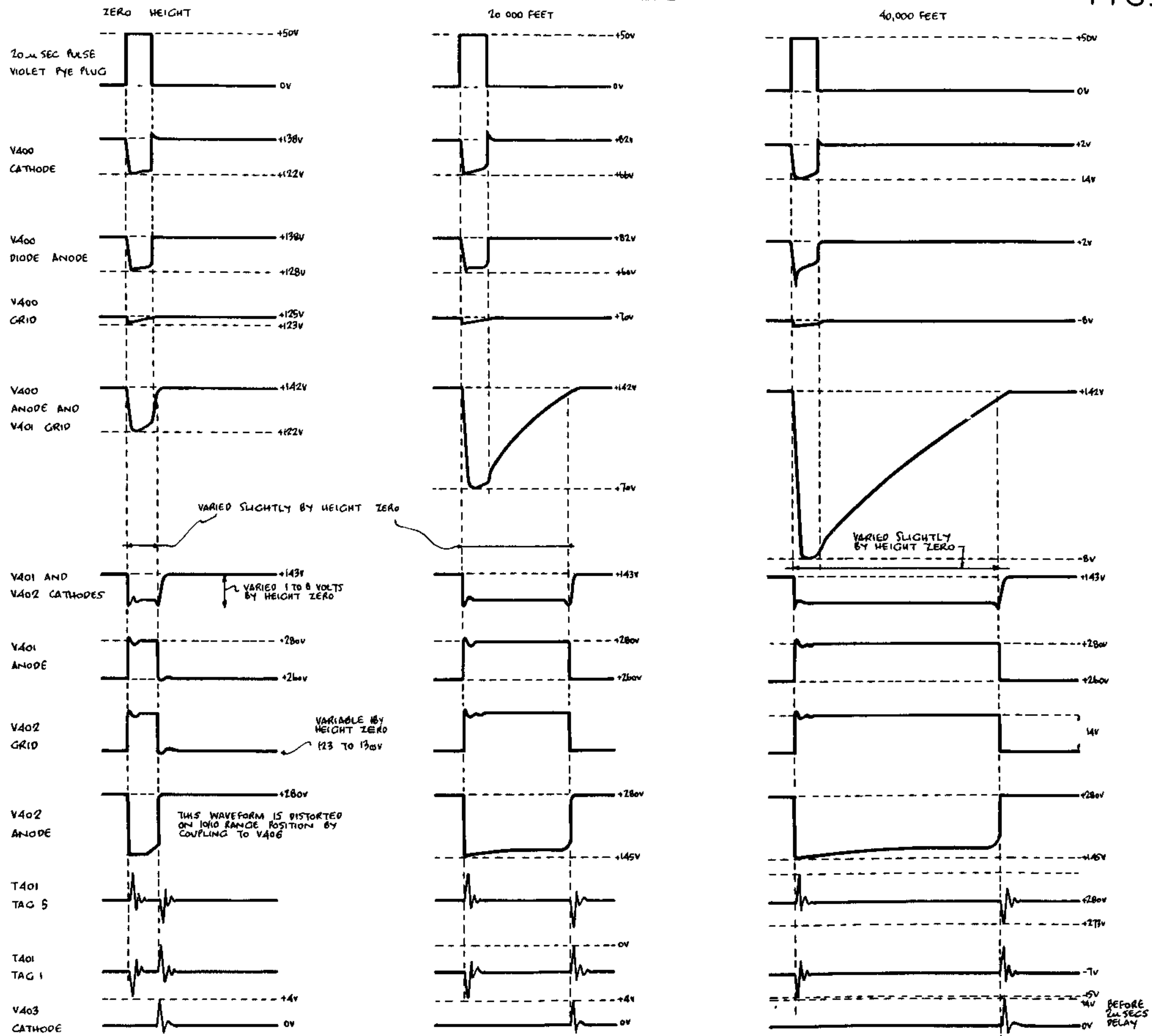
470. In our basic circuit we showed the limiter valve as a diode with its cathode held at about +140V. The actual circuit is shown in fig.96. Instead of a diode we actually have another double-diode triode, V.405. To illustrate the action of the stage we have again separated the triode and one diode section. The triode is connected as a cathode follower. The grid is tied to a +140V. potential (half H.T.) obtained from the bleeder in the switch unit which includes the wire-wound potentiometer that is used as both height and range control. The current passed by the valve through the 51K cathode load raises the cathode potential to about +140V. Since the cathode is common, the diode is then cut off until its anode potential rises to about +140V. When the diode opens we have a bleeder between the H.T. line and the common cathode at about +140V. The conducting impedance of the diode is so low in proportion with the anode load of the timing valve that the diode anode potential is held at about +140V. One diode section serves in this way as a limiter for the range marker circuit and the other diode section performs the same function in the height marker circuit.

The Actual Height and Range Marker Circuits

471. The major details of these circuits is shown in fig.90. Details of the constitution of pulse-forming networks used in V.408 anode and V.401 anode have been omitted. The same applies to the 2 microsecond delay network introduced in the cathode of the height marker output valve, V.403. The circuit shown is that of the Mark IIIA receiver-timing unit. This differs from the corresponding Mark IIC circuit mainly in the detail of the receiver output stage. Mark IIC receivers with serial numbers commencing with T will not include the shorting links of S.401. This only appears in some Mark IIC receivers with a serial number commencing with R.

DEVELOPMENT OF HEIGHT MARKER

FIG. 97



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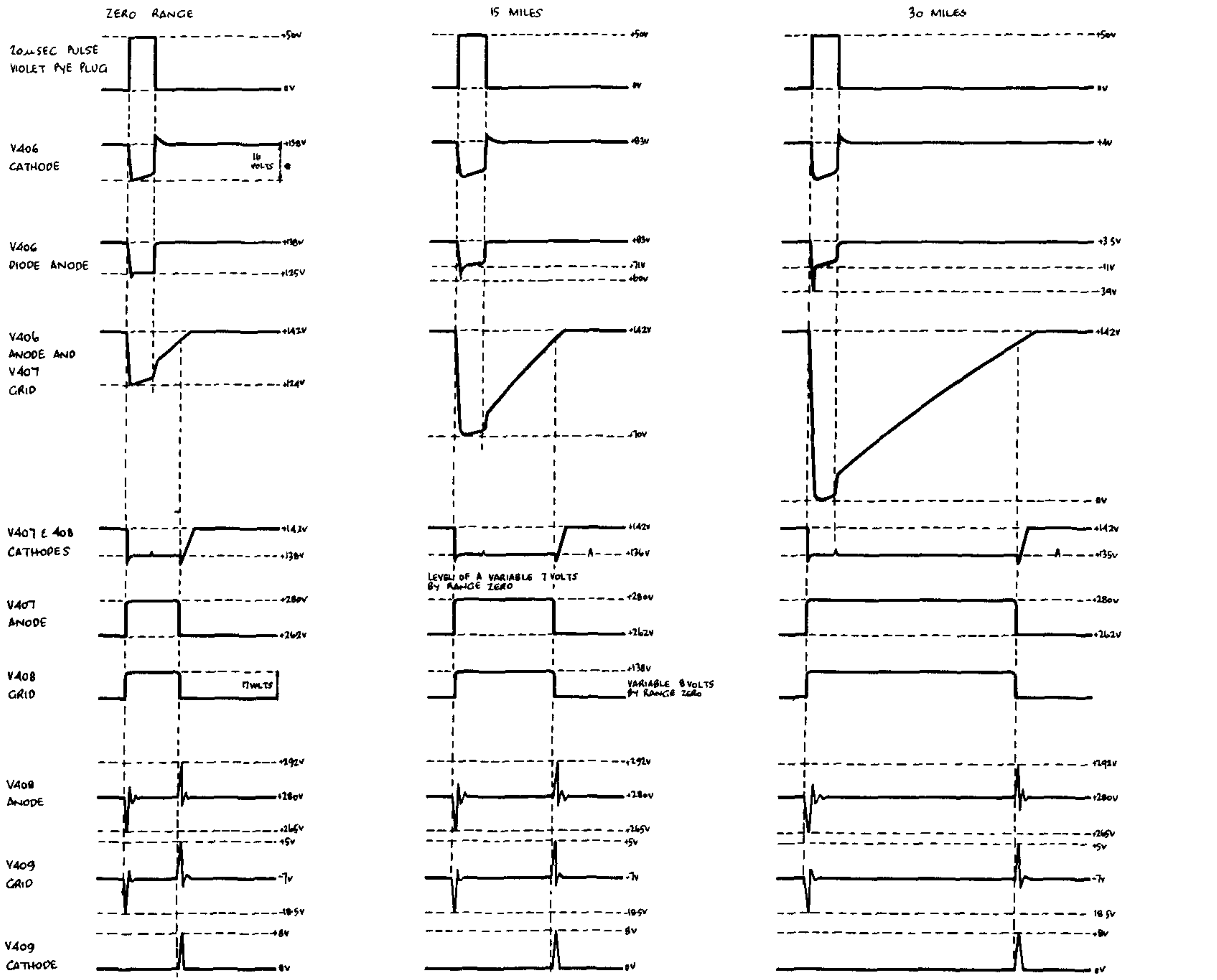
DEVELOPMENT OF RANGE MARKER – 30 MILE RANGE

FIG. 98



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DEVELOPMENT OF RANGE MARKER – 10 MILE SCALE

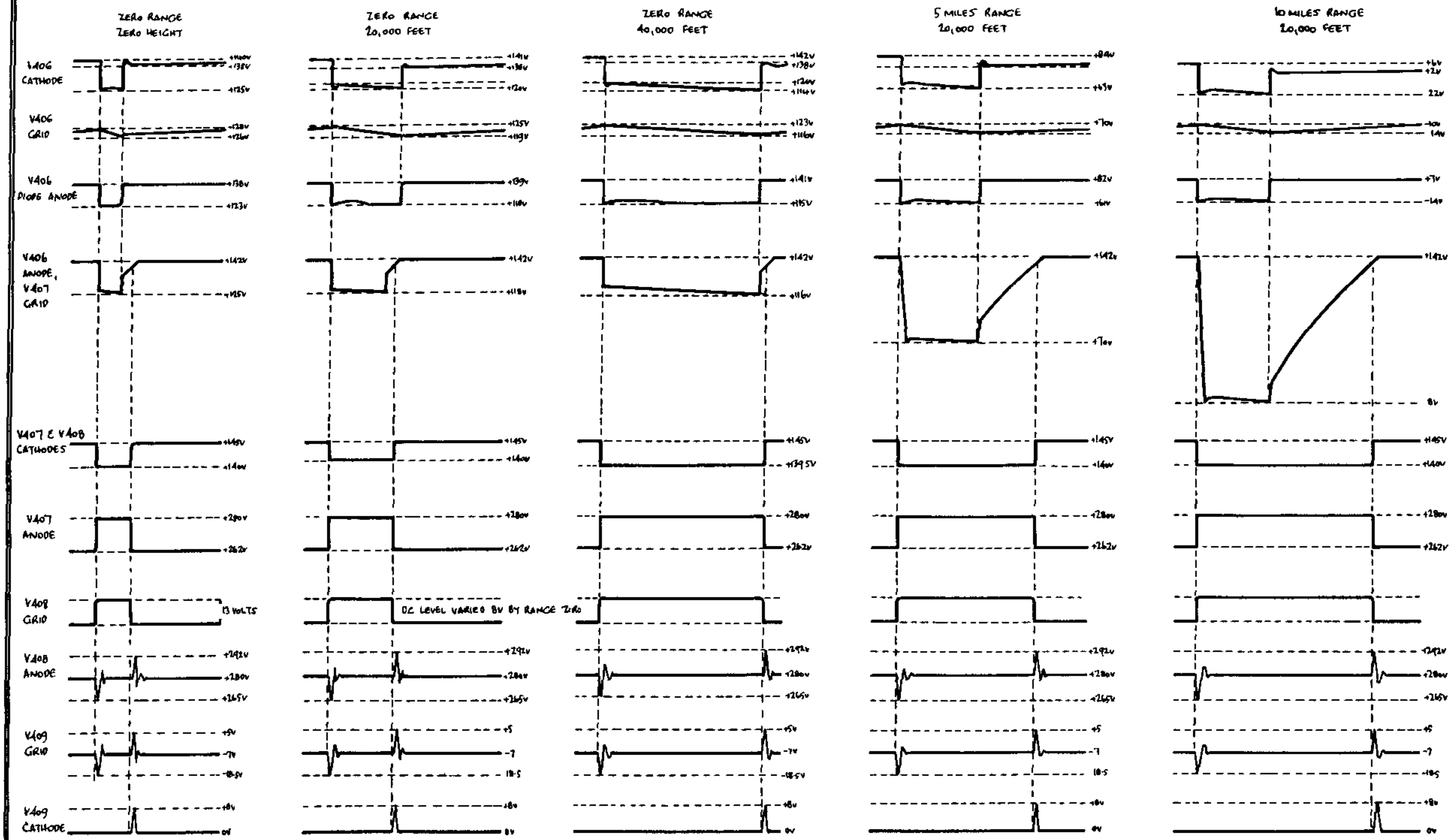

FIG.99

472. Assuming the S.401 links to be in the Bomber Command position we have the following conditions:-

(a) The top of T.401 primary is tied to H.T. via one link.
(b) The centre tap on T.401 primary is floating.
(c) The cathode of V.403 is tied to the 2 microsecond delay line in its cathode via a second link.
(d) The connection from the cathode of the range marker output valve, V.409, is floating.
(e) The cathode of the range marker timing valve, V.406, is connected via the third link to a relay contact. When the scan-marker switch is set for either the 30 or 100 mile marker range the relay completes the connection via contact 5 of the secondary of T.400 to give the triggering on the back edge of the 20 microsecond pulse, as we have already discussed it.

These are the conditions in the Mark IIC receivers which do not include the link.

The 10 Mile Marker Range

473. When the scan-marker switch is set for a 10 mile marker range the anode load of V.406 is reduced to R.464 (.5M). Contacts in the switch unit complete the 24V. supplies to relay A solenoid and contact 1 closes to short on R.433 - R.437. At the same time contact 6 changes over from its unenergised position connecting to 5, to contact with 7. We then have V.406 cathode connected to V.402 anode instead of to T.400 secondary. The significance of this change-over can be grasped most readily from a study of the waveforms in fig.99. The height marker circuit operates as before to form a height marker at V.403 cathode at the instant that V.401 grid is carried above cut-off by the exponential at V.400 anode. The reason for the 2 microsecond delay impressed on the height marker in V.403 cathode we shall discuss presently. The waveform at V.402 anode is a square wave which swings negative when V.402 comes on, i.e., when V.401 cuts off. Hence, we have V.402 anode and V.406 cathode swinging negative on the leading edge of the 20 microsecond pulse applied to V.400 cathode, for it is on this edge that V.400 goes into conduction and cuts V.401 off. V.400 and V.406 therefore go into conduction simultaneously just as they do when the 20 microsecond pulse is applied to both cathodes. The delay that ensues before V.401 grid is carried above cut-off will depend on the starting level of the exponential, i.e., on the setting of the height control in the switch unit. If this control has been adjusted to put the height marker opposite the leading edge of the ground echo on the height tube, the total delay between the back edge of the 20 microsecond pulse and the appearance of the marker on the display must be equal to the echo time of the ground echo. Since a 2 microsecond delay is impressed on the marker in V.403 cathode the delay introduced by the timing exponential must be two microseconds less than the actual echo time. The height marker must then actually appear at V.403 cathode 2 microseconds before it appears on the height tube. The height scale is, however, calibrated to read the total delay and hence the actual height.

474. Now at the instant the timing exponential carries V.401 grid above cut-off V.401 comes on and V.402 cuts off. Hence, at the instant the height marker is actually formed by the line in V.401 anode we have V.402 anode rising. V.406 cathode will then have been held down by V.402 anode from the leading edge of the 20 microsecond pulse until the instant when the height marker actually forms. At that instant V.402 anode rises and cuts V.406 off. V.407 grid then commences its exponential rise from a starting level set by the range control at the instant the height marker actually forms. How long a delay ensues before the range marker forms is determined by the setting of the range control. Suppose the range control is now adjusted to bring the range marker into coincidence with an echo blip on the height tube or a target indication on the P.P.I. The total delay between the back edge of the 20 microsecond pulse and the formation of the range marker must then be equal to the echo time which will be 10.7 x slant range. The delay introduced by V.400 exponential is 10.7 x height (neglecting the 2 microsecond delay which represents about 300 yards). The delay introduced

by V.406 exponential is therefore 10.7 x (slant range minus height). Hence, when the scan-marker switch is set for a marker range of 10 miles and the height marker is set to the ground encho, i.e., to the aircraft height, the range-marker exponential actually measures slant range minus height.

475. If we are given the value of h and s-h for a right-angles triangle we can construct the triangle and compute the ground range. For any selected height the delay introduced by the timing exponential of V.406 represents some specific ground range. However, if the height changes, the same delay represents a new ground range. Hence, although the rotation of the range control wiper could be calibrated to read ground range when V.406 is triggered by V.402, the scale would only be correct for the selected height. It would, of course, be possible to arrange a set of parallel scales corresponding to different heights and draw curves through points of equal ground range. This is, in effect, what we have on the switch unit range drum. Curves are provided labelled in ground range at half-mile intervals. The points on these curves may be imagined as lying on sets of parallel scales corresponding to different heights. As the height control is operated to set the height marker to the beginning of the echo, a metal pointer tracks across the range drum. As the range control is then operated to bring the range marker into coincidence with the selected target indication the drum moves relative to the pointer. When the setting is completed the ground range can be read by noting which ground range curve intersects the top of the pointer. If the adjustment leaves the pointer tip between two curves the departure from the nearest half-miles curve can be estimated.

Ground Speed Measurement

476. Since the curves represent ground range if the height marker is correctly set up, these scales can be used to measure ground speed. If the track marker is used, and the aircraft flies straight and level at a constant speed, the movement of a target indication along the track marker will be proportional to the ground speed. The range control can be set to say, 8 miles. When the target intersects the point where the track and range marker meet a stop-watch is started. The range control can then be set to 7 miles, bringing the range marker towards the P.P.I. centre. When the target has moved in along the track marker to the new intersection the stop-watch is stopped. The elapsed time represents the time to cover a mile ground range from which the ground speed is determined.

Direct Release Lines

477. For any given height and ground speed an ideal bomb should be released at a certain ground range ahead of its target. That is, for any given height and ground speed, when the target has moved in to the intersection of the track marker and some correct range marker setting, an ideal bomb should be released to fall on the target. Obviously, it would be advantageous to have an indication of these range marker settings. These are provided on the 10 mile range drum in the form of solid red direct release lines. They are labelled in ground speeds. Hence, when the H.2.S. operator has observed his ground speed, he can adjust the range control to bring the appropriate ground speed direct release line opposite the tip of the pointer. When the target has moved down the track marker to the new intersection with the range marker ring the ideal bomb should be released. An actual bomb will not carry as far as the ideal bomb so must be released slightly later. Correction tables tabulating the seconds delay required for different types of bomb load are provided for the H.2.S. operator who can then use a stop-watch to determine the appropriate release point.

Thirty Second Lines

478. A second set of release lines appears on the 10 mile range drum. These are in broken lines and again labelled in ground speeds. These appear higher up on the drum so set the range marker ring farther from the tube centre for the same aircraft height. These are lines which so set the range marker that the instant the target meets the intersection of the range marker and track marker represents 30 seconds before an ideal bomb should be released. By adding

the delay appropriate to the particular bomb load carried to the 30 seconds, the release time is again determined with a stop watch. The purpose of these 30 second lines is to deal with the difficulty experienced of keeping the target identified in the heavy general ground returns in the tube centre.

479. It must be emphasised that all measurements made with the 10-mile range drum, whether range, ground speed, or release points, can only be correct if the height marker has been correctly set to the beginning of the ground echo on the height tube. A further requirement is that the height and range zeros are correctly adjusted. If these adjustments are incorrect the scale calibration will be in error.

The Blackout Range Marker

480. So far, we have spoken of the range marker as a bright ring. When a target is of reasonable size the use of the direct release lines may set the range marker inside the brightened-up target area on the P.P.I. It is then impossible to tell where the intersection of the track marker and range marker occurs. To overcome this difficulty a switch may be fitted on the switch unit to operate a relay which changes the range marker output from the cathode to the anode as shown in fig.90. The range marker then appears on the P.P.I. grid as a negative-going signal, so forms a blackout ring which can be seen against of the track marker and the black-out ring and the direct release lines can then be used even if the range marker moves into the target indication.

Adjustment of the Height and Range Zeros

481. It has previously been emphasised that these preset controls are provided to permit setting of the grid cut-off levels of the first flip-flop valves to the values used in producing the prototype scales. It has also been pointed out that these controls function by varying the potential to which the second flip-flop grids are tied, thereby varying the current passed by the valves through the common flip-flop load. This, in turn, varies the common cathode potential which fixes the grid cut-off value of the first flip-flop valve. The question now arises as to how it can be checked that these zeros are set correctly. Obviously, we require some indication at a known delay after the beginning of the transmitter pulse. If a suitable permanent echo is available at, say, 1 - 5 miles from the workshop, and the range of the target is accurately known from an ordnance survey map, the height scale should read the correct range when the height marker is set to coincide with the echo. If the scale does not read the correct range it can be set to the correct range and the marker brought into coincidence with the echo by means of the height zero preset. If the H.T. voltage and timing CR. have the standard values the height marker should now read correctly throughout its scale. If a second permanent echo at a different accurately known range is available the tracking can be checked by means of this second echo. If the correct range appears on the height scale when the marker and echo coincide it is safe to assume that the zero is correctly adjusted and the scale is tracking correctly. Should the scale read an incorrect range for the second echo after adjustment of the zero on the first, either the timing CR or the H.T. voltage must be incorrect. The H.T. voltage should be satisfactory if the 300V. pack in the power unit is operating properly on a correct input and the stabiliser stage is not at fault. If the timing CR. is suspected the unit should be returned to the maintenance unit for realignment.

482. The measurement of range with the height scale may seem odd to the radar mechanic. It must be remembered that what is really being measured is a time delay, i.e., an echo time. Whether the patch of the e.m. waves is horizontal or vertical in no way enters into the operation of the circuit. The height scale can therefore be used to measure ground range when the set is on the ground or slant range when it is in the air.

483. Theoretically, we could set up the range zero in exactly the same way as the height zero if we set the scan-marker switch for a 30 mile marker range and used the 30 mile range scale along the inner edge of the range drum. The

difficulty arises in setting a short range accurately on the 30 mile scale. Moreover, there is only *one* range zero and we want accurate range indications on the 10 mile scale which is used for bombing. Hence, we should like to set up the range zero for accurate range indications on the 10 mile scale. This introduces the reason for the presence of the 2 microsecond delay network in the cathode of the height marker output valve, V.403.

484. It must be remembered first of all that when the scan-marker switch is set for a 10 mile marker range the range marker exponential begins when the height marker forms, i.e., two microseconds before it appears on the height tube. It was pointed out in para.468 that both the height and range marker exponentials are inaccurate over the first 2 microseconds, and that R.164 has been introduced in the circuit to prevent a reduction of these exponentials to less than 2 microseconds. This means that when the height control is set to zero there is still a 2 microsecond exponential at V.400 anode. Likewise, if the range control is set to zero there is still a 2 microsecond exponential at V.406 anode. The range marker is then forming 2 microseconds after the height marker when the range control is set to zero and the scan-marker switch is set for the 10 mile range marker. This applies regardless of the setting of the height control. Suppose now that the height control is set to bring the height marker into coincidence with a permanent echo and the height zero has been adjusted to give the correct range indication on the height scale. The height marker is actually forming 2 microseconds earlier. If the range control is set to zero the range marker must then form two microseconds after the height marker and will appear on the display at the same time as the height marker provided the range zero is correctly adjusted. If incorrectly adjusted, this is not necessarily the case. If the range zero is then offset to delay the range marker so it appears above the height marker and echo and is then adjusted for coincidence, it should be correctly aligned. Had the 2 microsecond delay not been included in V.403 cathode the range marker would appear 2 microseconds above the height marker when the range control is set to zero and this adjustment would then be impossible. Its inclusion in the circuit is to make possible this method of range zero adjustment. As the height control is operated to carry the height marker over the full scale, the range marker must, of course, remain in coincidence with the height marker as no changes are being introduced in the range marker circuit. <u>This, therefore, constitutes no form of check on the range marker circuits. It only serves to check that the height and range control wipers are making</u> contact with the potentiometer throughout their travel.

485. The permanent echo method of checking height and range zeros is open to the objection that it is not possible to check the accuracy of both the height and 10 mile range scales at operational heights and that rarely are there two or more permanent echoes which are suitable for tracking checks. What would be desirable is some form of calibrator which operates off the back edge of the 20 microsecond pulse and produces a set of calibration pips that can be used to check both zeros and tracking. Since it is difficult to obtain reliable calibration pips without the use of a crystal-controlled oscillator, a calibration test set, Test Set Type 202, has been designed around a crystal oscillator. The use of a crystal-controlled oscillator precludes the possibility of synchronising the calibration with the 20 microsecond pulse. The Test Set is therefore designed to supply a positive-going 20 microsecond pulse which can be used to trigger the marker circuits and the monitor 28. It can also be used to synchronise the modulator multivibrator or the master multivibrator. Details of the T.S.202 circuit operation and how the set is used for checking the H.2.S. markers are outlined in Chapter 11, paras. 779 - 811.

486. So far, we have discussed the height and range marker timing circuits as if the back edge of the 20 microsecond pulse were coincident with the start of the transmitter pulse. It was pointed out in Chapter 5 that there is a delay while the trigger pulse swings up and a further delay while the main gap breaks down in the spark gap switch. The spark gap delay will depend somewhat on how long the gap has been used. In addition to these delays, before the transmitter fires the returned signal experiences a slight delay in passing through the I.F. amplifier. The actual interval that elapses between the back edge of the 20 microsecond pulse and the appearance of a signal on the displays is then

the actual echo time plus the sum of these delays. In the case of the 10 mile marker range the sum of the height and range exponentials must exceed the true echo time by this delay. A nominal value of 1.4 microseconds has been assumed as the correction. This correction is applied in the calibration of the height scale. No correction is applied to the 30 and 100 mile marker range scales since these are mainly used for navigation and only give slant ranges which will be compared with maps giving ground ranges.

The Voltage Stabiliser, V.404

487. We have spoken of the 300V. stabilised supply as a necessity for accurate tracking of the marker scales. It is not actually necessary that this voltage be precisely 300V. but it is necessary that the voltage have a steady D.C. level, and be free from low frequency ripple. If we disregard R.419 and the tap into the -100V. line, the circuit is essentially the standard anti-jitter circuit with the difference that there would be no grid bias. The Gee anti-jitter circuit uses a cathode auto-bias. If we now add R.419 and the -100V. tap we have a biassing arrangement which not only provides a suitable operating point but also permits D.C. feedback from anode to grid. We can thus obtain reasonable stabilisation against a shift in the D.C. supply due to abnormally high or low engine speeds within reasonable limits. C.424 feeds low frequency ripple in the output to V.404 grid to develop an antiphase voltage change across R.421 as in the standard anti-jitter circuit. V.404 is therefore intended to provide stabilisation against both A.C. and D.C. changes in the input voltages. Nominal voltage values are:-

Input	290V.
V.404 anode	120V.
V.404 grid	0 - 2V.
Stabilised output	280V.

If any ripple reaches the grid of V.404 via the -100V. line, this will be amplified to a higher value at the anode.

The Switch Unit Marker Control Network

488. This network is also shown in fig.90. The stabilised output from V.404 anode at about 280V. is applied across the network via 12/11. The manufacturer adjusts the resistances, R.159, R.164 and R.169 so that the resistance between 12/11 and 6B/2 is equal to the resistance between 6B/2 and earth. Half the stabilised voltage is therefore taken off at 6B/2 for application to the grid of the limiter valve, V.5. The range control and height control can never carry the starting levels of the timing exponentials up to the voltage applied to the limiting grid because of R.164. On the other hand, these controls cannot carry the starting levels of the exponentials down to zero because of R.169. The normal range of variation available at either 6B/3 or 6B/4 is about +2V to +138V.

489. The range available at 6B/6 on the height zero is about 123 to 130 V.

490. The range available on the range zero depends on the setting of the scan-marker switch. When set for a 10 mile marker range contacts on the switch short out R.165 (7.5K.) and put into circuit R.167 (7.5K.). On settings of the switch giving either a 30 or a 100 mile marker range the reverse is the case. The voltage range available at 6B/5 depends then on the marker range in use. Nominal values are:-

10 mile marker range	127 to 135 V.
30 or 100 mile marker range	125 to 133 V.

491. From the network it is apparent that a change in the stabilised input at 12/11 will shift all the output voltages in the same direction. This helps to minimise the effects of any such change. For example, if the input falls slightly the starting levels fall. This tends to make the exponentials take longer to reach grid cut-off at the first flip-flop valve. But the zero controls are also applying a reduced voltage to the grids of the second flip-flop valves. These are then passing less current and the bias developed across

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THE RANGE MARKER PULSE FORMING LINE

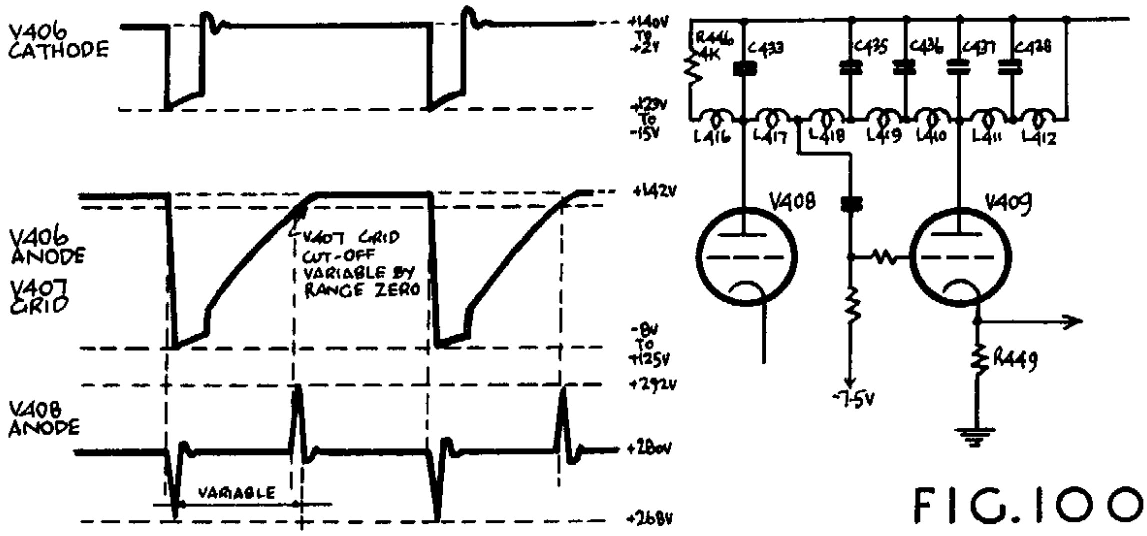

FIG. 100

THE HEIGHT MARKER PULSE FORMING LINE

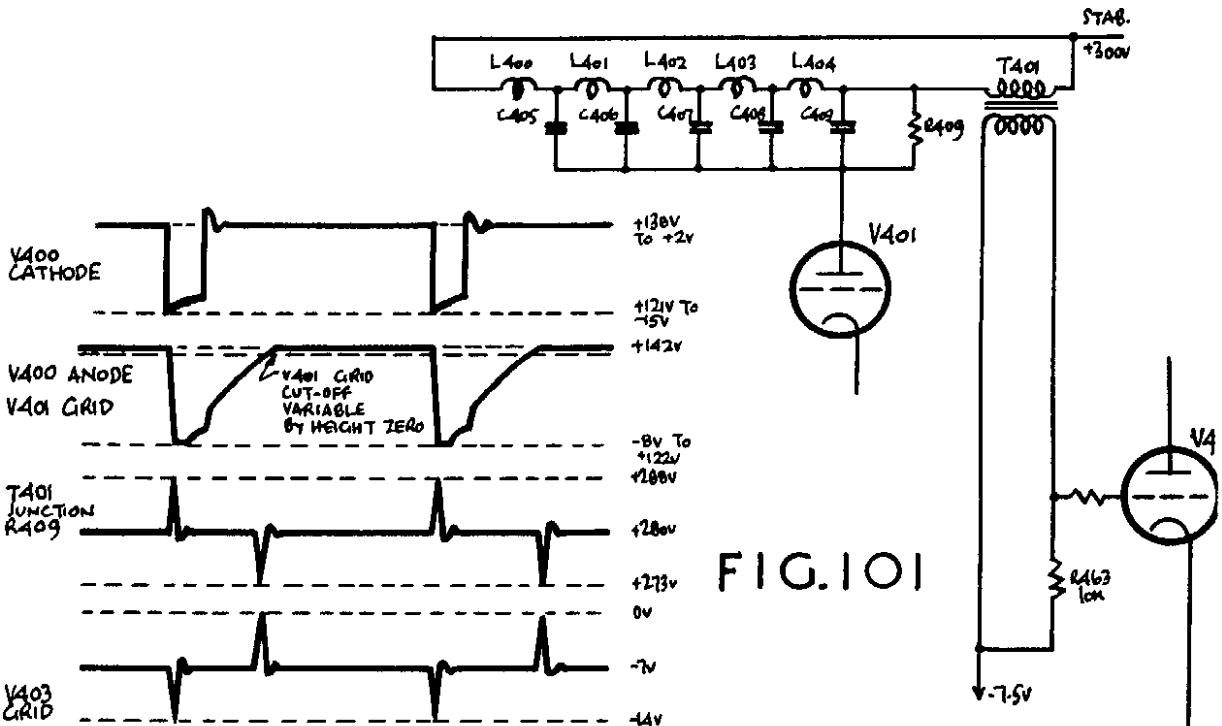

FIG. 101

THE HEIGHT MARKER DELAY LINE

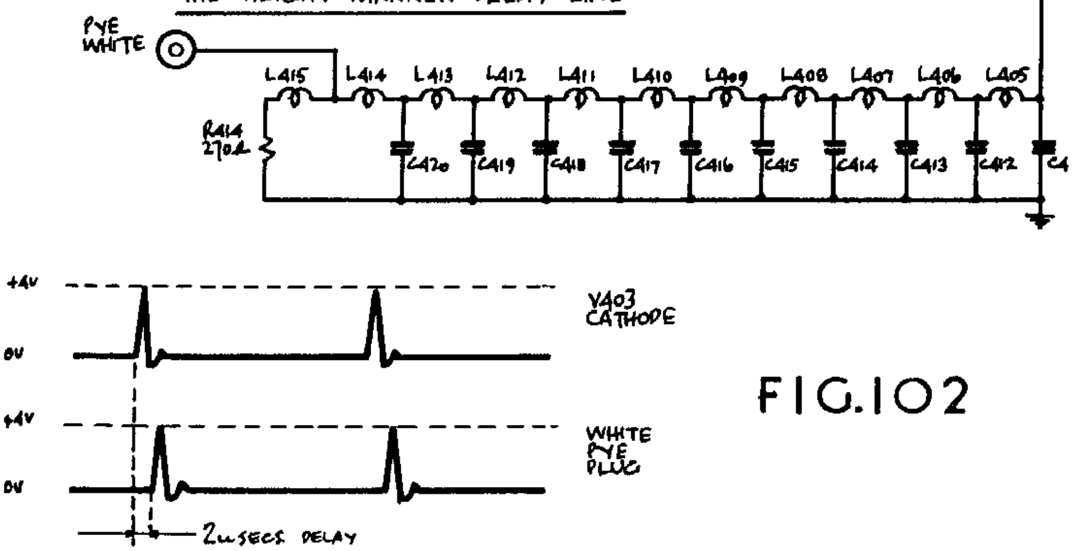

FIG. 102

the common cathode resistor has dropped. Hence, the grid cut-off values have also dropped. This effect tends to cancel, in part at least, the effect of a lower starting level.

492. We have said that absolutely accurate tracking of the marker scales is possible only if a set has the same timing CR, same stabilised H.T. value, and same grid cut-off levels in the first flip-flop stages as the standard set. This is actually the case. However, by virtue of this partially compensating supply arrangement, it is possible to obtain reasonably accurate tracking with minor variations in the stabilised H.T. voltage and consequent slight displacement of the grid cut-off or triggering voltages. In any case, if it is necessary to change either a switch unit or receiver-timing unit, it is desirable to remove both from the aircraft and set up the zeros on the bench before re-installing the units in the aircraft. Changing one unit and not the other may mean that slight realigning of the zeros is called for in order to obtain satisfactory accuracy and tracking.

The H.2.S. Pulse Lines and Networks

The Range Marker Pulse-Forming Line

493. Details of the circuit used to shape the range marker are shown in fig.100. We know that V.408 comes on when the leading edge of the 20 microsecond pulse brings V.406 on and cuts V.407 off. When V.408 opens an electron flow commences through L.416 and R.446 and the anode of V.408 falls. This fall will not be instantaneous for as soon as the anode potential is below that of the stabilised H.T. line electrons will start to flow through the other chokes and into the condensers. The result is a fall that takes about $\frac{1}{2}$ a microsecond. At the end of this period all the condensers will have charged to the potential difference developed across R.446 and L.416. Electrons will now discharge from the condensers through L.422 - L.417 to H.T. for approximately another $\frac{1}{2}$ microsecond and the anode current through L.416 and R.446 will drop to practically zero as the resistance of R.446 (4K.) is high compared with the resistance of the choke path. The anode potential then rises to practically H.T. as the condensers discharge in the second half-microsecond. We thus obtain a negative-going triangular pip in V.409 grid which has no effect since V.409 is already biassed to pass cut-off. V.408 continues to pass its current but it nearly all flows through the chokes L.417 - L.422.

494. When the timing exponential carries V.407 grid above cut-off the anode fall drives V.408 grid below cut-off. The electron flow through L.416 - L.422 is thus abruptly stopped. The magnetic field about the chokes then collapses and sets up an induced voltage which tends to keep the electron flow going in the same direction. As the current cut-off is first apparent at the junction of the anode and L.417 the collapse of the field commences at L.417 and develops an induced e.m.f. across L.417 tending to drive an induced electron flow in the same direction as before, i.e., toward L.418. This electron flow will come out of the lower plate of C.433 thus charging the condenser positively to H.T. As the field collapses around the successive chokes the same effect is produced on the other condensers. The missing capacity at the junction of L.417 and L.418 is supplied by the stray capacity associated with the output lead. The effect then is that C.433 is the first to start charging positively at the instant of cut-off. The effect then travels along the line all capacities charging simultaneously. The anode of V.408 will swing increasingly positive as the charging continues until the collapse of the field is complete. We thus obtain a positive pulse with a sloping leading edge. As soon as the collapse is complete C.433 will commence to discharge through L.416 and R.446, i.e., electrons flow into the lower plate of C.433 from the H.T. line which is actually 12 - 15 volts negative to the lower plate of C.433. As soon as the potential of the lower plate of C.433 has fallen slightly there is a potential difference across L.417 and the electrons in the stray capacity begin to discharge through L.417, L.416 and R.446. The discharge thus travels along the line through the terminating resistor until it is completed. The anode of V.408 meanwhile falls back to the H.T. level. Since R.446 provides a termination that matches the line this discharge takes place without anything more than the minor reflections.

We thus obtain a positive-going marker pip with sloping sides instead of the straight leading edge and exponential trailing edge that would be obtained if we used a short time constant to differentiate the square wave that could be developed by using a resistive anode load instead of the line. The triangular pip can be passed through the numerous subsequent stages without appreciably altering its characteristic shape. A pip produced by differentiation would tend to become progressively wider and more rounded off. The marker pip has a width of about 2 microseconds and an amplitude of 12 - 15 volts when applied to V.409 grid.

495. In transmission line terms, the action of the pulse forming line is described as follows:-

(a) On the leading edge of the 20 microsecond pulse when V.408 goes into conduction, a negative voltage wave travels down the line to the short-circuited end where it reflects with a phase reversal to give the rising edge of the pip.
(b) At the instant when the timing exponential carries V.407 into conduction and cuts V.408 off, a positive voltage wave travels down the line to the short-circuited end where it reflects with a phase reversal to give the falling edge of the pip.
(c) In each case there is no second reflection as the line is terminated at the other end in a resistor that matches the characteristic impedance of the line.

The Height Marker Pulse-Forming Circuit

496. The circuit details are shown in fig.101.

(a) When the exponential rise at V.400 anode carries V.401 grid above cut-off, the valve starts to pass anode current. When this flow commences both sides of the condensers in the line are at about 280V., the level of the stabilised H.T. line. There will be an initial flow of electrons to the anode plates of the condensers and a very small flow through R.409 and T.401 primary. The inductance of T.401 primary will be sufficiently high to make this path look almost like an open circuit as compared with the characteristic impedance of the line which is 2K. The actual current flow through R.409 and T.401 primary is then so small that it produces a negligibl voltage drop across R.409 but it is sufficient to cause a drop of about 7-8V. across the inductive reactance of T.401 primary. We then have, in effect, dropped the whole line through 7-8V. to put the junction of T.401 primary and R.409 at +273V. The anode side of the line condensers will be at very nearly the same value. We have now both sides of C.405 at about +273V. so have 7V. across L.400. Electrons then leak away from the top plate of C.405 to raise the potential of the top plate. As soon as the junction of L.400 and L.401 rises above 273V., electrons will start to flow out of C.406 through L.401. We thus have the line condensers charging consecutively over a period of about 1 microsecond. As the potenti across C.409 rises, the current which had been previously flowing to the anode plates of the condensers, i.e., into the line, now starts to flow through R.409. When all the condensers are fully charged the current flows through R.409 and the line chokes, instead of into the condensers. Also, as the flow across R.409 builds up, the potential at the junction of T.401 and R.409 rises from +273V. to +280V. and the voltage across T.401 primary drops to zero. Hence, we have a current flow through T.401 primary only for the 1 microsec period in which the line is charging up. We then obtain a negative pip across T.401 primary and the phase-reversed positive pip on T.401 secondary and V.403 grid. This positive pip causes the positive height marker pip at V.403 cathode. It appears every time that the exponential rise at V.400 anode carries V.401 grid above cut-off.
(b) When the leading edge of the next 20 microsecond pulse carries V.400 into conduction, the anode potential falls and V.401 is cut off on the grid. The whole line is then pushed up 7-8 volts above H.T. so

we have this positive voltage across T.401 primary. The condensers will now discharge in sequence in a 1 microsecond period. At the end of this time the junction of T.401 primary and R.409 is back to H.T. and there is no voltage across the transformer and hence no current. We thus obtain a 1 microsecond positive pip across T.401 primary and a 1 microsecond pip across the secondary on the leading edge of each 20 microsecond pulse. Since V.403 is already biassed to cut-off this negative pip has no effect.

The Height Marker Delay Line

497. When V.403 goes into conduction due to the application of the height marker on its grid, all the condensers in the network will be completely discharged with both plates at earth potential. The initial valve current will consist of an electron flow from the top plate of C.411. As this flow results in a rise of the cathode potential due to the charging of C.411, a potential difference appears across L.405 and electrons start to flow out of C.412 through L.405. This effect then travels progressively along the network charging one condenser after another. At the end of 2 microseconds it reaches the white Pye plug and develops the rising edge of the marker on the output cable. A little later the voltage appears across the terminating resistor, R.414.

498. As the grid of V.403 falls on the back edge of the marker pip, the valve current decreases and the current through the chokes tends to diminish. The collapsing field keeps the electron flow going in the same direction, but as the valve takes less and less, more and more goes back into the condensers. Thus, the top plate of C.411 returns to earth potential when the field across L.405 has collapsed completely. A little later C.412 will be completely discharged. In 2 microseconds the collapse of the field L.415 completes the decay of the delay marker at the white Pye plug.

499. In transmission line terms we describe this process as follows:-

(a) When the rising edge of the marker appears on the grid a positive voltage wave travels down the network. Since the line is terminated in a resistive load equal to its characteristic impedance no reflection occurs.
(b) When the falling edge of the marker appears on the grid a negative voltage wave travels down the network. Again, there is no reflection because the line is correctly terminated.

The Suppression Network

500. The action of this network is the same as that of the height marker delay line. The leading edge of the input is positive-going so a positive voltage wave travels down the line. The terminating resistor, R.457 (1K.), matches the characteristic impedance of the line so there is no reflection. Twenty microseconds later the negative-going edge of the waveform is applied. A negative voltage wave then travels down the line, and, due to the correct termination, there is no reflection. The actual delay tapped off depends on how far down the line the grid of the suppressor valve is tapped in.

General Artificial Line Principles and Applications

501. When any voltage change is applied to an artificial line the effect is the same as if we imagined a voltage wave of the same sense as the applied input travelling down the line.

502. If the line is terminated in a resistive load equal to the characteristic impedance of the line there will be no reflection. This is the principle of the delay line. The output is taken off at a point on the line that provides the desired delay. The transit time of the line must then be equal to the maximum delay desired.

503. If the line is short-circuited there will be a reflection in antiphase which will reappear at the input after a delay equal to double the transit time of the line. The positive-going edge of a square wave can thus be used to

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DISCHARGE OF ARTIFICIAL LINE

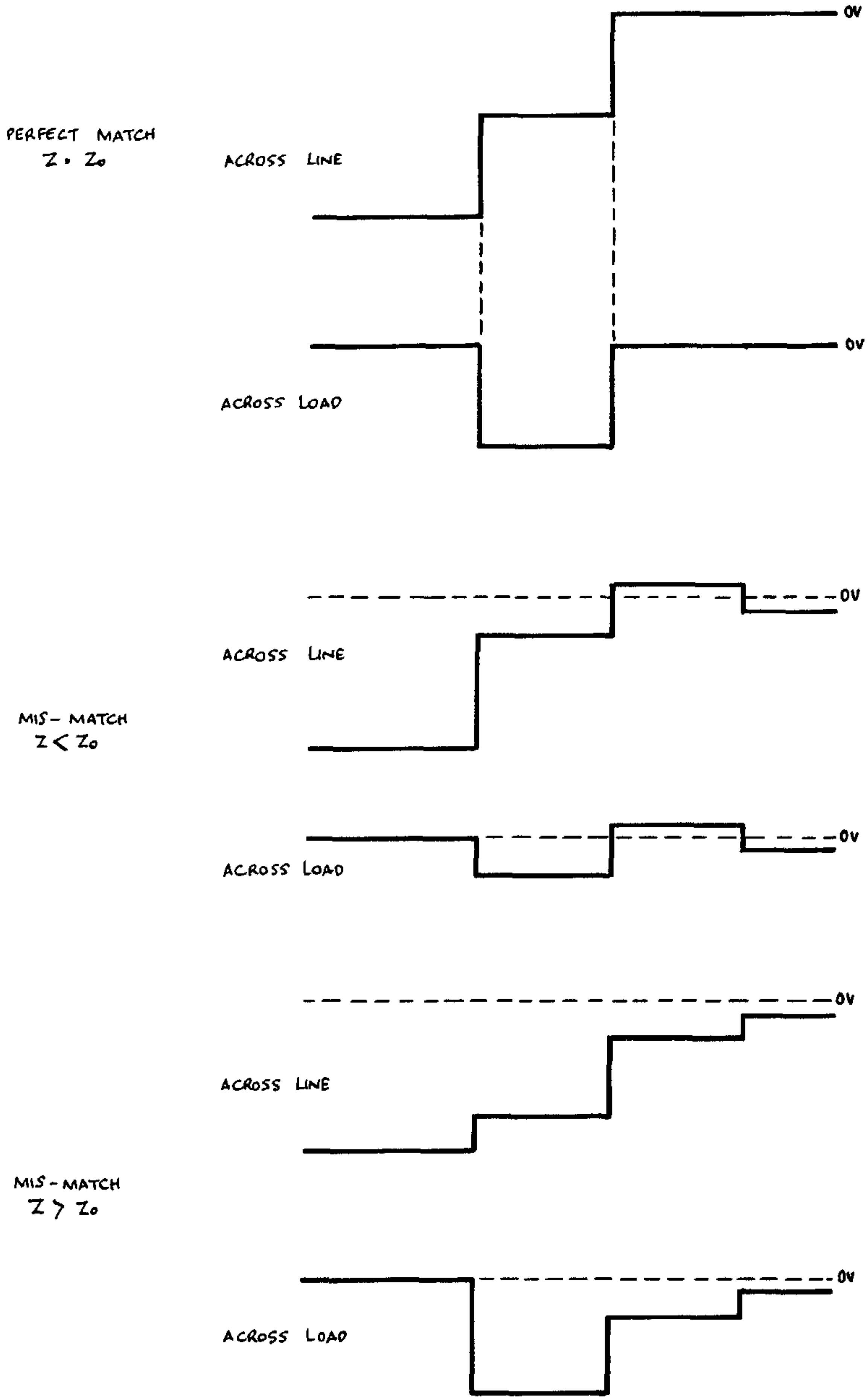

FIG. 103

produce a positive-going pip of any desired duration. The negative-going edge of a square wave will produce a negative-going pip of the same duration. This is the principle of the pulse-forming line as used in the range and height marker circuit.

504. To prevent reflection from the input end either the input must provide a correct match itself or a section is added which terminates in a correct match.

505. If the line is open circuited when the wave reaches the open end it will be reflected without phase reversal and will return to the input end in the same phase and will momentarily double the voltage applied at the input end and thus tend to discharge back through the input unless a suitable load is switched across the line instead. This is the principle of line modulation if no charging choke is used. The charging choke is added to make the charging time long and non-critical while the discharge time is short. The discharge time is equal to double the transit time of the line. In the artificial line used to modulate the magnetron we applied a -4KV. input through the charging choke. The reflection at the open end without phase reversal result in the development of a voltage of -8KV. at the input. Instead of letting the line discharge back through the input, the spark gap is triggered to connect a matched load across the line and the line discharges through the correct termination. At the instant the 80 ohm load is connected across the 80 ohm line charged to -8KV the line voltage drops to -4KV. and the other 4KV. appears across the matched load. This drop is equivalent to the application of a negative wave of 4KV. amplitude at the line input. The wave travels down the line to the open-circuited end where it reflects without phase reversal and comes back to the input end. Saying that the wave reflects without phase reversal merely means that the flow of energy out of the line continues in the same direction through the load. Since the reflected wave is of the same amplitude as the direct wave the current supplied remains at the same amplitude. When the reflected wave returns to the input end the line is completely discharged and the voltage across both line and load is zero. The voltage applied to the load consists then of a pulse of amplitude equal to half the voltage to which the line was charged and duration equal to twice the transit time of the line.

506. The characteristic impedance of a loss-free L.C. network line is purely resistive. Its value in ohms for a symmetrical line is given by $\sqrt{\frac{L}{C}}$ where L is the inductance per section in microhenries and C the capacity per section in microfarads.

507. The transit time per section for a symmetric line is given in micro-seconds by $\sqrt{LC}$ where L is in microhenries and C in microfarads.

508. If a modulating line is terminated in a resistive load, R, which is less than the characteristic impedance of the line, Z_o, the voltage appearing across the load will be $\frac{R}{R + Z_o} \times V$ where V is the voltage to which the line has charged. This voltage will continue for double the transit time. There will then be another pulse through the load given by $\frac{R}{R + Z_o} \times V_1$ where V_1 is the voltage to which the line was still charged after the first pulse ended. The line then discharges in a succession of bursts of diminishing amplitude but each of the same duration until it is completely discharged. It is this type of thing that goes on when the standing pulse appears on the height tube when a magnetron is going soft or an insulation breakdown is developing.

509. If a modulating line is terminated in a resistive load, R., which is greater than the characteristic impedance of the line, Z_o, the voltage appearing across the load is again $\frac{R}{Z_o + R} \times V$ where V is the voltage to which the line is charged. As $\frac{R}{Z_o + R} \times V$ is greater than $\frac{V}{2}$ where R is greater than Z_o, the effect of the wave reflected without phase change at the open end is to charge the line in the reverse sense to an amplitude equal to $\frac{R - Z_o}{R + Z_o} \times V$. We then get a discharge through the load in the opposite sense of amplitude $\frac{R}{Z_o + R} \times$ the new charging voltage. This process continues in the form of a series of current bursts alternating in sense and diminishing in amplitude until the whole energy initially stored in the line is dissipated. The duration of each burst will again be of duration equal to double the transit time of the line

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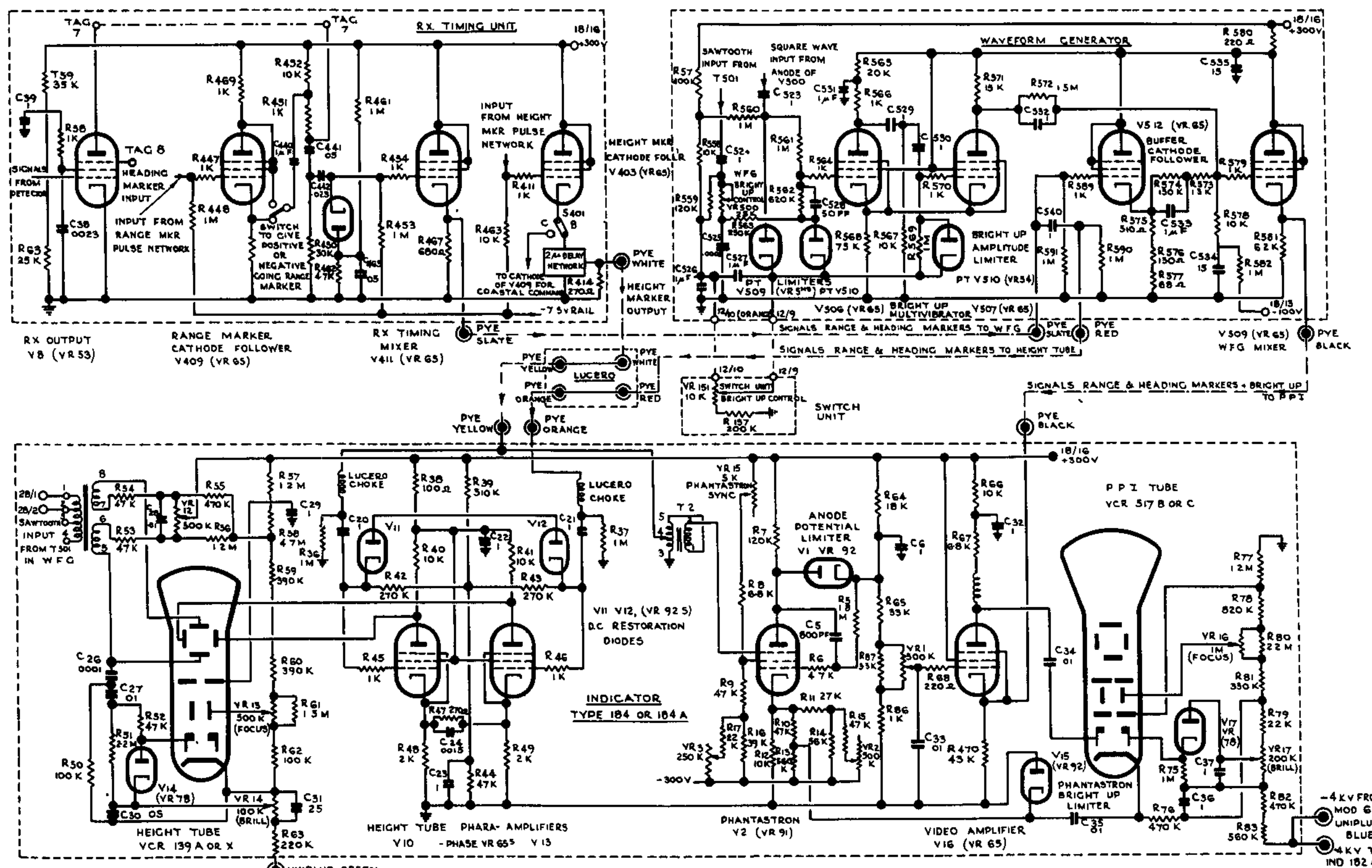

FIG 104

BRIGHT-UP, MIXING AND OUTPUT CIRCUITS.

FIG.104

CHAPTER 8 - BRIGHT-UP, MIXING, OUTPUT AND DISPLAY CIRCUITS.

510. We have traced the development of the timebase, transmitter pulse, received signals and markers. We must now consider:-

(a) How the signals and markers are mixed.
(b) How the bright-up waveform is developed and mixed with the signals for application to the P.P.I. grid.
(c) How the signals and bright-up are applied to the P.P.I. grid.
(d) Why a second bright-up waveform is required for the P.P.I. and how it is applied.
(e) How the signals and markers are applied to the height tube.
(f) How the height tube flyback-blackout is developed.
(g) How the height tube vertical shift voltage is developed.

511. The circuits involved in the functions tabulated above are distributed as tabulated below. The major circuit details are shown in fig.104.

Stage	Function	Unit	Valves
1. Rx Output Valve	Develops output consisting of:- noise, suppression break, positive-going signals at p.r.f. of 670, and heading or track marker at p.r.f. equal to r.p.s. of scanner, across anode load, R.451 (1K.)	Rx chassis of Rx-T unit	V.8 (VR.53)
2. Rx-Timing unit Mixer and Diode D.C. Restorer	Delivers positive-going output at cathode including noise, suppression break, positive-going signals, heading or track marker and range marker. Appears at slate Pye plug on Rx-Timing unit.	Rx-Timing Unit	V.411 (VR.65) Half of V.410 (VR.54)
3. (a) Bright-up M.V. (b) Square-Wave D.C. Restorer, (c) Sawtooth cutter, (d) Bright-up amplitude limiter.	To develop bright-up square wave of duration equal to part of of scan occurring after the Tx pulse.	W.F.G.	V.506, V.507 (VR.65) Pt.of V.509 (VR.54) Pt. of V.510 (VR.54) Pt. of V.5 (VR.54
4. Buffer Cathode Follower	Isolates P.P.I. output circuits from Height Tube output circuits. Synthesis listed in (2) crosses from slate Pye on W.F.G. to red Pye via C.540 for application at orange Pye on indicator 184. Same synthesis passes through V.512 to V.508 grid.	W.F.G.	V.512 (VR.65)
5. W.F.G. Mixer	Mixes bright-up M.V. output with input to grid from V512 cathode and delivers complete mixed signals, markers, etc. plus bright-up, from its cathode to the black Pye on W.F.G. for transfer to black Pye on indicator 184.	W.F.G.	V.508 (VR.65)
6. Video Amplifier	Amplifies mixed signals, markers and bright-up and delivers output at anode as positive-going signal for application to P.P.I. grid. Operates with V.508 in WFG.	Indicator 184 or 184A	V.16 (RPU) V.815 (Gramco) VR.91 in both models

Stage	Function	Unit	Valve
6. Video Ampflr. (contd.)	as a "gate" which can be used to cut either "tops" or "bottoms" according to setting of contrast control.		
7. Phantastron	In addition to its functions in the timebase circuit, it provides a second bright-up waveform applied to P.P.I. cathode	Indicator 184 or 184A	V.2(RPU) V.801(Gramco) VR.91 in both models
8. Phantastron Bright-up Diode	Limits amplitude of phantastron bright-up.	Indicator 184 or 184A	V.15 (RPU) VR.92 V.814(Gramco)
9. P.P.I. D.C.Restorer	D.C. restores input on P.P.I. grid,	Indicator 184 or 184A	V.17 (RPU) VR.78 V.816(Gramco)
10. Height Tube Paraphase Amplifier	Provides push-pull input to height tube Y-plates. Height marker is applied to grid of valve feeding right Y-plate via yellow Pye, and signal - range and heading marker are applied to grid of valve feeding left Y-plate.	Indicator 184 or 184A	V.10 & V13(RP V809 & V811 (Gramco) VR.65's in both models.
11. Height Tube Amplifier D.C.Restorers	Restore inputs to grids positively with respect to a constant D.C. level to keep D.C. level at anodes constant as range changes.	Indicator 184 or 184A	V11 &V12 (RPU) V810 & V812 (Gramco) VR.92's in both models.
12. Height Tube Blackout Circuit	Differentiates sawtooth to produce square wave which carries height tube grid below threshold level during flyback period.	Indicator 184 or 184A	C26 (.0001 R.50 (100K) in RPU sets. C.838 & 839 (50 pf.) in parallel & R.868 (100K) in Gramco. sets.
13. Height Tube D.C. Restorer	Negatively D.C. restores blackout waveform with respect to D.C. level set by brilliance control to blackout the flyback.	Indicator 184 or 184A	V.14 (RPU) V.813 (Gramco VR.78 in both sets
14. The P.P.I.	Provides main display	Indicator 184 or 184A	VCR series
15. The Height Tube	Provides display for height finding, beacon work and monitoring	"	VCR 139 series
16. Height Tube Shift Circuit	Permits depression of electron beam to bring only wanted second half of scan on the tube.	Indicator 184 or 184A	VR12, R55, R56 (RPU) VR814, R874 R875 (Gramco)

Receiver Output Valve.

512. This stage has been discussed in dealing with the Mark IIC and Mark IIIA receivers. In both cases the signals on the grid are negative-going and the heading marker input is a negative-going waveform applied to the suppressor. The output developed across R.451, the 1K. anode load, consists of positive-going signals at a p.r.f. of 670, and a positive-going heading or track marker with a p.r.f. equal to the r.p.s. of the scanner. The Mark IIIA circuit omits the I.F. choke on the anode and uses less elaborate screen decoupling as a cathode follower stage is introduced between the detector and the

Mixing Range Marker and Receiver Output.

513. When the positive-going range marker appears on V.409 grid the valve goes into conduction and the cathode potential rises about 8 volts. Both ends of R.451 are then carried up together and receiver output and range marker are mixed on R.450 (30K). The mixed output is applied via C.442 (.023) to the cathode of the D.C. restorer diode which is half of the VR.54, V.410. The other half of V.410 keeps the suppressor of the receiver output valve from swinging positive.

The D.C. Restorer.

514. R.461 (1M.) and R.462 (4.7K.) bridge in the anode of V.410 restoring section at about 2V. positive to earth. The cathode is returned through R.453 (1.M) to the negative bias line of around - 7.5V. The diode is, therefore, in steady conduction and the cathode will sit at around +2V when no signals are passing through C.442 during the suppression period. Any incoming signals will cause positive swings from the +2V. base level. If the negative-going black-out range marker is applied its amplitude is sufficient to give a brief depression of the cathode. The normal range marker will give positive swing of about 7 - 8 volts. Peak signals and the heading or track marker will give a positive swing of about 15 - 16 volts.

The Receiver-Timing Unit Mixer, V.411.

515. The grid of this stage is tied to the cathode of the D.C. restorer through a 1K. grid stopper so sits at the steady D.C. level of about +2V. fixed by the diode. This serves to keep a steady current through the 680 ohm cathode load, R.467, which fixes the D.C. level of the cathode at 5 to 6 volts. Positive-going signals and markers on the grid swing the cathode positive from this level through about 85 - 90% of the input voltage. The black-out range marker will, of course, swing the cathode negative to its D.C. level. The output from V.411 cathode containing suppression break, noise, signals, heading or track marker, and the range marker, is taken to the slate Pye plug on the panel of the receiver-timing unit. Thence it is taken to the slate Pye plug on the waveform generator panel.

The Bright-Up Requirements.

516. Before we can follow up the mixed signals we have delivered at the slate Pye plug on the W.F.G. panel we must study the development of the bright-up waveform which is to be mixed with them in the next mixing stage.

517. The bright-up waveform as developed by the bright-up multivibrator was designed for use in the indicator 162 and its predecessors. These indicators used a diametrical scan. The transmitter fired at approximately the centre of the sawtooth as discussed in Chapter 5. Echoes were only to appear on the second half of the scan as the C.R.T. spot moved from the tube centre to the circumference. A waveform was therefore required for mixing with the signals which would carry the P.P.I. grid up as the scan moved from the centre to the circumference and drop it back during the flyback and the first half of the subsequent swing. The amplitude of this positive-going bright-up square wave had to be such that it left the C.R.T. grid just below the threshold for all but the peaks of the superimposed valve noise. Signals or markers stronger than noise would then carry the grid above the threshold level and cause brightening of the display. When the square wave terminated at the end of the scan the P.P.I. grid would fall back to a level so low that no noise or long range signals could possibly appear in the flyback or on the first half of the subsequent sweep. These ideas are portrayed in fig.106. (a) and (b). With the introduction of the indicator 184 and a scan that commences from the tube centre the bright-up portion of the waveform can still serve to brighten up the radial scan and to black-out the flyback and waiting period. Difficulties arise, however, because we do not want the scan to start when the transmitter fires but when the height marker forms somewhat later. At the same time, we need the same bright-up waveform to brighten up the Fishpond scan which is a diametrical scan. On the Fishpond display we want the bright-up to commence when the transmitter fires. We are thus faced with two required starting points. A compromise has been

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FUNCTION OF THE BRIGHT-UP WAVEFORMS

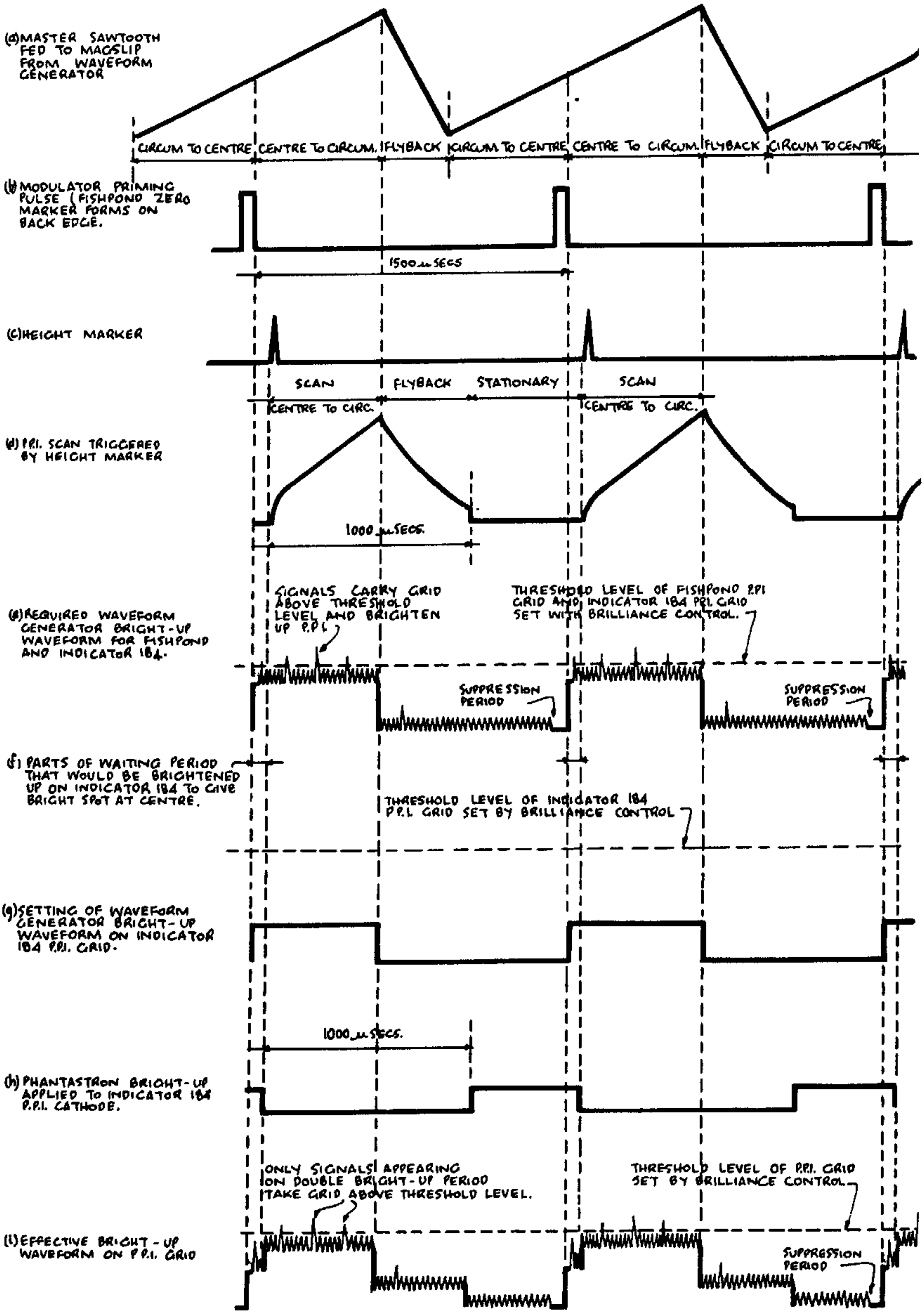

FIG. 106

effected by developing the bright-up waveform to meet the Fishpond requirements and combining a subsidiary bright-up waveform with it for the P.P.I. The ideas involved in this compromise can be appreciated from fig.106. (d), (f), (g), (h), and (i). Our study of bright-up circuits for Fishpond and the Indicator 184 P.P.I. then include the development of the W.F.G. bright-up waveform shown in fig.106 (e) or (g) and the phantastron bright-up waveform shown in fig.106(h).

Considerations in the Design of the W.F.G. Bright-up Circuit.

518. Before studying the circuit used to produce the W.F.G. bright-up waveform it is desirable to study the implications of the conditions to be fulfilled:-

(a) The amplitude of the bright-up waveform on the C.R.T. grid should remain constant as scans are changed. This makes it desirable that its amplitude should remain constant in the developing circuit.

(b) The leading edge of the bright-up waveform should not commence later than the back edge of the modulator priming pulse on any scan since the Fishpond zero marker occurs at that time. Since the modulator priming pulse is fixed on the 100/40 scan, this means we must be able to vary the leading edge of the bright-up waveform in the development circuit on this scan to ensure brightening-up of the zero marker. On the 10 mile and 20 mile scans we can move the modulator priming pulse relative to the master sawtooth with the 10 mile and 30 mile zeros, respectively, to shift the zero marker to the beginning of the bright-up pulse.

(c) On all scans the bright-up pulse must end with the end of the working stroke of the scan to avoid appearance of the flyback. This presupposes some cutting-off waveform that has a straight falling edge coincident with the end of the working stroke of the master sawtooth on all scans. The antiphase square wave at the anode of V.500, the first master multivibrator valve, swings up as the master sawtooth commences and falls as the working stroke ends. This waveform is therefore suitable for a cutting-off waveform.

(d) On all scans it would be desirable to have the bright-up square wave commence at a time that coincides with approximately the middle of the sawtooth since this will be the point where the back edge of the modulator priming pulse appears. This suggests that the sawtooth can be used to swing the grid of the first valve of a flip-flop above cut-off at the mid-pint

(d) On all scans it would be desirable to have the bright-up square wave commence at a time that coincides with approximately the middle of the sawtooth since this will be the point where the back edge of the modulator priming pulse appears. This suggests that the sawtooth can be used to swing the grid of the first valve of a fli-flop above cut-off at the mid-point of the sawtooth to cut off the second valve and produce the positive going edge of the desired bright-up square wave at the anode of this second stage. This is the principle of the bright-up flip-flop whose circuit is shown in figs.104 and 107. The sawtooth input condenser is C.524 (.1).

(e) If we are to use the antiphase master square wave as a cutting-off waveform, it must also be applied to the first valve of the bright-up flip-flop to cut the valve off on the grid as the working stroke of the sawtooth ends. The anode rise will then pull the grid of the second valve above cut-off. The fall at this second anode will then terminate the bright-up waveform. The square wave input condenser is C.523 (.1).

(f) To have triggering at the required point on the sawtooth the grid cut-off level must be adjustable to the required value. This suggests the use of an arrangement similar to the height and range zeros which can be seen in fig.104. The actual control is VR.151.

(g) The sawtooth amplitudes are not quite identical on the different scans so a setting of a control of the type mentioned in (f) will not necessarily apply for more than the input sawtooth.

on which it is adjusted. In addition to this amplitude difference, we shall be faced with the problem that the input condenser, C.524 (.1), will not pass the three different velocity master sawtooth waveforms without introducing some distortion. This distortion will be attenuation of the low frequency components. The distortion will result in a reduction of amplitude and in a rounding off of the top of the sawtooth. The 10 mile or 240 microsecond working stroke will be affected least. The 720 and 1200 microsecond working strokes will suffer more. These distortion factors will add to the problem of initial differences in amplitude. To surmount this problem a deliberate distortion is introduced into the circuit with a variable control. This distortion circuit is designed to work in opposition to the unavoidable distortion in the sawtooth input circuit. Its effect is to cause high frequency losses so it is most effective on the 10 mile sawtooth input. The components involved are V.R.500 and C.525.

(h) In the height and range marker flip-flop a limiter valve was provided to keep the timing exponential from carrying the first grid up to values which would result in prolonged flows of grid current. A similar limiter should obviously be provided to keep the sawtooth from carrying V.506 grid into heavy grid current. This sawtooth top-cutter is V.510(a), half of the VR.54, V.510.

(i) To fulfil the condition of constant output amplitude V.507 grid should swing through a fixed cut-off level and to a fixed peak level. The fixed peak level calls for an amplitude limiter diode. This is V.510(b), the other half of the VR.54, V.510. which is connected to V.507 grid. The fixed cut-off requires a fixed peak current through V.506 in its conducting state, through the common cathode load, R.568 (7.5K.). This has already been arranged by means of the sawtooth top-cutter diode section.

Operation of the Bright-Up Flip-Flop, V.506. V.507.

519. The major points in the operation of this circuit have already been implied in the preceding paragraph. The sawtooth input via C.524 swings the grid of V.506 up and down. The grid cut-off of V.506 can be varied by means of the preset, VR.151, which operates in the same way as the height and range zeros. By means of VR.151, V.506 grid cut-off can be so set that the 50 mile sawtooth input from T.501 carries V.506 into conduction to cut V.507 off and produce the leading edge of the bright-up pulse at a desired point on the Fishpond scan. By means of VR.500 the 10 mile sawtooth input can be so distorted as to cause triggering at the same point on the scan. This adjustment may upset the first one. By making a series of alternate adjustments with these controls on their respective scans it can be arranged to have the leading edge of the bright-up commence at approximately the same point on all three scans.

520. The diode section, V.510(a), goes into conduction when the sawtooth carries its anode above the common cathode potential set by VR.151. This serves to limit the rise of V.506 grid and the current passed by V.506.

521. The square wave input from V.500 anode via C.523 serves to cut off V.506 grid at the end of the working stroke of the sawtooth, and thus brings on V.507 to terminate the bright-up pulse at V.507 anode. V.509(b) serves to D.C. restore the square wave input negatively with respect to the common cathode potential.

522. The diode section V.510(b) limits the maximum grid potential of V.507 and hence the amplitude of the bright-up signal wave applied to V.508 grid where the signals are superimposed on the constant amplitude bright-up.

The Bright-up Controls

523. The control VR.151 (a screw-driven preset on the front of the switch unit) which we shall call the switch unit bright-up control, sets the D.C. level of V.507 grid and hence the current passed by V.507 through the common cathode load, R.578. This current fixes the common cathode potential when V.506 is cut-off and V.507 is conducting. This, in turn, fixes the level to which V.506 grid must be carried by the sawtooth to bring it into condution

524. The sawtooth input is obtained from the single-ended secondary winding of the sawtooth output transformer. The same sawtooth is applied to the grid of the transmitter-timing valve, V.505. The amplitude is about 150V. and the working stroke is positive-going. This sawtooth voltage is applied via C.524 (.1) and developed across the leak, R.559 (120K.). The low frequency components are attentuated in C.524 and the sawtooth output appearing across the leak is therefore somewhat distorted and reduced in amplitude. This distortion is most pronounced on the two slower scan inputs. In parallel with the leak we have VR.500, R592 and C.525. VR.500 is a screw-driver preset on the front of the W.F.G. panel which we shall call the W.F.G. bright-up control. The voltage appearing across C.525 we apply, via R.563, and R.562 to the grid stopper, R.564. Now VR.500 and C.525 form an integrating circuit. VR.500 offers equal impedance to all frequency components in the distorted sawtooth. C.525 offers an impedance that varies inversely as the frequency. The output obtained from C.525 will then be greater at the low frequency end and lower at the high frequency end of the spectrum. The distortion thus produced will represent both a reduction in amplitude (due to the attentuation in VR.500 which will be independent of frequency), and also a change in shape due to the frequency discrimination of C.525. The main effects will be to (i) reduce the slope and (ii) to bring down the output amplitude of the 10 mile sawtooth to a value more nearly comparable with that of the other two. As the W.F.G. bright-up control is most effective on the 10 mile sawtooth input it is used to make adjustments on this scan.

525. The objective is to find adjustments of the two presets which will enable the distorted sawtooth voltages impressed on V.506 grid to carry the grid above cut-off at the same point in each scan on the Fishpond display. This point will be the zero marker which will be about ½" from the centre on the 100/40 scan position. By means of the 10 mile zero and 30 mile zero the zero marker on the 10 and 30 mile scans can be adjusted to about the same diameter. The switch unit bright-up control shifts the cut-off level to which the sawtooth inputs must raise V.506 grid to produce the leading edge of the bright-up waveform. This control is used to set up the leading edge of the bright-up waveform so as to ensure brightening up of the Fishpond zero marker on the 100/40 scan. It may not be possible to actually retard the bright-up sufficiently to prevent it beginning slightly too soon. If this occurs, no harm is done. What is necessary is that the bright-up does not begin too late. Full details of the setting up procedure are given in Chapter 10.

526. The W.F.G. bright-up control is used with the 10 mile sawtooth input to so distort the sawtooth as to carry V.506 grid above cut-off when the Fishpond scan is again about ½" from the centre. The distortion introduced on the 50 mile sawtooth input by varying this control may alter the required setting of the switch unit control. However, by alternating between the two controls, a few adjustments will bring the leading edge of the bright-up to approximately the same point in the Fishpond scan for all three sawtooth inputs. The W.F.G. control will only be used with the 10 mile sawtooth input and the switch unit control with the 50 mile sawtooth input.

527. If the W.F.G. 43 is used to provide an independent bright-up for Fishpond, both the W.F.G. and switch unit bright-up controls should be set fully anticlockwise. The same settings apply when the indicator 184 is used without Fishpond.

The Bright-up Flip-Flop Waveforms.

528. The waveform at the junction of R.560 and R.561 may logically be expected to be the square wave input from V.500 anode negatively D.C. restored by V.509 (b) about the potential of the common diode cathode line. The

negative phase of the square wave is differentiated to some extent in the master multivibrator and it also has different amplitudes on different scans. The inclusion of the diode V.509 (b) ensures that the upswings of the square wave bring V.506 grid up to approximately the same level on all scans to provide a common starting level for the sawtooth rise.

529. The waveform across C.525 will show the attentuation introduced by VR.500 and a measure of shape distortion.

530. The waveform or V.510(a) anode will show the top-cutting of the sawtooth by V.510(a) when the anode is carried above the potential of the common diode cathode line

531. The waveform on V.506 grid will be the composite effect of (i) the tapped down square wave whose amplitude is dropped across R.561, (ii) the chopped-off sawtooth, and (iii) the effect of the condenser, C.528. Fig.107 (e) and (f) shown the idealised waveform and the actual waveform. C.528 was introduced for the early indicators. The sawtooth passed via the magslip and indicator transformers to the P.P.I. experiences a slight delay relative to the sawtooth fed directly from T.501 to the bright-up flip-flop. Without C.528 in the bright-up circuit the bright-up tended to terminate before the scan was completed on the P.P.I. The presence of the condenser counteracts the shunting effect of the stray capacities at V.506 grid which introduces high frequency losses that round off the grid waveform. The result is to steepen the waveform edges which serves to bring the valve into conduction earlier and also to hold it in conduction longer.

532. To appreciate the reason for the step in the waveform it is necessary to note the effects of the square wave and the sawtooth on V.509 (b) and V.510(a). When the working stroke terminates and the square wave collapses the tapped down drop cuts off V.506 grid. Capacitive effects round off the sharp drop. V.509(b) will, of course, be cut off as the anode is carried below the cathode by the input amplitude. V.510(a) will, however, remain in conduction because the sawtooth output from C.525 applied across R.563 and V.510(a) will be of sufficient amplitude to override the small effect of the square wave after tapping down across both R.561 and R.562. Hence, V.506 grid sits at a steady level determined by V.510(a) until the flyback of the sawtooth carries V.510(a) anode below the common cathode potential. The diode then cuts off and V.506 grid is carried down with the flyback of the sawtooth output from C.525 until the flyback ends.

533. At the commencement of the next working stroke the square wave swings up the junction of R.560 and R.561 from the level to which it climbed by differentiation. If V.509(b) were not present, the rise would be through the upswing from the differentiated level which varies with the scan. This would mean that the junction of R.560 and R.561 would rise to different levels on different scans. With the diode in the rise will be limited at the point fixed when the junction of R.560 and R.561 reaches the level set by the diode. The sharp rise is rounded off on V.506 grid waveform due to capacitive effects

534. After the initial sharp rise due to the square wave the rising sawtooth carries V.506 grid up again until cut-off is passed when the next bright-up pulse begins.

535. The waveform on V.507 anode is weirdly distorted because of the time constants used in the D.C. coupling to V.508 grid. These time constants are devised to permit D.C. coupling which will switch V.508 grid between two fixed levels with the bright-up square wave without distorting the square wave applied to V.508 grid. The fundamental idea is to anticipate unavoidable high frequency losses by introducing a capacitive path across the bridging resistor which will discriminate against the low frequency components. The input to V.508 grid then has an excess of high frequency components which are shunted out in the stray capacity at the grid and the parallel path to V.512 cathode. By suitable coice of components a good bright-up square wave is obtained at V.508 grid on all scans.

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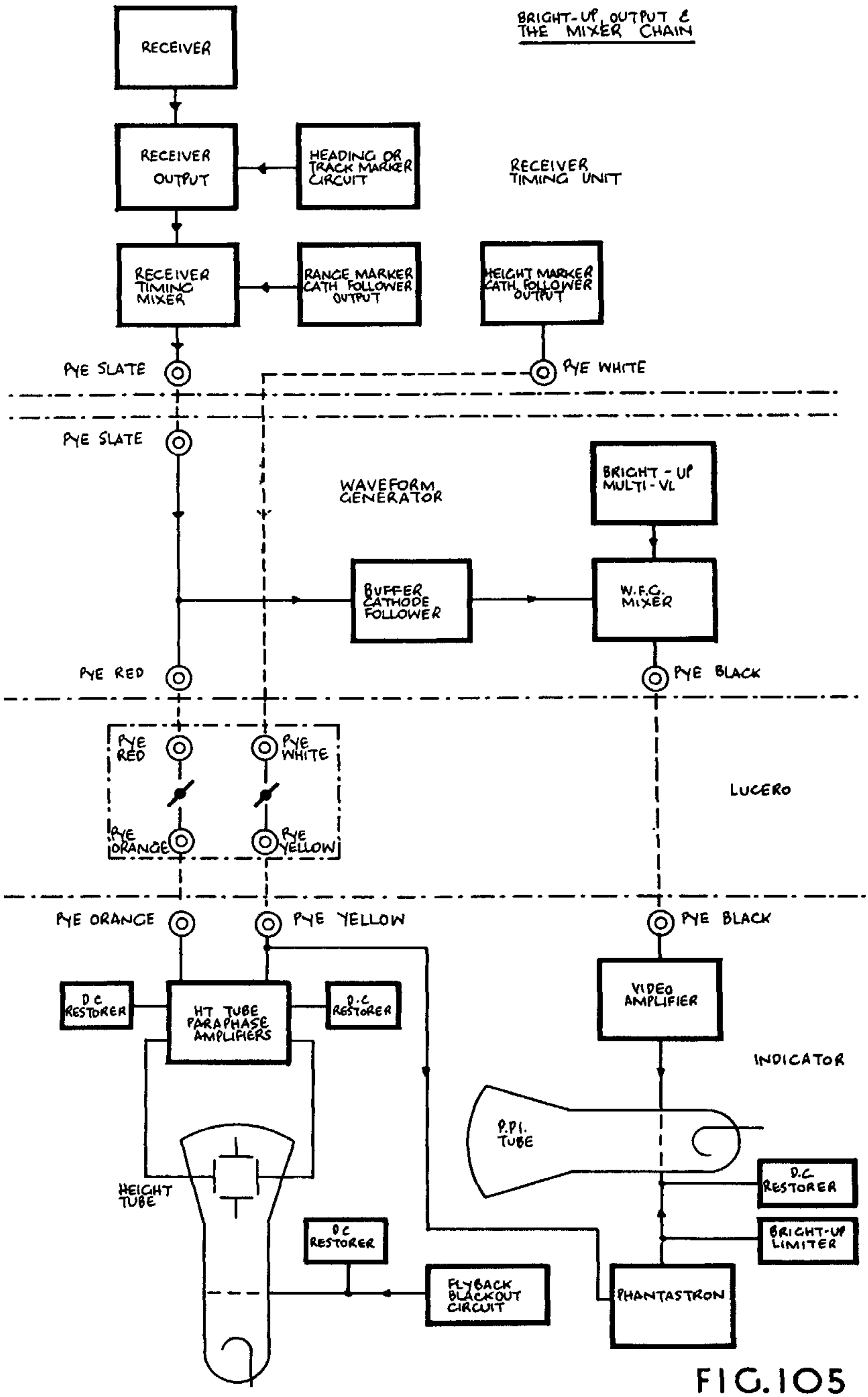

FIG.105

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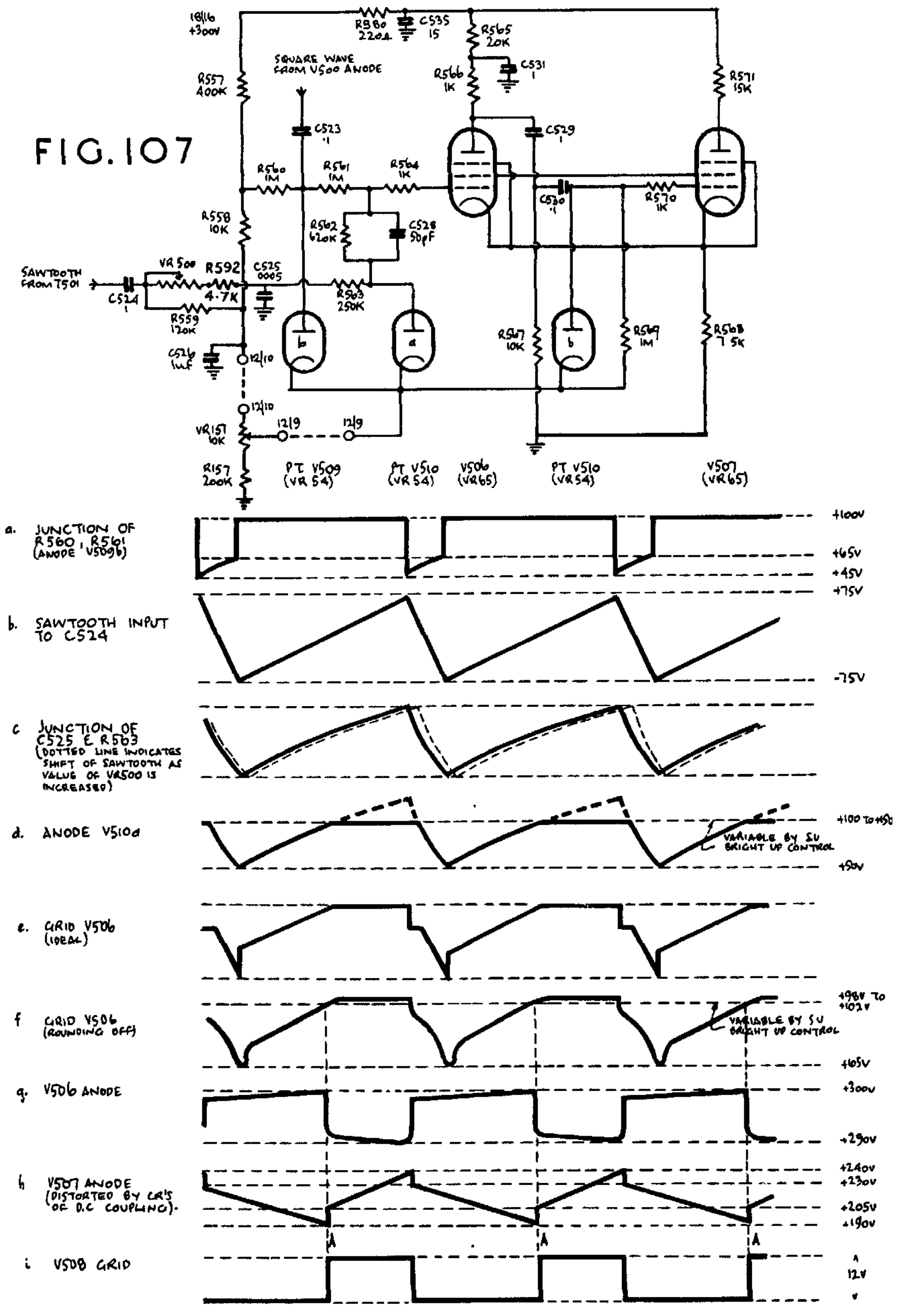
THE BRIGHT-UP FLIP-FLOP



	6 MILE RANGE	20 MILE RANGE	40 MILE RANGE
TIMING OF POINT A VARIABLE BY VR500 (W F G)	15 μSECS	10 μSECS	NEGLIGIBLE
" " " " " " VR151 (S U)	7 μSECS	15 μSECS	20 μSECS

The Buffer Cathode Follower, V.512

536. The next stage in the synthesis of output for ultimate application to the P.P.I. grid is the combination of the bright-up waveform with the mixed output from the receiver-timing unit mixer. This mixing of the bright up square wave with the result of the previous mixing is carried out in V.508, the waveform generator mixer. The relation of V.508 to the buffer stage, V.512, and the video amplifier in the indicator 184 is shown in fig.104. The component numbering on the video amplifier stage applies to the RPU indicator.

537. The input at the slate Pye plug on the panel of the W.F.G. includes valve noise, suppression break, signals, heading or track marker and range marker. All these signals are positive-going with the possible exception of the range marker which may be negative-going when a blackout marker is desired. This input is coupled to the red Pye plug via C.540 (.1) and R.590 (1M.). From the red Pye plug this output is passed to the red Pye on Lucero where it is cross-connected again to an orange Pye. From the Lucero orange Pye it is conveyed to the orange Pye of the indicator 184 for application to the grid of one of the height tube paraphase amplifiers. The bright-up waveform is not wanted on the height tube as it would cause a step on the trace. V.512 serves as a buffer between the stages feeding the bright-up waveform to the P.P.I., and the height tube paraphase amplifier. The output from V.512 is taken off at the cathode and developed across R.578 for application to V.508 grid. The bright-up waveform is D.C. coupled to V.508 grid and swings the grid between two levels fixed by the high and the low phases, V.512 cathode will also swing with the bright-up waveform but this signal cannot couple back to the grid and thence to the slate and red Pye plugs. The bright-up waveform is thus isolated by V.512 while the signal input is passed on for mixing with the bright-up waveform.

The Waveform Generator Mixer and Video Amplifier.

538. These two stages must be considered together as the cathodes are D.C. coupled by the black Pye cable from the W.F.G. to the indicator 184. The effective common cathode load is the equivalent resistance of the two cathode loads in parallel. The total cathode current drawn by the two valves will depend on their grid potentials. The grid potential of V.508 is swung between two levels fixed by the positive and negative phases of the bright-up square wave. The grid potential of the video amplifier can be varied over a considerabl range with the contrast control. When the contrast is fully counter-clockwise the video grid has its maximum positive value and the valve then passes the maximum current through the common cathode load. V.508 cathode is then at its highest level and V.508 current at its minimum level. Signals on top of the bright-up pulse will have minimum effect on the current passed by V.508 and so on the common cathode potential. Under these conditions only the top of the bright-up waveform and the superimposed signals will make V.508 conduct. This conduction means an increase in the current through the common cathode load and voltage rise of the common cathodes. With the video grid stationary the rise of the cathode is equivalent to a negative signal on the grid and therefore results in a positive output at the video anode.

539. As the contrast control is taken clockwise the grid potential of the video amplifier is reduced. The valve then takes less current through the common cathode load and the common cathode potential falls. Hence a greater proportion of the bright-up pulse is passed by V.508 and the amplitude of the bright-up waveform at the video anode increases. Since the video amplifier is now taking less current the same signals on V.508 grid are causing a greater change at the common cathode and hence a greater output at the video amplifier.

Setting of Contrast Control Required for Fishpond.

540. For the operation of Fishpond without an independent bright-up supply of its own, it is necessary that the contrast be carried far enough clockwise to permit adequate bright-up square wave to pass through V.508 and appear at the black Pye output plug. A parallel output carries the mixed bright-up and signals to the black Pye on the Fishpond panel. Thence it is condenser coupled to the cathode of a signal amplifier similar in design to the video amplifier

stage. The positive-going output is applied to the grid of the Fishpond P.P.I. which uses a diametrical scan. If there is an inadequate bright-up square wave passed to Fishpond the scan and the flyback will break through and make the display unreadable. Until such time as an independent bright-up unit becomes available for Fishpond the minimum contrast setting is determined by the bright-up square wave amplitude required to make Fishpond usable.

The Contrast Control as a Top-Cutter and Amplitude Limiter.

541. As the clockwise rotation of the contrast control is increased and the video current decreases while V.508 current increases, we presently reach the point where the peak swings at the common cathode due to signals on top of the bright-up at V.508 grid, will carry the video cathode up above the grid potential by the grid base. That is, the signal input is cutting the video amplifier off on the grid although applied to the cathode. If the contrast control is taken still further clockwise, thus lowering the video grid potential still more, the tops of the signals will be cut off. If a mixture of weak and strong signals is being received it is possible to so set the contrast control that the tops of the strong signals are cut off on the grid and the output at the anode will show equal amplitudes for the strong and weak signals. Used in this way the contrast control becomes an amplitude limiter or top-cutter. There may be some advantage in using such an advanced contrast setting when it is desired to make a target area show up as a solid mass in order to get an idea of target outline rather than target detail. It must be borne in mind that with this setting of the contrast control all the receiver noise and general ground return is being passed through the video amplifier and impressed on the P.P.I. grid. By a suitable setting of the brilliance control it is possible to cut away some of this noise and general ground return and leave primarily the mass of signals reduced more or less to a common amplitude and capable of producing only a bright blotch. Such a use of the contrast control can be used to get a mass response but cannot hope to give any details of a target area.

542. A high gain setting and well advanced contrast may also be used to get sharp land-water definition. With high gain and top-cutting, the land responses will give a high intensity against which the weak water responses will show as a relatively blank area on the P.P.I. display.

Contrast Setting for Maximum Target Detail.

543. If target detail is wanted, i.e., if strong signals are to show up with greater brightness than weak ones in order to differentiate between, say, densely built-up factory areas and suburban areas, we want the signal amplitude in the video amplifier output to bear a reasonable relation to the strength of the relative responses. This condition can probably be best fulfilled if the contrast control is so set that normal good signals just carry the video stage to cut-off. If the output at the video anode is scoped as the contrast control is carried clockwise the amplitude of a good signal or of the range marker will be seen to increase until the point is reached where top-cutting begins. Further clockwise rotation of the contrast control will result in further amplification of the bright-up and superimposed noise and an actual reduction of the range marker or signal amplitude. The setting of the contrast control to achieve maximum contrast between strong and weak signals is then at the point where the normal good signal is just carrying the video stage to the cut-off point. This setting can be approximated on the bench by observing the output at the video anode on the monitor 28. Alternatively, the range marker dot may be observed on the P.P.I. with the scanner stationary. Gain, contrast and brilliance should first be taken fully counterclockwise. The briliance is first brought up to show the scan and then turned back about 4 notches from the point where the scan fades out. If the contrast is now taken clockwise to the point where the radial scan appears and is then taken back about 1 notch from the point where the scan fades out, the position for maximum detail is approximately located.

The Sloping Bright-Up Top.

544. If the waveform on the P.P.I. grid or video anode is examined it will show a sharp initial rise and then a gradual climb to a peak value. This distortion results from the fact that decoupling condenser for the video anode H.T. supply does not offer negligible impedance to the low frequency components in the square wave. This can be seen by examining the waveform on the condenser. This distortion is not actually a disadvantage as it helps to minimise the effect on the display of the strong, close-in, general ground return. The 1 mh. choke is the standard video amplifier method of counteracting the shunting effect of stray capacity at the high frequency end of the band which the stage is required to amplify.

The P.P.I. D.C. Restorer.

545. When a measure of bright-up square wave is included in the video output applied to the P.P.I. grid the mean D.C. level of the P.P.I. grid will vary with the range in use. This follows from the fact that the P.P.I. grid mean level will be such that the area of the input waveform above the mean level will be equal to area below it. As the range diminishes the length of the positive-going bright-up square wave shortens. Hence the mean level of the P.P.I. grid will tend to fall as the shorter scans are brought into use. This means that the setting of the brilliance control should be altered as the scan is changed.

546. To eliminate the need for resetting the brilliance control as the scan is changed a D.C. restoration stage is connected to the P.P.I. grid. Details are shown in fig.104. The anode of the VR.78 restorer is tied to the slider of the brilliance control. The cathode of the restorer is returned through 1M. to the foot of the brilliance control. As the anode is thus held positive to the cathode the valve will conduct. The bleeder current therefore divides at the foot of the brilliance control. Part flows through the 1M. and the diode to the brilliance slider where it rejoins the current flowing straight up the bleeder. The other part flows through the brilliance potentiometer. The impedance of the conducting diode is low in comparison with that of the 1M. cathode resistor so the diode cathode and anode will be approximately at the same potential, i.e., at the potential of the brilliance slider. As the P.P.I. grid is tied to the restorer cathode it will likewise sit at approximately the brilliance slider potential.

547. When the bright-up square wave is applied to the P.P.I. grid it is also applied to the restorer cathode. This tends to cut the diode off so the diode current switches into the bleeder. As more current now flows through the bleeder the potential at the brilliance slider rises and raises the potential of the diode anode. The effect of the input signal is then to develop a voltage across the 1M. cathode load which serves to raise the potential of the diode cathode and anode together. This can be confirmed by scoping on the brilliance slider with a suitable high voltage condenser in the scope lead. At the end of the signals and bright-up pulse the P.P.I. grid and diode cathode are carried down and the diode current goes back to its peak value. The brilliance slider potential then falls back to its base level which is the on all scans so the same brilliance setting will result in the same intensity for a given signal amplitude regardless of the scan in use.

The Phantastron Bright-Up.

548. It was pointed out in para. 517 that the W.F.G. bright-up waveform could not simultaneously meet the Fishpond requirement of commencement on the back edge of the modulator priming pulse, and the indicator 184 requirement of starting when the eight marker forms. It was indicated that a subsidiary bright-up waveform was taken from the phantastron cathode and applied to the P.P.I. cathode. This input to the P.P.I. we shall call the phantastron bright-up. The effect of the two bright-up waveforms was illustrated in the waveform series shown in fig.106.

549. The relevant circuit details are shown in fig.104. The phantastron develops a negative-going square wave at its cathode commencing when the height marker forms and continuing for about 1000 microseconds. Details of the

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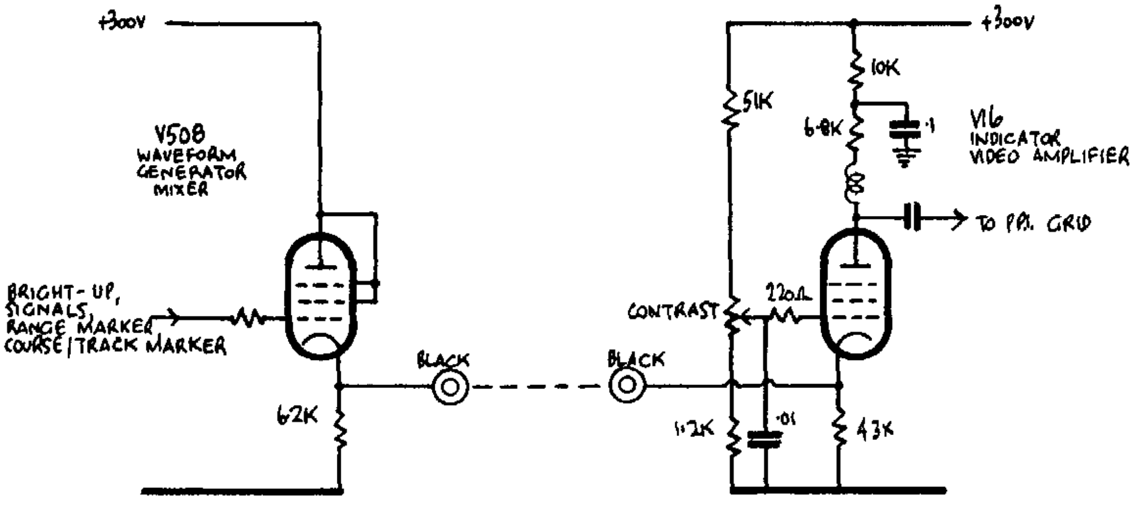
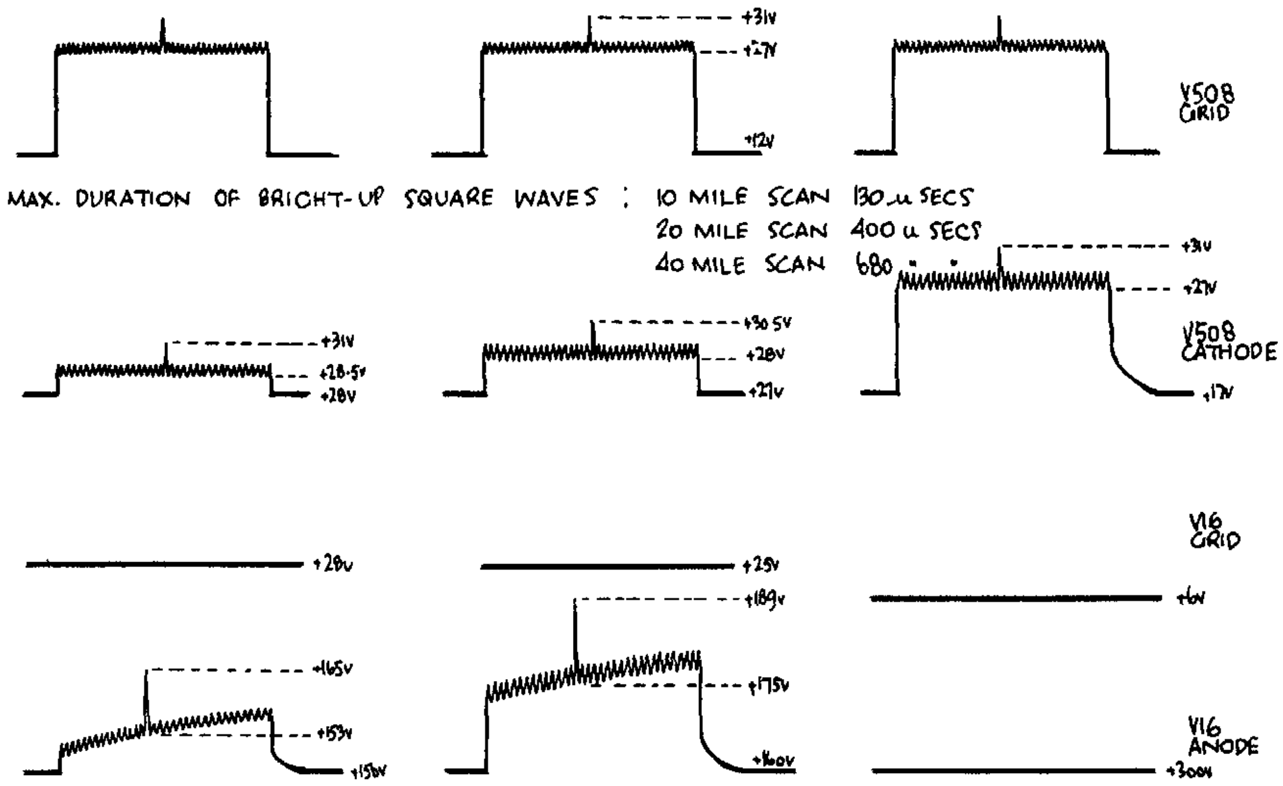
V508 AND VIDEO AMPLIFIER.



WITH CONTRAST CONTROL FULLY ANTI-CLOCKWISE

WITH CONTRAST CONTROL IN NORMAL SETTING

WITH CONTRAST CONTROL FULLY CLOCKWISE



V16 GRID BIAS AT MAX COMMON CATHODE POTENTIAL AT HIGHEST LEVEL - HENCE V508 PASSING MINIMUM CURRENT - MINIMUM AMPLITUDE OF BRIGHT-UP FED TO V16 CATHODE

NORMAL SETTING FURTHER CLOCKWISE ROTATION WILL CAUSE TOP CUTTING OF SIGNALS

AS CONTROL TURNED CLOCKWISE INCREASED TOP CUTTING OCCURS UNTIL EVENTUALLY V16 IS COMPLETELY CUT-OFF

FIG.108

the phantastron operation are discussed in paras. 158-162. The waveform on the cathode has an amplitude of around 60V. This is tapped down across 47K. in series with 560K. and applied to the cathode of a diode limiter. The tapping arrangement holds the diode cathode at a D.C. level of about + 5V. When the negative-going signal appears the diode then limits the amplitude of the swing on cathode to about - 5V. which is applied to the P.P.I. cathode. Driving the P.P.I. cathode negative has the same effect as driving the grid positive, i.e., to increase emission. As shown in fig.106, the setting of the brilliance control must be such that the added effect of the two bright-up waveforms holds the P.P.I. grid just short of the threshold of illumination. Superimposed signals and markers will be able to carry the grid above the threshold only while both bright-up waveforms are operative. In this way there is no possibility of valve noise causing a brightened up spot in the centre of the tube during the waiting period between the instant the transmitter fires and the instant the height marker forms. On the other hand, the fall of the P.P.I. grid when the W.F.G. bright-up ends will cause a sufficiently large drop to prevent the flyback showing up on the tube. This assumes that the contrast is set sufficiently clockwise to permit the passage of adequate bright-up square wave through V.508.

The Height Tube Paraphase Amplifier Stage.

550. (a) The relationship of this stage to the mixing and output circuits generally is shown in fig.104.
(b) Waveforms are shown in fig.109.

551. From fig.104 we see that the height marker is taken from the white Pye plug on the receiver-timing unit to the corresponding plug on the Lucero unit where it cross-connects to the yellow Pye plug. Thence it is taken to the yellow Pye on the indicator 184, and applied to the grid of the one amplifier. The mixed output of the receiver-timing mixer stage is applied to the slate Pye plug on the W.F.G. There it corss-connects to the red Pye and passes to the red Pye on Lucero where it cross-connects to the orange Pye. Thence it passes to the orange Pye on the indicator 184 and the grid of the other amplifier

552. Examination of the amplifier circuit in fig.109 shows the following significant points:-

(a) The 2K. cathode loads are strapped by a 270 ohm resistor.
(b) The 270K. grid leaks are returned to the decoupled junction of a bleeder across H.T. of 510K. and 47K. in series. This serves to give the grids a D.C. potential of around 27V.
(c) The grids are also returned to the same decoupled tapping point through diodes.
(d) Equal anode loads are used and the circuit is completely symmetrical.
(e) The anodes are D.C. coupled to the Y-plate of the height tube.
(f) The 270 ohm cathode strapping resistor is shunted by a .0015 condenser.
(g) $1\frac{1}{2}$ metre chokes are inserted in the grid inputs.

553. As the amplifier grids are returned to a positive potential the valves are in steady current which gives the cathodes a D.C. potential of about +29V. There is therefore a standing negative bias of about 2V despite the fact that the grids are tied to a positive potential.

554. Let us assume for the moment that only the yellow input is connected. The only input to the amplifier will then be the height marker. The positive-going marker swings the grid up so the valve passes more current. This will cause the anode potential to fall. At the same time the cathode potential will rise. Of this rise, a proportion given by $\frac{2000}{2270}$ or about 88% is applied to the other cathode. Since the second grid is stationary this rise represents the equivalent of a negative input on the grid. The result of the heiht marker input is then a simultaneous fall at the anode of the valve to which it is applied and a rise at the anode of the other valve. The net input signal on the first grid is the difference between the actual input and the cathode rise. The 270 ohm resistor is chosen to make this effective input approximately equal to the input on the second cathode. In this way one signal can be used to produce a push-pull output which is reasonably well balanced. By applying the negative-going output to the

right signal plate and the positive-going one to the left signal plate the electron beam will be reflected to the left to give the height marker blip as a deflection of the trace to the left.

555. The input on the other grid includes the valve noise, suppression break, range marker, signals, and heading or track marker. These signals will operate in precisely the same way as the height marker to give a push-pull output. The phase of this output will, of course, be opposite to that of the height marker so the deflections will be to the right. If the blackout range marker is used, it will appear on the left.

556. The absence of noise during the 20 microsecond suppression break will result in a clear trace for the suppression interval. As the suppression is reduced the transmitter pulse breakthrough will show at the end of the suppression period. It must not be assumed that the end of this breakthrough represents zero time. The width of the transmitter breakthrough pulse will depend on how much signal is generated in the magnetron due to overswinging of the pulse transformer despite the diode damping, and how much this magnetron output shocks the tuned circuits of the head amplifier and I.F. strip. Any attempt to set up the height zero by referring to the back edge of the transmitter breakthrough is therefore extremely likely to result in anything but a reasonable accurate adjustment.

557. The centring of the height tube trace is entirely dependent on the balancing of the D.C. anode potentials of the two valves since D.C. coupling to the signal plates is employed. Any change in the values of the resistors used as anode and cathode loads or any change in the emission of either valve will therefore result in a lateral shifting of the trace.

558. The 1.5 metre chokes inserted in the grid inputs are to block any signal from the Lucero transmitter pulses which may be picked up where the connections are made from one Pye plug to another inside the Lucero unit.

559. The .0015 condenser across the 270 ohm cathode strapping resistor is included to compensate for shunting of the high frequency components in the pulse edges by stray capacity. The high frequency components will find a lower impedance path across the condenser than the low frequency components. This discrimination tends to balance out the greater shunting of the high frequency components by stray capacity, and so results in a better pulse shape.

The Height Tube D.C. Restorers.

560. Valve noise is applied to the one amplifier grid (except during the suppression period) but very little noise will appear with the height marker. This effect alone would tend to shift the D.C. level of the one grid to a higher value than that of the other grid. The presence of all the signals and the heading marker on the same grid would tend to accentuate this effect. Since the period during which signals are received will vary in length with the scan in use, there would be a tendency for this displaced D.C. level to vary with scan changes. To ensure that the D.C. level of the two grids remains equal and constant the diode restorers are connected across the grid leaks to the decoupled tapping point. All signal and marker inputs will then swing the two grids from the common level which will be independent of the scan in use.

The Height Tube Black-out Circuit.

561. The height tube scan is obtained by feeding the push-pull master sawtooth output from the centre-tapped secondary of T.501 in the W.F.G. through an amplifying transformer whose split secondary provides a push-pull output to the time-base plates. As we do not want the flyback on the display some provision is required to carry the grid of the height tube below threshold level during the flyback period.

562. Details of the height tube circuit are shown in fig.110. The sawtooth output from one end of the split secondary of the sawtooth transformer is

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HEIGHT TUBE PARAPHASE AMPLIFIERS

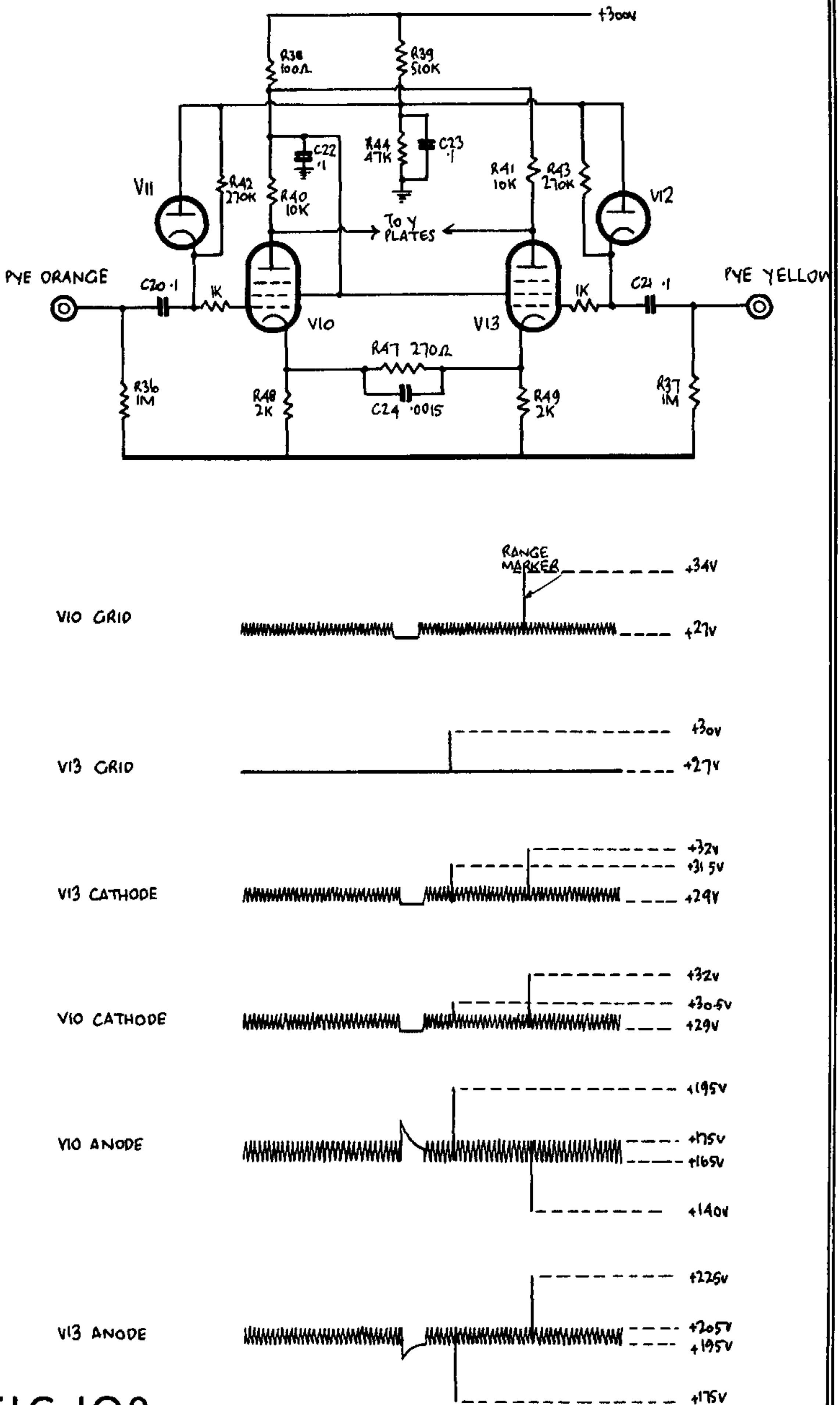

FIG. 109

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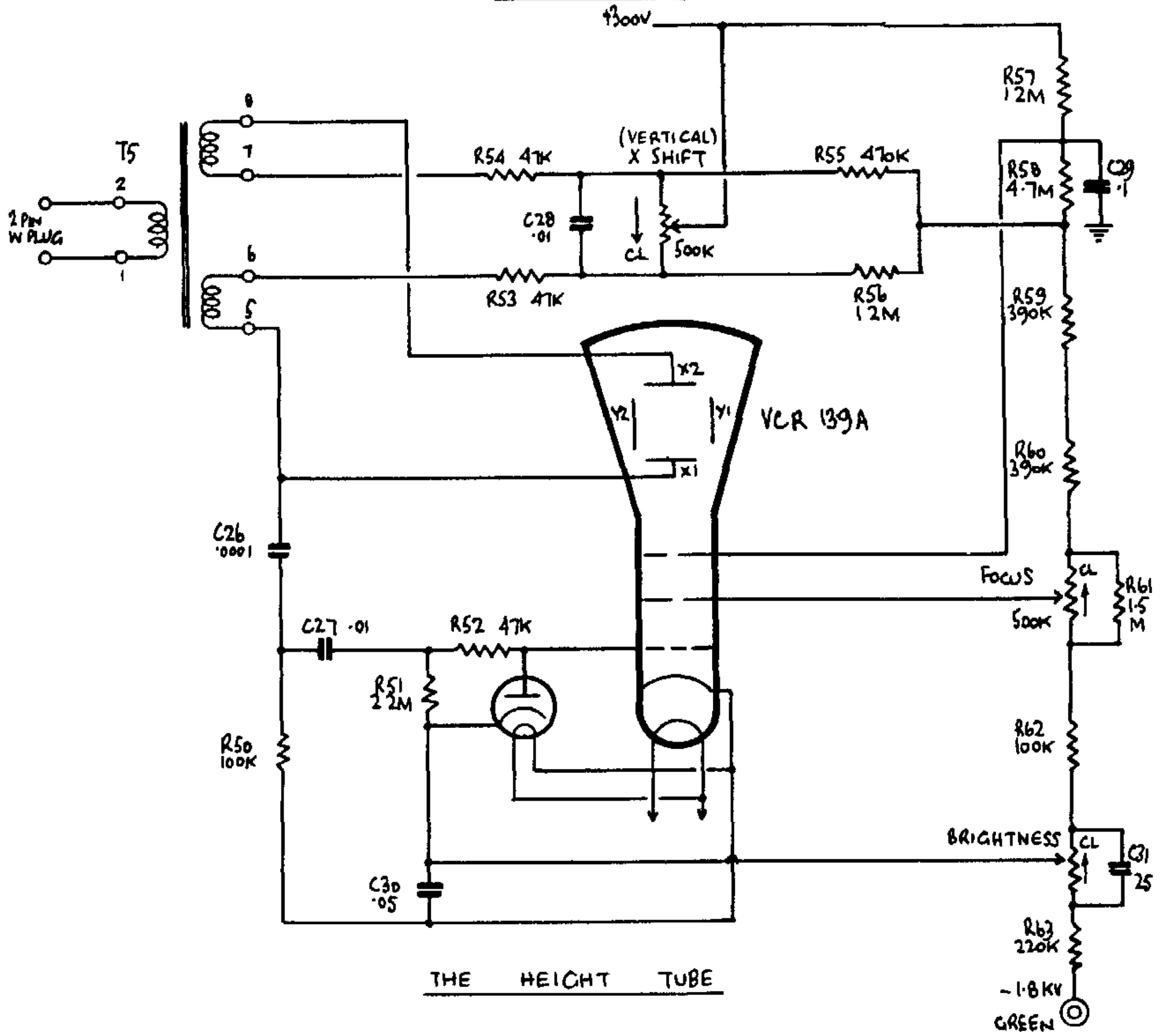
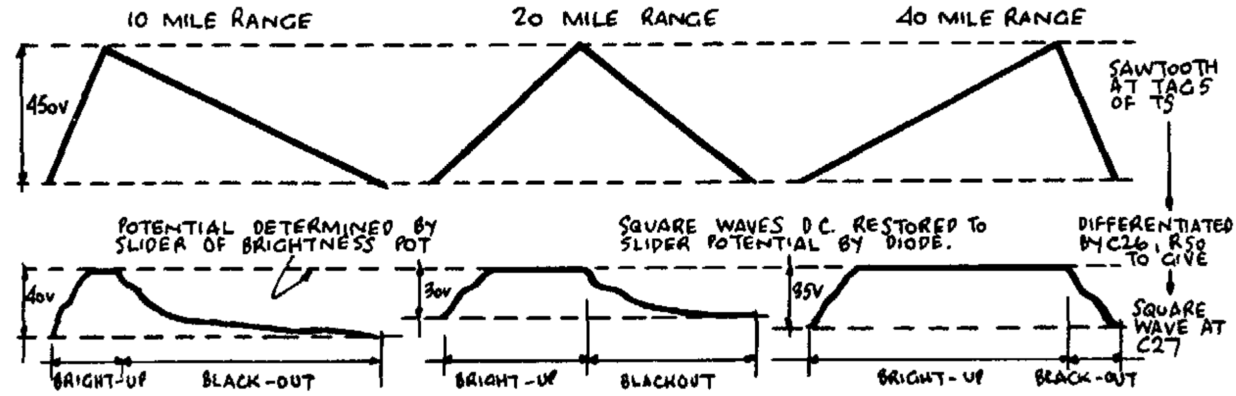
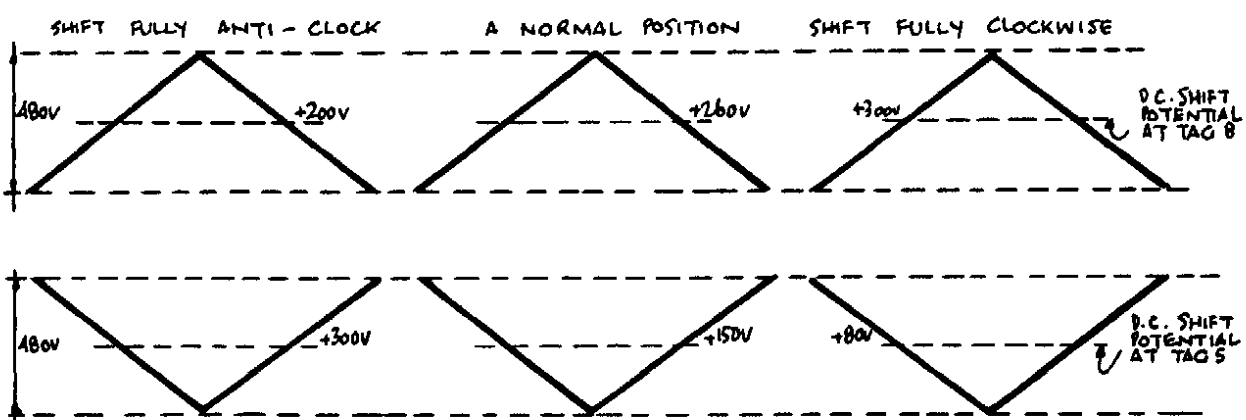


THE HEIGHT TUBE



HEIGHT TUBE BLACKOUT



HEIGHT TUBE SHIFT

FIG. 110

differentiated in the time constant provided by a .0001 (two 50 pf. in parallel in Gramco units) condenser, C.26, and a 100K. leak, R.50. The output voltage developed across the resistor is applied via a .01 condenser, C.27, to the D.C. restoration circuit of the height tube grid. The small condenser of the differentiating CR. offers a high impedance to the low frequency components in the sawtooth. The output across the 100K. leak therefore possesses an appreciable excess of high frequency components since these are passed by the condenser. The result is a squaring off of the sawtooth to give a squarish wave. The positive part of this squarish wave corresponds to the working stroke of the scan and the negative part coincides with the flyback. By negatively restoring this waveform with respect to the height tube grid potential, as fixed by the brilliance control, the negative part can be used to blackout the flyback.

563. The D.C. restoration circuit uses a VR.78. The cathode is tied to the brilliance slider and the anode is tied to the height tube grid. The brilliance slider is decoupled with respect to the height tube cathode by C.30 (.05). R.52 (47K) serves as grid stopper for the height tube. R.51 (2.2M) is the leak of the input time constant and C.27 (.01) is the condenser.

564. Assuming that we had no blackout input to C.27 the diode anode and cathode would be at the brilliance slider potential. The height tube grid would then be at the same level. When the positive part of the waveform is applied the effective input time constant is C.27, R.52, i.e., 470 microseconds. There will then be considerable differentiation of the positive part of the square wave. The positive voltage developed will appear across R.52 and the diode in series. As the conducting diode impedance is low in comparison with 47K. the diode anode and height tube grid will remain practically stationary at the brilliance slider level. When the scan ends and the falling edge of the input waveform is applied to C.27, the height tube grid and diode anode are then carried down and the flyback is blacked out. As the diode impedance is now infinite the effective input time constant is C.27, R.51 (22,000 microseconds). This time constant is so large in comparison with the blackout period that differentiation is negligible and the full flyback is therefore suppressed.

The Height Tube Vertical Shift

565. As we are only blacking out the height tube flyback the height tube grid is held above the threshold level for the entire scan. For navigation and bombing the transmitter fires at approximately the centre of the scan. The useful part of the scan is then only the second half following the suppression break. Since the height tube is small only a portion of the scan can be displayed on it. We must then have a vertical shift to permit setting the usual part of the scan to start at the bottom of the tube. The shift network consists of the shift control, VR.12, and the resistors R.55 (470K.) and R.56 (1.2M.) The slider of VR.12 is returned to +300V. while the common point of R.51 and R.56 is tapped down on the height tube bleeder. Electrons then flow from the tapping point through R.55 and the one side of VR.12 to the slider and thence to the 300V. line. A parallel flow occurs through R.56 and the other side of VR.12. These current flows must always be such as to develop equal voltage drops in the parallel paths. The magnitude of the current in either path will then vary as the resistance of the path is changed by altering the setting of VR.12. Hence, the voltage drops across R55 and R56 are varied as the setting of VR.12 is varied. The one Y-plate is held above the potential at the junction of R.58 and R.59 by the drop across R.55, and the other above the same potential by the drop across R.56. By suitably adjusting VR.12 the lower timebase plate is held sufficiently positive to the upper plate to depress the electron beam so as to bring the suppression break to the bottom of the tube.

566. As was pointed out previously, if the scan-marker switch is set to the 100/40 position the transmitter firing is advanced about 500 microseconds. The suppression break is then carried down into the depressed part of the scan and the visible part of the scan represents ranges of the order of 40 - 90 miles.

The Height Tube Bleeder Supply

567. The height tube bleeder current is taken from the -1.8KV. supply in the power unit. In the case of the Mark IIC installation this supply is brought

from the power unit to the tuning unit 207 for the klystron. A cross-connection is made to a parallel plug which is connected to the indicator to supply the height tube bleeder.

568. In the Mark IIIA installation the -1800V. supply is taken straight from the power unit to the indicator 184.

The P.P.I. bleeder supply

569. The current for the P.P.I. bleeder is obtained from the -4KV power pack in the modulator type 64. The input is brought from the blue uniplug to one of the blue uniplugs on the indicator which is connected to the bleeder terminus. The other end of the bleeder is returned to earth.

570. A parallel blue output plug is available on the indicator 184 from which a -4KV. supply is obtained to supply the Fishpond P.P.I. bleeder.

CHAPTER 9 - THE ROLL-STABILISED SCANNERS.

Purpose of Stabilisation.

571. When an aircraft is flying straight and level the axis of rotation of the scanner is perpendicular to the earth's surface. As the scanner rotates the H.2.S. beam rotates with it. If the aircraft banks the axis of rotation of the scanner is tilted with respect to the earth's surface. The H.2.S. beam them experiences two simultaneous displacements - the normal rotation, and a slide in the direction towards which the axis of rotation is displaced. This means that the H.2.S. display also slides. This can be appreciated if we think of the scanner as being stationary when the bank occurs. As the beam slides without rotating a different sector of the earth's surface is illuminated and indications from other targets or other parts of the same large target, will appear on the scan then occurring. This sliding of the H.2.S. display during evasive action on a bombing run makes it difficult to bomb accurately with H.2.S. To overcome this difficulty new scanners have been developed which are gyro-stabilised against roll. As soon as the scanner platform is displaced from 1 to $1\frac{1}{2}^{o}$ from the horizontal a gyro comes into action to develop a restoring force. This stabilisation remains effective for displacements of up to 30^{o} to either side. The platform is not stabilised against "pitch", i.e., displacement of the scanner's axis of rotation as the aircraft climbs or dives.

Stabilised Scanner Types.

572. The roll-stabilised scanner for use in the H.2.S. Mark IIIA installation is the scanner Type 71. The one to be used in the H.2.S. Mark IIC installation is the Type 63. These scanners differ mainly in the type of R.F. feeder employed and the dimensions of the waveguide radiator. The Type 71, since it uses a wavelength of approximately 3 cms., uses a waveguide feed. The Type 63, which is designed for use with a wavelength of about 9 cms, uses a coaxial feed. The Type 71 gives a beam width of about $3\frac{1}{2}^{o}$ and the Type 63 develops a beam width of about $8\frac{1}{2}^{o}$.

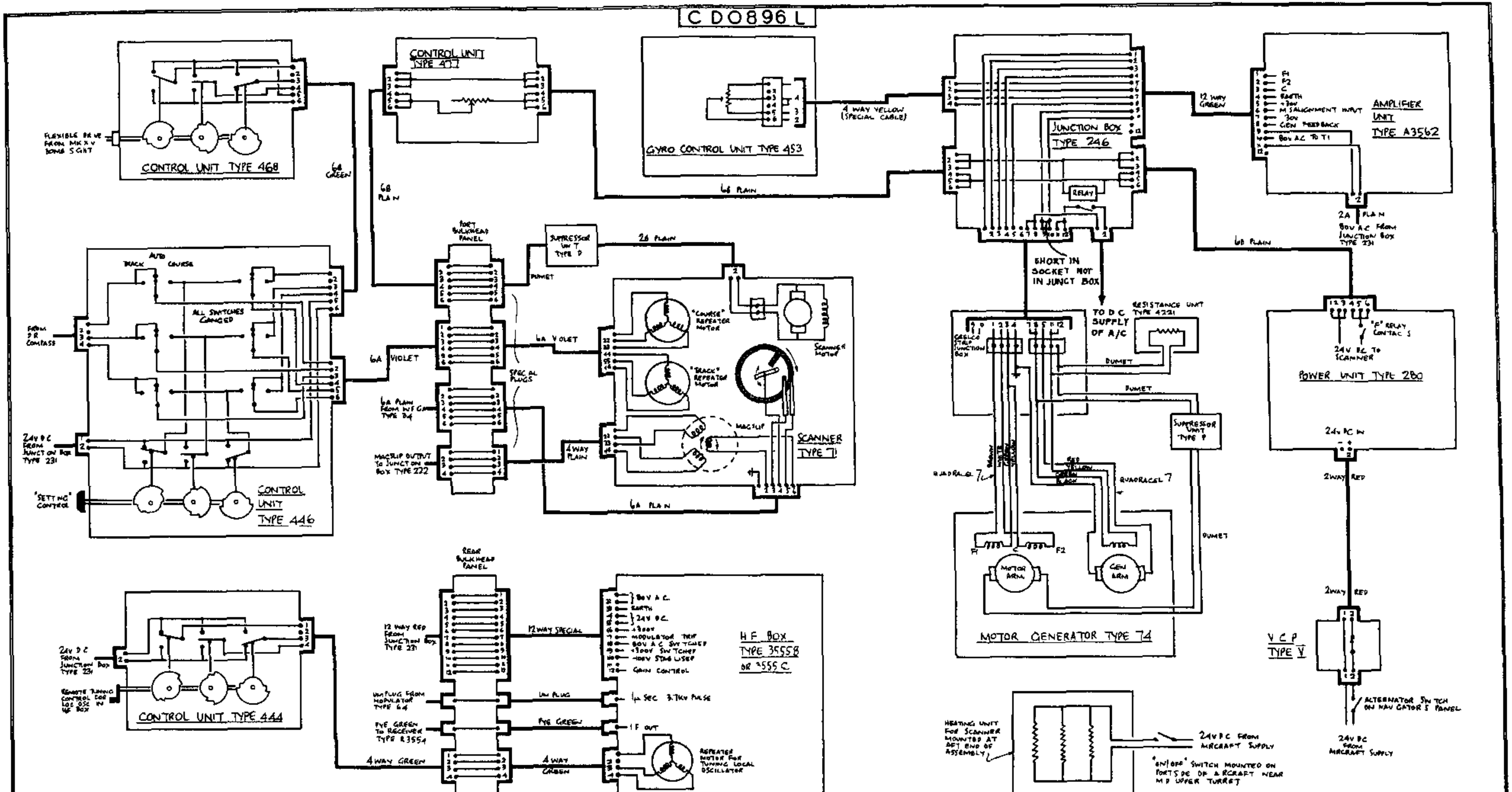
Major Components and their Primary Functions.

573. The main parts of the assembly are as follows:- (See fig.24)

(a) The fixed part of the platform which is rigidly attached to the aircraft frame.
(b) The moving part of the platform which carries the scanner proper, T2R or H.F. box, and gyro control unit.
(c) The gyro control unit which develops the misalignment voltage to operate a motor-generator Type 74.
(d) The motor-generator Type 74 which is mounted on the fixed frame and drives the moving frame.
(e) Balance weights attached to the moving frame to maintain a constant load on the motor.
(f) Junction box 246 and two bulkhead panels mounted on the fixed part of the platform to facilitate cabling connections.

Accessories Mounted Independent of Platform.

574. (a) An engine-driven vacuum pump which provides the suction employed to operate the gyro control unit.
(b) A D.C. amplifier unit to change the misalignment voltage produced by the gyro control unit into current changes which are applied to the fields of the motor-generator Type 74.



ROLL-STABILISED SCANNER - IN H2S MARK IIIA
INTERCONNECTION DIAGRAM

FIG. 111

FIG. 111

Principle of Operation

575. Assume that the aircraft is flying straight and level. The moving platform, swivelled on two brass bushes in line with the fore and aft axis of the aircraft, will be horizontal. The axis of rotation of the scanner will then be perpendicular to the fore and aft axis of the aircraft and to the earth's surface. The gyro axis will be horizontal. Rigidly attached to the gyro case is a slab-wound potentiometer. Attached to the gyro is the wiper contact of this potentiometer. The potentiometer winding is centre-tapped to earth. A D.C. voltage of about 60V. from a power pack in the D.C. amplifier unit is applied to the potentiometer so the ends will be at approximately +30V. and -30V. When the moving platform is level there is no relative displacement between the gyro case and the gyro. The wiper contact is then at the earth point of the slab-wound potentiometer. If the aircraft banks the fixed platform moves with the airframe. The moving platform is linked mechanically to the fixed platform so will be displaced with it and therefore will move the gyro mounting. The gyro itself will, however, maintain its axis of rotation horizontal. Hence there is a relative displacement between the gyro itself and the casing. That is, the slab-wound potentiometer moves relative to the stationary wiper contact and the contact is no longer at earth potential. The actual sign of the potential impressed on the contact will depend on the direction of the roll, i.e., to port or starboard. The magnitude would be determined by amount of roll if no restoring force were brought into play to return the moving platform to the horizontal position.

576. The voltage picked up by the wiper arm is termed the misalignment voltage. This voltage is taken from the gyro by a screened lead to the D.C. amplifier unit where it is used to alter the currents passed by a cathode-coupled VT60A paraphase amplifier pair. These valves provide the field currents for the split fields of the motor section of the motor-generator Type 74. When properly balanced, these field currents will be equal if the misalignment voltage is zero. The motor armature will then be stationary. As soon as a displacement of 1 - $1\frac{1}{2}^{\circ}$ occurs the misalignment voltage applied to the amplifier unit causes sufficient unbalancing of these field currents to cause the motor armature to turn. The motor-generator is mounted on the fixed frame but tied through mechanical links to the moving platform. The rotation of the motor armature operates these mechanical links until the moving platform is again horizontal when the misalignment voltage falls to zero. There is then no unbalancing of the currents applied to the split motor fields and hence no torque on the motor armature which then remains at rest if the bank has been completed. The motor continues to operate as long as there is a misalignment voltage, i.e., as long as there is aircraft roll in either direction. Since banks to opposite sides give misalignment voltages of opposite sign they result in opposite rotations of the motor armature.

The Misalignment Voltage Channel.

577. Details of this channel are shown on the Stabilised Scanner Interconnection Diagram, Fig.111. A quadramet cable links the J.B. Type 246 and the gyro control unit. This cable terminates in a special 6-way socket at the gyro end and in a 4-way coded yellow at the junction box. Cross-connections are shown below:-

Special 6-way	4-way	Carrying
Pin 1	Pin 1	+30V.) to slab-wound
5	3	-30V.) pot. from amp.unit
6	2	misalignment volts
4)	4	earth
3) strapped		
2 blank		

578. In J.B.246 cross-connections are made from the 4-way yellow to a 12-way green which goes to the amplifer unit. Pins 1 and 3 on the 4-way are

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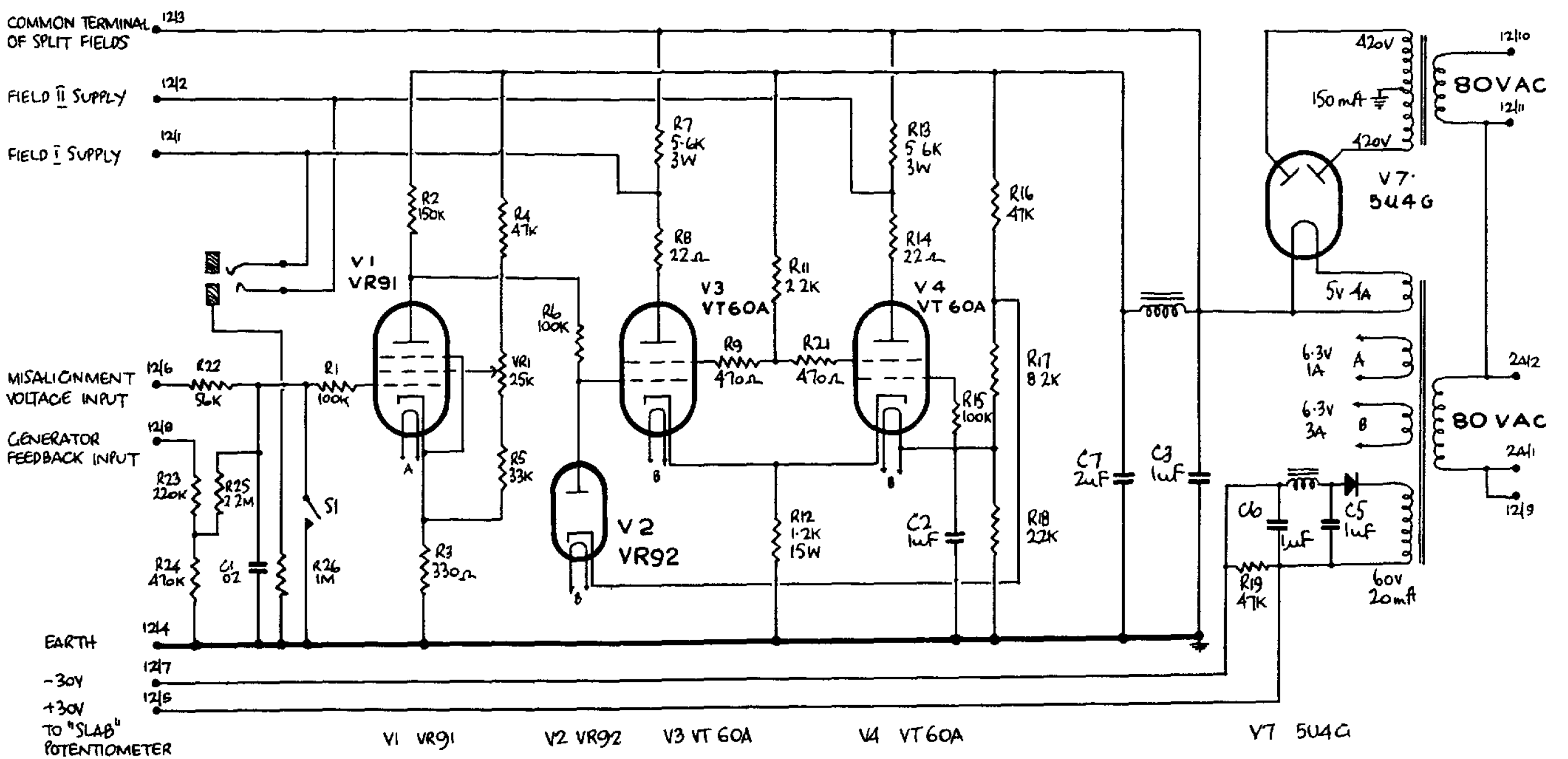

AMPLIFIER UNIT TYPE A3562

FIG.112

FIG.112

tied to pins 5 and 7 respectively. Pins 2 and 4 are tied to pins 6 and 4, respeceively. From the 12-way green on J.B. Type 246 a cable to the amplifier unit Type A.3562 carries the misalignment volts to the D.C. amplifier and brings the D.C. supply for the slab-wound potentiometer from the half-wave metal rectifier in the amplifier unit. These three leads are screened.

The Amplifier Unit, Type A3562 or A3562A

579. Circuit details are shown in Fig.112. V.1 (VR.91) is a straight D.C. amplifier. The misalignment voltage applied to the grid causes variations in the current passed by the valve and hence in its anode potential. R.1 (100K.) serves as a grid stopper. R.22 (56K.) and C.1 (.02) provide light decoupling against rapid changes.

580. V.3 and V.4 form a VT60A cathode-coupled paraphase D.C. amplifier. As V.1 anode potential varies due to the appearance on its grid of a misalignment voltage an antiphase voltage change appears at V.3 anode. V.4 grid is tied to a decoupled potential of about 110V. Suppose V.3 grid is carried positive. This will result in increased current through the common cathode load, R.12, and and increase in the cathode will have the same effect as a negative signal at V.4 grid so will cause V.4 anode voltage to rise. By means of VR1, the operating point of V.3 grid can be so set that the voltage drops across K13 in V4 anode and K7 in V3 anode are equal when V.1 grid is returned to earth, i.e. when the moving platform is horizontal. These voltages are applied to the split field windings of the motor-generator. One winding is in parallel with R.13 and the other with R.7. If V.1 grid is carried up the current in field 1 (in parallel with R.7) is reduced. At the same time the current through field 2 (in parallel with R.13) is increased. This results in rotation of the armature and the moving platform is pulled back to the horizontal when V.1 grid returns to zero and the fields are again balanced. If V.1 grid is carried down the unbalancing of the fields is in the opposite sense and the armature rotates in the opposite direction.

581. The diode, V.2, has its cathode returned to a potential of about 150 volts at the junction of R.16 and R.17. This diode then limits the potential to which V.3 grid can rise to about 150V. R.6 serves as a grid stopper as does R.15.

Balancing the Paraphase Amplifier.

582. A jack and push button switch are incorporated for this purpose. Early models combine the switch and jack, but in later models the two are separated. Pressing the switch S.1 earths V.1 grid and so sets up the same conditions in the amplifier unit as will exist when the moving platform is horizontal. By jacking in a meter at the jack-point the difference in the anode voltages of V.3 and V.4 can be measured. If these are not equal V.R.1 is adjusted until the meter shows no potential difference. Assuming matched valves and no tolerance in component values V.3 grid should then be sitting at the same level as V.4 grid. Where valve characteristics or component values differ this will not be the case when V.R.1 is adjusted for a balance.

The Power Pack.

583. T.1 and V.7 form a 5U4G full-wave rectifier stage. C.3, CK.1, and C.7 provide the necessary smoothing for an output of about 420V. Comparison of the Scanner Interconnection Diagram and the Amplifier Unit Circuit Diagram will show that the 80V. supply to T.1 primary is only completed if the 12-way plain cable from the motor-generator is connected to the J.B. Type 246. The 80V. supply from J.B. Type 83 (Mark IIC) or J.B. Type 231 (Mark IIIA) is brought to the amplifier unit on a 2-way cable. Pin 1 is tied to Pin 9 on the 12-way green on the amplifier unit. Pin 2 is connected to 12/11 and one side of T.2 primary. To complete the circuit 12/9 must be connected to 12/1o and the other side of T.2 primary. This connection is made when the 12-way from the motor-generator is connected to the 12-way plain socket on J.B.Type 246 since Pins 9 and 10 are strapped in the 12-way socket at the J.B.246 end of this cable. Since Pins 9 and 10 on the 12-way plain are cross-connected to Pins 9 and 10 on the 12-way green, Pins 9 and 10 on the 12-way green at the amplifier unit are then connected. This means that the H.T. supply will not

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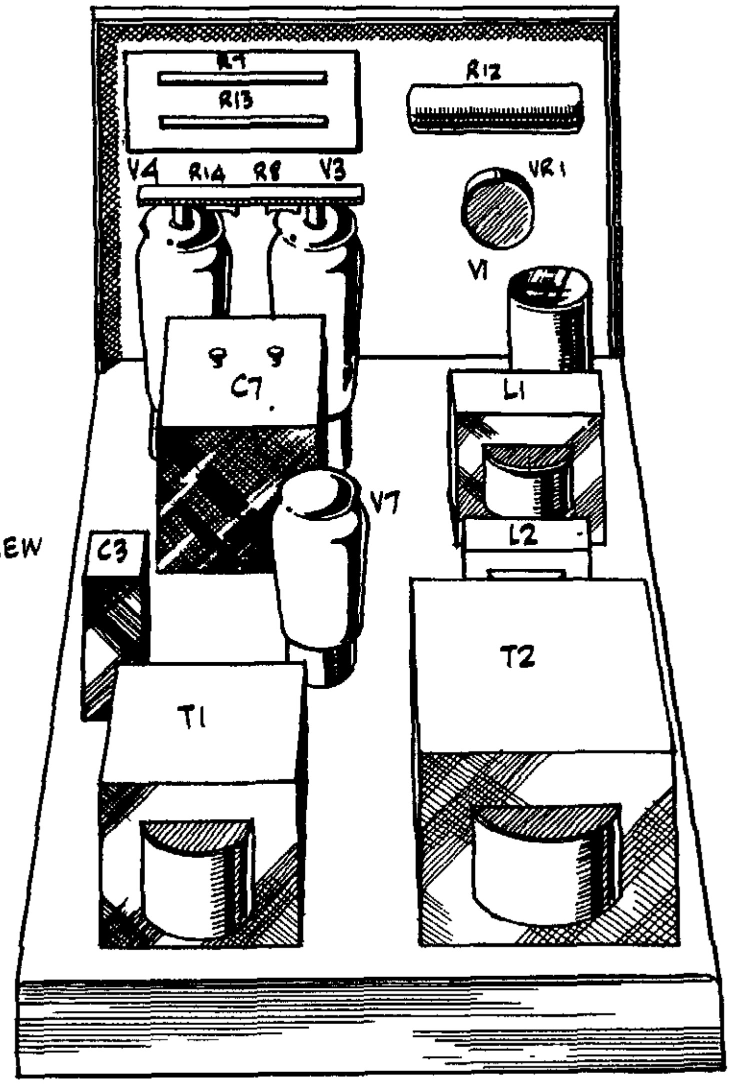
AMPLIFIER UNIT
REF. NO. 10U13 | 6041
CHASSIS LAYOUT

PERSPECTIVE VIEW OF CHASSIS



UNDERSIDE OF CHASSIS

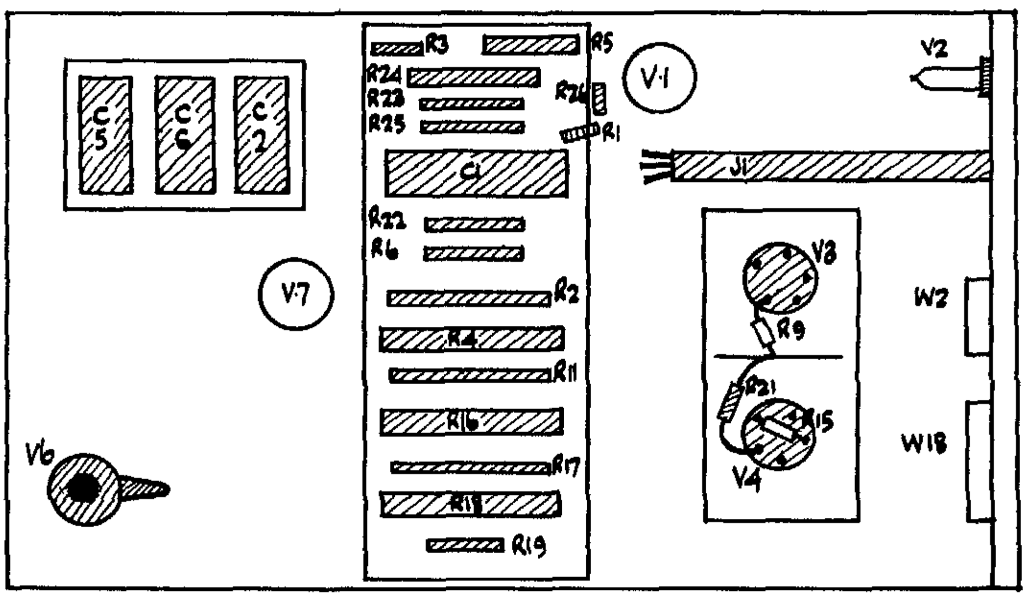


FIG. 113

be applied to the VT60A's in the amplifier unit unless the motor-generator cable is connected to J.B. Type 246. This precaution is necessary to protect the VT60A's. Should the motor-generator cable not be connected to J.B. Type 246 the split fields of the motor would not be across the VT60A anode loads. The effective anode loads would then be so high that the anode potential would fall to a very low value and secondary emission at the grids would damage the valves.

584. A separate transformer, T2, supplied directly from the 2-pin 80V. input, provides heater voltages for all the valves in the unit. The winding which supplies the heaters of V.3 and V.4 is strapped to the decoupled point to which V.4 grid is returned. Since the cathodes will normally be sitting some 120V. positive to earth, returning the heaters to earth might cause heater cathode leakage and insulation breakdown.

585. Another secondary on T.2 feeds a half-wave metal rectifier of the selenium type. The output is smoothed by C.5, CK.2, C.6 to provide a 60V. output. R.19 serves as a bleeder across the output. This is the D.C. supply for the slab-wound potentiometer in the gyro control unit. It is supplied to Pins 5 and 7 of the 12-way green when it is passed to J.B.Type 246. In the J.B.Type 246 cross-connections are made to the 4-way yellow as stated in para.578. From the 4-way yellow the channel is completed to the gyro control unit as shown in para.577.

The Motor Generator Type 74.

Motor Section.

586. The motor section of M.G. Type 74 is of the split field type. The two field windings are in parallel with the anode loads of V.3 and V.4 in the amplifier unit, via the 12-way green from the amplifier unit to the J.B. Type 246 and the 12-way plain from J.B. Type 246 to the motor-generator. Pin 3, tied to the amplifier unit H.T. line, goes to the common point of the split field windings. Pin 1 ties field 1 to the foot of V.3 anode load and Pin 2 ties field 2 to the foot of V.4 anode load. The principle of the motor's operation has been discussed in paras. 576 and 580. The resistance of the two field windings in series is 2500 ohms. The balanced field current is about 60 ma. in each winding.

Supplies for Motor Armature and Scanner Motor.

587. The motor armature current is about 5 amps. The supply is obtained via the Junction Box 246. This armature supply cannot, however, be applied until the H.2.S. scanner is operating. How these results are achieved can only be appreciated by tracing out the channels on the Scanner Interconnection Diagram, fig.111. Starting from the motor armature we pass to the filter unit via a Dumet cable. The other end of the filter unit is connected into a junction box containing two Grelco strips. One of the filter unit leads is taken out via a further Dumet cable to the resistance unit Type 4221. The return from this resistance unit is strapped via the Grelco strip to 7 and 8 of the 12-way cable to J.B.246. The other lead from the filter unit is strapped via the Grelco strip to 11 and 12 of the same 12-way cable. Passing to the J.B.Type 246, we find Pins 11 and 12 tied via a switched relay contact to Pin 2 (+) of a 2-pin plug coded red. Pins 7 and 8 of the 12-way plain are tied directly to Pin 1 (-) of the two-pin red. From the 2-pin red on the Junction Box 246 we pass directly to a point on the aircraft fuse panel where the 24V supply is picked up. From fig.111 it can be seen that the relay contact in the J.B.246 must be closed before the 24V supply to the motor armature can be completed.

588. When the switch unit push-buttons have been pressed and the amber light has come on, closing the scanner motor switch will put 24V. D.C. on the 6B plug at the power unit. From this plug a cable goes to the one plain 6B on the J.B. Type 246. From this 6B a cross-connection is made to the other 6B plain to put 24V. across the solenoid of the relay in this Junction Box. At the same time the 24V. supply is transmitted from this second 6B to a corresponding plug on the control unit Type 477 mounted above the Navigator's head. Cross-connections are made inside this control unit to a second 6B plug through a

variable 12 ohm rheostat by means of which the voltage actually applied to the scanner motor can be varied. The supply of the scanner motor goes from the second 6B on control unit Type 477 to the port bulkhead panel and thence via a Dumet 19 cable to the scanner motor. Pin 1 of the motor input goes to Pin 1 and Pin 2 to Pin 6.

589. Hence, when the scanner motor switch on the switch unit is closed, we simultaneously set the scanner in motion and energise the relay in the J.B. Type 246. This closes the contact which serves to complete the supply to the motor armature in the motor-generator Type 74 from the 24V. input. Since the scanner motor switch is not operative for about 40 seconds after the "L.T. ON" button is pressed, the motor-generator cannot come into operation for at least 40 seconds after switching on L.T.

The Resistance Unit Type 4221.

590. The supply for the motor armature of the MG Type 74 is drawn through a 4.5. ohm 120 watt limiting resistor. This resistor is mounted in a box on the fixed part of the platform and is inserted in the supply to the armature between the Grelco strip and the D.C. filter unit. This resistor is included to limit the armature current to about 5 amps. when there is no field to cause rotation and hence no back e.m.f. to limit armature current. Later models will have three $13\frac{1}{2}$ ohm resistors in parallel.

The Link Between the Motor and Moving Platform.

591. The motor-generator, mounted on the fixed platform, is connected to a moving arm which drives the moving platform via a step-down gear train of approximately 250 : 1. The moving arm is connected to the moving platform by means of a driving rod. A second rod, driven by means of balance weights, fitted to the moving platform keep the load on the motor constant regardless of the amount of displacement. The motor should come into operation for displacements of about 1° and be almost instantaneous in action.

The End Stops.

592. End-stops are fitted which allow a maximum movement of 30° to either side of the true horizontal. When the platform comes up against the end-stops a clutch-plate arrangement in the motor driving mechanism comes into play. This clutch arrangement then disengages the motor from the drive.

The Generator Section of the Motor-Generator Type 74.

593. When a misalignment voltage from the gyro control unit is applied to the grid of V.1 in the amplifier unit, the current changes in V3 and V4 develop the unbalanced voltages which are applied to the split field windings of the motor section of the motor-generator. This unbalancing of the field causes motor rotation in the sense appropriate to remove the misalignment voltage. Should, for any reason, a large misalignment voltage exist when the scanner motor is switched on and the supply to the M.G. Type 74 motor armature is completed, a large net field would exist. The motor would then experience a violent torque. Since the balance weight arrangements serve to provide a constant load, the motor would run at excessive speed. As the misalignment voltage fell, the motor would slow down due to the reduced field. To obtain smooth operation of the moving parts combined with a quick initial response, we want some form of negative feedback applied to the grid of V1 which is proportional to motor speed. If the motor is at rest and the aircraft rolls to produce a misalignment voltage the speed of the motor armature begins from zero as it starts to pull on the moving platform. While overcoming the inertia of this mechanical load the speed is low and there is little negative feedback and hence a strong field. As the inertia is overcome and the pull on the motor is reduced, the armature speed will not tend to reach excessive values if a negative back voltage is applied to V1 grid

which operates against this misalignment voltage to reduce the net motor field. By suitably arranging the magnitude of this feedback voltage for a given speed of the motor armature, it will be possible to get smooth by rapid starting, a suitable maximum speed, and operation that is non-jerky. The requisite negative feedback is developed by the genêrator section of the MG Type 74.

The Negative Feedback Circuit.

594. The generator field is fed from the same 24V line as the motor armature. This field supply is therefore completed when the scanner motor is switched on. One end of the generator armature is earthed via the black lead to the upper Grelco strip. The other end is taken via the red lead to the lower Grelco strip and thence via Pin 5 on the 12-way plain to J.B. Type 246. In the Junction Box a cross-connection is made from Pin 5 of the 12-way plain to Pin 8 on the 12-way green which is connected by a screned lead to the grid of V1 in the amplifier unit. The feedback voltage is applied across R23 (220K)+ R24 (470K). The grid of V1 is tapped in at the junction of R23 and R24 so receives about 2/3rd of the actual negative feedback voltage.

595. The motor-generator leads, coded as shown in the Scanner Interconnection Diagram, are taken away in two bunches to the two 4-pin Grelco strips mounted at the fixed platform. A Dumet cable brings the D.C. supply for the motor armature from the filter unit.

The Vacuum Pump Assembly.

596. This assembly will be necessary for carrying out D.I's. A separate D.C. supply will be required for the D.C. pump motor and a suitable length of flexible piping to convey the vacuum to the gyro.

597. Both pump and motor are of American manufacture. The motor is $\frac{1}{4}$ h.p., series wound, and takes 11 amps. The speed is 6600 r.p.m. The pump is required to maintain a vacuum equivalent to $4\frac{1}{2}$" of mercury (i.e. about 4.2 lbs per square inch) at the gyro and for correct gyro operation. The pump intake is connected to the gyro by a regulating valve attached to the pump, then by flexible pipe to the gyro. A gauze filter is fitted at the intake. The main outlet point blows straight out.

598. The vacuum pump motor also drives a second, smaller pump used to cool the motor. Air is drawn in and conveyed through a copper pipe to an inlet point at the motor commutator. The air escapes at the other end of the motor through a gauze filter.

Units Associated with the Roll-Stabilised Scanner

Control Unit Type 477.

599. This unit has been mentioned in para.588. Its purpose is to provide the Navigator with a means of controlling scanner speed. It is mounted above the Navigator's head in the Lancaster installation. The unit houses a 12 ohm rheostat. Later models will use a 24 ohm rheostat. A knob on the front provides the control. 24V. D.C. from the power unit is supplied to one 6B plug via the J.B. Type 246 where it energises the relay that completes the D.C. supply to the motor armature of the MG. Type 74. Cross-connections are made inside the control unit to a second 6B plug to insert the rheostat in the supply. From the second 6B the supply to the scanner is completed to the port bulkhead panel and thence by 2-way cable to the plug mounted on top of the scanner motor.

Control Unit Type 468 and Track Marker Facilities.

600. In addition to heading marker contacts which serve to develop a positive pulse when the scanner goes through the dead-ahead position, a track marker contact arrangement is provided in the Scanners Type 71 and 63. This contact can be brought into operation instead of the heading marker

contact when the switch on the Indicator 184 panel is set to the "Track" position. The contact itself is controlled by the Mk.14 bombsight. The flexible drive from the bombsight computor which conveys drift angle information to the bombsight head, is intercepted and used to drive a manual transmitter, similar to the cam arrangement in the H.C.U. This transmitter or cam arrangement is in the control unit Type 468 which is attached to the bottom right hand of the Mk.14 bombsight. When the drift setting on the bombsight computor is altered the flexible drive operates the cams and switches the D.C. connections to a "track" repeater motor in the scanner. The resultant rotation of the repeater motor armature moves the track marker contact to operate the heading marker circuit on the receiver-timing unit when the scanner is displaced from the dead-ahead position by the drift angle. The radial marker flashing up on the P.P.I. then gives the bearing of the actual aircraft track instead of its heading. When the switch on the indicator 184 is set to "Course" the usual heading marker is developed as the scanner goes through the dead-ahead position.

601. The armature of the "track" repeater motor displaces the track marker contact by means of a suitable worm gear drive. 31^{o} of drift corresponds to 18 revolutions of the flexible drive shaft which operates the transmitter in the control unit Type 468. On initial installation a check must be made that the "track" repeater rotates in the correct direction when the track marker is in use. This can be checked by comparing the way the radial marker on the P.P.I. is displaced when the Indicator 184 switch is moved from the "course" to the "track" position. The magnitude and sense of the actual drift can be read on a calibrated scale on the bombsight head.

<u>The Control Unit Type 446.</u>

602. This is the heading control unit used in the H.2.S. Mark IIC and Mark IIIA installations. The panel shows a setting knob and a three-position switch. The switch positions are labelled "Auto", "Course" and "Track". When set to the "Course" position, the setting knob is used to operate a transmitter in the unit which switches the D.C. connections to the "Course" repeater motor in the scanner. The motor armature then drives the magslip stators through a suitable gear arrangement. To set the H.2.S map, the bearing ring is set to the aircraft course. The indicator 184 and H.C.U. switches are set to "Course". The setting knob on the H.C.U. is then operated, thereby moving the magslip stators until the radial marker on the P.P.I. flashes up along the pointer on the bearing ring screen. If the H.C.U. switch is now set to "Auto", the D.R. compass transmitter is connected through to the "Course" repeater motor in the scanner. As the aircraft turns, the D.R. compass transmitter operates the repeater motor to move the magslip stators through an angle equal in magnitude and opposite in sense to the aircraft rotation. The position of the radial marker on the P.P.I. will now give the bearing of the aircraft heading as long as the Indicator 184 switch is left in the "Course" position, regardless of aircraft heading since the marker moves when the aircraft turns.

603. When the switch on the H.C.U. is set to the "Track" position, the transmitter in the unit is connected through to the "Track" repeater motor in the scanner which drives the track marker contact. If the switch on the Indicator 184 is set to the "Track" position and the windspeed indicator on the bombsight is set to zero (zero wind means zero drift angle), the track marker contact in the scanner can be aligned correctly by operating the setting knob on the H.C.U. until the radial marker on the P.P.I. flashes along the bearing ring pointer, set to the aircraft course. The track contact will then be aligned with the course contact.

604. When the H.C.U. switch is set to "Auto" it simultaneously connects:-

(a) The D.R. compass transmitter to the "Course" repeater motor in the scanner.
(b) The transmitter in the control unit Type 468 to the "Track" repeater motor which operates the track marker contact as the drift is computed by the bombsight. If the switch on the

indicator 184 is in the "Track" position the course contact in the scanner is taken out of circuit and the track contact brought into circuit. If the track contact has been aligned with the course contact as discussed in para.603, the track contact is offset from the course contact by the drift angle and the radial marker on the P.P.I. is now a track marker suitable for use in bombing runs. With the H.C.U. and indicator 184 switches in the "Track" position, it should be possible to shift the track marker + or - 60° from the heading marker position.

Mechanical Details of the Roll-Stabilised Scanner.

605. The main casting has been altered in shape and reduced in size to facilitate mounting on the moving platform along with the gyro control unit and H.2.S transmitter unit.

606. The scanner driving motor is of a smaller type. The actual motor assembly is the same type as that used for blower motors in H.2.S. Mark II. The motor is attached to the main casting by means of a flange and three bolts. The flange is part of the motor's outer casing.

607. The motor speed is approximately 5000 r.p.m. The current taken is about 0.7 amps. The drive to the scanner shaft is through an all-metal gear train with a step-down gear ratio of 134 : 1. No oiling holes are provided for the step-down gear bearings.

608. The scanner main bearing is of a new type which does not normally require any maintenance. It consists of a grease packed ball race mounted on a plate. The plate in turn is bolted to the interior of the casting. The rotating member of the capacity joint runs in an "Oilite" bearing.

609. The usual 1:1 drive to the magslip rotor is used.

610. The incorporation of track marker facilities has necessitated, not only the addition of a track marker contact arrangement, but a departure from the heading or course marker arrangements employed in the earlier H.2.S. scanners. A flat metal annular contact ring is mounted on a paxolin disc which in turn is placed on top of the magslip rotor driving gear wheel. The ring has a width of about ¼". At one point in its inner circumference it has a projection towards the centre about ½" long and ¼" wide. This projection we shall call the shorting contact. The ring of which this contact forms a part we shall call the contact ring.

611. Mounted above the contact ring by means of a bracket are two metal spring contacts. The outer of these is in continuous contact with the contact ring and is returned to earth. The inner one, which we shall call the course marker contact, is returned to the "Course" side of the "Course Track" switch on the Indicator 184. When the scanner passes through the dead-ahead position the contact ring will be in such a position that the shorting contact touches both spring contacts simultaneously. R.465 in the receiver-timing unit is then earthed through the shorting contact and the earthed spring contact. The suppressor of the receiver output valve is then carried down to develop the heading or course marker. Although the shorting contact has a width of only ¼", R.465 is earthed for a sufficiently long interval to discharge C.422 in the receiver-timing unit and so carry down the suppressor of the receiver output valve to the requisite level to ensure a marker of adequate duration. As the suppressor of the receiver output valve is thus carried down each time the scanner goes through the dead-ahead position, the marker flashes up once per scanner revolution.

612. In order that the marker may appear at the bearing of the aircraft course, it is necessary that the appropriate coupling occur between the magslip rotor and stators at the instant the scanner goes through the dead-ahead position. To have the heading marker appear on the P.P.I. display as the scanner goes through the dead-ahead position it is necessary to take the

usual precautions with regard to:-

(a) Mounting of the mirror on the casting.
(b) Contact alignment.
(c) Direction of rotation of repeater motor armature.

613. The phasing between the paxolin disc and the magslip rotor driving gear can be adjusted by loosening the 3 bolts securing these two items to the magslip rotor. The paxolin disc can then be rotated relative to the driving gear to obtain the heading marker at the correct time.

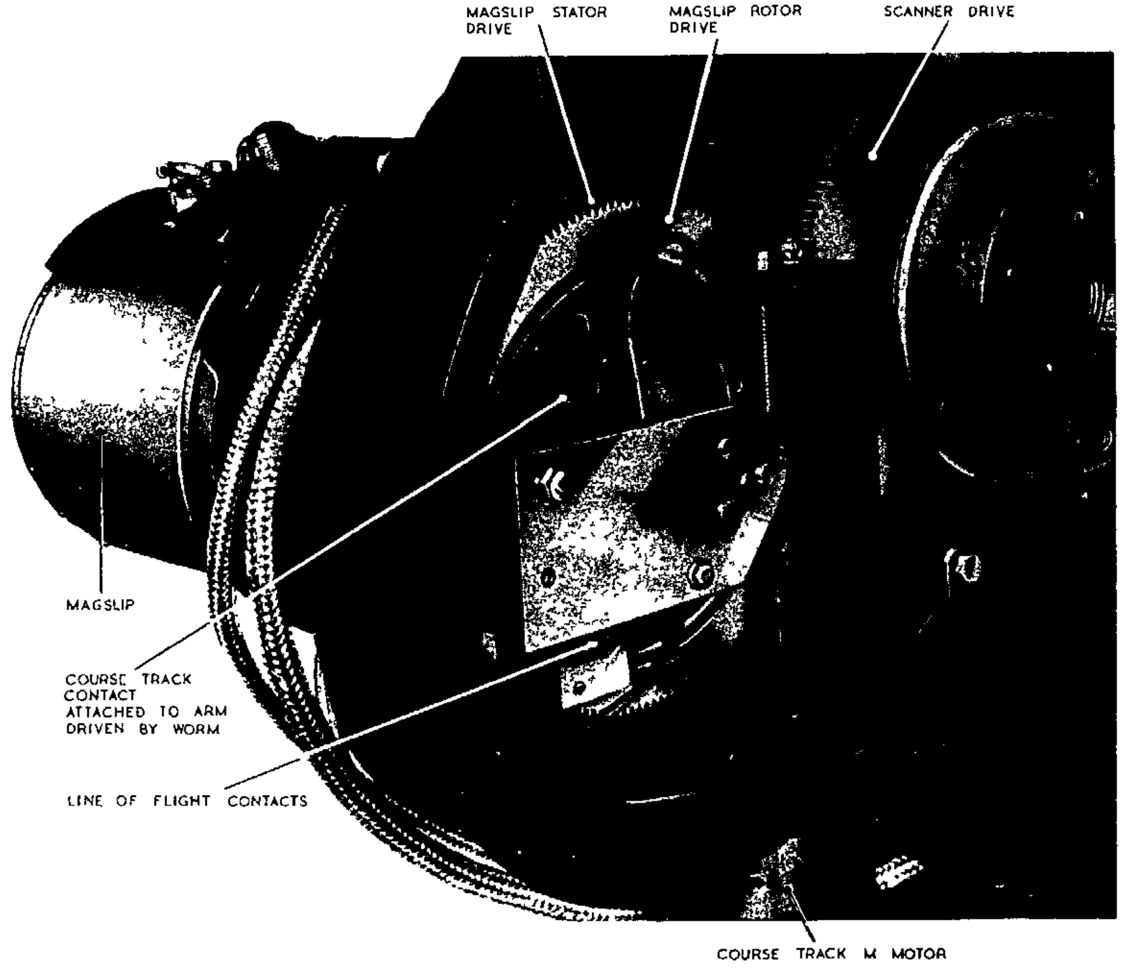
614. For the development of a track marker the same contact ring, shorting contact, and earthed spring contact are employed. An extra moveable spring contact is added which we shall call the track marker contact. This track marker contact is returned to the "Track" side of the switch on the Indicator 184. The contact is mounted above the fibre gear wheel to which the contact ring is mounted above the fibre gear wheel to which the contact ring is attached. It is swivelled on a bearing whose centre coincides with that of the gear wheel and contact ring. The contact has an arm extending back from this bearing. This arm engages a slotted bush. The bush, in turn, tracks up and down a worm driving rod. This rod is geared to the track repeater motor which is operated by the transmitter in the control unit Type 468 from the flexible drive from the Mk.14 bombsight. As the drift is set on the bombsight, the flexible drive operates the transmitter in control unit Type 468. The track motor armature is displaced accordingly and moves the worm driving rod to rotate the track marker contact about its bearing. At some point in the scanner's rotation the shorting contact will connect the track marker contact to the contact ring and therefore to earth through the ring and the earthed spring contact. At what point in the scanner's rotation this occurs depends entirely upon the setting of the moveable track marker contact. If this contact is suitably set the shorting contact will meet it at such a point that the marker then developed will be displaced from the position of the course marker by the drift angle. We thus obtain a track marker instead of a course marker. To align this contact properly the H.C.U. and Indicator 184 switches must be set to "Track" and the bombsight must be set for zero drift. By operating the setting knob on the H.C.U. the cams in that unit displace the track repeater motor armature and hence the track motor contact. The contact then rotates around its bearing and the marker appearing on the P.P.I. will rotate. It can thus be adjusted to coincide with the pointer on the bearing ring when the latter is set to the aircraft course. The marker will now appear at the same position on the P.P.I. regardless of the position of the indicator switch. This means the track marker contact is met by the shorting contact at the same instant as the course marker contact. Since we have assumed zero drift this is what is required. When the H.C.U. switch goes into "Auto", the track marker repeater motor is connected to the transmitter in the Control Unit Type 468. Any drift setting now made on the bombsight displaces the track marker contact through the drift angle. In order that the sense of this displacement may be correct the repeater motor must turn in the correct direction. The range of adjustment available allows the shorting contact to meet the track marker contact 60° before or after meeting the course marker contact.

615. The two M-type repeater motors are of the same type. They differ only from the one used in the earlier scanners in having the field connections brought out to terminals at the top of the motor outer casing.

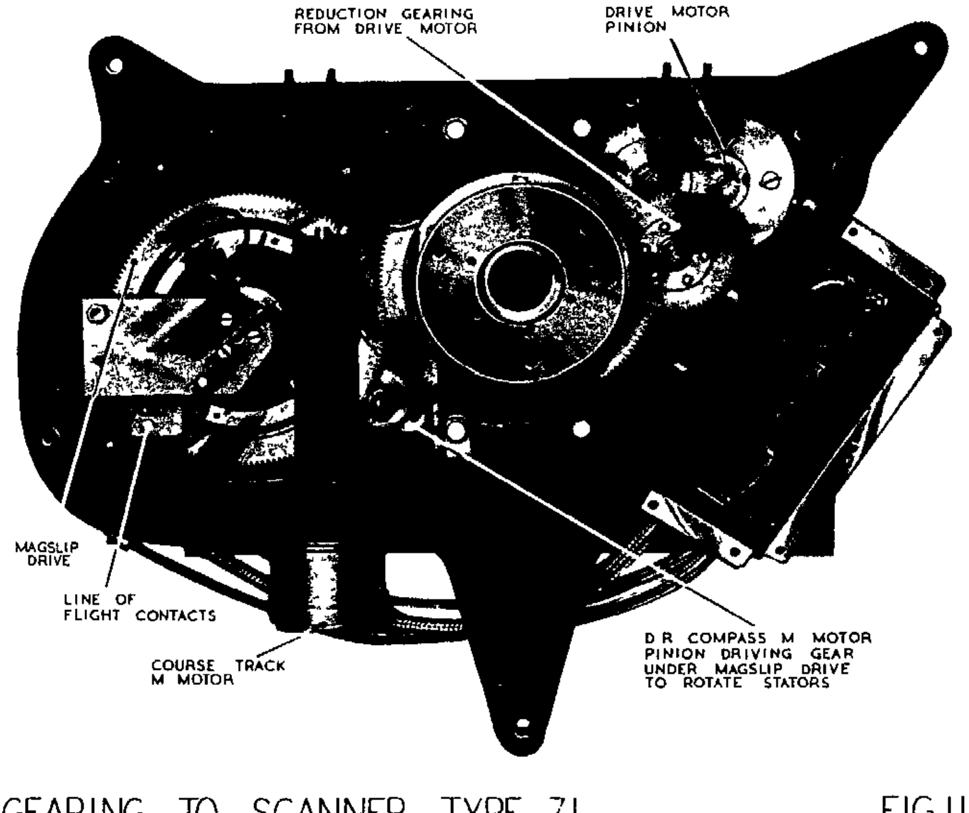
616. The track repeater motor is attached to the side of the main casting.

617. The magslip and course repeater motors are mounted on a sub-panel attached to the main casting by three bolts.

618. All cabling, with the exception of the course, track and common earth return contact connections runs external to the main casting. Connections are



DRIVE TO COURSE TRACK CONTACT FIG 114



DRIVE GEARING TO SCANNER TYPE 71 FIG 115 made between the components concerned through a small junction box attached to the side of the main casting. This junction box contains:-

(a) One 4-way carrying the sawtooth outputs from the magslip stators.
(b) One 6-way carrying the sawtooth input to the magslip rotor from the W.F.G. and carrying the track or course marker connections back.
(c) One 6-way coded violet carrying the D.C. lines for the repeater motor fields from the H.C.U.

619. The scanner motor supply goes directly to a 2-pin W plug mounted on the end of the motor casing.

620. The mirror is bolted into a plate instead of the wedge used in earlier scanners. This plate is secured to the main bearing.

621. To maintain a reasonable temperature in the cupola for the scanner and platform bearings, a heating unit is mounted on a bracket at the aft end of the platform. This unit consists of three heater elements wired in parallel and connected to the heater switch on the port side of the aircraft. The heater supply is taken direct from the aircraft D.C. supplies.

622. A spirit level is mounted on the scanner to facilitate the lining-up of the gyro.

The Capacity Joint for the Scanner Type 63.

623. The arrangement for holding the rotating member of the capacity joint has been altered from that used in the Type 3 scanner. Attached to the rotating member of the main bearing is a tube with an internal diameter equal to the external diameter of the rotating member of the capacity joint. This tube is approximately 8 - 9" long, extending right through the main casting into the lower half of the casting which can be split as before, for dismantl: and adjustment purposes. The end of the tube which protrudes when this lowe: half of the casting has been removed, is segmented into six tapered sections. A tapered locking nut screws over this end, thus holding the rotating member of the joint central and rigid.
The joint is so set up as to leave $1\frac{7}{8}$" between the end of the segmented tube and the end of the joint. A gasket is fitted between the main casting and the removable part of the casting which holds the stationary part of the joint. This removeable section is held in position by three readily accessible bolts. An improved clamping band has been incorporated to hold the stationary member of the rotating joint securely.

624. The Type 71 scanner used a tubular feeder of the waveguide type from the H.F. box to the scanner. A rotating waveguide joint is used inside the scanner instead of the coaxial type of capacity joint.

Summary of Main Items Associated with Scanner Type 71.

625.	Scanner Type 71	10AB/6454
	Comprises:-	
	Magslip	10AB/2278
	Driving Motor	10KB/1552
	M-Motors (2)	5U/2724
	Tubular feeder, Type 72	10AB/6373
	Stabilised Platform	10AB/6522
	Requires adaptor frame for holding platform to airframe:-	
	(a) for Halifax	10AB/6523
	(b) for Lancaster	10AB/6524

626. Comprises in addition to the structural assembly:-

(a)	Motor-Generator Type 74	10KB/954
(b)	Resistance Unit Type 4221	10C /15512
(c)	Suppressor Unit for MG.74	5C /1002
(d)	Suppressor Unit & connector for scanner motor	10H /7540
(e)	Fixing bracket for tray that holds HF box	10AB/6579

627. Units fixed to moving platform:-

(a)	Scanner Type 71	10AB/6454
(b)	Gyro Control Unit Type 453	10LB/6074
(c)	HF Box, TR.3555 or 3523	

628. Units mounted on fixed platform:-

(a)	Junction Box Type 246	10AB/2497
(b)	Connector set from bulkhead panels	10H /16060

629. Vacuum Pump Assembly for D.I's. only comprising

(a)	Pump Motor	137J/2725
(b)	Vacuum pumps	
(c)	Relief Valve	137J/501
(d)	Pipe flexible	32C /214 32C /214
(e)	Plug	5X/568
(f)	Suppressor Unit	5L/870
(g)	Relay	5C/723
(h)	Terminal Block	5C/483

630. Control Unit 477 — 10LB/6102
Provides control of scanner speed.

631. Control Unit 468 — 10LB/6091
Carries transmitter operated from bombsight for automatic control of track marker contact in scanner.

632. Amplifier Unit A.3562 — 10UB/6041
Amplifies misalignment voltage received from gyro control unit to operate motor generator type 74 and drive the platform.

633. Control Unit Type 446 — 10LB/6053
Heading control unit.

634. Scanner Heating Unit
To keep temperature in cupola from falling so low that scanner slows down and response of moving platform becomes sluggish.

635. Junction Box Type 247 — 10AB/6499
Used only in prototype installation.

Bulkhead Panels.

636. Two bulkhead distribution panels are fitted to the fixed frame to provide greater freedom of movement and to facilitate dismantling and assembling. One of these, mounted at the aft end of the platform, is referred to as the aft bulkhead panel on the Scanner Interconnection Diagram. The other bulkhead panel is mounted on the port side at the front of the fixed platform. This one is termed the port bulkhead panel on the Interconnection Diagram.

637. The aft bulkhead panel splits the following cables to the H.2.S. transmitter unit:-

(a) 12-way from the JB.231 to the H.2.S transmitter.
(b) The 4-way from the tuning unit Type 444.
(c) The uniplug pulse lead from the modulator Type 64 to the H.2.S. transmitter.
(d) The Pye green signal lead from the H.2.S. transmitter to the receiver.
(e) The vacuum line for the gyro control unit.

638. The port bulkhead panel carries the JB. 246; it also splits the following leads going to the scanner:-

(a) 6-way violet from H.C.U. to scanner.
(b) 6-way plain from W.F.G. to scanner.
(c) 4-way sawtooth output from magslip stators to JB.222.
(d) 6-way from control unit Type 477; Pin 1 goes to Pin 1 and Pin 4 to Pin 2 of a small 2-way which takes 24V. to the scanner motor.

639. The 12-way from the aft bulkhead panel to the H.2.S transmitter is of a special type. All leads are crossed in the cable. This is necessary as both leads are detachable from the bulkhead panel.

Provision for Fitting Scanners Type 63 or 71 Without Stabilised Platform.

640. If scanners Type 63 or 71 are installed without the stabilised platform mounting frames will be required:-

In Lancaster	10AB/6577
In Halifax	10AB/6578

641. The only significant differences in the tabulation of items if the scanner Type 63 is considered instead of the Type 71 are as follows:-

(a) For scanner Type 71 we have Type 63	10AB/6343
(b) The scanner uses:-	
(i) Internal H.P. feeder, Type 1859	10H/6598
(ii) External H.P. feeder, Type 4770	10HA/128
(c) Fixing bracket for T2R tray	10AB/6578
(d) Connector set from bulkhead panels	10H /16059

General Installation Points.

Gyro Control Unit.

642. (a) This is a very delicate instrument. When handled or transported, care must be taken to ensure that the locking screw is in position.
(b) On installation check that the cardboard cover over the air intake gauze filter is removed.
(c) Ensure that the blanking-off screws for alternative outlets are in position and secure.
(d) Check that the small screw which replaces the locking screw is in position and secure.
(e) Check that the clamping screws are holding the unit firmly.
(f) Check that the rubber mounting is all right.
(g) Check that the intake filter on the Gyro is of the fabric type and not the papier mache type.

643. The gyro takes at least 2 minutes to build up and settle down to a steady speed.

644. The vacuum at the Gyro must be between 3" to 5" as indicated on a suction meter, Stores Ref. 6A/757. To check this the suction meter will have to be connected into the Gyro by means of a flexible pipe and a special

union to fit into one of the blanking off screw points at the rear of the gyro.

645. As the gyro in the aircraft installation is supplied by one of the engine-driven pumps, this cannot be checked on D.I. The vacuum line in the aircraft will have a permanent suction meter installed. Should there be a leak in a pipe block or the line to the gyro, this will be indicated on the permanent meter. The instrument people will be responsible for maintaining the vacuum to the gyro.

646. To facilitate D.I., a change over valve and an intake point for an external pump will be fitted to the aircraft skin at a point of easy access. The vacuum line from the portable vacuum pump will have to be connected to this point and the stop tap turned to the external position. It is suggested that a suction meter be fitted permanently in the portable vacuum line supply at some point so that it can readily be checked that the gyro supply is within the required limits. With the regulating valve in the vacuum circuit using a flexible 20 ft. hose no difficulty should be experienced in maintaining the suction of 4". The following figures are quoted for general guidance for the vacuum pump assembly:-

(a) Suction obtained on a closed circuit without the regulating valve in, 20"
(b) Suction obtained with 1 gyro in circuit without the regulating valve in, 9".
(c) Suction obtained with 1 gyro at the end of 20' line with regulating valve in and measured at the gyro end, 4".
(d) Amount of variation by adjusting the regulating valve Adjustment was approximately ½" of suction.

647. Gyro servicing will be the responsibility of the instrument section.

Course and Track Repeater Motors.

648. On initial installation in aircraft these repeater motors will have to be checked for correct direction. The heading marker can be checked against a D.R. compass repeater card with the aid of the V.S.C. Should the heading marker move the wrong way a cure can be effected by changing over two of the course repeater motor field leads on the terminal strip on top of the repeater motor on the scanner. Access to this terminal strip can be obtained by loosening the "Jubilee" clip and removing the top cover on the repeater motor. On initial fitting all units involved should be checked for correct wiring and suitably modified if the wiring is incorrect. It is only in this way the operational difficulties can be avoided. Changing over the repeater motor leads to clear another fault should only be a temporary expedient.

6

649. Checking the track repeater motor can only be done in the air. The angle of port or starboard drift indicated by the track marker, i.e. difference between track and heading markers, can be checked against the calibrated scale on the bombsight. Should the direction of rotation be wrong, change over in the same manner as outlined for the course repeater motor, as a temporary measure if no time is available to correct the wiring. The wiring should be standardised on fitting, and at the earliest opportunity after difficulty is encountered due to the subsequent inclusion of units with non-standard wiring.

Motor-Generator Type 74.

650. On installation the motor may drive in the wrong direction or the feedback voltage from the generator may be positive instead of negative. All leads of the M.G. are colour-coded as shown in the insert on the Scanner Interconnection Diagram, fig.111

651. The following information was obtained by carrying out tests and should hold good provided that manufacturers maintain the same internal wiring.

Motor Field		Motor Arm.		Generator Field.		Generator Arm.		Motion viewed
Brown	White	Red	Black	Green	Yellow	Black	Red	looking at generator end of MG.74 Equiv. to standing aft of platform.
	V3ON	+	-	+	-	+	-	Clockwise
V4 ON		+	-	+	-	-	+	Anticlockwise.

652. The platform moves the opposite way to the MG.74 rotation. If the aircraft banks to port the misaligment voltage is positive and when it banks to starboard, the voltage is negative.

The Platform Assembly.

653. (a) The platform assembly is attached to an adaptor frame with 6 bolts. The adaptor frame is bolted to the airframe.
(b) Care must be exercised in transporting as rough usage will result in broken rivets. A stop is provided to keep the moving platform rigid during transportation.

Rubber Mountings.

654. All the rubber mountings require checking on installation and inspections.

Assembling and Dismantling.

655. The easiest method of assembly is to mount the scanner on the platform in the aircraft and then bolt the platform to the adaptor frame. The scanner must be mounted on the platform before bolting the platform to the adaptor frame. If the scanner requires changing, the platform must first be released from the adaptor frame.

D.I. Procedure.

General Points.

656. A vacuum pump assembly will be required to carry out D.I's. to supply the gyro control unit. A D.C. supply of 24 V. at approximately 12 amps. will be required to drive the motor. Owing to the heavy starting current this supply will have to be fuzed with a 40 amp. rating fuse. A suitable length of flexible piping will be required to convey the vacuum line to the intake point on the aircraft skin. A suction meter should be tapped in at some point, preferably at the end of the flexible pipe, to check that the suction is between 3 and 5".

657. This D.I. should be carried out after the normal H.2.S. D.I. This gives the amplifier unit time to settle down.

D.I. Routine.

658. After doing the normal H.2.S. D.I., switch on the vacuum pump and give the gyro two minutes to settle down. Then remove the 2-pin red from the JB.246. This removes the armature supply from the MG.74.

659. Insert a jack connected to a voltmeter, set to at least 250V. range. Press the earthing switch. The reading obtained may be either + or -. Adjust the "balance" preset from zero volts. A fine adjustment can be obtained by decreasing the voltmeter range. Remove the jack lead.

660. Set the moving platform level by observing the spirit level. Switch on the scanner at the switch unit.

661. Replace the 2-pin red at the JB.246 and note if the platform moves. Movement may be caused by misaligment of gyro. If movement occurs the gyro will have to be re-aligned. This can be achieved by loosening the 4 bolts securing the gyro. Small variations in either direction can then be achieved on the elongated fixing holes.

662. Remove the 2-pin red again and push the platform over to the 30° end stop limit in one direction. Replace the 2-pin red and check that the platform immediately returns to the level position. Repeat the procedure with the platform pushed to the opposite end stop.

663. Remove the 2-pin red to the JB.246 and offset the platform 1° as near

as can be estimated. Replace the 2-pin red and check that the platform levels immediately. Repeat this check in the opposite direction.

664. With everything working force the platform over first in one direction and then in the other against the motor driving force and check that the clutch slips immediately.

665. Remove the external vacuum supply and turn the valve to the internal position.

666. Check all cables are secure and do not foul at any point during platform movement.

CHAPTER 10 - FISHPOND.

Function of Fishpond.

667. The function of Fishpond is to provide aircrew with a visual indication on a P.P.I. display of aircraft within a range of 4 - 5 miles. The equipment involved is an indicator 182 or 182A, a junction box, type 222, and the necessary cables to link these two items into the H.2.S. installation. The Fishpond indications are derived from reflections by adjacent aircraft of the aircraft's H.2.S. transmission. The normal H.2.S. equipment converts these aircraft reflections into signals which are used to intensity-modulate the Fishpond P.P.I.

668. If we imagine a hemisphere with the Fishpond aircraft at its centre and radius equal to the aircraft height, we have the region within which another aircraft should be detected down to a minimum range of 400 - 600 yards.

669. A detected aircraft will give an indication on the Fishpond display in the form of an arc. When a push button on the front panel is pressed marker rings appear on the display to indicate ranges of 0, 1, 2, 3, 4 and perhaps 5 miles. The position of an aircraft relative to the marker rings will give the range. The position relative to the heading marker, which appears on the Fishpond display as well as on the H.2.S. P.P.I. display will give an approximate idea of bearing. Elevation cannot be displayed but some idea of the elevation may be obtained by putting the Fishpond aircraft into a steep bank and noting the movement of the indication relative to the heading marker. By observing whether or not the indication alters its course so as to follow the Fishpond aircraft when evasive action is taken, a detected aircraft can be identified as hostile or friendly.

Outline of Fishpond.

670. The sawtooth outputs from the magslip are applied to two cathode-coupled amplifier stages somewhat similar to the stages used to develop the indicator 184 timebase. The gain of these amplifiers is automatically adjusted as the setting of the scan-marker switch is varied to develop a display on which the distance from centre to circumference always represents about 5 miles regardless of the velocity of the input sawtooth from the magslip. The reflections of the H.2.S. pulses from aircraft appear as positive-going pulses in the mixed output at the black Pye plug on the W.F.G. A double output at this plug makes it possible to feed this mixed output, including the bright-up square wave, to both the video amplifier in the indicator 184 and a similar signal amplifier stage in the Fishpond indicator. As the Fishpond scan only covers a range of up to about 5 miles, the only indications for aircraft at operational heights of $3\frac{1}{2}$ - $4\frac{1}{2}$ miles will be echoes from other aircraft and a ground return ring around the edge of the display. The radius of this ground return ring will be equal to the aircraft height. Indications from aircraft at ranges greater than the aircraft height will tend to be lost in the ground return ring. The useful maximum range of Fishpond will then be governed by the height at which the aircraft flies.

671. Since the signal input to Fishpond is the same as that applied to the H.2.S. indicator, it includes the heading marker which moves around the Fishpond display as the aircraft alters course just as on the H.2.A. display. The Fishpond operator must be able to visualise immediately the approximate bearing of a detected aircraft relative to his own aircraft from the position of the indication arc relative to the heading marker, regardless of the position of the heading marker on the display.

672. Included in the Fishpond unit is a calibrator circuit which the operator can bring into operation by pressing the push-button switch on the front of the Fishpond panel. When this button is pressed the 20 microsecond pulse from one of the violet Pye plugs on the modulator is used to trigger on its back edge a circuit which rings at a frequency of 93 Kc/s. The positive peaks then occur at

intervals of 10.75 microseconds which represent the echo time for a target at 1 mile range. The positive peaks are converted into rather wide negative pips which are applied to the Fishpond P.P.I. cathode to produce marker ring on the display at intervals of 0, 1, 2, 3, 4 and 5 miles. From the positio of an aircraft indication relative to these rings the operator can instantly see the approximate range.

Diagrams.

673. (a) Circuit details of the Fishpond indicator, type 182A, are shown in fig.116. (Differences between the indicator 182 and 182A are tabulated in para.699).

(b) Component layouts are given in fig.117

(c) Waveforms are displayed in fig.119

(d) The relation of Fishpond and its junction box to the complete installation is shown in figs.13 and 14.

(e) The junction box and the supply channels are shown on the interconnection diagrams, figs.210 and 211.

Fishpond Circuit

674. The Fishpond timebase is developed from the magslip output by the two cathode-coupled paraphase amplifiers, V.1, V.2 and V.3, V.4 in fig. 116. Reference to the circuit diagram will show the following points which we shall use in our discussion:-

(a) The amplifier circuits are symmetrical but provision is made for varying the D.C. level of V.2 grid relative to that of V.1 with R.80, and for varying the potential of V.4 grid with regard to that of V.3 with R.79.

(b) The cathodes of each amplifier pair are strapped through preset potentiometers. Three are available in each stage. As the scan-marker switch is set for the different scans, these presets are switched by relays operating in synchronism with the relays in the W.F.G. which switch the master multivibrator and sawtooth switching valve components.

(c) The inputs to the two pairs are the outputs of the two magslip stators. The output of one stator is applied to the grids of V.1 and V.2 from pins 4 and 1 of the 4-way from the junction box 222. The output of the other stator is applied to the grids of V.3 and V.4 from pins 1 and 3 of the same 4-way. As the input pins are tied to earth through the leaks R.8, R.13, R.18 and R.28, the stators are effectively centre-tapped so the grids of each pair will always swing in antiphase to develop a push-pull output. One such push-pull output is A.C. coupled to the X-plates and the other to the Y-plates. Since the magslip stator outputs are always 90° out of phase, these push-pull outputs are also 90° out of phase. Since we have push-pull outputs across the X and Y-plates which rise and fall 90° out of phase as the scanner turns, we will obtain a rotating timebase as in H.2.S.

(d) One X and one Y-plate are returned to a fixed positive potential at the junction of R.46 and R.47 between +300V. and earth. The other plates in each pair are returned to a potential variable by the presets R.38 and R.40. These presets can then serve as shift controls.

675. The Fishpond Markers are developed by V.6 and V.7. When the push-button switch, S.1, on the Fishpond panel is depressed the 20 microsecond pulse from the modulator makes the 93 Kc/s tuned circuit in V.6 anode ring on its back edge. These rings back-bias V.7 with grid current so only carry V.7 into conduction on the peaks. Negative pips at 10.7 microseconds intervals, with the first occurring on the back edge of the 20 microsecond pulse, are applied to the P.P.I. cathode via C.21. These pips will appear on each timebase sweep to produce circular marker rings. How many will appear on the display depends on how long it takes the C.R.T. spot to travel across

the screen. If the velocity is correct, there will be 4, 5 - 6 pips to provide 0, 1, 2, 3, 4, and 5 mile range markers on each scan.

676. V.5 is the Fishpond signal amplifier. The input of the black Pye plug is applied to V.5 cathode through C.8 grid and reappears at V.5 anode and the P.P.I. grid as a positive-going signal. R.32 provides a measure of gain control. The input is the same as that applied to the video amplifier in the indicator 184 so includes an amount of bright-up waveform which depends on the setting of the contrast control.

The Fishpond Timebase Control Requirements.

677. The sawtooth inputs to the amplifier pairs will be of approximately constant amplitudes of the order 20 - 25V. The working strokes will be 240, 720 and 1200 microseconds respectively when the scan-marker switch is set for 10, 20 and 40 mile P.P.I. H.2.S. scans. We want the Fishpond scan to sweep from centre to circumference in about 5 x 10.7 or 53.5 microseconds regardless of the setting of the scan-marker switch. Since the transmitter fires at about the centre of the master sawtooth, this 53.5 microseconds must correspond to the first part of the second half of the master sawtooth. As we have no phantastron triggering arrangement to start the scan from the tube centre we must use a diametral scan on Fishpond which will carry the spot across the screen in around 107 microseconds on each scan. When the input sawtooth is at the midpoint Fishpond scan must be at the tube centre. The Fishpond sawtooth must, however have a sufficiently great velocity to carry the scan completely across the tube face in about 107 microseconds. It must therefore start some time after the input starts and terminate before it ends. This is equivalent to saying that we are merely taking the central section of the input sawtooth on the grid and amplifying it up to the required amplitude. In the case of the 10 mile scan the input has a working stroke of 240 microseconds and, say, a 25V. amplitude. If we take out the central 107 microseconds this represents a useful grid swing of $\frac{107}{240}$ x 25 or about 11 volts. If we consider the next scan with a working stroke of 720 microseconds, the central 107 microseconds represents a useful grid swing of $\frac{107}{720}$ x 25 or about 3.5 volts. For the slowest scan, with a working stroke of 1200 microseconds, the useful grid swing must be $\frac{107}{1200}$ x 25 or about 2.25 volts. In each case these useful swings must give the same amplitude at the anode. Since we are developing a push-pull output this will have to be half the voltage required for a deflection across the tube face. With useful swings at the grids of about 11, 3.5 and 2.25 volts and equal amplitude outputs, we must have gains in the ratio of 1:3:5 for the different sawtooth inputs. Furthermore, these changes in gain must be brought about automatically as the scan-marker switch is changed. To meet this requirement we have the three negative feedback control preset potentiometers strapping the cathodes of each amplifier pair. These presets are switched as the setting of the scan-marker is varied. They can be preset individually to provide the correct gains.

678. Since the timebase amplitude is the vector sum of the instantaneous amplitudes across the X and Y plates, the amplitude can remain constant around the tube face only if the maximum X and Y amplitudes are effectively equal, i.e., cause the same displacement of the electron beam. The actual amplitudes will not be quite equal as the deflection sensitivities of the two pairs of plates are slightly different. This means that a constant amplitude scan around the tube face calls for suitable balancing of the push-pull outputs of the two amplifier pairs. This requirement can be fulfilled by suitably adjusting the cathode presets in each amplifier pair on each scan. If the display shows the 0, 1, 2, 3, 4 and 5 mile marker rings, the gains of the amplifier pairs must be approximately correct. If the markers are not circular, the push-pull amplitudes are not correctly balanced. It is then necessary to make adjustments to the appropriate pair of presets until the individual amplitudes are both correct and balanced as indicated by the presence of the correct number of markers with a circular shape.

INDICATOR TYPE 182 A

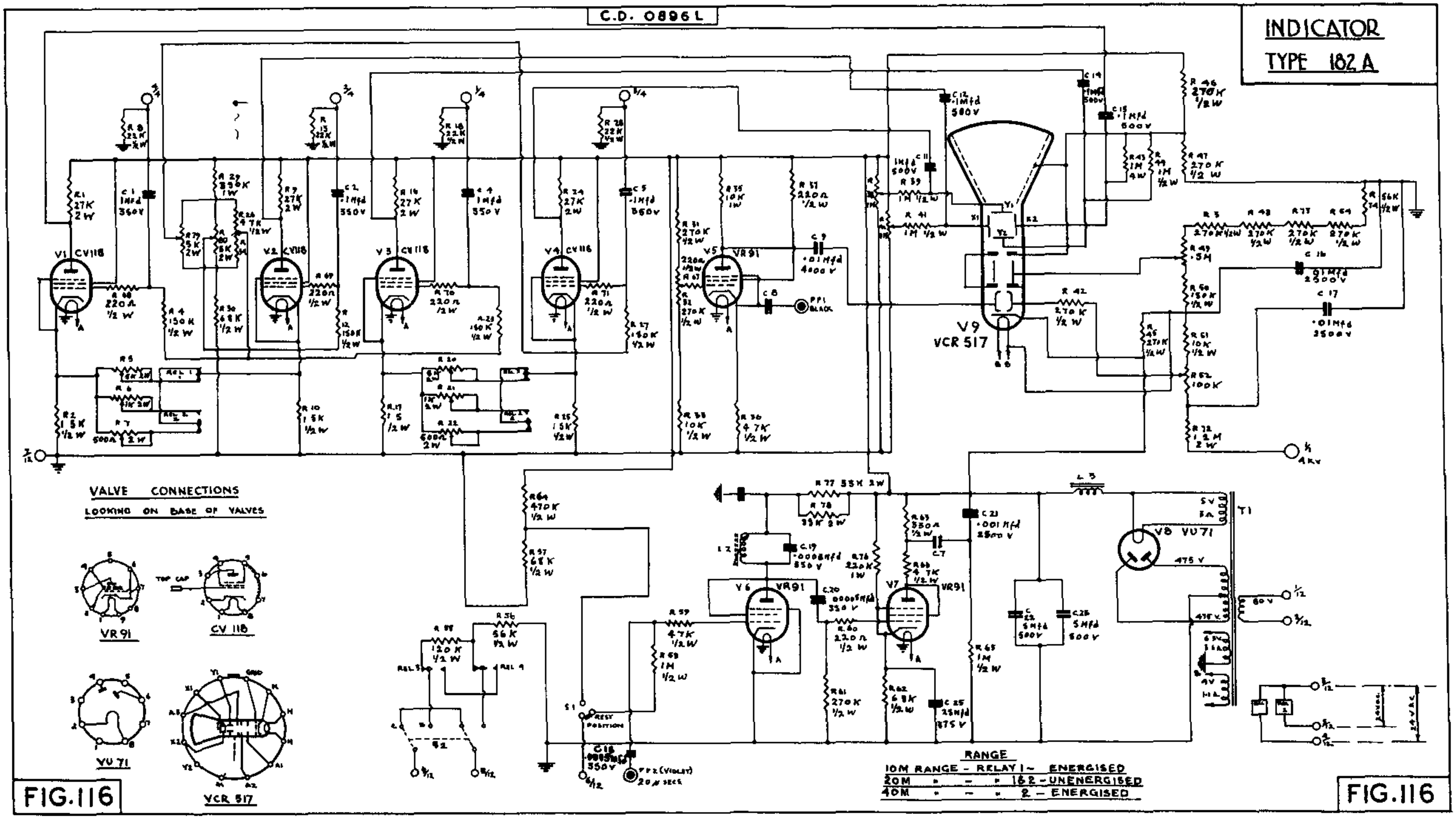
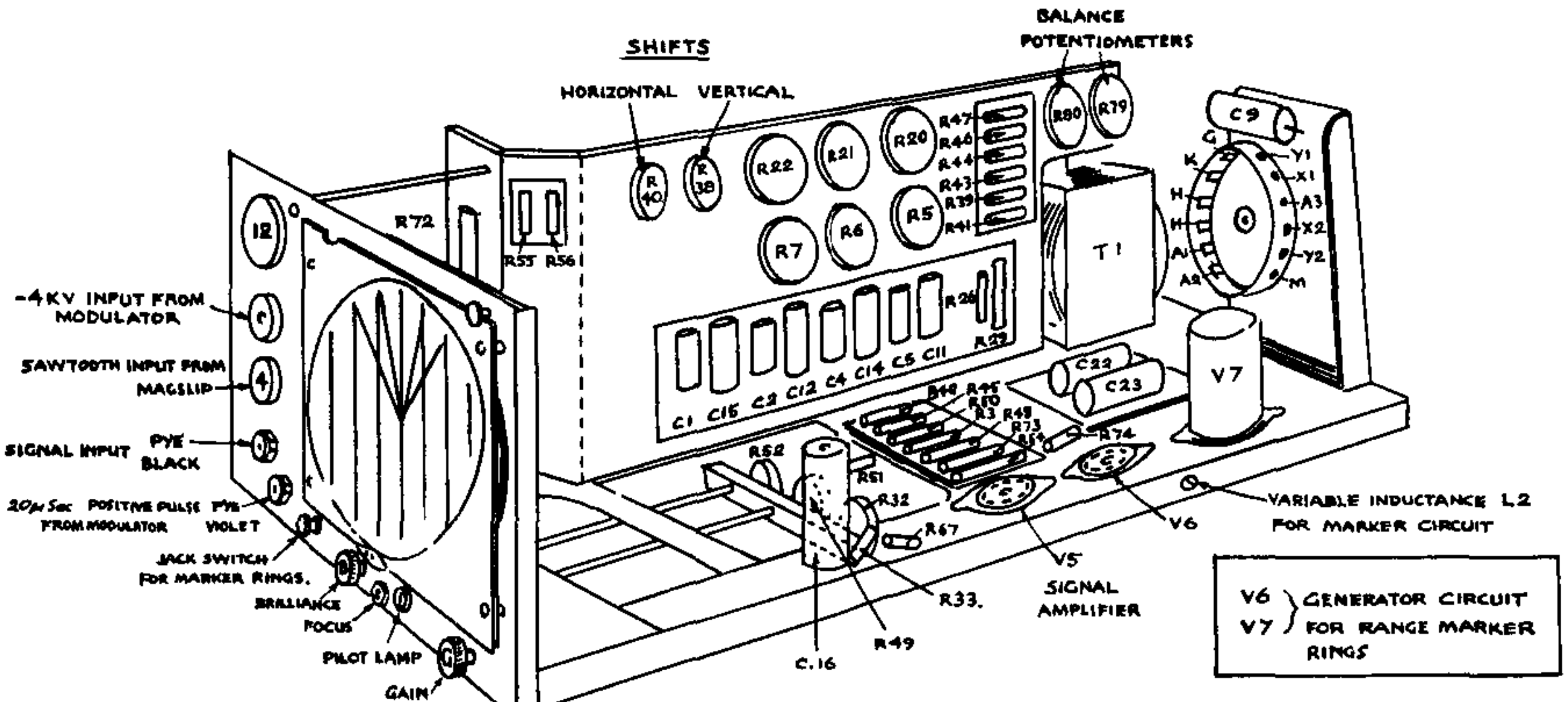
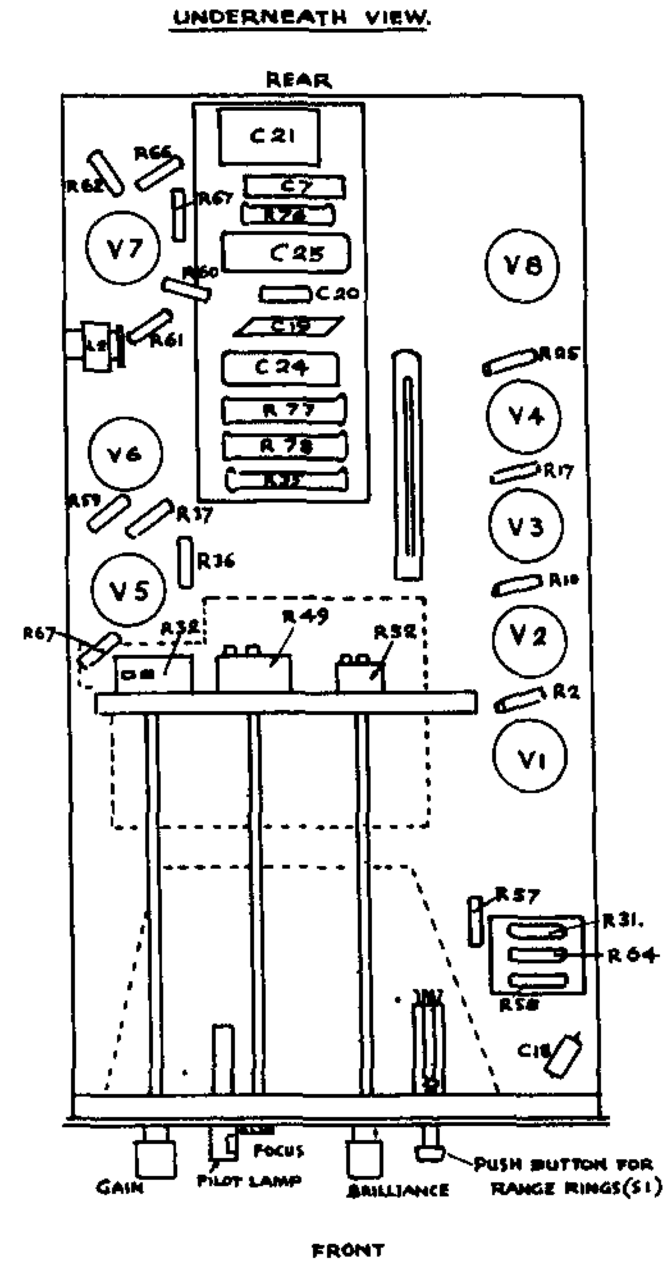


FIG. 116

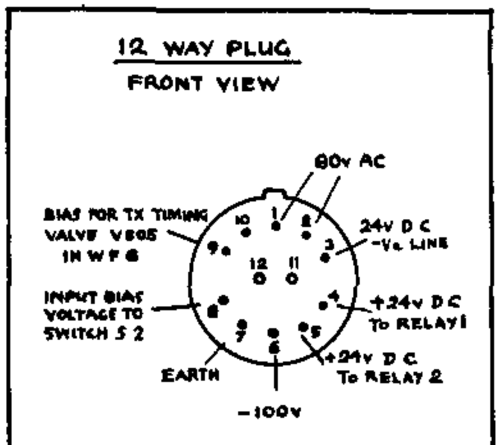
INDICATOR TYPE 182A. LAY-OUT

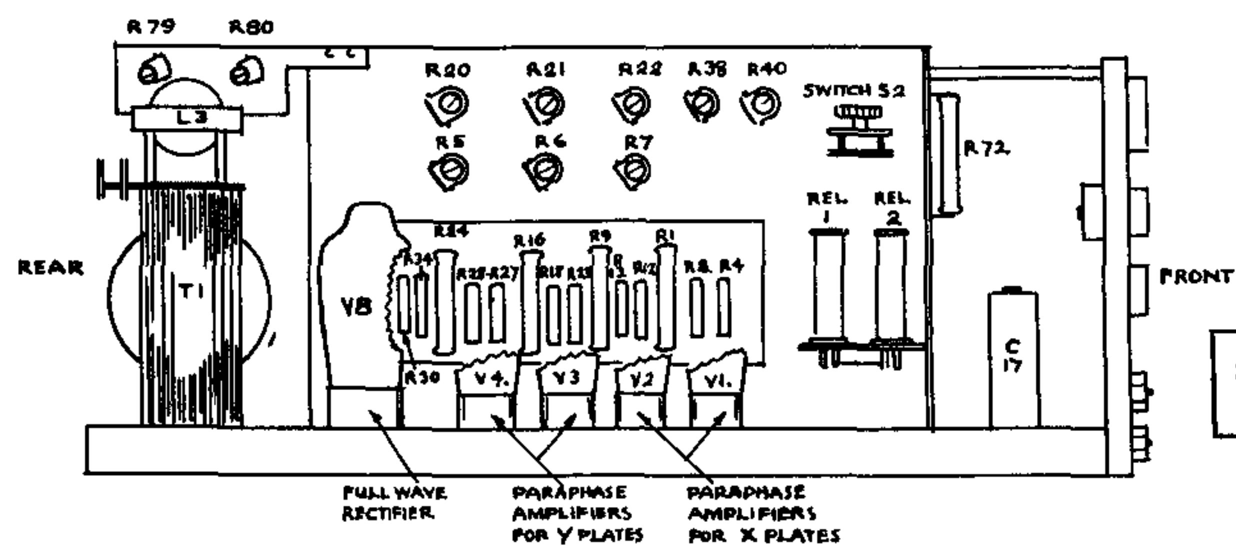




V6 } GENERATOR CIRCUIT
V7 } FOR RANGE MARKER RINGS

	H 25 RANGE SWITCH	10 Miles	30 Miles	50 Miles
V1. V2.	CATHODE COUPLING POTENTIOMETERS	R5.	R6	R7
V3 V4	" " "	R20	R21	R22





RELAY 1.- ENERGISED ON 10 MILE RANGE OF H25.
" 2.- " " 50 " " " "

FIG.117

FIG.117

679. So far we have assumed that we have perfect push-pull outputs from each amplifier pair. If this condition is fulfilled the voltage across each pair of deflecting plates will be balanced about the tube centre and the timebase will then revolve about the tube centre. If, however, the two valves in either pair develop unequal amplitudes, the deflecting voltage across the pair of plates will not be balanced about the tube centre but about some other point. The scan will, then, not rotate about the tube centre and may result in odd marker shapes depending on the degree of unbalance, whether present in both pairs, and whether combined with unbalanced overall amplitudes from the two pairs. We thus have the further requirement of a means of balancing the output amplitudes from the two valves in each amplifier pair. This requirement is met in the indicator 182A by the incorporation of the presets R79 and R.80. These controls vary the grid potential, and hence the gain, of one valve in the pair relative to the gain of its mate. In the indicator 182 valve matching is the only answer to this problem.

680. We have assumed that if we have balanced the outputs from the two valves in each pair the scan will revolve about the tube centre. This assumption presupposes that the C.R.T. spot is centred when there is no sawtooth input. This may not be the case if any deformation is present in the electrode structure. We have then a further requirement for shift controls to centre the C.R.T. spot when there is no input. This requirement is met by the inclusion of the shift controls R.38 and R.40. In practice it is perhaps more satisfactory to apply the sawtooth input and turn the scanner until, say, a vertical scan appears. If it does not pass through the tube centre, the H shift can be adjusted to bring it through the centre. By turning the scanner until a horizontal scan is obtained the shift can be set up in the same way.

681. The focus and brilliance controls, R.49 and R.52 perform their normal functions.

Fishpond Bright-Up Requirements.

682. While we want a scan that maintains a constant range coverage of about 5 miles regardless of the scan in use on the H.2.S. displays, we do not want the actual scan to show. We want only the target indications which are applied as positive pulses to the P.P.I. grid to cause brightening up of the Fishpond display. These indications can only appear after the transmitter fires which will be when the Fishpond scan is about a $\frac{1}{2}$" beyond the tube centre on the 50 mile scan. The 10 mile and 30 mile zeros can be used to adjust the transmitter timing to make the transmitter fire at about the same point on the other scans. This means that we have a useful radial scan which begins about $\frac{1}{2}$" from the tube centre and extends to the tube circumference. Our scanning sawtooth carries the C.R.T. spot through the centre along a tube diameter on the working stroke and the flyback carries it back again. It becomes necessary then to have a bright-up waveform which will permit signals to brighten up only the portion of the scan between about $\frac{1}{2}$" from the tube centre and the tube circumference. The flyback and the first half of the sweep must be prevented from breaking through by feeding to Fishpond the output from the black Pye plug on the receiver-timing unit which has the target indications and markers superimposed on the W.F.G. bright-up waveform. If the switch unit and W.F.G. bright-up controls are adjusted to start the Fishpond bright-up about $\frac{1}{2}$" from the tube centre on all scans, and the contrast control is set to pass an adequate bright-up waveform to Fishpond, the timebase bright-up requirements can be fulfilled.

683. The control, R.32, enables the Fishpond operator to have a measure of control over the gain of his signal amplifier as arranged at present.

684. The Fishpond brilliance and gain controls are variable controls on the Fishpond panel. The focus control is a preset on the panel. The balance potentiometers, shifts, and cathode presets are mounted inside the units. The marker push-button switch also appears on the panel. The position of all these controls is shown on the layout diagrams in fig. 117.

How the Fishpond Controls are Set Up to Fulfil their Functions

Focus

685. With H.2.S. contrast well anti-clockwise to prevent any bright-up being passed by V.508, turn up Fishpond brilliance until a diametral scan just appears and adjust the Fishpond focus to give the sharpest possible scan.

H-Shift (R.40) and Y-Shift (R.38).

686. Note bearing of heading marker on the H.2.S. and Fishpond P.P.I.'s. If they do not correspond, rotate the Fishpond tube in its base to obtain correspondence. Set the scanner for a vertical scan on Fishpond. If it does not pass through the centre, adjust the H-shift. Set scanner for a horizontal scan. If it does not pass through the centre use the V-shift to make the necessary adjustments.

The Balance Presets, R.79 and R.80.

687. These controls must be adjusted to get the scan rotating about the tube centre. This is done by setting the scan-marker switch to the 100/40 position and setting the scanner in motion. If unbalance is present the Fishpond scan rotates about a sloppy bearing. If the swing of the inner end of the scan is elliptical, the major axis of the ellipse is across the most badly unbalanced pair. If the swing is circular, the unbalance is approximately equal in the two pairs. The balance presets must be adjusted to get a scan rotating about the centre. The shift adjustments must have been made first. If the range of adjustment on the balance presets is inadequate, a fault should be suspected in the values of the anode or cathode loads, or in the valve emissions. In the case of the indicator 182, valve matching is necessary as the balance presets are not incorporated in the set. Perfect balancing may not be obtainable on the 50 mile scan because of the high gain, but the balance should be good enough to keep the scan centre reasonably stationary on the 30 mile input and quite stable on the 10 mile input.

688. The cathode presets control the gain and thus effectively become range controls and so determine how many markers can appear on the display. The relative gain of the two amplifiers determines whether or not the markers are circular.

689. The H.2.S. contrast control determines how much bright-up square wave reaches Fishpond.

690. The W.F.G. and switch unit bright-up controls determine at which point on the sawtooth, and hence at what point on the Fishpond scan, the bright-up waveform commences.

691. The Fishpond zero marker always forms on the back edge of the 20 microsecond pulse. Where this occurs on the sawtooth is fixed on the 50 mile input. It will be about ½" from the centre on a normal Fishpond scan. As the 20 microsecond pulse moves on the sawtooth with the 30 mile zero on the 30 mile input to Fishpond, and with the 10 mile zero on the 10 mile input, these controls can be used to make the zero marker come up at about the same distance from the tube centre when the three scans have the same range coverage. What we then wish to achieve with these controls is the following:-

(a) Contrast - Set to pass enough bright-up so that only indications and Fishpond markers brighten up the display and the full scan is actually blacked out.

(b) Bright-up Controls - Set to start the bright-up about a half-inch from the tube centre on all scans when they have the correct range coverage. The requirement is actually that the bright-up commences early enough on the 50 mile scan to brighten up the zero marker and that the starting point remains sensibly constant on the three scans.

(c)(i) 30 Mile Zero - Set to bring the zero marker up about ½" from the centre for the 30 mile input, i.e., at about the same point

(ii) 10 Mile Zero - To bring the zero marker up about $\frac{1}{2}$" from the centre for the 10 mile input.

These adjustments ensure that the display remains sensibly constant as scans are changed on H.2.S.

(d) The Range Presets. Set to fulfil the two conditions:-

(i) The correct range coverage of about 4-5 miles on each scan. This is indicated by the number of marker rings appearing.

(ii) Circular markers. This involves correct adjustment of the relative output amplitudes of the two amplifier pairs.

692. The setting up sequence for these controls can be best carried out in the following steps:-

H.2.S. Contrast.

(a) Set H.2.S. gain, brilliance and contrast fully anticlockwise.
(b) Bring brilliance clockwise to show H.2.S. flyback scan and then turn back about 4 notches from the point where the scan and flyback fade out.
(c) Bring contrast clockwise until radial H.2.S. scan appears, then turn back one notch beyond point where the scan fades out. Setting the brilliance back 4 notches from the fade-out point in (b) is to ensure that adequate bright-up is passed to Fishpond when the contrast is set as in (c).

Bright-Up Controls and Range Controls.

693. (a) Set Fishpond gain at maximum.
(b) Set scan-marker switch to 100/40 position to get 50 mile sawtooth input.
(c) Turn Fishpond brilliance up until radial scan just appears.
(d) Set scanner to make radial scan horizontal.
(e) Press marker push-button and note where innermost marker dot appears on the radial scan.
(f) Check whether or not this innermost marker is the zero marker by advancing Fishpond brilliance and noting whether any additional marker dots appear. If the bright-up adjustment is correct, the first dot will appear at the beginning of the radial scan since this represents the beginning of the bright-up pulse.
(g) If this is not the case, adjust the switch unit bright-up control until the zero marker dot coincides with the inner edge of the radial scan. In some cases it may not be possible to regard the bright-up sufficiently to prevent it commencing early. If this is the case, no harm is done so long as the bright-up does not commence early enough to allow the spurious pulse at the beginning of the 20 microsecond pulse to break through and produce a spurious marker inside the zero marker dot. This can be checked on all scans by removing all suppression on H.2.S. and letting the transmitter pulse break through on Fishpond where it will cause a "splash" widening out the true zero marker.

694. Select the range preset marked 50 which operates on the amplifier pair producing the horizontal sweep and adjust for 4, 5 and 6 marker dots on the scan. The zero dot should be $\frac{1}{2}$" to $\frac{3}{4}$" out from the tube centre. If the timebase sweep appears to rotate slightly as the control is adjusted it means that the C.R.T. is not set with the deflecting plates in the horizontal and vertical planes. With 4, 5 and 6 dots on the scan set the scanner rotating. Adjust the second range preset marked 50 (working on the other amplifier pair) until the marker rings trace a circle.

(a) Set scan-marker switch to 30/20 position to get a 30 mile sawtooth input.
(b) Check that first marker dot obtained is the zero marker by noting where H.2.S. range marker dot appears as the H.2.S.

range control is set to zero or by using the suppressor break-through. If necessary, adjust 30 mile zero to shift the 20 microsecond pulse on the sawtooth to bring the zero marker dot up on the bright-up.

(c) Use one range preset labelled 30 to get 4, 5 or 6 marker dots on the horizontal scan. Adjust the other to get 5 - 6 circular markers when the scanner is rotating. The zero marker should now be about the same distance from the centre as on the 100/40 scan, i.e., about ½" from centre. If necessary, set the 30 mile zero to get this result.

(c) Set scan-marker switch to the 10/10 position to get a 10 mile sawtooth input.

(d) Check as before the first marker dot appearing is the zero marker. If not, adjust the 10 mile zero to move the 20 microsecond pulse on the sawtooth so as to bring the zero marker on the bright-up.

(e) Use the range presets labelled 10 to get 4, 5 or 6 circular markers with the scanner rotating. The zero marker should again be the same distance from the tube centre as on the other scans. Should the bright-up not start early enough, adjust the bright-up control on the W.F.G. to start the bright-up about ½" from the centre.

695. Check through the scans now that the markers are present for all settings of the scan-marker switch and that the zero marker appears approximately the same distance from the centre on each scan. The bright-up should commence on each scan at the position of the zero marker. If this condition is not fulfilled, alternate adjustments should be made on the bright-up controls using the W.F.G. control on the 10 mile input and the switch unit control on the 50 mile input until the condition is met. With the scanner rotating the zero marker should now cut the commencement of the heading marker on the 10/10, 10/20, 30/20, 50/20 and 100/40 positions of the scan-marker switch.

Checking Fishpond Range Calibration.

696. It has been assumed that the ringing circuit in the anode of V.6 is actually producing marker pips at 1 mile (10.75 microsecond) intervals. If the switch unit range scales are in statute miles a check can readily be made as follows:-

(a) Set scan-marker switch to the 10/10 position and the height control to zero.

(b) Set the height control to zero.

(c) Adjust range control to bring H.2.S. range marker dot successively on each Fishpond marker dot and read the range scale. The readings should be approximately 0, 1, 2, 3, 4 and 5 miles. If any error is apparent, the inductance, L.2, can be unsealed and the core adjusted to give the current ringing frequency. Perfect correspondence cannot be expected due to the inaccuracy at the beginning of the height scale and the setting of the height zero for accuracy at operational height.

697. A check can be made as follows with the monitor 28. This check does not depend on the switch unit scales:-

(a) Use a Pye interceptor socket to feed the H.2.S. range marker from the red Pye plug on the W.F.G. to the monitor 28.

(b) Set the timebase switch for a 100 microsecond timebase.

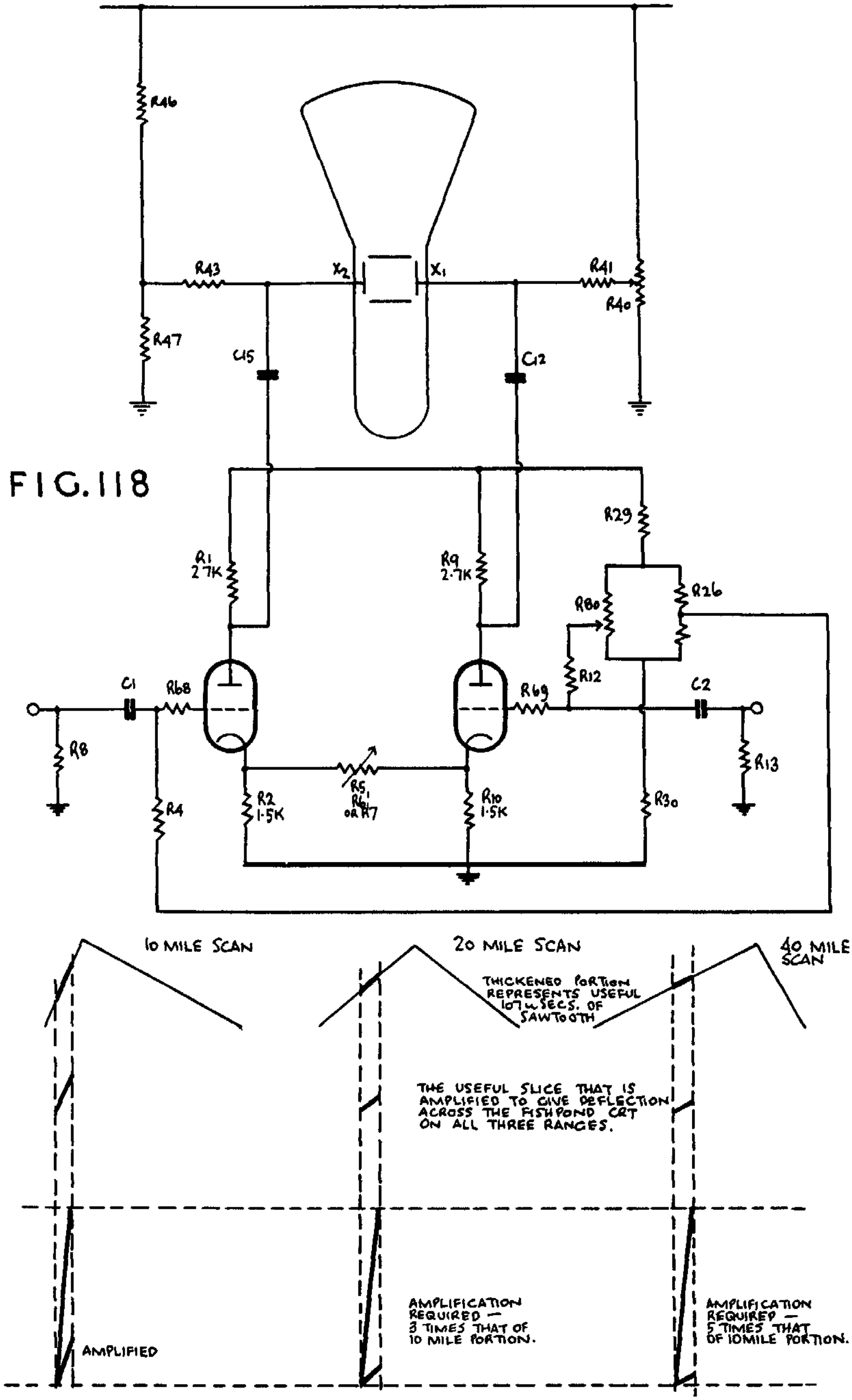
(c) Note the calibrated X-shift reading when the H.2.S. marker dot is on the centre of one of the Fishpond marker dots. Set the range control to bring the H.2.S. range marker up on the next Fishpond marker dot and again read the X-shift. The difference should be 10.75 microseconds.

698. Daily maintenance procedure for Fishpond is incorporated in the full D.I. procedure in Chapter 12.

C.D.0896L

PRINCIPLE OF FISHPOND TIME BASE AMPLIFIERS

FIG.118



FISH POND WAVE FORMS.

C.D.0896 L

WAVEFORMS OF ONE PAIR OF THE PARAPHASE AMPLIFIERS FOR THE TIME BASE

(ROTOR IN MAGSLIP AT MAXIMUM COUPLING TO THE STATOR FEEDING THE GRIDS OF VALVES 1 + 2)

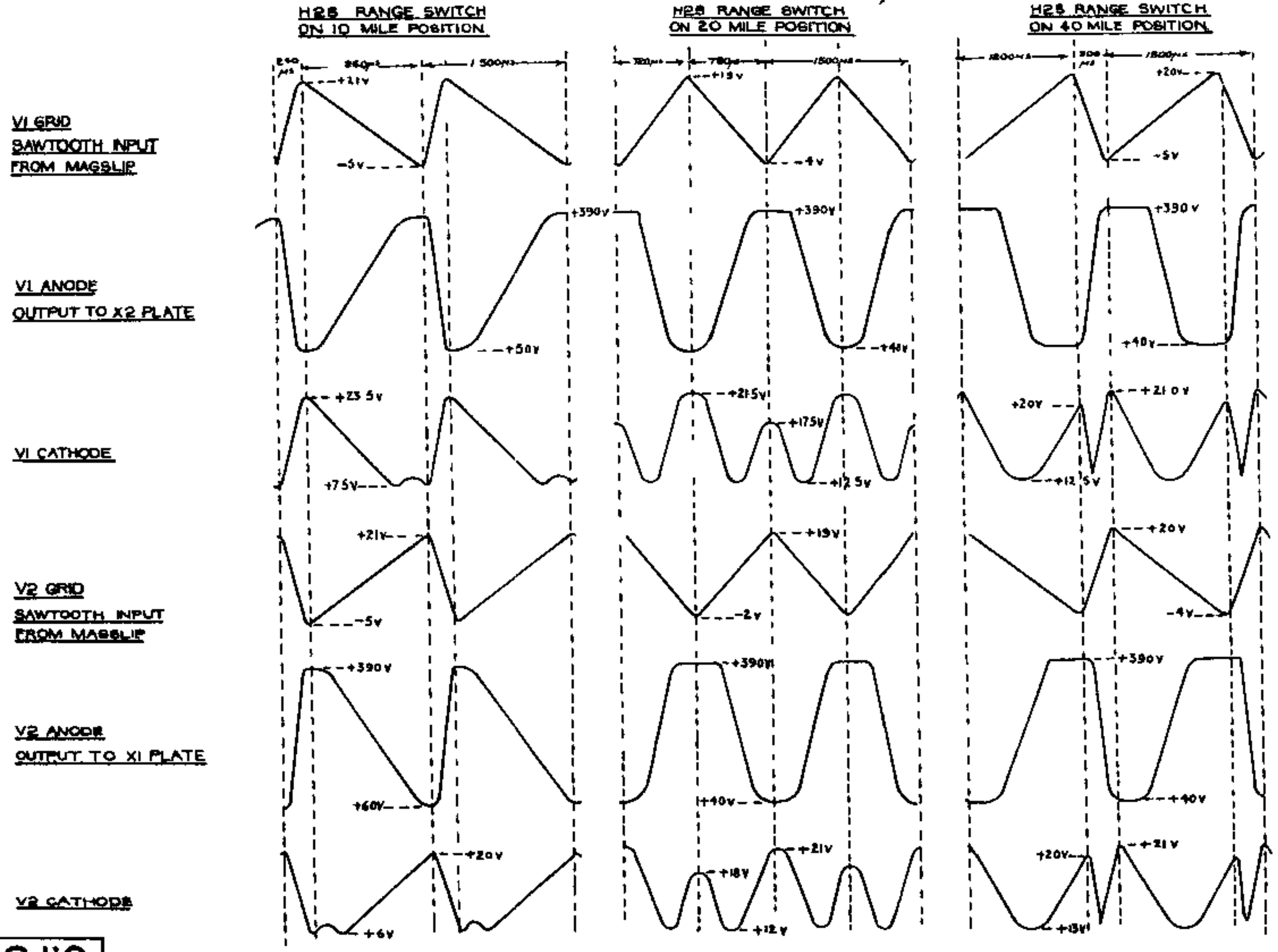


FIG.119

WAVEFORMS OF MARKERS CIRCUIT V6, V7.

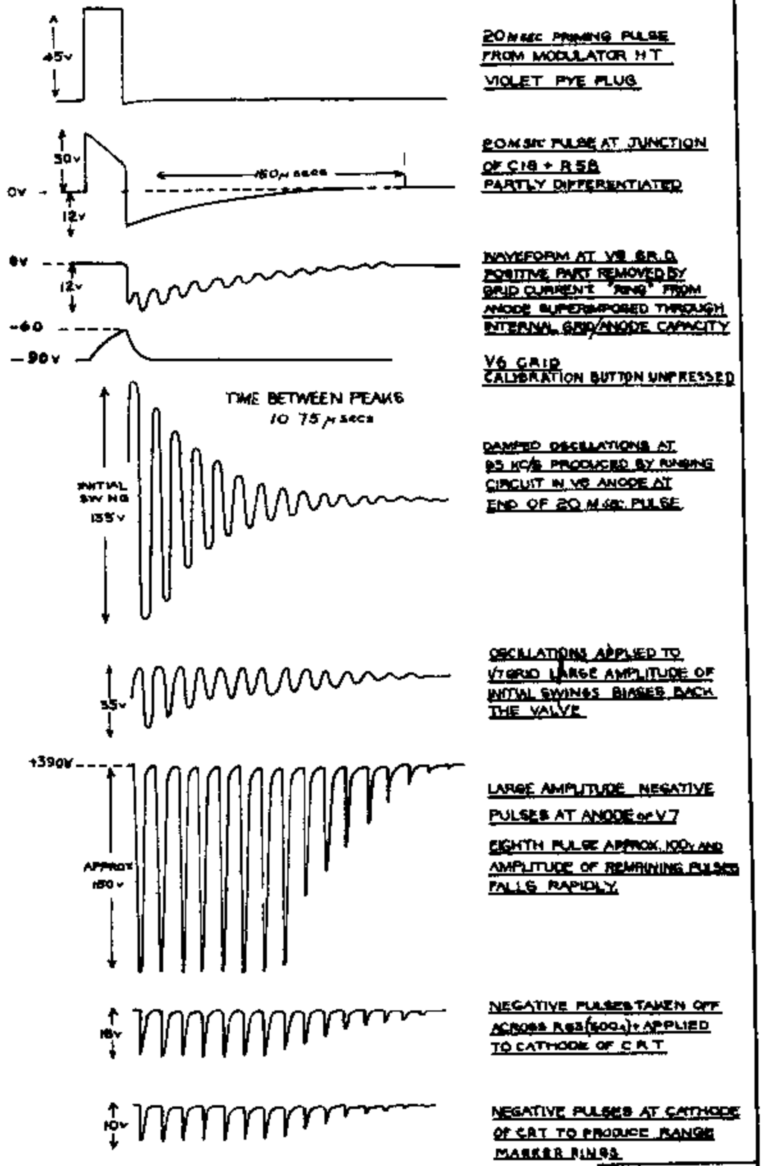


FIG.119

Differences between the Indicators 182 and 182A.

699. The first 200 Fishpond indicators are designated as type 182 and the balance as 182A.

(a) In type 182 units the 150K. grid leaks of V.1, V.2, V.3, V.4 are taken to the junction of a 390K. and 8.2K. forming a bleeder between H.T. and earth. The junction is decoupled to earth by a 0.1 mf. condenser.

(b) In type 182A units, the two-resistor bleeder is replaced by a series-parallel network. Details appear in the circuit diagram, fig.116. The grid leaks of V.1 and V.3 are taken to the junction of R.26 and R.24. The grid leaks of V.2 and V.4 are taken to the sliders of R.80 and R.79, respectively.

Detailed Study of the Fishpond Timebase Amplifiers.

700. So far, we have noted the following facts about the timebase amplifiers:-

(a) The circuits are symmetrical.
(b) The inputs are push-pull sawtooths with working strokes of 240, 720 and 1200 microseconds and amplitudes of the order of 50V.
(c) The presets strapping the cathodes are switched to so vary the gain as to get constant range coverage regardless of the input. This means gains in the ratio of 1:3:5 for the 240, 720 and 1200 microsecond working strokes.
(d) In each pair the grid potential of one valve can be varied relative to that of the other to get a balanced output.

701. No attempt has been made to explain fully how the cathode presets achieve the required changes in gain.

702. To appreciate the operation of either amplifier pair, more fully, let us refer to fig.118. Let us assume that V.1 grid is swinging positive and V.2 grid swinging negative with the sawtooth inputs applied through C.1 and C.2. The V.1 input will be balanced about the D.C. level to which V.1 grid is tied, i.e., about + 7V. V.2 input will be balanced about the level to which V.2 grid is returned by R.80. Let us assume for the moment that these levels are equal. The D.C. level of the cathodes is then about +9V. There is then a standing bias of about 2V. on the valves. If the cathode potentials remained stationary at this level the valves would conduct during the part of the grid swing that carried the grids between the cut-off and saturation levels. These would be the same on all scans, and the gain would be constant on all scans, so the output amplitude would be constant. The output velocity would, however, be in the same ratio as the input velocities, i.e., 1:3:5. Hence, the range coverages would be in this proportion. What we want to achieve is to so adjust the gain that while the grid swings through the central 107 microsecond portion of each swing the output voltage change is such as to carry the C.R.T. spot across the tube.

703. As shown in para.677, this means that the grids must move through about 11 volts while the spot crosses the tube diameter for a 10 mile input. When the 30 mile input is applied the slope of the sawtooth is only 1/3rd as great so in 107 microseconds the grid can only swing through a third of the 11V. or around 3.5V. Similarly, on the 50 mile input the grid has time to swing through only one-fifth of 11 or about 2.25 volts in the 107 microsecond sweep period. If we assume the required voltage change in the 107 microsecond period is 125V we want to have a grid swing of about 11V producing an anode swing of 125V. when the 10 mile input is applied. When the 30 mile input is applied we want a 3.5 volt swing to produce the same 125V. change at the anode. For the 50 mile input we want a 22.5V. swing to give an anode swing of 125V.

704. When the sawtooth carries V.1 grid above cut-off anode current flows and the cathode potential tends to rise and follow the grid up. If there were no cathode coupling we would then have a steady cathode rise while the

grid swings between cut-off and the saturation current level. The net input signal would be the difference between this cathode rise and the grid swing while the valve went from cut-off to saturation. There would thus be a measure of negative feedback which determined the actual anode potential swing while the grid went through the central 107 microseconds of its swing. But while one grid is swinging up and tending to carry its cathode up with it, the other grid is falling with the antiphase output from the other end of the magslip stator. The second cathode is then falling while the first is rising. If we now strapped the two cathodes directly and had perfectly symmetric circuits the fall at V.2 cathode would cancel the rise at V.1 cathode and the cathodes would remain stationary. There would then be no negative feedback and the amplifier would operate at maximum gain.

705. If instead we switch a resistance of value R between the two cathodes only a fraction of the voltage change at either cathode will be applied to the other cathode. This fraction will be given by $\frac{Rk}{R + Rk}$ where Rk is the cathode load. There is then a net cathode voltage change which provides negative feedback. The greater the value of R the greater will be the negative feedback and the lower will be the gain. By suitably adjusting R we can then make the push-pull voltage change at the two anodes of each amplifier pair have the value required to carry the spot across the tube in about 107 microseconds to give the desired range coverage of 5 miles. By having different presets for each input we can give R the required value for each scan. Since we need the highest gain on the 50 mile input R has then its minimum value. For the 30 mile input it will be higher and on the 10 mile input it will be higher still. The difference in the amount the cathodes follow the grids on the different scans can be seen on the waveforms in fig.

706. If P.80 is set to give V.2 a grid potential different from that of V.1 the gain of V.2 will be modified. In this way the output amplitude of V.2 can be varied so as to be equal to that of V.1, should slight difference in emission or component tolerances cause an unbalanced output and a display whose centre moved in a curved figure.

707. From fig.118 it is also apparent that the D.C. level of X.1 can be varied relative to that of X.2 if it is necessary to apply a correcting voltage for any deformation in the electrode structure.

<u>The Fishpond Marker Circuit.</u>

708. The following points have been made about the marker circuit:-

(a) If the push-button switch is pressed, the tuned circuit in the anode of V.6 rings at 93 Kc/s. to produce peaks at 10.75 microsecond intervals.
(b) The positive swings bias back V.7 grid on grid current so that it only conducts on the peaks.
(c) These peak conducting periods produce negative pips at the anode which are applied to the P.P.I. cathode.

709. The marker circuit appears in fig.116. The following points should be noted:-

(a) When the push-button switch is not depressed V.6 grid is returned to a potential of -100V. on pin 6 of the 12-way from JB.222. V.6 is therefore cut-off on the grid when the button is free since the 40V. amplitude of the positive-going 20 microsecond pulse is not sufficient to cause conduction.
(b) If the push-button is depressed V.6 grid is returned to the junction of R.64 and R.57 which form a bleeder between H.T. and earth. This bleeder then returns V.6 grid to a potential of around +40V. The valve is then in saturation current and the tuned circuit in the anode will not ring on the leading edge of the 20 microsecond pulse. The pulse is differentiated sufficiently during the 20 microsecond period to permit the collapsing back edge of the pulse to make the anode tuned circuit

ring heavily. The initial swing of the ring will be of the order of 130V. peak to peak.

(c) The cathode of V.7 is bridged in at the decoupled junction of R.76 and R.62 which form a bleeder between H.T. and earth. V.7 cathode is thus given a decoupled cathode potential of about +15V. This will hold V.7 cut off unless V.6 anode circuit is ringing.

(d) On the high amplitude positive swings V.7 grid passes grid current into C.20 which must leak away through R.61. This leak away through R.61 holds V.7 biassed back so that only the positive peaks cause conduction. These are amplified to form negative pips of about 15V. maximum amplitude at V.7 anode.

(e) An output is tapped off across R.63 and applied to the P.P.I. cathode via C.7 and C.21. As these pips swing the cathode negative they have the same effect as a positive signal on the grid and result in brightening up of the display.

The B-C Switch.

710. This switch must be set to the C position. Any new units should be checked that this adjustment has been made. The B position modifies the action of the 10 mile zero control in a way that is unsatisfactory for Bomber Command work.

H.T. and Heater Supplies.

711. The 80V. A.C. supply is obtained by taking cross-connections inside JB.222 from pins 6 and 8 of the 18-way to pins 1 and 2 of the 12-way coded black. These pins feed the primary of the power transformer, T.1. V.8 is a VU.71 double half-wave rectifier stage whose output is smoothed by L.3 and C.22, C.23. The output should be 400 ± 20v. which provides the main H.T. line. This is dropped by R.77 and R.78 and decoupled for V6.

712. Heater windings are provided on T.1 with outputs as shown on fig.116.

E.H.T. Supply.

713. The E.H.T. supply for the Fishpond P.P.I. bleeder is taken from the -4KV power pack in the modulator 64. A cable from the blue modulator output plug goes to the indicator 184. A parallel plug on the indicator 184 provides the output for Fishpond.

Bias Supply.

714. The -100V. is obtained from the metal rectifiers and applied to 18/13. A cross-connection from pin 6 of the 12-way black to 18/13 in JB.222 picks up this supply for Fishpond.

D.C. Supply for Fishpond Relays.

715. The relays 1 and 2 in Fishpond are parallel respectively with M(500) and N (501) in the W.F.G. The + 24V. supply for M and N relays is carried on pins 2 and 3 of the 12-way orange on the switch unit which passes to the 12-way orange on JB.222. The 12-way orange/green on the JB.22 is connected to the 12-way orange on the W.F.G. to complete the supply to M and N relays. For relay 1 in Fishpond a cross-connection is taken from pin 2 on the 12-way orange to pin 4 on the 12-way black in JB.222. For relay 2 a cross-connection is made from pin 3 on the 12-way orange to pin 5 on the 12-way black. The return or 24V. negative line to relays 1 and 2 is completed by taking a cross-connection inside JB.222 from the common D.C. negative line on 18/2 to pin 3 on the 12-way black.

The Waveform Generator, Type 43.

Function.

716. It has been emphasised that unless an adequate bright-up square wave is supplied to Fishpond, the flyback and diametral scan will tend to break through and make the display unreadable. It has also been pointed out that the amplitude of bright-up square wave that is passed by the W.F.G. mixer, V.508, depends on the setting of the contrast control. If the H.2.S. operator sets the contrast control too far anti-clockwise, the bright-up reaching Fishpond will be insufficient to prevent breakthrough of the scan and flyback and the unit becomes useless. The waveform generator 43 is a small added unit which is designed to provide an independent bright-up for Fishpond and thus eliminate the possibility of rendering Fishpond useless by an unfavourable setting of the contrast control.

Principle.

717. When not using the W.F.G. 43, the mixed bright-up, signals, heading or track marker and range marker are taken from the black Pye on the W.F.G. to provide the Fishpond signal input. When the W.F.G.43 is included in the installation the output from the slate Pye on the receiver-timing unit is split, part going to the W.F.G. 34 as before and part to the W.F.G.43. The 20 microsecond pulse from one of the violet Pye plugs on the modulator 64 is used to trigger a multivibrator of the same type as the modulator multivibrator. The output of this multivibrator is a 1500 microsecond square wave with the positive phase commencing on the back edge of the 20 microsecond input, i.e., when the zero marker forms. The duration of the positive phase is fixed at about 160 microseconds to provide brightening for the Fishpond scan. The signal input is mixed with the square wave in a stage similar to that used in the W.F.G. mixer, V508, and taken off from the cathode to a black Pye plug and thence to Fishpond. The amplitude of the bright-up square wave can be adjusted to a suitable level by means of a bias control on the mixer stage. The negative phase of the square wave serves to black out the flyback and first half of the diametral scan. The condenser in the input to the cathode of the Fishpond signal amplifier is removed to enable the Fishpond gain control to be used as a limiter in exactly the same way as the H.2.S. contrast control.

Installation and Cabling.

Mounting.

718. The $8\frac{1}{2}$" x $6\frac{1}{2}$" x 4" unit is suitable for mounting directly into the aircraft frame without the use of a mounting tray. The valves, etc. are mounted on an anti-vibration sub-chassis.

Power Supply.

719. The 18-way from the main junction box to the W.F.G. 34 is broken and the W.F.G. 43 inserted by using two 18-way plugs in parallel on the new unit. All eighteen pins of the added connector must be connected when the unit is inserted in Mark IID, Mark IIC, Mark IIIB or Mark IIIA installations. The H.T. supply is tapped off from pin 16. The 80V. supply for the heater transformer is tapped from pins 7 and 8 and pin 1 provides the earth line.

Triggering.

720. The violet Pye plug on the W.F.G. 43 is connected to one of the violet Pye plugs on the modulator 64.

Signal Input.

721. The slate Pye socket on the receiver-timing unit is fitted with a T-Pye plug to provide one output for the W.F.G.34 and one for the new W.F.G.43.

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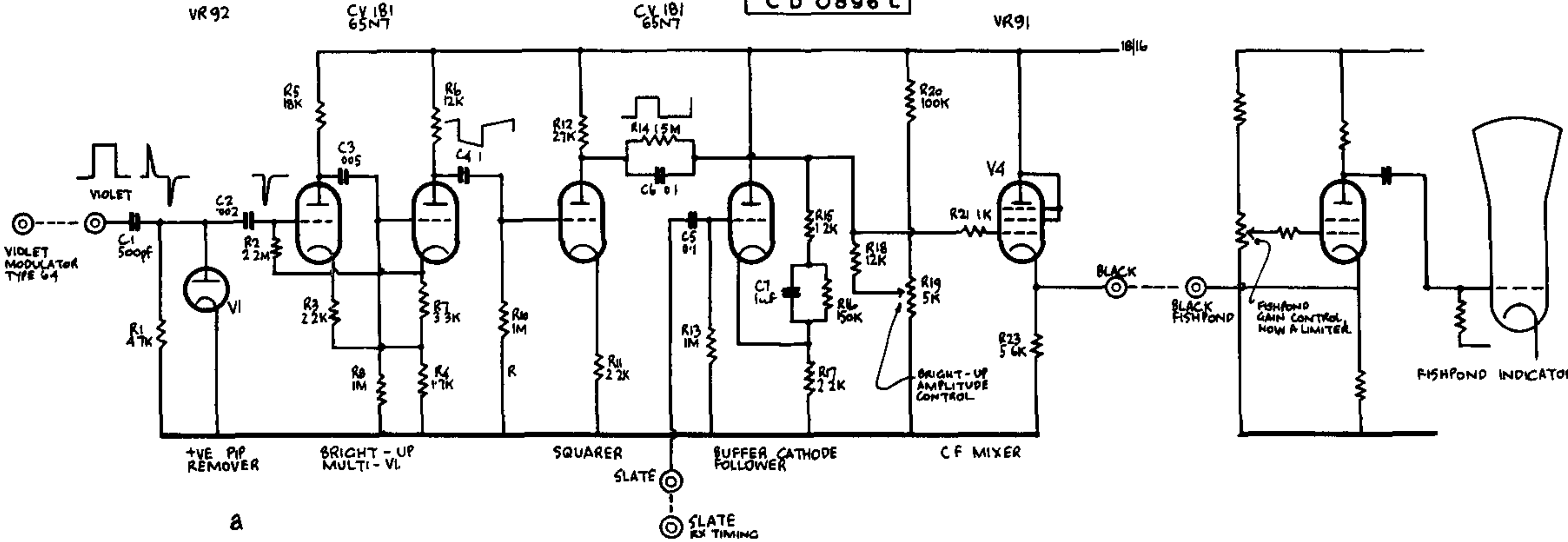
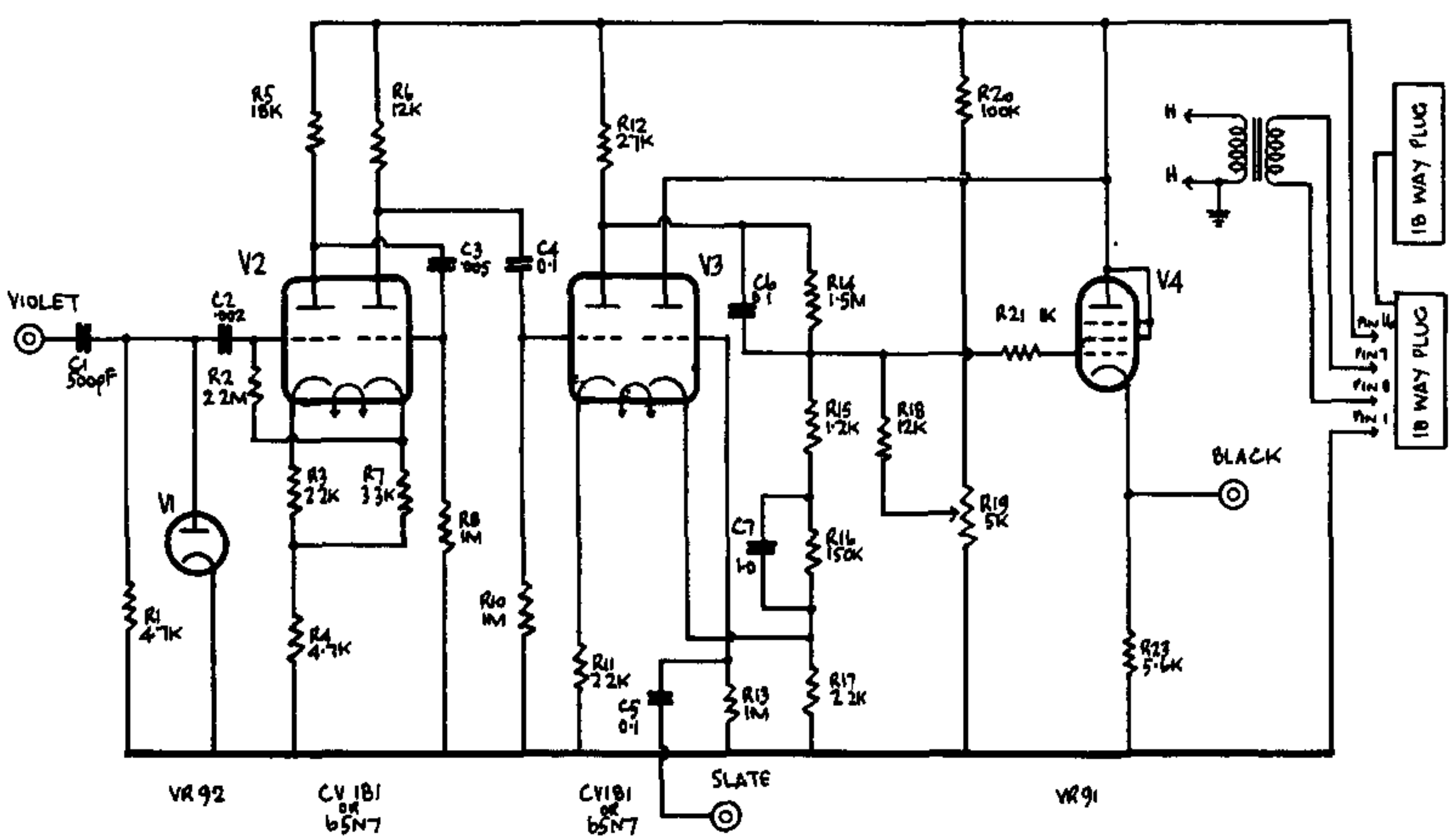


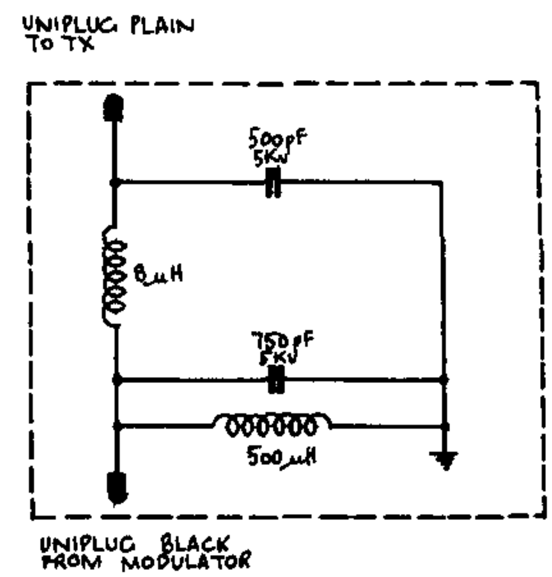
a

WAVEFORM GENERATOR TYPE 43

FIG. 120

b





FILTER UNIT TYPE 173

FIG. 121

Signal and Bright-Up Output.

722. The black Pye plug on the W.F.G. 43 is connected to the black Pye on Fishpond. C.8, between the Fishpond signal amplifier cathode and the black Pye plug, is removed to provide D.C. coupling between the W.F.G.43 mixer and the Fishpond signal amplifier.

Circuit Detail.

723. (a) The actual circuit is shown in fig.120(b)
(b) The effective circuit is shown in fig.120(a)
(c) Waveforms are shown in fig.122

The Bright-Up Multivibrator (V.2a, V.2b).

724. The double triode (CV.181) V.2, is wired up in a circuit very similar to that used for the modulator multivibrator. V2a is normally conducting and V.2b is cut off by the bias developed across R.4 by V.2a cathode current.

725. The 20 microsecond pulse is differentiated by C.1, R.1 to form positive and negative-going pips. V.1 cuts off the positive-going pip so we have a negative-going pip applied to V.2a grid on the back edge of the 20 microsecond pulse. As V.2a grid is carried down, the cathode current falls. This serve to carry V.2b grid up with the rise at V.2a anode. V.2b then starts to conduct. The effect will be to carry V.2a cathode up instantly with the increased voltage drop across R4 due to the cathode current taken by V.2b. V.2a grid also tends to rise by the amount of the voltage change across R.4 + R.7 when V.2b goes into conduction. But V.2a grid can only rise as rapidly as electrons can leak away from C.2 through R.2. Since this time constant is long, the instantaneous rise of V.2a cathode cuts V.2a off until the exponential rise of the grid towards V.2b anode a negative-going square wave which commences on the back edge of the 20 microsecond pulse and ends after a time determined by the time constant of C.2, R.2. The amplitude is about 100V and the duration is about 160 microseconds. This is inverted and cleane up in V.3a to provide the bright-up square wave.

726. Although the Fishpond radial scan is completed in about 40 - 50 microseconds the flyback does not commence for some time, and the spot merely sits off the edge of the screen. There is therefore no objection to having the bright-up square wave somewhat longer than the scanning period.

727. When V.2a grid has climbed exponentially to within its grid base of the cathode potential, V.2a goes back into conduction and the anode potential falls. This carries down V.2b grid and so reduces V.2b cathode current to carry V.2a cathode down and further reduce the bias on V.2a. V.2a then conducts harder. The effect is cumulative and quickly cuts V.2b off and brings V.2a on hard until the next negative pip arrives.

The Squarer (V.3a).

728. As a consequence of the component values used in the coupling between V.2a and V.2b, the bright-up waveform at V.2b anode is not flat-bottomed. The waveform is therefore unsuitable for immediate application to the mixer stage. To overcome this difficulty the output from V.2b anode is applied to a squarer stage which is half of a second CV.181 double triode. The large amplitude waveform carries V.3a into grid current and below cut-off to square off the waveform and produce at V.3a anode a flat-topped positive-going bright up square wave which is suitable for mixing with signals. The waveform observed will be distorted as a consequence of the D.C. coupling arrangements.

The Buffer Cathode Follower (V.3b).

729. To prevent the bright-up square wave from coupling back into the receiver-timing unit the input from the slate Pye plug is brought into the mixer stage through a buffer cathode follower stage. This stage is V.3b, the

second half of the double triode, V.3. The positive-going signal input is applied to the grid. R.17 (2.2K), in the grid input of V.4. serves as the cathode load. Part of the bright-up voltage appears across R.17 but cannot couple back to the grid and the slate Pye plug. V.3b thus provides a one-way channel for the signal input but isolates the bright-up waveform from the receiver-timing unit and W.F.G.34.

The Mixer Stage (V.5).

730. Mixing of the bright-up waveform and the signals is done in a cathode follower stage very similar to V.508 in the W.F.G. 34. V.4 is a VR.91 strapped as a triode. C.6 provides compensation for high frequency shunting by stray capacity at V.3a anode, and C.7 for high frequency losses due to shunting by stray capacity at V.3b cathode and V.4 grid. The bright-up square wave swings the grid of V4 through about 10 volts. By means of the preset, R.19, the D.C. level of V.4 grid can be varied. V.4 grid swings between 15V. and 25V. if R.19 is fully anticlockwise and between 0V. and 10V. if R.19 is fully clockwise. How much of the bright-up square wave appears on V.4 cathode will vary with the D.C. level to which V.4 grid is tied by R.19. Hence, by varying the setting of R.19, the amplitude of bright-up waveform on the common cathodes of V.4 and the Fishpond signal amplifier can be varied. A further variation can be introduced with the Fishpond gain control. When this control is fully clockwise, the signal amplifier grid is at its highest value and the valve takes the maximum current through the common cathode load. The mixer cathode is then at its highest level and therefore passes the minimum of bright-up. As the control is taken counter-clockwise less current is taken and the common cathode falls so more bright-up is passed. The control can thus be used to increase the bright-up until superimposed signals have their tops cut off as discussed in paras.541 - 542.

Setting-Up Procedure.

731. (a) Scan-marker switch to 100/40 position
(b) H.2.S. gain to midway position.
(c) Bright-up preset on W.F.G.43 (R.19) fully anticlockwise to hold mixer grid at lowest level and so cut bright-up output to minimum.
(d) Set Fishpond gain control (now used as a limiter) fully clockwise to make current passed by signal amplifier a maximum and thus take mixer cathode to its maximum level in so far as it is controlled by the Fishpond gain control.
(e) Scope the waveform at the anode of the Fishpond signal amplifier on the monitor 28.
(f) Advance the W.F.G.43 preset and observe the effect on the waveform on the monitor. Noise will appear first, then the bright-up pulse increasing in amplitude. Presently top-cutting will start to take off the noise peaks and ultimately only the bright-up pulse will remain. Leave the control set at the point where the entire noise is just cut off by limiting and the full bright-up pulse remains.
(g) Turn the Fishpond gain anticlockwise and note that the noise reappears and that when fully clockwise the bright-up and noise disappear completely due to cut-off on the amplifier grid.
(h) With brilliance at minimum, leave gain control at point where the radial scan just fades out.
(i) W.F.G. and switch unit bright-up controls are no longer required for Fishpond and should now be set fully anti-clockwise.
(j) The range presets must be set to give 5-6 circular markers on each scan and the 10 mile and 30 mile zeros set up to give a zero marker of about an inch diameter on the 10 mile and 30 mile sawtooth inputs.

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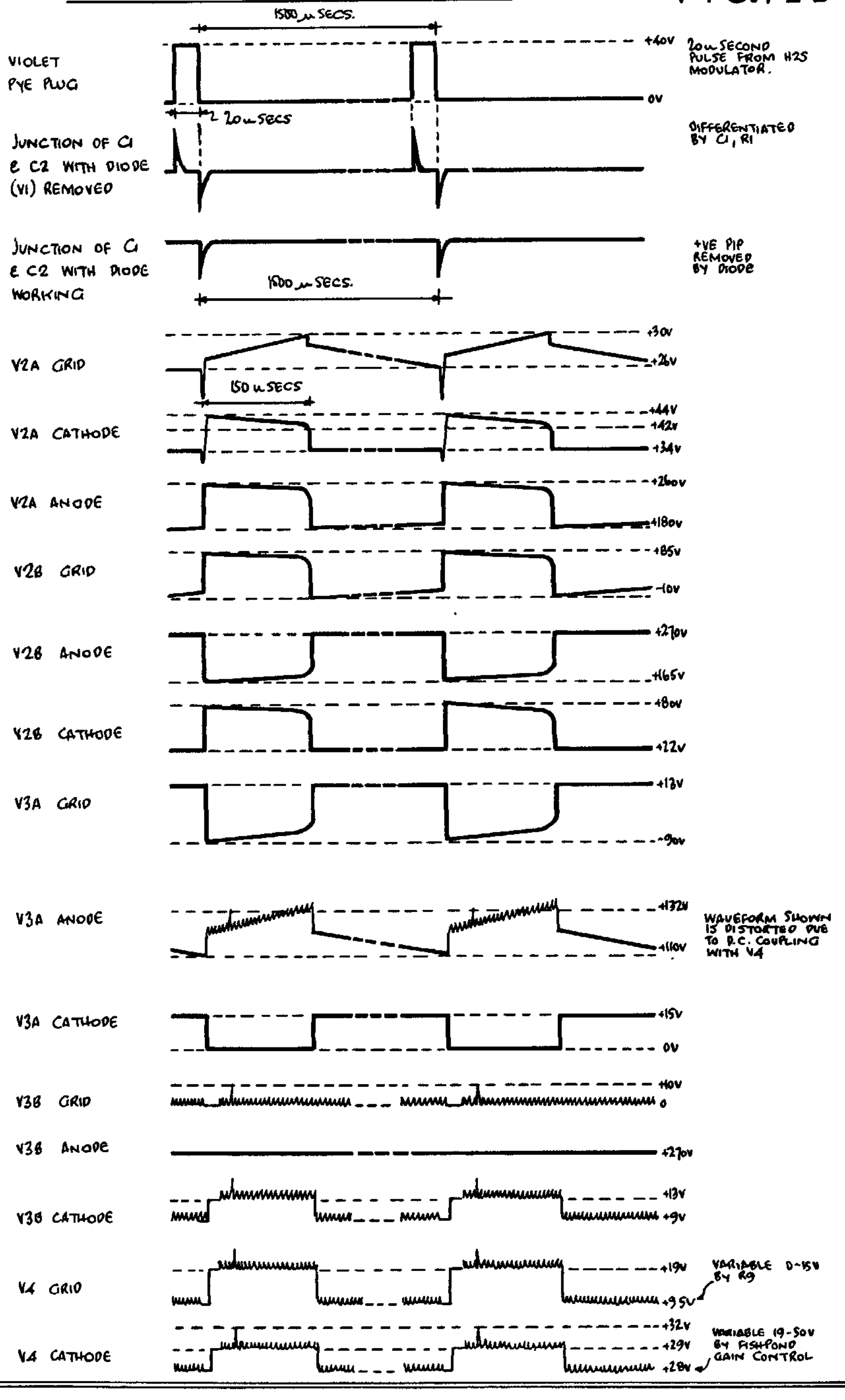
FIG.122

WAVEFORM GENERATOR TYPE 43 - WAVEFORMS



The Filter Unit Type 173.

Function.

732. This unit was designed to reduce the "splash" coming through on the Fishpond display after the conclusion of the main transmitter pulse. This "splash" varies in duration from set to set. If the suppression control on the receiver-timing unit is set to cut out this "splash" the I.F. amplifier is insensitive for the corresponding period and no signals can possibly get through to Fishpond. The Fishpond minimum range then is very poor depending on how long the receiver is suppressed after the primary pulse ends. An improved v version known as the filter unit 189 may supersede the type 173 units.

Principle.

733. If the suppression control is set to just cover the primary pulse, the Fishpond signals and the "splash" will get through to Fishpond. The minimum range will then be determined by the range at which the intensity of signals will exceed the intensity of the "splash". Obviously, anything that will reduce the "splash" intensity without reducing the signal intensity will then improve the minimum range. The filter unit which is inserted in the pulse lead from the modulator to the transmitter unit contains a low-pass filter which is designed to pass all frequencies up to around $5\frac{1}{2}$ Mc/s but sharply attenuate higher frequencies. This is intended to pass sufficient of the pulse components to obtain a satisfactory modulating pulse but to reject the higher frequency components which tend to cause ringing and standing waves on the pulse cable. Difficulties may arise from pulse cable radiation and pick-up on the head amplifier and I.F. strip. By attenuating the frequencies above $5\frac{1}{2}$ Mc/s. it is possible to reduce the amount of pick-up of this nature which gets through the receiver and hence to minimise the "splash" intensity. In addition to pick-up of this nature, there is also the problem of secondary pulsing of the magnetron with the resultant development of mixed frequencies in the cm. band which pass through the mixer to the head amplifier and thence to the receiver and the display. Reduction of the ringing of the modulating line and the pulse cable by virtue of the attenuation of the high frequency components should also reduce this factor.

Installation.

734. The filter unit is inserted in the pulse cable between the modulator and the transmitter unit, at the Modulator end.

Setting-Up

735. The filter cannot possibly have any effect unless the suppression adjusted to just cover the primary transmitter pulse, i.e., one notch beyond the point where the whole breakthrough appears.

736. In order to get the maximum contrast between "splash" and signals just stronger than "splash" the minimum of brilliance must be used.

Circuit.

737. The filter circuit is shown in fig.121.

CHAPTER 11 - TEST EQUIPMENT.

Monitor Type 28.

738. (a) The panel and chassis layouts are shown in figs. 123 - 125.
(b) The circuit is shown in fig. 126.
(c) Waveforms are shown in figs. 127 and 128.

Uses.

739. The monitor 28 finds widespread use in the servicing of H.2.S. equipment. It can be used for the following purposes:-

(a) Examination of waveforms.
(b) Measurement of voltage amplitudes of waveforms by means of a calibrated Y-shift and built-in voltmeter.
(c) Measurements of duration of waveforms with the calibrated X-shift or with the aid of the crystal-controlled calibrator, T.S. 202.
(d) Checking height and range marker calibration with the aid of T.S. 202.
(e) Determining approximate p.r.f.'s.
(f) Determining D.C. levels of waveforms with the aid of a suitable switching and meter arrangement.
(g) Measurement of Lucero transmitter power.

Panel Layout.

740. Details of the Monitor 28 panel are shown in fig. 123.

(a) Power Supply - The monitor contains its own power pack which operates from an 80V., 1000 c/s input via the 2-pin W-plug. The single-way W-plug provides a -2KV. output from the monitor power pack. This output has no present application in H.2.S. maintenance.
(b) Focus Control - Appears as a knob labelled "Focus".
(c) Brilliance Control - Appears ar a knob labelled "Bias".
(d) Signal Input - (i) Signals may be applied at the black screw terminal or at the Pye plug labelled "Input". The latter was not provided on earlier models.
(ii) A separate Pye input labelled "Int." is also provided. This is used to measure the power output of the Lucero transmitter.
(e) Input Switch - Signal inputs may be applied
(i) direct to the Y-plates
(ii) through an amplifier of calibrated gain.
(iii) to a diode detector whose rectified output is applied to the Y-plates.
Which of these options is employed is determined by the setting of a five position input switch. The positions indicated are:-
(i) Direct - Signal applied direct to Y.1.
(ii) X5, X10, X20 - Signal applied through amplifier of gain as selected.
(iii) Int. - This position is used when the Lucero output is applied to the "Int." Pye plug. The R.F. pulses are then applied to a peak rectifying diode whose output is applied direct to the Y.1 plate.
(f) Time Base Selector Switch - The monitor provides a choice of one free-running and four triggered timebases. The selection is made by means of a timebase selector switch. The positions are marked as follows:-
(a) 10 - 10 microsecond timebase.
(b) 100 - 100 microsecond timebase
(c) 1000 - 1000 microsecond timebase
(d) Freq. - 2000 microsecond timebase which is incomplete and shows only approximately 1500 microseconds on the display.
(e) V.A.R.- Free-running timebase of adjustable speed

(g) Timebase Speed Control - When the timebase switch is set to the V.A.R. position, the length of the free-running timebase can be varied by means of the control labelled "Speed" from about 5 to 10 milliseconds.

(h) Timebase Sync. Control - A knob labelled "Sync." is provided which is used to lock the scan when the free-running timebase is used.

(i) Trigger Input - When the monitor is to be used with H.2.S. on one of the triggered timebases, the 20 microsecond positive-going pulse from one of the violet Pye plugs on the modulator 64 is applied at the Pye plug labelled "Trig." When this input is used to trigger the monitor the timebase p.r.f. is that of the modulator multivibrator. If the modulator 64 is being synchronised by the transmitter-timing pulse, the timebase p.r.f. will be that of the master multivibrator and the complete H.2.S. installation. Any H.2.S. waveforms will then be automatically locked to the monitor timebase.

(j) Timebase Start Control - A variable resistor in a resistance capacity network incorporated in the monitor permits the base start to be varied between 2 and 3 microseconds before the trailing edge of the 20 microsecond pulse, and 2 to 3 microseconds after this trailing edge. This variable control appears on the panel as "T.B. Start". The range of variation available may vary slightly from one monitor to another. It will also be affected by the steepness of the back edge of the 20 microsecond pulse.

(k) Earth Connection - A brass terminal is provided for a monitor earthing connection to the unit under examination.

(l) Calibrated X-Shift - The angular displacement available on the X-shift is divided into 10 equal parts. Each division then represents a time interval equal to 1/10th of the timebase length, i.e., 1/10th of 10, 100, 1000 or 2000 microseconds. This calibration of the X-shift is provided to permit measurement of pulse widths. Since the calibrations on the knob are equally spaced they can only give accurate pulse width measurements if the timebase is perfectly linear, i.e., if the timebase velocity is constant throughout its full sweep. This is rarely the case so pulse width measurements with the calibrated X-shift are subject to an error which depends on the degree of non-linearity present

(m) Calibrated Y-Shift - A voltmeter (100-o-100 volts) is connected into the Y-shift circuit for the measurement of waveform amplitudes. When the signal input is being amplified the amplitude indicated on the meter must be divided by 5, 10 or 20 according to the amplification in use.

Using the Monitor 28 with H.2.S.

Connections.

741. (a) The power supply can be taken from the 2-pin 80V. A.C. plug on the H.2.S. junction box and applied to the 2-pin input on the monitor panel.

(b) The triggering waveform is taken from one of the violet Pye plugs on the modulator 64 and applied to the Pye plug labelled "Trig."

(c) The waveform to be examined is applied to either the input terminal or input Pye plug.

Examination of Waveforms.

742. The input switch should be set to "Direct" unless the amplifiers are needed. The timebase switch is set to 10, 100, 1000 or freq. to suit the width of the particular waveform being examined.

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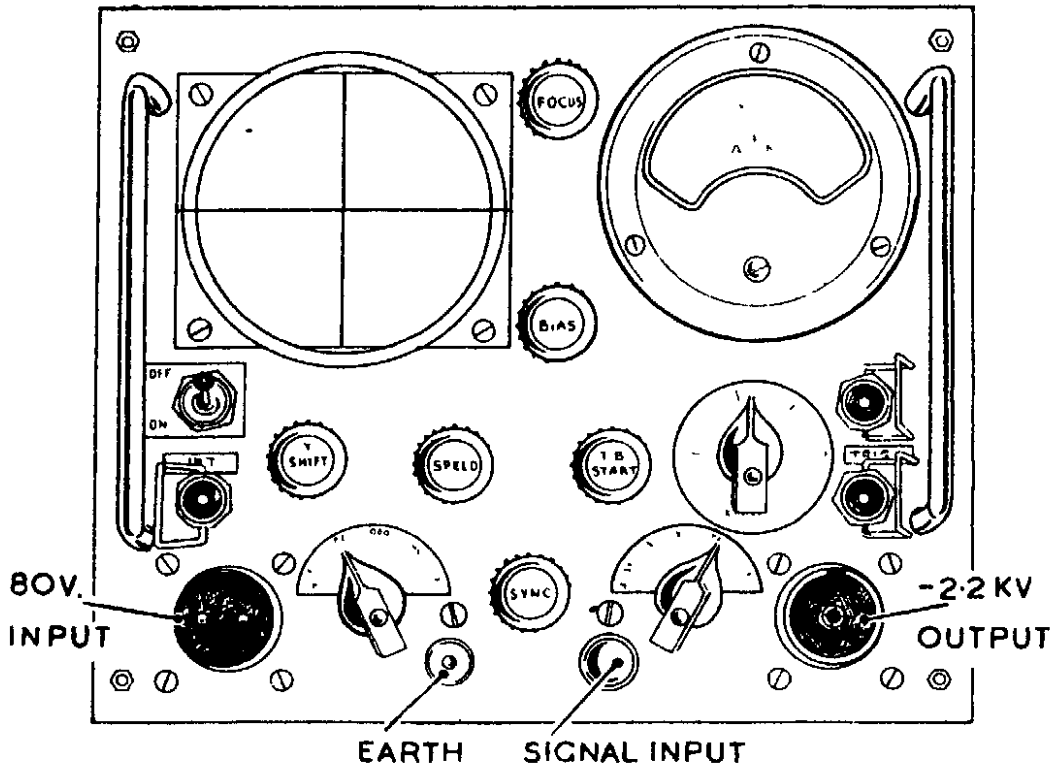
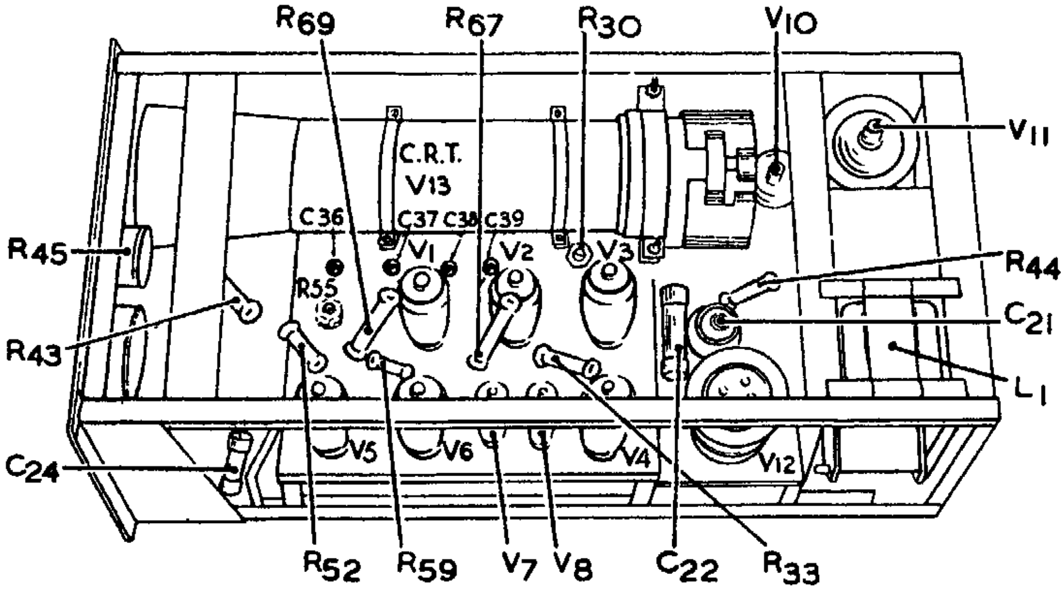


FRONT PANEL VIEW



TOP-SIDE VIEW

MONITOR TYPE 28 (DETAILS)

FIG.123

FIG.123

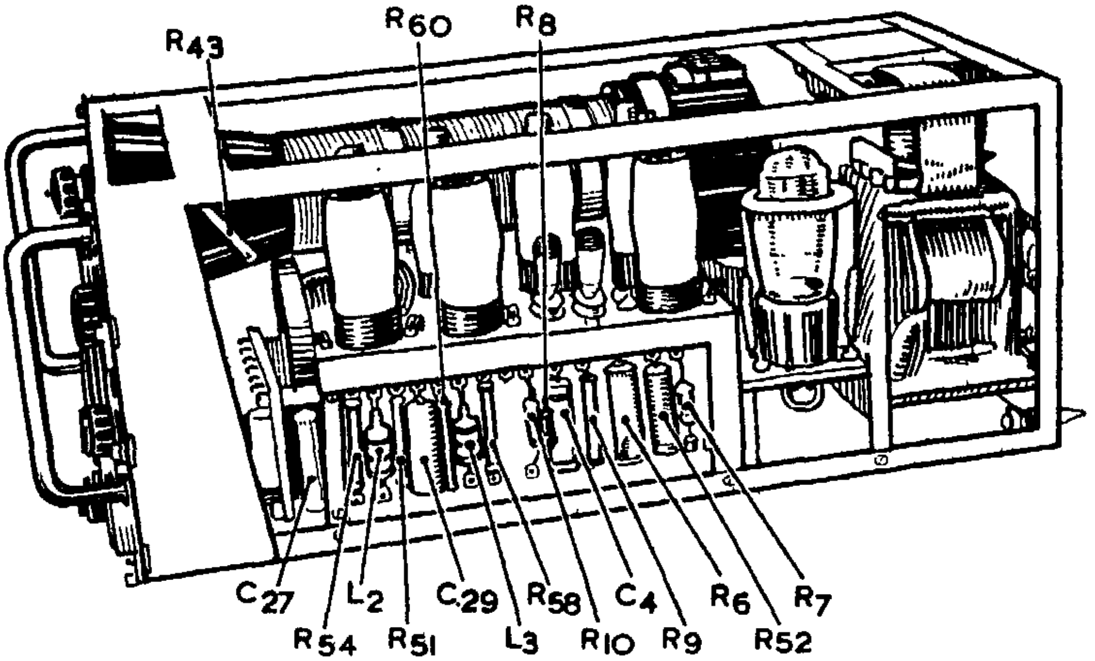


FIG.124 RIGHT-HAND SIDE VIEW

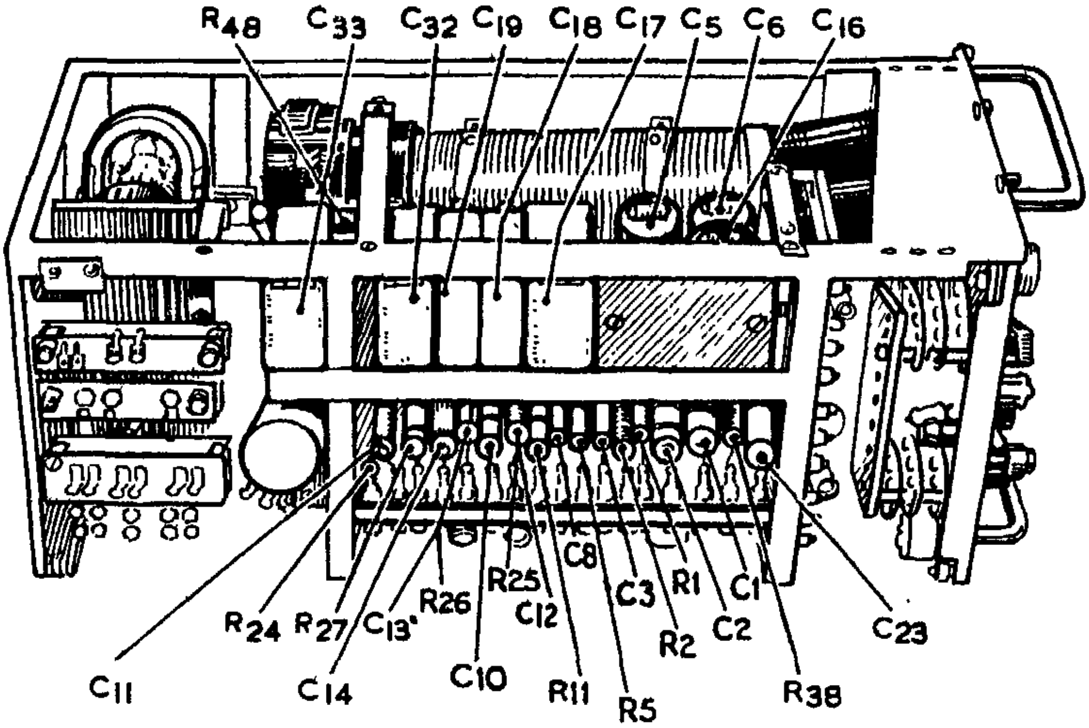


FIG.125 UNDER-SIDE VIEW

MONITOR TYPE 28 (DETAILS)

Measurement of Pulse Width.

743. The leading edge of the waveform is lined up with the vertical engraved line on the perspex screen over the tube face by means of the X-shift and the reading of the calibrated X-shift noted. The trailing edge is then brought into coincidence with the engraved line and the reading of the X-shift again noted. The number of divisions in the displacement is then multiplied by the time value of one division on the scan in use to obtain the pulse width. For example: a waveform requiring $3\frac{1}{2}$ divisions displacement on the 100 microsecond timebase would have a width of $3\frac{1}{2}$ x 10 or 35 microseconds, since 1 division represents 1/10th x 100 or 10 microseconds.

Amplitude Measurements.

744. Use the Y-shift to bring the bottom of the waveform into coincidence with the horizontal engraved line on the perspex screen and note the meter reading. Now bring the top of the waveform to the horizontal line and again note the meter reading. The difference between the two meter readings will give the amplitude of waveform applied to the Y-plates. If the input switch is on "Direct" the amplitude thus measured will be that of the input signal. If the switch is in one of the amplifier positions the signal amplitude is found by dividing the meter difference by the amplification in use. For Example: If readings of -20 and +35 are obtained with the input switch on x5, the input amplitude is $\frac{55}{5}$ or 11 V.

Checking H.2.S. P.R.F.

745. For this check the timebase switch must be set to "Freq." With this setting the timebase sweep commences on the back edge of the 20 microsecond pulse with a velocity designed to cover the tube face in 2000 microseconds. As the period is of the order of 1500 microseconds the leading edge of the next 20 microsecond pulse will occur before the scan is completed and cuts off the sweep. The next scan then commences on the back edge of the following 20 microsecond pulse. This means that the length of scan shown is what appears between the back edge of one 20 microsecond pulse and the beginning of the next. By using the X-shift the length of scan in divisions can be measured. Each division now represents 200 microseconds, so the approximate period is found by taking the number of divisions x 200 microseconds. For example: If the scan length is 7.7 divisions, the scan length is 7.4 x 200 = 1480 microseconds. To get the full period the 20 microsecond pulse width should be added. The p.r.f. is found by dividing the period in microseconds into 1,000,000 microseconds (1 second). A period of 1490 microseconds means a p.r.f. of $\frac{1,000,000}{1,490}$ = 671 c/s. How accurate any such calculation will be is again determined by what degree of non-linearity is present in the timebase.

746. The use of the monitor 28 in conjunction with the TS.202 in setting up the height and range markers is discussed under the T.S.202.

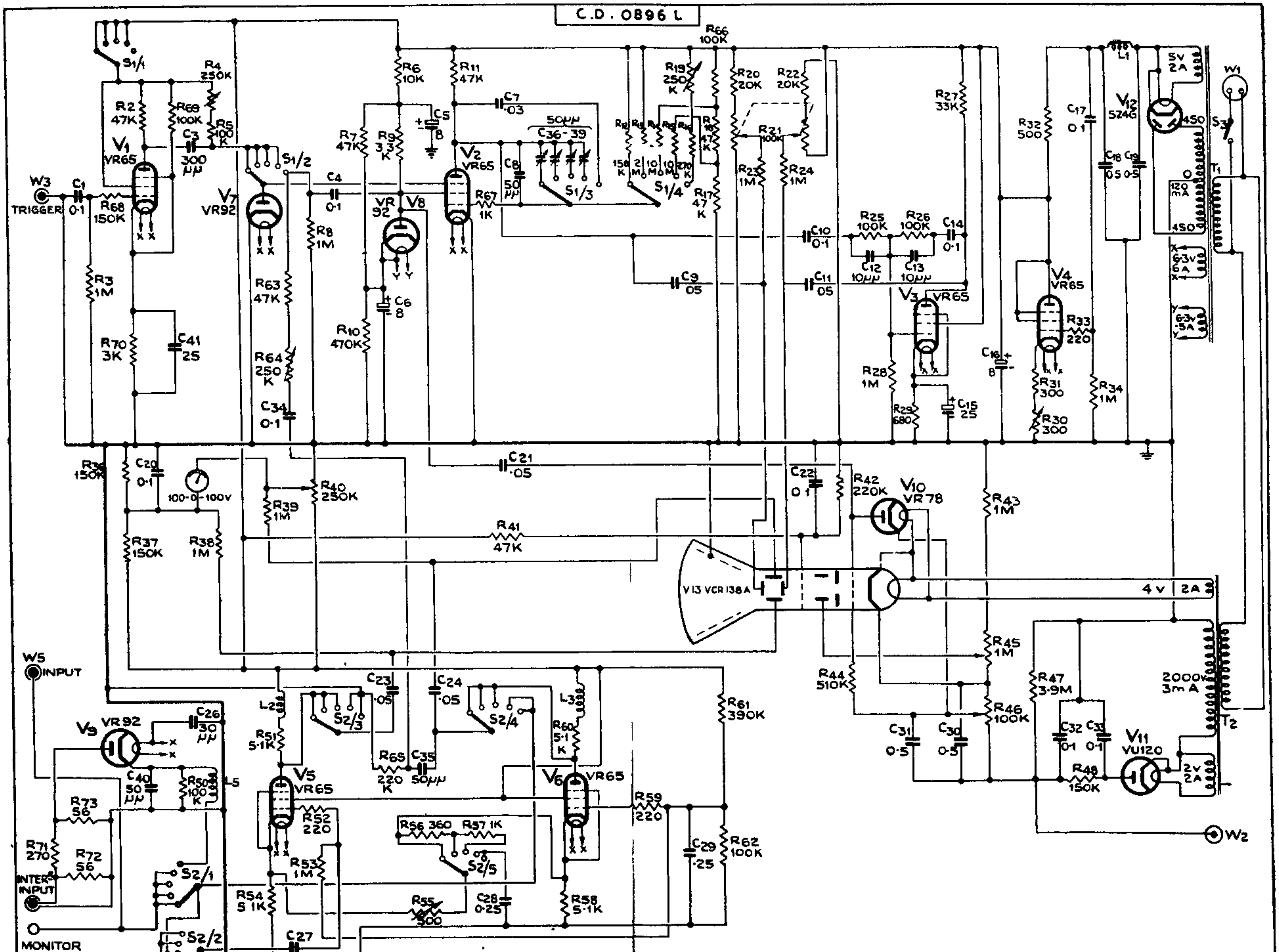
747. The use of the monitor 28 in conjunction with a D.C. scope attachment is discussed under measurement of D.C. levels.

Measurement of Lucero Transmitter Power.

748. Connect the R.F. output plug on the T.R.3160 to the "Int." Pye plug on the monitor with a length of uniradio 4. This connecting cable should be supplied with the monitor 28 and no other type of cable should be used as it alone has the correct 47 ohm impedance.

749. The monitor incorporates a diode peak voltmeter connected to a resistance network. This network terminates the 47 ohm feeder correctly and attenuates the input voltage by a ratio of 6:1. The rectified peak voltage may be read with the calibrated Y-shift. The power output may then be derived from the formula:-

$$\text{Peak Power} = \frac{(6V.)2}{94}$$



MONITOR TYPE 28, CIRCUIT

FIG. 126

FIG. 126

From this formula, the following table is obtained:-

Pulse Amplitude in Volts.	Peak Power in Watts.
10	40
15	85
20	150
25	235
30	340
35	460
40	600
45	760
50	940

750. The picture on the tube may be examined on either the 100 or 10 microsecond timebase. In either case, the pulse shape is not a true representation of the R.F. transmitter pulse because a long time constant cathode circuit to the diode is necessary to ensure that true peak voltages are recorded.

751. The power output measured in this way at the Pye plug on the transmitter sub-unit output socket should be nearly 600 watts. If measured at the aerial sockets 500 watts is a reasonable figure. If it is substantially less than these figures the fault is most likely to be in one of the following circuits:-

(a) E.H.T. supply.
(b) Transmitter filament supply.
(c) Drive from the modulation valve in the waveform generator to the modulator valve. The difference between the power readings at the two points gives an indication of the efficiency of the common T.R. system.

The Monitor 28 Circuit.

752. (a) The complete circuit is shown in fig.126
(b) Significant waveforms are shown in figs: 127 and 128.

The Timebase.

753. The 20 microsecond input is applied to the grid of V.1 via the long time constant C.1, R.3. The waveform is amplified and inverted at V.1 anode. C.3, R.4, R.5 provide a time constant variable between 45 and 105 microseconds which introduces a measure of differentiation dependent on the setting of R.4. This differentiated negative-going square wave is applied to the suppressor of V.2.

754. V.2 is the timebase stage arranged as a Miller circuit. The following circuit details are worth noting:

(a) Anode connected to grid through:-
(i) C.8 + trimmer C.36 with R.12 (150K) for grid leak to give 10 /us.T
(ii) C.8 + trimmer C.37 with R.13 (2M.) " " " " " 100 "
(iii) C.8 + trimmer C.38 with R.14 (10M) " " " " " 1000 "
(iv) C.8 + trimmer C.39 with R.15 (10M) " " " " " 2000 "
(b) For the 1000 /us. T.B. grid leak is tapped down to junction of R.6 and R.18
(c) For the 2000/us. T.B. grid leak is tapped down to junction of R.17 and R.18.
(d) For the free-running timebase, the screen and H.T. supply is disconnected from V.1 and V.2 anode is coupled to its grid through C.7 (.03) across C.8 with R.16 (270K) + R.19 (250K.) variable as grid leak. R.19 provides the timebase speed control.

755. When the negative-going pulse from V.1 anode is applied to V.2 suppressor the anode current cuts off on the leading edge of the 20 microsecond pulse to produce the flyback. V.2 will then be cut off on the suppressor until the suppressor is again brought above cut-off. If R.4 is

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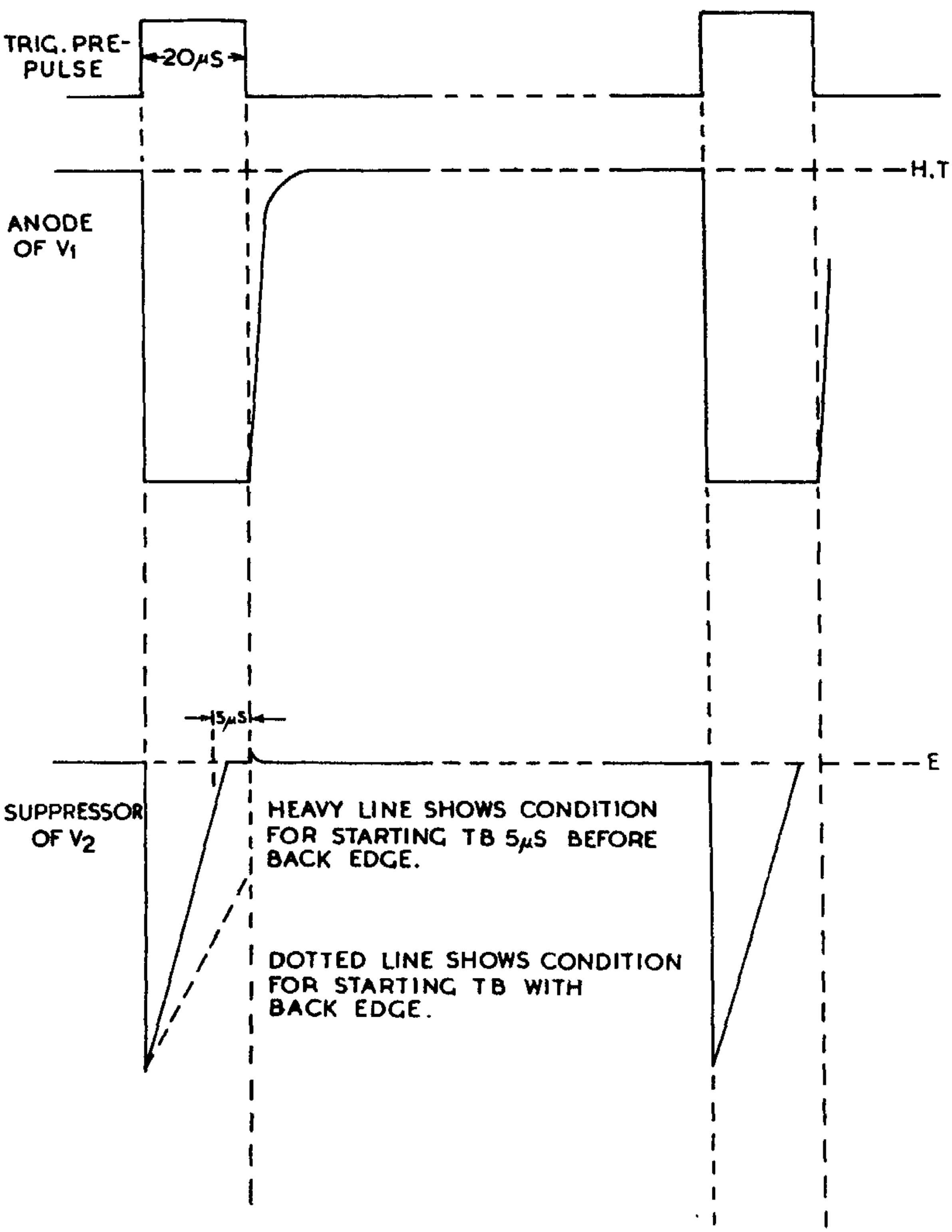

THE DEVELOPMENT OF THE TRIGGERING WAVEFORM OF THE TIME BASE

FIG. 127

FIG. 127

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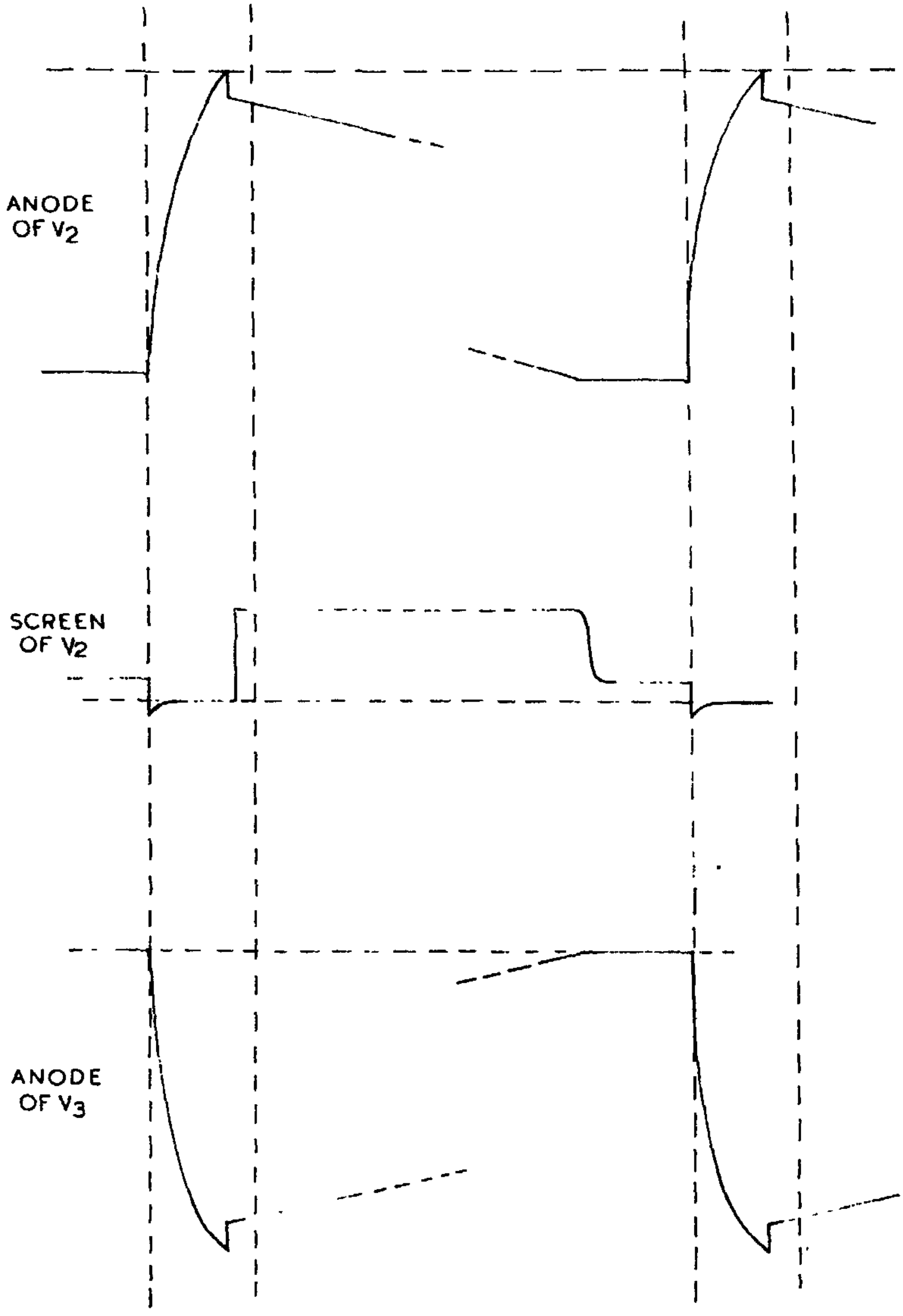


WAVEFORMS USED TO PRODUCE THE TIME BASE SWEEP

FIG. 128

FIG. 128

set to a sufficiently low value the differentiation of the pulse will bring V.2 suppressor above cut-off before the back edge of the 20 microsecond pulse occurs. R.4. is then the timebase start control on the panel. With R.4 full in the timebase may start after the back edge of the 20 microsecond input pulse, due presumably to distortion of the pulse applied to V.2. suppressor. That is, the 20 microsecond pulse on V.2 suppressor must be slightly wider than the input pulse. When V.2 suppressor crosses cut-off the usual Miller timebase action occurs to give a falling sawtooth at V.2 anode. V.7 keeps V.2 suppressor from swinging positive with the back edge of the differentiated waveform.

756. The sawtooth from V.2 anode is applied to the one X-plate, but this is not sufficient to give a full deflection so the paraphase amplifier, V.3, is used to develop an antiphase sawtooth of approximately the same amplitude. The coupling between V.2 and V.3 is similar in principle to that used between the timebase valve and paraphase amplifier in the Gee indicator. Bad cramping or non-linearity of the timebase at the beginning of its sweep has been cleared in a number of cases by replacing C15 in V3 cathode circuit.

757. R.21 is the calibrated X-shift control.

The Amplifier Circuit.

758. V.5 and V.6 constitute the calibrated signal amplifier, and S.2 is the signal input switch. V.5 and V.6 are arranged as a cathode-coupled amplifier similar to that used to develop the indicator 184 timebase. The cathodes are strapped by the preset, R.55, in the x20 position, R.55 + R.56 in the x10 and R.55 + R.56 + R.57 in the x5. The insertion of increasing resistance results in increased negative feedback and reduced gain. R.55 is used to initially set the gain to 20 for the first position of the input switch. The amplifier has a flat response over all frequencies up to 500 Kc/s.

759. The outputs from the anodes of V.5 and V.6 are applied via S.2 to the Y-plates for the x20, x10 and x5 positions of the input switch. In the fourth or "Direct" position, the signal input is connected straight through to Y.1. Y.2 is earthed through C.23.

760. R.40 provides the Y-shift and the meter reads the change in shift voltage required to move the waveform through its own amplitude, i.e., the amplitude of the waveform.

The Sync. Control.

761. When the timebase selector switch is set to the V.A.R. position, the problem of locking is simplified by having a synchronising signal applied to the timebase valve. This signal is applied via. C.34, R.64, R.63 and C.4 to V.2 screen. R.64 permits variation of the amplitude applied so serves as the Sync. control.

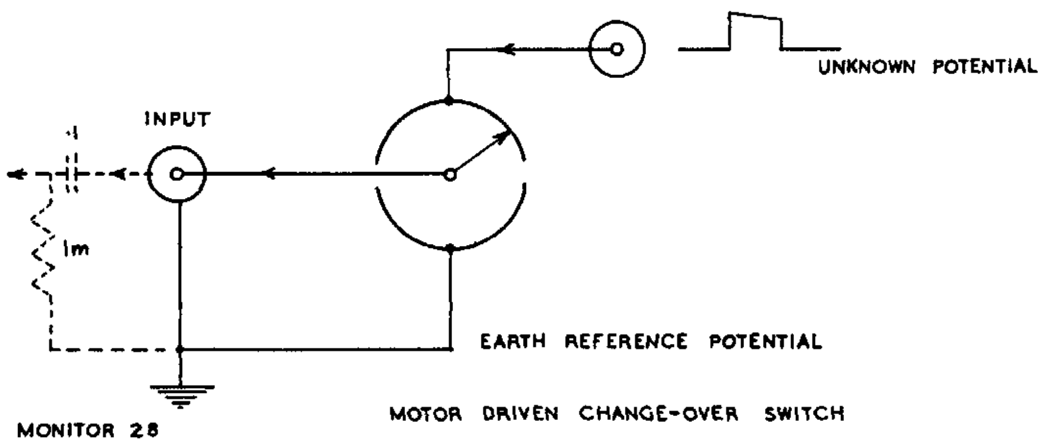
The flyback Blackout Circuit.

762. During the period that V.2 anode current is cut off on the suppressor the screen current rises so the screen potential falls and a negative-going square wave appears on the screen. Due to the differentiation of the pulse applied to the suppressor the screen waveform will not have a flat top. The waveform is therefore applied to the biassed diode, V.8, which cuts off the bottom part to give a square wave output which is applied to the C.R.T. grid. V.10 acts as a D.C. restorer which negatively restores the waveform about the level of the brilliance control slider. This negative-going waveform then carries the C.R.T. grid down while V.2 anode current is cut off on the suppressor, i.e., during the flyback period.

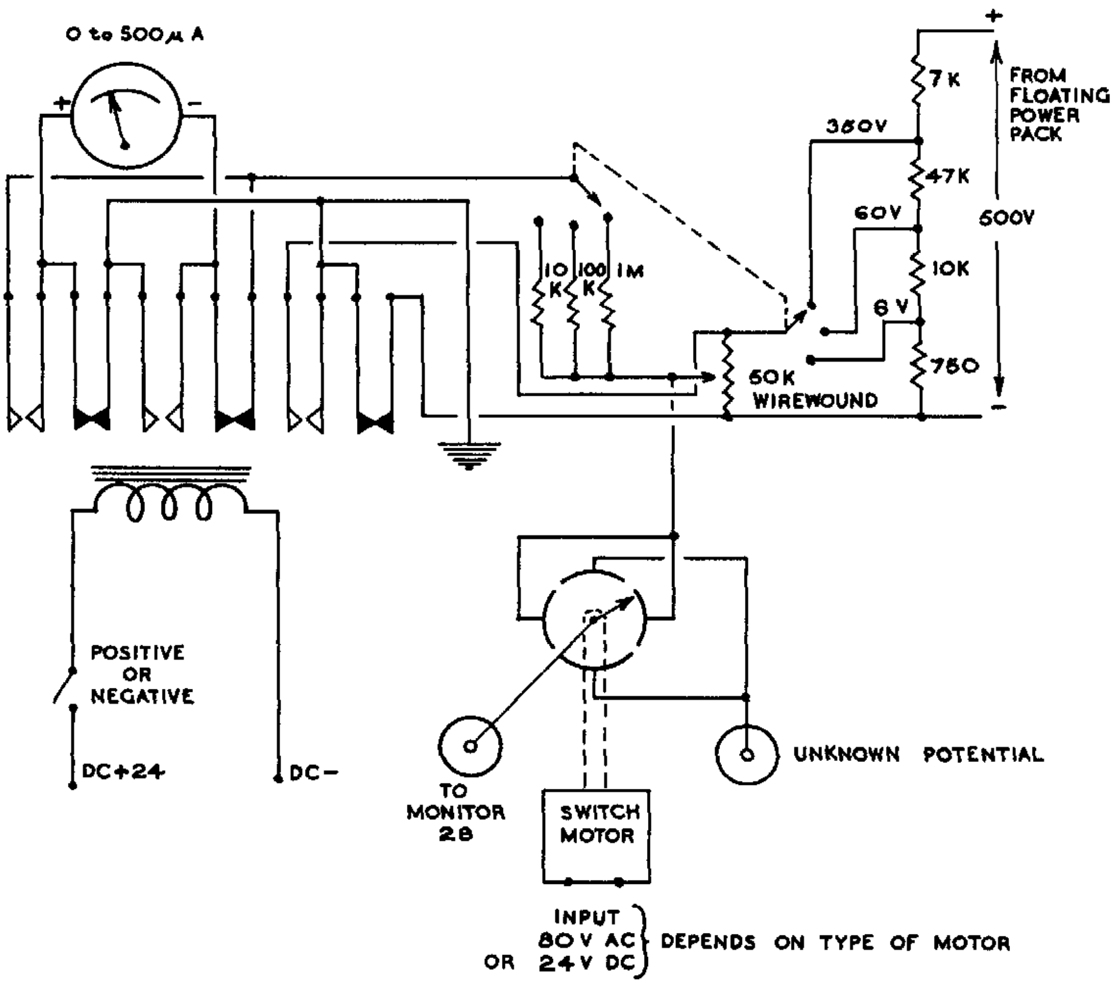
H.T. Supply.

763. V.12 is a 5Z4G full wave rectified which provides approximately 400V. (120 ma.) as the H.T. supply.

764. V.4 is an anti-jitter valve to eliminate low frequency ripply from the H.T. supply. R.30 is a preset used for adjusting the gain of V.4 to give



SIMPLE DC. LEVEL ATTACHMENT FOR MONITOR 28.



MORE ELABORATE DC. LEVEL ATTACHMENT FOR MONITOR 28.

FIG. 129.

FIG. 129.

zero ripple at the anode.

E.H.T. Supply.

765. V.11 is a VU.120 half-wave rectifier supplying about 2.3 KV. (3 ma.) for the C.R.T. bleeder.

The Diode Peak Voltmeter.

766. V.9 is the diode detector to which the input from the Lucero transmitter is applied via the Pye plug labelled "Int." if the input switch is set in the fifth or "Int." position. The rectified pulse envelope is applied via the choke L.1 and C.24 to Y.1. Its amplitude can be measured with the Y shift and the power found from the formula or table in para. 749.

D.C. Level Attachment for Monitor 28.

Introduction.

767. The monitor 28 has a calibrated Y-shift which can be used for measuring the amplitudes of waveforms. Very frequently it would be convenient to know the D.C. level of a waveform as well as its actual amplitude. This information cannot be obtained from the monitor as it stands, since the waveform is applied through a condenser which blocks the D.C. component. If this D.C. component is applied in the form of a square wave whose amplitude is equal to the magnitude of the D.C. level, it will effectively become an A.C. waveform which can be displayed on the monitor.

768. A D.C. level can be broken into a square wave be connecting to earth one of the input terminals of a switch motor (of the type used in A.S.V., A.I. or Visual Monica), while the other is connected to the point whose D.C. level is required. As the switch revolves its potential will be at earth for half of each revolution, and at the D.C. level wanted for the other half of each revolution. The output waveform will then be a symmetric square wave of frequency equal to the revolutions per second of the switch motor if it is of the two input type. If of the 4 input type the p.r.f. can be doubled by connecting opposite pairs of inputs. This is desirable in order to get the duration of each phase of the square wave short with respect to the input time-constant of the monitor. When this condition can be fulfilled the monitor timebase will appear at two levels on the screen. The one level represents earth potential and the other the required D.C. level whose value can be measured with the Y-shift in the normal way.

769. If the switching speed is not rapid enough to produce a square wave whose positive and negative phases have durations short in comparison with the input time constant of the monitor, the display will show a series of lines at different levels due to the partial differentiation of the square wave and the decay of the deflecting voltage applied on successive sweeps of the timebase. In this case the Y-shift must be used to measure the maximum potential difference between the lines present on the display.

770. The D.C. level observed on the display will appear above or below the earth level depending on whether the potential at the point under examination is positive or negative with respect to earth.

771. So far, we have assumed that one side of the switch motor is earthed in which case we are using earth as the reference potential. It is not at all essential that the reference potential be earth. Any other potential may be used provided its value is accurately known. The observed amplitude must then be added to or subtracted from the reference potential to get the D.C. level with respect to earth.

772. It is important that the input switch contacts should not overlap electrically. Should this occur the reference potential will be fed back at the point under observation. A check can be made by connecting an Avo set to the 10,000 scale across the input sockets when the motor is running. If no overlap is present an infinity reading will be obtained.

Applications.

Measurement of Voltages.

773. Frequently the introduction of a meter into a circuit will either upset the circuit operation or cause changes in the wanted voltage value. The attachment provides a ready means of checking such voltages as lie within its range of measurement.

Study of Waveforms.

774. Provided the switching speed is not too slow the waveform at a point in a circuit can be shown on the monitor 28. The D.C. level of the different parts of the waveform can be measured with the calibrated Y-shift. If distortion by the attachment is suspected the waveform can be applied in the normal way and its amplitude measured.

Double Beam Work.

775. If two waveforms are applied to the two input terminals of the switch they will appear on the screen separated by the difference in their D.C. levels. Phase shifts, etc., can then be observed.

Simple Unit.

776. The simplest arrangement is to use only a switch motor. The change-over contact will be connected to the monitor input. The other two contacts will be connected:-

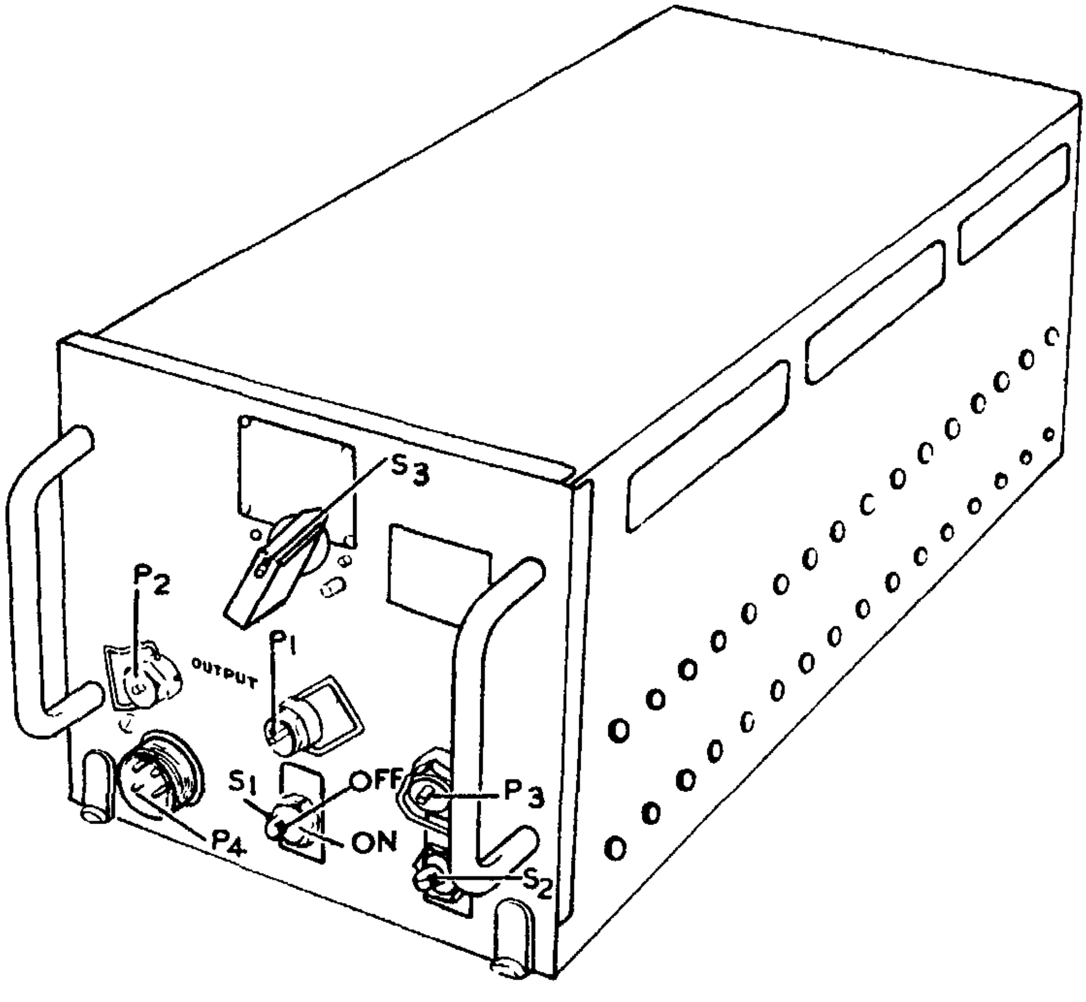
(a) To the unknown D.C. level which may have a waveform superimposed on it.
(b) To the reference potential which may be earth or any other accurately known value with respect to earth.

More Elaborate Unit.

777. A more elaborate arrangement is shown in fig.129. The following items are required:-

(a) A 500V. power pack (not shown in diagram) which has no connection to earth, to make it possible to obtain both positive and negative voltages. The required components can be obtained from a Gee power pack.
(b) A switch motor, preferably one which can be run at a higher speed than normal to eliminate differentiation in the input C.R. If an A.I. switch motor is used the effective speed of switching can be doubled by connecting opposite contacts as shown.
(c) A wire-wound 50K. potentiometer with a rating of at least 3 watts.
(d) A meter with a full scale deflection of 500 microamperes is preferable but not essential. The resistance values shown are approximately correct for a 0 - 500 microammeter. The series meter resistances will require adjustment by comparing meter readings with a standard meter to get direct reading on ranges of 0 - 5V., 0 - 50V., and 0 - 500V. Due to difficulty in obtaining a potentiometer capable of operating on a 500V. input, it was necessary in the actual model to limit the maximum voltage applied to 350V.
(e) A three-position Yaxley switch for changing the potential applied to the potentiometer and simultaneously changing the range of the meter. The type of switch used in the control panel of Mark II or Mark III I.F.F. is suitable.
(f) A triple-pole changeover switch or a relay energised from the 24V. supply and controlled by a single pole ON/OFF switch. The relay or switch changes the earth connections to the potentiometer (so as to obtain a voltage either positive or negative with respect to earth) and at the same time changes the polarity of the meter connections.

778. It is recommended that the circuit be built up in accordance with the components available as the same results can obviously be obtained in different ways

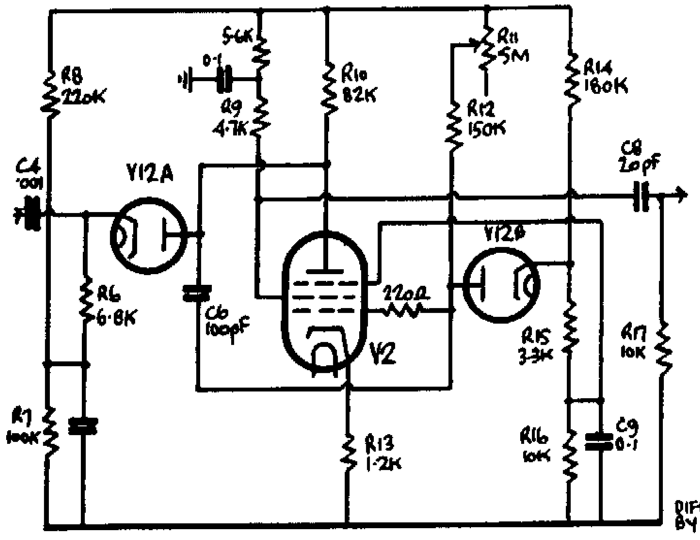


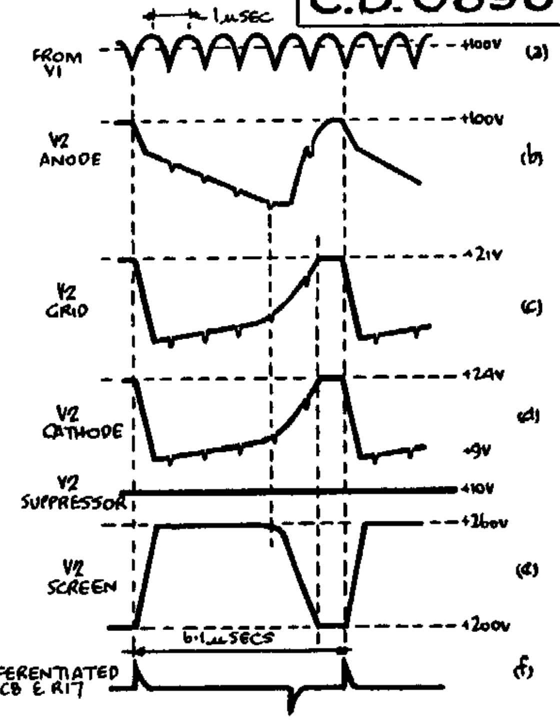
FRONT PANEL

TEST SET TYPE 202

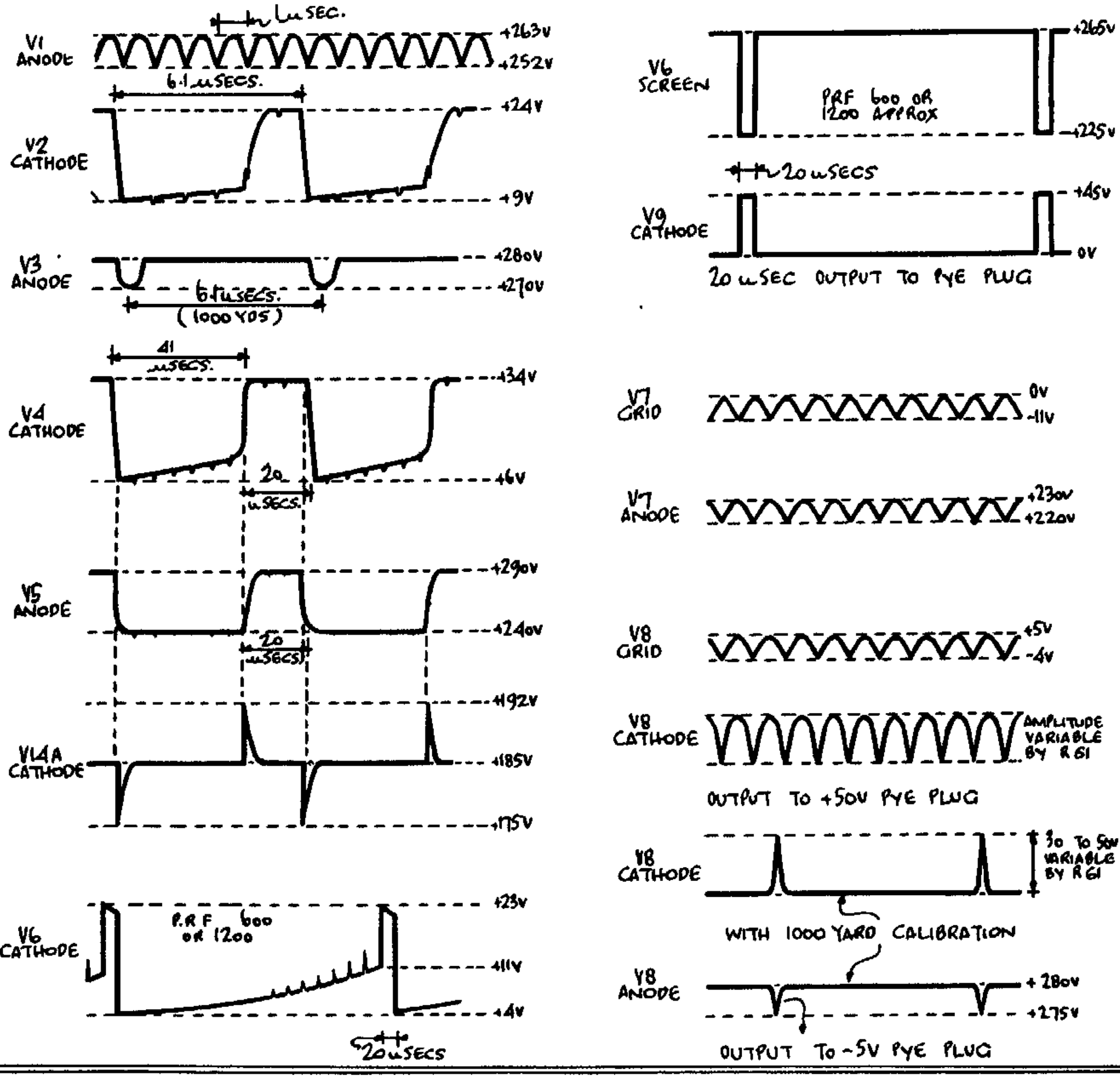
C.D. 0896L

TEST SET TYPE 202 PANTASTRON DIVIDER CIRCUIT FIG. 131





TEST SET TYPE 202—WAVEFORMS FIG. 132



TEST SET TYPE 202 (REF. 10SB/6002)

Introduction.

779. Test Set Type 202 is designed to give:-

(a) Calibration pips at intervals corresponding to 500 feet, 1,000 yards or 10,000 yards range
(b) A positive 20 microsecond triggering pulse at a repetition frequency of either 600 cycles or 1200 cycles per second. The calibration pips are locked to the back edge of this 20 microsecond pulse.

Power Supply.

780. The test set may be operated from 230 volt 50 cycles or 80 volt 1000 cycles.

For 80 volt supply use pins 1 and 2 of the 4 pin W plug.
For 230 volt supply use pins 1 and 4.

General Principles.

781. (a) A crystal oscillator whose frequency is 983.2 Kc/s. gives calibration pips at 1.017 microsecond (500 feet) intervals.
(b) Division by 6 gives pips at 6.1 microseconds, corresponding to 1000 yards range. Further division by 10 gives pips at 61 microsecond intervals (10,000 yards).
(c) A third division process gives us a 20 microsecond pulse at a repetition frequency of 1170 cycles by dividing by 14 or 606 cycles by dividing by 27.
(d) Presets are provided by means of which the repetition frequencies can be varied above or below these values.

The Divider Circuits.

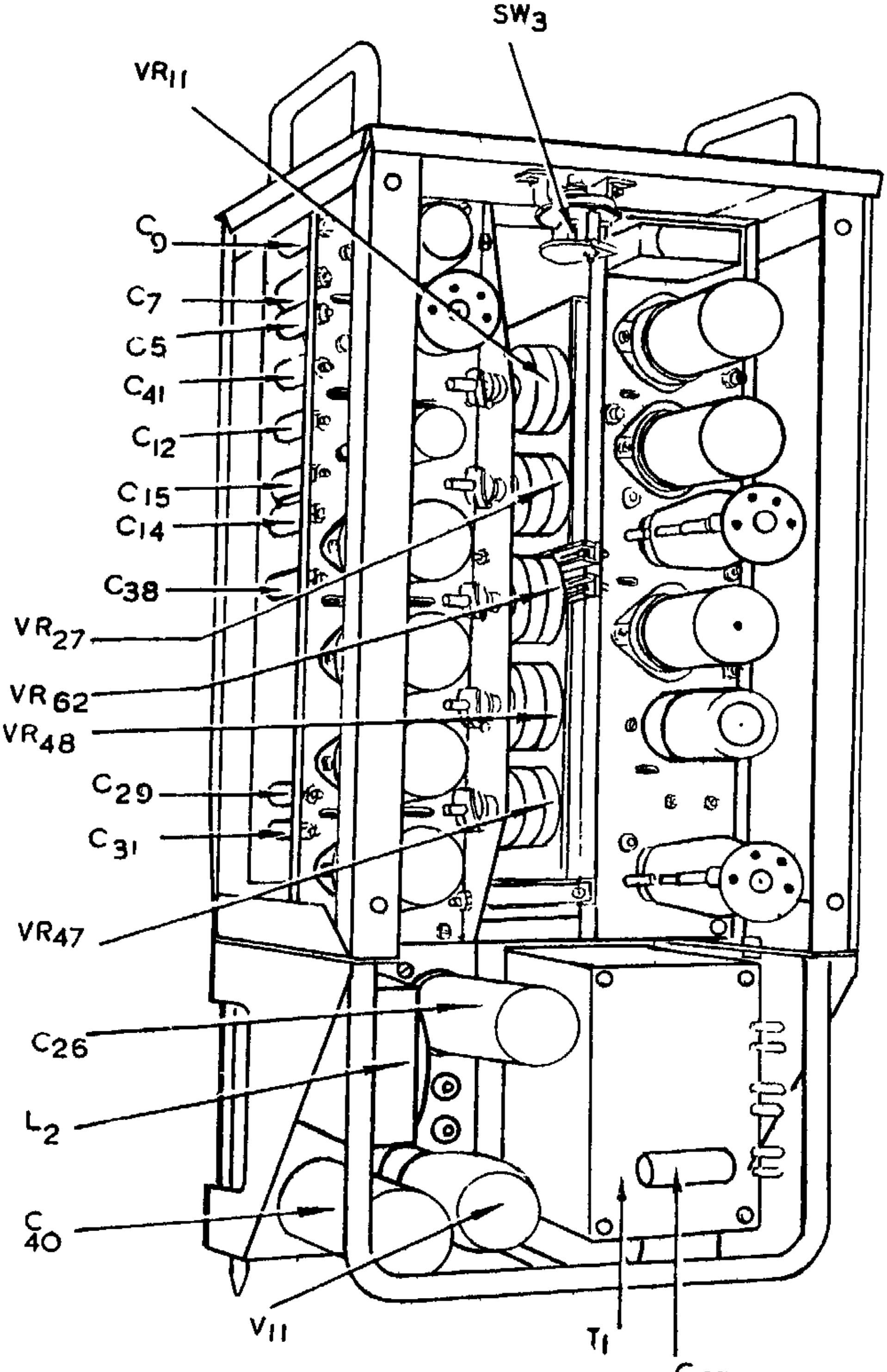
782. Division is obtained by the use of phantastron frequency divider stages. Fig.131 gives the circuit for the first divider stage together with waveforms. This may be taken as a standard example of frequency division by the use of a phantastron circuit.

Note the following points of the circuit:-

(a) Anode coupled to grid by C.6.
(b) Anode held at a potential determined by R.7, R.8 and the diode V.12A..
(c) The grid held at a potential determined by R14, 15 and 16. R.11 determines the potential to which the grid tries to rise but is unable to do so because of the diode V.12B
(d) The suppressor is held at a potential lower than that of the grid (and hence of the cathode) by the bleeder network R.14, 15 and 16.

783. The positive grid potential causes the cathode to emit fairly heavily and raises the cathode to around 24 volts. The suppressor potential is fixed at about 10 volts. Therefore with cathode at 24V. and suppressor at 10V., the flow of current to the anode is completely cut off and the screen is taking the entire cathode current. This drops the screen to about 60V. below the supply voltage.

784. A negative-going 983.2 Kc/s. pip is applied to the grid from V.1 via the diode V.12A and C.6. This drives down the grid sufficiently to reduce cathode current and bring down the cathode potential to about 9 volts. The suppressor bias has now been removed and current is switched to the anode whose potential will begin to fall. The anode would fall sharply if C.6



TOP OF CHASSIS

TEST SET TYPE 202

were not there. As it is the anode can only fall as fast as C.6 can discharge through R.12 and R.11 (Fig.131b). Actually, during this stage the grid rises slightly (Fig.131c). This means that electrons are leaking away from the grid plate of C6 slightly faster than they are flowing to the anode plate from V.2 anode. This rise in grid voltage serves to compensate for the falling anode voltage and the anode current remains fairly constant. This results in the anode falling almost linearly. Ultimately the anode voltage gets down to a point of equilibrium at which any further fall of anode volts would reduce anode current with a consequent rise of anode volts. Hence we say the anode "bottoms".

785. There is now no further flow of electrons to the anode plate of C.6. The same rate of leak away now represents a rise of grid voltage and the grid climbs rapidly. This grid rise increases cathode emission and cathode voltage rises with the grid voltage. The increased emission passes to the screen <u>not</u> to the anode.

786. When the cathode potential passes that to which the suppressor is tied suppressor bias again comes into action. Cathode current is then switched to the screen whose voltage falls and the anode current is quickly cut off by the suppressor.

787. The anode tries to return to its ctu-off level but must carry the grid with it through the coupling of C.6. The anode and grid therefore rise together until a further rise at the grid is stopped by V.12B coming into conduction. The cathode follows up with the grid and the screen falls accordingly, due to increased cathode emission.

788. The grid voltage is now steady. The cathode potential is fixed by the steady cathode current to the screen. The screen is now at its minimum level. The anode is rising exponentially as C.6 charges through R.10. Eventually it will reach a point at which the diode V.12A will conduct again and prevent any further rise.

789. Having reached this stable condition the next negative triggering pulse to come along will start the action over again.

790. By varying the potential to which the grid tries to rise, that is by varying R.11, we vary the rate at which electrons leak away from the grid side of C.6. This will vary the overall time for one cycle of the phantastron action. Hence by suitably adjusting R.11, we can arrange that the phantastron action is triggered off by every sixth 983.2 Kc/s. pip. Since these pips occur at intervals of 1.017 microseconds, the V.2 will complete its phantastron cycle in 6 x 1.017 or 6.1 microseconds.

791. The square wave from the screen thus has an overall time of 6.1 microseconds (6 x 1.017 microseconds). This waveform is passed to V.3 via C.8 and R.17 where it is differentiated. As indicated in Fig.131, the cathode waveform in a phantastron circuit is always in antiphase with the screen waveform.

792. In taking waveforms from the phantastron circuit it is better to use the cathode than any of the other electrodes, since the anode-grid capacity will be altered if test leads are put on anode or grid and the resulting waveform will not be a correct indication of the circuit action.

<u>Outline of Circuit.</u>

793. The test set 202 circuit is shown in fig.135. V.1 is a crystal controlled oscillator. The crystal frequency of 983.2 Kc/s. gives calibration pips at 1.017 microseconds (500 feet) intervals. The grid resistor R.1 is a high value so that the mean grid potential is well

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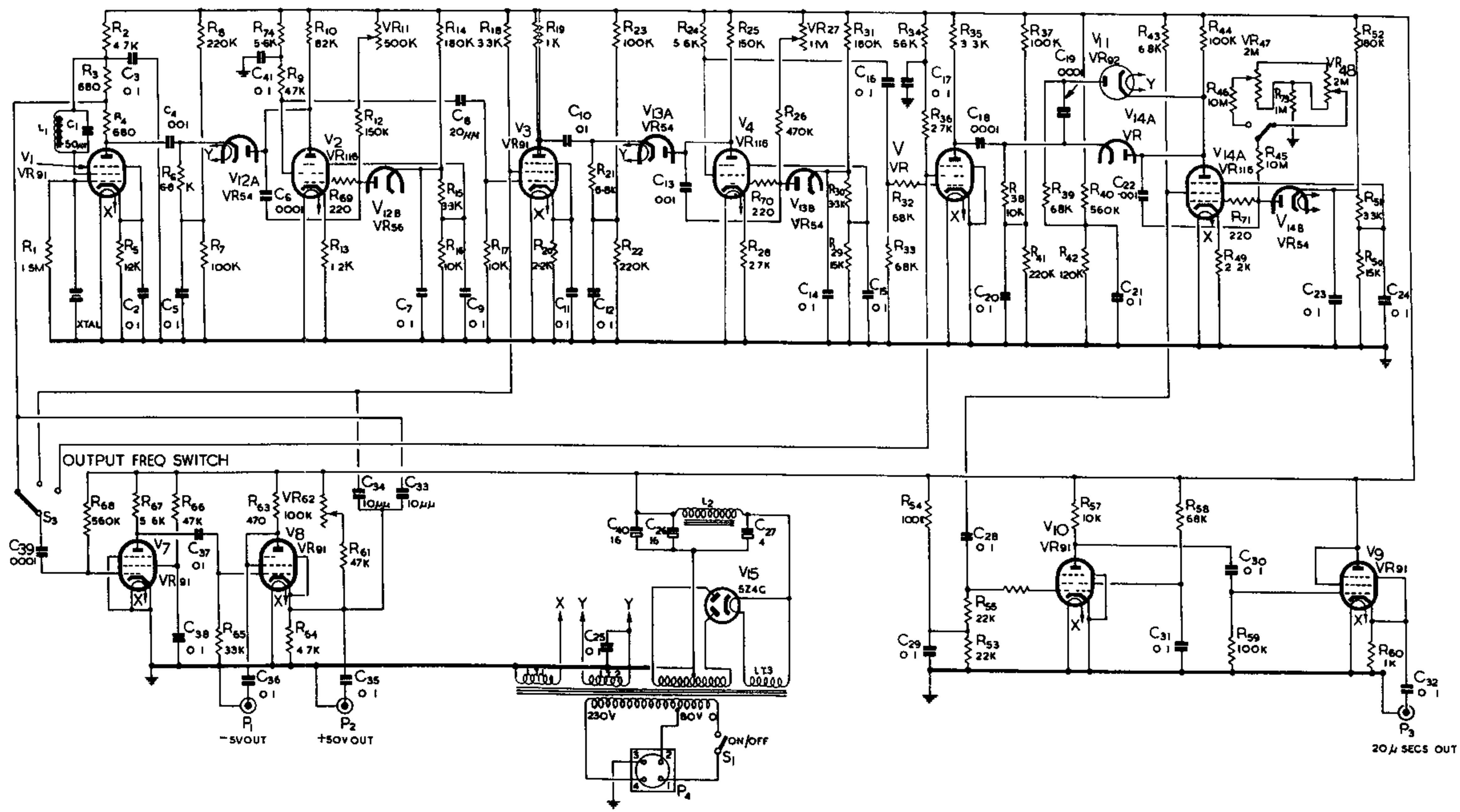


TEST SET TYPE 202 — CIRCUIT

FIG.135

FIG.135

beyond cut-off and only negative pips of voltage appear at the anode. These are used to trigger V.2.

794. V.2 action has already been described in paras. 782 to 791. The screen waveform of V.2 is differentiated by C.8 and R.17 (see Fig.135) and passed to V.3 grid. This valve is an amplifier biassed almost to cut-off so that only the positive pips of the differentiated waveform appear at the anode where they are negative going at 6.1 microsecond intervals.

795. These negative pips are used to trigger the second phantastron frequency divider, V.4. This stage divides by 10 and the overall time of each phantastron cycle is 61 microseconds. The preset for adjusting this stage is R.27. The output waveform from the screen consists of a positive portion 41 microseconds in length and a negative portion 20 microseconds in length.

796. V.5 amplifies, inverts and generally cleans up this square waveform from V.4 screen. The result is differentiated by C.18 and R.38 so that at V.14A cathode we have negative pips 61 microseconds apart with a positive pip 20 microseconds before each negative pip.

797. V.6 is the third phantastron frequency divider. V.11 (VR92) has its anode 200 volts below its cathode so that it is non-conducting. The phantastron action is started by a negative pip and V.6 anode begins to fall. When it has fallen almost 200 volts, a positive-going pip will be passed by V.11 to V.6 anode. This stops the fall of anode voltage and starts the flyback portion of the phantastron cycle. The flyback is rapid (C.22 charging through R.44) and the circuit has reached its stable state before the next negative pip arrives 20 microseconds later. This gives a 20 microsecond negative pulse at V.6 screen.

798. The repetition frequency of the 20 microsecond pulse depends upon the potential to which the grid leak of V.6 is returned. When the switch marked "Rep. Freq". is set to 600 c/s., the grid of V.6 is returned via R.45 and R.46 to the potential of the slider of R.47. If we examine the waveform at V.6 cathode or the output waveform as described in paragraph 801 (c)(1), we can observe the division ratio of this valve. If R.47 is so adjusted that division is by 27, then a 20 microsecond pulse occurs at the screen every 27 x 61 microseconds which is equivalent to a frequency of 606 c/s. If we vary the slider of R.47 the repetition frequency of the 20 microsecond pulse can be varied above or below 606 c/s. When the switch marked "Rep.Freq." is set to 1200 c/s. V.6 grid is returned via R.45 to the slider potential of R.48. If R.48 is adjusted so that V.6 is dividing by 14 the screen waveform will be a 20 microsecond negative pulse at a frequency of 1170 c/s. Moving the slider of R.48 will vary the repetition frequency above or below 1170 c/s.

799. The screen waveform from V.6 is squared up and inverted by V.10 and passed via the cathode follower (V.9) to the 20 microsecond output plug at an output impedance of about 200 ohms.

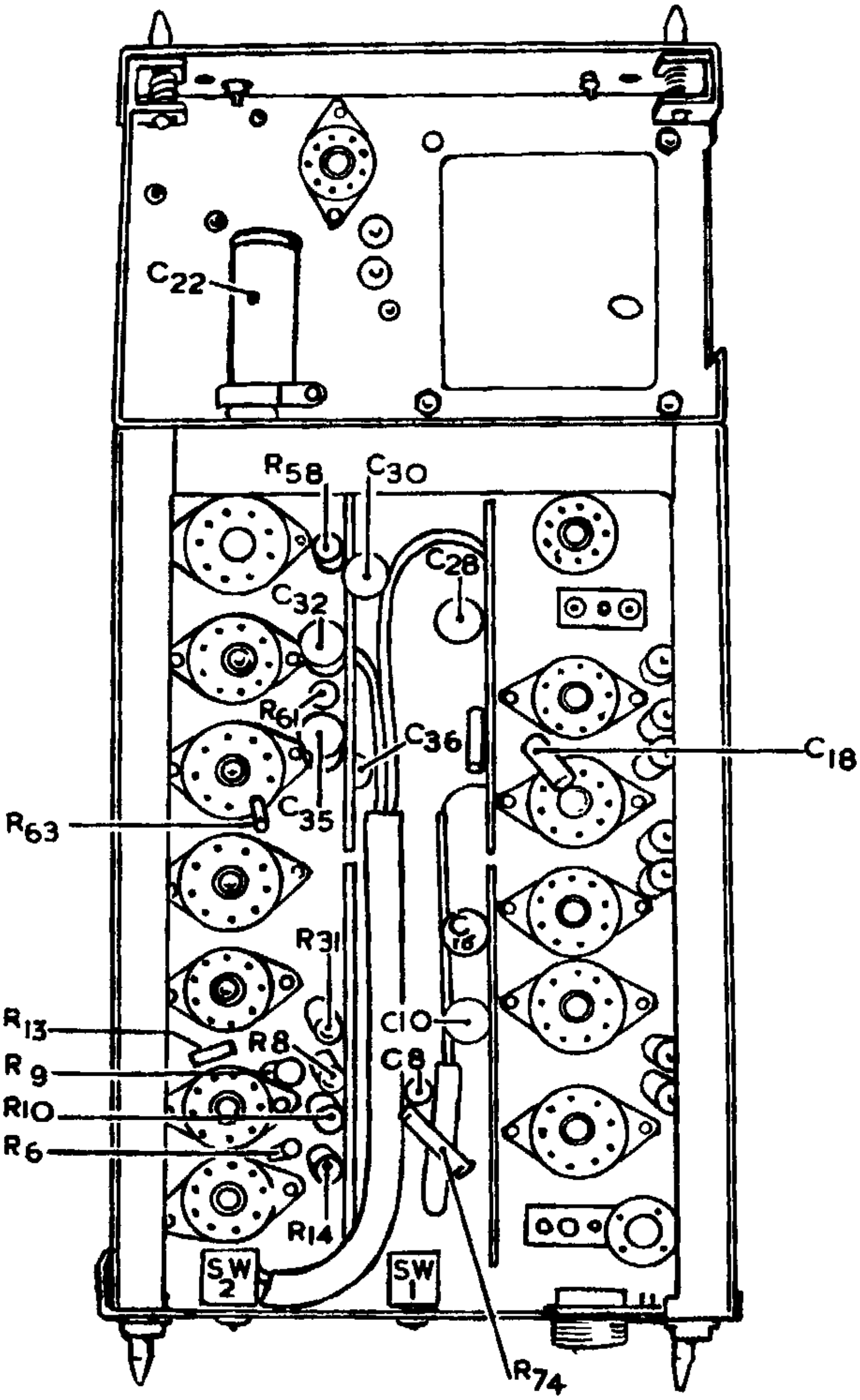
800. V.7 is an amplifier for the calibration pips which are passed to the cathode follower, V.8. V.8 has a variable bias control, R.62 (marked "Amplitude" on the potentiometer rack) giving variations in amplitude of the calibration pips. The negative output is taken from the anode which has a low value resistance load (R.63). The positive output is taken from the cathode.

<u>To Check Dividers.</u>

801. Trigger monitor type 28 with the 20 microsecond pulse from test set 202. Connect the 50V. positive output from test set 202 to the input plug of the monitor.

(a) <u>Division by 6.</u>

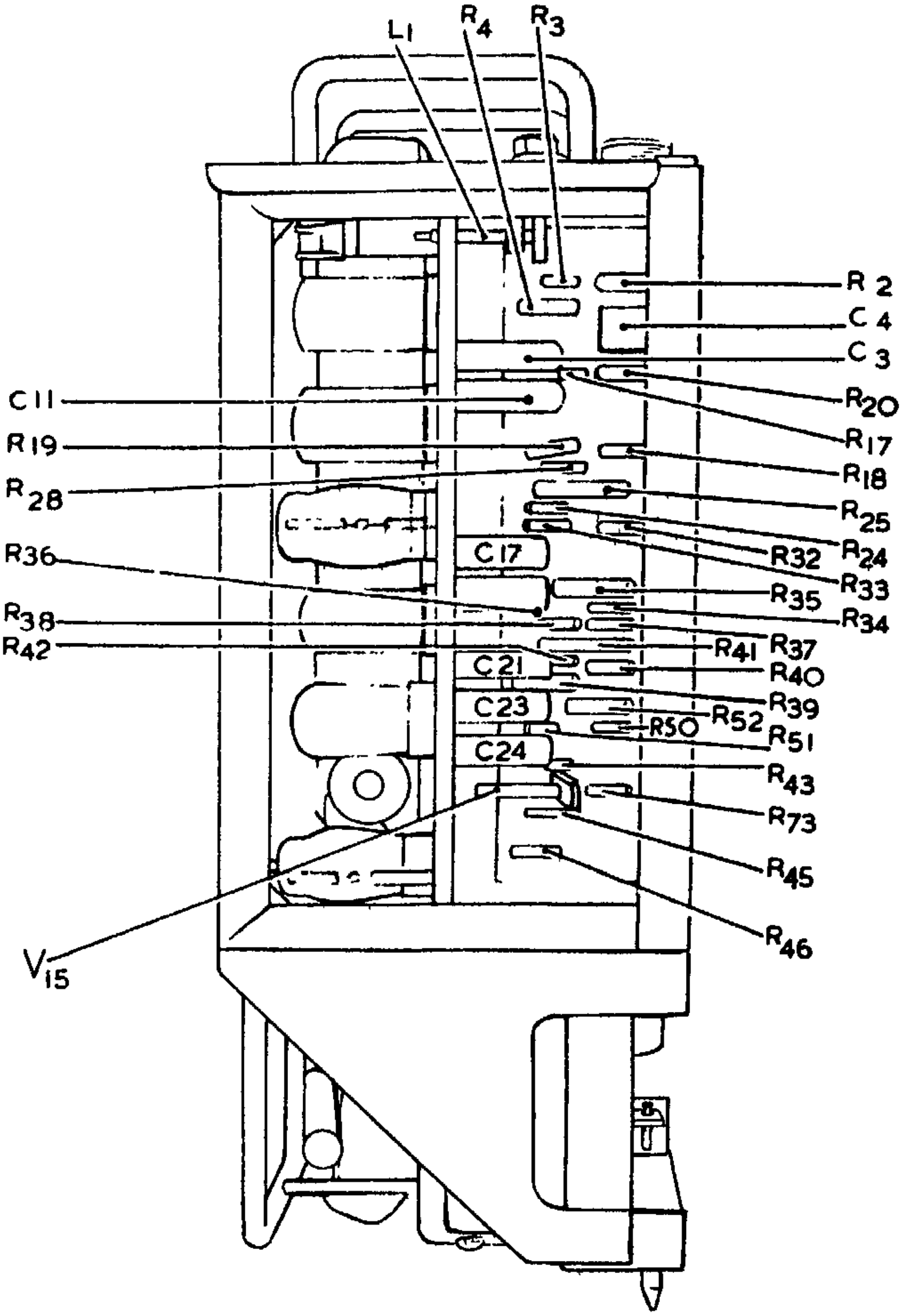
Set calibration interval switch to 500 feet. Set monitor T/B to 100 and Amplification to X20. The level of every sixth calibration pip should be lower than the others. If not, adjust R.11 (marked "X6") on the potentiometer rack of T.S.202.



UNDERNEATH CHASSIS

TEST SET TYPE 202

FIG.133A



LEFT SIDE OF CHASSIS

TEST SET TYPE 202

FIG.134

FIG.134

(b) Division by 10.

Switch to 10,000 yard calibrations. Set monitor T/B to 100 and amplification to X5. The output should show large pips at 10,000 yard intervals with smaller intermediate pips at 1,000 yard intervals, and still smaller pips at 500 feet intervals. Nine 1,000 yard pips should appear between each pair of 10,000 yard pips. If not, adjust R.27 (marked "X10") on potentiometer rack.

Note:- This breakthrough of intermediate calibrations is due to the fact that C.34 and C.33 feed a small fraction of the 500 feet and 1,000 yards calibration pip voltages on to the positive output circuit.

(c) 20 microsecond pulse repetition frequency.

(i) 600 c/s.

Calibration Interval Switch to 10,000 yards.
Rep. Freq. Switch to 600 c/s.
Monitor 28 T/B set to Freq.
Amplification set to Direct.
Monitor Time Base Start turned fully clockwise.

27 calibration pips should appear on the time base. Adjustment is by R.47 (marked "600 c/s."). The actual repetition frequency when dividing by 27 is 606 c/s.

(ii) 1200 c/s.

As above with Rep.Freq. switch set to 1200 c/s. 14 calibration pips should appear on the time base. Adjustment is by R.48 (marked "1200 c/s."). The actual repetition frequency when dividing by 14 is 1170 c/s.

Calibration of Monitor 28.

802. The monitor 28 time base is not perfectly linear and the X-shift calibrations are therefore only approximate. The monitor time base may be calibrated from the test set 202. If the monitor is directly calibrated by this means care must be taken to see that the position of the time base start remains fixed. Further, it is necessary to have one fixed position for the X-shift since any movement of the time base will result in incorrect calibration owing to the non-linear time base.

The H.2.S. Height and Range Markers.

803. The H.2.S. markers are pulses produced in the H.2.S. equipment at variable periods of time after the back edge of the 20 microsecond pulse. The H.2.S. transmitter firing is also controlled by this 20 microsecond pulse, but owing to a delay in the spark gap, the commencement of the transmitter pulse does not occur until nearly 2 microseconds after the end of the 20 microsecond pulse. Now the commencement of the transmitter pulse represents zero time and hence zero range and is the instant at which we start to measure the time interval for the production of our height marker for any height. For a height of 20,000 feet, the height marker must be produced at a time after the transmitter pulse equivalent to the echo time from a reflector at 20,000 feet distance. With the monitor 28 we are able to vary the start of the time base by a variable time up to about 5 microseconds depending upon the setting of the Time Base Start control. Therefore, if we put the transmitter breakthrough pulse on the monitor we can on most monitors, adjust the start of the monitor time base to correspond with the beginning of the transmitter pulse. The start of the monitor time base then represents zero time. If we now put the test set 202 calibrations on to the monitor we shall have a means of measuring time from zero time and we can ensure that the height and range markers are produced at the correct instant of time for any particular setting of the height and range controls.

Use of T.S.202 for setting up H.2.S. Markers.

804. (a) Check T.S.202 dividers as per para.801.

(b) Trigger the monitor 28 from the modulator 64 violet Pye Plug.
(c) Synchronise the modulator 64 with the T.S.202 to run at as nearly as possible the same p.r.f. as when triggered by the Tx-timing pulse. This can be done as follows:- With the modulator 64 triggered by the Tx-timing pulse and the monitor 28 triggered from the violet Pye on the modulator 64, mark the beginning and end of the T.B. sweep on the monitor screen when the T.B. switch is in the "Freq." position. Now trigger the modulator 64 from the T.S.202 and adjust the 600 c/s preset to give as nearly as possible the same length sweep on the monitor as before.
(d) T.B. switch to 10 and input switch to "Direct".
(e) Connect H.2.S. red Pye plug to monitor input through a 1K resistor. Adjust suppression control to set between 2 notches to remove all suppression. The monitor display will then show the Tx pulse breakthrough and the range marker. Turn the gain control to minimum. On some receivers it may be difficult to set the suppression control to allow the transmitter to break through although this can usually be arranged.
(f) Now adjust the T.B. start control to bring the leading edge of the Tx pulse to the beginning of the T.B. The start of the T.B. now represents zero time and the T.B. start control must be left set in this position. If the T.B. sweep shows a tendency to cramp badly at the beginning it may be possible to clear the fault by replacing C.15 in V.3 cathode circuit.

805. Now connect the T.S.202 and the monitor as follows:-

(a) 5 volt negative output from 202 to monitor input through a 1K resistor.
(b) Set calibration interval switch to 1,000 yards. Set Rep. Freq. switch to 600 c/s.
(c) Using the 10 microsecond time base identify the first 1,000 yard pip.
(d) Switch to the 500 feet (1 microsecond) calibrations and count the time in microseconds from the commencement of the time base to the first 1,000 yard marker. The first 1,000 yard marker occurs 6.1 microseconds after the end of the 20 m microsecond pulse. But the start of the time base has been delayed. This delay is the amount that we delayed the time base start to correspond with the delay in the spark gap and the I.F. strip. There is also a small delay in starting the monitor time base owing to the fact that the back edge of the 20 microsecond pulse is not straight. This latter delay may vary from one monitor to another. The time from the start of the time base to the first 1,000 yard marker will probably be about 2 microseconds.
(e) Having found the time from the start of the time base to the first 1,000 yard pip, switch to the 100 microsecond time base and set the calibration interval switch to 1,000 yards. We now know the time from the start of the time base to the first 1,000 yard pip represents 6.1 microseconds, so that now our monitor is set to measure from zero time.

Checking of Height Marker Setting.

806. With the T.S.202 and monitor 28 still connected as in para.805 put the height marker on the monitor. To do this connect the white Pye plug on receiver-timing unit to the Monitor input through a 1K resistor. Press H.2.S. "L.T. ON". The monitor should now show the height marker together with 1,000 yard pips.

807. If the first 1,000 yard pip represents 2 microseconds from zero time when the first 1,000 yard pip represents 1,000 feet (500 feet per microsecond). If it were 1.5 microseconds, it would be 750 feet. Each subsequent 1,000 yard marker will represent an increase of 3000 ft. and our second 1,000 yard marker will be somewhere about 4,000 feet. Set the height drum to whatever figure corresponds with this second 1,000 yard marker. It is not advisable to use the first 1,000 yard marker owing to inaccuracy of the height marker

below 2,000 feet. If necessary, adjust the height zero so that the height marker coincides with the second 1,000 yard pip. Move the height marker along by 1,000 yard steps, checking that the height drum reading increases by 3,000 feet steps. If the tracking is incorrect it may be advisable to adjust the height zero at somewhere around 20,000 feet since we are concerned more with accuracy at operational heights than at the bottom of the scale.

Checking of Range Marker.

808. (a) Leave the connections as in the previous paragraph.
(b) Set height to 20,000 feet. Adjust range zero so that the range marker coincides with height marker when the range drum is at zero. The H.2.S. range switch should, of course, be on 10/10 range.
(c) To check tracking of range marker set the height controls to the 100 yard marker nearest the 20,000 foot point and advance range marker by turning the range drum so that the range marker occurs 1,000 yards after the height marker. The range indicated on the range drum should be 1.9 nautical or 2.2 statute miles, according to which scale is in use.
(d) Continue advancing the range marker by 1,000 yard steps, checking the range with the figures given in the table below.

Height	Range Marker from Height Marker	Range in Miles	
		Nautical	Statute
20,000 feet	-	-	-
	1,000 yds.	1.9	2.2
	2,000	2.7	3.2
	3,000	3.5	4.0
	4,000	4.1	4.75
	5,000	4.7	5.5
	6,000	5.3	6.1
	7,000	5.9	6.8
	8,000	6.5	7.4
	9,000	7.0	8.0
	10,000	7.6	8.7

(e) It is not necessary to check all these points; a few of the more convenient ones may be selected.

Note:- The figures given in the table above are correct to .1 of a mile. Since it is not possible, under working conditions, to read the range scale to this degree of accuracy, it is not to be expected that these exact figures will be obtained. Greater accuracy of range is needed at ranges between 4 and 7 miles, and it may be necessary to adjust the range zero at some point within these two ranges by setting the range drum to one of the values given in the calibration table, and adjusting the range zero to obtain coincidence with the corresponding calibration pip. This difficulty will only arise if tracking cannot be obtained over the whole scale. The differences introduced by setting the height control to the 1,000 yd. marker nearest the 20,000 foot point instead of 20,000 foot will be less than the possible accuracy of reading on the range drum.

809. An alternative method of calibrating the markers may be used if the radar workshop is fortunate enough to receive an echo of definitely known range, providing this is not less than two miles. The height drum is set to the range of the echo and the height zero is adjusted to give coincidence between the height marker and the known echo on the height tube. The range control is then set to zero and the range zero is adjusted for coincidence between range

and height markers. The 10/10 position of the range switch is, of course, used for this setting up. Tracking can then be checked on the test set 202. The Time Base Start setting in this case is not important since the zeros have been set up from the known signal. The height and range tracking can be checked by 1,000 yard steps as already described. Since the calibration pips from the test set 202 are known intervals of time and hence represent known intervals of range, it can be seen that the test set 202 really provides us with signals of known range by means of which we can accurately check our height and range markers.

810. With some monitors type 28 it may be found that using the timebase start control to bring the leading edge of the pulse from the voltage monitor point on the modulator 64 to the beginning of the scan, results in cramping of the pulse due to a non-linear scan. In a number of cases it has been possible to clear this trouble by replacing C15. If difficulty is experienced in determining when the leading edge of the pulse coincides with the beginning of the scan, or if the range of adjustment on the T.B. start control is not sufficient to bring the Transmitter pulse to the beginning of the scan, it may be preferable to proceed as follows:-

(a) Get the Transmitter pulse well to the left of the timebase with the X-shift and put a mark on the perspex screen to coincide with the leading edge of the pulse.
(b) Proceed as in para.805(a), (b) and (c) and put a mark on the perspex screen to coincide with the leading edge of the first 1,000 yard marker.
(c) Switch to the 500 feet (1 microsecond) calibrations and determine the number of microseconds between the two marks on the perspex. This gives the time between zero time and the first 1,000 yard marker.
(d) Proceed as before when the time from zero time to the first 1,000 yard marker has been found.

811. A method of calibrating the monitor 28 for aircraft adjustment of the height zero for accurate height indications at 20,000' and range zero adjustment for accurate range indication at 4 miles, is outlined in chap.12, para.950.

TEST SET TYPE 83 (10SB/120)

Use.

812. This test set is a thermocouple unit which is used in conjunction with a unipivot thermal millivoltmeter to measure the field strength of the magnetron output.

Operation.

813. (a) Set the thermocouple on its stand about 12 feet away from the H.2.S. aerial. Ensure that the dipole elements of the thermocouple are in the same horizontal plane as the mouth of the scanner waveguide and that there is no obstruction between the H.2.S. aerial and the test set.
(b) Place the unipivot meter on the bench near the H.2.S. transmitter unit. Connect the lead from the thermocouple to the meter.
(c) Switch on H.2.S. and adjust the scanner mirror for maximum meter reading.
(d) Adjust the R.F. output adjustments on the transmitter unit for maximum meter reading.

Limitations.

814. It must be remembered that the reading obtained is only an indication of how much R.F. energy is being radiated. There is nothing to indicate whether the power is on a single frequency, mixture of frequencies, or jumping between different frequencies. A high indication on the meter is not necessarily an indication of a good magnetron. Within this limitation the meter reading provides a means of comparing the output of the same transmitter unit at different times or with different components, and of comparing the outputs of different transmitter units.

TEST SET 85.

815. This test set has largely replaced test set 83. The principle of its operation and the method of use are similar. The meter used is of a plug-in type. It may be plugged in at the rear of the thermocouple or used on a lead in the same way as the unipivot.

The Signal Generator Type 47 (10SB/143)

Uses.

816. The signal generator type 47 is designed to provide an R.F. output at wavelengths between 9.0 and 9.2 cms. This output is available either as C.W. or M.C.W. consisting of bursts of R.F. of about 500 microseconds duration separated by equal quiescent periods. A calibrated output circuit is provided which can be used to compare the overall sensitivity of the H.2.S. receiver.

(a) The panel is shown in fig.136
(b) Layouts are shown in figs.136 and 137
(c) The circuit is shown in fig.138.

Power Supply.

817. 80V.A.C. is applied at the 2-pin plug on the panel and fed through an R.F. filter to the power transformer, T.2, and the heater transformer, T.1. A three-position power switch appears on the panel. The positions are labelled "OFF", "L.T." and "H.T." This is the switch, S.1, in the circuit diagram.

(a) In the "OFF" position, the input to both T.1 and T.2 is broken.
(b) In the "L.T." position the input to T1 is completed and the heater supply is developed for the rectifier, V.1, the modulator, V.2 and the klystron oscillator, V.3.
(c) In the "H.T." position, the input to T.2 is also completed and V.1 develops a -1.8KV. output for the klystron.

818. The -1.8V. E.H.T. output is smoothed by L.1, C.1 and C.2 and applied across the bleeder formed by R.4, R.5, R.6, R.7, R.8. The klystron electrodes are tapped in on this bleeder. Stabilisation is provided by the neons, V.3, V.4, V.5, V.6.

819. If no other test equipment requiring 80V. A.C. is being used the 80V. input can be taken from the 2-pin on the H.2.S. junction box. If it is desired to use additional test gear requiring an 80V. input some form of junction box like the type 80 (10AB/1850) must be used.

The Klystron Oscillator Controls.

820. (a) V.7 is a CV.67 reflector klystron. The panel control labelled "Reflector" is the potentiometer, R.8, which serves to vary the potential of the reflector relative to the earthed rhumbatron to obtain the required feedback to get oscillation.
(b) The panel control labelled "Grid" is the potentiometer, R.4, which is used to vary the bias on the klystron. This provides additional control over the klystron feedback as it serves to vary the intensity of the electron stream. By suitably adjusting both the "Grid" and "Reflector" controls stable oscillation can be obtained over the entire range from 9.0 - 9.2 cms.

821. The fine tuning plunger is driven by means of the panel knob labelled "Tuning". The wavelength of the oscillations is given approximately by the calibrated tuning dial.

822. The R.F. output is taken from the resonant cavity by means of the usual coupling loop. This loop forms part of the circuit of a bolometer lamp whose filament glows with a brightness that depends on the strength of the R.F. output. The coupling of the output loop is variable by means of the output knob which appears at the centre of the wavelength dial.

The Calibrated Output Circuit.

823. The output taken from the cavity via the bolometer bulb is radiated into a piston attenuator which feeds the output plug. The output at the plug will depend on the length of the attenuator. The knob on the panel which

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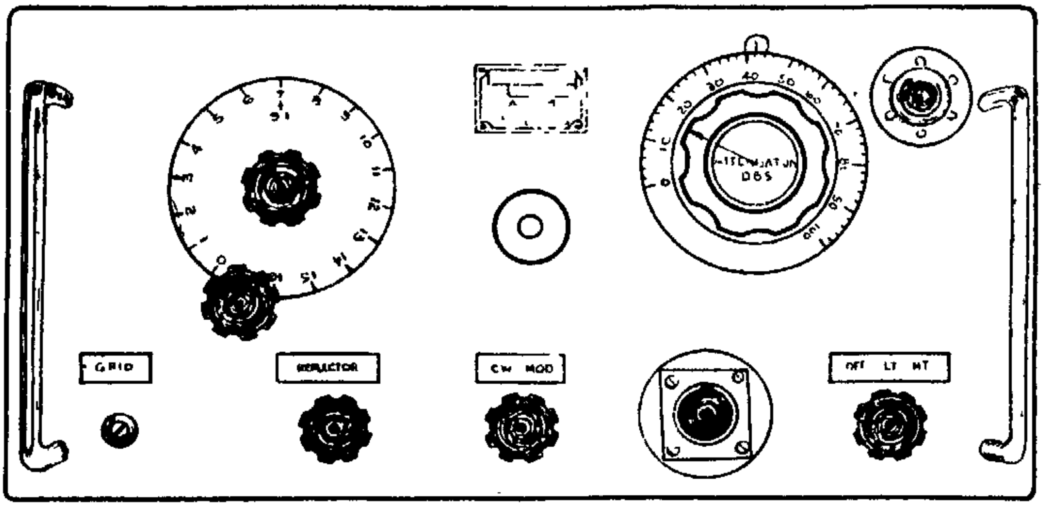
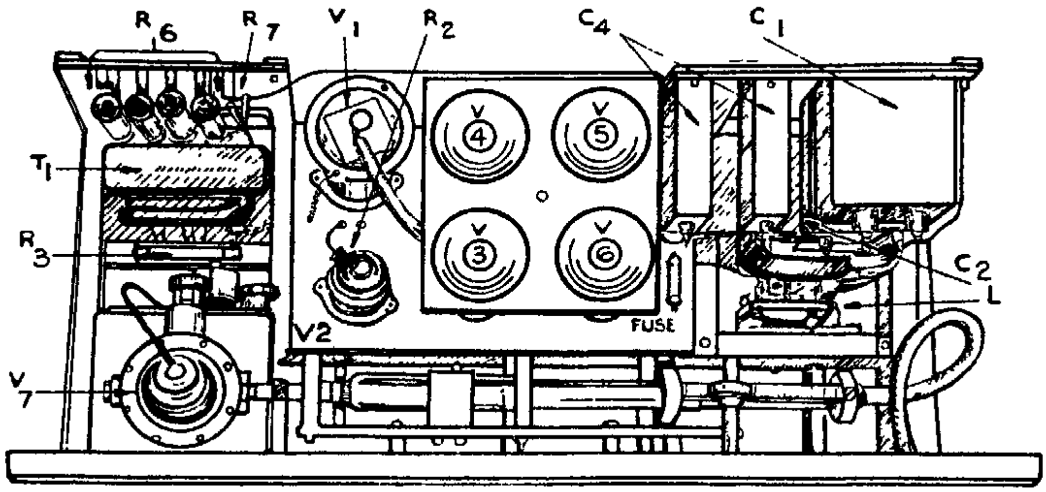
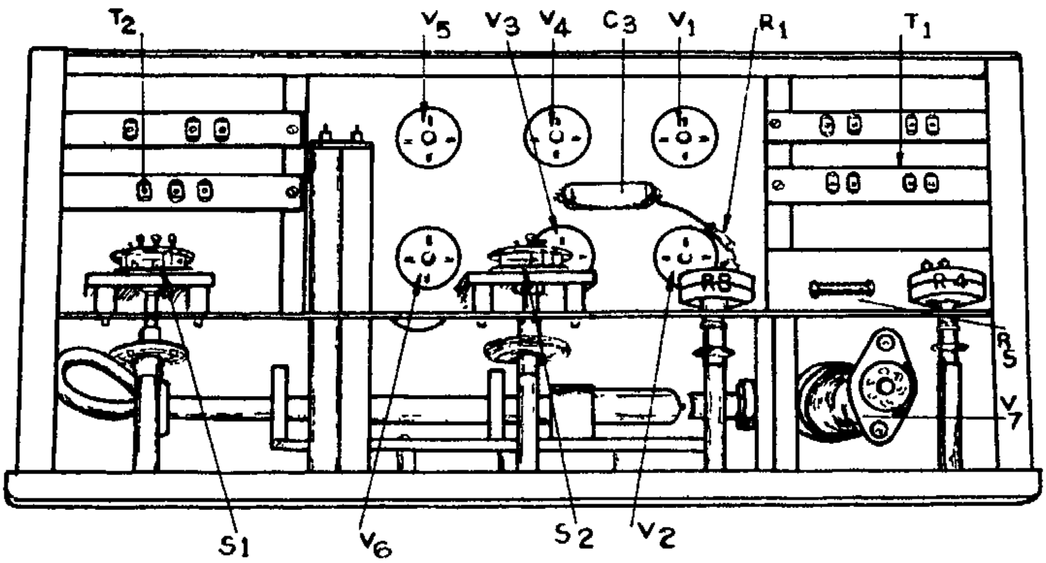


FRONT PANEL



TOP VIEW

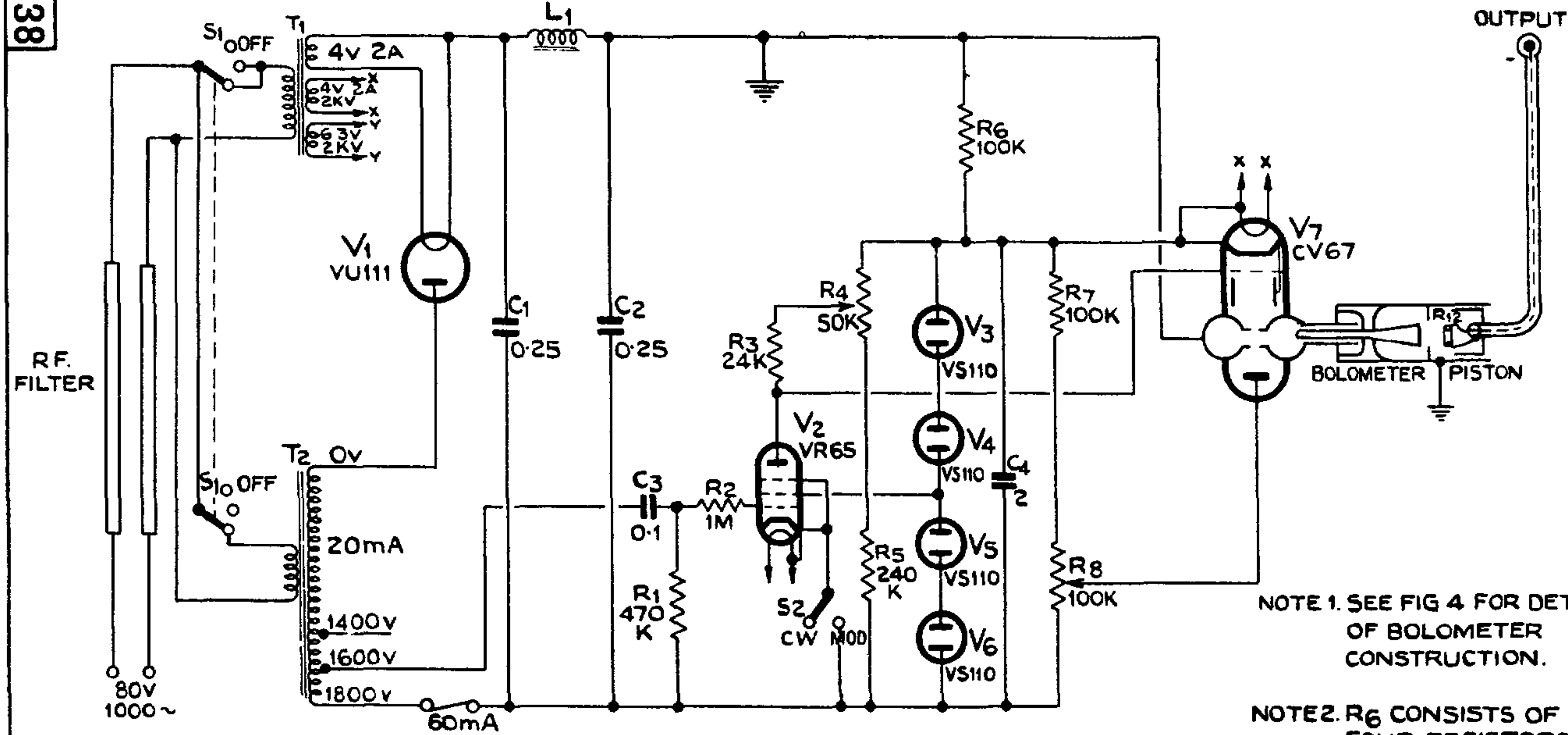


UNDERSIDE VIEW

SIGNAL GENERATOR TYPE 47 (DETAILS)

FIG. 136 FIG. 136

FIG. 138



SIGNAL GENERATOR TYPE 47, CIRCUIT

NOTE 1. SEE FIG 4 FOR DETAILS OF BOLOMETER CONSTRUCTION.

NOTE 2. R_6 CONSISTS OF FOUR RESISTORS EACH 25K, 10W IN SERIES.

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FIG. 138

tracks over a scale graduated in decibels varies the length of this attenuator.

824. Obviously, what absolute output is represented by any specific attenuator setting depends on the input to the attenuator. This input, in turn, depends on the setting of the coupling loop. How much power is being taken from the cavity by the coupling loop is indicated by the glow of the bolometer filament. This filament is visible through a small aperture in the front panel. The coupling is normally set so that the filament just glows and the output is then regarded as standard. If the signal generator is connected to a 75 ohm dummy load and the bolometer glow set to the point of just fading out the 0 db. position of the attenuator dial will give an output of approximately 60 millivolts. The attenuator reads in "decibels down". That is 0 db. means zero attenuation.

The Modulation Circuit.

825. The cathode of the modulator valve is taken by means of switch to the -1800V. line and the grid is taken via the stopper, R.2, and the blocking condenser, C.3, to a tap 200V. up on the secondary of T.2. If the cathode switch is closed V.2 operates as a squarer stage. The 200V. 1000 c/s. input swings the grid between saturation and cut-off to provide a 1000 c/s. square wave at the anode.

826. The cathode switch appears as a knob with two positions labelled "MOD." and "C.W." In the C.W. position V.2 cathode is floating and the valve is inoperative. The anode potential is then the same as the potential of R.4 slider. V.3 grid is then at this same slider potential. The klystron controls will be set up with S.2 in the C.W. position. The setting of R.4 will then fix V.3 grid at a suitable potential relative to the cathode for stable oscillations. When S.2. is set to "MOD." V.2 anode will be up at R.4 slider potential for the 500 microsecond cut-off periods and about 250V. below this value during the 500 microsecond conducting periods. These 250V. drops will cut the klystron off. The output will then consist of 500 microsecond bursts of R.F. separated by 500 microsecond quiescent periods.

827. It follows then that when S.1 is set to "MOD." the bolometer current is only flowing half the time. Hence, for equal glow, the input to the piston attenuator must be twice as large. To have the same peak output on the aerial the attenuation should therefore be doubled when switching from C.W. to MOD. with the coupling set for the same glow. But doubling the attenuation means the attenuation figure in decibels should be increased by 3. For example if the dial reads an attenuation of 20 db. in the C.W. position, the same peak voltage is applied to the aerial for an attenuation setting of 23 db. when the output switch is set for "MOD." and the coupling is adjusted for the same glow.

Setting-up the Signal Generator Controls.

828. (a) Connect the 80V. 1000 c/s input from the junction box to the S.G.47 and switch on L.T.
(b) Set the tuning control to 9.1 cms.
(c) Adjust the coupling to a midway position.
(d) Set the reflector voltage control to a midway position.
(e) Set the grid voltage control fully anticlockwise.
(f) Set the attenuator control at zero.

(g) Switch on H.T.
(h) Advance the grid voltage control clockwise until the bolometer bulb glows.
(i) Check the setting of the reflector voltage control by noting that anticlockwise rotation results in disappearance of the glow (indicating cessation of oscillation) and that further clockwise rotation results in reappearance of the glow.

FIG. 137

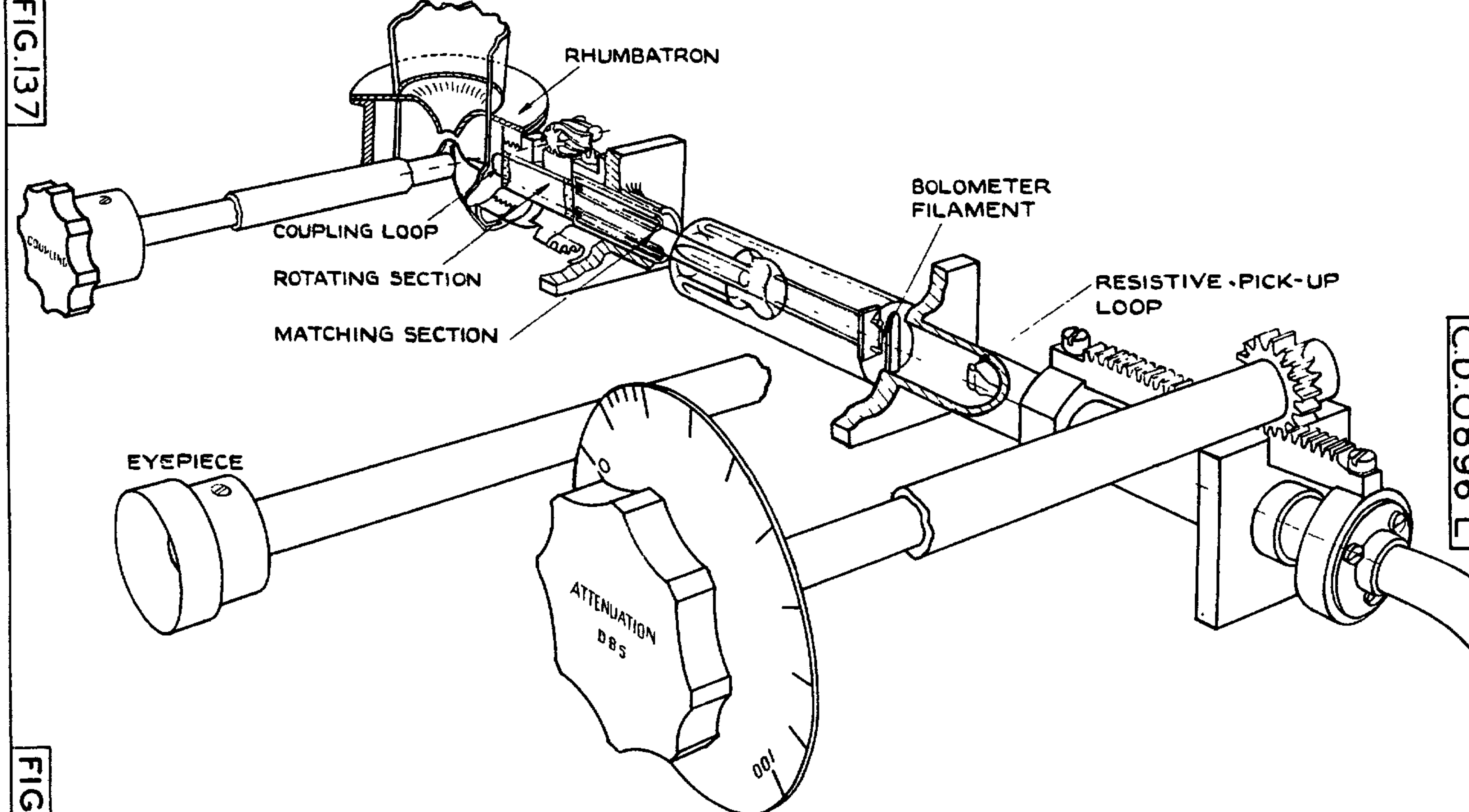

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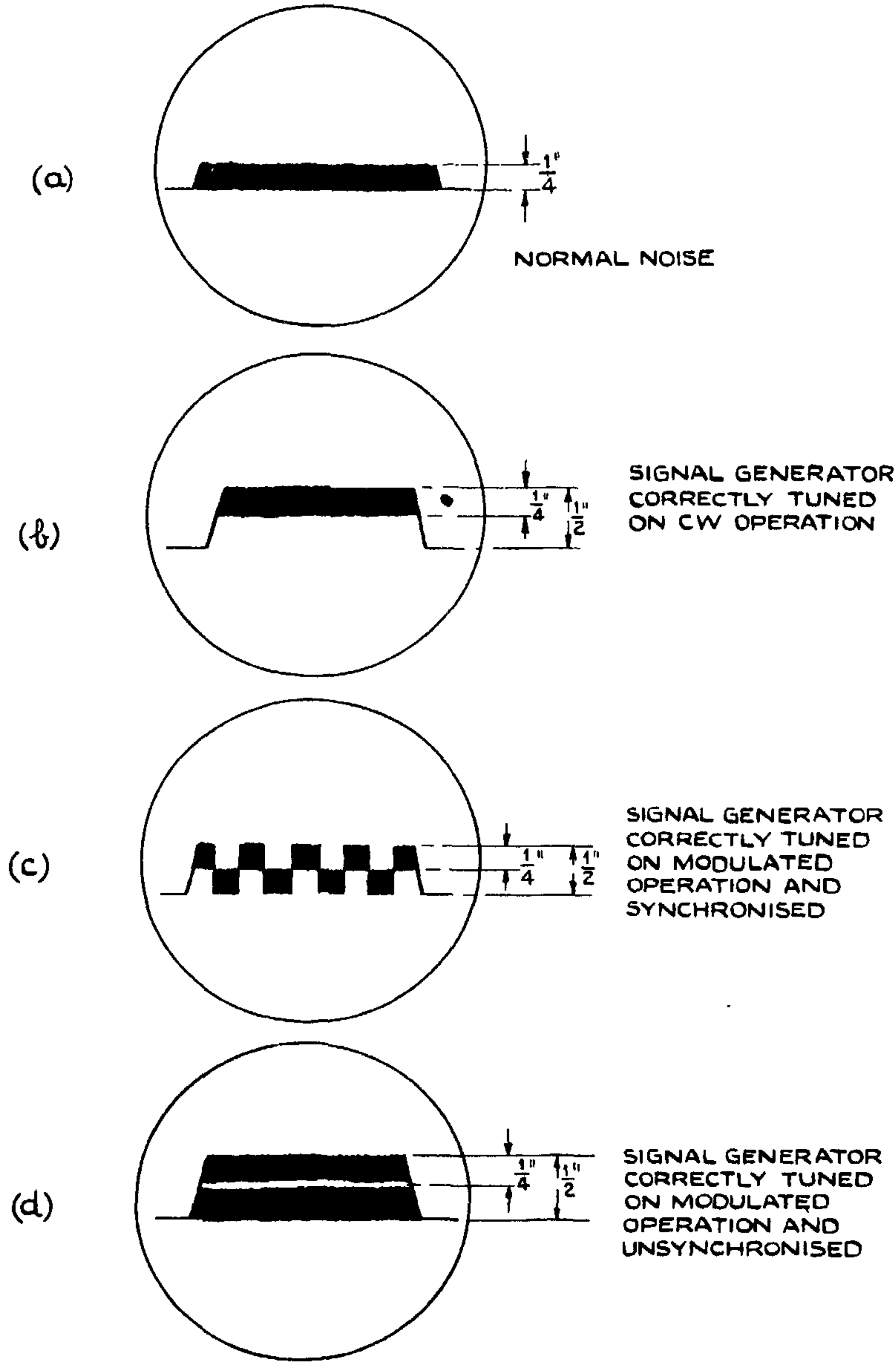
FIG. 137

SIGNAL GENERATOR TYPE 47. BOLOMETER CONSTRUCTION

C.D.0896 L



SIGNAL/NOISE PATTERNS

FIG.139

FIG.139

(j) Continue the clockwise rotation of the reflector voltage control. The glow will normally rise slowly at first, then peak sharply, and with further rotation will fall slowly. If the control is set just past the peak on the slowly falling side stable oscillation will be obtained.

(k) Attach the mirror and aerial assembly to the output plug of the S.G. 47 and line up the H.2.S. scanner to pick up the radiation.

(l) The S.C. 47 output may be piped into the transmitter unit by using the uniradio 21 feeder, connector Type 1179 (10H/2807) and the Adaptor Unit Type 76 (10AB/6005).

Comparison of Overall Sensitivity of Sets.

Principle.

829 The sensitivity of sets can be compared by determining the comparative strength of signal input required to give the same signal-to-noise ratio for a given noise amplitude. For example, if we adjust the gain of the receiver to show ¼" of noise on the monitor 28, and then apply an S.G. 47 signal of such a strength as to give a signal + noise amplitude of ½", the signal output must actually have an amplitude of ¼". The signal-to-noise ratio is then 1:1. From the attenuator dial a reading can be obtained corresponding to the output necessary to give a 1:1 signal-to-noise ratio in the receiver output from a good set, or several good sets. In this way a standard signal input figure can be obtained. Sets suspected of low sensitivity can be checked by comparing the attenuator reading required to give the same signal-to-noise ratio. As the required attenuator reading falls, the sensitivity of the set under test is falling since a lower attenuator setting means a higher input. Obviously, any comparative tests require operation with the same glow value on the signal generator and the gain setting of the receiver sufficiently low to prevent saturation.

Method.

830. (a) Apply the H.2.S. receiver output with the transmitter running to the monitor 28.

(b) Turn the gain up to about ½ maximum for a noise level of about ¼"

(c) Switch on the S.G.47, set up as in para.828 and adjust the tuning until signals appear which lift the whole trace to saturation. Two tuning points should be found of which the shorter wavelength should be used. Use the C.W. setting of the output switch.

(d) Reduce coupling until the glow of the bolometer bulb is just disappearing.

(e) Turn the attenuator dial until the signal is not saturating the H.2.S. receiver and then check the S.G.47 tuning for maximum signal amplitude.

(f) Set output switch to "MOD."

(g) Readjust coupling until bolometer glow is just fading out. The receiver noise and the pulsed R.F. signal will now be seen.

(h) Adjust the attenuator until the top line of signal from the S.G. 47 sits on top of and is just distinct from the receiver noise. The signal + noise amplitude must now be double the receiver noise amplitude. The S.G.47 is now providing an output signal whose amplitude is such as to give a 1:1 signal to noise ratio. The attenuator dial reading gives the comparative sensitivity of the set.

(i) Other combinations of transmitter and receiver can be tested in the same way. By comparing the attenuation reading with the value obtained with a known good set or mean value from a group of known good sets the sensitivity can be assessed as good or poor.

831. The noise contributions of different transmitter units can be assessed by using them with the same known good receiver.

832. Different receivers can be compared by using them with the same known good transmitter units.

833. The head amplifier may be checked by taking measurements with the head amplifier in circuit and with the head amplifier by-passed by feeding straight from the mixer to the green Pye input on the receiver.

834. Crystals can be tested for sensitivity by using them in the same set and comparing the attenuator readings.

835. Tests on CV.43's indicate that if the attenuator reading goes up by more than 2 db. when the test is made with the transmitter switched off, or with the CV.43 probe lead disconnected, the CV.43 is faulty. Faulty CV.43's may, however, pass this test.

836. Tests on the scanner and high power feeder can be made by making a comparison when the scanner and/or the feeder is changed.

Limitations of the Signal Generator Type 47.

837. Since the S.G.47 provides an output in the 9.0 - 9.2 cm. band, it is not suitable for use with the H.2.S. Mark IIIA. It may, however, be used in the same general way with other cm. equipment operating in the 9 cm. band.

The Cambridge Fluxmeter.

Use.

838. The Cambridge Fluxmeter is a test instrument available in limited quantities for measuring the field strength of transmitter unit magnets. It consists of a centre-zero meter and a suitable search coil. Different coils are required for use with the H.2.S. Mark IIIA magnets than with the H.2.S. Mark IIC magnets.

Details.

839. Levelling screws on the legs and a spirit level on the dial are provided to permit accurate levelling of the meter. Mechanical control in the meter is negligible so the pointer does not tend to return to any definite zero but is inclined to stop at the point on the scale to which it is deflected when the search coil is passed through a magnetic field. If the pointer tends to drift the instrument is not accurately levelled.

840. A push-button is available on the meter to return the pointer to zero. It is not necessary to make this adjustment when using the meter. Readings can be computed by determining the total number of divisions through which the pointer deflects when the search coil is used.

841. The search coil is connected to the two meter terminals. Polarity is immaterial.

Measurements.

842. (a) Level the meter by adjusting the levelling screws until the spirit level bubble is centred.

(b) Tests should be made with the cover on the transmitter unit. It is, therefore, desirable to retain a cover with a hole cut in the side of sufficient size to permit insertion of the search coil between the jaws of the magnet.

(c) Insert the search coil between the jaws of the magnet and note the meter reading when the pointer comes to rest. Pull the coil out sharply and note the new reading when the pointer comes to rest. Determine the number of divisions through which the pointer is displaced.
(d) Repeat (c) with the coil turned upside down.
(e) Mean the two deflections.
(f) Convert mean deflection to gauss by means of data or formula supplied with the coil.

Values.

843. (a) It has been laid down that magnets for Mark IIC H.2.S. should not have a field strength of less than 1250 gauss if reliable operation is to be obtained. A magnet tested without the cover on should show a field strength of 80 - 100 gauss above this value.

(b) Magnets used in the TR.3555 series transmitter units should have a field strength of at least 3000 gauss when tested as above.

The Cable Tester Test Set 209.

Use.

844. This test set is provided to test:-

(a) Continuity of cable cores.
(b) Insulation of individual cores to earth.

Power Supply.

845. The set runs off either an 80V. 1000 cycle or 230 volt, 50 cycle supply. The 4-pin power input plug appears on the front panel. Pins 1 and 2 must be used when the 80V. supply is used and pins 1 and 4 when the 230 volt mains are used.

Details.

846. For insulation tests an assembly is provided which will take plugs of all the types employed. This assembly is connected to the test set by means of an 18-way cable.

847. A second similar assembly is provided which has no external connection. This is used in conjunction with the first for insulation tests.

Indications.

848. (a) Visual indications are given by means of a magic eye indicator on the test set panel.
(b) The eye opens if a continuity test is made on a cable which is open-circuited or shows a high D.C. resistance.
(c) The closes on insulation tests when the insulation falls below a value to which the test set is calibrated.

Controls.

(a) Details of the panel and circuit are shown in figs.140 and 141.
(b) The use of these controls in making tests is given below.

Measurement of Insulation to Earth.

850. To calibrate for insulation tests press in the push-button marked "CALIBRATION" and put the two-position switch to "MEGOHMS". Set the calibrated "MEGOHM CONTROL" to 15M. and adjust the preset labelled "CAL. 15M". until the magic eye just closes.

851. (a) Connect the cable to be tested to the appropriate point on the insulation test assembly. Leave the other end of the cable free.
(b) See that the two-position switch is set to "MEGOHMS" and that the "CALIBRATION" push-button is pulled out.
(c) For a multiple core cable see that the "SELECT PIN" switch is turned to the number of the core under test. For pins 1 - 9 the snap switch above the "SELECT PIN" switch must be to the left and for pins 10 - 18 it must be to the right.
(d) If the insulation on any core is low the magic eye indicator closes wholly or partially depending on how far the insulation is down. By adjusting the "MEGOHM CONTROL" until the magic eye is fully open the insulation value can be read off the calibrated dial.

Continuity Testing.

852. To calibrate for continuity tests, push the "CALIBRATION" button in and set the two-position switch to "OHMS". Set the calibrated "OHMS" control to 1 ohm and adjust the preset marked "Cal. 1 OHM" until the magic eye just closes.

853. (a) Connect one end of the cable to be tested to the insulation test assembly and the other end to the continuity test assembly which serves as a shorting bar.
(b) See that the "CALIBRATION" push-button is pulled out and the two-position switch set to "OHMS".
(c) Use the "SELECT PIN" switch and the snap switch above it as before. If, as the "SELECT PIN" switch is moved from one position to another, a core is encountered which has a high D.C. resistance or open-circuit the magic eye will open.
(d) The resistance can be measured by adjusting the calibrated "OHMS CONTROL" until the eye again closes then reading the value off the calibrated dial.

Limitations.

854. Without adaptation, the test set cannot be used for measuring inter-core insulation. If such a breakdown is suspected a megger must be used for testing.

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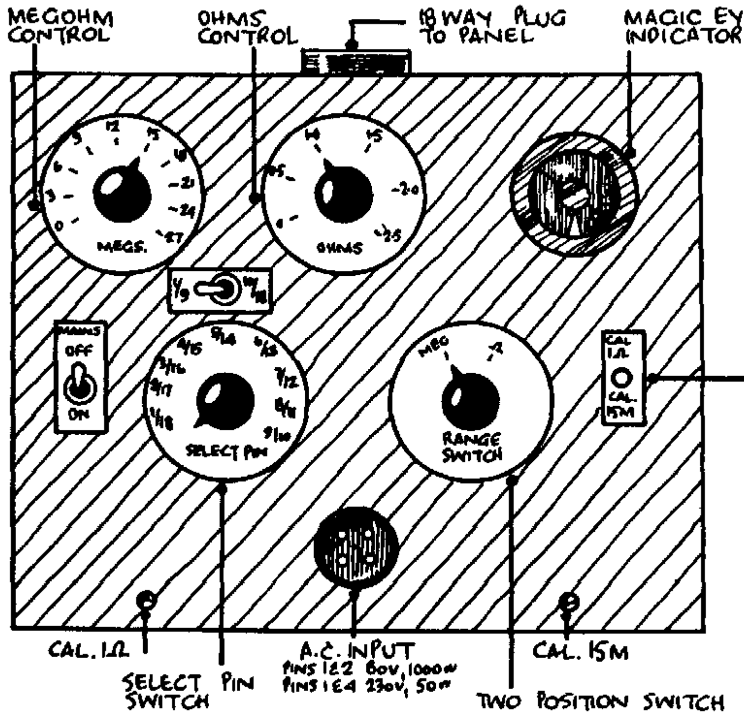
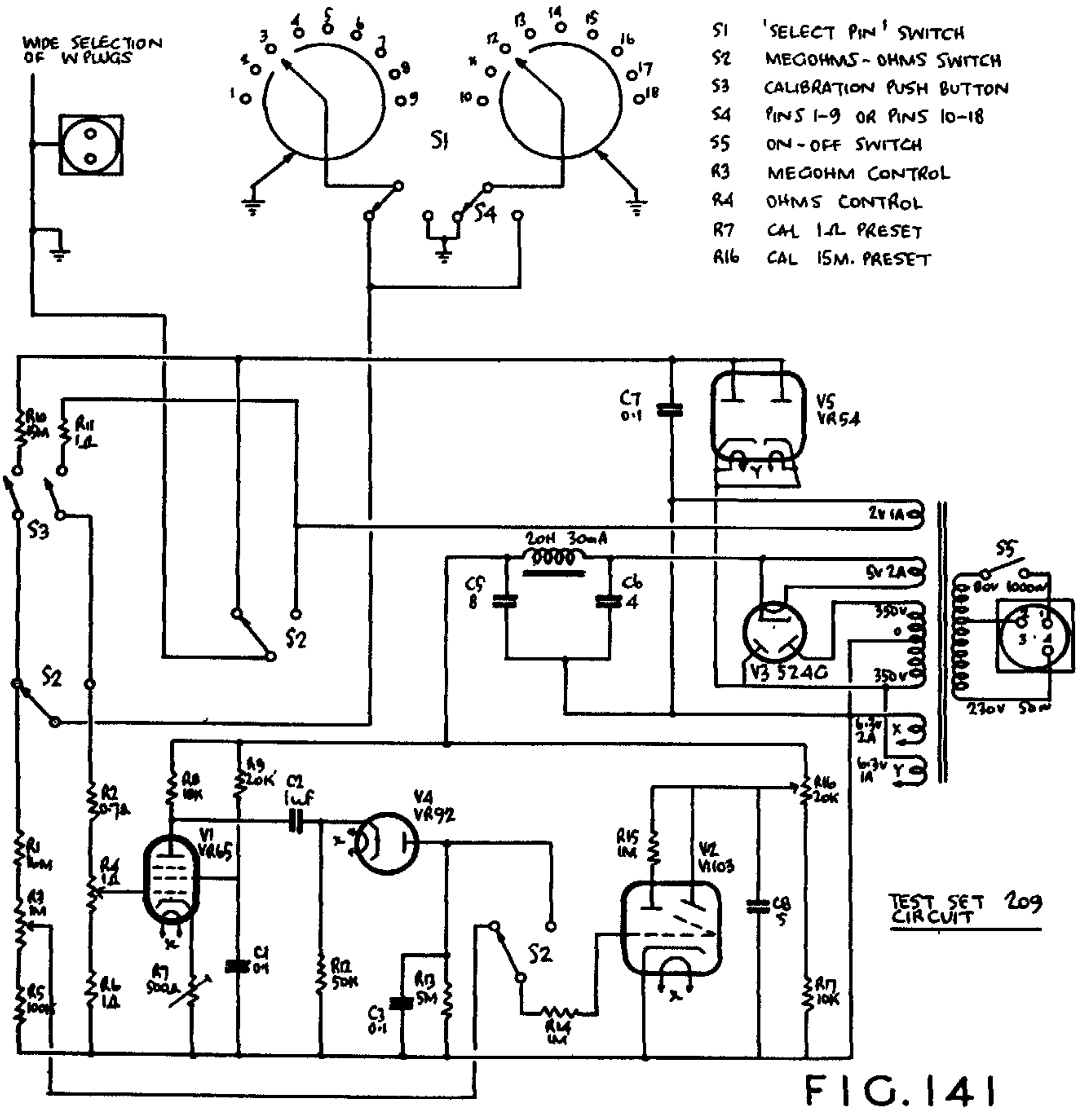
CABLE TESTER
TEST SET TYPE 209



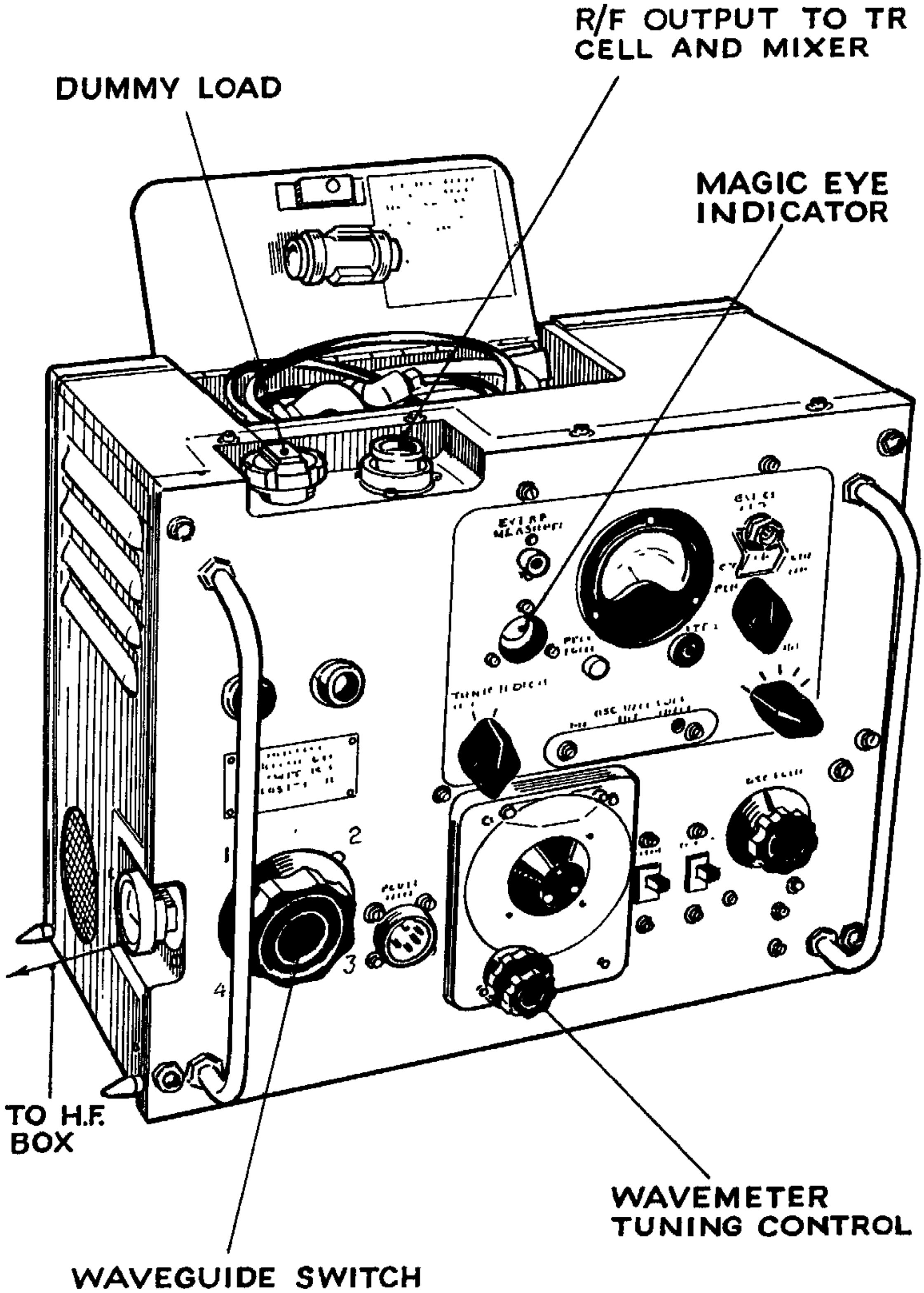
PANEL LAYOUT

FIG. 140



TEST SET 209 CIRCUIT

FIG. 141



TEST SET TYPE 205

FIG. 143

FIG. 143

The Test Set 205 or 205A.

Function.

855. This test set is used to line up the TR.3555 series of transmitting units. These transmitter units require the following adjustments:-

(a) Matching the magnetron to the waveguide for maximum power output consistent with frequency stability.
(b) Adjustment of the mixer piston to match the crystal to the mixing chamber in order to obtain the maximum I.F. power for a given signal input to the mixing chamber at the magnetron frequency.
(c) Tuning the TR. cell for maximum response to signals on the transmitter frequency and hence for maximum input to the mixing chamber.
(d) Adjustment of the anti-TR. chamber piston to effectively make the transmitter channel offer a high impedance to the incoming signals so as to direct the maximum flow into the receiver branch line.
(e) Adjustment of the klystron operating conditions for satisfactory frequency stability and power output to the mixer.
(f) Tuning the klystron 45 Mc/s. off the magnetron frequency for maximum I.F. input to the head amplifier when the transmitter works as a complete unit.
(g) Adjustment of the C.W.L.D. input to the mixing chamber for optimum heterodyning as indicated by a mixer current value determined from experience.

The test set 205 or 205A is used to make the adjustments (a), (b), (c), (d) and (f).

The Test Set Channels.

856. (a) The circuit details are shown in fig.142.
(b) The controls discussed in the following paragraphs appear on the panel layout shown in fig.143.

857. How the test set performs its various functions can most readily be appreciated by following the various channels employed on the circuit diagram.

858. The four-position waveguide switch, S.1, has its input channel connected to the transmitter unit. Position 1 feeds the R.F. input into the dummy power load. The power flow causes the neons V.12 and V.13 to take a current proportional to the power input. This current is indicated on the 0 - 100 microammeter when the selector switch is in position 1. By adjusting the R.F. output matching adjustments for maximum meter indication the magnetron is matched to its output channel for maximum power output.

859. At the same time some R.F. power leaks past the waveguide switch into the wavemeter channel. By tuning the wavemeter cavity to the magnetron frequency the maximum input will be applied to the crystal, V.10. If the P/I.F. (pulse/I.F.) switch is set to "P." the negative-going rectified pulse envelope is applied to the grid of V.1, V, and V.2 operate as a video amplifier. The negative-going amplified video pulses are applied to the diode V.3 which passes bursts of current into C.15. These are smoothed by the long time constant, R.2 and C.15, to impress on V.4 (magic eye) grid a negative D.C. voltage which is a maximum when the crystal output is a maximum, i.e., when the wavemeter cavity is tuned to resonate the magnetron frequency. The wavemeter dial setting then indicates the frequency of the matched magnetron. The scale reads from 0.5 to 3.5 indicating wavelengths from 3.05 cms. to 3.35 cms.

860. The V.9 stage with its associated power pack (V.7, V.6, V.5) is basically similar to the local oscillator and power pack in the TR.3555. If V.9 is tuned to the magnetron frequency it can act as a source of C.W. at the magnetron frequency. The signal can then be used to tune the TR.3555 T.R.

cell and mixing chamber to the magnetron frequency. It can also be used to beat with the TR. 3555 local oscillator output to tune the klystron 45 Mc/s. off the magnetron frequency. When the waveguide switch is set to position 2 the output from V.9 is launched into the wavemeter channel (via a probe as shown). Some of the power is rectified by the klystron crystal, V.11, and the current can be measured on the microammeter when the selector switch is in position 2. If the P./I.F. switch is set to "P", the selector switch (S.5a) provides a variable shunt across the meter. The klystron controls can then be set up to get a meter indication when the klystron is oscillating.

861. When klystron tuning is adjusted to the frequency at which the wavemeter cavity is resonant, i.e., the magnetron frequency, the C.W. is rectified by the crystal, V.10. A built-in mica washer acts as a smoothing condenser and the negative D.C. voltage developed is applied to terminal 3 of the selector switch Hence, by setting the selector switch to position 3, the klystron can be tuned to the magnetron frequency by tuning for maximum meter indication. The sensitivity switch setting can be varied as tuning proceeds.

862. If the waveguide switch is set to position 3 the test set klystron output is fed into the waveguide channel labelled "Waveguide output for tuning mixer and T.R. cell". With the klystron previously tuned to the magnetron frequency we now have a C.W. input in this channel at the magnetron frequency. A short piece of circular waveguide termed a "dummy T.R. cell" is provided with the test set. This section contains a "lossy iris" i.e., an iris that absorbs power. The power loss is that which should occur in a good T.R. cell of the C.V.114 type when correctly tuned. The mixer chamber from the transmitter unit is removed and fitted on top of the dummy T.R. cell. The crystal rectifies the C.W. input to produce a negative D.C. voltage whose amplitude depends on the tuning of the mixing chamber. This D.C. component is taken via a Pye lead from the mixer to the Pye plug on the front panel of the test set. This plug is connected to contact 4 of the selector switch and the negative meter terminal. Hence, by setting the selector switch to position 4 the mixer chamber piston can be adjusted for maximum response at the magnetron frequency as indicated by maximum meter reading.

863. Once the mixer has been tuned the dummy T.R. cell can be replaced by the actual T.R. cell which can be tuned for maximum response on the meter.

864. If the mixer chamber and T.R. cell are now replaced in the transmitter unit, both should give the best response to the magnetron frequency, i.e., to the frequency of the klystron in the test set. If the waveguide switch is now set to position 4 the klystron output is fed into the transmitter unit where it is passed through the T.R. cell to the mixer. If the mixer output is connected by Pye lead to the Pye plug on the test set panel, the smoothed negative D.C. voltage obtained from the rectified C.W. is applied to terminal 4 of the selector switch. With the selector switch in this position the anti-T.R. piston can be tuned for maximum meter indication. When this indication is obtained the effective flow into the receiver branch line will be a maximum for R.F. energy at the magnetron frequency.

865. The problem still remaining is setting up and tuning the transmitter unit klystron to a difference of 45 Mc/s. from the magnetron in order to get maximum amplification of signals from the I.F. strip. Setting up the klystron does not involve the test set so will not be discussed here. Tuning the klystron is done by varying its frequency until a beat frequency of 45 Mc/s. is obtained by feeding both the test set klystron signal and the transmitter unit klystron signal into the mixer. In order to determine when the tuning is correct we require an amplifier capable of amplifying C.W. of 45 Mc/s. and some form of output meter. This amplifier is provided by the head amplifier in the transmitter unit and V.1 and V.2 in the test set. V.1 and V.2 were used as a pulse amplifier, i.e., a video amplifier, when the magnetron frequency was determined by tuning the wavemeter for maximum response on the magic eye. To use the same stages as an I.F. amplifier instead of a video amplifier we require R.F. decoupling and a frequency sensitive anode load. This is provided when the P/I.F. switch is set to I.F. S.6c ties the parallel dropping

resistors, R.19 and R.20, to earth through C.8. The 45 Mc/s. tuned circuit in V.1 anode serves as the anode load. S.6d introduces C.13 into the circuit to perform the same function for V.2. The beat signal from the mixer is applied to the head amplifier stages in the transmitter unit. The output is taken from the green Pye plug on the transmitter unit and applied to the Pye plug on the test set panel. When the P./I.F. switch is set to I.F. the beat signal is applied via C.3 and S.6b to V.1 grid. The choke, L.2, blocks the signal from the meter. The amplified output from V.2 is rectified by V.3 and the smoothed negative D.C. voltage applied to the grid of the magic eye, V.4. The sensitivity switch, S.5d, varies the cathode load of V.1. When the L.O. in the transmitter unit is correctly tuned the switch must be set to minimum to prevent overlapping of the magic eye.

The H.T. Power Pack.

866. The power supplies for the test set 205 are brought in on a 6-way, preferably via a junction box 238 arranged to intercept the 12-way violet from the J.B.231 to the modulator. Reasons for this arrangement are discussed in paras. 874 - 875. The 80V. A.C. supply comes in on pins 1 and 2. If the panel switch labelled "Power" is closed the supply is completed to the primary of the H.T. power pack. V.8 (5Z4G) then provides the H.T. supply for V.1, V.2, V.3 and V.4. Heater windings are provided on the transformer as shown.

867. The single-ended 6.3V. 2A winding also feeds to the metal rectifier (shown near the meter) a voltage which can be adjusted by means of the 500 ohm potentiometer, R.48. The rectified output is taken to the positive side of the meter when the selector switch is in position 1 via S.4b. The rectified output is also taken via the meter to the neons, V.12 and V.13, via contacts on the press-button ionising switch and the external power measurement jack on the panel. The D.C. voltage applied to the neons depends on the setting of R.48. Since this voltage determines how heavily the neons conduct, R.48 can be adjusted for a suitable range of meter readings on R.F. power measurements. In prototype models of the test set a 1.5V. cell was used instead of the metal rectifier.

868. It will be noted that + 300V. is also applied via R.51 and R.53 to the normally open contacts on the ionising press-button switch. If the R.F. power input is insufficient to make the neons strike the button can be pressed to apply + 300V. The resistors, R.51 and R.53, prevent the current from becoming excessive when +300V. is applied to the neons.

The E.H.T. Power Pack.

869. The power pack for the test set klystron is fundamentally similar to that used in the transmitter unit which is discussed in Chapter 6, paras. 388 - 394. The 80V. input to the transformer is completed if both the panel switches labelled "Power" and "Oscillator" are closed. V.6 (VT.60A) is the variable impedance cathode load of the half-wave rectifier, VU.111. The screen voltage of V.6 is obtained from the +300V. line and dropped across R.46 to 130V. It is stabilised at this value by the neon, V.5. The 250K. potentiometer, R.41, permits an adjustable portion of any variation in the output voltage to be fed back on V.6 grid as well as varying the actual grid potential and effective impedance of V.6. Adjustment of R.41 then varies the effective cathode load of the rectifier and so varies the E.H.T. voltage developed. Any tendency of the output voltage to swing more negative due to a transient rise in the 80V. supply will drive V.6 grid more negative due to the increased flow in the bleeder. Hence V.6 impedance rises and the output is held at essentially the same level as before. The converse action occurs if the 80V. supply falls slightly. V.6 is thus a valve stabiliser for the E.H.T. supply to the klystron, V.9.

The Klystron Oscillator, V.9.

870. V.9 is a reflector klystron of the CV.129 type which is also used in the transmitter units of the TR.3555 series. The cathode potential of the klystron is determined by:-

(a) The E.H.T. voltage across the klystron bleeder.
(b) Klystron current drawn through R.36, R.35 and R.34. This current will depend on the setting of the grid volts control, R.34.

871. As the E.H.T. voltage which the power pack can sustain will depend on the klystron current which consitutes the major drain, there will be interaction between R.41 and R.34. As R.36 will vary the feedback and hence the amplitude of oscillation, it will have a secondary effect on the required setting of the other controls for a given cathode potential and klystron current. Should complete realignment be required the same type of setting-up procedure as is outlined for the transmitter-unit klystron in Chapter 12, paras.1022 - 1027, should serve to bring the klystron into operation. An E.H.T. current indication is obtainable by setting the selector switch to position 5. The negative side of the meter is then earthed and the positive side is connected to the 2.5 ohm cathode resistor of V.6. R.49 puts a fixed 330 ohm shunt across the meter. In the 205A model an external jack-point is provided instead.

872. The klystron is cooled by a blower motor operating on 24V. The supply is brought in on pins 3 and 4 of the 6-way power input plug. When the "Oscillator" switch on the panel is closed, the 24V. supply to the blower motor is automatically completed.

The Safety Indicators.

873. The test set panel shows a red and a green pilot lamp. The circuit shows that a cam and rocker arm arrangement operated by the waveguide switch serves to operate these lamps by connecting to them a 6.3V. supply from the 6.3V. winding on the H.T. transformer. The green lamp lights when the waveguide switch is in position 1. This indicates that it is safe to switch on the modulator and feed the magnetron output into the test set. In positions 2, 3 and 4 of the waveguide switch the red lamp lights. This is a danger warning. Do not switch on the modulator. Failure to heed this warning will result in serious damage to the test set.

The Test Set 205 Safety Circuits.

874. To protect the test set from the danger of an accidental switching on of the modulator 64 when the waveguide switch is not in position 1, it is desirable that the modulator should be automatically switched off when the switch is set to positions 2, 3 or 4. This protection can be provided if the +300V. supply to the CV.73 trigger valve is completed via contacts operated by the waveguide switch. To permit this remote control of the +300V. supply to the trigger valve the junction box type 238 is incorporated in the bench-testing installation.

875. (a) The letter coding of the plugs on the JB.238 is shown in fig.154. A 4-way cable is taken from the 4-pin test plug on the JB.231 to the plug B on JB.238. This brings the 80V. A.C. and 24V. D.C. supplies to the JB.238.
(b) The 12-way from the JB.231 to the modulator (carrying the switched +300V. supply) is taken to plug C on JB.238 instead of to the modulator.
(c) A 6-way is taken from plug D on JB.238 to the test set 205. This brings the switched +300V. supply from the power unit in on pin 5 to one of the contacts controlled by the waveguide switch. An output connection is taken from a second

contact to pin 6. If the waveguide switch is in position 1 the supply to pin 6 is automatically completed. In any other position the supply is broken. Hence, the +300V. supply is only fed back into J.B.238 when the waveguide switch is in the position when it is safe to operate the modulator and magnetron.

(d) A new 12-way cable is taken from plug A on the J.B.238 to the modulator to complete the +300V. supply to the trigger valve when the waveguide switch is in position 1.

876. If the test set 205 is taken out of the bench installation the 6-way cable from plug D to the test set is connected into plug F. The +300V. switched line is then completed from pin 9 on the 12-pin C via pin 6 on the 6-ways D and F to pin 9 on the 12-way A and thence to the modulator.

The Dual Purpose Amplifier, V.1, V.2.

877. We have already noted the two functions performed by this dual purpose amplifier. The anode of each valve is connected to H.T. through a 45 Mc/s. tuned circuit in series with two 47K. resistors in parallel. When the panel switch labelled "Pulse/I.F." is in the "Pulse" position the resistors form the effective anode load and we have a two stage video amplifier. When the switch is in the "I.F." position the resistors are decoupled to earth through .001 condensers and the tuned circuits become the effective anode loads to give us 45 Mc/s. I.F. amplifier.

The Selector Switch.

878. This switch is used to make the appropriate connections to the meter during the various stages in the setting-up procedure.

Position 1 - The smoothed metal rectifier voltage, the meter and the power measuring neons are connected in series. The 330 ohm fixed shunt, R.49, is across the meter.

Position 2 - The rectified output of the test set klystron is taken from the crystal, V.11, to the negative side of the meter while the positive side is earthed. The sensitivity switch section, S.5a, is introduced to provide a variable shunt across the meter.

Position 3 - As the test set klystron is tuned, the signal passing through the wavemeter cavity to the crystal, V.10, is rectified and applied to the negative side of the meter. The positive side is again earthed. The S.5b section of the sensitivity switch is introduced to provide a variable shunt across the meter.

Position 4 - The external crystal current from the mixer applied to the panel Pye plug is connected to the negative side of the meter while the positive side is earthed. The S.6a section of the sensitivity switch is introduced to provide a variable shunt across the meter.

Position 5 - The positive side of the meter is connected to the cathode resistor of the VT.60A stabiliser, V.6, and the negative side of the meter is earthed. R.49 provides a fixed 330 ohm shunt. An E.H.T. current indication can then be obtained in the meter.

The Sensitivity Switch.

879. (a) S.5a provides a variable shunt across the meter when setting up the test set klystron.

(b) S.5b provides a variable shunt across the meter when measuring the magnetron frequency and when tuning the test set klystron to the same frequency.

(c) S.5c provides a variable shunt across the meter while:-
   (i) Tuning the mixer with the dummy T.R. cell
   (ii) Tuning the T.R. cell.
   (iii) Tuning the anti-T.R. chamber.

(d) S.5d provides a variable cathode load for V.1 when tuning the transmitter unit klystron to a frequency 45 Mc/s. off the magnetron frequency.

The Magic Eye, V.4.

880. (a) When the P./I.F. switch is set to "P", the magnetron output leaking around the waveguide switch passes through the wave meter cavity to the crystal, V.10. The rectified pulse envelope is applied to the pulse amplifier, the smoothed negative voltage being applied to V.4 grid. The closing of the magic eye indicates that the wavemeter is tuned to resonate the magnetron frequency.

(b) When the P./I.F. switch is set to "I.F." the output obtained from the head amplifier by beating the signals from the test set and transmitter unit klystron, is applied to V.1 and V.2 operating as I.F. amplifiers. V.3 operates as a detector and the smoothed negative voltage is applied to V.4 grid. Closing of the magic eye indicates that the transmitter unit klystron tuning is approaching the correct frequency. S.5d provides variable sensitivity of the amplifier, as the tuning progresses.

The Power-Measuring Neons, V.12, V.13 (10E/223).

881. Only neons in which the outer cylindrical electrode is connected to the outer of the bayonet cap are suitable. To check for the correct type of neon press the ionising button to apply +300V. In the correct type the glow will be visible outside the cylindrical electrode. If incorrect, most of the glow will be inside the cylindrical electrode.

882. The neons are placed three-quarters of a wavelength apart. In this way any reflection introduced by the second will be 2 x $\frac{3}{4}$ or $1\frac{1}{2}$ wavelengths out of phase with that from the first. The phases will then be opposite and the two reflections will automatically cancel out.

The Waveguide system.

883. The switch operates on the principle discussed in Chapter 13, paras.1243 - 1245.

The power dummy load consists of a fishtail of graphite and asbestos loaded bakelite. This dummy load breaks up the wavefront in such a way as to result in complete absorption and no reflection of R.F. power. Cooling is provided by the klystron blower motor via a flexible pipe from the motor.

884. A 10 db. attenuating iris is introduced in the wavemeter channel to attenuate the R.F. power from the magnetron which leaks around the waveguide switch in position 1. This precaution is necessary to protect the crystals, V.10 and V.11.

885. A second attenuator iris is introduced between the test set klystron input probe and the crystal, V.11. This is to cut down the power applied to the crystal.

886. The matching iris behind the probe is to suitably divide the klystron power between the channel to V.11 and the alternative path to the wavemeter and other guide channels.

The Crystal Rectifiers.

887. V.10 and V.11 are CV.102 crystals. These are yellow spot crystals with an orange dot to indicate that they can take a higher voltage than the ordinary yellow spot, CV.101.

The Test Set 205A.

888. This model differs slightly from the test set 205 in panel layout, wiring arrangement, etc. It has already been pointed out that an external jack-point is provided on the panel for measuring E.H.T. current instead of using the test set meter as in the 205.

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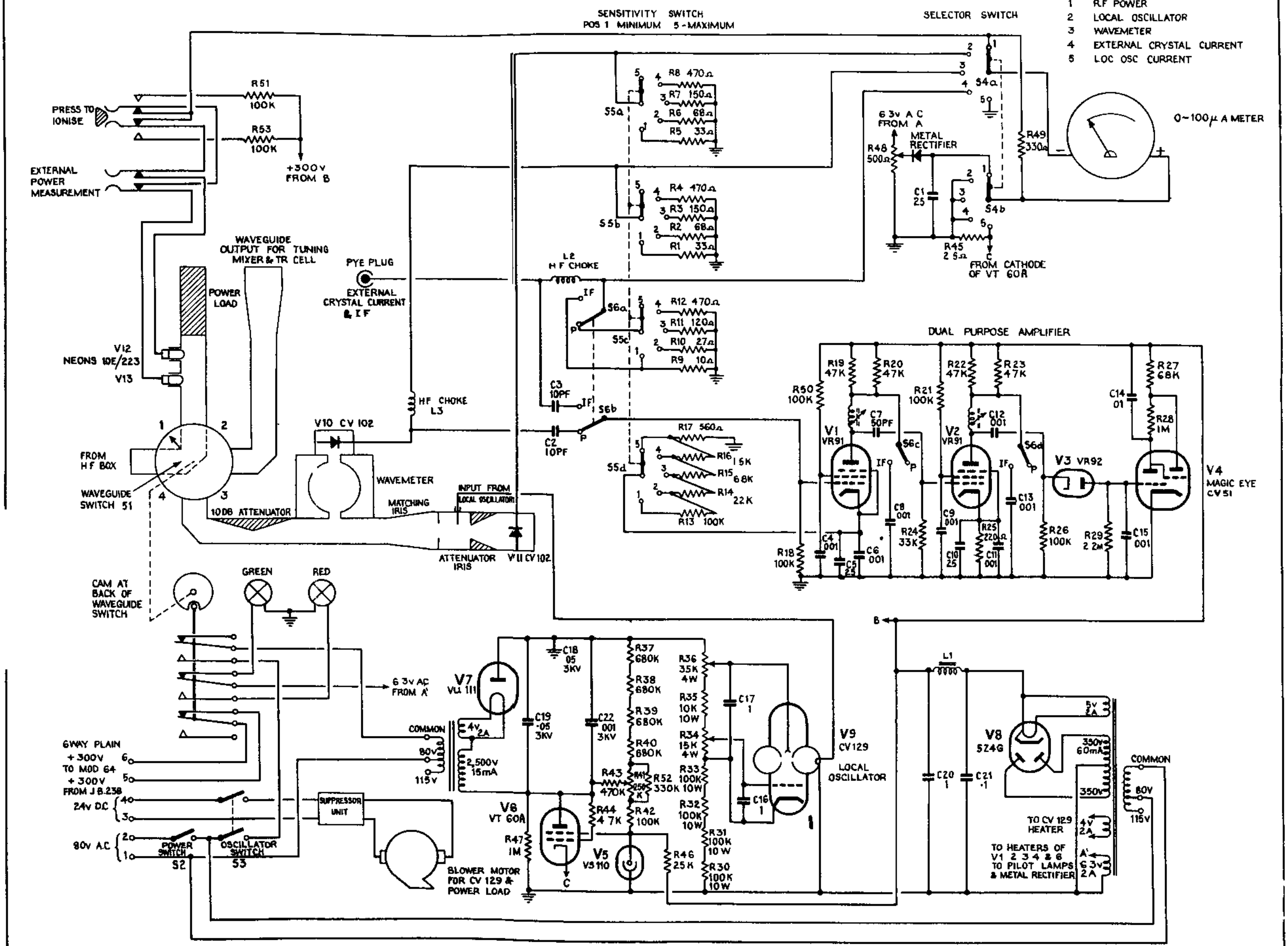


FIG.142 TEST SET TYPE 205 FIG.142

889. Some difficulty has been experienced with multiple tuning points while tuning the transmitter unit klystron in the final stages of the setting-up procedure. It has been found that the test set klystron is pulling the frequency of the transmitter unit klystron. The difficulty can be eliminated by pulling the coupling probe well out on the mixer while tuning the CV.129 in the transmitter unit. This probe must of course, be reset to the position giving 1.5 ma. of crystal current before attempting to receive signals.

The Junction Box Type 238 (10AB/6455).

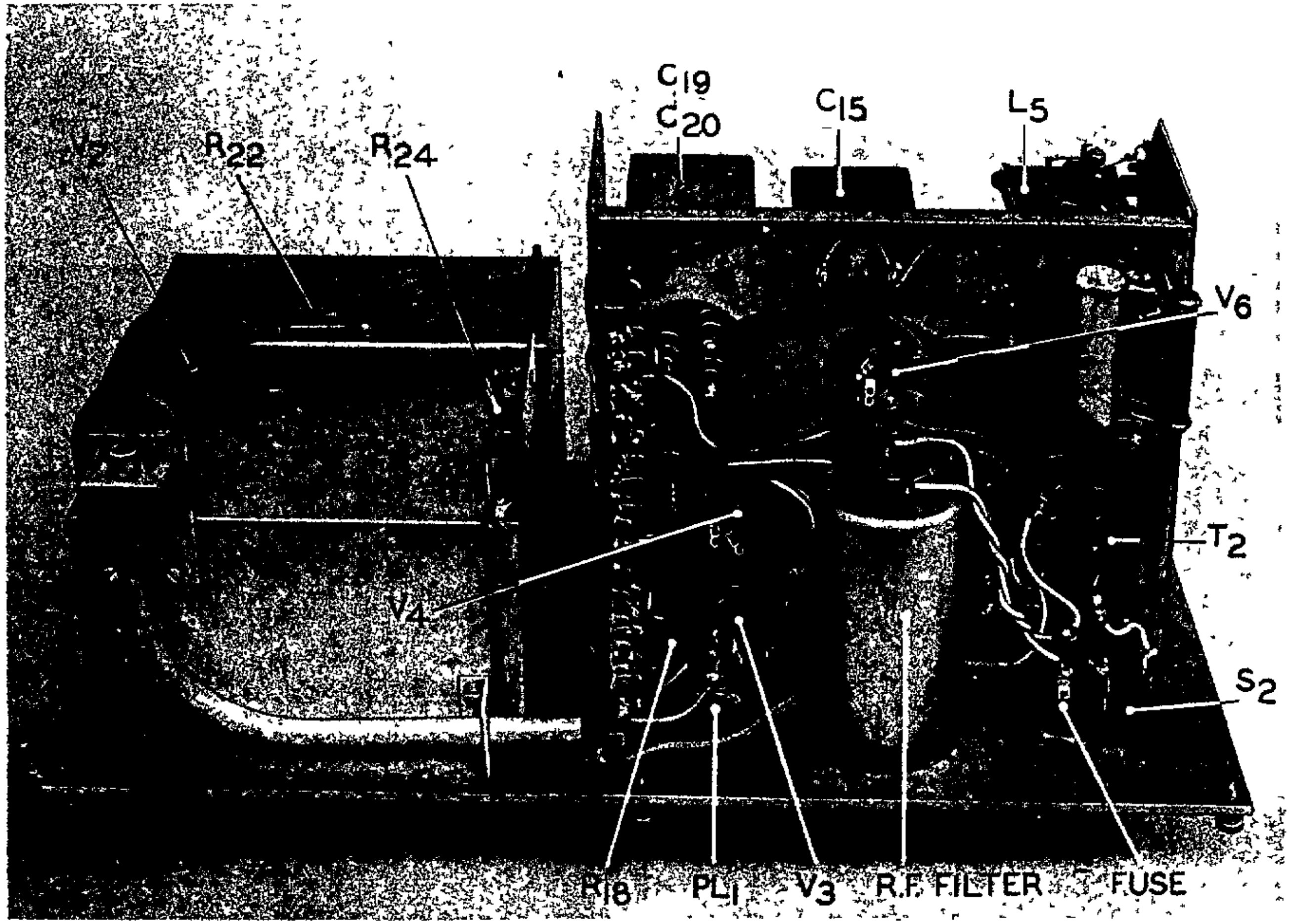
890. The application of this junction box to protect the test set 205 has already been discussed in paras.874 - 876. The spare plugs on the box provide a convenient means of supplying 80V. A.C. and 24V. D.C. to other items of test gear which may be required in the bench-testing installation.

The Mismatch Unit Type 257.

891. This unit is used in lining up transmitter units of the TR.3555 series with the test set 205. The power dummy load of the test set simulates the scanner load but does not provide for the variations in load presented by different scanners. A unit lined up in the test set 205 might operate normally on a bench scanner but show moding, or frequency pulling and gapping, when used with an aircraft scanner. To provide for this variation in scanners the mismatch unit can be used in conjunction with the test set dummy load to introduce a deliberate mismatch comparable to that produced by the worst scanner likely to be encountered.

892. The unit is a length of rectangular waveguide which has a quartz rod projecting into the guide. The maximum distance that this rod may project into the guide is fixed to leave a clearance of 7/32" between the rod and the far guide wall. This quartz projection introduces a standing wave whose amplitude is comparable with that which may appear in the transmitter unit guide system due to the worst scanner likely to be encountered. The phase of this deliberately introduced standing wave can be varied by means of a moveable carriage which supports the quartz rod. The transmitter output controls are detuned so that frequency stability is obtained regardless of the position of the mismatch carriage, i.e., regardless of the phase of the worst standing wave likely to be introduced by any scanner. This will involve a sacrifice of power output. The degree of power loss is an indication of the frequency stability of the magnetron. This stability may be influenced by the strength of the magnet, shape of the modulating pulse and amplitude of the modulating pulse, as well as the magnetron itself.

FIG. 144



UNDERSIDE VIEW

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FIG. 144

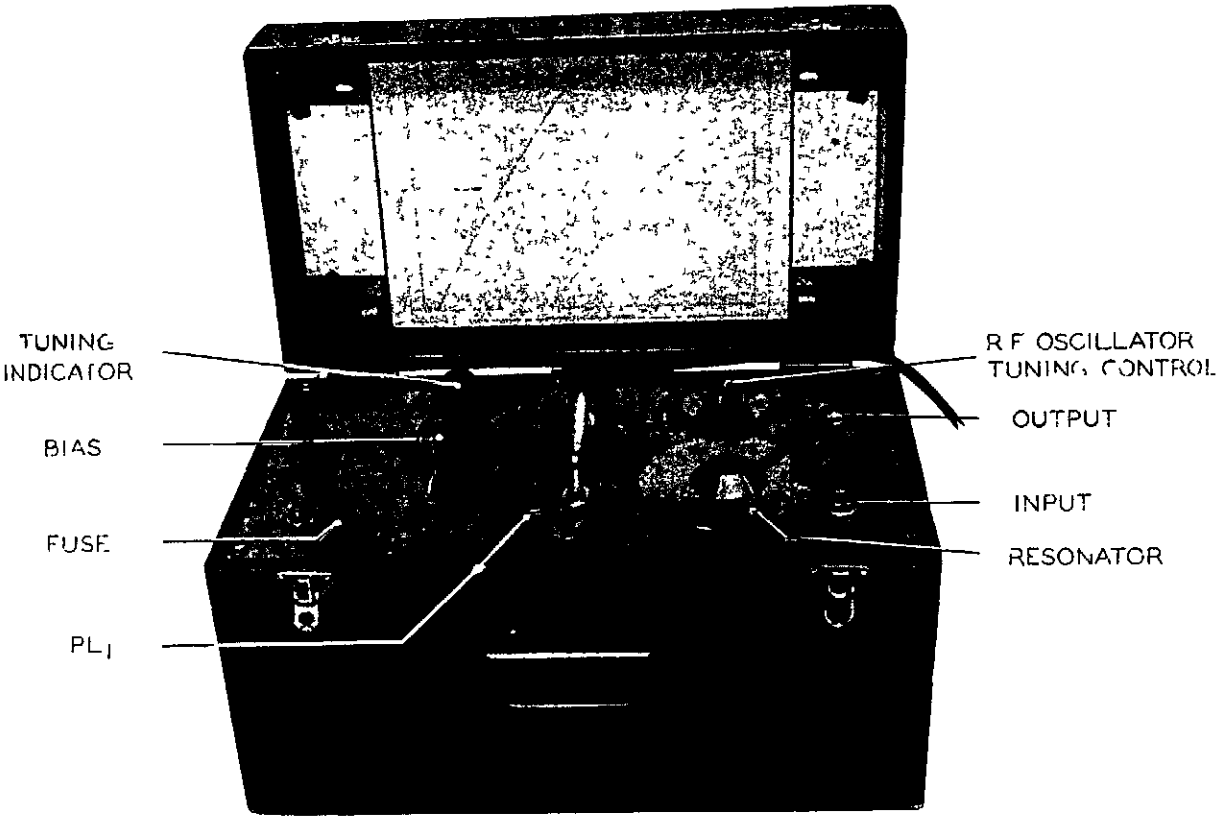


FIG. 145 PANEL

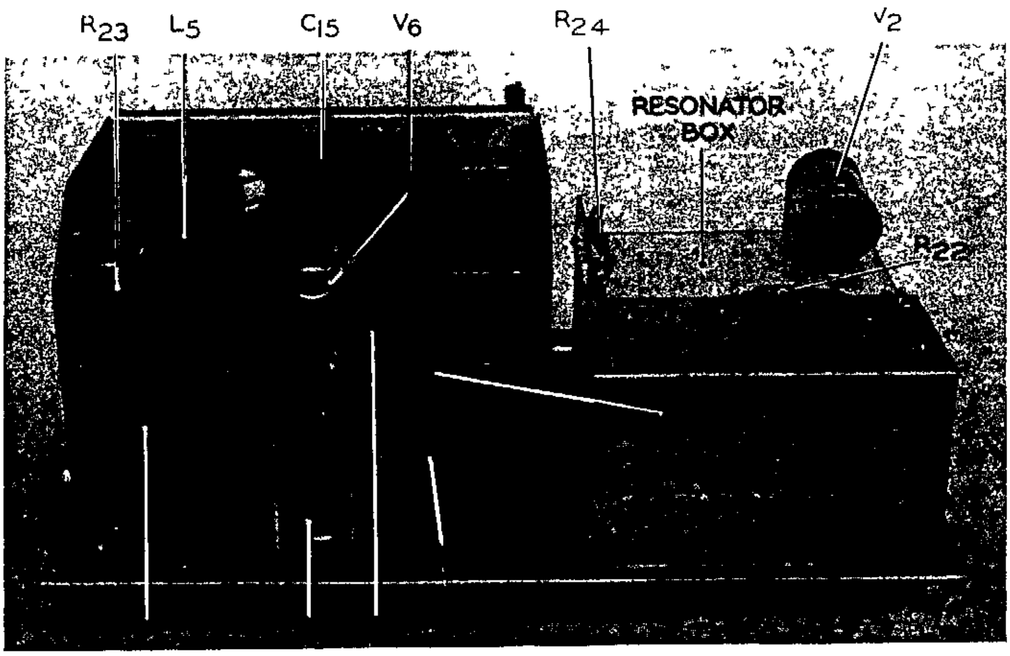


FIG. 146 TOP VIEW

WAVEMETER W. 1310

The Wavemeter W.1310.

Use.

893. The wavemeter W.1310 is an absorption type wavemeter covering the band 155 - 220 Mc/s. Its application in so far as H.2.S. installation is concerned will be mainly for tuning the Lucero transmitter and receiver, and for tuning Lucero blind approach beacons.

Outline.

894. (a) For checking transmitter tuning the transmitter signal is applied to a circuit tuned to the required frequency by means of a calibration chart. The output is applied to a diode rectifier which develops a positive output voltage which is used to bias the grid of an audio oscillator, thereby controlling the amplitude of oscillation. The audio oscillator output is rectified by another diode and applied to a magic eye indicator.
(b) For tuning receivers to a specified frequency and R.F. oscillator is provided which covers the 150 - 220 Mc/s. band. The oscillator frequency can be set to any value in the band since its output is loosely coupled to the resonant circuit of the wavemeter.
(c) A 6X5 or 6X5G power rectifier provides H.T.

Power Supply.

895. The unit is designed for mains operation. Before connecting to the mains it is essential to check that the connections on the mains transformer are suited to the supply voltage. By loosening the coin-slotted screws in the panel the instrument can be lifted out of its case. The mains tappings are on a tagboard under the chassis. The correct tappings are those whose sum equals the supply voltage. For 210V. mains.connections should be made to the tags marked 10 and 200. For a 240V. supply, the 0 and 240 tags would be used. Special supplies can also be used as listed in para.

The Circuit.

896. (a) Panel details are shown in fig.145
(b) Layouts are given in figs.144 & 146
(c) The circuit is given in fig.147.

Power Pack.

897. The mains supply is applied via a suitable R.F. filter and ON/OFF switch to the appropriate transformer tags on T.2. Smoothing is provided by the choke, L.5 (40H.) and the electrolytic condensers C.19 and C.20.

898. The tappings on the power transformer permit use with mains voltages of:-

(a) 200 - 250V., 50 c/s.
(b) 180V. 500 c/s.
(c) 80V. 2,000 c/s.

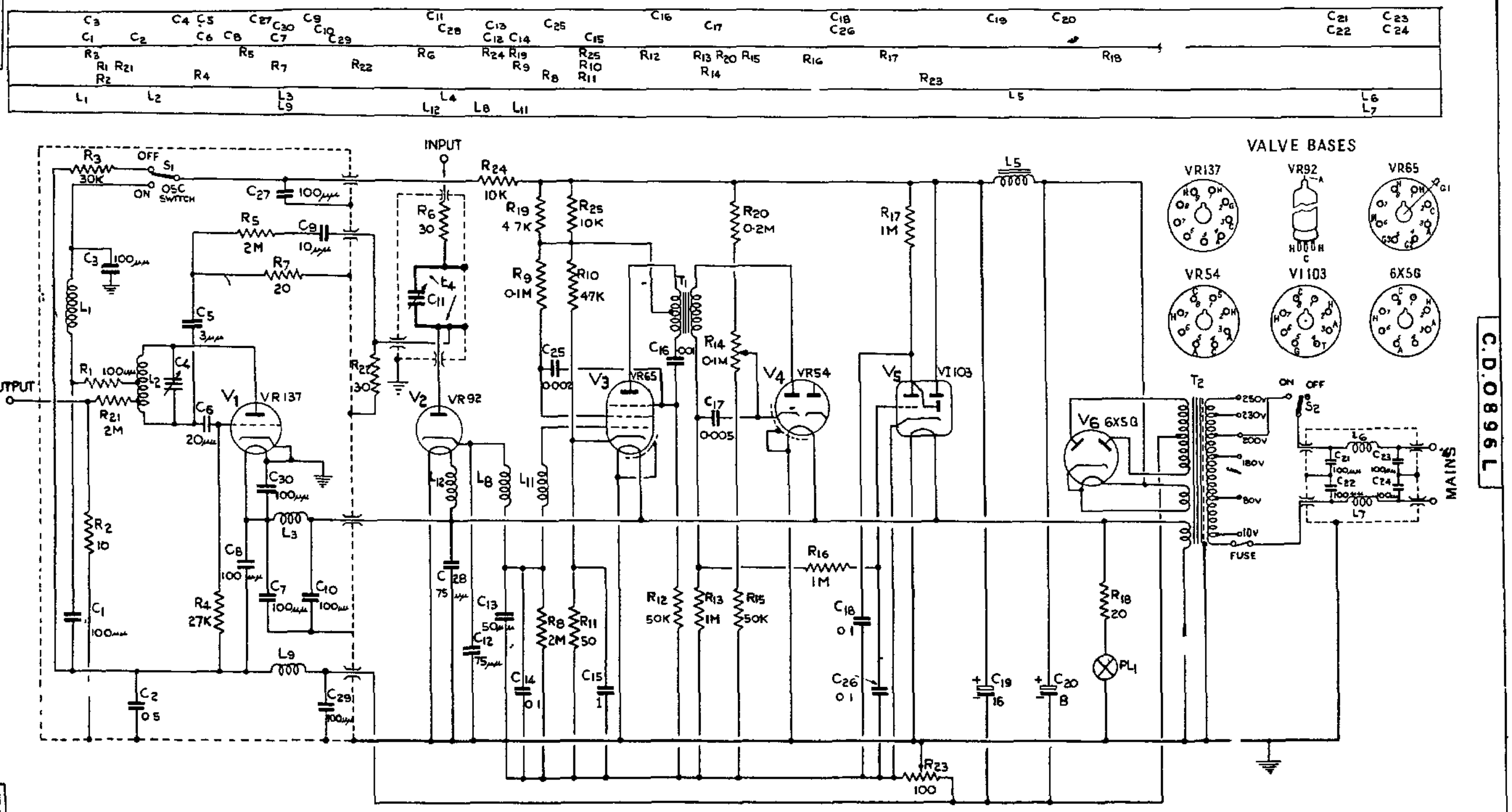
899. The output between L.5 and earth is approximately 250V.

The Absorption Circuit and R.F. Rectifier.

900. L.4, C.11 is the absorption circuit. C.11 is the calibrated RESONATOR control on the panel.

901. V.2 is the diode detector. R.8 is the cathode load. The values of R.8 and C.14 and those of the resistors and condensers used in the magic eye input are chosen to provide deflections free from flicker when the wavemeter is used with low p.r.f. transmitters.

FIG. 147



WAVEMETER, TYPE W.1310 - CIRCUIT.

FIG. 147

902. L.8, L.11, C.12, C.13 are included to keep R.F. off the grid of the audio oscillator, V.3.

The Audio Oscillator.

903. V.3 (VR.65) is arranged as a series-fed Hartley circuit, using the anode, cathode and suppressor as a triode. The oscillation amplitude is varied by the bias applied to the control grid from the diode load. As the transmitter frequency and resonator frequency approach coincidence the diode output carries V.2 grid more positive. The amplitude of oscillation rises to its peak value when the exact resonance point is reached.

904. The effective D.C. voltage on the control grid of V.3 is equal to the difference between the bias on V.3 cathode from the voltage drop across R.11 in the bleeder formed by R.25, R.10, R.11 and the adjustable preset, R.23, an the rectified positive voltage across R.8. Since R.23 negatively biasses the diode V.2 and thus modifies the output voltage, this preset can be used to correct the falling sensitivity with ageing of V.2 and V.3. When new val are fitted it may be desirable to apply increased bias. The bias can also be reduced when high sensitivity is called for in tests on pulse transmitters

The Audio rectifier.

905. The audio output of V.3 is applied to the VR.54 rectifier, V.4. by the secondary of the audio transformer, T.1. R.13 acts as an anode load across which a negative voltage appears. The amplitude of this voltage will increa as the amplitude of the oscillation in V.3 increases. But this depends on the amplitude of oscillation applied to V.2. Hence, V.4 output is proportio to the resonator circuit input. Thus, as resonance is approached, the outpu from V.4 increases. V.3 and V.4 together serve effectively as a D.C. amplifier for V.2 output.

906. The output from V.4 for a given input will depend on the bias applied to V.4 by R.14 which serves as a sensivity control. This is the control labelled "BIAS" on the panel.

The Tuning Indicator.

907. V.5 is VI.103 visual indicator valve. The screen is at H.T. and the anode and target are below H.T. by an amount dependent on the anode current, i.e., on the grid potential. The more current passed by the valve, the wide will be the shadow since the target is well negative to the screen. As the current decreases the potential difference between screen and target diminish and the shadow gets narrower. Hence, as resonance is approached, and V.5 grid is carried down by the rectified output from V.4, the magic eye continue to close. When the shadow angle is at the minimum point the resonance point is reached. Since the setting of the BIAS control determines V.4 output it can be used to set a suitable shadow angle on V.5.

The R.F. Oscillator.

908. V.1 is a VR.137 using a split-stator Hartley circuit. The panel control labelled "R.F. OSCILLATOR TUNING" is the condenser C.4. The tuned circuit is loosely coupled to the resonator circuit. The oscillator can be set up to a desired frequency by setting the RESONATOR control to the appropr ate setting as given by the calibration chart and then tuning C.4 for resonar with the magic eye. The frequency markings on the OSCILLATOR TUNING control are only rough indications for the purpose of preliminary setting to an appro mate value.

Setting-Up the Wavemeter.

909. (a) Connect to the mains, using the appropriate transformer tappings.

(b) Switch on, noting that the pilot lamp lights up.
(c) After a short warming-up period the magic eye screen will glow. By operating the BIAS control the shadow angle can be set to maximum corresponding to maximum output from V.4 and maximum sensitivity.

Measurement of Transmitter Frequency.

910. (a) Feed a small voltage from the transmitter into the input socket, using the screened plug and length of concentric cable supplied. If a direct connection to the transmitter is not possible, the probe, which is supplied with the instrument can be plugged into the open end of the concentric cable and placed in the field of the transmitter under test.
(b) As the R.F. oscillator is not required the oscillator switch should be in the OFF position.
(c) Rotate the RESONATOR dial until the shadow angle is a minimum. If zero angle is obtained before exact resonance is reached the BIAS control should be turned counterclockwise to again increase the shadow angle. The RESONATOR dial can then be adjusted for further closing. When the BIAS control is correctly adjusted, tuning to exact resonance should not fully close the magic eye as the effective discrimination of the resonator circuit is then reduced. From the dial reading and the calibration chart the frequency can be determined.

Transmitter Tuning.

911. (a) Set the BIAS control for maximum shadow angle.
(b) Apply transmitter input.
(c) Set RESONATOR dial to the required frequency.
(d) Tune transmitter for minimum shadow angle, readjusting the BIAS as necessary as resonance is approached.

Receiver Tuning.

912. (a) Set oscillator switch to ON
(b) Set RESONATOR dial to required value as deduced from calibration chart.
(c) Set BIAS for maximum shadow angle.
(d) Adjust OSCILLATOR TUNING to close the shadow angle to minimum readjusting bias as tuning proceeds.
(e) Feed signal of required frequency to the receiver and tune for maximum output
(f) Tuning sequence should be:-
(i) Local oscillator.
(ii) R.F. to L.O. coupling.
(iii) R.F. input circuit.

Faults and Checks.

913. Should operation of the BIAS control not close the magic eye, listen for the note of the audio oscillator. If missing, replace V.3, and if present, replace V.4.

914. If there is no response when a signal is applied, measure the voltage on V.2 cathode with a high resistance voltmeter, having a resistance of 2,000 ohms per volt or more. This voltage should be 0.5V. or more and should increase as the resonator circuit is brought in tune with the signal. If this does not occur the valve should be replaced.

915. If no magic eye response is obtained from the R.F. oscillator, remove the oscillator cover and measure the H.T. voltage between the tuning coil and earth. A reading of approximately 150V. should be obtained with satisfactory valve and power supply.

916. H.T. voltage should be about 250V.

CD 0896 L

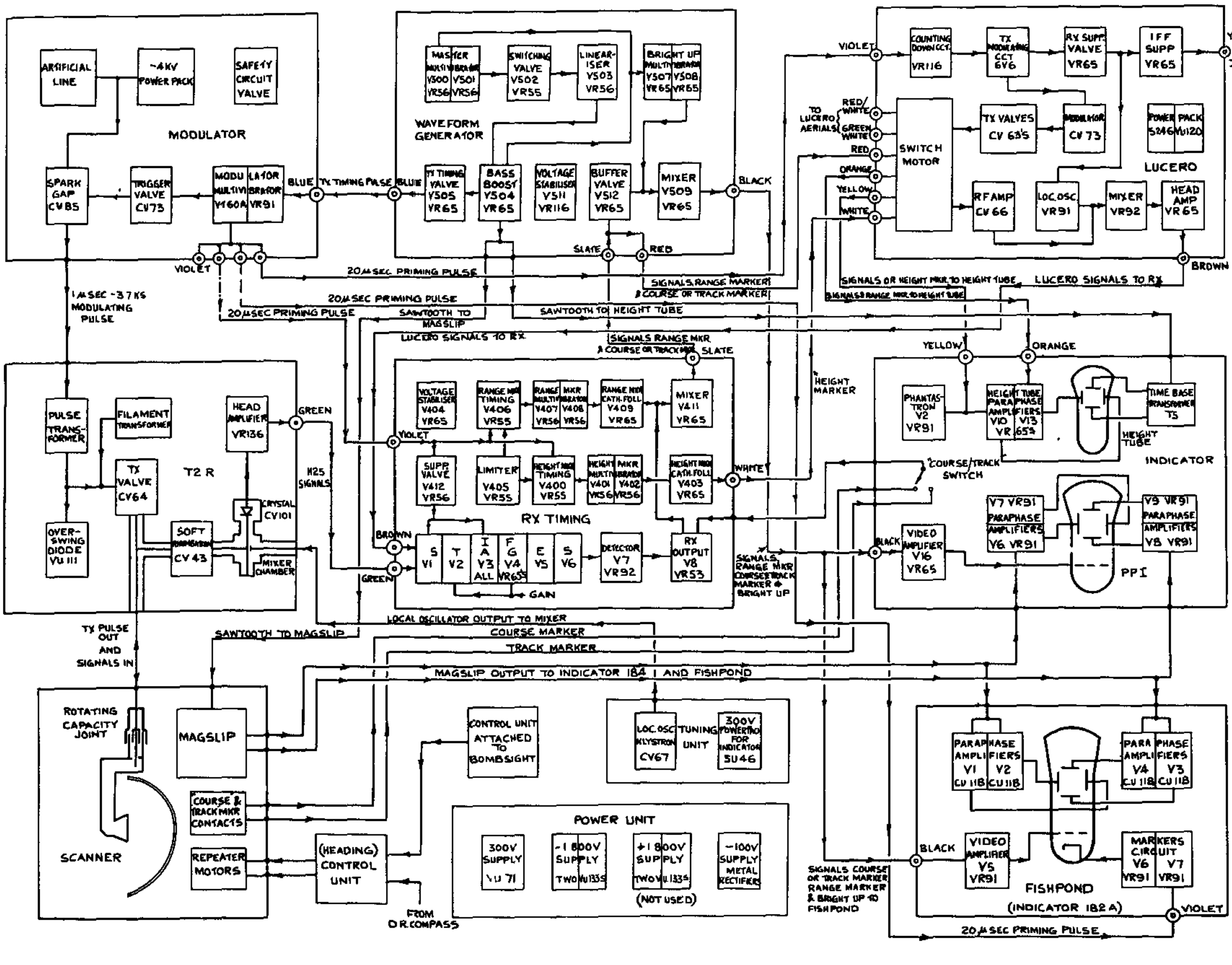
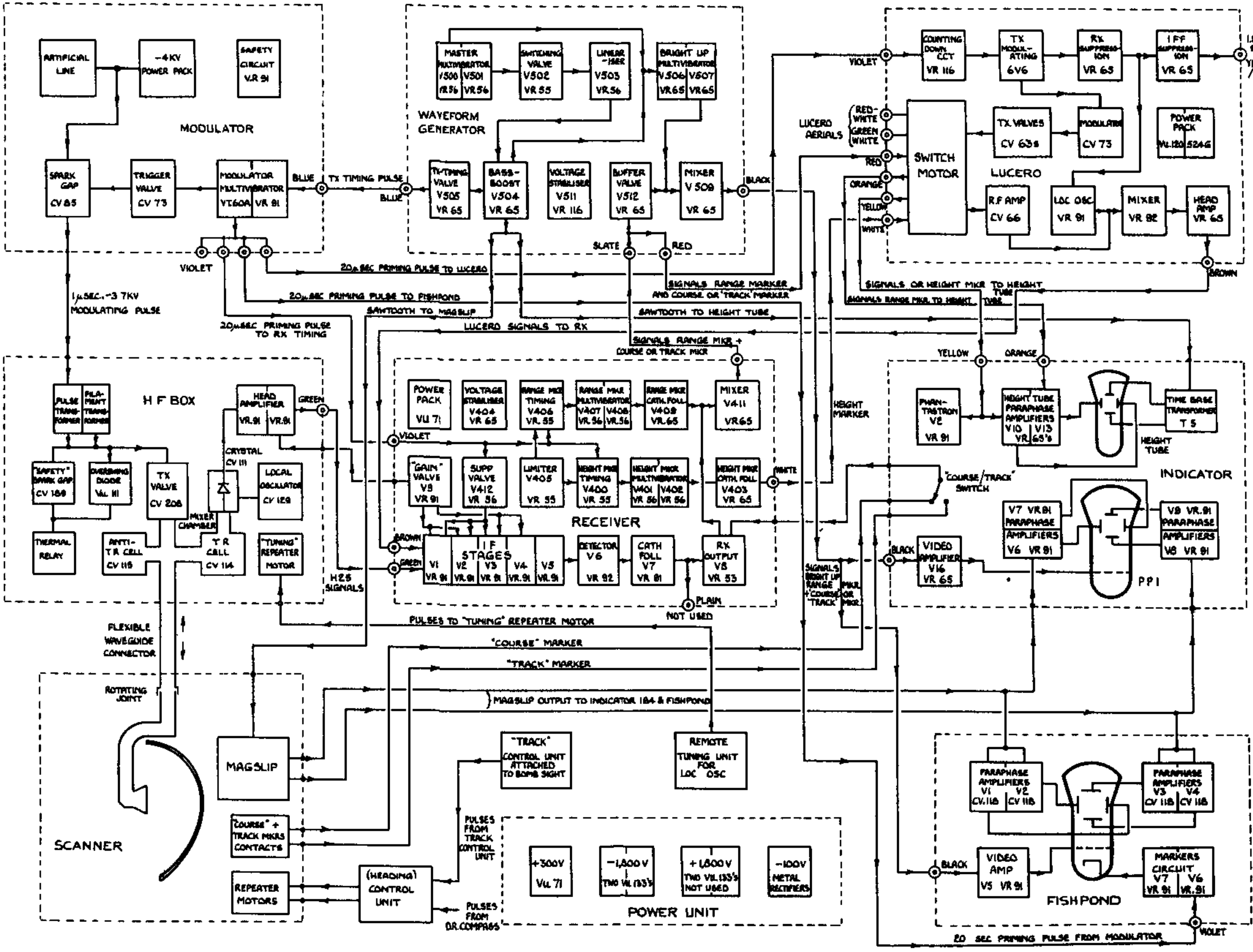


FIG.148 BLOCK SCHEMATIC. MARK IIC. FIG.148

C.D 0896 L.

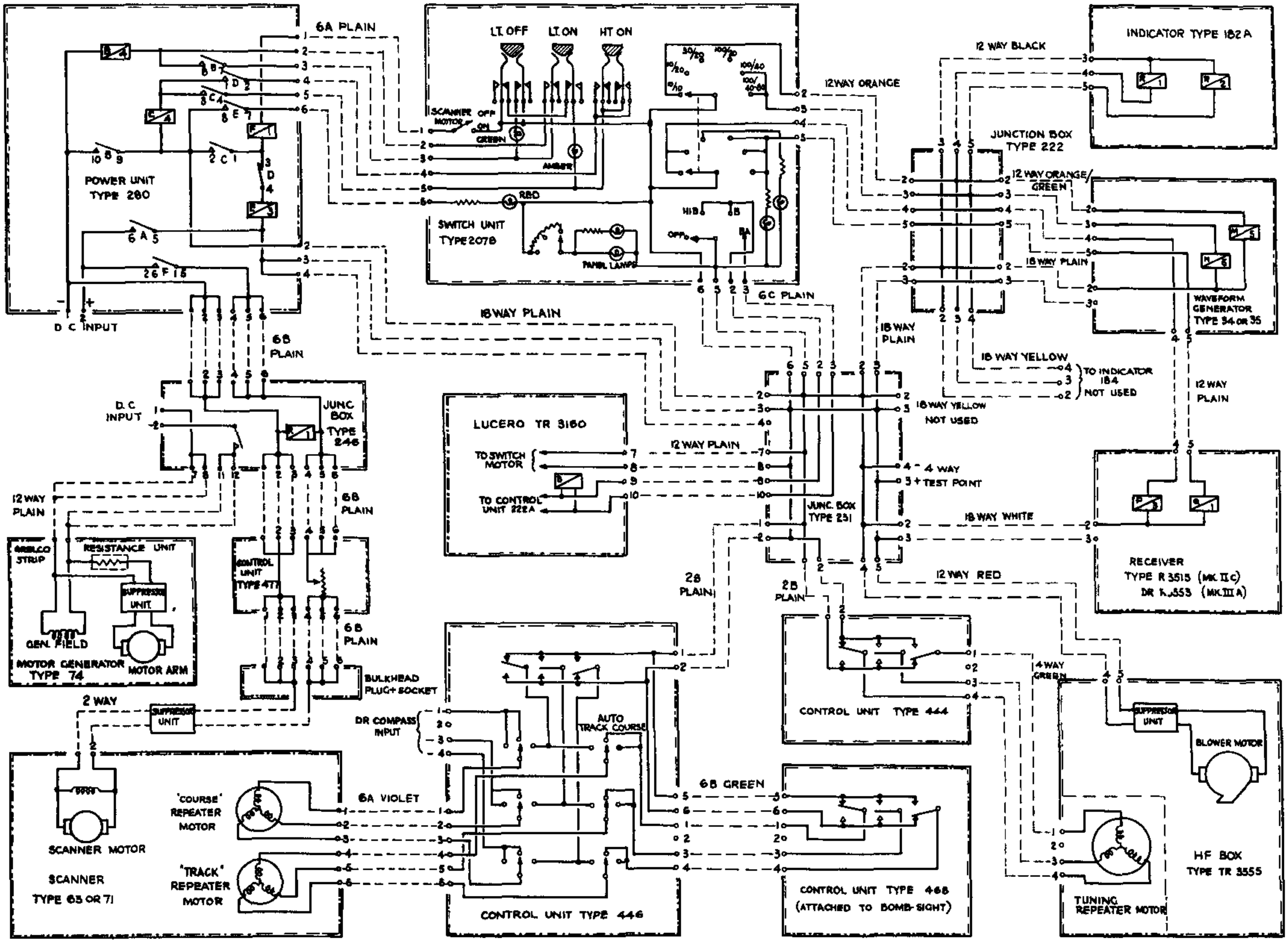


BLOCK SCHEMATIC. MARK IIIA.

FIG. 149

FIG. 149

C.D. 0896 L



FOR MARK II C, THE CONTROL UNIT TYPE 444 IS NOT USED, THE JUNCTION BOX TYPE 231 IS REPLACED BY JUNCTION BOX TYPE 88, THE D.C WIRING OF WHICH IS THE SAME EXCEPT FOR ONE LESS 2B PLUG, AND THE 12 WAY RED IS CODED VIOLET, AND THE H.F BOX TYPE TR 3555 IS REPLACED BY T2R TYPE 3191 WHICH HAS A BLOWER MOTOR BUT NO TUNING REPEATER MOTOR

FIG.150 24V D.C. INTERCONNECTION DIAGRAM MK. III A. FIG.150

CHAPTER 12 - SERVICING AND MAINTENANCE

Summary of the Signal Channels

917. (a) Tx-Timing Pulse - From anode of V.505 in W.F.G. to grid of VR.91 in modulator M.V. via blue Pye plugs on the W.F.G. and modulator 64.

(b) R.F. Output - From magnetron via R.F. output plug to scanner by waveguide or high power coaxial feeder.

(c) R.F. Input - From scanner back to transmitter unit and mixer stage.

(d) L.O. Signal - From klystron oscillator to mixer. In Mark IIC by uniradio 21 feeder from tuning unit 207 to transmitter unit. In Mark IIIA (TR.3555) via coaxial lead from klystron in transmitter to mixer cavity in same unit.

(e) Mixer Output - By Pye cable from mixer to head amplifier grid.

(f) Head Amplifier Output - From head amplifier anode to green Pye on the transmitter unit, thence to green Pye on the RX-T. unit and grid of first I.F.

(g) Lucero Output - From I.F. amplifier anode in Lucero Rx to brown Pye on Lucero, and thence to brown Pye on RX-T unit and grid of first I.F.

(h) Mixed Signals, Heading or Track Marker and Range Marker - From cathode of RX-T. mixer (V.411) to slate Pye on RX-T unit and thence to slate Pye on W.F.G., and grid of buffer C.F., V.512.

(i) Mixer Signals, heading or Track Marker and Range Marker for Height Tube - Taken by condenser inside W.F.G. from slate to red Pye plug. From red Pye on W.F.G. to red Pye on Lucero. Across to orange Pye by condenser (Lucero not operating). From orange Pye on Lucero to orange Pye on indicator 184. Applied to grid of one height tube amplifier valve.

(j) Height Marker - From delay network in cathode of height marker output valve (V.403) to white Pye on the Rx-Timing unit and thence to white Pye plug on Lucero. Across to yellow Pye plug on Lucero (Lucero not operating). From yellow Pye on Lucero to yellow Pye on indicator 184 and grid of other height tube amplifier valve.

(k) Mixed Signals, Heading and Track Marker, Range Marker and Bright-Up For P.P.I. - From cathode of V.508 to black Pye in W.F.G. and thence to black Pye on indicator 184 and cathode of video amplifier; D.C. coupling.

(l) Time Base for Height Tube - From centre-tapped secondary in V.504 anode to 2-pin on W.F.G. and thence to 2-pin on indicator 184 and through scan transformer to deflecting plates.

(m) Time Base for P.P.I. - From centre-tapped secondary in V.504 anode to pins 2 and 6 of 6-pin on W.F.G. and thence to scanner and magslip rotor. From magslip stators in scanner to indicator 184 on 4-pin (via a junction box 222 if Fishpond used). Non-linear timebase developed from magslip output in indicator 184 and applied from anodes of sawtooth amplifiers directly to the X and Y plates.

(n) Trigger Pulse for Markers and Suppression - From cathode of VT.60A in modulator M.V. to violet Pye plug and thence to violet Pye plug on RX-T unit. Direct feed into suppression delay network and delayed pulse fed to grid of suppression generator, V.412. Also fed to primary of transformer T.400. Phase inverted output from secondary goes to cathode of height marker timing valve (V.400). On 30 and 100 mile marker ranges it also goes to cathode of range marker timing valve (V.406).

(o) Signals, Markers and Bright-Up for Fishpond - From V.508 cathode to black Pye on W.F.G. and thence to black Pye on Fishpond. Applied to cathode of Fishpond signal amplifier through a condenser, i.e., A.C. coupling.

(p) Timebase for Fishpond - Master sawtooth from centre-tapped secondary in V.504 anode to pins 2 and 6 of 6-way on W.F.G. Thence to scanner and magslip rotor. Stator outputs on 4-pin to J.B.222. Picked up at J.B. on 4-pin and taken to Fishpond. Developed into required timebase in Fishpond unit.

(q) Trigger Pulse for Fishpond Markers - From cathode of VT.60A in modulator M.V. to violet Pye plug and thence to violet plug on Fishpond. Operates on grid of marker valve if push-button switch pressed.

(r) Trigger Pulse for Lucero - From cathode of VT.60A in modulator M.V. to violet Pye plug and thence to violet Pye plug on Lucero panel. Applied to grid of counting down valve.

(s) Lucero Output - From transmitter tank lecher taps to internal Pye plug and thence to T.R. junction box, switch motor, and aerial feed Pye plugs on panel. Green/white feeds port aerial and red/white feeds starboard aerial.

(t) Lucero Signal Input - From aerial Pye plugs to switch motor and thence to R.F. amplifier in Lucero receiver.

(u) Trigger Pulse for W.F.G.43 (Fishpond Independent Bright-Up - From violet Pye on modulator to violet on W.F.G. 43 and thence through short C.R. and diode to sync. grid of M.V.

(v) Mixed Signals and Markers for W.F.G.43 - From cathode of RX-T mixer to slate Pye on Rx-timing unit, and thence to slate Pye on W.F.G.43. Applied to grid of buffer C.F. stage.

(w) Mixed Signals, Markers and Independent Bright-Up for Fishpond - From cathode of W.F.G.43 mixer (where independent bright-up added) to black Pye on W.F.G.43. Thence to black Pye on Fishpond and direct to Fishpond signal amplifier cathode; D.C. coupling now employed.

Summary of Controls and Test Points

Power Supplies

918. (a) V.C.P. Switch - Determines whether the aircraft D.C. supply gets from input plug to output plug for alternator field.
(b) Alternator Switch - Determines whether regulated 24V. supply reaches alternator field and excites alternator.
(c) V.C.P. Trimmer - Adjusts D.C. supply to alternator field to get 80V. output at normal engine speeds.
(d) V.C.P. Compression Adjustment - Takes up slack in carbon pile to enable satisfactory regulation.
(e) Power Unit Jack Points - Provide checks on the separate power supplies in the unit.
(f) "L.T. ON" Button - Brings heater, 300V. H.T. and -100V. bias supplies into operation and puts +24V. on blower motor.
(g) "H.T. ON" Button - Puts +300V. switched supply into operation when the red light comes up. Trigger valve operates trigger gap on spark gap.

(h) Modulator 64 Switch - Puts 80V. A.C. on primary of -4KV. power pack transformer. If down, transmitter goes into operation when red light comes on.
(i) Scanner Motor Switch - Puts 24V. D.C. on scanner motor.
(j) Lucero "Trans. On" Switch - Puts +24V. on C relay which puts H.T. on W.F.G. Type 30 and brings modulating pulse valve into operation to bring transmitter on.

R. F. Output

919. (a) Modulator P.R.F. Control - Varies D.C. potential to which grid of VT.60A in modulator M.V. is returned and so adjusts p.r.f. of modulator M.V. to permit synchronisation by Tx-timing pulse and locking of Tx to time base.
(b) 30 Mile Zero - On 10/20, 30/20 and 100/20 positions of scan-marker switch it varies point at which sawtooth carries Tx-timing valve into conduction and hence point on sawtooth where Tx pulse appears. By varying point where Tx pulse appears point where signals appear is also varied. By varying point on sawtooth where 20 microsecond pulse forms, it varies point where Fishpond zero marker forms and where suppression, height and range marker appear on the displays.
(c) 10 Mile Zero - Achieves same results on the 10/10 position of scan-marker switch as in (b) but provides wider range of variation.
(d) Scan-marker Switch - Connects Tx-timing valve grid to 10 mile zero slider on 10/10 position, to 30 mile zero on 10/20, 30/20 and 100/20 positions, to 0V. on 100/40 position and to +60V. on 100/40-80 position.
(e) Blue/White Voltage Monitor Point on Modulator 64 - Permits measurement of amplitude of modulating pulse on T.S.28. Shape of pulse will indicate whether overswing diode circuit is operating and whether breakdown is developing in magnetron pulse transformer or heater transformer. Amplitude of pulse is approx. 64 x value measured on T.S.28.
(f) Brown/White Monitor Point on Modulator 64 - Permits measurement of current in modulating pulse. Shows antiphase waveform to that in (e). Current value in amps. is approx. equal to amplitude in volts on T.S.28.
(g) Matching Slug (Mark IIC) - Used to match magnetron to output line and usually set for best signal-to-noise ratio.
(h) R.F. Output Tuning Piston and Matching Iris (TR.3555 Mark IIIA) - Adjusted to get maximum power output from magnetron. May require detuning to avoid moding or frequency pulling.
(i) Tuning Rods and Carriage (TR.3555 Mark IIIA) - Alternative to (h).

R. F. Input

920. (a) Capacity Joint in Scanner Type 63 - Must be correctly aligned in Mark IIC to get best signal input.
(b) Matching Slug - Affects both magnetron output and strength of signal reaching CV.43 in Mark IIC. Set for best signal-to-noise ratio as stated above.
(c) CV.43 Tuning Plungers - Plunger on panel tunes CV.43 to resonance at magnetron frequency. Signal input to mixer reduced if not correctly tuned. Preset plungers fix band covered by panel control.
MK. IIC (d) CV.43 Input Coupling - Adjusted if overcoupling of Tx pulse into cavity causes too much ionisation as indicated by diffused glow in cavity and flat tuning.
(e) CV.43 Probe - Meter connected between input lead and probe to measure ionising current if crystal burning out. Value of current varies with type, see fig.73. Voltage measured with electrostatic voltmeter should be about -700V.

((f) Anti T.R. Tuning Piston - Used in TR.3555 (Mark IIIA) to effectively isolate the Tx channel while receiving signals. Tuned for best signal response as indicated by maximum input to CV.114.

Mk. IIIA ((g) CV.114 Tuning Plunger - Tunes CV.114 to resonance at magnetron frequency (TR.3555 Mark IIIA). Signal input to mixer reduced if not correctly tuned.

((h) Mixer Tuning Piston - Matches crystal mixer to waveguide mixing cavity to get strongest mixer output for a given input in TR.3555.

Local Oscillator

921. ((a) Reflector Volts Control - Varies potential of CV.67 reflector relative to cavity and so varies the feedback and therefore the amplitude of oscillation. Also pulls frequency to some extent.

((b) Coupling Control - Varies angle of coupling loop relative to H vector in cavity field thereby varying output applied to L.O. feeder.

((c) Klystron Output Plug - Crystal adaptor can be attached to check on klystron output by measuring rectified voltage on meter. Values of 8 - 12 ma. normal, depending on crystal.

((d) Klystron Cathode and Reflector - Electrostatic voltmeter used to check for correct potentials. Cathode potential must not drop to less than -1000V.

Mk. IIC ((e) Mixer Capacity Probe - Provides variable attentuation of L.O. input to mixer; used in conjunction with coupling to get maximum crystal current of 0.6 ma. by variation of reflector volts.

((f) Crystal Jack in Transmitter Unit - Used to observe crystal current as an indication of L.O. input to mixer. Also permits measurement of back and forward resistance of crystal. Crystal current should be set to 0.4 ma. and range of variation on reflector volts control should not take value above 0.6 ma. Should be set on slow side of curve.

((g) Tuning Control - Varies cavity volume to vary frequency by means of plunger threading into side. As plunger goes in cavity volume decreases and frequency rises. Adjusted to permit tuning above and below magnetron frequency.

((h) Reflector Volts Control (VR.2)) Effects are interlocked and must
((i) Grid Volts Control (VR.3)) be adjusted together to give
((j) E.H.T. Current Control (VR.1)) simultaneous requirement of
cathode voltage not more negative than -1600V. with an E.H.T. current not in excess of 7.5 ma.

((k) Coupling Loop - Set to maximum.

((l) Mixer Capacity Probe - Adjusted for crystal current of 1.5 ma. with coupling loop at maximum.

Mark IIIA using TR.3555 series ((m) E.H.T. (Klystron) Current Jack - Used to observe E.H.T. current while setting up VR1, VR2 and VR3.

((n) Crystal Jack - Used to observe crystal current while setting up mixer capacity probe and while setting up VR1, VR2 and VR3.

((o) Klystron Cathode - Electrostatic voltmeter connected to klystron cathode while setting up klystron controls to ensure voltage does not go more negative than -1600V.

((p) Remote Tuning Control - Switches D.C. to repeater motor on H.F. box which operates klystron tuning plunger (pressure tuning)

((q) Manual Tuning Control - Operates plunger directly.

Markers

922. (a) Height Zero - Varies potential to which grid of second flip-flop valve (V.402) is tied, thereby varying current through common cathode load and hence grid cut-off of first flip-flop valve. Must be adjusted to set this grid cut-off at the value for which scale was designed. Used to bring markers into coincidence with natural or artificial echo of known range when height control set to the known range.

(b) Height Control - Varies potential from which timing condenser starts its exponential rise and hence varies delay between zero time and time the height marker forms, i.e. when grid of first flip-flop is taken above cut-off.

(c) Height Timing Trimmer - Used by manufacturer to set timing C.R. to value for which the scale was designed.

(d) Range Zero - Performs same function in range marker flip-flop as height zero in height marker flip-flop. Adjusted so that with range control set to zero and scan-marker switch in 10/10 position the range marker and height marker coincide when height control set to 20,000 ft. (after previously setting up height zero).

(e) Range Control - Varies potential from which range marker timing condenser starts its exponential rise, thereby varying delay between zero time and time that range marker forms when grid of first flip-flop taken above cut-off.

(f) Range Timing Trimmer - Used by manufacturer to adjust range marker timing C.R. to value for which scale is designed.

(g) Line of Flight Switch - Puts +300V. on heading marker circuit.

(h) Course-Track Switch on Indicator 184 - Determines which contact in scanner earths the pulse-forming circuits in the receiver-timing-unit. (Set to "Track" when using scanner type 65 or 3 to obtain course marker).

(i) Course-Track-Auto Switch on H.C.U. - Set to "Course" to set up heading marker and to "Track" to set up track marker, and to "Auto" after both set up. Connects D.R. compass to course, and transmitter in control unit to track repeater motors when in "Auto" position. Connects manually operated transmitter in H.C.U. to respective repeater motors when in "Course" and "Track" positions.

(j) Setting Control on H.C.U. - Used to manually operate the course and track repeater motors in the scanner when switch set to "Course" and "Track" respectively. Switches the D.C. connections to the repeater motor windings.

(k) W.F.G. Course-Track Link - Set to "Course" for use with scanner type 65 or type 3. Set to "Course and Track" for use with scanner type 71 and type 63.

(l) The Scan-Marker Switch - Switches D.C. to relays which switch the anode load of the range marker timing valve to give the different marker ranges. Connects the range marker timing valve cathode (V.406) to the anode of the second valve in the height marker flip-flop on the 10/10 and 10/20 positions.

Timebase

923. (a) Scan-Marker Switch - Switches D.C. to relays which switch cathode loads of both master M.V. valves, anode load of 1st master M.V. valve, grid potential of switching valve, and cathode load of switching valve, to get different sawtooth working strokes.

(b) Sync. Control - Varies phantastron screen voltage. Set to give stable phantastron screen operation at the same time that the settings of the other two phantastron controls give freedom from unstable centre and scalloped edges on scan.

(c) Phantastron Screen Volts - Varies potential to which clamping edg cathode line is tied. Set to hold cathode line slightly below -100V. line while giving adequate clamping square wave.

(d) Phantastron Cathode Volts - Varies potential to which clamping diode anode line is tied. Set to hold anode line slightly above -100V. line while giving adequate clamping square wave. Two controls adjusted together.

(e) X-Amplitude Control - Varies negative feedback in X-amplifier pair to give required push-pull overall amplitude and range coverage.

(f) Y-Amplitude Control - Varies negative feedback in Y-amplifier pair to give required push-pull overall amplitude and range coverage. The two amplitude controls must be adjusted for circularity of range marker, i.e., correct relative amplitudes across X and Y plates, and for correct range coverage, i.e., correct vector sum of amplitudes.

(g) Hum-Eliminator Control - A 300 ohm potentiometer connected across the heater line to balance out as much as possible the 1000 cycle hum picked up on the heater line which causes apparent timebase bunching or "spoking". Fitted as a retrospective modification in earlier 184 indicators.

(h) Distortion Corrector - Varies the resistance in the complex charging C.R's to give the correct shape input on the grids of the scan amplifiers in order to obtain a distortion-free display and constant ground range coverage on all scans. Must be set to correct height.

Outputs and Displays

924. (a) Switch Unit Bright-Up Control - Varies potential to which grid of second valve in bright-up flip-flop is returned, thus varying current through the common cathode load and hence the grid cut-off potential of the first flip-flop valve. This permits variation of the point on the sawtooth where the sawtooth carries the first grid above cut-off to start the bright-up pulse. Used to adjust commencement of the bright-up in the 50 mile sawtooth.

(b) W.F.G. Bright-Up Control - Varies the resistance in an integrating circuit in the sawtooth input channel to introduce a deliberate distortion by shunting out high frequency components. This distortion is most effective on the 10 mile sawtooth input, because of its higher proportion of high frequency components. The distortion in the input C.R. results in low frequency loss which effects the 30 and 50 mile inputs most. By using the W.F.G. control only on the 10 mile sawtooth input, and the switch unit control only on the 50 mile sawtooth input, it is possible by means of a few alternate adjustments to start the bright-up at the same point in the scan in all three sawtooth inputs. As long as Fishpond has no independent bright-up these controls will be adjusted to get brightening up of the Fishpond zero marker on all three scans. The 10 and 30 mile zeros will previously have been adjusted to give a zero marker whose diameter is approximately the same on all three scans, i.e., about 1". When the W.F.G.43 is fitted to give Fishpond an independent bright-up both controls are set fully anticlockwise to start the bright-up as early as possible. This is to prevent the appearance of a hole in the centre of P.P.I. display at low altitudes due to the height marker forming and starting the scan before the W.F.G. bright-up commences.

(c) Contrast Control - Varies the potential to which the grid of the video amplifier is returned, thereby varying the current through the common cathode loads of the W.F.G. mixer and the video amplifier. This serves to vary the effective bias on the W.F.G. mixer and so determines how much bright-up square wave is passed by the W.F.G. mixer and applied to the video cathode. The contrast control thus serves as a bright-up amplitude control. As it is carried clockwise, the bright-up amplitude increases. For maximum target detail it should be adjusted to the position where the superimposed range marker just begins to show top-cutting. This setting will pass enough bright-up for Fishpond when no independent bright-up is available. Further clockwise rotation will result in top-cutting or limiting of signals. In the fully clockwise position the video amplifier may be cut-off on the grid.

(d) Gain Control (Mark IIC) - Varies cathode potential of second and fourth I.F. amplifiers to vary amplitude of H.2.S. and Lucero signals.

(e) Gain Control (Mark IIIA using TR.3555) - Varies screen voltage of first four I.F. amplifiers and second head amplifier to vary amplitude of H.2.S. and Lucero signals.

(f) Gain Control (Mark IIIA using TR.3523 series) - Varies screen voltage of first four I.F. amplifiers and of both head amplifiers.

In both Mark IIIA installations the control actually varies the grid potential of the gain control valve to vary the anode voltage which serves as the screen supply for the gain-controlled stages.

(g) Suppression - Varies the delay imposed on the 20 microsecond pulse applied to the grid of the suppression valve. The negative output at the anode is applied to the screens of the 1st and 3rd I.F. stages in Mark IIC and to the suppressors of the first three I.F. stages in Mark IIIA. This suppression pulse has an exponential tail and will keep the receiver insensitive for a time dependent on the suppression setting. Where Fishpond is employed the minimum range of Fishpond cannot be less than the time after the transmitter pulse for which the receiver is held insensitive by the suppression pulse. The suppression control should, therefore, be set for full transmitter breakthrough, then given one click in the opposite direction to apply suppression only for the duration of the primary magnetron pulse. The noise, etc. from the secondary pulses will then come through the receiver but close range Fishpond signals can also come through. As long as their amplitude exceeds the noise amplitude the signals can be seen if the low gain H.2.S. is used and low brilliance is used on Fishpond.

(h) P.P.I. Brilliance - Varies D.C. level of P.P.I. grid relative to its cathode and thus controls emission of P.P.I. and intensity of display. Since high emission means greater spreading of beam due to mutual repulsion between electrons in the beam, the best focus is obtainable with low brilliance.

(i) P.P.I. Focus - Varies potential of focussing anode relative to cathode to converge beam to the sharpest possible point at the screen.

(j) P.P.I. Horizontal and Vertical Shifts - Vary potential to which grid of second stage in each of the sawtooth amplifiers is returned, thereby varying D.C. level at anode of second stage relative to that of first. Since anodes are D.C. coupled to the deflecting plates the anode potential can be balanced to have the flyback take the spot back to the tube centre.

(k) Height Tube Brilliance - Varies D.C. level of height tube grid relative to cathode. Set so that blackout waveform carries grid down far enough to cut out the flyback.

(l) Height Tube Focus - Same operation as P.P.I. focus.

(m) Height Tube Shift - Serves to shift height tube scan vertically so as to put suppression break at the bottom of the tube to provide maximum useful range coverage on the scan. Actually varies the D.C. potential of one X-plate relative to that of the other. As tube is turned through 90° the X-plates are in the position normally occupied by the Y-plates. The control thus serves as a vertical shift although operating on the plates connected to the X-terminals on the base. The horizontal centring of the trace is determined by the relative D.C. levels at the anodes of the height tube paraphase amplifier since these anodes are D.C. coupled to the signal plates.

(n) The Scan-Marker Switch - When set to 100/40-80 position it ties grid of Tx-timing valve to +60V. and so causes the valve to go into conduction about 500 microseconds before the middle of sawtooth. Tx. then fires 500 microseconds earlier and the suppression is also advanced 500 microseconds so disappears off bottom of height tube. Range coverage on height tube then of the order of 40 - 90 miles for homing on long range beacons.

(o) Lucero Switch - When set to "OFF" cuts off 24V. and 80V. supply to Lucero so only normal H.2.S. displays obtained. If set to B + H, B or BA, the 24V. and 80V. supplies are taken to Lucero and the B relay in Lucero is energised to bring the switch motor and mechanical automatic frequency selectors into operation. B relay now disconnects height marker input from yellow Pye on Lucero, so it goes off the height tube. Switch motor now switches the mixture of signal and range markers taken in on the red Pye plug at Lucero between the orange and yellow Pye plugs to give a double sided display on the height tube. If the B + H position used, both Lucero and H.2.S. signals appear. If in the B position, the H.T. supply . s cut-off from the head amplifier in Mark IIC. In Mark IIIA, the H.T. and screen supply to the second head amplifier are broken in the TR.3555 series transmitter units. The H.2.S.

signals are thus eliminated and only Lucero signals appear on the double-sided display. In the BA position, the 24V. supply to B relay in Lucero is completed via pin 10 on the 18-way instead of pin 9, which provides the channel on the B + H and B positions. If a jumper socket is used on the 18-way on the Lucero panel, the change from B to BA will result in an automatic change of the Lucero tuned circuits to permit reception of signals from Lucero blind approach (BABS) beacons. The height tube display may be either single or double-sided depending on the aerial system employed for the reception of BA. signals.

(p) Receiver Monitor Point (Mark IIC) - Permits measurement of detector output for a given C.W.-input to check receiver sensitivity and bandwidth.

(q) Receiver Output Monitor Plug (Mark IIIA) - Spare Pye plug on panel of Rx-T. unit where output of cathode follower between detector and receiver output valve can be scoped or measured to check receiver sensitivity and bandwidth.

Fishpond

925. (a) Range Presets - Adjustable resistors strapping the cathodes of the sawtooth amplifiers. Vary the negative feedback and so adjust the gain to develop an output amplitude that will carry the spot across the screen in about 90 - 100 microseconds, regardless of the sawtooth input. Three presets for each amplifier, one for each sawtooth input. Must be adjusted to have the correct overall amplitudes from each pair which will combine vectorially to give circular markers and range coverage of 4-5 miles.

(b) Scan-Marker Switch - Switches D.C. to relays in W.F.G. which results in change of sawtooth working strokes and simultaneously switches D.C. to Fishpond relays to connect appropriate range preset between the sawtooth amplifier cathodes.

(c) Balance Presets - Vary D.C. level to which grid of second stage in each sawtooth amplifier pair is tied, thus varying gain of one valve relative to that of the other. Used to get push-pull output from each pair in order to get scan rotating about centre when shifts have been previously adjusted to compensate for any deformation of the electrode structure.

(d) Shifts - Vary D.C. potential of one deflecting plate in each pair relative to that of the other. Horizontal shift used to bring vertical scan through centre and vertical shift used to bring horizontal scan through centre.

(e) Brilliance Control - Varies D.C. level of C.R.T. grid relative to cathode. Should be kept as low as possible by operator to detect signals just above noise level.

(f) Gain Control - Varies potential to which grid of signal amplifier is returned and so permits some variation in gain of signal amplifier. When W.F.G. 43 fitted signal amplifier and mixer in W.F.G. 43 will be D.C.-coupled in same way as video amplifier and W.F.G. mixer, V.508. Gain control then operates as a contrast or limiter control. Should then be set for top-cutting of signals to intensify signal response relative to noise response. Brilliance must be low to get best comparative effect.

(g) Contrast Control on Indicator 184 - Determines amplitude of bright-up pulse reaching Fishpond when W.F.G. 43 not fitted. Must be set to provide at least enough bright-up pulse to permit blacking out of scan and flyback.

(h) W.F.G.43 Bright-Up Amplitude Control - Determines amplitude of bright-up pulse passed to Fishpond for a given setting of Fishpond gain control. Must be preset to value which permits adjustment of Fishpond control to cause top-cutting of signals when brilliance control is at minimum. Commencement of bright-up is fixed automatically to back edge of 20 microsecond pulse and Fishpond zero marker.

(i) <u>10 Mile Zero and 30 Mile Zero</u> - Vary potential to which grid of Tx-timing valve is returned on 10 and 30 mile scan, respectively. Thus vary point on sawtooth at which the Tx-timing pulse and 20 microsecond pulse appear. This, in turn, fixes point in Fishpond scan where zero marker appears on these scans. Set to give zero marker of about 1" diameter on their scans so as to get a display which remains sensibly constant as scans are switched.

(j) <u>W.F.G. and Switch Unit Bright-Up Controls</u> - Action outlined in paras. 924 (a) and (b). Adjusted alternately using W.F.G. control on 10 mile sawtooth and switch unit control on 50 mile sawtooth to get zero marker brightened up on all three scans when no W.F.G. 43 fitted.

(k) <u>Marker Switch</u> - Push-button switch which alters D.C. level to which grid of marker valve is returned from about -100V. to about +40V. so that valve is in saturation current on leading edge of positive-going 20 microsecond pulse but cuts off on back edge. Tuned circuit in anode then rings to give damped 93 Kc/s. oscillation whose + pips are used to produce the Fishpond markers. Gives zero marker on 1st positive swing on back edge of 20 microsecond pulse and successive markers at 10.7 microsecond or 1 mile intervals.

(l) <u>Frequency Control</u> - Dust core of coil in ringer circuit can be adjusted if necessary to vary effective inductance in ringing circuit and so get markers giving correct range indications.

<u>Stabilised Scanner</u>

926. (a) <u>Amplifier Unit Switch</u> - Earths grid of V.1 in amplifier unit to reproduce the same conditions in the amplifier unit as would exist when moving platform is horizontal and no misalignment voltage is applied to the amplifier unit.

(b) <u>Amplifier Unit Jack Point</u> - By jacking in a meter, the differences in the anode voltages of the VT.60A's in the D.C. amplifier can be measured.

(c) <u>Amplifier Balance Preset</u> - Varies operating point of grid of first VT.60A. Adjusted until meter reads zero when jack connected to meter inserted at jack point. Anode potentials of the VT.60A's should then be balanced and no net field current applied to motor generator whose armature should then be stationary.

Bench Setting-Up of H.2.S. Mark IIC Installation

Test Equipment Required

927. (a) Monitor 28
(b) Test Set 85
(c) Test Set 202
(d) Electrostatic voltmeter
(e) D.C. milliammeter 0 - 2 ma.
(f) AVO Model D.

Power Supply Checks

928. Before switching on the equipment check that the supply voltages are approximately 80V. A.C. and 28V. D.C.

929. (a) Check that modulator 64 switch is off (up)
(b) Press "L.T. ON" button on switch unit. Green pilot lamp should light.
(c) Check the blower motor is running in the transmitter unit.
(d) Check that indicator 184 panel lamp is functioning
(e) Check that the switch unit panel lamps are operating on the height and range drums. The scan marker switch will have to be switched through the different scans to check the range drum lamps.

930. (a) Check the +300V. and -100V. power supplies with the aid of a 0 - 2 ma. meter and jack at the power unit jack points. Normal readings are :-

	PU Type 280		Type 224	
Jack Point	Normal	Limits	Normal	Limits
+300V.	1 ma.	0.95 - 1.05 ma.	0.3 ma	0.28 - 0.33ma
300V. feed	0.85 ma.	Approx.	195 ma	180 - 210 ma
-100V.	1 ma.	0.95 - 1.05 ma.	1.0 ma	0.95 - 1.05 ma

(b) If these readings are proportionately high or low the V.C.P. 80V. supply is incorrect and requires adjustment.
(c) Should the two voltage readings be in disagreement, suspect the rectifiers.

931. (a) Turn the reflector voltage control on the tuning unit 207 fully anti-clockwise.
(b) Press "H.T. ON" button. Amber light should come on.
(c) Red lamp should come on in less than a minute.
(d) Check that height tube timebase appears.

932. Check the -1800V. supply at the power unit jackpoint. Reading should be 1 ma. ± 0.05 ma. on the P.U. 280 or 1.8 ± 0.05 ma. on the P.U. 224.

933. Check that an overload on the power packs in the power unit will cause the equipment to switch off by putting a 200 ohm resistance between one of the tag points marked "A" on the 300V. transformer and earth.

Crystal Checks

934. (a) Measure the forward resistance of the crystal. This should not exceed 200 ohms as a general rule if measured on an AVO Model D, using the 10K. range or on a Model H using the 20K. range.

(b) Measure the back resistance. This should not be less than 1000 ohms.
(c) Switch the modulator on and off about 6 times and again check the crystal to see whether the values found still hold good. This is to check the surge resistance of the crystal. Log the back resistance on card kept with the unit.
(d) Leave modulator switched off.

Measurement of forward and back resistance of crystals does not establish with absolute certainty that the crystal is either good or bad. The tests apply to the majority of crystals but crystals failing to pass the tests may occasionally give reasonably good sensitivity while crystals passing the tests may prove unsatisfactory. The only positive check on a crystal is the comparative sensitivity when the cyystal is put in a known good set instead of a known good crystal.

Initial Setting-Up of Crystal Current

935. (a) Set coupling loop of CV.67 to midway position using the preset on the tuning unit 207.
(b) Plug in a 0 - 2 ma. D.C. meter at the transmitter unit crystal current jackpoint.
(c) Turn the reflector volts preset clockwise while observing meter reading. Determine which is the stable or slow side of the crystal current peak. If reading tends to exceed 0.6ma reduce coupling at tuning unit 207 or adjust capacity probe at mixer until peak reading obtainable with the reflector volts preset does not exceed 0.6 ma. Set reflector volts to give 0.4 ma. on stable side of characteristic.

CV.43 Checks

936. (a) Switch off the -1800V. supply by pressing "L.T. ON" button.
(b) Check that amber light goes out.
(c) Disconnect lead to CV.43 top cap and connect to negative side of D.C. milliammeter. Connect positive side of meter to the CV.43 top cap.
(d) Press "H.T. ON" button to reapply -700V. to CV.43. The meter will read the ionising current between the probe and the earthed rhumbatron. Older type CV.43 had a normal current of about 1 ma. Later types take only about 0.5 ma. (see fig.73d). If satisfactory ionising current is present assume CV.43 is operating.
(e) Check CV.43 heater jacket after the equipment has been on for a few minutes when the bakelite jacket should show signs of becoming warm.

Obtaining Signals

937. Necessary conditions to obtain signals :-

(a) Scanner looking at a target.
(b) Transmitter supplying enough power to make possible the return of an echo of sufficient strength to produce a visible indication.
(c) CV.43 tuned so that magnetron frequency lies in the range which will resonate the CV.43 cavity.
(d) L.O. frequency differing from magnetron frequency by a value within the I.F. passband.

If follows then that if the matching slug, CV.43 tuning plunger and klystron tuning are badly misaligned, some difficulty may be experienced before a signal can be obtained on the display.

Points to bear in mind

938. (a) Magnetron output depends on setting of matching slug which gives best match to output line.
(b) Alteration of matching slug position may cause variations in magnetron frequency.
(c) Change in magnetic field strength may affect both magnetron frequency and power output. This is particularly applicable when working with cover on and cover off the transmitter unit when the magnetic field strength is near or below the critical value. The effects will be more significant on a poor magnetron than on a good one.
(d) Changes of the klystron reflector voltage will cause frequency changes as well. Changes in feedback and amplitude of oscillation will cause crystal current to fall. Frequency changes may occur without crystal current falling, but signal strength may still fall due to wrong I.F. coming out of mixer.
(e) Crystal sensitivity is normally at a maximum when the crystal current is 0.3 ma. or above. If the current falls below this value, due to retuning of klystron which upsets the feedback phasing, the sensitivity may fall. Hence as klystron tuning varied it is necessary to keep an eye on the crystal current and readjust reflector voltage if crystal current falls.

Matching the Magnetron

939. (a) Check that the high power feeder connections at the transmitter unit and scanner are clean and firm, and that any dielectric gap in the plugs is taken up by use of the washers provided.
(b) Check that amber and red lights are on at the switch unit. Switch modulator on.
(c) Check that to overload relay trip is functioning by removing the pulse lead from the modulator 64 to the transmitter unit. The relay should trip immediately.
(d) Rotate the scanner to shoot at the pre-positioned test set 85.
(e) Check that the R.F. output is up to the value known to be standard for good sets. Readjust matching slug if necessary to obtain this power output.
(f) Watch for any sign of arcing in the transmitter unit.

Searching for Signals with L.O.

940. (a) If satisfactory R.F. power output is forthcoming point the scanner in the direction of the strongest permanent echo available.
(b) Connect the monitor 28 input lead to the slate Pye plug on the receiver-timing unit. Use 100 microsecond timebase and amplifier in X5 or X10 position.
(c) Rotate tuning control on tuning unit 207 watching the monitor 28 for the appearance of a signal. Keep an eye on the crystal current while tuning and readjust reflector volts, if necessary, to keep current above 0.3 ma. and stable.

CV.43 Tuning

941. (a) As soon as a signal is obtained adjust CV.43 tuning plunger. Note sharpness of tuning. It should be possible to drop the signal amplitude with three-quarters of a turn of the tuning plunger from either side of the peak point.
(b) Should the tuning appear flat, particularly on short range signals, remove the tuning plunger and observe the ionisation at the lips. For correct operation a violet haze should be visible only across the lips and not spreading out into the cavity.

(c) If there is evidence of a diffused glow spreading out into the cavity the coupling from the CV.64 output line into the CV.43 cavity is too tight. To remedy this fault, it is necessary to remove the CV.43 from the transmitter unit and place a thin washer between the CV.43 bush (which carries the loop coupling into the cavity) and the cavity itself. Nominal washer thicknesses are of the order of 1/32" to 1/16". Before replacing the loop and bush ensure that the plane of the loop embedded in the polystyrene is left in the vertical plane in order to get the strongest input coupling for signals. The actual thickness of the packing washer must be limited to a value which serves to limit the diffused glow to the cavity lips but does not cause a decrease in the S/N ratio.

Final Setting of R.F. Controls

942. (a) Put cover on transmitter as far as possible while still permitting access to the matching slug. This precaution is to have the effective field strength of the magnet as nearly as possible at the value it will have when the cover is on the unit.

(b) Adjust matching slug for maximum signal to noise ratio. Alternate adjustments of matching slug and klystron tuning on the weakest stable signal will be necessary to obtain the best matching slug setting since the magnetron frequency is likely to shift as the slug setting is varied.

(c) When optimum point found tighten the matching slug.

(d) Adjust CV.43 tuning for best S/N ratio and lock the clamp.

(e) Check for two tuning points on the CV.67. If not obtainable adjust the fixed plungers until two tuning points are obtainable on the tuning control with a bit of leeway at each end of travel of control.

(f) Check the two tuning points for best S/N ratio, readjusting crystal current to 0.4 ma. at each point with the reflector volts control. Leave tuning control at point which gives the best S/N radio with reflector volts set for 0.4 ma.

(g) Adjust coupling preset so that reflector volts preset will give a variation of 0.2 to 0.6 ma. on the slow or stable side of the crystal characteristic. This may require readjustment of the capacity probe.

Field Strength of Magnet

943. (a) For optimum power output and maximum frequency stability the first strength of the magnet should not be less than about 1250 gauss, measured with the magnet on the chassis and the cover on. Use of the Cambridge fluxmeter for field strength measurement is outlined in chapter 11, paras. 838 - 843.

(b) A rough check can be made by comparing the readings obtained on a T.S.85 with the transmitter unit cover off and the matching slug adjusted for maximum output, with the reading obtained when the cover is put on as far as possible and the matching slug again adjusted for the maximum power output. Due to the reduction of the field strength when the cover is put on a normal reduction of about 10% may be expected with the average magnet and CV.64. A greater reduction implies a weak magnet.

Setting Suppression

Fishpond not used.

944. (a) Set gain to normal.

(b) Set suppression preset fully anticlockwise and observe breakthrough after suppression break on the monitor 28 trace.

(c) Advance suppression one notch at a time until breakthrough just eliminated. Should normally be possible to do this with 3 or 4 notches on the suppression control. Should more than this be necessary a faulty component or lead should be suspected. Dummy load elimination tests should then be carried out as outlined in para. 1088.

CHECKING TEST SET TYPE 202 DIVIDERS

C.D. 0896L

①

TEST SET 202

CAL INTERVAL SWITCH TO 500 FT
REP FREQ SWITCH TO 600N
+50V OUTPUT TO MONITOR INPUT

MONITOR 28

TB SWITCH TO 10 μSECS
AMPLIFICATION TO ×5

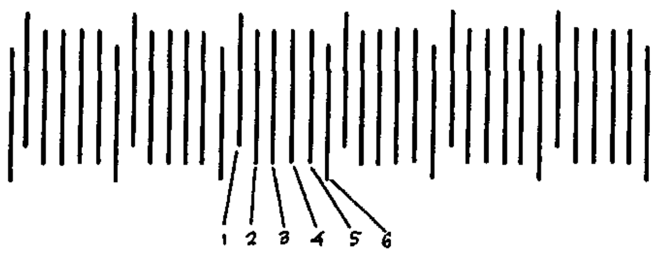
500 FT CAL PIPS (1·017 μSECS EACH)
IF CALIBRATIONS ARE UNSTABLE ADJUST "600N" POT.

②

AS ABOVE

TB SWITCH TO 100 μSECS
AMPLIFICATION TO ×5 OR ×10

CHECK DIVISION BY 6



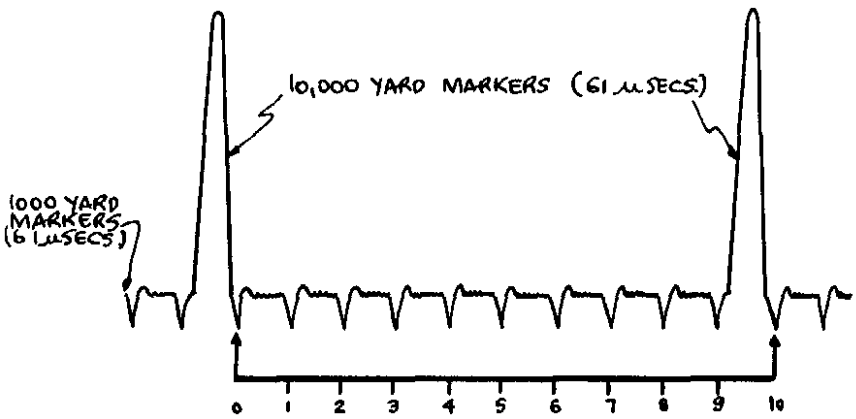
NOTE THAT LEVEL OF EVERY 6TH PIP IS EXTENDED, IF NECESSARY ADJUST POT MARKED "×6"

③

CAL INTERVAL SWITCH TO 10,000 YDS

MONITOR - AS PREVIOUS STAGE

CHECK DIVISION BY 10



TO OBTAIN CORRECT DIVISION BY 10 ADJUST POT MARKED "×10"

NOTE: TEST SET SHOULD BE ALLOWED TO RUN FOR A FEW MINUTES BEFORE CHECKING DIVIDERS WHICH SHOULD BE CHECKED WHENEVER THE TEST SET IS USED.

FIG. 151

TEST SET 202. BENCH CONNECTIONS.

C.D. 0896L

SHOWING TRIGGERING AND MONITOR INPUT CONNECTIONS
H2S CABLING IS NORMAL EXCEPT MODULATOR SYNC. (PYE BLUE), WHICH IS FROM TEST SET 202 20μsecs PULSE INSTEAD OF FROM W.F.G.

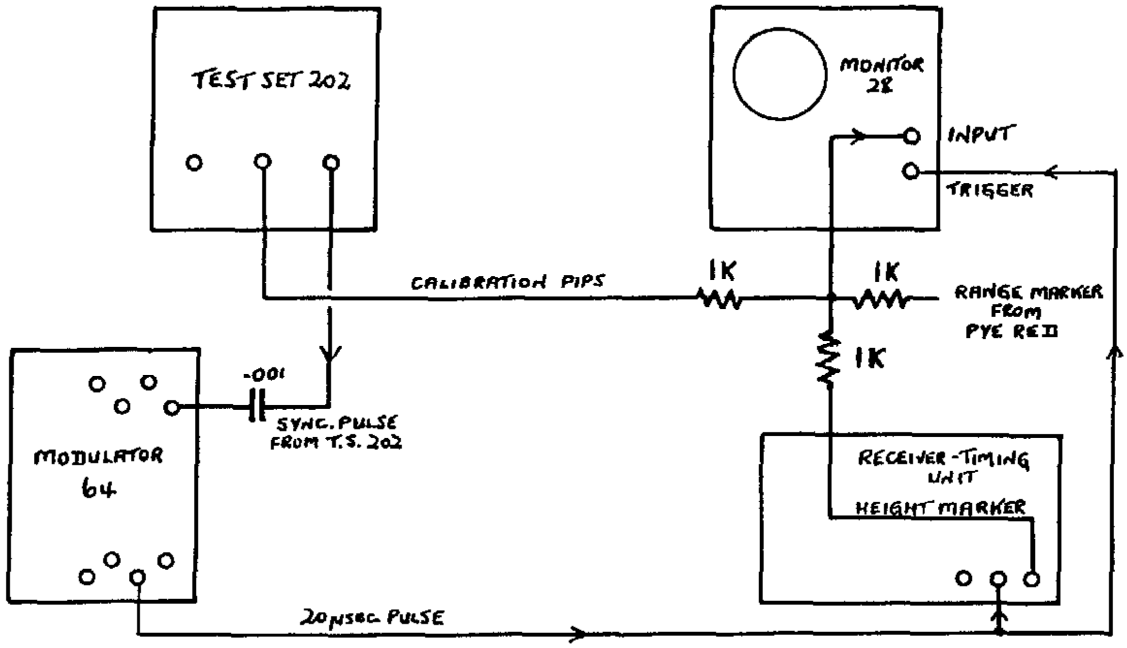
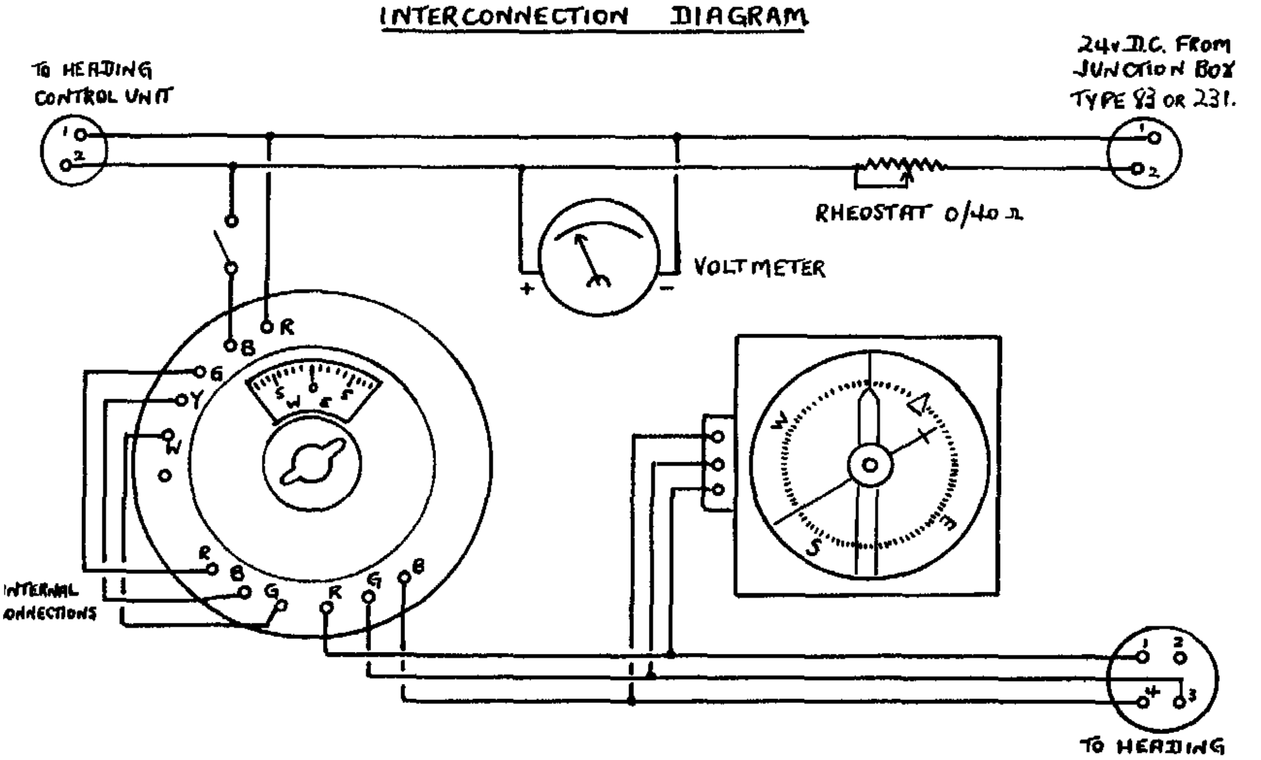


FIG. 152

REPEATER MOTOR TEST INSTALLATION INTERCONNECTION DIAGRAM



VARIATION SETTING CORRECTOR (V.S.C.) REF. 6A/1056.
D.R. REPEATER COMPASS (PILOT'S) 6A/742
RHEOSTAT. (40 OHMS) 5C/728

FIG. 153

Fishpond used :-

945. (a) Set gain to low level.
(b) Take suppression control fully anticlockwise and observe breakthrough after suppression break on monitor 28 trace.
(c) Take suppression one notch clockwise from point where all or nearly all of breakthrough comes through the receiver. This will permit some noise to come through on Fishpond but signals can also come through. Further suppression will mean that minimum range is definitely fixed by the time for which the suppression pulse holds it in the insensitive state. The objective is to apply suppression only for the one microsecond primary pulse and let the secondary pulses and close range signals come through together.

Setting up the Height Zero

946. (a) Check the T.S.202 dividers as outlined in chap.11, para.801.
(b) Set p.r.f. switch on T.S.202 to 600 position.
(c) Apply 20 microsecond output from T.S.202 to the blue Pye plug on the modulator 64 through a .001 condenser. The pulse is differentiated and the negative-going pip on the back edge serves to sync. the modulator M.V. instead of the Tx-timing pip.
(d) Trigger the monitor 28 from the violet Pye plug on the modulator 64.
(e) Check that the T.S.202 is synchronising the modulator 64 to run at a p.r.f. which is as close as possible to the p.r.f. obtained when the Tx-timing pulse is used. This can be done by adjusting the 600 c/s. preset on the T.S.202 to bring the length of the T.B. sweep on the monitor 28 in the "Freq." position as nearly as possible to the length obtained when the modulator is being synchronised by the Tx-timing pulse.
(f) Set monitor 28 for 10 microsecond T.B. and input switch to "Direct".
(g) Intercept the red and white Pye leads and connect these, together with the 5 volt negative calpips, to the monitor input. A 1K. resistor should be incorporated in each of these inputs to the monitor. Adjust the suppression control on the receiver so that it is between two notches (i.e., no suppression applied to the Rx). The Tx pulse breakthrough will then appear on the screw. Turn gain control to minimum.
(h) Adjust monitor 28 T.B. start so that the leading edge of the Tx pulse is at the commencement of the scan. The start of the scan now represents zero time and the T.B. start control must now be left in its present setting.
(i) Set calpip switch to 500' position. Observe the 1 microsecond pips on the trace. Now set switch to the 1000 yard position and note position of first 1000 yard marker. Calculate the time in microseconds from the beginning of the scan, i.e., zero time, to the first 1000 yard marker, by putting the 500' and 1000 yd. markers alternately on the timebase and noting which of the 500' markers coincides with the first 1000 yard marker. This time will normally be in the region of 2 microseconds. Suppose that the first 1000 yard marker appeared 1.4 microseconds after zero time. The position of the marker then represents a range of 1.4 x 500 = 700'. Each subsequent 1000 yard marker represents 6.1 microseconds or 3000'.
(j) Set T.B. switch for 100 microsecond T.B. and input switch for sufficient amplification to show both cal. pips and height marker on the trace.
(k) Determine what range the second 1000 yard marker represents by adding 3000 feet to range found for the first 1000 yard marker and set height drum to this range. If height marker does not now coincide with the second 1000 yard marker adjust the height zero till it does.

Checking Height Marker Tracking

947. (a) Vary the height control setting to shift the height marker from one 1000 yard marker to the next along the timebase, checking that the reading on the height scale increases by 3000 per step.
(b) If the tracking is incorrect it may be advisable to readjust the height zero for accuracy at the nearest calibration marker to the 20,000 point to obtain accuracy at operational heights.
(c) If tracking is badly out and the 300V. stabilised output is not out by more than ± 5%, the unit should be returned to the M.U. for realignment.

Setting Range Zero

948. Set height control to 20,000' (height marker not in coincidence with any of the calibration pips). Set scan-marker switch to the 10/10 position and range control to zero. Adjust range zero for coincidence between height marker and range marker. Since the range marker and height marker are of different widths the leading edges cannot be accurately aligned if the two markers are superimposed on any of the calibration markers.

Checking Range Marker Tracking

949. (a) Set the height control to the 1000 yard marker nearest the 20,000' setting of the height control. If the first 1000 yard marker represented 700 ft., this would be 18,700 ft.
(b) Check whether range scales are in statute or nautical miles.
(c) Set the range drum to put the range marker successively into coincidence with the 1000 yard markers along the trace while leaving the height control set to keep the height marker on the 1000 yard marker nearest the 20,000 point. Check the range drum reading against the figures in the appropriate column in the table below:

Height Control Setting	Range Marker from Height Marker	Range Drum Reading	
		Nautical	Statute
	-	-	-
	1000 yards	1.9 miles	2.2 miles
	2000	2.7	3.2
	3000	3.5	4.0
	4000	4.1	4.75
20,000'	5000	4.7	5.5
	6000	5.3	6.1
	7000	5.9	6.8
	8000	6.5	7.4
	9000	7.0	8.0
	10000	7.6	8.7

The figures tabulated are based on a height setting of 20,000 ft. and are accurate to 0.1 mile. The accuracy of reading will hardly be sufficiently great to show differences from these values for any setting of the height control to the 1000 yard marker nearest the 20000' point.

(d) If the tracking does not follow the above table closely, readjust the range zero to obtain the greatest accuracy in the range 3-7 miles.

(e) If tracking is badly out and the stabilised 300V. supply is not out by more than ± 5%, the unit should be returned to the M.U. for realignment.

Calibration of Monitor 28 for use in Aircraft

950. (a) Having correctly set up the height and range markers with the Test Set 202, the monitor 28 may now be calibrated for use in aircraft. Using the H.2.S. set that has been correctly set up and the X-shift on the monitor set to "10", adjust the T.B. start so that the leading edge of the Tx pulse is in line with the cursor line on the celluloid window. It may be necessary to mark a new line to the left of the original or to turn the knob of the X-shift relative to its spindle.

(b) Set the height drum to exactly 20,000 feet and the range drum to 4 miles, and apply the height and range markers to the monitor. Turn the X-shift until the height marker comes in line with the cursor and mark the X-shift scale "20,000 ft." (This will be about 40 microseconds after the leading edge of the Tx pulse, but as the timebase is not linear it is unlikely to agree with the original calibration markings).

(c) Move the X-shift further anticlockwise until the range marker is behind the cursor line and mark the shift scale "4 Miles 10/10".

(d) The monitor 28 is now calibrated for the adjustment of height and range zeros in aircraft. The range of 4 miles and height of 20,000 feet have been selected to ensure the greatest possible accuracy at the release point at operational height. When calibrating the monitor and when using it in an aircraft, it is essential that the A.C. input should be 80 volts ± 1 volt. The marking of the X-shift should be done in ink and the calibration must be checked on the bench on the day that the monitor is used in the aircraft. Further details regarding the use of the monitor in the aircraft after it has been calibrated in this manner, are given under D.I. procedure in para. 1041.

Setting up the Indicator 184 P.P.I. Display

Points to be borne in mind on the timebase controls :-

951. (a) The timebase must be triggered by the height marker. This involves clamping the grids of the 1st stage in the X and Y timebase amplifiers until the height marker forms.

(b) The timebase must always start its sweep from the tube centre when triggered by the height marker. This means that the flyback must return the spot to the tube centre. Since the sawtooth paraphase amplifier anodes are D.C.-coupled to the X and Y plates, the D.C. levels at the anodes of each pair must be balanced if no electrode deformation is present. If any deformation is present the D.C. levels at the anodes must be suitably unbalanced to compensate for this deformation. This balancing can be done with the shift controls which vary the D.C. level of the grids of the second stage in each amplifier pair relative to that of the first grid and thus vary the standing currents passed by the two valves during the 500 micro-second clamped period.

(c) To obtain a constant amplitude radial scan, i.e., freedom from "squaring", it is essential that the clamping waveform amplitudes exceed the maximum swings at the grids of the first stage in each sawtooth amplifier during the scanning period. If this condition is not fulfilled the diodes may open before the scan is completed and cut the scan short. The same result may be produced if the amplifiers show signs of "bottoming", i.e., the anode potentials fall so nearly to the cathode potential that a further rise at the grid (or fall at the cathode) does not result in a further anode fall.

(d) Unstable centre effects may appear if either the strapped diode cathode line has a D.C. level positive to the clamping level or the strapped diode anode line has a D.C. level negative to the clamping level.

(e) The simultaneous fulfilment of the conditions of adequate clamping waveform amplitudes and correct D.C. levels for the strapped diode lines results in a very narrow range of settings for the phantastron cathode and screen volts controls.

(f) The phantastron operation must be stable at the time time as providing the correct D.C. levels for the diode lines and adequate clamping amplitudes. To provide a narrow range of adjustment of phantastron operating conditions we have the sync. control which varies the screen potential of the phantastron.

(g) The phantastron must not be capable of spurious triggering during the 500 microsecond clamping period. This requires that anode current be cut off in this period.

(h) The range coverage obtained on any setting of the scan-marker switch is governed by the rate at which the anode potentials change in the sawtooth amplifiers for a fixed given rate of change on the grids. The rate of change at the anode for a given rate of change at the grid is fixed by the gain of the valve. Since the controls strapping the cathodes of the sawtooth paraphase amplifiers vary the negative feedback of the stage they vary the gain, and therefore, serve to obtain a certain swing at the anode in the time corresponding to a given range; i.e., they serve as velocity or range controls as well as amplitude controls.

We may then summarise the timebase problem as follows:-

952. (a) If we are getting some form of scan we know the phantastron is triggering.
(b) By observing the phantastron screen waveform we can see whether the phantastrong operation is stable, and if not, we can adjust the sync. control for stability.
(c) With the scanner rotating it is possible to see whether "squaring" or unstable centre effects appear and adjust the cathode volts and screen volts controls for freedom from both these effects, thus indicating that the D.C. levels of the diode anode and cathode lines are satisfactory and that adequate clamping waveform amplitudes are available. If necessary, the sync. control can be readjusted.
(d) If a Cossor scope or D.C. scope attachment is available a check can readily be made that the phantastron anode current is being cut off during the 500 microsecond clamping period. If not available, a check can be made by connecting a meter in the phantastron anode with the height marker triggering removed.
(e) The scan can be centred by adjusting the shift controls.
(f) The range coverage can be adjusted by means of the amplitude controls.

Setting up the Phantastron Controls.

953. (a) Set scan-marker switch to the 100/40 position.
(b) Switch on and note whether some form of scan is present. Contrast and brilliance may require some adjustment to make it appear.
(c) Disconnect the signal input at the red Pye plug on the indicator 184 and apply instead the signal picked up at the slider of the phantastron screen volts control. This is the positive-going clamping square wave from the phantastron screen which will now appear as a deflection to the right on the height tube. This may appear as follows:-
  (i) Steady square wave.
  (ii) Unstable square wave with flickering top.
  (iii) Square wave with trace through base indicating that phantastron is not triggering on each height marker.
  (iv) No square wave at all (if no scan on P.P.I.)
(d) Adjust the sync. control to the mid-point of the range of adjustment which gives a stable square wave. If necessary to get a reasonable range of stability, slightly readjust the screen and cathode volts controls.
(e) Remove the height marker triggering by disconnecting the yellow Pye plug and note whether the square wave disappears. This check is important to ensure that the phantastron is not triggering on stray pickup. If such spurious triggering occurs, readjust the sync. and cathode and screen volts to eliminate it, and reset the sync. control to the mid-point of the stable range. With the height marker reconnected, check that square wave commences coincident with the height marker and moves with the height marker as the height control setting is varied. If difficulty from spurious triggering not curable by adjustment of phantastron controls, check that anode current in phantastron is cut off when height marker disconnected.
(f) Adjust brilliance and contrast to bring up the W.F.G. bright-up on the P.P.I. and set the amplitude controls for minimum scan amplitude.
(g) If the scan starts badly off-centre adjust the H and V shifts for approximate centring.

(h) With scanner rotating check for presence of unstable centre and/or scalloped edges. The check for scalloped edges is most readily made by setting the range marker to the end of the scan and noting its shape. Adjust the screen and cathode volts controls to get rid of unstable centre and scalloped edges or squaring.
(i) Switch to 10/10 position and note whether same freedom from both effects obtained. If necessary, slightly readjust cathode and screen volts controls.
(j) Switch back to 100/40 position and recheck sync. control for setting in centre of stable range by putting square wave on height tube again.
(k) Readjust H and V shifts for better centring if necessary.

Setting of Hum-Eliminator Control.

954. (a) Turn scanner for horizontal scan.
(b) Turn Y-amplitude control to maximum but leave X-amplitude control at minimum.
(c) The timebase will now appear as a series of traces due to effect of 1000 c/s pick-up on the heater line appearing at the anodes of the Y-amplifiers and hence across the Y-plates.
(d) Adjust the hum-eliminator control until the width of the band of traces is reduced to a minimum.
(e) Turn Y-amplitude control back to minimum.

This adjustment is only required in earlier 184 indicators which are not provided with a centre-tapped heater system.

Setting up Amplitude and Shift Controls.

955. (a) Set scan-marker switch to 30/20 position.
(b) Set range control for 20 statute or 17 nautical miles.
(c) Adjust amplitude controls for reasonably circular range marker at outer edge of tube. Due to differences in the deflection sensitivities of the X and Y plates the marker may remain slightly elliptical with the Y-diameter rather greater than the X-diameter.
(d) Set range control to bring range marker about half-way out and check that it is circular. If necessary, slightly readjust the amplitude controls.
(e) Readjust H and V shifts for centring, if necessary. As varying the setting of the amplitude controls may alter the relative currents through the two valves in each amplifier pair a slight readjustment may be needed.
(f) Switch to 10/10 position and set distortion corrector to 25,000.
(g) Set range control to 10 statute or 8.5 nautical miles.
(h) Adjust 10 mile zero so that range marker appears at edge of scan. Remove 10 mile zero knob.
(i) If no Fishpond fitted or W.F.G.43 fitted to supply independent bright-up for Fishpond, set the W.F.G. and switch unit bright-up controls fully anticlockwise. This ensures that the W.F.G. bright-up starts as early as possible.
(j) Check that no hole appears in the centre of the P.P.I. when the height is reduced and the distortion corrector setting is varied accordingly. The appearance of a hole indicates that the W.F.G. bright-up is commencing after the formation of the height marker and phantastron bright-up.

Checking Distortion Corrector.

956. Check that range coverage obtainable with the range marker remains sensibly constant as distortion corrector and height control are varied in step from 25,000 to 5,000'.

Setting-Up Contrast, Brilliance and Focus.

957. (a) Set contrast, brilliance and gain fully counter-clockwise.
(b) Turn brilliance clockwise until trace and flyback just appear then turn brilliance back four notches.
(c) Turn contrast clockwise until radial scan just appears, then turn back one notch from fadeout point. This is a convenient way of setting the contrast control to the point where top-cutting of the range marker and strong signals just commences. Put index line on contrast knob and dot on panel behind it.
(d) With scanner stationary, adjust focus for sharpest range marker dot.
(e) Turn brilliance back counter-clockwise until range marker luminosity just starts to fall. This fall of luminosity must not be confused with any alteration in the shape of the range marker dot. The normal movement will be 3-5 notches. Put index line on brilliance knob and dot behind it on panel.
(f) Turn gain to a normal setting.

The inexperienced navigator would be well advised to leave the brilliance and contrast controls set at these index marks and work on gain only. Further clockwise rotation of the contrast control will result in top-cutting of signals and loss of target detail. To bring up coast-lines, lakes and rivers, this will be desirable. The same may apply when it is desired to get a target outline rather than target detail. The experienced navigator may be able to obtain slight improvements on these settings but can always use these settings to get a normal display.

Setting up Height Tube Controls.

958. (a) Adjust brilliance to suitable level and check that flyback is blacked out.
(b) Adjust shift to bring suppression break to bottom of tube.
(c) Adjust focus for sharpest picture.

Adjusting Synchronisation of Tx.

959. Vary setting of modulator p.r.f. control and note from height tube display the point or points at which the signals and markers become unlocked. If two points observed set the control at the mid-point. If only one point observed set the control three notches back from the point. The locking point should normally be within ± 3 notches of the red index dot.

Checking Modulating Pulse.

960. (a) Check amplitude of modulating pulse by scoping at the blue/white voltage monitor Pye plug on the modulator 64 panel. Take amplitude at mid-point of the second "ring" rather than at first sharp spike. This will normally be of the order of 50V. Multiplication by 64 gives the approximate voltage.
(b) Check current value of modulating pulse by scoping at one of the brown/white current monitor points on the modulator 64 panel. Measure amplitude to the mid-point of the "rings" on the top of the pulse. This amplitude gives the approximate current value which will be of the order of 50 amps.
(c) If the observed values are radically different from normal values check the -4KV. voltage with an electrostatic voltmeter and a suitable voltage divider.
(d) Check width of pulse at half amplitude. It should be approximately 1 microsecond.
(e) Check that the first positive overswing on the voltage waveform is not of abnormal amplitude and that subsequent overswings are negligible. If this is not the case suspect overswing diode or its load.
(f) If other abnormalities appear when -4KV. supply is normal, suspect magnetron, pulse transformer, filament transformer pulse cable and pulse leads.

Scanner and Control Unit Checks.

Checking Scanner Speed.

961. (a) Check that scanner revolves freely when the scanner switch is closed on the switch unit.
(b) By varying the control unit 477 speed control, check that the scanner speed can be varied smoothly between 20 and 60 r.p.m.

Checking Course and Track Marker Circuits and Controls.

962. (a) Set indicator 184 switch and H.C.U. switch to "Course". Check that heading marker is present and that it can be moved with the manual setting control on the H.C.U.
(b) Set indicator 184 switch and H.C.U. switch to "Track" and note that a marker appears. Check that it can be displaced $\pm 60^\circ$ from the heading marker on the P.P.I. by varying the setting control on the H.C.U.

Checking Repeater Motor Operation.

963. (a) Connect up the testing equipment as indicated in fig.153.
(b) Adjust rheostat to give 18-20V. reading on meter.
(c) Set H.C.U. switch to "Course".
(d) Check that heading marker can be moved without sticking through 360° in both clockwise and anticlockwise directions with the setting control on the H.C.U.
(e) If the course repeater motor passes this test, set the heading marker to read the same bearing as the repeater compass and put H.C.U. switch to the "Auto" position.
(f) Switch on the V.S.C. and turn the control knob on the V.S.C. slowly till rotation of the repeater card and heading marker commences. After a few revolutions stop the V.S.C. and check the bearings of the repeater compass and heading marker. If no slipping of the repeater motor has occurred the readings will coincide. It may then be assumed that the repeater motor will follow the D.R. compass.
(g) Should slipping appear, the scanner must be taken down and the repeater gear train cleaned and greased as outlined in scanner maintenance, paras.1064 and 1066.

964. (a) Set 184 and H.C.U. switches to the "Track" position.
(b) Check that by using the manual setting control the track marker can be moved 60° either side of the heading marker with the D.C. supply set at 18-20V.
(c) If this is impossible, the repeater motor and the driving link must be cleaned and greased as outlined in scanner maintenance, paras.1064 - 1067.

Alignment.

965. (a) Check that scanner is looking dead ahead when the white lines on scanner base casting are lined up.
(b) Check that the "course" contact just comes into contact with the shorting contact as the scanner comes into the dead-ahead position, by taking a continuity test between pins 10 and 12 at the 12-way on the receiver-timing input. The scanner must be rotated in its normal direction of rotation and continuity should be established as the white lines come into coincidence.
(c) If misalignment appears the "Course" contact must be aligned as outlined in para.1071.

Stabilised Scanner and H.C.U. Type 446 Wiring.

966\. (a) The wiring of Control Unit 446 and the Course and Track M motors on the Scanner (Scanner Type 63 in H.2.S. Mark IIC and Scanner Type 71 in H.2.S. Mark IIIA) has been arranged so that in both the Course and Track 'manual' positions on the Control Unit clockwise rotation of the control knob gives clockwise rotation of the markers on the Indicator 184.

(b) In the 'Auto' Course position, the Course marker bearing will follow the aircraft heading, assuming the aircraft D.R. compass wiring is correct; in the 'Auto' Track position the Track marker is correctly synchronised to the Bombsight Computer. In the latter case, clockwise rotation of the flexible shaft on Control Unit 468 should give anti-clockwise rotation of the track marker on the Indicator.

967\. The M Motors on the Scanners 63 and 71 are connected to a 6-way W plug (violet) and the connections on the M motors are labelled 1, 2 and 3. In order that the above conditions of rotation be satisfied, the W plug connections to the M motor must be as follows:-

Pin	1	connected	to	1	on	Course	M Motor.
"	2	"	"	32	"	"	" "
"	3	"	"	2	"	"	" "
"	4	"	"	1	"	Track	" "
"	5	"	"	2	"	"	" "
"	6	"	"	3	"	"	" "

968\. The first few Type 71 Scanners from the manufacturers have been wired differently. On Scanners Type 71 with serial number less than 26, this wiring should be checked before installation, and if wrong, corrected. Scanners with serial numbers above 25 will be correctly wired.

969\. The earlier RPU versions of Control Unit 446 are known to cause the Course marker to rotate in the opposite sense to the aircraft in the 'Auto' Course position. This unit should be ground tested in the aircraft in the 'Auto' Course position by means of the V.S.C. If the course marker rotates in the wrong direction, then interchange the connections to two pins on the 4-way W plug on the Control Unit front panel. Later RPU Control Units 446 are wired to give the correct rotation of marker but the above check should be made on every unit.

970\. The ATE versions of Control Unit 446 are correctly wired. The RPU units can be distinguished from the ATE ones by the wiring. RPU use 22 SWG with grade E sleeving, while ATE use a thinner wire with a cotton sleeving material. The ATE units are usually a darker shade of grey then the RPU ones but this test is not reliable.

Fishpond Bench Alignment.

Preliminary.

971\. (a) Connect up units in accordance with cabling diagram.
(b) Carry out normal alignment of H.2.S. installation.

Internal B-C Switch.

972\. Check that the B-C switch is in the fully clockwise or C position.

Focus.

973\. (a) Fishpond gain at minimum (fully anticlockwise).
(b) Fishpond brilliance up till diametral scan just appears.
(c) Adjust focus for sharpest scan.

Shifts and Tube Orientation.

974. (a) Adjust scanner for vertical trace on H.2.S. P.P.I.
(b) Check that Fishpond trace is also vertical. If not, rotate Fishpond C.R.T. until a vertical trace is obtained.
(c) Adjust H shift to bring the vertical scan through the tube centre by using the graticule.
(d) Rotate scanner till trace horizontal.
(e) Using the graticule, adjust the Y-shift to bring the horizontal trace through the tube centre.

Any deformation of the electrode structure should now be corrected by the shift voltages.

Balance Check for the Valves in each Amplifier Pair.

975. (a) Scan-marker switch to 100/40 position.
(b) Scanner rotating.
(c) Note whether the diametral scan rotates about the centre of the tube on a sloppy bearing. If so, the amplitudes of the output at the two anodes of either one or both amplifier pairs are unbalanced.
(d) Adjust the balance presets (VR.79 and VR.80) until rotating trace is as stable as possible about the tube centre. On the 100/40 scan it will rarely be possible to get absolute stability of the centre of rotation due to the high gain of the amplifiers. Reasonable stability should be obtained on the 100/20, 30/20 and 10/20 positions. High stability should be obtained in the 10/10 position.

Bright-Up Amplitude (W.F.G.43 not fitted).

976. The bright-up amplitude will be sufficient if H.2.S. contrast has been set up as outlined in para.957.

Bright-Up Commencement and Range Controls.

977. (a) Fishpond gain to maximum.
(b) Scan-marker switch to 100/40 position for 50-mile sawtooth input.
(c) Fishpond brilliance so that radial scan just appears.
(d) Scanner turned to give horizontal scan.
(e) Press marker push-button and note where innermost marker dot appears on the radial scan. Check whether this is the zero marker by advancing Fishpond brilliance and noting whether any additional marker dots appear. If the bright-up adjustment is correct the first dot will appear at the beginning of the radial scan, since this represents the beginning of the bright-up pulse.
(f) If this is not the case, adjust the switch unit bright-up control until the zero marker dot coincides as nearly as possible with the inner edge of the radial scan. In some cases it may not be possible to retard the bright-up sufficiently to prevent it commencing early. Should this occur no harm is done so long as the bright-up does not commence sufficiently early to allow breakthrough of the spurious pulse at the beginning of the 20 microsecond pulse. Such a breakthrough will produce a false marker inside the zero marker dot. The present of such a false marker can be checked by removing the H.2.S. suppression completely and letting the transmitter pulse break through on Fishpond to produce a "splash", that widens out the true zero marker.
(g) Select the range preset marked 50 which operates on the amplifier pair producing the horizontal sweep. Adjust for 4, 5 or 6 (depends on individual sets whether 6 obtainable) marker dots on the scan. The zero dot should be $\frac{1}{2}$" - $\frac{3}{4}$" from the tube centre. With 4, 5-6 dots on the scan set the scanner rotating. Adjust the second range preset marked 50 (working on the other amplifier pair) until the markers trace a circle.

978. (a) Set scan-marker switch to 30/20 position to get a 30 mile sawtooth input.
(b) Check the first marker dot obtained is the zero marker by noting where the H.2.S. range marker dot appears when the range control is set to zero or use suppression check.
(c) If necessary, adjust the 30 mile zero to shift the 20 microsecond pulse on the sawtooth so as to bring the zero marker dot (occurring on its back edge) up on the bright-up.
(d) Use one range preset labelled 30 to get 5-6 marker dots on the horizontal scan. Adjust the other for circular markers when the scanner is rotating.

979. (a) Scan-marker switch to 10/10 position for a 10 mile sawtooth input.
(b) Check as before that the first marker dot is the zero marker. If not, adjust the 10 mile zero to move the 20 microsecond pulse along the sawtooth until the zero marker on its back edge appears on the bright-up.
(c) Use the range presets labelled 10 to get 4, 5-6 circular markers with the scanner rotating.

980. (a) Check through the scans now for the correct number of markers on each scan.
(b) Check that the zero marker appears approximately the same distance from the centre on all scans. This should be about ½".
(c) Check that bright-up commences about ½" from the centre on all scans, i.e., that the zero markers are on the inner edge of the bright-up on all scans.
(d) If this is not the case, alternately adjust the switch unit bright-up control on the 100/40 position and the W.F.G. bright-up control on the 10/10 position until the bright-up does commence about ½" from the centre on all scans as shown by the position of the inner edge of the heading marker.
(e) If the zero markers on the 30/20 and 10/10 positions are not at the commencement of the bright-up now adjust the 30 and 10 mile zeros to bring them, respectively, to this point.
(f) With the scanner rotating the zero marker should now cut the commencement of the heading marker on the first five positions of the scan-marker switch.

<u>Checking Range Calibration.</u>

981. (a) Scan-marker switch to 10/10 position.
(b) Height control to zero.
(c) Adjust range control to bring H.2.S. range marker dot successively on each Fishpond marker dot and read the range scale. If calibrated in statute miles the readings should be 0, 1, 2, 3, 4 and 5 miles (approximately - see para.696).
(d) If any error is apparent the inductance, L.2, can be unsealed and the core adjusted to give the correct ringing frequency.
(e) An alternative method which is not dependent on the switch unit range scales is as follows:-

(i) Feed H.2.S. range marker from red Pye plug on the W.F.G. to the monitor 28 (Use interceptor socket).
(ii) Set timebase switch for a 100 microsecond timebase.
(iii) Note the calibrated X-shift setting when the H.2.S. range marker dot appears on the centre of one of the marker dots on Fishpond. Set the range control to bring the H.2.S. range marker up on the next Fishpond marker dot and again read the X-shift. The difference should be 10.75 microseconds.

Changes in Procedure if W.F.G. 43 Fitted.

Preliminary.

982. (a) Connect as outlined in chap.10, paras.719-722 and check that condenser between black Pye plug and Fishpond signal amplifier cathode is removed.
(b) H.2.S. alignment as normal except that W.F.G. and switch unit bright-up controls can be set fully anticlockwise.
(c) B-C switch, focus, shifts and balance presets as usual.

Bright-Up Amplitude.

983. (a) Scan-marker switch to 100/40 position.
(b) H.2.S. gain to mid-way position.
(c) Bright-up preset on W.F.G.43 (R.19) fully anticlockwise to hold mixer grid at lowest level and so cut bright-up output to minimum.
(d) Set Fishpond gain control (now used as a limiter) fully clockwise to make current passed by signal amplifier a maximum and thus take the mixer cathode to its maximum level in so far as it is controlled by the Fishpond gain control.
(e) Scope the waveform at the anode of the Fishpond signal or video amplifier on the monitor 28.
(f) Advance the W.F.G.43 bright-up preset, watching the waveform of the monitor. Noise will appear first, then the bright-up pulse increasing in amplitude. Presently top-cutting will start to take off the noise peaks and ultimately only the bright-up pulse will remain. Leave the control set at the point where the entire noise is just cut-off by limiting and the full bright-up pulse remains.
(g) Turn the Fishpond gain anticlockwise and note the noise reappears and that when fully clockwise the bright-up and noise disappear completely due to cut-off on the amplifier grid.

Range Presets.

984. (a) Set Fishpond gain and brilliance for a faint radial scan.
(b) Scan-marker switch to 100/40 position.
(c) Scanner for horizontal scan.
(d) Adjust appropriate range preset labelled 50 for 5-6 marker dots. Set scanner rotating and adjust other 50 preset for circular markers.

985. (a) Scan-marker switch to 30/20 position.
(b) Scanner for horizontal scan.
(c) Adjust appropriate range preset labelled 30 for 5-6 marker dots.
(d) Adjust 30 mile zero to start radial scan and first dot ½" from the tube centre.
(e) Adjust other 30 preset for circular markers with scanner rotating.

986. (a) Scan-marker switch to 10/10 position.
(b) Scanner for horizontal scan.
(c) Adjust appropriate range preset labelled 10 for 5-6 marker dots.
(d) Adjust 10 mile zero to start radial scan and first dot ½" from the tube centre.
(e) Adjust other 10 preset for circular markers with scanner rotating.

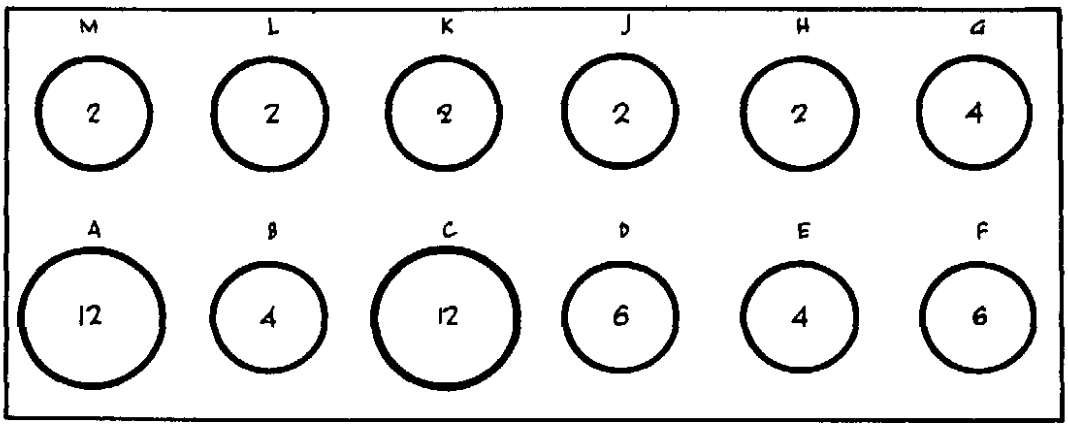
Checking Range Calibration.

987. (a) As in para.981.
(b) As alternative method if range scale is in nautical miles is to trigger the W.F.G. 43 and Fishpond from the test set 202 and inject the test set 1000 yard calpips at the black Pye plug on Fishpond. The calpips represent ½ nautical mile intervals so can be checked with the H.2.S. range marker.

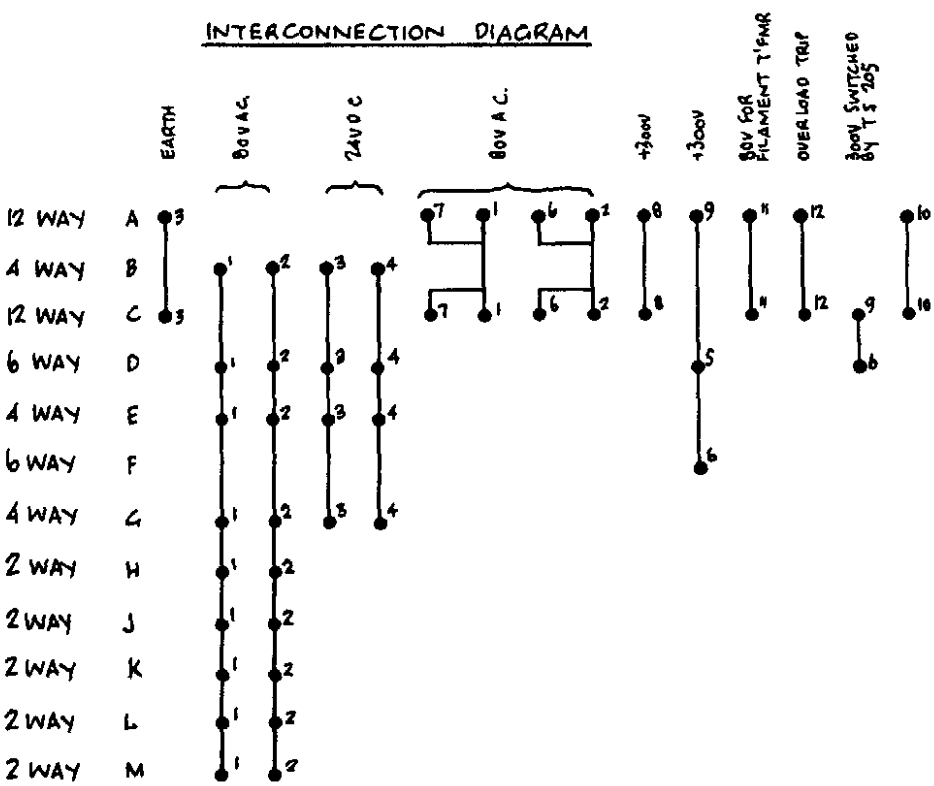
C.D. 0896L

JUNCTION BOX TYPE 238
FOR USE IN MK III A BENCH LAYOUT

PANEL LAYOUT



INTERCONNECTION DIAGRAM



SWITCHED 300V LINE TO TRIGGER VALVE IN MODULATOR

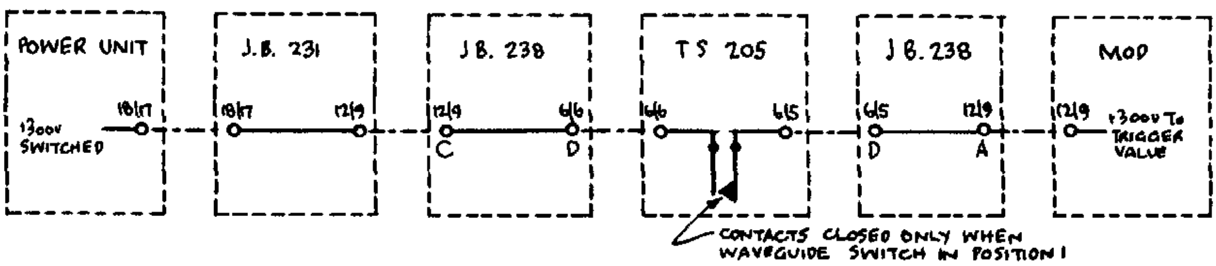


FIG. 154

Suppression.

988. As outlined in para.945.

Brilliance and Gain.

989. (a) Set brilliance to minimum.
(b) Set Fishpond gain to give a radial scan then back to fadeout point.

Aircraft Checks.

990. (a) Fishpond indicators and bright-up units should preferably be kept in pairs as the setting of the bright-up amplitude preset on the W.F.G.43 will vary with different Fishpond indicators.
(b) The balance and range presets have been set up with a certain amplitude of sawtooth input obtained from the bench W.F.G. and magslip. If the sawtooth amplitude supplied to Fishpond from the aircraft magslip is different, the following difficulties may arise:-
(i) Incorrect number of markers.
(ii) Markers not circular.
When a unit is installed in an aircraft after bench alignment, the Fishpond display must be checked on each of the first five scan positions.

Bench Setting Up of H.2.S. Mark IIIA (Using T.R.3555 Series Transmitter Units and T.S.205).

Test Equipment Required:-

991. (a) Monitor 28.
(b) Test Set 205 or 205A.
(c) Test Set 202.
(d) Test Set 85.
(e) Two D.C. milliammeters. 0-2 ma and 0-10 ma.
(f) Electrostatic voltmeter. 0 - 3.5 K.V. or 0-5KV.
(g) Avo. Model D.
(h) Mismatch Unit Type 257
(i) Junction Box Type 238.

Power Supply Checks.

992. As outlined for setting up of H.2.S. Mark IIC

Transmitter Unit Test Installation.

993. To prevent damage to the test set 205 by switching on of the modulator when the waveguide switch is not in position 1, the J.B.238 should be used to intercept the 12-way violet from the J.B.231 to the modulator. Connections are made as follows:-

(a) Disconnect the 12-way cable from the modulator and connect to plug C of J.B.238.
(b) Connect plug A to the 12-way plug on the modulator.
(c) Connect the 4-way plug on J.B.231 to plug B. This supplies 24V. D.C. and 80V. A.C.
(d) Connect plug D (6-way) to test set 205.

994. The flexible rubber guide section normally used to feed the R.F. output to the scanner is connected to the input channel for the test set 205.

995. (a) The electrostatic voltmeter is connected between the cathode of the transmitter unit klystron and earth. A suitable tapping point is on the rearmost tag on VR.3 which is connected directly to the cathode.
(b) Jacks connected to the milliammeters are plugged in at jackpoints for crystal current and power pack current.

996. Remove the graphite and asbestos fishtail dummy load from the waveguide power channel. Fasten the mismatch unit on top of the waveguide and insert the fishtail in the mismatch unit. Withdraw the quartz probe on the mismatch unit so that it does not extend into the guide to introduce a standing wave.

Preliminary Check of the Local Oscillator and its Power Pack.

997. (a) Switch on L.T. and check the meter readings. There will be an initial surge after which the readings will settle down to a steady level. These should not exceed:-
(i) -1600V. for the klystron cathode
(ii) 7.5 ma. for the E.H.T. current.
(iii) 1.5 ma. crystal current.
(b) If any of these figures is exceeded:-
(i) Turning VR.1 (E.H.T. volts control) clockwise will reduce the klystron cathode volts
(ii) Anticlockwise rotation of VR.3 (klystron grid volts control) will reduce the E.H.T. current since this serves to increase the klystron bias thereby reducing the klystron current which is the major portion of the E.H.T. current.
(iii) Withdrawal of the mixer probe will reduce the crystal current since the C.W. input to the mixer is thus attenuated.

R.F. setting up Sequence and Objective.

998. (a) Adjusting the R.F. output matching controls for maximum power output consistent with frequency stability.
(b) Tuning test set wavemeter to magnetron frequency to permit tuning of test set klystron to same frequency. The test set klystron can then act as an R.F. oscillator at the magnetron frequency for lining up the R.F. receiver controls.
(c) Setting up the test set klystron for oscillation at the magnetron frequency.
(d) Feeding the test set klystron input into the mixer chamber through a dummy T.R. cell and tuning the mixer for maximum response to the magnetron frequency.
(e) Inserting the actual T.R. cell instead of the dummy and tuning the T.R. cell for resonance at the magnetron frequency.
(f) Replacing mixer and T.R. cell in the transmitter unit and tuning the anti-T.R. chamber for maximum flow into the receiver branch line at the magnetron frequency by feeding the C.W. from the test set into the transmitter unit.
(g) Setting up the local oscillator power pack for correct operating conditions.
(h) Tuning the local oscillator 45 Mc/s. off the magnetron frequency by beating the test set klystron signal with the local oscillator signal and feeding the rectified beat signal through the head amplifier to the 45 Mc/s. I.F. amplifier in the test set. Correct tuning is indicated by maximum output from the test set amplifier.
(i) Adjust L.O. input to mixer for optimum input as indicated by correct crystal current value.

Lining Up the R.F. Output Controls.

999. Throughout all lining up operations the transmitter unit cover should be kept on as far as possible to avoid a fall in the field strength of the magnet when the cover is replaced at the close of the setting up.

(a) W.G. switch to position 1 to feed magnetron output into test set dummy load and power measuring neons.
(b) Selector switch in position 1 to connect neons in series with test set meter.
(c) Sensitivity switch is out of circuit so position is immaterial. May as well be set to Max. for next test.
(d) P./I.F. switch - immaterial, but may as well be set to "P" for next test.
(e) Power switch closed.

1000. (a) Wait at least three minutes after time "L.T.ON" pressed before pressing "H.T.ON". This is to ensure that magnetron cathode is properly heated before modulator pulse is applied.
(b) When red light comes up check that the CV.115 fires within 10 seconds. The gap is visible through the hole in the side of the waveguide. If this cell fails to ionise, magnetron power is flowing into the anti-T.R. chamber and a reflected wave, i.e., unwanted reactance, is causing a mismatch which should not be present while adjusting the magnetron matching controls. Readjust magnetron matching controls till C.V.115 fires.
(c) If no reading is obtained on the test set meter when the red light comes on and the transmitter fires, the mismatch is so bad that the R.F. power flowing into the dummy load is insufficient to cause the neons to strike. Press the "Ionise" button to apply +300V. to the neons and strike them. Once struck, the power flow into the dummy load is sufficient to keep them ionised and thus sustain a meter indication.

1001 (a) In the Bush boxes with the threaded plunger, set the plunger full in. Move the iris through its full range of travel and set at the point of maximum meter indication.
(b) Move plunger out slightly and readjust iris for maximum meter indication.
(c) Repeat until point found where maximum output is obtained.

1002. (a) If other boxes used with sliding plunger, set iris at one end of travel and move plunger through its full range of travel and set to point of maximum meter indication.
(b) Move iris by rotating the adjusting ring about 1 turn and again slide plunger through full travel and set it to position for maximum meter indication.
(c) Continue until iris has been taken through its full range of travel. Finally set iris and piston to the positions which gave maximum meter reading.

1003. (a) With boxes using the silica tuning rods on a moveable carriage there is much less interaction between the two adjustments. With the rods projecting in about $\frac{1}{4}$", slide the carriage through its full travel and set at the position for maximum meter reading. Now adjust distance the rods project into the guide for maximum meter reading.
(b) Check whether displacement of carriage gives any improvement, and if so, whether further slight readjustment of the distance of probe projection gives further improvement. Set at optimum position of carriage and distance of projection.

Moding Check.

1004. (a) C.V.108's are inclined to show "moding", i.e., transmitting at random on two different frequencies. C.V.208's may show the allied problem of "frequency splitting", i.e., transmitting on two frequencies in the same pulse. These faults are most likely to appear at maximum loading, i.e., when matched for maximum power output.

(b) To check for this form of frequency instability, the rectified transmitter breakthrough getting through the T.R. cell is taken from the mixer output plug by Pye lead to the monitor 28. Set the monitor for a 10 microsecond timebase and maximum amplification. Adjust the mixer piston for maximum response. The negative-going rectified pulse envelope should then be observable on the monitor.

(c) Push in the probe on the mismatch unit and move the mismatch unit carriage through its travel. If the pulse remains clean and steady no moding is occurring. If it becomes jittery and ragged and varying in shape, or if a smaller pulse appears inside the larger, moding is taking place. This can usually be cured by clockwise rotation of the matching iris control to bring the iris nearer the magnetron.

(d) A careful check must be kept on the power output and the meter reading should not fall more than 10% from its peak value when a clean stable pulse has been obtained. One or two revolutions of the iris control are normally sufficient.

Wavemeter Tuning.

1005. (a) Waveguide switch to position 1
(b) Selector switch to position 1
(c) P./I.F. switch to "P".
(d) Sensitivity switch to "Max."

1006. R.F. from the magnetron leaks around the waveguide switch in sufficient quantity to excite the wavemeter cavity when the latter is tuned to the resonant frequency. The leakage through the cavity to the cavity crystal is rectified and smoothed by the crystal assembly. With the P./I.F. switch set to "P", the negative-going video pulse is applied to the two-stage amplifier, which operates now as a video amplifier. The negative-going output pulse passes through the diode and is converted to a negative-voltage at the magic eye grid by an integrating or long time constant smoothing C.R. This negative voltage increases in magnitude as the cavity is tuned to resonance at the magnetron frequency. The sensitivity switch varies the gain of the amplifier.

1007. (a) Tune wavemeter to make magic eye close.
(b) If overlapping occurs, reduce sensitivity with the sensitivity switch and continue tuning for maximum closing without complete closing or overlap.

Frequency Pulling Check.

1008. (a) C.V.208's in particular are susceptible to frequency pulling and "gapping" due to varying reactance coupled back by varying reflection from a slightly assymmetrical perspex cupola.

(b) To make a frequency pulling check, with the mismatch unit probe into its stop slide the carriage of the mismatch unit up and down and note whether any opening of the magic eye occurs. Such opening indicates that the magnetron frequency has shifted. Some indication of the amount of frequency change can be obtained by retuning the wavemeter. The dial calibrations, 0.05 to 0.35, indicate wavelengths from 3.05 to 3.35 cms. The frequency change can be reduced to a minimum by a clockwise rotation of the matching iris control.

(c) Care must be taken not to drop the power output by more than 10% by the readjustment of the iris. The 10% reduction of output is recommended as a safeguard against probable frequency pulling.
(d) Check that the wavemeter is tuned to resonance. Lock the wavemeter tuning controls, the matching iris and the tuning plunger.

Lining Up the R.F. Input Controls.

Preliminary:-

1009. (a) Press "L.T. ON" as switch unit to switch off the -4KV. and ± 1.8KV. supplies.
(b) Disconnect the pulse cable and the 12-way red from the transmitter unit.
(c) Close the "Oscillator" or E.H.T. switch on the test set 205 and allow a few minutes for warming up.

Setting-up the Test Set Klystron.

1010. (a) Waveguide switch to position 2, the "blind" position, which blocks the escape of any klystron output.
(b) Selector switch to position 2, to connect rectified output from test set klystron crystal to the test set meter.
(c) Sensitivity switch to maximum.

1011. (a) If the klystron is oscillating the meter will show an indication
(b) If not oscillating, the setting up drill will follow that for the local oscillator outlined in paras.1022 to 1027.
(c) When oscillating, vary the tuning to check that it is oscillating throughout its range.

Tuning the Klystron to the Magnetron Frequency.

1012. (a) Waveguide switch to position 2.
(b) Selector switch to position 3 to connect the rectified output from the wavemeter crystal to the meter.
(c) Sensitivity switch to maximum.

1013. (a) Tune klystron until meter needle shows sharp rise to indicate that klystron is oscillating on the frequency to which the wavemeter is tuned, i.e., the magnetron frequency.
(b) This operation requires considerable care as the tuning is very sharp. If the tuning control on the klystron is rotated too rapidly it is possible to pass through the resonant point before the meter needle has time to indicate it.
(c) During this stage it is advisable to occasionally set the selector switch back to position 2 to check that the klystron is still oscillating.

1014. When the klystron is thus tuned to the magnetron frequency it provides a relatively low power source of C.W. at the magnetron frequency which we can use to adjust the R.F. input controls for maximum response at the magnetron frequency.

Mixer Tuning.

1015. (a) Attach the dummy T.R. cell to the waveguide section protruding from the top of the test set with the end with two small holes uppermost.
(b) Remove the mixer chamber from the transmitter unit and mount it on top of the dummy T.R. cell. The chamber should be in the same plane as in the transmitter unit.
(c) Take a Pye lead from the mixer output plug to the Pye plug on the test set panel.

1016. (a) Waveguide switch to position 3 to feed test set klystron signal into mixer chamber.
(b) Selector switch to position 4 to feed rectified and smoothed D.C. voltage from crystal in mixer via the Pye lead to the meter.
(c) Sensitivity switch to maximum unless meter reading is too great.

1017. (a) Adjust mixer piston for maximum meter reading reducing sensitivity switch setting as required.
(b) Rotate crystal holder in the mixer chamber for maximum meter reading. This is to get the tungsten whisker in the position which gives the maximum response.
(c) Note meter reading. If below that normally obtained on the test set the crystal should be checked by substituting a new one.

T.R. Cell Tuning.

1018. (a) Remove the dummy T.R. cell and insert the CV.114 in its place. Ensure that it is mounted in the same plane as in the H.F. box.
(b) Tune the T.R. cell for maximum meter indication. The control should be moved only one notch at a time as tuning is very sharp.
(c) Retune mixer chamber.
(d) Note meter reading. It should normally be at least 90% of that obtained when the dummy T.R. cell was used.

Tuning the Anti-T.R. Chamber.

1019. (a) Replace the mixer chamber and T.R. cell in the transmitter unit but do not insert the L.O. probe. If this probe is inserted appreciable signal power will couple back into the L.O. and this loss will cause a big drop in meter reading from the value above in (d).
(b) Couple the mixer output plug to the Pye plug on the test set by a Pye lead.

1020. (a) Waveguide switch to position 4 to feed the output from the test set klystron into the transmitter unit.
(b) Selector switch to position 4, as before, to feed smoothed rectified output from mixer crystal via the Pye lead to the test set meter.
(c) Sensitivity switch to maximum.

1021. Adjust anti-T.R. piston for maximum meter indication. Tuning may be very flat, depending on the phase of the wave that goes up to the magnetron and reflects. When maximum meter indication is obtained the maximum power flow is going up the receiver branch line. The R.F. receiving side of the transmitter unit should now give the optimum response to signals at the magnetron frequency.

Setting up the Local Oscillator Power Pack.

1022. (a) Replace the red 12-way cable to the transmitter unit.
(b) Check that the electrostatic voltmeter is properly connected to the klystron cathode and that the milliammeters are jacked in at the crystal current and E.H.T. current points.

1023. (a) Turn V.R.1 (E.H.T. voltage control) fully clockwise. This takes the VT.127 grid as far negative as possible and thus reduces the E.H.T. voltage to a minimum.
(b) Turn VR.2 (reflector volts control) fully clockwise to reduce the potential difference between reflector and cathode to a minimum.

(c) Turn VR.3 (grid volts control) fully anticlockwise to put the maximum bias on the klystron and so reduce the klystron (and therefore E.H.T.) current to a minimum.

The conditions required for stable oscillation are:-

1024. (a) Cathode potential approximately -1600V. but not more negative than this value.
(b) Total E.H.T. current 7 - 7.5 ma.
(c) Crystal current 1.5 ma.

The controls will interact, particularly VR.1 and VR.3.

1025. (a) Set the L.O. coupling loop to maximum.
(b) Set the probe in just far enough to get a crystal current indication when the klystron starts oscillating, in order to prevent pulling of the L.O. frequency by the signal from the test set klystron coupling back into the L.O. cavity via the mixer and the coaxial from the mixer to the L.O. This precaution applies in the next test when the L.O. is being tuned.
(c) Set the waveguide switch to position 3. This precaution is to prevent the signal from the test set klystron reaching the mixer and giving a crystal current indication before the L.O. is actually oscillating.

1026. (a) Rotate VR.1 anticlockwise until klystron cathode voltage is -1600V. Note E.H.T. current reading.
(b) The reading will normally be low. Turn VR.1 back (clockwise) and advance VR.3 (clockwise) a few notches. Now take VR.1 anticlockwise again until the cathode voltage again reaches -1600V. Note E.H.T. current again.
(c) If the value is still low, repeat the procedure in (b) until E.H.T. current of about 7.5 ma. is obtained with a cathode voltage of -1600V. VR.1 must be turned back each time before advancing VR.3 or the cathode voltage will be above -1600V. when the required klystron current is obtained. This will shorten the life of the CV.129.

1027. (a) When the correct operating conditions are obtained, rotate VR.2 anticlockwise until oscillations are obtained as indicated by a crystal current reading and a sharp kick of the E.H.T. current meter needle.
(b) If on rotating VR.2 the crystal current shows a sharp and slow side, set VR.2 just past the peak on the slow side.
(c) The crystal current value may remain low in actual value due to the klystron frequency being a long way off that of the T.R. cell and mixer cavity, and because of the attenuation at the probe. The probe setting should be such as to make satisfactory indications obtainable but no more.

<u>L.O. Tuning to 45 Mc/s. off Magnetron Frequency</u>.

1028. (a) Waveguide switch to position 4 to feed output of test set klystron at the magnetron frequency into the mixer where it will beat with the L.O. signal. The rectified I.F. envelope from the mixer to the head amplifier will then be at a frequency equal to the difference in the frequencies of the two klystrons.
(b) Connect the mixer output plug to the Pye plug on the head amplifier with the normal lead.
(c) Connect the head amplifier output pye plug to the Pye plug on the test set 205.
(d) Set the P./I.F. switch to I.F. The two stage amplifier in the test set now has the necessary R.F. decoupling applied to operate as an I.F. amplifier. The anode loads are resonant at 45 Mc/s. The output to the diode detector will then be a maximum when the beat frequency fed from the mixer into the head

amplifier and from the head amplifier to the test set amplifier is 45 Mc/s. The detector output is smoothed by the long C.R. and the negative D.C. voltage applied to the grid of the magic eye. The magic eye will therefore close as tuning progresses towards the 45 Mc/s. difference frequency.

1029. (a) Tune the L.O. until the magic eye closes to show that the correct frequency difference of 45 Mc/s. has been obtained. The L.O. will now operate 45 Mc/s. off the magnetron frequency.
(b) Adjust the setting of the mixer probe for a crystal current of 1.5 ma.

1030. (a) Disconnect the test set from the transmitter unit and connect the latter to the scanner.
(b) Replace the pulse cable from the modulator 64 to the transmitter unit.
(c) Rotate the scanner to pick up a permanent echo and check the tuning of the L.O., mixer and T.R. cell on signals.
(d) Do not touch the magnetron output controls.
(e) Securely lock all controls.
(f) Set the Geneva wheel so that the L.O. can be tuned on either side of the resonant point.

1031. Although the test set has been disconnected from the transmitter unit, the waveguide switch must be left in position 1 while tuning on signals if the J.B. 238 is used. This requirement arises out of the fact that the waveguide switch is controlling the +300V. supply to the trigger valve in the modulator and only completes this supply in position 1. If it is required to use the junction box 238 with the test set 205 temporarily removed, the trigger valve supply may be completed by returning the Test Set 6-way to plug F on the junction box 238. Then plugs D and F will be joined by the 205 6-way and the 300 volt supply will be completed to the trigger valve.

Summary of Setting-Up Procedure

1032.

Test	Waveguide Switch	Selector Switch	P./I.F. Switch	Sensitivity Switch	Test
					Switch on L.T. and wait at least 3 minutes before switching on H.T.
1	1	1	P	-	Tune Tx output line for max. output as denoted by meter. Check for moding and frequency drift.
2	1	1	P	Max.	Tune wavemeter to Tx frequency, denoted by closing of magic eye. Switch off modulator. Disconnect pulse and 12-way cables from H.F. box.
3	2	2	P	Max.	Check oscillator in Test Set on meter.
4	2	3	P	Max.	Tune Test Set oscillator to frequency of wavemeter. Denoted by sharp rise of meter needle.
5	3	4	P	Max.	Place mixer chamber on top of waveguide on Test Set, inserting dummy T.R. cell in between Pye lead between mixer and Pye plug on Test Set. Tune mixer for max. meter reading.
6	3	4	P	Max.	Replace dummy T.R. cell by T.R. cell. Tune T.R. cell. Meter reading should not fall more than 10%.
7	4	4	P	Max.	Replace mixer chamber and T.R. cell in H.F. box, retaining Pye lead between mixer and Test Set. Tune anti-T.R. cell for max. meter reading.
8	3				Replace 12-way cables to H.F. box. Allow a few minutes to warm up. Set up local oscillator in H.F. box.
9	4	4	I.F.	Min.	Mix outputs from oscillator in Test Set and Local Oscillator, and tune local oscillator for 45 Mc/s. difference frequency as denoted closing of magic eye.
10	1				Recheck tuning of local oscillator, mixer chamber, TR. and anti-TR. cells on signals. Set crystal current to $1\frac{1}{2}$ ma.
11					Lock all controls securely. Set the Geneva wheel so that the local oscillator can be tuned either side of the resonant point.

1033. Rest of setting-up procedure as for H.2.S. Mark IIC commencing at para.944.

Suggested D.I. Procedure for H.2.S. Mark IIC and Mark IIIA

Power Supply

1034. (a) Couple P.E. set to V.C.P. and start P.E. set.
(b) Check that V.C.P. is switched on.

Crystal Checks

1035. (a) Measure back and forward resistance of crystal at the transmitter unit jackpoint. Forward resistance should not exceed 200 ohms, and back resistance should not be less than 1000 ohms, or less than half the value measured on preceding D.I. although still over 1000 ohms. The back resistance should be logged and kept on a card at the unit. A sharp fall in the back resistance indicates a dying crystal.
(b) If crystal does not appear satisfactory replace with a known good crystal. A few spare good crystals should be carried on D.I.'s. These should be kept wrapped in cotton waste to protect them from shock and in a metal box to protect them from R.F.

Power Supply Checks

1036. (a) Press "L.T. ON" and check that green lamp lights.
(b) Check panel lamps on switch unit and indicator. After at least three minutes warm-up period, press "H.T. ON". Check that the amber and red lights come on. (With the new resistors fitted in the switch unit it will be possible to switch on even if the green and amber bulbs are faulty).
(c) Connect the Avo Model H to the test point on the junction box. Check that the reading lies within 78 ± 2V.
(d) Check the power pack voltages <u>at all the test points</u>. The voltage jackpoints should read 1 ma. ± .05 ma. The 300V. feed point should read about .85 ma. (PU 280 - for PU 224 see para. 930).
(e) If the readings are <u>all</u> proportionately high or low, the V.C.P. voltage should be modified as required by means of the trimmer adjustment.
(f) If the voltage readings are at variance, the voltage divider or rectifier at the abnormal jack-point require checking.
(g) Check the V.C.P. regulation by switching the modulator on and off and noting the variation at one of the voltage monitor points on the power unit. Also vary the speed of the P.E. set and note the effect on the 80V. reading and the jackpoint readings.

Crystal Current and Tuning (Mark IIC)

1037. (a) Check the crystal current at the jackpoint on the transmitter unit for a value of about 0.4 ma.
(b) If considerably out the reflector voltage and coupling loop require readjustment at the tuning unit 207. To carry out this adjustment two mechanics must work together using head-sets and the A/C i/c system. The coupling loop should be so set that the crystal current can be varied smoothly (on the stable side) between about 0.2 and 0.6 ma. with the reflector volts control.
(c) Turn the scanner by hand to point toward the best permanent echo avilable. The location of such echoes and the strength of signal to be expected at various dispersal points can only be found by experience.

(d) Adjust tuning control for maximum signal. This should be obtainable for two positions of the tuning control. Set the control to the one giving the best S/N ratio if there is any choice. Before deciding which is the better, it is necessary to check that the crystal current is 0.4 ma. when the S/N ratio is being assessed in both cases.

(e) Estimate the sensitivity of the set from a comparison of the response with that normally obtained at the dispersal point with a good set. If the sensitivity appears sub-standard replace the crystal with a known good crystal. Check the crystal current and log the back resistance of the new crystal.

(f) If this fails to give any improvement in sensitivity check the CV.43 tuning plunger and the output line matching slug. Check that both are locked after any readjustment. If insensitivity persists the transmitter unit should be bench-tested.

Crystal Current and Tuning (Mark IIIA using TR.3555 Series)

1038. (a) Rotate the scanner to face best permanent echo available.

(b) Tune klystron for maximum signal amplitude. The sensitivity of the set can only be estimated from a knowledge of the signal strength normally obtained on the particular dispersal point for the direction in which the aircraft is facing.

(c) After signals are correctly tuned in, check the crystal current by means of a meter jacked in at the crystal jack point on the transmitter unit. The reading should be 1.5 ± .2 ma.

(d) Tap the transmitter unit and watch meter indication to see that the CV.129 is stable.

(e) Manual adjustment of tuning cannot be made at the repeater motor with the 4-way still connected.

Suppression

1039. (a) If no Fishpond fitted adjust suppression to just cut out the transmitter pulse breakthrough on the height tube.

(b) If Fishpond fitted, take the suppression off completely (fully anticlockwise) then turn clockwise one notch beyond the point where the suppression actually starts to catch the transmitter breakthrough. The object of this adjustment is to apply only one notch of effective suppression, i.e., to suppress only the breakthrough due to the primary transmitter pulse. Further suppression means that the Fishpond minimum range is automatically held at about 400 yards or more depending on how many notches of actual suppression are applied. Each notch represents an increase in the minimum range of around 200 yards.

Height and Range Marker

1040. These should not require adjustment if set up on the bench with a test set 202. If either the switch unit or receiver-timing unit have to be changed, both should be replaced by a matched pair lined up on the bench with a test set 202.

Use of Monitor 28 for checking Height and Range Zeros

1041. (a) The monitor 28 may be used in the aircraft for checking the height and range zeros. If these have been correctly set up on the bench, they should not require adjustment, but a periodic check at intervals of a week can be made with a monitor 28 that has been calibrated as described in para.950. The calibration of the monitor must be checked on the bench immediately before use in the aircraft.

(b) Check with the Avo Model H that the aircraft A.C. supply is 78 volts ± 1 volt. Apply the blue/white pulse to the monitor. Set the X-shift at "10" and adjust the T.B. start so that the leading edge of the pulse is in line with the cursor line.

(c) Set the range switch to 10/10 position and height and range drums to 20,000 feet and 4 miles respectively. Apply the height and range markers to the monitor using a .001 condenser for coupling the height marker.
(d) Set the X-shift to "20,000 ft." and the height marker should be in line with the cursor. If necessary, adjust the height zero to bring it in line. Then turn the X-shift to "4 miles 10/10" and if necessary adjust the range zero to make the range marker coincide with the cursor.

Contract, Brilliance, Focus and Gain

1042. (a) Turn contrast, brilliance and gain fully anticlockwise.
(b) Advance brilliance till scan and flyback just appear then back 4 notches. Check that index line on knob coincides with index dot on panel.
(c) Advance contrast till radial scan just appears then back one notch from the fadeout point. Check that index line on knob coincides with index dot on panel.
(d) Adjust range control to bring range marker dot in centre of display. Adjust focus for the sharpest range marker dot.
(e) Reduce brilliance until luminosity of range marker just strats to fall.
(f) Switch scanner on and check for a clearly defined heading marker and range marker ring.
(g) Set gain control to a normal value.

Height Tube Display

1043. Adjust focus, brilliance and shift if necessary.

P.P.I. Display (Fispond not fitted or W.F.G. 43 fitted)

1044. (a) Set distortion corrector and height control to 25,000' and range control to 8.5 nautical or 10 statute miles. Adjust 10 mile zero until outer edge of bright-up just reaches the range marker near the edge of the tube.
(b) Check that the W.F.G. and switch unit bright-up controls are fully anticlockwise to start the bright-up as early as possible.
(c) Set height control and distortion corrector to 20,000'
(d) Using the range marker, check for the following range coverages:

10/10	-	$8\frac{1}{2}$ nautical or 10 statute miles.
10/20,30/20		
100/20	-	approximately 17 nautical or 20 statute miles
100/40	-	approximately 34 nautical or 40 statute miles

(e) Set the range control to, say, 6 miles on the 10/10 scan. Start the height control and distortion corrector at 25,000 ft. and bring them down in 5,000' stages. Note that the range marker remains in a sensibly fixed position on the display to check the functioning of the distortion corrector. Note that no hole appears at the centre of the display for settings above 2,000'.
(f) Check that the P.P.I. trace rotates about the tube centre. Adjust X and Y shifts if necessary.

Course and Track Marker

1045. (a) Set H.C.U. and indicator 184 switches to "Course".
(b) Check that the heading marker can be taken smoothly through 360° in either direction with the H.C.U. setting control. Set heading marker to the bearing shown on the navigator's repeater card.

(c) Switch on the D.R. compass. The heading marker and repeater card will oscillate slightly till the master compass settles down. Move the V.S.C. through a few degrees in either direction. The heading marker and repeater card should remain in step and always indicate the same bearing. This check should be made to ensure that the heading marker does not rotate in the wrong direction on operations.

(d) Return the V.S.C. to its original setting and switch off the D.R. compass.

1046. (a) If the roll-stabilised scanner is fitted set the H.C.U. and indicator 184 stwitches to "Track".

(b) Check that the track marker can be moved smoothly through 60° on either side of the heading marker.

(c) Set indicator switch back to "Course" and H.C.U. switch to "Auto".

Fishpond

Controls

1047. (a) Scan-marker switch to 100/40 position.

(b) Scanner rotating to give circular markers.

(c) Heading marker switched on.

(d) Fishpond gain to maximum (W.F.G. 43 not fitted).

(e) Brilliance to point where radial scan just appears.

(f) Focus for sharpest scan.

(g) Brilliance to where scan just fades out.

(h) If W.F.G.43 fitted, set brilliance to minimum and gain for radial scan then back to where scan just fades out.

Bright-Up (W.F.G. 43 not fitted)

1048. (a) Switch through the first five scan-marker switch positions and check that the inner edge of the heading marker commences about ½" from the tube centre on all positions.

(b) If this condition not fulfilled, alternately adjust switch unit bright-up control on the 100/40 position and W.F.G. bright-up control on the 10/10 position until the bright-up does commence about ½" from the tube centre in all five positions.

If W.F.G. 43 fitted no bright-up adjustments are necessary.

Markers

1049. (a) Press marker button and check for following points:-

(i) Markers circular and centred about tube centre.

(ii) Presence of 0, 1, 2, 3, 4 and perhaps 5 mile markers.

(iii) Zero marker about ½" out from centre.

(iv) No spurious markers before or after the zero marker. This can be checked by noting whether any marker rings appear when the marker button is released.

(b) Scan-marker switch to the 30/20 position.

(i) Markers circular and centred about tube centre.

(ii) Correct number of markers and no spurious markers.

(iii) The zero marker is about ½" from tube centre and just overlaps the inner edge of the heading marker. Adjust 30 mile zero to move the marker if its distance from the centre is incorrect.

(c) Scan-marker switch to the 10/10 position. Press marker button and make same checks as in (b). If zero marker not the correct distance from the tube centre (app. $\frac{1}{2}$"), adjust the 10 mile zero.
(d) Check that heading marker reads the same bearing on Fishpond as on the indicator 184.

Miscellaneous

1050. (a) Check all W and Pye plugs to see they are securely fastened and that no Pye clips are missing.
(b) Check that cupola is free from oil, water, rubbish, "window" etc.
(c) If no roll-stabilised scanner fitted, disconnect P.E. set and connect up the A.C. and D.C. cables to the V.C.P. correctly.
(d) Check that V.C.P. and modulator 64 switches are both on.

Stabilised Scanner

Requirements

1051. (a) Vacuum pump assembly to drive the gyro control unit.
(b) D.C. supply of 24V. at about 12 amps. to drive vacuum pump motor. Owing to heavy starting current this supply will require a 40 amp. fuse.
(c) Suitable length of flexible piping will be required to connect the vacuum line to an intake point on the aircraft skin.
(d) A suction meter should be tapped in, preferably at the end of the flexible pipe, to check that the vacuum of 3-5" is obtained since the gyro control unit requires a vacuum in this range to operate correctly.
(e) The scanner D.I. should be carried out after the normal H.2.S. D.I. to give the gyro and amplifier unit time to settle down.

Amplifier Balance Check

1052. (a) After doing normal H.2.S. D.I., remove the 2-pin red from J.B.246 to disconnect the armature supply from the M.G.74.
(b) Insert jack connected to voltmeter (on range not lower than 250V.) at amplifier jack point.
(c) Press earthing switch on amplifier panel and note reading which may be either + or -.
(d) Adjust balance preset for zero volts to ensure the M.G.74 is stationary when platform is level. A fine adjustment can be obtained by decreasing the voltmeter range. Remove the jack.

Gyro Control Unit Alignment Check

1053. (a) Set the platform level by observing the spirit level.
(b) Switch on the scanner at the switch unit.
(c) Replace the 2-pin red to make the M.G.74 capable of operation.
(d) Note whether the platform moves. Movement may be caused by Gyro control unit incorrectly aligned. Movements in excess of $\pm 1^\circ$ normally must be attributed to this cause.
(e) Gyro realignment can be done by loosening the 4 bolts securing the gyro which permits small variations in either direction on the elongated fixing holes.

Stabilisation and Sensitivity Checks

1054. (a) Remove 2-pin red again and push platform over to the 30° end-stop limit in one direction. Replace the 2-pin red and check that the platform immediately returns to the level position.

(b) Repeat the procedure with the platform pushed to the opposite end-stop.
(c) Remove the 2-pin red to J.B.246 and offset the platform 1° as nearly as can be estimated. Replace the 2-pin red and check that the platform levels immediately.
(d) Repeat same check in the opposite direction.

Clutch Check

1055. (a) With everything working, force the platform in one direction against the torque of the motor. Check that the clutch slips immediately.
(b) Repeat same test in the opposite direction.

Miscellaneous

1056. (a) Remove the external vacuum supply and turn the valve to the internal position.
(b) Check that all cables are secure and do not foul at any point during platform movement.
(c) Disconnect P.E. set and connect up the A.C. and D.C. cables to the V.C.P. correctly.
(d) Check that V.C.P. and modulator 64 switches are left on.

Use of the Scanner Jig (10AB/8136) for A.R.I. 5564 - 5583 (Mark III H.2.S.)

1057. (a) The jig consists of a blued steel body which can be clamped to the flared end of the waveguide feed to the scanner, and three distance arms by which the location of the flare can be checked. These arms are identified respectively by marks 1D, 2D, or 3D stamped on them close to the point about which they pivot.
(b) Arm 1D serves to check that the waveguide is central with respect to the outer edges of the mirror.
(c) Arm 2D serves to check the distance from the waveguide to the back of the mirror, and
(d) Arm 3D checks the distance of the waveguide from the top edge of the barrel section.

1058. (a) Certain tolerances can be allowed in the position of the flare with respect to the back of the mirror and with respect to the top edge of the barrel section.
(b) The tolerance range is provided on arm 2D by an extension which is variable through 1.5 millimetres.
(c) Tolerance on arm 3D is allowed by the width of the slot provided to receive the top edge of the barrel section.

1059. (a) To check a scanner, screw back the clamping plate in flare recess and fit the jig body over the waveguide mouth. Arm 3D should be vertical and arm 1D should be below the level of the feeder mouth.
(b) With an inverted scanner on the bench the jig should slide on from the left. In an aircraft installation it should slide on from the right.

1060. When in position the clamp should be tightened to hold the jig firmly.

(a) Bring arm 2D against its stop (arm horizontal) and check whether the tip touches the back of the mirror within its range.

(b) Adjust arm 3D until it touches the barrel section and check that the edge of the mirror fits in the slot provided.
(c) Swing arm 1D to one side of the mirror and adjust the screw extension until the under side of the head touches the edge of the mirror.

1061. Turn the arm to the other side of the mirror and check that the same condition holds.

Scanner Maintenance

Inspection of Scanners Type 63 and 71

1062. (a) Mount scanner, motor downwards, on a scanner stand and remove the mirror.
(b) Check that the gear trains are clean and free from any foreign matter other than a coating of anti-freeze grease.
(c) Connect up the cables to the scanner and switch on.
(d) By operating the H.C.U. setting control, check that the course step-down gear train and the track worm drive operate smoothly throughout their full range of movement.
(e) Using the repeater motor test installation check the operation of the repeater motors as outlined in paras.963 and 964.
(f) Rotate the scanner main drive by hand to see if it turns smoothly.
(g) Mount the mirror over the locating studs on the main drive and start the scanner. Check that on 26-28V. D.C. supply the scanner speed can be varied smoothly between 20-60 r.p.m. using the speed control on the control unit 477.
(h) Examine the course and track marker contact assembly for cleanliness and correct contact tension.

Maintenance of Scanners Type 63 and 71

General Points

1063. (a) The scanner casting has been designed to reduce the amount of maintenance required.
(b) The faults most likely to develop after several hours' operation are:-
(i) Faulty course or track marker contact.
(ii) Sticking repeater motor drives.
(iii) Dirty contacts on the magslip slip-rings.
(iv) Excessive sparking on the motor commutator causing noise.

Bearings

1064. (a) The ball-races in the driving motor and magslip assembly are grease-packed by the manufacturer and should not normally require any greasing or oiling.
(b) The main bearing ball-race is also grease-packed.
(c) The ball-races in the two repeater motors will be dealt with in para.1066-1067.
(d) All other bearings used in the step-down gear trains, including the bearing for the rotating member of the capacity joint, are of a special type known as oilite bearings. These are made of a porous phosphor bronze and impregnated with anti-freeze oil.

Whenever these bearings are removed they should be cleaned and left to steep in anti-freeze oil before replacing.

(e) If ball-races require attention, they should be washed out with paraffin, thoroughly dried and repacked with anti-freeze grease.

(f) The teeth on the metal gear wheels should be lightly greased with anti-freeze grease.

Cleaning and Adjusting Course and Track Marker Contacts

1065. (a) Remove the four 2bA nuts clamping the sub-casting which supports the magslip and course repeater motor to the main casting. Separate the sub-casting from the main casting.

(b) Thoroughly clean the annular contact ring and the fibre disc mounted on top of the magslip stator drive with carbon tet. Clean the three contacts mounted on the main casting and check for correct tension. If necessary, adjust the tension by bending the contacts.

Checking the Course Repeater Motor Drive

1066. (a) Slacken the jubilee clip around the repeater motor and remove the top cover.

(b) Disconnect the three field connections, noting the colour coding.

(c) Remove the three 6BA bolts securing the repeater motor casting. The repeater motor can now be withdrawn from the sub-casting and gear train.

(d) Check the freedom of the armature. It should turn very easily. Lightly oil both bearings with anti-corroding oil (34A/43). Access to these bearings can be had through the end plates without removing the armature.

(e) Thoroughly cleanse all gear wheels in the step-down gear train to the magslip stators by brushing with petrol, and smear all the teeth with anti-freeze grease.

(f) Ascertain that the magslip stators move freely through 360° without any sign of binding spots.

Checking the Track Repeater Drive

1067. (a) Remove the repeater motor.

(b) Check and lubricate as outlined for the course repeater motor.

(c) Thoroughly clean the worm drive and step-down gear and smear lightly with anti-freeze grease.

Checking Magslip Brushes and Slip Rings

1068. (a) Remove the cover of the slip ring assembly.

(b) Note and record the arrangement of the six leads running from the slip rings to the terminals on the bakelite housing, then remove the leads.

(c) Remove the leads and bolts from the terminal points on the brush mountings and the brush contact arms. The brushes can now be withdrawn. Examine them for wear and replace if length less than $\frac{1}{4}$".

(d) Remove the six 6BA bolts around the base of the slip ring assembly. Withdraw the slip ring assembly. Examine and thoroughly cleanse all slip rings.
Note their connections, then

(e) Remove the 4 leads coming up through the bakelite end plate from the terminals on the bakelite housing.

(f) Remove the contact arms and the three rotor brushes. Examine the brushes for wear. Replace them if length is less than $\frac{1}{4}$".

(g) Remove the four 6BA bolts securing the bakelite end plate to the magslip stators. Withdraw the housing. Thoroughly cleanse the three slip rings on the rotor end.

Scanner Motor Check

1069. (a) The motor can be removed from the main casting by removing the three 2BA nuts.
(b) Access may be had to the commutator and brushes by removing the two 4BA bolts securing the 2B socket to the top of the motor. The end cap can then be pulled off. Check the brushes for perfect seating. Replace if length is less then ¼".
(c) Cleanse the commutator.

Reassembly Cautions

1070. Care must be exercised with regard to the following points when reassembling:-

(a) Magslip connections.
(b) Repeater Motor connections.
(c) Aligning the course marker contact.
(d) Aligning the rotating joint.
(e) Replacing the mirror correctly.

Course Marker Alignment

1071. (a) Line up the white marks on the scanner casting and the rotating plate.
(b) Connect an Avo across the course contacts for a continuity check.
(c) Slacken off the three 4BA bolts clamping the fibre disc (which holds the contact ring) to the magslip rotor.
(d) Turn the disc relative to the gear wheel in a clockwise direction (looking into scanner base) till the meter just indicates a short. Tighten the three 4BA bolts to clamp the disc to the magslip rotor.

Mirror Replacement

1072. When replacing the mirror check that all white marks are aligned.

Capacity Joint Alignment (Scanner Type 63).

1073. (a) Adjust the position of the rotating member of the joint so as to measure 1⅛" from the end of the segmented tube to the end of the rotating member.
(b) Clamp in this position by means of the tapered locking ring.
(c) Replace the casting carrying the stationary member of the joint but omit the gasket.
(d) Slacken off the clamping band which secures the stationary member to its supporting casting.
(e) Push down the stationary member until metallic contact is heard. Tighten the clamping band.
(f) Remove the casting and the clamped joint section and reassemble with the gasket in place.

Rotating Joint (Scanner Type 71)

1074. (a) The spacing between the two sections is set to 1 mm. automatically on assembling.
(b) Care must be taken not to deform the waveguide system in the scanner during any maintenance work.

Repeater Motor Rotation

1075. The direction of rotation may readily be reversed by changing over any two field connections coming out from the field windings to the terminal block on the end of the motor. This should only be done if the wiring is correct in the HCU and scanner. If these units are incorrectly wired they should be corrected.

R.F. Faults in H.2.S. Mark IIC

Faults Causing Low Sensitivity

Insensitive Crystal

1076. (a) If a set is insensitive replace the crystal by a known good crystal.
(b) Crystal previously in use can be checked for forward resistance of less than 200 ohms and back resistance of more than 1000 ohms but these are not conclusive tests.
(c) Crystals are perhaps best sorted on a bench set by inserting them in a lined-up set and comparing crystal current passed and sensitivity with that of a known good crystal without making any adjustments to the controls. Good crystals are normally those that pass a good crystal current and give a good S/N ratio.
(d) If crystals are sorted in this way, they should be wrapped in paper or dry waste to avoid damage from vibration and stored in a metal container to prevent damage from R.F. pick up.

Faulty-Pye Cables

1077. (a) The green Pye cable and, to a lesser extent the slate, may account for low sensitivity.
(b) A rough check can be made by turning the gain to maximum and noting the noise level on the height tube. If both cables are in order and make proper contact, the observed noise level should be of approximately the same amplitude as the range marker.
(c) Disconnect the Pye green cable. If the noise level does not drop the head amplifier is faulty). If the noise disappears entirely the gain of the IF strip is low.

Soft Rhumbatrons

1078. (a) The CV.43 is a common cause of low sensitivity. This may arise from development of noise or from delayed de-ionisation.
(b) If the noise level goes down considerably when the transmitter is switched off the CV.43 is suspect.
(c) If the CV.43 tuned very flatly, especially on short range signals, delayed de-ionisation due to overcoupling of the magnetron input is the probable trouble. See paras. 322-323.
(d) If crystals are continually burning out, the CV.43 is most probably not ionising at all due to broken copper glass seals or cracks. If no glow appears across the lips when the plunger is removed and the transmitter is operating, the CV.43 is u/s.
(e) If the life of crystals is shorter than usual it is probable that the probe voltage is incorrect or absent.
(f) The normal ionising currents for the commonly used types are shown in fig.73(d).
(g) When changing CV.43's care should be taken to reassemble the heater jacket so as to complete the 24V. supply through the heater winding.

Low R.F. Output due to Faulty Components

1079. (a) May be due to (i) Weak magnet
(ii) Faulty CV.64.
(iii) Faulty modulating pulse.
(iv) Faulty H.P. feeder or waveguide.

(b) Cover on/cover off test (see para.943b) will give a rough check on the magnet.
(c) Modulating pulse can be checked at the monitor points on the modulator (see para.960).
(d) Magnetron, feeder and guide can only be checked by substitution.

Low Sensitivity Due to Misalignment

1080. Displacement due to aircraft vibration or faulty securing of any of the following:-

(a) Matching slug.
(b) C.V.43 plunger.
(c) Capacity joint.
(d) Mixer probe.
(e) Klystron coupling loop.
(f) H.F. feeder.

H.P. Feeder Faults

1081. (a) Arcing may occur between the magnetron output probe and the inner of the output line if the contact is slack or dirty.
(b) Arcing may occur if the braiding used to form the flexible coupling to the magnetron probe becomes frayed and loose ends start breaking away.
(c) Arcing will occur if the matching slug has any play and is not in perfect electrical contact with the outer.
(d) Arcing at any of these points may be observed by looking through the slug tracking slot.
(e) Arcing may occur in the H.F. plugs if there is an air gap due to the polystyrene dielectric being below the level of the terminating outer. This trouble is cured by fitting of the "sticky" washers. The face contact area of the outer and of the plug and socket on the inner should be clean and secure. Any arcing occurring at these points can be checked by looking for signs of carbon deposit on the surface.
(f) All external feeders used in the aircraft and bench installations should be of the correct lengths.
(g) The rubber washers must be removed as they prevent proper seating and perfect electrical contact. This also applies to the uniradio 21 feeder.

Waveguide and Scanner Faults

1082. (a) Any deformation or displacement will cause polar diagram distortion and probably mismatch problems.
(b) Oil or dirt on the waveguide inner surface, mirror or cupola will cause attenuation and reflection.

Noisy Valves and Pick Up

1083. (a) Heavy noise can be introduced in the head amplifier stage due to a low emission VR.136 or faulty earthing connections or valve base contacts. A check can be made by by-passing the head amplifier by feeding straight from the mixer Pye plug into the receiver.
(b) I.F. valves can cause trouble in the same way.
(c) A "noisy" blower motor may cause trouble. This can be checked by removing its supply plug.
(d) Scanner motor noise can appear if the suppression unit is faulty.
(e) A crystal may be noisy if it is not securely held and making firm contact with the mixer inner.
(f) An unstable klystron can produce considerable noise because of the arcing between the reflector and rhumbatron as it goes in and out of oscillation. The fundamental cause of this trouble will probably be the setting of the reflector volts or the supply voltages.
(g) Arcing at the 4K resistor is another source of noise.

Suggested Low Sensitivity Investigation Procedure in Aircraft

1084. (a) Check on noise level with gain control (para.1077b) to check whether fault is in I.F. Pye cable or in R.F. side.
(b) Check that transmitter output is up to standard by putting finger, screw-driver or neon on waveguide. The standard will have to be determined from experience.
(c) Replace crystal with a crystal known to be good.
(d) Check that matching slug and CV.43 plunger are secure.
(e) Inspect H.P. feeder, scanner and cupola for points in paras. 1081 and 1082.
(f) Remove transmitter unit for bench test. Check alignment of matching slug and CV.43 tuning. Test output on T.S.85 after realignment.
(g) If low output persists make cover on/cover off magnet check.
(h) If output satisfactory, check CV.43 for correct ionising current and absence of overcoupling and flat tuning.
(i) Make head amplifier bypass check and CV.43 noise check.
(j) If no fault apparent, suspect scanner, H.P. feeder and modulator in aircraft. Return to aircraft with original transmitter unit and serviceable modulator, H.P. feeder and scanner.

Insulation Breakdown Troubles

General

1085. Aside from low sensitivity problems the main faults come under the heading of insulation breakdowns, mostly in the modulator and transmitter unit. The chief indications of this class of faults are a standing pulse on the height tube (in earlier stages) and overload relay tripping or complete switching off in later stages.

Warning Indications

1086. Several of the major insulation breakdown problems result in mismatch conditions between the artificial line output and the transmitter unit before the final breakdown comes. These mismatch conditions usually cause a series of reflected pulses along the pulse cable after the initial main pulse. Evidence of these can usually be obtained by scoping at the monitor points on the modulator 64 which will show some form of abnormality. A further indication is obtainable from the number of notches of suppression required to prevent any breakthrough on the height tube. If more than 3 or 4 notches of suppression is called for, insulation and mismatch trouble should be suspected. An alternative cause may be a dying spark gap which is de-ionising very slowly.

Suspect Components

1087. Aside from a dying spark gap which is not a common fault, the following items are the chief suspects when either the suppression setting or waveform at the modulator monitor points indicates trouble:-

(a) Filament transformer.
(b) Pulse transformer.
(c) Lead from spark gap to pulse output socket on modulator 64.
(d) Pulse cable from modulator 64 to transmitter unit.
(e) Lead from transmitter unit input socket to pulse transformer.
(f) Magnetron.
(g) Overswing diode and 4K resistor.
(h) Artificial line.

Dummy Load Tests

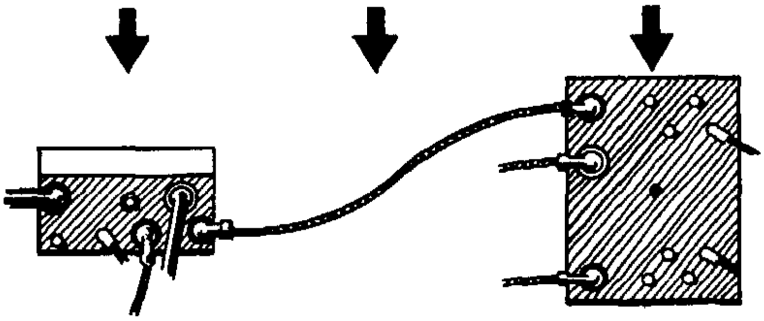
1088. (a) The dummy loads and the elimination tests are discussed in general terms in Chap.5, para.310.

DUMMY LOAD ELIMINATION PROCEDURE

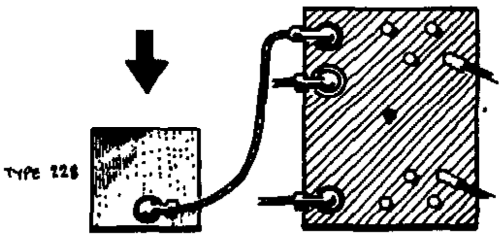
C.D.0896L

THE FAULT MAY BE :

IN THE T2R — IN THE PULSE CABLE — IN THE MODULATOR



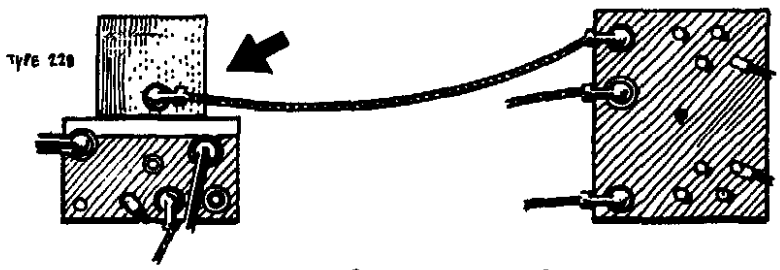
REPLACE T²R BY 80Ω DUMMY LOAD



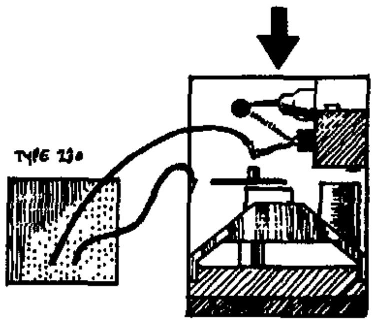
IF THE FAULT PERSISTS SUSPECT MODULATOR

IF THE FAULT IS CLEARED SUSPECT THE T²R OR PULSE CABLE

CHECK CABLE BY PUTTING DUMMY LOAD ON T²R END OF PULSE CABLE



IF THE FAULT IS LOCALISED IN T²R, SWITCH OFF, DISCONNECT BOTH LEADS TO MAGNETRON, THEN CONNECT 1·5K DUMMY LOAD ACROSS THE PULSE TRANSFORMER SECONDARY AND SWITCH ON.



IF THE FAULT DISAPPEARS THE MAGNETRON IS FAULTY

IF THE FAULT PERSISTS, SWITCH OFF, DISCONNECT FILAMENT TRANSFORMER AND SWITCH ON

IF FAULT IS CLEARED REPLACE FILAMENT TRANSFORMER.

IF FAULT STILL PERSISTS THEN PULSE TRANSFORMER OR LEAD TO PULSE TRANSFORMER ARE AT FAULT CHANGE PULSE TRANSFORMER AND IF FAULT STILL PERSISTS IT IS THE LEAD.

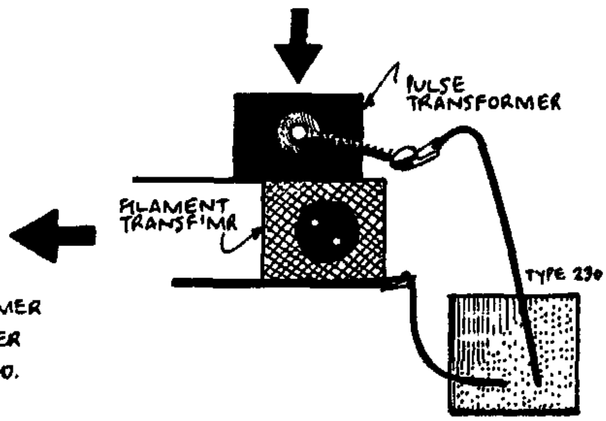


FIG.155

(b) Disconnect pulse cable at transmitter unit and connect 80 ohm dummy load to end of cable. If the equipment switches on and the overload relay ceases to trip, items (a), (b), (c) and (d) are eliminated. If the overload relay continues to trip the most probable fault is a faulty lead from the CV.85 to the output terminal.

(c) The pulse cable can be checked by running the modulator into the 80 ohm load at the pulse output plug.

(d) If the fault is beyond the pulse cable, i.e., in the transmitter unit, the 1500 ohm dummy load is connected into circuit in place of the magnetron. Disconnect both heater leads from the magnetron and make sure they are well clear of any earth point. Connect one of the dummy load crocodile clips to the loose heater lead previously connected to the uppermost magnetron leg and connect the other crocodile clip to earth. If the equipment runs normally now the magnetron was at fault.

(e) If trouble persists, remove the link between the pulse transformer and filament transformer. The filament transformer is now out of the circuit. If the equipment operates now the filament transformer was at fault.

(f) If trouble continues, look for the series of exponentially decaying "rings" on the height tube after the suppression break. Presence of these indicates that the overswing diode circuit is faulty.

(g) If no fault is apparent in the overswing diode circuit, change pulse transformer and check pulse lead from pulse input to pulse transformer.

Other R.F. Faults

4K Morganite Resistor

1089. (a) Once the resistor has been fixed to the metal end connections it should not be broken from them as this will cause the metallised coating to break away and peel off, thus causing arcing at the point of contact.

(b) Occasionally the clamp is not circular and only contacts the metallising over a limited area. The heat developed destroys the metal and develops a high resistance contact and the transformer ringing is no longer damped.

Low Klystron Output or Unstable Klystron

1090. (a) Incorrect voltages. Values should be:-
(i) Cathode -1200V.
(ii) Reflector -1300V to -1600V.

Klystron operation may become critical if the cathode voltage falls to the vicinity of -1000V.

(b) Broken copper glass seal or reflector pinch.

(c) Damaged cathode due to over-running with light loading and maximum feedback.

No Crystal Current

1091. (a) Klystron not oscillating.
(b) Broken klystron loop.
(c) Faulty uniradio 21 feeder and contact ends.
(d) Faulty Pye cable from head amplifier to mixer.
(e) Burnt out crystal.
(f) Faulty contacts on jack.
(g) Faulty capacity probe.

Faulty CV.85

1092. (a) Arcing at contact pins.
(b) Not de-ionising quickly.

Other Insulation Breakdown Faults.

1093. (a) Repeated trouble has arisen over breakdowns of the 2 KV. condensers in the power unit and the transformer T.302.
(b) Occasional high voltage condenser breakdowns occur in the indicator 162 and in Fishpond.
(c) Such breakdowns bring the overload transformer in the power unit into operation and cause the equipment to switch off.

Miscellaneous Servicing Points on H.2.S. Mark IIIA

Modulators Type 64

1094. Only modulators 64 with serial numbers above 300 are suitable for use with the Mark IIIA transmitter units (TR.3555 series and TR.3523).

Jackpoint Polarity

1095. (a) Early units had both the E.H.T. current and crystal jacks wired so that the tip of the jack was negative and the sleeve positive.
(b) Later B.T.H. boxes wired the E.H.T. jack to make the tip of the jack positive and the sleeve negative in accordance with the usual procedure. The crystal jack remains as before.

Jackpoint Danger

1096. The E.H.T. jack point is normally around 1000V. to ground. Precautions should therefore be taken when using the jackpoint.

Switching on at High Altitudes

1097. When the equipment is switched on the indirectly heated VT.127 does not operate for several seconds after the VU111 E.H.T. rectifier. During this period the E.H.T. current jack and various other points will be at over 2KV to ground. For this reason the equipment should not be switched on at high altitudes as the clearances which can be allowed are insufficient. Since the VU.111 power pack is operated by the "L.T. ON" button, there is no objection to switching the modulator off and on if "L.T. ON" was switched on before gaining height.

VU.111 High Voltage Lead Breakdown

1098. The VU.111 in the L.O.P.P. is held in position by 2 metal springs joined by a cord passing over the top of the valve. Voltage breakdowns have occurred when the VU.111 high voltage lead was caught between one of these springs and the valve envelope. A check should be made to ensure that this lead is adequately spaced from earthed points.

Lodge Plugs

1099. Insulation breakdowns have occurred in both the external plug inserts on the aircraft cables and in the internal plug inserts inside the TR 3555 units. The rubber insulation of the cable was found blackened and "powdered" on the underside of the short straight portion immediately before the cable enters the porcelain section of the plug insert. It was found that the yellow cambric covering separating the rubber from the braiding had been cut back, leaving the rubber open to the air inside the metal right angle tube. In repaired plugs, the cambric was left on and allowed to penetrate the procelain section for $\frac{1}{8}$" to afford added protection to the rubber.

L.O. Gear Box Replacement

1100. If for any reason the gear box on the transmitter unit is disengaged from the L.O., care should be taken in replacing it to ensure that the limt of turning in either direction is imposed by the gear box and not the L.O. A Geneva gear limits the gear box to five revolutions of the external pinion.

Iris Adjustment

1101. In the course of lining up the TR.3555 units on the bench the iris tube may jam in the waveguide. To clear, it is necessary to dismantle the iris adjusting mechanism and work the iris up and down the guide by means of a piece of wood. The inside surface of the guide should then be wiped clean. Until a non-attenuating lubricant is available it is not safe to apply any lubricant.

Klystrons for which no tuning point can be found

1102. It may happen that in the last stage of the setting up procedure it is impossible to find a tuning point on the L.O. which will close the magic eye. This may mean that the frequency coverage of theklystron L.O. does not come within 45 Mc/s. of the frequency of the magnetron in the unit. An estimate of the klystron frequency can be made as follows with the test set 205:-

(a) Connect transmitter unit to the test set 205 and set the waveguide controls as in the last test for tuning the L.O.
(b) Set L.C. tuning control at tuning limit nearest the magnetron frequency.
(c) Tune the test set klystron until the magic eye closes.
(d) Set the waveguide switch and selector switch to position 1 and tune the wavemeter to the test set klystron frequency by tuning for maximum meter indication. The wavemeter dial will then indicate approximately the limiting wavelength of the klystron.
(e) It is pointed out that the observed wavemeter reading will differ by 45 Mc/s from the 40 wavelength as it gives the wavelength of the test set system.

One test indicated a klystron whose lower unit was 3.23 cms. when the wavelength of the associated CV.208 was 3.18 cams. The corresponding frequencies are 9298 Mc/s. for the klystron and 9434 Mc/s. for the magnetron.

The Test Set 205 CV.114 Test

1103. The drop in meter reading when the dummy T.R. cell is replaced by the T.R. cell correctly tuned can do little more than indicate when the CV.114 is completely unserviceable as indicated by an abnormally high fall. The CV.114 should not be rejected on the strength of this test unless a power loss of 8 db. is indicated or CV.111's are being burnt out.

Non-Striking of CV.115

1104. Failure of the CV.115 to strike may cause the transmitter output to be low, but it cannot be assumed that the CV.115 is u/s because it has failed to strike and the transmitter output is low. A wrong position of the matching plunger may be responsible for both the low output and the failure of the CV.115 to strike. Matching adjustment should, therefore, always be tried before assuming that the CV115 is u/s.

I.F. Strip Tests

1105. The test set 160 may be used as a 45 Mc/s. signal generator for I.F. strip tests. The dial should be set to 45 Mc/s. and the aerial replaced by a screened lead attached to the aerial terminal at the back of the box. This lead is then used to feed signals into the I.F. strip via the grids and anodes of the valves. The fault can thus be localised to one stage. The output is examined on the monitor 28.

Non-Magnetic Screwdrivers

1106. Only non-magnetic screwdrivers should be used in working on Mark IIIA transmitter units. The strong magnetic field is likely to cause repeated breakage of magnetrons if magnetic screwdrivers are used. The use of magnetic screw drivers will also cause more rapid deterioration of the field strength of the magnets.

Dummy Loads

1107. The same dummy loads are used for elimination tests in Mark IIIA as in Mark IIC. Since the pulse and filament transformers are enclosed in one unit the elimination process is shorter.

CV.208 Handling

1108. In these valves the positioning of the cathode within the valve is critical in determining the efficiency and therefore the output. Cathode position is altered by any deformation of the metal sections of the legs carrying the heater leads. Care should therefore be taken in handling these valves. The instructions printed on the CV.208 refer to the possibility of the cathode leg being displaced if the valve is laid down incorrectly. The wall thickness of the metal section is of the order of 3/1000".

Vibrating Joint Adjustment

1109. Power loss becomes appreciable if the gap between the flanges exceeds $\frac{1}{8}$". The horizontal run of the waveguide is supported at the front panel and on a bracket attached to a vertical frame member. To adjust the gap width proceed as follows:-

(a) Slacken off the mixer chamber clamp.
(b) Slacken off the screws holding the supporting bracket which is now adjustable vertically through a short distance.
(c) Set the bracket so that the gap in the joint is about 1/16". Care must be taken to ensure that the flanges do not touch at any point or flash-over will occur.
(d) Retighten all clamping screws.

The term "choke joint" is commonly used to describe joints of this type when their primary function is to allow for tolerances in the dimensions of components.

BRITISH STANDARD BASES — C.D.0896 L.

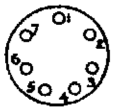
X . INDICATES NO PIN EXCEPT IN C.R.T. TUBES
— INDICATES PIN BUT NO CONNECTION

B4 = BRITISH STANDARD 4-PIN
B5 = " " 5-PIN

CENTRE PIN NOT FITTED ON B4

PIN Nº	CV188 VS70	CV189	VU111	VU120	VU133	VS110	10F8/977	
1	+VE	+VE	—	—	—	+VE	SWITCH	
2	—VE	—VE	—	—	—	—VE	SWITCH	
3	—	—	CH	CH	CH	—	H	
4	—	—	H	H	H	—	H	
(5)	X	X	X	X	X	X	X	
TOP CAP(S)			A	A	A			

B7 = BRITISH STANDARD 7-PIN



PIN Nº	CV73
1	—
2	G1
3	BF
4	H
5	H
6	C
7	G2
TOP CAP(S)	A

B9 = BRITISH STANDARD 9-PIN
B9G = " " 9-PIN (GLASS)

B9

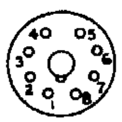
B9G

PIN Nº	CV66	VR91	VR136	VR137
1	G	H	H	H
2	G	G2	A	G
3	C	A	G2	C
4	H	G3	S	A
5	H	S	S	—
6	G	C	G1	—
7	G	G1	S	—
8	A	S	S	—
9	A	H	H	H
TOP CAP(S)				

IO - INTERNATIONAL OCTAL

PIN Nº	VU71SM6	CV67	CV129	VR53	VR54	VR55	VR56	VR67	VT103	6V6G	5Z4G
1	—	G	G	M	M	M	M	M	—	—	—
2	H	H	H	H	H	H	H	H	H	H	H
3	X	—	—	A	A2	A	A	A	A	A	X
4	A1	—	—	G2	C2	D1	G2	X	TA	G2	A1
5	X	—	—	G3	A1	D2	G3	G	G	G1	X
6	A2	—	—	X	X	X	X	X	X	X	A2
7	X	H	H	H	H	H	H	H	H	H	X
8	CH	C	C	C	C1	C	C	C	C	C	CH
TOP CAP(S)		REFLTR	REFLTR	G1		G	G1				

MO = MAZDA OCTAL

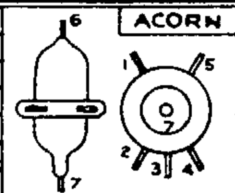


Pin	CV51	CV63	CV118	VR65 CV118	VT127
1	H	H	H	H	H
2	C	G	C	C	C
3	A	C	A	A	X
4	G2	A	G2	G2	G2
5	G3	X	G3	G3	G1
6	M	X	M	M	X
7	X	X	X	X	X
8	H	H	H	H	H
T.C.	G1		G1	G1	A

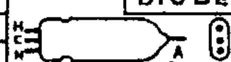
EUROPEAN 8 SIDE CONTACT

Pin		
1		
2		
3		
4		
5		
6		
7		
8		
T.C.		

ACORN VALVE



DIODE VALVE



VR78
VR92

AMERICAN (SMALL)

USS4 4-PIN

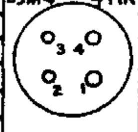
Pin		
1		
2		
3		
4		
T.C.		

USS6 6-PIN

Pin		
1		
2		
3		
4		
5		
6		
TC		

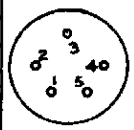
AMERICAN (MEDIUM) BASES

USM4 4-PIN



Pin		
1		
2		
3		
4		
T.C.		

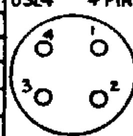
USM5 5-PIN



Pin	VT60	
1	H	
2	G2	
3	G1	
4	C	
5	H	
T.C.	A	

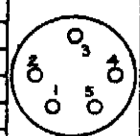
AMERICAN (LARGE)

USL4 4 PIN



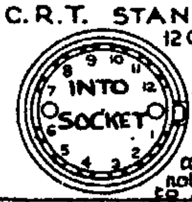
Pin	
1	
2	
3	
4	
T.C.	

GIANT 5-PIN



Pin	
1	
2	
3	
4	
5	
TC	

C.R.T. STANDARD 12 CONTACT BASE



*A1 if not strapped to A3
‡Internal coating if not strapped to A3

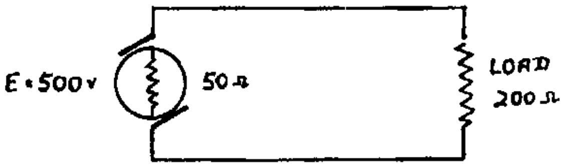
Con	V.C.R. 517	V.C.R. 138	V.C.R. 139
1	G.	G	No. PIN
2	C	C	Y1
3	H	H	X1
4	H	H	A3
5	A1 *	A1 *	X2 *
6	A2	A2	Y2
7	Int. Coat'g ‡	Int. Coat'g ‡	No PIN
8	Y2	Y2	A2
9	X2	X2	H
10	A3	A3	H
11	X1	X1	G
12	Y1	Y1	C

FIG. 156 VALVE BASE CONNECTIONS FIG. 156

R.T.P./m.m./1586-100-11/43

THE PRINCIPLE OF MATCHING

(a)



$I = \frac{500}{250} = 2$ AMPS

DROP IN ARMATURE = 100 V

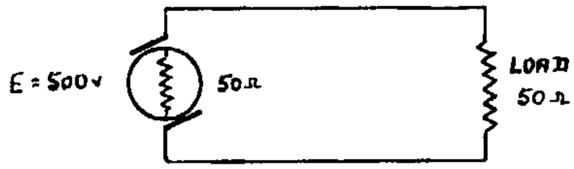
DROP IN LOAD = 400 V

POWER SUPPLIED TO LOAD 400 × 2 = 800 WATTS

POWER DISSIPATED IN ARMATURE

50 × 2 = 100 WATTS.

(b)



$I = \frac{500}{100} = 5$ AMPS

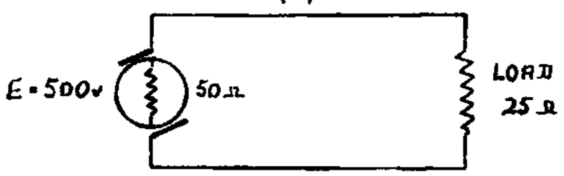
DROP IN ARMATURE = 50 × 5 = 250 V

DROP IN LOAD = 50 × 5 = 250 V

POWER SUPPLIED TO LOAD = 250 × 5 = 1.250 WATTS

POWER DISSIPATED IN ARMATURE 250 × 5 = 1.250 WATTS

(c)



$I = \frac{500}{75} = 6\frac{2}{3}$ AMPS

DROP IN ARMATURE = 50 × $6\frac{2}{3}$ = $333\frac{1}{3}$ V.

DROP IN LOAD = 25 × $6\frac{2}{3}$ = $166\frac{2}{3}$ V

POWER SUPPLIED TO LOAD = $166\frac{2}{3}$ × $6\frac{2}{3}$ = 1.111 WATTS

POWER DISSIPATED IN ARMATURE = $333\frac{1}{3}$ × $6\frac{2}{3}$ = 2222 WATTS

MATCHING PRINCIPLES

THE POWER TRANSFERRED FROM A GENERATOR WITH AN INTERNAL IMPEDANCE THAT IS PURE RESISTANCE TO A LOAD THAT IS A PURE RESISTANCE WILL BE A MAXIMUM WHEN THE LOAD RESISTANCE IS EQUAL TO THE INTERNAL RESISTANCE OF THE GENERATOR.

FIG. 157

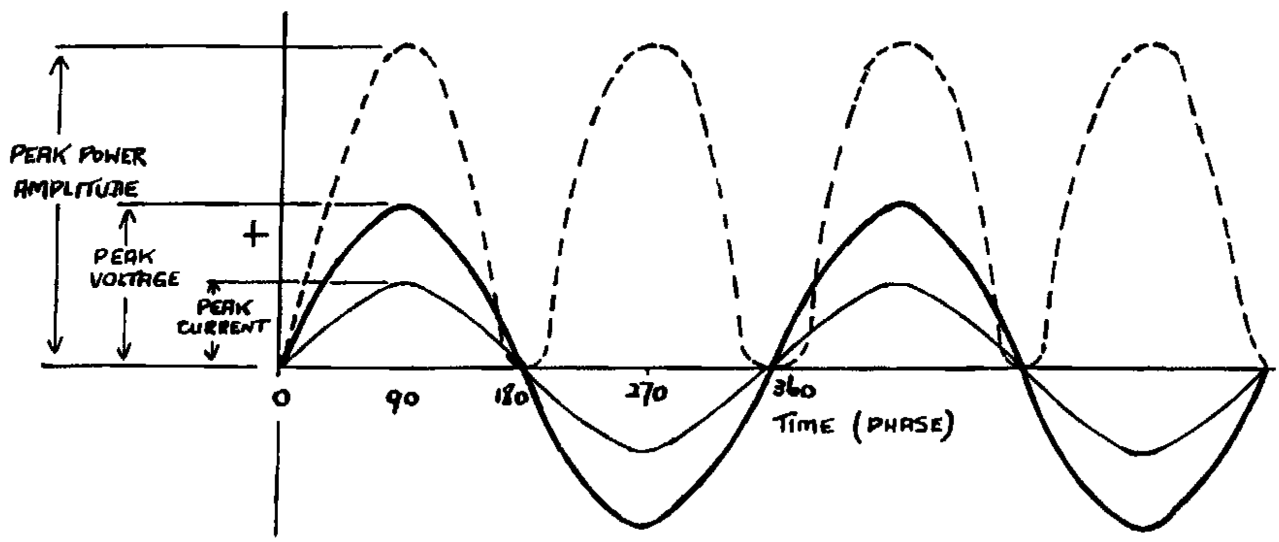
A.C POWER IN A RESISTIVE CIRCUIT.

FIG. 158

——— VOLTAGE DROP ACROSS LOAD = V

——— CURRENT THROUGH LOAD = i

– – – – POWER SUPPLIED TO LOAD = P = ei



INSTANTANEOUS POWER $p = ei = i^2R$

$$\text{RMS POWER} = \frac{\text{PEAK POWER}}{2} = \frac{\text{PEAK VOLTAGE}}{\sqrt{2}} \times \frac{\text{PEAK CURRENT}}{\sqrt{2}} = \text{RMS VOLTAGE} \times \text{RMS CURRENT}$$

POWER OUTPUT WHOLLY POSITIVE AS VOLTAGE AND CURRENT ALWAYS IN PHASE.

CHAPTER 13 - PRINCIPLES OF TRANSMISSION LINES AND WAVEGUIDES

Introduction

1110. Once microwave power has been generated by an oscillator valve the following fundamental output problems arise:-

(a) Matching the oscillator to some form of transmission line in order to get a reasonable output from the valve on the line.
(b) Conveying the power along the line with the minimum of loss due to:-
    (i) Resistive losses.
    (ii) Radiation losses.
(c) Matching the line to the radiating array to get the maximum of radiation.
(d) Giving the radiation the desired directivity in both azimuth and elevation.

1111. Where common T. and R. systems are employed, the following further problems arise:-

(a) Keeping the transmitter power from flowing into the receiver channel at the junction between the receiver branch line and the common output and input line.
(b) Effectively directing the returns into the receiver channel in such a way as to get the maximum signal output for a given transmitter output.

1112. An allied problem is the design of transmission line channels in such a way as to reduce noise and interference pick-up to a minimum in order to obtain the best possible signal to noise ratio for a given transmitter power output.

1113. To approach these problems with the minimum of mathematics the radar mechanic must accept the results of experiments and engineering experience without worrying unduly about a rigid analysis of the fundamental scientific basis of some of these results. This chapter will therefore state many results without attempting to present the full story behind them.

The Concept of Matching

1114. Before dealing with transmission lines themselves we must first study the concept of matching. Let us consider an A.C. generator with an internal resistance of 50 ohms which is capable of developing an e.m.f. of 500 volts. Suppose it is connected to a resistive load of 200 ohms. Then the current delivered is given by $I = \frac{E}{R} = \frac{500}{250} = 2$ amps. The voltage drop across the load is then $2 \times 200 = 400$ volts and the voltage drop across the internal resistance of the generator is $50 \times 2 = 100$ volts. The power supplied to the load is given by $E \times I = 400 \times 2 = 800$ watts. This could also have been found by $I^2 \times R = 4 \times 200 = 800$ watts. The power dissipated in the internal resistance will be $E \times I = 100 \times 2 = 200$ watts. This again could have been found by $I^2 \times R = 4 \times 50 = 200$ watts.

1115. Suppose that instead of 200 ohms a 50 ohm resistive load were used. The current would be $\frac{500}{100} = 5$ amps. The voltage drop across both the load and the internal resistance would be $5 \times 50 = 250$V. The power supplied to each would be $E \times I = 250 \times 5 = 1250$ watts. Hence, the power supplied to the load has increased although the load has been reduced.

1116. Suppose that now we further reduced the load to 25 ohms. The current would be $\frac{500}{75} = 6\frac{2}{3}$ amps. The voltage drop across the load would be

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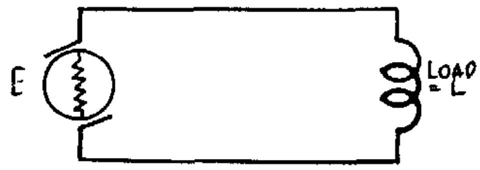
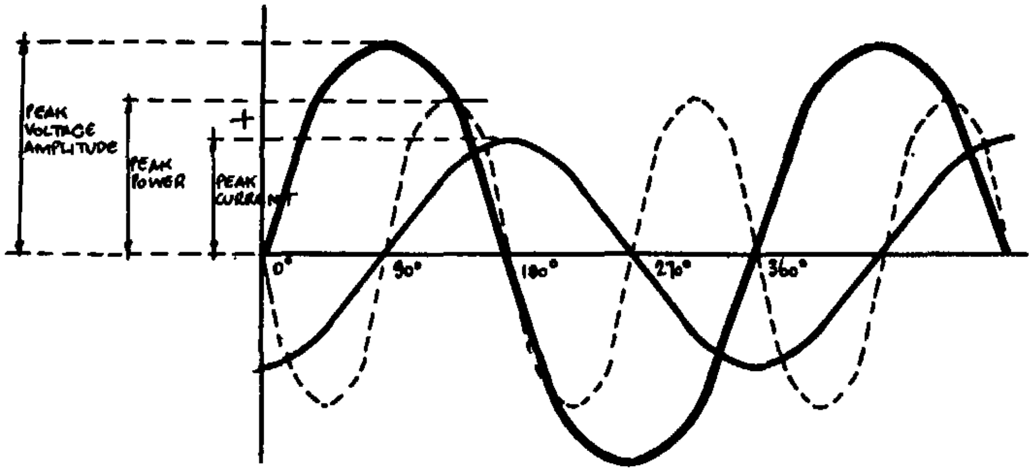
FIG.159

A.C. POWER IN AN INDUCTIVE LOAD

- (thick line) VOLTAGE DROP ACROSS LOAD $e = L\omega i$
- (thin line) CURRENT THROUGH LOAD i
- (dashed line) POWER SUPPLIED TO LOAD $ei = i^2R$



CURRENT LAGS VOLTAGE BY 90°



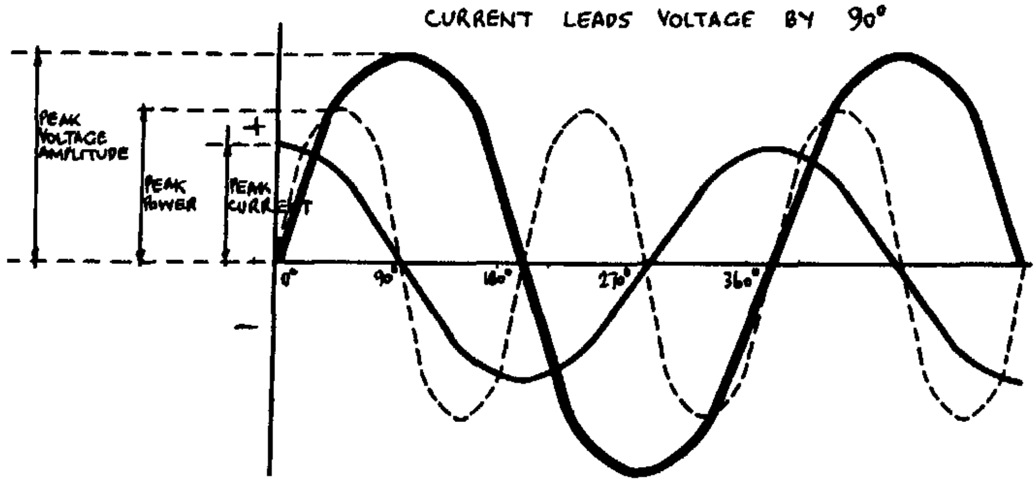
NET POWER OUTPUT ZERO AS POWER CURVE SYMETRIC ABOUT TIME AXIS
NEGATIVE POWER EQUALS POSITIVE POWER WITH A PURE INDUCTIVE LOAD

MEAN POWER = 0

FIG.160

A.C. POWER IN A CAPACITIVE LOAD

CURRENT LEADS VOLTAGE BY 90°



NET POWER ZERO AS POWER CURVE SYMETRIC ABOUT TIME AXIS
NEGATIVE POWER EQUALS POSITIVE POWER WITH A PURE CAPACITIVE LOAD

MEAN POWER = 0

$25 \times 6\frac{2}{3} = 166\frac{2}{3}$ V. The power supplied to the load would be $166\frac{2}{3} \times 6\frac{2}{3}$ = 1111 watts. The voltage drop across the internal resistance would be $50 \times 6\frac{2}{3} = 333\frac{1}{3}$ V. The power dissipated would be $333\frac{1}{3} \times 6\frac{2}{3}$ = 2222 watts.

1117. It appears then that the power supplied to a resistive load is a maximum when the load resistance is equal to the internal resistance of the generator. This is the fundamental concept of matching for power output. It is immaterial whether the generator is a battery, an alternator, or an oscillator. The same rule still applies.

Resistive Loads

1118. If we have an alternator supplying a pure sinewave output to a resistive load, the voltage and current will always be in phase as shown in fig. 158. The instantaneous power curve is obtained by taking the product of the ordinates of the current and voltage curves. Since voltage and current are simultaneously negative the power curve is entirely positive. The mean power is found by drawing the ordinate which "smoothes" out the power curve by putting as much of the area above as below. The numerical value is thus given by peak power ÷ 2. Hence when A.C. power is supplied to a resistive load there is a steady flow of power into the resistance. This power varies with time but is always given by e x i, where e is the instantaneous voltage drop across the load and i the instantaneous current through the load. The mean value of the power is given by

$$P_{mean} = \tfrac{1}{2}P_{peak}$$

$$\text{But } P_{peak} = E_{max.} \times I_{max.}$$

$$\text{Therefore } P_{mean} = \tfrac{1}{2}E_{max.} \times I_{max.}$$

Alternatively, since $e = iR$

$$P_{mean} = \tfrac{1}{2}(I_{max.})^2 \times R.$$

$$\text{But } I_{R.M.S.} = \frac{I_{max.}}{2} \;\&\; E_{R.M.S.} = \frac{E_{max.}}{2}$$

$$\text{Therefore } I_{max.} = 2I_{R.M.S.} \text{ and } E_{max.} = 2E_{R.M.S.}$$

$$\text{Therefore } P_{mean} = 2E_{R.M.S.} \times 2I_{R.M.S.}$$

$$\text{Therefore } P_{mean} = E_{R.M.S.} \times I_{R.M.S.} = I^2_{R.M.S.} \times R$$

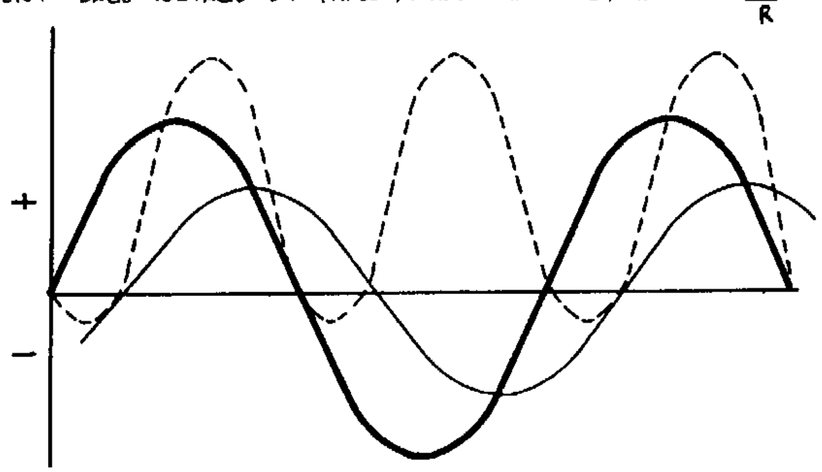
Inductive Loads

1119. If we have the same alternator connected to a pure inductive load the current flow in the inductive load lags 90° on the voltage drop across the inductance. The voltage, current and power curves will then appear as in fig.159. Since the power surve is symmetrical about the time axis the positive part means power flowing from the alternator to the load and the negative part means power flowing from the load to the alternator. What this signifies is that while the current builds up through the inductance energy is stored in the magnetic field instead of being converted into heat. When the magnetic field collapses the current flow is in the opposite sense to the applied e.m.f. and reduces the current that would flow if a resistive load of the same impedance value were used. The result is then the same as if power were being returned from the load to the alternator. Since the curve shows as much power returned as power received the net power taken from the alternator is zero. In practice, this cannot be achieved as an inductance will always have at least a small amount of resistance but it is approximated. We see then that if a load consisting of pure inductive

A.C. POWER IN LOAD CONTAINING INDUCTANCE & RESISTANCE

FIG. 161

CURRENT LAGS VOLTAGE BY PHASE ANGLE GIVEN BY $\tan\theta = \frac{L\omega}{R}$



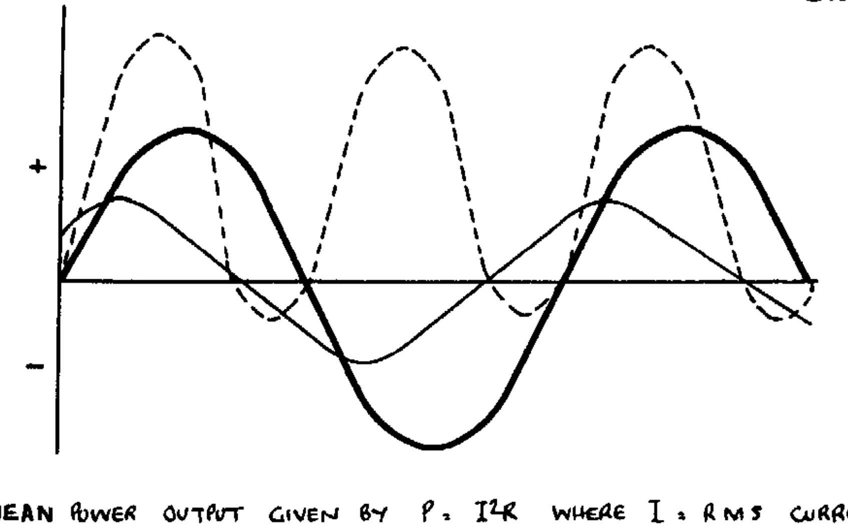
NET **MEAN** POWER OUTPUT GIVEN BY $P = I^2R$ WHERE I = R.M.S CURRENT

SOME NEGATIVE OR REACTIVE POWER DUE TO PRESENCE OF L

A.C. POWER IN LOAD CONTAINING CAPACITANCE & RESISTANCE

FIG. 162

CURRENT LEADS VOLTAGE BY PHASE ANGLE GIVEN BY $\tan\theta = \frac{1}{C\omega R}$



NET **MEAN** POWER OUTPUT GIVEN BY $P = I^2R$ WHERE I = RMS CURRENT

SOME NEGATIVE OR REACTIVE POWER DUE TO PRESENCE OF C

MAX. POWER OUTPUT ONLY OBTAINED IF REACTANCE = ZERO reactance is applied to any form of generator (whose internal impedance is pure resistance) there is no net power output.

Capacitive Loads

1120. If the load is pure capacitive reactance the current in the capacitance always leads the voltage drop across it by 90°. The power curve is again symmetrical about the time axis as shown in fig.160. Hence, when a load is pure capacitive reactance there is no net transfer of power from generator to load.

1121. We may generalise them as follows:-

(a) When a generator is connected to a resistance load power is delivered to the load.
(b) The amount of power delivered is a maximum when the value of the resistive load is equal to the value of the internal resistance of the generator.
(c) When a load is pure reactance, either capacitive or inductive, there is no net power transfer to the load.
(d) Reasoning conversely, if there is no net power transfer to a load, the load appears to the generator as pure reactance.

Mixed Loads

1122. Suppose we consider next a load impedance that contains both inductive and resistive components. The impedance will be given by

$Z = \sqrt{(Lw)^2 + R^2}$. The voltage drop across the load will be $IZ = I \times \sqrt{(Lw)^2 + R^2}$
$= \sqrt{(LwI)^2 + (IR)^2} = \sqrt{(\text{V. drop across inductance})^2 + (\text{V. drop across Resistance})^2}$

The current will lag behind the voltage drop by an angle given by

$$\text{Tan } \phi = \frac{VL}{VR} = \frac{XLI}{RI} = \frac{XL}{R}$$

Hence, the greater the ratio of the inductance to the resistance, the greater will be the phase angle ϕ. If we assume a phase angle of 45°, we shall obtain voltage, current and power curves as in fig.161. We see that there is a net flow of power into the load since the positive part of the power curve is larger than the negative part. We can imagine the entire power having been supplied but the negative part having been returned because of the reactance in the load. The net mean power input will be given by $(I_{R.M.S.})^2 \times R$.

1123. If we have a load consisting of capacitive reactance and resistance the only difference introduced is that the current will lead the voltage drop across the load by a phase angle given by

$$\text{Tan } \phi = \frac{VC}{VR} = \frac{XcI}{RI} = \frac{Xc}{R} = \frac{1}{CwR}$$

The curves for voltage, current and power will then appear as in fig.162 which again shown the presence of negative or returned power. The power output is again given by $(I_{R.M.S.})^2 \times R$.

1124. It follows then that the presence of a reactive component in any load results in returned or reflected power. This suggests that we can only get the maximum power transfer to a load under the following conditions:-

(a) The effective load reactance is zero.
(b) The load resistance is equal to the internal resistance of the generator.

1125. So far we have assumed that the generator impedance is purely resistive. This is not necessarily the case. If there is reactance in addition to resistance the total impedance in the circuit is increased. Hence the current flow is reduced. Also, since reactance in the load increases the total impedance, the current flow is again reduced. We may then say that we can only obtain maximum current flow when the total impedance is a minimum, i.e. equal to the sum of the internal resistance and the resistance of the load. We may then restate the requirements for maximum power transfer to a load as follows:

(a) Reactance of system is zero
(b) Load resistance is equal to the internal resistance of generator.

1126. Since the voltage drop across a capacitive reactance is opposite in sense to that across an inductive reactance we can eliminate any reactance by introducing an equal and opposite reactance. Hence, when an alternator has an inductive component in its internal impedance we can eliminate its effect at any selected frequency by inserting a suitable capacitance in the load.

Transmission Line Properties

1127. In so far as radar work is concerned, it is normally not feasible to couple the generator directly to the load, i.e., the oscillator to the radiating array or the local oscillator to the mixer. Some form of transmission line therefore must be introduced. Before we can see how we must modify out basic matching law as stated in para.1125 (a) and (b) to deal with the insertion of a transmission line between generator and load, we must consider the constance of transmission lines and the commoner basic forms in which these lines appear.

Types of Transmission Lines

1128. Transmission lines using the "go and return" circuits, appear in four basic forms:-

(a) Parallel wire line separated and supported by suitable insulators.
(b) Single wire line using the conducting earth as the return circuit.
(c) Shielded pair, usually embedded in a dielectric.
(d) Coaxial line, with air or other dielectric.

These are illustrated in fig.164.

Transmission Line Constants

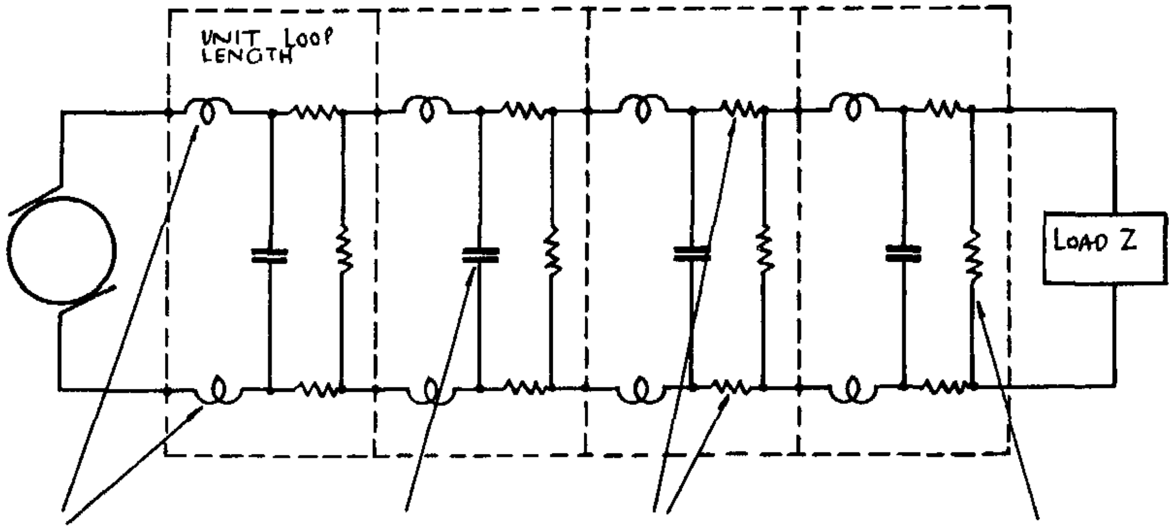
1129. All transmission lines are described in terms of four fundamental constants:-

(a) L - inductance per unit loop length.
(b) C - capacitance per unit loop length.
(c) R - resistance per unit loop length.
(d) G - conductance or leakance per unit loop length.

By loop length we mean unit length of both the "go" and "return" conductors.

1130. (a) L represents the self-inductance of unit length in both sides of the line.
(b) C represents the capacitance across unit length of the line in the case of the shielded pair and coaxial line. In the case of the single wire line it will represent the capacitance to ground and adjacent objects. In the case of the parallel wire line it will be the net effect of capacitance across the line and capacitance from either side to ground and other conductors.
(c) R represents the ohmic resistance per unit length of both the "go" and "return" paths.

EQUIVALENT CIRCUIT OF A TRANSMISSION LINE



L = INDUCTANCE PER UNIT LOOP LENGTH

C = CAPACITANCE PER UNIT LOOP LENGTH

R = RESISTANCE PER UNIT LOOP LENGTH.

G = CONDUCTANCE LEAKAGE PER UNIT LOOP LENGTH

$$\text{CHARACTERISTIC IMPEDANCE} = \sqrt{\frac{(L\omega)^2 + R^2}{(C\omega)^2 + G^2}}$$

FOR HIGH FREQUENCIES, R NEGLIGIBLE IN COMPARISON WITH $L\omega$
G NEGLIGIBLE IN COMPARISON WITH $C\omega$

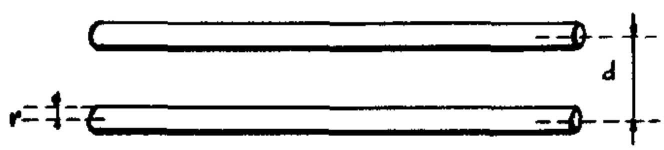
$$\therefore Z_0 = \sqrt{\frac{L}{C}}$$

FIG. 163

CHARACTERISTIC IMPEDANCE FORMULAE

PARALLEL WIRE OPEN LINE (EARTH MAY BE USED AS SECOND CONDUCTOR)

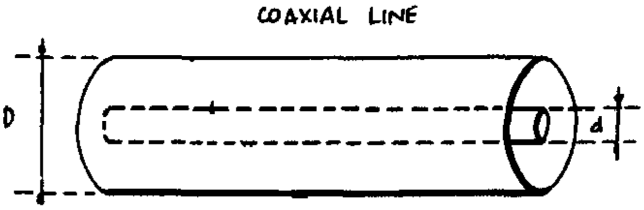
(a)



$$Z_0 = 276 \log \frac{d}{r}$$

COAXIAL LINE

(b)



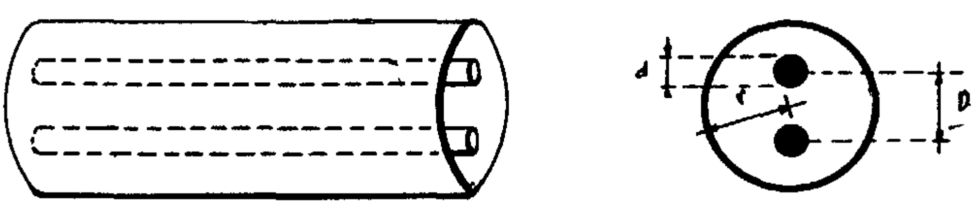
$$Z_0 = 138 \log \frac{D}{d} \quad \text{FOR AIR DIELECTRIC}$$

$$Z_0 = \frac{138}{\sqrt{K}} \log \frac{D}{d}$$

FOR DIELECTRIC CONSTANT K

EMBEDDED SHIELDED PAIR

(c)



$$Z_0 = \frac{276}{\sqrt{K}} \log \left[\frac{2D}{d} \left\{ \frac{1 - \left(\frac{D}{2r}\right)^2}{1 + \left(\frac{D}{2R}\right)^2} \right\} \right]$$

FIG. 164

(d) G represents the leakage from one side to the other per unit length due to ionisation, dielectric leakage, insulator leakage, &c.

We may then represent any type of transmission line in the form shown in fig.163

Characteristic Impedance of a Transmission Line

1131. We may define the characteristic impedance of a line in terms of the constants in para.1129 by the formula:-

$$Z_o = \sqrt{\frac{R^2 + (Lw)^2}{G^2 + (Cw)^2}} \text{ ohms}$$

At frequencies such as are used in radar with the type of lines we use, R becomes negligibly small compared with Lw and G becomes negligibly small in comparison with Cw. We may therefore use the approximation

$$Z_o = \sqrt{\frac{(Lw)^2}{(Cw)^2}} = \sqrt{\frac{L}{C}}$$ ohms where L is in microhenries per mile and C is in microfarads per mile. Z_o will be regarded as pure resistance for our purposes.

Rules for the Characteristic Impedance of Practical Lines

1132. For the parallel wire line, Z_o is given by the formula $Z_o = 276 \log \frac{d}{r}$ where d is the centre-to-centre distance of the wires and r is the radius of the wires. This assumes air as the dielectric. The value of Z_o will only vary slowly for a wide range of variation in the ratio of $\frac{d}{r}$. Such lines usually have a Z_o of about 600 ohms.

1133. For the coaxial line we have the formula $Z_o = 138 \log \frac{D}{d}$ where D = diameter of outer and d = diameter of inner when the dielectric is air. If a dielectric of dielectric constant K is used, the formula becomes

$$Z_o = \frac{138}{\sqrt{K}} \log \frac{D}{d}$$

1134. For the embedded pair, the rule takes the form

$$Z_o = \frac{276}{\sqrt{K}} \log \frac{2D}{d} \frac{\left(1 - \left(\frac{D}{2r}\right)^2\right)}{\left\{1 + \left(\frac{D}{2r}\right)^2\right\}}$$

where D = distance from centre to centre of conductors.
d = diameter of conductors.
r = radius of earthed sheath.

What Happens When a Transmission Line is Connected to a Generator.

1135. If a transmission line is connected to an A.C. generator the one side of the input end of the line will swing alternately positive and negative with respect to the other end as the generator goes through its cycle. While swinging positive, electrons flow from the conductor into the armature. We thus have a rarefaction or thinning out of electrons travelling away from the generator. This will build up to a maximum and then decay to zero while the generator goes through a half-cycle. During the next half-cycle the armature is pushing electrons into the same conductor, so the rarefaction is followed by a condensation of electrons which builds up to a maximum and decays to zero while the generator goes through the second half-cycle. In a loss-free line this disturbance travels with the speed of light, i.e., 3×10^{10} cms. or 186,000 miles per second. For a frequency of 50 cycles per second a full period takes 1/50th second. The disturbance will then travel about 3720 miles

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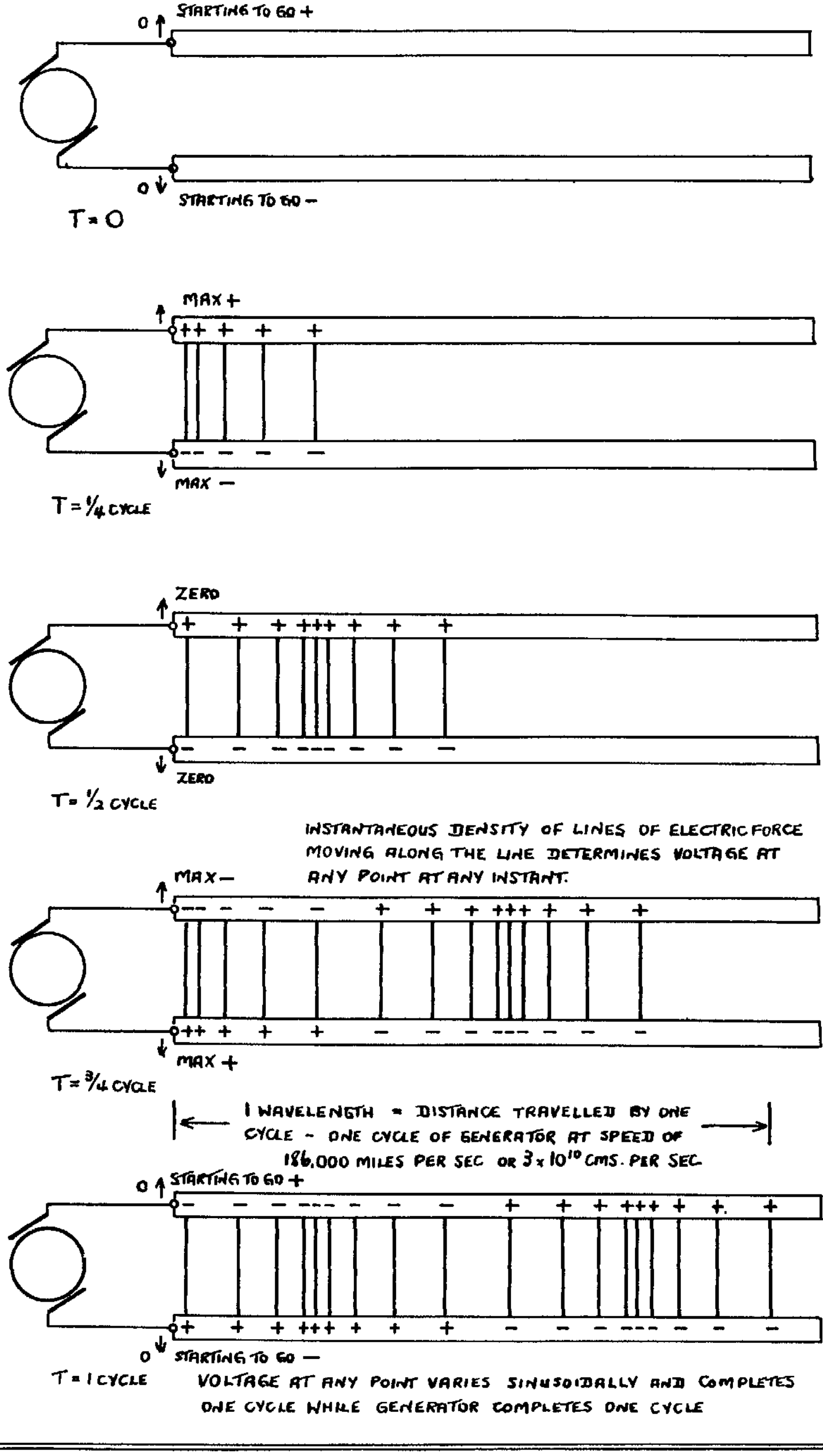
HOW A VOLTAGE WAVE TRAVELS ON A TRANSMISSION LINE

FIG. 165



during one cycle. This distance we call a wavelength. If we think of a generator with a frequency of 3300 Mc/s. the wavelength becomes about 9 cms. When we have an A.C. generator connected to a line with one side earthed, we send down the "hot" conductor a series of electron condensations and rarefactions. If the line is balanced the electron movements will be in antiphase in the two conductors. Since the electron density is different the potential is different along the line. Assuming the one side to be "earthy" we will then have a potential difference distribution along the line that is determined by the electron concentrations along the "hot" line. If the input is sinusoidal the voltage distribution will be sinusoidal at any instant. But the electron distribution is continually changing at any point. Hence, if we consider the changes at any point, the electron concentration will vary sinusoidally with time and the voltage at that point will vary sinusoidally with time. This is equivalent to saying that voltage wave is travelling along the line. The wavelength of this wave is found by finding how far an electromagnetic wave will travel while the generator completes one cycle.

The Infinite Line

1136. If a line were of infinite length the voltage wave could travel away from the generator forever. While this case is a practical impossibility we shall be interested in what current flow would take place if it were possible. In para. 1131 it was pointed out that a transmission line has a characteristic impedance given by $Z_o = \sqrt{\frac{L}{C}}$ ohms which is pure resistance. If the generator e.m.f. is V and the internal resistance of the generator is R, the current flow would be given by $I = \frac{V}{R + Z_o}$. The voltage drop across the line would then be $I \times Z_o$ or $V \times \frac{Z_o}{R + Z_o}$. If $Z_o = R$, we have a voltage drop of $\frac{V \times Z_o}{2Z_o}$ or $\frac{V}{2}$ across the line and an equal voltage drop in the armature. We say the line is then matched to the generator. The infinite transmission line may then be regarded as a pure resistive load of value = Z_o ohms. Such a line will take the maximum power from a generator when $Z_o = R$ = internal resistance of the generator.

The Finite Line with Resistive Termination equal to Z_o.

1137. If a finite length of line is completed by putting a pure resistance of magnitude Z_o across the two conductors it looks the same as an infinite line to the generator. The steady A.C. current is then given by $I = \frac{V}{R + Z_o}$ just as above. If Z_o is equal to R, the internal resistance of the generator, we get the maximum power transferred to the load. The power flows to the load in the form of a steady travelling wave of the same type as would flow away from a generator if connected to an infinite line.

1138. The terminating resistance need not be an actual resistance. A resonant circuit whose dynamic resistance is equal to the Z_o of the line would be equally satisfactory. A resonant aerial would therefore be a suitable termination for a line whose Z_o was equal to the radiation resistance of the aerial.

Line with a Resistive Termination Greater Than Z_o

1139. Suppose we have a generator of internal resistance R feeding into a line of $Z_o = R$. A sinusoidal current of value $I = \frac{V}{2R}$ (where V is the generator e.m.f.), would then start to flow into the line. When an electron condensation reached the end the electrons could not flow through the load to the earthy side as rapidly as they were moving down the line. They would then tend to pile up and repel the oncoming electrons back. We might think of it as a surge of electrons hitting the termination and some of them passing on through it while the others bounce back to give a reflected condensation.

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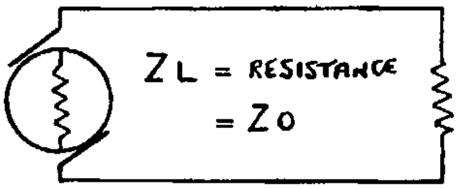
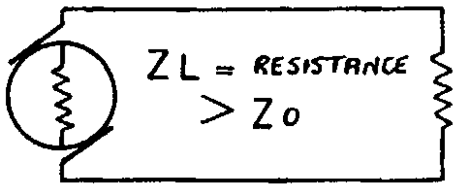
REFLECTED WAVES ON TRANSMISSION LINES

(a)



NO REFLECTION AT TERMINATION
FULL ABSORPTION

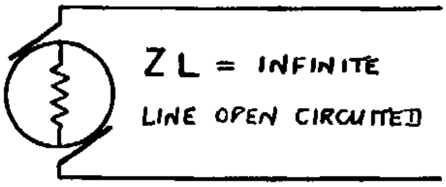
(b)



PARTIAL ABSORPTION AT TERMINATION
PARTIAL REFLECTION WITHOUT PHASE REVERSAL

$$\frac{V_{REF.}}{V_{INC.}} = \frac{Z_L - Z_o}{Z_L + Z_o}$$

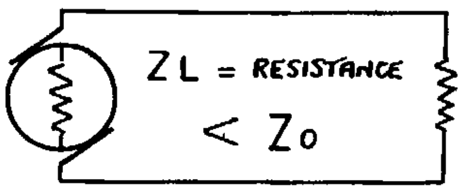
(c)



COMPLETE REFLECTION AT TERMINATION
WITHOUT PHASE REVERSAL

$$V_{REF.} = V_{INC.}$$

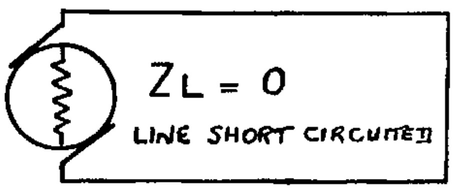
(d)



PARTIAL ABSORPTION AT TERMINATION
PARTIAL REFLECTION WITH PHASE REVERSAL

$$\frac{V_{REF.}}{V_{INC.}} = \frac{Z_o - Z_L}{Z_o + Z_L}$$

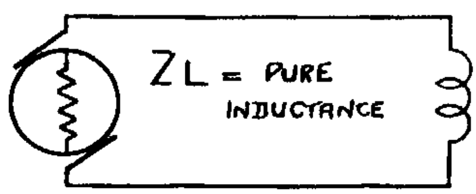
(e)



COMPLETE REFLECTION AT TERMINATION
WITH PHASE REVERSAL

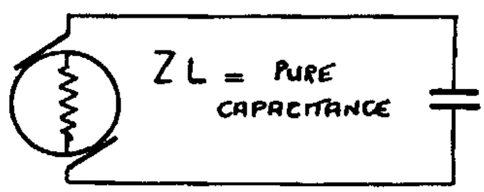
$$V_{REF} = V_{INC.}$$

(f)



COMPLETE REFLECTION AT TERMINATION
WITH A PHASE RETARD DEPENDING
ON VALUE OF X_L.

(g)



COMPLETE REFLECTION AT TERMINATION
WITH A PHASE ADVANCE DEPENDING
ON VALUE OF X_C.

FIG. 166

We say then that when the line is terminated in a resistive load greater than the Z_0 of the line the voltage wave reflects in the same phase, i.e., without phase reversal, since condensation travelling to the termination results in the reflection of a condensation at the termination.

The Open-Circuited Line

1140. The amplitude of the reflected wave will be dependent on the extent to which the termination exceeds Z_0. The more the magnitude of Z_L (the resistive load impedance) exceeds Z_0, the greater will be amplitude of the reflected wave. If we go to the limiting case of the open-circuited line the entire wave must be reflected so the amplitude of the reflected and incident waves must be equal.

The Line Terminated in a Resistive Load Less Than Z_0

1141. If Z_L is a resistance less than Z_0 we may imagine an effect at the termination rather like the effect when an automobile which has been climbing a hill reaches the top. If the same acceleration is provided the speed will suddenly increase when the opposing force is reduced. When the electron condensation reaches the termination there is a tendency to shoot across the low resistance termination to the other side of the line at a greater rate than the flow can be sustained. The effect of the overshoot is to send a rarefaction back toward the generator. We say then that when the line is terminated in a resistive load, Z_L, which is less than Z_0, we have a reflected voltage wave whose phase in opposite to that of the oncoming wave, i.e., we have reflection with phase reversal. By saying we have phase reversal at the termination we mean that when a condensation arrives at the termination a rarefaction is reflected back.

The Short-Circuited Line

1142. Obviously, the amplitude of the antiphase reflected wave will be dependent on how much the value of Z_L is below the value of Z_0. In the limiting case of the short-circuited line the amplitude of the antiphase reflected wave will be equal to that of the incident wave.

Summary

1143. We may gather up these points as follows:-

(a) When a line is terminated in a resistive load, $Z_L = Z_0$, there is a steady travelling wave passing down the line to the load. There is then no reflection.
(b) When a line is terminated in a resistive load, $Z_L > Z_0$, there is partial absorption and partial reflection without phase reversal. The amplitude of the reflected wave increases as the ratio of $Z_L : Z_0$ increases.
(c) When a line is open-circuited, $Z_L = \infty$, and the wave is completely reflected without phase reversal, i.e., the reflected wave has an amplitude equal to that of the incident wave and is in phase with it at the termination.
(d) When the line is terminated in a resistive load, $Z_L < Z_0$, there is partial absorption and partial reflection with a phase reversal. The amplitude of the antiphase reflected wave increases as the ratio of $Z_0 : Z_L$ increases.
(e) When the line is short-circuited, $Z_L = 0$, and the amplitude of the antiphase reflected wave is equal to that of the incident wave so we have total reflection.

Standing Waves

1144. If a piece of steel wire or gut is suitably bowed, it will show standing waves, i.e., certain points are practically at rest while points half-way between are vibrating through a wide amplitude. The stationary points are called nodes and the points of maximum displacement are called antinodes. The distance between nodes or antinodes is a half wavelength. Such standing waves are produced whenever we have two travelling waves going in opposite directions, i.e., an incident wave and a reflected wave.

1145. We have noted that on a transmission line we have a direct wave and a reflected wave when the resistive termination Z_L is not equal to Z_o. The two waves travelling in opposite directions will interfere to form a standing wave on the line. If Z_L Z_o, the reflected voltage wave and the incident voltage wave are in phase at the termination and we have a voltage maximum or voltage antinode at the termination. A quarter wavelength back there will be a voltage minimum or voltage node. At the termination the current is low so there is a current node and a quarter wave back there is a current maximum or antinode. Voltage and current maxima and minima are then displaced by 90°in a standing wave.

1146. If the line is open-circuited the amplitude of the voltage maximum at the open end will be 2V where V is the amplitude of the direct wave. The amplitude of the voltage a quarter wavelength back from the open end will be zero as the direct wave and reflected wave are 180° out of phase. This follows since the direct wave is 90° short of the in-phase point and the reflected wave is 90° beyond the in-phase point at the open end. The amplitude of the standing wave then varies between 2V and zero on the open-circuited line.

1147. In the general case of a termination $Z_L > Z_o$, the amplitude of the standing wave varies between Vi + VR and Vi - VR, where Vi is the amplitude of the incident and VR the amplitude of the reflected wave. Voltage maxima or antinodes occur at the termination and at half-wave intervals back toward the generator. Voltage minima occur at odd quarter wavelengths from the termination. Current maxima occur with voltage minima and vice versa.

1148. In the case of the short-circuited line the amplitude of the reflected wave is equal to that of the incident wave at the short-circuited end and is in antiphase. The amplitude of the standing voltage wave is then zero at the shorted end as one would logically expect. The current will, of course, be a maximum. We then have current maxima and voltage minima at half wavelength intervals from the shorted end and voltage maxima and current minima at odd quarter wavelength intervals from the shorted end.

1149. If the resistive termination $Z_L < Z_o$, the voltage amplitude is Vi - VR at the termination and Vi + VR at half wavelength intervals from the termination.

Standing Wave Ratio

115. The degree of mismatch present on a line is indicated by the ratio of the voltage amplitude at the nodes and antinodes. We may define the standing wave ratio as

$$\frac{Vi + VR}{Vi - VR} \text{ or } \frac{V_{max.}}{V_{min.}}$$

In the extreme case of total reflection, the ratio is infinite. If there is a perfect match and VR = 0, the standing wave ratio is 1. Hence, as the standing wave ratio falls towards 1, we progress from total reflection and zero absorption of power, to zero reflection and total absorption. Any method of measuring the standing wave ratio then provides an indication of the degree of mismatch present at the termination. On an open wire line, neon bulbs may be used to indicate standing waves. If the glow set up varies as the neon is moved along the line, the voltage must be varying along the line and standing waves are present. If the glow remains at a constant intensity the R.M.S. voltage value is constant along the length. There is then only a travelling wave and complete absorption and a perfect match between line and load.

Flat Lines and Resonant Lines

1151. A line which is matched to its termination and shows no standing waves is called a flat line. A line which shows standing waves because it is not matched to its termination is called a resonant line.

Losses on Resonant Lines

1152. If a generator is matched to a line the maximum power is taken from the generator to the line. Obviously, we want the maximum possible transfer of power from the line to the termination. We know that the power will flow steadily into the termination if Z_L (resistive) = Z_o. The question arises as to what happens to the power that is reflected at the termination. One effect will be a tendency to cause flashover at the voltage antinodes or maxima. These flashovers, and corona discharges from rough edges or tiny projections due to a surface that is not perfectly smooth, will cause heating of the air dielectric in either an open wire line or in a coaxial line with air dielectric. In dielectric-filled lines, flashover is improbable but there will be heating and softening of the dielectric. In each case power is wasted. Furthermore, flashover and discharges will tend to be more troublesome as altitude increases. With dielectric-filled lines dielectric breakdown is more likely at bends where there is an added mechanical strain on the dielectric.

1153. Whenever standing waves are present, there is also a tendency for energy to be radiated. This effect becomes more and more pronounced in open wire lines as the wavelength becomes comparable with the spacing of the lines. In shielded lines of the coaxial or embedded pair type, no radiation should be possible if the outer sheath could be kept at a true R.F. earth potential. At very high frequencies some radiation seems to escape even from such lines.

1154. It follows then that standing waves result in wasted power, reduced efficiency and reduced output. In addition, flashover and corona discharges in air dielectric line tends to cause noise and interference and a much impaired signal to noise ratio. It is, therefore, imperative to avoid standing waves as much as possible in radar work.

Composite Lines

1155. In radar work it is frequently impossible to connect a generator to its load by means of a single continuous section of transmission line. In general, the line may have to include several sections of different dimensions, dielectric and design. These different sections will have usually different characteristic impedances. Where the two sections meet we shall encounter the same problem that appears when the line terminated in a load whose resistiv value is different from the Z_o of the line. That is, reflections occur either in phase or in antiphase, depending on whether the Z_o of the next section is greater or less than that of the preceding section. The amplitudes of these reflected waves and the resultant standing waves will depend on the degree of mismatch just as before.

Functions of Matching Devices

1156. We see then that the maximum power output from a radiating array depends on fulfilment of the following conditions:-

(a) The generator must be matched to the line to get the maximum power from the generator into the line.
(b) Where a composite line is required the various sections must be matched to each other to prevent progressive reflection at each discontinuity.
(c) The final line section must be matched to the radiating array.

We are, therefore, faced with the requirement of finding impedance transformers and other matching devices to fulfil these conditions.

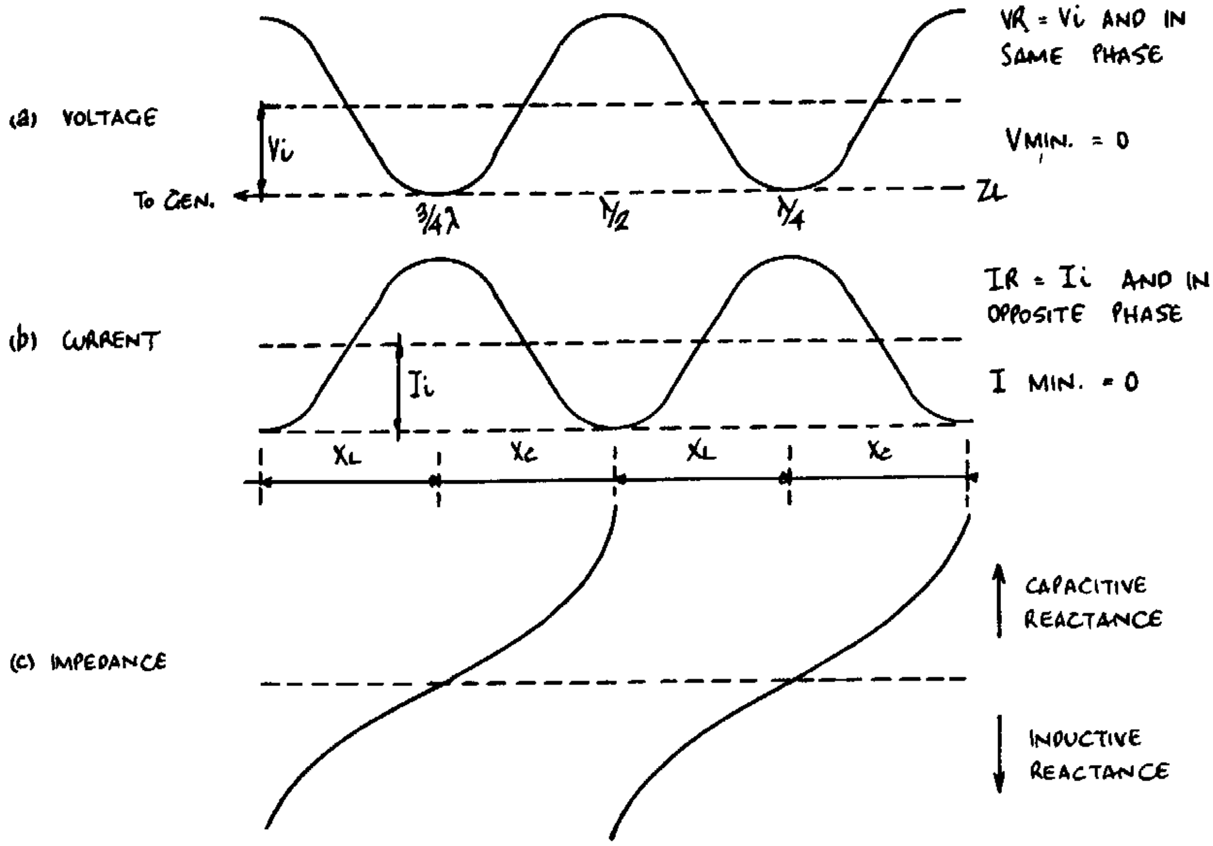
Impedance Transformations by Transmission Lines

The Correctly Terminated Line

1157. We have noted in para.1152 that if a generator of internal resistance R is connected to a load given by $Z_L = R$ by means of any length of transmission line of $Z_o = R$, there is no standing wave on the line but the steady maximum flow of power to the load. It follows then that when a line is terminated

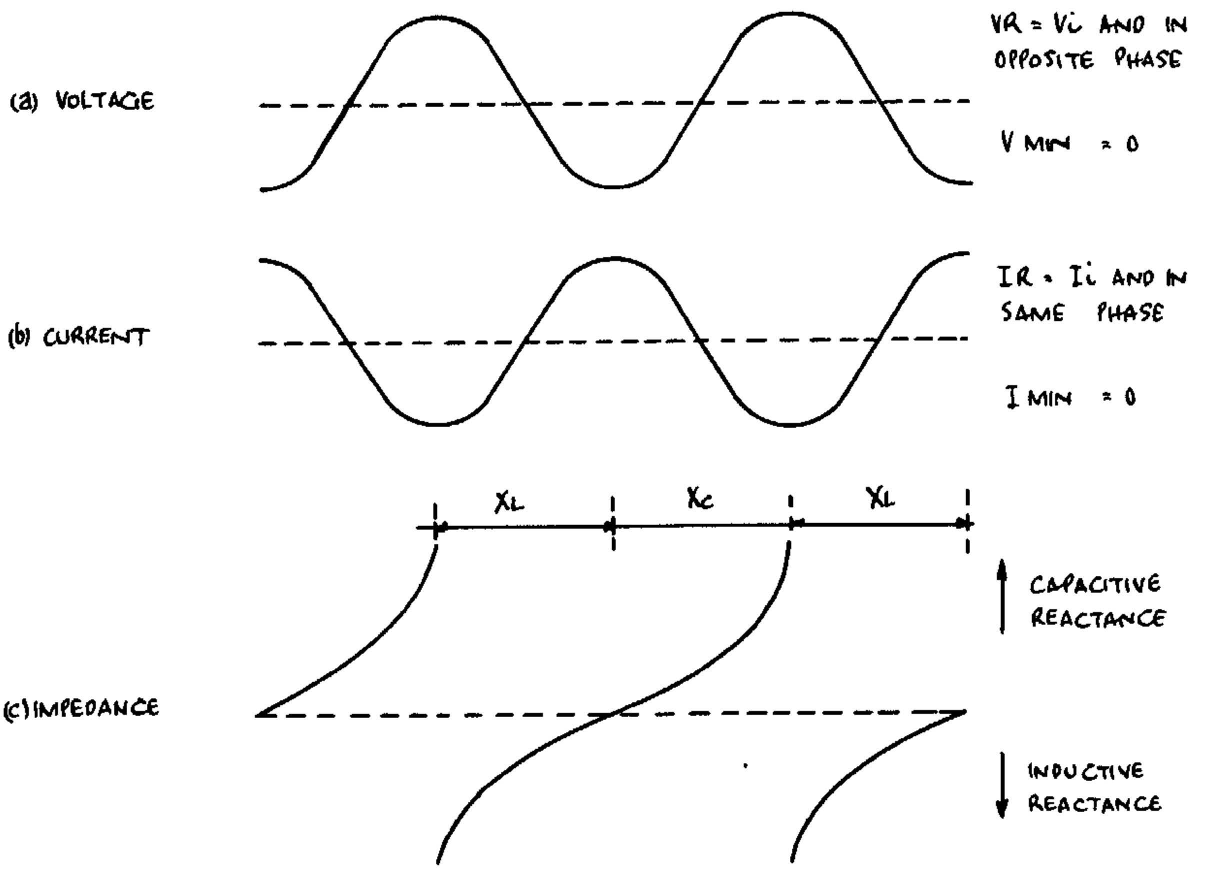
STANDING WAVES ON OPEN CIRCUITED LINE

FIG.167



STANDING WAVES ON SHORT CIRCUITED LINE

FIG.168



in a resistive load equal in value to Z_0, the effect is the same as if the line were absent. We note, therefore, that any length of line of characteristic impedance Z_0 will act as a 1 : 1 impedance transformer when terminated in a resistive load $Z_L = Z_0$. We also noted in para.1151 that such a line is a flat line. That is, that if a neon bulb or other form of R.F. voltmeter were moved along the line, it would show the same R.M.S. voltage at all points along the line. This voltage would be given by $V = IZ_0$ where I is the R.M.S. value of the A.C. current taken from the generator. The value of I would be given by $I = \frac{E}{Z_0 + R} = \frac{E}{2Z_0}$ or $\frac{E}{2R}$ where E is the E.M.F. developed by the generator. Also, since the effect is the same as if the generator were coupled directly to the resistive load, voltage and current are in phase at all times at all points along the line.

The Open Circuited Line

1158. In para.1141 we noted that when a line of characteristic impedance Z_0 is open circuited the incident wave is reflected without phase change at the termination and that the amplitude of the reflected wave is equal to that of the incident wave. The two waves interfere to give a standing wave with voltage maxima and current minima at the open end at half-wave intervals, i.e., even multiples of a quarter wavelength. The voltage minima and current maxima occur at odd quarter wavelength intervals from the open end. Since all the power is reflected such a line obviously acts like a pure reactance. The value of the reactance it presents at any point will be given in magnitude sense by $Z = \frac{V}{I}$ where V and I are the R.M.S. voltage and current at the point. If we plot the values of Z found from this rule against values of ℓ measured from the open end, we get a graph as shown in fig.167. The impedance is a capacitive reactance varying between ∞ and zero in the first quarter wavelength and an inductive reactance varying between ∞ and zero in the second quarter wavelength. All following half-wavelengths repeat the same cycle. Hence, a half wavelength of open line can be used to provide any value of either capacitive or inductive reactance by tapping in at the appropriate point.

The Short Circuited Line

1159. In para.1148 we noted that a short-circuited line differs only from the open-circuited line in having the voltage minimum and current maximum at the shorted end and at even multiples of a quarter wavelength while the voltage maxima and current minima occur at odd quarter wavelengths from the shorted end. The impedance curve for the shorted line then appears as in fig.168 which is just fig.168 moved a quarter wavelength. Since all power is reflected the line again acts like a pure reactance. The first quarter wavelength gives all values of inductive reactance between 0 and ∞ and the second quarter wavelength gives all values of capacitive reactance between ∞ and 0. Hence, a half wave-length of shorted line also shows the full range of reactance variation but in a different sequence to the half wave-length of open line.

The Line with Z_L (Resistive) $> Z_0$.

1160. We noted in para.1147 that such a line absorbs some power and reflects the balance. The resultant standing wave has a voltage maximum and current minimum at the termination and at even quarter wavelengths from the end. The voltage minima and current maxima occur at odd quarter wavelengths from the termination. Since we have both absorption and reflection the effect is similar to what happens when a generator is coupled directly to a load containing both a reactive and a resistive component. At all quarter wave points the impedance offered is a pure resistance. At the odd quarter wavelength points the value of this resistance is given by $\frac{Z_0}{Z_L}$. At the even quarter wavelength points the value is the same as the termination, i.e., Z_L. In the first quarter wavelength the impedance consists of resistance + a capacitive term, corresponding to the capacitive value shown by the open-circuited line in the first quarter wavelength. In the

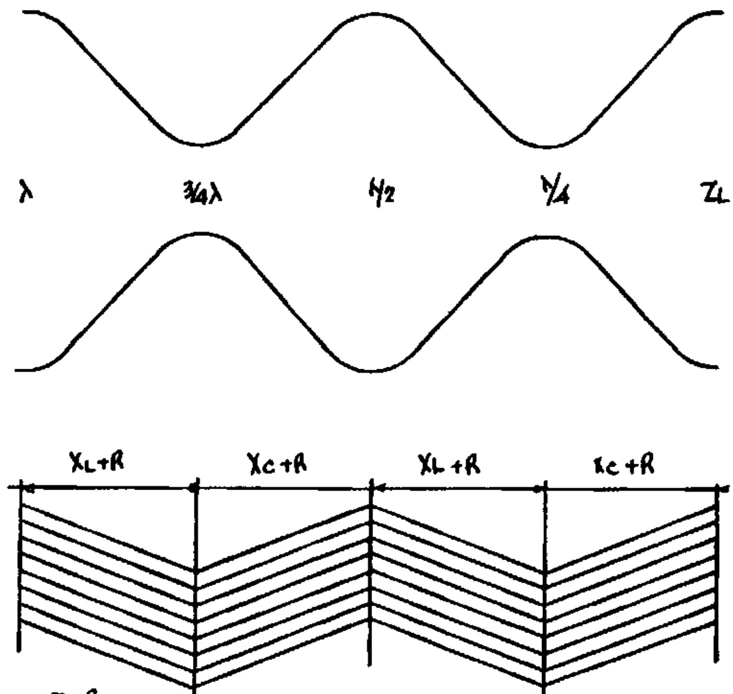
STANDING WAVES ON LINE WITH Z_L (RESISTIVE) $> Z_0$

FIG. 169

(a) VOLTAGE

(b) CURRENT

(c) IMPEDANCE



$V_R < V_i$ AND IN SAME PHASE

$$\frac{V_{MAX}}{V_{MIN}} = \frac{Z_L + Z_0}{Z_L - Z_0}$$

$I_R < I_i$ AND IN SAME PHASE

$$\frac{I_{MAX.}}{I_{MIN.}} = \frac{Z_L + Z_0}{Z_L - Z_0}$$

$Z = \dfrac{Z_0^2}{Z_L}$ = PURE RESISTANCE AT ODD QUARTER WAVE POINTS

$Z = Z_L$ = PURE RESISTANCE AT EVEN QUARTER WAVE POINTS

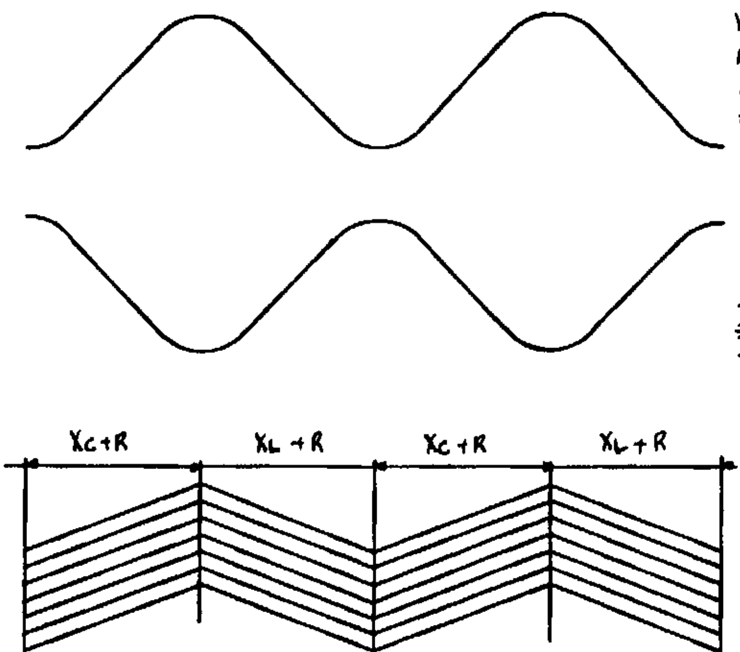
FIG. 170

STANDING WAVES ON LINE WITH ZL (RESISTIVE) $<$ Zo

(a) VOLTAGE

(b) CURRENT

(c) IMPEDANCE



$V_R < V_i$ AND IN ANTI PHASE

$$\frac{V_{MAX.}}{V_{MIN.}} = \frac{Z_0 - Z_L}{Z_0 + Z_L}$$

$I_R < I_i$ AND IN SAME PHASE

$$\frac{I_{MAX}}{I_{MIN.}} = \frac{Z_0 - Z_L}{Z_0 + Z_L}$$

$Z = \dfrac{Z_0^2}{Z_L}$ = PURE RESISTANCE AT ODD QUARTER WAVE POINTS.

$Z = Z_L$ AT EVEN QUARTER WAVE POINTS

IF LOAD IS $R + X_C$ THE MAXIMA AND MINIMA ARE NOT AT QUARTER WAVE POINTS BUT SHIFT TO THE RIGHT

IF LOAD IS $R + X_L$ THE MAXIMA AND MINIMA ARE NOT AT QUARTER WAVE POINTS BUT SHIFT TO THE LEFT second quarter wavelength the impedance consists of resistance + an inductive term, corresponding to the inductive value during the second quarter wave-length of the open-circuited line.

The Line with Z_L (Resistive)$<Z_o$

1161. When Z_L was a pure resistance $<Z_o$ we also had absorption and reflection, but the voltage minima and current maxima occurred at the termination and even quarter wavelength intervals, while the voltage maxima and current minima occurred at the odd quarter wavelength intervals. Since we again have both reflection and absorption the effect is the same as if we had both resistive and reactive components in the load. The line will again offer a pure resistance at the quarter wavelength points. At the odd quarter wavelengths the value of this resistance is again given by $\frac{Z_o^2}{Z_L}$ value is a gain given by Z_L. This transformation holds good, then, for any resistive mismatch. The reactive components in this case may logically be expected to correspond to the shorted line, i.e., resistance + inductance in the first quarter wavelength, and resistance + capacitance in the second quarter wavelength.

1162. We have not previously discussed loads which consisted of both reactance and resistance. If we have a load containing a resistive component plus a reactive component, the essential difference is that the whole standing wave is shifted bodily by an amount which depends on the amount of reactance present. The direction of the shift is to the right if the reactance is capacitive and to the left if the reactance is inductive. The impedance variations along the line will be the same as before if we use as a reference point the first voltage maximum for the case when $Z_L > Z_o$ and the first voltage minimum for $Z_L < Z_o$.

Summary

1163. We may gather up the following major points about impedance transformations by transmission lines:-

(a) Any length of line terminated in a resistive load equal in value to the characteristic impedance of the line acts as a 1 : 1 transformer. That is, the input impedance is always equal to the load and to $Z_o = Z_L = R$.

(b) Any length of open-circuited line acts as pure reactance. Lengths up to a quarter wavelength act like a condenser and lengths between a quarter and a half wavelength act like an inductance. For the first quarter wavelength we may substitute any odd number of quarter wavelengths, and for the second quarter wavelength, we may substitute any even number of quarter wavelengths.

(c) Any length of short-circuited line acts like a pure reactance. The odd quarter wavelengths act like an inductance and the even quarter wavelengths like a condenser.

(d) If we take a shorted quarter wavelength or an open half wavelength the impedance is infinite as either of these acts like a rejector circuit (L and C in parallel).

(e) If we take a shorted half wavelength or open quarter wavelength, the impedance is zero, so these act like an acceptor circuit (L and C in series)

(f) Lines with unmatched loads, whether purely resistive or a combination of resistance and reactance, show a pure resistive impedance at voltage maxima and voltage minima. The range of variation is from $\frac{Z_o^2}{Z_L}$ to Z_L. Between the quarter wavelength points the impedance shows both resistive and reactive components. Proceeding from the termination toward the generator from any voltage minimum (current maximum) to the next voltage maximum (current minimum) the reactance is always inductive. Passing from the voltage maximum to the next voltage minimum the reactance is always capacitive.

(g) All impedance values are repeated at half-wavelength intervals. Any integral number of half wavelengths of line will, therefore, act as a 1 : 1 transformer since the input impedance is equal to the termination.

(h) The input impedance a quarter wavelength from the termination is always given by $\frac{Z_o^2}{Z_L}$. We may rearrange this in the form of $Z_{input} = \frac{Z_o^2}{Z_{output}}$ or $Z_{input} \times Z_{output} = Z_o^2$. This is true at any odd number of quarter wavelengths from the termination.

<u>Matching By Means of Transmission Line Impedance Transformations.</u>

1164. From para. 1163(a) it follows that we can couple any generator of internal impedance R to a resistive load of the same value by any length of cable if its characteristic impedance is also equal to R. <u>Such a system is matched at all frequencies.</u>

1165. From para. 1163(g) it follows that we can couple any generator of internal resistance R to a resistive load of the same value by a line of any characteristic impedance if its length is an integral number of half wavelengths. <u>Such an arrangement is matched only at the frequency for which the line length is an integral number of half wavelengths.</u> This method of matching is termed half-wave transformer matching. It is accompanied by phase inversion as in a normal mutual transformer.

1166. From para. 1163(h) it follows that we can match a length of line of characteristic impedance Z_1 to a line of characteristic impedance Z_2 by means of an odd number of quarter wavelengths of line of characteristic impedance Z_o where the value of Z_o is determined by the equation $Z_1 \times Z_2 = Z_o^2$. This method of matching is called quarter wave transformer matching. The principle is essentially that a reflection occurs at the input end of the transformer. An equal amplitude reflection occurs at the output end. Since the second wave has travelled forward a quarter wavelength and back a quarter wavelength it is a half wavelength or 180° out of phase with the first reflected wave. The two reflections are then equal in amplitude and in antiphase, so cancel out. There is then no effective reflection so there is an effective match.

1167. From para. 1163(f) it follows that between any maximum and minimum there will be a point where the resistive component of the impedance into which the line has transformed the load is equal to Z_o. This follows since the resistive component varies between $\frac{Z_o^2}{Z_L}$ and Z_L. If $Z_L > Z_o$ then $\frac{Z_o^2}{Z_L} < Z_o$. Hence, the resistive component passes through the value Z_o in its range of variation. If $Z_L < Z_o$ then $\frac{Z_o^2}{Z_L} > Z_o$ so the resistive component again passes through the value of Z_o in its range of variation. In general, there will also be a reactive component at this point. That is, the load looks like a resistance $R = Z_o$ shunted by either a condenser or an inductance. If we could connect in parallel with this reactive component the opposite reactance which would resonate it at the frequency in use, we should have $R = Z_o$ now shunted by a rejector circuit which would be equivalent to an infinite shunt resistance, i.e., an open circuit across $R = Z_o$. We could thus eliminate the unwanted reactive component completely. The line from the generator to the matching point will then be working into a matched impedance at the matching point, so there will be no reflected wave back to the generator and hence no standing waves on this part of the line. If the matching is done near the load, standing wave losses are eliminated from most of the line.

<u>Stub Matching</u>

1168. We know from para. 1163(c) that we can obtain any desired value of inductive reactance from a shorted length of line up to a quarter wavelength long and any value of capacitive reactance from a shorted length between a quarter and a half wavelength long. Hence, if we can find the first point

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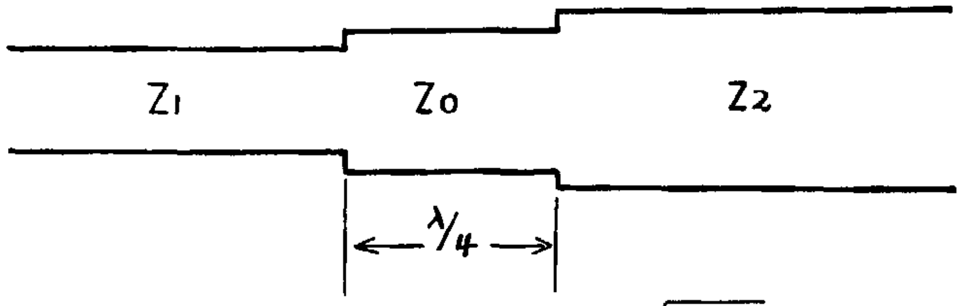
THE QUARTER WAVE MATCHING TRANSFORMER

FIG. 171

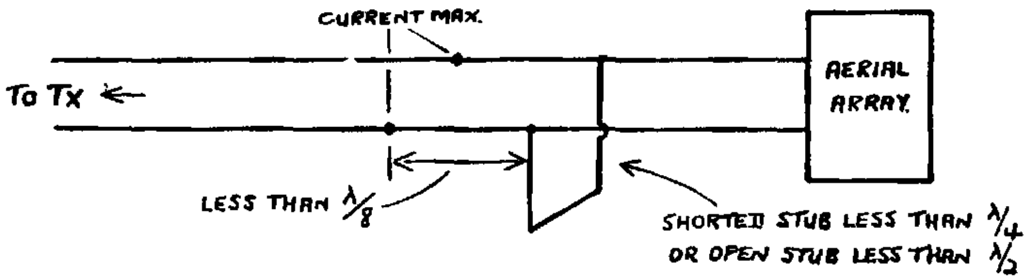


$$Zo^2 = Z_1 Z_2 \quad \text{. OR} \quad Zo = \sqrt{Z_1 Z_2}$$

RULES FOR STUB MATCHING

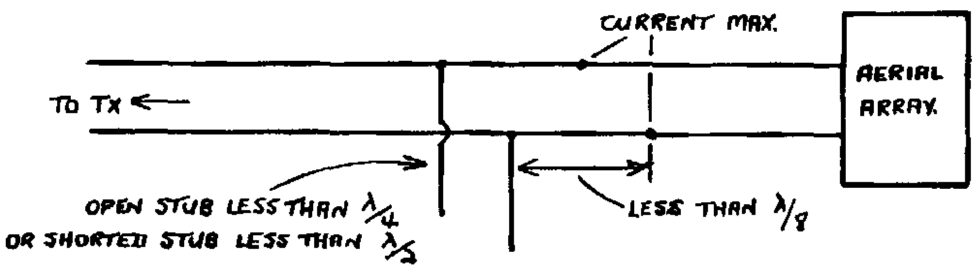
FIG. 172

(a)



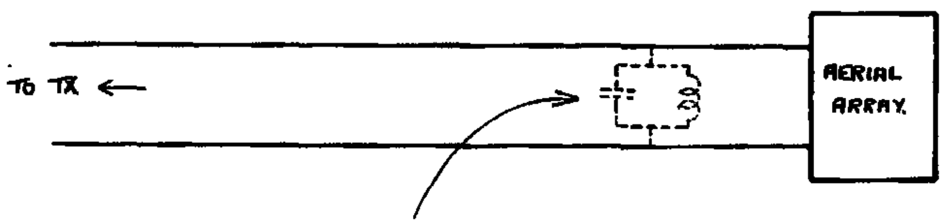
MATCHING STUB IS INDUCTIVE TO MATCH OUT CAPACITATIVE REACTANCE

(b)



MATCHING STUB IS CAPACITATIVE TO MATCH OUT INDUCTIVE REACTANCE

(c)



STUB IS EQUIVALENT TO A REACTANCE WHICH TUNES OUT REACTANCE PRESENT AT THE TAPPING POINT BY RESONATING IT TO PUT AN INFINITE IMPEDANCE REJECTOR CIRCUIT ACROSS THE LOAD RESISTANCE.
THE LOAD THEN LOOKS LIKE A PURE RESISTANCE AND THERE ARE NO REFLECTIONS BETWEEN TX AND THE TAPPING POINT.

back from the load where the resistive component of the impedance presented to the line is equal to Z_o, and can tap in at that point a shorted stub of the length which will resonate the reactive component at that point, we shall have matched the line to the load. This is the principle of stub matching. What we have really done is so adjusted the stub length that the wave travelling down the stub, reflecting with a 180° phase change at the shorted end and coming back up and reflecting back toward the generator, is equal in amplitude and opposite in phase to the wave reflecting at the tapping point. The two reflected waves returning toward the generator then cancel out so there is no effective reflected wave and only a travelling wave from the generator to the load. There is, however, a standing wave on the stub.

1169. From para.1163(b) it follows that the appropriate length of open-circuited stub might also be used. In general, it is easier to work with an open stub and vary the position of a shorting bar to get the desired length of shorted stub.

A general rule for stub matching may be stated as follows:-

(a) Locate the first current maximum or voltage minimum back from the load (generally a radiating array). Somewhere within the $\frac{1}{8}$th wavelength towards the aerial a match can be made with a length of shorted stub less than a quarter wavelength long.
(b) Alternatively, a match can be made with a length of open stub less than a quarter wavelength long within the $\frac{1}{8}$th wavelength from the current maximum back toward the transmitter.

These rules are equally applicable to coaxial and open wire lines but more difficult to achieve in the case of coaxial lines.

Matching a Generator to a Line

1170. We have seen that a line can be matched to an aerial by some form of stub matching. We have also noted that different sections of a composite line can be matched to one another by means of quarter wave transformers. We have not, however, discussed the problem of matching a generator to the first section of the line. This matching involves an impedance transformation that will make the Z_o of the line offer a resistive impedance to the generator that matches the internal resistance of the generator. If the generator has any internal reactance, the transformation must also present an equal and opposite reactance. If the internal impedance of the generator is a pure resistance the latter problem does not arise. In so far as the transmitters familiar to the radar mechanic are concerned, the method used for the transmitters in the $1\frac{1}{2}$ metre band is usually to take off aerial taps on the transmitter lecher lines. What is then effectively being done is that the lecher line is being used as a transformer. Since it is an oscillatory circuit, it is effectively a coil and condenser tank circuit with the high impedance end of the tank circuit connected to the oscillator valves. Tapping the aerial feeders in towards the bottom end of the lechers is equivalent to tapping down on a coil at the point where the tank circuit dynamic resistance matches the impedance of the feeder. If the feeder is correctly matched to the aerial the maximum power flow goes to the aerial.

1171. In the case of transmitters using actual coil and condenser tank circuits, the aerial feeder may be transformer-coupled by means of another tuned circuit or merely tapped in at the appropriate point on the main tank coil. The impedance transformation is then the same as that achieved by any transformer. The basic rule is

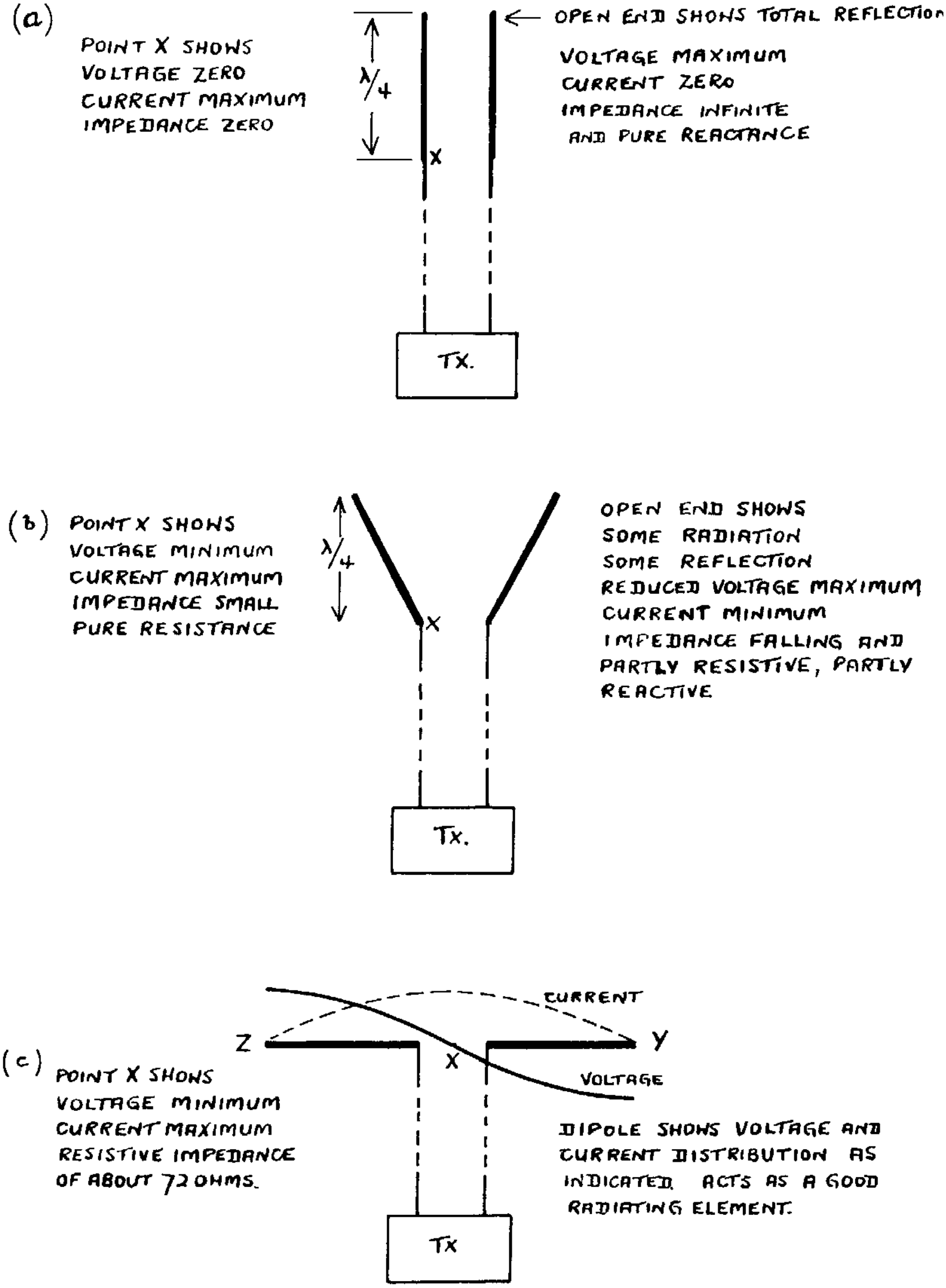
$$\sqrt{\frac{Z \text{ feeder}}{Z \text{ tank circuit}}} = \frac{T \text{ aerial coil}}{T \text{ tank coil}}$$

where T aerial coil is the turns on the aerial coil and T tank coil is the turns on the tank coil.

Where a tapped coil is used the action is that of an auto-transformer.

DEVELOPMENT OF THE HALF WAVE DIPOLE

FIG. 173



IF LENGTH NOT AN ELECTRICAL HALF WAVE DIPOLE WILL SHOW SOME REACTANCE

1172. If the aerial is not correctly matched to the feeder there will be reflections from the aerial and a standing wave on the feeder. This is equivalent to saying that input impedance of the feeder now contains a reactive component. When the generator is an oscillator it automatically adjusts its frequency to the value where the net reactance of the tuned circuit and the reactance effectively coupled in by virtue of the standing wave becomes zero. Hence, a variation in the standing wave will cause frequency changes. For frequency stability the minimising of standing waves on feeders becomes essential. In the case of airborne transmitters the impedance presented by an aerial to the feeder may vary as guns are swung, or, in the case of aerials near propellors, as the propellors turn. These changes may result in frequency shifts due to reactance coupled back into the oscillatory circuit.

1173. In the case of tightly coupled circuits, i.e., when a tank circuit is tapped or transformer-coupled to get the maximum power from the transmitter to the feeder, there may be two frequencies at which the net reactance may be zero, depending on the amount of aerial current. Hence, as the current builds up and decays, the frequency may jump between the two values. To avoid this difficulty it is necessary to reduce coupling, i.e., work with a coupling that takes less power from the transmitter. We then have a mismatch between transmitter and feeder. This does not cause any standing waves. The result is only to reduce the power applied to the feeder. The loading of the transmitter is reduced and its frequency stability is improved.

1174. In the case of cm. equipment like the Mark IIC H.2.S. installation, the matching of the coaxial feeder to the magnetron transmitter is done by combining the principle of the quarter wave transformer and impedance transformations by transmission lines of other lengths. Details are discussed in paras. 262-266.

Matching a Cable to a Receiver

1175. The problem of matching a feeder to a load also crops up in radar receivers. When signals come from the aerial or other stage to an amplifier on a coaxial feeder, the power must be transferred to the tuned input circuit. The coil of this input circuit is normally used as the impedance transformer. As the impedance of the tuned circuit will normally be higher than that of the feeder used the feeder will usually be tapped down on the coil. The tapping point that results in the greatest power transfer to the input circuit will be given by

$$\sqrt{\frac{Z\ \text{feeder}}{Z\ \text{input circuit}}} = \frac{T\ \text{feeder coil}}{T\ \text{input coil}}$$

T feeder coil will be the turns between the tap and the earthy end of the coil. T input coil will be the full coil turns.

The action is again that of an auto-transformer. The tapping point which gives the best power transfer will not necessarily give the best signal-to-noise ratio due to the relation between nose generated in an input circuit and bandwidth of input circuit.

The Half-Wave Dipole

1176. The properties of the half-wave dipole may be deduced from the open-circuited transmission line. Suppose we consider first fig.173(a). We know that we shall have in-phase reflection at the end of the line to produce a voltage maximum and current minimum. At the quarter wavelength point X we shall have a voltage minimum and current maximum. The open end is an infinite impedance point and the quarter wavelength point X is a zero impedance point. We also know that all the energy is reflected. There will be standing waves on the line but if the wires are close together the fields of one wire will largely cancel those of the other, so there will be little net radiation.

1177. If we bend back the quarter wavelength at the end of the line as in fig.173(b), this cancellation will no longer hold. Hence, there is some

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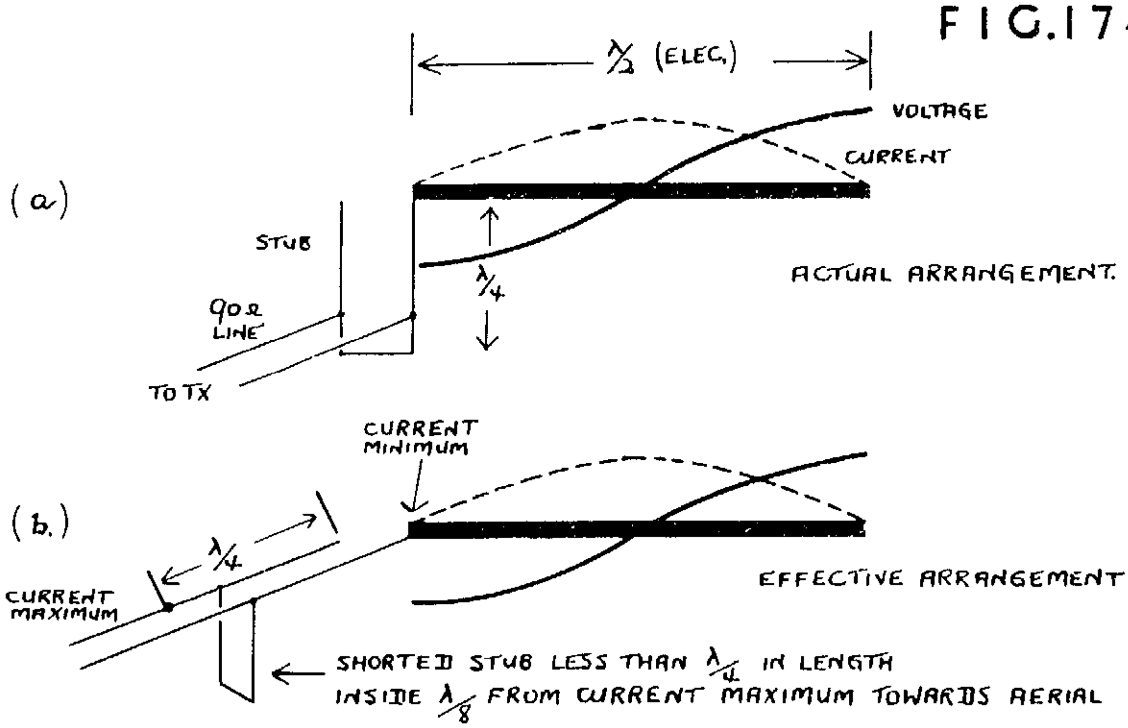
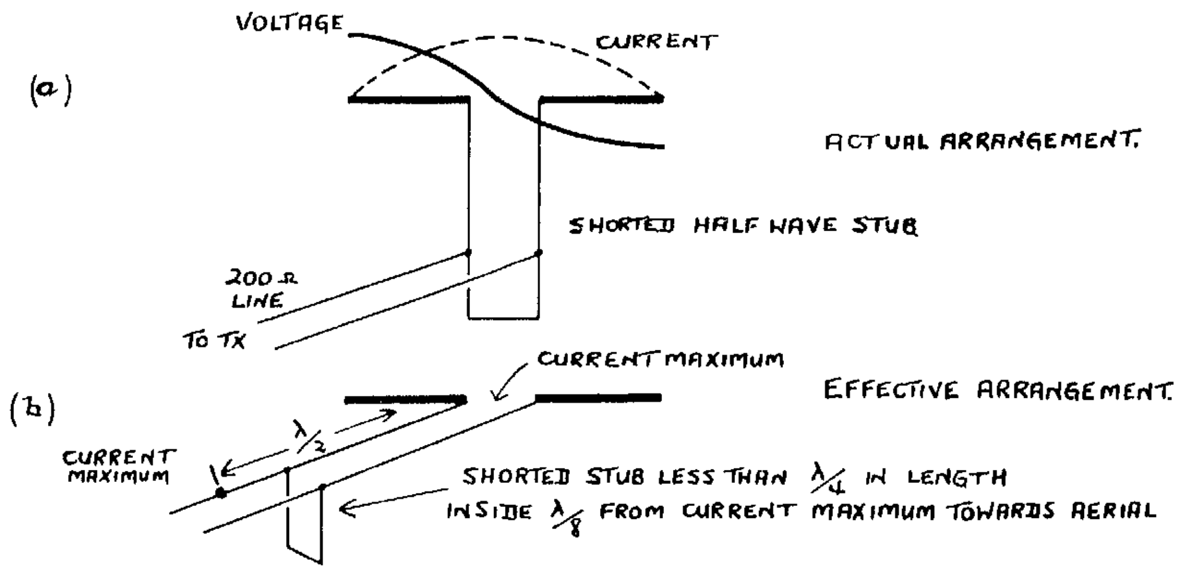
VOLTAGE FEEDING

FIG.174



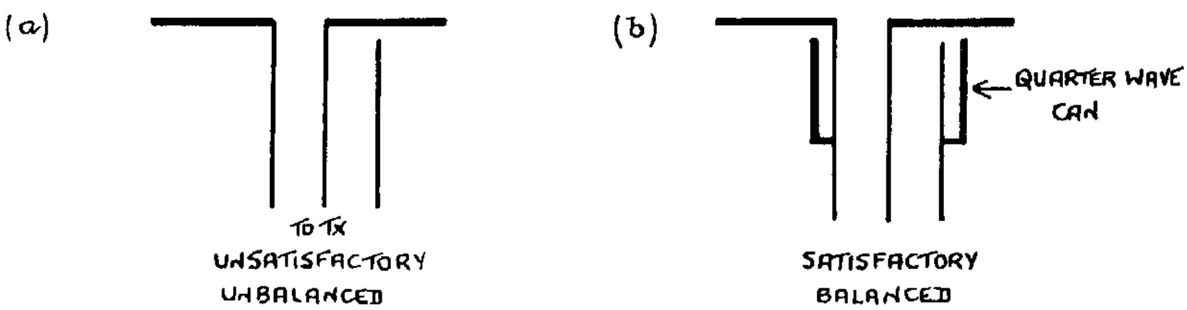
CURRENT FEEDING

FIG.175



COAXIAL FEED TO HALF-WAVE DIPOLE

FIG.176



radiation from each of the bent sections. This means that some power is actually being taken from the generator and we are obtaining the same effect as if we had a high resistance as a termination. The amplitude of the reflected wave therefore falls and the standing wave is reduced. The voltage at X is then no longer zero. We see then that as the ends are bent back the impedance at X rises (because the voltage rises) and the impedance at the end falls as the voltage falls.

1178. If we continue the bending until the two quarter wavelengths are at right angles to the line there is considerable radiation as cancellation between the two fields is now a minimum. The impedance at X then reaches its highest value of around 72 ohms. The sections XZ and XY now constitute a half-wave dipole radiating element or aerial which offers a resistive load of about 72 ohms to the line. Since the energy is being radiated into space, the effect, in so far as the generator is concerned, is the same as if a 72 ohm resistor were connected across the line. We say then that the half-wave dipole has a radiation resistance of about 72 ohms when in free space. This value will be modified if it is in a dipole stack or associated with reflectors or directors.

1179. To feed such a dipole with a travelling wave the characteristic impedance of the line should obviously be 72 ohms if the line length is not to be critical. At one particular frequency it would, of course, be possible to use a line an integral number of half wavelengths long and obtain a travelling wave regardless of the Z_o of the line. In general, it is preferable to match the line to the aerial by some form of stub matching employing the principles discussed in para.1169.

Voltage Feeding

1180. Fig.174 shows a voltage-fed half-wave dipole. By voltage feeding we mean feeding at a point of high voltage and low current, i.e., at a high impedance point. The free end of the dipole will be a current minimum or voltage maximum. The same condition holds at the input end, back a half wavelength, since the impedance cycle always repeats every half wavelength. Hence the input end is a high impedance or high voltage point. If the one side of the line were linked directly there would be a mismatch unless the Z_o of the line matched the aerial. Matching may be done conveniently by fitting the aerial to a shorted quarter wave stub and then tapping the feeder in at the point on the stub which results in a negligible standing wave on the line. The portion of the stub below the tap then becomes the matching stub and the balance of the stub becomes part of the feeder. As the end of the feeder is a current minimum the first current maximum would occur a quarter wavelength back along the feeder. Our stub is between this point and the aerial so we are using the rule in para.1169(a). This case must not be regarded as a 72 ohm load across the line as the aerial is not being centre fed but is being end-fed, i.e., at a point where it presents a high impedance. The considerations are then those that apply when a line feeds a resistive load of value greater than Z_o. The first quarter wavelength of line shows resistance plus capacitive reactance. The stub is therefore an inductive reactance.

1181. An alternative way of looking at the shorted quarter wave stub is to regard it as a rejector circuit. The aerial is tapped in at the high impedance end of the equivalent coil and the feeder is tapped down so that the feeder impedance is stepped up to match the aerial.

Current Feeding

1182. Current feeding a dipole means that the feeder is connected at a low voltage, high current point, i.e., at a low impedance point. This suggests the 72 ohms offered by a centre-fed half-wave dipole. This is illustrated in fig.175. Assuming a 200 ohm line and a 72 ohm load, we have $Z_L < Z_o$. The centre of the dipole is then a current maximum. The first current maximum on the feeder will be back half a wavelength. According to the rule in para.1169(a), a match can be obtained within the ¼th wavelength towards the aerial with a shorted stub less than a quarter wavelength long. This condition is obtained by feeding the aerial from a shorted half-wave stub and tapping the feeder in as shown.

Current Feeding with Coaxial Feeder for Microwave Dipole

1183. When using a parallel wire line to centre-feed a half-wave dipole the two sides of the line are balanced with respect to earth by some form of symmetrical or centre-tapped feed at the input end. The fields of the two wires will then essentially cancel out both in so far as current flow to the aerial is concerned and insofar as fields induced on the feeder by electromagnetic waves in space. The only effective radiating and receiving element is then the dipole. When a coaxial line is used one side of the dipole is connected to the inner and the other to the outer which is earthed. We then have an unbalanced arrangement in which the potential fluctuations are all on the inner. Radiation from the aerial or other waves in space may induce voltages on the outside of the outer which are applied to the dipole section attached to the outer in addition to the voltage induced in the dipole itself. No such components will appear on the half of the dipole connected to the inner. This will destroy the directional properties of the aerial. To overcome these difficulties it is merely necessary to convert the unbalanced arrangement to a balanced one in which there is no tendency for power to flow from the dipole section attached to the outer down the outer surface, nor for voltages induced on the outer to reappear at the aerial. This condition is achieved by means of a shorted quarter wave arrangement. Surrounding the outer is a cylinder a quarter wavelength long making metallic contact with the outer of the feeder. As such a shorted stub offers a high impedance or acts as a rejector circuit, there is no tendency for any power to flow down the outside of the feeder. Conversely, any voltage appearing on the outside of the can would likewise be rejected at the mouth of the stub so would not reach the dipole section. This principle is also employed in the capacity joint in the scanner type 63 to prevent loss of R.F. down the outside of the coaxial feeder.

Physical Lengths of Half-Wave Dipoles

1184. A resonant half-wave dipole, that is, a dipole that acts like a pure resistance at some frequency, is slightly shorter than the physical half wavelength because of a small amount of capacity between the ends and ground or other adjacent surfaces. If an aerial is too short for the frequency applied it acts like a resistance + capacity. If it is too long it acts like a resistance plus inductance. In either case the standing wave shifts as discussed in para.1162. The position of a matching stub is therefore also shifted. Its length will also be affected. To effectively correct aerial lengths loading units are used (as in Gee) instead of stubs at the longer wavelengths.

Parasitic Aerial Elements

1185. Where it is desired to concentrate all the energy radiated by an aerial in a small arc parasitic aerial elements are introduced. These are excited by the radiation from the driver element and re-radiate in such a way that the combined effect of their radiation and that of the driver element is to achieve cancellation in all but the required sector where reinforcement is obtained. This calls for a spacing that will result in antiphase relations between the waves travelling where no radiation is wanted, and in-phase relations in the direction where radiation is wanted.

1186. A reflector will be placed behind the radiator and a director is placed in front of it. Reflectors are normally about 5% longer than the radiator and directors rather shorter. Spacing and lengths must be adjusted to give the desired type of beam.

The Shorted Quarter-Wave Stub as an Insulator

1187. Since a shorted quarter wave stub acts as a rejector circuit it can be used to support transmission lines in preference to the usual type of insulator which will tend to show leakage and losses due to dielectric heating.

Transmission Lines as Tank Circuits for Oscillators

1188. Since the resonant frequency of a tuned circuit is given by $\frac{1}{2\pi\sqrt{LC}}$, the development of high frequencies calls for a small value of $\sqrt{LC}$. We can reduce $\sqrt{LC}$ by reducing C until we are using only the self-capacity between the coil turns. For further reductions in $\sqrt{LC}$ we must reduce L by using smaller and smaller coils. This involves a reduction in the value of the dynamic resistance of the tank circuit which is given by $\frac{L}{CR}$ and in the value of its Q which is given by $\frac{\omega L}{R}$. The fall in dynamic resistance means a fall in output voltage for a given R.F. current. The fall in the Q value means a reduced frequency stability. To get over these difficulties sections of transmission line may be used as tuned circuits. The familiar push-pull lecher bar tank circuit is essentially a half wavelength of line but round and centre-tapped to earth. It thus becomes effectively the shorted quarter wave stub rejector circuit. By centre-tapping to earth the open ends oscillate 180° out of phase which is the same result as is obtained in the normal push-pull oscillator using an L.C. tank circuit with a centre-tapped coil. The large surface area that can be provided to carry R.F. currents makes it possible to keep the resistive losses down and thus obtain a high Q and high frequency stability.

Line Resonators

1189. In general, a shorted quarter wavelength and an open half wavelength of line have the property of acting as a resonant circuit at the frequency which makes them an electrical quarter or half wavelength, respectively. Capacitive effects to ground or other surfaces will normally result in electrical lengths which are shorter than the corresponding physical lengths. The mixer line used in Mark IIC H.2.S. is an example of a resonant coaxial line section. How such resonance comes about can be visualised by realizing that in the case of the shorted line whose length is an odd number of quarter wavelengths, a wave travels to the shorted end, reflects with a phase change of 180°, and returns to the mouth where it is in phase with the incoming wave. This phase relation arises out of a travel path which is an even number of quarter wavelengths (i.e., an odd number of half wavelengths) + a phase change of 180° at reflection. Since the two waves are in phase at the input end the voltages add to give a high voltage across the mouth of the stub or a high impedance joint.

1190. The same type of argument holds for an open circuited line whose length is any integral number of half wavelengths since there is no phase change on reflection. In both cases the voltage is high at the input end and suitable for matching to a high impedance source or load. Other impedances can be matched by tapping in at a suitable point.

Limitations of the Quarter-Wave Matching Transformer

1191. We noted in para. 1166 that two line sections of characteristic impedance Z_1 and Z_2 could be matched by a section of line a quarter wavelength long of characteristic impedance $Z_o = \sqrt{Z_1 Z_2}$. This same method can, of course, be used to match a line to an aerial or other load. When used to match aerials to the main feeder, the term Q-bars is sometimes applied to the quarter-wave transformer section. Such a transformer can only match at the frequency for which its length is a quarter wavelength. Where frequency tends to vary something less selective is called for. This is sometimes achieved by a section of line of gradually varying Z_o. In the case of the open line the spacing is gradually varied. In the case of the coaxial line the diameter of the outer is gradually changed. Where such a section is introduced, it is possible to pass gradually from a load impedance or a generator impedance to a line impedance without heavy reflections over a range of frequencies. This idea is utilised in the flared coaxial line section which is attached to the magnetron in the Mark IIC transmitter unit.

Keeping Returned Signals out of the Tx in Common T. and R. Systems

1192. A transmission line problem that arises in radar equipments where a common aerial is used for transmission and reception is the effective prevention of interference between signals coming directly into the receiver channel, and signals that travel down the transmitter channel to the cold transmitter where they reflect and come back in such a phase as to partially cancel the signals coming straight into the receiver channel. This may be achieved by so selecting the line lengths that the cold transmitter impedance is transformed to a high value at the junction point in comparison with the matched impedance presented by the receiver.

Limitations of the Coaxial Line for Microwaves

1193. When the 9 cm. and of wavelength is reached dielectric losses and softening of dielectric due to R.F. heating, in addition to R.F. heating of the skin of the inner, render the use of coaxial feeders for high power work rather wasteful. Once the 3 cm. band is reached such feeder losses become prohibitive. Obviously, the R.F. skin resistance losses would be reduced if the surface of the conductor available for carrying the R.F. currents could be increased. Dielectric losses would not be serious if air dielectric could be used. These two requirements are achieved when waveguide transmission is used instead of the familiar "go" and "return" type of transmission.

The Inosphere and the Earth's Surface as a Waveguide

1194. Long range radar transmission is achieved at low frequencies by directing radiation toward the inosphere where it reflects back to the earth's surface. The electromagnetic waves travel around the earth in the form of successive reflections between the inosphere and the earth's crust. These two surfaces may thus be visualised as a gigantic waveguide which serves to guide the wave around the earth.

Waveguide Equivalents of Voltage and Current

1195. It has been found that e.m. waves can be set up and guided from one place to another by means of metallic tubes of suitable dimensions. A wave is launched at one end and travels inside the guide to the required load. Since we no longer have two conductors the ideas of voltage and current are no longer very appropriate in the way we normally think of them. We must go back to the ideas behind voltage and current.

1196. We know that an electric field exists between two surfaces that are at a different potential, i.e., have a voltage across them. Hence, in so far as waveguides are concerned, we shall use the electric field concept instead of voltage. If we have an electric field or E vector of a given frequency we can detect its presence and variations in intensity by means of a pea lamp whose filament leads are brought out as little dipole elements to form a half-wave dipole which is resonant at the frequency involved. The direction of the E vector at any point in a guide is given by the direction of the dipole when the lamp glows most brightly.

1197. We also know that a moving magnetic field causes an induced current in a conductor placed perpendicular to the magnetic field. We can therefore use our pea lamp to detect an alternating magnetic field. When the dipole is held to give the maximum brilliance in an R.F. magnetic field the dipole is perpendicular to the H vector. The H vector is the waveguide analogue of current.

The Electromagnetic Wave in Free Space

1198. When an e.m. wave travels in space we have a moving magnetic field and a moving electric field. At any point in the path of the wave the E vector rises and falls sinusoidally at the frequency of the wave, in a direction at right angles to the direction of propagation. The H vector does likewise but in a direction perpendicular to the plane containing the E vector and the direction of propagation. This plane is called the plane of polarisation. There is no E or H vector present in the direction of propagation. Such a wave is called a transverse wave as the E and H vectors are perpendicular or transverse to the direction of propagation.

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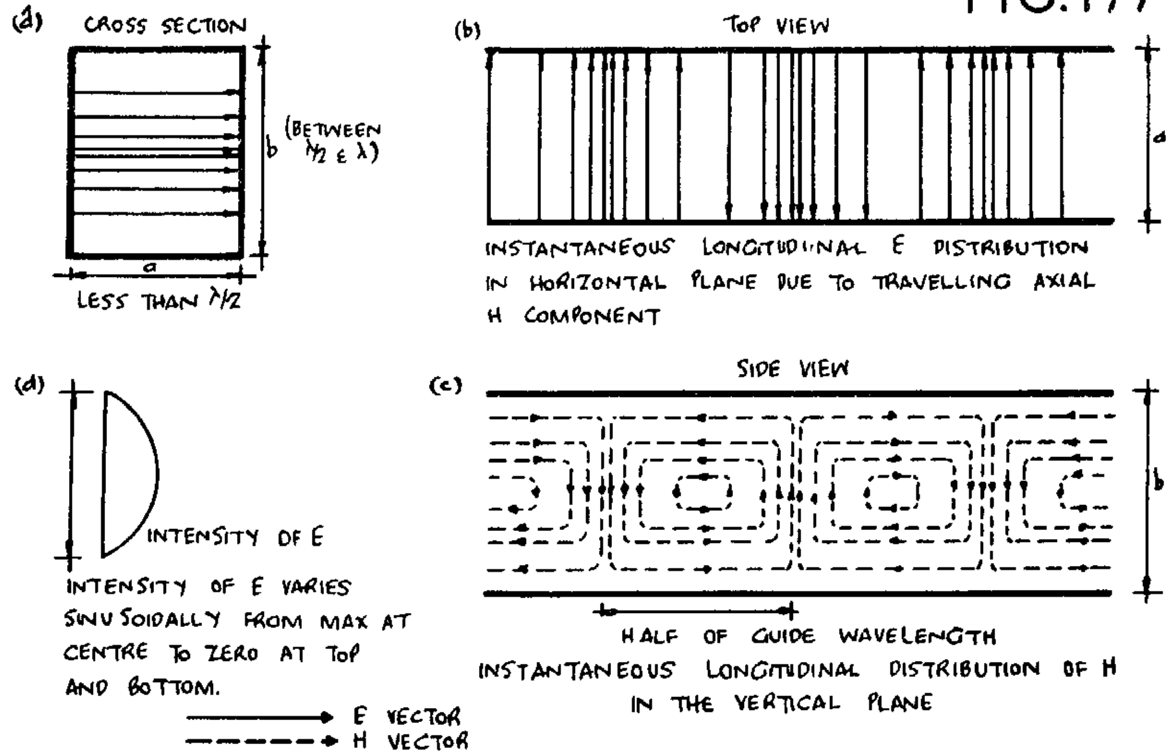
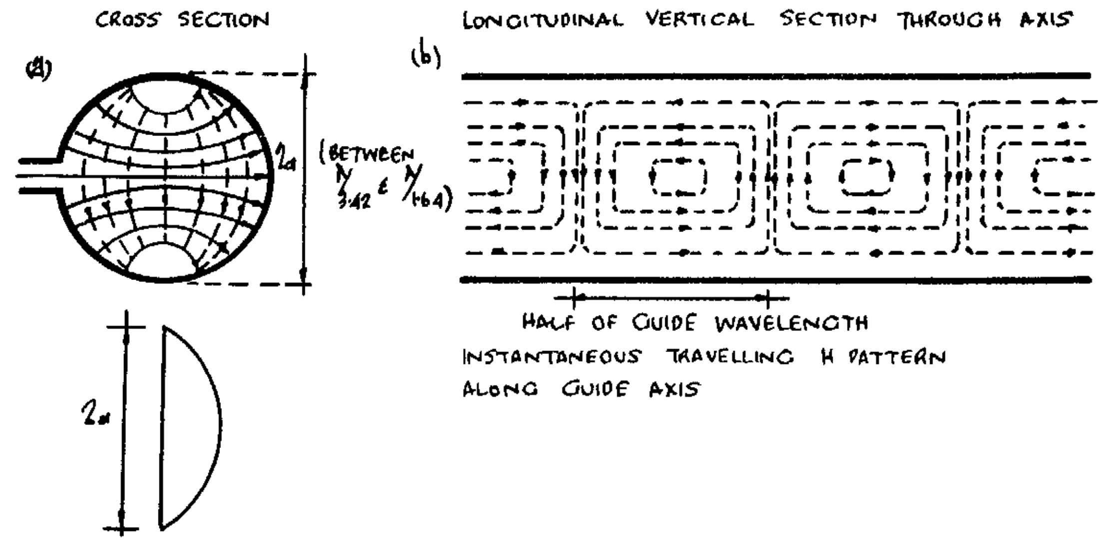
H10 WAVE IN RECTANGULAR WAVEGUIDE

FIG. 177



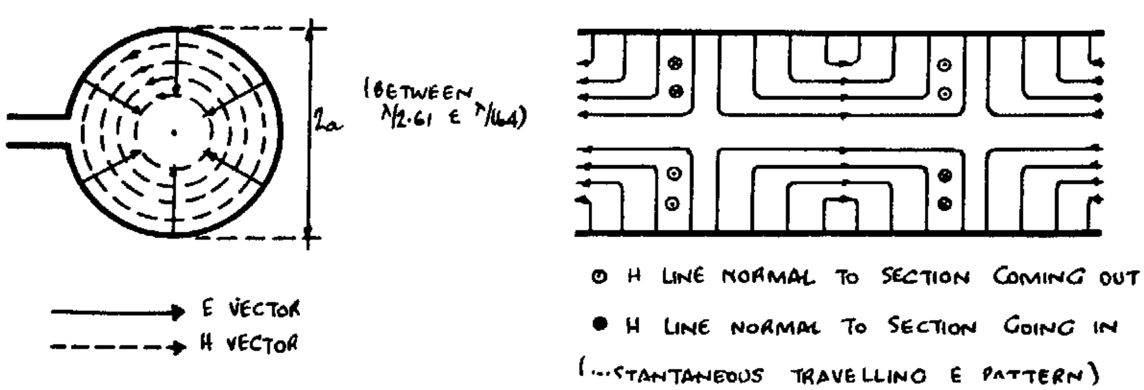
H1 WAVE IN A CIRCULAR GUIDE

FIG. 178



E0 WAVE IN A CIRCULAR GUIDE

FIG. 179



The Electromagnetic Wave in a Waveguide

1199. In the guided wave we find a new component in addition to the transverse E and H components appearing in the free space wave. In some cases a dipole-fitted pea lamp held in a guide with the dipole along the longitudinal axis of the guide will light up. This means that there is an R.F. variation in the E vector, along the length of the guide. That is, the wave in the guide has an E component in the direction of propagation. Such a wave is called an E wave in England and a transverse magnetic or T.M. wave in America. The term T.M. indicates that there is a travelling R.F. magnetic field associated with the travelling electric field whose H vector is perpendicular or transverse to the direction of propagation.

1200. Another type of wave is found in guides where the pea lamp remains lighted if the dipole is held perpendicular to the longitudinal axis of the guide. This indicates that there is an R.F. H component perpendicular to the dipole, i.e. along the guide axis, and a transverse E component. Such a wave is called an H wave in England and a transverse electric or T.E. wave in America.

1201. We see then that guided waves have a longitudinal E or H component which we regard as transferring the R.F. power along the guide. If the longitudinal component is electrical we shall call the guided wave an E wave and look for it with the dipole pea lamp along the guide axis. If the longitudinal component is magnetic we shall call the guided wave an H wave, and look for it with the pea-lamp dipole perpendicular to the guide axis.

1202. An alternative method of detecting guided waves is by means of crystal rectifiers. If a crystal is fitted with a probe and connected in series with a meter it will work in the same way as the pea-lamp. If the crystal is fitted with a coupling loop it must be held at right angles to the R.F. H vector. Hence, the plane of the loop will be parallel to the guide axis when it picks up an E wave, and perpendicular to the guide axis when picking up an H wave.

Guide Shapes

1203. Guides in practical use are in general either rectangular or circular. Guides of elliptical cross-section have been investigated but have not appeared in equipment.

Exciting Guides

1204. If a probe is taken from a magnetron along the axis of a guide it will start an E wave in the guide. If the launching probe is introduced at right angles to the guide axis we shall obtain an H wave in the guide.

The H.10 Wave in Rectangular Guides

1205. To produce an H wave in a rectangular guide, it would appear possible to introduce the launching probe at right angles to the guide axis in either the horizontal or vertical plane. Suppose we consider first the case when the probe is horizontal. If the dimension "b" in fig.177(a), is progressively reduced, it will be found that when b becomes less than a half wavelength the waves will die out. This means that we cannot pass an H wave down the guide unless we make the dimension perpendicular to the launching probe at least a half wavelength wide. We say then that $b = \lambda/2$, where λ is the free space wavelength, is the cut-off or critical dimension. If $a = \lambda/2$ or greater, we could put the probe in vertically as well as horizontally and the wave would be passed down the guide in two ways. If $a < \lambda/2$, there is only one way in which we can launch the wave and propagate it down the guide. The wave then obtained is the simplest H wave that can be formed in a rectangular guide. It is called an H.10 wave.

1206. Since the H.10 wave is the wave we most commonly use we shall be interested in the field patterns across the mouth of the guide and along its length. These patterns are shown in fig.177. The end view shows that we have a distribution of E that is a maximum at the centre and falls off sinusoidally to zero at the top and bottom. This can be demonstrated by moving the dipole-fitted pea-lamp across the end with the dipole held horizontally. This pattern would appear in any section along the guide length. The top view and side view are instantaneous views of the E and H distributions along the length of the guide in the horizontal and vertical longitudinal sections. These patterns travel along the guide when it is correctly matched to some load. If a mismatch exists there will be a stationary longitudinal pattern. Where the E vector has its maximum distribution across the guide walls in this stationary pattern there will be danger of flash-over. The minimum width i.e., minimum value of "a" is fixed by this factor.

1207. The subscript "1" in the name H.10 indicates that we have one half-wave E pattern across the longer dimension "b". The subscript "0" indicates that number of half-wave E patterns across the shorter dimension "a". Since there is no E pattern across "a", we usually drop the subscript "0" and merely speak of H.1 waves in the rectangular guide.

1208. If the guide dimensions are such that "b" lies between $\lambda/2$ and λ and "a" is less than $\lambda/2$ the H.1 wave is the only type that can be propagated in the guide. The appearance of unwanted modes can be prevented by using this cut-off or filtering property of waveguides.

The H.1. Wave in the Circular Guide

1209. If a launching probe is inserted along the diameter of a circular guide an H wave will appear in the guide. If radius is between $\lambda/3.42$ and $\lambda/1.64$, where λ is the free space wavelength, we obtain the simplest H wave that can be produced in a circular guide. The E pattern across a section of the guide is shown in fig.178(a). The travelling H pattern in a vertical section through the guide axis is shown in fig.178(b). The E distribution in the cross sectio would show the same sinusoidal fall in the value of the E vector as in the rectangular guide if tested with the dipole-fitted pea lamp held with the dipole horizontal. This wave is termed an H.11 wave when given its full name. It is usually called an H.1 wave in a circular wave guide. It is worth noting that the pattern is very similar to the H.1 wave in a rectangular guide. It is the wave that calls for the smallest circular guide. A circular guide can therefore be made large enough to pass the H.1 wave but no other form of wave whatever. For this reason, as well as the saving in material, the H.1 wave is usually used in circular guides unless other considerations call for a different wave type.

1210. If a dipole-fitted pea-lamp is inserted along the axis of a circular guide passing an H.11 wave, or a rectangular guide passing an H.10 wave, no glow will appear. This indicates that there is no axial or longitudinal E component in these waves.

The Eo Wave in a Circular Guide

1211. If a launching probe is inserted along the axis of a circular guide an E wave will be set up. If the guide radius lies between $\lambda/2.61$ and $\lambda/1.6$ the E wave obtained will have field patterns as shown in fig.179. In this case we have a radial E vector which is symmetric in the cross-section but always in antiphase along opposite sides of the same diameter. There is also a travelling E component along the guide axis. If the dipole-fitted pea lamp is inserted along the axis the lamp will glow. If the guide is properly terminated the glow will be uniform along the axis. If standing waves are present, the glow will vary in intensity as the lamp is moved, keeping the dipole parallel to the axis.

1212. The H vector distribution in the cross-section appears in the form of concentric circles whose density diminishes from the centre toward the circum ference. If the pea-lamp detector is moved along a radius with the dipole parallel to the longitudinal axis the intensity of the glow will fall sinusoidally from a maximum at the centre to zero at the circumference.

1213. It should be noted that the size of the guide required to pass the Eo wave is sufficiently large to permit passage of the H.1 wave at the same time It will therefore be necessary as a rule to provide some form of filter to eliminate the H.1 wave when it is necessary to use the Eo wave in a circular guide.

1214. The Eo wave is mainly used in rotating waveguide joints where its circular symmetry with respect to the axis of rotation is an advantage, particularly if there is to be a bend beyond the rotating joint.

Wavelengths in Guides

1215. Wavelengths of guided waves are longer than in free space. In the TR.3555 series transmitter unit the 3.2 cm. radiation in the form of the H.1 wave has a wavelength of 4.14 cms. in the rectangular guide, and a wavelength of 5.95 cms. in the circular guide.

Wave Impedance of Guides

1216. The term applied to waveguides which corresponds to the characteristic impedance of a transmission line is wave impedance. For a loss-free guide the wave impedance is a pure resistance. The value of this wave impedance depends on:-

(a) Whether the guide is circular or rectangular, and its dimensions.
(b) Frequency used.
(c) Whether H wave or E wave.
(d) Kind of H or E wave.

In a circular waveguide the lowest impedance is about 350 ohms. In a rectangular waveguide the impedance may take any value depending on the ratio of the two dimensions. The value is proportional to the narrow dimension. For a fixed wide dimension and a fixed frequency, the impedance may be varied between o and about 465 ohms by varying the narrow dimension.

Waveguide Matching Problems

1217. When using waveguides as transmission lines the following matching problems arise:-

(a) Matching a generator to a guide.
(b) Matching different sections of guide to each other.
(c) Matching a guide to a load.
(d) Matching out the reactance introduced by any form of discontinuity.

1218. The primary radar applications coming under (a) will be the question of matching an oscillator of the magnetron or klystron type to a guide.

1219. Under (b) we shall come up against the problem of establishing matches where it is necessary to change from rectangular to circular guides and vice versa. These problems arise in the H.2.S. Mark IIIA transmitter unit and in the scanner.

1220. Under (c) the chief applications are matching a guide to a mixer and matching a guide to free space. The latter problem arises when we use the mouth of a waveguide as a radiator. As the guide is supplying power to free space we must consider free space as constituting a load. This load is 377 ohms resistance provided there are no capacitive effects due to adjacent surfaces which introduce reactance.

1221. Under discontinuities we must consider such things as breaks in the guide walls, sharp bends, branch lines, and obstacles of any description such as filters, etc. Where such discontinuities occur there will be reflections. As in transmission lines we may regard any such reflection as due to a reactance in parallel with the guide.

How to Tell When Matching Is Achieved

1222. A generator will be matched to a guide or a load when the maximum power is taken from the generator.

1223. A guide will be matched to a load when there is no standing wave on the guide.

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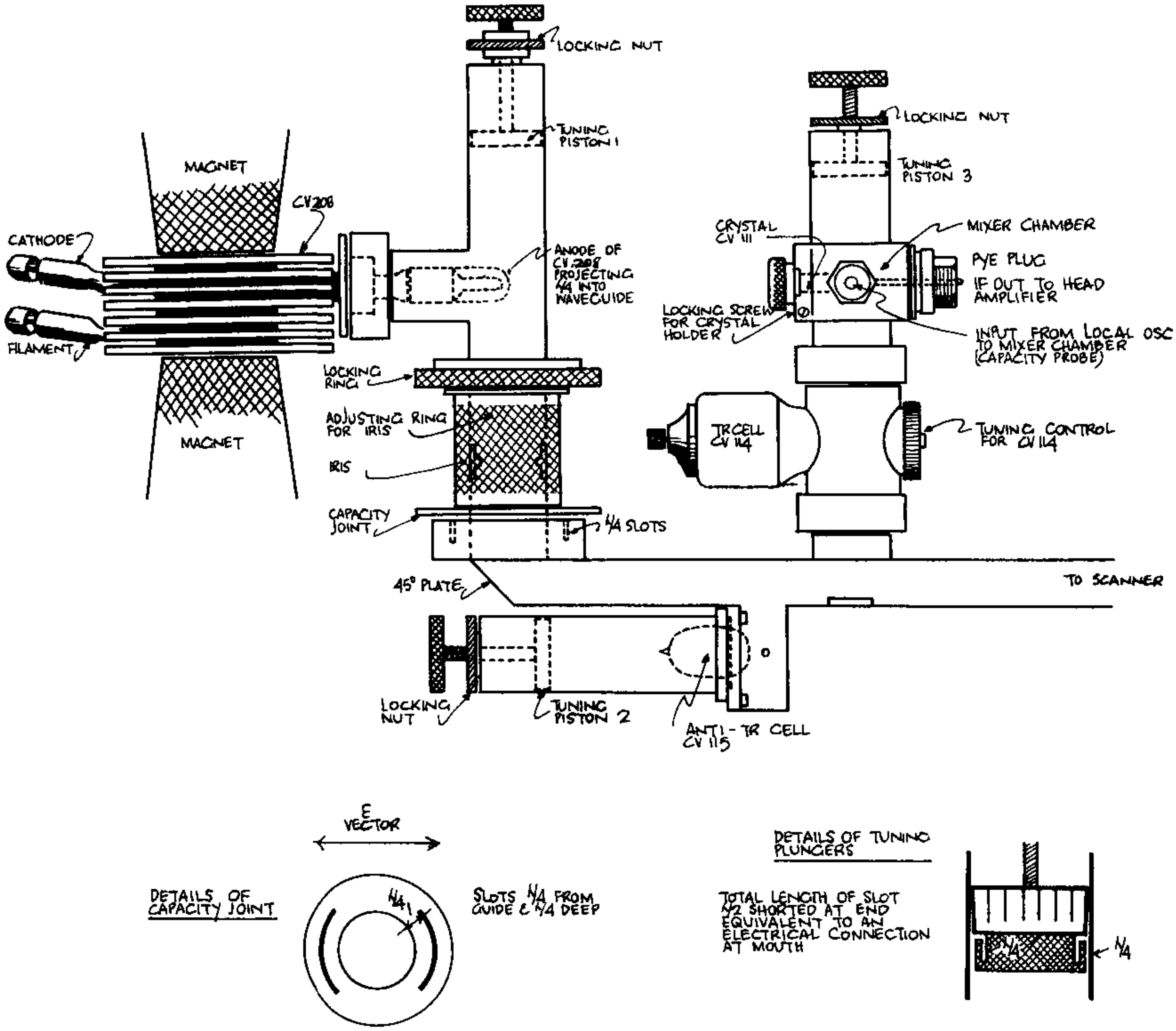

CONTROLS

TUNING PISTON 1 AND IRIS THESE TWO CONTROLS TOGETHER MATCH THE OUTPUT IMPEDANCE OF THE CV108 TO THE WAVEGUIDE, AND ARE TUNED FOR MAXIMUM POWER OUTPUT

TR CELL CV 114 IS TUNED FOR MAXIMUM RECEPTION OF SIGNALS - PROTECTS THE CRYSTAL FROM THE TX PULSE BY "ARCING OVER" DURING TRANSMISSION AND THUS PRESENTING A HIGH IMPEDANCE AT THE MOUTH OF THE BRANCH WAVEGUIDE TO THE MIXER CHAMBER

ANTI-TR CELL CV115 & TUNING PISTON 2 THE PISTON IS TUNED FOR MAXIMUM RECEPTION IT VARIES THE LENGTH OF WAVEGUIDE SO THAT THE "COLD" IMPEDANCE OF THE MAGNETRON APPEARS AS A HIGH IMPEDANCE ACROSS THE GUIDE AT THE BRANCH TO THE MIXER CHAMBER AND THUS TURNS ALL INCOMING SIGNALS INTO THE TR CELL AND HENCE TO THE MIXER. THE CV115 "ARCS OVER" DURING TRANSMISSION AND REJECTS THE TX PULSE FROM THE ANTI-TR CELL BRANCH LINE.

TUNING PISTON 3 TUNES MIXING CHAMBER TO FREQUENCY OF CV108 - IE MAXIMUM RECEPTION

FIG.180

H2S MARK III WAVEGUIDE ASSEMBLY OF HF BOX

FIG.180

1224. Sections of guide will be matched if there are no standing waves on the guide.

1225. In the case of a transmitter the best match to the guide will be found when the matching adjustments cause the maximum power output to appear at the radiating end of the guide or in some load inserted in the guide.

The Fundamental Problem of Matching a Generator to a Guide

1226. This problem is the same as in the case of the transmission line:-

(a) The wave impedance of the guide must be transformed to be equal to the resistive impedance of the generator.
(b) Any reactive component in the output impedance of the generator must be matched out by means of an equal and opposite reactance.

Matching a Magnetron Launching Probe to a Guide

1227. When the output probe of a magnetron is introduced into a guide at right angles to the longitudinal guide axis to launch an H.1 wave, the probe is operating as a dipole radiating element. The energy radiated makes the probe show a radiation resistance. The more energy actually radiated the greater will be this radiation resistance. The problem of matching for maximum output into the guide then becomes a matter of making this radiation resistance match the wave impedance of the guide. According to a mathematical development by Slater this radiation resistance can be varied by means of a moveable piston behind the probe. This corresponds to varying the distance of a reflector behind a dipole in an ordinary aerial array. The position of the reflector will modify the radiation resistance of the aerial. This type of matching adjustment is used in the TR.3555 series of transmitter units.

1228. If a dipole is sufficiently close to other surfaces to show capacitive effects it also shows a reactive component in its impedance which should be matched out. In the same way the presence of the guide walls makes a launching probe show a reactive component which should be matched out. We may think of this reactive component as alternately pushing power out and getting it back in the same way as when an alternator feeds a transformer on no load. If we can introduce a reflected wave that is equal in amplitude and opposite in phase we can eliminate the reflection due to a reactive component. This is done in the older TR.3555 units by means of an adjustable quarter wave matching iris. This iris is merely an adjustable guide section of smaller diameter inside the main guide. The inside diameter of this iris must, of course, be greater than the H.1 cut off dimension. By sliding this iris the reactive component is matched out. The two adjustments are not independent since the position of the piston relative to the probe varies the reactive component to be matched out. Alternative adjustments are therefore required until the maximum power is fed down the guide.

1229. In later TR.3555 units, the matching device consists of an adjustable carriage which moves two silica rods projecting into the guide. These silica rods are separated by a quarter wavelength and the distance they project into the guide is variable. By varying the distance the rods project into the guide a reflected wave of any amplitude can be set up. By varying the position of the carriage relative to the probe the phase of this reflected wave can be varied. By using the two adjustments a reflected wave can be introduced which is equal in amplitude and opposite in phase to that appearing between the probe and the fixed end of the guide due to both resistive and reactive mismatch factors. Hence a match is obtainable.

Matching Guide Sections to Each Other

1230. Where a guide section of one wave impedance is joined to a guide section of another wave impedance we have reflection without power absorption, i.e., we have a reactance. Matching out this reactance is done by introducing something that causes a reflected wave of the same amplitude but opposite phase. Any form of obstacle or discontinuity will introduce some reactance. If it is resistive it will also absorb power and cause losses. What we wish to

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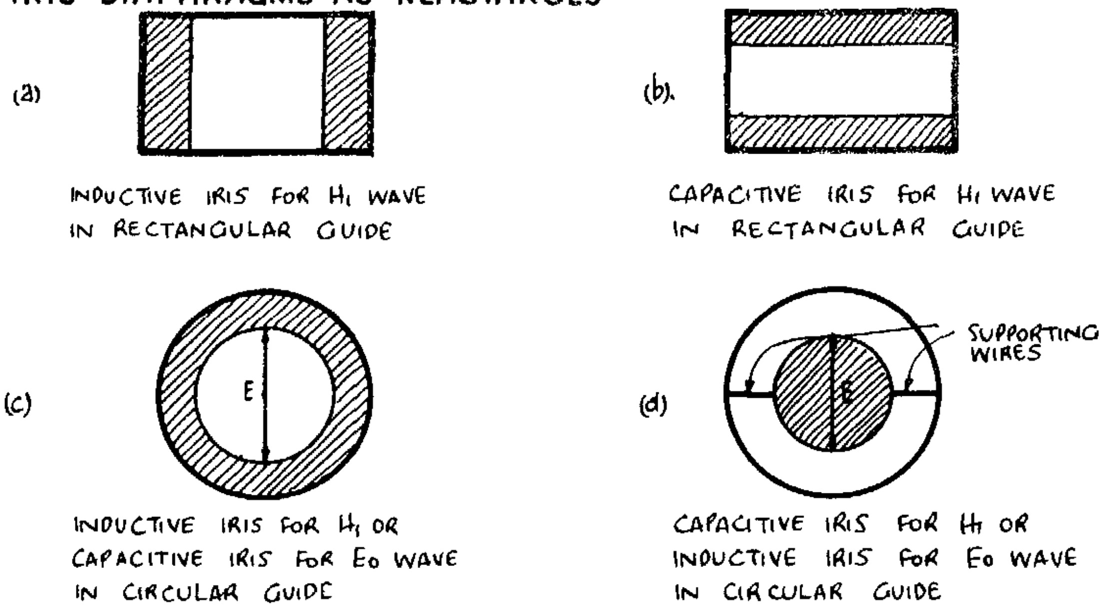
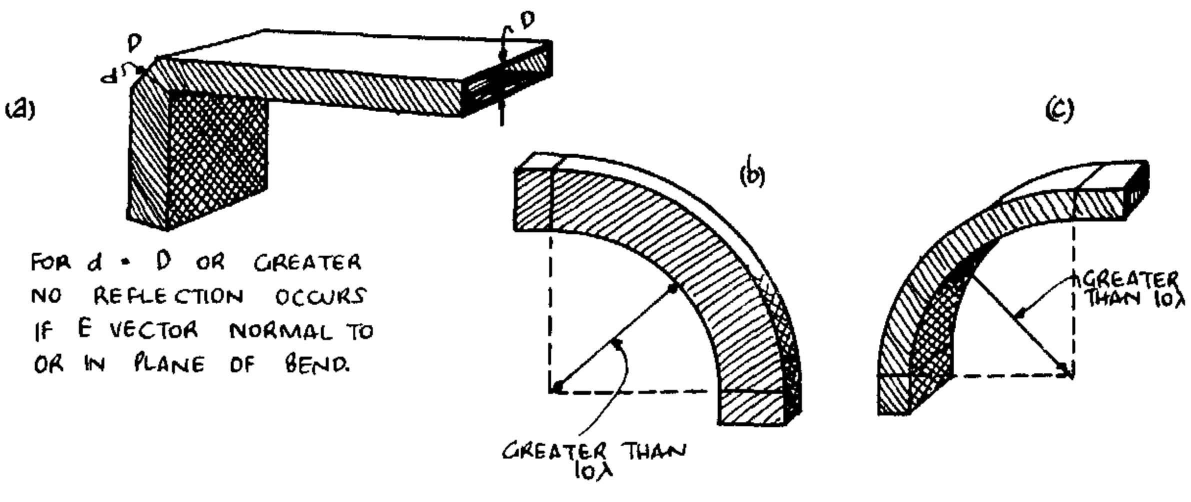
FIG. 181

IRIS DIAPHRAGMS AS REACTANCES



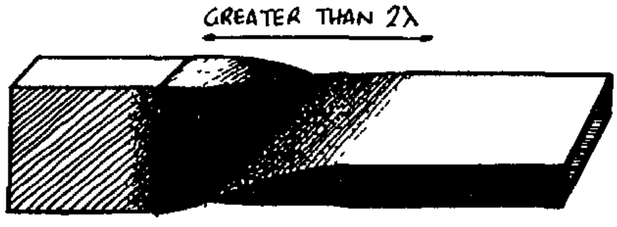
BENDS IN WAVEGUIDES

FIG. 182



POLARISATION SHIFTER

FIG. 183



achieve is reflections without loss of power. A screw tapped into a guide wall so as to cut the travelling magnetic field will serve to introduce a reactance. Plates inserted through the guide wall will achieve the same result. If they cut across a travelling transverse E vector they act as capacitive reactances. If they are across the path of the travelling H vector they act as inductances. Such reactive diaphragms are called irises. Types for both circular and rectangular guides are shown in fig.181.

Filters as Reactances

1231. Where a guide dimension is sufficiently large to pass more than one mode or wave pattern it is necessary to introduce filters. This may be rings or diaphragms that reduce the guide dimensions below the cut-off for the unwanted wave while permitting the flow of the wanted wave. Since such obstacles are discontinuities they will introduce reflections. By inserting two separated by an odd number of quarter wavelengths, the second reflected wave will have travelled an additional odd number of half-wavelengths (from 1st and 2nd filter and back). The two waves will then be in antiphase so will cancel out.

Matching out the Reactance Due to Bends

1232. Where a sharp bend occurs there is a tendency for part of the wave to reflect back along the path already traversed and then return and partially cancel out the wave passing directly into the second guide section. To annul the effect of this reflected wave, a shorted extension may be introduced at the bend which will also introduce a reflected wave. By correctly choosing the length of this shorted section the phase of its reflection will be such as to cancel the other reflection. Alternatively, some form of iris diaphragm arrangement may be employed.

Design of Bends to Avoid Reflections

1233. The introduction of fixed matching adjustments for bend reflections is frequency sensitive so it is preferable, where possible, to design bends that will not produce reflections. These methods involve either the use of inclined corner plates as shown in fig.182(a), or rounded bends whose radius of curvature is large in comparison with a wavelength. The rounded bench is used in the feed to the mirror of the scanner type 63 and 71. The inclined plate is used in the TR.3555 transmitter unit series at the junction of the circular and rectangular guides. The perpendicular from the inner side of the bend on the corner plate should equal or exceed the narrow dimension of the guide. If this condition is fulfilled no reflection occurs when the E vector is perpendicular to or in the plane of the bend. The Eo wave is undisturbed by bends since the transverse E vector is radial.

Matching a Guide to Free Space

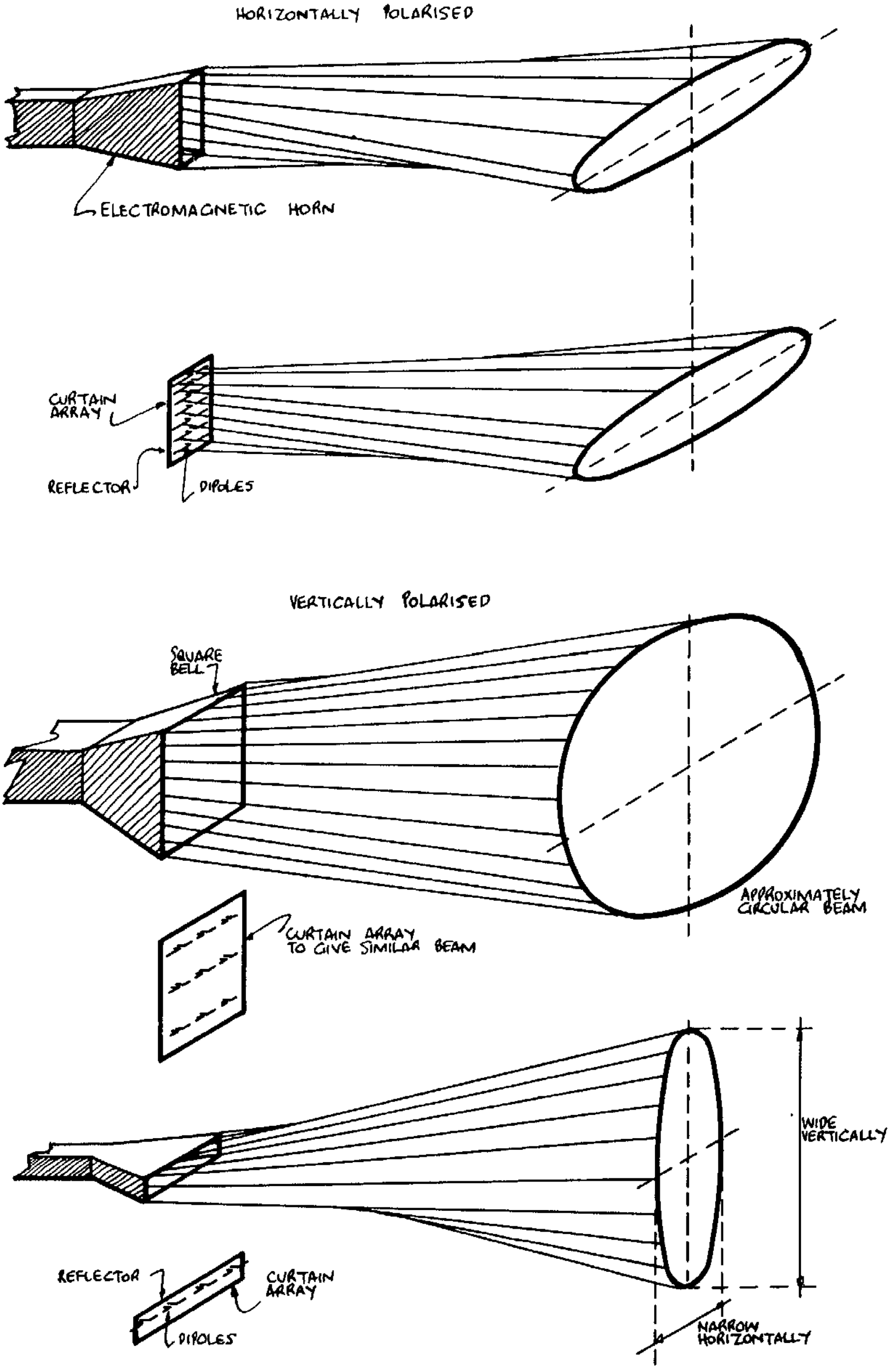
1234. If a circular or rectangular guide is left open at the output end it will not show complete reflection as in the case of the open-circuited line. Some energy will be radiated and some will be reflected. A waveguide can therefore be used as a radiator, but unless some form of matching is used, the reflections will set up standing waves in the guide. To minimise such standing waves the impedance of the guide is altered gradually by flaring out the guide mouth in the form of a horn. By suitably choosing the horn dimensions a reasonable freedom from reflections is attainable.

The Waveguide as a Radiator

1235. The shape of the beam radiated from the horn termination of a waveguide will depend on the horn design. Some patterns produced by horn terminations are shown in fig.184. In the case of the H.2.S. scanners the

THE WAVEGUIDE AS A RADIATOR

FIG. 184



horn is used to radiate into the paraboloid mirror to obtain a much sharper beam than could be obtained with the horn alone. It will be noted that the beam has its minimum width in the plane at right angles to the plane of polarisation. The paraboloid mirror serves to produce a 90° rotation to give us a narrow beam in the horizontal plane with horizontal polarisation.

Polarisation Shifting

1236. In many cases it is necessary to twist a guide in order to bring the horn termination into the position which gives the desired polarisation for feeding a scanner. This can be done without introducing appreciable reflections if the twist is gradual.

Rotating Joints and Waveguide Transformers

1237. In the H.2.S. scanners type 65 and 71, a waveguide feed is employed. One part must rotate with the scanner but the other section must remain stationary. To keep the two sections opposite each other, a circular guide must be used for the rotating joint. Furthermore, to prevent reflections due to distortion of the field pattern by the rotation, it is necessary to use the Eo wave in this circular section because of the symmetry of the pattern about the axis of rotation. We shall, however, want an H.1 wave again to obtain a horizontally polarised beam, and we also feed an H.1. wave to the scanner. We are thus faced with the problem of transforming the H.1 wave to an Eo and the Eo back to the H.1. The basic details of the transformations are shown in fig.185. The H.1. wave is brought into the circular guide with a vertical polarisation. Since the circular guide is in the vertical plane, the E vector is along the guide axis. The wave is then transformed partly into the Eo wave and partly into the H.1 circular or H.11 form which will exist on a circular guide smaller than that required for an Eo wave. Suitable filters are inserted to remove the H.11 wave. A fixed matching section is used at the junction to match out the bend reactance.

1238. At the other end the procedure is exactly reversed. The rectangular guide taps into the circular guide at right angles to the longitudinal axis of the circular guide. The axial E components of the Eo wave then appears across the narrow dimension of the rectangular guide and an H.1 wave is set up in the rectangular guide. A suitable matching section is incorporated at the junction.

1239. The two circular sections are separated by a gap 1 mm. wide. This is so narrow that the escape of energy is negligible.

Vibration Joints

1240. To allow for vibration or tolerances in the size of components it may be necessary to break guide sections. Such breaks constitute possible sources of loss due to radiation. To prevent such losses we must effectively close the gap while leaving it physically in existence. This can be done by fitting flanges and cutting ditches a quarter wavelength deep at right angles to the E vector and a quarter wavelength from the guide wall as shown in fig.180. The R.F. currents flowing in the upper flange beyond the ditch will be a half wavelength out of phase with those beyond the ditch in the lower flange. This follows since the currents in the lower flange had to flow down one wall of the ditch and up the other, i.e., a path of an extra half wavelength. The fields therefore neutralise beyond the ditch and there is no escape of energy. The arrangement therefore acts like an R.F. choke. When the primary purpose of the joint is to allow for tolerances in the dimensions of components the term "choke joint" is commonly used to designate this type of joint.

Resonant Irises

1241. We noted in para.1230 that the metal diaphragms placed across guide walls could act as either condensers or inductances in parallel with the guide, i.e., in parallel with the resistive wave impedance of the guide. This suggests that if we suitably combined the two types we could produce a resonant circuit across the guide. Such a combined iris then gives us a resonant iris.

C.D. 0896L

FIG. 185

ROTATING JOINT TRANSFORMER

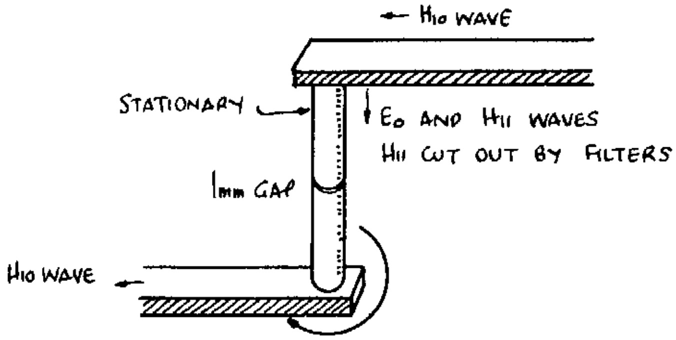
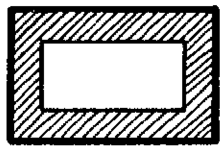


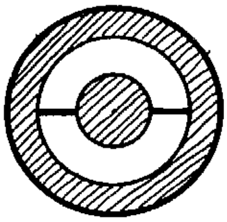
FIG. 186

TUNED OR RESONANT IRIS FOR H_1 WAVES COMBINES INDUCTIVE AND CAPACITIVE ELEMENTS IN CORRECT PROPORTION FOR RESONANCE



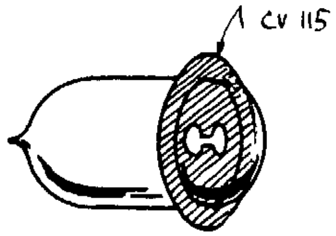
(a)

GAP PASSES RF ENERGY AS IF IRIS WERE NOT PRESENT



TUNED OR RESONANT IRIS FOR H_1 WAVES IN CIRCULAR GUIDE

(b)



RESONANT IRIS WHICH ARCS OVER DUE TO HIGH VOLTAGE ACROSS SLOT

(c)

FIG. 187

RING FILTER

WHEN SLOT IN FIG 186( ) IS REPLACED BY METAL RING MUCH OF ENERGY IN H_1 WAVE IS REFLECTED. DOES NOT AFFECT E_0 WAVE. USED TO FILTER H_1 WAVES FROM E_0 IN ROTATING JOINT IF TIPPED THROUGH 90° WILL PASS H_1 WAVES SO CAN BE USED AS A WAVEGUIDE SWITCH BY USING IT IN A TRANSVERSE PLANE TO CUT OFF H_1 WAVES AND IN AXIAL PLANE TO PASS H_1 WAVES

METAL RING CORRESPONDING TO SLOT IN ( ) ABOVE

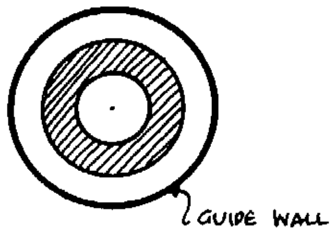
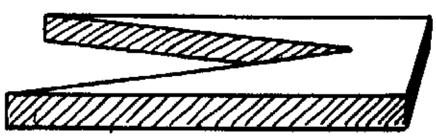


FIG. 188

DUMMY LOADS



FISHTAIL OF "LOSSY" MATERIAL FOR RECTANGULAR GUIDE

CONE OF "LOSSY" MATERIAL FOR CIRCULAR GUIDE

The CV.115 used in the TR.3555 series transmitter units is an application of this principle. When set into violent oscillation by the transmitter pulse the voltage across the slot becomes so great that the argon filling flashes over and the slot becomes a conducting path which effectively seals the guide wall.

1242. When there is no ionisation the iris acts like a very high impedance rejector circuit in parallel with the relatively low resistive impedance of the guide. There is then no loss of power in the iris and the result is the same as if the iris were not present.

1243. Another form of the resonant iris for circular guides is shown in fig.186. Such an iris of the correct dimensions has no effect on the flow of energy if the supports for the centre section are perpendicular to the transverse E vector. As both metallic portions act as reflectors it must be the gap which is passing the energy. Hence, if we insert a metal ring of the same dimensions as the gap with its supports parallel to the transverse E vector, it will completely reflect H.1 waves. In the case of Eo waves the transverse E component is radial so it is always perpendicular to the ring so the Eo wave will not be affected.

The Ring Filter

1244. This property is employed to separate the H.11 (H.1) wave from the Eo wave in the rotating joint used in the scanner type 71. Filter rings of the correct dimensions are mounted on trolitul supports in the two circular sections of the rotating joint.

Ring Switches

1245. If provision is made to throw such a blocking ring across the guide when it is desired to effectively seal off the guide, and to drop the ring so it lies along the guide axis when the guide is to be opened, we have a waveguide power switch. Such an arrangement is used in the TS.205 input switch.

1246. Another application of the same principle is in aerial switching.

Waveguides as Resonant Cavities

1247. The radar mechanic will be familiar with the acoustic resonance that can be set up in tubes and other cavities. Similar resonance properties appear in sections of waveguide. A familiar example is the mixer cavity used in the TR.3555 transmitter units. Less obvious examples are the resonant cavity to the Klystron and the soft rhumbatron. These cavities are effectively distorted shorted half wavelength guide sections. Echo boxes constitute another application of the waveguide as a resonant cavity. If a calibrated moveable piston is fitted, an echo box can be used as a wavemeter.

Sealing off Branch Lines

1248. In common T. and R. working, it is necessary to seal off the received branch line while the transmitter pulses. This can be achieved by putting a short across the branch line any integral number of half wavelengths from the junction. When such a short is introduced the wave passing into the branch line reflects back into the main guide. It will have travelled an integral number of wavelengths so will be in phase with the direct wave in the main line and will not therefore cause any interference or standing waves. The effect is then the same as if branch line were completely sealed off. To introduce such a short it is possible to use either a resonant iris type of valve like the CV.115 or a resonant cavity type like the CV.114. In either case, resonance results in ionisation and an effective short at some integral number of half wavelengths from the guide. The shorted half wavelength of waveguide thus serves the same purpose as the shorted quarter wave stub in transmission lines.

Coupling Into and Out of Resonant Cavities

1249. Coupling may be by means of probes or coupling loops. Probes must be parallel to the E vector and loops must have their plane perpendicular to the H vector for maximum coupling.

1250. In the case of loop coupling, the tightness of coupling can be varied by moving the loop away from the position where the concentration of magnetic flux is a maximum by rotating the plane of the loop, by changing its size or placing a shield around part of it to effectively short it out.

1251. In the case of probe coupling, the coupling can be varied by varying the distance the probe projects into the field, the angle relative to the E vector, or the position of the loop relative to the part of the field where the E vector has its maximum value.

Effectively Sealing off the Transmitter for Returned Signals

1252. The common T. and R. problem of preventing loss of returned signal power due to a flow into the transmitter channel arises in waveguide systems as in transmission line systems. The problem may be viewed as a matter of interfering waves. The incoming signal divides at the junction, part going into the receiver channel and part into the transmitter channel. At the end of the transmitter channel reflection occurs and the wave returns to reach the junction in some phase that depends on the length of path. If this length were such that the reflected signal would be in phase with the direct signal as it passes into the receiver line, no adjustment would be required. Normally, this is not the case and interference occurs to reduce the effective input to the receiver channel. To eliminate this difficulty provision is made to introduce another reflected wave to cancel out the wave which passes into the transmitter channel. This calls for a second branch line of adjustable length so that the phase of the deliberately introduced reflection can be controlled. This is the function of the anti-T.R. chamber in the TR.3555 series transmitter units. Details are discussed in Chapter 5.

Dummy Loads for Waveguides

1253. In experimental or test work it is sometimes necessary to have a non-reflecting, i.e., a resistive termination, to absorb the R.F. power in a waveguide. For this purpose, various types of dummy load are used. One type used in rectangular guides is a fish-tail cut in piece of wood. For circular guides, a wooden cone may be used. Such terminations serve to break up the wave front and the whole energy is used to heat the dummy load. Other forms of dummy load use resistive plates or resistive irises which absorb the R.F. power.

CHAPTER 14 - LUCERO

Outline of the Lucero System

1254. The H.2.S. installations as used in Bomber Command are designed to provide for the inclusion of the Mark II Lucero interrogator system whenever this may be desirable. The additional items required are :-

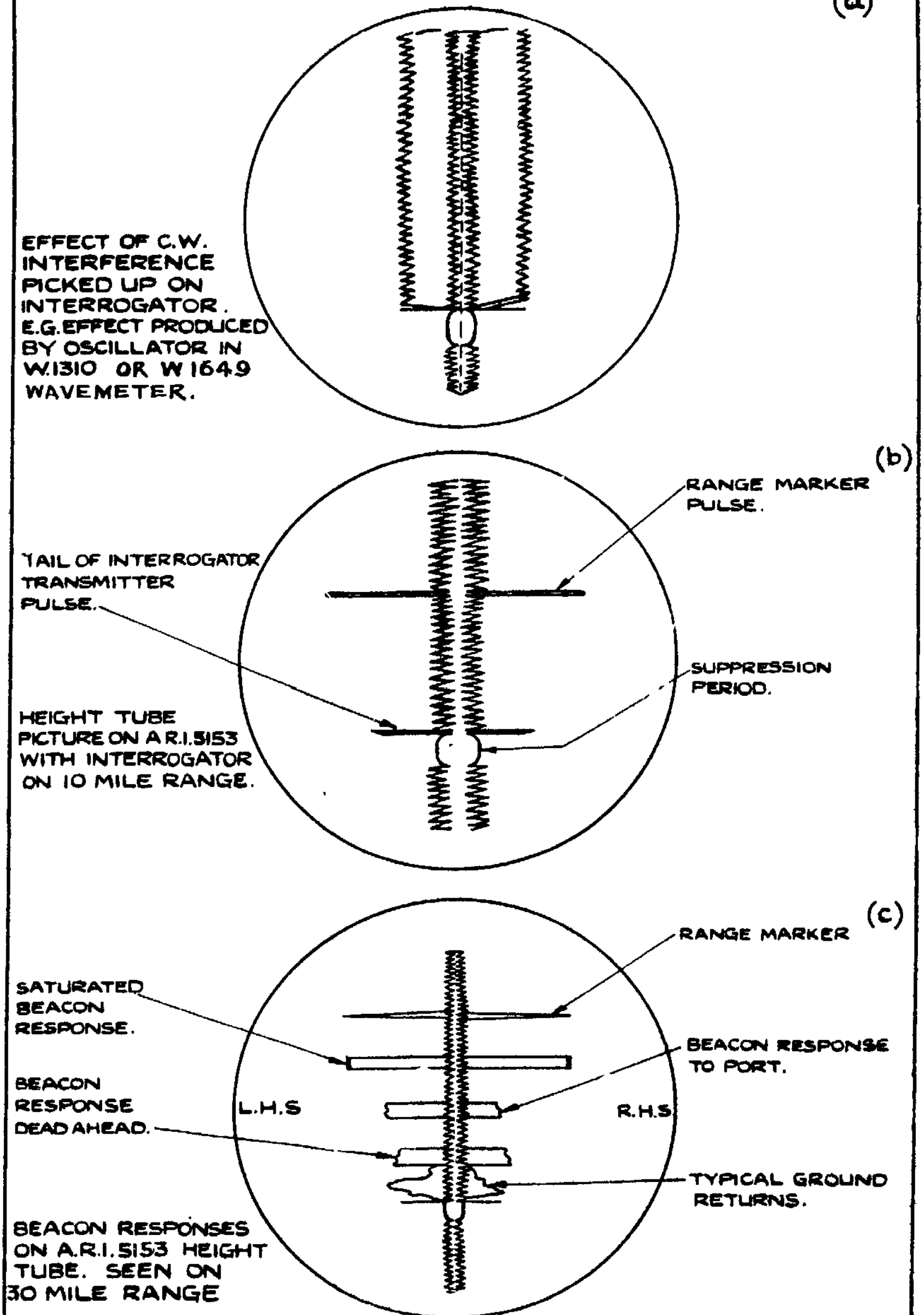
(a) The main Lucero unit - TR.3160 or TR.3160A (Mark IIC) or TR.3566 (Mark IIIA)
(b) The push-button control unit - Type 222A.
(c) The TR. beacon aerial system - Type 184 (port and starboard)
(d) The BABS receiving aerial - Type 308
(e) Aerial change-over switch - Type 78A

The Lucero unit contains a push-pull lecher-line transmitter. If the Lucero switch on the switch unit is set to B + H, B or BA, this transmitter is indirectly triggered from the 20 microsecond pulse from one of the violet Pye plugs on the modulator 64. The pulse is applied to a counting down circuit (or frequency divider stage) which divides by 3 to develop a 5 microsecond modulating pulse on the back edge of every third 20 microsecond pulse. The Lucero transmitter is thus operated in synchronism with the H.2.S. transmitter but only on a p.r.f. of about 220. The 5 microsecond pulse, radiated from vertical type 184 port and starboard aerials, can be used to trigger any one of the following :-

(a) Lucero blind approach (BABS) runway beacons
(b) Long range responder beacons
(c) Light portable beacons of the Eureka type
(d) Mark III I.F.F. sets

1255. The triggered equipment re-transmits and after a time determined by its range from the aircraft, the response is received on the same aerial as was used for transmission. The system thus is of the common T. and R. type. The received signals are fed to a switch motor which connects the aerials alternately to the receiver section of the Lucero unit at a changeover rate of 40 times per second. These switched signals pass through one stage of R.F. amplification and are fed into a mixer along with an L.O. signal whose frequency is such as to give an I.F. output at the same frequency as that used in the H.2.S. installation. The I.F. signal passes through one stage of I.F. amplification and is then delivered to a brown Pye plug on the Lucero panel.

1256. From the brown Pye plug on the Lucero unit the I.F. output is taken to the brown Pye plug on the H.2.S. receiver-timing unit and thence into the I.F. strip. If the Lucero switch on the switch unit is set to B + H, H.T. will be applied to the H.2.S. head amplifier and the H.2.S. signals will simultaneously be applied to the I.F. strip via the green Pye plug. The receiver output valve will then deliver to the receiver-timing unit mixer stage the H.2.S. signals, the responses from the Lucero-triggered equipment, and the heading or track marker. If the Lucero switch is set to "B", the H.T. supply to the head amplifier is cut off and only Lucero signals are fed into the I.F. strip. If the control unit type 222A is not fitted and a jumper socket is fitted to the 18-way plug on the Lucero panel, the L.O. and mixer frequency will be changed automatically (see para. 1264) to receive responses from BABS runway beacons if the Lucero switch is set to BA. If the control unit type 222A is fitted, the appropriate push-buttons are used to make this change-over. The range marker is added in the receiver-timing unit mixer whose output goes via the slate Pye plug to the waveform generator. The signals are fed from the slate Pye plug to the red Pye plug via a condenser and thence to the red Pye plug on Lucero.



DISPLAY TR3160 OR TR3566

FIG.189

FIG.189

1257. The input at the red Pye plug on Lucero is fed back into the switch motor which feeds the signals alternately to the yellow and orange plugs.

1258. The outputs from the yellow and orange Pye plugs on Lucero are applied to the corresponding plugs on the indicator 184 and thence to the grids of the height tube paraphase amplifier valves. Since the signals appear alternately on opposite grids the height tube display now becomes double-sided. The noise and range marker will appear as deflections to both right and left. Homing beacon responses will likewise appear as wide double-sided blips. Their distance up the tube will be a measure of the range which can be measured with the range marker and the range control. The relative amplitudes of the two sides will indicate whether the beacon is to port, starboard or dead ahead. This is possible because the switch motor operation is such that signals picked up on the port aerial appear as deflections to the left on the height tube while signals picked up on the starboard aerial appear as deflections to the right. With a symmetric polar diagram the two deflections will be of equal amplitude if the beacon is dead ahead. If a blip gives a larger deflection to the left the port aerial is receiving a stronger signal than the starboard aerial which is partly shielded by the aircraft. The beacon must then be to port. By altering course until the amplitudes become equal it is possible to home on the beacon. Different beacons can be identified by having them radiate their responses so as to give the visual impression of a morse signal on the height tube.

1259. When the Lucero switch on the switch unit is set to B + H, B or BA, a relay is energised in the Lucero unit which disconnects the white Pye plug from the yellow one and thus cuts off the height marker from the height tube.

Lucero and Blind Approach

1260. Lucero blind approach (BABS) runway beacons can be used in conjunction with Lucero to assist aircraft in making runway approaches in conditions of bad visibility. If the aircraft carries some form of absolute altimeter such as the A.Y.D. to give accurate height indications, landings can be made under bad operating conditions. Lucero + BABS alone, however, can only give the range and runway direction. The BABS transmitter when triggered by Lucero, feeds equal signals alternately to two directional aerials which provide two broad, diverging beams of radiation. One aerial radiates a 1.2 microsecond pulse while the other is arranged to radiate a 5 microsecond pulse. The aerials are switched so that each is connected 50% of the time and the switching rate is 20 changeovers per second i.e. half the airborne switching frequency. The height tube display will then show a narrow blip inside a broad one, the two having a common base line.

1261. Due to propeller modulation these blips may show flickering tips, if the port and starboard beacon aerials are used to provide a double-sided display. Since great steadiness is required for accurate lining up of the tips of the two blips it is unsatisfactory to use the homing aerials for blind approach purposes. A third aerial is therefore fitted which can be connected to one side of the switch motor by means of an aerial change-over switch. As signals are then applied to only one side of the switch motor a single-sided display is obtained on the height tube.

1262. The Lucero blind approach (BABS) beacon is located at the end of the runway in use. When properly aligned, the lobes from the two beacon aerials will overlap just down the centre of the runway. If the aircraft is approaching straight down the centre, i.e., in the equisignal region, the BABS aerial will receive equal strength signals from both beacon transmissions The amplitudes of the wide and narrow blips on the height tube display will then be equal and their tips will therefore coincide. If the aircraft is to either side of the runway the one blip will be wider than the other. In making an approach it is then necessary to alter course until the tips of the two blips coincide when the aircraft will be flying straight down the centre of the runway.

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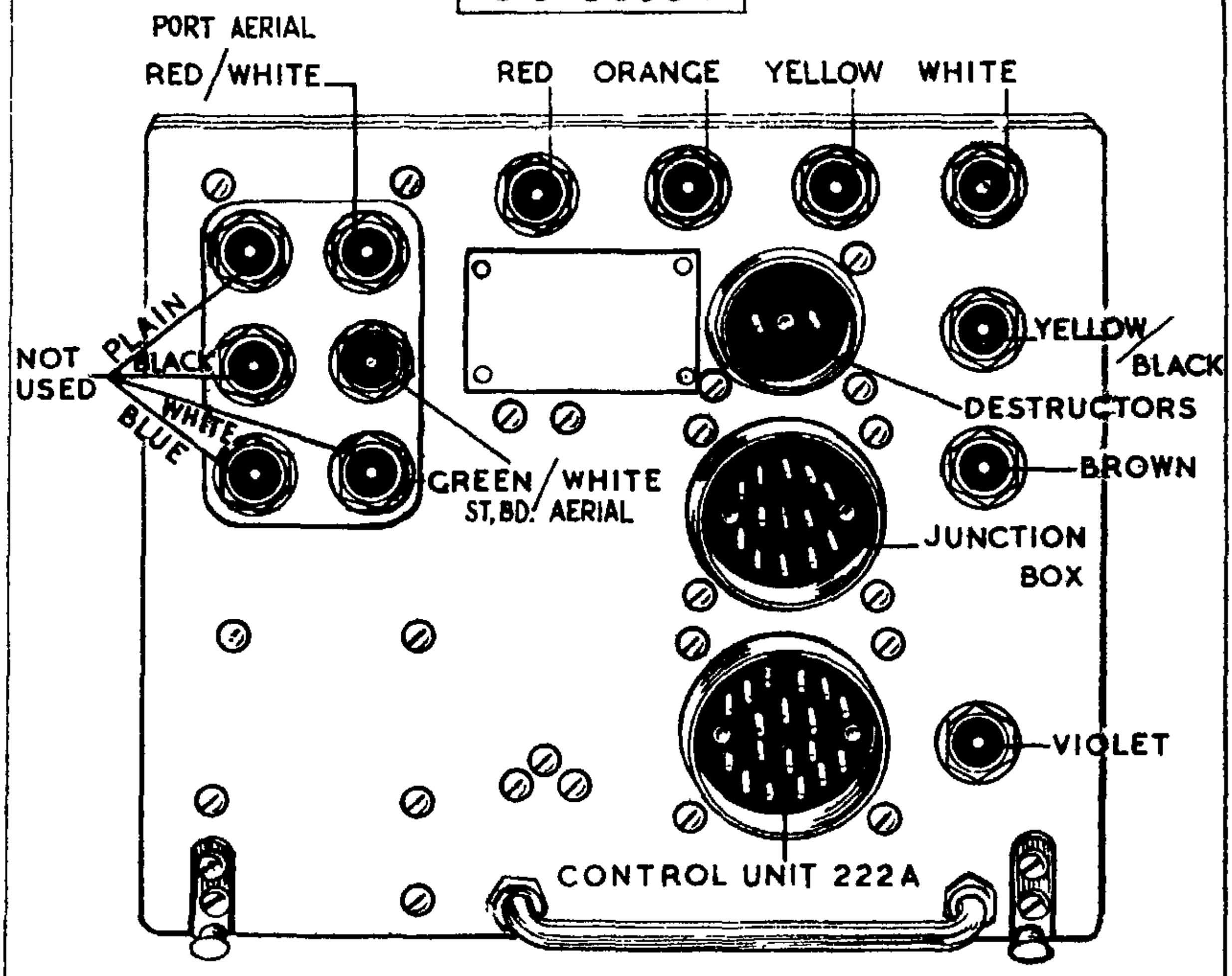
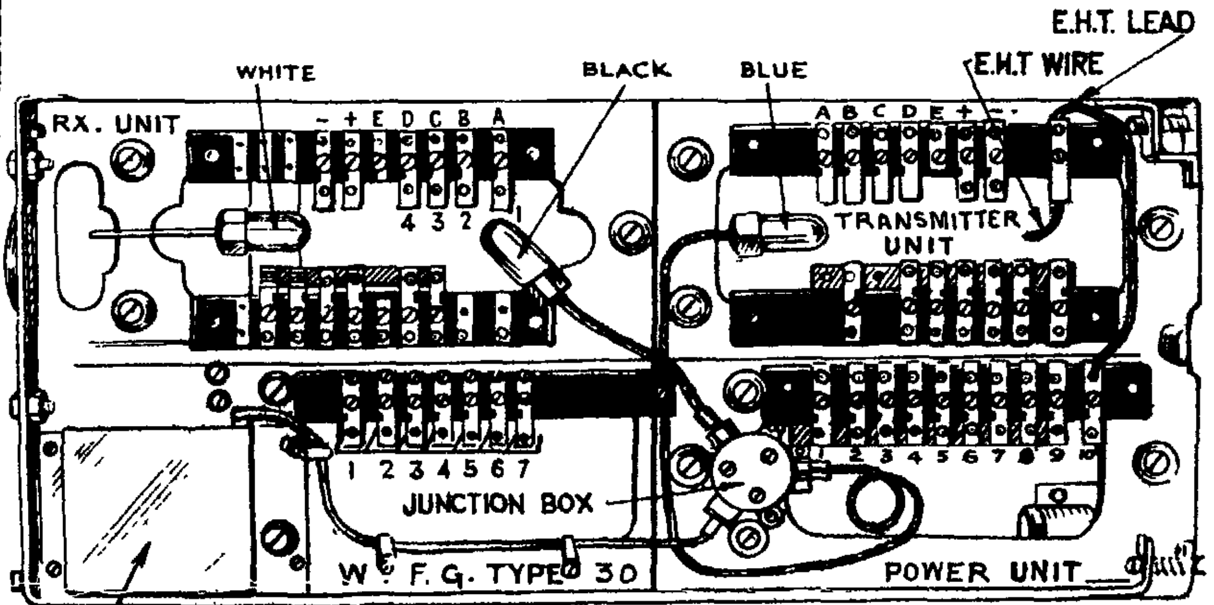


T.R. 3160. FRONT VIEW



T.R. 3160. UNDERSIDE VIEW

T.R. 3160 COMPLETE ASSEMBLY

FIG. 190

FIG. 190

1263. The range of the beacon can be determined by means of the range control. An indication of height is given by the height marker. For accurate indications at low altitudes some form of absolute altimeter is required. Some form of glide path indicator may also be employed to give the correct angle of descent from a known height at a known range.

1264. To eliminate ground returns as much as possible the BABS signals are transmitted on a frequency differing from that of the transmitted signal by several megacycles. Different tuned circuits are therefore required in the Lucero receiver section. The changeover can be made by means of the appropriate push-buttons on the control unit type 222A. If the C.U.222A is not fitted only two of the four possible receiver channels and one of the transmitter channels are usable. As normally connected up these are the Coastal Command frequencies 177 Mcs and 173 Mcs for reception and 176 Mcs for transmission. In Bomber aircraft the Control Unit will always be used. In Coastal aircraft the change is effected, as with Lucero Mk.I, by changing from either the H + B or the B switch position, to the BA position.

Multiple Band Facilities

1265. The Lucero transmitter is tuned by means of a series of four condensers mounted on a motor-driven mechanism called a turret. The R.F. amplifier and local oscillator in the Lucero receiver section have four preset tuning circuits which also are mounted on motor-driven turrets. The 4 condensers for the transmitter tuning and the inductances in the receiver tuned circuits provide frequency coverages as listed in the table below. The table also gives the push-buttons on the control unit to bring these channels into operation.

Push-Button	Transmit	Receive
A	171-181 Mc/s	171-181 Mc/s
B	212-226 Mc/s	168.5-178.5 Mc/s
C	222-236 Mc/s	210-228 Mc/s
D	222-236 Mc/s	220-238 Mc/s
E	Inoperative	Inoperative

1266. (a) The A buttons are intended to cover the 176 Mc/s homing beacon channel and also to provide I.F.F. interrogation.
(b) The combination of button A (transmit) and B (receive) is designed to take care of the 176/173.5 Mc/s BABS channel.
(c) The various available combinations of B, C and D (transmit) with C and D (receive) provide beacon and BABS channels on various combinations of 214, 219, 224, 229 and 234 Mc/s.
(d) The E buttons are inoperative. When either E button is accidentally pressed the frequency remains unchanged.

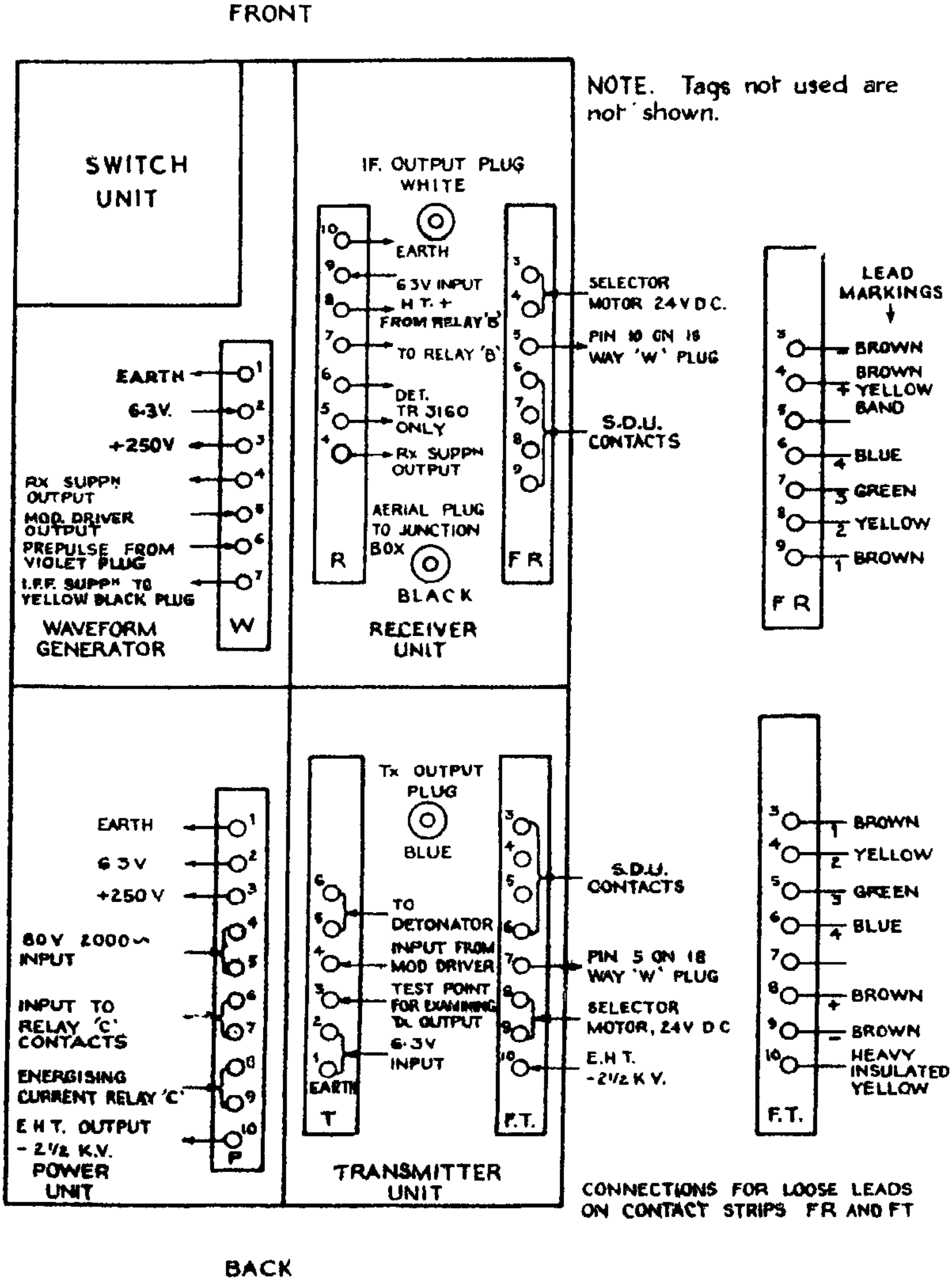
The Lucero Equipment

1267. Mark II Lucero is built on the "brick" or sub-assembly principle. Any particular Mark II Lucero will include the following sub-assemblies :-

(a) Chassis assembly
(b) Transmitter unit
(c) Receiving unit
(d) Waveform generator
(e) Power unit
(f) Switch unit

These individual sub-sections will differ according to the requirements of the A.R.I. installation into which the particular composite Mark II Lucero unit is to be used. Differences arise mainly over the following points :-

(a) Whether the aircraft supply is 12 or 24V.
(b) Whether the A.R.I. intermediate frequency is 13.5 Mc/s., 30 Mc/s., or 45 Mc/s.



CHASSIS CONNECTIONS (TR.3160, TR.3566)

FIG.191

FIG.191

(c) R.F. coverage demanded of the receiver
(d) R.F. coverage demanded of the transmitter

1268. Bomber Command requirements are tabulated below :-

		Constituents					
Unit	Ref.No.	Chassis Assembly	Tx-Unit	Rx-Unit	W.F.G	Power Unit	Sw. Unit
TR.3160 for H.2.S. Mark IIC 24V.	10DB/868	Type 101 10DB/6100	Type 105 10DB/6099 RF(171-178Mc/s (212-236Mc/s	Type 159 10DB/6098 IF.13.5Mc/s RF(171-181Mc/s (210-238Mc/s	Type 30 10VB/ 6007	Type 532 10KB/ 6035	Type 115 10FB/ 556
TR.3566 for H.2.S. Mark IIIA 24V	10DB/6348	Type 127 10DB/6545	Type 127 10DB/6099 RF(171-181Mc/s (212-236Mc/s	Type 161 10DB/6106 IF.45 Mc/s RF(171-181Mc/s (210-238Mc/s	Type 30 10VB/ 6007	Type 532 10KB/ 6035	Type 115 10FB/ 556

1269. 200 pre-production models are called TR.3160A, ref. 10DB/6636. These have minor differences in the chassis assembly, 13.5 Mc/s receiver, and transmitter. These sub-units carry type and reference numbers as follows :-

(a) Chassis Assembly Type 123 - Ref. 10DB/5689
(b) Receiver Unit Type 194 - Ref. 10DB/6688
(c) Transmitter Unit Type 117 - Ref. 10DB/6690

Wave Form Generator Type 30 (Fig.197)

1270. Performs the following functions :-

(a) Divides the repetition frequency of the 20 microsecond input pulse from the modulator 64 violet Pye by 3 to give an output of about 220c/s.
(b) Generates the five microsecond modulating pulse for the transmitter at the counted down p.r.f.
(c) Generates the "gating" waveform used to bring the receiver into operation for about 1300 microseconds after the termination of each transmitter pulse.
(d) Develops a waveform suitable for suppressing a Mark III I.F.F. set in the same aircraft. This suppression waveform will be at the counted down repetition rate.

The Receiving Unit Type 159 or 161 (Figs. 201 and 202)

1271. Has four stages as follows :-

(a) R.F. amplifier stage
(b) Local oscillator with four preset tuning circuits selected by the push-buttons on the control unit. The selected tuned circuit is connected into circuit by means of a motor-driven "turret" mechanism.
(c) Mixer stage
(d) I.F. amplifier stage at 13.5 Mc/s in type 159 and 45 Mc/s in type 161.
(e) It also includes the selector drive unit and turret mechanism for switching the R.F. amplifier and L.O. tuned circuits.

Transmitter Unit Type 105 (Fig.200)

1272. Comprises the following stages :-

(a) Series modulator valve stage
(b) Push-pull lecher line transmitter whose power output is about 0.5KW. at p.r.f. of about 220 and pulse width of 5 microseconds.
(c) Also includes the tuning condenser turret and the selector drive unit.

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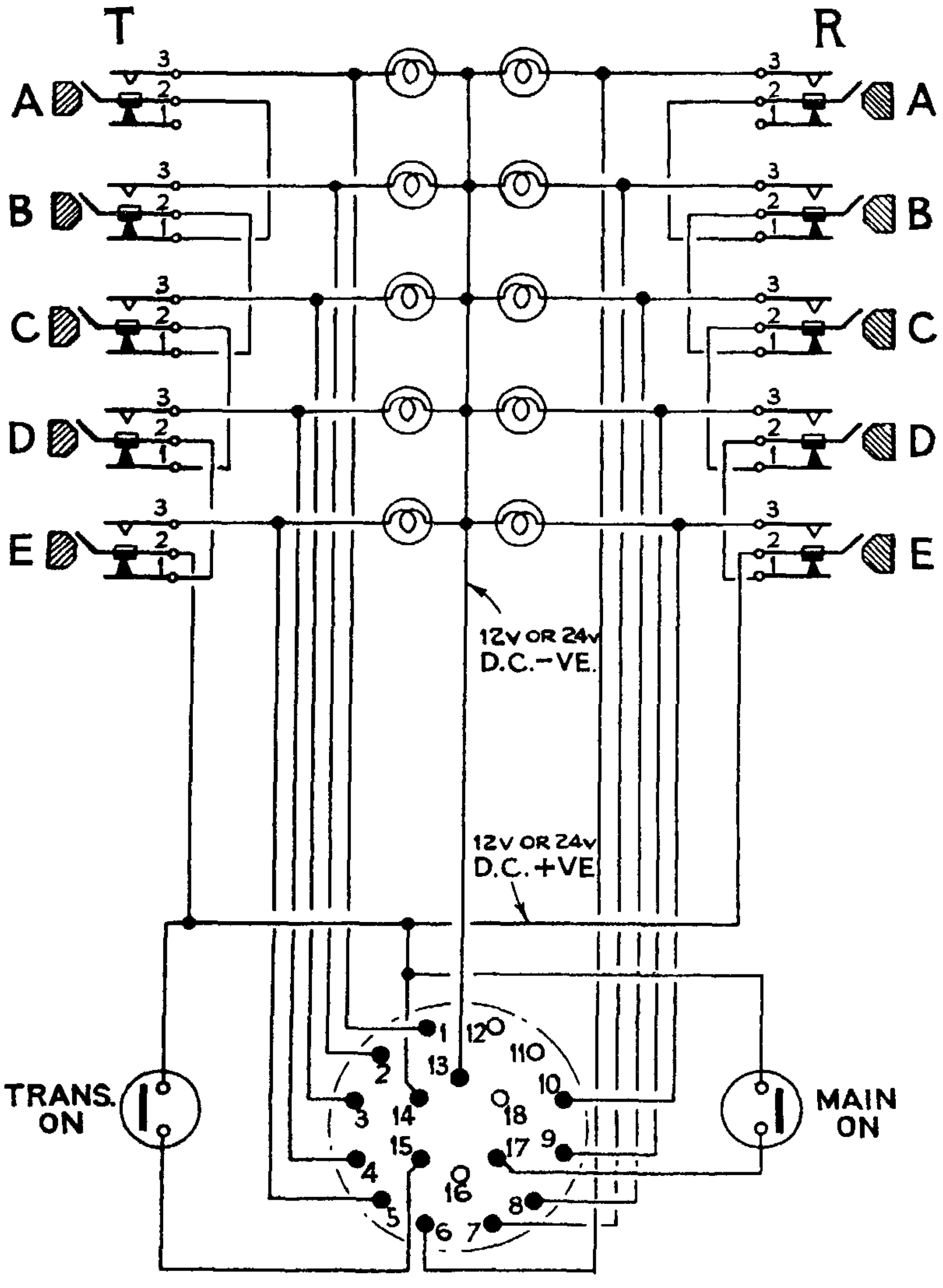


CONTROL UNIT, TYPE 222 A, CIRCUIT

FIG. 192

Power Unit Type 532 (Fig.196)

1273. Includes the following :-

(a) VU.120 half-wave rectifier -2.5 KV + (15% - 0%) 3 ma for the transmitter E.H.T.
(b) 5Z4G full-wave rectifier 250 ± 25V, 40 ma. for the H.T. supply.
(c) Heater supplies of (i) 2 ± 0.1V., 2 ma., for the VU.120
(ii) 5 ± 0.25V., 2 ma., for the 5Z4G.
(iii) 6.3 ± 0.3V. 8 ma., for other valves
(d) Relay C which is energised when the "Trans.-ON" switch on the control unit type 222A is pressed after H.2.S. is switched on at the switch unit.

Chassis Assembly Type 101 (Figs. 190 - 191)

1274. The chassis assembly serves to connect the various units and to mount them. It also provides for the connections to the control unit type 222A and to the H.2.S. units. B relay, which switches the signals to the red and orange plugs, is mounted on the chassis. The common T. and R. links and their junction box are mounted on the chassis external to the transmitter and receiver sub-units.

Switch Unit Type 115 (Figs. 204 and 205)

1275. This is the Lucero switch motor which connects the aerials alternately to the transmitter and receiver, and simultaneously switches the receiver output alternately to the two paraphase amplifier grids to get the two-sided homing beacon presentation with port signals to the left and starboard signals to the right. The port and starboard aerials are connected direct to the switch which connects one or other of them to the transmitter and receiving unitsat a changeover rate of 40 times per second. Relay type contacts are used which are operated by cams and push rods. The cams are mounted on a common shaft rotating at 600 r.p.m. and driven by a 6:1 reduction gear from the motor shaft which runs at 3,600 r.p.m. The output contacts on the switch overlap in angular duration of contact. The aerial changeover occurs during the output overlap to avoid undesirable effect on the height tube.

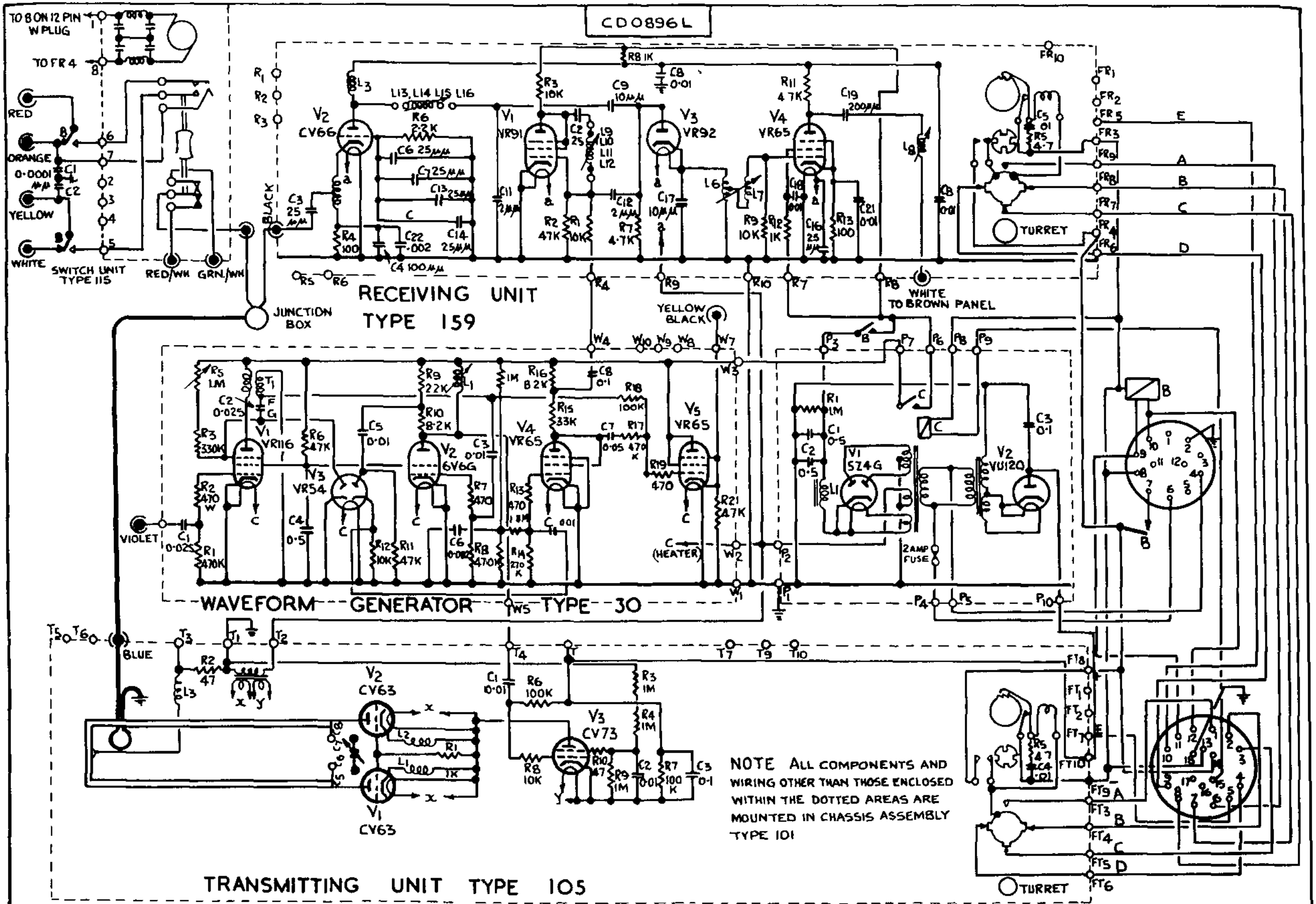
1276. The switch unit section shows six Pye plugs on the front of the Lucero panel (fig.190), of which only the red/white and green/white are used. The red/white is connected to the port and the green/white to the starboard aerial.

The Control Unit Type 222A (Fig.192)

1277. (a) This unit houses the transmitter and receiver frequency selector push-buttons which serve to operate the selector drive units. The drive units rotate turret mechanisms to bring the desired components into circuit.
(b) The unit also carries the "Trans.-ON" switch. This switch must be closed in order to energise C relay in the power unit type 532 and connect the H.T. supply to the W.F.G. type 30. Until this supply is completed no modulating pulse is developed from the 20 microsecond input from the modulator 64 and the transmitter remains therefore inoperative.

The Aerial System, Type 184 (Fig.203)

1278. This aerial system comprises two vertical half-wave dipoles, one on the port and one on the starboard side of the aircraft. The dipoles are provided with directors.



DESTRUCTOR

RELAY

T.R. 3160 CIRCUIT.

FIG.193

FIG.193

The Aerial System Type 308

1279. This is the aerial system used for receiving the runway beacon signals. A changeover switch is used to disconnect the port and starboard homing beacon aerials and to connect this aerial instead when a landing approach is being made to a runway with a BABS beacon. The aerial is of the quarter wave type and is provided with a director. The signal input is so applied as to obtain deflections to the right.

The Common T. and R. System

1280. To use the same aerials for both transmission and reception, it is necessary to make the following arrangements :-

(a) That the minimum of transmitter output gets into the receiver
(b) That the receiver is suppressed while the transmitter is pulsing to prevent overloading on transmitter breakthrough.
(c) That the minimum of receiver signal power is lost into the transmitter.

To meet the (a) and (c) requirements as well as possible, the transmitter output line and receiver input line are taken to a junction box (see fig. 193) on the chassis assembly. From the junction box, a transmitter output link goes to the switch motor which feeds the signal alternately to the two aerials. The returned signals picked up on the aerials come back on this link to the junction box and then pass to the receiver. The length of link from the transmitter to the junction box is so chosen that it looks like a high impedance stub to incoming signals which then go mainly to the receiver. The link from the junction box to the receiver input is chosen to look like a relatively high impedance compared with the output path to the switch motor. The greater part of the transmitter output is thus applied to the aerials.

1281. To meet condition (b) a suitable receiver suppression waveform is developed in the waveform generator section of the TR.3160.

Cabling Installation

1282. The panel of the Mark II Lucero unit is shown in fig.190. Figs. 13 and 14 show how the TR.3160 and control unit type 222A are fitted into the aircraft installation.

The Lucero Circuit

1283. (a) The TR.3160 circuit containing the sub-units appropriate to H.2.S. Mark IIC is given in fig.193.
(b) For H.2.S. Mark IIIA the receiver unit type 159 must be replaced by type 161. The type 161 circuit is shown in fig.202.
(c) The control unit type 222A is shown in fig.192.

Power Switching

1284. To appreciate how the Lucero switch on the switch unit 207 B and the "Trans. ON" and "Main ON" switches on the control unit type 222A are interrelated it is necessary to study fig. 194. When H.2.S. is switched on, + 24V. is applied to pin 7 and -24V. to pin 8 of the Lucero 12-way. Pin 8 applies -24V. to one side of both B and C relays and the switch motor, -24V. is also applied to one side of the control unit push buttons via 18/13 and one side of the "Trans. ON" switch via relay C and 18/15 of the 18-way from Lucero to the control unit 222A.

1285. The +24V. line comes in on pin 7 of the Lucero 12-way to one of the contacts (B/1) on B relay. This line is also connected to the Lucero switch on the switch unit.

1286. Contacts B + H and B on the Lucero switch are strapped and linked to

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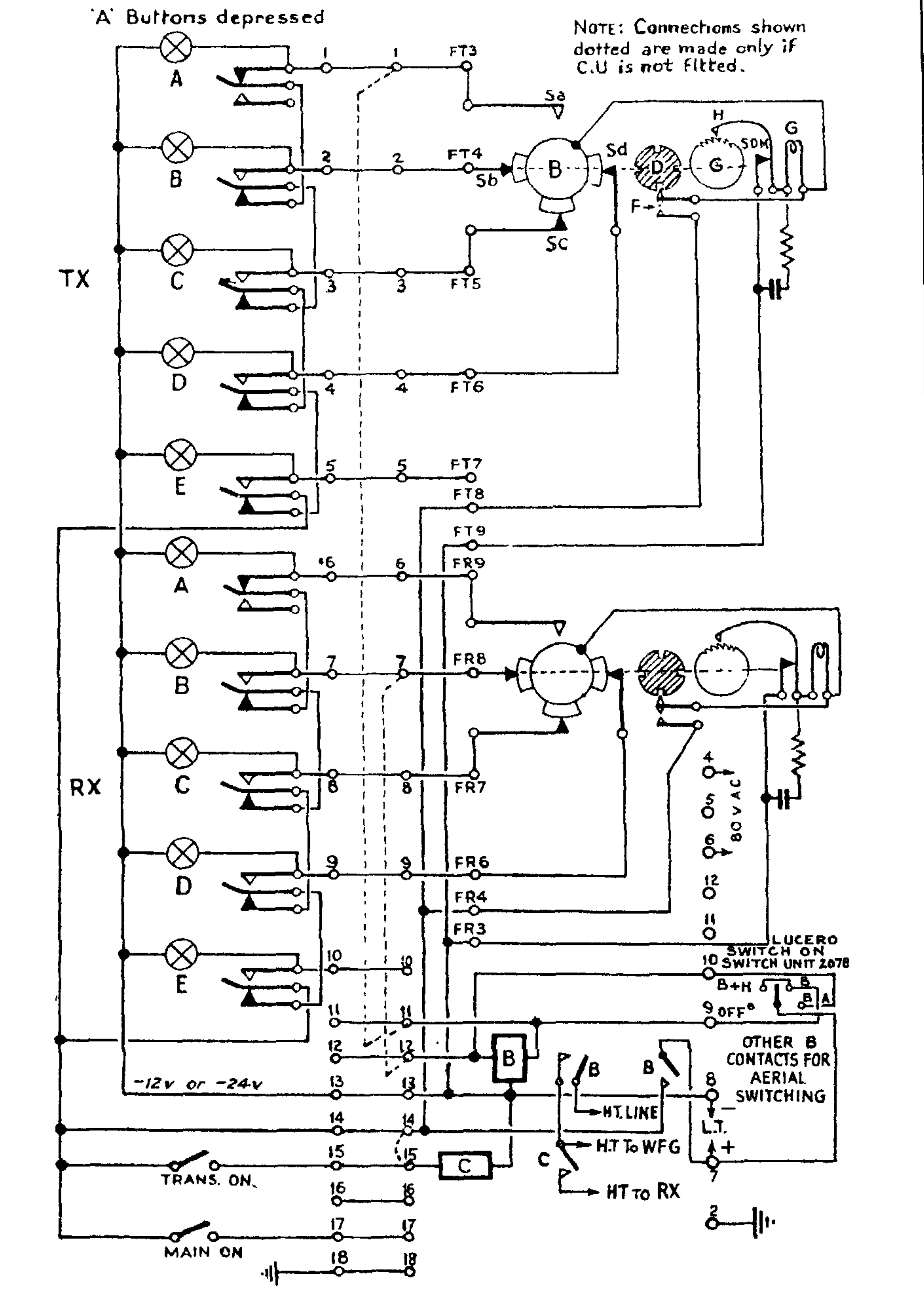


FIG. 194 LUCERO CONTROL CIRCUITS (T.R. 3160) FIG. 194

the other side of B relay via pin 9 of the Lucero 12-way. The BA contact on the Lucero switch is returned to pin 10 of the Lucero 12-way and thence to another winding on relay B. Hence, when the Lucero switch is set to B + H, B or BA, relay B is energised. If the Lucero switch is set to "OFF" the D.C. supply to relay B is not completed. The changeover contacts, B/3 and B/4, shown in the upper right-hand corner of fig.193, then connect the red Pye to the orange and the white to the yellow. The normal H.2.S. presentation is then obtained. As soon as B relay is energised by setting the Lucero switch to any of the other three positions the contacts change over. The red Pye is then connected to the switch motor which switches the output from the receiver-timing unit mixer, V411, between the orange and yellow Pye plugs. Signals from the port aerial go to the yellow and signals from the starboard aerial to the orange Pye plugs. When B/4 changeover contact connects the yellow Pye plug to the switch motor the white Pye plug is floating and there is no height marker input to the height tube.

1287. Referring now to fig.194, we note that when relay B is energised, contact B/1 connects + 24V. from 12/7 to FR.4 on the receiver and thence to the other side of the switch motor (see fig.193).

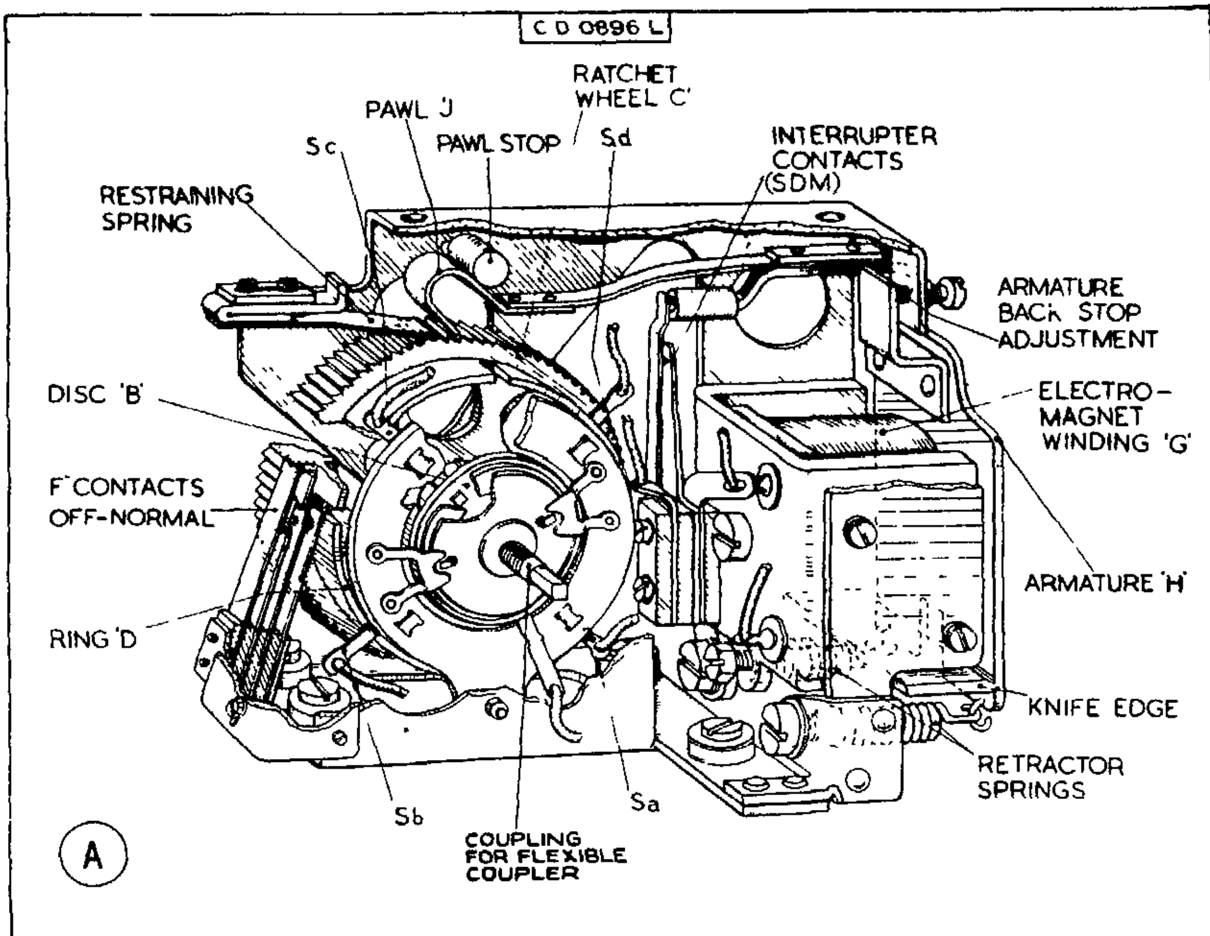
1288. B/1 also connects +24V. via pin 14 of the 18-way to the control unit to "Trans. ON", "Main ON" and push-buttons. If the "Trans. ON" switch is closed, +24V. is connected to the other side of C relay which now becomes energised.

1289. To appreciate the function of C relay we must first consider the 80V. A.C. channel. This supply comes to TR.3160 on pins 4 and 6 of the Lucero 12-way from the main junction box. From fig.193 we see that 12/4 and 12/6 feed to P.4 and P.5 and then to the power transformer in the power unit type 532. The 250V. H.T. and -2.5KV. E.H.T. supplies are then developed. The +250V. passes via P.3 and B/2 to the receiver which now becomes operative. The -2.5KV. supply passes via P.10 to T.8 and the CV.73 modulator valve. R.7, R.9, R.4, R.3 and R.2 form a bleeder between -2.5 KV. and earth, which holds the modulator cathode so positive to the grid that the modulator valve is cut off until a positive modulating pulse is applied to the grid. This pulse comes from the anode of V.2 in the Lucero waveform generator via W.5 and T.4. But the H.T. to the waveform generator is completed via relay C. Hence, until relay C is energised there is no H.T. to the waveform generator and no modulating pulse. As soon as the "Trans. ON" switch is closed, the waveform generator develops the modulating pulse which renders the modulator valve conducting for 5 microseconds after the back edge of every third 20 microsecond pulse applied via the violet Pye plug to the grid of V.1 in the waveform generator.

1290. The heater supply for the CV.63 transmitter valves is obtained from the isolating heater transformer in the transmitter unit. The supply to the primary is obtained via T.2 and P.2 from the power unit transformer. This supply is completed as soon as H.2.S. is switched on. The transmitter is thus ready to go into operation as soon as the "Trans. ON" switch is closed to energise relay C and bring the waveform generator into operation to develop the modulating pulse.

1291. Summing up, we have the following major points :-

(a) When H.2.S. is switched on, the 80V. supply to the power unit is completed via 13/4 and 12/6 and +250V., -2.5KV., and heater supplies are developed. The modulator valve is held biassed to cut off and the transmitter is inoperative.
(b) The -24V. supply is completed to :-
   (i) One side of relays B and C via 12/8
   (ii) One side of the "Trans. ON" switch via C relay solenoid and 18/15.
   (iii) One side of the switch motor.
(c) The +24V. supply is completed via 12/7 to the back contact of B/1.
(d) When the Lucero switch on the switch unit is set to B + H or B, the +24V. supply is completed to the other side of



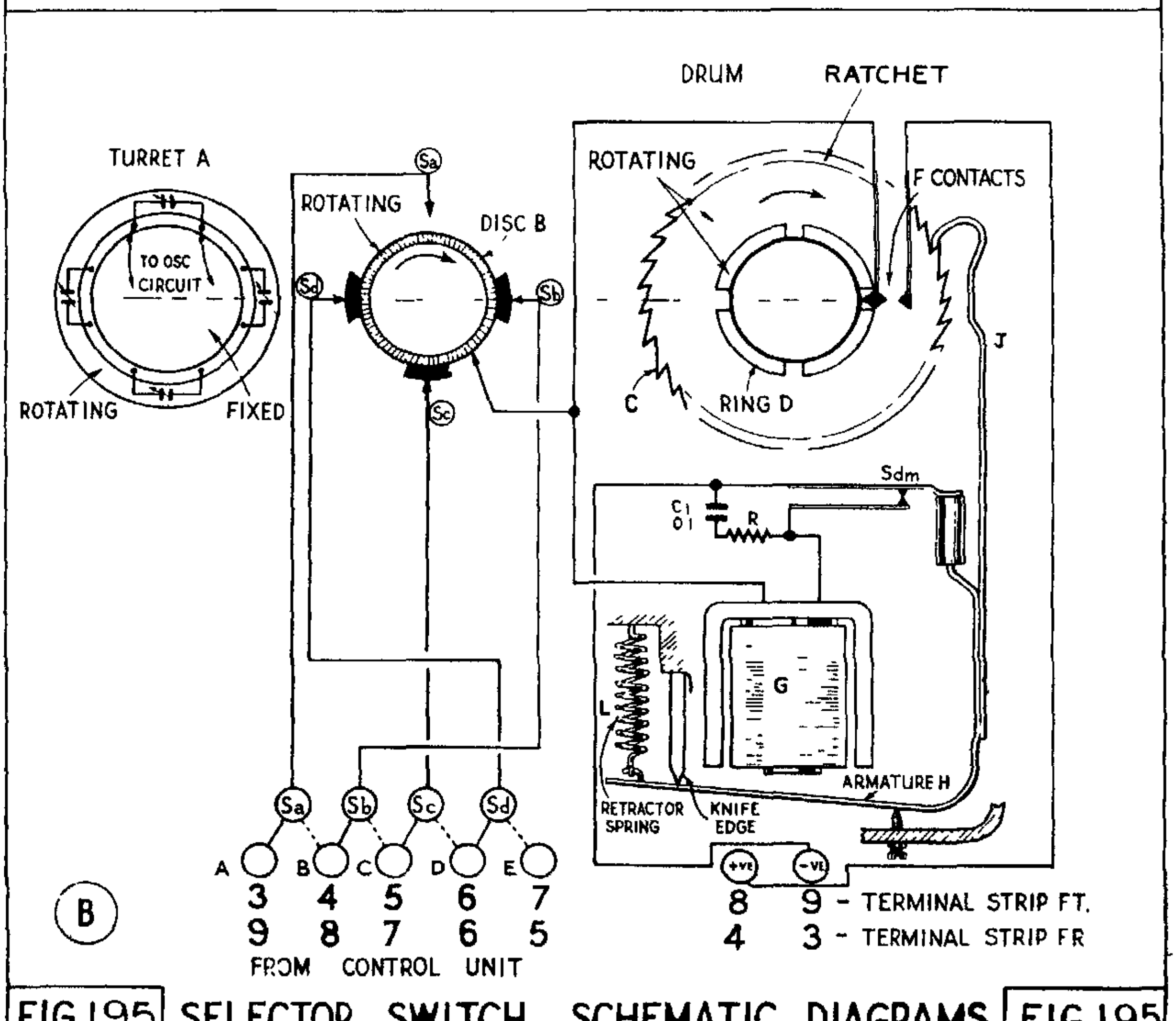


FIG.195 SELECTOR SWITCH. SCHEMATIC DIAGRAMS FIG 195

relay B via 12/9 and relay B is energised with the following results :-

(i) B/1 closes and connects +24V. to the push buttons and the other side of the "Trans. ON" switch and puts +24V. on the switch motor via FR.4.
(ii) B/2 closes and connects +250V. to the contact on relay C.
(iii) B/3 changes over and connects the red Pye to the switch motor and via the switch motor to the orange Pye for signals from the starboard aerial.
(iv) B/4 changes over (leaving the height marker floating) and connects the red Pye via the switch motor to the yellow Pye for signals from the port aerial.

The whole equipment is now ready to go into operation on homing beacons when the H.T. supply to the waveform generator is completed.

(e) If the "Trans. ON" switch is closed the 24V. supply to C relay solenoid is completed and C relay is energised. The contact closes and puts H.T. on the waveform generator which now develops the modulating pulse to bring the modulator valve and transmitter into operation.
(f) If the Lucero switch is set to BA, the +24V. supply is completed to another winding on relay B via 12/10. This second winding is incorporated to permit use of independent jumper socket channels for automatic frequency selection by means of the Lucero switch for either homing beacons or blind approach beacons. Its significance does not appear if the control unit type 222A is used. In this case the appropriate frequency selection must be done by means of the push-buttons on the control unit. All the Lucero switch then does is to energise B relay, regardless of whether the B or BA position is used. The push buttons determine the frequency selection.

Frequency Selection

1292. The mechanical details of the selector drive unit mechanism are shown in fig.195. The essentials of the operation can be gathered from fig.194. which shows what the conditions would be if both A push-buttons had been pressed. We note the following points :-

(a) -24V. is applied to the pilot lamps via 12/8 and 18/13.
(b) -24V. is applied via the lamps of the free buttons and the open contacts of these buttons to the 3-sector disc and thence to one side of the electromagnet solenoid, G.
(c) -24V. is applied via FT.9 and FR.3 to the other side of the electromagnets via the S.D.M. contacts.
(d) +24V. is applied via 12/7, B/1 and 18/14 to the push-buttons in series.
(e) The 24V. supply is completed through the pilot lamps of the two closed buttons.
(f) The +24V. contacts from the closed push-buttons to the sector discs are floating.
(g) +24V. is connected via B/1 to FT.8 and the F contact (normally open) of the transmitter selector drive unit. The corresponding connection to the receiver is made via FR.4.
(h) The turrets will be so rotated as to put the A frequency condenser into circuit in the transmitter and the A frequency tuned circuits into the R.F. amplifier and local oscillator in the receiver.

1293. Suppose that now button B is pressed for the transmitter. The following events will occur :-

(a) The mechanical interlocking of the transmitter buttons will release the A button which will fall back into the open position, breaking the supply through the pilot lamp which goes out. -24V. is now applied to the sector contact, Sa.
(b) The +24V. supply is connected to B lamp which now lights.
(c) The +24V. supply is connected through B lamp, 18/2 and FT.4 to Sb, and thence through the sector disc to the one side of the solenoid.
(d) The electromagnet is energised and attracts the armature.
(e) The movement of the armature rotates the ratchet, the ring D, the sector disc B and the turret.
(f) The S.D.M. contact breaks and the armature flies back under the tension of the retractor spring to complete the contact again and give the ratchet another pull.
(g) When the contact Sb slides off its sector, the +24V. line via the sector disc is broken. The channel is, however, completed via the F contact which will be out of its notch and completing the supply via FT.8 and B/1.
(h) Movement continues until F contact drops back into its notch when Sb is opposite the blank section of B. There is then no further energising of the electromagnet and the turret is stationary with the B frequency condenser in the transmitter circuit.

1294. The operation of the receiver push-buttons is identical.

1295. If E button is pressed nothing happens as it has no connection to the sector disc.

1296. The connections shown dotted in fig.194 are made with a jumper socket fitted on the 18-way when the control unit is not used. Pins 1, 6 and 11 are strapped so that when the Lucero switch is set to B or B + H, the transmitter and receiver automatically tune to frequency A. Similarly pins 7 and 12 are strapped so that when the H.2.S. switch is in the BA position the transmitter remains on frequency A but the receiver tunes to frequency B.

1297. Since the "Trans. ON" switch brings the transmitter on via C relay, it can be used as a morse key for cathode ray signalling with Lucero. If the jumper socket is fitted, pins 14 and 15 of the 18-way are connected so that C relay is energised by B relay. The morse facility is then lost unless this strapping is broken and a morse key or switch fitted in its place.

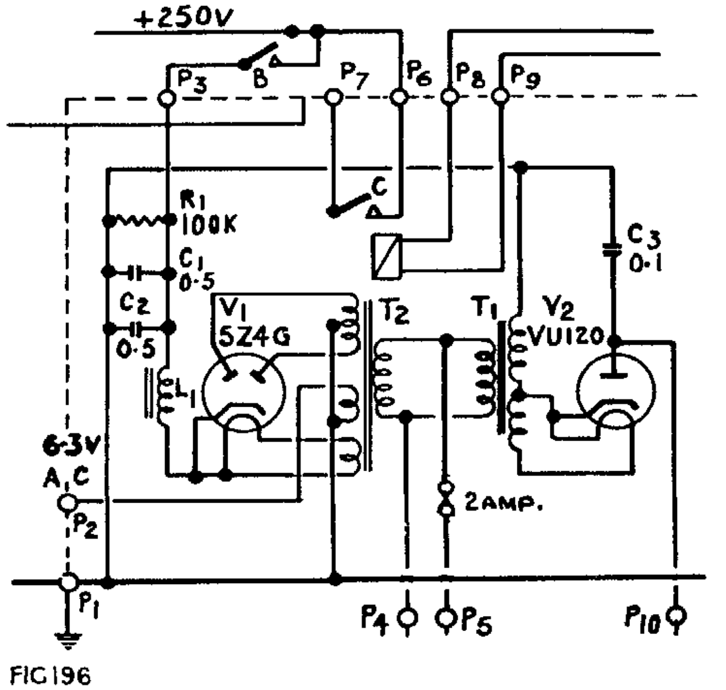


FIG 196

The Power Unit Type 532

1298. The circuit is shown in fig.196 and mechanical details in fig.208.

1299. The following voltages should appear on the terminals, measured on load :-

Terminals	Avometer Range	Reading
1 to chassis	Low ohms	Zero ohms
2 to chassis	12V. AC.	6.3V (± 0.3)
3 to chassis	750V. DC.	250V. (± 25)
4 and 5	120V. AC.	83V.

1300. The E.H.T. voltage at P.10 can be measured with an electrostatic voltmeter. The reading should be -2.5KV. + 15% - 0%.

1301. Care must be taken in checking the heater voltage of V.2 as the heater is 2.5KV. below earth.

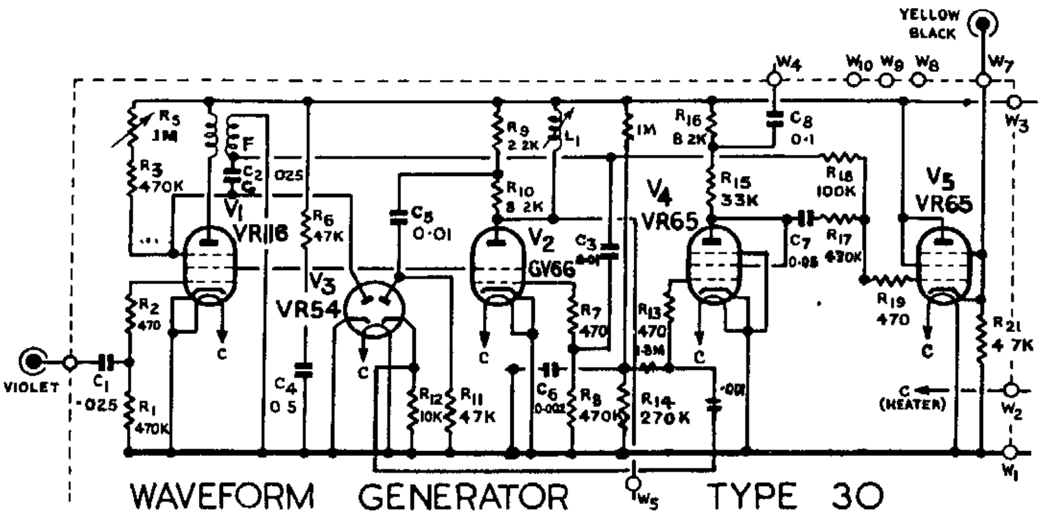


FIG 197

The Waveform Generator Type 30

1302. (a) The circuit is shown in fig.197 and mechanical details in fig.206.
(b) Theoretical waveforms are shown in fig.198.
(c) Waveforms as observed on the monitor 28 are shown in fig.199.

The Counting-Down Circuit

1303. The Waveform Generator should count down, with stability, by two, three or four with an input of 670 per second recurrence frequency and three, four and five at 1200 recurrence frequency. R5 is adjusted so that it counts down by three for a 670 recurrence frequency input. V.1 (VR.116) and half of V.3 (VR.54) perform the function of counting down. The 20 microsecond 40-50V. positive pulse from the violet Pye plug is applied to V.1 grid through the time constant, C.1 R.1, with a value of about 12,000 microseconds. The grid current flow into C.1 during the pulse period develops an autobias across R.1 that holds the valve cut off on the grid except during the pulse periods. When V.1 goes into conduction the flow of anode current through T.1 primary causes point F to swing positive. C.2 (.025) then takes current through the diode, V.3. On the back edge of the 20 microsecond pulse V.1 cuts off due to grid current bias and point F swings negative and drives V.1 suppressor about 120V. below earth. Anode current in V.1 is then cut off until the negative charge on C.2 can leak away through R.3 and R.5 to H.T. By adjusting R.5,

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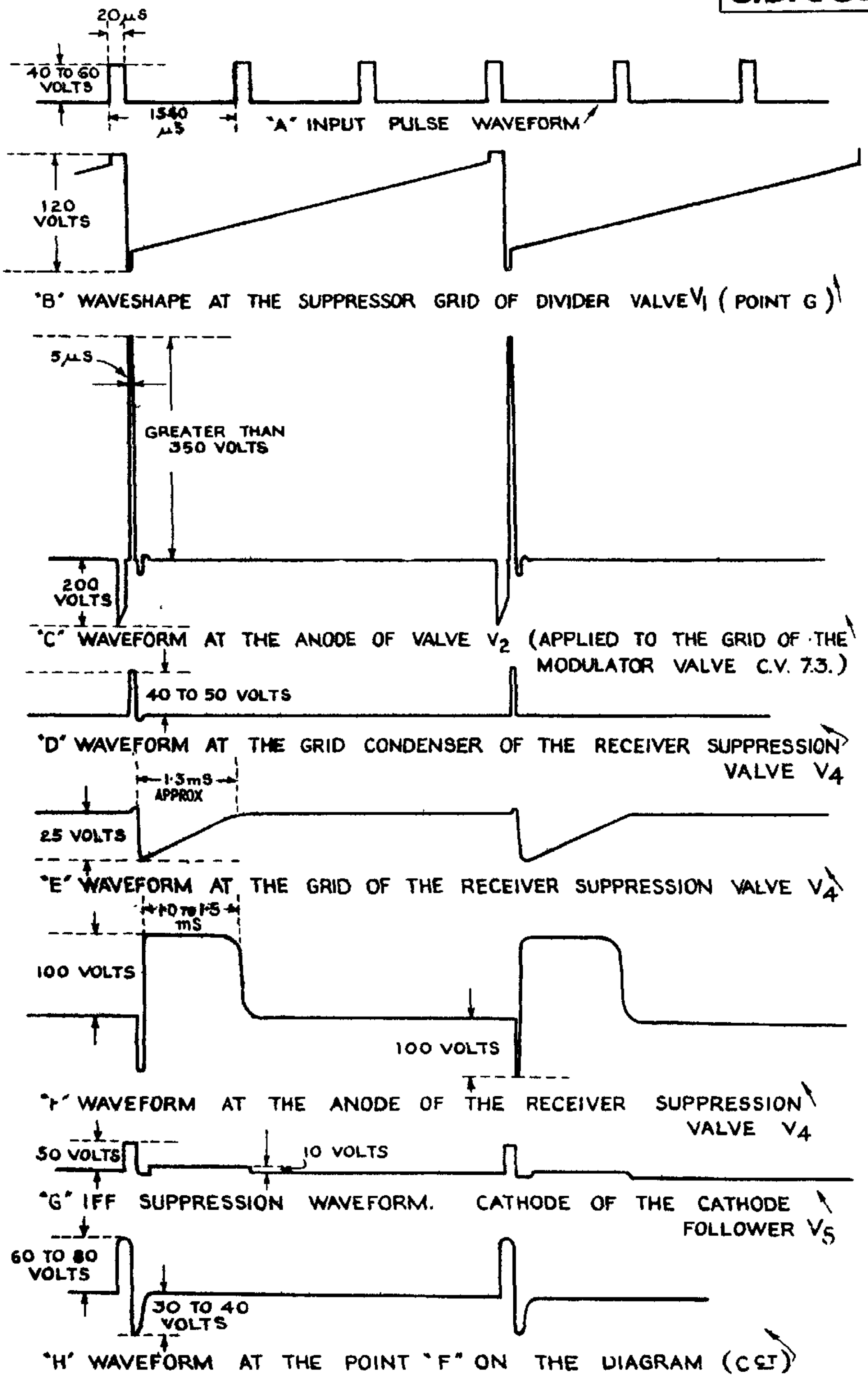


W. F. G. TYPE 30, WAVEFORMS (THEORETICAL)

FIG. 198

FIG. 198

the discharge period can be adjusted so that V.1 can only pass anode current on every third 20 microsecond pulse (p.r.f. of 670). The counted down waveform from F at about 220 c/s is applied to the grids of both V.2 and V.3.

1304. R.5, the Lucero p.r.f. control, is a preset situated on the waveform generator chassis (see fig.206).

Transmitter Modulation Pulse

1305. V.2, a 6V6G high current tetrode, is used to develop the modulating pulse. Its anode load is a permeability-tuned coil, L.1, which resonates with its stray capacity at about 100 Kc/s. A half-cycle will then take 5 microseconds. The input to V.2 grid is the counted down ring at the point F. This ring has a positive swing of 60-80 volts corresponding to every third 20 microsecond pulse and a negative swing of 30-40 volts on the back edge of these pulses. The positive swings carry V.2 into heavy grid current which develops sufficient autobias to keep V.2 cut off between inputs. During the conducting periods energy is stored in the magnetic field of L.1. The negative overswing on the back edge of the input pulse serves to cut V.2 off very sharply. V.2 anode potential then swings up several hundred volts as the magnetic field about L.1 collapses. R.9 and R.10 serve to damp the ring out so that only the first positive swing is of consequential amplitude. The setting of the core of L.1 determines the pulse width. The position of L.1 is shown in fig.206.

1306. The anode waveform is taken out on W.5 and applied to the grid of the modulating valve in the transmitter unit via T.4.

The Receiver Suppression Waveform

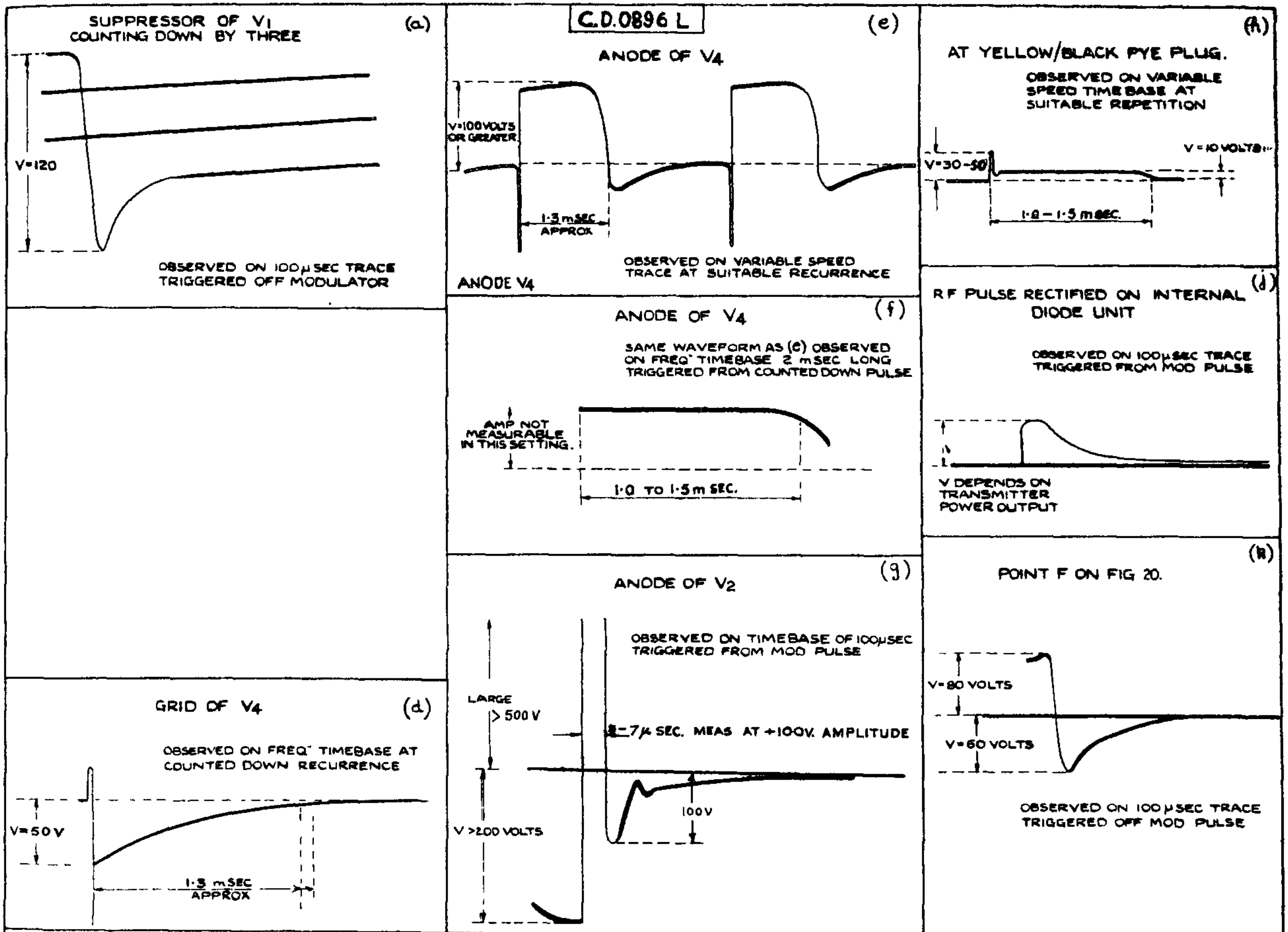
1307. It is desirable to have the receiver suppressed at all times except for a period of approximately 1500 microseconds commencing on the back edge of the transmitted pulse. We require, therefore, a 1500 microsecond sensitising waveform which begins on the back edge of the output at V.2 anode. This waveform is developed by V.4 and the second half of V.3. It is applied to the grid of the local oscillator.

1308. Approximately one fifth of the amplitude at V.2 anode is tapped off across R.9 and applied across C.5 and R.11. When V.2 cuts off the positive swing applied to C.5 carries the diode into conduction and a positive voltage is developed across the cathode load, R.12. This rise is applied to V.4 grid via C.9 and swings V.4 into grid current which charges C.9 negatively. When the modulating pulse at V.2 anode collapses, the diode is cut off and the cathode potential falls from around +40V. to 0V. This fall is applied to V.4 grid and carries the grid well below cut-off. The anode potential will then rise to H.T. and will remain there until the charge of C.6 leaks away through R.23. This leakaway period is of the order of 1300 microseconds so we have the desired 1500 microsecond positive pulse at V.4 anode commencing on the back edge of the modulating pulse. The anode output is tapped down across R.16 and taken to W.4 via C.8. From W.4, it is taken to R.4 and the local oscillator grid (see fig.193). The first such pulse carries the local oscillator into grid current and charges C.8 negatively. On the back edge the local oscillator grid is carried below cut-off. The effect is then that the waveform is negatively D.C. restored at the local oscillator grid by grid current so serves only to lift the grid to 0V. for 1300 microseconds after the transmitter has pulsed and then takes it below cut-off until after the next transmitter pulse.

The I.F.F. Suppression Waveform

1309. I.F.F. suppression involves two requirements :-

(a) The I.F.F. set must be rendered so insensitive during the transmitter pulse period that it cannot be triggered.
(b) After the transmitter pulse has terminated, the sensitivity of the set must be kept down sufficiently to prevent it from radiating a small amount of R.F. modulated at the quench frequency. Such radiation would act as interference.



W.E.G. TYPE 30 WAVEFORMS (AS VIEWED ON MONITOR, TYPE 28)

FIG 199

FIG 199

These requirements call for a composite waveform with one part of duration at least equal to the pulse period and a second part of much smaller amplitude for the duration of the 1300 microsecond sensitive period. This result is achieved by utilising the counted down ring from F on T.1 secondary and the positive-going 1300 microsecond waveform at V.4 anode which are applied to V.5 grid.

1310. The positive swing at F when V.1 cuts on puts a positive swing of about 50V. on V.5 grid. This is followed by a small negative overswing which is of no consequence as the large positive pulse from V.5 cathode will have rendered the I.F.F. set inoperative in this period via the I.F.F. suppression stage. The positive 1300 microsecond waveform from V.4 anode is tapped down across R.17 and also applied to V.5 grid to produce a corresponding 10 volt positive swing at V.5 cathode. The composite suppression waveform, shown in figs. 198 and 199, is taken to the yellow/black Pye from V.5 cathode for application to the suppression plug on the I.F.F. set. A cathode follower output is used to permit matching to low impedance cable without distorting the waveshape.

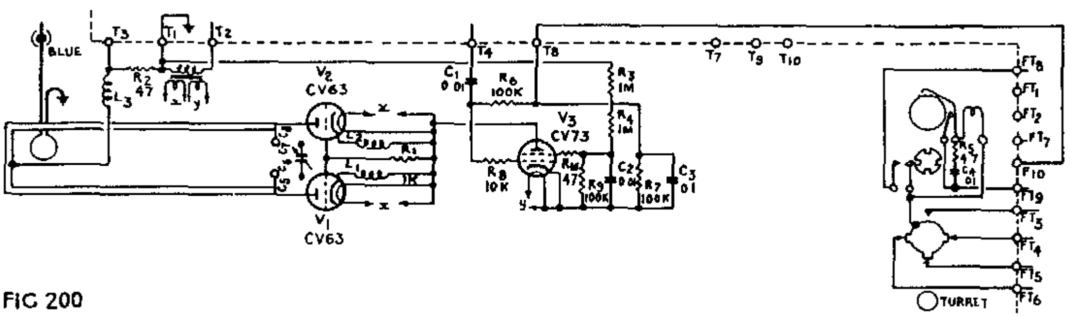


FIG 200

The Transmitter Unit Type 105

1311. (a) Circuit details are shown in fig. 200
(b) Mechanical details are shown in fig. 209

1312. The modulator valve, V.3, is a CV.73 beam tetrode. The push-pull oscillator, V.1, V.2, employs CV.63 triodes. The valves are connected as a series modulation circuit. The transmitter valve anodes are returned to earth through the lecher line. The cathodes are tied to the anode of the modulator valve. The 02.5KV. H.T. from the Lucero power unit comes in on FT10 and develops its output voltage across the bleeder formed by R.7 (100K.), R.9 (100K.), R.4 (1M.), R.3 (1M.), and R.2 (47 ohms). This bleeder fixes the non-operating D.C. levels of the electrodes of V.3. V.3 grid is held sufficiently negative to the cathode to keep the valve cut off when no modulating pulse is applied to the grid.

1313. When the grid of V.3 is carried up with the positive-going modulating pulse applied via C.1, V.3 passes a current of about 1 amp. which is drawn from C.3, the E.H.T. reservoir condenser in the power unit. The 1 amp. of cathode current during the pulse period charges up C.3 across the cathode load, R.7, and this effect added to the standing bleeder bias, holds V.3 grid about 250V. negative to the cathode between modulating pulses. The effective E.H.T. across the transmitter during the pulse period is about 2KV. The remaining drop is across the bleeder and V.3.

1314. The frequency changing is done by mechanically changing the tuning condensers, C.5, C.6, C.7, C.8 across the lecher lines. These condensers can be preset to desired values within their respective coverage bands. Operating the transmitter push-buttons on the control unit type 222A introduces the selected condenser through the mechanical action of the transmitter selector drive unit.

1315. The transmitter valves have their anode and grid leads brought to the top of the bulb. The anodes are connected to suitable lecher lines and the grids are strapped by a short flexible connection. This link serves as the grid inductance which combines with the anode-grid valve capacities to form the grid tuned circuit. The cathodes are choke-fed from the modulator anode and are strapped to one side of the heaters. The chokes are provided to keep the R.F. out of the modulator and heater circuits. Since high voltages exist at the cathodes the heater supply is insulated from earth by an isolating transformer. The same transformer provides an insulated 4.2V. supply for V.3.

1316. A negative 5 microsecond pulse is available across R.2 in the anode circuit of V.1 and V.2. Its amplitude is about -50V. and it is fed out via T.3. This pulse is not used in the circuit operation of the TR.3160.

1317. The R.F. pulse is coupled to the feeder system by a coupling loop on the anode lechers and is fed to the blue Pye plug on the underside of the transmitter unit. Thence it goes via the T-link to the chassis junction box and the switch motor for application to the aerials. The degree of coupling between the loop and anode lines is a compromise between the requirements of maximum power output and minimum change of frequency with variations in aerial loading. This coupling is fixed and no attempt should be made to change it.

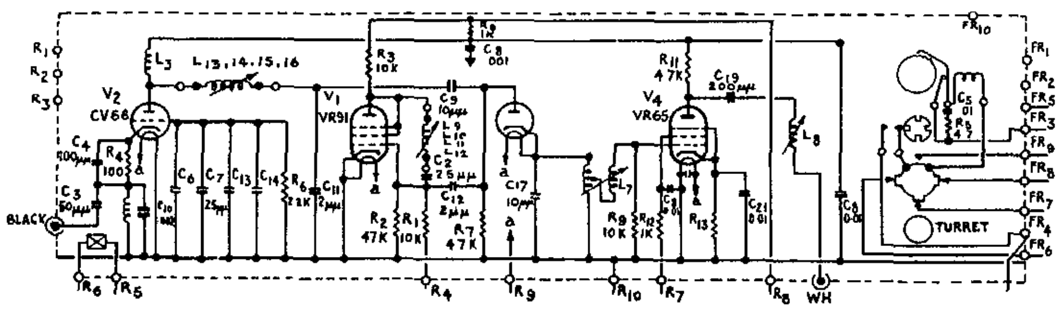


FIG 201

The Receiver Unit Type 159 (Mark IIC)

1318. The circuit diagram is shown in fig.201 and the mechanical details in fig.207.

Local Oscillator

1319. The L.O. valve is V.1, a VR.91 strapped as a triode in a series fed Hartley circuit. The four tuning inductances, L.9, L.10, L.11, L.12 are switched in mechanically by means of the push-button controlled selector drive unit mounted in the receiver. The receiver suppression waveform is brought in from the waveform generator on R.4 and applied to the grid across R.1. As pointed out in para. 1308, the waveform is negatively D.C. restored by grid current and keeps V.1 grid below cut-off for all but the desired 1300 micro-second conducting period.

The R.F. Amplifier

1320. V.2, a CV.66 grounded grid triode, serves as the R.F. amplifier. The R.F. input from the switch motor passes to the TR. junction box and thence via the receiver link to the black Pye input plug. The signal is applied via C.3 and the input coil, L.2 to V.2 cathode. The grid is effectively earthed for RF. by means of the condensers C.6, C.7, C.13, C.14. The anode circuit is tuned by the turret-mounted inductances, L.13, L.14, L.15 and L.16. These can be preset to selected spot frequencies within their respective bands by adjustable brass eddy-current tuning slugs.

The Mixer

1321. V.3 is the VR.92 diode mixer stage. The outputs of V.1 and V.2 are applied to the mixer anode by C.12 and C.9. The I.F. voltage is developed across the band-pass I.F. coils, L.6, L.7.

The I.F. Amplifier

1322. V.4 (VR.65) provides one stage of I.F. amplification at 13.5 Mc/s before injecting the Lucero signals into the H.2.S. I.F. strip. L.7 is the input tuned circuit and L.8 the anode tuned circuit. Both are permeability tuned. The overall bandwidth of the receiver unit type 159 and the H.2.S. I.F. amplifier is 1.5 Mc/s for 6db. drop. However, in certain cases adequate selectivity may not be available to separate beacon channels 4 Mc/s. apart. If this is so, filter unit 171 may be employed between TR.3160 and the H.2.S. I.F. amplifier. This filter unit has the effect of steepening the sides of the response curve. The output is taken to the brown Pye plug in the panel and thence to the H.2.S. I.F. amplifier.

1323. The range marker is mixed in at the mixer stage in the receiver-timing unit whose output goes to the slate Pye and thence to the slate Pye on the W.F.G. Condenser coupling takes the signal to the red Pye and thence back to the red Pye on Lucero for application to the switch unit which switches the video signals between the orange and yellow Pye plugs. From these, the video homing beacon signals are alternately applied to the two height tube amplifier stages and the height tube Y-plates. BABS signals are, of course, applied to only one height tube amplifier grid.

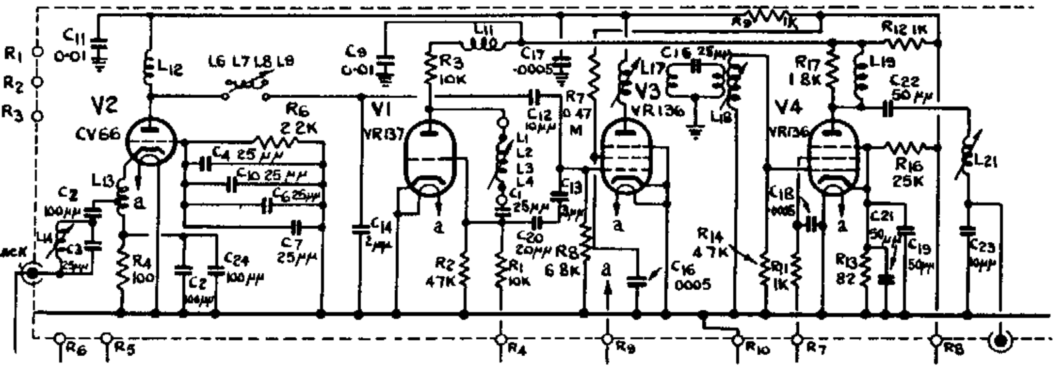


FIG 202

The Receiver Unit Type 161 (H.2.S. Mark IIIA)

1324. (a) Circuit details are shown in fig. 202
(b) This receiver unit is designed to provide an I.F. output at 45 Mc/s. for application to the Mark IIIA I.F. strip.

C.D. 0896L

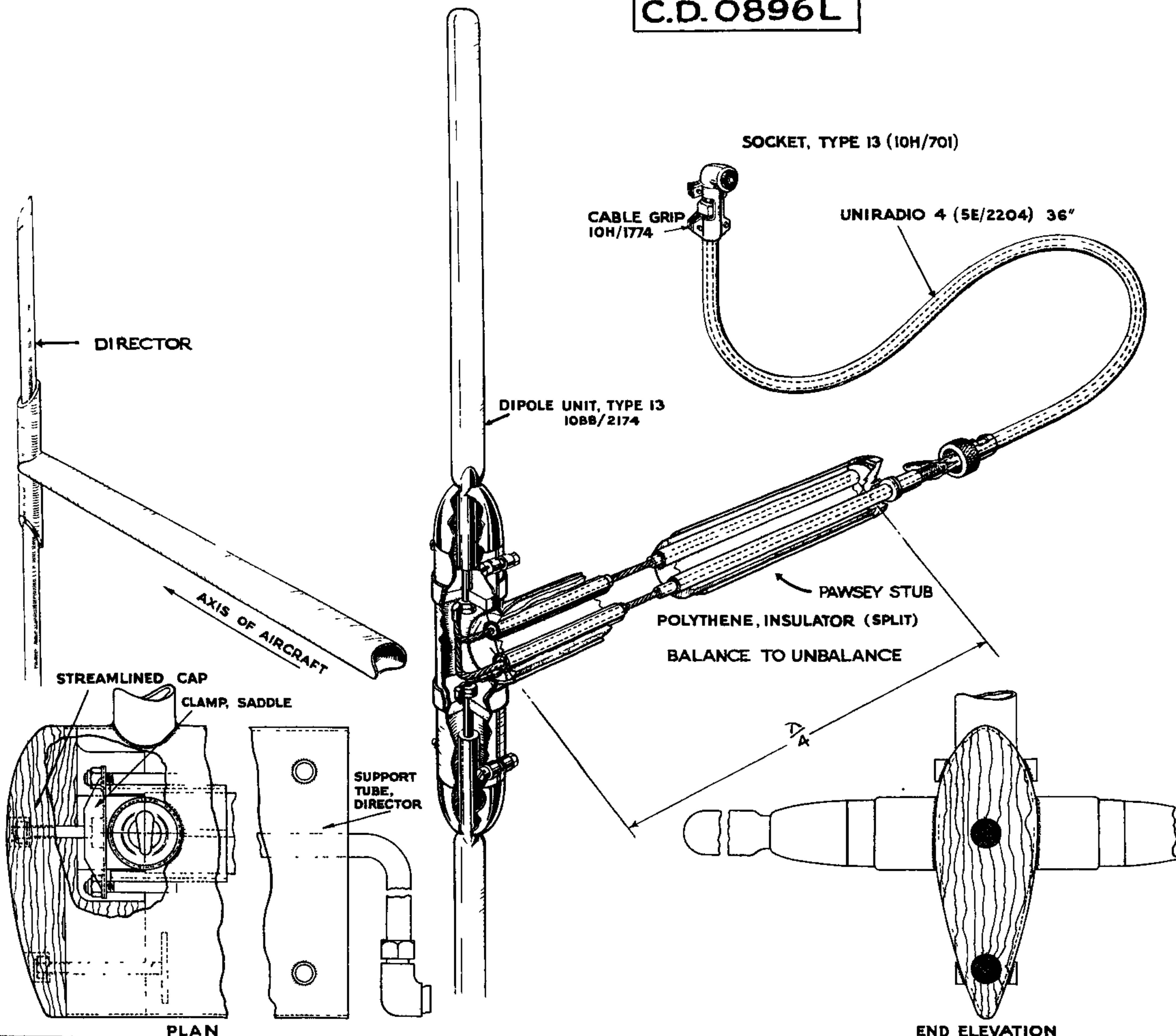


FIG. 203 AERIAL, AIRCRAFT, TYPE 184 FIG. 203

The Local Oscillator

1325. The local oscillator stage, V.1, employs a VR.137 working in a series fed Hartley circuit and biassed by grid current through R.2. The tuning coils, L.1, L.2, L.3, L.4 are switched mechanically to the selector drive unit. The suppression voltage is applied to V.1 grid via R.1.

The R.F. Amplifier

1326. This stage uses a CV.66 grounded grid triode. The signal input from the common T.R. junction box is applied to V.2 cathode via the tuned circuit L.14, C3. This circuit serves to reject direct I.F. pickup. The coupling condenser, C.2, taps into the input coil, L.13, which resonates flatly with strays and valve capacity at about 200 Mc/s. The grid is held at R.F. earth by the condensers C.4, C.10, C.6, C.7. The anode tuned circuits are L.6, L.7, L.8 or L.9, turret-mounted and switched mechanically. These coils are tuned by C.14 and the anode/earth stray capacity. H.T. is fed to the valve through L.12 which has a high impedance over the whole band covered.

The Mixer

1327. The mixer stage is a VR.136 operating as an anode bend detector. V.1 output is applied to the grid via C.13 and V.2 output via C.12. R.8 is a grid leak which develops a small negative bias from rectified oscillator input. The anode load is a band-pass filter tuned to 45 Mc/s. A 4.7K. damping resistor, R.14, is connected across the output winding, L.18. A pentode mixer is used to provide the additional gain required because the 45 Mc/s. I.F. strip has a lower gain than its 13.5 Mc/s. counterpart in H.2.S. Mark IIC.

The I.F. Amplifier

1328. A further VR.136 stage is used for the I.F. amplifier, V.4. The anode load is the permeability-tuned inductance, L.21, which resonates with C.23 and anode/earth capacity. H.T. is fed to V.4 anode through the high impedance choke, L.19, shunted by R.17. The output impedance at the white Pye plug is made accurately 100 ohms by choice of R.17, L.21 and C.23. The output goes to the brown Pye plug on the panel and thence to the H.2.S. I.F. strip. Para. 1323 outlines the remaining channels.

The Aerial System, Type 184

1329. This aerial system comprises two half-wave vertical dipoles provided with directors. Assembly details are shown in fig. 203.

1330. Each aerial-director assembly is attached to the aircraft by a streamline section tube which contains a Pawsey stub comprising a quarter-wave matching section and a quarter wave stub. The former connects the two halves of the dipole to the concentric feeder. The short tail of uniradio 4 has its braid removed where it enters the Pawsey stub and continues through the brass tube therein to connect to the upper dipole. The brass tube itself is connected to the lower dipole. The Pawsey stub assembly is secured mechanically to the dipoles by a guide tube and saddle clamp. The saddle clamp is secured by a 2BA bolt to a Permali cap. This cap is attached to the streamline section by 2BA studs which are fixed to brackets inside the section. The screw holes in the Permali cap and also the edges of the streamline section meeting it, are waterproofed by the application of Bostick compound. The director is attached to the streamline section by means of a welded steel tube.

1331. A rectangular box is fitted inside the aircraft on both port and starboard sides. The inside dimensions are sufficient to accommodate the section or fairing carrying the Pawsey stub. The aerial is set up with the director pointing up and down and the steel tube connecting the director to the fairing parallel to the axis of the aircraft when in flight. The director must be in front of the radiating element. The distance from the dipole to the skin of the aircraft is adjusted to be exactly 25 cm. The assembly is then secured in position by means of 4 bolts passing through the box and the transverse steel tubes in the fairing. The mouth of the box in the aircraft skin is then closed by means of a steel plate cut to the shape of the fairing. The whole aerial system is painted but care is necessary that no paint be left on the dipole insulators or on the Permali cap.

Switch Unit Maintenance and Servicing

1332. Details of the unit are shown in figs. 204 and 205.

Contacts

1333. Remove switch cover and examine all contacts carefully. The rounded contacts should fit truly on one another. They should be clean and not contaminated with oil, graphite or flux. If they require cleaning use a Contact Cleaner No.1 (1H/6). A solvent such as carbon tetrachloride or aviation spirit may be used with advantage.

Cams and Push Rods

1334. The cams should not be over-lubricated as oil is then likely to get on the contacts. The lubricant to be employed is a mixture of anti-freezing oil (specification DTD.201) and graphite oildag. The push rods should be clear in the holes in the springs through which they pass. If there is any fouling the motor should be replaced.

Springsets

1335. The adjustment of the springsets should be undertaken with great care and, in general, only if replacements cannot readily be obtained.

1336. The two moving springs in each set which are operated directly by the push rods should sit on the insulating buffer blocks when not making contact with the actuated springset. When making contact they should be lifted clear of the buffer block. In general, this will ensure that adequate contact pressure is being maintained. If this condition is not found to be correct the springs concerned should be adjusted with the spring adjusters. Bending should be done by moving the adjuster smoothly along the spring blade with a stroking motion.

1337. The second requirement is that angles over which contact is made should be correct for the springsets. The X and Y aerial contacts should "make" for a period corresponding to 80-85° of rotation of the camshaft. The P and Q output contacts should "make" for 100-110° of rotation. During the overlap period the aerial contacts must change over. To measure the angles of contact the switch must be removed from the chassis. This involves unscrewing the 4 panel bolts and disconnecting the feeder from the transmitter socket. Switch tester (10SB/113) is supplied for testing the contact angles.

1338. This item is a circular plate marked in degrees from 0-360° with a small transparent pointer and the necessary screws for fitting to the switch.

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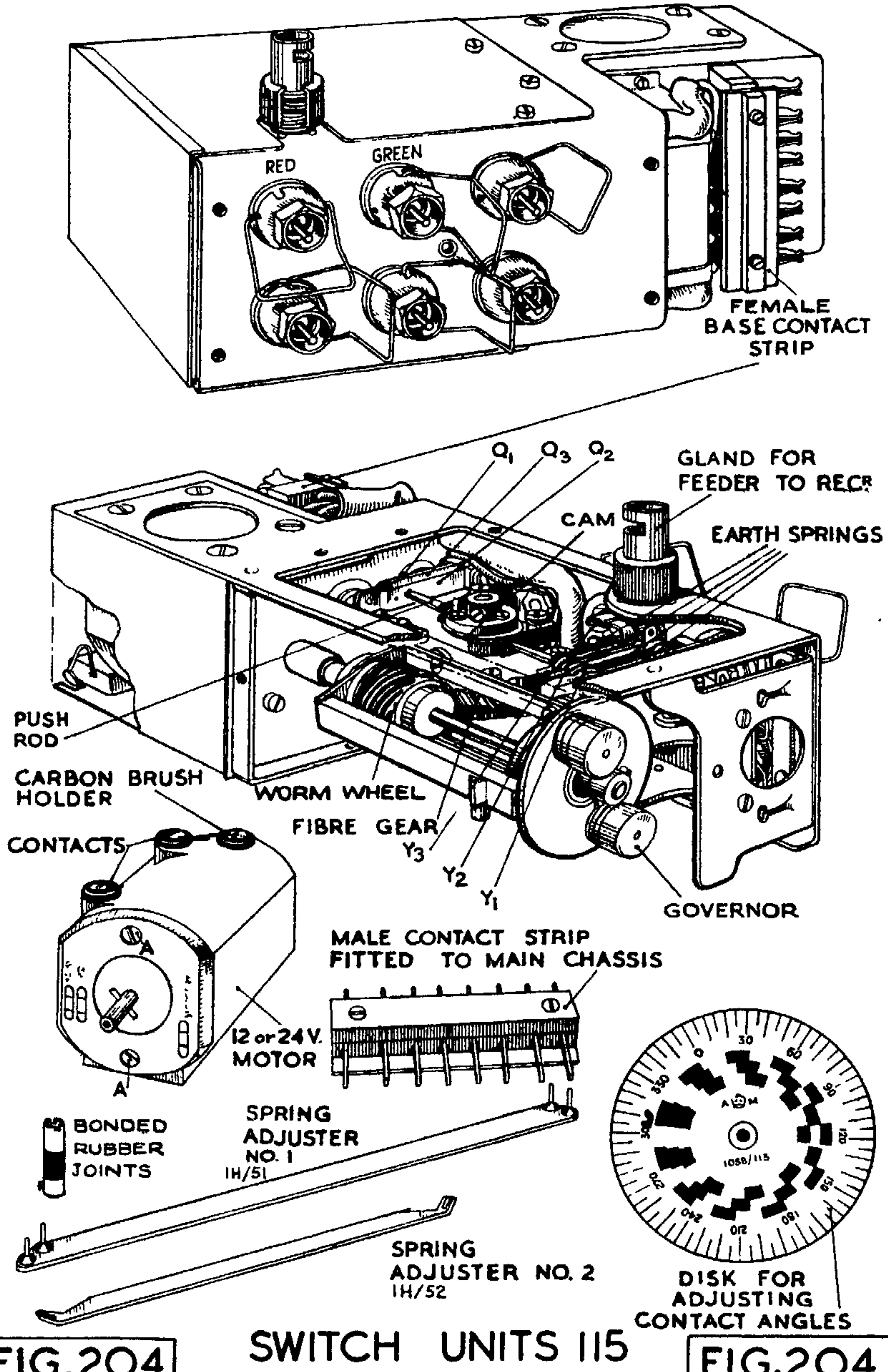
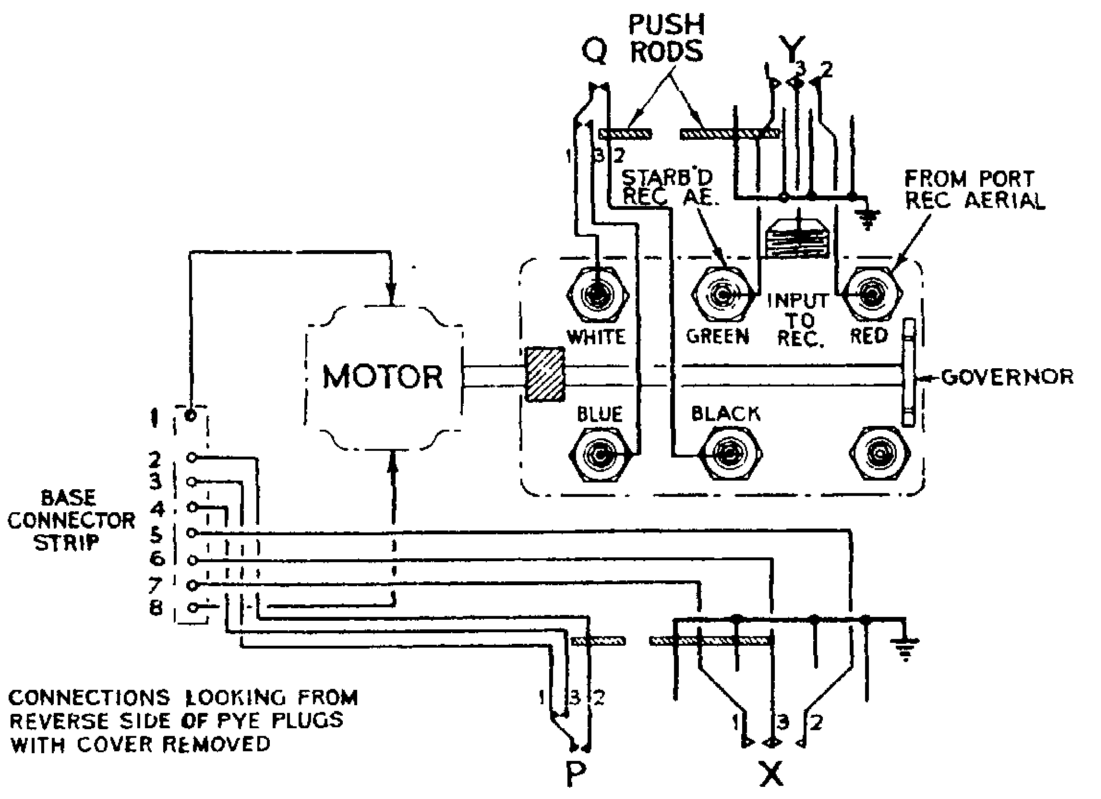
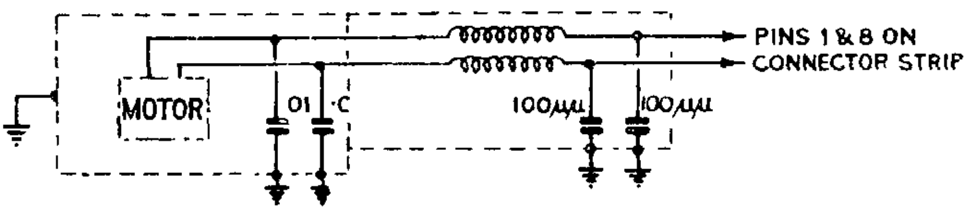


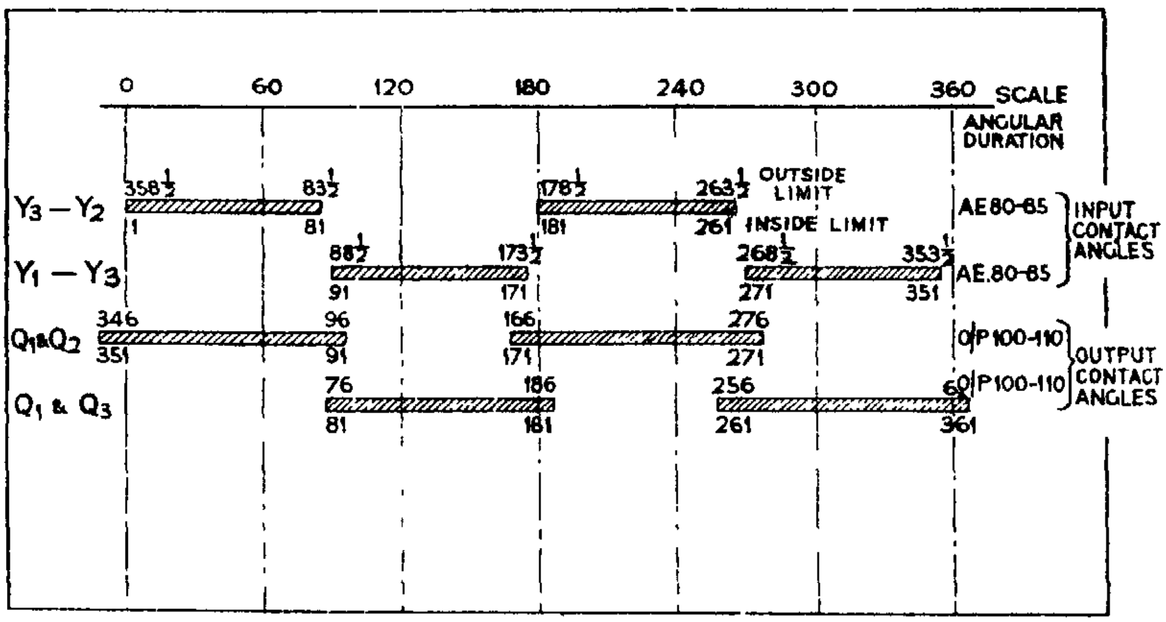
FIG.204 SWITCH UNITS 115 FIG.204

CD 0896 L





INTERFERENCE SUPPRESSION



SWITCH UNIT, TYPE 115 AND 116

SCHEMATIC

FIG. 205

FIG. 205

The black markings in the centre of the plate are for a stroboscopic check of the switch speed. This is not normally required for the switch unit type 115 where speed is not critical. The engraved plate is fixed to the end of the camshaft on the side remote from the feeder outlet and held by the 8BA screw supplied. The pointer is screwed on to the switch frame and spaced from it by the special collar also provided. The closing and opening of the contacts should be observed on an Avometer set to the resistance range 0-1000 ohms, or by means of a battery and a lamp continuity tester. The switch should be slowly rotated by hand, always in the same direction, and the contact angles noted in a table. A table of results obtained in a typical test is given below :-

Contact	1st Quadrant	2nd Quadrant	3rd Quadrant	4th Quadrant	Contact Periods
Red Aerial	From 80°	To 163°	From 260°	To 312°	83, 82
Green Aerial	To 73°	From 170°	To 253°	From 350°	83, 83
P.2 output	To 81°	From 160°	To 264°	From 338°	104, 103
P.3 output	From 68°	To 176°	From 248°	To 355°	108, 107

The other springsets are not used in TR.3160. The table shows the fulfilment of the two requirements of limits 80-85° for aerial contacts and 100-110° for output contacts, and the completion of the aerial changeover in the overlap period. If a switch does not pass this test the contact angles should be adjusted by suitably bending the springs with spring adjusters. No attempt should be made to unlock the cams on the crankshaft. If adjustment of springsets does not give the required results the switch should be replaced.

Governor

1339. This requires no adjustment or oiling and should not be interfered with.

Bearings

1340. The two ball-races on the mainshaft and the bearings on the camshaft should be lubricated when necessary with anti-freezing oil (DTD.201).

Wormwheel

1341. One or two drops of oildag may be placed on the wormwheel when required. Only the minimum quantity of lubricant must be used and care taken to ensure that it does not get on to the contacts.

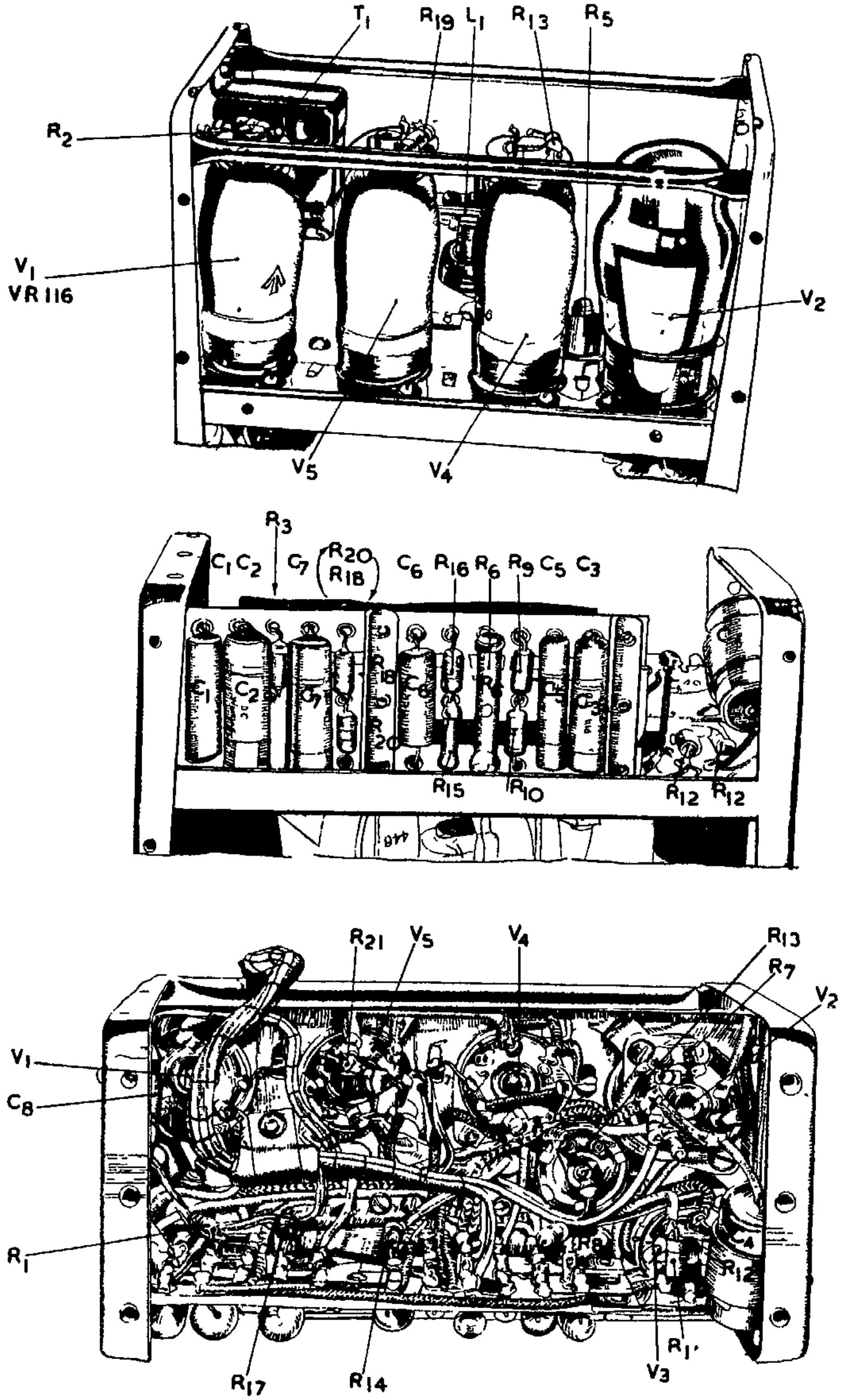
Motor

1342. The motor can be removed for inspection or replacement by removing the four countersunk bolts securing it to the switch frame. In general it is not recommended to adjust or service the motor. The following procedure is described for emergency only.

(a) The drive shaft should rotate freely and show no evidence of rough spots or stiffness. At the same time there should be no undue side or end play in the shaft.

(b) Before dismantling inspect the commutator and carbon brushes. The brushes are mounted at the end remote from the shaft in either paxolin or bakelite holders. They can be removed by undoing a screw. After removing the brushes inspect the commutator through the aperture with the aid of a bright light. If the commutator requires cleaning it may be possible to do it with a small piece of rag soaked in carbon tetrachloride introduced on the end of a match stick. Alternatively, very small pieces of fine glass paper may be used. Emery paper is not recommended. When replacing, take care that the brush is so put in that the concavity fits back on the commutator. When replaced, the brushes should move freely in their holders and not chafe the sides. The brush holder should not touch the commutator.

C.D. 0896 L



WAVEFORM GENERATOR, TYPE 30
DETAILS

FIG.206

FIG.206

1343. To dismantle the motor for lubrication or checking of the internal wiring, undo the nuts securing the end plate. The armature and end plate can then be withdrawn. To separate the armature from the end plate push out the small pin through the driving shaft. This allows the shaft to be drawn through the bearing. In making the withdrawal collect the balls from the ball-race in a cloth or large paper. To lubricate the ball-race use a very small quantity of high melting point grease. Vaseline must not be used as it melts too easily.

1344. When reassembling make sure that the brushes have been removed before fitting the armature into position. The end plate must be done up tightly and the pin through the shaft replaced. Finally the brushes should be replaced.

1345. When putting the motor back into the switch assembly, make sure that the pin through the shaft engages correctly with the flexible insulating coupler which is keyed to accept it. It is important that the contacts on the motor make firm contact with the springs that supply the current.

Bench Setting-Up Procedure

1346. (a) Switch on the equipment and set the 4 position Lucero switch on the H.2.S. switch unit to "B" so that H.T. to the head amplifier is cut off and no H.2.S. signals are visible on the height tube.

(b) Set the gain control almost to maximum. The range marker and tail of the Lucero transmitter pulse should appear on a double-sided display. If the aerials are connected and there is a homing or beam approach beacon within range (a mile or so), locked and possibly unlocked beacon responses may appear. The noise amplitudes on the two sides should be equal.

Counting Down Potentiometer, R.5

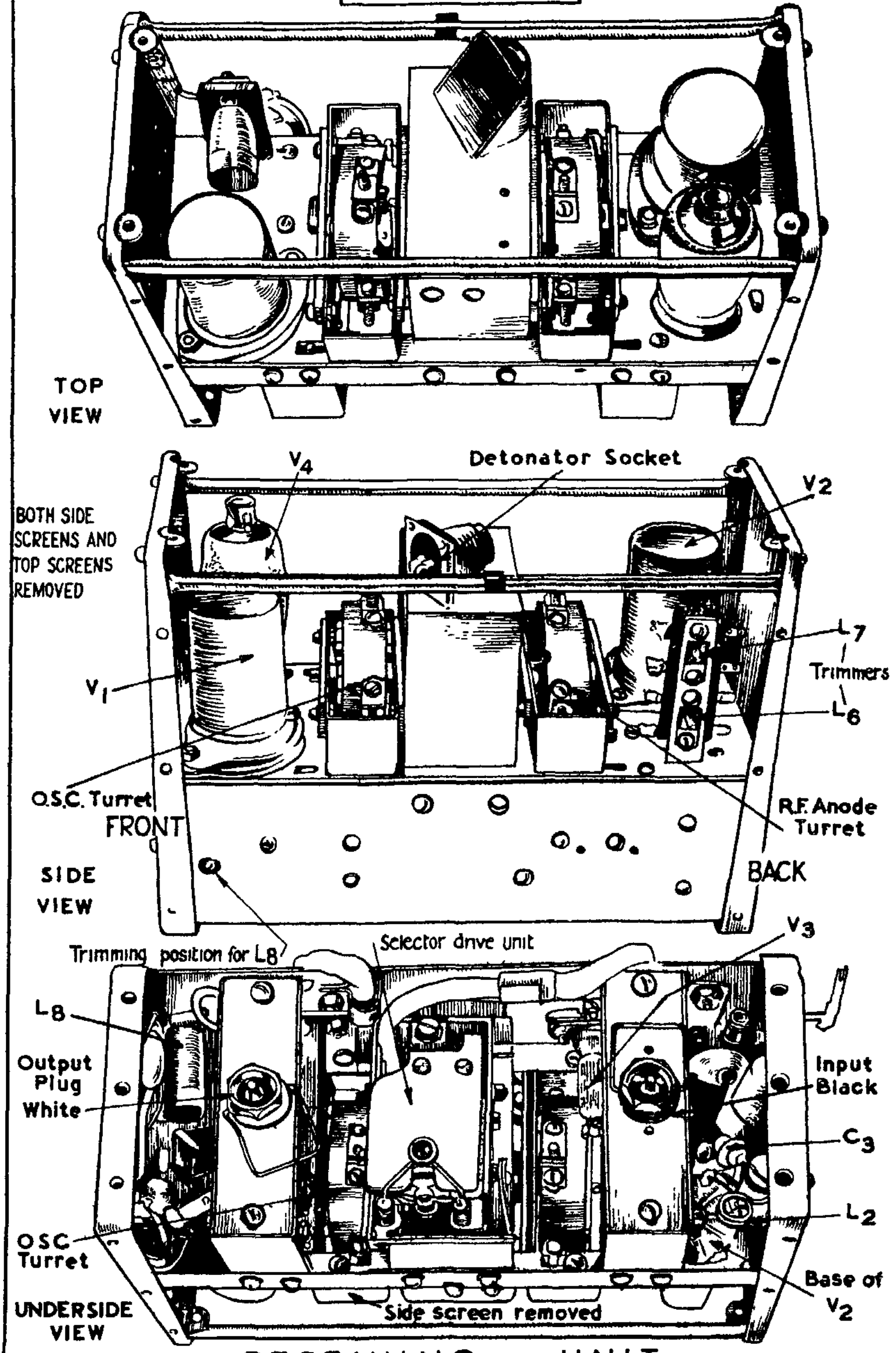
1347. Using Monitor 28 :-

(a) Trigger monitor from 20 microsecond pulse (Pye violet).
(b) Time base switch to "Frequency".
(c) Monitor input switch to "Direct".
(d) Transmitter switch on control unit 222A in "ON" position.
(e) Apply waveform at junction of R.3 and R.5 to the monitor 28 and adjust R.5 to give 3 lines on monitor screen. Set the control to the centre of the range which gives the 3 lines and lock in this position (see fig. 199a).

1348. Using phones :-

(a) Connect phones across the yellow/black I.F.F. suppression plug.
(b) By turning the counting down control, R.5, the 3 ranges of setting, corresponding to counting down ratios of 2, 3 and 4 to one, will be made obvious by changes in pitch of note.
(c) The small unstable ranges are detectable by an unsteady pitch. Adjust the control to the centre of the range giving a steady note of the intermediate frequency, showing that the counting down is 3:1. Lock the potentiometer R.5 in this position.

Note : Familiarity with this note enables a simple check of the counting down stage to be made on the daily inspection.



RECEIVING UNIT
TYPE 159 DETAILS

FIG 207

FIG.207

Receiver Tuning

1349. (a) With the Lucero unit on its side detach the trimming tool from the side strut of the chassis. Set the 4-position Lucero switch on the H.2.S. switch unit to the "B" position.

(b) Press the "A" Rx button on the control unit 222A. Check that the Rx turrets rotate into position 1. The number of the turrets should be visible through the cut-out in the base-plate.

(c) Connect the "Sig.Gen" output on the W1649 to one of the aerial sockets through the attenuator provided. Set the appropriate frequency on the black dial scale (labelled "Sig. Gen") opposite the index. Set the incremental dial to zero. Plug in the head-set jack at the wavemeter jack-point.

(d) Check the dial calibration against the wavemeter crystal as follows :-

(i) Set the wavemeter switch in the "Xtal" position.

(ii) Rotate the main dial to bring the nearest multiple of 5 Mc/s under the index. For example, if the wanted frequency were 177 Mc/s the dial would be set to 175 Mc/s on the black "Sig. Gen." scale. If the calibration is correct the beat note will be heard in the phones. The wavemeter dial will then be set to 177 Mc/s on the "Sig. Gen." scale and the receiver tuned as outlined below.

(iii) If the beat note is not heard, rotate the main dial until it is obtained and note the reading. Suppose it is 175.5 Mc/s. This means that 175.5 on the dial means 175 Mc/s. That is, the dial reads 0.5 Mc/s high. Hence, if a signal of 177 Mc/s is wanted the dial must be set to 177.5 Mc/s on the "Sig. Gen." scale. Had the dial read 174.8 when the beat note was heard the dial would read 0.2 Mc/s low. To get a 177 Mc/s output the required setting would be 176.8 Mc/s on the "Sig.Gen" scale.

(e) Set the wavemeter switch to "ON". Lock the main dial at the setting on the "Sig.Gen" scale that will give the required frequency, as determined in (d). The height tube should now show C.W. interference. Set the gain control on the H.2.S. switch unit well below the level which will cause saturation of the H.2.S. Rx. With the trimming tool adjust the Lucero L.O. tuning control No.1 for maximum response. As tuning proceeds the H.2.S. gain should be checked to ensure that saturation is not occurring.

(f) Tune the RF turret condenser No.1 in the same way.

(g) Repeat the same routine for the B, C and D positions of the Rx push-buttons on the control unit.

Transmitter-Tuning

1350. (a) Only preliminary approximate tuning can be done on the bench. Press the "A" Tx button on the control unit 222A. Check that the Tx turret stops in position 1.

(b) Set up the W1649 as a wavemeter, on the appropriate frequency as follows :-

(i) Set the wavemeter switch to the "Xtal" position

(ii) Suppose the required frequency is 176 Mc/s. Set the nearest multiple of 5 Mc/s, i.e. 175 Mc/s, on the red wavemeter dial scale under the index. Set the incremental dial to zero. Rotate the main dial slightly until the beat note is heard in the phones. Lock the main dial in this position, which means that the W1649 oscillator is working at 160 Mc/s and the mixer IF coil is tuned to 15 Mc/s.

(iii) Set the incremental dial to +1. This means that the mixer IF coil is now tuned to 16 Mc/s. If an external pulsed signal at a frequency of 176 Mc/s is now applied to the mixer valve, the signal will beat with the 160 Mc/s. W1649 oscillator signal to produce pulses at the IF of 16 Mc/s, to which the mixer anode load is tuned. The mixer output voltage is applied to the cathode follower detector grid. The 10 Microsecond CR in the cathode of the CF detector will follow the envelope of the pulses and apply video pulses of a frequency equal to the Lucero p.r.f. to the grid of the output valve. The p.r.f. note will then appear in the phones. If the external signal applied to the W1649 does not differ from the W1649 oscillator signal frequency by the IF, the mixer output will not be at its maximum value and the p.r.f. note in the phones will not be at maximum intensity.

(c) Set the wavemeter switch to "ON" and set up the W1649 aerial rod (or apply a signal to the input Pye plug). Tune the transmitter condenser No.1 for maximum signal in the phones.

(d) Repeat the same routine for the "B", "C" and "D" Tx push-buttons or the control unit 222A.

Installation in Aircraft

1351. (a) Connect up the installation and check that all Pye plugs are firmly in their sockets and secured by their wire clips.

(b) Connect up the P.E. set and switch on H.2.S. L.T.

Checking Transmitter Frequency

1352. Set up the wavemeter 1649 in the aircraft. Tune the transmitter condensers to the appropriate frequencies.

Checking the Displays

1353. Check the appearance of the displays on the height tube when set for H.2.S. only, H.2.S. + beacons, beacons only, BABS only, etc., to ensure that the switch motor, aerials and changeover switch are operating correctly.

Checking DF

1354. If there is a beacon in the vicinity responses should be visible on the timebase. These can be used to check the sense of the D.F. aerials. If the beacon is to port, the left wing of the response should be larger than the right wing. If the sense is wrong, check that the aerial feeders are correctly connected.

Daily Inspection Recommended by T.R.E. for normal Blind Approach Use of Lucero

1355. (a) Connect P.E. set and switch on the equipment.
(b) Set Lucero switch to "OFF" and normal H.2.S. display should be obtained.

(c) Set Lucero switch to B + H. The local homing beacon signal should appear on the display. If the control unit 222A is used the appropriate push-buttons must be operated.
(d) Set Lucero switch to B. Beacon display alone and local ground returns diminished.
(e) Set Lucero switch to BA (if jumper socket used) or operate appropriate push-buttons for the local BA signals. Set changeover switch for BA signals. Check that all ground returns disappear and only BA signals appear.

1356. Check operation of gain control, scan-marker switch and range control.

1357. Check that no undue or unusual amount of interference appears on the trace. If such interference appears check whether it is due to the switch motor or external pick-up. If it is still present when both aerial feeders are disconnected from the TR.3160, the switch motor is at fault.

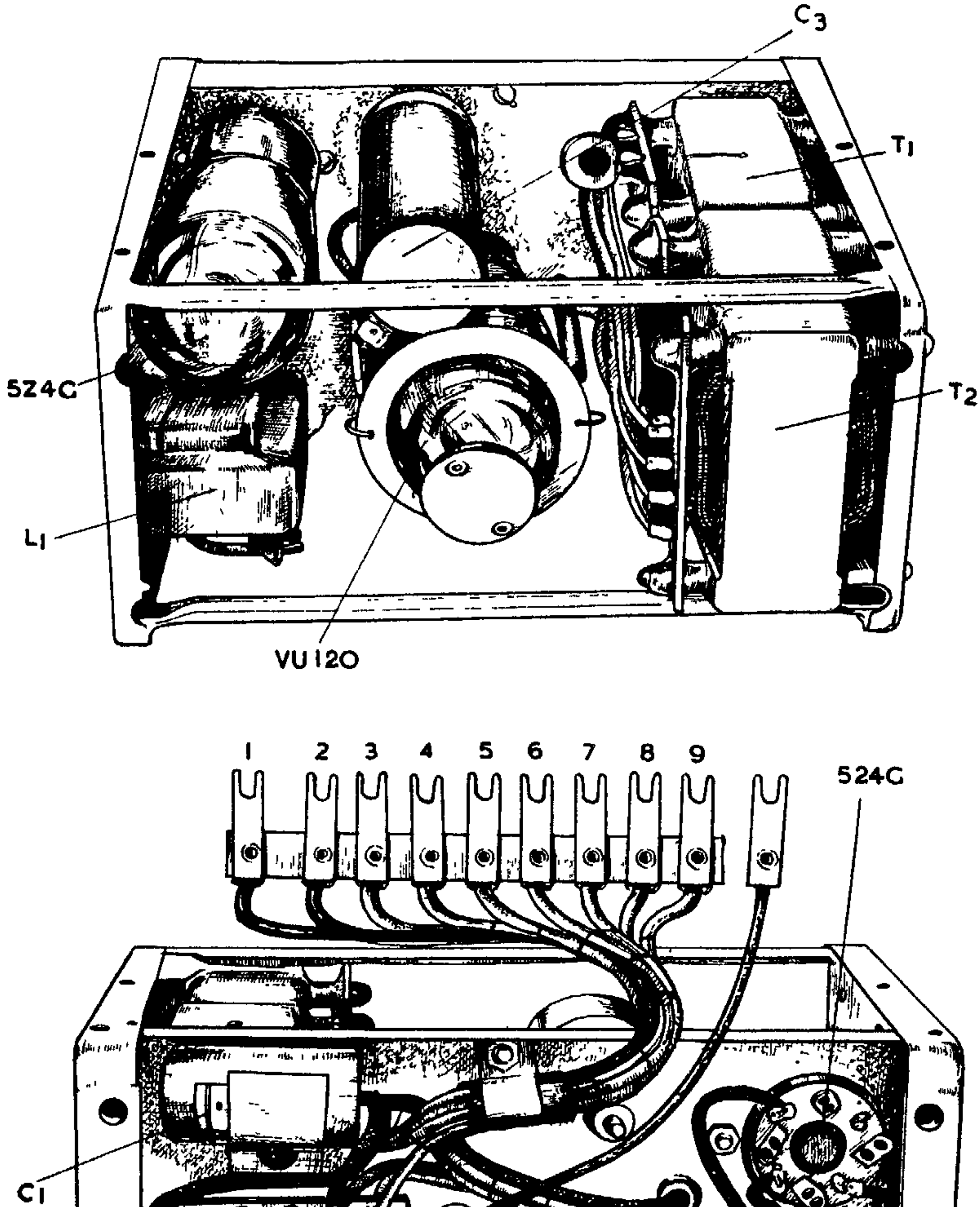
1358. Check transmitter frequencies with the wavemeter and adjust if necessary.

1359. Check aerials for continuity and insulation with an Avometer and 500 volts megger.

1360. Check all Pye sockets for tightness of gland nut and small grub screw in the centre.

Note :- If Lucero BA is to be used for accurate location of the beginning of runways and for blind landing in conjunction with other equipment such as a glide path indicator, a precision method of setting up the H.2.S. markers, will be incorporated in the D.I. and bench alignment.

C.D. 0896 L

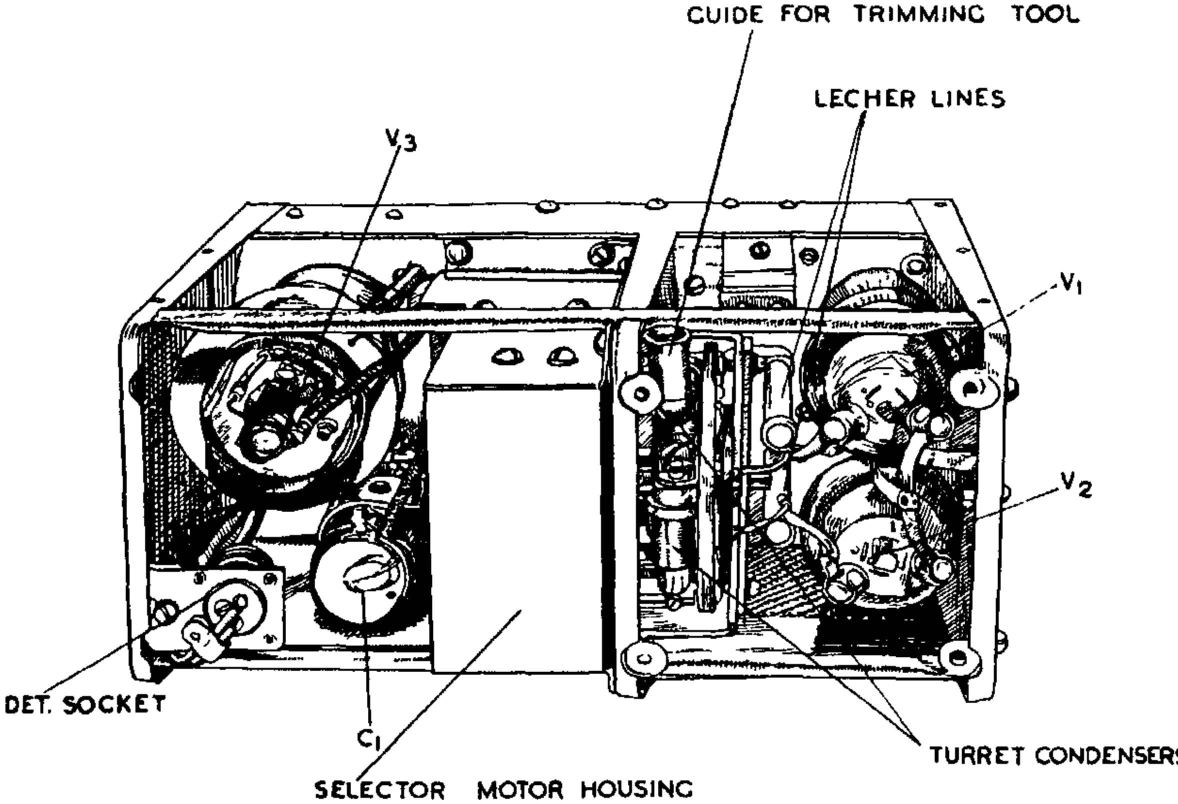


POWER UNIT, TYPE 532
DETAILS

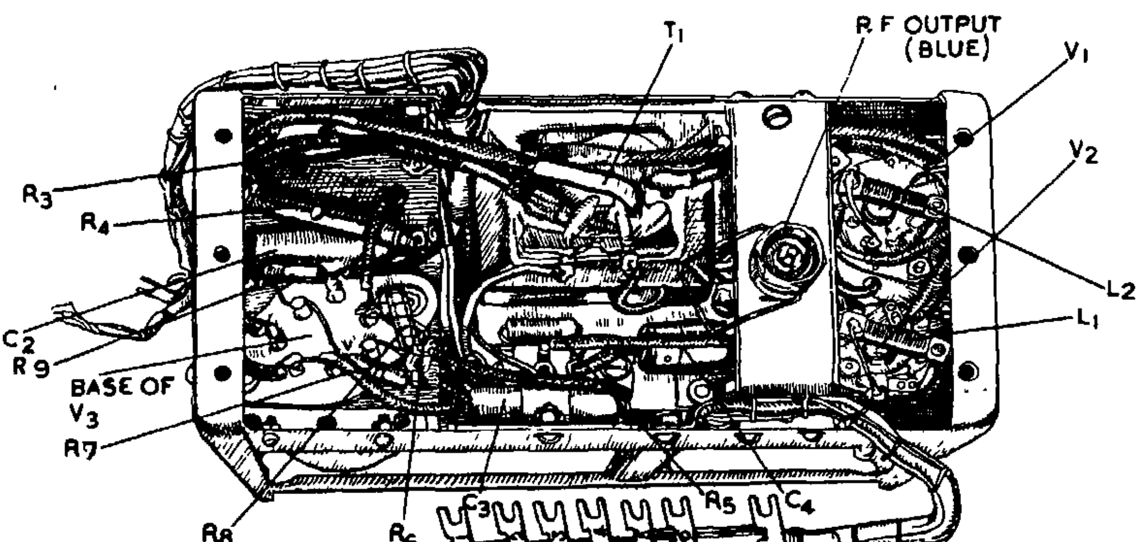
FIG.208

FIG.208

C.D. 0896 L



TOP AND ONE SIDE SCREEN REMOVED

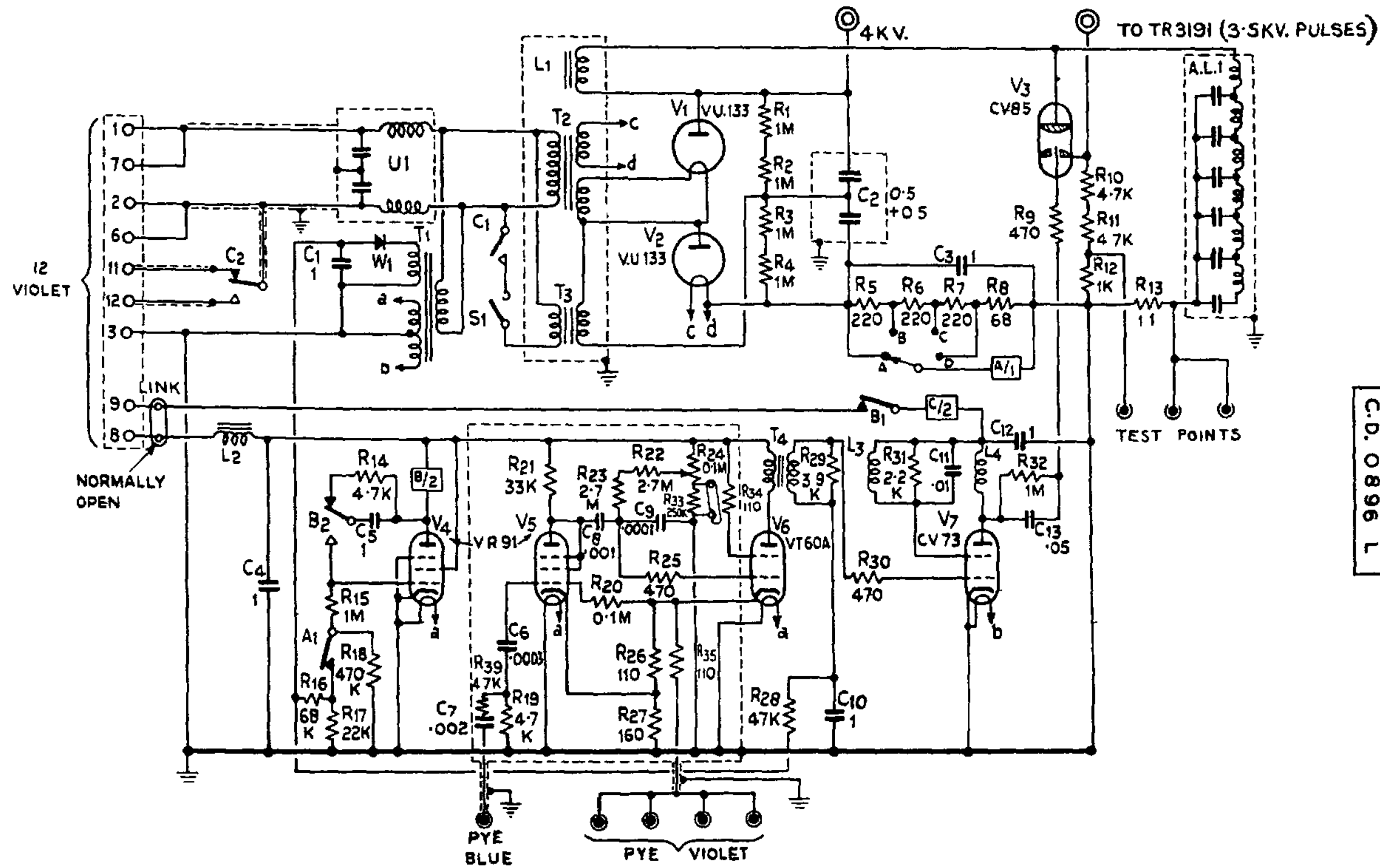


TRANSMITTER UNITS, TYPES 105, DETAILS

FIG.209

FIG.209

FIG.212

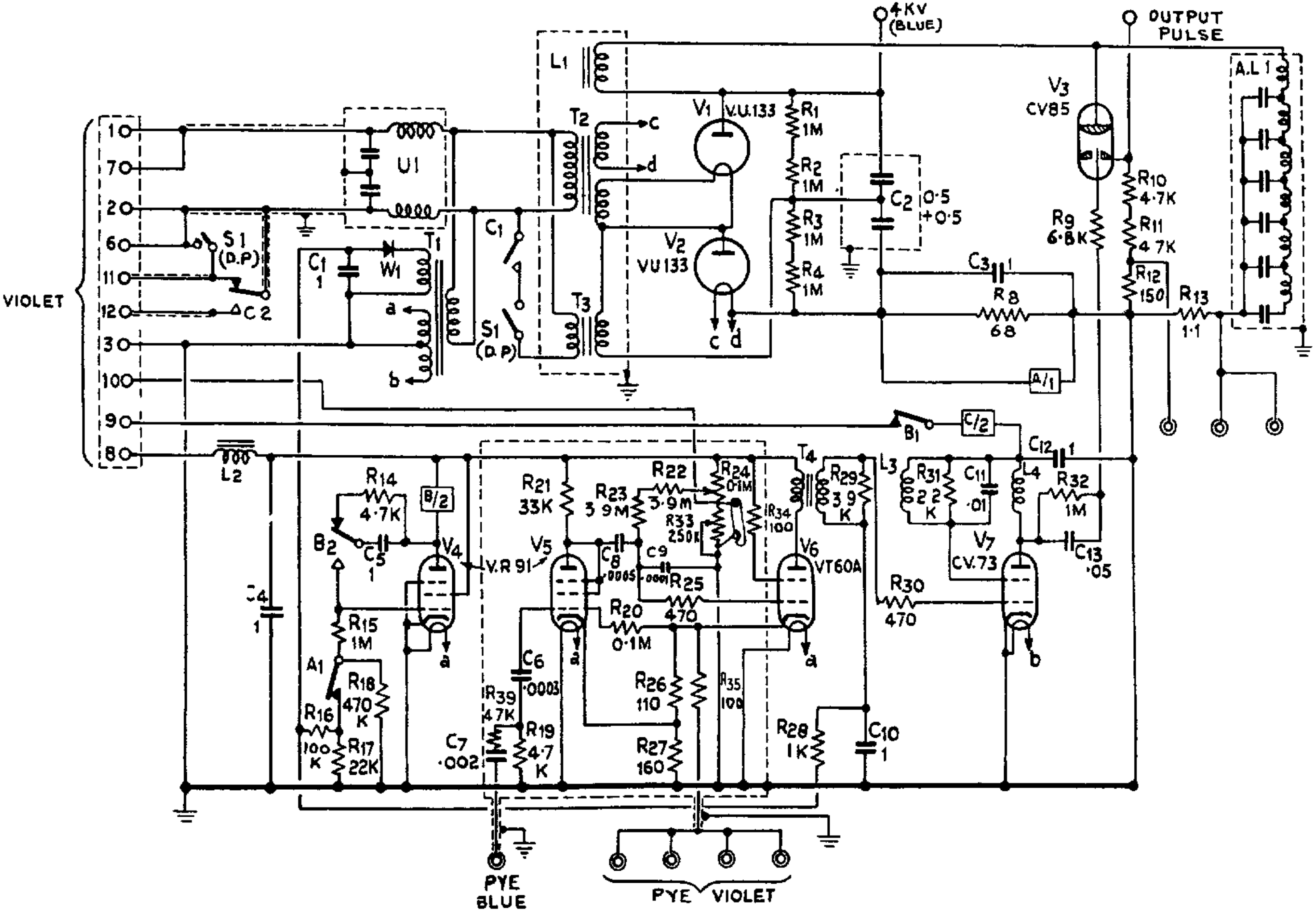


MODULATOR UNIT, TYPE 64—CIRCUIT SERIAL Nº UNDER 300

C.D. 0896 L

FIG.212

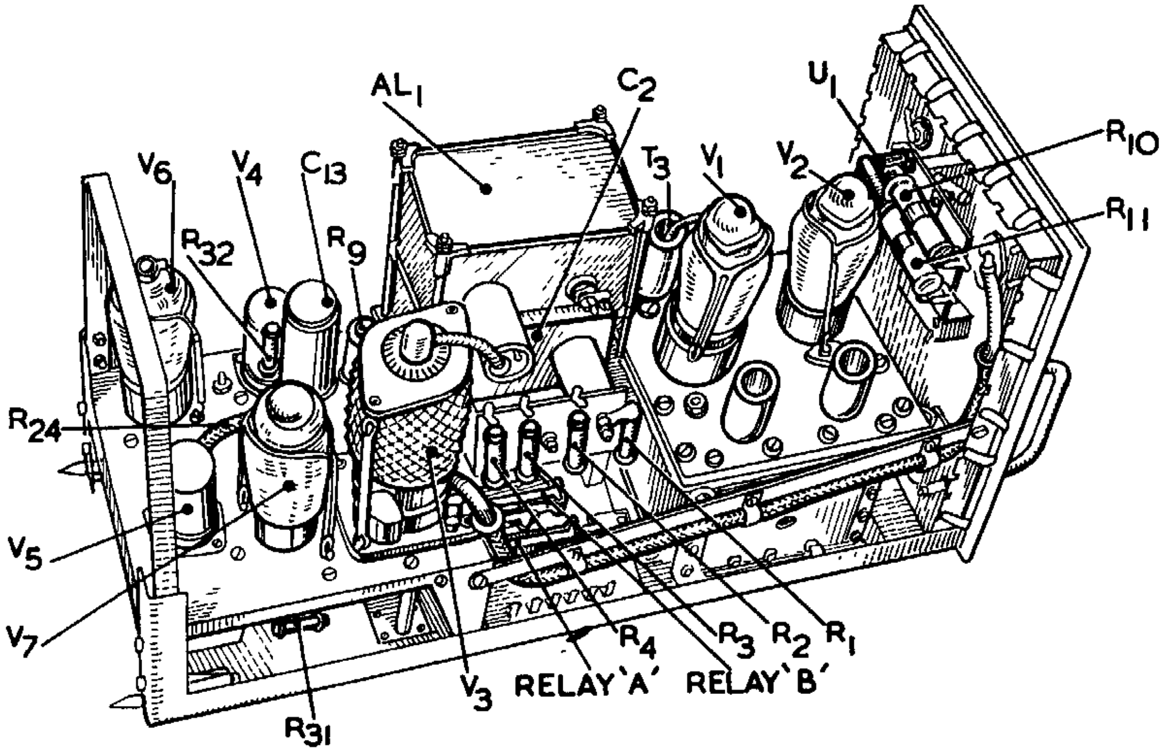
FIG. 213

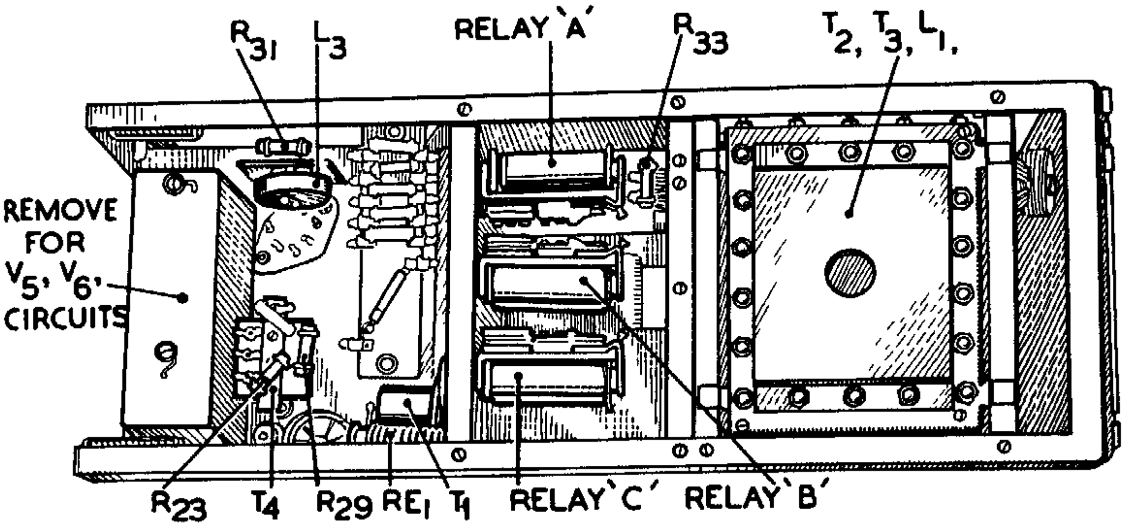


MODULATOR TYPE 64
(SERIAL NUMBER OVER 300)

C.D.0896L

FIG. 213



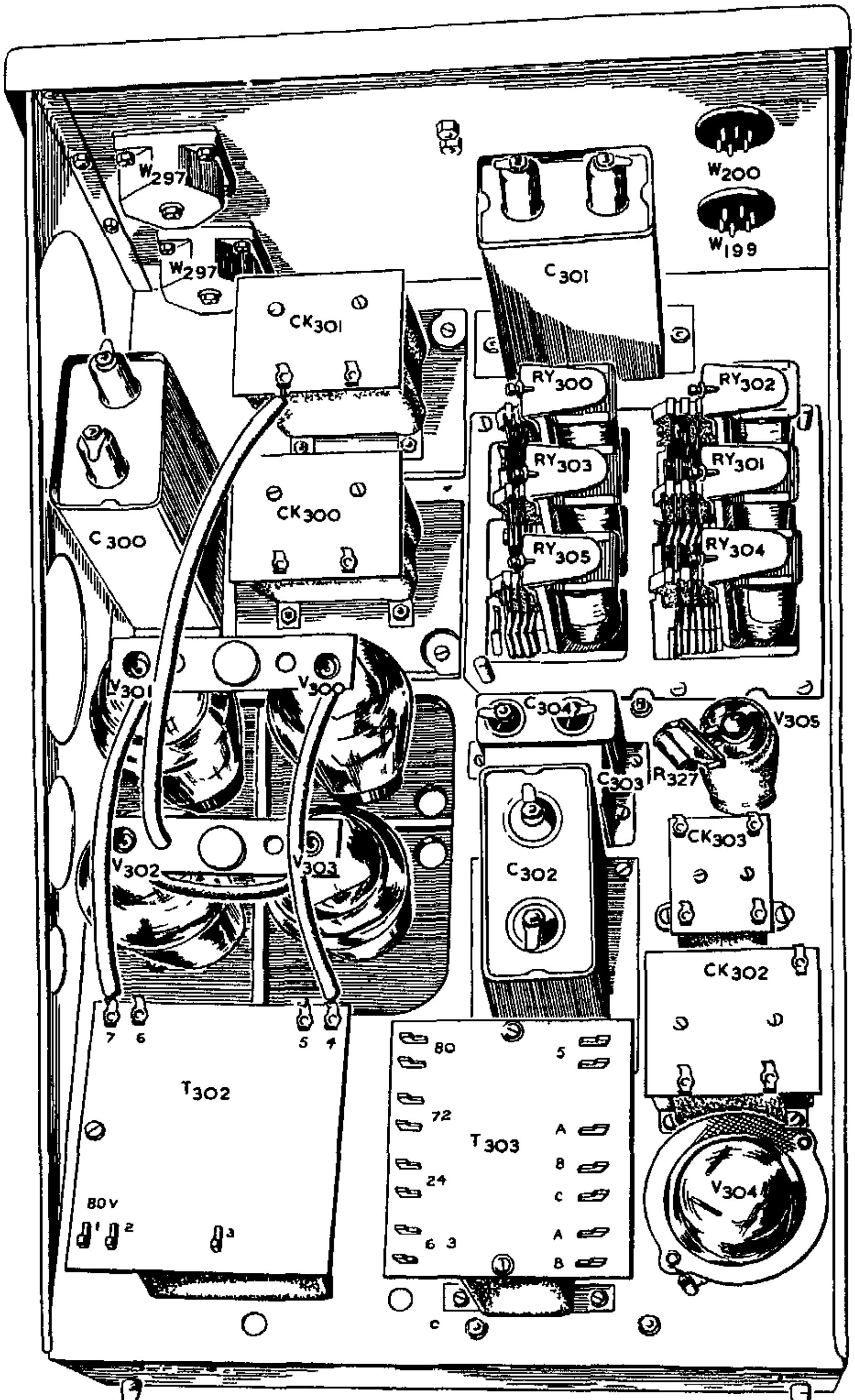


GENERAL VIEWS

MODULATOR TYPE 64

FIG. 214

FIG. 214



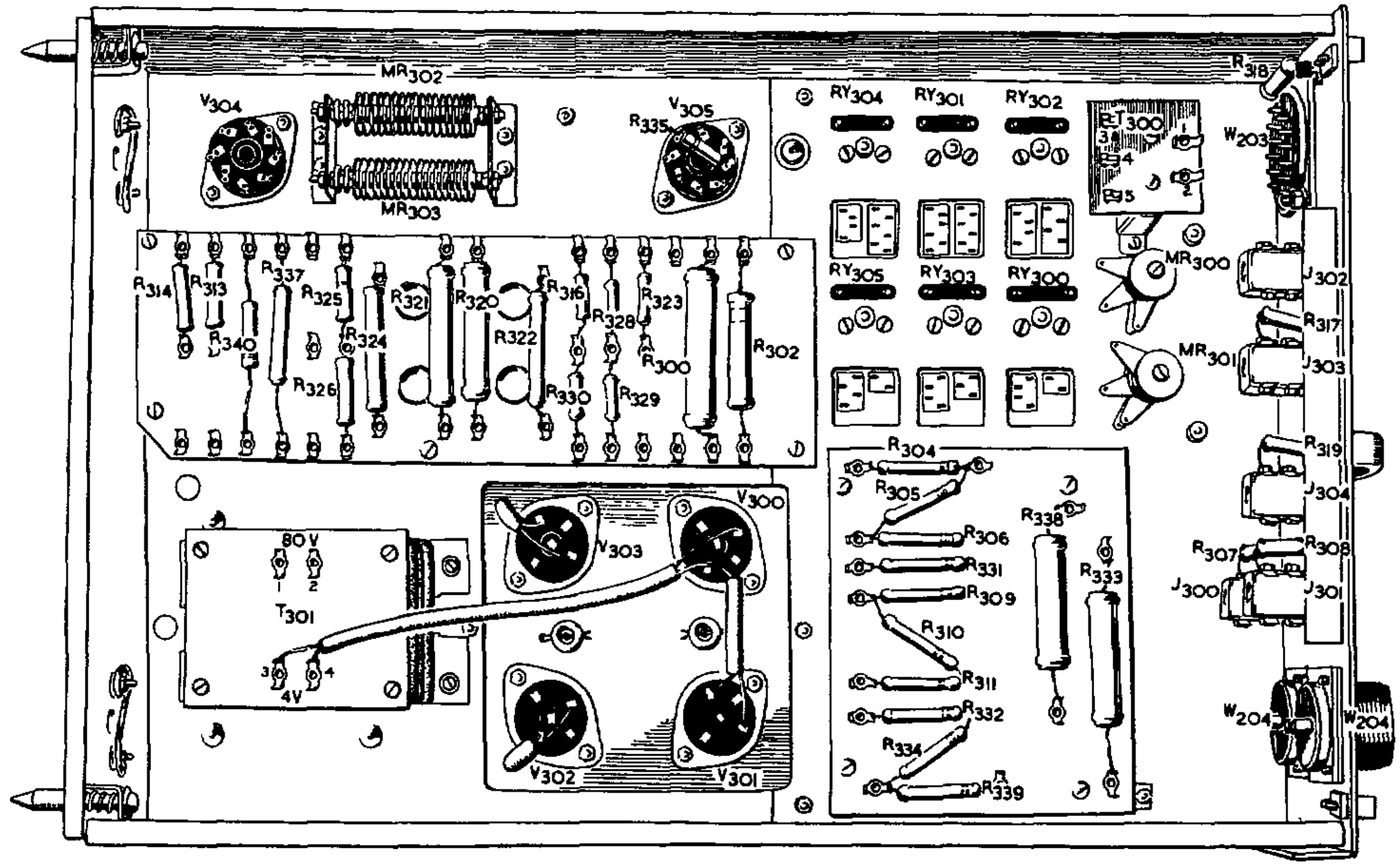
POWER UNIT TYPE 280

TOP VIEW OF CHASSIS

FIG.215

FIG.215

FIG.216

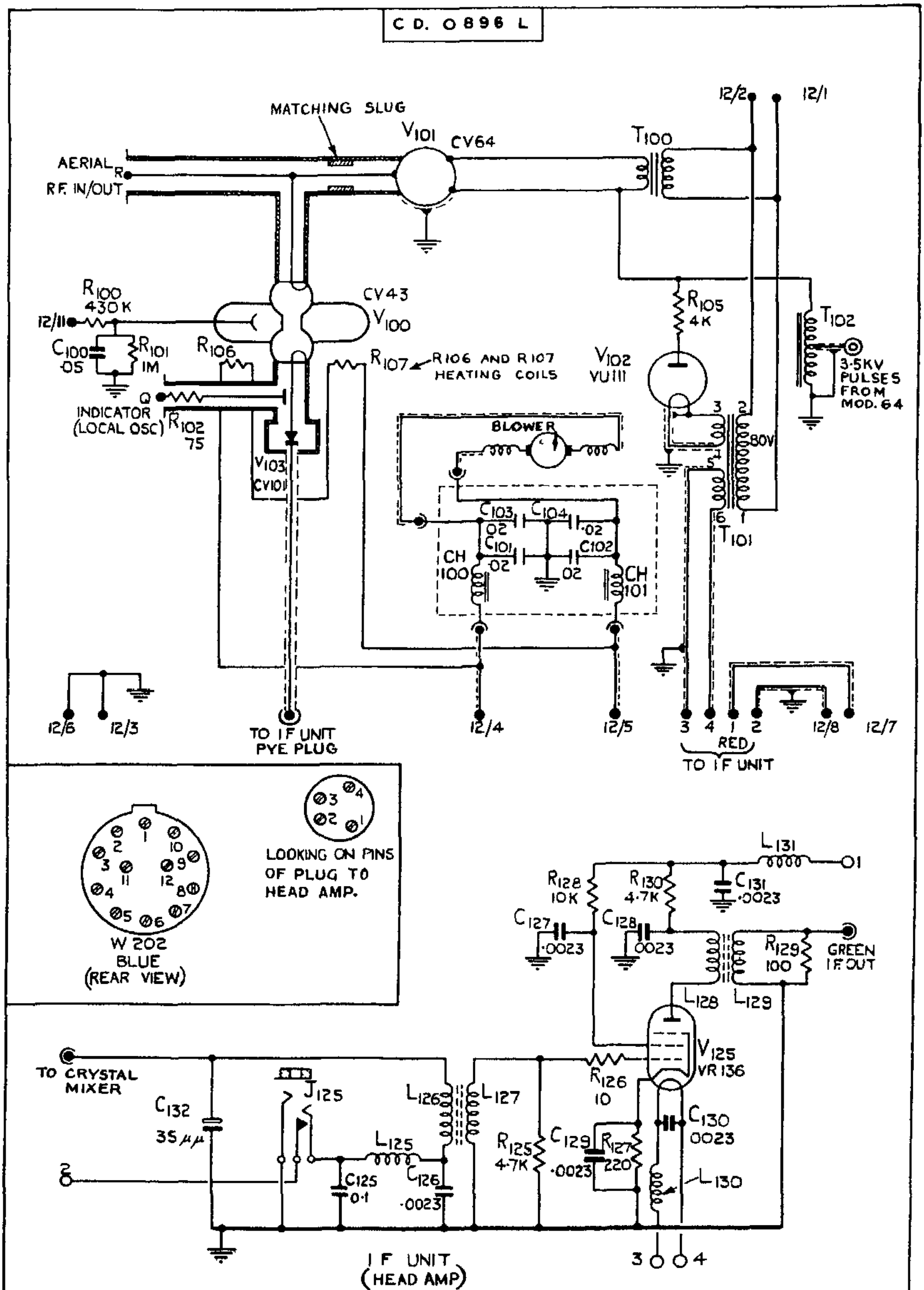


POWER UNIT TYPE 280

UNDERSIDE VIEW

C.D.0896L

FIG.216

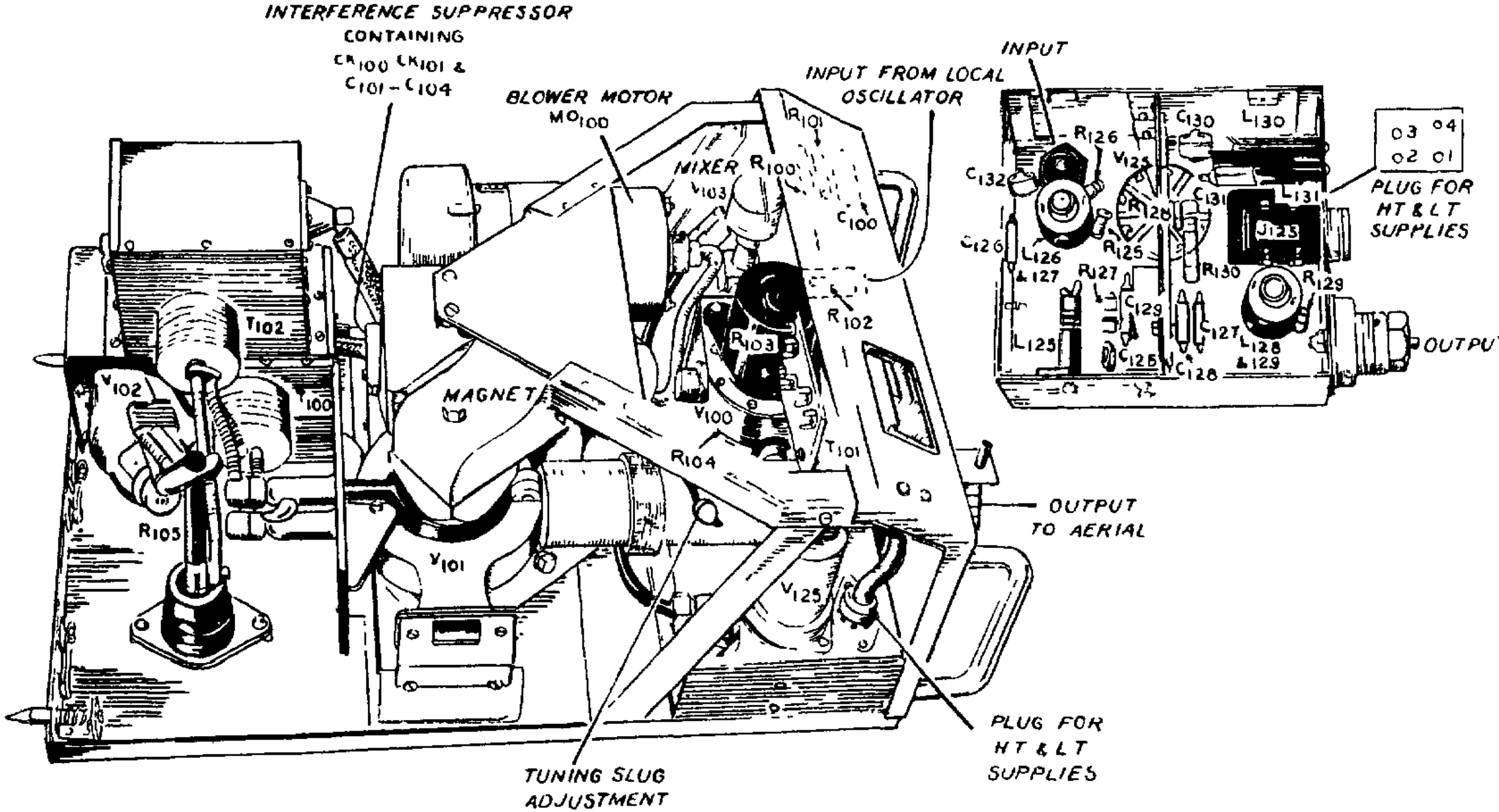


T.R.3191–CIRCUIT

FIG. 217

FIG. 217

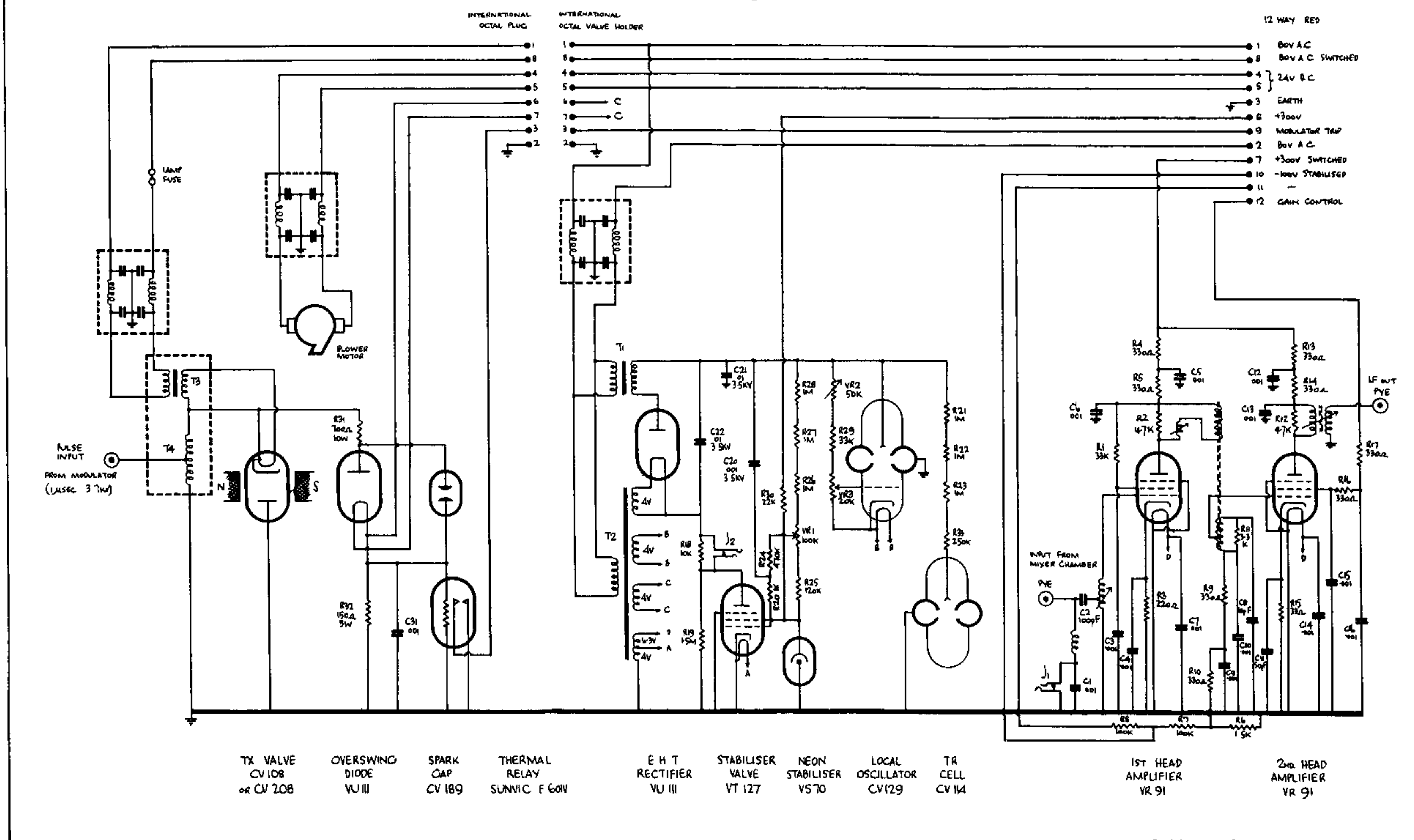
FIG.218



C.D. 0896 L

INTERNAL VIEWS OF TRANSMITTER RECIEVER TYPE TR.3191.

FIG.218

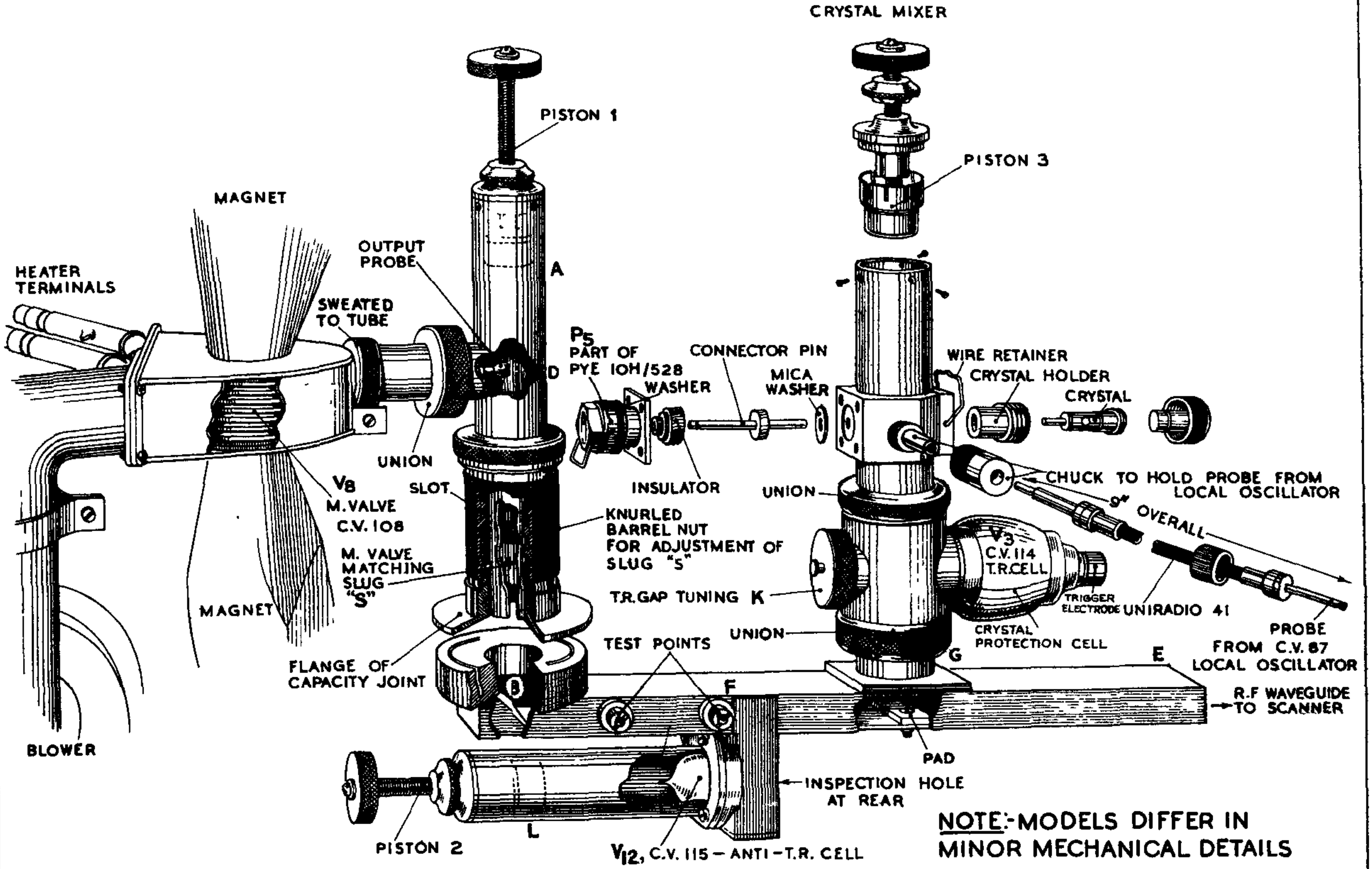


H F BOX TYPE TR 3555

FIG. 219

FIG. 219

C.D.0896 L



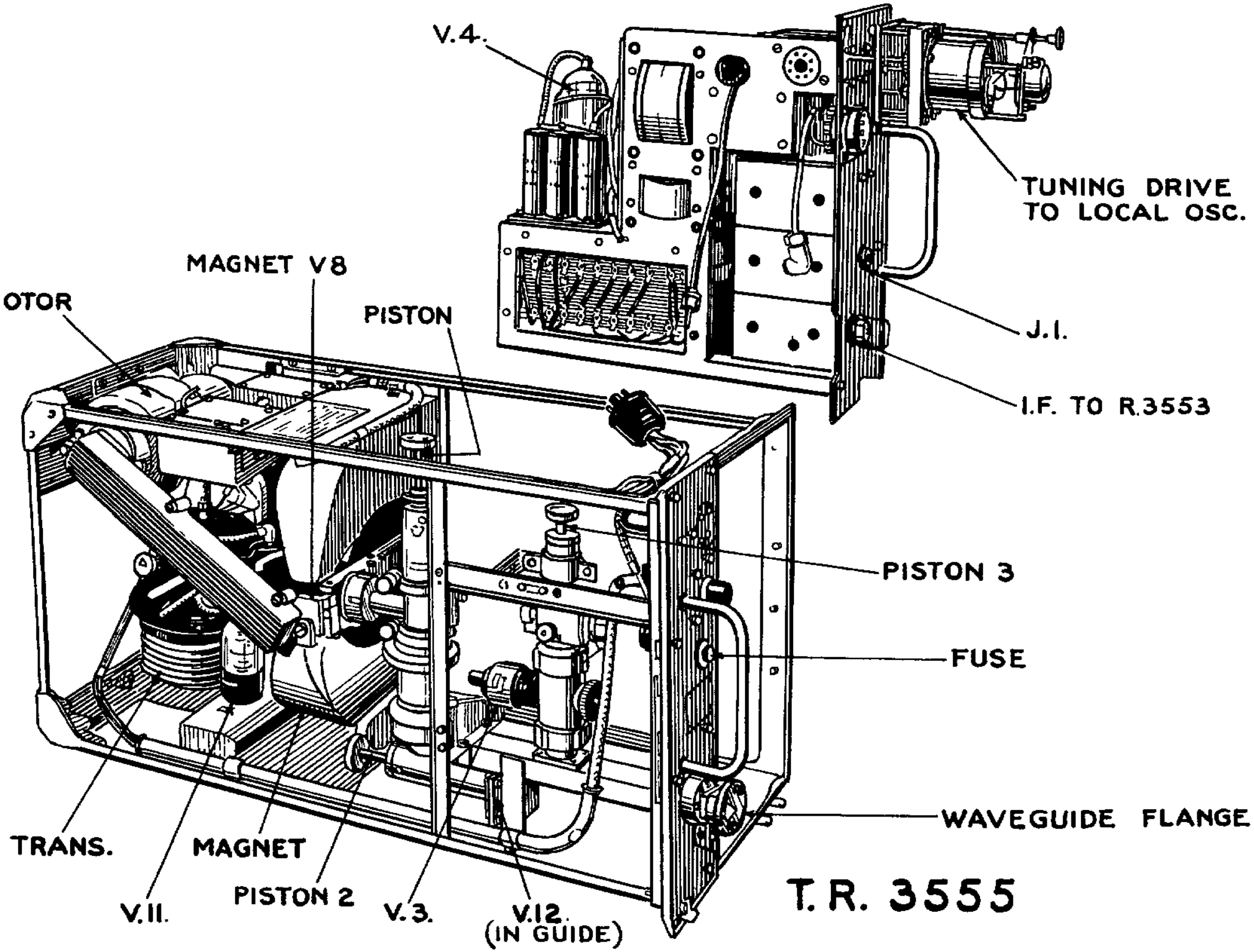
NOTE:-MODELS DIFFER IN MINOR MECHANICAL DETAILS

T.R. 3555 - WAVEGUIDE ASSEMBLY

FIG.220

FIG.220

FIG. 221

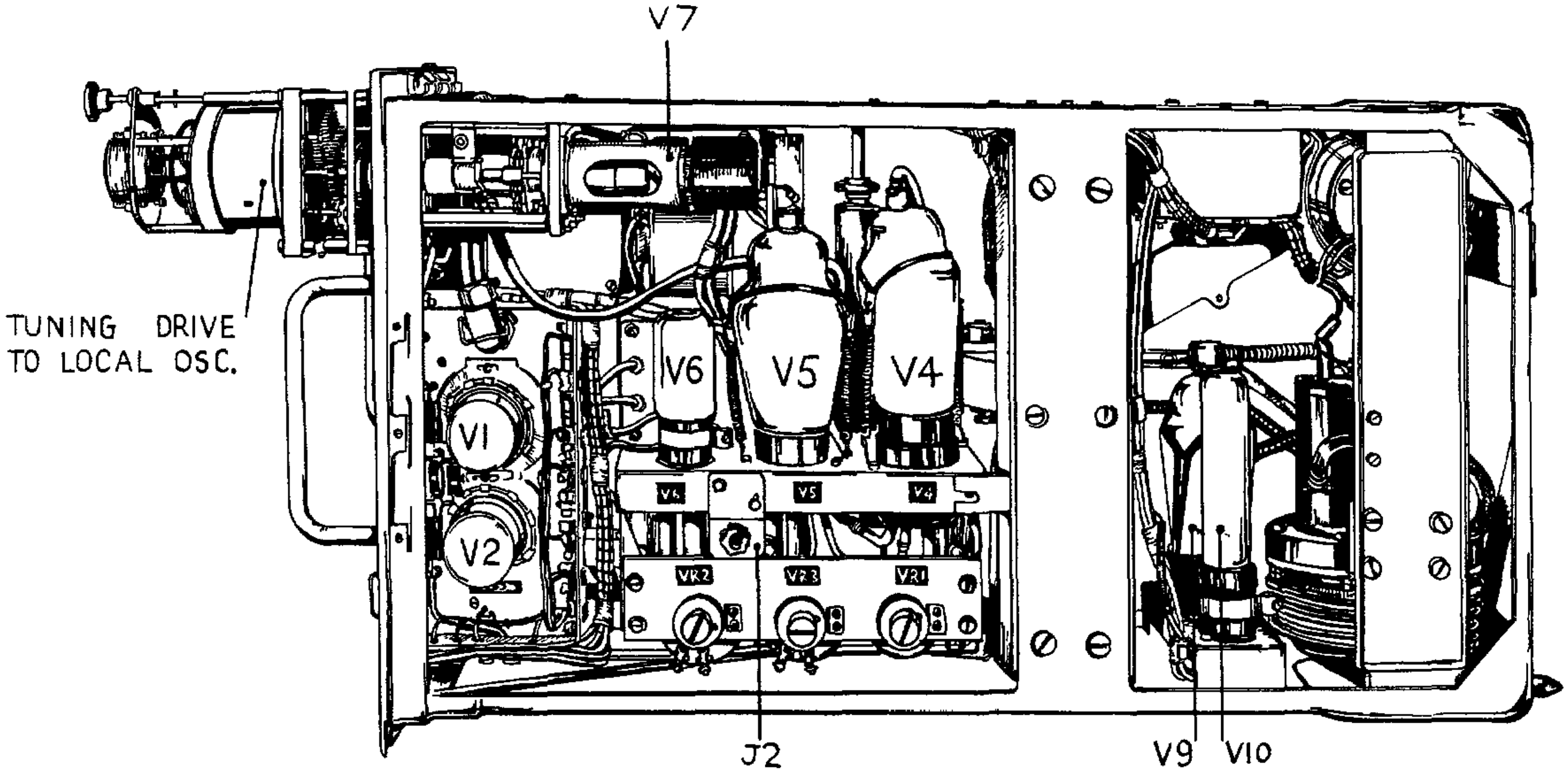


T.R. 3555

C.D. 0896 L

FIG. 221

FIG. 222



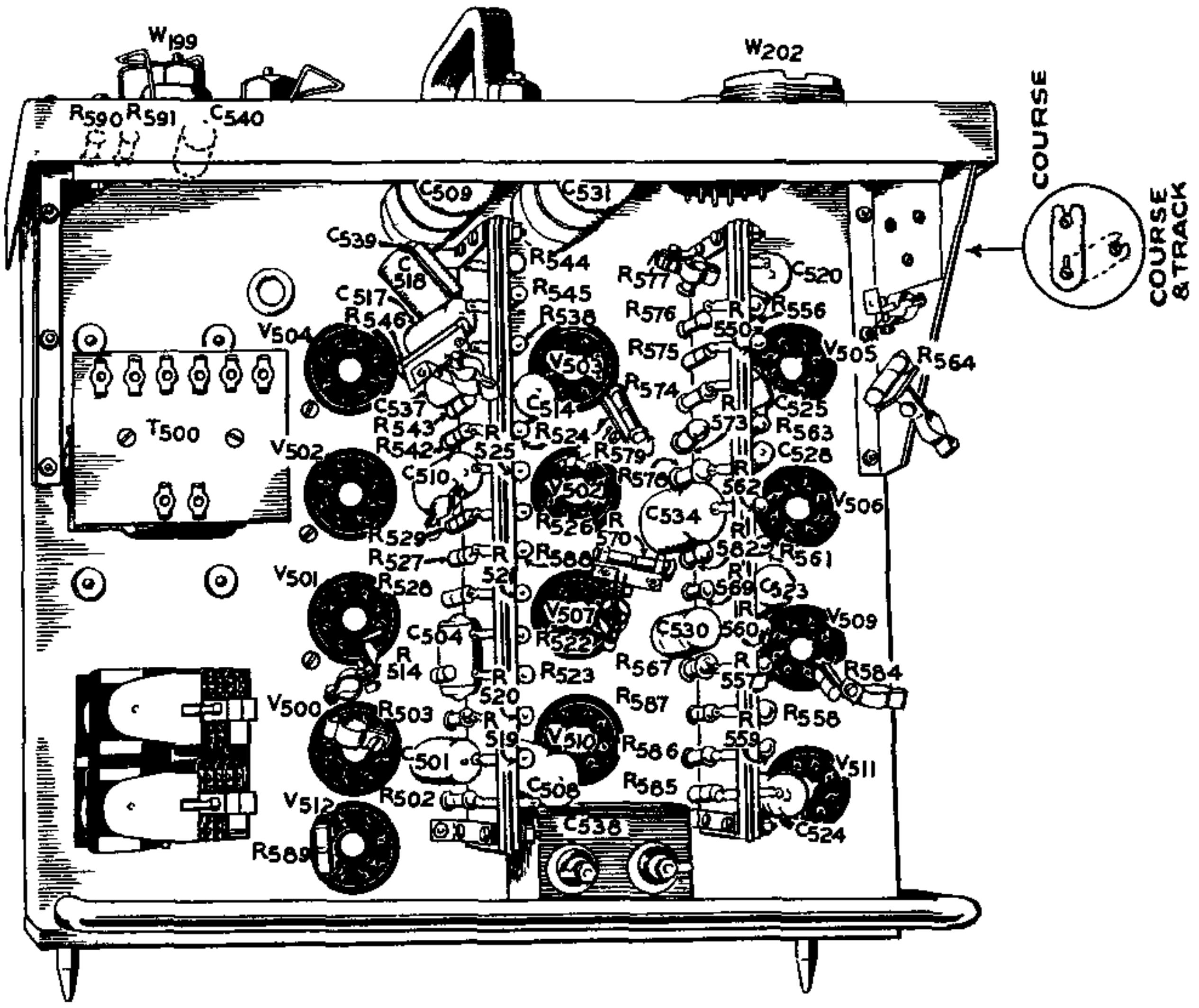
SIDE VIEW

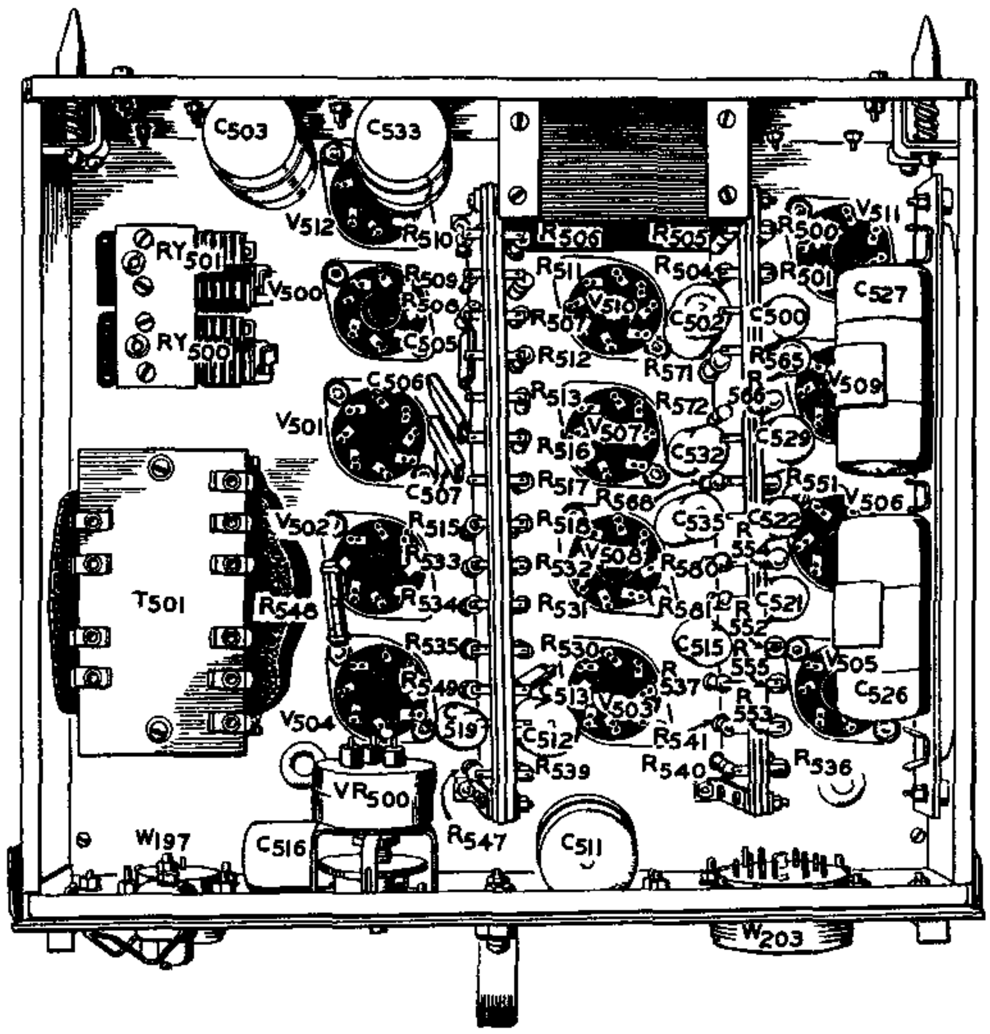
TR 3555

CD 0896 L.

FIG. 222

C.D. 0896 L



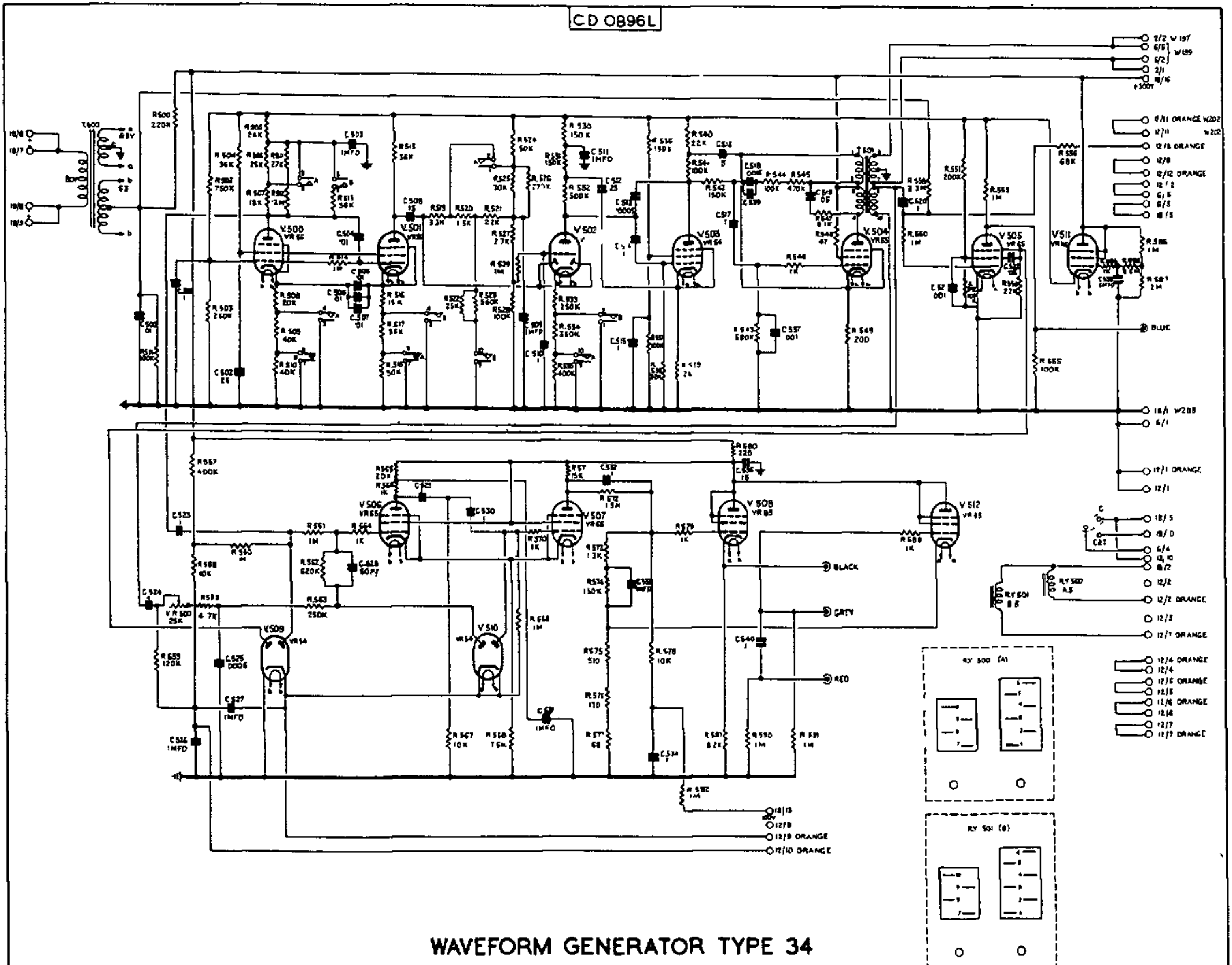


WAVEFORM GENERATOR TYPE 34

VIEWS OF CHASSIS

FIG.223

FIG.223

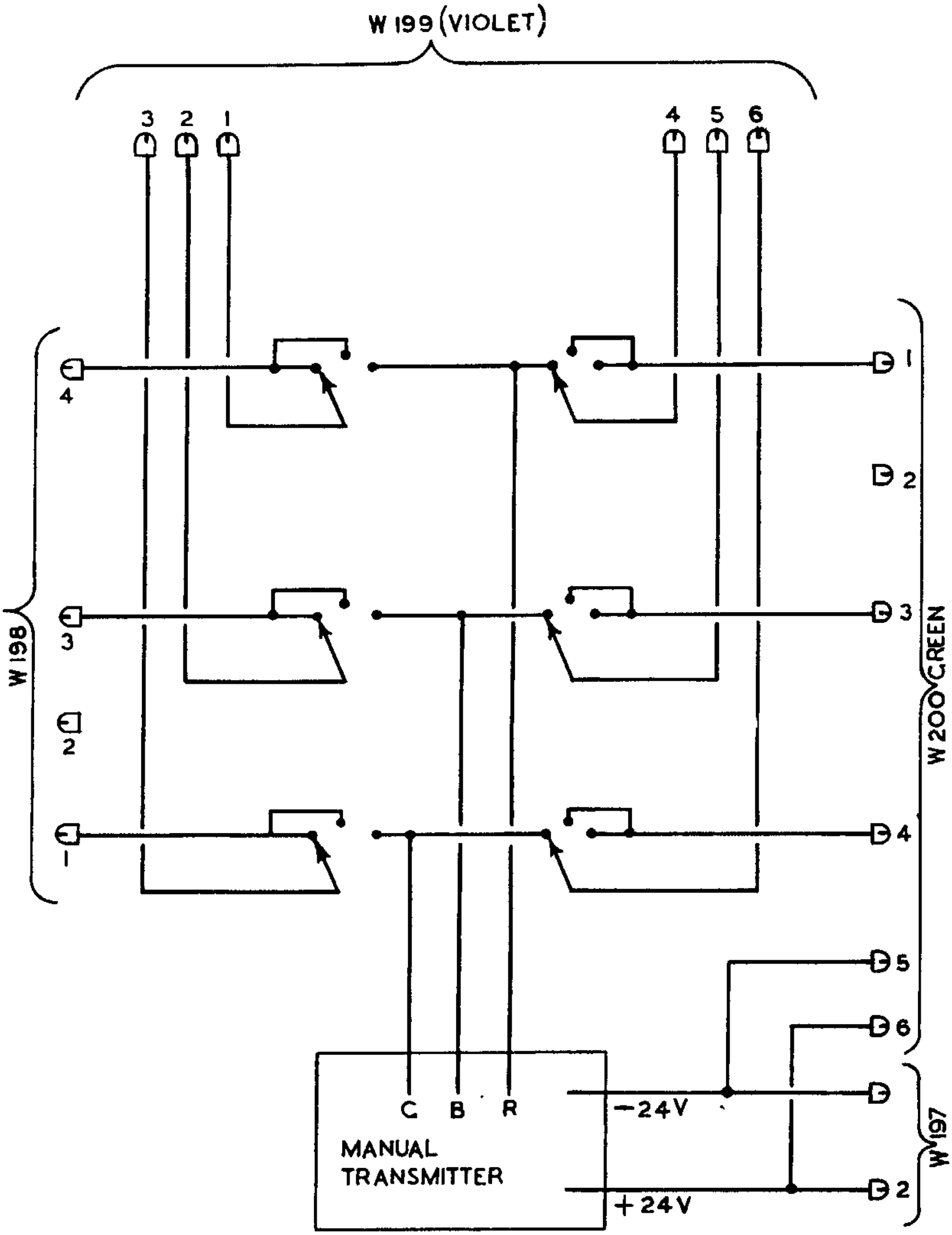


WAVEFORM GENERATOR TYPE 34

FIG.224

FIG.224

C.D.0896 L



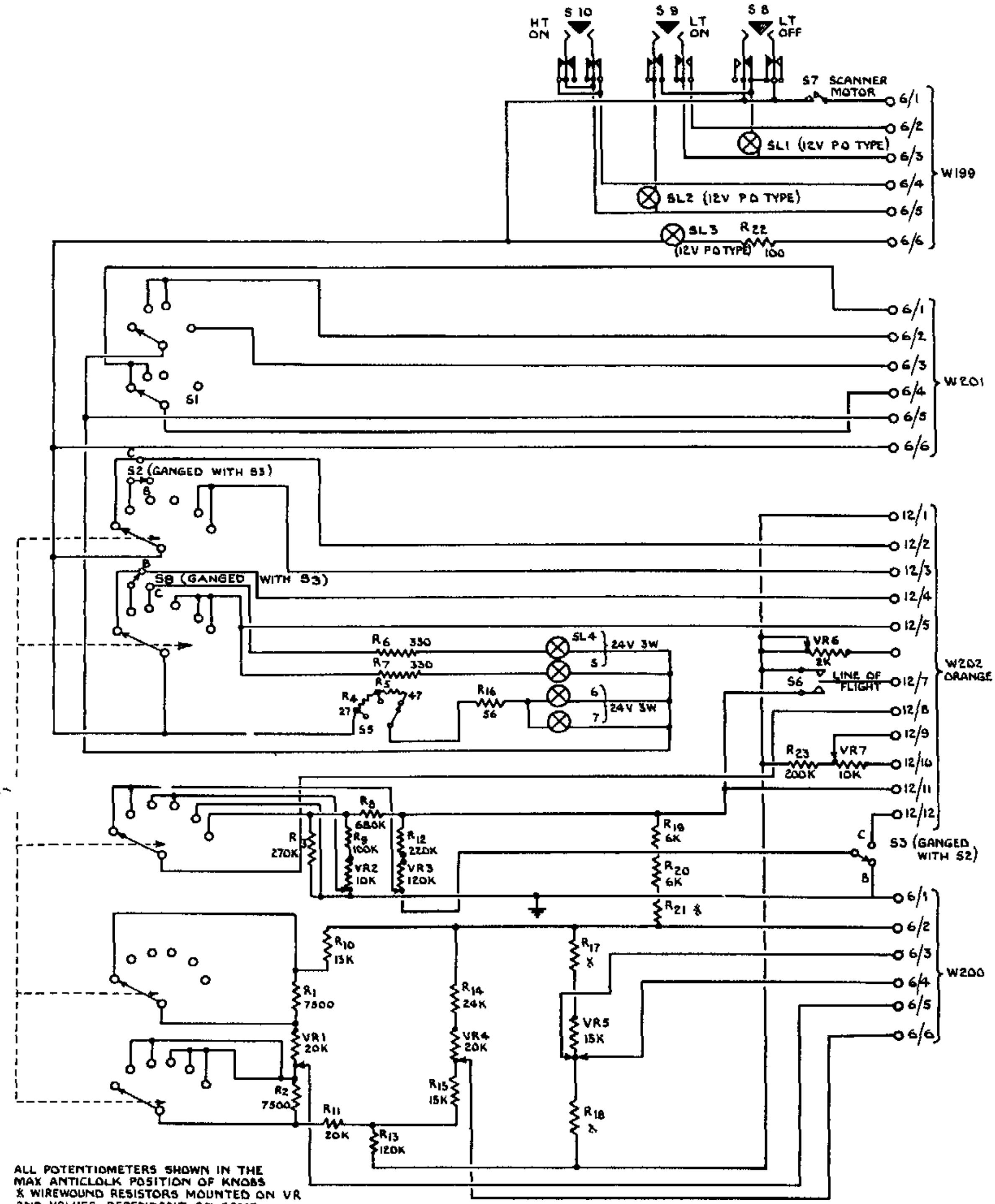
SWITCHES SHOWN IN MAX. ANTICLOCKWISE POSITION AS VIEWED FROM FRONT

ALL SWITCHES GANGED TOGETHER

CONTROL UNIT TYPE 446, WIRING DIAGRAM

FIG.225 FIG.225

CD. 0896 L

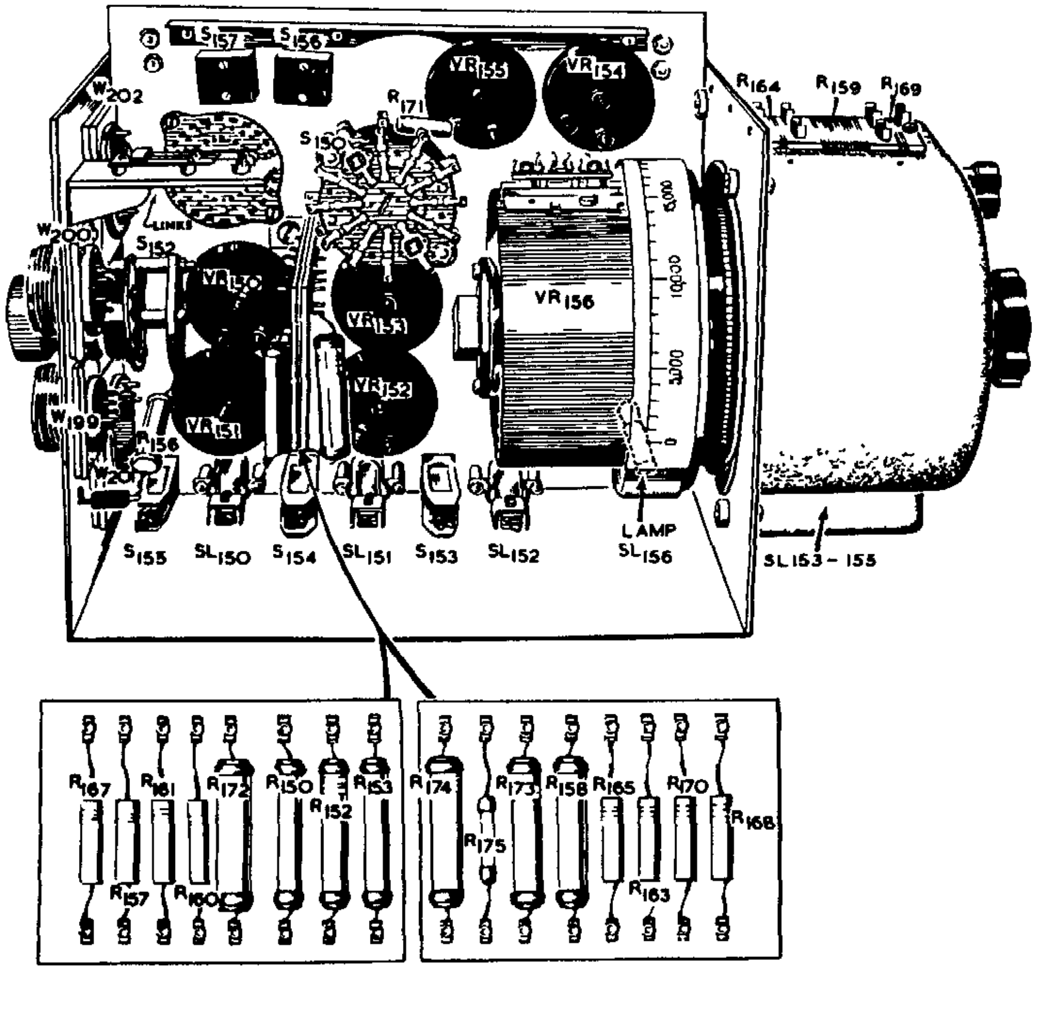


ALL POTENTIOMETERS SHOWN IN THE MAX ANTICLOCK POSITION OF KNOBS
X WIREWOUND RESISTORS MOUNTED ON VR AND VALUES DEPENDANT ON SAME

SWITCH UNIT, TYPE 207B. CIRCUIT DIAGRAM

FIG.226

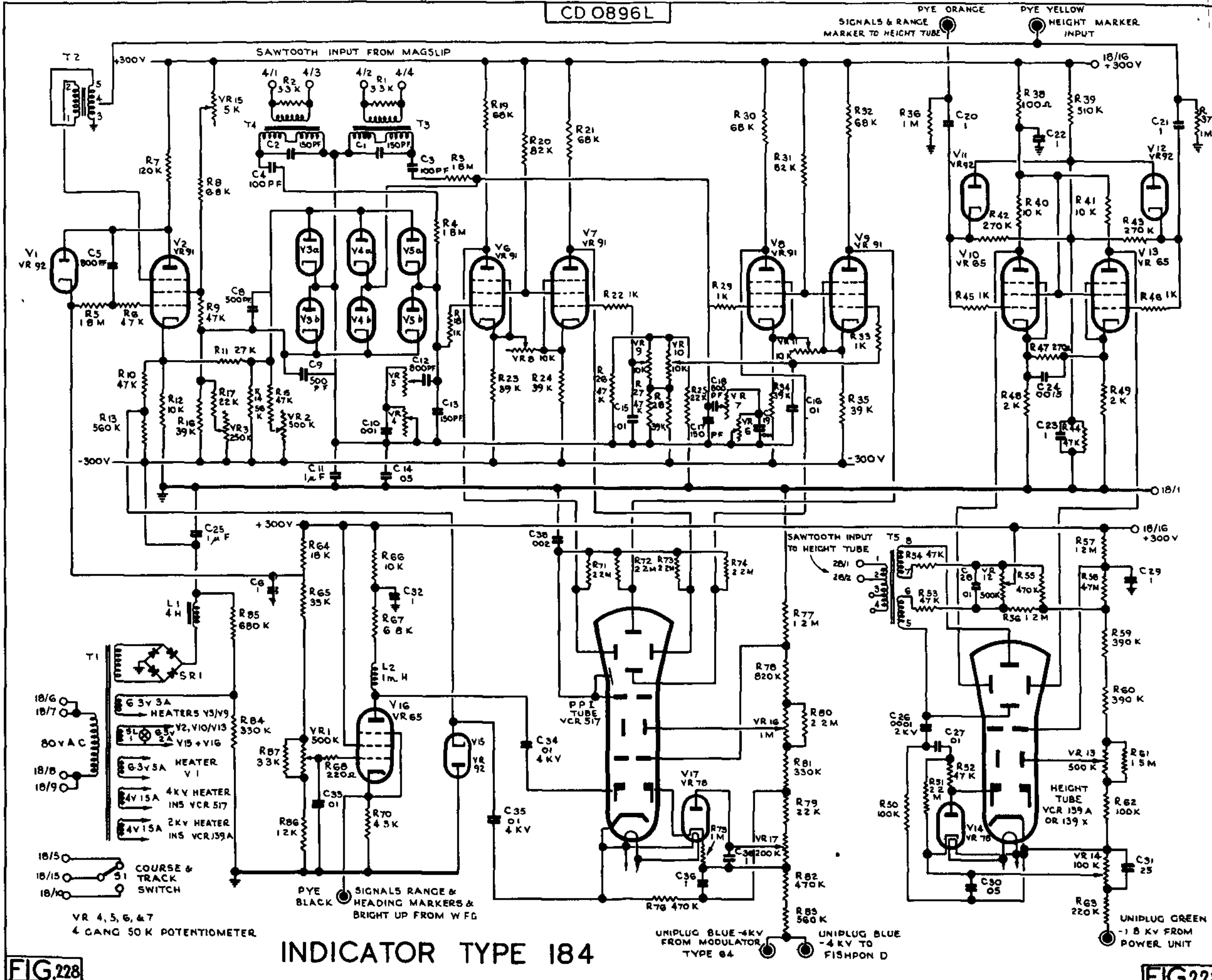
FIG.226



SWITCH UNIT TYPE 207B
INTERNAL VIEW

FIG.227

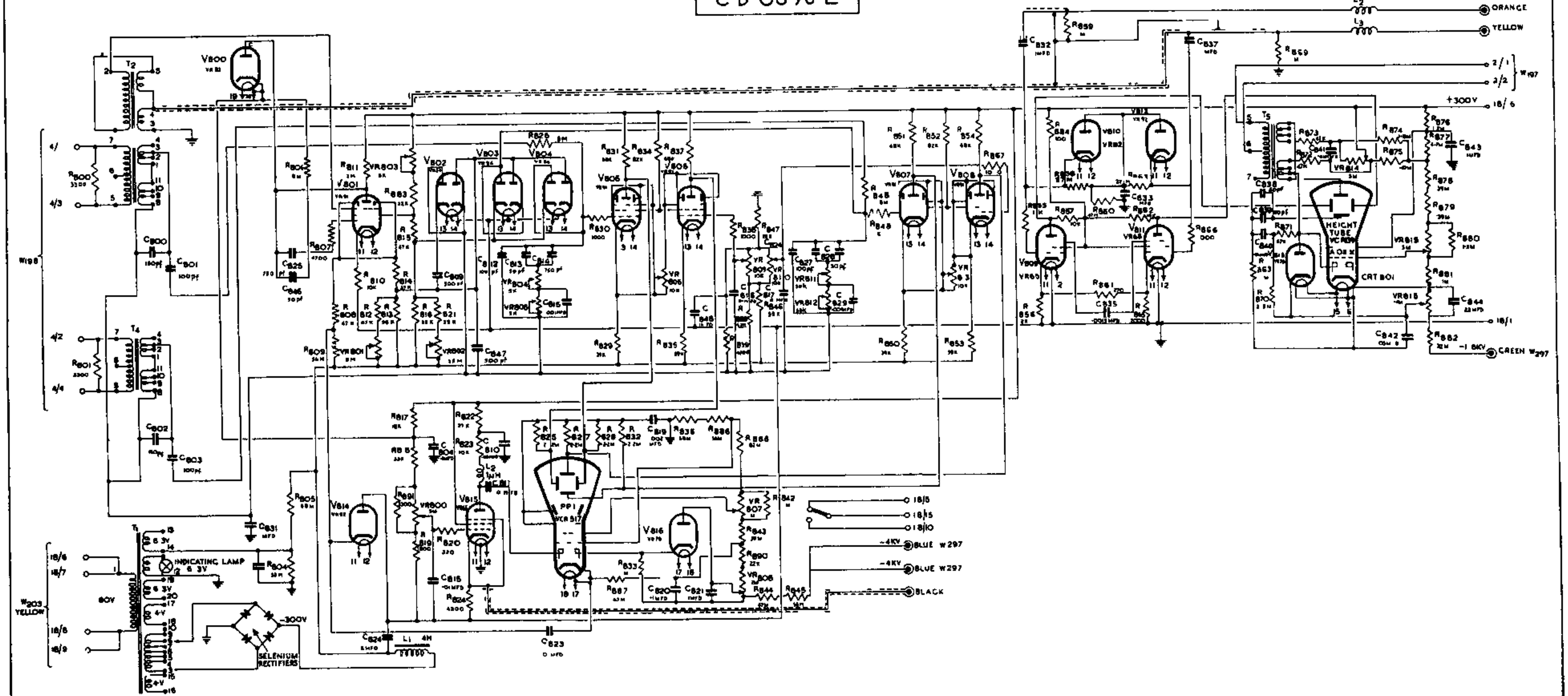
FIG.227



INDICATOR TYPE 184

FIG. 228

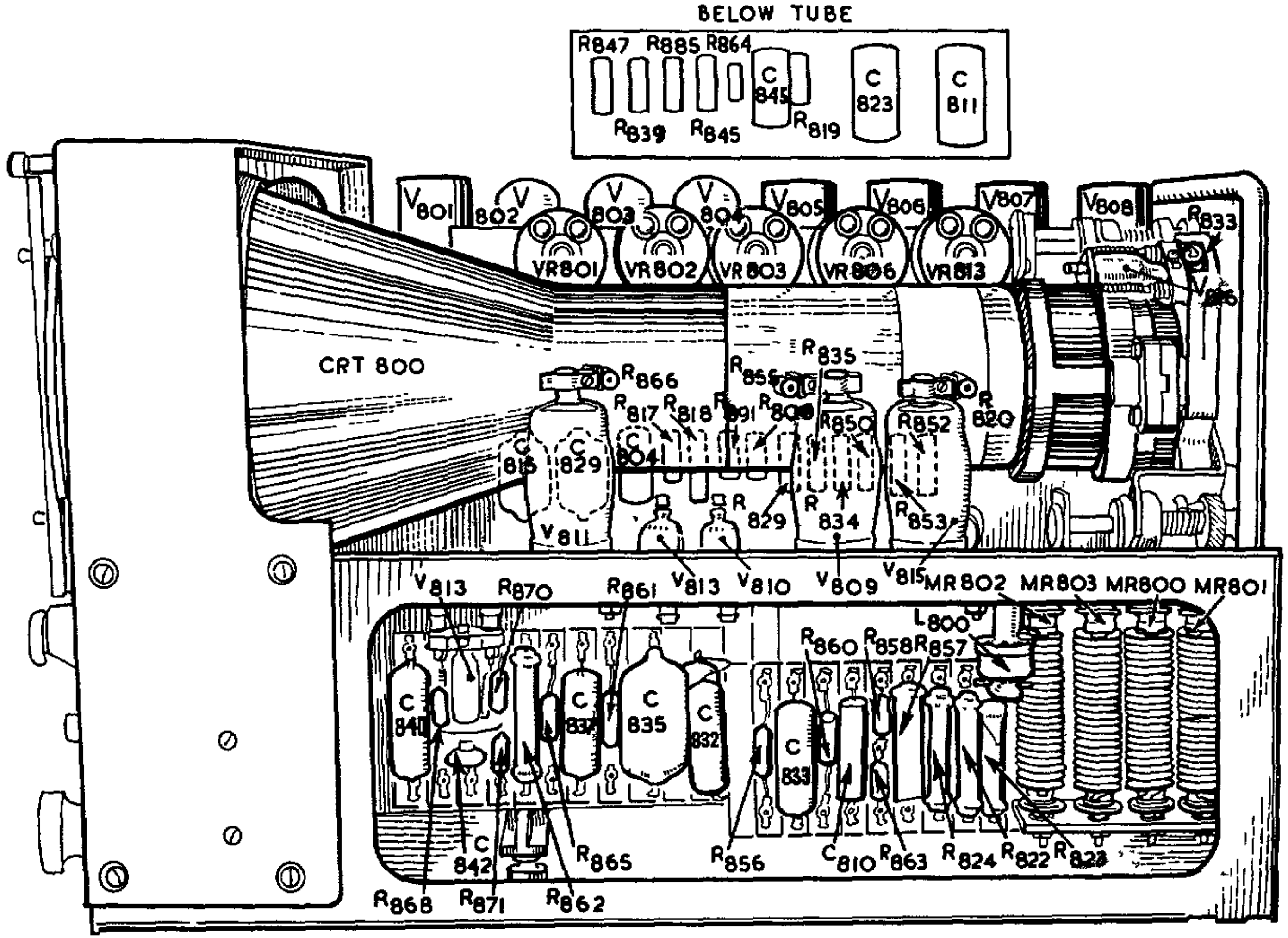
CD 0896 L



INDICATOR UNIT TYPE 184 A

FIG. 229

FIG. 229

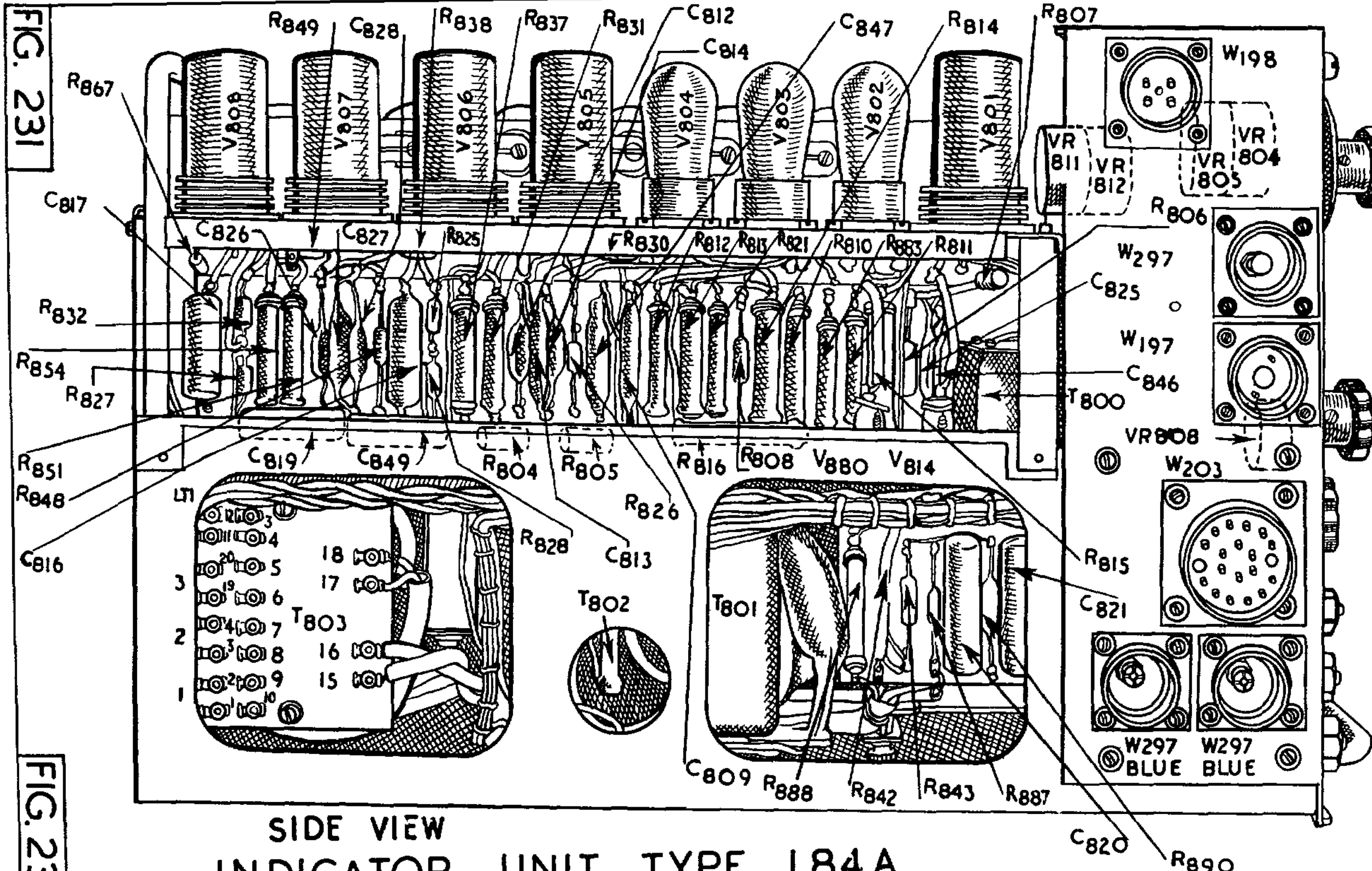


SIDE VIEW

INDICATOR UNIT TYPE 184 A

C.D.0896 L

FIG. 231



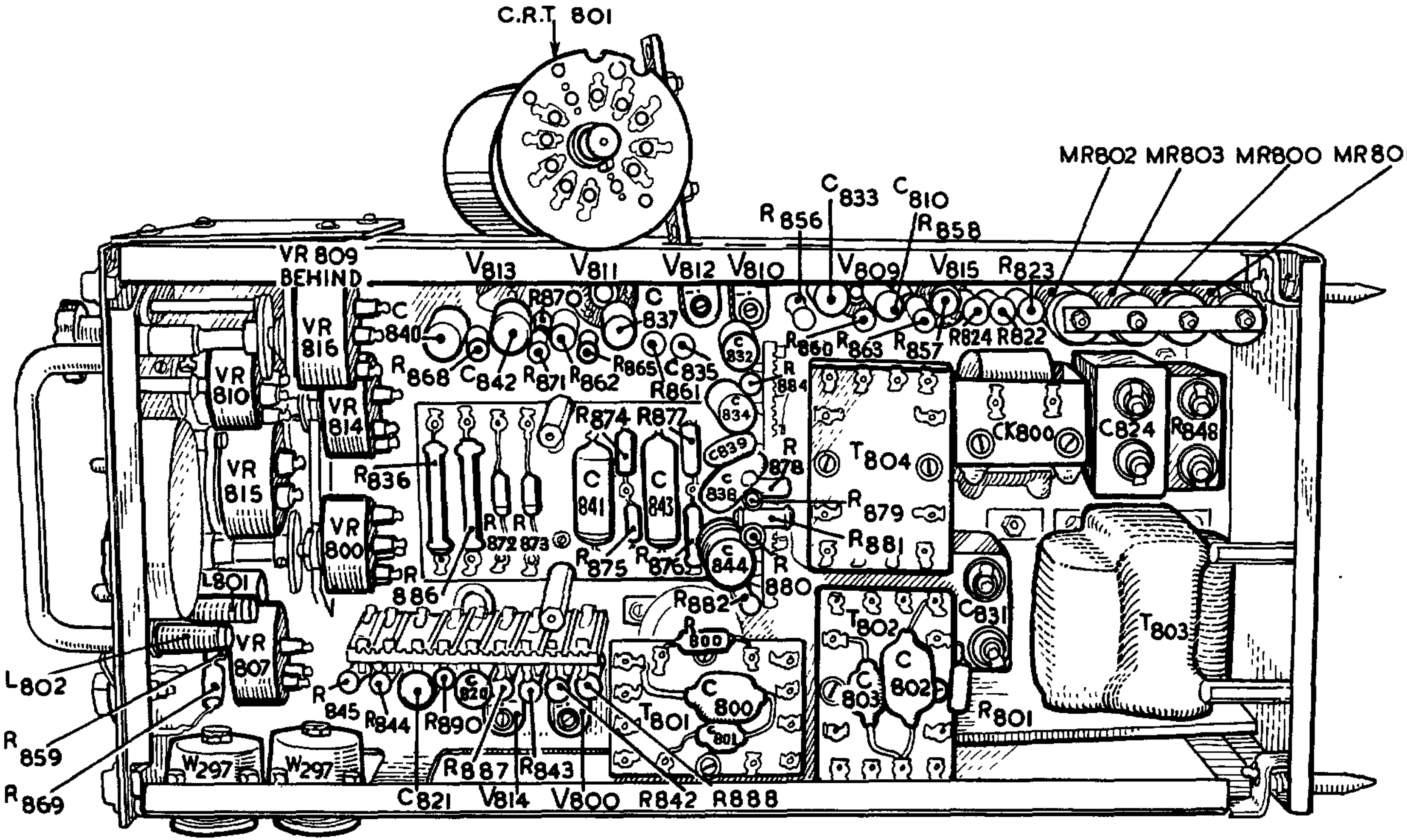
SIDE VIEW

INDICATOR UNIT TYPE 184A

FIG. 231

C.D. 0896 L

FIG.231A

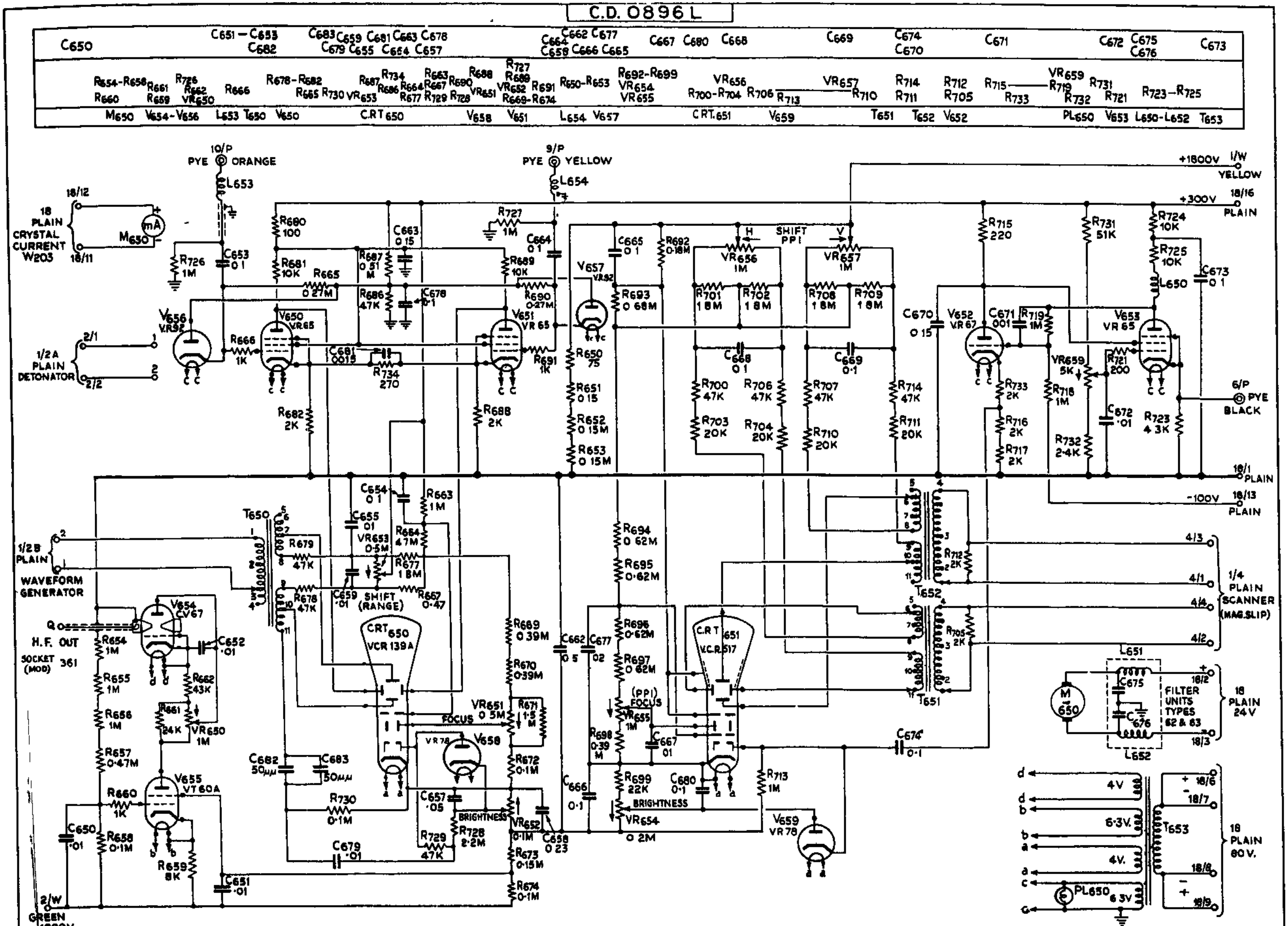


UNDERSIDE VIEW

INDICATOR UNIT TYPE 184A

C.D.0896 L

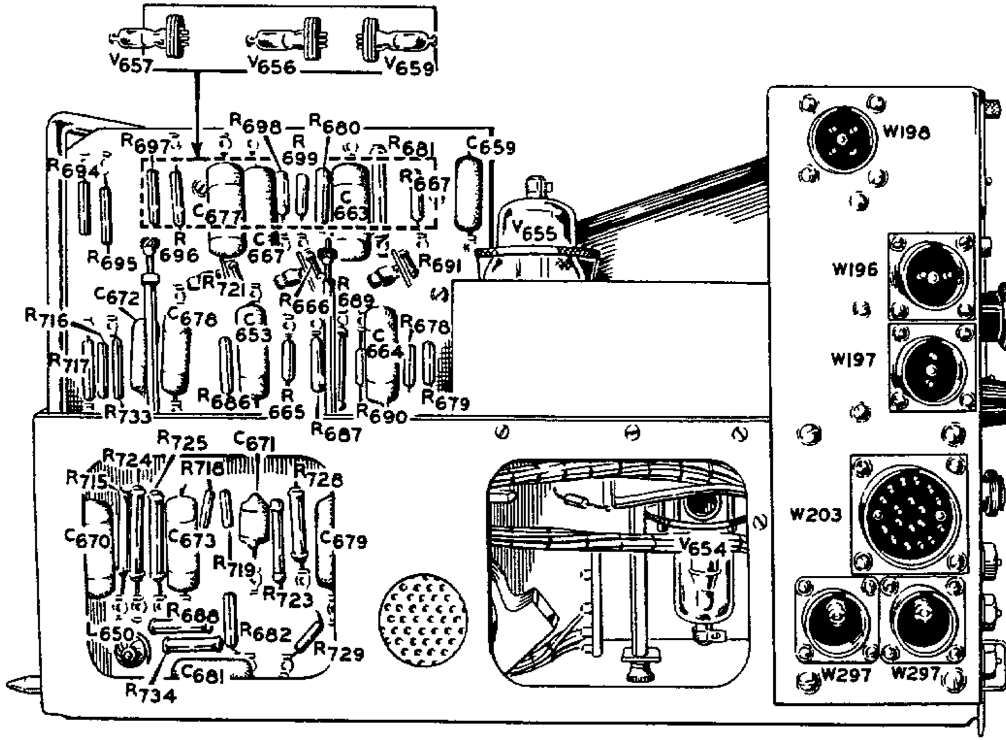
FIG.231A



INDICATOR UNIT, TYPE 162——CIRCUIT

FIG.232 FIG.232

FIG.233

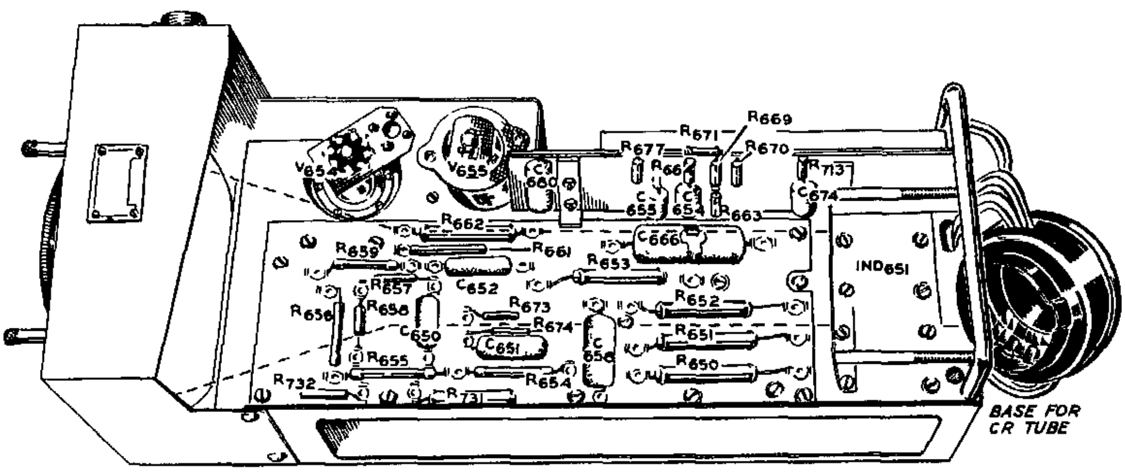


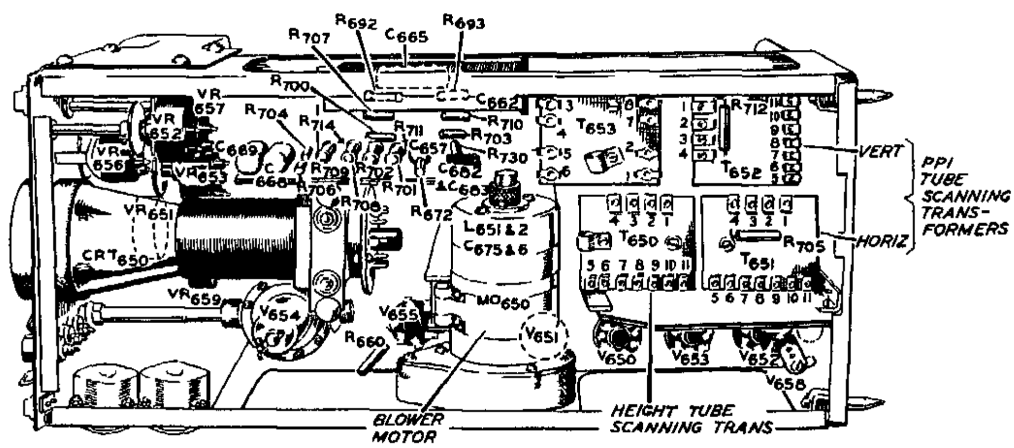
INDICATOR UNIT TYPE 162

SIDE VIEW

C.D.0896 L

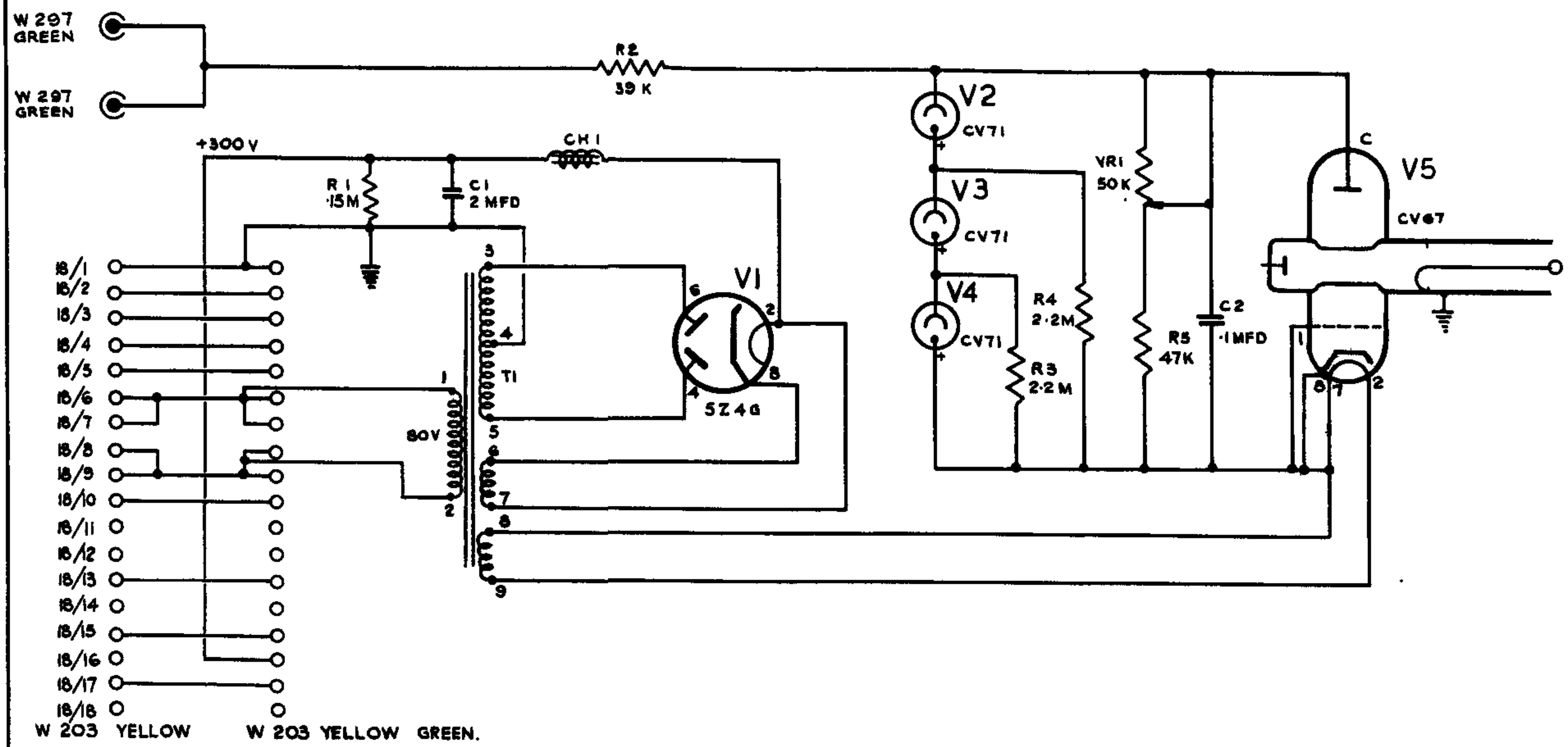
FIG.233





INDICATOR UNIT TYPE 162
TOP AND BOTTOM VIEWS

C.D. 0896 L



TUNING UNIT TYPE 207
CIRCUIT DIAGRAM.

FIG. 235

FIG. 235

C.D. 0896 L

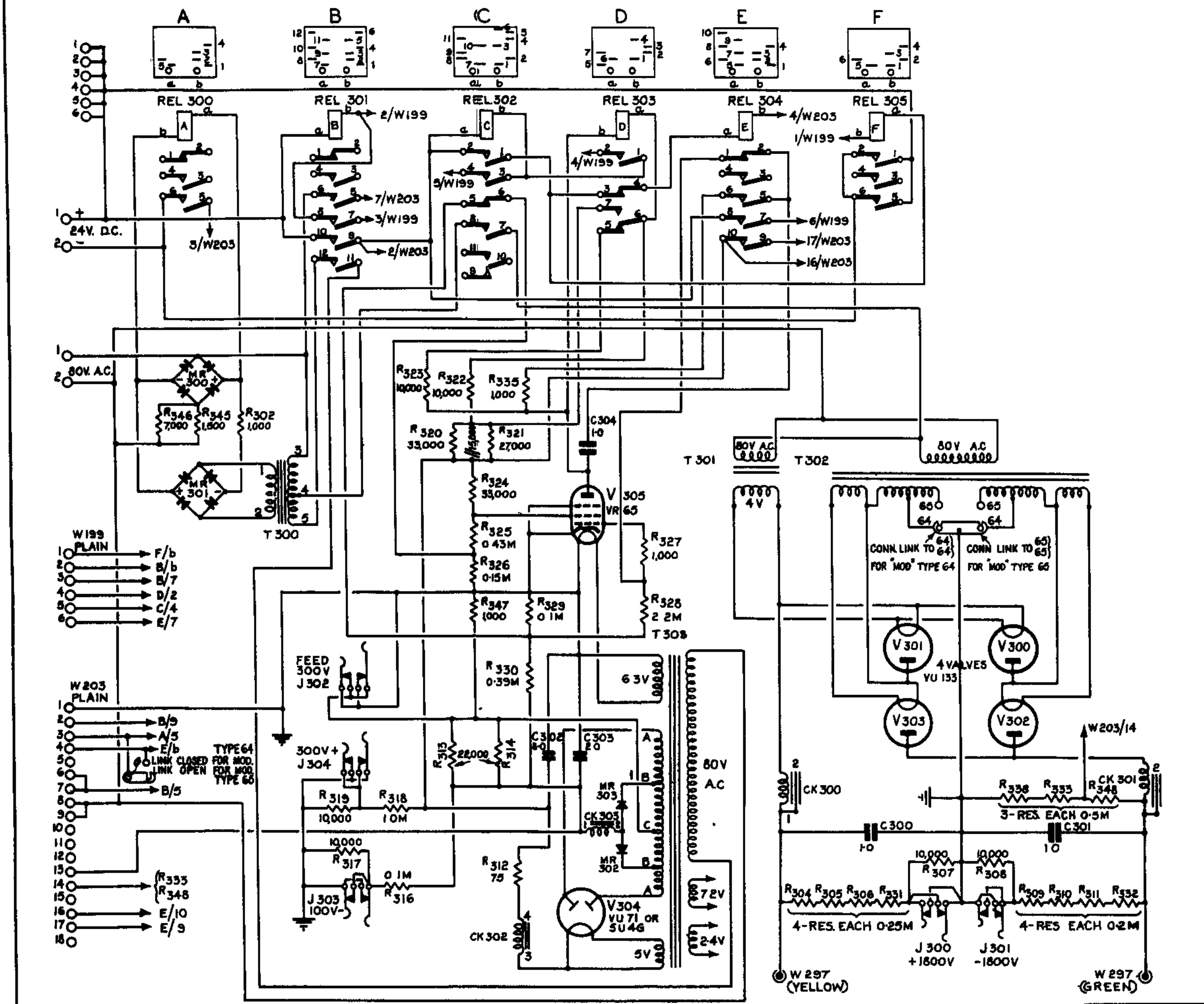
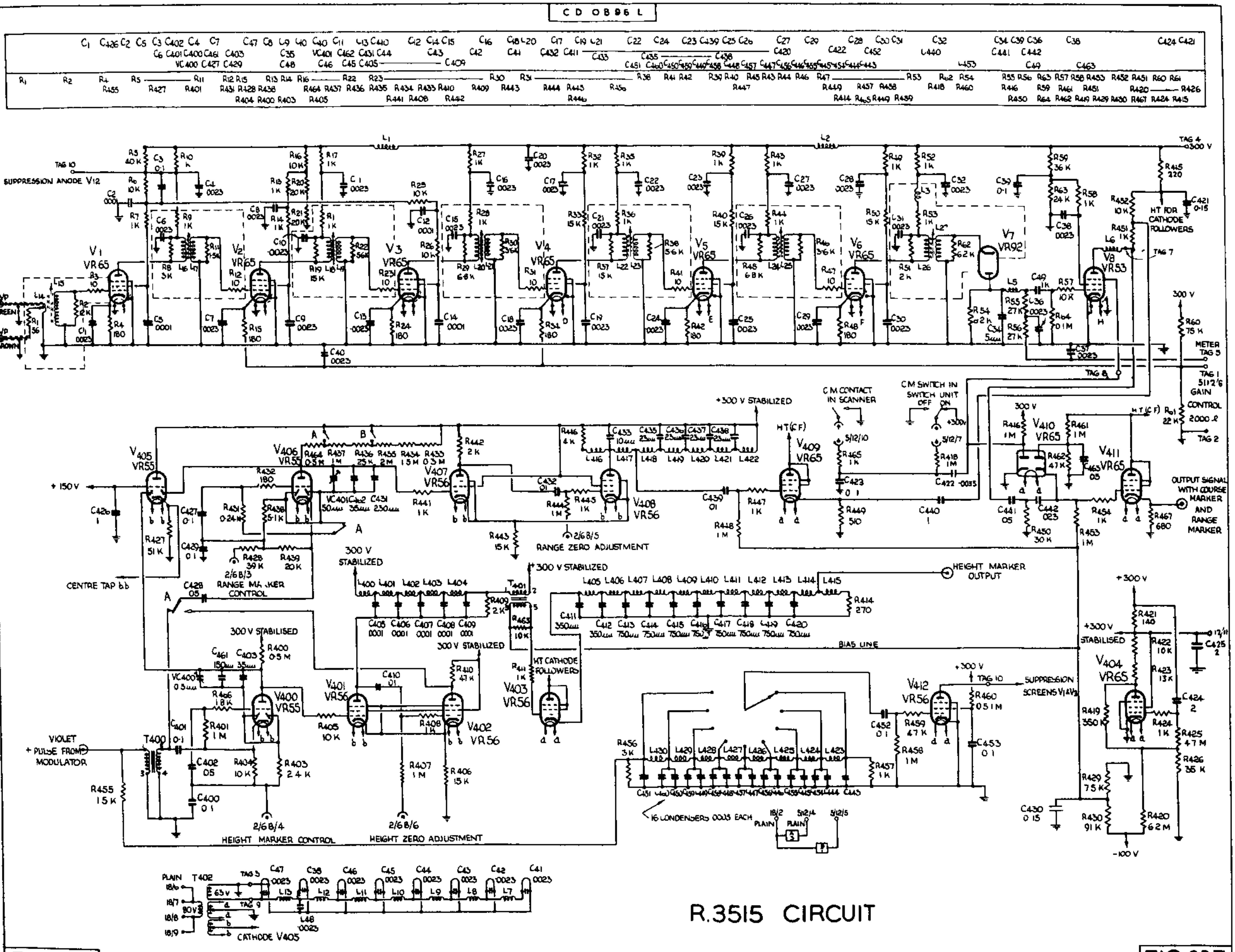


FIG. 236

POWER UNIT TYPE 224

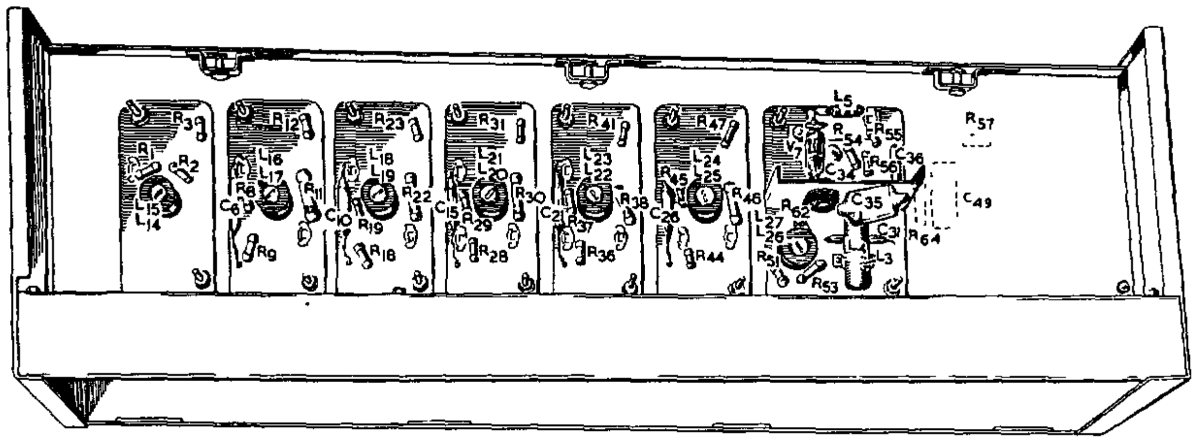
FIG. 236

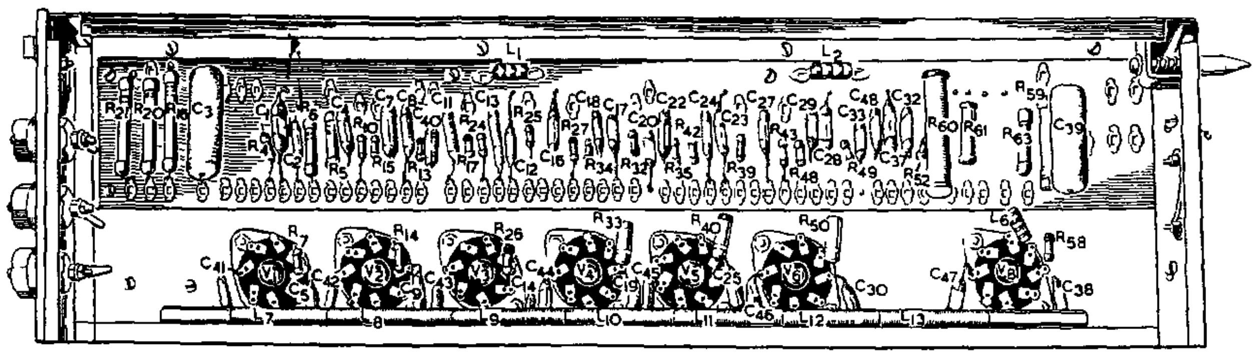


R.3515 CIRCUIT

FIG.237

FIG.238



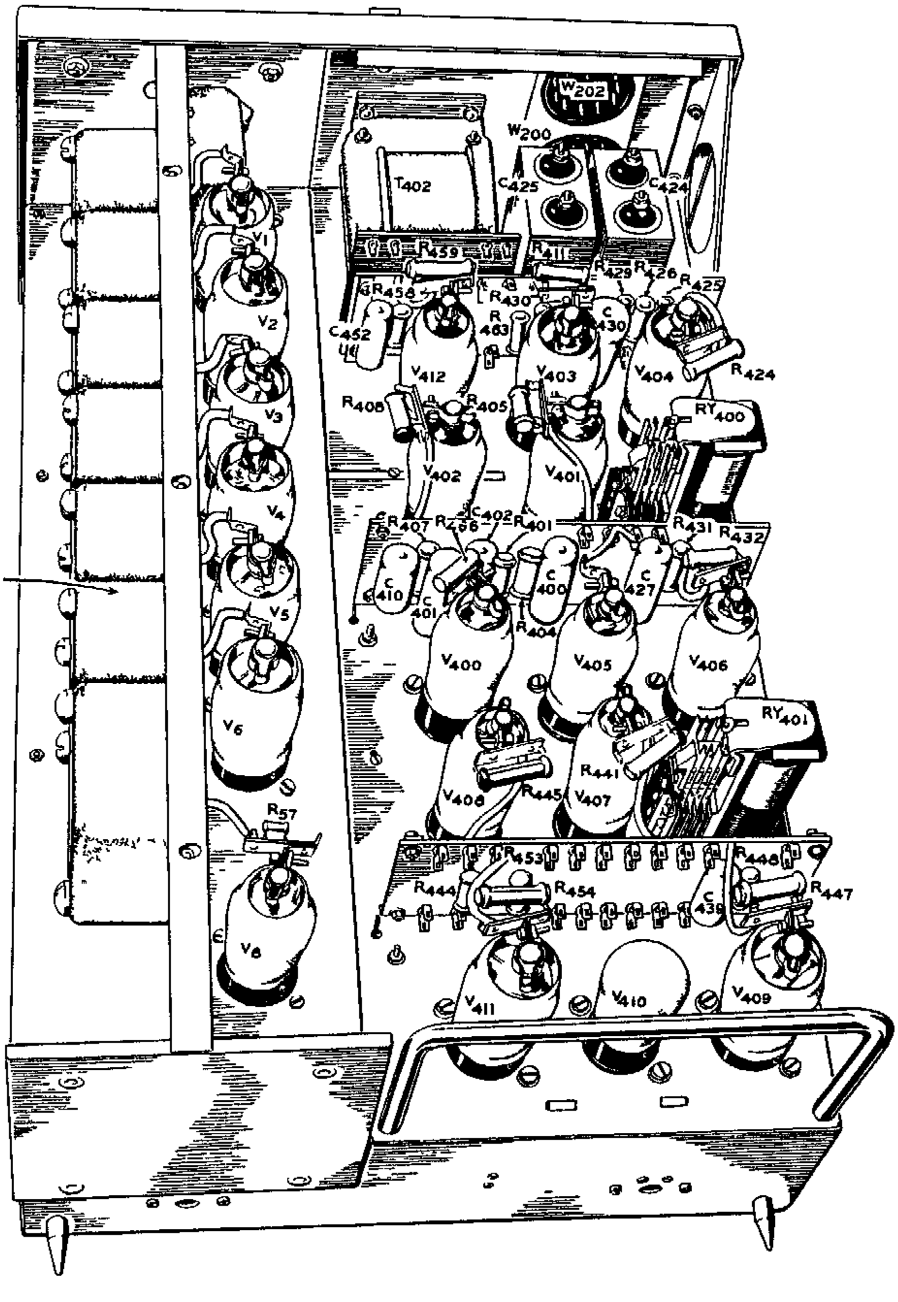


RECEIVER UNIT TYPE 3515

VIEWS OF RECEIVER CHASSIS

CD 0896 L

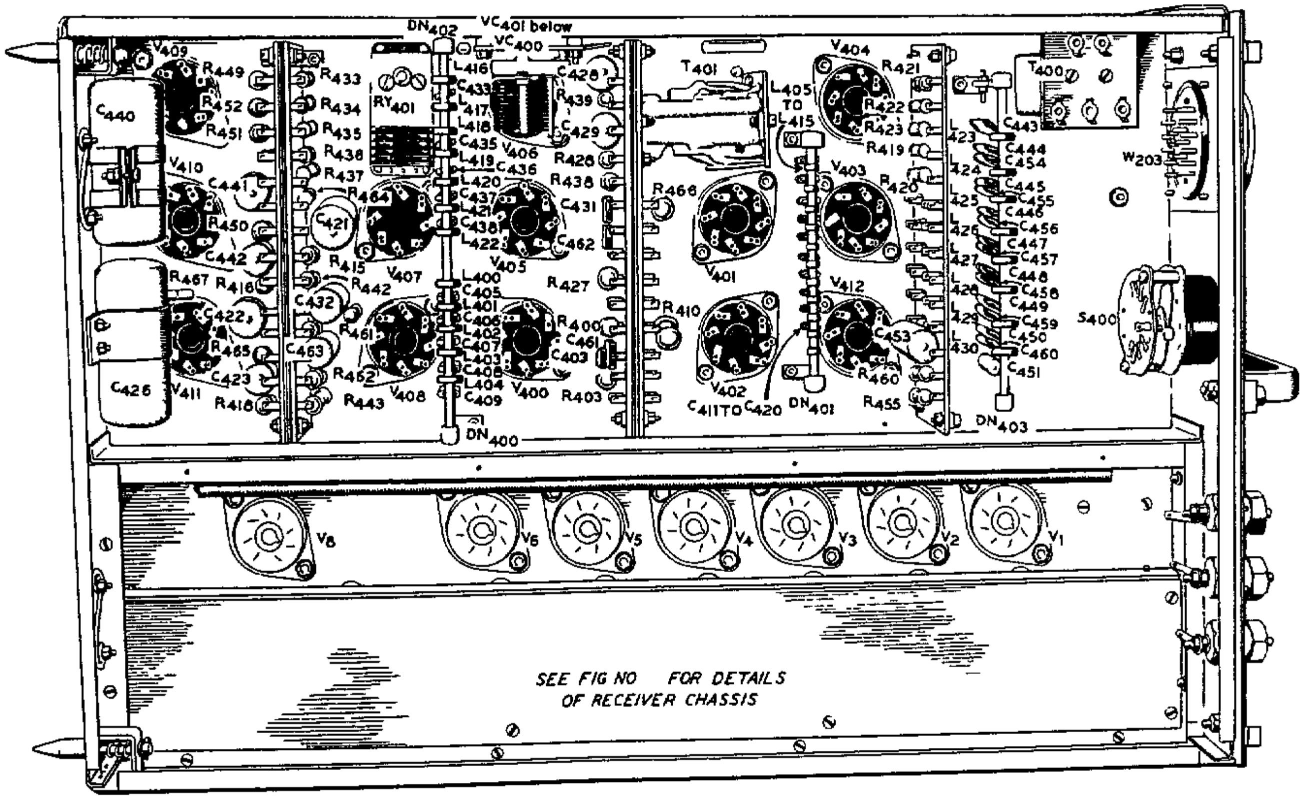
FIG.238



TOP VIEW OF RECEIVER UNIT TYPE 3515
DETAILS OF TIMING CHASSIS

FIG.239

FIG.240



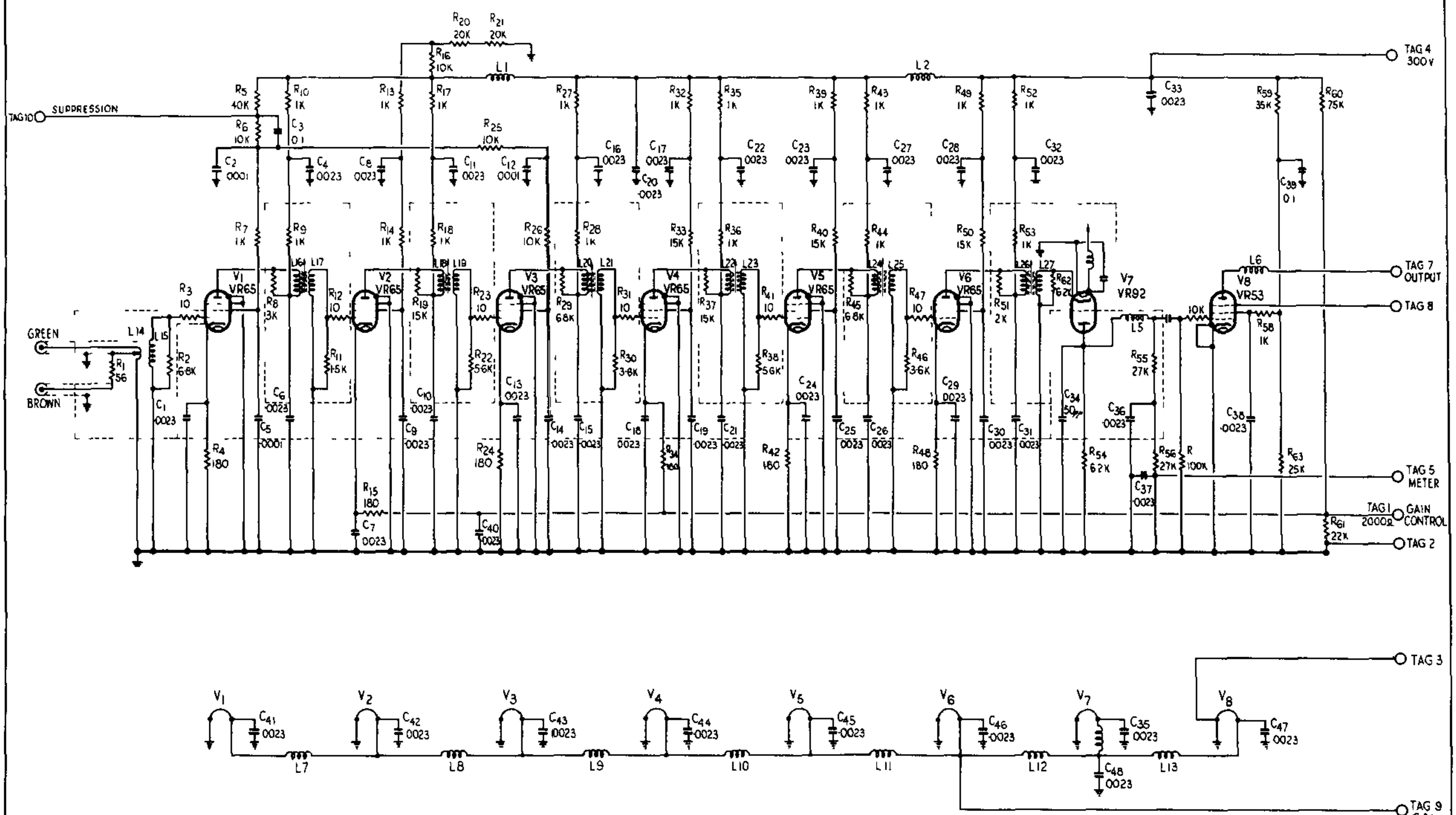
C.D.0896 L

UNDER VIEW OF RECEIVER UNIT TYPE 3515

DETAILS OF TIMING CHASSIS

FIG 240

CD 0896 L

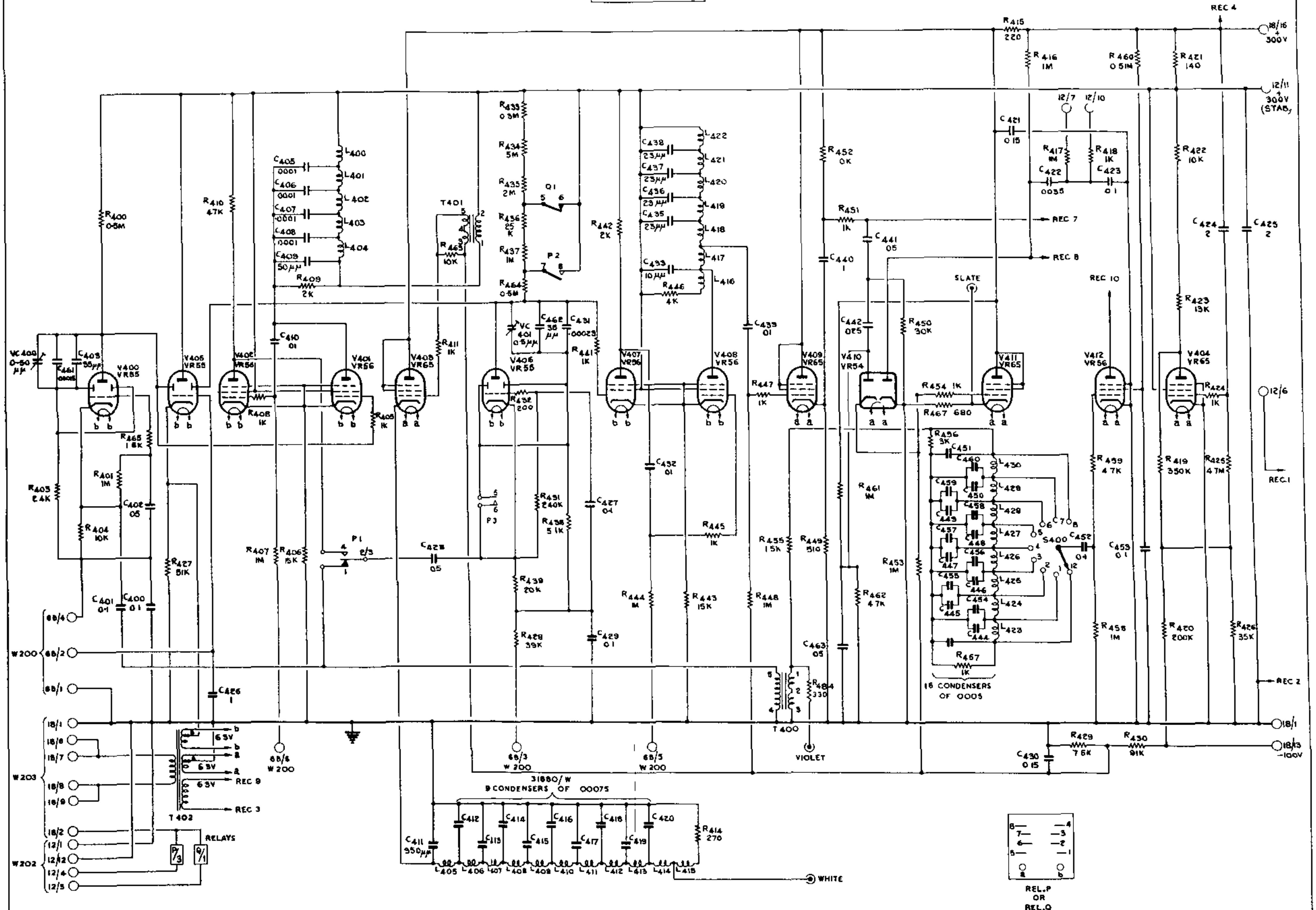


R 3516 RECEIVER - CIRCUIT.

FIG. 241

FIG. 241

CD0896 L



R.3516. TIMING UNIT.

FIG. 242

FIG 242

CD0896L

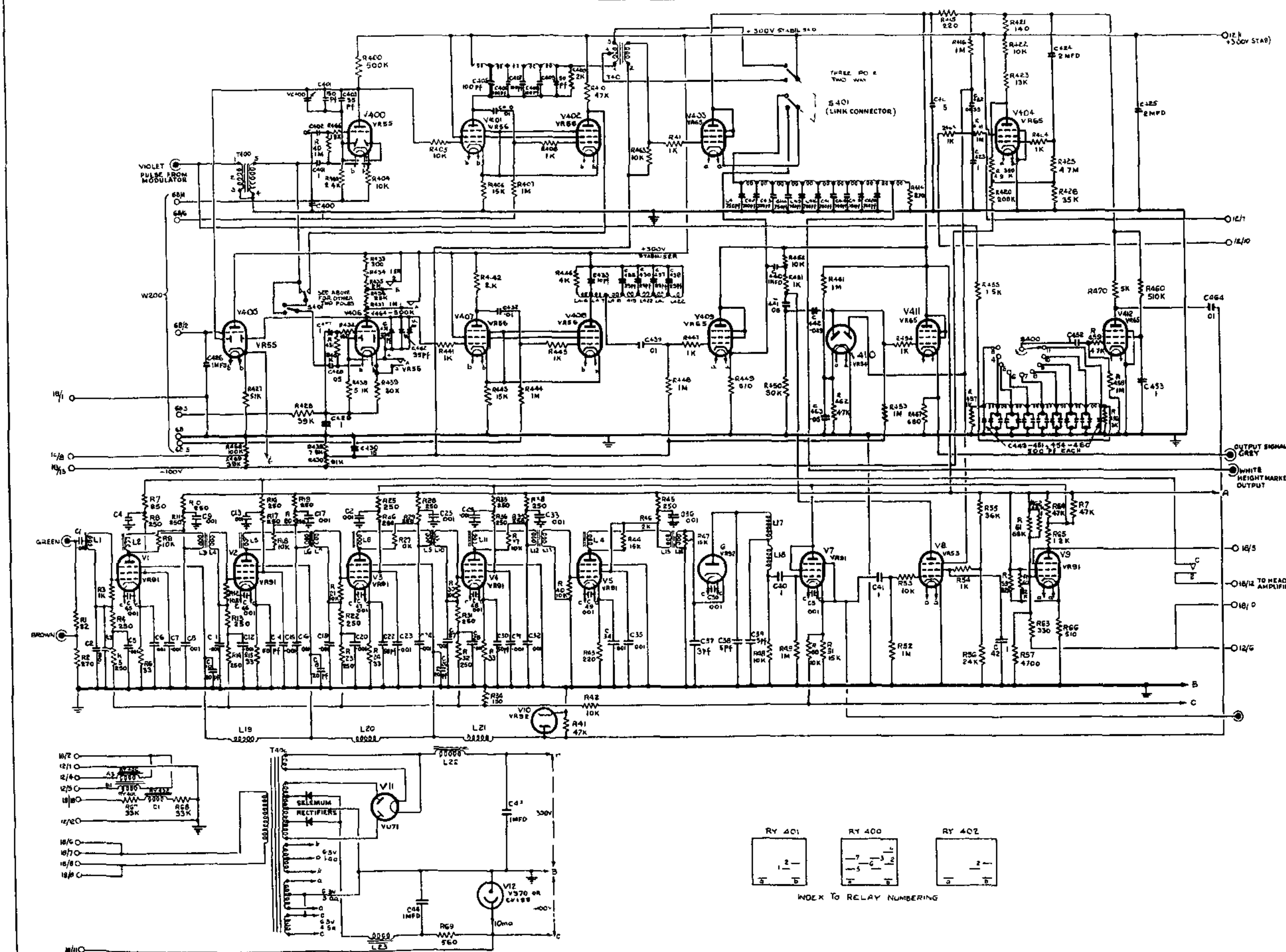
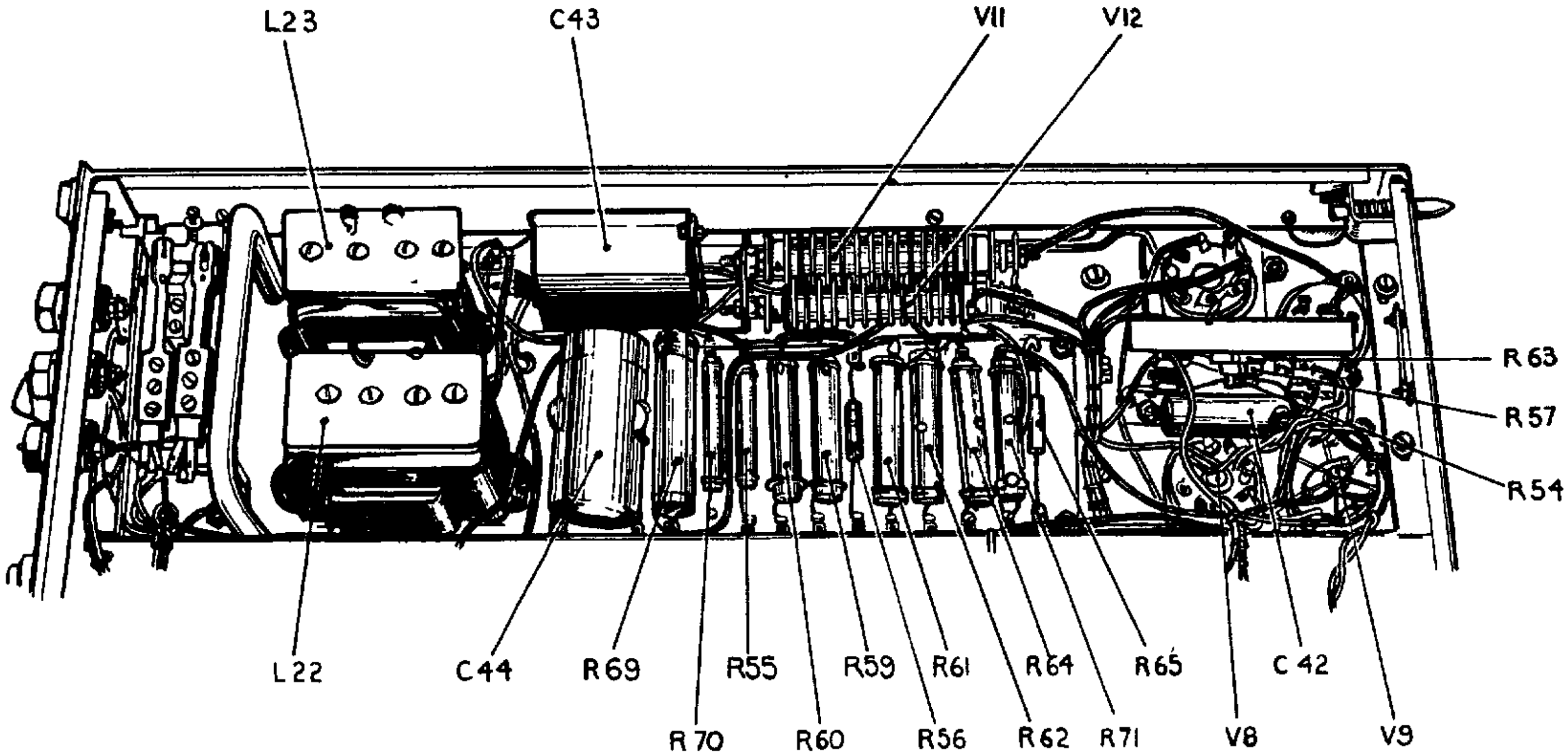


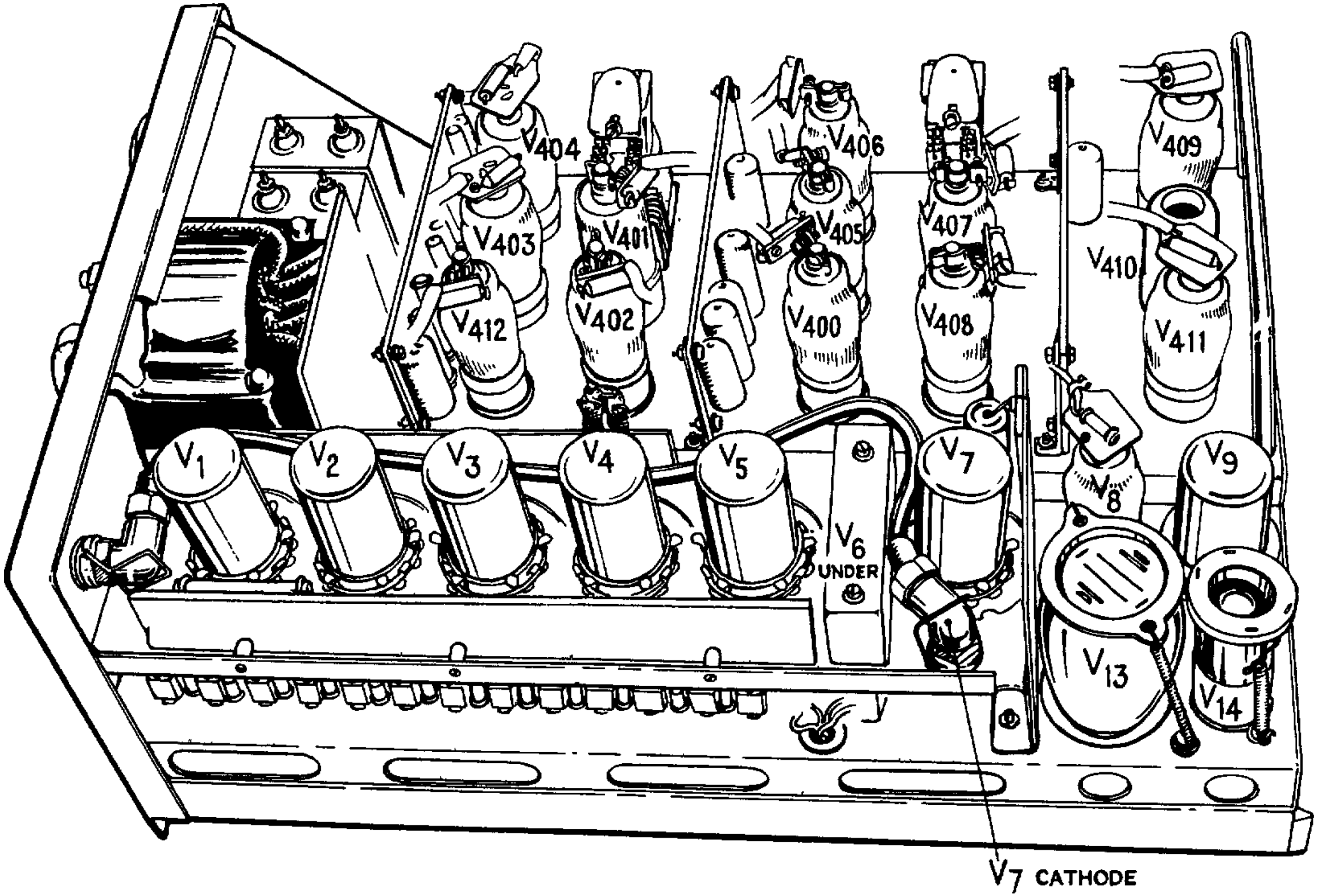
FIG.243 R3553 CIRCUIT FIG 243



R. 3553 UNDERSIDE VIEW

FIG. 244

FIG. 245



R 3553 TOP VIEW

C.D. 0896 L

FIG. 245