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OSCILLOSCOPES

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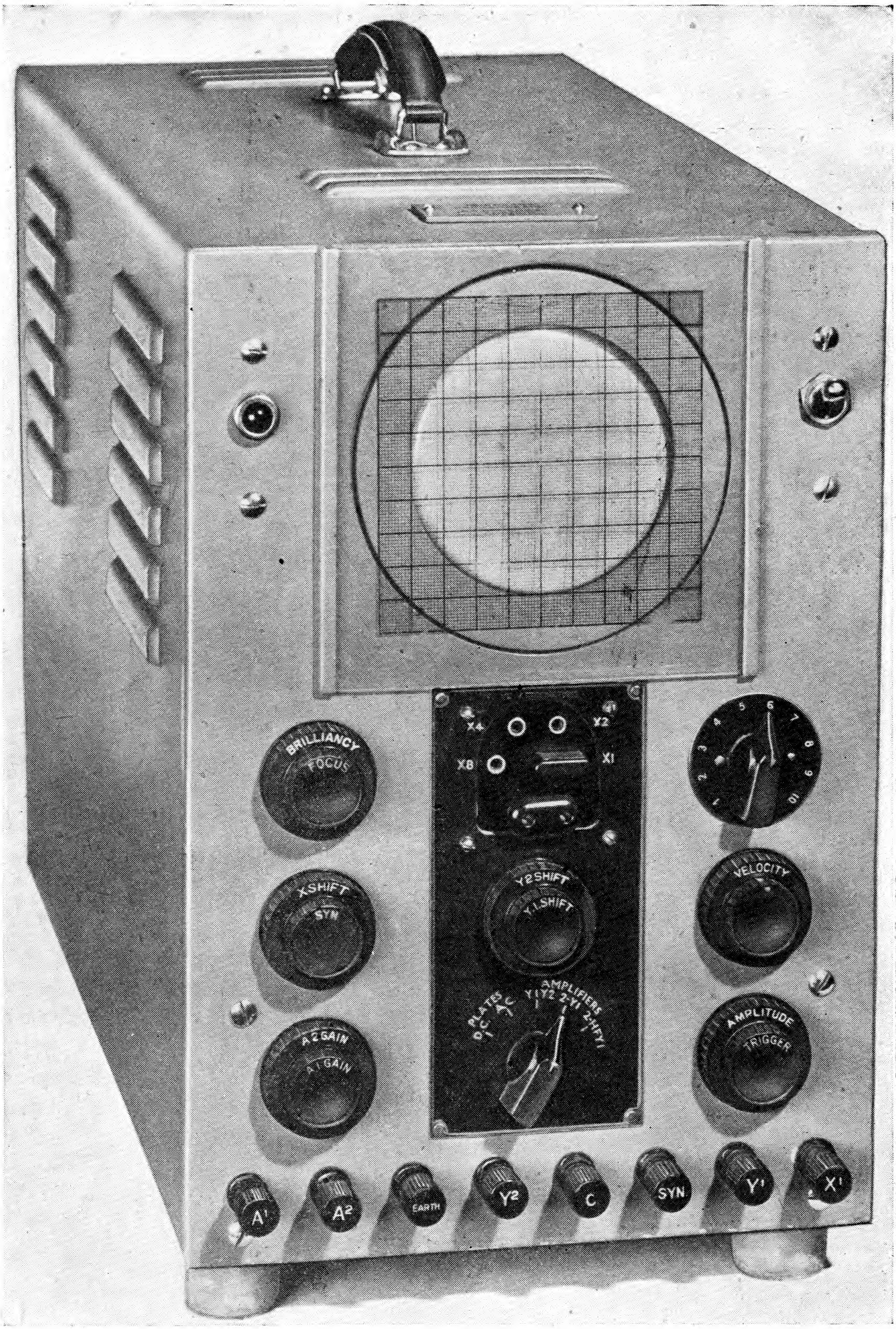

Fig. 1.—Oscilloscope, type 7.

OSCILLOSCOPES

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INTRODUCTION

1. The oscilloscope, type 7, is a portable cathode ray oscillograph using a 3½in. diameter single beam tube and is intended to give a graphical representation, as a function of time, of any effect which can be made to produce an equivalent electrical effect irrespective of whether the initial effect is of an essentially electrical character or not. It provides qualitative information given by the instantaneous two-dimensional recording facilities of a cathode ray tube. When suitably calibrated, quantitative results may also be obtained. The oscilloscope, type 10, is identical in all respects with type 7, except that it is fitted with a double-beam tube, enabling two phenomena to be examined simultaneously, using the same time base.

2. The instrument is fitted with a recurrent linear time base circuit of three valves, operating over a range from 5 to 250,000 c/s, permitting the continuous visual examination of repeating waveforms up to frequencies of the order of 3 to 5 Mc/s. The time base is of the hard valve type designed to give stability and positive synchronization at the highest frequencies without loading the work circuits under test. Provision is also included to enable photographic recording of transient traces by adapting the time base for single stroke operation.

3. Self-contained resistance-capacitance coupled amplifier circuits are included to provide either a single asymmetrical stage or a single stage symmetrical input and output amplifier. Alternately the two valves may be connected in cascade to provide a two stage asymmetrical amplifier to enable measurements to be made of voltages of the order of 10 mV and over. A 10 cm. graticule is provided. Seven valves in all are employed, four pentodes, a triode and two rectifiers.

10. As soon as the cathode of the triode V3 has travelled sufficiently negative to approach the potential present on the grid of that valve it will commence to pass current and a voltage drop will be present across the combined resistance R2 (variable) and R46. This will swing the suppressor grid of V5 negative causing the anode of V5 and, in consequence, the grid of V3 to travel positive. This action is cumulative and the condenser C therefore discharges rapidly through V3 until, when it becomes discharged, no further current flows through R2/R46 and the cycle repeats.

11. The value of R2 plus R46 has a lower limit set by R46 and is adjustable by R2. This value affects the amplitude of the triggering impulse present in the grid circuit of V5. Due to its presence in the discharge path it also modifies the flyback period. This control of R2 is designated TRIGGER.

12. The voltage developed across the condenser C before each successive discharge through V3 is dependent upon the extent by which the grid of that valve is maintained negative relative to its anode by the voltage drop across the variable resistance R4. Adjustment of the magnitude of this resistance, therefore, provides control of AMPLITUDE.

13. Synchronization of the time base is effected by injecting a fraction of the work voltage into the control grid of V5. The rate of charge of the condenser C depends upon the capacitance of C and the current flowing through V4. In the circuit diagram of fig. 2 the condenser C is represented by the bank of nine condensers C6 to C13 and C28, selected by the switch S1. This selection gives rough control whilst a progressive adjustment is provided in the form of a VELOCITY control potentiometer R43 varying the screen volts on the pentode charge valve V4.

14. The switch S1 is part of a control labelled CONDENSER, and it selects the various time base condensers in descending order of capacitance. In the last position only the circuital stray capacitances remain in the circuit. On the fastest two time base speeds, as imposed by the condenser C13 and the " strays," a negative signal is injected into the grid of the C.R.T. during the time base flyback in order to suppress the return trace during this period. In the same way, *via* R39 and R40 through the switch S3 a positive impulse of an amplitude which increases with frequency is applied to the same circuit so as to increase the brilliance with increase in speed without necessitating manual adjustment of the BRILLIANCE control R36.

Single stroke time base

15. For certain applications, however, it is far more convenient to operate the time base once only at a chosen time. Such conditions apply particularly to the investigation of transients. For this purpose it is essential that the time base sweep should be capable of initiation at the appropriate point in time, and a recurrent sweep would, in any case, introduce confusion of the final trace.

16. Referring to fig. 3, the injection into the grid of V5 of the voltage drop produced across R2–R46 when the condenser C becomes charged to a voltage sufficient to cause current to flow through the triode V3, allows the time base to become self-running. Thus, if arrangements are made to prevent this voltage from being applied to the pentode V5, by short-circuiting the grid of that valve with the switch S1, the time base will no longer repeat.

17. After switching ON, the voltage across C will gradually increase until it carries the cathode of V3 to a value sufficiently near the voltage drop across R4 for V3 to pass an anode current equal to that flowing through V4. Once this condition has been realized the voltage across C will remain constant at an equilibrium value which corresponds to slightly more than full screen deflection on the cathode ray tube.

18. All that is now needed in order to produce a single stroke sweep is to discharge the condenser C very rapidly and it will then charge up to the equilibrium value again at a speed which depends upon the setting of the VELOCITY control R43 and the value of the condenser C. This rapid discharge of the condenser C, prior to the effective time base sweep, can be achieved very simply by injecting a negative pulse to the synchronizing terminal.

19. In order to reduce the required injection voltage to a minimum, a further switch S2 is included in the circuit. This short-circuits the resistance-capacitance filter which is normally included in the synchronizing circuit. The contacts of the switches S1 and S2 are mounted on a single switch wafer and this is, in turn, mounted in such a way that it can be operated automatically when the trigger control is rotated to its limit of travel in an anti-clockwise direction.

20. It will be appreciated that the negative pulse applied to the synchronizing terminal SYN causes anode current in V5 to cease, thus permitting the grid of V3 to assume the voltage of the H.T. positive line. This brings about almost complete discharge of the condenser C.

21. For most purposes, however, it is essential that the single stroke sweep should occur as quickly as possible after the application of the control pulse. It will be realized that C cannot commence to charge and, thus, produce the single stroke, until anode current has again been restored in the valve V5. The negative pulse applied to the SYN terminal should, therefore, be of only sufficient duration to discharge C fully and the grid of V5 must then return to earth in order to allow the sweep to occur. A condenser of suitable value is, to allow for this, connected externally between the SYN terminal and the negative supply providing the control pulse.

Amplifiers

22. The amplifier pentode valves V6 and V7 are utilized in a conventional resistance-capacitance coupled circuit. Inductance compensation by the coils L3 and L4 is introduced for the wide band frequency range. The valves, type V.T.60A, have a large dissipation and high slope and this provides the frequency range and voltage swing required.

23. The amplifier circuits are associated with a single control switch providing five different circuit combinations. The single control governs switch contacts of S4, S5, S6 and S7. The five positions are labelled " PLATES–D.C., " PLATES–A.C.", " AMPLIFIERS, Y1, Y2," " AMPLIFIER, 2Y1 " and " AMPLIFIER, 2HFY1."

24. When the switch is in the " PLATES–D.C." position the condensers C39 and C38, which normally isolate the Y1 and Y2 deflector plates from the terminals Y1 and Y2, are short-circuited. A direct connexion is thus provided which enables measurements to be made in either Y1 or Y2 with both direct voltages and alternating voltages of low periodicity, provided the voltages to be measured are of sufficient amplitude to produce an adequate deflection. It is assumed that the low potential end of the voltage source is applied to the EARTH (E) terminal.

25. In addition to the direct connection to the terminals, each plate is also connected through a resistance R30 for Y1 and R31 for Y2. These resistances are of a value in the region of 3 megohms and it is important to remember this condition when making quantitative measurements from D.C. sources, more particularly if the source has impedance comparable with that value. These considerations will be dealt with more fully in the operational portion of this chapter.

26. When the switch is at " PLATES–A.C.", a coupling condenser C38 or C39 is interposed between the terminals Y1 and Y2 and the corresponding plates. Observations on A.C. voltages of the same order as the D.C. voltages available (para. 24–25) may be made and the beam deflection represents peak to peak voltage and not R.M.S.

27. At the position of " AMPLIFIERS–Y1, Y2," the Y1 and Y2 plates are each connected to the output of the single stage amplifier. Input to the Y1 amplifier is then made *via* the terminal A1. Likewise the signal from the Y2 plate is made *via* A2. Work voltage is therefore applied symmetrically across A1 and A2. The gain of the two amplifiers is adjusted independently by means of R18 for A1 and R25 for A2. The maximum gain from each in this switch position is of the order of 28 times. The time base is synchronized to whichever work voltage may be required by connecting either of the terminals Y1 or Y2 to the SYN terminal.

28. By changing the switch to the position " AMPLIFIER–2Y1," the valve which was previously employed between A2 and Y2 is transferred to the Y1 circuit and connected in cascade with the other amplifying valve to provide a two-stage high gain amplifier between

terminal A1 and terminal Y1. The Y2 plate is connected *via* the isolating condenser C38 to the terminal Y2 and should be externally joined to the Earth terminal.

29. In this switch position both the GAIN controls R18 for V6 and R25 for V7 are applicable to the same beam and a maximum gain of the order of 900 times is available. To synchronize the time base Y1 is connected to SYN terminal.

30. The general circuit arrangement is basically the same as the foregoing when the switch is in position 5 or " AMPLIFIER, 2HFY1," that is to say, two stages in cascade, apply between terminals A1 and Y1 whilst the Y2 plate may be used without amplification. The anode loads of V6 and V7 are, however, modified so that the useful band-width is extended to approximately 2 Mc/s. The gain is reduced to 106 times, but this drop in gain does not preclude the examination of R.F. signals of relatively small amplitude, the sensitivity being still sufficient for this purpose.

31. To synchronize the time base the SYN terminal is connected to either Y1 or Y2. The maximum time base available is above 250 kc/s and it is, accordingly, possible to carry out wave-form examinations on signals of frequencies of from 2 to 5 Mc/s.

32. It is possible to use the AMPLIFIER 2HFY1 position of the amplifier as an aperiodic R.F. amplifier in investigations, and when necessary, by re-arranging connections. In this event a rectifier, which may be either of the thermionic or of the barrier-layer type, is inserted in the Y1 sockets provided.

Y2 Attenuator

33. An attenuator device is incorporated in the circuit to be used at mains and audio frequencies to reduce the input in fixed ratios of ×2, ×4 and ×8. This attenuator is associated with the resistance potentiometer of R48, R49, R50 and R51. The device is not frequency compensated. The movable arm or link is connected to the Y2 plate and the full resistance end to EARTH through the condenser C34. The attenuator application will be more fully dealt with under the operational notes of this chapter.

CONSTRUCTIONAL DETAILS

34. The illustration of fig. 1 shows the general arrangement of the oscilloscope with front panel controls and terminals. All the operational controls and terminals are mounted on the front panel of the instrument and, wherever possible, tandem controls have been used. The oscilloscope consists of two parts, comprising the instrument proper and its outer case. The latter holds the carrying handle and is fitted with ventilating louvres and a detachable rear panel. The instrument slides into the case and is secured thereto by means of two 2 B.A. rear fixing screws, the edge of the front panel locating the open end of the case.

35. A top view of the oscilloscope, type 7, arranged for the V.C.R.138, with cover removed is given in fig. 4. The instrument is built on a chassis with the front panel secured to one end and the C.R.T. supporting bulkhead a short distance from the opposite end. Beyond the bulkhead is located the mains transformer T1 and rear connection panel. A mu-metal shield is mounted, at one end, on a bracket fixed to the bulkhead and, at the opposite end, to a cylindrical tube locating collar fixed to the front panel. Extra shielding is obtained by means of a mu-metal foil wrapped round the tube neck. The oscilloscope, type 10, differs slightly as regards the C.R.T. holder, mu-metal screen and coil assemblies and other tube fixings for the V.C.R.518 or C.R.T.09J double beam tubes.

36. The C.R.T. is supported at the rear by a tube holder mounted on a plate fitted with a central spindle. The spindle is located in a bush on a metal adaptor flexibly mounted to the bulkhead by fixing through rubber bushes. The central spindle is fitted with a locking screw which can be loosened to enable the C.R.T. to be rotated and secured in the required position. The C.R.T. is supported in the front by the cylindrical rubber escutchen which fills the gap existing on the front panel between the sides of the tube locating collar and the tube bulb itself.

37. The 10 cm. graticule fits into a camera guide (*see* fig. 1) and can be inserted irrespective of whether a viewing hood is used or not. It is only removed when the camera is inserted. The correct axial position of the tube is with the crown of its screen set flush with

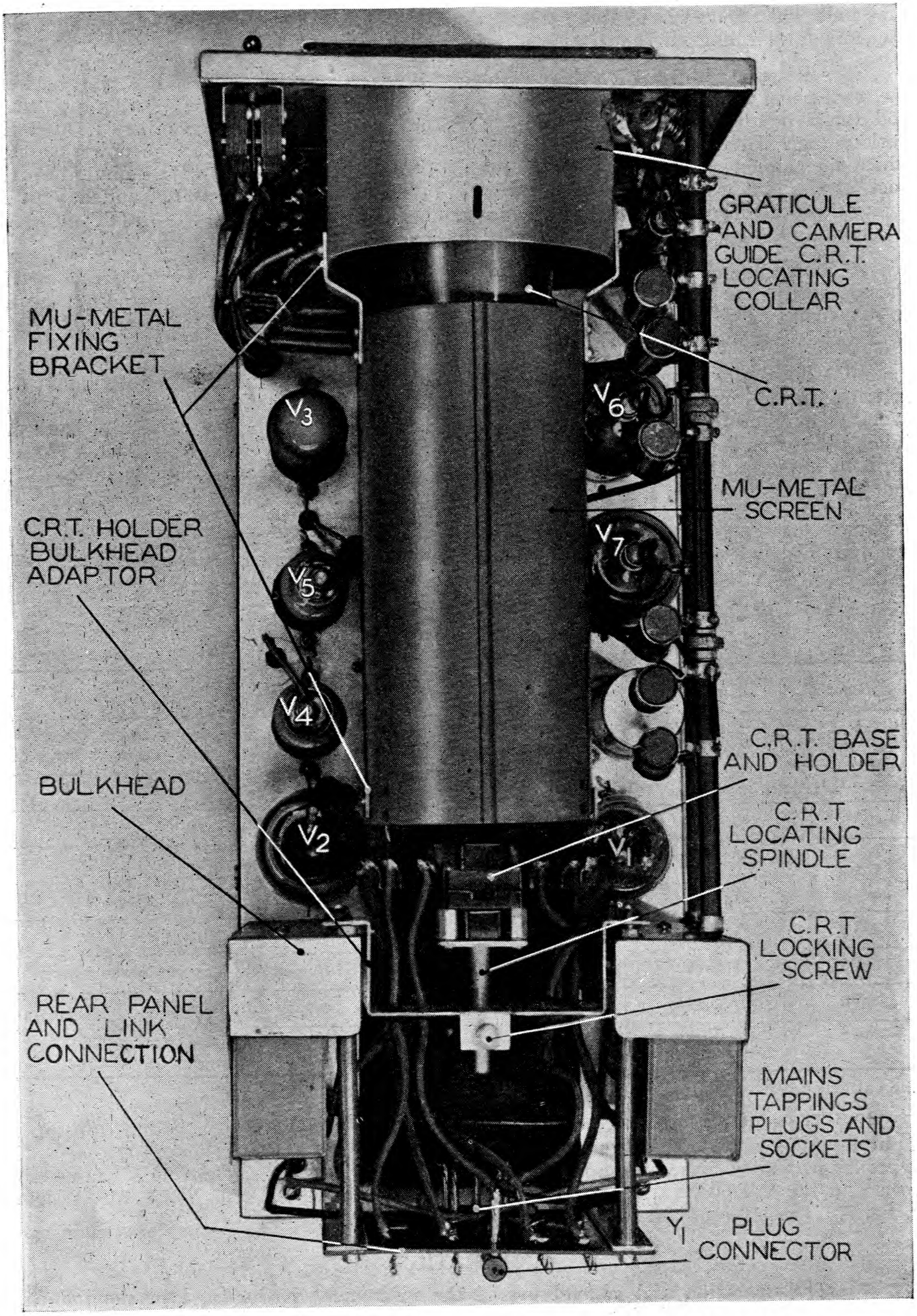

Fig. 4.—Chassis top deck view, cover removed with V.C. R.138.

the surface of the front panel so that the transparent 10 cm. scale rests lightly against the tube bulb when placed in position, the horizontal sweep of the time base being parallel with the horizontal ruling on the graticule.

38. Referring to fig. 4 it will be seen that, on the two sides of the C.R.T. and between the front panel and the bulkhead, are located the valves. An illustration showing the C.R.T. and shield removed is given in fig. 5. Underneath the mu-metal screen are located the various high voltage electrolytic smoothing condensers of the low voltage power supply, whilst the canned paper condensers for the high voltage C.R.T. supply are mounted on the back of the bulkhead above the transformer T1 which is chassis mounted and has all its connections taken to a panel located on the underside of the chassis as shown (TP) in fig. 6. A diagram showing the numbered tags of this panel is shown in fig. 8 (b).

39. The majority of the instrument connections are made on the underside of the chassis through the centre of which is located the amplifier switch (S4, S5, S6 and S7) serving to re-arrange the various circuits to the front panel terminals and tube electrodes. Parts of the chassis underside are subdivided for screening purposes.

40. The mains connection is made *via* a lead permanently fixed to the instrument and entering through a rubber grommet on the left-hand side of the chassis close to the front panel. The mains switch and a pilot lamp (PL1) are fitted on the top corners of the front panel, the switch being to the right and PL1 to the left (fig. 1). A two-poles switch (S8 and S9) is mounted on the TRIGGER control and is used solely for single-stroke facilities of the time base.

VALVES AND POWER SUPPLIES

41. The following Table A gives a list of the valves used in this apparatus :—

TABLE A

VALVE SCHEDULE

Annot.	*A.M. Type*	*Stores Ref.*	*Function*
C.R.T.	V.C.R.138 or V.C.R.518	10E/407 10E/767	High vacuum oscilloscope, single beam ,, ,, ,, double beam
V1	5Z4G	10E/598	Full-wave rectifier
V2	V.U.120	10E/121	Half-wave rectifier
V3	6J5G or	110E/68	I.H. triode discharger (time base)
	V.R.67	10E/11448	
V4	V.R.56	10E/11402	I.H.H.F. pentode charger
V5	V.R.56	10E/11402	I.H.H.F. pentode aux. discharge valve
V6	V.T.60A	110E/8	I.H. pentode amplifier
V7	V.T.60A	110E/8	I.H. pentode amplifier

The cathode ray tube and valve bases are shown in fig. 12.

42. The power supplies are derived from the single-phase A.C. mains and transformer input tappings provide for voltages of 110, and 200 to 250 volts at 40 to 100 c/s. The approximate power consumption for the seven valves is 120 watts. The C.R.T. draws 1,100 volts and the V.T.60A valves 500 volts maximum. The C.R.T. type V.C.R.138 is shown in fig. 7. The screen diameter is 88 mm., overall length 332 mm.

OPERATION

43. The operation and general use of the instrument is discussed in the following paragraphs. Because difficulties are only likely to be encountered when endeavouring to apply the instrument to the best advantage to a specific test, it has been thought preferable

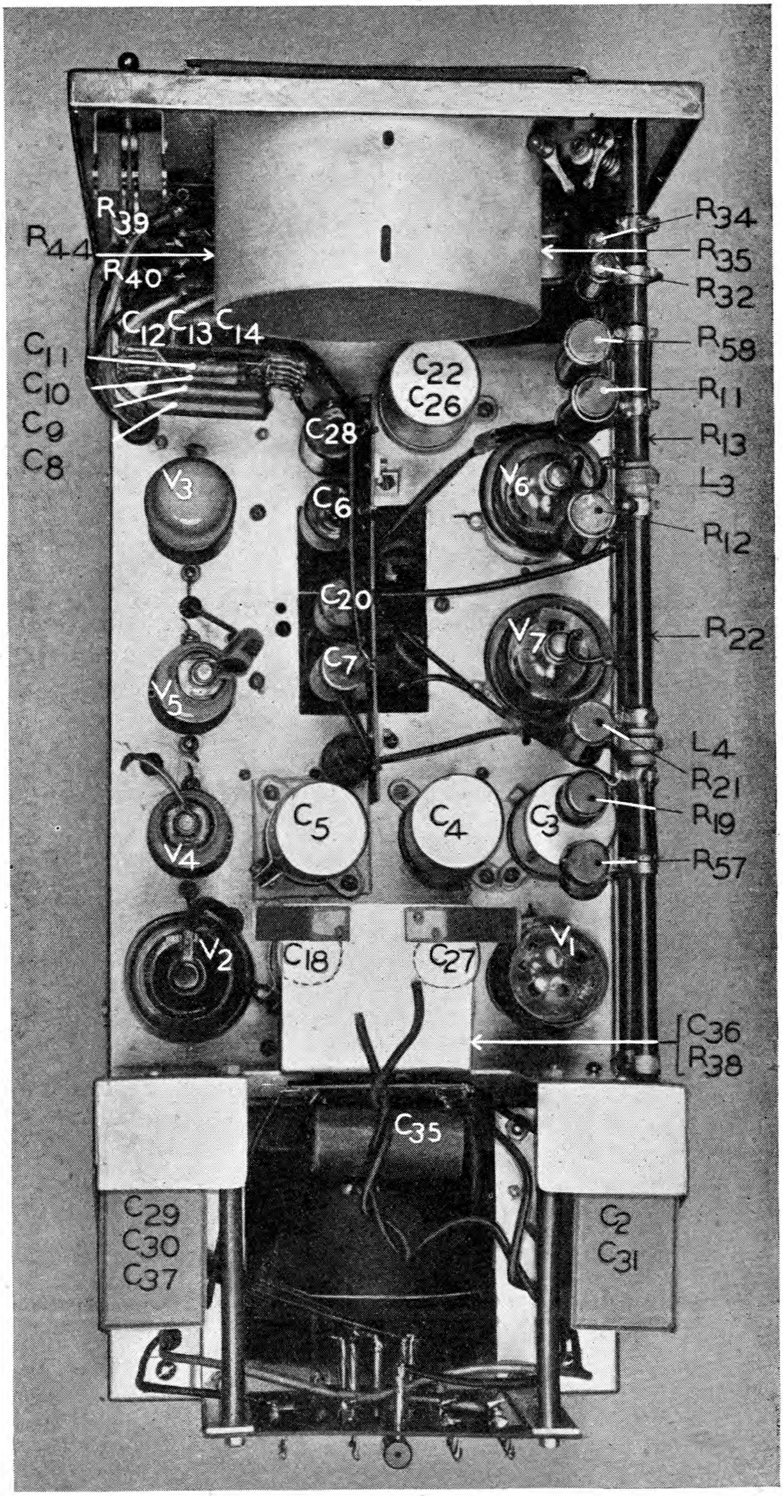

Fig. 5.—Chassis top deck view, C.R.T. removed.

to cover all the likely connections met in the practical use of the instrument under the heading "General Operation." These instructions are designed to follow the normal operating sequence, and the consideration covering all likely cases are thus discussed as a matter of course as and when they apply to any given control, terminal or connection. When deemed necessary or useful, repetitions have been made.

44. *Rear plate.*—A detachable plate secured by small instrument screws is located towards the top at the rear of the case. Removal of this plate gives access to a bakelite panel on which are mounted (*a*) the mains voltage selector, (*b*) the tube connecting links, of which the one corresponding to Y1 is formed by three sockets in a line and the 2-pin shorting plug, and (*c*) two cylindrical fuse holders containing a fuse for each H.T. supply. The 2-pin shorting plug of (*b*) is normally connected across the top and central sockets. Refer to illustration of rear chassis shown in fig. 9.

45. *Mains supply.*—Before the instrument is switched on, it is most important that the mains voltage sector be set to the position appropriate to the mains supply available. A mains switch and pilot lamp are located on the front panel.

46. *Mu-metal shield.*—The cylindrical mu-metal shield is provided to surround the tube as a precaution against external magnetic fields and those due to the instrument itself. A further screening is provided by the aid of a length of mu-metal foil wrapped round the lower end of the tube neck. The shield is fixed by means of small brackets to the front panel cylindrical tube guide, and, in the same manner, to the rear bulkhead. The tube can be placed in position without removing this shield. The necessity for its removal should therefore never arise in practice, even when servicing the instrument. Should this be attempted for any reason, or in any other circumstances in which the chassis is being handled, care must be taken to avoid the possibility of a sharp knock on the shield, as this is liable to alter its magnetic characteristics.

47.—*Earth.*—The EARTH terminal serves essentially to connect to the oscillograph the return or "earthy" side (low potential end) of the external circuits, or apparatus, with which the instrument is being operated. The oscillograph will generally operate satisfactorily without being connected to a true earth point, although whenever it is convenient, such a connection should be made. This applies particularly when the instrument is operating permanently on a given bench, or when the instrument is installed on a rack. The independent earth connection is particularly advantageous when the instrument is being used in a strong interference field or when the amplifiers are being used at high gain. In general, all effects due to mains pick-up can be avoided or reduced by the use of a good earth.

Tube controls

48. The following controls affect the C.R.T. :—

(i) Y SHIFT.—Two are provided, one for each Y plate, and these enable the spot independently to be positioned vertically on the tube screen. Should the single beam on type 7, or on type 102 produce no visible trace, the concentrically-mounted Y SHIFT control knobs should be set to the mid-point of their travel. This will ensure that the beam is not deflected beyond the limits of the screen diameter whilst the other adjustments are being made.

(ii) X SHIFT.—Provides the means of positioning the spot or trace in the horizontal direction, and should be adjusted in the same manner. *See* para. 71 for the use of these controls with type 7.

(iii) BRILLIANCE.—This control should be advanced gradually in a clockwise direction to show up the spot if no trace is visible notwithstanding the central positioning of the SHIFTS. The BRILLIANCE control varies the negative bias applied to the grid of the tube and should be set always at a position that provides just sufficient brightness for the work in hand.

(iv) FOCUS.—This control may then be adjusted to its optimum value. It operates by varying the voltage on the 2nd anode of the cathode ray tube.

NOTE.—Slight readjustment of both the FOCUS and BRILLIANCE controls may be found desirable when the instrument is actually being used, as at high writing speeds greater beam current, and therefore a more advanced setting of the latter control, is necessary in order to produce sufficient luminosity of the trace.

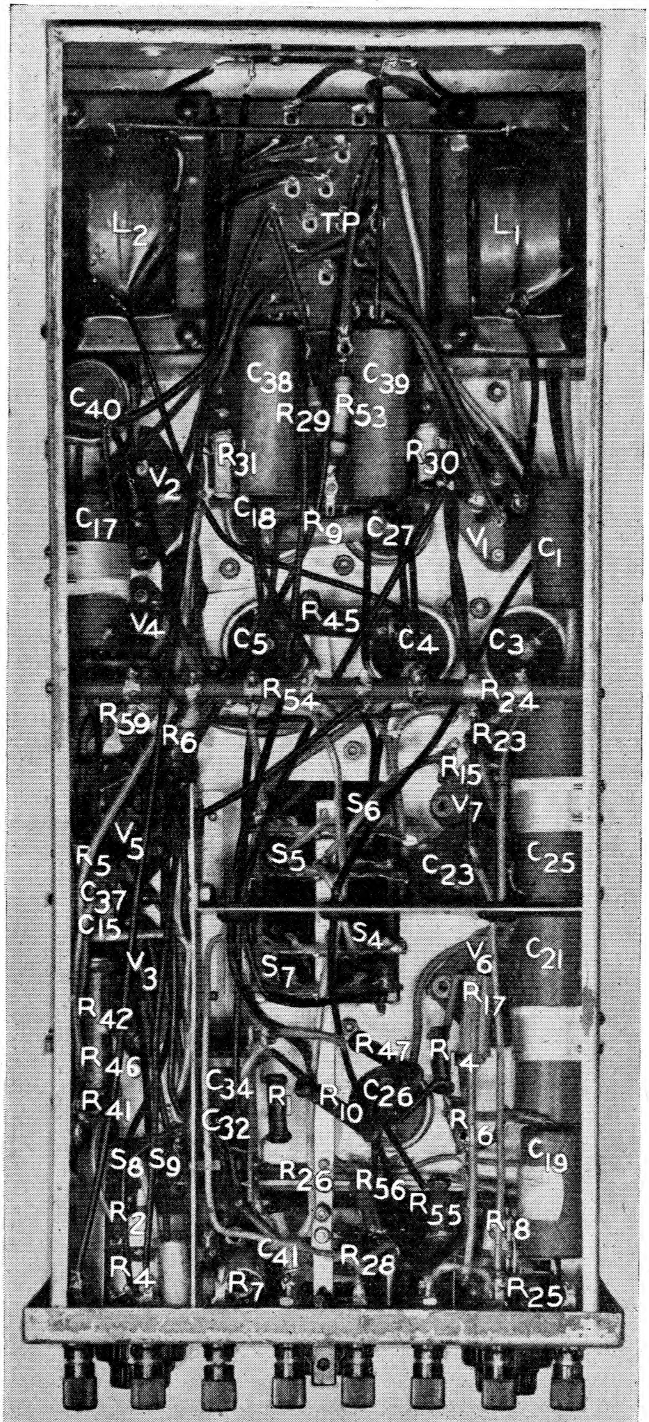

Fig. 6.—Chassis under-side view.

Fig. 7.—C.R.T. type V.C.R.138.

Horizontal or X axis controls

49. All the controls and circuit conditions which affect the operation of the cathode ray tube in the *horizontal* direction will be discussed in the following paragraphs 50 to 69.

50. X SHIFT.—The X SHIFT control provides the means of placing the trace in any required position on the horizontal axis. The X shift voltage is applied to the X2 deflector plate of the cathode ray tube, whilst the time base (or external X deflection, if applied *via* the X1 terminal on the front panel) is applied to the X1 deflector plate.

51. The X shift may, therefore, be used irrespective of the nature of the X-axis signal whether it be A.C. or D.C. This arrangement is made possible by the adoption of an electrode construction in the tube which gives correction for trapezium distortion and allows the use of an asymmetric time base which thus frees one of the X plates for shift purposes only.

52. X1 *terminal*.—The X1 plate is available for external use when the condenser switch is rotated fully anti-clockwise and the time base thus rendered inoperative. In this position the X1 plate is entirely disconnected from all the internal circuits but remains applied to the X1 terminal onthe front panel. This permits injection of any external X deflection voltage and enables phase shift and other composite X- and Y-axis tests to be conducted. With the condenser switch in any other position, that is, with the time base working, the time base voltage is present at the X1 terminal and may be used externally. An instance of this latter application is the use of the time base for frequency modulation with the R.F. alignment oscillator.

53. The use of this terminal with the time base inoperative is particularly indicated for D.C. voltage measurements, not only because of the high input impedance, but also because the independent shift on the X2 plate enables the spot to be placed at such a position on the screen as to make use of its full diameter when unidirectional (D.C.) voltages are applied. Unidirectional voltages up to 250 may be measured. When accurate quantitative results are required it is advisible to calibrate each axis separately, as the sensitivity in the X-axis is less than that of the Y-axis.

54. As the X1 terminal has no direct connection to earth within the instrument when the time base is switched off, no error is introduced by the use of a relatively high resistance potentiometer should it be desired to increase the range of direct voltage which can be measured. It is essential that an external path for direct current should exist between the X1 and EARTH terminals when an outside signal is being applied, or the trace will not represent the true conditions. Such an external path can be provided by connecting across the X1 and EARTH terminals a high resistance of the order 1–3 megohms maximum. When the time base is inoperative and no voltage is applied to the X1 terminal, as in the case of the photography of slow transients, the EARTH and X1 terminals should be short-circuited.

55. When it is necessary to measure large direct voltages, these can be applied in the X direction, using an external potentiometer to extend the range. This step is not necessary with A.C., as voltages corresponding to more than normal full screen X-axis deflection may be measured or investigated in the Y-axis by use of the Y2 input potentiometer.

56. *Time base controls*.—The time base incorporated in this instrument is of the hard valve type. On this instrument the controls affecting the time base are engraved CONDENSER, VELOCITY, AMPLITUDE, TRIGGER AND SYN. (representing SYNCHRONIZATION).

57. The CONDENSER control takes the form of a switch which, in its fully anti-clockwise position, disconnects the time base from the X1 deflector plate. A spark internal to the instrument may be expected when moving the control to this position. Clockwise rotation of the CONDENSER control selects the various time base condensers in descending order of capacitance, until at the last position only the " strays " are left in circuit. This switch therefore provides a coarse control of time base frequency. Full clockwise rotation produces the highest time base speed, whilst the last position but one in the anti-clockwise direction produces the slowest time base speed.

58. On the fastest two ranges a negative signal is injected into the grid circuit of the cathode ray tube during the time base flyback in order to suppress the return trace during this period. In the same way a positive impulse of an amplitude which increases with frequency is applied to the same circuit so as to increase the brilliance with increase in speed without necessitating manual adjustment of the BRILLIANCE control R36 for this purpose.

59. The VELOCITY control R43 provides the means of obtaining a continuous variation of time base frequency over the entire range. The adjustment is sufficient to ensure frequency overlap between the ranges covered by the adjacent condenser switch position. The VELOCITY control takes the form of a voltage control in the screen circuit of the time base condenser charge valve. Clockwise rotation of the control increases the anode current of the charging valve, and therefore increases the time base speed.

60. The AMPLITUDE control R4 provides maximum amplitude when set fully clockwise, and its action will be appreciated when reference is made to the description of the time base circuit. This control enables the length of the X-axis deflection produced by the time base to be adjusted.

61. The TRIGGER CONTROL R2 is mounted concentrically with the AMPLITUDE, and the amount of trigger increases with clockwise rotation. The TRIGGER resistance controls the degree of coupling between the discharge and auxiliary discharge valves in the time base and varies the flyback time. This adjustment is not critical and, in general, the control should be rotated as far anti-clockwise as is consistent with regular operation of the time base. The fact that the TRIGGER control varies the flyback time may be made use of at high sweep frequencies, when it will be found to provide a smooth, fine adjustment of frequency.

62. The minimum trigger control setting is consistent with maximum linearity of time base traverse. In the fully anti-clockwise position this control operates the trigger switch.

63. The TRIGGER SWITCH serves a double purpose. In the off position it prevents recurrence of the time base, a fact which is used for single stroke operation of the time base itself. In the on position, and in conjunction with the consequent operation of the trigger control, it starts off the time base on a recurrent traverse. This item is comprised by a double switch S8 and S9 mounted on an extension spindle of the trigger control. In the off position, that is, fully anti-clockwise rotation of the trigger control, switch S9 serves to short-circuit the fixed resistance R5 in the grid of the auxiliary discharge valve and the other (S8) to short-circuit the small series condenser C16 in the synchronising input control network.

64. The synchronizing control engraved SYN is mounted concentrically with the X SHIFT, and controls the attenuation between the SYN terminal and that electrode of the time base auxiliary discharge valve by which synchronism is achieved. Connection to the synchronizing circuit at a separate terminal allows of flexibility in operation as the time base may be synchronized with any desired signal, such as the work voltage, mains frequency, or any independent or master frequency, Clockwise rotation increases the applied signal and the control should always be kept as far anti-clockwise as possible in order to avoid introducing distortion of the trace due to velocity modulation of the time base.

65. The procedure which should be adopted is to set the SYN. control in its fully anti-clockwise position and adjust the velocity control until the time base is operating as nearly as possible at the frequency to which synchronism is required. Slight rotation of the SYN. control in a clockwise direction will then suffice to lock the time base.

66. The injection of excessive synchronizing voltage causes the time base traverse to shorten and will also tend to produce non-linear and generally erratic behaviour of the time base. This is particularly the case if for any reason the time base is operated at a frequency higher than that of the work voltage. Consequently, the most satisfactory results are obtained at the lowest SYN. control setting which is consistent with stable synchronism.

67. The synchronism attainable with the time base is of a positive nature, and is characterised by two other features of importance. Firstly, the synchronizing circuit is isolated from the time base by a valve, and in consequence does not inject saw-tooth time base voltages into the work source, whilst secondly, the input impedance of this circuit is high, and remains sensibly constant irrespective of the setting of the SYN. control.

68. Where it is desired to synchronize the time base from the incoming work voltage applied to the A1 or A2 terminals, that is, when an amplifier is being used, the SYN. terminal should always be connected to the output of the appropriate amplifier, and not to the input, that is, the SYN. terminal should be connected to the corresponding Y1 or Y2 terminal. This applies particularly under high gain conditions, as in these circumstances the input may be so small as to be quite incapable of affording satisfactory synchronism.

69. A link is provided, connected to the SYN. terminal, which can be swung on to either the Y1 or CAL. terminals situated at either side for synchronizing either to the work circuit or to the A.C. mains frequency in the manner prescribed. It is understood in the former case that the circuit to which the time base is to be synchronized is applied to the A1 or Y1 terminal.

Vertical or Y-axis controls

70. The controls and circuit conditions which affect the operation of the cathode ray tube in the vertical direction will be discussed in the following paragraphs 70 to 102. It will be found that the Y-axis controls are concentric, in particular the Y1 and Y2 shifts and the A1 and A2 gain.

71. *Y1 and Y2 shifts.*—Two Y shift controls are provided operating respectively on the Y1 and Y2 deflector plates. With the single beam tube fitted to type 7, the two potentiometers should be manipulated as one. Their relative position is set in a manner to provide a balanced Y shift which reduces astigmatism and also, to some extent, deflection defocussing. To secure this it is sufficient to rotate the controls to the limit of their travel in one direction and the two knobs are interlocked by means of a countersunk screw. *See* Appendix I for use with double beam tubes.

72. Another method of doing this is described in the paragraph 76 on " Position 1—plates D.C." In practice, the positions of the respective controls in relation to the fixing pin have been set to ensure the best condition to avoid the effects mentioned above, and it will be found that these controls are permanently locked in the manner stated. It may be found that, as a result of the setting obtained it may not be possible to adjust the shifts to the same extent as when set independently.

73. *Y1 and Y2 terminals.*—These two terminals are connected directly to their respective deflector plates with the amplifier switch in the first position (" Plates—D.C.") and are connected to the deflector plates through the medium of isolating condensers in every other position of the amplifier switch. In the fourth and fifth positions of this switch the Y1 terminal is also connected to the output of the two amplifier valves in cascade should it be desired to use these externally. In the third position the Y1 and Y2 terminals are connected to the outputs of the A1 and A2 amplifiers respectively.

74. *A1 and A2 terminals.*—In positions 3, 4 and 5 of the amplifier switch, terminal A1 is connected through an isolating condenser to the grid of the amplifier applied to the Y1 deflector plate. In the third position terminal A2 is connected through a condenser to the input of that amplifier connected with the Y2 plate ; in the first, second, fourth and fifth positions the A2 terminal is inoperative.

Amplifier switch

75. The amplifier switch has been designed to provide a single control by which the instrument can be set to any required operating condition. The switch provides five different circuit combinations. In the information given below the anti-clockwise limit of rotation of the switch is regarded as position 1, and the limit of clockwise travel as position 5.

76. *Position 1, " plates–D.C."*—With the switch in this position the condensers isolating the Y1 and Y2 deflector plates from the terminals carrying these markings are short-circuited. A direct connection is thus provided which enables measurements to be made on either Y1 or Y2 with both direct voltages and alternating voltages of low periodicity, provided the voltages to be measured are of sufficient amplitude to produce an adequate deflection. It is assumed that the low potential end of the voltage source is applied to the EARTH terminal. In addition to direct connection to the terminals, each plate is also connected through the medium of a 3-megohm resistance to its appropriate shift potentiometer, and it is important to remember this condition when making quantitative measurements from D.C. sources. This applies particularly when the source has an impedance comparable with 3 megohms.

77. When the input D.C. source is of low resistance its effect is, virtually, to short-circuit the shift voltage on the Y1 and/or Y2 deflector plate used. The corresponding SHIFT control is therefore inoperative. However, for D.C. measurements it is in any case advisable to operate the plates with no shift potential. This condition may be arrived at by connecting the Y1 and Y2 terminals to earth and setting the two Y shift potentiometers independently to the positions at which there is no displacement of the beams when the amplifier switch is moved alternately to positions 1 and 2.

78. When applying an asymmetric work voltage in the Y direction it can be connected to either Y1 or Y2. The resulting deflection when applied to one plate is spatially 180° out of phase when applied to the other plate. The plate which is inoperative should be joined to earth by the EARTH terminal of the instrument *via* a large condenser. The shift voltage which will then be effective is the one operating on this plate.

79. Full screen deflection can be used for testing unidirectional or D.C. voltages if the working Y plate has zero shift, and shift, if required, is applied by means of the other Y plate.

80. For other waves of low periodicity, as would be applied in this position, a maximum equivalent to 40 v. R.M.S. is possible, but in this case the peak to peak deflection covers the whole screen (at 0·45 v. R.M.S. per mm.).

81. *Position 2, "plates–A.C."*—(a) *External signals on Y1 and/or Y2.* A coupling condenser is between the Y1 and Y2 terminals and the appropriate plates with the switch at this setting. With the instrument set in this way all the usual voltage observations may be made on A.C. over the same voltage values as specified for D.C. (position 1). The deflection obtained will represent the peak to peak voltage and not its R.M.S. value. In this switch position only alternating voltages down to a frequency of about 20 c/s can be tested ; on the other hand the input capacitance of the instrument provides the first factor limiting the highest frequency which can be investigated in this position.

82. The work voltage can be applied either to the Y1 or Y2 terminal. There is a 180° phase shift between the trace obtained on each. In the case of A.C. work voltage, to whichever deflector plate it is applied the other should be joined directly to the EARTH terminal. The isolating condenser in the deflector plate leads inside the instrument will avoid the shift voltage being short-circuited in the A.C. position of the amplifier switch.

83. For A.C. voltages greater than 100 v. R.M.S. the Y2 attenuator should be used. When it is desired to synchronize the time base to either the signal applied to Y1 or that applied to Y2, the terminal marked SYN. should be connected to the corresponding terminal.

84. (*b*) *External signals on X and Y.*—When it is desired to apply two separate external signals of the same frequency in the X and Y directions, as in the case of phase shift tests, this may be done by stopping the time base and following the instructions given later (para. 88) covering the case of an external voltage applied in the X direction.

85. *Position 3, "amplifier—Y1Y2."*—(*a*) *Normal setting—amplifiers on Y1 and Y2.*—In this central position of the switch the Y1 and Y2 deflector plates are each connected to the output of the single stage amplifier, the input to the Y1 amplifier being made *via* terminal A1. Likewise, the signal for the Y2 plate is made *via* A2. The work voltage is accordingly applied symmetrically across A1 and A2. Although the gains of the two amplifiers may be controlled independently they must be adjusted to give the same deflection for the same input voltage on A1 and A2. The maximum gain from each in this switch position is of the order of 28 times.

86. The maximum deflection obtainable in this position without distortion covers well over the full screen diameter. The time base is synchronized to either work voltage by connecting the SYN. terminal either to Y1 or Y2. This amplifier switch position provides balanced amplified deflection from any signal source which is balanced about earth, a condition which reduces deflection defocussing and residual astigmatism in the tube.

87. Another advantage of this method of operation is in the observation of voltages across two points which are both of a high impedance with reference to earth and cannot therefore be applied without provoking distortions both in amplitude and phase, chiefly of the higher components of the wave, brought about by the different capacitances to earth of the usual input terminals A1 and EARTH used with normal asymmetrical working.

88. (*b*) *Abnormal setting—amplifiers applied to X and Y.*—It may happen that for some applications it is necessary to apply an external signal to both the X- and Y-axes, and that both these signals have to be amplified, using the amplifiers within the instrument. When two separate external signals of the same frequency are applied in the X and Y direction, as in the case of phase shift tests, it will entail connecting the Y2 amplifier to the X1 plate by rearranging the rear panel connections, as discussed later.

89. The time base, which is not used when an external voltage is applied to the X-axis, is made inoperative by rotating the CONDENSER control to the fully anti-clockwise position. This frees the X1 deflector plate, which remains directly connected to the X1 terminal.

90. To apply the two signals to the X- and Y-axes, the X1 tag is then connected to the lower Y2 tag on the rear panel, the link removed from the Y2 plate and the latter earthed. A one to three megohm resistance must be joined between the X1 and EARTH terminals. Any input signal applied at A2 will then be present amplified at the X1 terminal, and thus produce the X deflection on the tube, the other signal being applied to the A1 terminal.

91. *Position 4, "amplifier-2Y1."*—By changing the switch to this position the valve which was previously employed between A2 and Y2 is transferred to the Y1 circuit and connected, in cascade, with the other amplifying valve to provide a two-stage high gain amplifier between terminal A1 and terminal Y1. The Y2 plate is connected, *via* an isolating condenser, to the terminal of the same designation, and should be joined to the EARTH terminal.

92. With this switch position both the amplifier gain controls are, of course, applicable to the same beam, and a maximum gain of the order of 900 times is available. Also the maximum deflection obtainable in this position without distortion covers well over the full screen diameter. It must be appreciated that, with gains of the order mentioned, the greatest care is necessary in connection with the input wiring in order to avoid excessive hum pick-up. To synchronize the time base as usual, connect SYN. to Y1. The procedure with separate external signals on the X- and Y-axes has already been given.

93. *Position 5, "Amplifier–2HFY1."*—The general circuit arrangement is fundamentally the same with this switch position as in position 4. That is to say, two stages, in cascade, apply between A1 and Y1, whilst the Y2 plate may be employed without amplification. The anode loads of the amplifiers are, however, modified so that the useful bandwidth is extended to approximately 2 megacycles. The gain obtainable is 106. This results in a corresponding drop in gain, but the sensitivity is still sufficiently great to enable radio frequency signals of relatively small amplitude to be investigated.

94. On account of the high maximum time base speed available (above 250 kc/s.), it is possible to carry out wave-form examination on signals having frequencies of 2 to 5 Mc/s. To synchronize the time base, connect SYN. to either Y1 or Y2. The maximum deflection obtainable, without overload, with the amplifiers in this position is almost full scale. The procedure with separate external signals on the X- and Y-axes has already been given.

95. It is possible to use the 2HFY1 position of the amplifier as an aperiodic H.F. amplifier in high frequency investigations and when necessary, by re-arranging the rear panel connections, to interpose a rectifier for detecting the low frequency envelope or modulation, before application to the tube deflector plates. The detector can be of the thermionic or barrier-layer type, inserted in the Y1 sockets provided.

Amplifier gain controls (A1 and A2)

96. These two concentrically mounted controls affect the gain of the two amplifier valves independently. With the amplifier switch in the third position the foremost knob is that controlling the amplifier feeding the Y1 deflector plate. In the case of the fourth and fifth positions, both knobs affect the gain to the Y1 deflector plate.

97. Any signal of such an amplitude as to require a gain of less than two times to prevent over-sweeping of the screen of the cathode ray tube is, necessarily, sufficiently large to give a serviceable image with no amplifiers at all (position 2), and by taking advantage of the fact it has been possible to adopt a form of gain control having no undesirable effect upon the frequency response of the amplifiers. As a result of this, not only is there the usual higher limit to the voltage amplitude than can be applied to the amplifier input without overload, but the GAIN control is not designed to reduce the output deflection to zero or thereabouts with input signals of sufficient amplitude to provide half-screen deflection without amplification.

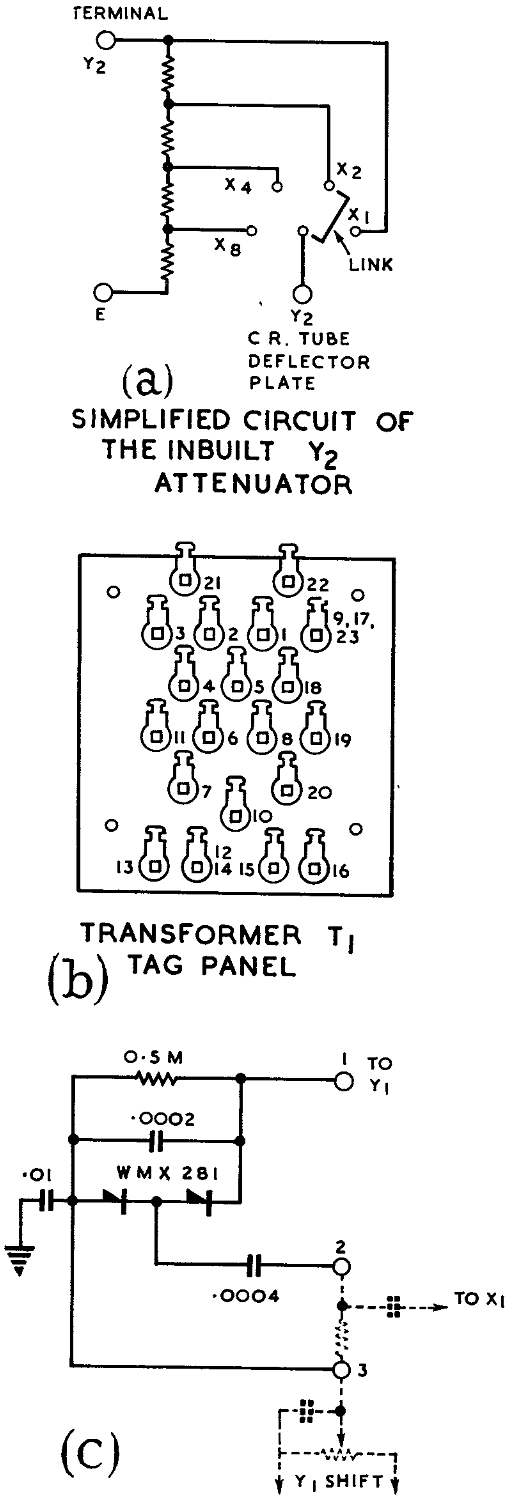

Fig. 8.—Circuit details.

98. The gain controls are always effective independently for each amplifier valve, irrespective of the position of the amplifier switch, and care should be taken in their adjustment to avoid overloading of either stage in the cascaded positions 2Y1 and ZHFY1. The maximum gain control setting which can be applied, in any given case, without causing overload, is readily determined by trial, the setting chosen being, preferably, as much as possible below the point at which distortion appears on the trace. It is better to operate the first amplifier at near its maximum gain without overloading the second amplifier, which is adjusted to the required level.

Y2 attenuator

99. This device is located on the small multi-socket panel at the top of the front panel escutcheon. The two lower sockets, into which is fitted a special plug, are intended solely for the deflector coils ; the spacing of the sockets is such as to make it impossible to interconnect these with the attenuator sockets. These latter are situated above, and the central socket is connected directly to the Y2 deflector plate of the cathode ray tube, while the ×1 socket is connected to the Y2 terminal on the front panel of the instrument. Fig. 8 (a) shows the details of this circuit. The shortcircuiting or link plug would, normally, be connected between the centre socket and the ×1 socket, so that the voltage applied to the Y2 terminal goes direct to the corresponding deflector plate of the tube (as is always the case with the Y1 terminal).

100. When the input voltage has to be reduced the link plug is withdrawn and inserted between the centre socket and one of the remaining three surrounding sockets, providing the required reduction ratio. The factor for each position is engraved on the escutcheon itself. Because the cathode ray tube cannot be damaged by an overload of the order involved, a mistaken connection will not produce ill effects.

101. The Y2 terminal is used because it is free from the amplifier at all positions of the amplifier switch except position 3, giving a Y1Y2 condition of operation. After using the attenuator it is important to return the link plug to the ×1 setting whenever position 3 of the amplifier switch is in use. Unless this is done the full output and gain of the Y2 amplifier will not be utilised.

102. With shifts applied to each Y plate, the shift circuit resistances, and therefore also the position of the shift control, materially affect the reduction ratio of the attentuator, more especially on the high reduction ratio steps, and whilst the attentuator itself can be used to reduce the amplitudes of very low frequencies, it cannot serve for quantitative measurements on these same low frequencies or D.C. The attentuator is not frequency compensated, and cannot be used at frequencies much higher than the audio frequency range.

Calibration

103. In order to provide an approximate means of calibrating the deflector plates for quantitative work a calibration winding (17–18, fig. 2) is included in the instrument. This winding has an output of 50 volts peak to peak, and one side (17) is connected internally to the chassis of the instrument, the live end (18) being terminated at the "C" terminal. It will be appreciated that as this voltage is derived from the mains transformer, measurements based upon it are subject to errors due to mains voltage variations. In the majority of cases, however, an accuracy within 10% may be expected. For accurate work the calibration voltage can be determined for a given mains voltage by means of an accurate voltmeter, and by using the 10 cm. scale graticule as shown in the illustration of fig. 1.

104. A protecting resistance R54 is connected in series with the calibration winding to avoid the risk of damage to the mains transformer T1 should the lead from the "C" terminal accidentally touch the chassis or other earth point.

105. It will be noted that the trace of the voltage obtained from the calibration terminal shows small kinks not present on the A.C. mains voltage when applied directly (attenuated if required) to the Y2 terminal. These kinks are due to the current changes resulting from the action of the instrument's rectifiers, which operate from the same mains transformer. This effect is of no practical consequence.

OPERATING CONDITIONS.

106. This section is devoted to a discussion of the less obvious points connected with the operation and conditions of use of the oscillograph, points which are certain to arise in practice, and where difficulties are likely to be encountered, particularly with users who have not considerable experience with the use of oscillographs.

107. *Amplifiers.*—One factor which should be remembered in connection with the amplifiers used in this instrument is that they impose a virtually constant load on the input source irrespective of the gain control setting. In addition, any phase distortion introduced in the amplifiers is minimised by reduction of the gain, and where very low frequency phenomena are being observed it is frequently advantageous to tolerate a slightly smaller picture and reduce the gain setting on account of the improvement in amplifier performance thus produced, at both low and high frequency ends of the characteristic.

108. *Use as a high frequency amplifier.*—The inevitable limitations of the amplifier performance at very low frequency and at D.C. can be circumvented in all those cases where the effect investigated is made to modulate an R.F. carrier, such as on radio circuits (for oscillator tracking and modulation tests) or on R.F. polarized pressure indicating devices and bridge circuit measurements. The necessary amplification can be done by the instrument at R.F. and a rectifier added to operate directly at the deflector plates.

109. Fig. 8 (c) shows an arrangement using two type WMX281 rectifiers as voltage doubler replacing the rear panel Y1 link. The addition of a low capacity D.P.D.T. switch would allow the device to be used as a permanent fitting. The dotted wiring in the diagram indicates existing instrument circuits. For carrier waves using a supersonic frequency up to 100 kc/s., customary in mechanical investigations, the Y1Y2 or 2Y1 position of the amplifier can be used. When higher carrier frequencies are used, such as are common in radio practice, the 2HFY1 position of the amplifier is necessary.

110. To simplify the connections and procedure in this important case, instead of a soldered link being used for the Y1 connections three sockets in line and a 2-pin shorting plug are provided on the rear panel. This latter is withdrawn from its normal position across sockets 1 and 2 from the top and the circuit is connected as shown.

111. A cathode ray tube probably disturbs the conditions of electrical circuits less than any other measuring instrument. Nevertheless, for accurate work, particularly at radio frequencies, due allowance should always be made for such circuit disturbances as are produced.

112. In those cases where the impedance of the test circuit is high and the one megohm input resistance of the instrument is still liable to affect the result, a series resistance of from one to five megohms can be added to the lead. This expedient should also be adopted when, as in the case of alignment of intermediate frequency circuits, a low frequency signal comprised by the rectified modulation envelope of the R.F. carrier is obtained from the R.F. circuit. In this case the series resistance serves to remove the input capacitance, due to the instrument and leads, from affecting the test circuit. The series resistance should then be applied at the free end of the screened input lead of the oscillograph.

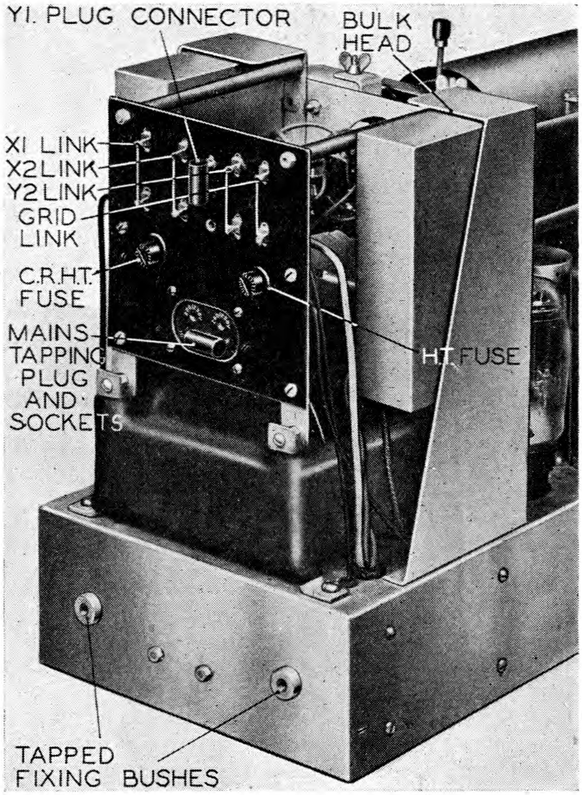

Fig. 9.—Chassis, rear view.

113. When applying signals to either the Y1 or Y2 terminals the resistive component of the input impedance is sufficiently high (three megohms) to be disregarded for most work.

114. Although the capacitance imposed, in shunt, across the external circuit may be disregarded for most work at power and audio frequencies, its effect on radio frequency circuits, and more especially on those of a resonant nature, may be considerable. This condition frequently arises in connection with the same alignment tests mentioned above when it is desired to inspect the selectivity of radio frequency and intermediate frequency transformers by examining the modulated radio frequency envelope present across the windings.

115. In such cases the fifth position of the amplifier switch may be used ("2HFY1"), when it will be found that the gain is sufficient to allow the connection from the oscillograph lead to the actual test point to be made with a very small condenser of 1 or 2 $\mu\mu$F. It will be appreciated that when this is done the change in the resonant frequency of the tuned circuit will be very slight, particularly in the case of intermediate frequency transformers, as such circuits usually employ tuning capacities which are very large by comparison with 1 $\mu\mu$F.

116. It must be remembered that the effect of this latter is to reduce the effective signal input to the oscillograph in proportion to the ratio between the equivalent impedance of this small series capacitance (at the required frequency) and the impedance corresponding to the sum of the capacitance of the instrument input and connecting leads.

117. When the amplifiers are being used and the time base is being synchronised with the work voltage, the synchronising circuit loading does not appear across the work circuit, as the SYN. terminal is connected to the output of the amplifier. On the other hand, when the signal is being applied straight to the plates without the intermediate use of an amplifier any synchronism with the incoming signal necessitates the presentation of the synchronising circuit impedance across the source.

118. In this instrument not only is this loading very slight but in a number of cases it will be found possible to obtain perfectly satisfactory synchronism with a high value of resistance as the connection between the SYN. terminal and the work voltage. As much as 5 megohms may frequently be employed and the effect of a load of this order is completely negligible on most circuits.

Rear panel link strip

119. For certain work it will be found convenient to make use of the link panel at the rear of the instrument (*see* fig. 8). The links carried by this panel serve to connect the four deflector plates and grid of the cathode ray tube to those parts of the oscillograph circuit with which they are normally associated. These links may be disconnected by unsoldering when it is desired to have direct access to these tube electrodes. The top tags go to the cathode ray tube socket and lower tags to the instrument circuits and terminals.

120. The flexibility allowed by this arrangement permits a number of practical applications with the oscillograph, and such applications generally fall under one of the following headings :—

(i) Measurements for which it is essential to present a minimum of capacitive loading across the external circuit.

(ii) Applications, chiefly on symmetrical work circuits, where the instrument is used simply as a cathode ray tube unit and none of the internal circuits are required.

(iii) Applications which call for rearrangement of the instrument circuits.

121. Examples of the first class of application are the taking of measurements at high radio frequencies (and with intermediate frequency and video amplifiers), or the use of the grid connection for beam triggering, for time marking purposes on transients and for general photographic investigations. The most usual case of the second class is when the work circuits provide large voltages, usually of the push-pull type, which can be applied directly to the tube. A further important case is the study of the relative timing of events using the circular time base.

Grid connection

122. Reference should be made to the use of the grid connection because this is often required in practice—chiefly for beam switching and for timing purposes, usually in connection with photographic recording. In such cases use should be made of the rear panel link strip. In all the applications the resultant action involves a change of intensity in the cathode ray tube beam, that is, both timing and beam switching are obtained by intensity modulation. This may be achieved by removing the grid link and replacing it by a resistance. As in the case of plate return resistances, the value must be chosen with regard to the work on hand, but, in general, a 100,000-ohm resistance may be used.

123. The intensity modulation voltage should be applied to the upper of the two grid tags through a condenser capable of withstanding the full tube voltage of 1,100 volts. Caution should be observed when making any adjustments to these links, as, even after the instrument has been switched off for some seconds, an unpleasant shock may still be obtained from certain parts of the circuit due to the retention of charge by various smoothing condensers. This general precaution applies particularly in the case of alterations in the grid circuit of the cathode ray tube, as this point is 1,100 volts negative with regard to earth, and almost 2,000 volts negative relative to the time base and amplifier anode supply.

Time base

124. Practical application of the time base occurs on frequency comparison tests. The procedure and adjustments remain the same, irrespective of the size and shape of the recurrent trace and whether one or more waves are to be inspected at the same time, and whether their frequency is 50 c/s or 5,000,000 c/s. The only slight difference is at the higher frequencies, where recourse can be made to the trigger rather than the velocity control for adjusting to exact synchronism, because of the finer means of adjustment it provides.

125. It should be remembered that the fundamental relation of all time base circuits makes the capacitance, charging resistance, voltage amplitude and frequency directly dependent on one another. This means that interdependence of the time base controls is unavoidable, and that from the practical point of view the change in amplitude will affect frequency, and vice versa. This latter fact is useful on investigations at very high frequencies, because it makes possible the examination of a single wave by reduction of the sweep amplitude, which provides a higher sweep frequency.

126. By reduction of the amplitude control to zero or thereabouts and using the Y2 amplifier by rearranging the rear panel links, it is possible to use the time base of the instrument in the third position of the amplifier switch Y1Y2 as an amplified time base in those applications which require the possibility of changing the amplitude without change of frequency and thus readjustment of the other time base controls.

Single stroke time base

127. The switching arrangements included in the instrument in order to enable the operator to use the time base circuit for producing a single stroke traverse have already been described in principle. There are, however, a number of points which must be remembered when making use of this facility. The necessity to provide a negative pulse of the correct duration has already been mentioned and the following suggestions may be followed. In the ordinary way, a 16-volt negative supply will be adequate and may be provided conveniently by two 9-volt grid bias batteries in series. This voltage may then be applied between the SYN. terminal of the instrument and EARTH, through a series condenser, the capacitance of which should be varied to suit the sweep speed required.

128. It has already been mentioned that it is not necessary to provide a different capacitance condenser for each of the time base COND. switch positions, and a 0.005 μF condenser will be found suitable for the slowest three condenser speeds on the time base, whilst a 0.0002 μF condenser will cover the next three faster speeds. Above the sixth condenser stud, the discharge of the time base condenser prior to the single sweep becomes rather long compared with the sweep speed, and single stroke operation on the fastest three time base condenser switch positions is not normally to be recommended. A 5-megohm resistance should be connected in parallel with the injection condenser so that this condenser may discharge automatically between successive sweeps.

129. In order to use this single stroke facility the TRIGGER control should first be rotated to its limit of travel in an anti-clockwise direction. This will cause the time base to cease recurring. The X SHIFT control should then be rotated in a clockwise direction until the beam is deflected just beyond the right-hand limit of the screen diameter.

130. The time base speeds obtained under single stroke working will be similar to the speeds obtained at the corresponding CONDENSER and VELOCITY settings when the time base is operating under recurrent conditions, and from a consideration of the work in hand, a decision can be made as to which condenser switch position should be used.

131. Having decided this point the appropriate injection condenser value suggested above may be adopted, and the application of the negative voltage through such a condenser will produce rapid discharge of the time base, causing the spot to travel from right to left across the screen, followed by the actual single stroke from left to right.

132. The behaviour of the time base will, however, depend somewhat critically on the setting of the SYN. control. This should first be rotated to its fully anti-clockwise position, at which setting the time base will not operate at all. This control should then be rotated slowly in a clockwise direction whilst negative pulses are applied at frequent intervals.

133. As the SYN. control is advanced it will be seen that successive applications of a negative pulse produce an increasing length of sweep until eventually a setting of the SYN. control will be found at which the spot just traverses a complete screen width. This is the correct setting of the SYN. control for the particular velocity conditions, and the same adjustment technique may be adopted whenever the CONDENSER or VELOCITY controls on the time base are adjusted. The AMPLITUDE control should be kept at maximum (i.e., fully clockwise) whenever the single stroke facility is being employed.

134. The applications for which this type of time base is most suitable are the visual investigation of slow transients and for photographing relatively fast transients, such as those associated with the make and break of circuits during short circuit tests. A long afterglow tube, if available, should be used in the former case.

135. For convenience in reference the following average specification figures are summarized. They are, of course, approximate and the normal production tolerances may be expected :—

(i) *Input impedance :—*

	Capacity $\mu\mu$F.	*Resistance megohms*
To input terminals	70	3·0
Direct to tube panel	20	As required
Through amplifier	40	1·0
Synchronisation (added)	20	2·0

(ii) *Calibration —*

50 volts peak to peak
17·7 volts R.M.S.

(iii) *Y2 attenuator :—*

Maximum voltage range	400 v. A.C. R.M.S.
Frequency range for A/C only	From 30 c/s to 15,000 c/s. Not frequency compensated.
Reduction ratios	×1, ×2, ×4, ×8.

(iv) *Time base :—*

TABLE B

Sweep Frequency Ranges

Frequency range

Condenser Switch Position	Velocity control	
1	Time Base Min.	Inoperative Max.
2	6	15
3	11	60
4	50	270
5	250	1,000
6	850	3,500
7	3,000	13,000
8	10,000	30,000
9	20,000	70,000
10	50,000	250,000 and above

(v) *Amplifier :—*

	Gain (approx.)	Frequency Band in c/s ± 3 db.	Sensitivity in mV R.M.S./mm. VCR.138 tube
1 Stage	30	10–100,000	15
2 Stage :—			
High gain position .	900	10–100,000	0·5
Wide band position .	106	10 to above 2,000,000	4·25

APPENDIX I

DOUBLE BEAM TUBES

Theory

1. To enable two phenomena to be investigated simultaneously, using the same time base, a special form of cathode ray tube has been developed. In this tube, a third plate, shown as the splitter plate in fig. 10 is introduced between the Y-plates. The electron beam, focused by the anodes through which it is passed, is split in half, lengthwise, by this plate, one half lying between the splitter plate and Y1, and the other between the splitter plate and Y2.

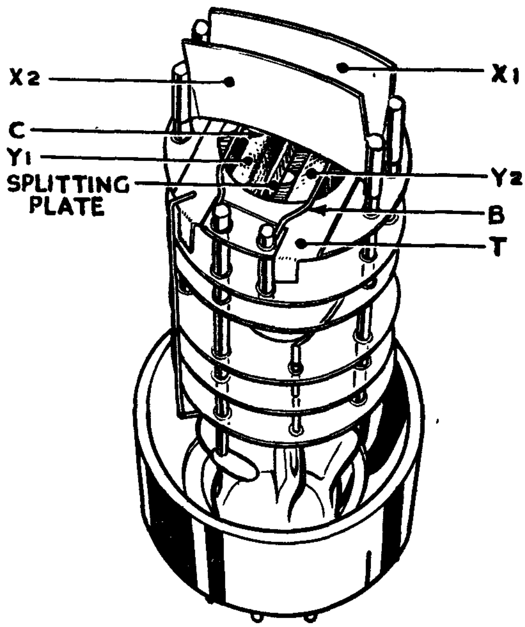

Fig. 10.—C.R.T. type V.C.R.518.

2. The splitter plate is connected internally to the third anode of the C.R.T. and consequently only asymmetrical deflecting voltages can be applied to give Y deflection to both the beams. This tends to give rise to *trapezium* distortion. To overcome this, while enabling the tube still to be used with balanced signal voltages, the leading edges of the X plates are curved, as shown at C, fig. 10, and a curved shield B is interposed between the X and Y plate assemblies.

3. To reduce intermodulation, which arises from interaction between the electrostatic fields of the various plates from the return current from the screen, and from the asymmetric characteristics, of the deflector plate-voltage/current curve, bucking wires B, fig. 10, are fitted, also a cylindrical shield surrounding the whole electrode structure, and a hood anode A4. The latter also serves to reduce *pimple effect* caused by a voltage being set up across the Y deflector plate load around the central position of the beam by that part of the return current which, in other positions of the beam, is taken by the X plate.

Operation

4. The double beam tube is especially useful for comparing the waveforms at the input and output of an amplifier, for investigating phase-shift, for examining the effects of differentiating or integrating circuits, frequency multipliers or pulse shaping circuits. In general, wherever the comparison as regards shape or time relation of two oscillograms is necessary, the use of the double beam tube is desirable if not essential.

Amplifiers

5. When either or both of the voltages which it is desired to investigate are small and require amplification, the input from the work circuit should be applied between the A1 and/or A2 terminals and earth. Should one of the voltages be sufficiently large to require no amplification this signal should be applied to the Y2 terminal, whilst the smaller signal should be connected to A1. The fourth or fifth positions of the amplifier switch will then provide amplification only for the smaller signal. In the majority of cases, even though the use of the fifth position may not be necessary from the point of view of amplifier frequency response, the maximum gain provided in this position will be more than enough and the use of the fourth position, with its high gain, may be found less convenient.

6. One of the test conditions most frequently encountered is that in which the input and output from a circuit call for examination simultaneously, and for circuit tests of this nature the fifth switch position will be found very convenient. In this way the output of the test circuit, which is generally of relatively high level, may be applied to the Y2

terminal, whilst the input, which is generally of low level, may be applied to A1. In cases such as this when the frequency of the signals applied to Y1 and Y2 are the same it is immaterial whether the " SYN " terminal is connected to Y1 or Y2. It should, however, be remembered that with whichever beam synchronism is required, that synchronism should be achieved by connection to the appropriate Y terminal and not by connection to the amplifier input terminals A1 and A2.

7. With the amplifier switch in the fifth position the frequency range of the amplifier extends to above 2 megacycles, whilst in the fourth position (" 2Y1 ") the useful frequency response extends to above 100k/cs. In this latter condition the maximum gain is of the order of 900 times. The gain is much lower, 106, in the fifth position " 2HFY1 ", and lower still, 28, in the third position " Y1Y2." The necessity for care in screening the input is a real one when using any of these amplifier positions, particularly that at high gain. The fifth position is intended primarily for the direct observation of television and radio frequency wave-forms. It can also be used as an H.F. amplifier.

8. With the amplifiers in the Y1Y2 setting, or in the cascaded setting 2Y1, the voltage swing obtainable in practice provides almost full screen deflection without distortion. On the other hand, in the wide range cascaded setting 2HFY1 of the amplifiers, the voltage swing available is only of the order of 30 to 35 mms. deflection before over-loading occurs. This fact should always be reckoned with when using this amplifier setting.

9. When using the gain controls with the amplifier in the cascaded positions 2Y1 and 2HFY1, difficulty may arise as to the correct settings required in view of the possibility of the signal overloading the first stage and the first stage itself overloading the subsequent stage. Because of the type of gain control used not only can a wider frequency band be covered by a lower setting of these controls, but a notable reduction is secured of the tendency to overload in the valve stages themselves. The concomitance of this effect and the one of hum and " noise " makes the theoretical deduction of the best settings of the two gain controls for each individual application an apparently involved problem. These considerations, however, resolve themselves very simply in the general rule given in paras. 96-98 which is the best in practice, and that is to operate the first stage at near maximum gain and make whatever further adjustments are required to the A2 gain control of the second amplifier stage.

10. One factor which should be remembered in connection with the amplifiers used in this instrument is that they impose a virtually constant loan on the input source irrespective of the gain control setting. In addition, any phase distortion introduced in the amplifiers is minimized by reduction of the gain, and where very low frequency phenomena are being observed it is frequently advantageous to tolerate a slightly smaller picture and reduce the gain setting on account of the improvement in amplifier performance thus produced, at both low and high frequency ends of the characteristic.

Focussing

11. It will be appreciated that when obtaining two beams from one by a " splitting " device, any departure from symmetry in the division gives rise to dissimilarity of current content in the two beams, and will therefore produce spots of different brightness. The degree of symmetry achieved in practice is very high, but it must be understood that it is influenced not only by minute geometric inaccuracies in the tube itself, but also by the magnetic and electrostatic fields to which the beams are subjected, and a certain difference in brightness between the two beams is sometimes to be expected.

12. In cases where a difference is present it will be most noticeable at low brilliance because of the more marked differences existing at the bottom bend of their characteristics. It will not, however, prove troublesome because it can be corrected in various ways. The simplest method is to advance the brilliance control, thus operating both beams on the straight portion of their curves. This method of correction is feasible provided the setting at which beams of approximately the same brilliance are obtained is still below the point beyond which defocussing occurs. When this procedure is adopted in photography the spot brilliance may be greater than is required for the recording speed involved. Reduction of the spot brilliance will produce spot dissimilarity, and therefore the only alternative is to fit an iris diaphragm to the lens system and reduce in this way the amount of light used for recording.

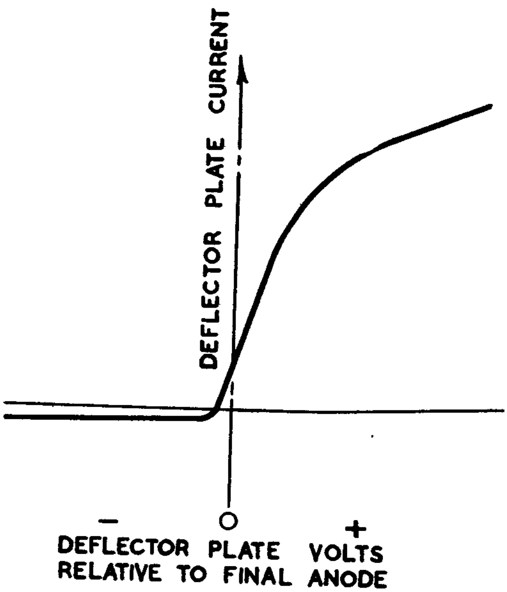

Fig. 11.—Deflector plate voltage/current characteristics.

13. Complete correction can, however, be secured by means of a small, permanent magnet suitably placed near the neck of the tube. By this means the two beams can be made to acquire the same brilliance under all conditions. The magnet can be permanently fixed and provided with a suitable method of adjustment.

14. At the same time it should be remembered that the tube life is dependent upon the current which the cathode is called upon to supply, and the brilliance should therefore be kept as low as is consistent with the work in hand. Accordingly the instrument should be so positioned that a minimum of direct light falls upon the tube screen, the apparent luminosity thus being increased. This enables the beam current to be set to as low a value as possible for any given conditions with a corresponding gain in tube life. The use of the viewing hood is advocated.

15. With a double Beam Tube the Y deflection voltage is necessarily applied asymmetrically, and thus affects the focus of the beam to a slight degree. Due to this effect, if the beam is focussed whilst approximately central on the tube the trace loses sharpness slightly in a progressive manner as the beam is deflected towards the edge of the screen. This effect is inherent to all types of cathode ray tubes under conditions of asymmetrical operation and although the phenomenon, which is called " deflection defocussing," obviously increases with the angle of deflection, it is not usually troublesome. However, as that setting of the "FOCUS" control which produces the highest degree of sharpness when the beam is undeflected may not exactly correspond with the optimum setting when a signal is being applied, it is always worth while rotating the "FOCUS" control slightly either way in order to obtain the best overall focus condition before making any detailed wave-form examination. An improvement is obtained in this respect when using a single beam tube and balanced Y deflection.

Intermodulation

16. The intermodulation is due to effects resulting from the asymmetric deflector plate voltage/current characteristic, fig. 11, and increases with the beam current. Also, the higher the impedance of the deflector plate return path, the greater the effect produced by a given current. It will be appreciated that because the plate return current characteristic is asymmetric, the intermodulation is also asymmetric, and is therefore dependent on both the polarity and amplitude of the voltage at any of the deflector plates. In other words, the effect will depend on the relative positions of the beams, notably in the opposite cases of normal and crossed positions, the complication being increased by the effects being dependent on both the electrostatic volts (Shift positions) and the varying voltages applied to the deflector plates.

17. Notwithstanding that perfection could be obtained in the design, a certain amount of intermodulation due to the inter-penetration of the fields of the two Y deflector plates was deliberately retained so as to avoid any tendency for an early cut-off of the beams. This provides the desirable feature of enabling each beam to be used on any part of the tube screen, and more particularly in the crossed-over position, which would otherwise not be possible with a very effective type of splitter plate construction. The beam cut-off is therefore effective only when the spot is situated around the opposite periphery of the tube diameter, and is therefore of small consequence.

18. Because the intermodulation effects are functions of the beam current, they have been eliminated over the current range normally required. Thus it is to be expected that some effects may still be present at extreme beam current conditions, such as those required in photography, but these can be eliminated by circuit conditions given below. The obvious method which suggests itself for avoiding these effects from a study of fig. 10 by biassing both Y deflector plates negatively is not generally practicable and introduces other distortions, notably astigmatism and deflection defocussing. Furthermore, these plates are still the seat of currents which follow a complicated law with deflection, which are equally liable to produce unexpected effects on high impedance circuits.

19. As the intermodulation increases with the impedance of the deflector plate circuit, the correction has been arranged to cover all conditions likely to be met in practice, and the maximum impedance encountered in the oscilloscope type 10 is 3 megohms. The lower the deflector plate impedance (a condition which is general when using the internal amplifiers and time base or external circuits) the lower the intermodulation effects obtained.

20. When residual intermodulation effects may be experienced, in the exceptional case of operation at high beam currents and on high impedance circuits, they can be eliminated by operating the beams in the crossed position. This is a further advantage of the design of this double beam tube.

21. It must be remembered that there are certain inevitable limitations on the use of the instrument at high frequencies of which it is as well the user should be aware. These result from coupling effects existing between the Y1 and Y2 deflector plates or either or both of these and the X plates, whether the plates are used directly or through the amplifiers, and/or time base circuits. These produce another form of intermodulation and can be due to a variety of causes, such as direct coupling between the respective plates, which is generally small, but more often by coupling between the various amplifiers and/or work and time base circuits and input leads, as also coupling *via* the power supply circuit, or even through the earth returns. These are in addition to the intermodulation effects resulting from the cathode ray tube itself as discussed in the previous paragraphs.

22. The total couplings due to the instrument and tube are so small that they are without effect up to frequencies of the order of 100 k/cs. and that is, within the range of operation of the amplifier switch positions D.C.A.O. Y1Y2 and 2Y1. Whatever effects may be present can be eliminated by suitable precautions.

23. The effects of these couplings obviously increase with frequency and they are thus noticeable in the range covered by the 2 HFY1 amplifier switch position. Whilst they are more marked when the cascaded amplifier is used, they are still present when the signal is applied to the Y1Y2 and X1 terminals, or even, though to a much less degree, when applied to these same tube deflector plates directly by connecting to the rear panel links.

24. The effects produced are in the form of reciprocal modulation between the independent deflection axes X1 and Y1 and/or Y2. When using the time base, because of its constant velocity, its effect on the Y1 and Y2 plates is to produce a constant change of amplitude of the wave forms. The wave-forms of the Y axes will also affect the time base on the X axis, the nett result of which is to cause an apparent tilt of the traces on the Y axes.

Deflection

25. So that the beams may be displaced either side of the centre of the tube, the shift potentials are adjustable to both positive and negative values relative to the final anode of the tube, which is operated at earth potential. To provide these shift voltages by connecting the shift potentiometer network between the positive time base supply and the negative tube supply would result in changes in the beam positions whenever the time base supply voltage changed due to adjustment of the time base or amplifier controls. The alternative method of providing the required shift voltages is by connecting the positive pole of the tube supply to earth through a resistance large enough to drop at least half the required overall shift voltage. This leads to slight changes in beam position when the brilliance of the tube is altered, but renders the beam positions independent of time base and amplifier conditions. As the time base and amplifiers are subjected to repeated adjustment in the course of most experiments, whereas the brilliance may be set at the commencement of any series of measurements and then left unchanged, the second of the two alternative shift networks has been adopted.

26. It is important under this heading to premise the fact that in the design of the instrument the deflection requirements to cover the normal operating conditions have been purposely restricted to half screen deflection. Thus the input circuit arrangements, the amplifiers, the Y2 attenuator and the double beam cathode ray tube itself are made to provide complete and satisfactory operating conditions within the useful field of movement of each beam, this latter being assumed to correspond to one half of the screen diameter whether the beams are used centrally, overlapping or apart in the normal or in the crossed over position. This arrangement is justified on the grounds that half scale deflection gives a sufficiently large indication for practical requirements, and because more is not required when a double beam tube is used, as the remaining half of the screen is normally occupied by the trace of the other beam. This applies particularly to the Y2 attenuator and amplifiers. Secondly, even when d.c. voltages are measured, either using the Y2 attenuator or the d.c. position of the amplifier switch, a unidirectional voltage can only affect one half of the screen. It can therefore be seen that the design restriction does not cause a limitation in the intrinsic performance as full advantage is obtained of the useful diameter of the tube.

27. Notwithstanding this restriction, however, it is possible, except in position 5 (2 HFY1), to deflect each beam of the double beam tube (or the beam of a single beam tube) by almost the whole screen diameter without distortion.

28. The various intermodulation effects have already been discussed and their effect on deflection conditions is described in the paragraphs that follow.

29. As the oscilloscope type 10 has been designed to cover the widest field of application, the independent deflector plate impedances have been made as high as possible, a condition which, as was stated in paras. 16 onwards of this appendix, increases the intermodulation effects.

30. In consequence of these facts it must be remembered that when the instrument is switched on and operating under, what may be termed, "open circuit" conditions, as when the instrument is used simply for the purpose of handling the controls, it will be operating under its most adverse conditions, and, if, therefore, the tube is set at high brilliance, some of the resultant intermodulation effects mentioned in para. 16 on may become apparent. These effects need cause no concern because they will disappear as soon as the instrument is connected to internal or external work circuits of average impedance.

31. When using the internal amplifier in the "Amp. Y1Y2" position, intermodulation effects are automatically eliminated because of the low output impedance of these stages The same condition applies to the Y1 deflector plate in the "2Y1" and "2HFY1" positions of the amplifier switch. Some effects may be present in the "d.c." and "a.c." position, of the amplifier switch, or when the switch is set to the "2Y1" and "2HFY1" positions, because in the first two positions either or both the Y deflector plates may be at high impedance, whilst in the case of the two latter positions the Y2 deflector plate circuit may be of high impedance. These effects may be completely avoided by so adjusting the "Y SHIFTS" that each beam operates over the opposite section of the tube screen from that embraced at the normal shift setting, that is, by operating the beams in the crossed position, and by joining the Y2 and E terminals when this beam is not used.

32. The recommendations given above, whilst important, need rarely be resorted to in practice. Generally, either the oscillograph amplifiers are used, or the external work circuits encountered prove to be of fairly low impedance. In point of fact, such circuits rarely have an impedance much in excess of 100,000 ohms. When high impedance circuits are encountered, such as in radio test works, the voltage obtainable is usually too small for direct inspection and the instrument amplifier must be used, so that the required conditions for freedom from intermodulation are automatically obtained.

33. It may be found that the most satisfactory operation of the beams for general use is provided in the crossed position, and it is quite in order to use the instrument in this manner. The advantages obtained are freedom from intermodulation and somewhat better focus, its disadvantages are beam current cut-off and consequent reduced brilliance at the screen edges. This is an inevitable effect due to the gradual cut-off the beam by the splitter plate. The design of the double beam tube has been so arranged that this effect begins to be felt when the spot has gone beyond the useful working area of a given beam on the tube screen. This effect can often be of assistance in locating the beams.

34. The normal shift positions are those at which each beam is operating on that part of the screen over which it produces the brightest trace, when the uppermost trace will correspond to the Y1 beam, viz. Y1 on the A1 terminal.

35. The beams can be used to provide either entirely separate records in their respective halves of the tube screen, or overlapping records disposed centrally on the tube screen. In the former case the beams can be operated in the crossed position if required.

Deflector coils

36. The deflector coils provided enable current measurements to be made directly. Deflection to the full screen diameter is obtained with a current of approximately 50 mA. R.M.S. When the instrument is being operated in the normal way with a double beam tube the Y axis deflection produced by the coils is applied equally to both beams. In such cases it is generally less confusing to displace one beam from the screen by the use of the appropriate "Y SHIFT" control, the trace then becoming virtually the equivalent of that obtained on a single beam tube. It is well to note in this connection that, as an alternative, an effect approximately equivalent to the use of a single beam tube can be obtained with deflector coil operation by making both spots coincide. This is done by joining the Y1 and Y2 terminals to the T terminal with the amplifier switch in the first position ("Plates—D.C.") This overcomes the need to bias one beam off the tube and avoids the slight defocussing effect previously mentioned.

37. The coils are located by spring clips pressing on the neck of the tube, and lie within the mu-metal screens. They are prevented from travelling backwards or forwards when the tube is being changed by a spigot working in a slot. This slot extends around sufficient of the circumference of the coil former to allow rotation of the coils through slightly more than 90°. In this way the coils may be arranged to give deflection along the X or Y axes or, of course, along an axis bearing any desired angular relationship to the normal X and Y axes. Angular adjustment is achieved by moving the small handle which will be found between the back edge of the mu-metal screens and the front edge of the tube clamp.

38. In addition to their normal use for current measurements, the coils can also serve for independent time marking, or as a supplementary Y or X shift in certain experiments when those available on the instrument cannot be used. A suitable accumulator and variable resistance are all that are required for this latter purpose.

APPENDIX II

NOMENCLATURE OF PARTS (Oscilloscopes types 7 and 10)

This list of parts is issued for information only. When ordering spares refer to Volume III of this publication, if available, or to the appropriate section of A.P.1086.

Stores Ref. No.	*Nomenclature*	*Circuit Ref.*	*Remarks*
10SB/180	Oscilloscope, type 10 —		
10SB/102	Oscilloscope, type 7 —		
	consisting of :—		
10A/15330	Caps, valve, type 73		Assembly of valve top and resistor
10C/12661	Chokes, L.F., type 404	L1, L2	18 henries, d.c. resistance, 435 ohms.
10C/13049	Chokes, H.F., type 513	L3, L4	120 turns of 38 S.W.G., wax dipped, 150 μH. $\pm$ 3 μH.
10QB/287	Coil assemblies, deflecting, type 5	—	Type 10 only.
10C/13050	Condensers, type 4198	C2, C31, C29, C30	·5 + ·5 μF., 1,500V, d.c. wkg
10C/3474	Condensers, type 1717	C17, C40, C36	12 μF, 200 V, electrolytic.
10C/3469	Condensers, type 1716	C21, C25	300 μF, 6 volts, dry electrolytic.
10C/3485	Condensers, type 1719	C3—C5, C18, C27	8 μF, 750V.
10C/13051	Condensers, type 4199	C22+C26	8 μF + 8 μF, 500V.
10C/11128	Condensers, type 3364	C1	·25 μF, 350V, d.c. wkg., tubular, paper.
10C/11127	Condensers, type 3363	C32, C33, C34	·1 μF, 500V, paper, tubular.
10C/11123	Condensers, type 3359	C15	·01 μF, 1,000V, paper, tubular.
10C/12347	Condensers, type 3890	C13	100 $\mu\mu$F, moulded, mica.
10C/2108	Condensers, type 982	C41	5 $\mu\mu$F + 5%, 500V, ceramic, disc.
10C/10512	Condensers, type 379	C11	·001 μF $\pm$ 15%, 750V, moulded, mica.
10C/13088	Condensers, type 4221	C12	400 $\mu\mu$F $\pm$ 15%, 750V, stacked, foil, mica.
10C/7901	Condensers, type 120	C16	·001 μF $\pm$ 25%, 350V, moulded, mica.
10C/3696	Condensers, type 1871	C10	·003 μF $\pm$ 15%, 750V, moulded, mica.
10C/11125	Condensers, type 3361	C8	·05 μF $\pm$ 20%, 500V, d.c. wkg., paper, tubular.
10C/11129	Condensers, type 3365	C20, C24	·25 μF $\pm$ 20%, 500V, paper, tubular.
10C/798	Condensers, type 849	C38, C39	·1 μF $\pm$ 15%, 1,000V, paper, tubular.
10C/2024	Condensers, type 934	C7	·25 μF + 15%, 1,000V.
10C/11131	Condensers, type 3367	C19, C23	·5 μF $\pm$ 20%, 500V, paper, tubular.
10C/11128	Condensers, type 3364	C14	·25 μF $\pm$ 20%, 350V, paper, tubular.
10C/11130	Condensers, type 3366	C28, C6	·5 μF $\pm$ 20%, 350V, paper, tubular.
10H/2424	Connectors, type 785		
10H/535	Fuses, type 55	F2	60 m/A.
10H/95	Fuses, type 19	F1	150 m/A.
10H/376	Holders, fuse, type 13		For panel.
10H/1870	Holders, valve, type 161		American, 5 pin for V6, V7.
10H/493	Holders, valve, type 73		International octal for V1, V3, V4, V5.
10H/3801	Holders, valve, type 250		4-pin, high voltage, for V2.
10H/13132	Holders, valve, type 199		12-pin socket for V.C.R.139A, type 10 only.
	alternatively :—		
10H	Holders, valve, type 125		ditto. for type 10 only.
10A/15835	Knobs, type 340		Engraved : " A.1 GAIN.'
10A/15837	Knobs, type 342		" Y1 SHIFT."
10A/15838	Knobs, type 343		" TRIGGER."
10A/15839	Knobs, type 344		" SYN."
10A/15840	Knobs, type 345		" A.2. GAIN."
10A/15841	Knobs, type 346		" Y.2 SHIFT."
10A/15842	Knobs, type 347		" Amplitude."
10A/15841	Knobs, type 346		" Y.2 SHIFT."
10A/15842	Knobs, type 347		" Amplitude."
10A/15843	Knobs, type 348		" Brilliancy."

Stores Ref.	*Nomenclature*	*Circuit Ref.*	*Remarks*
10A/15844	Knobs, type 349		" X. SHIFT."
10A/15845	Knobs, type 350		" Velocity."
10A/12241	Knobs, type 30		
5L/1319	Lamps, filament, 12 volt, 2·4 watt		Miniature Edison screw.
10A/11846	Lampholders, type 5		Red bullseye.
10A/15850	Links, type 16		1 ½in. × ½in.
10A/15851	Mask, C.R.T., type 19		Black rubber, for type 7 only.
10H/2372	Plugs, type 437		2-pin.
10H/2425	Plugs, type 443		2-pin.
10H/2426	Plugs, type 444		2-pin shorting, fits " Z " helical sockets.
10W/7074	Resistances, type 7074	R43	50,000 ohms ± 15%, 1·5 watt, potentiometer.
10W/6125	Resistances, type 6125	R26+R27	Tandem potentiometer, 2 meg. front knob, 2 meg. rear.
10W/6126	Resistances, type 6126	R33+R36	Tandem potentiometer, 250,000 ohms front knob, 35,000 ohms rear.
10W/6127	Resistances, type 6127	R8+R27	Tandem potentiometer, ½ megohm front knob, 2 megohms rear.
10W/7265	Resistances, type 7265	R2+R4	Tandem potentiometer, 3,000 ohms front knob, 100,000 ohms rear.
10W/10915	Resistances, type 3636	R18+R25	Tandem potentiometer, 2,500 ohms front knob, 2,500 ohms rear.
10W/8192	Resistances, type 8192	R7	2·2 megohms ± 20%, ¼ watt, carbon.
10W/6704	Resistances, type 6704	R14, R15	100 ohms ± 20%, ¼ watt, carbon.
10W/6962	Resistances, type 6962		1 megohm ± 20%, ¼ watt, carbon.
10W/8139	Resistances, type 8139	R52	470 ohms ± 20%, ¼ watt, carbon.
10W/8144	Resistances, type 8144	R39	470,000 ohms ± 20%, ¼ watt, carbon.
10W/8151	Resistances, type 8151	R40	100,000 ohms ± 20%, ¼ watt, carbon.
10W/8594	Resistances, type 2102	R49	820,000 ohms ± 10%, ¼ watt, carbon.
10W/8303	Resistances, type 8303	R50, R51	390,000 ohms ± 5%, ¼ watt, carbon.
10W/10321	Resistances, type 3281	R30, R31	3·3 megohms ± 20%, ¼ watt, carbon.
10W/6961	Resistances, type 6961	R29, R34, R1, R59, R55, R56	100,000 ohms ± 20%, ½ watt, carbon.
10W/10247	Resistances, type 3236	R5	2·2 megohms ± 20%, ½ watt, carbon.
10W/9096	Resistances, type 2456	R13, R22	47 ohms ± 20%, ½ watt, carbon.
10W/8597	Resistances, type 2105	R17, R24	120 ohms ± 10%, ½ watt, carbon.
10W/6605	Resistances, type 6605	R16, R23	1 megohm ± 20%, ½ watt, carbon.
10W/6595	Resistances, type 6595	R37, R44	10,000 ohms ± 20%, ½ watt, carbon.
10W/9017	Resistances, type 2389	R54	2,200 ohms ± 20%, ½ watt, carbon.
10W/7004	Resistances, type 7004	R48	1·6 megohms ± 5%, ½ watt, carbon.
10W/8186	Resistances, type 8186	R53	22,000 ohms ± 20%, ½ watt, carbon.
10W/6847	Resistances, type 6847	R6	47,000 ohms ± 20%, 1 watt, carbon.
10W/7465	Resistances, type 7465	R10, R47	100,000 ohms ± 20%, 1 watt, carbon.
10W/1830	Resistances, type 2/19	R38	10,000 ohms ± 20%, 1 watt, carbon.
10W/10179	Resistances, type 3185	R35	2·2 megohms ± 20%, 1 watt, carbon.
10W/6417	Resistances, type 6417	R41, R46	2,200 ohms ± 20%, 1 watt, carbon.
10W/8756	Resistances, type 2206	R9	2,200 ohms ± 20%, 2 watt, carbon.
10W/1796	Resistances, type 1796	R32	470,000 ohms ± 10%, 2 watt, carbon.
10W/7897	Resistances, type 7897	R45	4,700 ohms ± 10%, 2 watt, carbon.
10W/6559	Resistances, type 6559	R42	47,000 ohms ± 10%, 2 watt, carbon.
10W/8617	Resistances, type 2122	R58, R11	12,000 ohms ± 5%, 3 watt, carbon.
10W/7007	Resistances, type 7007	R12	2,000 ohms ± 5%, 3 watt, carbon.
10W/10914	Resistances, type 3835	R19, R57	11,000 ohms ± 5%, 3 watt, carbon.
10W/9918	Resistances, type 3082	R21	2,400 ohms ± 5%, 3 watt, carbon.
10A/13387	Retainers, valve, type 37		Black rubber, 4in. long.
10A/15849	Scales, type 43		Clear celestoid.
10F/987	Switches, type 713		Rotary 3 wafer.
10F/164	Switches, type 240		Double pole.
10A/15846	Tag Boards, type 317		5 sockets.
10H/2373	Socket, type 383		7 sockets.
	including :—		
10H/2374	Terminals, type 25		Engraved, " A1."
10H/2375	Terminals, type 26		Engraved, " A2."
10H/2376	Terminals, type 27		Engraved, " Earth."

Stores Ref. No.	*Nomenclature*	*Circuit Ref*	*Remarks*
10H/2377	Terminals, type 28		Engraved, "Syn."
10H/2378	Terminals, type 29		Engraved. "Y1."
10H/2379	Terminals, type 30		Engraved, "Y2."
10H/2380	Terminals, type 31		Engraved, "X1."
10H/2381	Terminals, type 32		Engraved, "Cal."
10K/1261	Transformer, type 1327		Mains transformer.
10E/407	Tube, cathode ray, type V.C.R.138		Single beam, for type 7 only.
	alternatively :—		
10E/767	Tubes, cathode ray, type V.C.R.518		Blue trace, double beam, for type 10 only.
	OR		
10E/524	Tubes, cathode ray, type C.R.T.09J		Double beam, for type 10 only.
	OR		
10E/810	Tubes, cathode ray, type V.C.R.518A		Green trace, double beam, for type 10 only.
110E/68 10E/348	Valves, type 6J5G		Triode, international octal base.
	OR		
10E/11448	Valves, type V.R.67		Triode, international octal base.
110E/8	Valves, type 807		Screened tetrode "USM5" base.
	OR		
10E/587	Valves, type V.T.60A		Screened tetrode "USM5" base.
10E/598	Valves, 5Z4G		Full-wave rectifier, international octal base.
10E/121	Valves, type V.U.120		Half-wave, rectifier, British 4-pin base, top anode.
110E/11402	Valves, type V.R.56		Screened pentode, international octal base, top grid.
10F/1650	Wafers, switch		Spare wafer for Yaxley type switch (2 pole, 5 way, shorting section).
10F/13007	Wafer, switch		Spare wafer for Yaxley type switch (D.P. on-off section).

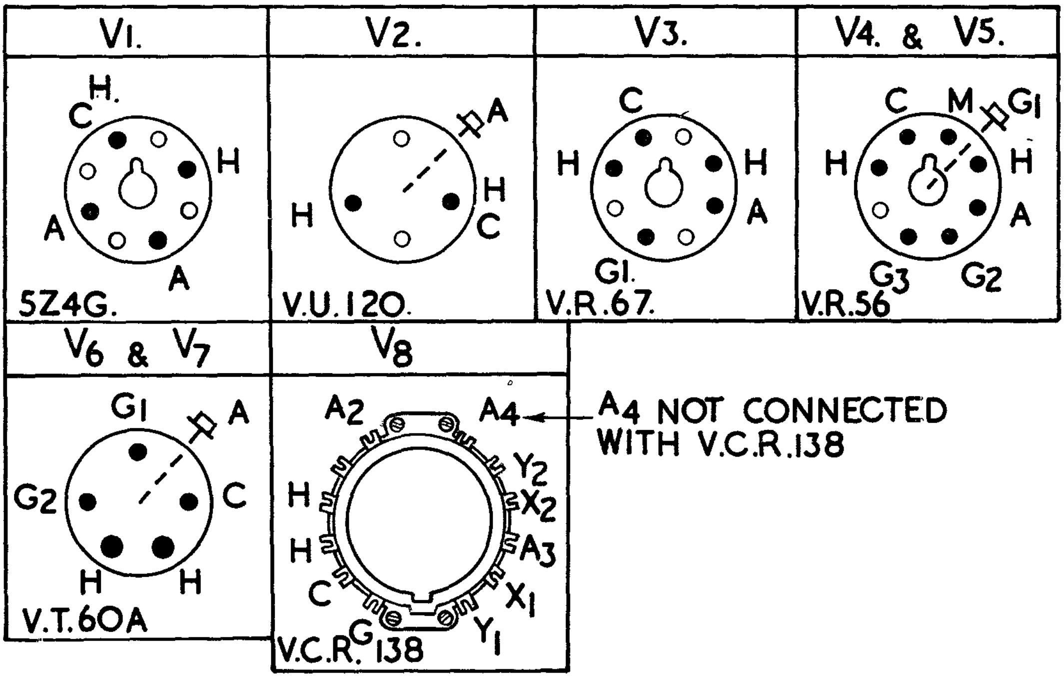

Fig. 12.—Valve bases.

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