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UNDULATOR, MORSE, TYPE 3 (MARCONI TYPE UG6A)

GENERAL AND TECHNICAL INFORMATION/REPAIR AND SERVICING

BY COMMAND OF THE DEFENCE COUNCIL

(Prepared by the Ministry of Technology)

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Chapter 1

GENERAL AND TECHNICAL INFORMATION

CONTENTS

TABLE

ILLUSTRATIONS

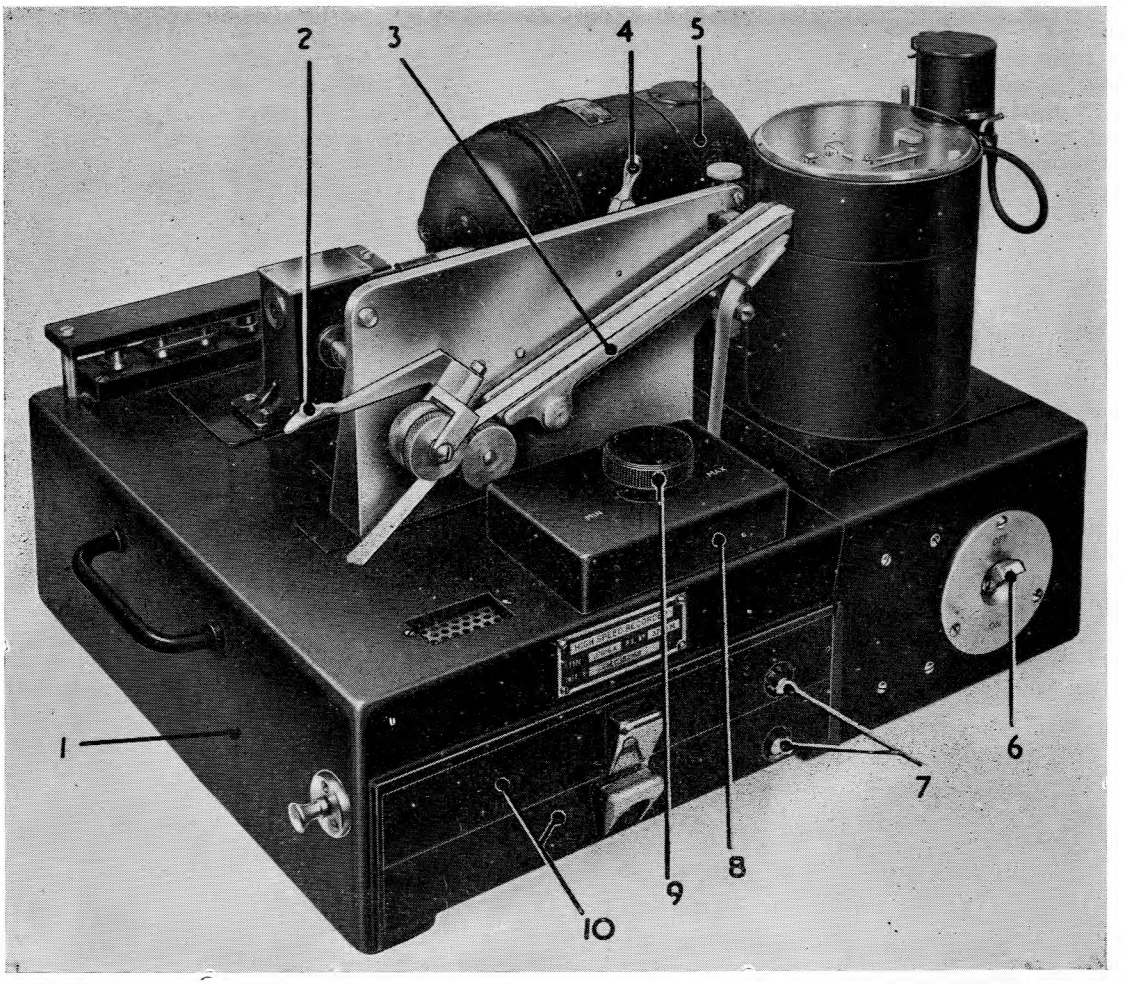
APPENDIX

LEADING PARTICULARS

Supply voltage	240 *volts*, 25-65 *Hz*		
Morse operating speed	25-300 *w.p.m.* (*max.*)		
Paper speed	*Up to* 12·2 *metres/min.* (40 *ft/min.*)		
Pen	*Single pen operation*		
Overall dimensions	*Width*	*Depth*	*Height*
	47 *cm* (11·25 *in*)	34·5 *cm* (18·5 *in*)	28·5 *cm* (13·5 *in*)
Weight	30·6 *kg* (68 *lb*)		
Ref. No.	10*G*/36		

Introduction

1. The undulator is an instrument for recording high-speed Morse signals. The record obtained is in the form of a continuous ink line on a paper tape. Signals are recorded by a special recording pen which moves backwards and forwards across the tape under the control of the "marking" and "spacing" signalling impulses. At the same time a motor-driven tape puller draws the tape underneath the pen at a constant speed. The combination of the two motions produces an undulating line along the tape. These specimen tapes are shown in fig. 2. The top example shows the "ideal" record which may be produced from a perfect signal input and was recorded at 25 words per minute. The other two examples were recorded at 170 and 200 w.p.m. respectively under fairly good conditions. The speed of the tape was, of course, adjusted between each recording. The long and short "bumps" standing on the lower horizontal line of the record will be seen to represent characters in Morse code, and can be translated by trained operators. With the undulators dealt with in this chapter a maximum working speed of the order of 300 words per minute can be attained under suitable conditions. Ideal conditions seldom prevail, however, and the subject of maximum working speeds and methods of connection of the signal input to the undulator are discussed more fully in para. 13 to 17.



1. Undulator base
2. Paper roller jockey arm
3. Paper guide
4. Platen operating arm
5. Motor
6. Supply switch
7. Guillotine operating knobs
8. Switch cover
9. Speed control switch
10. Tape drawers.

Fig. 1 The undulator, Type 3

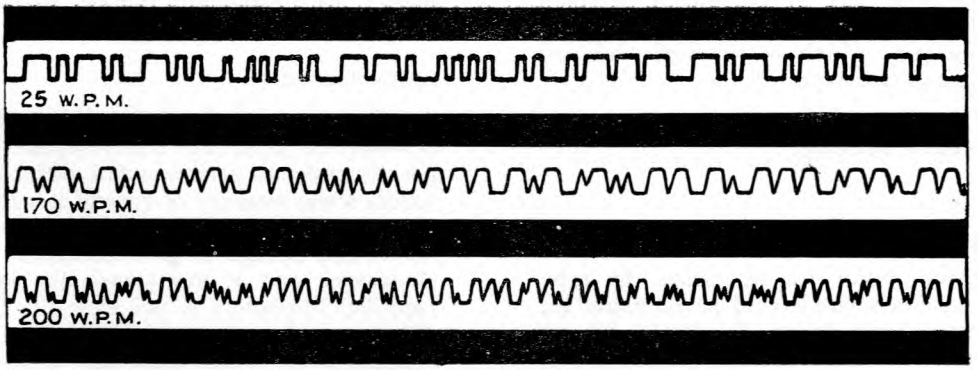


Fig. 2 Specimen undulator records

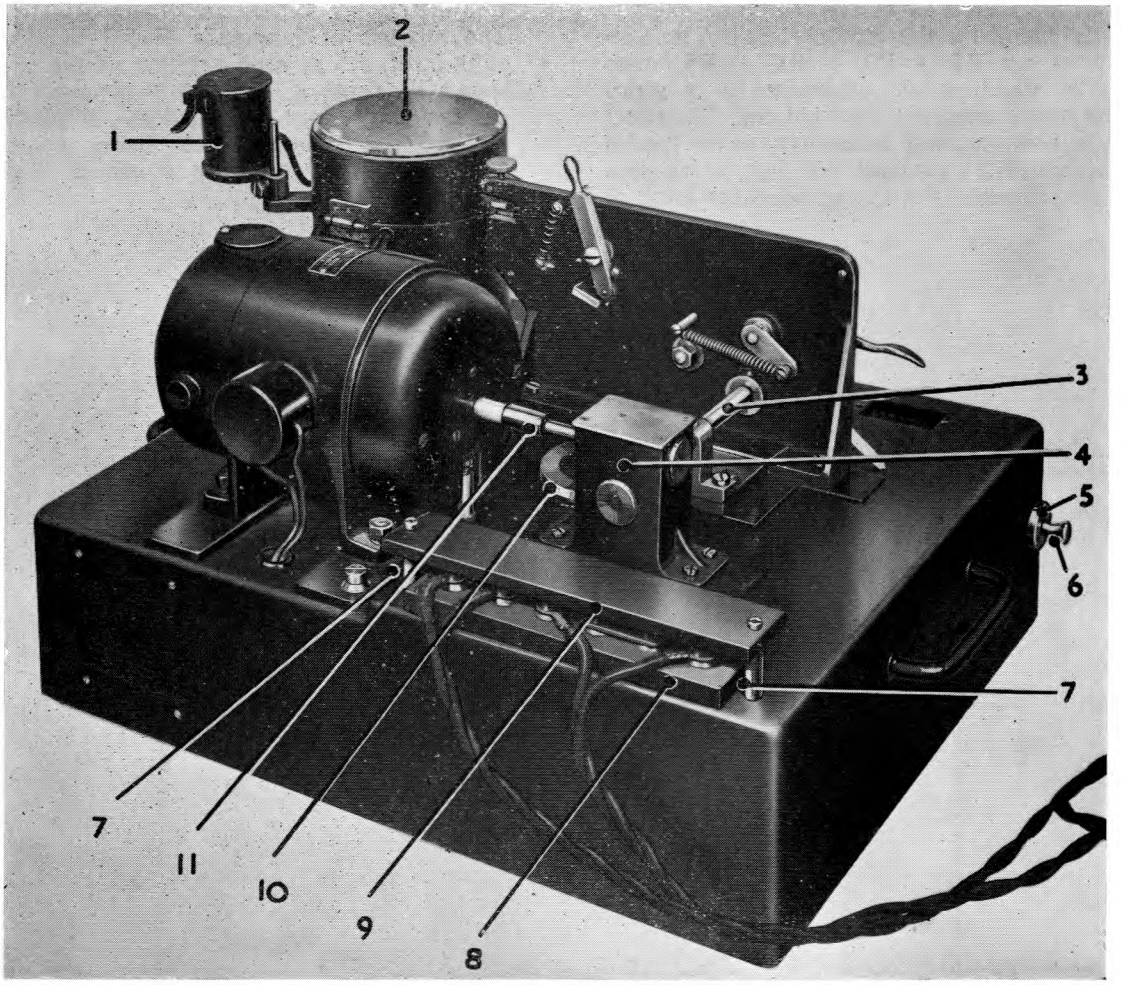
DESCRIPTION

2. The main features of construction can be seen from fig. 1, which is an illustration of an undulator, Type 3. Another view is given in fig. 3. The essential parts are: —

(1) An electric motor. This operates the paper drive roller through a suitable reduction gear.

(2) An adjustable platen. The tape is drawn along the platen, at the top end of which it is lightly in contact with the recording pen when in use.

(3) Two tape drawers. These each hold a reel of tape on a turntable.



1. Inkwell
2. Glass for relay cover
3. Paper drive spindle
4. Gearbox
5. Drawer catch plate
6. Drawer catch knob
7. Cover plate support
8. Terminal board
9. Cover plate for terminal board
10. Bezel for window
11. Coupling

Fig. 3 Rear view of undulator, Type 3

(4) The relay. The received signal is applied to the moving coil of the electro-magnetic relay. The movement of the coil actuates the recording pen, which is supplied with ink from a small reservoir.

The Type 3 undulator has a moving-coil relay with 20 + 20 ohms windings.

The driving motor

3. The driving motor for operating the tape-pulling device is a series-wound single-phase a.c. motor of conventional design. It operates directly from 240 volt a.c., 25-65 Hz mains. It is bolted securely to the cast metal base of the machine and the shaft is coupled flexibly to the worm gear of a 40: 1 reduction gearbox. The drive from the gearbox is flexibly coupled to the paper drive roller. The complete circuit diagram of the undulator is shown in fig. 4 and the disposition of the electrical components mounted in the base will be seen from fig. 5. Referring to the circuit diagram, consider the mains connected to the two terminals (which are on the terminal strip at the back of the machine). On pressing the special switch S1 both arms of the switch close, and the arm S1B completes the motor circuit. The arm S1A shorts out R2 + R3 + R4 + R5, some portion of which would otherwise be in series with the motor armature and field coil. The effect of S1A is, however, only momentary as the special construction of S1 provides for S1A to re-open under the influence of a spring when the knob of the switch is released. Arm S1B on the other hand is self-locking and remains closed.

Speed regulation

4. The speed of the motor determines the rate at which the paper tape is drawn past the recording pen. In order to accommodate different signalling speeds some measure of control is necessary. This control will ensure that at high speeds the tape moves fast enough to give reasonably long Morse characters, and at low speeds the length of the recorded characters is not excessive. Either condition would make interpretation more difficult and the latter would also lead to waste of tape. Regulation of speed is effected by the switch S2. Reference to the circuit diagram will show that this switch may be set to any one of eleven positions, each of which is connected to a different point in the chain of resistors R2 + R3 + R4 + R5. The motor can thus be run at eleven different speeds, depending on the amount of resistance connected in series with it through the switch S2. The resistor R5 has a maximum value of 600 ohms and is pre-set by the manufacturers to suit the motor in use. Tape speeds up to about 12·2 metres per minute are obtained in this way. The amount of resistance placed in circuit in addition to R5 at each position of the switch is shown in Table 1. The figures given in the last column may vary considerably with different motors, those speeds quoted being typical. The equivalent paper speed in ft/min is shown in brackets.

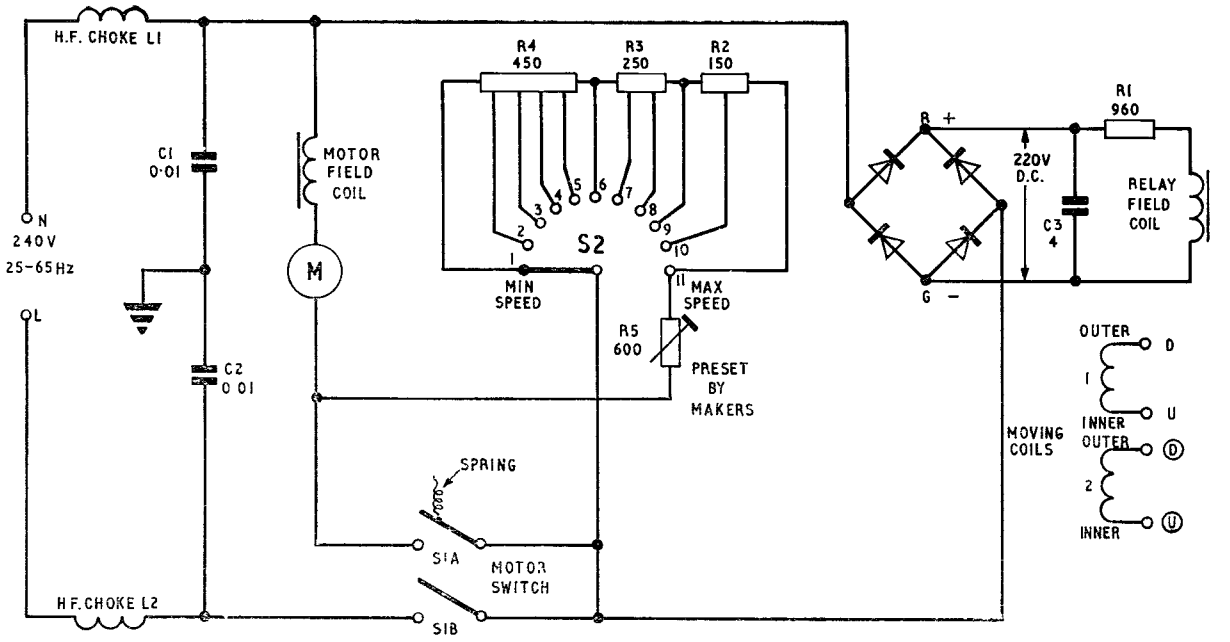
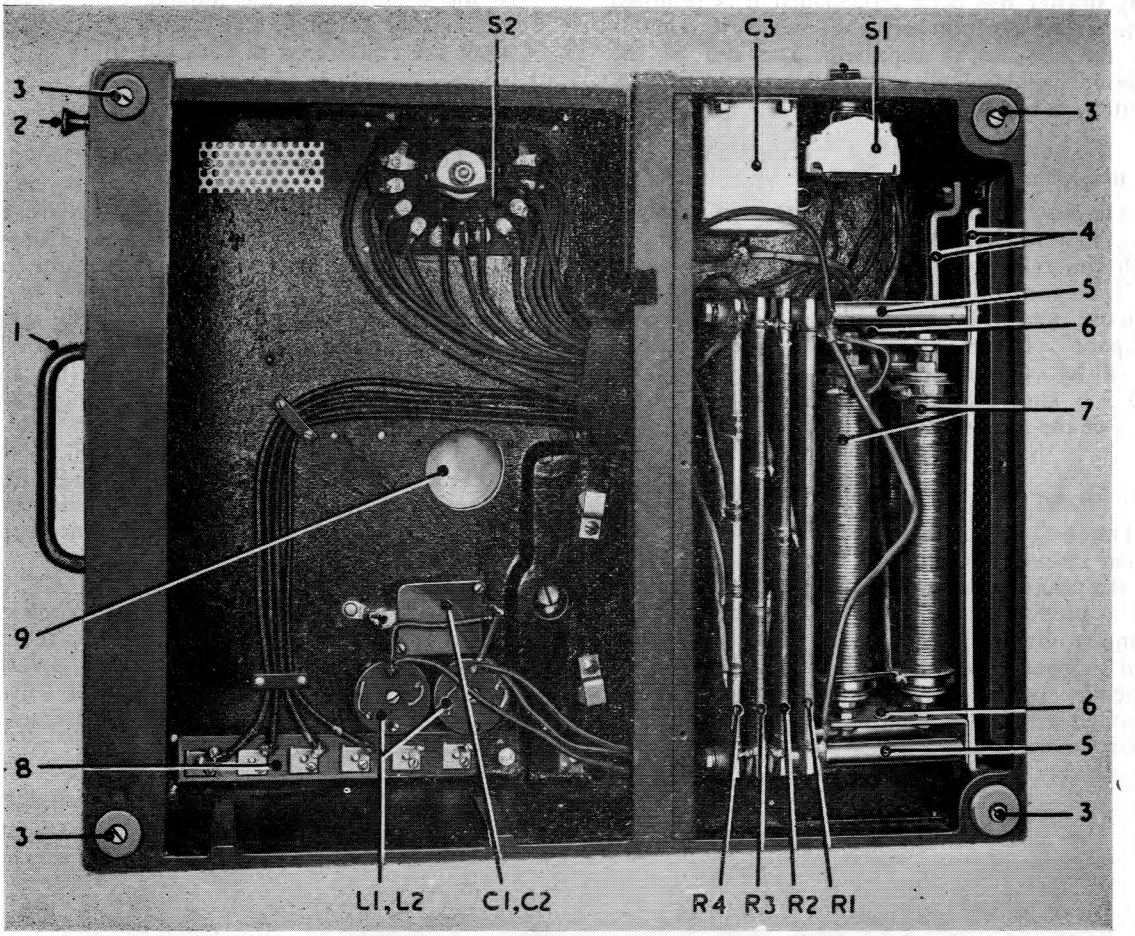


Fig. 4 Circuit diagram



1. Lifting handle
2. Drawer catch knob
3. Recorder base rubber foot
4. Resistance unit bracket
5. Resistance unit distance piece
6. Rectifier mounting bracket
7. Relay rectifier unit
8. Terminal board
9. Window

Fig. 5 Underside view with tape drawers removed

TABLE 1

Speed regulation data

Stud	Additional resistance (ohms)	Approximate paper speed (metres/min)	
1	850	zero	
2	745	0·91	(3)
3	635	1·83	(6)
4	570	3·66	(12)
5	485	6·10	(20)
6	400	7·64	(25)
7	316	10·06	(33)
8	233	11·89	(39)
9	150	13·11	(43)
10	75	14·02	(46)
11	0	14·94	(49)

Tape feeding arrangements

5. The tape from the tape drawer emerges through a slot in the main base and is fed upwards through the paper guide, over the platen roller and down the platen. At the lower end of the platen it is gripped between the paper drive roller and the paper jockey roller. The platen is pivoted near its lower end and the upper end can be moved up and down by the spring-controlled platen operating arm. When recording is not in progress the platen should be lowered to remove the paper from contact with the pen.

The tape drawers

6. A tape drawer containing a partly used reel of tape is shown in fig. 11. The roll of tape rests on a light turntable, and the free end is passed round a jockey roller controlled by a light spring. It then passes between the blades of a guillotine which is triggered by a button protruding through the front of the drawer. Next the tape passes under a paper guide roller at the right-hand side of the drawer, through an aperture in the drawer, and up through the slot in the main base. Two drawers are provided in order to preserve the continuity of the record. The lower drawer contains the roll in use. The upper one is the reserve. When the paper supply in the lower drawer is exhausted and the drawer is removed the upper

one drops into the lower position. When the empty drawer has been replenished it is returned to the upper position (reserve) where it remains until the process is repeated. The use of the guillotine will be dealt with under the section on operation in para. 22.

The magnetic relay

7. A close-up photograph of this item is given in fig. 6, and details of the link mechanism by which the relay operates the pen are shown in fig. 7. In the top illustration the pen is shown at "mark" and in the lower illustration it is shown at "space". The electrical circuit diagram forms part of fig. 4. The relay used in the undulator Type 3 is known as the magnetic relay, Type 63 and is of the moving coil type.

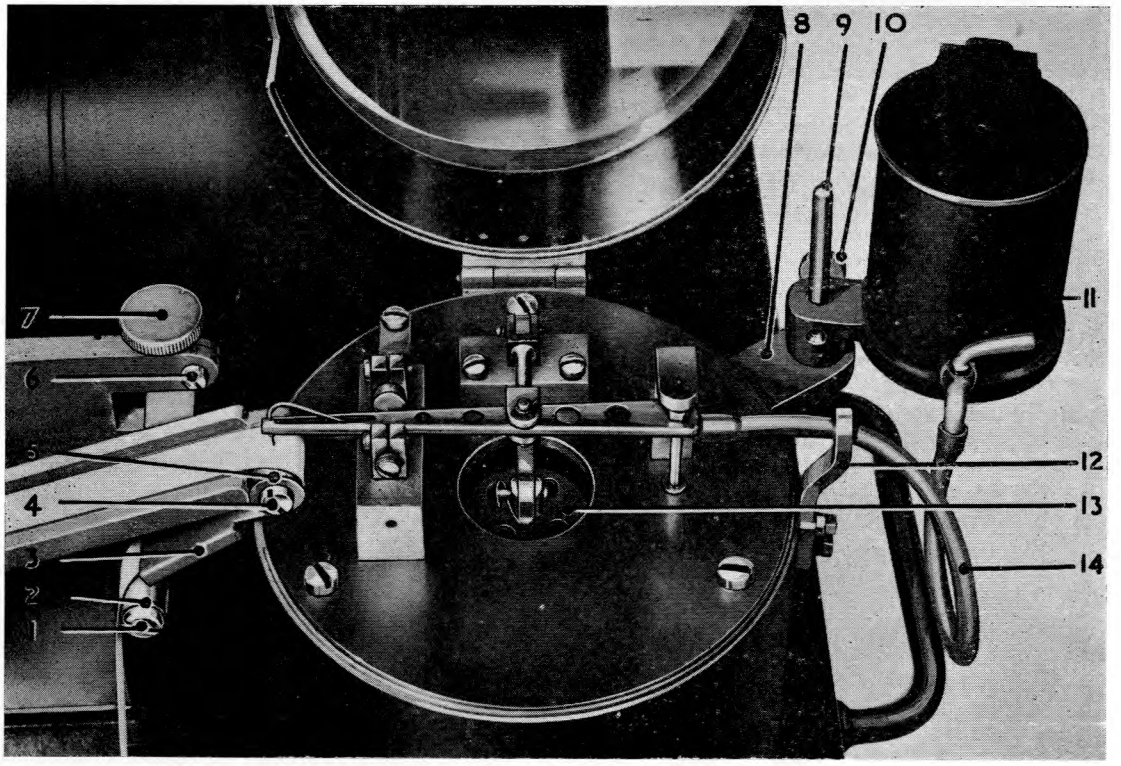
Relay circuit

8. The a.c. mains supply is fed to a bridge rectifier circuit consisting of four metal rectifiers. The d.c. output from the bridge, at about 220 volts, is used to produce a strong magnetic field by passing it through the iron-cored field coil. The signal currents are usually rectified audio-frequency signals, or d.c. pulses from a valve-controlled circuit, where one valve supplies the marking currents and another the spacing currents. Alternatively the spacing current may be supplied from a steady source. These currents are applied to the windings on the moving coil. Alternative methods of coupling the undulator to the signal input are considered in para. 13 to 16.

Mechanical construction

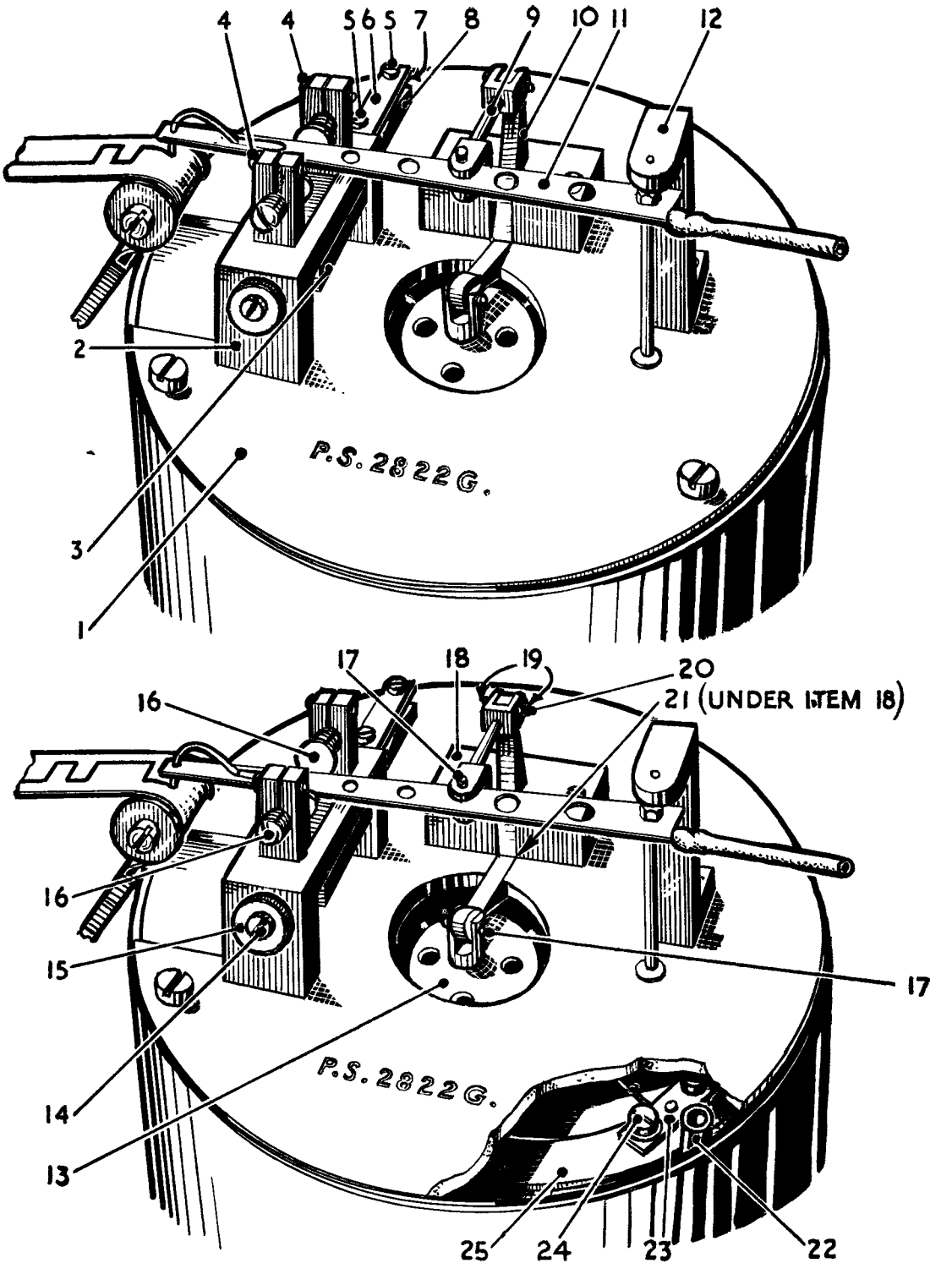
9. The former carrying the moving coil is suspended in a small air gap between the field coil and the iron core. Movement of the coil can take place only in a vertical direction. Current is applied to the windings through thin flexible bronze wires. The coil unit is attached to a bell crank. This, in turn, is coupled through the siphon arm link to the siphon arm. By means of this linkage any vertical movement of the moving coil is transmitted as a horizontal movement to the siphon arm, on which the fine steel tube forming the recording pen is carried. The pen receives its ink supply from an inkwell through a flexible tube. Care must be taken to turn off the tap on the inkwell when recording is not in progress.

10. The effect of the signals passing through the windings of the moving coil is to move the coil in a vertical direction according to the polarity of the signal currents. Marking currents cause the coil to move upwards, and spacing currents move the coil downwards. These movements are transmitted to the siphon arm which is thus moved



1. Screw for spindle
2. Paper roller
3. Paper guide
4. Roller spindle
5. Platen roller
6. Platen stop locking screw
7. Platen stop screw
8. Inkwell support
9. Inkwell support rod
10. Inkwell thumbscrew
11. Inkwell with tap
12. Rubber tube support
13. Relay coils
14. Ink siphon tubing

Fig. 6 Top of Magnetic Relay Type 64, showing recording pen



1. Relay base plate, complete with pivot bush
2. Siphon arm stop bracket
3. Siphon arm stop support bridge
4. Stop clamping screw
5. Damping spring adjusting screw
6. Damping spring top plate
7. Siphon arm stop damping spring
8. Damping spring adjusting block
9. Siphon arm link
10. Bell crank
11. Siphon arm
12. Bracket
13. Coil assembly
14. Siphon arm stop adjusting screw
15. Moving bracket stop screw locking nut
16. Siphon arm stop
17. Moving coil pin
18. Bell crank fulcrum block
19. Retaining rings for bell crank pins
20. Link bell crank pin
21. Bell crank fulcrum pin
22. Relay base plate support
23. Moving coil terminal block
24. Terminal screw
25. Moving coil terminal insulation ring

Fig. 7 Details of recording pen operating linkage

backwards and forwards transversely across the tape as the siphon arm deflects. Simultaneously the tape is being pulled forward at a uniform rate by the motor. The pressure of the tip of the pen on the paper must not be too heavy, otherwise the friction on the paper will cause indifferent results. A simple damping device is provided for smoothing out any ragged effect on the record which might otherwise be caused by the siphon arm rebounding from the stops. The siphon arm stop bracket is so mounted that it can travel slightly to and fro horizontally as the siphon arm strikes it. The amount of travel of this stop bracket can be adjusted by a small screw fitted in the end of the bracket, and a jockey spring provides a friction adjustment for restraining the horizontal movement.

INSTALLATION

Signal input to the undulator

11. When Morse signals are to be read by ear, it is usual to arrange for the alternating current output from the receiver to operate telephone headsets at some suitable audio frequency. If the transmitted signal is already modulated at some suitable audio frequency, e.g. 1,000 Hz, this modulation may provide the alternating current to the headsets. When the transmitter is sending continuous wave signals, the necessary audio-frequency signals are produced in the receiver by beating the received signal with the output of a local heterodyne oscillator.

12. In order to operate the undulator, however, it is necessary to pass direct currents through it. These must correspond in direction and duration to the elements of the Morse characters. For example, when a Morse dash is being transmitted, a direct marking current corresponding in length to a "dash" must be applied to the undulator coil to move the recording pen over to the marking position and hold it there. On cessation of this marking current at the end of the dash, the pen must move over to the space position. At high speeds the change from mark to space must be extremely rapid. If a modulated Morse signal is used to operate the undulator the alternating current normally used to operate telephone headsets must be rectified into d.c. pulses before being applied to the undulator coils. Alternatively in some receivers especially designed for the purpose the actual carrier frequency, or the intermediate frequency of a superhet receiver, is rectified and passed to the undulator coils as pulses. In this connection it is necessary to ensure that all tone components be removed from the signal in the process of rectification. This point is important because if a strong tone component of comparatively low frequency be present in the input to the undulator, the relay may attempt to reproduce this frequency during the recording of each Morse character, as well as recording the Morse characters themselves. Each dot and dash on the tape record would then appear split into several smaller elements, making interpretation more difficult. The standard item of equipment for carrying out the processes required to make the receiver output suitable for operating the undulator is a high-speed bridge unit.

Methods of connection

13. The output from the high-speed bridge units, mentioned in the previous paragraph, consists of a mark output which is the anode current through the mark output valve. The space output consists of the anode current through the space output valve. There are various methods of connecting these output currents to the undulators, Types 3 and 10. The Type 10 undulator can employ either a relay with 1,000 + 1,000 ohm windings or 20 + 20 ohm windings. The Type 3 has a relay with 20 + 20 ohm windings. One reason for the use of an undulator with low-resistance coils, is that a heavier gauge of wire can be used. This allows a more robust construction and makes the equipment less susceptible to breakdown under tropical conditions. A more important point is that a substantial pulse of current is required to overcome the inertia of the moving parts of the relay and change over rapidly from the mark to the space condition. It is desirable to make this transit as rapid as possible, because if carried out slowly the changes from mark to space or vice versa will appear as sloping lines on the tape, making interpretation more difficult. Once the transit of the recording pen has been effected it requires a relatively small current to hold it against either of the stops until the polarity of the signal changes. The use of low-resistance coils, therefore, in conjunction with a step-down transformer input helps to achieve this rapid movement. High-resistance coils are useful, on the other hand, where the highest speeds are not required. A high-resistance undulator, such as the Type 10 can then be connected directly to a valve circuit delivering a current of the order of 30-60 mA. The three most commonly used methods of connecting the undulators are given in the ensuing paragraphs. The coils, except for the field coils, are changed to suit high speed requirements.

Direct connection

14. For this method the undulator Type 10 can be used with a circuit such as that given in fig. 8. One winding of the moving coil is connected directly in the anode circuit of the mark output valve. The other winding is similarly connected directly into the anode circuit of the space output valve. The current through each coil will be about 30 mA (max.) from the high-speed bridge unit Type 3, or 60 mA (max.) from the high-speed bridge unit Type 4. As the spacing and marking currents are of substantially constant amplitude, the acceleration of the recording pen between the stops is limited. The maximum speed of this arrangement is in the neighbourhood of 100-150 w.p.m. To obtain the highest speeds the amplitude of the tape record must be adjusted to a small value.

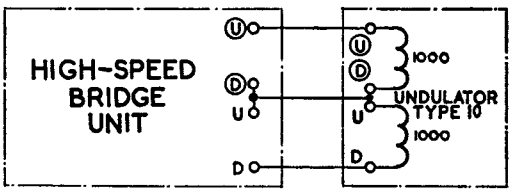


Fig. 8 Connections for direct coupling

Working through a high-speed relay

15. In order to attain greater speed the output from the high-speed bridge unit may be applied to a high-speed relay, see fig. 9. A relay having a resistance of about 25 ohms per coil such as the magnetic relays, Type P or Type 405 should be used with an operating current of, say, 20 to 30 mA per coil. The low inertia small movement, and rapid action of the relay tongue is such that it can accommodate comparatively high working speeds. The contacts of the high-speed relays are used to switch a local centre-tapped d.c. supply to send corresponding currents through the undulator windings. This locally-provided current can be regulated to a suitable value for operating the undulator relay. As already mentioned in para. 13 it is very desirable to pass a large current through the undulator windings at the beginning of the changes from mark to space, and vice versa, in order to reduce the transit time to a minimum. Having effected this transit, a small current suffices to hold the recording pen against the stop. When an undulator is operated through a high-speed relay, it is therefore usual to place a resistance in series with the undulator relay coils and to shunt this resistance with a capacitor. The battery

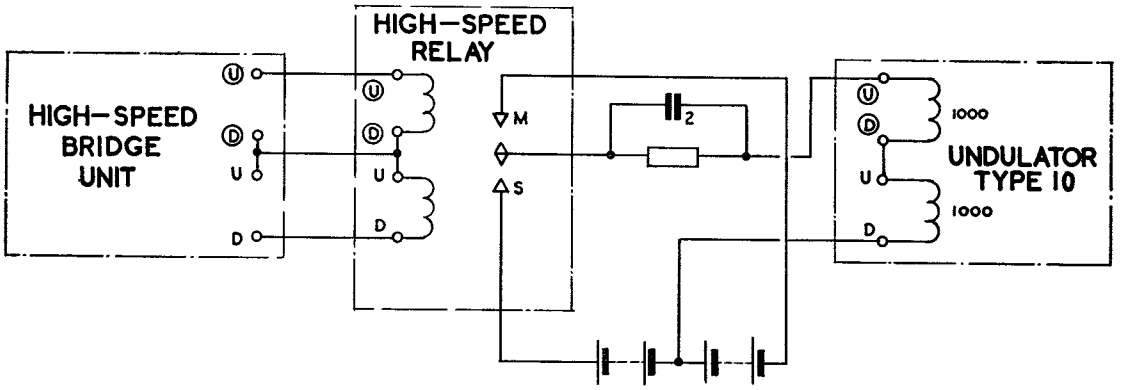


Fig. 9 Connections for relayed working

voltage should be sufficient to permit this. The resistance should be of such a value as to control the *steady* current through the undulator coils at about 15 mA. The capacitor in parallel with the resistance gives a high initial current through the undulator at the instant the high-speed relay tongue makes contact with its mark or space contacts. At this instant the capacitor is charged by the battery through the undulator coil, giving rise to a high initial current. As soon as the capacitor is fully charged the current settles down to the steady value determined by the resistance. By using this method of connection speeds in excess of 300 w.p.m. can be obtained. The coils of the high-speed relay are connected directly to the valve anode circuits, one coil being used for the marking currents and one coil for the spacing currents. If the relay is near enough to the receiver aerial it will induce heavy interference in the latter. This is due to the peaky waveform of interference set up by the relay in making and breaking comparatively large currents. The magnetic relay, Type 405, which is fitted with radio interference suppressors should be used in such circumstances in preference to the relay Type P which is not so fitted.

Transformer coupling

16. The method of producing the large initial currents required for accelerated movement of the recording pen when high speeds of working are desired, is to drive the undulator coils from the valve circuit of the bridge unit through a step-down transformer, see fig. 10. The Type 3 undulator, which has low-resistance coils, is used for the application. The undulator is coupled to the output valves of the high-speed bridge unit in a manner very similar to that adopted in transformer coupled moving coil loudspeakers to the output stage of a receiver. An auto-transformer is used and each undulator coil is connected in parallel with a portion of the transformer winding. Part of the d.c. anode current through the transformer winding is thus diverted to the undulator coil, and provides the current required to hold the recording pen at mark or space, during steady conditions. When, however, the signal changes from mark to space, and there is a reversal of current in the transformer windings, a very high e.m.f. is induced across the transformer primary and a proportionate e.m.f. across the secondary. By arranging the turns ratio so that the load imposed by the undulator is matched to the valve impedance a very high transient current will be induced in the secondary winding. As both coils of the undulator are connected to the common transformer the transient current at the moment

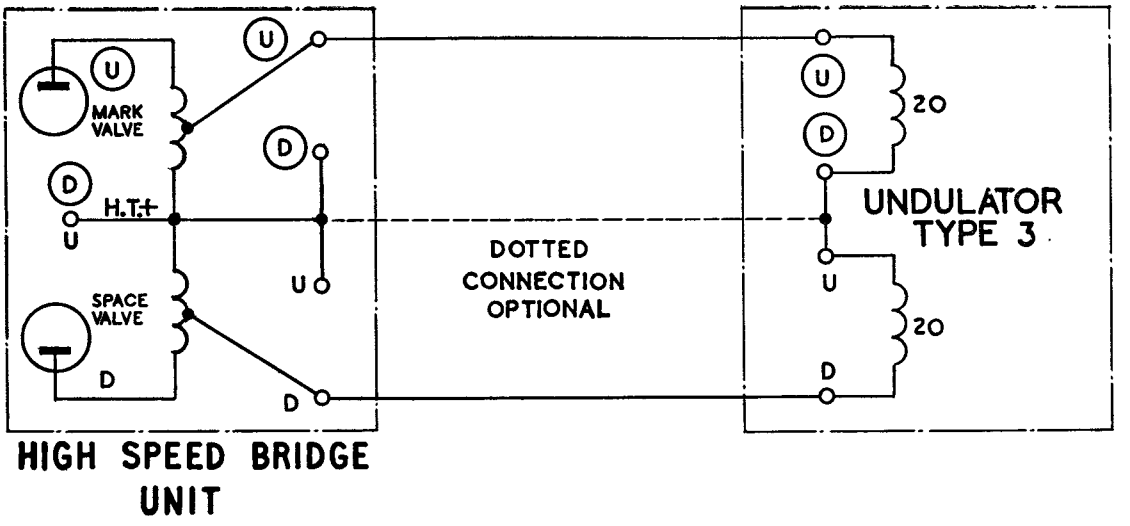


Fig. 10 Connections for transformer coupling

of change from mark to space acts in the correct phase in both coils. Greater efficiency is thus obtained than with direct connection to the valves, where only one coil is operative. The steady holding current, is, of course, effective through one coil only. A speed of 225-250 w.p.m. is obtainable with transformer coupling using the undulator, Type 3 and a high-speed bridge unit, Type 3 or Type 4.

Maximum speeds

17. It should always be remembered when discussing maximum speeds obtainable with undulators that the speeds quoted assume a perfect signal input. It is only on rare occasions that high-speed Morse signals received over a radio link are free from some form of distortion. When the high-speed bridge unit is operated from such signals some degree of varying bias is usually present in spite of the various signal-forming and limiting circuits in the bridge unit. It will be appreciated that if either mark or space limits are shortened momentarily by such variations of bias the effect is the same as if the signalling speed were increased. Thus although the nominal speed of transmission is within the capabilities of the undulator, failure will result if the distortion increases the effective speed above that which the undulator can handle.

Automatic gain control

18. On any receiver used for the reception of high-speed Morse signals it is desirable to incorporate means for controlling the time constants of the a.g.c. system and also its intensity of operation. As the intelligent use of a variable a.g.c. system is a matter for the operating staff, consideration of this point is deferred until para. 24 to 27.

OPERATION

Preliminaries

19. See that the equipment is plugged in to the power supply and that it is connected up to the high-speed bridge unit. Check that the recording pen is functioning properly, and that there is sufficient ink in the inkwell.

Loading a tape drawer

20. The rolls of paper tape used may be either ungummed or gummed. For temperate climates gummed tape is generally used, and moistened by using water in the gumming box. when affixing to form 2054. In tropical and damp climates it is more satisfactory to use ungummed tape and, when it is required to affix the tape to form 2054, to use gum in the gumming box. To load the drawer with a new tape proceed as follows:—

(1) Set the guillotine by lifting its moving blade on to the top of the guillotine operating catch.

(2) Place the new roll of tape on the turntable so that it rotates clock-wise when the free end of the tape is pulled.

(3) Guide the tape round the jockey roller and, gummed side upwards, between the blades of the guillotine, see fig. 11.

(4) Draw the paper under the guide roller and through the aperture in the side of the drawer until a length of about 15 cms (6 in) is free.

(5) Slide the drawer into position on top of the drawer in use, guiding the free end of the tape into the slot in the main base. Special care must be taken not to shear the tape during this operation as the clearance is very small.

1. Tool compartment cover
2. Jockey roller
3. Roller spindle
4. Jockey stop pins
5. Jockey arm
6. Arm spindle
7. Jockey arm spring
8. Tape guard bracket
9. Tape guard
10. Tape wheel bush

Fig. 11 Interior of tape drawer

In fig. 12 is shown the guillotine, the top view shows it set and the lower view depicts the guillotine operated. Details of the paper drive rollers and platen-operating levers are given in fig. 13.

Feeding in a new tape

21. To feed in a new tape proceed as follows:—

(1) Lower the platen away from the tip of the recording pen by means of the platen operating arm.

(2) Gently pull the free end of the tape from the lower drawer through the slot in the main base. Thread it up to the left of the paper roller, through the paper guide, over the platen roller, along the platen (gummed side down), and between the paper drive roller and paper jockey roller.

(3) Raise the platen when recording is to start.

Changing tapes while recording

22. When the tape feeding out of the lower drawer is nearly exhausted, as will be indicated by its red colouring, feed in the tape from the new reel in the upper drawer as follows:—

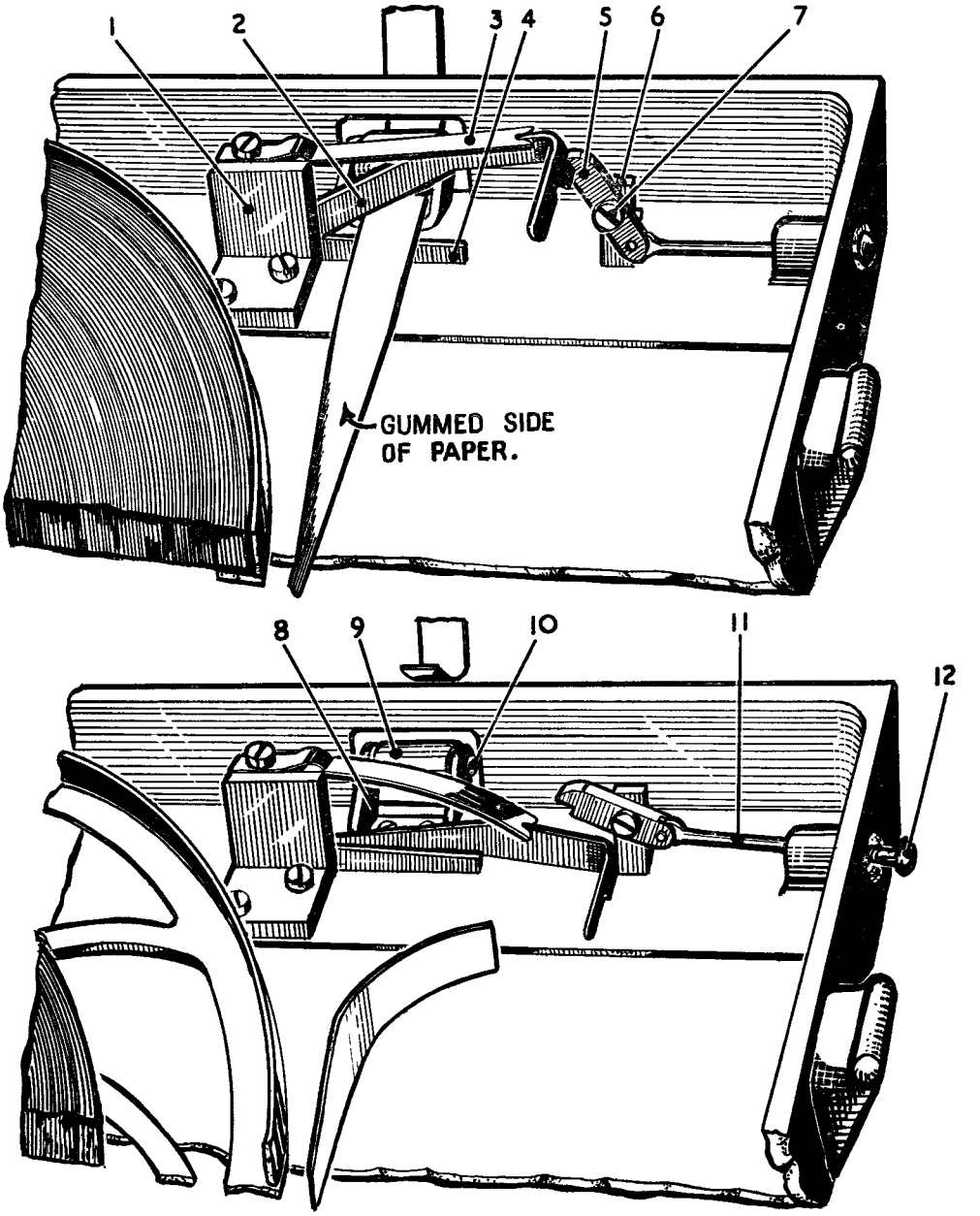
(1) Thread the new tape up through the paper guide and between the old tape and the platen roller. It will feed forward with the old tape until it is gripped between the paper drive rollers.

(2) When the new tape has reached the paper drive rollers, and not before, press the guillotine button of the lower drawer and remove the drawer.

(3) The upper drawer now falls into the place of the lower one.

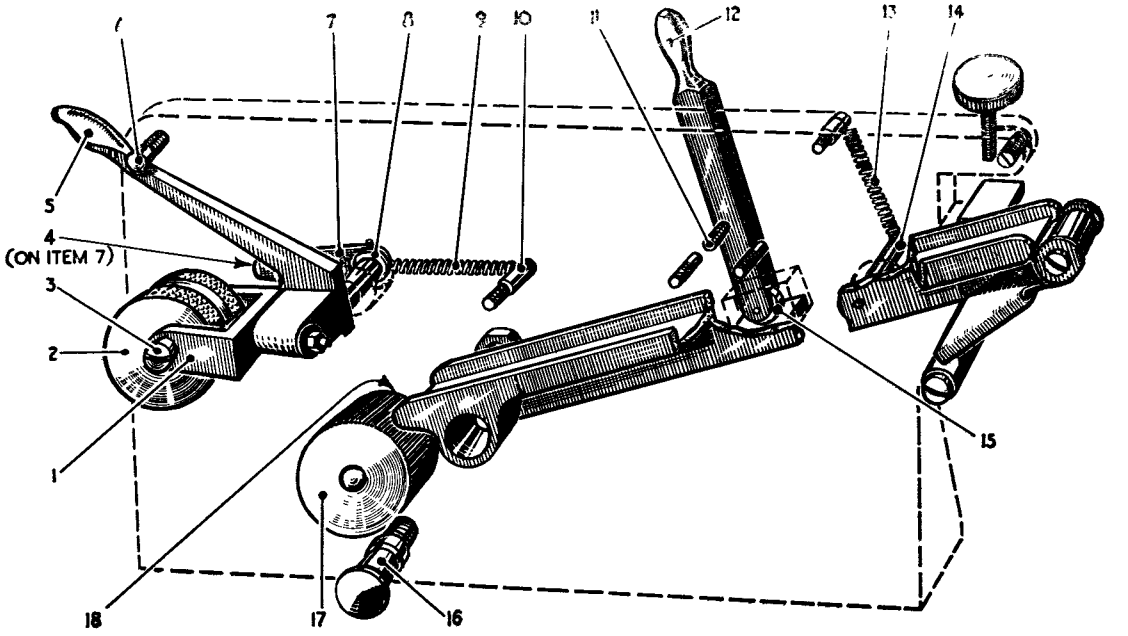
(4) Reload the empty drawer with tape as described in para. 20.

23. Adjust the speed of the tape by means of the switch S2 to suit the signalling speed. The speed should be as low as possible, consistent with legibility. As a guide, adjustment to a speed which produces dash elements of about the same length as the amplitude of the recording pen will generally be found satisfactory.



1. Guillotine bracket
2. Guillotine moving blade
3. Guillotine springs
4. Guillotine fixed blade
5. Gullotine operating catch
6. Catch support bracket
7. Catch pivot screw
8. Roller bracket
9. Paper guide roller
10. Roller spindle
11. Catch connecting rod
12. Guillotine operating knob

Fig. 12 Details of guillotine



1. Bracket
2. Paper jockey roller
3. Paper jockey roller spindle
4. Spring anchor
5. Paper roller jockey arm
6. Jockey arm stop
7. Spring arm
8. Washer for spring arm
9. Paper jockey spring
10. Paper jockey spring anchor
12. Platen operating arm
13. Platen tension spring
14. Platen spring anchor
15. Roller for platen operating arm
16. Platen pivot pin
17. Paper drive roller
18. Roller grub screw

Fig. 13 Paper drive rollers and platen-operating levers

Effect of receiver operation and design on undulator working

Automatic Gain Control systems

24. The normal a.g.c. system of a receiver is not always suitable when the reception of high-speed signals is to be undertaken. It will be realised that the incoming signal must pass through the receiver and be rectified and smoothed by the a.g.c. system before the control voltage can be fed back to affect the gain of the amplifying stages. The processes of rectifying and smoothing introduce a time constant. There is, therefore, a small but finite delay between the application of the signal to the receiver and the final condition when the receiver gain has adjusted itself. Similarly, the a.g.c. system keeps the receiver gain reduced for a very short time after the signal input has been removed. For telephone headset reception the time constants of the a.g.c. system can be adjusted to meet the average degree and rapidity of fading of the carrier wave. When, however, a transmitter is being keyed on and off by Morse keying there is no longer a continuous carrier and the time constants of the a.g.c. circuit must be such that the gain of the receiver is held at the prevailing average value during spaces between signal elements (i.e. between dots and dashes). These time constants may not be suitable for dealing with the fading and changes in level of the signal. It is therefore not always possible to secure such a rigid control of telegraph signals as can be obtained with telephone signals. A detailed technical examination of this subject is outside the scope of this chapter. The following paragraphs are however included to assist operating staff to understand the conflicting considerations which must be taken into account in designing an a.g.c. system suitable for high-speed signalling. An understanding of certain effects by the operating staff will assist them to make intelligent use of the controls provided on the receiver and bridge unit and so obtain the best undulator record possible under difficult conditions.

25. *"Off" time constants.* If a signal can drop to a small percentage of its original value within a small fraction of a second, and if it takes the a.g.c. system one or two seconds to adjust its controlling output voltage to the new signal strength, there will be a short period during which the receiver gain is set to the original strong signal level but is receiving the new and very much weaker signal level. When a signal is varying very rapidly in strength it follows that a short off time constant in the a.g.c. system is desirable. The maximum time which can be allowed for the a.g.c. system to become inoperative after the signal is removed must therefore be fixed in terms of the

speed at which a signal may fade or alter its strength. The minimum limit to the time taken by the a.g.c. system to become inoperative after a signal is removed is set by the speed of transmission and the signal-to-noise ratio. In order to appreciate this point it must be remembered that, in the absence of an input signal the a.g.c. system adjusts the receiver to its most sensitive condition, as no a.g.c. control voltage is being produced. Random noise picked up by the aerial, or inherent receiver noise, may therefore be sufficient to produce an unwanted record on the tape in such circumstances. When a signal is strong enough to operate the a.g.c. system the gain of the receiver is automatically lowered until it is just adequate to deal with the signal in question. Under these circumstances the random noise referred to will be insufficient to give random records on the tape. If the signal is being keyed at a comparatively slow speed, the off time constant must be so long that the receiver gain does not rise to its full value during the interval between words, in order to ensure that during these intervals the tape remains clear of random noise records. A comparatively long time constant is therefore desirable.

26. *"On" time constants.* In order that the initial characters of a high-speed Morse transmission may not be lost before the a.g.c. system has correctly adjusted the receiver gain to suit the signal strength, it might appear desirable that the time taken for the a.g.c. system to operate after a signal is applied should be as short as possible. An a.g.c. system capable of operating as soon as possible after a single dot is applied to it will, however, also tend to operate on any atmospheric or other peaky waveform of interference. Such considerations as these make it desirable to incorporate in high-speed signalling receiving equipment controls for varying the a.g.c. time constant and also its intensity of operation.

Signal-to-noise ratio

27. The high-speed bridge unit incorporates limiting circuits to ensure that the output currents to the undulator are independent of changes in signal input above the minimum value necessary for operating the bridge unit. But limiting circuits cannot think, and therefore cannot discriminate between the signal on the one hand and random clicks produced by noise on the other. A skilled wireless operator can receive signals as much as 6 or 8 dB below noise. Since the high-speed bridge unit does not possess the aural characteristics of the trained human ear, the signal-to-noise ratio for automatic reception must always be in favour of the signal. About 6 dB signal-to-noise ratio may be regarded as the minimum necessary for undulator reception.

Receiver bandwith

28. The high-speed keying of dots imposes a modulation frequency on the transmitter carrier. This means that the transmitter is radiating a carrier wave and side-bands. Receiver circuits therefore must pass the necessary band of frequencies. Except at very high speeds of working it will be found that receiver l.f. pass bands much narrower than those used for broadcast receivers can be employed. This gives a corresponding improvement in the protection offered by the receiver from noise and other unwanted transmissions. For most transmitting speeds likely to be met with in practice total bandwiths down to 1,000 Hz can be used. Narrower pass bands such as 300 or 100 Hz may only be usable at slower transmission speeds. Such narrow bands will tend to give heavy bias at high speeds. This can be corrected within limits by the bias control on the high-speed bridge units Types 3 or 4. The frequency stability of the transmitter and the first oscillator in the receiver will also influence the choice of pass band to be used.

Appendix 1

LIST OF PARTS

This Appendix contains a list of principal parts, with the Stores Reference numbers (where they have been allotted), and also a reference to an illustration to enable most of the items to be identified. As far as possible, items have been grouped to facilitate search. The makers' Refs. quoted in the last column are those of the latest patterns known at the time of writing. In a few instances there are minor differences between the items illustrated and the latest patterns. The most important of these concerns the Relay Rectifier Unit, which formerly consisted of four separate copper-oxide rectifiers wired as a bridge. It now consists of a single selenium rectifier appropriately constructed and tapped to provide a bridge. The new type of rectifier mounting bracket also should be ordered when a new-type rectifier unit is ordered as a replacement for the early type. When demanding spares for this equipment, reference must be made to AP.2980A, Vol. 3, if available, or to the appropriate sections of AP.1086. Where the maker's nomenclature differs from that used by the R.A.F., both have been shown in the first column the maker's nomenclature being in brackets.

Name of part	Shown in Fig. No.	Shown in Item No.	Stores Ref.	Makers Ref.
Undulator, type 3 (complete equipment)	1	—	10G/36	UG.6A PS.3744Q
Relay, magnetic, type 63 (*for undulator, type* 3) ...	7	—	10F/51	PS.2822G
Coil assembly (20 ohms + 20 ohms) ... ... (*for relay, magnetic, type* 63)	7	13	10F/54	WSK.3056, Edn. A
Relay base plate complete with pivot bush	7	1	—	5/60871/B
Relay base plate support	7	22	—	6/60871/B
Bracket complete with pivot bush	7	12	10F/2146	8/60871/B
Siphon arm complete with 2 bushes	7	11	10F/52	10/60871/B and 8A/60871/B
Siphon arm link	7	9	10F/56	15/60871/B
Bell crank	7	10	10F/53	13/60871/B
Link bell crank pin	7	20	10F/59	16/60871/B
Retaining rings for bell crank pins	7	19	10F/61	19/60871/B
Bell crank fulcrum pin	7	21	10F/58	14/60871/B
Bell crank fulcrum block	7	18	10G/3305	1/WSK.1537
Moving coil pin or siphon arm pin	7	17	10F/57	18/60871/B
Split cotter pin	—	—	10G/3301	20/60871/D Sht. 2
Siphon arm stop support bridge	7	3	—	22/60871/B
Siphon arm stop bracket	7	2	—	24/60871/B
Siphon arm stop	7	16	10G/13664	25/60871/B
Stop clamping screw	7	4	10G/13665	26/60871/D
Siphon arm stop damping spring	7	7	—	28/60871/B
Damping spring adjusting block	7	8	—	27/60871/B
Damping spring top plate	7	6	—	29/60871/B
Damping spring adjusting screw	7	5	10G/13666	30/60871/D
Syphon arm stop adjusting screw	7	14	10G/13667	45/60871/D
Moving bracket stop screw locking nut	7	15	10G/13668	46/60871/B
Moving coil terminal insulation ring	7	25	—	31/60871/A
Moving coil terminal block	7	23	—	33/60871/B
Terminal screw	7	24	10G/13669	34/60871/D
Insulation	—	—	—	50/60871/A
Rubber tube support	6	12	—	36/60871/B
Inkwell with tap	6	11	10G/13670 or 10F/55 or 10F/68	3/W3805/C
Inkwell thumbscrew	6	10	10G/13671	40/60871/B
Inkwell bracket	6	8	—	41/60871/A
Inkwell support rod	6	9	—	42/60871/A
Plate for inkwell bracket	—	—	—	43/60871/A
Glass for relay cover	3	2	10F/62	66E/38454/C
Recorder base rubber foot	5	3	10G/3302	SK.42486
Washer	—	—	—	288/SK40457
Lifting handle	5	1	—	45/62055/F
Drawer catch	—	—	—	26/62055/E
Drawer catch spring	—	—	—	27/62055/E
Drawer catch plate	3	5	—	28/62055/E
Drawer catch knob	3	26	—	29/62055/E
Drawer, feed, paper, complete	11	—	10G/42	—
Tape wheel spindle	—	—	—	6/62055/D
Tape wheel bush	11	10	—	4/62055/D
Tape wheel bearing plate	—	—	—	5/62055/D
Tape guard	11	9	—	11/62055/E
Tape guard bracket	11	8	—	12/62055/E
Jockey roller	11	2	10G/3867	70/38468/D
Jockey arm	11	5	10G/3868	8/62055/D
Roller spindle	11	3	10G/3869	7/62055/D
Arm spindle	11	6	10/3870	9/62055/D

Name of part	Shown in Fig. No.	Shown in Item No.	Stores Ref.	Makers Ref.
Jockey arm spring	11	7	10G/3316	10/62055/D
Jockey stop pins	11	4	10G/3317	40/62055/F
Guillotine bracket	12	1	—	13/62055/E
Guillotine fixed blade	12	4	10G/3871	18/62055/E
Guillotine moving blade	12	2	10G/3318	19/62055/E
Guillotine springs	12	3	10G/3319	17/62055/E 46/62055/F
Guillotine operating catch	12	5	10G/3320	20/62055/E
Catch support bracket	12	6	—	22/62055/E
Catch pivot screw	14	7	—	21/62055/C
Catch connecting rod	12	11	—	23/62055/E
Guillotine operating knob	12	12	—	24/62055/E
Guillotine catch spring	—	—	10G/3323	25/62055/E
Paper guide roller	12	9	10G/3872	15/62055/E
Roller bracket	12	8	—	14/62055/E
Roller spindle	12	10	10G/3873	16/62055/E
Tool compartment cover	11	1	—	30/60881/E (not used on latest models)
Motor, a.c., single-phase, series wound, 25-65 Hz 230V	1	5	10G/33	6/WIS. 754
Brush	—	—	10G/34	—
Brush, cap	—	—	10G/35	—
Clip	5	—	—	127/60881/E
Coupling	3	11	10G/3874	1/WSK.3048
Gear box 40 : 1	3	4	10G/3875	WSK.3047.Edn.A
Paper drive spindle	3	3	10G/3876	1/WSK.3052
Paper drive roller	13	17	10G/3877	44/60881/D
Roller grub screw	13	18	10G/3878	P.11751 (SK.42836)
Paper roller jockey arm	13	5	—	46/60881/C
Bracket	13	1	—	47/60881/C
Paper jockey roller	13	2	10G/3879	50/60881/C
Paper jockey roller spindle	13	3	10G/3880	51/60881/C
Washer for spring arm	13	8	—	303/WSK.40457
Spring arm	13	7	—	53/60881/E
Spring anchor	13	4	10G/3881	55/60881/E
Paper jockey spring anchor	13	10	—	56/60881/E
Paper jockey spring	13	9	10G/3315	57/60881/E
Jockey arm stop	13	6	—	58/60881/E
Platen pivot pin	13	16	—	30/62055/E
Platen spring anchor	13	14	—	41/62055/F
Platen tension spring	13	13	10G/3326	66A/60881/E
Platen roller	6	5	10G/3882	38/62055/F
Roller spindle	6	4	—	39/62055/F
Platen stop screw	6	7	10G/3883	72/60881/D
Platen stop locking screw	6	6	—	84/62055/A
Platen operating arm	13	12	—	31/62055/E
Roller for platen operating arm	13	15	—	32/62055/E
Pivot screw for platen operating arm	13	11	—	33/62055/E
Paper guide	6	3	—	37/62055/F
Paper roller	6	2	10G/3884	74/60881/E
Spindle for paper roller	—	—	10G/3885	75/60881/E
Screw for spindle	6	1	—	76/60881/E
Terminal board	3	8	—	92F/60881/D
Cover plate for terminal board	3	9	—	94/60881/D

Name of part	Shown in Fig. No.	Item No.	Stores Ref.	Makers Ref.
Cover plate support	3	7	—	95/60881/D (not used on latest models)
Resistance units, 230V, 50 Hz supply				
Motor:- 3 sections				
Resistance, type 694	5	R2	10W/253	DW.1021. Edn. AA
Resistance, type 695	5	R3	10W/254	DW.1021. Edn. AB
Resistance, type 696	5	R4	10W/255	DW.1021. Edn. AC
Relay:- 1 section				
Resistance, type 693	5	R1	10W/252	DW.1021.Edn. Z
Resistance unit distance piece	5	—	—	220/SK40460
Resistance unit bracket	5	4	—	43/62055/F
Bush for relay leads	—	—	—	WP.514 (WSK.2357)
Bush for motor leads	—	—		42/SK40447
Wiring cleat	—	—		3/SK41223
Choke, h.f., type 60 (interference suppressor choke) ...	5	L1 L2	10C/249	WSK.3203 PS.8838A
Terminal	3	—	—	CP.6776
Capacitor, type 640 (interference suppressor capacitor 0·01 μF)	5	C1 C2	10C/250	195/62055A, Sht. 9
Resistance protection cover for a.c. models	—	—	—	2/62055/G
Resistance unit distance piece for a.c. models	5	5	—	161/62055A, Sht. 14
Distance piece for a.c. models	—	—	—	162/62055A, Sht. 14
Rectifier, metal, type 19 (relay rectifier unit — 4 per machine)	5	7	10D/51	WIS. 1549 (early models)
or				
Relay rectifier unit (1 per machine)	—	—	—	WIS.2971, ref. 3 (later models)
Switch cover	1	8	—	WSK. 6052
Insulation for switch S.2	—	—	—	WSK. 6053
Tubing, bicycle valve (siphon rubber tube, 2½ in. long) ...	6	14	323/54	53/60871/D
Switch, type 200 (switch complete with base)	5	S2	10F/49	—
Switch, type 201 (supply switch, "Twinob" 5 amps) ...	5	S1	10F/50	IS. 161
Window	5	9		89/60881/D
Bezel for window	3	10		90/60881/D
Capacitor, type 641 (smoothing capacitor 4 μF)	5	C3	10C/251	3/SK46163
Rectifier mounting bracket	5	6	—	3/62055/G (early models) or W.10505/C ref. 3 (later models)
Accessories:—				
Crystals, green malachite	—	—	33C/794	Note 1
Ink, undulator, special black	—	—	—	H890. Note 2
Papers, filter, circular 24cms. diameter	—	—	33C/795	Note 3
Tape, paper, slip No. 1	—	—	10G/7530-99-901-1480	Note 4
Wire, steel, 36 s.w.g. (for cleaning siphon)	—	—	10G/3968	—

Note 1. I.C.I. Ltd., London, S.W.1.

2. Waterlow & Sons Ltd., London, E.C.2.

3. H. Reeve Angel Ltd., London, E.C.4.

4. Oid Ref. No. was 10G/2.

Chapter 2

REPAIR AND SERVICING

CONTENTS

APPENDIX

Introduction

1. The purpose of this chapter is to provide Service personnel with information and guidance concerning the repair and servicing of the recorder. The servicing consists of electrical, mechanical and lubrication maintenance. Before applying lubricant, reference should be made to Appendix 1 at the end of this chapter.

ELECTRICAL

Motor and relay circuits

2. The following information is given should it become necessary to remove any of the principle electrical components associated with the motor and relay circuits.

Motor

3. The motor is removed from the recorder by disconnecting the wires from the terminal block and then removing the four 0 BA nuts and washers which clamp the motor to the base. With the brushes removed, the armature should be checked for freedom of rotation by slowly rotating the armature by hand to discover any tight spots. Remove the end covers over the ball races and make sure that the bearings are secure on the shaft and in their external housings.

4. By removing the inspection hole at the top of the motor it can be seen if the commutator is dirty. (In the running condition this inspection will detect any sparking of the brushes on the commutator). If the commutator requires cleaning, this can be achieved with crocus paper but *not* emery paper. If the carbon brushes are more than half worn they should be changed. The normal length, when new, is about 1·7 cm. They should be bedded-in in the direction of rotation of the armature with the crocus paper wrapped round the armature (coarse side facing outwards), and the armature turned by hand.

Speed regulator control

5. In order to gain access to the speed regulator control, S2, the knob must first be removed. The cover which is sprung into position over the switch base may then be released. To remove the switch, unsolder the external wires attached to the underside of the switch studs and release the four countersunk screws which secure the base of the switch to the casting.

Resistance elements

6. The motor resistance elements R2, R3 and R4 are housed in the underside base of the equipment and to gain access it is first necessary to remove the base fibre cover. These resistances are wire-wound on a flat former and have tappings taken from them which are connected to the various studs associated with the speed control circuit. To remove the resistance elements (and also the Westinghouse rectifiers) remove the four 2 BA countersunk headed screws and nuts which hold the brackets to the right-hand side of the base casting.

Relay field coil supply

7. Resistor R1 is mounted in the same under-chassis compartment as R2, R3 and R4. Component R1 and the two rectifier units are located in the same way by removing the base cover. To remove R1 for any reason, resistors R2 and R4 have to be taken out first as given in the preceding paragraph.

Moving coil relay

8. To remove the relay, first remove the ink container and raise the platten. The relay assembly itself may be removed as a complete unit by releasing the three 4 BA screws immediately underneath the base of the recorder. To carry out this operation, the resistance elements mentioned in para. 6 and 7 must be removed to gain access to the 4 screws.

9. To dismantle the relay, carry out the following sequence in the order given: —

(1) Remove the parallel and split pins which secure the fulcrum of the moving coil to the bell crank.

(2) Release the three 4 BA steel screws that secure the top plate of the relay. The top plate and the spacing pieces can now be removed. Care should be exercised not to stretch the moving coil spring end connections.

(3) Remove the moving coil by releasing the spring wires attached to screws on the terminal plates which are mounted upon an ebonite ring and secured to the top of the relay cover.

(4) Remove the external moving coil connections and withdraw wires through the side of the relay case.

(5) Remove the two flexible field winding connections—these are soldered to points on the understand of the undulator base.

(6) Unscrew the two 8 BA countersunk screws at the base of the relay—this releases the relay case.

(7) Unscrew the three 6 BA countersunk screws in order to remove the ebonite ring which is situated at the top of the magnet pot. The terminal plates of the ebonite ring are anchors for the moving coil wires.

(8) To gain access to the field winding bobbin it is necessary to extract the six 4 BA countersunk screws, three at either end of the pot, which secure the central pole piece and the two ends. It is now possible to lift out the bobbin complete with leads.

10. To re-assemble the eight items mentioned in the previous paragraph, the procedure should be carried out, but in the reverse order. It should be noted that the correct position for the moving coil, when being remounted, is for the OUT 2 coil connection to be connected to the left-hand front terminal plate of the relay.

MECHANICAL

Gearbox and couplings

11. The gearbox is secured and held in position on the base of the undulator by four 4 BA screws. In order to release the steel universal coupling between the gearbox and motor remove the four fixing screws.

Tape pulleys

12. The top tape pulley may be removed by unscrewing the steel screw upon which the pulley revolves and which secures the pulley between the fork portion of the handle. The bottom tape pulley is removed by releasing the 4 BA grub screw which secures the pulley to the gearbox shaft.

Platten

13. The platten is removed by unscrewing the steel shouldered stud upon which it moves. The stud screw is pinned and held by an 0 BA locking nut and washer. The tape roller on the platten is held in place by a left-hand threaded bearing screw.

Ink supply mechanism

14. The pen should be occasionally cleaned with clean water, or methylated spirits to prevent it clogging. The syphon requires cleaning regularly in clean water—methylated spirits must *not* be used as this affects the lacquer. Should the syphon require removing, release the link connecting the bell crank to the centre of the syphon arm by removing the parallel and split pins and also by removing the rear bracket supporting the syphon top pivot. The remaining parts secured to the relay top plate can now be easily detached. If the recorder is to be left out of service for a period of time, both the pen and the syphons should be cleaned out. The ink container holds enough ink for 2 weeks normal working, but it is advisable only to fill it for immediate needs.

LUBRICATION

Motor

15. The series motor is fitted with grease cups on the underside of each bearing. These should be periodically checked and replenished with grease when necessary.

Gearbox

16. The gearbox is filled with grease and should be examined at regular intervals and kept full of grease.

Tape pulley rollers

17. The journal bearings of the tape pulley rollers have an oil hole which requires a small quantity of oil applied at frequent intervals.

Miscellaneous

18. Most moving parts of the recorder require an occasional check and a very small amount of oil can be applied.

Appendix 1

LUBRICATION

This Appendix contains information regarding the lubrication of the undulator and the points requiring lubrication are as shown below. Any surplus oil or grease should be removed with a piece of clean material such as non-fluffy rag.

Part or bearing	Lubricant	Application
Motor	Grease	Grease cups on the underside of each bearing.
Gearbox	Ball-bearing grease	Inside gearbox. Keep full with grease.
Tape pulley rollers	Thin oil	Journal bearings. Apply a small quantity of oil through oil hole on tape pulley roller.
Other moving parts	Good quality clock oil	To each moving part as required. Apply sparingly.

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