COSSOR

DOUBLE BEAM

OSCILLOGRAPH

MODEL 339

INSTRUCTION MANUAL

CONTENTS.

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1. INTRODUCTION.

The new Cossor Double Beam Oscillograph has been produced to make the best use of the characteristic features of the Cathode Ray Tube in an inexpensive, self-contained unit. It is the most comprehensive instrument of its type so far produced, possessing a wider field of application than any other portable oscillograph.

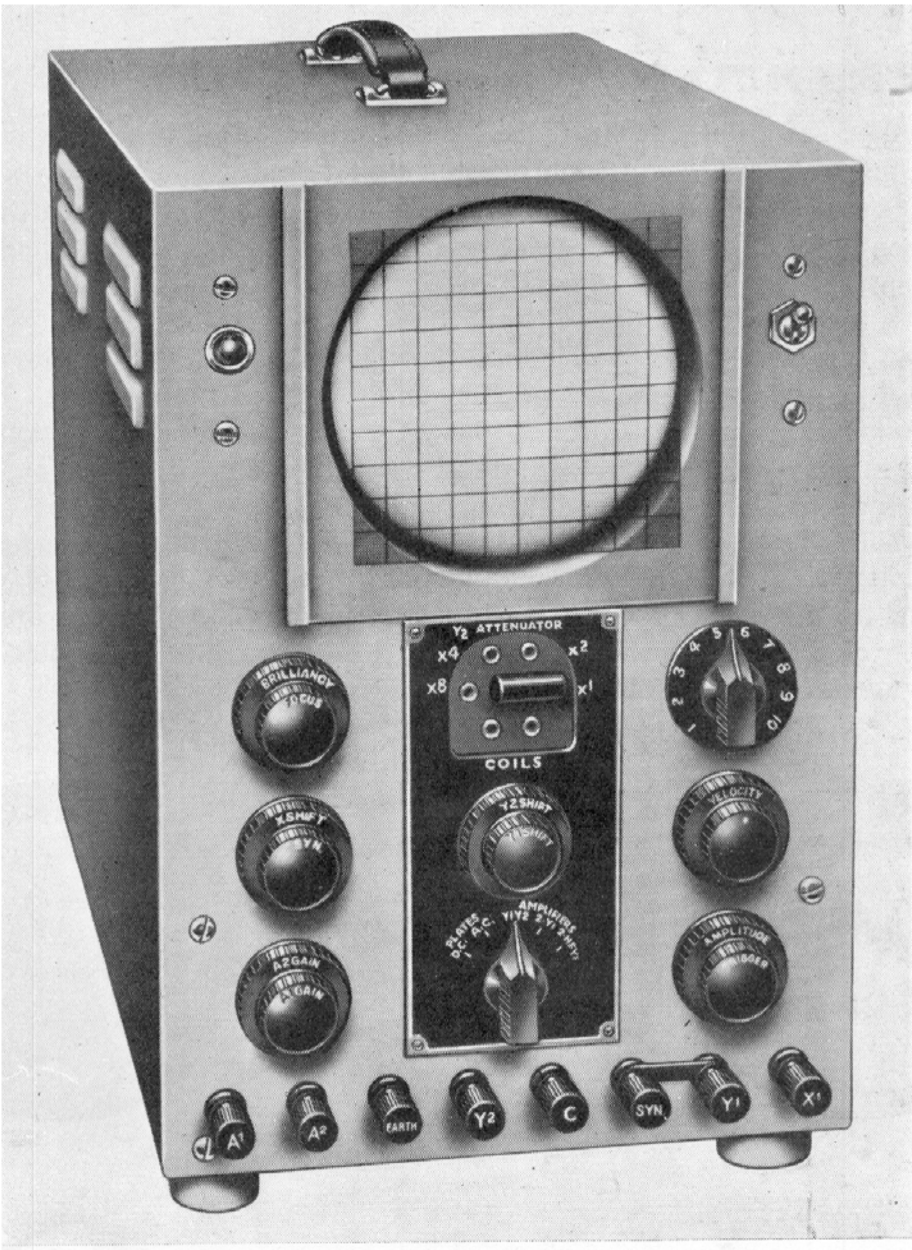


FIG. 1.

COSSOR DOUBLE BEAM OSCILLOGRAPH MODEL 339.

CATHODE RAY TUBE.

The Cossor Company, who pioneered the development of the modern Cathode Ray Tube and related Electronic Instruments, first saw that it was possible to provide a considerable increase in the performance of the self-contained, portable type of oscillograph by suitable design without necessarily involving an undue increase in size or cost, even when using a tube of 4½" diameter. This latter is considered a most satisfactory minimum size for serious work. With the relatively small increase in diameter from the 3" usual to the 4½" adopted, the useful area of the tube screen is doubled and the dimensions of the trace obtainable are increased by at least 50%. Furthermore, the larger Cathode Ray Tube is superior electrically and provides a finer focus.

DOUBLE BEAM TUBE.

The Double Beam Cathode Ray Tube has been standardized because it increases the scope of the instrument enormously and makes it almost the equivalent of two oscillographs. The results obtained in practice confirm the wisdom of this decision, for the Double Beam Tube has been found invaluable even in numerous applications where its usefulness had not been foreseen.

The main advantage of the Double Beam Tube is that it provides the only satisfactory method of solving the problem of investigating two variables simultaneously. The value of this can hardly be over-estimated, for it is more the rule than the exception to find in practice that at least two effects require inspection at the same time, even though they may be only voltage and current in the same circuit, whilst many problems are incapable of solution without this facility. As will be seen, the Double Beam Tube renders obsolete the Electronic Switch method previously employed. The superiority of the double beam method lies not only in the matter of simplicity and cost—for the average Electronic Switch usually costs as much as a complete Oscillograph—but also in its technical advantages of complete absence of phase delay and frequency limit.

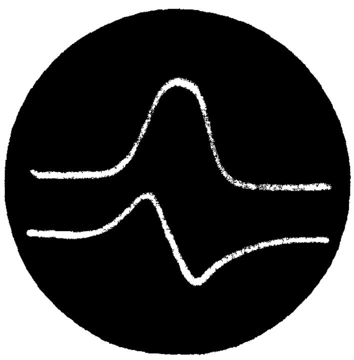
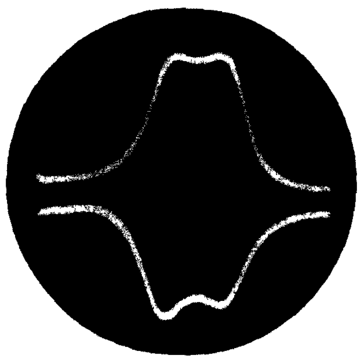


FIG. 2.

Photographic record of tuned circuit responses in a radio receiver at the diodes.

(Left) Detector and Automatic Frequency Control.

(Right) Primary and Secondary of I.F. transformer.



SINGLE BEAM TUBE.

Apart from the many features of the instrument as a Double Beam Oscillograph, it remains fundamentally a conventional Single Beam Equipment insofar as it may be used as such, thanks to the interchangeability of Cossor Single and Double Beam Tubes. This fact leads to a further advantage in the provision of symmetrical input and output operation not otherwise obtainable in instruments of this type with Single Beam Tubes.

AMPLIFIERS.

The amplifiers were designed to meet the requirements of Television Video Frequency, which called for a wider frequency band than probably any other application. The instrument is thereby made to embrace in its scope almost every other field of use. Special high slope valves capable of large anode dissipation have had to be used. The amplifiers can provide either a high gain, 900, or a wide frequency range up to 2,000,000

TIME BASE.

The Cossor Company were the pioneers of the original Hard Valve Time Base circuit, the performance of which is still unsurpassed both in linearity and frequency range. This latter extends from 5 to some 250,000 c.p.s., and it has been found possible to include this valuable circuit with all its refinements in the Oscillograph without undue increase in cost, even though three valves are necessary for its operation.

SINGLE STROKE TIME BASE.

Furthermore, it is possible to make use of certain inherent features of this same Cossor Hard Valve Time Base circuit by converting it by simple means into a satisfactory Single Stroke Time Base possessing the notable advantage of a linear law. The device is suitable for a range of speeds covered by the photographic recording ability of the tube, and therefore meets the most general applications met in practice, chiefly Industrial Test work. It will be appreciated that single stroke operation represents an important and indeed unique feature for an instrument of this class.

ADDITIONAL FEATURES.

Notwithstanding the exceptional features of the Tube, Time Base and Amplifiers described above, the additional refinements detailed below have been included to enhance the value of the instrument.

Trapezium Corrected Tubes.

Both the Single and Double Beam Cathode Ray Tubes for the instrument are fully corrected for trapezium distortion, an inherent defect in Cathode Ray Tubes of orthodox design. This allows asymmetrical operation without distortion.

Photographic Type Fluorescent Screen.

The Cathode Ray Tube fitted as standard has a blue (J) type fluorescent screen to provide the best photographic results.

Symmetrical Input and Output Working.

With a Single Beam Tube it is possible to operate same symmetrically from a symmetrical input through a two-valve, single stage, symmetrical amplifier.

Time Base Linearizing Valve.

Linearity of the Time Base is ensured by following the accepted Cossor practice of charging the Time Base condensers through a screened pentode valve used as a constant current device.

Flyback Black-out.

At high repetition Time Base frequencies the beam of the Cathode Ray Tube is automatically blacked out during flyback.

Calibration Voltage.

This is obtained from additional winding on the mains transformer.

Deflector Coils.

These have been added to serve for the direct investigation of currents when used with a Single Beam Tube.

Tandem Controls.

This is an innovation which simplifies the operation of the instrument considerably. These are used for the control of associated circuits.

Efficient Synchronization.

Synchronization of the Time Base is positive and is assisted at high frequencies by the Trigger control, which varies the flyback time and thus provides an additional fine adjustment to frequency.

Automatic Spot Brilliancy Control.

Automatic adjustment of the trace brilliancy is provided at high Time Base speeds.

Single Multiple Connection Switch.

The single Amplifier switch serves to set the instrument for all possible operating conditions, that is, D.C. or A.C. direct connection to the plates, or A.C. connection through amplifiers, single stage to both beams, or two-stage in cascade on one beam.

Rear Connector Panel.

A detachable plate at the rear of the case gives access to a link panel, enabling connections and inter-connections to be made directly at the tube socket.

Shift and Astigmatism Controls.

Shift controls are provided for the X and both the Y deflector plates. These latter, when used simultaneously with a Single Beam Tube, correct for residual astigmatism.

Calibration Voltage.

This is obtained from additional winding on the mains transformer.

Double Mu-Metal Shield.

Included to guard against interference from magnetic fields.

Viewing Hood and Scale.

A transparent 10 cm. graticule is supplied to assist in quantitative work. The guide into which it fits on the front panel also serves for mounting the Viewing Hood, available as an extra.

Film Camera.

A special Film Camera, using inexpensive, unperforated, 35 mm. paper or film, is available as an extra. When fitted with an external drive it can be used as a Moving Film Camera for the recording of slow transients.

2. DESCRIPTION OF INSTRUMENT.

2.1. CONSTRUCTION.

The Oscillograph consists of two parts, comprising the instrument proper and its outer case. This latter holds the carrying handle and is fitted with ventilating louvres on top and sides and a detachable rear panel.

The instrument is built on a chassis with the front panel secured to one end and the Cathode Ray Tube supporting bulkhead a short distance from the other end. Beyond the bulkhead is located the mains transformer and rear connector panel. The chassis slides into the case and is secured thereto by means of two rear fixing screws, the edge of the front panel locating the open end of the case.

2.2. TUBE AND SHIELD MOUNTING.

Joining the cylindrical tube locating collar fixed to the front panel and the bulkhead through an adaptor panel and brackets is mounted the mu-metal shield.

The adaptor panel is fitted with a rubber-lined stirrup and clamp, by means of which the tube is supported at the neck. The fixing is done by means of two wing nuts. The tube socket is unsupported.

The correct axial position of the tube is when the crown of its screen is set flush with the surface of the front panel so that the transparent 10 cm. scale provided rests lightly against the tube bulb when placed in position, the horizontal sweep of the Time Base being parellel with the horizontal ruling on the graticule. When required to obtain correct alignment with the scale, the tube fixing clamp is loosened and the tube rotated and secured at the required position.

2.3. VALVES.

On the two sides of the Cathode Ray Tube and between the front panel and bulkhead are located the valves. On the left side facing the front the valves are in the following order from the bulkhead to the front panel : 5Z4G full wave rectifier for Time Base and Amplifier circuits and two 807 amplifiers. On the other side and in the same order are the SU2150A single wave rectifier for Cathode Ray Tube supply, two OM5 H.F. pentodes, respectively the pentode charger valve and auxiliary discharge valve, and the 6J5G triode charger valve of the Time Base.

2.4. POWER PACK.

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 Cathode Ray Tube supply are mounted on the rear side of the bulkhead and in each corner thereof above the transformer.

The transformer is chassis mounted and all its connections are taken to a panel located underneath. These connections are numbered as per Figs. 47 and 50 in Section 12. On the underside of the chassis on each side of the transformer are fixed the two smoothing chokes for the Time Base and Amplifier power supply.

2.5. CHASSIS.

The bulk of the instrument connections are made on the underside of the chassis through the centre of which is located the Amplifier switch, which serves to rearrange the various instrument circuits to the front panel terminals and tube electrodes, as described later. Parts of the underside of the chassis are subdivided for screening purposes.

2.6. COMPONENT LOCATION.

Figs. 3, 4, 48 and 49 illustrate various views of the instrument by means of which the description given in the present section may be followed. These illustrations are annotated both for the location of the various components, such as resistances, condensers, chokes and valves, as per circuit diagram, page 90, and for the mechanical features, as per the following code :—

1. Rear Panel and Link Connections.
2. Y1 Plug Connector.
3. C.R. H.T. Fuse.
4. H.T. Fuse.
5. Mains Tapping Plug and Sockets.
6. Mains Transformer.
7. Tapped Fixing Bush.
8. Bulkhead.
9. Deflector Coil Adjustment Lever.
10. Wing Nuts and Stirrup Clamp for O9J Tube Fixing.
11. C.R. Tube Base and Holder.
12. C.R. Tube Holder Bulkhead Adaptor.
13. Mu-Metal Fixing Bracket.

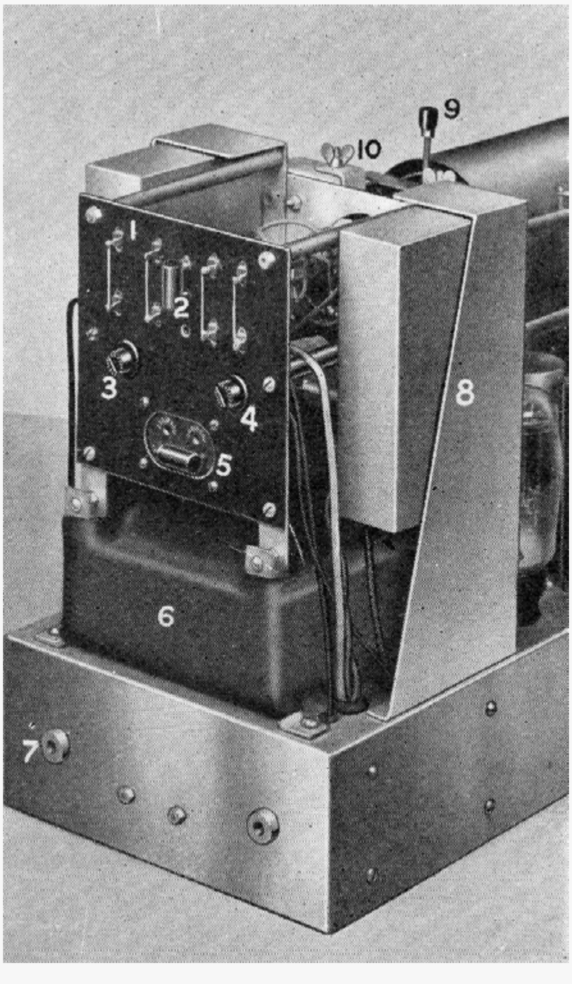


FIG. 3 REAR PANEL.

14. Mu-Metal Screen.
15. Cathode Ray Tube.
16. C.R. Tube Front Panel Locating Collar.
17. Mains Switch.
18. Pilot Lamp.
19. Graticule and Camera Guides.
20. Time Base Condenser Switch Assembly.

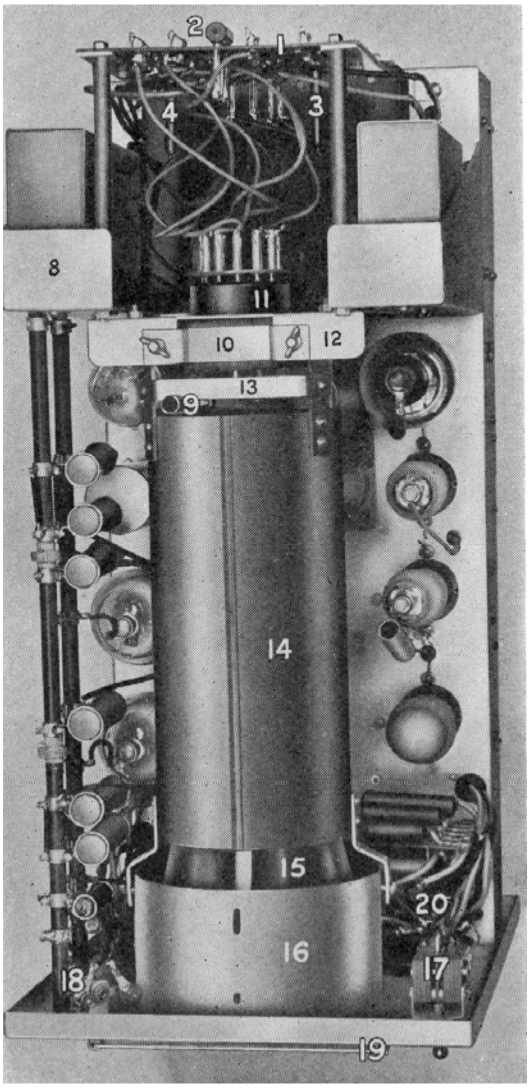


FIG. 4 TOP VIEW OF CHASSIS.

2.7. MAINS.

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. A mains switch and a pilot light are fitted on the top corners of the front panel, the mains switch on the right and the pilot lamp on the left.

2.8. CONTROLS.

All the operational controls and terminals are mounted on the front panel of the instrument, and when possible, tandem controls have been used to reduce their encumbrance on the front panel and facilitate the functional use of the instrument.

The only exception is the Y2 Input Attenuator, located for convenience at the top centre to form a common panel with the deflector coil sockets. A shorting plug is supplied for the Attenuator and a connecting plug for the coils. The two plugs are not interchangeable.

The instrument controls are located as follows : Those for the Time Base are on the right-hand side facing the instrument. The Time Base condensers controlled by the panel switch are placed immediately behind the panel above the chassis. Of the central and left-hand side controls, those uppermost are the Cathode Ray Tube controls, and the lower ones (including the switch) concern the input circuits and amplifiers. In these is also included the Synchronizing, forming the top section of the left-hand central control, which serves to connect the Input and Time Base circuits. A two-pole switch is mounted on the Trigger control and serves solely on those occasions when the single stroke facilities of the Time Base are used. The method of operation is described later.

2.9. PURPOSE OF THE INSTRUMENT.

The instrument may be used to give a graphical representation as a function of time of any cause which can be made to produce an equivalent electrical effect (viz., voltage change), irrespective of whether the effect investigated is of itself electrical or not. It is the qualitative information provided by the instantaneous two-dimensional double beam recording facilities of the Cathode Ray Tube which is so useful in practice. Quantitative results may be obtained with equal success provided the necessary precautions and calibrating arrangements are made.

In this latter respect the instrument is no more than the equal of other devices except for the much greater consistency in the results obtained. The reason for this is that for constant tube H.T. voltage the readings are only dependent on the geometry of the tube and are not modified during the tube life by wear of moving parts, as with other devices.

The Double Beam Oscillograph is a most useful and versatile instrument, indispensable to all Research Laboratories and suitable for a great variety of test work in the workshop, production line and on the Service bench. Its portability makes it invaluable also for outside inspection and repair work.

As a result of the advanced design and the exceptional performance provided, it can be relied upon to remain an effective laboratory instrument for many years.

2.10. INSTRUCTION MANUAL.

In preparing this Manual endeavour has been made to provide as much useful information as possible, in fact, more than is customary in such cases. This has not been limited solely to matters of practical utility, but also to fundamentals and other data which it is hoped may suggest—in conjunction with the List of Applications and the Bibliography—a solution of any Research or Test problem for which the instrument may be required. Beyond the first reading the booklet is intended to serve for reference purposes. The value of the information given can best be appreciated only when the Oscillograph is in actual use.

3. INSTRUMENT COMPONENTS.

The following notes are intended to give information on the component sections of the Oscillograph, and to describe in particular the technical features of the Cathode Ray Tube and the circuit operation of the Time Base and Amplifiers.

3.1. CATHODE RAY TUBE.

The association of the Cossor Company with Cathode Ray Tubes dates back to the year 1902, and its pioneer work contributed considerably to the development of the remarkable qualities of the Cathode Ray Tubes used to-day.

Amongst other things, the Cossor Company first produced the split beam type of Double Beam Tube, which appeared for the first time on a commercial instrument in the present Oscillograph when it was first produced.

3.1.1. ELECTRON GUN.

The electron gun in both the Double Beam Tube—Type 09—and Single Beam Tube —Type 26—suitable for the present instrument is of the high vacuum type, where three anodes are used for electron optical focussing, the 1st and 3rd Anodes being strapped together within the tube and operated at the accelerating voltage applied to the tube, viz., 1,100 volts. The cathode is of robust construction and is indirectly heated, providing abundant emission and long life, whilst the construction of the tube is arranged to ensure accuracy in assembly.

3.1.2. TUBE CONSTRUCTION.

Both the Double Beam and Single Beam Tubes used in the instrument have an overall length of 375 mms. (about 15″) and an overall diameter of 114 mms. (about $4\frac{1}{2}$″). The diameter of the fluorescent screen is 110 mms. The front of the bulb is almost flat over the greater part of the useful surface. The base and socket of the Cathode Ray Tube have been designed to avoid the use of the socket as a means of support for the tube, and in the instrument the tube is supported at the bulb and around the neck. The special 12-pin base used has a central spigot provided with a key, which locates in the socket and renders replacement of the tube a simple and foolproof matter, even in an inaccessible and badly lit location. The base connections are shown in Fig. 5, the view being that obtained when looking at the tube from the pin end towards the screen.

3.1.3. TRAPEZIUM EFFECT.

The tube is provided with important refinements, notably the correction of trapezium distortion. This effect is an apparent change in the sensitivity of the Y pair of plates when an asymmetrical voltage is applied to the X pair of plates, and shows up as a shortening of the vertical deflection at one side of the screen. When equal asymmetrical voltages are applied to the two pairs of deflector plates to form a raster pattern, as used in Television, a trapezium shape is obtained, and not the square which should normally be expected. For this reason the name " trapezium " was given to this effect. This distortion is present on all Cathode Ray Tubes of orthodox design. The effect can be overcome by symmetrical operation of the X deflector plate system. It is inconvenient, and generally far too expensive, to provide symmetrical Time Base voltages or push-pull Amplifiers within or without the Oscillograph.

To meet practical requirements, therefore, it is customary and essential that all Oscillographs have had to be designed for operation with asymmetrical voltages, and in consequence it has been necessary previously to tolerate the resulting trapezium distortion, usually of the order of 10%. In some cases endeavours have been made to remedy this defect by a special design of the Cathode Ray Tube. Unfortunately, the method usually adopted to correct this effect within the tube renders the deflector plate system asymmetric, which, whilst overcoming the trapezium effect from asymmetric work voltages, prevents

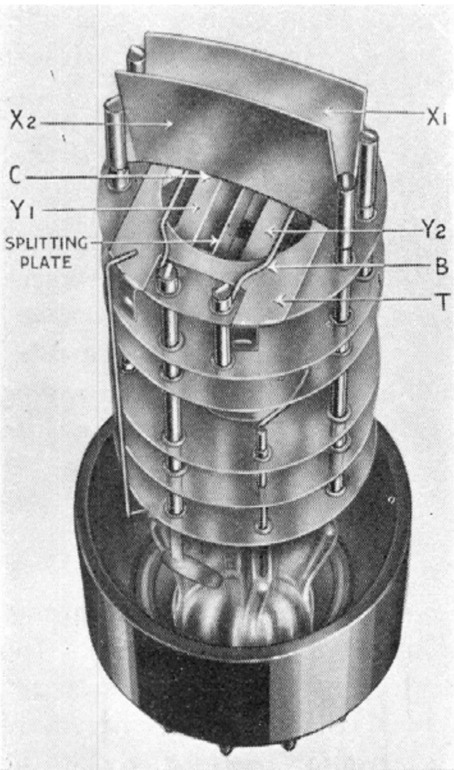


FIG. 6
Internal construction with cylindrical shield electrode removed. "C" is the curved leading edge of X plate and "T" the shield, both correcting for trapezium effect. "B" indicates the bucking wires to reduce intermodulation. A4, the additional hood electrode to avoid "pimple effect" is not shown.

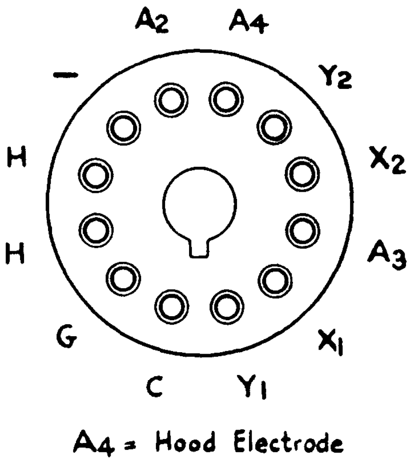
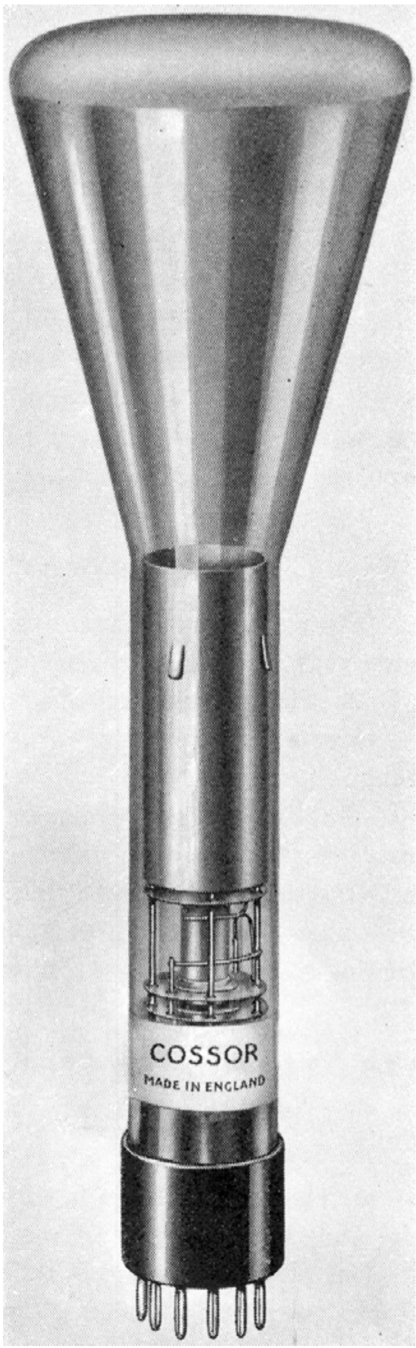


FIG. 5 (left)
BASE CONNECTIONS.

FIG 7 (right)
COSSOR DOUBLE BEAM CATHODE RAY TUBE



the use of the tube from a balanced signal. With the unique method of trapezium distortion correction used in Cossor tubes, however, the X structure is not rendered geometrically asymmetric, and the tubes may therefore be used, not only for asymmetrical deflection, but also from a balanced input signal. Fig. 6 shows the construction employed, which takes the form of a curved leading edge on the X plates operating in conjunction with a special curved shield placed between the X and Y plates. The whole structure is so designed that, irrespective of the Y deflection angle, the beam enters the field of the X deflector plates normal to the tangent drawn to this field, and therefore suffers no unwanted deflection in the Y direction on entering the X plate region.

3.1.4. INTERMODULATION and SECONDARY EMISSION EFFECTS.

Whatever type of Double or Multiple Beam Tube can be evolved, a certain amount of intermodulation is inevitable. It can be due to the penetration of the electrostatic field of one work plate into the zone nominally controlled by the other. Curiously enough, this effect, which is characteristic to the double beam, is the easiest to avoid, and by the split beam construction of the Cossor Double Beam Tubes and the correction devices used, it has been possible to control this effect and reduce it to negligible proportions (about 1%).

There are, however, other and much more serious effects encountered which are not all due to double beam construction but are inherent with all Cathode Ray Tubes and are therefore present in more or less degree also in all Single Beam Tubes of conventional construction. The explanation of these effects is involved. They are due to the return current from the screen (secondaries) and the well known asymmetric characteristics of the deflector plate voltage/current curve resulting therefrom in the specific condition of operation involving high impedance deflector plate return paths. See Fig 11.

it is generally convenient to label the effects resulting from interactions between the various plates and electrodes of the tube under the generic, even though not strictly accurate, name of " intermodulation."

By means of the special devices adopted in the tube design, all the different intermodulation effects can be fully controlled. These devices comprise the cylindrical shielding of the deflector plate system, special construction of the splitter plate, addition of " bucking " wires, and hood electrode. This latter serves, incidentally, to avoid the " pimple effect " due to a voltage being created across the Y deflector plate load around the central position of the beam by that part of the return current which, in other beam positions, is taken by the X deflector plate.

3.1.5. FLUORESCENT SCREENS.

The " J " type fluorescent screen, providing a blue response, has been chosen as standard for the tube in the present instrument because it is the best for general use, covering both visual and photographic work. The colour of the spot is both pleasant and non-fatiguing, even for long visual tests, and is equally satisfactory when operating the instrument in daylight or artificial light. The absence of afterglow (10 μ. sec.) is also an advantage.

When ordering spare tubes the type of screen required must be specified by quoting the reference letter immediately following the type number of the tube, e.g., 09J. Tubes fitted with " D " and " G " screens can only be supplied as extras.

The " D " type of fluorescent screen, providing a green response, as is generally used in competitive oscillographs, is also available if required, but the photographic qualities are distinctly inferior to those of the " J " tube and the afterglow is often troublesome in visual investigations of slowly varying effects. It may have advantages in cases where the instrument is used solely for visual work and for long periods. The colour is restful and agreeable to the eye, which is more sensitive to green than to any other colour. This is probably the most satisfactory screen for use in artificial light. Afterglow is about 10 m. sec.

The " G " type of screen is suitable for specialized work, such as the visual investigation of slow transients, where use can be made of the long afterglow of the screen. This screen is sufficiently actinic to be useful also for photographic work. Although superior to the " D," it is none the less much inferior to the " J " screen in this respect. The primary fluorescence is blue-green with a green afterglow, lasting approximately 10 seconds, the exact time depending on the anode voltage beam current and incident light.

The spectral response curves for the fluorescent materials for these screens are shown in Fig. 36.

3.1.6. DOUBLE BEAM TUBE.

The Cossor Double Beam Tube standardized in this instrument is the most remarkable development in Cathode Ray Tubes used for oscillographic work. By virtue of the electrode structure employed, two phenomena may be examined simultaneously without electronic switching circuits or other additional apparatus, and yet the Double Beam Tube is completely interchangeable with the corresponding Single Beam Tube.

More noteworthy still is the fact that the focus obtainable with each beam of the Double Beam Tube is very fine and at least the equal of that of a Single Beam Tube. The spot brightness is necessarily somewhat less because the same beam current of the Single Beam Tube is in the Double Beam Tube distributed between the two beams. This does not interfere with the visual qualities of the tube and produces only a reduction in the photographic writing speed.

The double beam is obtained by placing a screen between the Y plates to split the focussed beam as it leaves the final Anode, the splitter plate itself being directly connected to the 3rd anode within the tube, and is thus at earth potential. Each Y plate thus affects one-half of the beam independently to provide the two vertical traces. Because of this construction the traces, when electrically in phase, are spatially 180° out of phase, which is an advantage in most cases because it enables fuller use to be made of the tube screen without the two traces interfering with each other. The X deflector plates provide the usual horizontal deflection and are common to both beams. Therein lies the main advantage of this method of investigating two effects over other methods, for it is the only one which can provide absolute simultaneity between the two traces without phase delay or frequency limit.

3.1.7. SINGLE BEAM TUBE.

For certain work a Single Beam Tube will be found more convenient, in particular when the maximum photographic writing speed is required. A Type 26 Single Beam Tube is available as an optional extra and has exactly the same dimensions, operating characteristics and basing, so that no mechanical or electrical alterations whatsoever have to be made to the instrument when changing from one tube to the other.

The Single Beam is also required when measuring currents direct or when symmetrical input and output working is necessary.

3.2. TIME BASE.

In order to apply a Time Base deflection to an Oscillograph it is generally desirable to obtain what is called a linear saw-tooth voltage wave-form, that is to say, a voltage which increases uniformly with time for a certain period and is then restored to its starting value in a very much shorter period. Such voltages are obtained from so-called relaxation oscillators producing saw-toothed waveforms derived from the sequential gradual charging of a condenser through a high resistance and its sudden discharge. The various devices adopted for the purpose and also the other details connected with Time Bases generally used for oscillographic work, are well known, but various aspects of the circuit used in this instrument warrant individual mention.

The special feature of the Cossor Time Base used in the present instrument is that it employs hard valves throughout, and therefore provides stable operation over the very wide frequency range of 5 to 250,000 c.p.s. The frequency limit is determined entirely by the minimum circuit capacities and the voltage sweep required, and not by any such factors as the deionization time of a gas which apply to the Gas Discharge Triodes so often used in Time Bases. This factor is also partly responsible for the erratic behaviour frequently exhibited by such circuits at frequencies much above 15,000 cycles.

A further advantage of the Cossor Time Base is that extremely effective synchronization is obtained without materially increasing the loading on the work circuit. This is connected to a high impedance circuit associated with the auxiliary discharge valve,which also acts as a buffer between the work circuit and Time Base itself.

Another important feature is the charging of the condenser through a constant current device consisting of a screened pentode operating over the flat part of the Anode voltage Anode current characteristic. This not only provides the best means of obtaining a truly linear time base, but also permits operation at a much lower high tension voltage than in the case of the usual resistance charging method which relies on using a small and approximately linear portion of the exponential overall condenser charging characteristic.

The Time Base possesses a " TRIGGER " control, which is additional to those usually required in other types. This slight additional complication could have been avoided by replacing the control by a fixed resistance, but it was found preferable to retain it because of its valuable properties of controlling the flyback time. This provides a fine control of frequency and is thus the most effective means of adjusting to synchronism at high frequencies.

The Time Base incorporates other refinements, including flyback black-out and automatic adjustment of the brilliancy of the trace at high repetition frequencies.

As an aid to a better appreciation of the significance of those controls associated with the Time Base, the following explanation of the operation of the circuit may be of interest.

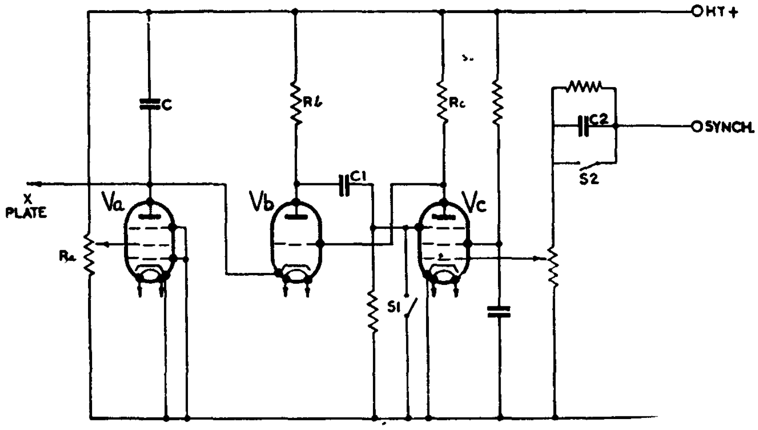


FIG. 8. SIMPLIFIED CIRCUIT OF COSSOR HARD VALVE TIME-BASE.

Referring to Fig. 8, it will be seen that Time Base condenser " C " will charge linearly through the Pentode Va, thus carrying the cathode of Vb more and more negative relative to its Anode. The control grid of this valve is, however, appreciably negative relative to the Anode due to the voltage drop produced in Rc by the Anode current of Vc. As soon as the cathode of Vb has travelled sufficiently negative to approach the potential present on the control grid of this valve, Vb will commence to pass current and a voltage drop will be present across Rb. This will swing suppressor grid of Vc negative, causing the Anode of Vc, and therefore the control grid of Vb, to travel positive. The action is cumulative and condenser " C " therefore discharges rapidly through Vb until, when it becomes discharged, no further current flows through Rb and the cycle repeats. The value of Rb affects the amplitude of the triggering impulse present in the grid circuit of Vc and also modifies the flyback period due to its presence in the discharge path. This control is designated " TRIGGER." The voltage developed across condenser " C " before each successive discharge through Vb is dependent upon the extent by which the grid of Vb is maintained negative relative to the Anode by the voltage drop across Rc. Adjustment of the magnitude of this latter resistance therefore provides control of amplitude. Synchronization of the Time Base is effected by injecting a fraction of the work voltage into one of the grids of Vc. The rate of charge of the condenser " C " depends upon the capacity of this component and

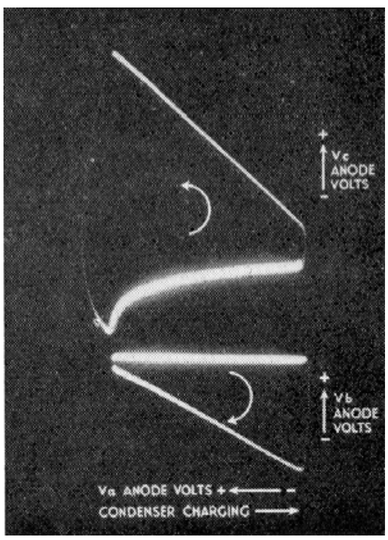


FIG. 9.

the current flowing through Va. In the present instrument advantage is taken of both these factors, rough control being effected by the selection of any one of nine condensers, whilst a progressive adjustment is provided in the form of a " Velocity " control varying the screen volts on the pentode charge valve. The oscillogram of Fig. 9 shows the electrical action of this time base circuit.

3.2.1. SINGLE STROKE TIME BASE.

For a number of 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. In order to cope with this requirement the present instrument has a switching arrangement which enables the user to obtain single stroke operation of the Time Base with a minimum of external complication.

The method adopted can best be explained by reference to Fig. 8. It will be remembered from Section 3.2 that the Time Base incorporated in the instrument is self-running by injection into the suppressor grid of Vc of the voltage drop produced across Rb when the condenser C becomes charged to a voltage sufficient to cause current to flow through Vb. Thus, if this voltage is prevented from being applied to Vc—by shorting the suppressor grid of Vc with switch S1—The Time Base will no longer repeat. After switching on, the voltage across C will gradually increase until it carries the cathode of Vb to a figure sufficiently near to the voltage drop across Rc for Vb to pass an anode current equal to that flowing through Va. Once this condition has been realised 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.

All that is now needed in order to produce a single stroke sweep is to discharge condenser C very rapidly, and it will then charge up to the equilibrium value again at a speed which depends on the setting of the velocity control Ra and the value of the condenser C. This rapid discharge of condenser C prior to the effective Time Base sweep can be achieved very simply by injecting a negative pulse to the synchronising terminal. In order to reduce the injection voltage required to a minimum, a further switch contact (S2) is included in the instrument to short out the resistance-condenser filter, which is normally included in the synchronising circuit. Contracts S1 and S2 are mounted on a single switch wafer and this is, in turn, mounted in such a way as to be operated automatically when the trigger control (see Section 4.4.3.4) is rotated to its limit of travel in an anti-clockwise direction. From a little further consideration of this circuit it will be appreciated that the negative pulse applied to the synchronising terminal causes anode current in Vc to cease, and thus allows the grid of Vb to assume the voltage of the H.T.+ rail. This results in the condenser C discharging almost completely.

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 realised that C cannot commence to charge, and thus produce the single stroke, until anode current has again been restored in Vc, and the negative pulse applied to the Synch. terminal must therefore be of only sufficient duration to discharge C fully, and the grid of Vc must then return to HT— in order to allow the sweep to occur. It is therefore necessary for the user to connect between the Synch. terminal and the negative supply providing the control pulse a condenser having a suitable value, though it is not necessary to change the value of this condenser every time the Time Base condenser switch is altered, as a considerable measure of adjustment is available on the synchronising control. The practical requirements to be complied with in this direction are covered in Section 5.11.

3.3. AMPLIFIERS.

The Amplifiers used in this instrument are of conventional design inasmuch as they employ resistance-capacity coupling throughout, with inductance compensation for the Wide Band frequency range. Special valves with a large dissipation and the high slope of 11 mA/v have had to be used in order to provide the frequency range and voltage swing required. Two such valves are used. In one case they are connected to provide individual single stage amplification for each beam on the Double Beam Tube, which arrangement, when used with a Single Beam Tube, provides symmetrical input and output working. The gain obtained is 28 over a frequency range of 20 to 100,000 c.p.s. In the other cases the amplifier valves are connected in cascade to provide alternative conditions of operation giving either a high gain (900) over a frequency range of 20 to 100,000 c.p.s., or a gain of 106 over a wide frequency range of 20 to 2,000,000 c.p.s. Whilst the cut-off on this latter range is sharp, that on the high gain position is gradual, and a considerable gain still remains at 500,000 cycles, making the high gain Amplifier useful even at this frequency.

3.4. DEFLECTOR COILS.

Deflector coils are provided to enable current measurements to be made directly. Deflection to full screen diameter is obtained with a current of about 50 mA. R.M.S., but larger currents can be read by the use of standard shunts. The coils are intended chiefly for use when a Single Beam Tube is used in the instrument, but as explained in Section 4.5.6, they also serve with the Double Beam Tube for many purposes.

3.5. INPUT ATTENUATOR.

This is a small but valuable feature which has been added to the many original features possessed by this Oscillograph.

Contrary to the general assumption, the Cathode Ray Tube, although very versatile and almost unique in its inertialess, two-dimentional indicating facilities, is none the less a very insensitive device, and the paramount problem presented to the designer of an oscillograph is to provide the necessary amplifier to implement this deficiency. As a consequence the reverse problem of attenuation has generally been overlooked.

The fact remains that it is often necessary in Electrical work to study wave-forms having an amplitude considerably in excess of the direct deflection voltage range of the Cathode Ray Tube. For this purpose, therefore, a self-contained Attenuator providing known reduction ratios is a very useful adjunct and the present instrument is the first oscillograph fitted with this useful device. The device was designed only for use at mains and audio frequencies to reduce the input in fixed ratios of $\frac{1}{2}$, $\frac{1}{4}$ and $\frac{1}{8}$. For reasons explained in 4.5.7, the control is of limited use at lower frequencies or D.C. Furthermore, because the device is not frequency compensated, its use is restricted at the higher frequency range for quantitative work of the same order of accuracy. Consequently its main use is contained within the field of frequencies covered by power and audio voltages.

4. OPERATING INSTRUCTIONS.

The operation and general use of the instrument is discussed in the following paragraphs. Preliminary abridged operating instructions of a reference character have been omitted because a few minutes acquaintance with the instrument is sufficient to provide once and for all the essential information on the function and behaviour of all the controls. 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 in this booklet to cover all the likely connections met in the practical use of the instrument under the heading "General Operation." These instructions are being designed to follow the normal operating sequence, and the considerations covering all likely cases are thus discussed as a matter of course as and when they apply to any given control, terminal or connection, and thus, when deemed necessary or useful, repetitions have been made. For those who favour preliminary simplified instructions, these can be obtained by taking the whole of the present section for the purpose. A further simplification and reduction to about ten pages can be obtained by omitting paragraphs 2, 3 and 4 of both Sections 4.4.2 and 4.5.4.1 and the whole of Sections 4.5.4.2 (b), 4.5.4.3 (b), 4.5.6, 4.5.7 and 4.5.8.

4.1. INSPECTION OF INSTRUMENT.

The instrument should be inspected carefully on receipt, as although the carton in which it is despatched has been designed to protect the tube and controls, damage may result in exceptional circumstances.

4.1.1. METAL CASE AND CHASSIS.

After undoing the two screws at the rear of the instrument the chassis should be withdrawn from the case by gripping the sides of the front panel towards the lower edge. The chassis will then slide out.

First remove the valve retaining rubbers, and ascertain that valves and tube (Figs. 4/48) are securely in their holders with the anode cap connectors in position. If these are displaced from the valves but do not touch the metal screens the power pack will be operating without the load of these valves and the resultant voltage rise may cause a condenser breakdown. On the other hand, should these caps make contact with any metal screens, excessive current will be drawn from the power pack, thus subjecting to severe overload, not only this part of the circuit, but also the anode feed resistances of the amplifier valves. In either case these will not function, and correct operation of the tube will be impossible. Before returning the instrument to its case it should be inspected both above and below the chassis to verify that no components or leads have come adrift as a result of severe transit conditions. The fixing screws should be secured firmly.

4.1.2. TUBE FIXING.

The tube socket is not used for fixing the tube. This is achieved by clamping the neck of the tube in a rubber lined stirrup, which, with the clamp itself, is mounted on the top flange of the bulkhead. The forward end of the tube is located in the front panel assembly by adjustable rubber pads. The tube may be changed by removing the socket and the two clamping screws, when it may be slid out forwards through the double mu-metal shields.

If for any reason the tube fixing has been disturbed, the tube should be rotated about its axis until the X deflection is horizontal before the clamping nuts are screwed right home. The correct axial position for the tube is with the crown of its screen just flush with the surface of the front panel, so that the transparent 10 cm. scale provided (see 4.1.5) rests lightly against the tube bulb when placed in position.

4.1.3. 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 (Section 5.6), of which the one corresponding to Y1 is formed by three sockets in a line and the 2-pin shorting plug normally connected across the two top sockets ; (c) two fuses on the H.T. secondary of the two power supplies, one of 60 mA. for the tube supply on the left and the other of 150 mA. for the Amplifier and Time Base power supply on the right of the panel.

4.1.4. MAINS SUPPLY.

Before the instrument is switched on, it is most important that the mains voltage selector be set to the position appropriate to the mains supply available.

The mains lead is taken out from the side of the case close to the front panel in a maner that does not impede the withdrawal of the chassis. A mains switch and a pilot light are provided. These are respectively placed on the right and left top corners of the front panel.

4.1.5. SCALE.

A 10 cm. scale on a transparent slide is provided with the instrument. This is despatched wrapped in tissue paper and should be placed in the vertical guides to be found to either side of the tube screen. This graticule is of particular assistance in quantitative and comparative tests. A viewing hood (Fig. 43) into which can be fitted this scale is available as an extra and is designed to fit the same guides.

4.1.6. MU-METAL SHIELD.

A double cylindrical concentric mu-metal shield is provided to surround the tube as a precaution against external magnetic fields and those due to the instrument itself. It 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 and the deflector coils 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.

4.1.7. MAINS TRANSFORMER PANEL.

On the rear underside of the instrument is located the mains transformer panel with numbered connections conforming to the circuit diagram of Fig. 47 and Fig. 50.

4.2. CONNECTIONS.

The method of connecting to the instrument will be given when the use of the terminals, and the circuits with which they are associated within the instrument, is described. The only preliminary connections are to the earth and the mains, and these are stated below.

4.2.1. EARTH.

Apart from those components mounted upon the rear panel (4.1.3), all the terminals and controls of the instrument are on the front panel. The earth terminal, " E," 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, such as a water-pipe, whilst on the other hand, earthing to wiring conduits should be avoided.

4.2.2. MAINS.

The instrument should first be connected to the mains and switched on. The pilot lamp will light up. It is possible that whilst the amplifier valves are warming up a slight hissing noise may be heard from the surge limiting condensers. This will subside after a few seconds.

4.2.3. INPUT.

The connecting leads required for use with the Oscillograph on external circuits do not form an integral part of the instrument, and must therefore be provided by the user. On the other hand, because the problem of connecting leads with the Oscillograph possessing a performance which makes it suitable for connection to almost any type of circuit is not always a simple one, a Kit of Leads, Cossor Model 426, has been specially designed to cover likely requirements. This useful accessory is mentioned and illustrated in Section 11.3, and can be obtained as an extra. This Kit is designed to cover the difficult requirements of Radio, and for this reason it is suitable for most other applications.

Although some information on the matter of input connections is given in Section 5.5, it may be useful here to give some general advice. For most applications a pair of screened input leads for use on the A and/or Y terminals, with the screening connected to the E terminal, will meet most requirements for D.C., A.C. such as Low Frequency circuits and general Supersonic Frequency work circuits up to 100,000 c.p.s. For higher frequencies, such as Radio and Television Video frequencies, and on high impedance circuits, either the effect of the leads and instrument input impedance (capacity and resistance) must be taken into account, or special arrangements adopted. These may necessitate the use of a Low Capacity screened lead terminated at the free end by a small series capacity in the former case, or a screened lead with a high resistance termination in the latter case.

4.3. TUBE CONTROLS.

An interesting feature of the instrument is the use whenever possible of tandem controls on related circuits. The controls which are thus coupled are the following :—

Tube Focus and Brilliance.
Y1 and Y2 Shifts.
X1 Shift and Time Base Synchronization.
Time Base, Amplitude and Trigger.
A1 and A2 Amplifier Gains.

Y SHIFTS

Two are provided to enable the two beams of the Double Beam Tube to be positioned vertically on the tube screen. Should either or both of the beams produce no visible trace, the concentrically mounted " Y1 and Y2 SHIFT " control knobs should be set to the mid-point of their travel. This will ensure that the beams are not deflected beyond the limits of the screen diameter whilst the other adjustments are being made.

X SHIFT

Provides the means of positioning the spot or trace in the horizontal direction, and should be adjusted in the same manner.

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.

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.

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.

4.4. HORIZONTAL OR X AXIS CONTROLS.

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.

4.4.1. X SHIFT.

The " X SHIFT " control provides the means of placing the traces in any required position on the horizontal axis, the X deflection plates being common to both beams. 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. The X Shift may therefore be used irrespective of the nature of the X axis signal voltage 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.

4.4.2. XI TERMINAL.

As has been mentioned previously, the XI plate is available for external use when the Condenser switch is rotated fully counter-clockwise and the Time Base thus rendered inoperative. In this position the XI plate is entirely disconnected from all the internal circuits but remains applied to the XI terminal on the 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, i.e., with the Time Base working, the Time Base voltage is present at the XI terminal and may be used externally. An instance of this latter application is the use of the Time Base for frequency modulation with the Cossor Model 343 Ganging Oscillator.

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 (DC.) voltages are applied. It has to be remembered that such voltages will affect both beams identically, and the displacement will be horizontal. When used in this manner the direct voltage which may be measured is about $1\frac{1}{2}$ times greater than is possible in the Y direction. Thus unidirectional voltages up to 250 may be measured. When accurate quantitative results are required it is advisable to calibrate each axis separately, as the sensitivity in the X axis is greater than that of the Y axis.

As the XI 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 XI and E 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 XI and E terminals a high resistance of the order of 1—3 megohms maximum. When the Time Base is inoperative and no voltage is applied to the XI terminal, as in the case of the photography of slow transients, the E and XI terminals should be short circuited.

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 described in Section 4.5.7.

4.4.3. TIME BASE CONTROLS.

The Time Base incorporated in this instrument is of the original Cossor hard valve type, and for the benefit of those users interested in its working a description is given in Section 3.2. On this instrument the controls affecting the Time Base are " CONDENSER," " VELOCITY," " AMPLITUDE," " TRIGGER," and " SYNCHRONIZING."

4.4.3.1. CONDENSER.

The " CONDENSER " control takes the form of a switch which in its fully counter-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 capacity, until at the last position only the stray capacities 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 counter-clockwise direction produces the slowest Time Base speed.

On the two fastest 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 for this purpose.

4.4.3.2. VELOCITY.

The " VELOCITY " control 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.

4.4.3.3. AMPLITUDE.

This control 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 in Section 3.2. This control enables the length of the X axis deflection produced by the Time Base to be adjusted.

4.4.3.4. TRIGGER CONTROL.

This 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 counter-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.

The minimum trigger control setting is consistent with maximum linearity of Time Base traverse. In the full counter-clockwise position this control operates the Trigger Switch (see under).

4.4.3.5. TRIGGER SWITCH.

This 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, as in Section 5.11. 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 mounted on an extension spindle of the Trigger control. In the off position, that is, full counter-clockwise rotation of the Trigger control, one switch serves to short-circuit the fixed resistance in the grid of the auxiliary discharge valve and the other to short-circuit the small series condenser in the synchronising input control network.

4.4.3.6. SYNCHRONIZING.

This control 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 the greatest possible 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 counter-clockwise as possible in order to avoid introducing distortion of the trace due to velocity modulation of the Time Base.

The procedure which should be adopted is to set the " SYN." control in its fully counter-clockwise position and adjust the Velocity control until the Time Base is operating as nearly as possible at the frequency to which sychronism is required. Slight rotation of the " SYN." control in a clockwise direction will then suffice to lock the Time Base. The injection of excessive synchronising 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.

The synchronism attainable with a Time Base of this type is of a very positive nature, and is characterized by two other features of paramount 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 " SYNCH." control.

Where it is desired to synchronize the Time Base from the incoming work voltage applied to the A1 or A2 terminals, i.e., 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 under these circumstances the input may be so small as to be quite incapable of affording satisfactory synchronism.

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 synchronising either to the work circuit or 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 synchronised is applied to the A1 or Y1 terminal.

4.5. VERTICAL or Y AXIS CONTROLS.

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. When using the Double Beam Tube two signals may be recorded simultaneously in the Y axis.

On quantitative work it is useful to remember that the two Y axis deflector plates have not necessarily the same sensitivity, and each should be separately calibrated, or alternatively, when the amplifiers are used, the corresponding Gain controls should be adjusted to provide equal deflection for the same voltage input, should this be required as on comparative tests.

4.5.1. Y1 AND Y2 SHIFTS.

Two Y Shift controls are provided. That controlled by the foremost knob affects the potential applied to the beam which is controlled by the Y1 deflector plate, whilst the rearmost control affects the other beam in a Y direction. When using a Single Beam Tube the two potentiometers should first be rotated to their limit of travel in one direction and the two knobs then manipulated as one. In this way a balanced Y Shift is applied, which is advantageous as a means of reducing astigmatism and also, to some extent, deflection defocussing. When required it is possible to set both controls permanently for single operation as when using a Single Beam Tube by screwing the countersunk screw on the face of the small knob into the tapped hole provided in the larger knob, thus locking the two knobs together. The positions of the respective controls in relation to the fixing screw has been set at the factory to ensure the best condition to avoid the effects mentioned above. This is stated as it is likely that because of this it may not be possible to adjust the Shift to the same extent as when set independently.

When an asymmetrical, low-frequency voltage is applied from a low impedance work circuit to the Y1 plate when using a Single Beam Tube and the Amplifier switch is in the first or D.C. position, the Y1 Shift voltage is short-circuited and the Shift action will be obtained almost entirely by the Y2 Shift control, whether or not the two controls are linked together.

4.5.2. 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.

When the instrument is fitted with a Single Beam Tube Type 26J and the work voltage is applied to one of the plates, usually Y1, asymmetrically, it is desirable to short-circuit the remaining plate, Y2, to earth, joining it either directly to the E terminal, when the Amplifier switch is in position 2, AC, or through a large condenser when it is in position 1, DC, if inter-modulation effects are to be avoided.

For symmetrical working with a Single Beam Tube the work voltage is applied either directly across the Y1 and Y2 terminals, in positions 1 and 2, DC and AC, of the Amplifier switch, or indirectly through the Amplifier when connected across the A1 and A2 terminals, in positions 3, 4 and 5 of the Amplifier switch. In the case of D.C. coupling with the Amplifier switch in position 1 the Shift voltages may be short-circuited when the work circuit is of low impedance. If Shifts are required the deflector coils can be used when connected to a battery through a variable resistance, or if a D.C. Amplifier is used this latter should include its own Shift arrangements.

4.5.3. A1 AND A2 TERMINALS.

In positions Y1Y2, 2Y1 and 2HFY1 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.

In normal double beam operation work voltages are applied asymmetrically to these terminals, that is, across A1 or A2 and E. This also applies with a Single Beam Tube except that the remaining Y plate should be earthed, except in the case of symmetrical working, when the voltage on test is applied across the A1 and A2 terminals.

4.5.4. AMPLIFIER SWITCH.

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 is located in the centre of the panel of the instrument, and provides five different circuit combinations. In the information given below the counter-clockwise limit of rotation of the switch is regarded as position 1, and the limit of clockwise travel as position 5.

4.5.4.1. 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 both Y1 and 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 " 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.

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 to the positions at which there is no displacement of the beams when the Amplifier switch is moved alternately to Positions 1 and 2. In the case of the Y1 beam the spot will then appear approximately central on the screen and will move vertically upwards with a positive direct voltage and downwards for a negative voltage, and vice versa (because of the spatial 180° Phase Shift due to the tube) in the case of the Y2 beam. Thus only half the screen can be used for testing a unidirectional or D.C. voltage, and for this reason it is in general more convenient either to use the X1 terminal for direct voltage measurements, as indicated in Section 4.4.2,

When using the instrument fitted with a Single Beam Tube the work voltage is usually applied asymmetrically to one deflector plate, Y1. In this case the Y2 terminal should be short-circuited by means of a large condenser connected across Y2 and E. On a low impedance work circuit the Y1 Shift is inoperative and the Y2 Shift alone will serve, whether or not the two controls are locked. A certain amount of astigmatism and deflection defocussing is to be expected under these conditions. When the voltages are applied symmetrically, that is, through a D.C. Amplifier, both Shift networks are then made inoperative and the Shift can be obtained either from the D.C. Amplifier itself or by the use of deflector coils in conjunction with the battery and a variable resistance.

For D.C. or unidirectional voltages a maximum reading of 150 volts is possible for the half screen deflection as mentioned above (at 3 volts per mm.).

For other waves of low periodicity, as would be applied in this position, a maximum equivalent to 110 v. R.M.S. is possible, but in this case the peak to peak deflection covers the whole screen (at 1.1 v. R.M.S. per mm.).

4.5.4.2. POSITION 2. "PLATES—A.C." (a) EXTERNAL SIGNALS ON Y1 AND Y2.

A coupling condenser is present 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.p.s. can be tested ; on the other hand the input capacity of the instrument provides the first factor limiting the highest frequency which can be investigated in this position.

For A.C. voltages greater than 100v R.M.S. the Y2 Attenuator should be used as explained in Section 4.5.7.

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.

When using the Single Beam Tube Type 26J the voltage is usually applied asymmetrically to the Y1 plate. In this case the Y2 terminal should be joined to the E terminal. Occasionally the work voltage is applied symmetrically across the Y1 and Y2 terminals. In both cases the two voltages will still be operative and no astigmatism or defocussing will result if the controls are locked together, as previously described.

(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 in paragraph 4.4.2 covering the case of an external voltage applied in the X direction. Further information is given in Section 6.1.4. et seq and Fig. 26.

This class of test is best made with a Single Beam Tube, but it can none the less be carried out equally successfully with a Double Beam Tube, the only inconvenience being the presence of the trace of the unwanted beam. This latter can either be deflected off the tube screen by adjusting the corresponding Y Shift control, or else, if it is preferred to avoid the resultant slight defocussing, the unwanted beam may be left in some position on the screen which does not interfere with the wanted record, when its presence can be ignored. Because the unwanted trace will usually be a horizontal straight line, this fact can be of some advantage, for it can be used as an X axis or baseline for the wanted trace, or even as a moving marker for quantitative determinations or reference purposes. In this case the corresponding Y Shift may be used to displace the line to the required position on the screen. A wise precaution in such cases is to connect the Y terminal concerned to earth or across a low resistance (say 100,000 ohms) when the Y Shift is used.

Fig. 26 illustrates the results obtained under conditions envisaged in this paragraph.

4.5.4.3. POSITION 3. "AMPLIFIERS—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 a separate single stage Amplifier, the input to the Y1 amplifier being via terminal A1, the signal for the Y2 plate being applied via A2. The Gain controls for the two amplifiers are mounted concentrically, the potentiometer controlled by the front knob affecting the amplifier connected with the Y1 plate. The gains of the two amplifiers may be controlled independently and the maximum available from each in this switch position is of the order of 28 times. The Time Base is synchronised to either work voltage by connecting the SYN. terminal to either Y1 or Y2. The maximum deflection obtainable in this position without distortion covers almost the full screen diameter.

When using a Single Beam Tube this position enables amplified deflection of any signal source which is balanced about ground. The work voltage is applied across the A1 and A2 terminals. The locked Shift controls are both effective. This operating condition reduces deflection defocussing and residual astigmatism.

(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 directions, as in the case of Phase Shift tests, this can best be done by using a Single Beam Tube, although if the horizontal trace resulting from the unwanted beam is ignored, a Double Beam Tube can be used in precisely the same manner as has been described under the heading of Position 2, Section (b), 4.5.4.2.

The use of a Single Beam Tube will entail connecting the Y2 amplifier to the X1 plate by rearranging the rear panel connections, as discussed in 5.6.1.

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 counter-clockwise position. This frees the X1 deflector plate, which remains directly connected to the X1 terminal. To apply the two signals to the X and Y axes the X1 terminal is then connected to the Y2 terminal, from which connection a 1 to 3 megohm resistance is joined to the " Earth " terminal. 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 A1 terminal.

This procedure does not necessitate rearranging the rear panel connections when the Double Beam Tube is used if the unwanted beam in this case is ignored. In fact, as the Y2 beam is affected by the same voltage in both X and Y directions, the effect will show up as a tilt of this trace across the screen. This trace will be a straight line inclined to the vertical and will not interfere with the other trace. It is possible to bias this Y2 beam off the screen, but because the trace is tilted, part of it may still appear at the edge of the tube. In certain experiments this may be desirable to separate the two traces to avoid confusion and to enable the wanted record to occupy the most favourable position on the tube screen. On the other hand, this expedient is not altogether without disadvantages, because slight defocussing occurs on both beams when they are considerably displaced from one another. Thus it is usually better to leave the unwanted beam in the centre of the screen, as it is not likely to interfere with the wanted record. The only case in which this unwanted trace may be objectionable is when photographic records are being made, in which case the use of a Single Beam Tube is preferable, and the rear panel connections are altered accordingly.

4.5.4.4. 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 plate controlling the second beam (Y2) is connected via an isolating condenser to the terminal of the same designation. 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 almost 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. For further information on this matter see Section 5.4. To synchronise the Time Base as usual connect " SYN." to either Y1 or Y2. The procedure with separate external signals on the X and Y axes is as given in Sections 4.5.4.2. (*b*) and 4.5.4.3. (*b*) above.

When used with a Single Beam Tube the work voltage is applied across the A1 and E terminals, whilst the Y2 terminal is connected to E. The locked, balanced Shift control remains effective in this position.

4.5.4.5. POSITION 5. "AMPLIFIER—2HFY1."

The general circuit arrangement is basically 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 band-width is extended to approximately 2 megacycles. 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. On account of the high maximum Time Base speed available (above 250 kcs.) it is possible to carry out wave-form examination on signals having frequencies of 2 to 5 mcs. To synchronise Time Base, as usual, connect " SYN." to either Y1 or Y2. The maximum deflection obtainable without overload with the amplifiers in this position is 30 to 40 mms. For further information see Section 5.4. The procedure with separate external signals on the X and Y axes is as given in Sections 4.5.4.2. (*b*) and 4.5.4.3. (*b*) above.

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 rearranging the rear panel connections (5.6.1) 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, see end of Section 5.4.1.

When used with a Single Beam Tube the work voltage is applied across the A1 and E terminals, whilst the Y2 and E terminals are joined together. The locked, balanced Y Shift controls remain effective in this position.

4.5.5. AMPLIFIER A1 & A2 GAIN CONTROLS.

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. Their operation is covered in the previous paragraphs and in Section 5.1.

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 this 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 that 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.

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 2HFY1. 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.

4.5.6. DEFLECTOR COILS.

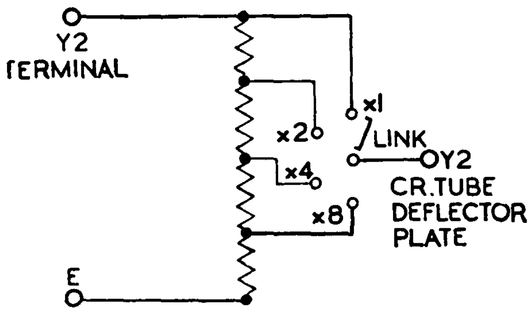
The deflector coils provided enable current measurements to be made directly. Deflection to the full screen diameter is obtained with a current of approximately 50 mA. R.M.S. When the instrument is being operated in the normal way with a Double Beam Tube the Y axis deflection produced by the coils is 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 E 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.

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.

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.

4.5.7. Y2 ATTENUATOR.

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 x1 socket is connected to the Y2 terminal on the front panel of the instrument. Fig. 10



SIMPLIFIED CIRCUIT OF THE INBUILT Y2 ATTENUATOR.

FIG. 10.

shows the details of this circuit. The shorting or link plug would normally be connected between the centre socket and the x1 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). 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.

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 x1 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 utilized.

Because of the necessity on the Double Beam Tube of applying both Shift and signal voltages to each Y plate, the Shift circuit resistances, and therefore also the position of the Shift control, materially affects the reduction ratio of the attenuator, more especially on the high reduction ratio steps, and whilst the attenuator 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 attenuator is not frequency compensated, and cannot be used at frequencies much higher than the Audio Frequency range.

The attenuator is designed to withstand a maximum operating voltage of 400 volts A.C. R.M.S., and the device can be used satisfactorily in this way over the whole of the Audio Frequency range. Under these conditions, with the use of a Double Beam Tube and maximum attenuation, half the screen deflection is obtained, which, as previously stated, is presumed to cover the normal operating conditions, for reasons which are explained in Section 5.3. Though the stated figure could be exceeded when using the maximum attenuation range on the assumption of using the whole tube diameter when testing A.C., the type of escutcheon panel which can be fitted to this instrument is such that it would not be safe to operate at higher voltages. In such cases it is best to provide an external attenuator using " high voltage " type resistances.

4.5.8. CALIBRATION.

In order to provide an approximate means of calibrating the deflector plates for quantitative work a calibration winding is included in the instrument. This winding has an output of 50 volts peak to peak (17.35 volts R.M.S.) and one side is connected internally to the chassis of the instrument, the live end 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 10cm. scale graticule as shown in the illustration of Viewing Hood, Fig. 43.

A protecting resistance is connected in series with the calibration winding to avoid the risk of damage to the mains transformer should the lead from the "CAL." (" C ") terminal accidentally touch the chassis or other earth point. It is well to note that the presence of this resistance renders the calibration less accurate when applied to the deflector coils, because of the current taken by the coil circuit.

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 large 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.

5. OPERATING CONDITIONS.

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.

5.1. FOCUSSING.

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.

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.

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.

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.

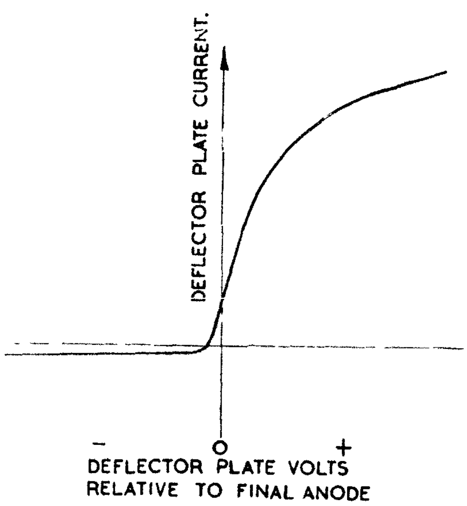
With a Double Beam Tube the Y deflection voltage is necessarily applied asymmetrically, and thus affects the focus of the beam to a slight degree. Due to this effect, if the beam is focussed whilst approximately central on the tube, the trace loses sharpness slightly in a progressive manner as the beam 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.

5.2. INTERMODULATION.

As explained in Section 3.1.4. 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.

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.

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. 11, 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.



TYPICAL DEFLECTOR-PLATE VOLTAGE/CURRENT CHARACTERISTIC.

FIG. 11.

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 present Oscillograph 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.

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 significant advantage of the design of the Cossor Double Beam Tube. Needless to say, these intermodulation effects are also corrected in the Cossor Single Beam Tube, and the same operating precautions are required. For further information consult reference 3, Section 10.2 (a).

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.

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 kcs., that is, within the range of operation of the Amplifier switch positions D.C., A.C., Y1Y2 and 2Y1. Whatever effects may be present can be eliminated by suitable precautions.

The effects of these couplings obviously increase with frequency and they are thus noticeable in the range covered by the 2HFY1 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.

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.

5.3. DEFLECTION.

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 (see Fig. 47) 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.

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.

Notwithstanding this restriction, however, it is possible, except in position 5 (2HFY1), 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.

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

As the present Oscillograph 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, it will be seen from Section 5.2. increases the intermodulation effects. It would have been easier to reduce these impedances—as on most competitive instruments—from the 3 megohms provided to a value of 100,000 ohms or even 10,000 ohms, but such a step is not consistent with the intention to make the scope of the instrument as wide as possible.

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 Section 5.2 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.

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.

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 Work, 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.

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 of 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.

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.

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.

5.4. AMPLIFIERS.

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.

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 to 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.

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 100 kcs. 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 as described in Section 5.4.1.

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 35mms. deflection before over-loading occurs. This fact should always be reckoned with when using this amplifier setting.

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 Section 4.5.5, 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.

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 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.

5.4.1. USE AS 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. polarised 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. The circuit of Fig. 12 (see page 38) shows an arrangement using two barrier layer rectifiers (Type WMX281 Westectors or equivalent selenium metal rectifiers) as voltage doubler replacing the rear panel Y2 link. The addition of a low capacity 2.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 kcs. 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.

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 of Fig. 12 is connected as shown.

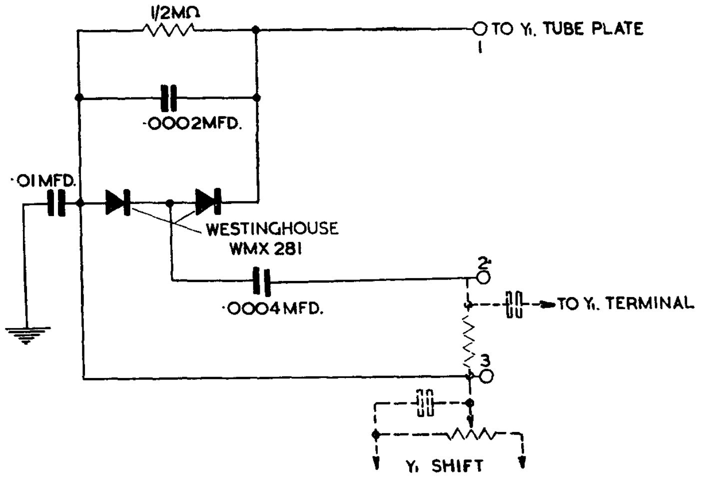


FIG. 12.

METHOD OF RECTIFYING THE OUTPUT OF OSCILLOGRAPH AMPLIFIER TO PRODUCE DIRECT DEFLECTION FROM A MODULATED SIGNAL (1 2 & 3 ARE REAR PANEL Y1 SOCKETS).

A valve rectifier can, of course, be used if desired, but this entails a heater connection and more elaborate mounting, if attempted within the instrument. This can be taken from the mains transformer winding at taps Nos. 15 and 16 on the transformer panel feeding the Amplifier valve heaters. The transformers have been designed to allow for this extra current drain provided not more than the total 2 amps. are called for.

5.5. INPUT IMPEDANCE.

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.

In those cases where the impedance of the test circuit is high and the instrument's input resistance of 1 megohm is still liable to affect the result, a series resistance of from 1 to 5 megohms can be added to the lead. This expedient must 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 capacity 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.

When applying signals to either the Y1 or Y2 terminals the resistive component of the input impedance is sufficiently high (3 megohms) to be disregarded for most work.

Although the capacity 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. 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 some 1 or 2 mmfds. 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 mmfd. 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 capacity (at the required frequency) and the impedance corresponding to the sum of the capacities of the instrument input and connecting leads. Cossor Model 426 Radio Service Kit, illustrated in Fig. 45, Section 11, has been designed for use with this Oscillograph to provide leads and devices to meet the above and all other test requirements.

When the Amplifiers are being used and the Time Base is being synchronized with the work voltage, the synchronizing 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 synchronizing circuit impedance across the source. 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.

5.6. REAR PANEL LINK STRIP.

For certain work it will be found convenient to make use of the link panel at the rear of the instrument (4.1.3). 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 the lower tags to the instrument circuits and terminals. The flexibility allowed by this arrangement is valuable for quite a number of practical applications with the Oscillograph, and such applications generally fall under one of the following headings :—

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

(2) 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.

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

Examples of the first class of application are the taking of measurements at high radio frequencies (and with intermediate frequency and video amplifiers for television), or the use of the grid connection for beam triggering (as described in Section 6.2.3), for time marking purposes on transients (as described in Section 8.3), 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 (as described in Section 7.2.2). Examples of the third class are described in the following paragraphs, because they involve modification of the operating conditions of the instrument.

One useful special case has already been given in Section 5.4.1., for which purpose, instead of a soldered link, three sockets in line and a 2-pin shorting plug are provided for the Y1 connection so as to facilitate its use in the manner described.

5.6.1. REARRANGEMENT OF INSTRUMENT CIRCUITS.

Considering that two independent internal Amplifiers and an independent internal Time Base, together with a variety of external auxiliary time bases and work circuits, may be available for application to the Oscillograph under given conditions, it is obvious that with four deflector plates and three independent displacements in the case of a Double Beam Tube, there are a large number of possible rearrangements of the instrument circuits which may occur under practical conditions. It is impossible to cover all these cases, nor is this necessary, because the circuit rearrangements are usually a simple matter, dictated by work circuit conditions and the general requirements of the experiment.

As an example of this class of application it may be desired to employ both the double beam facilities in the Y axis and a stage of amplification in the X. We will take this case as a practical example to show the general procedure to be adopted. Let us assume that we desire to apply a signal through one stage of amplification to one of the Y deflector plates, a signal with no amplification to the other Y plate, and a signal through an amplifier to the X plate. The Amplifier switch may be put to the third position and the Y deflection voltage requiring amplification applied to A1 in the ordinary way. The Time Base should be switched off by full counter-clockwise rotation of the Condenser switch, and the X1 and Y2 links at the back of the instrument removed. In their place connections should be made from the lower X1 tag to the upper Y2 tag and from the upper X1 tag to the lower Y2 tag. An input applied to A2 will then appear, amplified, on the X deflector plate, whilst the Y2 plate will be available at the X1 terminal. No internal D.C. path exists between this terminal and earth, and a suitable resistance should therefore be connected externally between these points. With these particular connections no vertical shift is available on this beam, and therefore any positioning which is required must be effected by connection of a suitable voltage between the " earthy " end of the plate return resistance and the Earth terminal proper. A 60 volt dry battery will serve the purpose, and a variable shift can be obtained either in steps by changing the tappings, or continuously through the aid of a suitable high resistance potentiometer connected across the battery, the slider arm being taken to the lower end of the plate return resistance. If the mid-point of the battery is joined to earth, in either case positive and negative shift can be obtained and the tube spot can thus be displaced above and below its normal position. The potentiometer should be disconnected when not in use to avoid discharging the battery. The control which provided the Y2 shift will temporarily operate as an additional X shift.

One important case is when it is found that in a particular Cathode Ray Tube fitted to a given instrument the less bright of the two beams is the one connected to the Y1 axis. As a result it may be found that when the spot is used at high writing speeds with the Amplifiers in circuit in the "2Y1" and "2HFY1" switch positions, the trace becomes very faint. This is particularly the case with radio frequency work. In such cases it may be advantageous to interchange the tube connections to the Y1 and Y2 deflector plates. This will alter the instrument circuits accordingly, and the brighter beam will thus serve in conjunction with the A1 terminal and the cascaded position of the Amplifiers. It must then be remembered that the statements in previous paragraphs with regard to the beam position will have to be modified accordingly. See 5.7 (f) and 5.10 for Amplified Time Base.

5.6.2. GRID CONNECTION.

Reference must be made to the use of the grid connection because this is often required in practice—chiefly for beam switching, as described in Section 6.2.3, and for timing purposes, as described in Section 8.3—usually in connection with photographic recording. In such cases use must 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. For more information on this point refer to Section 8.3. 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. It need hardly be mentioned that 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.

5.7. CALIBRATION VOLTAGE.

The use of this voltage is by no means restricted merely to calibration of the deflector plates; it can be used for many other purposes, most of which are given herewith.

Should it be desired to employ the calibration source to measure the Amplifier sensitivity approximately at any given Gain setting the "C" terminal should not be connected directly to the "A1" or "A2" terminals because this would appreciably overload the amplifier valves. A fixed potentiometer should be connected between the "C" and "E" terminals and a known fraction of the calibration voltage thus applied to the "A1" or "A2" terminals. When one stage of amplification is being used a suitable potentiometer may be made from a 10,000 ohm and a 100 ohm resistance in series, the small resistance being connected between the Amplifier Input terminal and earth and the larger between the Amplifier terminal and the Calibrate terminal. If the amplifiers are being used in cascade at high gain settings the attenuation of approximately 100 times given by these values will be insufficient and the values should be modified accordingly.

Amongst the other uses of the Calibration terminal the following may be mentioned :—

(a) By connecting this terminal to the "SYN." terminal the Time Base may be synchronized at mains frequency or some sub-multiple of this frequency.

(b) By applying a suitable fraction of the calibration voltage to the A1 or A2 terminal a deflection at mains frequency is produced on one beam and may be used as a reference for frequency comparison or timing indication with any wave applied to the other beam.

(c) By connecting the "C" terminal to one side of the deflector coils the other side of the deflector coils being connected to earth, a magnetic sinusoidal time base is obtained. A variable resistance in series can serve to control amplitude.

(d) By injecting a proportion of the calibration voltage into the grid circuit of the Cathode Ray Tube (see 5.6.2) the beams may be intensity modulated for timing purposes, or this modulation may be used in conjunction with the sinusoidal time base obtained in the manner outlined in (c) above in order to obliterate the return trace. In order to provide this obliteration over the width of the screen and not merely over that part of the screen corresponding to the negative half cycle of the applied calibration voltage, the modulation voltage should be applied to the grid through a simple differentiating circuit consisting of a short time constant coupling. A coupling condenser of .001 mfd. in conjunction with a 500,000 ohm leak will be found satisfactory.

(e) When a greater degree of temporal resolution is required against a sinusoidal base than that provided by direct connection from the Calibration terminal to the "X1" terminal, the X deflection may be amplified by making the alterations to the link panel referred to in 5.3 for the provision of one stage of amplification to the X plate. A fraction of the calibration voltage may then be applied to the Input terminal of the amplifier concerned. If only a single beam trace is required there is no need to modify the link strip connections. The procedure in this case is to apply a fraction of the calibration voltage to either A1 or A2, the output of the amplifier being taken from either Y1 or Y2 and connected to terminal X1 with the Condenser switch at its fully counter-clockwise position and the Amplifier switch in the third position. That beam which suffers sinusoidal vertical deflection should be displaced from the screen by means of the appropriate "Y Shift" or retained on the screen and ignored if the best focus condition is desired. See Section 7.1 for further information.

5.8. SINGLE BEAM TUBE.

The only purely operational difference between the Single and Double Beam Tubes lies in the manipulation of the Y Shift controls. When the Single Beam Tube is being used, instead of employing these controls singly they should first be turned (in the same direction) to their limit of rotation. The position of the trace in the Y direction is then achieved by turning the two knobs as one. In this way approximately balanced Y Shift potentials are applied, and the attendant advantages of freedom from astigmatism and reduction of deflection defocussing are obtained. Provisions are, however, made on these controls, as explained in Section 4.5.1, to lock them permanently for this purpose, an expedient which should be adopted when a Single Beam Tube is used permanently on the instrument. The setting of the Y Shift controls in relation to the common fixing pin is arranged at the factory to provide as nearly as possible true symmetrical deflection, and when operated in this manner it may be found that the Y Shift sweep obtained is not so large as when the controls are adjusted independently, but this effect is of no importance.

Should the Y Shift knobs ever have to be removed, care should be taken to ensure that they are returned to the same position on the spindles. The dents caused by the grub screws will serve for reference purposes.

In cases of other than symmetrical operation of a Single Beam Tube, that is, when only one Y deflector plate is used, say, Y1, the other, Y2, plate, should be connected to E if asymmetric inter-modulation effects are to be avoided at high beam current.

Furthermore, with a Single Beam Tube use of the 3rd Amplifier switch position, Sections 4.4 and 4.5, provides balanced amplified deflection from any signal source which is balanced about ground, a condition which reduces deflection, defocussing and residual astigmatism in the tube. 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 capacities to earth of the usual Input terminals A1 and E used with normal asymmetrical working.

5.9. MAGNETIC FIELDS.

The Cathode Ray Tube in the instrument is well protected from magnetic fields, and it is difficult to find any location in which successful operation of the instrument is in any way impaired by external fields. However, the power transformer in the instrument itself necessarily has a considerable field, and when making investigations on high gain amplifiers having line matching or microphone input transformers the possibility of hum being induced into such transformers from the Oscillograph should not be overlooked. As has been mentioned in Section 3.3, the load imposed by the input circuits of the amplifier valves is sensibly constant under all normal working conditions.

5.10. TIME BASE.

Most of the points concerned with the operation of the Time Base are covered in Section 3.2 and 4.4.3 and following. The practical application is treated in Section 6.1.3 on Frequency Comparison Tests, in which the method of using the range of controls is given together with the interpretation of the patterns obtained. 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.p.s. or 2,000,000 c.p.s., thanks to the flexibility of the Time Base. The only slight difference is at the higher frequencies, where recourse will be made to the Trigger rather than the Velocity control for adjusting to exact synchronism, because of the finer means of adjustment it provides.

It should be remembered that the fundamental relation of all Time Base circuits makes the capacity, 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.

By reduction of the Amplitude control to zero or thereabouts and using the Y2 amplifier by rearranging the rear panel links (5.6.1), it is possible to use the Time Base of the instrument in the first three positions of the Amplifier switch (D.C., A.C. and 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.

5.11. SINGLE STROKE TIME BASE.

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 been described in principle in Section 3.2.1. 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 synchronising terminal of the instrument and earth, through a series condenser, the capacity of which should be varied to suit the sweep speed required. It has already been mentioned that it is not necessary to provide a different capacity condenser for each of the Time Base " COND." switch positions, and a 0.005 mfd. condenser will be found suitable for the three slowest condenser speeds on the Time Base, whilst a 0.0002 mfd. 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 three fastest 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.

5.11.1. SINGLE STROKE ADJUSTMENTS.

In order to use the 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 beams (or beam in the case of a Single Beam Tube) are deflected just beyond the right-hand limit of the screen diameter.

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 one can therefore decide from a consideration of the work in hand, which condenser switch position should be used. 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. The behaviour of the Time Base will, however, depend somewhat critically on the setting of the " SYNCHRONISING " control. This should first be rotated to its fully counter-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. As the " SYNCHRONISING " 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 " SYNCH." control will be found at which the spot just traverses a complete screen width. This is the correct setting of the " SYNCHRONISING " 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.

5.11.2. SINGLE STROKE APPLICATIONS.

The applications for which this type of Time Base is most suitable are the visual investigation of slow transients, such as are encountered in cardiography, 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 with a " G " type screen should be used in the former case.

The arrangements made to apply the negative triggering impulse must necessarily depend on the nature of the work in hand, but in the main some form of mechanically operated switch can be adopted. Such a switch need only make for short periods, and it may be operated by hand, or in certain cases it may take the form of a Contact Breaker, such as Cossor Model 350, Fig. 42a. This device is particularly suitable if it is desired to investigate some short duration impulse associated with a rotary device having rotation time which is long compared with the impulse itself, for by suitably phasing the make and break of Model 350 small fractions of the cycle can be examined successively in detail. For work of this nature the Contact Breaker can be driven directly from the rotary motion.

For photographic work it is often possible to couple the Time Base operating switch to the shutter mechanism of the Camera, and, in fact, Cossor Model 427 Camera incorporates a switch which is suited to this purpose. The single stroke operation of the Time Base by purely electrical means is a rather more complicated application, and generally involves the use of some form of electronic switch circuit, such as a Kipp relay, and it is somewhat beyond the scope of this booklet to give information on such devices, which are, in any case, generally necessary only for work which is itself somewhat beyond the scope of the instrument. For those cases where such a unit is, however, required, no difficulty should be experienced in making up a suitable unit, as a number of articles have appeared in the Technical Press dealing with this problem.

6. FUNDAMENTALS OF OSCILLOGRAPHIC TECHNIQUE.

It is not possible to cover the use of the instrument in every field of application, but it is possible to provide some basic information on fundamental oscillographic tests, which are invariably required in almost every application, and it is for this reason that the following sections have been added to the present booklet.

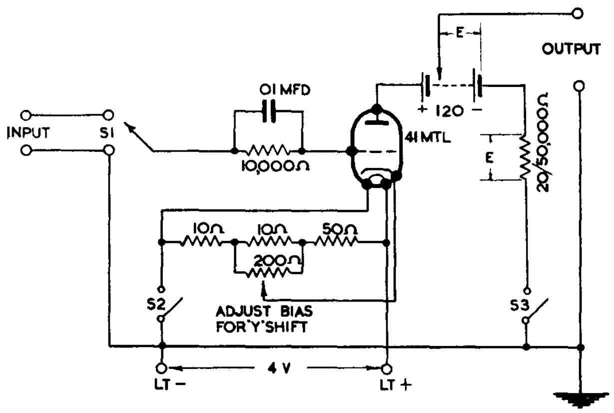
6.1. GENERAL TESTS.

These cover the fundamental determinations required when testing electrical quantities qualitatively, comparatively and quantitatively, such as voltage, current, phase, frequency and amplitude. The following sections cover mainly the principles involved, their application to oscillograph technique and the resulting test procedure. Much of the information on these matters will, however, be found in the text on "Operating Instructions." The following paragraphs are therefore complementary to these.

6.1.1. VOLTAGE TESTS.

This is the most general of oscillographic tests and needs no further specific mention, because the general conditions governing such tests and the appropriate procedure are covered fully in Sections 4.4.2., 4.5.4.1. to 4,5.4.5., and 4.5.7., comprising what can indeed be considered as the fundamental purpose of the Cathode Ray Oscillograph.

The only important case not covered in the text, because it is not provided in the instrument, is the facility for investigating low voltage, very low frequency and quasi-D.C. effects. In such cases a special D.C. Amplifier is necessary, which, for reasons of stability, must obviously be provided externally. Such a D.C. Amplifier can be of considerable importance in certain applications, and as a satisfactory arrangement can be assembled readily from standard components, a suitable circuit for the purpose is given in Fig. 13. This circuit, which provides a gain of approximately 25, is satisfactory up to a frequency of 50,000 c.p.s. If higher gains are required this instrument can be duplicated and the two sections connected in cascade, the OUT terminals of the first amplifier connecting to the IN terminals of the second. The resultant gain is the product of the individual gains. Greater gain can be obtained from the single stage arrangement by increasing the Anode resistance of the valve, but this will produce a corresponding decrease in frequency range.



SINGLE STAGE DIRECT-COUPLED AMPLIFIER
(S1, S2, S3, — GANGED ON-OFF SWITCH)

FIG. 13.

It is desirable to insulate the H.T. battery from earth to reduce capacity effects if the full frequency range is required. (An alternative method is given in Section 5.4.1).

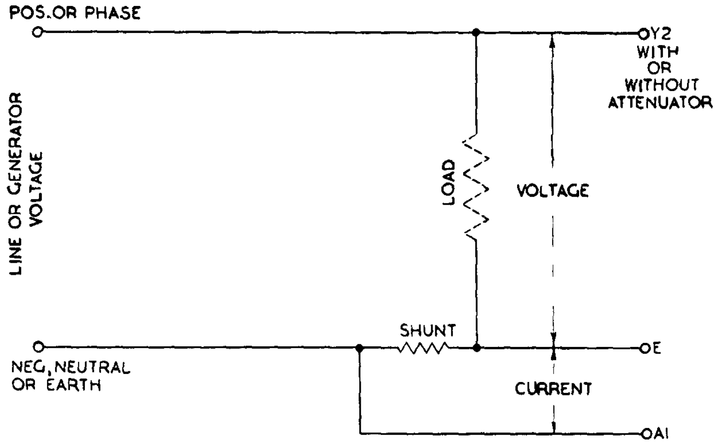
6.1.2. CURRENT MEASUREMENTS.

Often it will be found more convenient in practice to measure current by the electrostatic method rather than by using the electromagnetic deflector coils provided in the instrument, the reason being that the inductance and resistance of the coils are of such an order relative to the constants of some circuits as to introduce errors of appreciable magnitude. In such cases, and, in fact, for most current measurements, it is almost always possible to obtain the desired result electrostatically.

The voltage across a small non-inductive resistance in series with the load circuit can be taken as a measure of the current provided the voltage drop is small compared with the total voltage in the system. Because such voltage drops are necessarily small they need to be amplified if they are to be indicated by the Cathode Ray Tube. It is often possible to arrange for a voltage drop of the order of 0.5 volt without causing appreciable changes in the power factor of the circuit being investigated. In such cases, quite apart from the electrical advantage of this electrostatic method of taking current readings, there is the advantage that, as only one stage of amplification need be employed, the third Amplifier switch position " Y1Y2 " may be used, and two simultaneous current records may be obtained on the Double Beam Tube, allowing the phase relationship between two circuits to be assessed accurately.

On the other hand, it will be found more convenient in general to use the cascaded positions 4 and 5 of the Oscillograph Amplifier switch. On account of the very high gain available in the fourth switch position "2Y1," more than sufficient deflection may be obtained by utilizing the voltage drop across standard ammeter shunts. In fact 75 mV. would be represented by a deflection equivalent to more than twice the screen diameter with the amplifiers operated at maximum gain. In some cases the drop across two points on the busbar may be sufficient for the purpose. In fact, a voltage as low as 3 mV. gives a legible deflection of 1 cm. on the Cathode Ray Tube. When steep fronted wave-forms are encountered the fifth ("2HFY1 ") position of the Amplifier switch will provide more accurate results, because less attenuation and phase delay of the H.F. components of the wave will be produced.

The more important advantages of using the Double Beam Tube features and the 2-stage position of the Amplifier are that, as a result of the former, simultaneous voltage and current tests are possible, and because of the latter the test circuit can be arranged, as shown in Fig. 14, to correct for the spatial 180° phase shift present on the Double Beam Tube, and thus enable inspection of current and voltage simultaneously in their true phase relationship. A further advantage of this arrangement is that the Y2 terminal has no amplifier connected to it and thus not only can the voltage be applied directly to the tube, but when this voltage—as is usually the case—is much larger than necessary to scan the tube, the Y2 attenuator can be used to reduce it to a convenient known fraction to contain it within the tube screen area. The possibility of an additional phase shift through the Amplifier should be remembered, and any allowance made, after determination.



CIRCUIT FOR SIMULTANEOUS VOLTAGE AND CURRENT TESTS USING DOUBLE-BEAM FACILITIES APPLICABLE TO REPEATING AND TRANSIENT CONDITIONS.

FIG. 14.

The shunt is placed at the low potential end of the system and the voltage drop across it is connected across the A1 and E terminals, the lowest potential or " earthy " point normally being connected to E. If it is intended to compensate for the spatial 180° phase shift of the tube, the A1 and E connections are reversed, as shown in Fig. 14.

6.1.3. FREQUENCY COMPARISON TESTS.

Frequency comparison is an important part of oscillographic work, for it is required in many applications. The basic method makes use of the Time Sweep frequency itself synchronized to the accurately maintained mains frequency, against which the work or Test frequency is compared. In such measurements either the frequency ratio or the frequency difference is measured, or else a combination of both.

The Double Beam Tube is best suited for this type of test because the two frequencies which are to be compared can be examined simultaneously when applied one to each beam. The Time Base is set to run in synchronism with, and at a sub-multiple of, one of the two frequencies. The mains frequency or a known frequency from any other source, such as an Oscillator, can thus be used for comparison purposes.

As an alternative, when using the Oscillograph in the conventional way, or with a Single Beam Tube, the more usual method of comparing frequencies against the Time Base frequency can be adopted.

6.1.3.1. FREQUENCY CALIBRATION.

The classical example is the calibration of an Audio Oscillator. The procedure adopted in this experiment is the one best fitted to illustrate the principles here involved. The method shown can be applied to all frequency comparison tests. For this reason it is given herewith.

The " SYN." and " C " terminals of the Oscillograph are linked together throughout the experiment. This is to ensure that the Time Base be synchronized at all times to the mains. The " SYN." and " Y1 " terminals can then be joined and the " CONDENSER " and " VELOCITY " controls adjusted to set and synchronize the Time Base to run at around the lowest stable frequency available from the Oscillator under test. Sufficient "SYNCH" control is applied to lock the picture. By counting the number of waves the frequency of the Time Base is determined as a sub-multiple of the mains. The "Y1" or "A1" terminal is then freed from the "SYN." and "C" terminals and the Time Base will continue to run at the frequency thus synchronized to the mains.

The Oscillator output is then applied to the "Y1" or "A1" input terminals of the Oscillograph (the "E" terminals of the instruments are joined together) and its frequency is varied until a single wave is obtained on the screen. The frequency of the Oscillator is then that of the fixed Time Base. Other Oscillator calibration points are easily obtainable by keeping the Time Base frequency constant and adjusting the Oscillator control to settings giving 2, 3, 4 and more whole waves on the screen to corresponding multiples of the Time Base frequency.

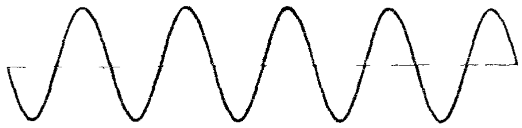
The practical limit of this procedure is reached when the number of whole waves increases to such an extent that, being compressed together, they are difficult to read. Also, when there is considerable difference between the Time Base and test frequencies, the pattern becomes less stable. It is therefore necessary to increase the Time Base frequency. This is done by replacing the Oscillator voltage by the calibration voltage on the "Y1" or "A1" terminal of the Oscillograph by joining "C" to "Y1" or "A1," and the Time Base frequency increased so that it corresponds to a smaller whole number of mains frequency waves. From this new Time Base setting the Oscillator frequency is again checked at 1, 2, 3 and more full waves and the whole process is repeated with higher settings of the Time Base frequencies obtained in the same manner.

It will be found, in fact, that it is possible to synchronize the Time Base to sub-multiples of a standard frequency down to about 1/10th. This will allow convenient calibration of the Audio Oscillator or other device under test at as many points between 1/10th of the frequency standard and ten times same, with every point determined as accurately as the standard frequency itself, which can be the A.C. mains or other source.

6.1.3.2. LISSAJOUS FIGURES.

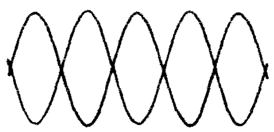
When synchronism is obtained under the above range of conditions a whole number of waves need not necessarily be obtained. It will often be found that the stable figure obtained is an intricate pattern, which at first sight appears difficult to interpret.

Synchronism or stable figures occur when the ratio of the Time Base and work frequency n the one case or the mains ("C") and Time Base frequencies in the other case can be expressed as an integer that is, a whole number or a ratio of two whole numbers. The resulting traces are called Lissajous figures, and their configuration depends on the relative phase of the two frequencies. If the ratio of the frequencies is not an integer but nearly so, the pattern weaves about as though there was a continuous change in the relative phase of the two waves. If they differ considerably the pattern becomes confused. Figs. 15, 16 and 17 show typical patterns obtained.



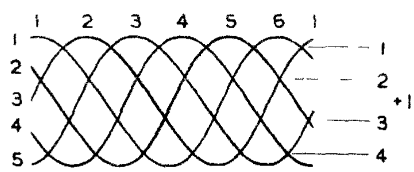
FIVE FULL WAVES AS THEY APPEAR ON THE SCREEN RATIO 5:1

FIG. 15.



TYPICAL PATTERN WHEN RATIO IS 5 2

FIG. 16.



LISSAJOUS FIGURE FREQUENCY RATIO 6 5

FIG. 17.

The ratio of the two frequencies involved can be read in one of two ways :—

(a) The ratio of the number of complete peaks of the waves in the horizontal direction to the number of end loops in the vertical direction.

(b) The ratio of the number of times the horizontal boundary is tangential to the pattern to the number of horizontal lines joining similar points of intersection of the waves of the pattern, plus one.

Thus in Fig. 17 there are six vertical peaks and five end loops (or four intersecting lines plus one=five), giving a ratio of 6 : 5. Likewise Fig. 16 gives ratios of 5 : 2 and Fig. 15, 5 : 1.

When the frequency ratio is not that of two single-number integers the figure becomes too complicated. The rule cannot, therefore, be readily applied. The difficulty is overcome in this case by increasing the deflection along one axis so that the spot travels beyond the screen diameter, and by thus spreading out the trace it is possible to count the number of times the path of the spot crosses a line drawn anywhere at right angles to the lengthened axis. This axis is then returned to normal and the increased amplitude of deflection is applied in the other direction, and the number of intersections of the trace with a line drawn at right angles to this axis is counted. The two numbers obtained give the ratio of the two frequencies. When two independent frequencies are compared, one or both of which are variable, the pattern obtained will change from one aspect to another gradually and will follow a certain sequence before returning to its original aspect. This process will repeat itself at long or short intervals. Each series of such changes represents the loss of one or more cycles by the lower of the two frequencies over the equivalent sub-multiple of the higher frequency. In such cases the determination of the frequency ratio requires noting the type of pattern which appears to be the probable stable one in the series of changes and recording the rapidity of recurrence.

6.1.3.3. OTHER FREQUENCY PATTERNS.

When the ratio between the work and sweep frequency is large, the pattern becomes so complicated, with the front and back portions of the figure in the same plane, that it is difficult to determine by inspection what is the exact ratio. This limit occurs at a ratio of about 10 : 1. Other arrangements must therefore be made.

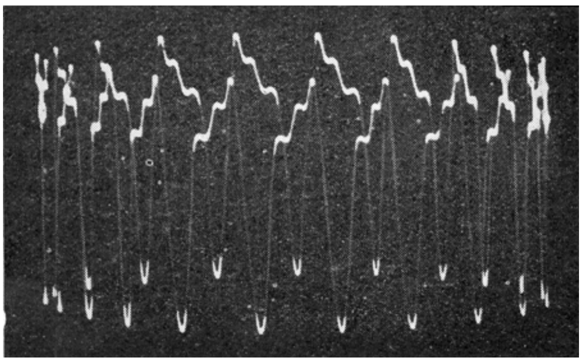


FIG. 18.

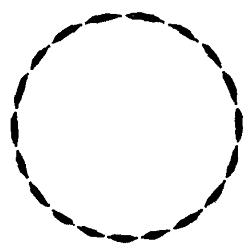


FIG. 19.
Modulated Circular Trace.

One of these is to separate the backward and forward motions of the spot in the sweep frequency direction by using an elliptical traverse. When one of the two frequencies is exactly divisible by the other and the resulting fractional integer has unity for nominator (such as 1/21) the figure will close upon itself in one revolution of the spot around the ellipse, giving a stationary single trace, and the work frequency wave shape is shown clearly as though wrapped round a drum, as in Fig. 18. The peaks of the higher frequency can then be counted. If the denominator frequency is increased the pattern will rotate uniformly, the speed of rotation giving the slip frequency.

To obtain the elliptical or circular traverse the well known resistance-capacity phase-splitting circuit is made use of, as shown in the circuit diagram of Fig. 39 By this means an out-of-phase component of the work voltage frequency from the Y terminal is applied, either directly or through a transformer, to the X1 terminal of the Oscillograph. This is provided by additional components externally to the instrument.

Another method is to connect the same phase-splitting circuit to the X and Y terminals so as to apply an out-of-phase fraction of the lower or sweep frequency to the Y terminal, and thus obtain a circular traverse, and then to apply the higher or test frequency to the Cathode Ray Tube grid. so that it modulates the intensity of the beam and at peak amplitudes extinguishes it. This will cause the circle to appear as composed of a series of dots, illustrated in Fig. 19, the ratio of frequencies being again given by the number of dots.

The dotted circle will appear to rotate if the frequency ratio is nearly but not exactly expressible by a simple ratio of whole numbers. A slip frequency up to 4 to 5 c.p.s. can be determined. When the departure is considerable the figure is confused.

It may be necessary to ascertain whether two adjacent dots represent successive cycles or not, for if the frequency ratio does not happen to be integral, the dots during the second revolution may occur between those of the previous one. A simple test to ascertain whether this is so is to move the whole diagram laterally and rapidly, such as by moving the magnet near the beam or applying a current in the deflector coils. If the dots move in a line the frequency ratio is an integer, represented by the number of dots on the Time Base cycle. If, however, alternate dots move different amounts and the lines seem to break up in two or more rows, the frequency ratio is an improper fraction equal to the total number of dots divided by the number of rows. This arrangement makes an excellent method of checking the ratio of input to output frequencies of a multi-vibrator oscillator.

6.1.4. PHASE SHIFT TESTS.

Phase relationship tests are required in a large number of experiments, and cover the determination of the phase between two electrical quantities (or vectors as they are called) of the same frequency, such as :—

(a) Two voltages.
(b) Voltage and current.
(c) Primary and secondary of any transforming device.
(d) Input and output of any circuit, rectifying device, amplifier, net-work, transmission line, conversion unit, etc.

When using a Double Beam Oscillograph, two methods of measuring phase relationship are available :—

(a) The two voltages to be examined may be applied respectively to the two beams with the instrument Time Base running synchronized at a known sub-multiple of the frequency of the work circuit on test. By noting along the time axis the interval separating identical points of the cycle, the phase shift may be determined and also the delay time can be read directly. This is the most obvious and easy method for Phase Shift Tests, because it exploits the existing double beam facilities directly.

(b) In the second method the Time Base is not required and a Single Beam Tube can be used. The voltages derived from the two quantities between which the phase relationship is to be ascertained are respectively applied, either directly or through an Amplifier, to the X and Y plates of the instrument. When applied independently these voltages will therefore provide deflections which are perpendicular to one another on the Cathode Ray Tube, and when applied simultaneously a resultant figure will be produced which represents their (vectorial) composition.

The following are the two most general Phase Shift Tests in method (b) :—

(*1*) *VOLTAGE AND CURRENT PHASE TEST.*

This is arranged in the same manner as the circuit of Fig. 14 for current measurements in Section 6.1.2, the two voltages obtained being applied to the X and Y direction, the current in the Y via terminal A1 and the voltage to the X directly, or via an external Attenuator.

(2) *INPUT AND OUTPUT PHASE TEST.*

Two conditions are encountered in this case :—

(i) When the test is carried out in a circuit or network in which there are no transforming or amplifying devices.

The voltages then derived from the two quantities between which the phase relationship is being examined are applied, if both are large enough, direct to the X and Y1 terminals. When their amplitudes differ the instrument amplifiers may be used as required in one or other of the methods mentioned in Sections 4.5.4 and following, 5.4, and 5.6 and following.

(ii) When the test is carried out on a transformer or amplifier.

The input voltage is applied across the A1 and E terminals and amplified as required The output voltage of the system is applied across the X and E terminals, if necessary via an Attenuator. If it is intended to use the Y2 attenuator fitted to the instrument, this would mean changing over the axis in both cases by rearrangement of the instrument circuit to use one of the amplifiers in the X direction, as described in Sections 4.5.7 and 5.6.1.

When making Phase Shift Tests it is well to remember that all devices comprising condensers and inductances are reactive components and possess a phase shift of their own. Thus amplifier stages in particular are not to be used unless the phase effect introduced is small or known. It is always best to determine their phase shift.

6.1.4.1. INTERPRETING PHASE SHIFT PATTERN.

If the deflecting voltages in each direction are of equal phase the resultant trace will be a straight line, whilst if the voltages are out of phase an ellipse will be produced. The angle of the slope is determined by the X and Y sensitivities and voltage amplitude. With equal or unequal amplitudes, however, the ellipse becomes broader as the phase difference ncreases.

Therefore the relative amplitude and phase of the two vectors affect the character of the ellipse. The amplitudes can be ascertained easily by obtaining the trace of each voltage on the X and Y plate in turn.

The effect of altering only the amplitude and not the phase of one of the voltages is shown in Fig. 21. The size and shape of the ellipses is changed but the vertical projection on each ellipse coincides at the point F and all curves intercept this axis at the point E. This latter point corresponds to the time when one voltage is zero and the other voltage lags by an angle θ. If the amplitude is altered also for the voltage in the other direction (again without changing its phase), although the positions of points E and F will change, the ratio of their respective distance from the point O will remain the same. This indicates that the phase measurement is independent of the relative amplitudes of the respective voltages.

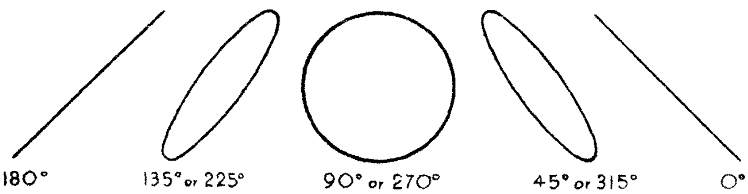


FIG. 20.

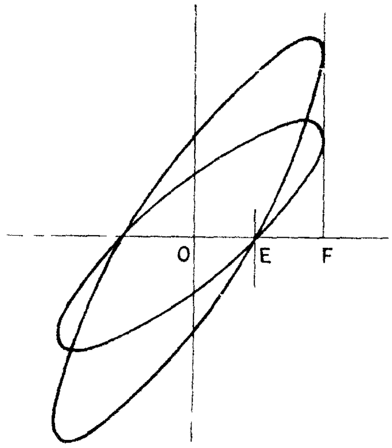


FIG. 21.

The correct phase in respect of the possible total 360° can be ascertained from the orientation of the major axis of the ellipse as shown in Fig. 20 and the direction in which the spot travels. The reason is that the ellipse can be resolved into two components, which may be represented by points moving uniformly in two circles X and Y, as in Fig. 27. The direction of motion of the spot therefore makes it possible to determine the true phase without ambiguity. Without this knowledge, however, the possible uncertainty can be eliminated by shifting the phase of one of the deflecting voltages in a known direction and noting the effect on the pattern, although this may not always be possible. Thus in Fig. 20 the phase difference is either 45° or 315°. Adding 45° to the shift will give a circle for 45° shift or a straight line for 315° shift. A Phase Adjuster network can be used for this purpose (reference 21, section 10.2).

It will be noted that the phase diagrams of Fig. 20, made on the assumption that the voltages are applied to the X1 and Y1 terminals, are the reverse (180° out of phase) of what would normally be expected from the conventions of cartesian co-ordinance.

This results because the voltage generated by the Time Base is negative and it must therefore be applied to the left X deflector plate facing the tube to provide the left to right traverse as required. Furthermore, for reasons discussed in Sections 4.4.1 and 4.4.2, and the practical convenience of applying to this same free X1 plate, not only the Time Base voltage but also the signal voltage, in phase shift and other tests, it inevitably follows that this obliges a reversal of the diagram.

This reversal can be overcome, if necessary, either by applying the X signal, as implied by convention, to the right hand,and thus X2, deflector plate by connecting to the rear panel link, or by the simpler artifice of applying the Y signal to the Y2 deflector plate. These conditions obtain whether a Single or Double Beam Tube is used. In the case of the latter the Y2 beam is used, as it provides spatially the 180° phase shift required. When using deflector coils to provide either the X (or Y) deflection magnetically and the Y (or X) deflection electrically, the conventional position of the diagram can always be obtained by reversing the coil plug on the instrument front panel.

It must be remembered that when using amplifiers, excluding their own phase shift effect, each stage changes the phase of the diagram by 180° to whichever axis the stage is applied. Thus two stages, whether applied one to each axis or both to one axis, produce a total 360° shift and return the diagram to the normal setting of Fig. 20. The latter of these two conditions is the one which generally applies on voltage and current Phase Test when using the 2Y1 or the 2HFY1 switch position as discussed in Sections 6.1.4 and 6.1.2.

The direction of motion of the spot can, however, be determined directly by applying to one of the axes a saw-toothed wave-form, such as that of an external Time Base. The spot direction of this wave is obvious, when it is inspected as a Y deflection on another Linear Time Base X axis, as in Fig. 29. Thus the appearance of a small amplitude Time Base voltage on the ellipse will clearly show, as in Fig. 30, the direction of travel of the spot.

Fig. 29

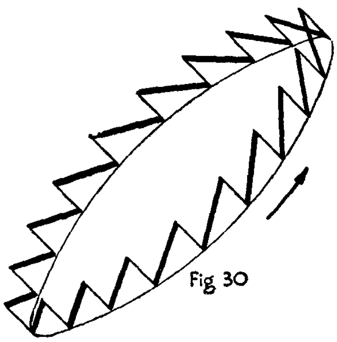


Fig 30

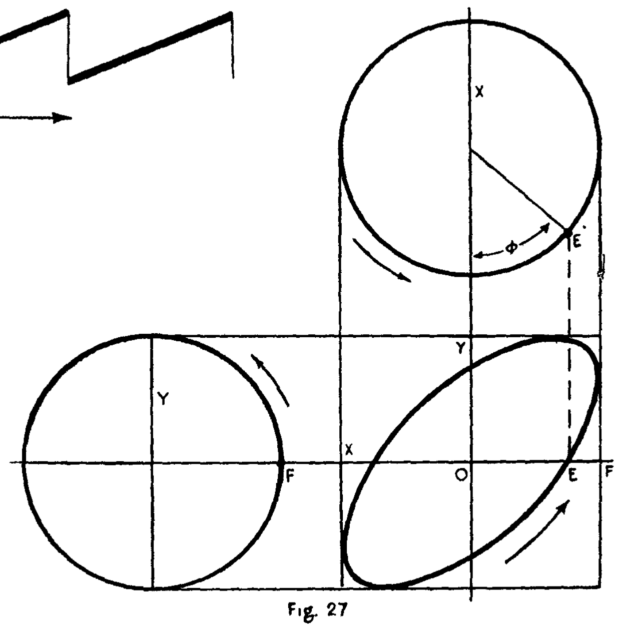


Fig. 27

Whether or not the pattern will remain stationary, drift or vary in shape depends on the constancy of frequency and phase relation between the quantities. If one of the sources changes frequency the pattern will drift. If the phase relationship varies, the shape of the pattern will change.

Distortions either in frequency, phase or amplitude are shown up by irregularities or movements of the patterns and their cyclical or transient character, viz., intermittent effects readily perceived.

When either or both waves are distorted, or when two voltages of different wave-form, such as sinusoidal and saw-tooth, are combined for Phase Shift Tests, the resulting pattern can be of various forms other than the usual straight line and ellipse. Fig. 22 shows an example of such a case. The character of each wave-form can always be ascertained by examining it on the Time Base traverse.

6.1.4.2. PHASE SHIFT MEASUREMENT.

The phase difference between the two deflecting voltages A and B applied to the Oscillograph can be determined from Fig. 23 by the relation

$$\sin \theta = \frac{C}{B}, \text{ as per figure, whilst } \frac{A}{B} = \tan \alpha$$

gives a close approximation of the inclination of the major axis of the ellipse, applying chiefly in the case of narrow ellipses. It is therefore a measure of the ratio of the peak voltages. The quantities A and B can be measured on the scale provided by applying thereto in turn the voltages in each direction. Their peak value will be given by half the total deflection in each case. In the case of a narrow ellipse the phase can be obtained readily by a relation obtained from Fig. 25, that is

$$\sin \theta = \frac{lw}{4AB}$$

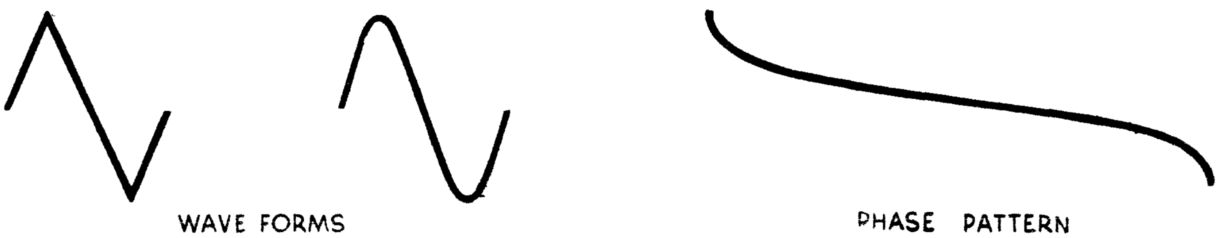


Fig. 22

If, in Fig. 38, C and R are replaced respectively by a capacity standard (S) and an unknown (U), the slope of the resultant straight line will be a measure of their ratio. The cotangent of the angle with the X axis equals U/S. Conductivity will only cause the loops to widen, which fact can thus be used as its measure. This method is suitable for testing liquid dielectrics.

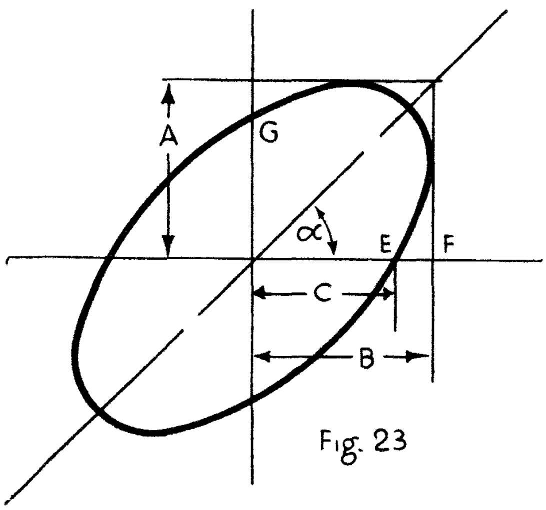


Fig. 23

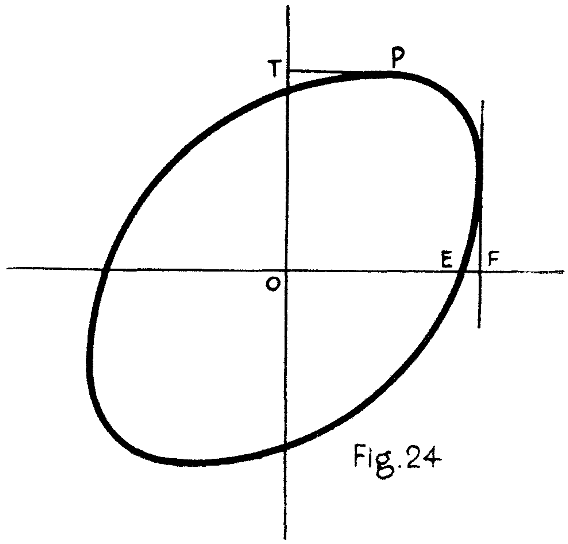


Fig. 24

When the ellipse approximates in shape to a circle, or when the ellipse is very narrow and approximates to a straight line, it is difficult to measure the phase accurately in the manner just described. In such cases the phase angle can be determined by the ratio of the distance of the tangent point (P) Fig. 24 on the curve from the vertical axis (TP) and the maximum horizontal deflection (OF). This ratio gives cos θ directly. The accuracy obtained, however, depends on the accuracy of determination of the tangent point. When the ellipse is nearly a circle, it is better, when possible, to shift the phase of one of the supply voltages by 90°.

Also in the case of narrow ellipses the accuracy is very low, because of the difficulty of measuring the width. It is thus convenient to adopt the expedient of displacing the ellipse laterally by using the linear time base and applying the X deflection to X2 at the rear panel and replacing the X2 link by a 3MΩ resistance. A series of loops shown in Fig. 26 will be obtained, the other beam serving to mark the X axis.

The speed of the spot is adjusted so that the points of intersection of the loops fall on the X axis (which can be located by using the other beam). The distance " s " between the points of intersection are equal and can be measured directly. Greater accuracy can be obtained by measuring the Time Base traverse covering all the complete loops and dividing by the number of loops. The absolute value of the phase angle can then be determined by the relation

$$\sin \theta = \left| \frac{s}{4B} \right|$$

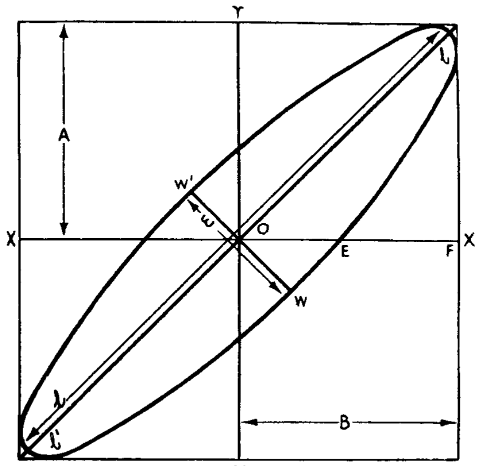


FIG. 25.

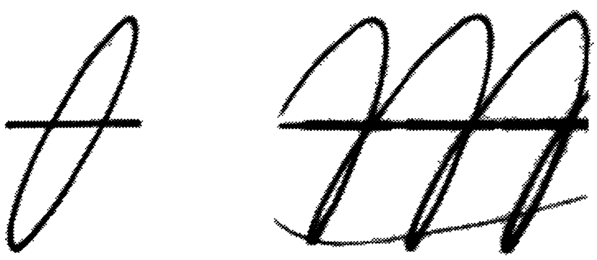


FIG. 26.

The thickening along part of the X axis trace of the other beam seen in Figure 26 is due to the resulting return motion of the spot over the corresponding section producing greater spot brilliance, a result of which use can, on occasion, be made.

When determining the Power Factor or dielectric losses in condensers when the area of the ellipse has to be determined, this can be obtained by the relation πwl. In the case of narrow ellipses care must be taken to allow for the width of the trace, and, of course, in all measurements allowance must be made for differences between the X and Y sensitivity of the tube.

6.1.4.3. PHASE DELAY.

The phase shift as measured by the ellipse method can be converted into phase delay by the following formula :—

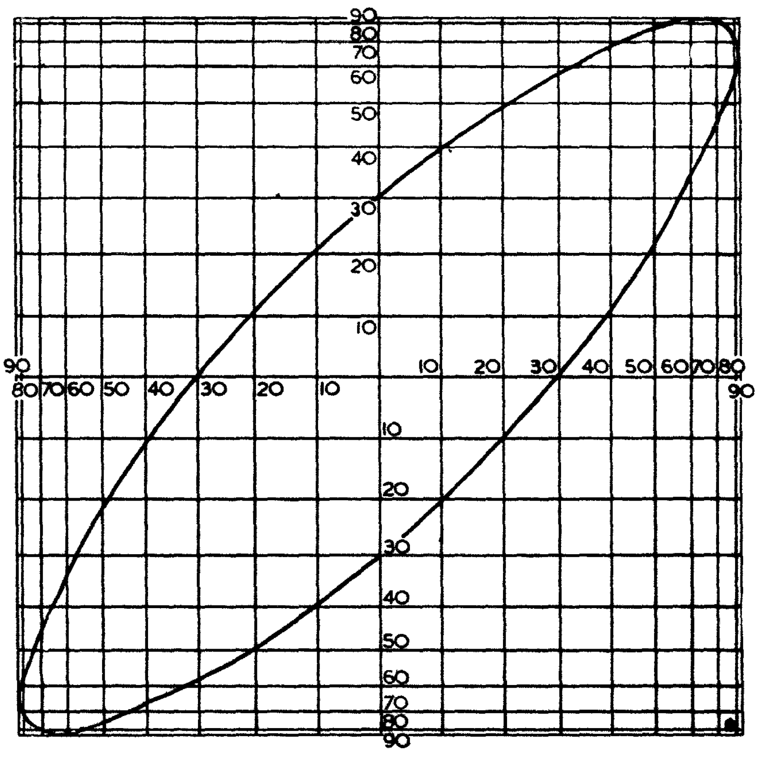
$$\text{Phase delay} = \frac{\text{phase angle}}{360 \times \text{frequency}}$$

This expression gives the actual time in seconds required for a cycle of given frequency to go from the input to the output of the Amplifier or network under test.

If the time is the same for all frequencies, there will be no phase distortion. This condition of constant phase delay is equivalent to that of having a phase shift proportional to frequency. This is to-day the recognized method of interpreting phase distortion in amplifiers, chiefly Television amplifiers, where phase distortion is particularly objectionable. The variation of the phase delay over the frequency band may thus be taken as a true measure of the phase distortion present.

6.1.4.4. PHASE SCALE.

It is possible to measure the phase shift directly by using a suitable scale on the Oscillograph as illustrated in Fig. 28, where the displacement in the vertical and horizontal directions follows the sinusoidal law.



PHASE-SHIFT SCALE

FIG. 28.

It suffices to arrange for the peak to peak amplitudes of the vertical and horizontal vectors to be equal to the sides of the square to be able to read directly the phase shift in degrees at the points where the ellipse crosses either axis.

6.1.5. TESTING MAGNETIC MATERIALS.

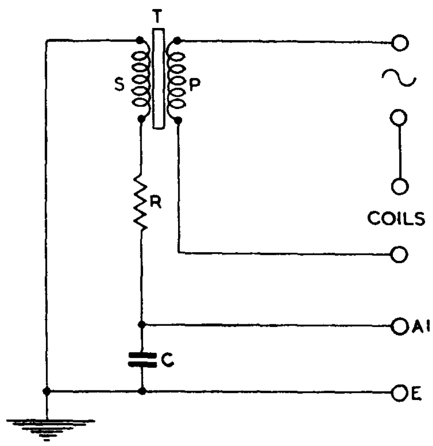
An important application of Phase Shift Tests is the determination of B/H curves and hysteresis loops. Fig. 31 shows the circuit connections. T is the iron core test piece and P and S are the primary and secondary coils wound round the specimen.

The Y deflection is obtained from the voltage across condenser C, which is proportional to the time integral of the secondary electromotive force, on the assumption that at the frequency of the test the impedance of C is small compared with the resistance R. In general the voltage developed across C will be small, especially at 50 c.p.s. mains frequency, as is usual on such tests, and the use of an Amplifier is necessary ; thus for this reason the circuit is connected to the A1 terminal. The secondary electromotive force so obtained is proportional to the rate of change of flux density (B) in the iron, and thus the voltage across C is proportional to the flux density at any instant. At 50 c.p.s. suitable component values for this test are :—

$C=2\ \mu f.$ $R=500{,}000$ ohms. Secondary=200 volts.

when about 2 volts will be developed across C.

The X deflection is obtained by the magnetizing current, which is made to pass through the deflector coils fitted in the instrument, preferably with a shunt. This current is therefore proportional to the field H. This is known as the Cozens method.



METHOD OF TESTING MAGNETIC MATERIALS AND TRACING HYSTERESIS LOOP. FIG. 31.

The deflector coils in the instrument are normally disposed to provide deflection in the vertical direction. Therefore it will be necessary to withdraw the instrument chassis from the case and move the coil lever provided at the rear of the tube mu-metal casing (Figs. 8 & 9) to rotate the deflector coils by 90° and set the deflection obtained in the horizontal direction. This should be checked by injecting through the coils a current at mains frequency, as described in Sections 4.5.6 and 5.7. By this means the hysteresis loop obtained will be in the conventional position. By using the "triple exposure" method described at the end of section 6.2.1. the X and Y axis can also be shewn on the photographic record as in Fig. 34 (b). See also reference 27 in the Bibliography, Section 10.2, for an all Electrostatic method of test.

6.1.6. POWER MEASUREMENTS.

Essentially it is the Phase Shift Test which is applied for this purpose. If the applied voltages denoted by B and A (see Fig. 23) in the X and Y direction are proportional to the current and voltage in a given circuit, as described in the No. 1 method of Phase Test of Section 6.1.4, the area of the ellipse is proportional to the reactive power loss in the circuit.

The actual power can be read by dividing by the scale constants. The method can thus be used for measuring the Power Factor cos θ, from sin θ = C/B. This enables one to test and detect faulty condensers or insulating material, poor coils, etc.

Another method of measuring power is that shown in Fig. 32, known as the Ryan method. The deflection in one direction is made proportional to the instantaneous integral of the current, which is equivalent to the charge on the capacity C, the deflection in the other direction being proportional to the instantaneous voltage. The connections to the

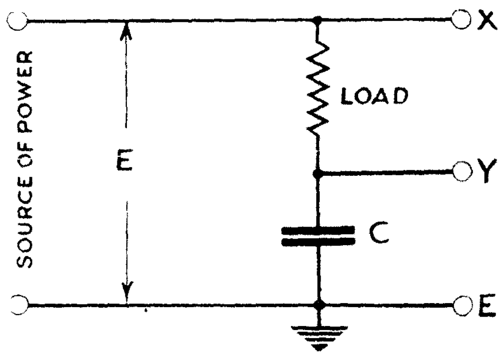


FIG. 32—*Circuit for power measurement by the Ryan method.*

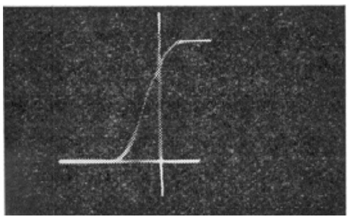
Oscillograph are as shown. The closed pattern thus traced is proportional to the average power loss per cycle. Whilst the experiment is useful for comparative tests, quantitative results can be obtained by calibration or by measuring the change in area in the diagram brought about by the introduction of known losses, such as that obtained by a resistance, and calculating the relation between area and power from the operating sensitivity of the Oscillograph. The millimetre scale enables a rapid reading of the area to be made. Alternatively this can be done by a tracing or photograph and the use of a planimeter, or by cutting out the pattern obtained by either of these two processes on a suitable board and comparing its weight with a known (square) area of identical material. This experiment covers the measurement of power and power losses in circuits, loss in cables, transformer oil, insulating materials, condensers, coils, transformers, chokes, etc.

6.1.7. IMPEDANCE MEASUREMENTS.

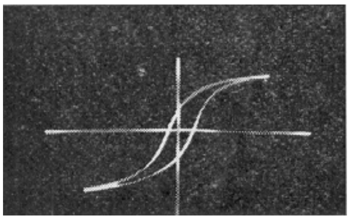
Impedance measurements can also be made by the same methods ; and in practice they comprise an important class of test such as the measurement of loudspeaker impedances over the operating frequency range. Fig. 33 shows the standard circuit connection, Z being the impedance (such as a loudspeaker). The voltage developed across R1 is applied to the Y plate. The resistance R1 is matched to the impedance Z. In the case of a loudspeaker resistance R2 should be made equal to the internal resistance of the valve normally operating with the speaker, in which case the applied voltage E will be the same as present across the valve in the practical case. The frequency and amplitude of E can be varied over the desired range and the Power Factor obtained by the methods already described. The impedance will be :—

$$Z = \frac{K.B.R1}{A} \qquad \text{(See Fig. 33)}$$

where B and A are the peak horizontal and vertical deflections as in Fig. 23.
The factor K is equal to the ratio of the deflectional sensitivities in both directions, and since this is a function of the physical dimensions of the deflecting systems alone, the operating conditions and the calibration of the Cathode Ray Tube need not be known. A comparative test on a known impedance will establish the value of K for the instrument. This test can be done over the audio frequency range for other impedances, such as transformers, chokes, resistance-capacity coupled networks, etc.



(*a*) *Thermionic Valve Characteristic.*



(*b*) *B.H. curve for magnetic material.*

FIG. 34.
"Triple Exposure" Records of Asymmetric Traces with X and Y axes superimposed.

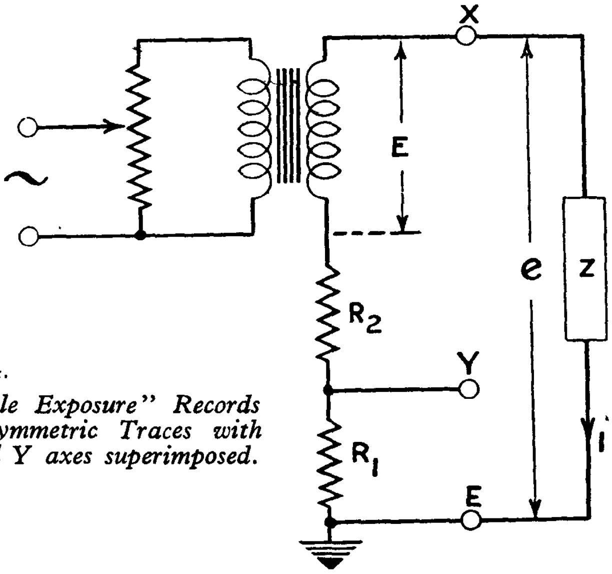


FIG. 33—*Circuit diagram for Impedance measurements.*

6.1.8. RESISTANCE, CAPACITY & INDUCTANCE MEASUREMENT.

The Oscillograph, in conjunction with its Amplifier, can be used as a very effective null indicator for the measurement of Resistances, Capacities and Inductances by using appropriate Bridge circuits. The technical details and procedure involved will not be discussed further in this booklet because these are fully covered in the Instruction Booklet for the Cossor Model 389 A.C. Impedance Bridge, which was designed and is available precisely for this purpose. It may be useful, however, to state some advantages of this method:—

(1) The Cathode Ray Tube cannot be damaged by overload.

(2) The visual indication shows in which direction—positive or negative—the null adjustment is off balance. This is conducive to more rapid tests.

(3) Harmonics do not interfere with the accuracy of measurement because it is possible to discriminate between these and the Bridge excitation signal.

(4) There is no frequency limit to the Cathode Ray Tube as an indicating device. Therefore the Bridge can theoretically be operated at any frequency.

(5) The use of the Double Beam Tube provides a great reading accuracy around null point and a true zero for the scale.

(6) Ability to discriminate between out of balance of Phase or Power Factor and out of balance of Impedance.

(7) Ability to detect faults of an intermittent or variational character.

(8) The possibility of establishing visual tolerance limits for both the resistive and reactive components of unknown impedances and the measurement of Power Factor on Production Testing.

(9) Extremely high degree of comparative accuracy, usually better than 0.1%.

6.1.9. AMPLIFIER TEST.

The input and output Phase Test method No. 2 of Section 6.1.4 is used in this case. If an Audio Oscillator is used it is possible to test the Amplifier for Phase Shift, Amplitude and other distortions and frequency response over the entire range. Distortion is shown by the deformation of the pattern. The amplifier input is applied to the Y and the output to the X plates respectively. It may be necessary in the former case to use an amplifier and in the latter an attentuator and adjust the relative amplitudes of deflection in both directions. A straight line will be obtained in the case of a distortionless amplifier without phase delay. Amplitude distortion will cause the ends of the straight line to curve. Phase delay will change the line into an ellipse. The requirements given in Section 6.1.4.3 are met when the ellipse shows constant phase delay with change of frequency. Any other deformations of the pattern are signs of distortion. Another and better method of test, using a Cossor Model 391 Square Wave Generator, by which the transient response is determined, is preferable for wide range amplifiers.

6.2. PHOTOGRAPHY.

Whilst the two-dimensional visual recording feature of the Cathode Ray Tube represents the most valuable attribute on all test work, none the less the necessity for a permanent record of the results obtained frequently occurs in practice. In such cases photography becomes an essential complement and a Camera a necessary accessory.

It is well to note that the present Oscillograph was not designed to provide an outstanding photographic performance, because this would entail much higher anode voltages than the 1,100 volts used in the instrument—which is the higher limit usual on portable instruments. For this reason the features required by the electrical performance of the instrument for visual work were given priority in the design. On the other hand, as it has been possible to produce a Cathode Ray Tube with a finer spot and greater beam current than is customary in similar cases, it possesses thereby the essential qualities of a good photographic tube. By providing it further with the most actinic of the fluorescent screens available, the photographic performance obtained becomes sufficiently outstanding to be of considerable practical value. Apart from its obvious use on all stationary patterns, it is even suitable for recording many types of transients. In fact, most effects met in general Electrical and Mechanical Engineering practice come within the upper limit of the photographic writing speeds indicated in paragraph 6.2.4.

6.2.1. STATIONARY RECORDS.

With recurrent wave-forms producing stationary patterns on a synchronized time axis of the type generally investigated visually with an Oscillograph, the photographic problem is not a difficult one. By means of a few practical tests the best conditions can be determined for any given case. Almost any camera is suitable for this purpose, and no precuations are needed beyond correct positioning of the Camera relative to the Cathode Ray Tube and the use of a darkened room. If photographic records are required expeditiously or continually, it is more convenient to work under normal lighting conditions, and a permanent fitting may be made comprising a light tight hood adaptor incorporating a support for whatever Camera is being used. This adaptor can be fixed conveniently to the screen guides provided on the Oscillograph for this purpose.

In some cases it may be possible to obtain a photograph of a single cycle of a recurrent event when this is desired, providing a variable speed shutter is fitted to the Camera used.

It may, on occasion, be useful to know that in the photography of asymmetrically shaped recurrent patterns, such as thermionic valve characteristics and hysteresis curves, where the exact location of the zero point is required for further detailed study of the record, the trace of both the X and Y axes themselves can be secured by means of the "three-exposure" method. By this means the X and Y axes are traced in turn on the same stationary record as the trace itself, by shorting in turn the X and Y deflection voltages. As a precaution it is better to close the Camera shutter between each operation. See Fig. 34.

6.2.2. TRANSIENT RECORDS.

For high speed transient work it will be found that the greatest possible brilliance is required. This calls for the use of the maximum available beam current, and is achieved by clockwise rotation of the " BRILLIANCE " control. The optimum setting can only be verified by an actual photographic test, and it may well be that the best photographic results are obtained when the brilliance has been increased even beyond the point at which visual defocussing and the resultant enlargement of the spot (usually to about 1.5 mms. in diameter) occurs. It does not follow that this apparent enlargement of the spot will give rise to halo or fogging effects at high speeds, and a photographic test is therefore the only true criterion. This fact is mentioned because it is common to all Cathode Ray Tubes, and may on occasion apply in some degree to both the Double Beam and Single Beam Tubes for this Oscillograph. In general, however, it will be found that in both these Cossor tubes the focussing holds good over the whole brilliance range, even at maximum beam current.

For exposures of short duration with such tubes a lens aperture of at least F/4.5 is required and a larger aperture is always to be preferred, whilst a ground-glass screen for focussing purposes is almost essential unless a fixed focus Camera or one having a coupled range finder is being used. The photographic trace should preferably be smaller in size than the screen image because a higher writing speed may be realized when this condition is fulfilled. An analysis of the factors affecting the results obtained is given in section 6.2.4.

Two methods are commonly employed for obtaining photographic records of transient phenomena. The first comprises the use of a moving film to provide the necessary resolution with respect to time, the Oscillograph being relied upon only to produce a Y axis deflection proportional to the applied voltage. The moving film Camera employed is usually expensive and either the speed of movement of the film is arranged to be constant or, alternatively, the speed of movement may be determined accurately by some method of time marking. This may be achieved by applying to one of the beams of the Double Beam Tube an oscillatory voltage of known frequency. For recording by this method the Time Base of the Oscillograph is rendered inoperative by full counter-clockwise rotation of the Condenser switch and connecting XI terminal to E. For Time Marking see section 8.

For the second method of transient investigation a Single Stroke Time Base is employed, and the use of the instrument for this purpose has been described in Section 3.2.1

6.2.3. BEAM SWITCHING.

When the phenomenon to be recorded on a Cathode Ray Tube is recurrent, a momentary, and preferably timed, opening of the Camera shutter is sufficient, but if the event is a transient and of short duration, suitable means must be provided to synchronise the event and exposure. This is obtained by means of beam switching, which is therefore an important aid in photography, as it provides the only satisfactory means of obtaining short exposures with stationary Cameras using a Single Stroke Time Base, or of synchronising moving film Cameras on high speed phenomena.

There are two alternative methods of beam switching, one using beam modulation and the other beam deflection.

(a) *BEAM MODULATION SWITCHING.*

There are two alternative arrangements by this method :—

(i) Direct beam modulation.

(ii) Trigger valve operated beam modulation.

Both methods can be operated mechanically or function electrically to provide a pulse of suitable polarity applied in the former case directly, and in the latter case indirectly, to the grid of the tube in a manner which cancels the beam cut-off bias previously applied thereto and thus return the spot brightness to the value required for photographic recording as set by the Brilliance control. In this case the spot position in the quiescent condition is central on the tube screen, the spot itself being extinguished after previous alignment with the Camera lens system. The spot motion is generally limited to one axis only. The Camera can be set with open shutter without risk of fogging. This method is generally used with moving film or drum Cameras.

(b) *BEAM DEFLECTION SWITCHING.*

This method is generally used with Single Stroke Time Base operation and a stationary Camera. A switch contact or an electrical pulse derived from the event on test, directly or indirectly applied, can be arranged to trip the Single Stroke Time Base. The method by which this is effected is explained in Section 5.11. By this method the spot is, in the quiescent condition of "no signal," deflected either to one edge of the screen or beyond by a voltage equivalent to a deflection of a few screen diameters. The beam brilliance setting is kept constant at the pre-determined value required for photographic recording. In this case also the Camera can be set with open shutter without risk of fogging. The Camera in this case is usually of the stationary type.

METHODS OF APPLICATION.

In presupposing the use of the above-mentioned beam switching arrangements, which are described later, there are various ways of applying beam switching according to the type of application and the apparatus used.

(a) By fitting a contact of the beam trigger switch related to the circuit or mechanism under examination so that the beam is turned on for the moving film method or released for Single Stroke Time Base operation at the instant of operation. The contacts can be set for simultaneous or staggered operation. This method serves either to enable the operator to release the event or mechanism and beam with the correct relative timing to record the event, or for the whole operation to be similarly carried out automatically by the moving film or drum Camera mechanism, or the mechanical apparatus on test itself.

(b) By using control contacts, such as on a Camera shutter control, so that the event and exposure are initiated simultaneously—directly by the operator, or indirectly by the mechanism on test via relays, as provided on Model 427 Camera.

(c) By obtaining the electrical pulse required for both modulation and deflection switching, either from some part of the circuit under test or from an independent circuit-cum-electronic device, operated by the mechanism on test and applied via a suitable coupling network or valve stage.

(d) By arranging the event itself or a voltage derived therefrom to trip the Single Stroke Time Base.

Of these alternatives (a) and (b) are only applicable to phenomena of a controlled nature, whereas (c) and (d) are applicable to events which are either independent or controlled. In the case of (c) the arrangement is similar to that required for a synchronising pulse, as described in Section 8.2. With the exclusion of (d), which can only be used on deflection switching, all methods can be used for both modulation or deflection triggering.

It is important to bear in mind that because in the instrument the Shift voltages must necessarily be obtained from the H.T. supply of the tube, a change in beam brightness is liable to cause a change in spot position. Consequently, when using the beam switching on moving film recording, a slight displacement of the spot may occur. This may interfere with the accuracy obtainable on quantitative work, especially when the work circuit is directly coupled to the tube deflector plates or when using D.C. Amplifiers. In other cases the displacement may be such as to move the spot outside the field of the lens when the Film Camera is fitted with a slit type aperture. In both cases allowance must be made for the spot displacement. This can only be done when independent Shifts are provided. A simple method of doing this is to disconnect the X and Y deflector plates used for Shift purposes from the Shift network within the instrument by disconnecting the links on the rear panel, and use external batteries, if necessary in series with the work circuit in the case of Y deflection. By this means the spot can be placed in the required position, where it will remain irrespective of the Brilliance setting or the position of the Beam Trigger. The Y Shift deflection can also be obtained by the use of deflector coils in conjunction with an accumulator or battery, the positioning being obtained by means of a series resistance.

6.2.3.1. BEAM MODULATION.

Beam modulation as described in section 8.3 turns on the beam instantly, but it can be arranged to turn on the beam with a delay whenever this is required by inserting a resistance-condenser network of suitable time constant. The time will then be dependent also on the voltage of the pulse. In the former case the brilliance obtained will be dependent on the amplitude of the voltage pulse, which therefore, if D.C., will produce continuous illumination, and if A.C., will provide an intermittent trace of graded brilliance in the same manner as when this method is used for timing purposes, Section 8.2.

The method of using beam modulation is obvious, and does not need further description.

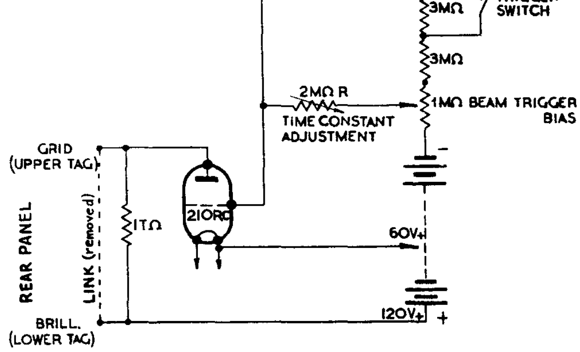
6.2.3.2. BEAM TRIGGER.

In the trigger valve operated beam modulator the primary object is to enable the beam to be switched on and off at given times for the duration required, whether this is used for photography or time marking purposes. The valve operated beam trigger is direct coupled, and consequently is essentially a constant brilliance device.

A suitable circuit for this purpose is shown in Fig. 35, and the time for which the beam is visible can be arranged to suit the requirements of any given experiment by changing the time constant of the combination of condenser C and resistance R. The device operates by providing a voltage pulse obtained from a suitable battery, or from the work circuit, and released either by a switch or by the event itself, which is operated in conjunction with the photographic arrangements.

This beam trigger turns on the beam momentarily, but allows it to be switched off again automatically in a time dependent on the time constants of C and R, the amplitude of the voltage pulse, and the bias setting o the trigger valve. These all provide a ready means of adjusting the time over a considerable range. Such a circuit, of course, will rarely be used in practice except when investigating the faster transients.

The beam trigger is similar to a lens shutter on the Camera, but operates much faster. Its use also avoids fatiguing the Tube screen with stationary spots at high brilliance prior to taking the record. The main advantage is in photographic recording with a moving film or drum Camera. By this means the beam may be turned on and off very suddenly for the experiment.



EXTERNAL CIRCUIT NETWORK PROVIDING MECHANICAL AND ELECTRICAL BEAM–TRIGGERING FACILITIES.

FIG. 35.

6.2.3.3. MECHANICAL TRIGGERING.

Both the beam modulator and the valve operated beam trigger can be used with mechanical operation. In the case of the beam trigger valve the beam is instantly applied and a sustained action is obtained which continues to hold the beam on as long as the beam switch contacts are open, and only turns it off, equally rapidly, when the contacts are closed, the action being the simple one of applying and/or shorting the tube bias voltage either directly or through a directly connected valve-coupled trigger stage.

The mechanical arrangement can comprise a simple switch operated, either as a controlled contact on the Camera shutter, or by the mechanism under examination, or independently by the operator, as detailed in applications (a) and (b) in Section 6.2.3.

Deflection switching can also be operated mechanically—usually by means of a simple switch—either by the operator or in conjunction with the Camera mechanism.

6.2.3.4. AUTOMATIC BRILLIANCY CONTROL.

The provision of automatic control of the brilliancy of the trace in sympathy with the speed of spot for the Y or work voltage deflection is beyond the range of practical application of the present Oscillograph, for the maximum writing speed is too low to warrant the complication of the apparatus involved. It has, nonetheless, been incorporated within the instrument for the High Speed positions (Studs 9 and 10) of the Time Base deflection, as mentioned in 3.2, as this represented a valuable refinement which could be achieved relatively simply.

6.2.4. PHOTOGRAPHIC WRITING SPEEDS.

In the case of the photography of stationary repetitive patterns the question of recording speed is hardly important except as an aid to the determination of the correct exposure for varying conditions of experiment. In other cases it is often necessary to know what maximum writing speed of the spot can be recorded with a given tube under particular electrical and photographic conditions.

The optical factor in question is expressed in a simple formula giving the relative light intensities of the image and object.

$$\frac{I_i}{I_o} = \frac{1}{76F^2\left(1+\frac{1}{R}\right)^2}$$

I_i is the light intensity of the image. I_o is the light intensity of the object.

R is the linear ratio of object size to image size or reduction ratio.

F is the aperture number (or F number of the lens).

The formula indicates that from the point of view of realizing the maximum recording speed on the photographic paper or film, a relatively large geometrical reduction is necessary between the trace produced on the tube screen and the optical image. This much is obvious in that a reduction in the size of the image results in an increase in its actinic effect due to the total available illumination being dissipated over a smaller area. On the other hand, too high a ratio reduces the effective resolution, and for this and other reasons it is generally more convenient to use a moderate reduction ratio of from 2 : 1 to 6 : 1. As the formula itself shows, further reduction beyond this latter figure does not materially increase the writing speed. The formula, of course, breaks down when the theoretical image size of the recording spot becomes smaller than the circle of confusion of the lens, and this factor is responsible for the failure to obtain the expected degree of resolution with excessive reduction ratios. The recording velocity, together with the diameter of the spot on the fluorescent screen are a measure of the temporal resolution obtainable.

Because of the practical difficulties in the way of the user determining for himself the light intensity of the image and/or object, a more convenient expression giving the effective maximum photographic writing speed (V_{max}) at the screen of the Cathode Ray Tube is :—

$$V_{max} = \frac{k}{F^2\left(1 + \frac{1}{R}\right)^2} \text{ kms./sec. (or mm/}\mu\text{.sec.)}$$

The k in the above formula is not, of course, a true numerical constant, for it has the dimensions of velocity and is itself comprised of many variables. The table on photographic writing speeds provides data covering the effects of changed conditions on k, with the use of both Single and Double Beam Tubes and differing fluorescent screens, on the assumption of fixed Cathode Ray Tube voltages and beam current and photographic operating conditions.

It may be of interest to certain users, however, to know the chief variables affecting k for determining the direction of possible improvement in the writing speed under altered photographic conditions for any particular experiment.

The expression for k varies inversely as the tube spot diameter, and directly as the tube accelerating potential, the beam current, the sensitivity of the photographic material to the prevailing frequency in the spectral response of the fluorescent screen, the light output of the fluorescent screen and the goodness of the lens or its permeability, this latter, of course, being a constant.

The true beam current cannot well be measured, but the cathode current taken by the tube is usually a sufficiently accurate indication. Under conditions of average brilliance, i.e., when the tube is being operated with little incident light, this current will be of the order of 20 to 50 microamps, but at full brilliance the figure may increase to 100 to 200 microamps. The tube was operated under this latter condition when arriving at the figures quoted in the table of Section 6.2.6.

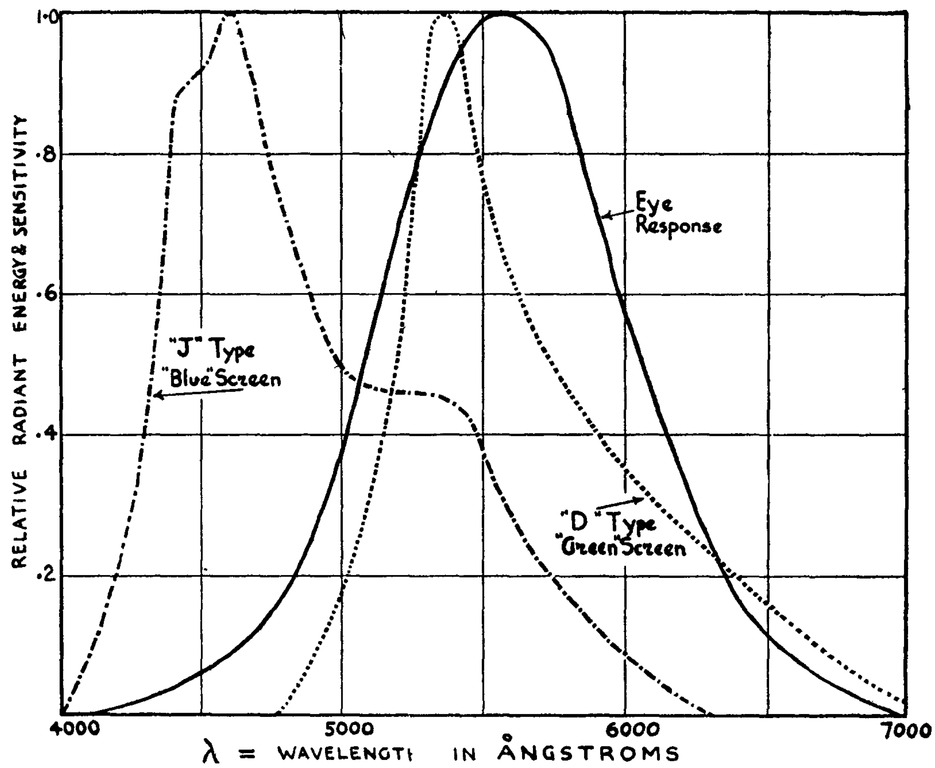


FIG. 36. SPECTRAL RESPONSE CURVES.

The spot diameter is also difficult to determine because of the halo and other effects present when the spot is stationary. With the spot moving in a straight line at a reasonable speed, however, an approximate measurement may be made as the line will have well defined edges. At optimum focus the diameter of the spot may be approximately $\frac{1}{2}$ mm., but when operating at 200 microamps beam current the spot may increase to approx. 1 mm.

Any improvement in this respect can only be surmised by estimation or measurement of the resulting intrinsic spot resolution on a photographic record, preferably by enlargement if greater accuracy is required.

The goodness of the lens, usually termed its permeability, is a number which is always less than unity and generally lies between 0 5 and 0.8. The sensitivity of the photographic material can be obtained from the makers, but use should not be made of the figure quoted without making comparison between the spectral response curve of the photographic emulsion and the curves given in Fig. 36, for the two types of screen materials used. The average spectral response of a human eye is also given in Fig. 36 as a standard of comparison. The light yield of the fluorescent screen in lumens per watt is approximately constant for a given screen material under conditions of fixed Anode voltage, and it can be seen, therefore, that the only oscillographic factors which it is within the means of the user conveniently to vary are the spot diameter and beam current. From the photographic side the only possibility of improvement lies in the selection of the most suitable lens and photographic material.

The combined effects of these are made available for practical use in the table of 6.2.6. where the figures give the photographic writing speeds for different photographic materials fluorescent screens and types of tubes. This last factor must be considered on account of the differing beam currents obtainable with Single and Double Beam Tubes.

We have defined in the previous paragraphs the interpretation given in this booklet of the photographic writing speed of the Cathode Ray Tube, but confusion may still arise in certain instances when undefined writing speeds are mentioned. Thus the writing speed of the spot on a high vacuum Cathode Ray Tube screen is practically without limit in the electrical sense. The upper limit is set only by the finite time an electron requires to travel through the tube deflection plate field. This " Transit Time " with the tube and voltages in the instrument is of the order of 10^{-8} sec. Even when photographic writing speeds are considered, confusion may arise as to whether the speed is referred to as the speed of the spot on the screen or on the photographic film. It is greater in the former case because of the optical reduction generally employed between the tube and film. Accordingly the photographic writing speeds are given for the spot on the Cathode Ray Tube, because this can more easily be determined by inspection of the actual size and shape of the trace and the time taken by the event investigated. The figures quoted are in terms of centimetres per millisecond which is numerically 100 times the figure in kms/sec. for a lens aperture (f number) of F 1 and for a reduction ratio of 1 : 1. The formula can thus be revised to take into account any given photographic condition or any change.

Although the Double Beam Tube has a lower intrinsic photographic writing speed than the Single Beam Tube, it may still be the most suitable for the general investigation of transients because the remaining beam can be used for timing purposes, as described in Section

8.1 and 8.2. In this connection, if it so happens that one beam is somewhat brighter than the other, the fainter of the two beams should be used for timing and the more brilliant beam for the transient record. On the fainter beam used for timing it is always possible to obtain a record by reducing the amplitude of the wave. On a satisfactory tube, however, the difference in brilliance should never be more than about 25% except at very low brilliancies.

Dissimilar spot brilliance on the Double Beam Tube can be troublesome in the special case of very slow-moving film photography, that is, film speeds below 10 cms./sec., when it is necessary to reduce the spot brilliance to avoid fogging the film. This entails operating the tube at the bottom end of the " modulation voltage-beam current " characteristics, where the effect is greatest. There are two remedies. The first is to use a small permanent magnet suitably placed round the neck of the tube and within the mu-metal shield in manner to cause more of the current to flow in the weaker beam. The magnet can be retained permanently in position and be provided with means of adjustment. This is the correct and only method of compensating completely for dissimilar spot brilliance. This is carried out by adjusting for both beams to extinguish simultaneously. The other method is to fit an iris diaphragm to the lens system of the recording camera so that the amount of light affecting the film can be controlled independently of the tube brilliance control. This latter can therefore be adjusted at a higher setting corresponding to the linear section of the characteristics of the two beams, where dissimilarity in brightness is a minimum.

6.2.5. SCREEN CURVATURE ERROR.

The ideal C.R. Tube screen should be a flat surface, as by this means not only the tube screen spot deflection, but also the resulting photographic trace, will be linearly related to the work voltage applied to the deflector plates, as this latter is proportional to the tangent of the angle of deflection.

Unfortunately, for reasons of mechanical strength, it is not possible, except on very small diameter tubes or in some special cases with the adoption of other than the normal technique, to provide a flat screen surface. The bulb, and to a lesser extent, the screen itself, must take the form of the familiar curved, convex surface.

For reasons of convenience, and also because of the resulting reduction in deflection defocussing, the useful part of the screen is not only made of constant curvature, but its centre is located at or near the centre of the Y deflector plate zone, or between the X and Y deflector plates, so that the deflection lever (L) sensibly equals the radius of curvature (R) (see Fig. 37).

As the permissible range of deflection embraces the relatively small angle (θ), the screen deflection PM (measured circumferentially) is approximately proportional to the tangent of the angle as is required. This is sensibly equal to AM, product of the deflection lever (or radius) times the tangent. Consequently, for visual work or direct measurement on the tube screen the curvature error is limited, almost constant and of the order of 1% to 2% in most tubes.

Unfortunately these conditions no longer obtain with photographic recording. In Fig. 37 the lens situated at the chosen distance (D) sees the tube deflection PM as the

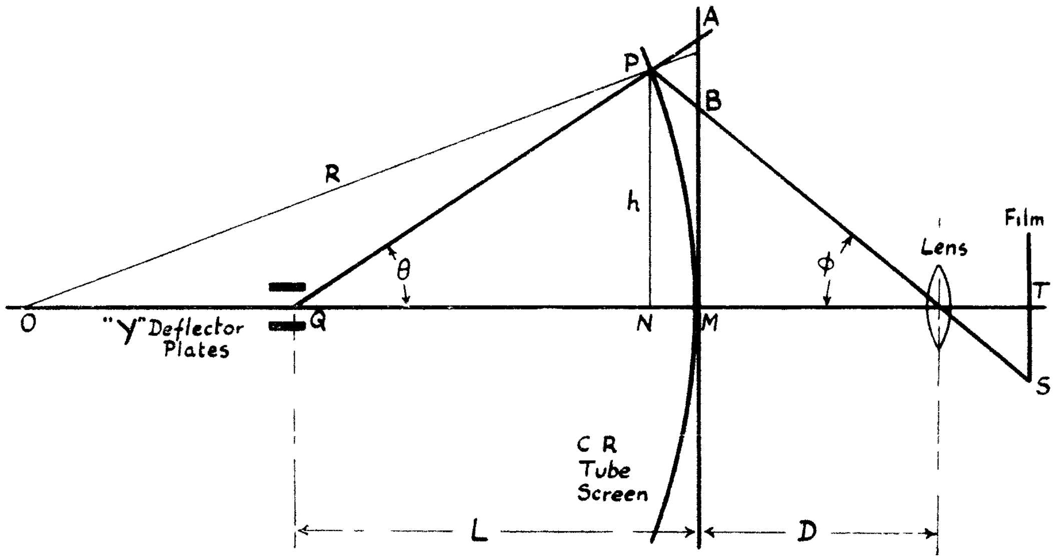


FIG. 37.

height BM to which will be proportional the film trace TS. But the photographic record, to vary as the applied voltage and be free from error, must be proportional to AM, itself proportional to the tangent of the angle of deflection. Consequently the relationship between AM and BM will indicate the law of variation between the deflecting voltage and photographic deflection. The absolute error is (AM-BM) = AB and the fractional error AB/AM. The resulting formula is a complicated one, more so in the general case when the radius of curvature differs from the deflection lever. The error increases, and not linearly, with deflection.

From the practical point of view the only considerations that matter are either the maximum error resulting from the maximum screen deflection (this latter corresponding to the point where the screen curvature changes at the edge of the bulb), or the determination of the deflection to correspond to a maximum permissible error. This is best done by examination of the outline drawing of the Cathode Ray Tube bulb in relation to the optical arrangement used for photographic recording.

However, on the assumption that the radius of curvature of the tube bulb and the deflection lever for the Y plates are quoted for the tube, the determination of the error can be simplified if a further parameter is provided. This is the height h = PN of the semi-chord at the point where the screen curvature changes, and therefore corresponds to the maximum deflection. We then have the relation :

$$\text{Fractional Error} = 1 - \frac{D\,(L - R + \sqrt{R^2 - h^2})}{L\,(D + R - \sqrt{R^2 - h^2})}$$

from which can be obtained the maximum error. Alternatively the value of h corresponding to a given percentage error can also be derived from the same expression, from which can be determined the corresponding maximum permissible deflection measured directly on the tube screen. These two quantities are in the ratio of the arc to the chord.

In the case of the bulb for the Double Beam Type 09 and the Single Beam Tube Type 26 used on the present Oscillograph, the question of curvature error has been carefully considered. By the device of making about 5 mms. of the central area of the tube flat the error has been reduced considerably and is much smaller than is usual on Cathode Ray Tubes. The remainder of the screen is a portion of a sphere of radius R = 270 mms.

Over the central, flat portion there is, of course, no error, whilst with maximum possible deflection the error is of the order of only 3%. The application of the formula in this case is complicated by the necessity of determining the difference between the hypothetical error at the point where the screen ceases to be flat and that at maximum diameter on the assumption of constant curvature.

The Model 427 Camera designed for the instrument and described in Section 11.2 is intended to cover an area of a maximum of 6 cms. diameter, that is, 7.5 cms. on the screen bulb. This limits the total possible error to less than 1%, even though the distance of the lens from the screen is only 130 mms.

6.2.6 MEASUREMENT DATA.

The following table is given to indicate the order of the writing speeds attainable with this Oscillograph utilizing both Single and Double Beam Tubes and " J " screens :—

First and final Anode voltage on C.R. Tube	1,100
Object/image reduction	1 : 1
Lens aperture	F/1.0
Cathode current	...200μAmp.

All writing speeds are expressed in terms of spot speed at Cathode Ray Tube screen, *not* speed of traverse across film. The speeds are quoted in terms of cms./msec. (that is, centimetres per millisecond).

PHOTOGRAPHIC WRITING SPEEDS.

Tube	Screen	Sensitized Oscillograph Paper.			Fast Ortho-Chromatic Film.			Fast Panchromatic Film.		
		cms./msec.			cms./msec.			cms. msec.		
		A	B	C	A	B	C	A	B	C
09	J	3	34	550	5	83	550	5	70	550

The letters A, B and C defined below indicate arbitrary levels of image density on the record by which the relative performance is visually judged.

A = Speed below which a reduction in lens aperture is necessary to avoid over-exposure.

B = The nominal optimum writing speed above which all visual evidence of halo on the trace disappears. Also defined as the speed above which optimum resolution is obtainable.

C = Maximum writing speed above which no useful record can be obtained.

For different photographic conditions, that is, lens aperture, F number and reduction ratio R, the figures of the table are to be multiplied by the following factor :—

$$\frac{4}{F^2\,(1 + 1/R)^2}$$

to obtain the photographic writing speed that applies.

Thus when using the Cossor Model 427 Camera, which is specially designed for the instrument, and having $F = /3.5$ and $R = 2$, the figures of the table are to be multiplied by the constant 0.145. With this camera the limiting photographic writing speed with the standard Double Beam Tube Type 09J fitted to the Oscillograph and using orthochromatic material is 167 cms./m. sec., that is, $1\frac{2}{3}$ kms./sec.

The photographic writing speed for the " D " type green fluorescent screen is somewhat lower than for the " J " type blue fluorescent screen of the figures of the above table. For the same photographic material the speed is three times slower. Similarly, with the " G " type long afterglow screen the figures must be divided by the factor of 2. In both cases if special green sensitive material is used higher photographic writing speeds can, of course, be obtained. The tests in which the photographic writing speeds were obtained were carried out with the following representative types of photographic material : Ilford FPI paper, Kodak R50 fast orthochromatic film and Ilford HPX panchromatic film.

The writing speed for the Single Beam Tube Type 26 is somewhat more than twice that of each Beam of the Double Beam Tube for each type of screen.

The significant point to note regarding the photographic writing speeds given above is that the inexpensive, sensitized oscillograph paper allows of the same maximum, photographic writing speed as the best orthochromatic or panchromatic film. Its only disadvantage is that it is not suitable when enlargements or multiple copies are required.

For stationary photography any of the usual media suitable for the Camera can be adopted after preliminary experiments on conditions of exposure and setting of the " BRILLIANCE " control.

When a moving film method of recording is adopted on slow transient work, standard 35 mm. stock may be used on Cameras which are designed for this purpose, such as standard moving film Cameras. Even the smaller varieties of moving film Cameras using 16 mm. paper may be adopted, although these are very rarely used for oscillographic work. It was to overcome the difficulty in obtaining a suitable photographic method of oscillographic recording that the Model 427 Camera was designed and made available as an extra for use with this instrument.

7. AUXILIARY TIME BASES.

In certain applications, Time Bases other than of the linear type provided in the instrument may be required. A few notes are given herewith on some of the more valuable of these various Time Bases, because in certain applications they may enable the user to solve problems to which the internal Time Base is not applicable.

These can either be arranged by making use of the internal circuits of the instruments, if necessary with the aid of a few components connected to the instrument terminals, or entirely disposed externally.

7.1. SINUSOIDAL TIME BASE.

This can be obtained simply by using the mains supply voltage, preferably via an isolating transformer. An output of 100 volts R.M.S. from the secondary of this is sufficient to scan the width of the tube. This voltage is applied across the X1 and E terminals after the instrument's self-contained Time Base has been made inoperative, as mentioned in Section 4.4.3.1. The calibration voltage of the instrument can be used for this purpose, though it is not large enough to provide a Time Base of full screen amplitude. It may, however, be amplified as described in Sections 5.7, paragraph " f " by rearranging the instrument circuit at the rear link panel. It is important to remember that such a Time Base is non-linear and that the forward and return strokes are identical. In order to avoid elliptical effects and the appearance of part of the trace on the return stroke, it is preferable to black-out the return stroke. This can be done by connecting on the rear link panel strip a .005 mfd. 1,500 v. working condenser between the upper X1 and grid tags, and a 100,000 ohm resistance between the upper and lower grid tags after removing the grid link.

The best method of obtaining a sinusoidal Time Base is to arrange for the mains isolating transformer to provide a voltage of three to four times that required to scan the tube screen, that is, 350 to 500 volts R.M.S. The overload will not damage the tube, and that part of the sinusoidal Time Base which is located in the centre of the tube screen will be practically linear. This method has important applications and is one of the best ways of inspecting the details of television wave-forms, which are usually synchronized sub-multiples of the mains frequency. Needless to say, the Time Base voltage amplitude should be controllable, for it also provides the only means of controlling spot velocity and thus the temporal resolution obtainable.

7.2. CIRCULAR TIME BASES.

Circular Time Bases are occasionally used when investigating relative times of events, which is in itself an important field of application. It is for this reason that a few notes are given on this subject. It is not practicable for any such Time Base to be an integral item of a portable Oscillograph, especially as one type of Circular Time Base can be arranged externally without much difficulty. In fact it will generally be found that all types of special Time Bases—and there are many—are best assembled externally and applied to the Cathode Ray Tube deflector plates, usually directly, by making use of the rear panel link strip and rearranging the instrument circuit as described under Section 5.6.1.

Before describing these circular Time Bases it may be useful to mention that the electrical pulses obtained from the effects being timed must necessarily be derived from separate apparatus specially designed for the purpose. This may in itself be complicated, or quite simple, such as a small battery in conjunction with a series resistance connected across a contactor to provide the voltage pulses required to measure circumferential spacings or consecutive make and break on any form of rotating device. Circular Time Bases are generally intended for use with Single Beam Tubes.

7.2.1. PHASE SPLITTING TYPE FOR VERTICAL DEFLECTION.

This type of Time Base is obtained by applying in the X and Y axes, quadrature components of the same voltage obtained as shown in Fig. 39. If the voltages applied in the X and Y directions are of the same effective amplitude (correction being made for the difference between the X and Y sensitivities), and are strictly 90° or 270° out of phase, a true circle is obtained. As it is usual to use a resistance and condenser, the required condition is that $R = \frac{1}{\omega C}$. With other conditions of amplitude and phase an elliptical pattern will result. When using the mains supply it will be necessary to interpose an isolating transformer. The voltages derived from the effects which are to be timed are applied to the Y axis, and the resulting deflection will then be vertical and not normal to the circle, see Fig. 38, in certain applications this is a definite disadvantage. This method can be used with a Double Beam Tube (see Fig. 26).

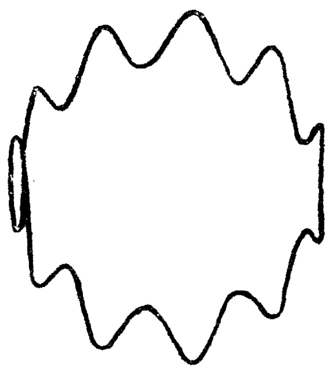
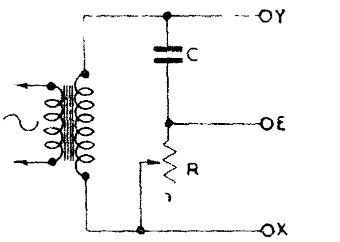
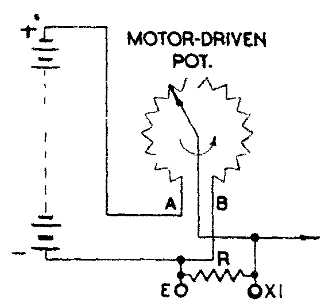


FIG. 38.



PHASE-SPLITTING CIRCUIT FOR ELLIPTICAL OR CIRCULAR TIME-BASE

FIG. 39.



METHOD OF PRODUCING A LOW SPEED TIME BASE DEFLECTION BY MECHANICAL MEANS

FIG. 40.

7.2.2. DOUBLE PUSH-PULL METHOD FOR RADIAL DEFLECTION.

It was to overcome this disadvantage and provide a deflection normal to the trace that the push-pull type of circular Time Base was devised. This latter is the only satisfactory method of obtaining a circular Time Base for the relative timing of events. The method, the circuit for which is illustrated in Fig. 41, is called the Valve Modulation Method, and was developed by the Radio Research Board. This method, providing radial deflection upon a circular Time Base, is suitable for small voltages, and is also suitable for examining without sensible distortion transients whose durations are very short compared with the period of the time scale. The time scale which is the rate of recurrence of the circular Time Base is usually a 50 cycle mains frequency, or alternatively, obtained via an external oscillator of known frequency. The C and R in this Time Base are adjusted to be quadrature components of the same impedance at the frequency of the input which provides the circular Time Base, exactly in the same manner as the case of Section 7.2.1. The condensers C1 are inserted to provide a low impedance path for transients and other phenomena of much higher frequency than the Time Base. R1, R2, R3 and C2 are the usual amplifier load and coupling comdonents, the stages being designed to cover the frequency range required and to provide sufficient voltage to produce a circle of the required size on the tube screen. Such a deflection voltage would be of the order of 100 to 150 volts. The valves and components should be matched so that the output voltage of each stage in combination with the sensitivity of the corresponding deflector plate will provide equal deflection in all four directions.

The resistances R2 are set so that the valves are at the bottom bend or curved (parabolic) part of the characteristic, a condition essential to obtain from the circular Time Base radial deflection which is proportional to the instantaneous value of the applied voltage.

The requirements implied by this condition of operation are automatically obtained when using Frequency Changer valves. Therefore the above classical circuit can be improved by the substitution of Triode Hexode valves, such as the Cossor 4.THA. One of the grids can be used for the work voltage and the other for the circular Time Base voltage. When using this type of valve selection for matching can be avoided, because additional electrodes are available which can be adjusted for this purpose. In other respects the circuit would remain the same.

It may be added that a Spiral Time Base may be obtained by this arrangement by applying a linear Time Base across the Input terminals. The work voltage would be applied in series with this.

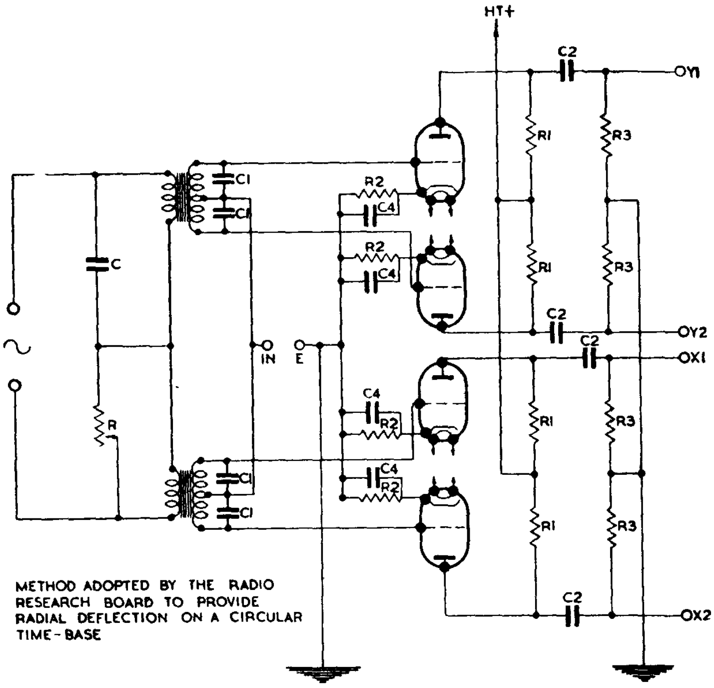


FIG. 41.

It is obvious that the method can only be used with a Single Beam Tube and by applying the output from the Time Base itself directly to the two X and Y deflector plate links on the rear panel link strip. The method enables comparisons to be made between the reference frequency of the Time Base and a much greater integral multiple of that frequency because of the resolution provided by the extended trace.

With such a Time Base it is advantageous to use a polar scale, which can take the form either of a transparent slide similar to the graticule with the instrument and intended to replace it in its guide, or the sca can be drawn on the tube bulb itself, when greater accuracy is required when the instrument is used permanently on such class of tests. Fig. 43b.

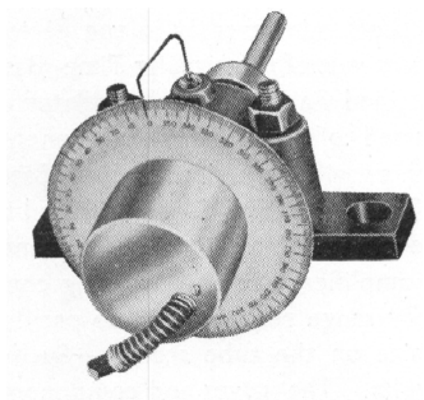


FIG. 42a.—*CONTACT BREAKER. Model 350. High Speed Rotary type.*

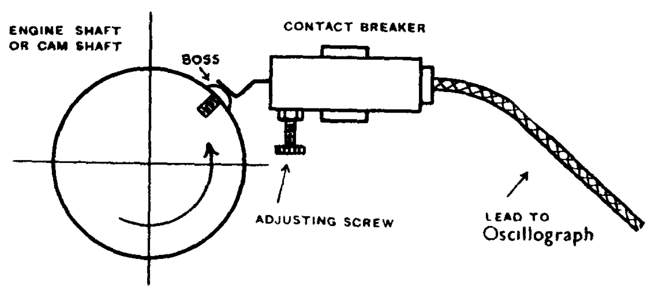


FIG. 42b.—*CONTACT BREAKER. Model 299. Stationary Switch type.*

7.3. MECHANICALLY OPERATED TIME BASES.

When investigating mechanical effects it is often required that the Time Base be synchronized to the effect examined. Mechanical arrangements are therefore usually essential for this purpose, converted when necessary into equivalent electrical effects. The more important cases using the existing facilities of the instrument have already been mentioned in Section 5.10. Other methods may on occasion be required in certain applications, and a few of the more useful cases are considered in the following sections.

7.3.1. EXTERNAL.

On the assumption that the effect—as is generally the case—is being investigated as a function of the speed of some sort of rotating machine, a simple Time Base is required which may be operated by the machine itself, and is therefore synchronous with it. This can be arranged simply by connecting a suitable resistance across a 120 or 240 volt high tension battery. The resistance should have as high a value as possible to reduce the current drain from the battery. Fig. 40 shows a schematic of the arrangement suggested. The resistance should be a potentiometer in which the slider arm can revolve continuously, the insulated gap between points A and B serving to provide a continuous passage of the slider without short-circuiting the battery. This serves to return the spot across the screen. In consequence only that fraction of the cycle covered by the gap would be lost on the trace. The main advantage of this type of Time Base is that any given point on the trace obtained can be referred accurately to the corresponding point in a cycle. The device can be calibrated directly, and its phase can also be determined and adjusted mechanically. The resistance (R in Fig. 40) connected between the slider of the potentiometer and earth to close the X1 plate whilst the arm of the potentiometer passes the gap, should be very high in value compared with the normal resistance between A and B. There are other methods of obtaining the same result, such as using a Photo Cell or variable capacity operating in conjunction with a cam the profile of which complies with the law required. Both these latter are more complicated than the one suggested, also because a pre-amplifier is required.

7.3.2. INTERNAL.

(a) OPERATED BY CONTACT BREAKER.

For higher speeds than can be catered for by the mechanical device described above, an electrical Time Base may be used having mechanical control. A simple Contact Breaker device which makes and breaks once in each revolution is all that is required for this purpose. Two types are possible, the stationary switch type Cossor Model 299 illustrated in Fig. 42b suitable for slow speeds, or a Rotary type suitable for high speeds. This latter arrangement can often be assembled by the experimenter by using standard ingition contact breaker parts provided the spacing of the contacts is made sufficient to withstand the maximum Time Base voltage of about 350 v. D.C. The additional refinement of a phasing scale in angular degrees can be added. The two leads from these devices can be connected across the anode and cathode pins of the Time Base Discharge Triode (6J5G) after removing the valve. Model 350 of Fig. 42 (a), because designed for very high speeds, can only be connected across a few volts and is therefore not suitable in this case.

(b) OPERATED BY SYNCHRONISING PULSE.

Another method is to arrange for the rotating machine to generate an electric pulse at each revolution which is applied to the " SYN." terminal for synchronising the internal Time Base in the normal manner, as explained in Section 4 4.3.5. This can be done electrically by the cyclical shorting of a battery with protective resistance in series, or electronically by means of a polarized capacity, electromagnetic pick-up, or Photo Cell arrangement with Bridge circuit inputs and Amplifiers. The Electronic method, though more complicated, offers the advantage of not requiring a direct mechanical connection to the rotating device. These same arrangements can be used for timing purposes, as mentioned in Section 8.2, or for indicating pressures, movements, velocities, vibrations, etc,

An elegant method is to use the Single Stroke Time Base facilities of the instrument, as described in Sections 3.2.1 and 5.11, by providing the mechanically controlled recurrency as described in Sections 5.11.2 by using the Cossor Model 350 Contact Breaker of Fig. 42 (a), which is suitable in this case because of the low voltage of the make and break. The arrangement provides both the phasing scale and the ability to examine in detail fractions of a cycle, as obtainable with a high voltage Rotary Switch by the method of paragraph (a) above.

8. TIMING DEVICES.

In addition to circular Time Bases there are other methods of timing, more used for the purpose of indicating time intervals on transient records obtained photographically. The permissible methods will be mentioned only briefly here.

8.1. TIMING OSCILLATOR.

Using the Double Beam Tube, it is possible to obtain the transient record on one beam and apply the timing voltage on the other. Either an external oscillator can be used, such as a tuning fork or crystal control type, or for less accurate work the mains frequency can be employed. A suitable voltage for this purpose can be obtained from the calibration terminal of the Oscillograph. In both cases the voltage is applied to one of the beams, or when both are used, applied to the Modulator of the tube, as described below.

8.2. SUPERIMPOSED PULSES.

This method can be used with either a Single or Double Beam Tube since either one beam can be used entirely for these timing pulses, or else the pulse itself can be superimposed on the work voltage applied to the Y axis. These pulses can be generated by mechanical means and converted into an equivalent electrical effect, or they can be generated entirely by electronic means, in much the same way as described in Section 6.2.3 for Beam Switching and Section 7.3.2. (b) for Synchronizing Pulses. A useful artifice is to differentiate the pulse electrically so that it marks the time axis as required and causes less interference on the trace.

8.3. GRID MODULATION.

A final method of timing is that of applying the timing wave or pulse obtained either externally or from the calibration winding of the Oscillograph (or a suitable proportion thereof) to the grid of the Cathode Ray Tube by applying it to the rear panel link strip and rearranging the instrument circuit as described in paragraphs 5.6.1 and 5.6.2 under the heading " Grid Connection." The effect of this is the intermittent dimming and brightening of the beam to the frequency of the timing wave. This method, which would generally be, used on a Single Beam Tube, can also be used on a Double Beam Tube, but both traces would obviously be affected similarly.

9. APPLICATIONS.

A list of some of the applications of the Double Beam Oscillograph is given herewith. It is neither intended nor possible that this list should be complete, for new uses are being found almost daily. The general division made between Radio and Electrical applications is not, of course, restrictive. The Double Beam Oscillograph can be used alone or in conjunction with other apparatus for every type of investigation, including mechanical, optical, physiological and other experiments, the only requirement being that the effects investigated must be made to provide an equivalent voltage change for application to the Oscillograph.

It is not possible to give details of how this conversion may be effected in any given case, but means can be devised readily by applying the better known principles of physics and mechanics and by making use wherever possible of established Electronic Devices. For example, various Piezo-electric Crystals, certain types of Resistances, Electro-magnetic Pick-ups and suitably constructed Condensers—DC. or AC. polarized—can be applied to the measurement of pressures. Many of these devices can generally be employed to the best advantage in conjunction with some circuit which operates differentially, such as a bridge network. Some of these same devices, together with Photo Cells and other Electronic Tubes, also lend themselves to the investigation of size tolerances, velocities, movements, accelerations, vibrations, acoustic experiments, and a host of other effects. With the Double Beam Tube any two of these can be inspected simultaneously. (See Section 5.4.1).

When the effect can be made to produce a large enough voltage there is no practical limit to the ability of the Cathode Ray Tube to provide a true record. When the voltage obtained is small and the instrument Amplifiers are used, the record obtained will be limited necessarily by the range of performance of the Amplifier and Time Base or any other external apparatus used in the circuit. This consideration applies chiefly to the lower end of the frequency response characteristic because most effects encountered in practice are below an upper limit of frequency of the order of 100,000 c.p.s., which is well within the scope of the Amplifiers, even when operated at maximum gain. When low frequency and D.C. effects of small amplitude are involved, a special Amplifier must be used, such as that described in Section 6.1.1. An alternative method is given in Section 5.4.1.

A very important field of application is the relative timing of events, for which purpose some useful information and circuits are provided in Sections 7.2 and 8. The Double Beam Oscillograph provides the additional advantage of indicating in this instance the effects nvestigated and their time relations.

In the routine use of the Oscillograph for test work the necessity for a satisfactory test signal source suitable for visual investigations must be considered, more so because the Cathode Ray Tube enables the delineation as a whole of effects covering a wide range in frequency, time or other variable. The requirements can be met by either mechanical or electronic devices. The former are generally more simple to make, but the latter are generally more satisfactory because of their greater flexibility and inherent synchronism. In investigations over a frequency range, Frequency Modulated Oscillators are required, and the Cossor Ganging Oscillator, operated on the electronic principle, has been specially designed for R.F. and I.F. work. Another type of signal source suitable for transient investigations on Amplifiers is also available in the Cossor range in the Model 391 Square Wave Generator.

In the applications of the Oscillograph many, and in general all wave-form examinations, require the use of a Linear Time Base. This latter is provided in the instrument. When the effect is non-recurrent the Time Base motion can be obtained externally by using a moving film or by single stroke operation described in Section 5.11. Both entail photography, which is discussed in Section 6.2

There are many other applications which do not require an independent Time Base, and in particular, all those making use of the Phase Shift Test described in Section 6.1.4. et seq. belong to this class. Further details of the procedure are given in Sections 4.5.4.2(b) and 4.5.4.3(b).

Finally there are applications which require an independent base or X axis deflection which is other than time, or when the electrical quantity is to be delineated against a variable, which is not generally provided by the circuit under examination. The most important of such variables, at least in Radio work, is frequency. A representative case of such an application is the use of the present Oscillograph with the Cossor Frequency Modulated Alignment Oscillator, which is fully described in the Instruction Booklet for this latter instrument. The notable feature of this method, which, incidentally, lends itself for adoption in other instances, is that by means of an electronic device the internal Linear Time Base is itself made to provide the linear frequency axis.

To these must be added, as another distinctive feature of the Cathode Ray Tube, the further facility of obtaining the trace of the effect investigated on a scale to any required law. For example, by converting—with the use of electronic devices—the linear voltage change into one following a logarithmic law, the vertical deflection giving the tuned circuit response in the application mentioned in the previous paragraph can be shown directly on a decibel scale. If the same is done for the X axis deflection on Audio Frequency response curves, the conventional trace on a logarithmic axis is obtained. In such cases either a linear/log or a log/log scale as required, should be used in place of the graticule provided, and the calibration arranged accordingly.

One final word of advice on the question of applying Cathode Ray Oscillographs is a reminder of the statements made in the Introduction. When an accurate graphical representation of a natural law, or any other type of qualitative information, is required, the Cathode Ray Tube is not merely the best, but is the only device available that can fulfil this requirement completely. When quantitative information is required, this can also be obtained with greater consistency of results than by other means, but not necessarily with greater accuracy unless the necessary precautions are taken to ensure same. This usually entails elaborate precautions, which run counter to the characteristic expeditiousness of the instrument in producing its results. This is chiefly because, whereas other instruments are designed for one application and their meters are calibrated accordingly, the Cathode Ray Oscillograph is suitable for use on almost every application, and it is therefore impossible to calibrate the tube scale for every case. Therefore when quantitative results are required the necessary calibration has to be made. For further information see Section 5.12.

RADIO

Where a **DOUBLE BEAM** Tube is advantageous or essential.

- Aligning band-pass intermediate and radio frequency circuits in Radio Receivers.
- Tracking of oscillator and pre-selector circuits in superhets.
- Adjusting automatic frequency control (A.F.C.) circuits.
- Comparative sensitivity and selectivity tests.
- Adjustment of variable selectivity circuits.
- Functional tests on A.V.C. and Q.A.V.C. circuits.
- General frequency comparison tests for calibration at both R.F. and A.F.
- Comparison between the input and output of amplifiers and networks without the need of a pure signal source.
- Television synchronization tests.
- Frequency doubling and Monitoring tests on Radio Transmitters.
- Matching of radio coils, R.F., I.F., etc.
- Matching variable condensers.
- Comparative observation of related wave forms.
- Comparative band-width measurements.
- Adjusting rejector and acceptor circuits.
- Adjustment of phase splitting circuits in both transformer and valve-coupled stages.
- Testing and adjusting of push-pull and other types of symmetrical circuits.
- Comparative tests on all television waveforms ; video signals, D.C., synch. etc.
- Testing amplifiers by application of transients (square wave-forms).

Where a **SINGLE BEAM** Tube is sufficient.

- Fault tracing in Radio Sets.
- Aligning R.F. and I.F. circuits when only single response curves are required.
- Hum tracing and observation of rectifier ripple and smoothing efficiency.
- Valve characteristics, static, dynamic and oscillatory.
- Phase Shift tests in general, such as for impedance measurements and input and output tests on amplifiers and networks.
- Frequency comparison by Lissajou figures.
- Radio interference testing.
- Monitoring in radio, television, talking film and gramophone recording.
- Use as an R.F., A.F. or D.C. Voltmeter.
- Modulation tests.
- Television wave-form analysis.
- Wave-form observation of valve oscillators and amplifiers.
- Detection of parasitic oscillation.
- Measurement of aperture distortion in television transmitters.
- Transient effects in loudspeakers.
- Study of speech and music wave-forms.
- Detection of motorboating and other decoupling and feed-back effects, together with over-load and distortions in amplifiers.
- Examination of tone control circuits.
- Testing variable resistances.

ELECTRICAL AND GENERAL ENGINEERING

Where a **DOUBLE BEAM** Tube is advantageous or essential.

- Comparative wave-form and timing investigations on telegraphs and telephones.
- Examination of the making and breaking of circuits and timing thereof.
- Measurement of explosions and rate of change of pressure.
- Measurement of operating times of relays etc.
- Investigations on the velocity and acceleration of moving parts.
- Bullet muzzle velocity investigations.
- Chronometric investigations.
- Investigation of hunting and synchronization of alternators.
- Pressure recording and engine indicator diagrams.
- General electrical problems involving the relative timing of successive events.
- Detection of winding unbalance in generators.
- Testing of losses in cables, transformers, oil and insulating materials by null method.
- Testing symmetrical and multiphase circuits.

Where a **SINGLE BEAM** Tube is sufficient.

- Study of wave-form on alternators and transformers.
- Ripple in D.C. generators, commutators and rectifiers.
- Wave-form tests on telegraph and telephone signalling apparatus.
- Physiological phenomena (cardiography and encephalography).
- Measurement of phase delay in transmission lines and circuits.
- Sea depth recording.
- Properties of dielectric materials.
- Properties of magnetic materials, B.H. curve and hysteresis loss.
- Cathode ray compass and drift indicator.
- Measurements on mercury arc apparatus.
- Investigation of magnetic fields.
- Iron saturation and leakage in transformers and electro-dynamic machines.
- Investigations in mechanical vibrations.

N.B.—All the tests shown for Single Beam can also be made with Double Beam Tubes.

10. BIBLIOGRAPHY.

A brief bibliography is given herewith for the assistance of users of the Oscillograph who would like to consult further sources of information on the operational features of the Cathode Ray Tube and component items of the Oscillograph, and more particularly with regard to the application of the instrument to specific problems.

A list of books is indicated, some of these being of an elementary character, others being recognized text-books on the subject, and therefore more advanced.

The Cathode Ray Tube and oscillography in general is a relatively new science, and therefore by far the greater bulk of the useful information is still found in original articles published in scientific journals. Therefore a brief list of some of the more important articles which have appeared on the subject is also added. This list must necessarily be representative. It will usually be found that the bibliographical references added to each of the original articles are sufficient to enable the user to link up with almost all the literature on the subject.

The list is completed by reference to a few Cossor leaflets and booklets, which contain further useful information.

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10.3. COSSOR PUBLICATIONS.

(1) Model 339 Double Beam Oscillograph. Instruction Manual. C.B. 55 C	Price	3/6
(2) Model 343 Ganging Oscillator. Instruction Manual C.B. 56A	Price	3/6
(3) Model 389. A.C. Impedance Bridge. Instruction Manual	Price	1/6
(4) Model 3391 Square Wave Generator. Monograph on its use for testing Amplifiers	Price	6d.
(5) Cossor Cathode Ray Tube Leaflet	Free	
(6) Cossor Instruments. Descriptive leaflet of various equipment	Free	

11. ACCESSORIES.

It is to be expected that in the use of the Double Beam Oscillograph in the wide field of applications within its scope, accessory apparata and devices will on occasion be required. Some of these which are likely to serve in general use have been made available and are described in the present section. Further items of the same class are likely to be added to these in time, and for this reason it is useful to enquire from the Cossor Company in such cases. Certain accessories can often be obtained from different sources, but it will be found that in general such other accessories as may be necessary will have to be made by the user. Many of these, being mechanical devices, should not present much difficulty.

11.1. VIEWING HOOD.

This item is illustrated in Fig. 43a, and is an obvious addition for the purpose of screening the tube from incident light when, as is usually the case, the instrument has to be used for long periods in a lighted room. The hood is designed to hold the 10 cm. scale. Thus both can be withdrawn simultaneously when the Camera 427 is to be used or the screen viewed directly.

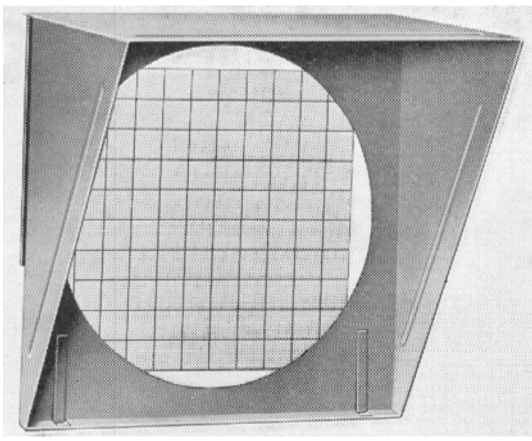

FIG. 43a

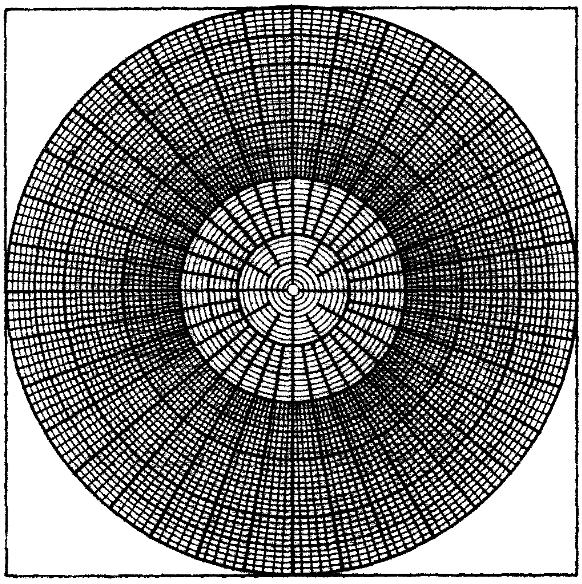

FIG. 43b.—POLAR SCALE

11.2. CAMERA MODEL 427.

The Camera has been specially designed for use with this Oscillograph. It provides the simplest possible means of recording oscillograph pictures either by taking single shots of stationary wave-forms synchronised to the Oscillograph Time Base, or by taking continuous records of non-recurrent wave-forms or slow transients by the moving film method, Fig. 44.

To make this possible the photographic medium used is standard 35 mm. film or paper contained in rolls of 25 feet in an appropriate Loading cassette, and it is driven, after exposure, into a Receiving cassette. This is done manually through a knurled knob in the case of sequential stationary records, and by a motor added externally and driven through a spindle extension provided for this purpose in the case of moving film records. In this latter case any motor mechanism available can be attached by means of a coupling. Alternatively, a flexible drive can be used when the driving motor is at a distance or fixed on a bench independently from the equipment. A very convenient arrangement is a motor, such as the Klaxon type HK5CB1, preferably driving through a variable speed gear-box, which can be fixed to the Camera casing, forming a single unit. When only one speed is required, motors are obtainable with integral gearing. A 1/40 H.P. motor is sufficient, but some form of clutch should be incorporated if spindle speeds exceeding 1,000 R.P.M. are required. Such motors have to be obtained separately and provided and fixed by the user.

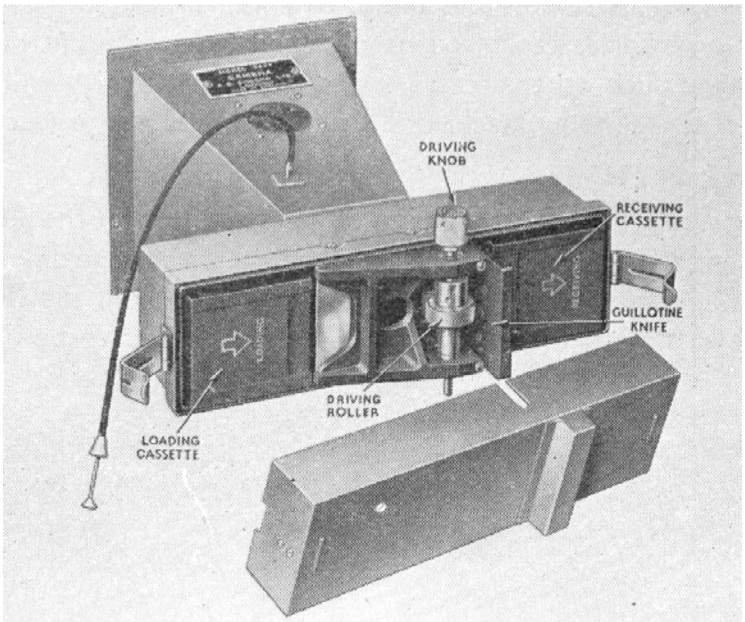

FIG. 44—MODEL 427 CAMERA, WITH BACK REMOVED.

The maximum speed at which the Camera can be driven is 6 ft./sec. (about 1,700 R.P.M. of the driving spindle), but not more than six to ten feet of film or paper can be accepted by the Receiving cassette at this speed. When direct coupling is arranged the drive calls for a vertical spindle type motor. Should a horizontal spindle type only be available, the Camera can be turned 90° in the Oscillograph mounting, so that the Camera spindle becomes horizontal. Under these conditions the work voltage should be applied to the X1 terminal instead of to the Y terminals of the Oscillograph, and the instrument circuits should be rearranged accordingly (see Section 5.6.1), if the amplifiers are required.

The Camera is fitted with a lens with an aperture of F/3.5, which gives ample recording speed, both for stationary shots and for a wide range of moving film records. For transient investigations using a Type 26J Single Beam Tube in the Oscillograph the limiting writing speed is 2 kms./sec. The size of the image required on the tube screen to give a full 3 cm. record on the photographic paper is 6 cms., which represents the best compromise for the lens used. The limited area thus covered ensures high brilliancy of the spot and reduces distortion effects brought about by various causes, such as those due to wide angle deflection, and the effects on the photographic record of curvature of the bulb. The shutter is of the three-blade type and is arranged to operate a switch, which can be used for beam switching and other purposes, as explained in Sections 6.2.3. *et sec.*

The Camera provides rapid daylight recording, and, because also of the inexpensive recording medium used—that is, 35 mm. unperforated paper—the scope of the Oscillograph is considerably extended by the added facility of obtaining permanent records.

11.3. KIT OF LEADS Cat. No. 426.

It has been general in the past for the user to arrange his own connecting leads and provide his own means to meet the conditions imposed by any given test. Such arrangements have perforce to be made in haste and with the use of mateaial at hand, Some test requirements are thus inevitably neglected or provided for by temporary arrangements, which are often imperfect, and invariably in a short time become unusable and are discarded. This fact has often been responsible for unsatisfactory results, and for occasional unwillingness to use the equipment because of the trouble of providing the required connections, with the consequent loss of the advantagss the instrument provides.

It is because of all these considerations that the present Service Kit has been made available. It comprises all the assentiol items, most of which cannot be obtained elsewhere. They are designed to meet ezactly the scientific requirements of the test, and are sufficiently robust to withstand the conditions of everyday use.

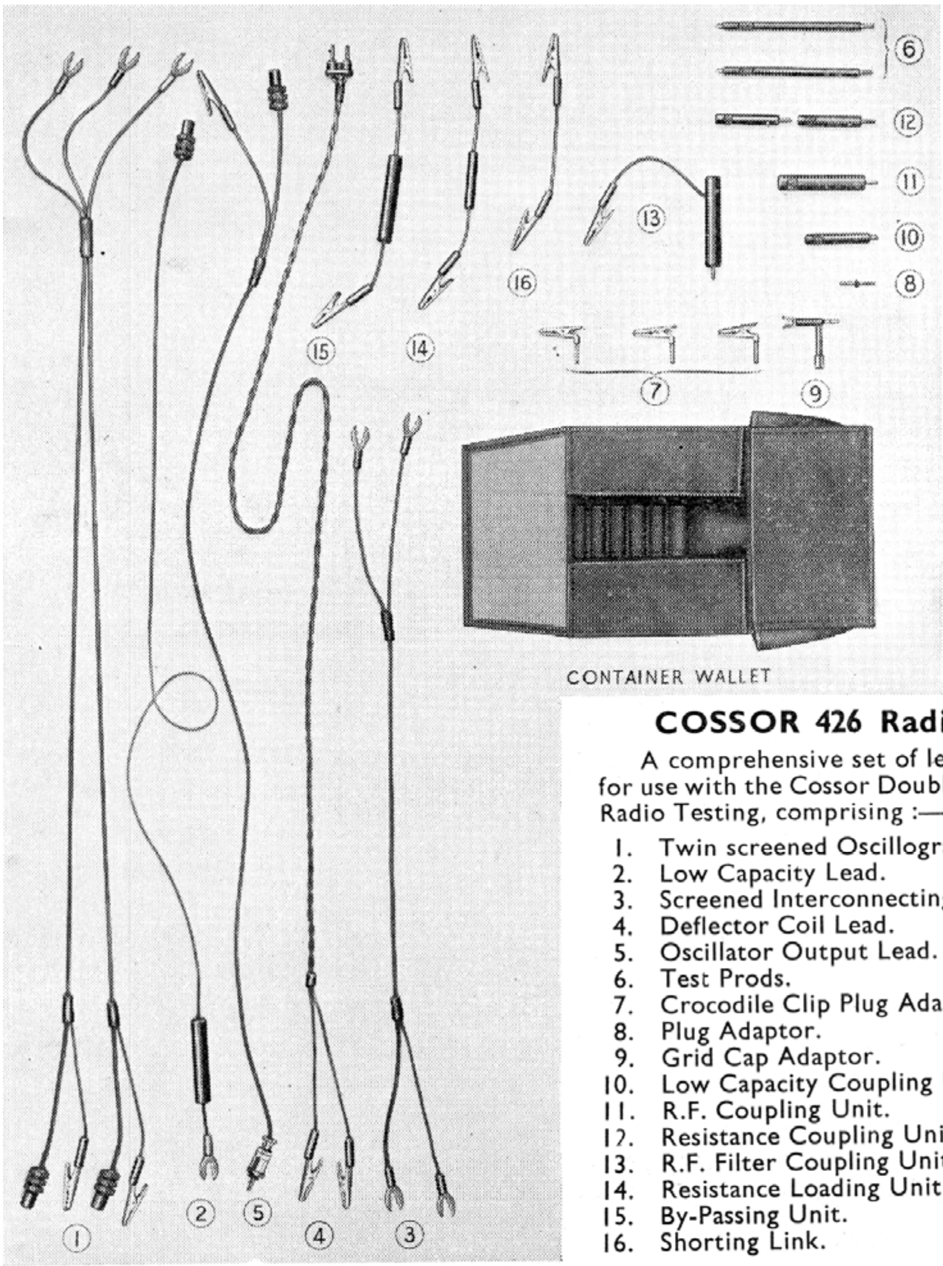

FIG. 45.

COSSOR 426 Radio Service Kit.

A comprehensive set of leads and test Accessories for use with the Cossor Double Beam Oscillograph for Radio Testing, comprising :—

1. Twin screened Oscillograph Input Leads.
2. Low Capacity Lead.
3. Screened Interconnecting Lead.
4. Deflector Coil Lead.
5. Oscillator Output Lead.
6. Test Prods.
7. Crocodile Clip Plug Adaptors.
8. Plug Adaptor.
9. Grid Cap Adaptor.
10. Low Capacity Coupling Unit.
11. R.F. Coupling Unit.
12. Resistance Coupling Unit (White dot).
13. R.F. Filter Coupling Unit.
14. Resistance Loading Unit.
15. By-Passing Unit.
16. Shorting Link.

11.4. RACK AND PANEL MOUNTING.

The " rack and panel " mounting of apparatus is now a well established practice in telegraph, telephone and radio engineering. If offers various important advantages, such as the vertical disposition of the instruments, with consequent saving in space, and the standardisation of dimensions and parts, thus affording convenient interchangeability. It was with the object of making use of these advantages that Cossors have planned their range of Instruments, whether for the Laboratory or Radio Service, for Rack mounting and have made suitable Racks available for this purpose.

The instruments are permanently fixed and thus the risk of damage due to excessive moving about is avoided. An important point is that the instruments can be permanently connected up ready for use, a fact which ensures greater use being made of the gear with more expeditious results.

The Radio Service Rack comprising one Model 413 Rack with one A55 and one A56 Panel for inclusion of Model 339 Oscillograph and Model 343 Ganging Oscillator.

The Racks have been designed in such manner that two or more can be mounted together so that an expanding Instrument Panel is ensured. For this purpose detachable interchangeable feet, brackets and panels are used, this being made possible by the standard spacing of the fixing-screw drillings on the frame. (See Fig. 46.)

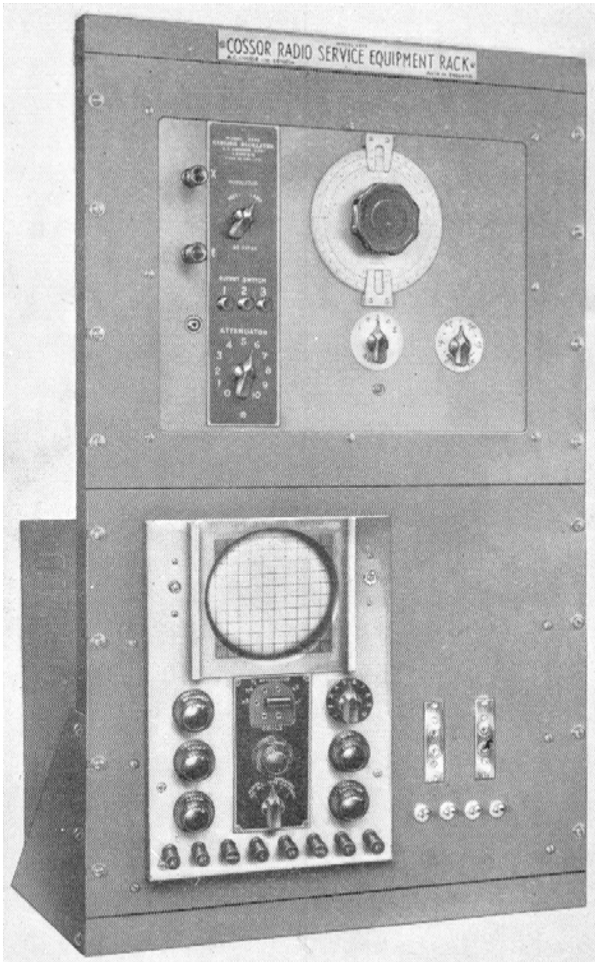

FIG 46

11.5. SCALES.

In addition to the transparent 10 cm. square scale supplied for general use, the user can provide other scales to suit special requirements. This can be done readily by cutting to the required size and drawing on a suitable piece of transparent material (cellastoid or other) the scale intended. The phase scale illustrated in Fig. 28, Section 6.1.4.4, or the polar scale Fig. 43b, Section 7.2.2, or the logarithmic scales mentioned in Section 2, are cases in point. Other scales can be prepared for calibration purposes when the instrument is frequently used on a specific application. When making such scales the relative X and Y axis sensitivities should be remembered, or Amplifiers used with Gains adjusted to give equal X and Y sensitivities.

11.6. AUXILIARY INSTRUMENTS.

Auxiliary instruments in the Cossor range are the following :—

1. Model 343 Ganging Oscillator ... ... Providing a 100 Kcs. sweep frequency or 400 c.p.s. amplitude modulated signal from 20 Mcs. to 100 Kcs. for Radio Test work.
2. Model 391 Square Wave Generator ... Producing a square wave signal of controllable characteristics for the transient testing of Amplifiers.
3. Model 389 A.C. Impedance Bridge ... For measurement of Resistances, Condensers and Inductances with the present Oscillograph.

For full particulars on these and other instruments consult the appropriate leaflet or booklet when such is available.

11.7. TABLE OF ACCESSORIES AND EXTRAS.

Part No.	*Description.*	*Price* £	s.	d.
	Instruments.			
427	Camera	26	10	0
343	Ganging Oscillator	30	0	0
389	A.C. Impedance Bridge	20	0	0
391	Square Wave Generator	30	0	0
	Accessories.			
350	Contact Breaker	17	6	6
A39	Viewing Hood		10	0
426	Radio Service Kit	2	10	0
413	Rack	1	10	0
A55	Oscillograph Panel and Shelf for Rack	1	15	0
A56	Instrument Rack Panel		10	0
A57	Blank Rack Panel		10	0
A104	Canvas Instrument Cover		15	0
A36	Spare Millimetre Scale		3	0
A20	Camera Loading Cassette		15	0
A21	Camera Receiving Cassette		15	0
CB55C	Extra Operating Instruction Booklet		3	6

Prices do not apply outside Great Britain and Northern Ireland and are subject to alteration without notice. Orders can be accepted only at prices ruling at date of invoice and subject to stocks being available. Prices do not include any Taxes that may be applicable.

The Company reserves the right to vary specifications if necessary.

12. MAINTENANCE AND SERVICE.

Cathode Ray Oscillographs are extremely reliable pieces of apparatus and can operate for long periods without attention. The present instrument is devoid of critical adjustments and other special conditions which might tend to restrict its reliability or call for special attention. It is robust and well able to withstand normal operating conditions indefinitely.

In consequence of this the only likely faults are either those due to accidents or the minor ones caused by the failure of individual components, such as the condensers and resistances.

With condensers in particular, some are more liable than others to gradual deterioration with time, temperature and humidity. Many users of the instruments, particularly Radio and Electrical Engineers, are familiar with these types of components and their characteristic faults, and can easily trace them with the assistance of the usual instruments or by interpretation of the effects obtained and careful reading of the circuit diagram. Any reputable make of condenser or resistance can be used for replacement purposes provided it complies with the rating specified on the original component.

The only components where difficulty may be experienced with replacement—because they are specialized articles—are the tandem potentiometers, but even in this case standard potentiometers of the same nominal value operating independently will suffice as a makeshift pending the arrival of the special potentiometers required. These can be obtained either from A. C. Cossor Ltd. or direct from the manufacturer, when it is desired to avoid the return of the instrument.

Such return is sometimes inevitable in the obvious case of serious mechanical damage or voltage breakdown due to accidents, such as that due to a mains voltage of 200 or more being applied to the instrument when set for 110 volts, or other causes, which may require extensive replacements (mains transformer, condensers, etc.). In most other cases it is feasible for the user to endeavour to locate the faults and effect the repair himself, because in general few difficulties are likely to be experienced. The following notes have therefore been prepared to assist the user in this task.

12.1. CONTINUITY TEST.

There are two continuity tests (a) circuit continuity, which is an insulation or resistance test ; (b) signal continuity, which is strictly a functional test and is covered in Section 12.3. In the former the instrument is switched off and in the latter switched on. In both cases the test is carried out with the assistance of the circuit diagram, Fig. 47, and the views of the instrument, Figs. 48 and 49, indicating the location of the components.

In the circuit continuity test the mains transformer windings and all the various circuits should be tested, and the components also checked for their value as marked thereon. The ohmmeter should be capable of reading up to 5 megohms to cover all possible circuits. In particular the leads from the tube deflector plate should be tested and should show D.C. continuity to chassis of 5 megohms or less, except when the Time Base is set in the "OFF" position of the X1 plate. This plate has been purposely left free under this condition, for reasons explained in Section 4.4.2.

By means of this test open circuited and short circuited components, such as resistances and condensers, can be located and replaced. To facilitate the work the resistance of all coils and transformer windings and variable potentiometers are shown on the circuit diagrams, Figs. 46 and 47. The condenser values are marked on the components themselves and the resistances are colour coded. The most important continuity test is the tube H.T. supply potentiometer chain.

12.2. VOLTAGE AND CURRENT TEST.

The instrument is then switched on and the voltages checked with the values shown on the circuit diagram. For satisfactory operation, the readings obtained need only be approximate to the value stated. Because of the number of high resistance circuits in the instrument a high resistance voltmeter is preferable, such as electrostatic or thermionic type—but even a good quality moving coil instrument may be used if allowance is made for the current which it draws from the circuit on test.

Should the instrument cease to function and no spot be present on the tube screen the tube supply voltages should be checked. A glow at the rear of the tube is proof that the tube heater is operating. After this, the transformer secondary A.C. voltages are tested, as also are the D.C. voltage points across the H.T. chain.

Important points are the voltage of the grid and second anode of the tube. These are necessary to ensure focussing and spot brilliance. These can be measured by probing the appropriate tube socket pins, remembering that, excluding the resistance providing the Shift voltage range, the H.T. + point of the rectifier is connected to the tube anode and is earthed, and therefore all tube potentials are negative from this point.

Care must be taken if inspecting and testing the instrument when switched on because of the high voltage—1,200 volts—present across the tube power supply, which, in combination with the separate H.T supply for the Time Base and Amplifier, makes a total possible potential difference of close on 2,000 volts This can be dangerous

The normal current circulating in each circuit and drawn by each valve is shown in the circuit diagram, but it should not often be necessary to test this because it entails breaking the circuit, which is best avoided It can easily be done with valves such as 807 by inserting the meter in between the valve top cap lead, or with other valves by the use of split pin valve adaptors

It should be noted that the operating conditions of the amplifier valves are modified by the Amplifier switch position this chiefly with regard to the anode voltages which vary as follows — Anode Volts of 807

In 2HFY1 switch position	300–350 v D C
In all other positions	220–270 v D C

The bias voltage on the grid of both valves is from 3 to 4 v D C

12 3. FUNCTIONAL TESTS.

The continuity and voltage tests indicated are rarely required to be carried out completely when fault tracing A selective procedure by means of which the circuit points suspected are probed is usually preferable because more expeditious

It is first necessary, however to ensure that the Cathode Ray Tube is functioning, and this means to obtain a spot on the tube If absent, the tube supply voltages should be checked A glow at the rear of the tube is proof that the tube heater is operating The transformer secondary A C voltages should be measured as also the D C voltage points across the H T potentiometer chain

Further fault tracing can then be carried out by means of Functional tests which should enable the fault to be located by a judicious interpretation of the effects obtained on the Cathode Ray Tube

In the Signal Continuity test the calibration or mains voltage or a fraction thereof is applied at consecutive points in the various signal paths in particular the Amplifier and deflector plate circuits It is preferable to start from the latter and to work backwards to the input points In this case the Cathode Ray Tube itself serves as the indicator either automatically because the tube is linked with the affected circuits, or deliberately by connecting to one of the three connector plates a lead and test prod with which the various circuit points are tested

If a tube fault is suspected, such as an internal disconnection, or a fault in the deflector plate circuits, check by connecting all the deflector plates to earth, as shift or work voltages may cause the spot to go off the screen

Inaction of the Y Shift controls implies open or short circuit of these, or a short circuit in C32 and C34 decoupling condensers Absence of shift when these deflector plate terminals are earthed or connected to a low impedance circuit is due to failure of C38 or C39 coupling condensers—always on the assumption that the Amplifier switch is not in the D C position, as this would produce the same effect Should the X Shift be inoperative and the control itself not at fault, C33 or its associated wiring must be shorted to earth

Should it be impossible by means of the Shift controls to set and keep the Cathode Ray Tube spot stationary in a chosen position, and it drifts slowly in a given direction, eventually going off the tube screen, this indicates an open circuited deflector plate The defective circuit is indicated by the direction of spot motion, which can be interpreted on the basis that the free plate is gradually acquiring a negative charge from the electron beam, and is therefore repelled by the plate on which the negative potential accumulates Violent movement of the spot with changes in brilliance will confirm this fact

Next comes the Time Base circuit Should its various variable resistances, when operated, produce no effect, or only produce definite effects at one or both extremes, this signifies that they are defective This applies both to the tube and Time Base controls In this latter case it may also mean that the Time Base itself is not functioning, in which case one of the Time Base valves is to be suspected, and all three should be tested Apart from definite faults on the Time Base coupling and decoupling components, which can be traced, tested and replaced by the usual sequential procedure from the circuit diagram, no functional fault is likely which does not produce on the tube itself some indication, the careful interpretation of which provides a complete diagnosis Thus the presence of a high speed Time Base on any of the lower stud positions of the Condenser switch indicates an open circuited Time Base condenser from C6 to C13, which can thus be easily tested and replaced Also, lack of synchronisation may mean either the omission of the connecting link to the Y1 or Y2 terminals, or open circuited or disconnected components R8, C16 and R7

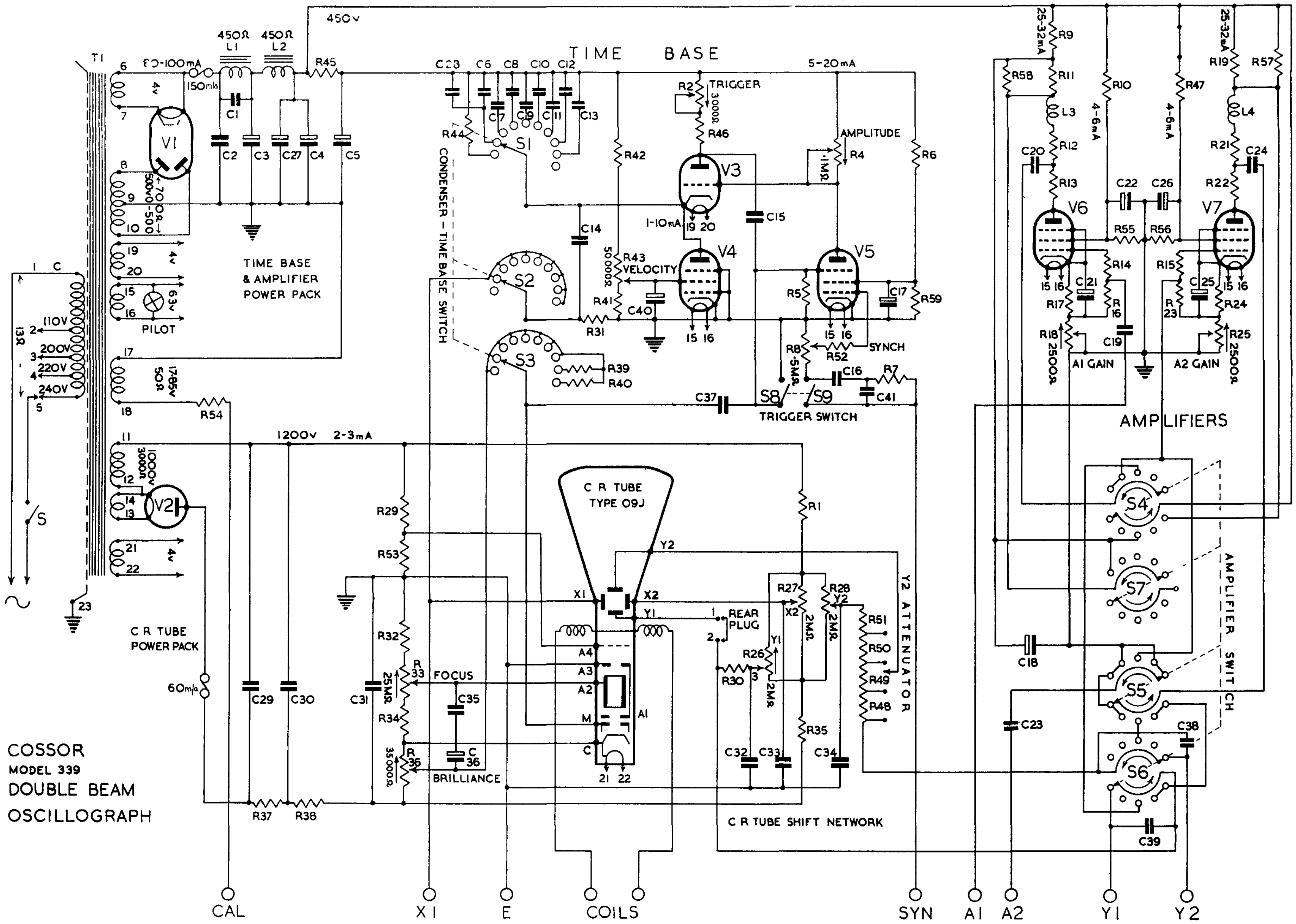

FIG 47. CIRCUIT DIAGRAM

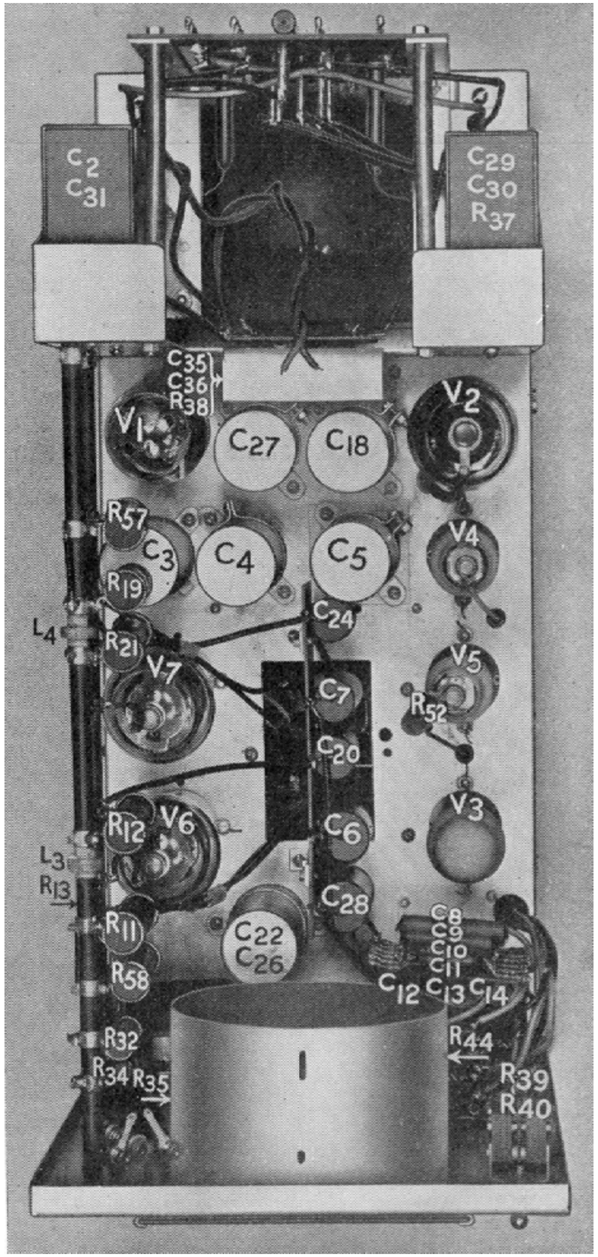

FIG 48 TOP VIEW OF CHASSIS

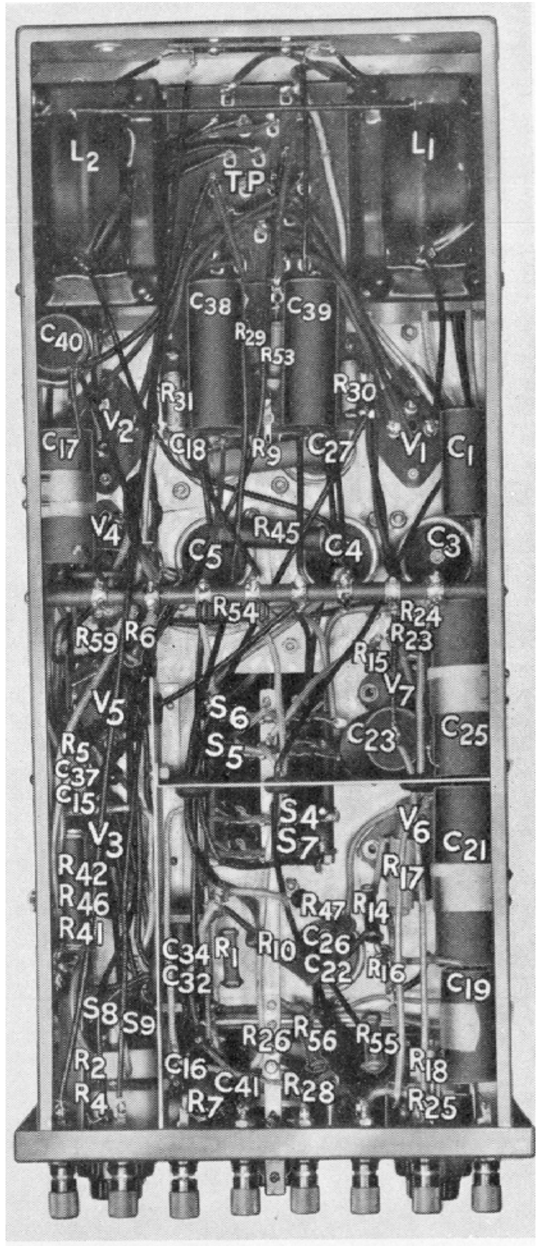

FIG 49 UNDFRSIDE OF CHASSIS

The Amplifier circuits should then be tested. These are usually the most simple. The non-operation of the Amplifier valves may be due to the anode cap coming adrift, producing conditions explained in Section 4.1.1 of Operating Instructions, or occasionally to failure of the Gain controls. Should such a fault remain undetected for any length of time the appropriate amplifier valve will probably have suffered damage. Again, the de-coupling and coupling condensers require close inspection. Any deterioration of the low frequency response by evidence of Phase Shift effects when dealing with frequencies around 50 c.p.s. may be due to defective cathode by-pass condensers C21 and C25, or defective coupling condensers C20 and C24. In this latter case the cause of the trouble may be leakage, which is serious because of the high voltage present on the anodes of the valves and can—in the case of C.20—cause damage to V.7 and premature overloading.

12.4. GENERAL ADVICE.

Care should also be taken when attending to the instrument to avoid altering the position of wires and components, because their positions have been carefully chosen. This applies particularly to the case of condensers C20, C24, C39, C38, C19 and C23. Any displacement of these is accompanied by the risk of moving them into A.C. mains fields due to valve heaters or mains transformer, or A.C. leads at high tension carrying large current near the mains transformer or rectifiers. Some of these effects could have been avoided by screening the components and their attendant leads, but this would restrict the H.F. performance of the amplifiers.

A remaining item is the Amplifier switch. This is the most complicated single item in the instrument because of the different circuits and different qotentials rearranged by its action. Because of the stringent requirements in the matter of insulation, resistance, low capacity, etc., care must be taken in handling the various switch wafers to avoid dust and moisture, and above all, to avoid them being soiled by greasy substances, such as are present in many soldering fluxes. Only resin cored solder should be used in re-making any of the connections to the instrument. The same applies to all components fixed on insulating panel strips. Provided there is no mechanical damage and the switch wafers are clean they should give continuous service without attention. The switch contacts are self-cleaning.

It is useful to remember that, because of the heat dissipation within the instrument, the ventilation has had to be carefully planned, and as a result a considerable volume of outside air passes through the instrument in a given time. Consequently, with the fair amount of small dust normally present in the air, it will be noticed that this tends to accumulate around the points of high voltage, and to adhere more firmly at points of high temperature. It is therefore advisable when removing the case to inspect the instrument for one reason or another to take the opportunity of wiping off these particles, as this will avoid eventual accumulation of the dust, which, with the aid of moisture due to occasional condensation of the humidity of the air, may form a semi-conductive path on the high voltage sections of the instrument sufficient in time to interfere with their correct operation, and, in serious cases, to cause a breakdown.

The Cathode Ray Tube and valves age and must necessarily be replaced in due course. Loss of tube emission and thus spot brightness will generally be the determining consideration in the case of the former.

Many users of the instrument are Radio or Electrical Engineers possessing suitable instruments and means for carrying out their own service and maintenance because familiar with this work. Other users, such as Mechanical Engineers, with less experience in this work, may prefer to see the instrument attended to by experts but would like to avoid the expense and delay of returning the instrument to the manufacturer. In such cases it can safely be said that most Service and Maintenance work on the instrument can be entrusted to a well-equipped local Radio Serviceman, because most of them are familiar with the Oscillograph, and are as likely as not to be using one in their own Test work. This same Radio Serviceman will generally be in a position to replace sundry condensers and resistances when required by suitable components from stock, and in most cases he is also equipped to test and replace valves. Therefore no difficulty is likely to be experienced in practice in retaining the instrument in best condition.

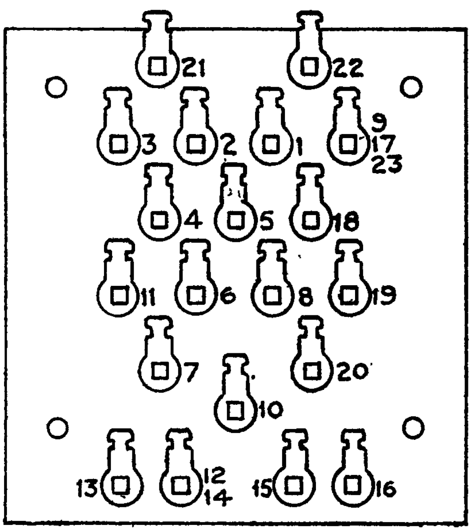

FIG. 50. TRANSFORMER TAPPINGS.

12.5. REPLACEMENTS PARTS LIST.

Part No.	Description.	Price Each.
09J	Double Beam Cathode Ray Tube	6 12 0
26J	Single Beam Cathode Ray Tube	6 12 0
6J5G	Time Base Triode	7 6
EF36	Time Base Pentode	11 6
807	Pentode Amplifier	1 5 0
5Z4G	Full Wave Rectifier	9 0
SU2150A	Single Wave Rectifier	1 0 0
TA10034	Mains Transformer	
TA10033	Smoothing Choke	
ZA5157	Deflector Coil Assembly	
ZA5278	Anode Terminal Rod Assembly and Coil	
Z1774	10-way Amplifier Switch	
ZA5202	Mu-metal Shield	
ZA5285	Y2 Attenuator Panel	
ZA5235	Rear Panel Assembly	
ZA5287	Anode Connector	
Z2569	Fuse Holder	
Z1786/3	Voltage Change Panel	
Z1786/2	,, ,, Plug	
Z2163/2	Condenser Switch Control	
Z2012	Escutcheon	
Z2014	Time Base Condenser Dial	
Z2567	Signal Lamp Holder	
Z2594-3	Handle	
Z2576	Mains D.P.S.T. Switch	
M14342	Rear Panel Link Plug	
M14343	Coil Plug	
M13863	Attenuator Plug	
ZA5206/2	Trigger Control and S.S.T.B. Switch	
Z2599	Tandem Gain Control	
Z1684/2	,, Y Shift Control	
Z1684/7	,, Focus and Brilliance Control	
Z1684/4	,, X Shift and Sync	
M199112	C.R. Tube Rubber Buffers	
M199110	Rubber Feet	
G1172-53 2	International Octal Valve Holder	Prices on Application
M12163	5-pin American Valve Holder	
M12164	Tube Rectifier Valve Holder	
Z1697	Terminals as per Markings	
Z1758	Single Control Knob	
Z1594	Large Knob of Tandem Control	
Z1756	Small Knob of Tandem Control	
Z2013	Pointer Knob	
Z1947	Link	
M240772	10 cm. Scale	
S7840	Mains Lead	
0775/4	150 mA Fuse.	
0775/3	60 mA Fuse	
Z2568	0.5 + 0.5 mfd. 1,500 v. C2, C31, C29, C30	
Z1691	8 mfd. 750 v. C3, C4, C5, C18, C27	
Z2555/2	8 + 8 mfd. 500 v. C22, C26	
Z2566	Inspection Cover Plate	
ZA5271	Tube Plate Bulkhead Adaptor	
Z1693/2	12 mfd. 200 v. C17, C40	
Z1693	300 mfd. 6 v. C21, C25	
M12974/15	Ceramic 5 mfd. C41	
M12935/14	0.0001 mfd. 1,200 v. Mica. C37	
MC101147	0.01 mfd. 1,000 v. C15	
MC10162/2	0.25 mfd. 375 v. C1	
MC101122/2	0.1 mfd. 500 v. C33	

All resistances are of Erie type as per value, tolerance and wattage shown on the component per colour code.

Prices do not apply outside Great Britain and Northern Ireland and are subject to alteration without notice. Orders can only be accepted at the prices ruling at the date of invoice and subject to stocks being available. The prices shown do not include taxes which may be applicable. The Company reserves the right to vary the specification if necessary.

13. GENERAL SPECIFICATION.

The figures given are representative of the average. Some differences arising from normal production tolerances must be expected on individual instruments.

POWER RATING.

A.C. mains voltage	110, 200-250 volts.
A.C. mains frequency	40 to 100 c.p.s.
Power consumption	120 watts approx. (7 valves).
H.T. voltages	Tube 1,100 v. Amplifiers, etc., 500 v.

DIMENSIONS (Overall).

Height	13¼″	34 cms.
Width	8¾″	22 cms.
Length	19½″	49 cms.
Weight	40 lbs.	20 kgs.

CATHODE RAY TUBE.

Heater	4 v. 1 amp.
Screen diameter	114 mms.
Overall length	375 mms.
Type	Trapezium Corrected High Vacuum Tube.
Standard	09 Double Beam Tube.
Non-Standard (as extra)	26 Single Beam Tube.
Fluorescent screen	" J " type with blue response.
Beam intermodulation	Maximum 2%.
Sensitivity for Y1Y2	3.1 v. D.C., 1.1 v. R.M.S. (v/mm.).
Sensitivity for X	2.25 v. D.C., 0.8 v. R.M.S. (v/mm.).

INPUT IMPEDANCE.

	Capacity mmF.	*Resistance. Megohms.*
To Input terminals	10	3.0
Direct to Tube Panel	20	As required
Through Amplifier	40	1.0
Synchronisation (added)	20	2.0

CALIBRATION ... ... 50 volts Peak to Peak.
17.75 volts R.M.S.

DEFLECTOR COILS ... ... Sensitivity. 2 mms./mA. R.M.S.
Maximum current. 60 mA. R.M.S.

Y2 ATTENUATOR.

Maximum Voltage Range	400 v. A.C. R.M.S.
Frequency range. For A/C only ...	From 30 c.p.s. to 15,000 c.p.s. Not frequency compensated.
Reduction ratios	x1, x2, x4, x8.

TIME BASE.

Frequency range ... ... 6 to 250,000 c.p.s.

	Condenser Switch Position.	*Velocity Control. Min.*	*Max*
	1	Time Base Inoperative.	
	2	6	15
	3	11	60
Approximate Sweep Frequency Ranges.	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.

AMPLIFIER.

	Gain (approx.)	*Frequency Band in c.p.s. ± 3db.*	*Sensitivity mV. R.M.S. mm.*
1 stage	28	10-100,000	43.0
2 stage—			
High Gain position	900	10-100,000	1.30
Wide Band position	106	10-2,000,000	10.00

VALVES.

The instrument is fitted with the following Cossor type commercial valves, which are identically replaceable by the Service Preferred types, as indicated.

Description.	*Cossor Type*	*Service Preferred Type.*
Half Wave Voltage Rectifier ... ... For Cathode Ray Tube H.T. Supply.	SU2150A	VU120
Full Wave Voltage Rectifier ... ... For Time Base and Amplifier H.T. Supply.	5Z4G	5Z4G
Triode ... ... Time Base Discharge Valve.	6J5G	6J5G
H.F. Pentodes ... ... (*a*) Time Base Charging Valve. (*b*) Time Base Auxiliary Discharge Valve.	OM5	VR56
Output Pentodes ... ... Two Amplifier Valves.	807	VT60