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## *Commentary*

COMPONENT manufacture has been going on ever since the first radio receiver was made, but forty to fifty years ago there were practically no components as we know them today. Such components as there were, were made by scientific instrument manufacturers and were far from suitable. The early set maker was thus forced to make all or nearly all his own " bits and pieces ", but he quickly learnt that the making of valves, resistors, capacitors and the like is a specialist business and that in the end it is cheaper and more satisfactory to obtain the bulk of his requirements from the component industry itself.

This brought about a two-fold benefit. The set maker is able to take his components for granted—perhaps not all set makers will agree with this statement—and is free to concentrate on problems of circuit design and production. The component manufacturer, on the other hand, by directing his attention to a relatively few types of components can produce a more satisfactory article and a larger market ensures a cheaper product. This is nothing new, of course, for the same state of affairs exists in other branches of industry. No motor car manufacturer, for example, makes his own tyres and batteries.

The importance, therefore, of the component section of the radio and electronic industry cannot be overemphasized. Its growth since the war has been remarkable, particularly in the export market, and today its annual output is valued at nearly £26m. Whereas before the war the imports of components into this country exceeded our exports, the position in the post-war years has changed in our favour and this country is now the world's largest exporter. From a modest £½m in 1938 the value of component exports rose to £7¾m in 1952.

In the pre-war days with a small export market some 90 per cent of the component output went into the making of domestic radio and television receivers, but the extensive development of radio and radar apparatus during the war greatly stimulated the demand for components. The need then was for enormous quantities of the highest reliability and much valuable experience was gained by the component industry in meeting the exacting requirements of the armed services. The post-war demand has shown no signs of slackening and on the contrary is increasing, due no doubt to rearmament, the increasing use of electronic equipment in industry, and to the expansion of television. The manufacture of domestic radio and television receivers accounts for something like 40 per cent of the output of a vastly enlarged component industry, while the remainder is divided about equally between direct exports and home needs for control and measuring apparatus for research and industry, radar and communication equipment.

The annual exhibition, therefore, of the Radio and Electronic Component Manufacturers Federation which comprises all but a few per cent of the component industry, is always an important event and the tenth annual exhibition to be held at Grosvenor House from April 14-16 promises to be the largest of its kind. Nearly 120 exhibitors will be displaying some 300 different types of components ranging from cored solder, tags and screws to complete tape recording decks and rectangular cathode-ray tubes. As we have to go to press about a month before the exhibition opens, details of the individual exhibits are somewhat incomplete at this stage, but even so, enough information is to hand to form a view of major trends and developments, and a preview of the exhibition is included elsewhere in this issue.

No less important is the Physical Society's 37th Annual Exhibition of Scientific Instruments and Apparatus which is being held concurrently from April 13-17 and a welcome feature of this year's exhibition is the return to former practice in locating the whole of the exhibition in the main building of the Imperial College of Science and Technology.

This exhibition, too, promises to break all previous records for no less than 150 exhibitors, including the main research departments of the Ministry of Supply and the Department of Scientific and Industrial Research, will be present.

The main emphasis at this exhibition is, as always, on measurement and the increasing use of electronic techniques in general laboratory and industrial instruments will be much in evidence.

# A Six-Channel Recorder

By A. L. Whitwell,* A.M.Brit.I.R.E.

*In a recent article on Pulse Brightening Discrimination[1], which describes a method of distinguishing the sign of the modulation component in the output of initially balanced bridge circuits without the need for rectifier type demodulators, brief mention was made of a six-channel film recorder operating on this principle. In the present article it is proposed to describe various features of the complete recorder and to indicate typical applications in which the instrument may be employed.*

THE recorder, which is illustrated in Fig. 1, is of the continuous type (i.e. the film is driven at constant speed in front of the images on the various display tubes), and the resultant film trace is a series of graphs, with time as the common abscissa. With the aid of various electromechanical transforming devices, known as transducers, a great variety of physical effects can be permanently recorded on the film so that events which take place so rapidly that direct observation is impossible may be inspected and subjected to detailed analysis after recording. Recording of this type is also useful in circumstances where it is desirable to reduce the amount of direct observation and measurement at the time of the test to a minimum. In aircraft flight trials, for instance, it would normally be difficult, and in many cases impossible, to arrange for simultaneous direct observation of the magnitudes of such typical parameters as airspeed, altitude, wing load and pressure, etc., but the pilot or an observer can record all such factors simultaneously by the operation of a switch controlling a suitable film or telemetering recorder. Alternatively the recording periods may be selected by automatic control to take place under predetermined conditions of flight or synchronized with other instrumentation equipment.

Fig. 1. The six-channel recorder

A schematic diagram of the recorder is shown in Fig. 2 The transducers are provided with balance controls for zeroing in the " no signal " state. Between the output from each transducer circuit and the corresponding amplifier is a relay operated switch which is employed to feed a calibration signal of selected amplitude to the amplifier and display tube. The calibration traces provide reference levels for interpreting the signal traces quantitatively; they also serve as a check to ensure that no variation in the overall sensitivity of the channel has occurred during the recording interval. The latter may occur in certain field applications such as aircraft flight tests when only a limited storage cell capacity may be available. Reference traces of this type also give an unmistakable indication of partial or complete failure of any part of the recording system with the exception of the transducers which have to be checked by other methods. Nevertheless it is a great practical advantage to be able to check the stability of each channel in this manner.

Each channel of the recorder is isolated from the others, consequently there is no possibility of cross modulation between channels operating at widely different sensitivity levels.

Transducer connectors, balance controls, calibration relay, amplifier and display tube for each channel are contained in a compact tray type unit (Fig. 3) which is pushed into the main framework from the rear of the instrument. A reasonable degree of compactness is thus achieved while all components are accessible for examination or replacement. The display unit also contains a reflecting mirror and lens which focuses the image on to the surface of the recording film. The oscillator and discriminator units are constructed on a single chassis, the front panel of which can be seen on the upper right side of the illustration in Fig. 1. Power supplies and timing and event markers are operated by controls mounted on the smaller panel beside the magazine gearbox. The moving-coil instrument above the magazine indicates oscillator output voltage.

The remote control unit shown in Fig. 4 is conveniently small and can, for instance, be strapped to an observer's knee during flight tests. It may be used with a notepad and stop watch for " on the spot observations ". Controls are provided for mains switching, recording, and manual or automatic calibration. For laboratory measurements where remote operation is not required these controls are duplicated on the power unit panel.

Finally, to complete this brief preliminary description it is perhaps worth mentioning that the recorder may be operated from either 230 volt single phase mains or a 115 volt three-phase supply.

### Transducers and Associated Circuits

A transducer is a device which makes use of one or several of the known methods of converting a physical

* *Formerly Boulton Paul Aircraft Ltd.*

change of state or of motion into a proportional change in any convenient electrical parameter. Familiar examples are the change in potential or resistance caused by displacement of the wiper of a variable resistor or potentiometer, the E.M.F. developed when the junction of a thermo-couple is heated and piezo-electric and magnetrostriction effects, etc. A very great number of such devices exist and it is a matter of some difficulty to decide to what extent a practical recording system should be self-contained so far as transducer supplies and controls are concerned. The recorder described here is intended for the measurement of static and dynamic strain, force, vibration, etc., in a field where the frequency spectrum of major interest ranges from zero to one or two hundred cycles per second. Transducers for work of this type include the wire resistance strain gauge, the differential inductor, variable transformer and wire track potentiometers, etc. Provision is therefore made for transducers having electrical circuits of the general type indicated in Fig. 5. In order to extend the usefulness of the equipment for special applications, the internal wiring to the transducer controls and amplifier is arranged to enable alternative input circuits to be employed between the display unit and the transducer if these should be required. Typical circuits are shown in Figs. 5(b) to (e). In these diagrams the transducer elements are distinguished by rectangular enclosures and the connexions to the display unit are indicated by reference to the connector coding in Fig. 5(a). At points where two code letters are coupled together such as B-A in 5(c) it is necessary to short-circuit the two points at some convenient external junction.

With the exception of the self-generator type, all the transducers shown are supplied with A.C. In type (a) the transducer output voltage will be proportional to the input amplitude and to the displacement of the wiper of the potentiometer. The output voltages for the differential transformer and the bridge circuits will usually be proportional in amplitude and phase to the magnitude and sign respectively of the operating force or displacement. Under dynamic conditions the output from the potentiometer is an amplitude modulated wave which, in the limit approaches 100 per cent modulation depth, while the output from the other transducers corresponds to an amplitude modulated wave with the carrier suppressed. It is unnecessary to demodulate either type of waveform before recording providing that some means of distinguishing the phase of the carrier is available. This is achieved in the present instance by means of the discriminator in which two brightening pulses are derived during each carrier frequency period and applied to the cathode-ray display tube grids to modulate the brilliance of the displays. The pulses are arranged to be of short duration and variable, controlled, phasing with respect to the carrier frequency so that brightening of the trace can be made to occur at the peak and zero amplitude point of the carrier frequency component of the modulated waveform respectively.

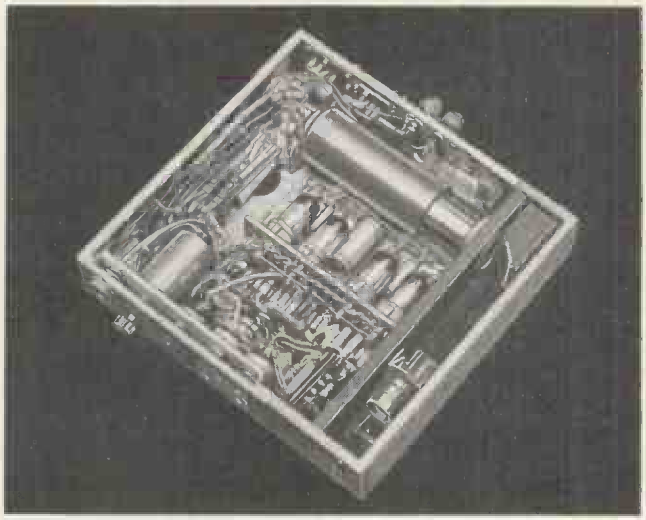
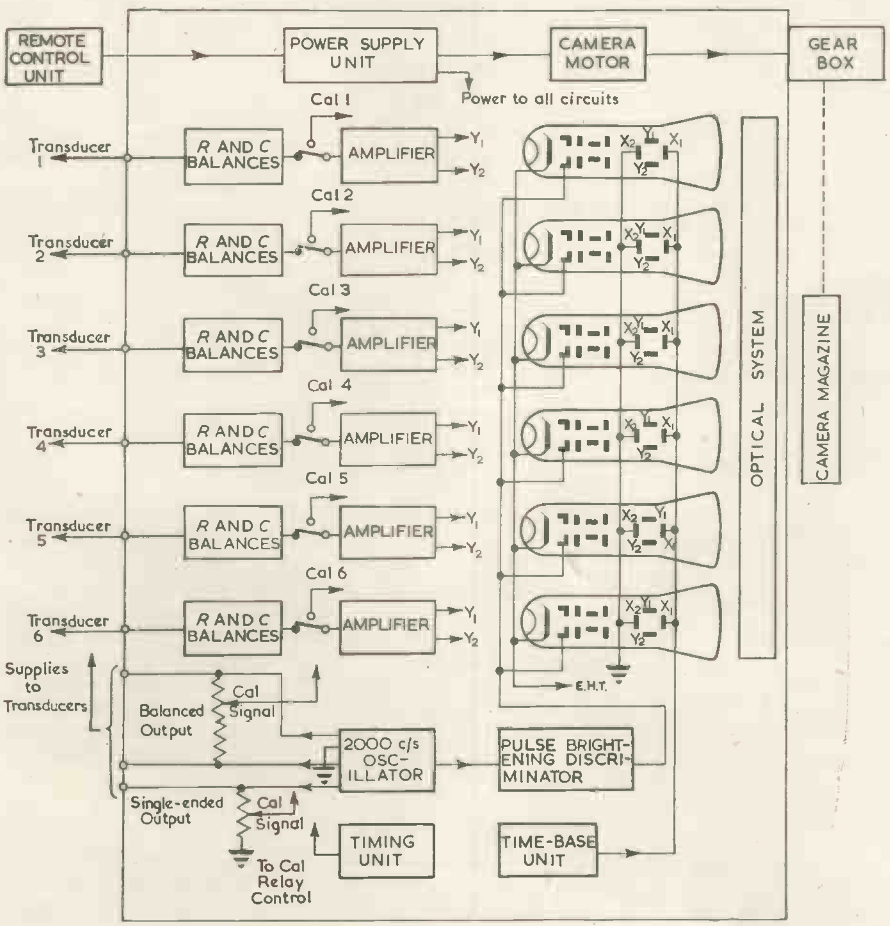


Fig. 3. Single-channel tray unit

Fig. 2. Block diagram of the recorder




## Calibration

The underlying principle of the calibration arrangements is that all transducers can be assigned a sensitivity factor which defines the magnitude of the output voltage as a proportion of the voltage supplied to the transducer from the carrier frequency oscillator. For example, let us suppose a certain pressure transducer has a sensitivity factor of 0·01 measured at a pressure of one pound weight per square inch. If the transducer is operated at a pressure

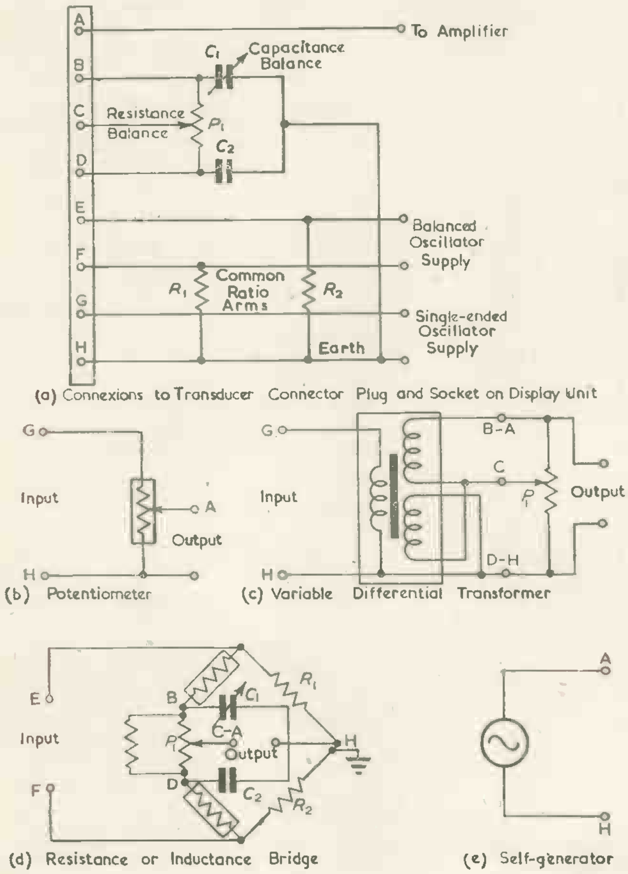
Fig. 4. Remote control unit

of 5 lb./sq. in. and has a supply of 10 volts R.M.S., the output would then be $10 \times 0{\cdot}01 \times 5 = 0{\cdot}5$ volts. In order to determine the true pressure from the magnitude of the deflexion of the trace on the display tube it is convenient to compare this deflexion with that due to a known proportion of the transducer supply voltage termed the "calibration factor". The pressure is then simply the product of two ratios or:

$$\text{Pressure} = \frac{\text{Pressure trace amplitude}}{\text{Calibration trace amplitude}} \times \frac{\text{Calibration factor}}{\text{Sensitivity factor}}$$

It should be particularly noted that this result is

Fig. 5. Transducer circuit arrangements




independent of the absolute sensitivity of the amplifier and recorder or the voltage supplied to the transducer circuits, consequently long-term changes in recorder sensitivity and supply voltage do not affect the accuracy of film analysis.

A diagram of the calibration circuit is shown in Fig. 6. For convenience the calibration and signal switching circuits are included in the diagram although, in practice, they are contained in the display unit chassis. Two electrically isolated carrier voltage supplies are available from the oscillator unit, one is used for bridge circuits and is balanced with respect to earth by means of ratio arms which are common to all the transducer circuits operating from the balanced supply; the alternative supply is "single-ended" with respect to ground and is suitable for supplying power to transducers which operate as potentiometers or transformers.

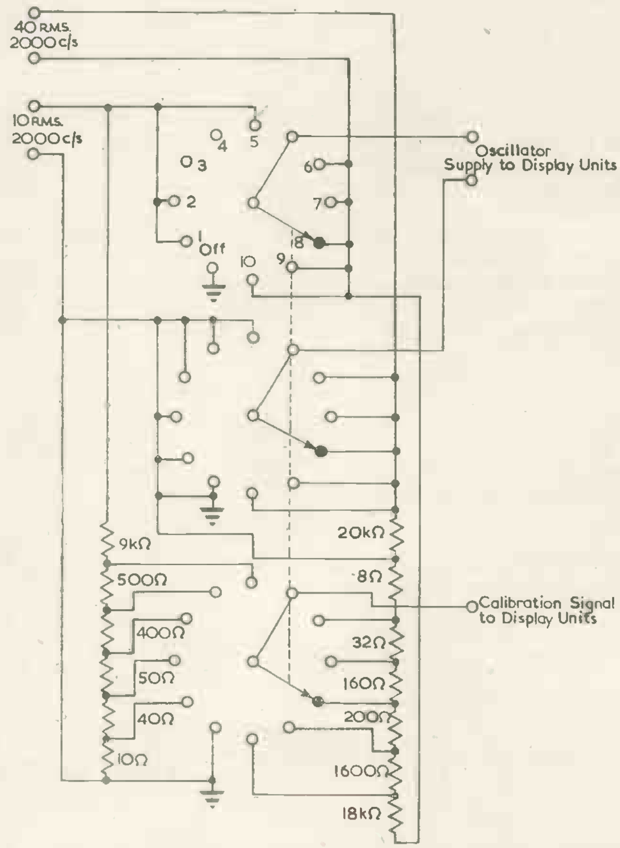



Fig. 6. Calibration switch circuit.

*(Repeated six times using same chain of calibration resistors)*

Each channel of the recorder is provided with an 11-position calibration selector switch, which is also ganged to a two-pole switch for selecting the oscillator supply. Positions 1-5 of the single ended supply provide calibration signal levels of 0·1, 0·5, 1·0, 5·0 and 10 per cent of the supply voltage, while the corresponding levels available on the balanced supply are 0·02, 0·1, 0·5, 1·0 and 5·0 per cent. Different levels are available, because in general the bridge type transducers are less sensitive than the potentiometric or transformer types.

## Oscillator and Discriminator

As mentioned previously, a 2kc/s supply is provided for operating the transducers, calibration circuits and the discriminator units. A Wien bridge oscillator $V_1$ (Fig. 7) is followed by an amplifier and phase splitter $V_2$ which supplies the push-pull output stage $V_{3,4}$. The output transformer $T_2$ has two main secondary windings which provide a maximum of 40 volts and 10 volts R.M.S. for the balanced and single-ended outputs respectively. A small tertiary winding provides negative feedback over the amplifier section of the oscillator.

The discriminator is supplied from a separate output stage $V_5$ in order to eliminate the possibility of interference between the two circuits. Two centre-tapped secondaries on $T_1$ have phase shifting networks $C_{18}VR_5$ and $C_{19}VR_4$ respectively. The component of the primary impedance of $T_1$ due to the secondary load will depend to a certain extent on the position of the wipers of the two potentiometers. While this effect is of no concern in the circuit arrangement shown here, serious changes in the balance conditions for transducer circuits could occur if the phase shifting networks were coupled into the oscillator output stage, primarily because the effective source impedance of the spectrum of the modulated waveform. If, for instance, there was a significant third harmonic component of the carrier frequency having unit amplitude, the maximum velocity of which would therefore be $4\,000\pi$ units per second, a pulse having a duration of two microseconds would extend over about 0·025 amplitude units.

**Display Unit**

The various circuits associated with the oscillographic displays are assembled within a flat, rectangular chassis (Fig. 3) which is fitted into the main unit framework from the rear and held firmly in position by means of guide flanges on the frame and rubber pressure pads on the back-plate. A circuit diagram of the unit is shown in Fig. 8.

The output from the transducer is connected via the relay calibration switch contact to a four-stage amplifier which has a frequency response which is level within $\pm$ 1db between 50c/s and 20kc/s. This performance is more than adequate for accurate reproduction of carrier sidebands

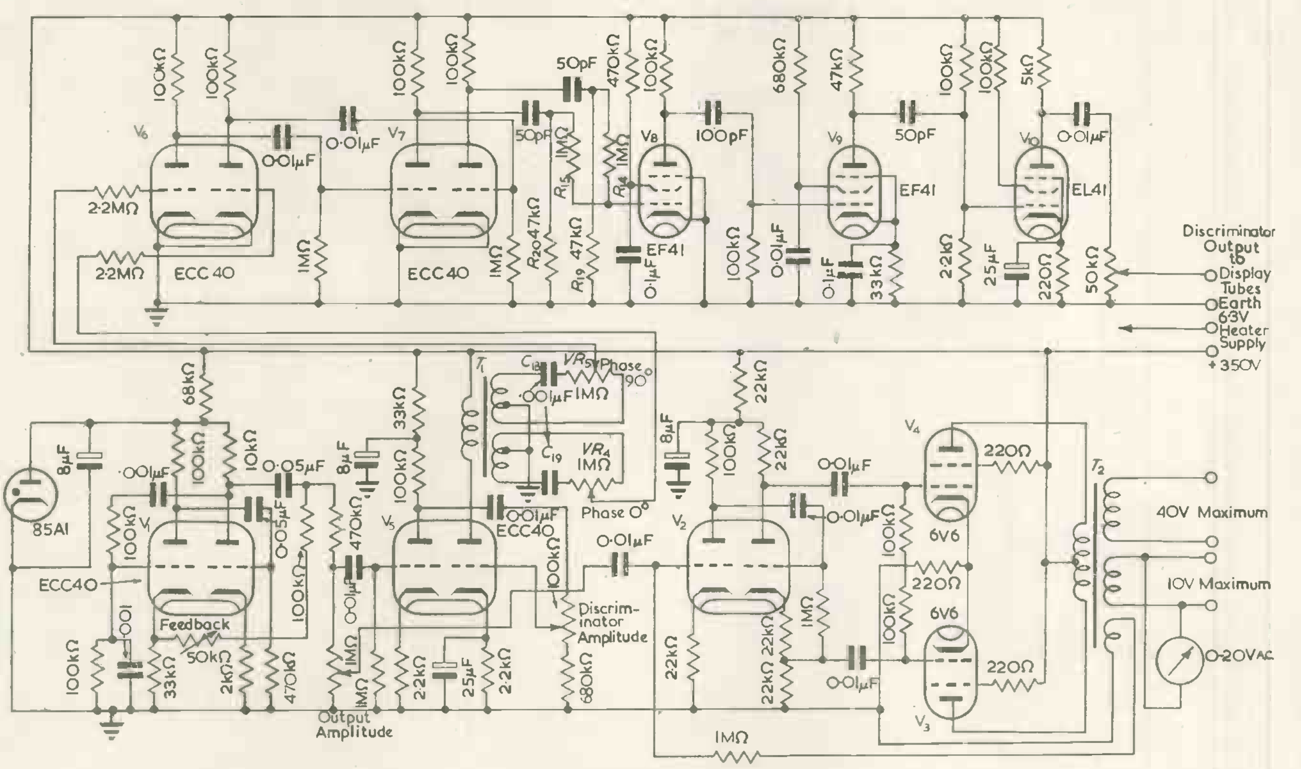



Fig. 7. The oscillator and discriminator units

the oscillator balanced supply would vary with discriminator phase adjustment. The phase-adjusted signals from $VR_4$ and $VR_5$ are amplified by the first two stages of the discriminator unit, $V_{6a}$, $V_{7a}$ and $V_{6b}$, $V_{7b}$ respectively. Squared waveforms are produced at the anodes of $V_7$ due to the current saturation limiting effect of this valve. The two pulses are then differentiated by the networks $C_4R_{20}$ and $C_3R_{19}$ and added through the common junction of $R_{15}$ and $R_{14}$. After further amplification and differentiation in stages $V_{8,9}$ and $V_{10}$ pulses of approximately 30 volts amplitude and two microseconds duration are produced at the anode of the output stage.

The ability of pulse brightening to discriminate against the presence of third and higher harmonic components of the bridge residual has previously been described[1], but this purpose can only be achieved if the brightening pulses are of very short duration in comparison with the period of the highest effective frequency component included in in the region 1 800 to 2 200c/s. The maximum effective voltage gain of the amplifier is about 100 000 and full screen deflexion on the display tube can be obtained for an input of one millivolt R.M.S. Both amplifier and display tube circuits are designed in accordance with normal practice. It is perhaps worth noting that it was found necessary to feed the discriminator brightening pulses to the grid of the display tubes via 80Ω coaxial feeders in order to preserve the discriminator pulse shape.

A noticeable feature of the unit is the arrangement of the various components to provide reasonable accessibility, even though a considerable degree of compactness is achieved. The chief mechanical features are as follows:—

The four-stage amplifier is built as a complete sub-assembly on a plate which is provided with anti-vibration mountings, in order to minimize valve microphony, for attachment of the unit to the base-plate of the display unit sub-chassis.

Transducer balance controls and plug attachment, together with the calibration relay, are fixed in a convenient group arrangement near the inner front part of the sub-chassis.

C.R.T. electrode control potentiometers and their associated circuits are grouped along the inner front facing edge of the sub-chassis.

The cathode-ray tube is mounted at right-angles to the axis of the camera lens and a 45° mirror is used to deflect the object path through 90°. This arrangement enables a considerable saving in space to be made.

A screwdriver adjustment is provided to allow the lens position to be adjusted so that perfect focusing of the image on to the film surface can be obtained.

Anastigmatic lenses are employed in this unit so that a high degree of optical accuracy is obtained. The image and object distances give an optical reduction of approximately 25 per cent.

**Camera Unit and Recording Arrangements**

A standard R.A.F. type F.24 camera magazine is used for recording purposes. This takes up to 56ft of 5½in. film and may be loaded on to the recorder and removed in daylight, although a dark room is necessary for loading the cassettes inside the magazine housing. Film speeds can be provided up to a maximum of 18in./sec. The prototype equipment has four speed ranges, ½, 3, 9 and 18in./sec. Gear boxes are interchanged when it is required to alter the film speed.

The recorder may be remotely controlled from any convenient position by the control unit (Fig. 4) which is sufficiently small to be strapped to an observer's leg during flight, and also contains calibration and timing controls, note-pad, indicator lights and main control switches. The equipment can therefore be switched on, timing and calibration controlled if required, and films taken during each test run.

A light-shielded ground glass screen is used with the equipment. When this is clipped on to the indicator frame in place of the magazine, the six images can be examined visually and bridge controls adjusted to a null if required. The calibrators can be operated manually so that each channel can be set to the required sensitivity which is determined quite simply by reference to the sensitivity of the transducers and the maximum force to be measured. A suitable calibration signal is then selected and the amplifier gain increased until the maximum signal to be recorded produces full scale deflexion on the screen (i.e., 0·70in. peak-to-peak).

In order to allow optimum balance and discriminating conditions to be obtained, a time-base, common to all channels, can be connected to the displays. The expanded trace so produced is useful for enabling the waveform of residuals to be observed and the optimum null balance obtained on each transducer. Having obtained the best balance possible, the discriminator contrast control can then be increased to the point where the brightening spots can be seen on the screen. A calibrating signal is then switched manually on to the unit and the "Phase 90°" control on the discriminator adjusted to position the brightening spot at the peak of the sine wave. The "Phase 0" control is adjusted until alternate switching from "Calibrate" to "Signal" causes negligible vertical displacement of the brightening spot. This condition is illustrated in Fig. 9.

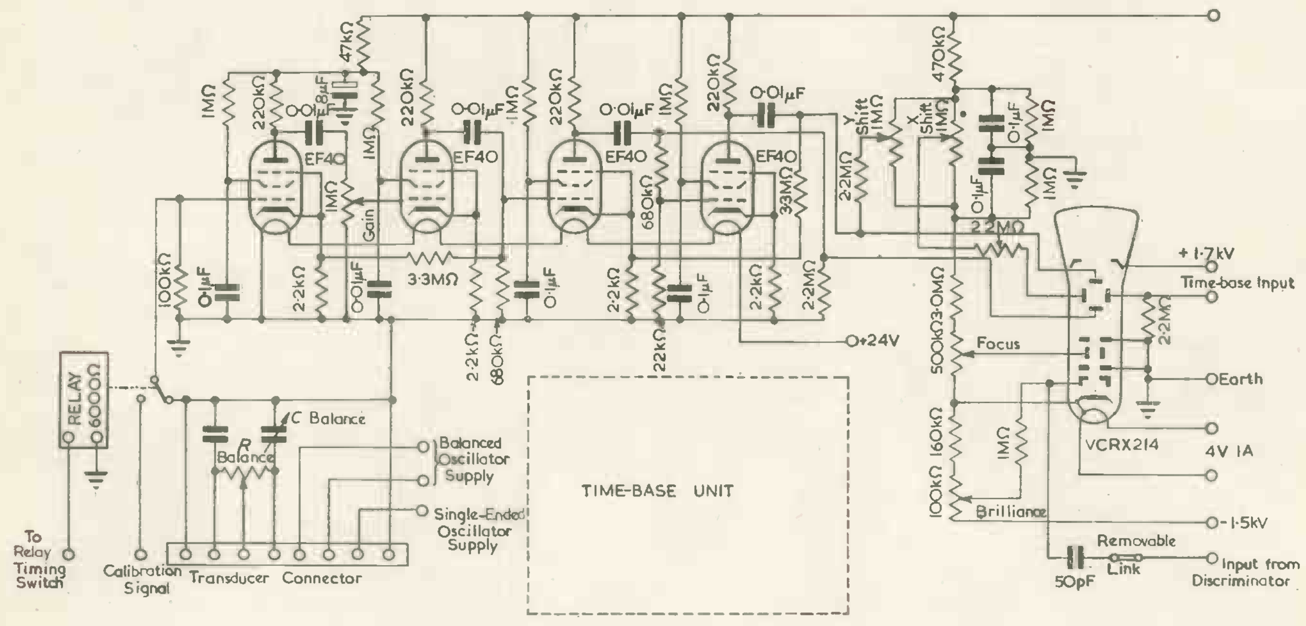



Fig. 8. An amplifier and display unit

**Applications**

Recording equipments for the simultaneous film recording of events on a number of separate channels are employed quite extensively in many present-day engineering measurement laboratories, and in medical and physical research organizations, etc. In the structural measurement laboratory, for instance, film recorders are used for work which includes the following:—

Comparisons of loads, pressures, stresses or movements on points of a structure subject to dynamic vibrations, loads, etc.

Measurements on hydraulic systems to produce force/time graphical histories which enable the performance and efficiency of the system to be assessed.

Hydraulic and mechanical servo-mechanism response (i.e. frequency, amplitude and phase). Examination of transient effects.

Response and dynamic parameters of aircraft power operated controls, jacks, actuators, etc. Response under static load conditions in the laboratory or while in flight.

Load measurement on aircraft control surfaces, dive-brakes, linkages, landing gear, etc.

Investigation of incipient structural vibration in flight. Effects of impact and acceleration.

INCORRECT SETTING

CORRECT SETTING

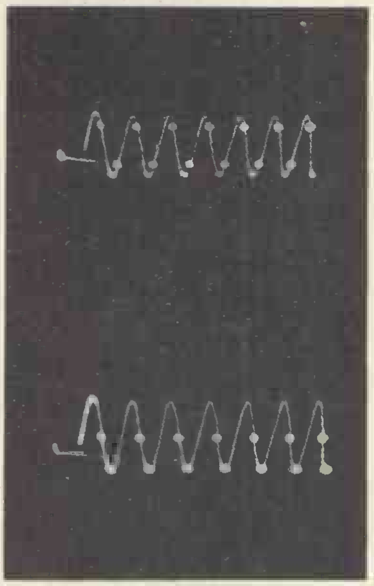


Fig. 9. Setting up discriminator

Relative movements of control surfaces and actuators.

Vibration measurements on the ground for general vibration analysis. (In this connexion it is interesting to note that since the recorder reproduces the modulation waveform of the vibration exactly, it is possible to distinguish between harmonic components of the vibration. Thus this system has an important advantage over certain other methods which merely give an indication of the R.M.S. value of the modulation waveform.)

An example of a recording obtained during an aircraft ground resonance test is shown in Fig. 10. In this reproduction, the various calibration signals are shown together

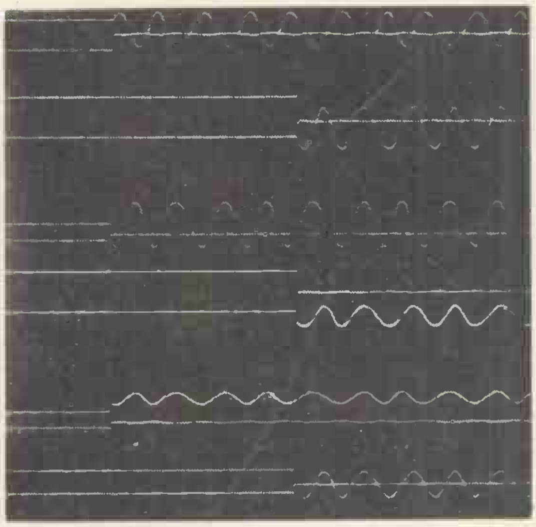


Fig. 10. Typical vibration recording

with a short specimen representing the response of six major points on an aircraft structure to a forced vibration.

**Acknowledgment**

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REFERENCE

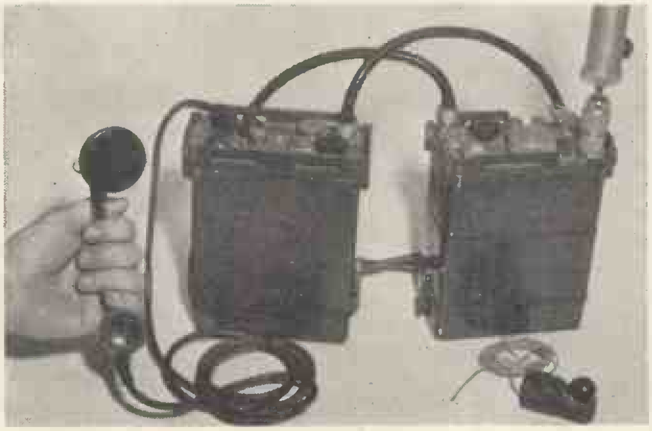
1. WHITWELL, A. L. Pulse Brightening Discrimination. *Electronic Engng.* 24, 362 (1952).

## NEW AUSTRALIAN PACK-SET

*Amalgamated Wireless (Australasia) Ltd. have recently gone into production on a new pack-set which has been designed by the Army branch of the Australian Department of Supply.*

*This transmitter-receiver, complete with batteries, can be carried in two ammunition pouches on a signaller's belt. The weight of the prototype equipment was 17lb, but this has since been reduced to 15lb.*

*A broad bandwidth is used to facilitate the speedy establishment of contact. Used as a pack-set with a whip aerial it has a range of about 5 miles, while set up as a ground station with a somewhat more elaborate aerial it has a range of 50 to 100 miles.*



# The Investigation of Ionospheric Absorption by a New Automatic Method

**(Part 1)**

## Measurements on Vertical-Incidence Pulse Signals

By J. B. Jenkins*, M.Sc., and G. Ratcliff*, M.Sc.

*The present manual method of measurement of ionospheric absorption is discussed and it is shown that the method suffers from several drawbacks. A new equipment is described which carries out the measurements automatically and this system is shown to be far superior to the manual system. The new equipment produces a permanent record in the form of a pen recording. It is anticipated that the equipment might find application in other fields where the pulse method is used.*

THE method of measuring absorption to be described is applicable to the pulse method of ionospheric investigation.

Pulses of radio frequency energy are transmitted at vertical incidence at a repetition rate related to the supply frequency, in this case 50 per second. The pulse width, which determines the resolution obtained between adjacent ionospheric layers, is of the order of 500$\mu$sec.

At the receiver a pulse is received over the short ground path at the instant that the pulse is transmitted. The transmitted pulse will, in general, be reflected from an ionospheric layer and this echo pulse will be picked up by the receiver after a time interval $T$ proportional to the apparent height of the reflecting layer.

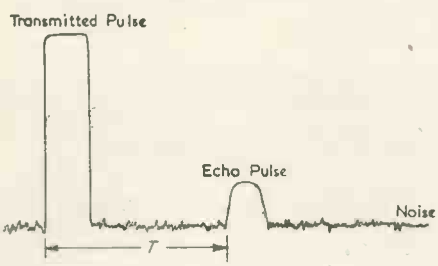



**Fig. 1. A typical pulse display**

If the output of the receiver is displayed on a cathode-ray tube it will appear as shown in Fig. 1.

A measurement of the echo pulse amplitude will enable the energy absorbed from the transmitted pulse in its path to and from the reflecting plane to be determined. The shape of the echo pulse, when received, may have been considerably modified and it is necessary to arrive at an average value of the amplitude of each echo pulse.

The average amplitude of individual echo pulses will be found to exhibit certain short-term variations and, in order to be able to perceive general trends in absorption, it is usual to derive a mean value of echo pulse amplitude over a period of, say, one minute.

The method at present in use is for an operator to observe the amplitude of the echo pulse on a cathode-ray tube display and to note down, at perhaps 10-second intervals, what he judges to be a mean amplitude. Six such readings may then be averaged arithmetically to give a mean figure for a one-minute period.

Ionospheric pulse transmissions use normal broadcast frequencies and further, the maximum power transmitted is limited by local regulation. When making ionospheric observations conditions of poor signal-to-noise ratio are thus often unavoidable.

The presence of large spurious signals renders it very difficult to make reliable estimates of echo pulse amplitudes from cathode-ray tube displays. The presence of spurious signals also raises the position of the echo signal which leads to over-estimation of echo amplitudes. Further, it will be observed that the method just described is essentially a sampling process and while it may be admissible when the echo pulse amplitude is varying slowly, it becomes unreliable under conditions of rapid fading.

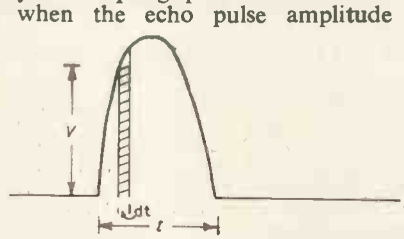



**Fig. 2. Simplified diagram of a typical echo pulse**

The method suffers the further disadvantage of requiring the continuous concentration of a skilled operator and results may well be dependent on such factors as skill, experience and fatigue.

An equipment is now described which automatically measures echo pulse amplitude and produces in permanent form a series of discrete recordings at minute intervals. Each recording represents the summation of all echo pulse amplitudes received over that minute period.

### Measurement of mean Echo Pulse Amplitude

The mean amplitude of an echo pulse may be measured by integrating the signal. Thus, if the pulse shown in Fig. 2 is applied to an integrating circuit, the integrator delivers an output proportional to $\int_0^t Vdt$, and if the pulse duration is constant for every pulse, each measurement

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can be considered to give an output proportional to the mean pulse amplitude.

Consider now the injection of $n$ pulses distributed at $1/50^{th}$ second time intervals. At the end of the first pulse the integrator output will be proportional to the mean amplitude of the first pulse. While no signal is applied between first and second pulses, the integrator output remains substantially constant at this value. The second pulse contributes an increase to the integrator output which is proportional to the mean amplitude of the second pulse. If the first, second—and $n^{th}$ mean pulse amplitudes are $V_1$, $V_2$—and $V_n$ then the integrator delivers an output proportional to:

$$(V_1 + V_2 \ldots\ldots\ldots + V_n)/n$$

which is the average of the mean amplitudes of $n$ pulses. In practice, an integration period of one minute is allowable, for which $n = 3\,000$.

This method of measurement is obviously superior to the sampling process used in the manual method since it takes into account the average amplitude of every echo pulse received.

If spurious signals are present with the echo signal then these would be integrated together with the echo signal and would introduce errors into the measurement similar to those existing in the manual method.

The effect of spurious signals may be balanced out if a sample of these signals taken from a part of the time scale in which there is no echo pulse is fed into a second exactly similar integrator. The difference between the outputs of the two integrators will give a measure of the echo pulse amplitude independent of the spurious signals. Thus, let the echo signal be denoted by $V$, and let the spurious signals be denoted by $n$.

Then:—

Input to first integrator $= V + n$

Input to second integrator $= n$

Output from first integrator $= \int_0^t V dt + \int_0^t n dt$

Output from second integrator $= \int_0^t n dt$

Difference in integrator outputs $= \int_0^t V dt$

## Principles of Operation

A block schematic diagram of the complete equipment together with the waveforms appearing at certain points in the circuit is shown in Fig. 3.

The receiver output would normally be as shown in Fig. 1. It was found that the presence of the large transmitted pulse caused difficulties in the receiver and in the other circuits and it was found necessary to disable the receiver during the period when a pulse is being transmitted. Thus, the receiver output is as shown at L in Fig. 3.

It is now necessary to select two portions of this signal, one which includes the echo and its associated noise for feeding to one integrator, and the other which includes noise signals only for feeding to the second integrator.

Selection of a portion of the signal is performed by passing the signal through a special amplifier, known as a gated amplifier, which is operative for a short period only, the operative period being determined by a selector pulse injected into the amplifier.

Thus the signal from the receiver is supplied to two gated amplifiers which are respectively controlled by the selector pulses M and N in Fig. 3. If these selector pulses are properly adjusted then one integrator may be supplied with the echo signal and attendant noise as at O and the other integrator supplied with a sample of noise from another portion of the time scale as at P.

For the noise balancing arrangement to operate correctly it is imperative that the time duration of the signals O and P supplied to the integrators (and therefore the time duration of the selector pulses M and N) must be equal. These time durations must exceed the pulse width of the echo signal.

Finally, after integration has proceeded for a period of one minute, the difference in the output voltages of the integrators is applied to a pen recorder. Both integrators are then reset to zero and integration recommences for a second minute interval. These switching operations are performed by the timing circuits controlling appropriate relays.

## Circuit Details

Circuit diagrams of sections of the equipment are shown in Figs. 4(a) and 4(b). It is to be noted that some circuits are duplicated in the complete equipment.

The various sections of the apparatus may now be considered in greater detail.

### Synchronization

It is necessary to synchronize the operation of a number of circuits with the sending out of the transmitted pulse; accordingly, a trigger impulse coinciding with the leading edge of the transmitted pulse is derived from the transmitter modulation circuits in one case, and in another case from the mains voltage.

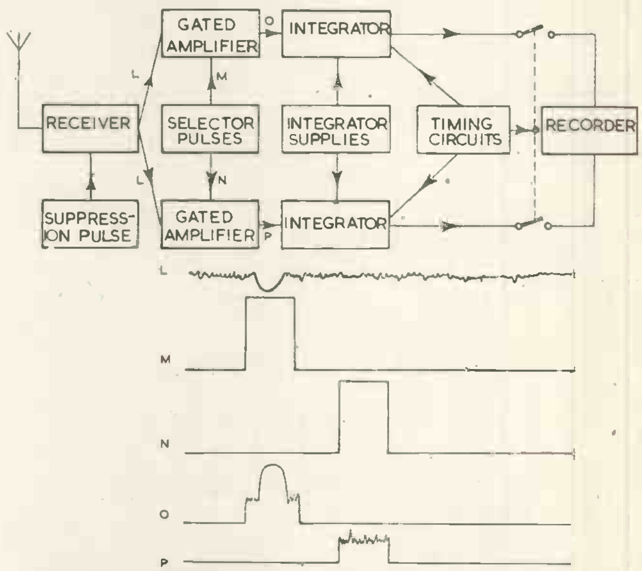


Fig. 3. Block schematic diagram of the circuits with some waveforms

### The Receiver

The receiver is a standard communications receiver which has been modified for this particular application. The modifications made are as follows:

(a) In order to reduce the distortion of the echo pulses to a minimum, the pass-band of the receiver was widened by damping the I.F. transformers. Also, the time-constants of the detector circuit were considerably reduced.

(b) The receiver was disabled during transmission by applying a pulse of $-100$ volts to the suppressor grid of the final I.F. valve. This pulse is derived from a multivibrator circuit $V_8$ which is initiated by the trigger pulse from the transmitter. One half of $V_9$ is used to correct the D.C. level of the pulse. It is important to notice that the width of the pulse which is controlled by $R_{33}$ should be at least as great as the width of the transmitted pulse.

(c) To prevent the transmitted pulse desensitizing the early stages of the receiver all A.V.C. filter capacitors were short-circuited.

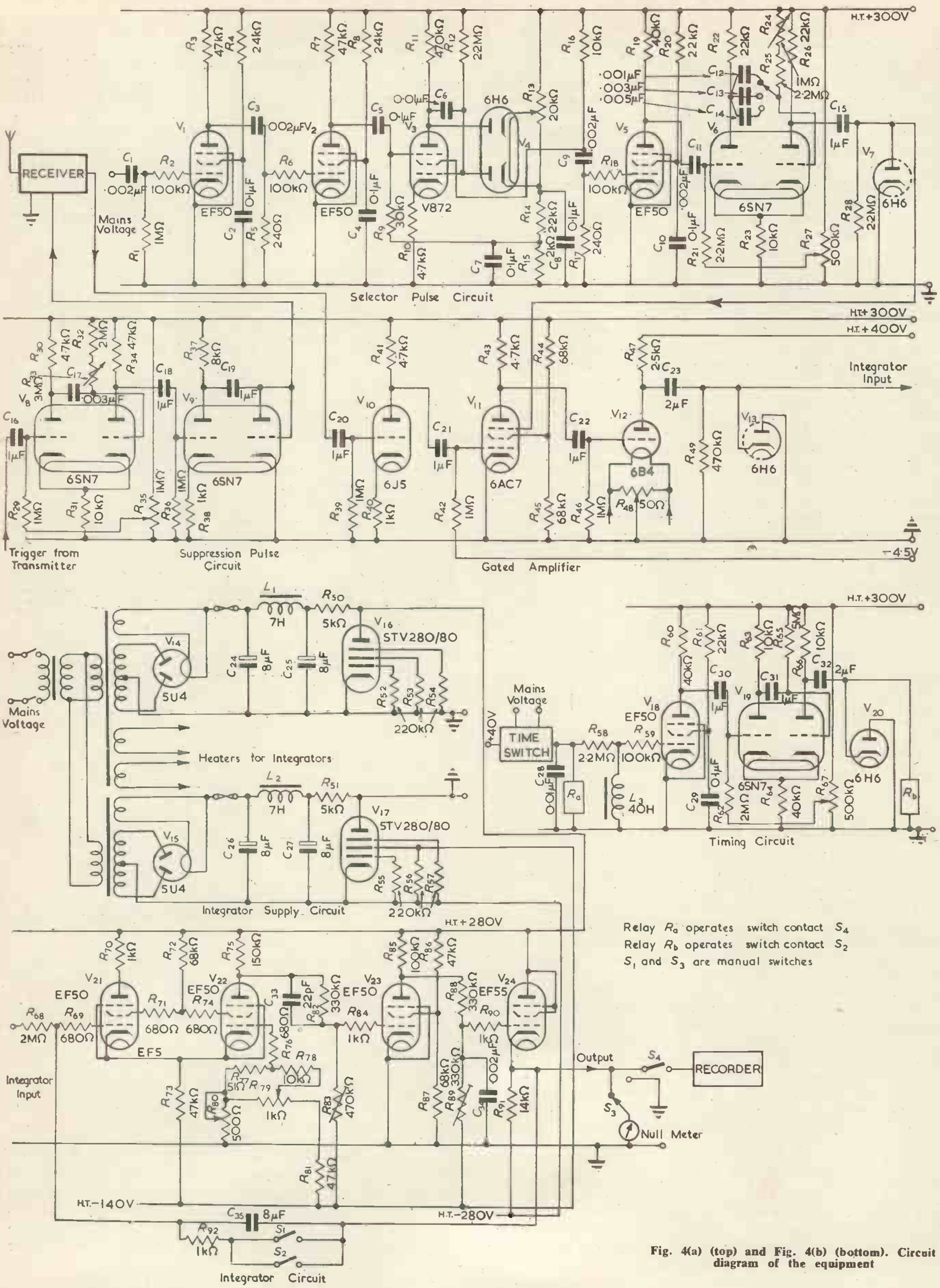


**Fig. 4(a) (top) and Fig. 4(b) (bottom). Circuit diagram of the equipment**

(d) The original continuous gain control was replaced by a calibrated step gain control.

## Selector Pulses for Gated Amplifiers

A trigger impulse derived from the mains voltage is used to initiate the operation of the phantastron circuit $V_5$ which is capable of producing a controlled delay.

A trigger derived from the phantastron is used to initiate the multivibrator circuit $V_6$, the pulse from which, after D.C. restoration in $V_7$, is used to operate the gated amplifier. The circuit is, of course, duplicated in the complete apparatus.

The position of the selector pulse in the time scale depends on the delay produced by the phantastron and is controlled by $R_{13}$. The selector pulse width depends on the multivibrator and is controlled by capacitors $C_{12}C_{13}C_{14}$ and resistors $R_{24}R_{25}$.

## The Gated Amplifier

The requirements of the gated amplifier are somewhat rigorous. It is required to:

(a) provide a phase change of 180°;

(b) provide a large output level to feed the integrators;

(c) include a means whereby it is normally inoperative but may be brought into operation by an injected selector pulse;

(d) be capable of providing linear amplification (when operative) for a very large range of signals.

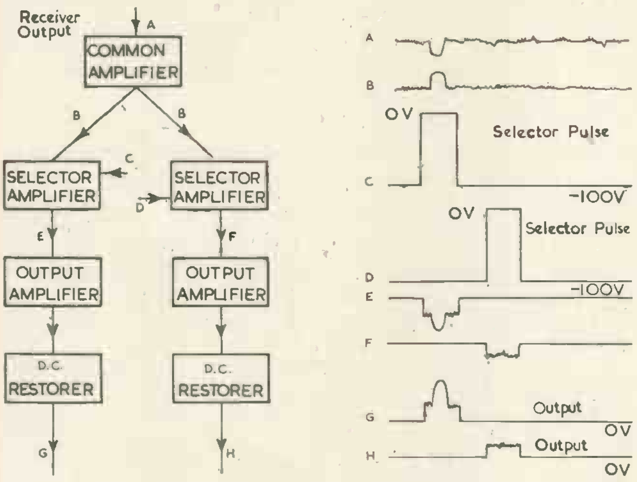


**Fig. 5. Block schematic diagram of the gated amplifier with waveforms**

The block schematic diagram of Fig. 5 illustrates the stages involved in the gated amplifier and the waveforms corresponding to each stage. The circuit diagram for the gated amplifier is shown in Fig. 4(a). The gated amplifier is seen to be in three stages.

A common amplifier $V_{10}$ with a low gain reverses in phase the receiver output as illustrated by waveforms A and B. The common amplifier output is resistance-capacitance coupled to the grid of the selector amplifier $V_{11}$ held at a potential of $-4{\cdot}5$ volts. Because of capacitance coupling, variations of the signal amplitude to this grid cause variations of the bias potential and if the transmitted pulse were not suppressed in the receiver this pulse would bias back the selector amplifier grids below cut-off.

The signal input to the selector amplifier must not exceed 4·5 volts so that the receiver gain control setting is important. A gain of 2·5 for the common amplifier and a maximum receiver output of 1 volt ensures that all signals will be linearly amplified; at the same time a factor of safety of $4{\cdot}5/2{\cdot}5 = 1{\cdot}8$ is contained in the selector amplifier. Whenever measurements are taken a receiver gain control setting must be chosen so that the maximum signal output does not appreciably exceed 1 volt.

The valve in the selector amplifier cannot conduct when its suppressor grid is held at $-100$ volts; however, conduction in the valve will take place when the suppressor voltage rises to zero volts. The amplifier output shown in waveform E is seen to consist of signal superimposed on a "pedestal" voltage, the pedestal voltage being caused by the change in valve conduction due to the selector pulse voltage.

The output amplifier $V_{12}$ has a long grid base to accommodate large signals, and this amplifier delivers positive-going signals to the D.C. restorer circuit $V_{13}$ which fixes the lower level of the signals at zero volts.

From the waveforms shown in G and H it is obvious that a new voltage, that is a pedestal voltage, has been introduced which requires cancellation after integration. However, by using equal selector pulse widths and identical amplifiers the pedestals give rise to equal integrator outputs. Although amplitude variation of waveform B affects the biasing potentials at the selector amplifier grids, and consequently the pedestal voltages, waveform B is the common input to both amplifiers so that both pedestal outputs vary in the same way.

In the complete circuit stages $V_{11}$, $V_{12}$, and $V_{13}$ are duplicated.

## The Integrator Circuit

The circuit used for the integrator has been described in a previous paper[1]. The circuit diagram is shown in Fig. 4(b) and in the final equipment this circuit is duplicated.

Testing of this circuit indicated that a linear relationship existed between the integrator output and the product (pulse width × pulse amplitude). Since in absorption measurements the pulse width remains substantially constant, the integrator output bears a linear relationship to the pulse amplitude. Values of $R_{68} = 2\text{M}\Omega$ and $C_{35} = 8\mu\text{F}$ were eventually adopted; these values ensure that the integrator output does not "bottom" for maximum input signals over an integration period. In order that the integrating capacitor may be able to retain its charge accurately for a long time the capacitor must have low leakage and selection from a batch of capacitors was necessary. However, as the capacitor charge builds up, even low leakage becomes important, so that long period integration and accurate integration become incompatible factors.

An integration period of one minute represents the maximum period for which accurate measurements hold. The integrator may be reset to zero output by direct shorting of the capacitor, but to prevent deterioration it was considered desirable to shunt the capacitor with a 1 000Ω resistor for this purpose.

Drift was encountered in the initial "breadboard" model and care had to be taken to reduce the drift to negligible proportions in the final model; precautions taken included isolating the power unit from the integrator circuits, choosing low leakage components and keeping filament wirings as short as possible. The two integrators required are mounted on the same chassis and are as nearly identical as possible.

The integrator supplies are stabilized in two stages; a constant voltage transformer is used for A.C. stabilization. The stabilized A.C. is fed to the rectifying system which incorporates stabilovolt tubes for stabilizing the H.T. supplies. Using this system the maximum voltage variation encountered in H.T. supplies is 0·033 per cent for a mains variation of 5 per cent.

## Timing Circuits

A time switch, the contacts of which close for two seconds every minute, is used to operate relay $R_a$ thereby applying the difference of the integrator output voltages to the pen recorder.

To reset the integrators to zero, relay $R_b$ short-circuits the integrating capacitor terminals through resistors $R_{92}$. A trigger impulse is derived from the trailing edge of the voltage pulse operating $R_a$. The trigger impulse initiates operation of multivibrator $V_{19}$, the output of which is applied to $R_b$ thereby resetting the integrators after the pen recording has been made.

## Performance

### The Spurious Signal Balance Test

In order to test the instruments' ability to give a measurement corrected for the effect of spurious signals the apparatus was tested in the absence of a pulsed trans-

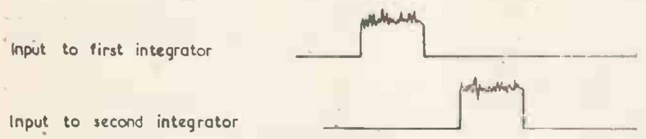


Fig. 6. Integrator input waveforms for the balance test

mission; a receiver frequency was chosen at which large spurious signals, in this case noise signals, were received. Both selector pulses were arranged to gate noise, and the integrator inputs are shown in Fig. 6. The difference in integrator outputs was measured on a pen recorder whose zero was offset to allow the recording of both positive and negative variations.

The record obtained for a test period of 30 minutes shows only very slight variations of the offset zero; the variations involved are so small compared with the variations obtained by normal echo signals that they may be neglected. This justifies the assumption that spurious signals and pedestal voltages can be balanced out.

### The Comparative Method of Testing

The only method by which the overall performance of the equipment may be assessed is by comparison with the manual method since no other standard exists. Both measurements must be carried out simultaneously. The automatic record obtained will consist of discrete recordings at one-minute intervals and the mean of six manual readings may be compared with a discrete automatic recording. Having analysed the manual readings, both sets of results are plotted, and consecutive points for each system of measurement are joined up. The curves obtained are useful in that they clearly show trends. It should be

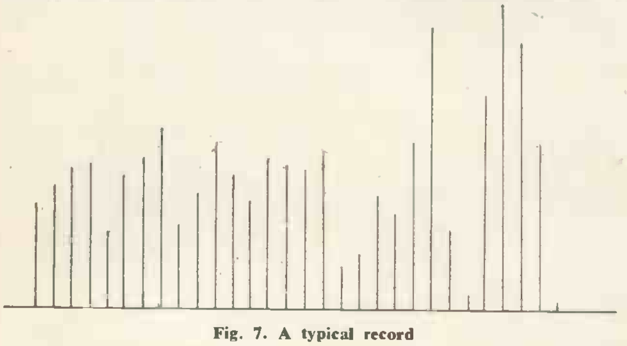

Fig. 7. A typical record

noticed that both scales are arbitrary so that an actual reading on a curve has no direct meaning.

### Measurements Under Good Conditions

This test was carried out under conditions of good signal-to-noise ratio and freedom from rapid fading of the echo pulse. The automatic record obtained is shown in Fig. 7.

Fig. 8 is a plot of the measurements by both methods. Both curves rise and fall at the same times. If the scale of one of the curves were altered so that the mean value of each curve were approximately the same, very few cross-overs would be shown. Thus, under good operating conditions, the automatic method gives readings which are consistent with the manual readings.

### Measurements Under Poor Conditions

During the course of this test a series of difficult conditions were encountered. For the first 10 minutes rapid fading was encountered; this was followed by a six-minute period during which morse signals and heavy noise were received. For the remainder of the test good conditions prevailed. The readings are plotted in Fig. 9.

Under conditions of rapid fading marked divergencies in the two curves are exhibited by the many points at which the curves cross over. Although the general form

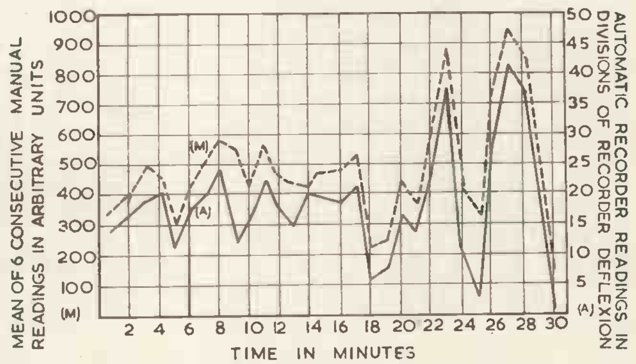


Fig. 8. Curve of measurements taken under good conditions

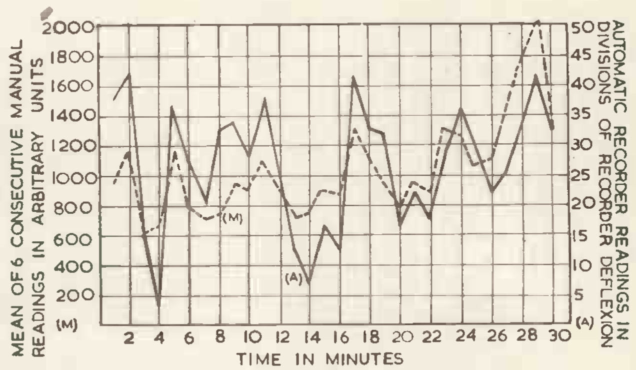


Fig. 9. Curve of measurements taken under poor conditions

of both curves is the same, wide discrepancies can be observed. The same remarks can be extended for the interval between $t = 10$ minutes and $t = 16$ minutes. For the remainder of the test, under good conditions of reception, wide divergencies are still shown but the curves are more in sympathy with one another.

The test shows that under poor conditions of reception wide divergencies between the measurements take place. It does not show that the automatic method is more accurate than the manual method, but considerations of the accuracy of the manual method impose the belief that this method is inaccurate under these conditions. The new equipment was designed to measure every pulse and to be self-compensating for spurious signal reception and this is the justification for stating that the new method is more accurate than the manual method.

### Measurements Under Conditions of Strong Broadcasting Signals

The test was made at a frequency at which strong broadcasting signals were received. During the middle of the test these signals became very severe—conditions under which manual readings would not normally be taken. The two sets of readings are plotted in Fig. 10.

At times the broadcasting signals were comparable to the echo amplitude. Under these conditions an operator invariably reads the peak of the spurious signals instead

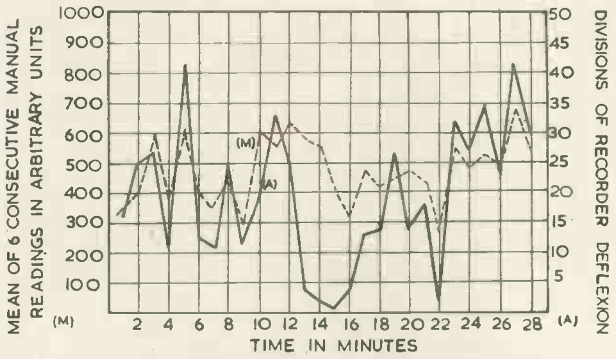


**Fig. 10.** Curve of measurements taken under conditions of strong broadcast signals

of the echo amplitude relative to the spurious signal amplitude. The automatic record should indicate low readings under these conditions. Several points in Fig. 10 actually indicate the compensating properties of the automatic equipment; at $t = 15$ minutes and $t = 22$ minutes this correction is clearly defined.

## Conclusions

Although no experimental proof can be applied to definitely show a greater degree of accuracy in the new method, each individual unit has been tested and its accuracy established so that there is no reason to doubt the accuracy of the overall equipment. The tests illustrate the instruments' ability to make corrected measurements.

Judicious choice of a receiver gain control setting introduces the human element, and this appears to be the one drawback of the method since a wrong choice can lead to the equipment overloading. However, experience has shown that the choice is not difficult to make; all that is necessary is a short period observation of the echo amplitudes with each gain control setting and some experience of the variations likely to be encountered.

It will be readily seen that the principles of operation and the block schematic diagram of Fig. 3 are perfectly general and with certain modifications the technique might well be applied to other fields where the pulse method is used, such as radar, echo-sounding devices and supersonic testing for metal flaws.

*(To be continued)*

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# RADAR ANTENNA BEAMWIDTH


R. C. Coile*


In radar system design, it is necessary to consider the size of the antenna and its effect on the performance of the radar at various frequencies. The resolution of the radar is affected by the width of the antenna and the frequency. The radar antenna beamwidth $\theta$ in degrees is given to a good approximation by the formula[1]

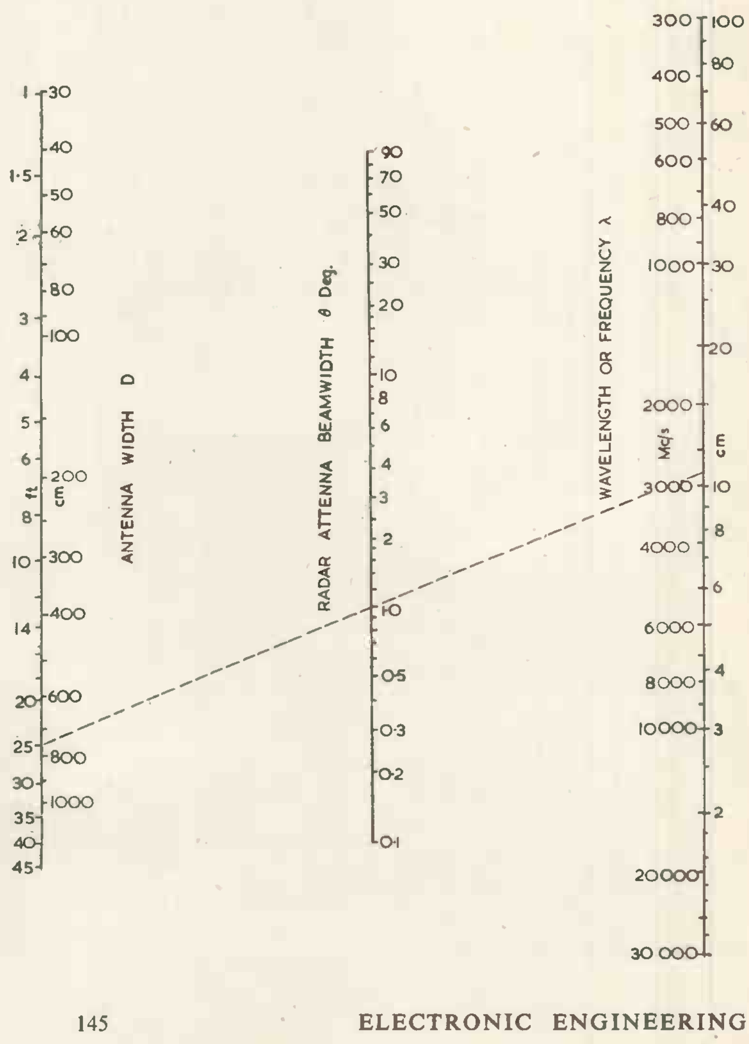
$$\theta = 70 \lambda / D$$

where $\lambda$ = wavelength

$D$ = width of antenna

both measured in the same units.

The nomograph permits rapid evaluation of the effects of various antenna sizes and frequencies of operation on the radar antenna beamwidth. For convenience, the antenna width scale is marked in both feet and centimetres, and the wavelength scale has wavelength in centimetres and frequency in megacycles per second. To find the antenna beamwidth of a radar with an antenna 25 feet wide and operating in the 10·7cm wavelength band, a straightedge laid between 25 feet on the antenna width scale and 10·7cm on the wavelength scale gives the answer of 1·0 degrees on the radar antenna beamwidth scale.

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* *Massachusetts Institute of Technology.*

# Time-Division Multiplex Systems

(Part 4)

## Pulse-Code Modulation

By J. E. Flood*, Ph.D., A.M.I.E.E.

PULSE-CODE modulation systems† were first described by A. H. Reeves[75] in a French patent specification in 1939 and an American specification in 1942. A practical system was demonstrated by the Bell Telephone Laboratories[76] in 1947. In P.C.M. the modulating signal waveform is sampled at regular intervals, as in other methods of pulse modulation, but the samples are transmitted over the system by means of groups of pulses which uniquely represent the values of the samples in some code. At the receiving end, each group of pulses is decoded to reconstruct the corresponding sample of the signal waveform and the train of recurring samples is demodulated to give the waveform.

Because each group of pulses which is transmitted can have only a limited number of possible combinations, the system can transmit only a finite number of amplitude

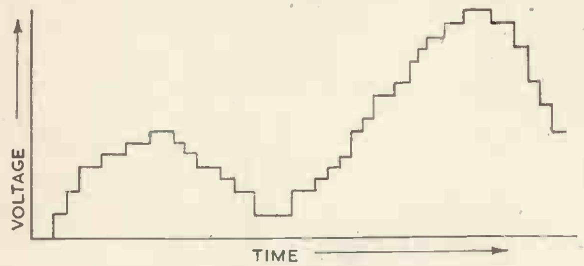

Fig. 33. Quantized signal

gradations of the modulating signal. The effect of this is to replace the original waveform of the modulating signal by an approximation consisting of a series of rectangular steps as shown in Fig. 33. This process is called quantization.

### The Binary Code

The method of coding usually employed is to represent each sample by a group of pulses, each of which can have only two values, it is either " on " or " off ". A group of $n$ pulses can thus represent $2^n$ values; conversely, the number of pulses required to transmit $l$ amplitude levels is $n = \log_2 l$. Each group of pulses represents the sample value in the binary scale of numbers which uses only two symbols, " 0 " and " 1 ".

The number 13, for example, written in the decimal system represents $1 \times 10^1 + 3 \times 10^0$; the same number could be written in the binary system as 01101 which represents $0 \times 2^4 + 1 \times 2^3 + 1 \times 2^2 + 0 \times 2^1 + 1 \times 2^0$, i.e. $0 + 8 + 4 + 0 + 1 = 13$. Fig. 34 shows how this number would be represented by a group of five pulse positions. The different combinations of a group of five pulse positions can represent all the integral numbers between 0 and 31.

The bandwidth $w$ in cycles per second required for the transmission of a P.C.M. system is theoretically equal to half the number of pulses per second which must be transmitted[78]. If the number of channels is $m$, the channel sampling frequency is $f_r$ and the number of pulses which comprise each code group is $n$, the bandwidth required is thus:

$$w = \tfrac{1}{2} mnf_r$$

$$\text{But } n = \log_2 l$$

$$\therefore w = \tfrac{1}{2} mf_r \log_2 l$$

The bandwidth is thus proportional to the number of digits used, and is therefore proportional to the logarithm of the number of quantizing levels ($l$).

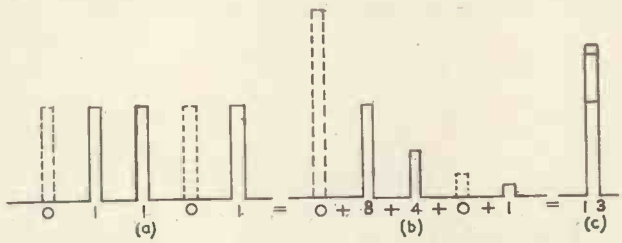

Fig. 34. (a) Binary code group of pulses. (b) Weighted equivalent. (c) Decoded sample

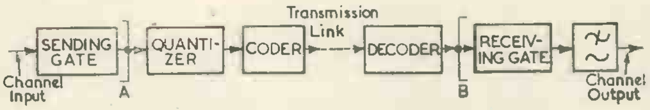

Fig. 35. Basic components of a pulse-code modulated T.D.M. system (one direction of transmission only is shown)

### Methods of Pulse Code Modulation

The essential components of a P.C.M. system are shown in Fig. 35. At the transmitting end, the quantizer and coder can be made common to all the channels of a T.D.M. system; the modulating signals of the channels are sampled by means of gates which are operated by a set of equally spaced pulse trains and the outputs from the gates are commoned to the quantizer at point A. Similarly, at the receiving end a common decoder is connected at point B to gates which are operated by spaced pulse trains so that each sample of signal from the decoder is fed to the correct channel.

Grieg[77] and Black and Edson[80] have described pulse-code modulated T.D.M. systems in which the coding is performed by means of a binary counter as shown in Fig. 36(a). The channel modulators of a pulse-length modulated T.D.M. system feed a common quantizer and coder. The quantizer consists of a gate to which is applied a train of pulses with a very much higher P.R.F. and much shorter duration than the length-modulated pulses. Each length-modulated pulse opens the gate and admits to the coder a number of pulses which is thus proportional to the quantized length of the channel pulse.

The coder consists of a binary counter which counts the number of pulses which it receives and indicates the total

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† *Sometimes called pulse-count modulation.*

by means of the presence or absence of potentials to register "0" or "1" on each of a number of leads. These leads are connected to gates to which are applied pulses which are spaced in time as shown in Fig. 36(a) and which occur in the intervals between the length-modulated channel pulses. Each of the leads which is registering "1" opens the corresponding gate and a group of pulses appear on the common output lead which represent the value of the quantized sample in the binary code. A pulse which occurs immediately after each code group resets each stage in the counter to "0" ready to receive the train of pulses representing the next digit.

At the receiver the incoming code pulses operate a circuit which produces pulses whose lengths are proportional to the "weight" of the digits represented by the incoming pulses as shown in Fig. 36(b). Each group of weighted pulses is received by the appropriate channel gate and demodulated by a low-pass filter.

A disadvantage of the binary counter method of coding is the very high speed at which the counter has to operate,

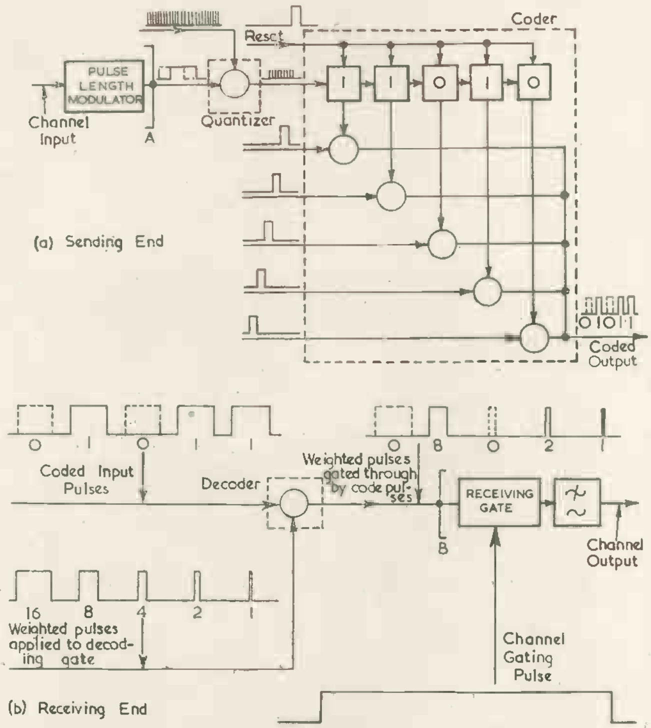



Fig. 36. (a) P.C.M. system using binary counter sending end. (b) P.C.M. system using binary counter receiving end

making it impracticable for a large number of quantizing levels. For example, if the sampling rate for a 10-channel system is 10kc/s and there are 128 quantizing levels, the longest possible channel pulse is 10 microseconds and this will gate 128 pulses through to the counter whose first stage would therefore have to operate at 12·8Mc/s.

Goodall[79] has described a five-digit (32 level) system which uses the principle of feedback subtraction. A block schematic of the system is shown in Fig. 37. The channel modulators are commoned at point A to form a pulse-amplitude modulated T.D.M. system which feeds a common coder. Each amplitude-modulated pulse is applied to a pulse lengthener circuit where its value is stored as charge on a capacitor. The comparison circuit compares the P.D. across the storage capacitor with a reference voltage which corresponds to the amplitude of an unmodulated channel pulse, and therefore represents a height of 16 quanta. If the sample height is greater than the reference voltage the difference is a positive voltage which gates through a short pulse from the pulse generator. This pulse, which corresponds to the digit of weight "16" in the binary code group, is amplified and transmitted, but is also fed back through a delay line to a subtraction circuit which discharges the storage capacitor sufficiently to reduce the voltage across it by 16 units. If the sample height is less than 16 units the difference between it and the reference potential is a negative voltage and no pulse is gated through from the pulse generator. This corresponds to the absence of the digit of weight "16" from the binary code group. No voltage is therefore fed back to the subtraction circuit and no reduction is made in the P.D. across the storage capacitor. The reference voltage is reduced by successive steps, timed by the pulse generator, to 8, 4, 2, and 1 units and a similar comparison with the remaining sample voltage is made at each stage. The group of pulses which are transmitted during this process represent in the binary code the quantized height of the original sample.

At the receiver, a storage capacitor is charged by the pulse generator to the voltage which represents the peak amplitude (31 units). Each pulse which is received causes the charge on the capacitor to be reduced, the charge subtracted by the presence of pulses in successive positions being halved in steps timed by the pulse generator. At the end of each code group, the voltage remaining across the storage capacitor is equal to 32 units minus the height

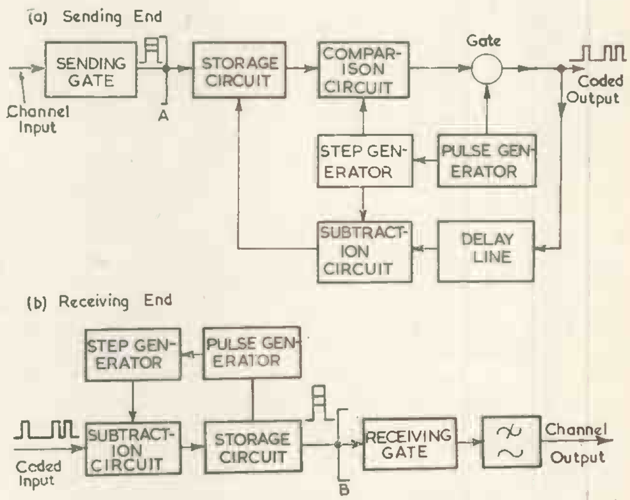



Fig. 37. P.C.M. system using feedback subtraction coder

of the original sample. These reconstructed samples are fed to the receiving gates of the channels which are commoned at point B.

Meacham and Peterson[36] have described a system which uses a special form of cathode-ray tube for the coder. The signal of each channel is sampled every 125 microseconds and the outputs from 12 channel modulators are commoned to form a pulse-amplitude modulated T.D.M. system. Because the operation of the coder takes longer than 10·4 microseconds two coders are provided, each dealing with alternate channels.

The essential features of the coding circuit are shown in Fig. 38 and photographs of the coding tube[81] and its aperture plate are shown in Fig. 39. The aperture plate is perforated with the 128 combinations of 7 binary digits with holes for units and solid metal for zeros. When the electron beam is switched on it is deflected by the stored sample voltage to the corresponding vertical height and is moved across the aperture plate by a linear sweep. As the beam passes the holes in the aperture plate current flows to the collector plate producing the coded group of output pulses; the beam is switched off and retraced in readiness for coding the next sample. In front of the aperture plate is the quantizing grid of 129 wires between which are

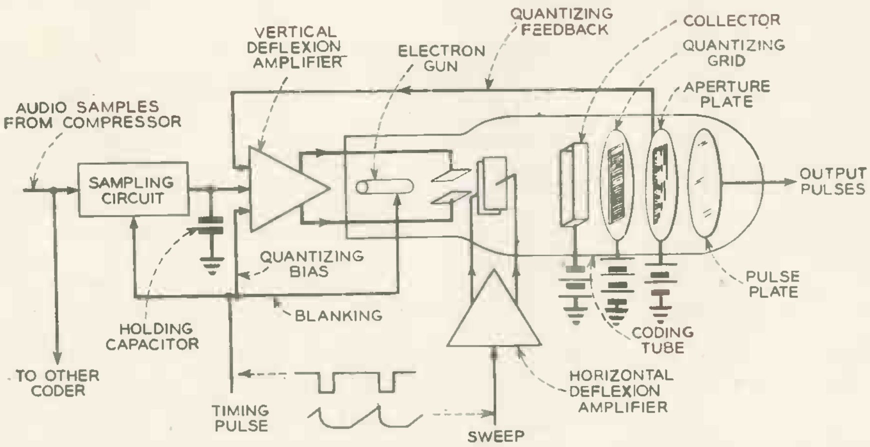



**Fig. 38. Functional diagram of coding tube**

spaces in line with the row of holes in the aperture plate. The wires are used to centre the beam accurately on a row of holes in the aperture plate: without it the beam might wander between two rows during the scan and false coding would result. During the scan a bias voltage is applied which tends to move the beam upward, but when it strikes one of the wires of the quantizing grid secondary electrons are emitted which are attracted to the collector. The signal from the collector is fed back to the vertical amplifier and deflects the beam downwards so that it is kept in a stable position just beneath the quantizing wire.

At the receiver the method of decoding used is based on that due to C. E. Shannon. In the Shannon decoder a capacitor is shunted by a resistor of such a value that the voltage across the capacitor decays to half its initial value in a time equal to the interval between pulses of the code group. The pulses in the group occur in order of increasing significance; the first represents "1", the second "2", and so on. Each pulse received by the decoder causes an equal charge to be placed on the capacitor. Immediately after receipt of the last digit the charge remaining on the capacitor due to each pulse is proportional to its weight in the binary code; the voltage across the capacitor is therefore proportional to the value of the original sample as shown in Fig. 40. The basic Shannon decoder depends on very accurate location of the sampling time in order to obtain exact decoding. An improvement by A. J. Rack makes such precise timing unnecessary[82]. A damped resonant circuit is used in conjunction with the resistance-capacitance elements so that the resulting output voltage is horizontal over regions one code period apart. Two decoders are provided; one is receiving a group of code pulses, while the other is feeding to the receiving gates the decoded sample of the preceding channel.

### Quantization Distortion

The quantization process shown in Fig. 33 is a particular form of non-linear distortion, the relation between the input and output voltages of the quantizer being as shown in Fig. 41(a). When a sinusoidal signal is applied the output comprises a fundamental frequency component and a large number of harmonics. If the signal is sampled before being quantized, harmonics (including the first) of the pulse repetition frequency will be present and intermodulation products between the harmonics of the modulating frequency and of the pulse repetition frequency. Many of these components will be filtered out at the receiver but those whose frequency is less than half the P.R.F. will remain. The amplitudes of these remaining distortion components depends on the size of the steps between the quantizing levels; the smaller the quanta the smaller is the total distortion power. The voltage ratio between the distortion and the maximum signal is approximately equal to the reciprocal of the number of quanta[77,84]. Thus for a five-digit system (32 levels) the distortion is about 3 per cent and for a seven-digit system (128 levels) the distortion is less than 1 per cent.

When the signal comprises a band of frequencies instead of a single frequency the distortion products tend to have a constant amplitude and random phase distribution over the frequency band. The result of quantization distortion is then to produce a background hiss which is called quantization noise. A simple derivation[78] of the signal-to-noise ratio for this case is as follows:

If the signal amplitude is very much greater than the size of the quantizing steps, there will be substantially no correlation between the errors introduced into successive samples by the quantizing. The maximum error which can occur is equal to half a step and all values of error less than this are equally likely.

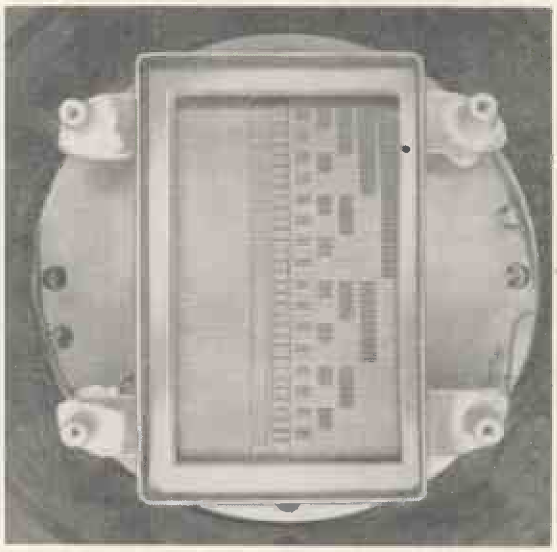
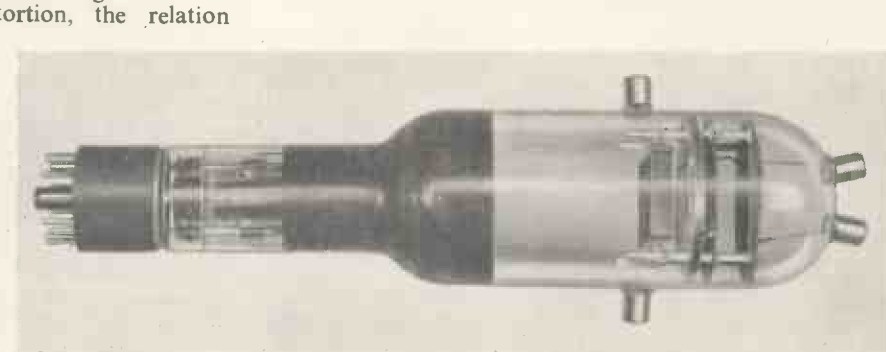


Fig. 39. (Above) the aperture of the coding tube viewed from the gun end; (below) the complete tube



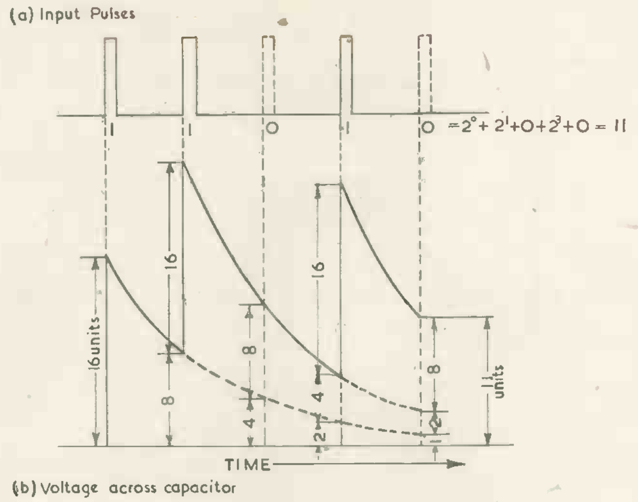



**Fig. 40. The operation of the Shannon decoder**

Therefore:

$$\frac{\text{mean square error}}{(\text{max error})^2} = \int_0^1 x^2\,dx = 1/3$$

and

$$\frac{\text{root mean square error}}{\text{height of a single step}} = 1/2\sqrt{3}$$

At the receiver we therefore get the original signal together with a uniform noise whose R.M.S. amplitude is $1/2\sqrt{3}$ times the quantum height. Therefore:

$$\frac{\text{peak signal voltage}}{\text{R.M.S. noise voltage}} = 2\sqrt{3}\,l$$

where $l$ is the number of quantizing levels. Because the signal-to-noise voltage is proportional to the number of levels and the bandwidth required is proportional to the logarithm of the number of levels, it follows that the signal-to-noise ratio expressed in decibels is proportional to the bandwidth used.

When all the quantizing steps are equal the noise produced is independent of the signal level. For loud speech signals the effect of the noise is negligible, but the noise becomes very noticeable when the signal level is low. In order to minimize the effect of the noise with variable signal levels, the size of the quanta should increase with the signal voltage[85,86,88] as shown in Fig. 41(b). The noise level then falls when the signal level is reduced so that the noise remains masked by the speech. The effect of non-uniform quantization can be obtained using a quantizer with equal levels by compressing the level range of the signal before applying it to the quantizer. If the compressor used is of the instantaneous type[83] it can be made common to all the channels of a T.D.M. system by connecting it between the common output of the transmitting gates (point A in Fig. 35) and the quantizer.

**Fig. 41. Relation between input and output with (a) uniform quantization; (b) tapered quantization**

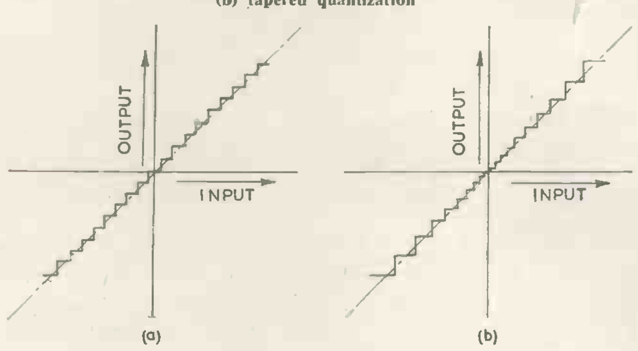



Fig. 42 shows the relation between the input voltage and the output voltage of the compressor and the result of quantizing the output voltage. At the receiver an instantaneous expander is used with the inverse characteristic of the compressor used at the transmitter; it can be made common to all channels by inserting it at point B in Fig. 35. The Bell Telephone Laboratories[87] have shown that a P.C.M. system with compandors has a sufficiently low level of quantization noise for a trunk telephone system if seven digits are used.

## Noise

In order to reproduce the signal correctly when the binary code is used, the receiver only has to detect the presence or absence of each pulse; small changes in the size, shape or timing of the pulses will not introduce any noise. If a slicing circuit is used, then an interfering voltage can only produce noise at the output of the receiver if it exceeds the slicing level. For fluctuation noise, the proportion of time for which the noise voltage exceeds a given level decreases as that level is increased with an error function law as shown in Part 3. Oliver, Pierce and Shannon[78] have calculated how the rate of occurrence of errors, caused by noise exceeding the slicing level, varies with the signal-to-noise ratio at the input to the receiver; their results are shown in Table 1.

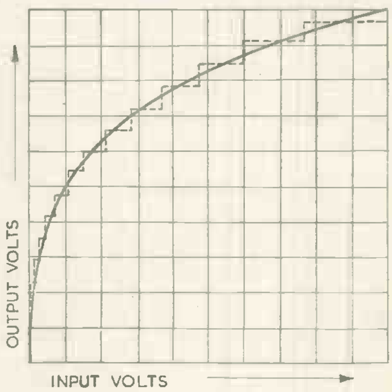



**Fig. 42. Compressor characteristic**

*(the broken lines show how uniform quantization of the output is equivalent to tapered quantization of the input).*

**TABLE 1**

| SIGNAL-TO-NOISE RATIO $20\log_{10}\frac{\text{Peak pulse voltage}}{\text{R.M.S. noise voltage}}$ | PROBABILITY OF ERROR | THIS IS ABOUT ONE ERROR EVERY |
|---|---|---|
| 13·3db | $10^{-2}$ | $10^{-3}$ sec |
| 17·4db | $10^{-4}$ | $10^{-1}$ sec |
| 19·6db | $10^{-6}$ | 10 sec |
| 21·0db | $10^{-8}$ | 20 min |
| 22·0db | $10^{-10}$ | 1 day |
| 23·0db | $10^{-12}$ | 3 months |

There is thus a clearly marked threshold effect. If the signal-to-noise ratio at the receiver is better than 20db the effect of noise introduced during transmission is negligible and the overall signal-to-noise ratio is determined by the quantizing noise alone. Because the noise introduced by transmission over a link can be negligible, many P.C.M. links can be connected in tandem using regenerative repeaters. In practice, therefore, the transmission requirements for a link in a P.C.M. system are almost independent of the total length of the system*, whereas the noise in most transmission systems is cumulative.

* *Strictly, the effect of noise in P.C.M. is cumulative. If p pulses per sec may be incorrectly received over a 100-link system, then the permissible rate of error for a single link is 0·01 p. Table 1 shows that a hundredfold reduction in errors only requires an improvement in signal-to-noise ratio of about 1db. With most transmission systems however, the signal-to-noise ratio for a single link of a 100-link system is required to be 20db better than the signal-to-noise ratio required overall.*

P.C.M. differs from other systems in that once the threshold level is exceeded further improvements in the signal-to-noise ratio at the input to the receiver produce no significant improvement in the signal-to-noise ratio at the output. This is because, when the threshold is exceeded, the signal-to-noise ratio is substantially determined by the quantizing noise alone. The signal-to-noise ratio expressed in decibels is then proportional to the bandwidth, so that if the ratio for a system is initially 40db, then by doubling the bandwidth (and the number of digits in the code) the ratio can be improved by 40db. In most other systems, such as P.P.M. and F.M., doubling the bandwidth only improves the signal-to-noise ratio by 6db. It can be shown[78] that P.C.M. enables bandwidth and signal-to-noise ratio to be exchanged in such a way as to approach very closely to the maximum theoretical rate at which a given channel can transmit information.

The immunity of P.C.M. systems from the effects of interfering voltages less than the slicing level also makes P.C.M. links free from inter-channel crosstalk (some crosstalk may be introduced before the coder and after the decoder at the terminal stations). P.C.M. systems can also permit a high level of interference from other radio systems using the same or neighbouring wavelengths. This offsets to some extent the large bandwidth required for a P.C.M. system by enabling the frequency separation between systems to be small and allowing several systems, with directional aerials, to use the same wavelength, although in fairly close proximity. In conditions of severe fading, however, the performance of P.C.M. has been found inferior to that of F.M.[94]. This, together with economic considerations has lead the Bell Telephone Laboratories to use the F.M. rather than the P.C.M. in their microwave relay system.

### Other Forms of Coding

Although, as described above, P.C.M. systems usually use a group of pulses transmitted in sequence to represent the value of each quantized sample of the modulating signal by means of the binary code, other forms of coding are possible. For example, if each pulse transmitted had three, four or ten possible values instead of only two, then ternary, quaternary or decimal codes could be used. A higher signal-to-noise ratio would be required on the transmission link, but the bandwidth needed would be smaller because the rate of transmission of pulses would be lower. The ternary code would be particularly suitable for line transmission, the three values for each pulse being represented by positive, zero and negative current. A. H. Reeves described in his patents[75] the use of codes with pulses having more than two amplitude values and codes in which the pulses of each group are sent simultaneously over different circuits or by means of different carrier frequencies instead of being sent in time sequence. The Bell Telephone Laboratories have recently sent television signals using P.C.M. by transmitting the pulses of each code group simultaneously over different circuits[92].

An interesting form of coding for a multiplex system has been suggested by F. H. Raymond[93]. If the values of the quantized samples of the signals of the $m$ channels are represented by numbers $n_1, n_2, \ldots n_m$, then a number $P(n_1, n_2, \ldots n_m)$ can be chosen to correspond uniquely to each sequence $n_1, n_2 \ldots n_m$. The number $P$ is then transmitted over the link in binary code and is decoded at the receiving end to give the values $n_1, n_2 \ldots n_m$ of the signals of the individual channels. It can be shown that this method of coding requires the same bandwidth as a binary P.C.M. multiplex system using T.D.M., but it does not need synchronized distributors to separate the signals of the different channels because this is included in the decoding process. An analogous system has been proposed by Valensi for transmitting colour television.

Delta modulation[19] resembles P.C.M. to the extent of using a quantizing process, but it is a quantization of rate of change rather than of amplitude as in P.C.M. At each sampling time a pulse is sent only if the modulating signal has increased since the previous pulse was sent; if the signal has decreased, no pulse is sent. At the receiving end, each pulse can be used to charge a capacitor whose rate of discharge is adjusted so that the fall in voltage across it in the period between pulses is one half of the increase in voltage caused by a pulse. If alternate pulses are omitted, the P.D. across the capacitor oscillates about a steady mean which will rise if more pulses are sent or fall if fewer are sent. If the P.R.F. is sufficiently high, the output signal at the receiving end will follow the modulating signal with an error which does not exceed the change in potential across the capacitor which occurs between adjacent pulses. This error results in a random noise voltage resembling the quantization noise in a P.C.M. system. It is claimed that with the same rate of transmission of binary pulses a delta modulation system has the same noise performance as a P.C.M. system using six digits, but uses much simpler and cheaper equipment.

In a P.C.M. system the first digit defines the signal value with imperfect accuracy, but entirely without ambiguity of value, whereas subsequent digits give greater accuracy with an increasing amount of ambiguity. For example, in a two-digit system with decimal coding the first digit indicates the signal value unambiguously to an accuracy of 10 per cent of the maximum value, whereas the second digit gives an accuracy of 1 per cent, but corresponds to ten possible values, the correct value being indicated by the first digit. Earp[74] has compared this two-digit P.C.M. system with his ambiguous index system in which two pulses are used, both of which represent the signal value with equal accuracy and ambiguity. The systems are closely related, but the latter does not use quantization.

**Acknowledgments**

Acknowledgment is made to the Engineer-in-Chief of the G.P.O. for permission to make use of information contained in these articles. Fig. 32 in Part 3 is taken from the Proceedings of the Institution of Electrical Engineers and Figs. 38 and 39 are taken from the Bell System Technical Journal by kind permission of the publishers.

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# The Measurement of "A" Matrix Elements of Passive Networks

By W. R. Hinton*, A.M.I.E.E.

*The determination of the " A " matrix elements of a passive four-terminal network is an obvious but useful extension of the well-known method of finding the equivalent circuit from measurements of looking-in impedance with the distant end of the network first open and then short-circuited. The elements so found are those for the frequency at which the measurements were made only.*

IN the development of communication apparatus one frequently encounters the need to analyse the effect of changing a section in a four-terminal transmission chain, and perhaps the least laborious method of doing this is to use "A" matrices. The advantage of this technique is that the " A " matrix of each four-terminal section of the transmission chain is unaffected by circuit changes external to its terminals, and relatively simple rules exist for the calculation of the overall " A " matrix of the interconnected system, and hence its properties. Thus the effect of a change in any one of the transmission elements can be calculated with a minimum amount of labour because only the local four-terminal section containing the element has its " A " matrix affected. Once this new " A " matrix has been found, only routine computation is required to determine the effect on the complete system.

The general method of using the "A" matrix is described and demonstrated in a previous article by the author[1], which shows how the matrices are written down by inspection of the network elements when these are known. Quite often, however, all of these elements are not known or perhaps some are inaccessible for measurement, and in such cases the author has found it convenient to determine the matrix elements from measurements of the looking-in impedance at the sending end of the network or system, when the receiving end is first open- and then short-circuited. (This is an obvious extension of the well-known method of determining the elements of an equivalent four-terminal network from open- and short-circuit impedance measurements, as the following theory shows.)

**Theory**

In the four-terminal network shown in Fig. 1, the " A " matrix is defined by the equation:

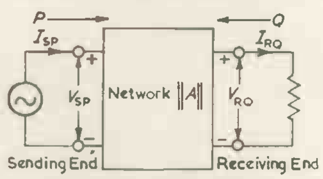


Fig. 1. The general four-terminal network

$$\left\|\begin{matrix} V_S \\ I_S \end{matrix}\right\| = \left\|\begin{matrix} a_{11} a_{12} \\ a_{21} a_{22} \end{matrix}\right\| \times \left\|\begin{matrix} V_R \\ I_R \end{matrix}\right\|$$

such that:

$$V_S = a_{11}V_R + a_{12}I_R$$
$$I_S = a_{21}V_R + a_{22}I_R$$

Thus notice that the " A " matrix elements, $a_{11}$, $a_{12}$, $a_{21}$ and $a_{22}$ are defined as follows:

$$a_{11} = \frac{V_{SP}}{V_{RQ}} \text{ when } I_R = 0 \quad \text{i.e. on open-circuit at the receiving end}$$

$$a_{12} = \frac{V_{SP}}{I_{RQ}} \text{ when } V_R = 0 \quad \text{i.e. on short-circuiting the receiving end}$$

$$a_{21} = \frac{I_{SP}}{V_{RQ}} \text{ when } I_R = 0 \quad \text{i.e. on open-circuit}$$

$$a_{22} = \frac{I_{SP}}{I_{RQ}} \text{ when } V_R = 0 \quad \text{i.e. on short-circuit}$$

Considering the two open-circuit cases we have:

$$\frac{a_{11}}{a_{21}} = \frac{V_{SP}}{I_{SP}} = Z_{OCP} \qquad (1)$$

and for the two short-circuit cases:

$$\frac{a_{12}}{a_{22}} = \frac{V_{SP}}{I_{SP}} = Z_{SCP} \qquad (2)$$

If the network is now turned end over end so that the direction of transmission is now from $Q$ to $P$, the " A " matrix for the network under these conditions differs, in general, from that for transmission in the other direction and is say:

$$\|B\| = \left\|\begin{matrix} b_{11} b_{12} \\ b_{21} b_{22} \end{matrix}\right\|$$

It can be shown that numerically, $b_{11} = a_{22}$, $b_{12} = a_{12}$, $b_{21} = a_{21}$ and $b_{22} = a_{11}$. That is:

$$\left\|\begin{matrix} b_{11} b_{12} \\ b_{21} b_{22} \end{matrix}\right\| = \left\|\begin{matrix} a_{22} a_{12} \\ a_{21} a_{11} \end{matrix}\right\| \qquad (3)$$

Thus treating this " B " matrix in the same way as the " A " matrix above, but remembering that the direction of transmission is now from $Q$ to $P$; by comparison with Equations (1) and (2) we have:

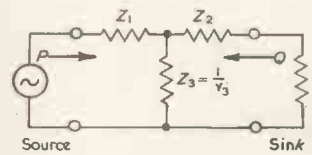


Fig. 2. Equivalent T-section of network $\|A\|$

$$\frac{b_{11}}{b_{21}} = \frac{a_{22}}{a_{21}} = Z_{OCQ} \qquad (4)$$

and

$$\frac{b_{12}}{b_{22}} = \frac{a_{12}}{a_{11}} = Z_{SCQ} \qquad (5)$$

* *Ministry of Supply.*

Now it is well known that at a given frequency, any four-terminal passive network can be represented by an equivalent simple $T$ section, and for the section shown in Fig. 2, the "$A$" matrix is:

$$\|A\| = \begin{Vmatrix} (1+Y_3Z_1) & (Z_1+Z_2+Y_3Z_1Z_2) \\ Y_3 & (1+Y_3Z_2) \end{Vmatrix} \quad \ldots\ldots (6)$$

Also it can be shown[2] that the section elements, $Z_1$, $Z_2$, and $Z_3$, can be calculated from the open- and short-circuited impedances as follows:

$$Z_3 = \pm\sqrt{(Z_{OCP}\,Z_{OCQ} - Z_{OCQ}\,Z_{SCP})}$$
$$Z_1 = Z_{OCP} - Z_3$$
$$Z_2 = Z_{OCQ} - Z_3$$

(The sign of the surd is taken so as to make the real part of $Z_3$ positive, since the network is passive.) Putting these values in Equation (6) we see at once:

$$a_{21} = \frac{1}{\pm\sqrt{(Z_{OCP}\,Z_{OCQ} - Z_{OCQ}\,Z_{SCP})}} \quad \ldots\ldots (7)$$

$$a_{11} = 1 + \frac{Z_{OCP} - Z_3}{Z_3}$$
$$= \frac{Z_{OCP}}{\pm\sqrt{(Z_{OCP}\,Z_{OCQ} - Z_{OCQ}\,Z_{SCP})}} \quad \ldots\ldots (8)$$

$$a_{22} = \frac{Z_{OCQ}}{\pm\sqrt{(Z_{OCP}\,Z_{OCQ} - Z_{OCQ}\,Z_{SCP})}} \quad \ldots\ldots (9)$$

and from Equations (2) and (9):

$$a_{12} = \frac{Z_{SCP}\,Z_{OCQ}}{\pm\sqrt{(Z_{OCP}\,Z_{OCQ} - Z_{OCQ}\,Z_{SCP})}} \quad \ldots\ldots (10)$$

Now since the performance of a four-terminal network is completely described by its "$A$" matrix, and since an equivalent network is defined to be one having the same performance as the original network, at the frequency considered, an alternative definition of equivalence is that: "Networks are electrically equivalent at a given frequency when their "$A$" matrices are equal at this frequency."

Thus, at the frequency at which the open- and short-circuited impedances were measured, the "$A$" matrix of the original four-terminal passive network is:

$$\|A\| = \text{(Transmission } P \text{ to } Q) \begin{Vmatrix} \dfrac{Z_{OCP}}{\pm\sqrt{[Z_{OCQ}(Z_{OCP}-Z_{SCP})]}} & \dfrac{Z_{OCQ}\,Z_{SCP}}{\pm\sqrt{[Z_{OCQ}(Z_{OCP}-Z_{SCP})]}} \\ \dfrac{1}{\pm\sqrt{[Z_{OCQ}(Z_{OCP}-Z_{SCP})]}} & \dfrac{Z_{OCQ}}{\pm\sqrt{[Z_{OCQ}(Z_{OCP}-Z_{SCP})]}} \end{Vmatrix}$$

It will be noticed that only one short-circuit condition impedance is required, namely $Z_{SCP}$, and in practice one chooses ends $P$ and $Q$ so as to give the more convenient measurement of $Z_{SCP}$; then if the "$A$" matrix for the opposite direction of transmission is required, this is simply obtained by transposing the principle diagonal elements. (See Equation (3)).

**Acknowledgment**

In conclusion, the author wishes to acknowledge the permission of the Chief Scientist of the Ministry of Supply to publish this article.

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# Transfer Matrix of a Four Terminal Passive Network in Terms of its Image Parameters

By H. P. Biggar

THE constants in the fundamental simultaneous equation relating the input and output voltages and currents for a linear four terminal passive network have a particular significance and may be used to derive the transfer matrix of any network in terms of its image parameters. The latter comprise the image impedances $Z_{I_1}$ and $Z_{I_2}$ and the image transfer constant $\theta$ (see Fig. 1).

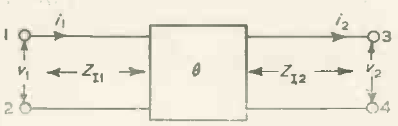



**Fig. 1. Four-terminal passive network**

The former are defined such that if the output terminals 3 and 4 are closed through an impedance $Z_{I_2}$ the input impedance of the network is $Z_{I_1}$ and if the input terminals 1 and 2 are closed through an impedance $Z_{I_1}$ the output impedance of the network is $Z_{I_2}$. When a network is terminated by its image impedances the input and output voltages and currents $v_1 i_1 v_2 i_2$ (Fig. 1) are related by the equation:

$$\frac{v_1 i_1}{v_2 i_2} = e^{2\theta} \quad \ldots\ldots (1)$$

where $\theta$ is the image transfer constant.

One of the fundamental simultaneous equations relating input and output currents and voltages for any linear four terminal passive network is usually written:

$$\left.\begin{aligned} v_1 &= a_{11}v_2 + a_{12}i_2 \\ i_1 &= a_{21}v_2 + a_{22}i_2 \end{aligned}\right\} \quad \ldots\ldots (2)$$

If the network is open-circuited $i_2 = 0$ and substituting for $i_2$ in Equation (2) gives:

$$a_{11} = \frac{v_1(oc)}{v_2(oc)} \quad \ldots\ldots (3)$$

$$a_{21} = \frac{i_1(oc)}{v_2(oc)} \quad \ldots\ldots (4)$$

the suffix OC denoting that the values are those for the open-circuit condition.

Similarly if the network is short-circuited $v_2 = 0$ and substituting in the simultaneous equation gives:

$$a_{12} = \frac{v_1(sc)}{i_2(sc)} \quad \ldots\ldots (5)$$

$$a_{22} = \frac{i_1(sc)}{i_2(sc)} \quad \ldots\ldots (6)$$

Dividing (3) by (4) we obtain:

$$a_{11}/a_{21} = \frac{v_1(oc)}{i_1(oc)} \quad \ldots\ldots (7)$$

which is the input impedance of the network with the output terminals open-circuited and is conveniently written $Z_{12(34OC)}$.

Similarly from (5) and (6):

$$a_{12}/a_{22} = \frac{v_{1(SC)}}{i_{1(SC)}} \quad \ldots\ldots\ldots\ldots (8)$$

which is the input impedance of the network with the output terminals short-circuited usually written $Z_{12(34SC)}$. Now it may be shown* that the image impedances can be expressed in terms of the open- and short-circuit impedances as follows:

$$Z_{I_1} = \sqrt{(Z_{12(34OC)} \times Z_{12(34SC)} \ldots)} \quad \ldots\ldots (9)$$

and

$$Z_{I_2} = \sqrt{(Z_{34(12OC)} \times Z_{34(12SC)} \ldots)} \quad \ldots\ldots (10)$$

Substituting for $Z_{12(34OC)}$ and $Z_{12(34SO)}$ in (9) from (7) and (8) gives:

$$Z_{I_1} = \sqrt{\left(\frac{a_{11}a_{12}}{a_{21}a_{22}}\right)} \quad \ldots\ldots\ldots\ldots (11)$$

To derive the expression for $Z_{I_2}$ write equation (2) in matrix notation, viz. $\begin{matrix} v_1 \\ i_1 \end{matrix} = \begin{Vmatrix} a_{11}a_{12} \\ a_{21}a_{22} \end{Vmatrix} \times \begin{matrix} v_2 \\ i_2 \end{matrix}$ which makes it easier to obtain the simultaneous equation for $v_2 i_2$ in terms of $v_1 i_1$.

Thus it follows at once that:

$$\begin{matrix} v_2 \\ i_2 \end{matrix} = \begin{Vmatrix} a_{11}a_{12} \\ a_{21}a_{22} \end{Vmatrix}^{-1} \times \begin{matrix} v_1 \\ i_1 \end{matrix}$$

$$= \frac{1}{|A|} \begin{Vmatrix} a_{22} & -a_{12} \\ -a_{21} & a_{11} \end{Vmatrix} \times \begin{matrix} v_1 \\ i_1 \end{matrix}$$

Now $|A| = 1$ for passive networks such as we are considering so that by inspection of the last equation we may write:

$$v_2 = a_{22}v_1 - a_{12}i_1$$
$$i_2 = -a_{21}v_1 + a_{11}i_1$$

Proceeding as before and putting first $v_1 = 0$ and then $i_1 = 0$ in this equation we obtain:

$$Z_{34(12OC)} = -a_{22}/a_{21}$$
$$Z_{34(12SO)} = -a_{12}/a_{11}$$

Substituting these expressions for the open- and short-circuit impedances at the output terminals in Equation (10) gives:

$$Z_{I_2} = \sqrt{\left(\frac{a_{12}a_{22}}{a_{11}a_{21}}\right)} \quad \ldots\ldots\ldots\ldots (12)$$

The expression $\theta$ in terms of the constants of the transfer matrix can be shown to be*:

$$\theta = \text{logh}\,[\sqrt{(a_{11}a_{22})} + \sqrt{(a_{12}a_{21})}] \quad \ldots\ldots (13)$$

whence

$$e^{\theta} = \sqrt{(a_{11}a_{22})} + \sqrt{(a_{12}a_{21})} \quad \ldots\ldots (14)$$

and

$$e^{-\theta} = \sqrt{(a_{11}a_{22})} - \sqrt{(a_{12}a_{21})} \quad \ldots\ldots (15)$$

It follows from (14) and (15) that:

$$\sqrt{(a_{11}a_{22})} = \cosh\theta \quad \ldots\ldots (16)$$

$$\sqrt{(a_{12}a_{21})} = \sinh\theta \quad \ldots\ldots (17)$$

Equations (11), (12), (16) and (17) enable us to derive the constants of the transfer matrix in terms of the image parameters, viz.:

$$\left.\begin{aligned} a_{11} &= \sqrt{(Z_{I_1}/Z_{I_2})}\cosh\theta \\ a_{12} &= \sqrt{(Z_{I_1}Z_{I_2})}\sinh\theta \\ a_{21} &= \sinh\theta/\sqrt{(Z_{I_1}Z_{I_2})} \\ a_{22} &= \sqrt{(Z_{I_2}/Z_{I_1})}\cosh\theta \end{aligned}\right\} \quad \ldots\ldots (18)$$

By equating the values of the constants in this equation to the corresponding constants in the transfer matrix of any desired network the values of its elements may be readily determined in terms of the desired image parameters.

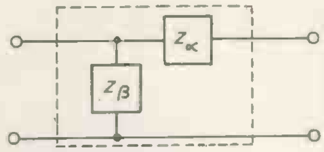



Fig. 2. L-network

A good example of this is the "L" network which has a number of radio frequency applications (see Fig. 2).

The transfer matrix of this network is easily shown to be:

$$\|A\| = \begin{Vmatrix} 1 & Z_\alpha \\ 1/Z_\alpha & 1 + Z_\alpha/Z_\beta \end{Vmatrix} \quad \ldots\ldots (19)$$

now as $a_{11} = 1$ Equation (18) gives:

$$\sqrt{\frac{Z_{I_1}}{Z_{I_2}}}\cosh\theta = 1 \text{ whence } \cosh\theta = \sqrt{\frac{Z_{I_2}}{Z_{I_1}}} \quad \ldots\ldots (20)$$

By means of Equation (20) the constants in Equation (18) may be re-written for the $L$ network:

$$\begin{aligned} a_{11} &= 1 \\ a_{12} &= Z_{I_1}\sinh\theta\ \ \cosh\theta \text{ or } Z_{I_2}\tanh\theta \\ a_{21} &= \tanh\theta/Z_{I_1} \text{ or } \sinh\theta\ \ \cosh\theta/Z_{I_2} \\ a_{22} &= \cosh^2\theta \end{aligned} \quad \ldots\ldots (21)$$

Comparing the above with the constants in the matrix of the $L$ network Equation (19) it is clear that the elements have the values:

$$\begin{aligned} Z_\alpha &= Z_{I_1}\sinh\theta_1\ \cosh\theta \text{ or } Z_{I_2}\tanh\theta \\ Z_\beta &= Z_{I_1}/\tanh\theta \text{ or } Z_{I_2}/\sinh\theta\ \ \cosh\theta \end{aligned} \quad \ldots\ldots (22)$$

whence

$$Z_\alpha/Z_\beta = Z_{I_1}Z_{I_2} \quad \ldots\ldots (23)$$

and

$$Z_\alpha/Z_\beta = \sinh^2\theta \quad \ldots\ldots (24)$$

The last two equations are sufficient to design an $L$ network for any specified phase shift or impedance ratio. For example, if the network is to be used for matching resistive impedances $R_1$ and $R_2$ so that $Z_{I_1} = R_1$ and $Z_{I_2} = R_2$ the values of $Z_\alpha$ and $Z_\beta$ can be determined from Equations (20) and (22) as follows:

From Equation (20) $\cosh^2\theta = R_2/R_1$

Now $\cosh^2\theta - \sinh^2\theta = 1$; hence $\sinh^2\theta = R_2/R_1 - 1$.

Multiplying Equations (23) and (24) gives:

$$Z_\alpha^2 = R_1R_2(R_2/R_1 - 1) \text{ or } Z_\alpha = \pm R_2\sqrt{(1 - R_1/R_2)} \quad \ldots (25)$$

Similarly dividing (23) by (24) gives:

$$Z_\beta = \pm R_1/\sqrt{(1 - R_1/R_2)} \quad \ldots\ldots (26)$$

It is important to note that this network is only used when $R_2 < R_1$ as $Z_\alpha$ and $Z_\beta$ are then both imaginary, i.e., reactances of opposite sign. In general $Z_\alpha$ is made inductive and $Z_\beta$ capacitive in order that the network may serve also as a low pass filter in some applications. On the other hand if $R_2 > R_1$, $Z_\alpha$ and $Z_\beta$ are both real, i.e. resistive, which is impracticable for R.F. work as the network would then introduce a power loss. This kind of network has, however, a well known L.F. application in the form of fixed or variable attenuators, commonly known as db pads. In the limit when $R_1/R_2 \gg 1$, $Z_\alpha = \pm i\sqrt{(R_1R_2)}$ and $Z_\beta = \mp \sqrt{(R_1R_2)}$, i.e. the reactances are equal and opposite. This is the condition which obtains in a lightly damped tuned circuit, such as might be used in the grid and anode circuits of a tuned R.F. amplifier or oscillator.

* *see for example "Electric Circuits and Wave Filters" by Starr (Pitman)*

# Electrical Telemetering and Automatic Process Control

**(Part 1)**

By J. R. Boundy*, B.Sc., M.I.E.E.

*The first part of this article gives the historical background to electrical telemetering, and shows how it leads quite naturally into the automatic process control field. Details are then given of the circuit arrangements of an automatic electronic process controller.*

*The second part will be composed of examples of applications of this equipment in the field, together with some of the advantages which have been shown for this new technique. Finally some information will be given on the methods for ensuring the safe working of these equipments in hazardous atmospheres where there is a danger of an explosion being caused by an electrical spark.*

THE oldest and simplest form of electrical telemetering was the use of a variable resistance type transmitter connected to a D.C. supply and a milliammeter indicator as shown in Fig. 1. For simplicity of description, a liquid level float operated type of transmitter is shown and it will be used in the various examples given subsequently. In practice, of course, the spindle of the potentiometer may be rotated by any one of the standard detecting elements such as Bourdon tubes, bellows, flowmeter, spindles, etc. This simple D.C. milliammeter system has the obvious weakness that a change in either the D.C. supply voltage or the resistance of the line connecting the transmitter to the receiver would cause inaccuracies in the readings.

The next advance was, therefore, to remove inaccuracies caused by changes in the D.C. supply voltage. This was achieved by the use of an ohmmeter type of receiver in place of the milliammeter. This arrangement is shown in Fig. 2. The ohmmeters contain essentially two coils, rigidly secured at an angle to each other, and mounted on the same axle, being free to rotate in the field of a permanent magnet. One coil, called the deflecting coil, is in series with the resistance of the transmitter, and corresponds to the coil of the milliammeter in Fig. 1. The control spring of the milliammeter is, however, replaced by the second coil, which is called the control coil, and is connected across the D.C. supply. As variations in voltage affect both coils alike, the instrument gives a true reading of the resistance in the circuit, and is unaffected by voltage changes.

The next stage was to remove the inaccuracies created by any changes in the line resistance. The types of telemeter which first did this were of the "follow-up" arrangement, of which the Evershed-Midworth was an example. A schematic arrangement of this device is shown in Fig. 3. It will be seen from the diagram that the control movement is made to follow the originating movement pointer. Any difference between the two movements causes a contact to be made, which runs a motor driving a potentiometer until the current through the milliammeter is again such as to re-align the two movements. This means that any changes in supply voltage or circuit resistance will now be corrected. In addition, the transition from a movement of the detecting element to a change of resistance of a potentiometer in the transmitter, has been eliminated. This

* *Evershed and Vignoles Ltd.*

*The above illustration shows a typical console control desk.*

later form of transmitter follows the originating movement directly without the intermediary of the resistor.

The last and final stage in this development was the substitution of a thermionic valve for the motor and resistor arm of Fig. 3. The contacts detecting misalignment now merely modify the voltage on a capacitor between the grid and cathode of a thermionic valve, the anode current being used as the indicating and balancing current. The latest

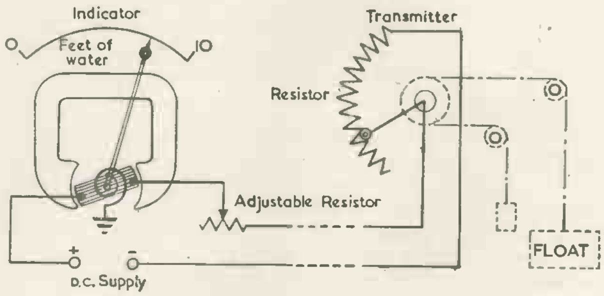



Fig. 1. D.C. milliammeter system

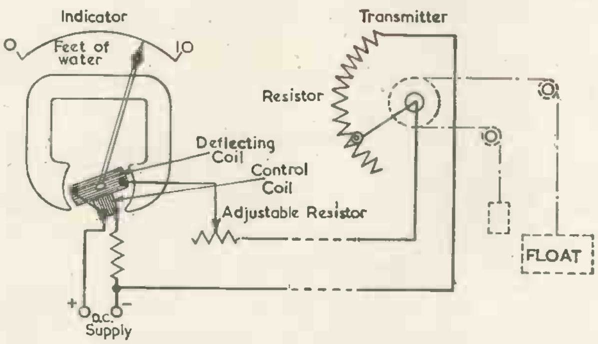



Fig. 2. Ratiometer or ohmmeter system

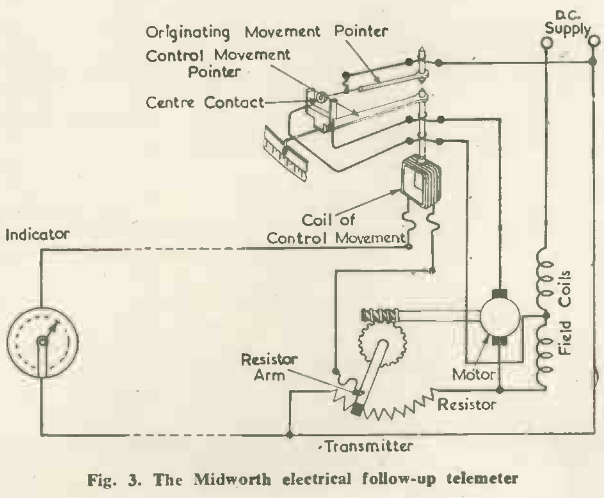



Fig. 3. The Midworth electrical follow-up telemeter

arrangement of this form of telemetering is shown in Fig. 4. It will be seen that in addition to replacing the motor and resistor by a valve, the opportunity was taken to convert the transmitter into a torque balance arrangement. The originating movement pointer now winds up an instrument type spring. The torque of this instrument type spring is then equally and oppositely opposed by the electro-magnetic torque of the coil and magnet assembly. This system therefore retains all the advantages of the "follow-up" system, but has the additional advantage of reducing movement in the transmitter itself. In addition, where it is possible, it permits the direct opposition of the originating movement by the electro-magnetic force, without the intermediary of a spring and thereby produces a true null balance system.

From Fig. 4 it will be seen that the fixed contacts of the transmitter are supplied with biasing voltages through terminals E and F, the bias through E being more negative, and through F more positive than the negative of the H.T. rectifier. These biasing voltages are obtained by use of the additional half-wave rectifier shown joined to the negative of the H.T. full-wave rectifier network.

The operation of this unit is perhaps best understood by assuming a condition of stability in which the spring torque is equally and oppositely opposed by the coil and pot magnet. Any increase in the physical quantity being

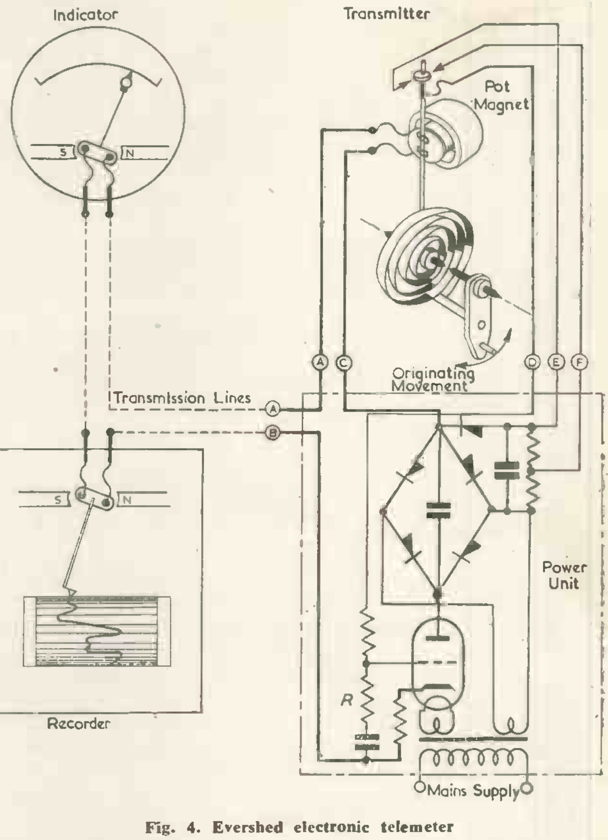



Fig. 4. Evershed electronic telemeter

measured will give rise to an increase in the spring torque. The coil will be pushed into the magnet and the centre moving contact carried by the coil arm will close on the positively biased side contact. Current will then be fed from the biasing potential down through terminal D to modify the charge on the capacitor between the grid and cathode of the valve. In this particular example the current will flow so as to make the voltage across the capacitor less negative, and therefore increase the anode current. This increase of anode current will be following the change in the voltage across the capacitor instantaneously and will continue until the anode current has increased sufficiently to move the coil out of the magnet and break the biasing contact. Thus a new condition of balance will be obtained. This new anode current will, of course, be flowing through the indicators or recorders to show the new value of the quantity being measured.

Since the torque balance has an on-off action due to the contacts, and naturally has some inertia, it has a tendency to hunt. The stability of the system can, however, be improved by placing a resistor, $R$, in series with the capacitor between grid and cathode. Its effect is that when the centre contact moves over to one of the biasing contacts, the subsequent current which flows through this resistor will create a voltage drop which will be algebraically added to the voltage across the capacitor so far as the grid of the valve is concerned. This voltage will always be in such a direction as to exaggerate the change in the voltage of the capacitor. Therefore the coil sitting in the magnet will attempt to move into the central neutral position earlier than it would otherwise, thus removing the effect of the lag due to the inertia of the torque balance system.

The next step, after normal telemetering, was the provision of a contact on the indicator or recorder which was made by the pointer or pen-arm. This permitted the remote operation of audible and visual alarms. Thus in a pumping station for a reservoir a low level in the reservoir could attract the pump operator's attention by ringing an alarm. The next stage was to arrange for two contacts on the indicator, one at a pre-set high level and another at a pre-set low level. These contacts could then be arranged to replace the pump attendant by automatically starting up the pumps when the low level contact was made and automatically stopping them when the high level contact was reached. This gave the first automatic control, the operation being of the "on/off" or "two-step control" type. The next development was the provision of tighter control by closing in the normal contacts, and then having outside them another set of contacts which would run the pumps at a higher speed than the inner contacts. In other words, it became a two speed automatic control. The natural follow up to this arrangement was to control pumps continuously and make their speed vary with the measured level.

## Automatic Control

This requirement for continuous adjustment of pumps in accordance with level is a typical example of what is now better known as automatic process control. The example given, i.e., reservoir and pumping station, is perhaps the most easily understood of these automatic process controls, but the requirement is quite universal and is equally applicable to maintenance at a constant value of pressures, flows, temperatures, levels, pH etc. The simplest form that this control takes is that similar to the pumping station example quoted previously. In other words, alteration of the regulating unit (speed of pumps, valve position etc.) in proportion to the change of the physical quantity being measured. This simple form of control is now known as proportional control. In practice, of course, it is essential to change the sensitivity of such an arrangement so that the ratio between the movement of the regulating unit and the change of the physical quantity being measured can be adjustable. This brings in the need for the unit known as the automatic process controller. In its simplest form, this controller has only the proportional action in it, and is sometimes known as a single term controller.

## Process Controllers

The arrangement described earlier is the basis of the standard automatic process control. Any continuous process, no matter how complex, can be broken down into a number of individually controlled closed loop systems of the basic form of Fig. 5. Irrespective of the form the process takes, the essential characteristics of the closed loop remain the same. The measuring unit measures the controlled quantity, and passes this information to the process controller, where it is compared with the desired value. The process controller has an output signal, which is transmitted to the regulating unit, which is normally a pneumatically operated process control valve. This regulating unit adjusts the physical quantity, upon which the controlled quantity depends, in order to restore it to the desired value.

The task of the process controller is therefore to take note of the size, rate of development and direction of movement of any difference between the measured and desired value, and according to the control functions contained in the controller, pass a suitable signal to the regulating unit. As already mentioned earlier the simplest form is single term or proportional control. In addition to this single term control, there are two other common modes of control, and they are known as integral and derivative. The operation of these three sections are as follows:

### Proportional Action

In this case the movement $V$ of the regulating unit is proportional directly to the error, $\theta$, and is hence expressed by $V = -K_1\theta$ the negative sign signifying the 180° phase displacement necessary to produce a correcting action. The constant $K_1$ is a measure of the sensitivity of the system and is known as the proportional band, being expressed as the percentage of full-scale change of measured quantity required to produce 100 per cent movement of the regulating unit. As an error must be present to produce this form of control there will always be a departure of the controlled quantity from the desired value when this form of control is used. This departure is known as the "offset".

### Integral Action

This action is required when the offset due to proportional action must be removed. The regulating unit movement in this case is proportional to the integral of error with respect to time and is expressed as $V = -K_0\int\theta dt$. The integral action time is defined as the time interval in which the integral action, in a controller having proportional and integral action, increases by an amount equal to the proportional action when the error is unchanging. The integral action time can hence be expressed as $K_1/K_0$. It will be seen from the expression that the integral control will be present whenever there is an error, therefore removing the inherent droop of the proportional action.

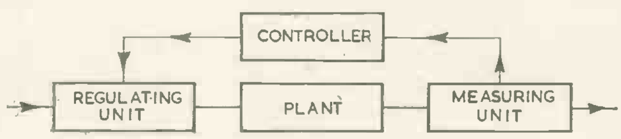



Fig. 5. Diagram of standard process control loop

### Derivative Action

This may be regarded as a damping term and produces a regulating unit movement proportional to the rate of change of error, being represented by the expression $V = -K_2 d\theta/dt$. The derivative action time is defined as the time interval in which proportional action, in a controller having proportional and derivative action, increases by an amount equal to the derivative action when the error is changing at a constant rate. This form of control is only present when the error is increasing or decreasing and is independent of the magnitude of the error. It can hence usually be used only in conjunction with another mode of control.

## Controller Equation

The complete equation with which a three term process controller of any type must comply is therefore the sum of the foregoing functions, that is

$$V = -K_1\theta - K_0\int \theta dt - K_2 d\theta/dt.$$

The controller which is described complies with the equation by electro-mechanical means.

The schematic circuit diagram Fig. 6 gives details of the circuit used.

**Proportional Control**

The electronic measuring unit mentioned earlier provides, in conjunction with valve $V_1$ and its associated components, a D.C. current $I_m$ of up to 30 milliamperes proportional to the measured quantity. The desired value is represented by current $I_c$ and is adjustable up to 30 milliamperes. This current $I_c$ is supplied from a neon stabilized source and is adjusted by potentiometer $R_4$ and represents the value at which it is required to stabilize the physical quantity being measured. These two currents, $I_m$ and $I_c$, are compared by passing them in opposition through one of the two coils of movement $M_1$. This movement is basically a milliammeter movement but has two coils wound on its coil former instead of the usual single coil. In addition, the standard pointer has been replaced by a small aluminium shutter. This shutter moves between a small electric light bulb and a fixed shutter with two slots in it. When there is no current in either of the coils of the movement then the moving shutter sits centrally between the slots of the fixed shutter. The moving shutter's width is such that in this position it is covering half of each slot of the fixed shutter. Thus when the moving shutter is displaced from its central position by a current in the coils it will decrease its coverage of one slot and increase its cover over the other. Therefore the light passing through the slots will be varied differentially by movement of the shutter. The light passing through these slots falls on two photocells $PE_1$ and $PE_2$ arranged immediately behind the slots.

These photocells are the Mullard 90CV type and they control the grid potential of valve $V_2$ whose anode current is fed back through the second coil of the movement to provide a torque balance system. This means that the current through this second coil will always be made the same as the current $I_\theta$ (which is the difference between $I_m$ and $I_c$) passing through the first coil. The photocells exercise their control of the grid of valve $V_2$ by modifying the charge on capacitor $C_1$. They are of the emissive type, i.e. current producers, and are biased well above their saturation voltage by the voltage drop across resistor $R_5$. The light falling on the two cells is varied differentially by the shutter carried on movement $M_1$ and in the balanced condition the light is equal on both of them and no current flows to modify the voltage on capacitor $C_1$. Any unbalance of movement $M_1$, such as that caused by a change of current $I_\theta$, will unbalance the light falling on the photocells and current will flow from them to change the voltage on capacitor $C_1$ until the anode current of valve $V_2$ is the correct amount to again restore balance in the movement.

A rectifier, *MR*, is used to send current through the second coil of movement $M_1$ in opposition to the anode current of valve $V_2$. This makes the resultant current $I_{pr}$ "centre zero" so that it can reverse in direction to follow the reversals of current $I_\theta$.

The current $I_{pr}$ passes through the regulating unit and a proportional control action having a proportional band of 100 per cent is obtained. If a shunt $R_4$ is fitted as shown across the second coil of movement $M_1$, the proportional band may by variation of the shunt be varied in theory from zero to infinity. As in either of these cases the power in the relay would be zero they are not practical, and the adjustment is, in fact, calibrated from 2 to 600 per cent.

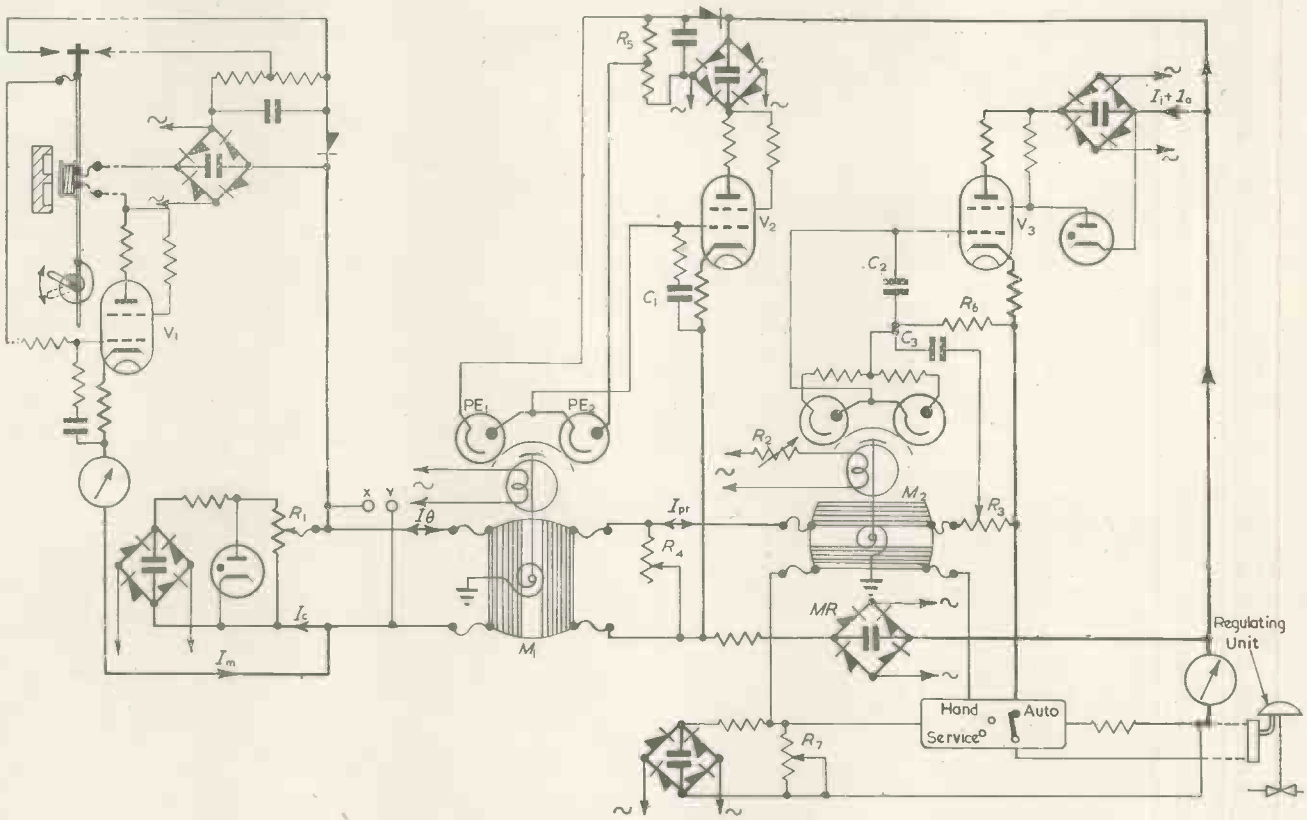



Fig. 6. The automatic process controller

**Integral Action**

To obtain an integral of error it is first necessary to have a device sensitive to the magnitude of error. This takes the form of a photocell movement $M_2$ similar to that mentioned under proportional control, but arranged to have a greater angular movement of the coil. The proportional current $I_{pr}$ is passed through the coil of this relay which is in the same circuit as the regulating unit. This proportional current only exists when there is a difference between the measured value and the desired value and it is directly proportional to this difference. This current will create an unbalance of light on the photocells which will cause a current proportional to it to flow in the output circuit from the bridge. This current is used to charge an 8$\mu$F capacitor $C_2$ in the grid cathode circuit of valve $V_3$, the voltage across the capacitor hence being proportional to the integral of the originating error. The output from valve $V_3$ passes through the regulating unit in the same manner as the proportional current.

The photocell units are Mullard 90CVs and above their saturation voltage of 30 volts are insensitive to voltage changes. They may therefore be regarded as a current source and the integration rate will therefore be independent of the state of the capacitor charge. This condition is, of course, not true with the normal type of *RC* network or the equivalent pneumatic arrangement. The voltage across the capacitor will therefore be a true integral of error with respect to time. This integral time is controlled by a variable resistor $R_2$ inserted in series with the lamp illuminating the photocells.

### Derivative Action

The rate of change of error is identical with that of the current $I_{pr}$. It is therefore measured by inserting a variable resistor $R_3$ in the proportional current circuit from valve $V_2$. The voltage drop across this resistor is used to charge a large capacitor $C_3$ through a fixed resistor $R_6$ of 5 megohms which is in series with the integral capacitor in the grid cathode circuit of valve $V_3$. It will be seen that any change of current through the variable resistor $R_3$ will produce a charging current in the loop thus made which will be proportional to the rate of change of the measured quantity. The voltage drop across the fixed resistor $R_6$ will also be proportional to this quantity which is the derivative of error. The output of valve $V_3$ will hence contain a component proportional to the rate of change of error. The control of derivative time being effected by the variable resistor $R_3$. This is added to the functions in the output circuit, as already described under "Integral Action".

### Hand Control

To enable a process to be started manually when necessary a three-position switch labelled AUTO-HAND-SERVICE is provided. This switch is shown in block form only in Fig. 6. However, the actual connexions are not too difficult to visualize. In the AUTO position, which is the normal operating condition, the automatic output of the controller passes direct to the regulating unit, by means of a small indicator on the front of the controller. It is therefore possible to see from the controller the exact position of the regulating unit.

In the central switch position labelled HAND, the position of the regulating unit is now determined by an independent supply controlled by a potentiometer with which the operator adjusts the value of the current. In this position therefore the operator is manually positioning the process valve while the automatic output of the controller is switched to a dummy load. It is, however, essential that the automatic output of the controller be made to follow the current being fed to the valve by the HAND circuit. This is essential because when the operator decides to go back from hand control to automatic, then he must be able to do so by merely restoring the switch from HAND to AUTO, without any reaction at the regulating unit. If this is not suitably arranged, in other words, if on switching back to automatic the regulating unit jumps to a different setting, then the process plant will be again disturbed and it may be necessary to go back to hand control again to recover reasonably stable conditions.

This arrangement for the automatic output of the controller to follow the hand current is contrived by adding a second winding to the integrating movement $M_2$. This second winding is made to carry, in the HAND position of the switch, both the automatic output of the controller and the hand control current. If these two currents, which are in opposition through the coil, are not equal and opposite, then the coil will be moved from its central position and the integral current $I_i$ will be modified until the two currents are again made equal. This means that the automatic output of the controller is made to follow, as a slave, the hand control current. It is always possible to check that this action has taken place by simply reading the indicator showing the automatic output of the controller, and ensuring that it is the same value as that shown on the hand control setting. Similarly to revert from automatic to hand control without creating a large disturbance, it is only necessary to line up the hand control setting with that of the automatic output indication before switching.

The third position SERVICE is provided so that the instrument mechanic can test the actions of the controller while

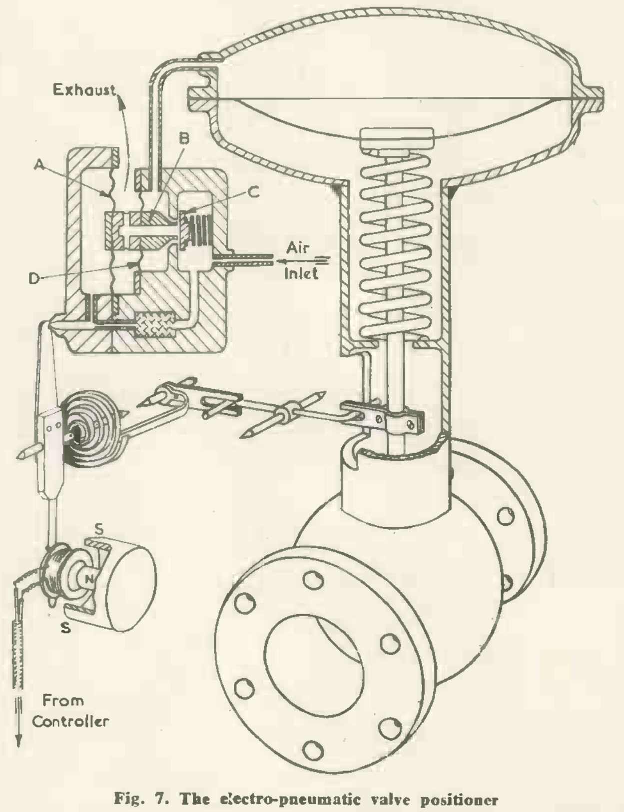


Fig. 7. The electro-pneumatic valve positioner

the hand control circuit is controlling the position of the regulating unit. In other words, the automatic follow-up is cut out and the normal response of the controller can be tested through a dummy load without disturbing the hand control circuit.

### Cascade Control

To allow the desired value of the system to be adjusted from an external source, provision is made for introducing a signal directly into a coil of movement $M_1$ by connexion to the terminals XY. This current, which may be the output of a second controller then acts in conjunction with the current $I_c$ and $I_m$, produced as described in the preceding paragraphs, to vary the value $I_{pr}$.

### Regulating Unit

The regulating unit in the majority of cases takes the form of a diaphragm operated control valve using air pressure as a motive power. A conversion unit is necessary to translate the electrical output of the controller into terms of valve position. This is accomplished by the electro-pneumatic relay or valve positioner mounted on the control valve head.

PRINCIPLE OF OPERATION

The principle of operation can best be understood by reference to Fig. 7.

In the relay is a pivoted beam, at one end of which is a coil operating in the field of a permanent magnet, and through which passes the signal from the process controller. At the other end of the beam is a flapper operating in conjunction with the nozzle of a low-bleed type air relay, the output from which is fed to the diaphragm head of the valve under control.

The beam is attached to the inner end of an instrument type spring which exerts a turning moment about its pivots, while the other end of the spring is connected to an adjustable feedback lever fitted to the valve stem. Movement of this lever therefore varies the torque exerted by the spring which is so arranged as to oppose that generated by the moving coil.

When the system is in balance, the spring torque is equal to that produced by the moving-coil which in turn is proportional to the controller output, and any change in this output will, therefore, unbalance the beam, causing a movement of the flapper with respect to the air relay nozzle.

This will vary the air flow through the nozzle and hence the pressure on the primary diaphragm A which will move, carrying with it the hollow plunger B, operating in conjunction with the spring loaded valve C. Increase of pressure on A will connect the diaphragm head of the controlled valve to the air pressure inlet, while decrease in pressure will connect it to atmosphere.

Variation of pressure on the diaphragm will move the valve stem carrying with it the feedback lever, and hence moving the outer end of the instrument type spring. This movement is in such a direction as to correct the unbalance between the spring and moving coil torques, and a state of balance is restored with the valve stem in a new position.

As movement of the valve stem bears a linear relationship to the spring torque operating on the beam, it will be seen that the valve position is directly proportional to the input signal irrespective of air pressure and friction loading upon the valve.

*(To be continued)*

# Moment of Inertia/Torsional Oscillation

By A. E. Maine*

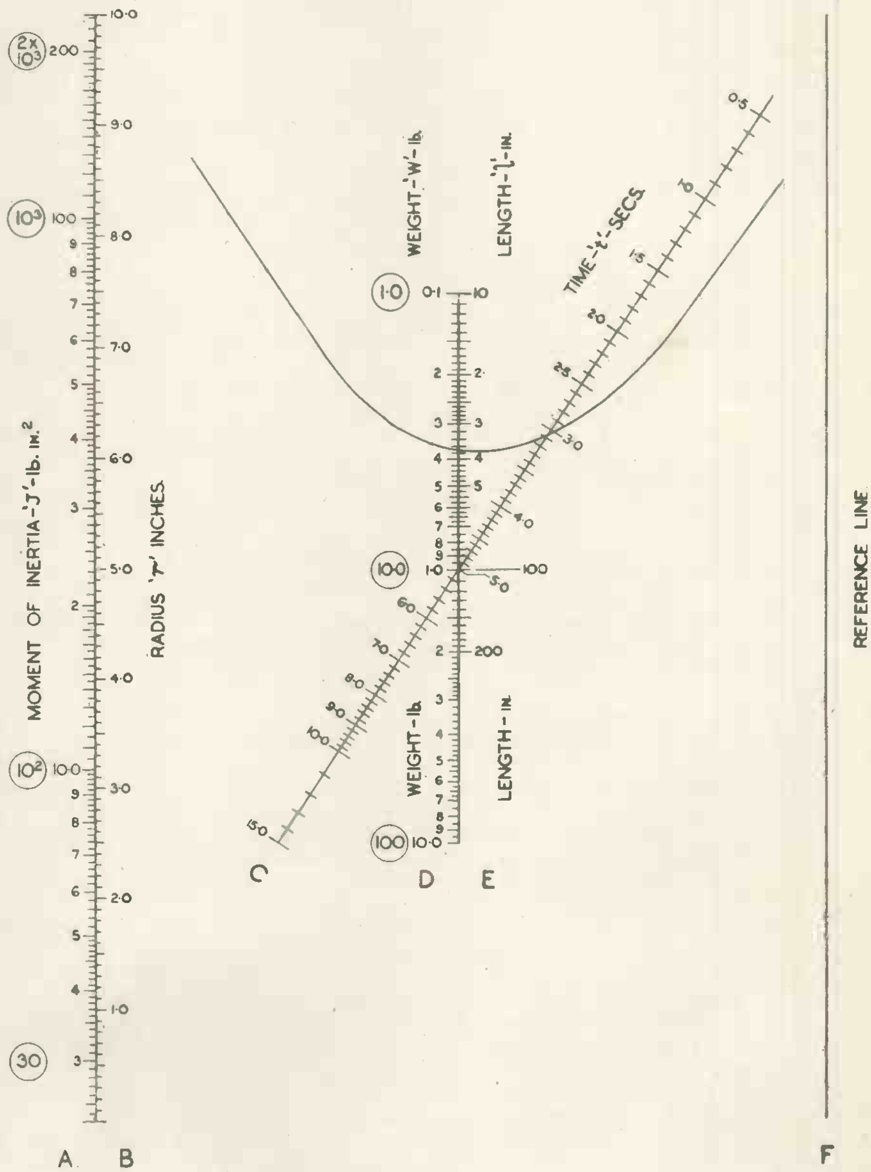
This chart is primarily intended for calculating quickly the moment of inertia of a body from experimental data obtained by means of timing the period of oscillation with the mass suitably suspended.

**Example**

A gear wheel weighing 2lb is suspended on thin strings 70in. long and spaced by 9in. The mean period measured over a number of cycles after the application of a small torque is 4·5 seconds. What is the moment of inertia of the body about the axis measured?

A rule is placed between 4·5in. on the radius scale and 4·5 seconds on the time scale. From the intersection with the reference scale (F) a tangent is drawn to the curve, which intersects scale "B". From this point a line is projected through the weight scale (D) at 2lb, meeting the reference scale a second time. From this new intersection, a second projection through the length scale (E) at 70in. gives the answer at Scale "A"—in this case J = 115lb.in$^2$.

The range of the nomogram may be extended by means of multiplying scales A, D and E by suitable factors. Scales B and C, however, cannot be treated in this manner.




* De Havilland Aircraft Ltd.

# Voltage Stabilization

**(Part 1)**

By F. A. Benson*, M.Eng.Ph.D., A.M.I.E.E., M.I.R.E.

*It is only recently that a monograph was published[1] which was based on a series of articles in* ELECTRONIC ENGINEERING[2] *and which aimed at reviewing the various methods of stabilizing voltage. Since this was written a fairly large additional amount of information on the subject has appeared. In view of the importance of voltage stabilization it is felt that another series of review articles will be of considerable interest. Some results of work on the characteristics of glow-discharge tubes which have not previously been published are also given.*

## Glow-Discharge Tubes

### Examination of Characteristics

Much work has been done recently on the characteristics of glow-discharge tubes. The suitability of such tubes for use in precision electronic circuits has been investigated by the author[3]. These investigations have been carried out on 135 new tubes of 14 different types. Many characteristics with which few engineers are acquainted are discussed. The tube types examined are: CV45(6), CV71(6), CV188(6), CV284(2), CV1070(36), S130(19), 85A1(34), KD60(6), G50/IG(2), G120/1B(2), G180/2M(2), VR105(2), VR150(6) and NT2(6). The figures in brackets indicate the number of each type tested.

Studies of the variations in striking voltages and running voltages, including step and hysteresis effects, have been made. The temperature coefficient of each tube and its initial drift have been recorded. The effects of overloads, magnetic and electric fields, vibration and storage have been noted. Some figures for voltage drifts to be expected during the life of a tube are also included and it has been determined whether improvements can be made by ageing tubes before putting them into service.

From this work it is concluded that glow-discharge tube characteristics show considerable variations, not only from tube to tube, but also with the passage of time and with changes in ambient temperature. Many of these variations have been largely unrecognized in the past. A careful revision of tube specifications seems necessary, since, in many cases, they are somewhat misleading.

Some high-stability tubes, namely, the 85A1 and miniature KD60 types, have been examined in the above work and these are found to show substantial improvements over the earlier designs. However, for precision work no glow-discharge tubes are suitable unless they are specially chosen and then used under carefully-controlled conditions.

Two other types of miniature high-stability tube, namely, the QS83/3 and 85A2 types, have since been examined in considerable detail and the results have been published recently together with the figures for some further KD60 tubes[4]. These three types are the only miniature high-stability tubes available in this country at present although, it is understood, that at the time of writing, production is about to commence on a high-voltage one (type G400/1K with a running voltage of 312 ±5V and a current range 2/4mA.) In the work referred to above[4] the value of maximum current for the 85A2 tube was taken to be 8mA. The tube was originally designed for a maximum current of 6mA, but it was later specified as 8mA and after the work was completed and accepted for publication it was specified as 10mA. The preferred operating current for the tube has also changed from 4·5mA to 6mA. Tests on the tubes at a current of 10mA show that the running voltage is still within specification, but only just in some cases. There are positive-initial drifts in running voltage of the tubes at 10mA which are much larger than the figures published for 8mA operation[4]. For 6 tubes examined the new figures for positive drift are 0·35 MAX., 0·29 MEAN, and 0·26 MIN., where the units are percentages of running voltage. The negative initial drifts and the durations of the drifts appear to depend very little on this change of current.

It has been pointed out by the manufacturers[5] that the 85A2 tube is intended as a reference element and should be operated at the preferred current. In spite of this it appears that it is still often being used as a simple stabilizer although, under these conditions, the performance of the tube is severely reduced. In fact, it has been stated[5] that a tube once used as a simple stabilizer should not thereafter be used as a high-stability (constant current) reference-level device.

It has also been found that if either the 85A1 and 85A2 reference tubes are run with reversed polarity for even a few seconds their stability will be seriously impaired and it may require some hundreds of hours' running in the normal direction before the tubes return to their original performance. Care should be taken, therefore, to test the polarity of the circuit before a tube is inserted.

Some tests have been carried out on the 85A1 tube for currents up to 30mA. The current-voltage characteristics of 6 tubes of this type over the range 1 to 30mA have been recorded and lie within the two dotted lines shown in Fig. 1. It will be seen that the regulation over the current range of 1 to 30mA is of the order of 10V and that all tubes pass the upper limit of specified voltage (87V) at a current less than 15mA. It is also interesting to see that the variations in the characteristics from tube to tube are not very great. The cathode glow at a current of 30mA extends right down to the bottom of the cathode supports. There are also large positive initial drifts at 30mA as might be expected. For 6 tubes the figures for this positive drift given as percentages of running voltage are: 3·06 MAX., 2·13 MEAN, and 1·37 MIN.

Life tests have been carried out on the four types of high-stability tube. The KD60 type has a limited life which seems to depend markedly on the tube current. For the 85A1 type there is no indication that the useful life is being approached even after 20 000 hours of continuous operation at 5mA. The 85A2 and QS83/3 miniature types have been examined so far for about 4 000 hours continuous operation at 5mA and 3mA respectively and show quite small variations of running voltage.

85A1 tubes have been operated continuously at 30mA but their running voltages increased rapidly with time. Life tests on 85A2 tubes at the new maximum current of 10mA show the tubes behave in a similar manner to that reported already for 5mA operation.

Although many investigations have been carried out to determine the characteristics and limitations of glow-discharge tubes the author was unable to find any litera-

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ture dealing with variations of extinction voltages. This information does not form part of the tube specifications either but for some applications it is desirable to know it. In view of this the extinction voltages of 137 tubes covering 15 different types have now been recorded and the results published[6]. The extinction voltage may vary considerably from tube to tube even of the same design. For all types of tube, however, the variation of extinction voltage is a good deal less than the variation of striking voltage. In many cases the extinction voltage is slightly higher than the running voltage at minimum specified tube current due to the existence of voltage steps at low currents. It is also interesting to note that a few tubes of the CV1110 (S130) type tested possessed extinction voltages higher than the specified maximum running voltage. Tubes of the CV1070, 85A1 and 85A2 types were run continuously for long periods at approximately constant tube currents of 5mA and the extinction voltages were recorded at intervals. In the case of the CV1070 tubes the extinction voltage rises gradually by a few per cent during the first 1 000 to 1 500 hours of life and then increases more rapidly. Tubes of the 85A1 and 85A2 types

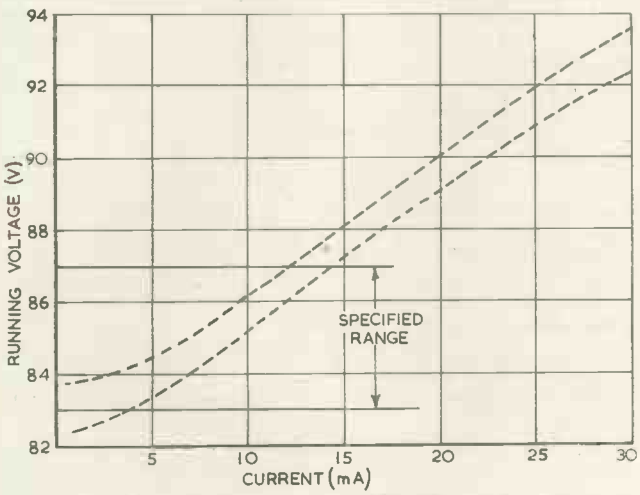


**Fig. 1. Voltage/current characteristic limits for six 85A1 tubes**

show practically no change of extinction voltage with life even after several thousand hours' operation.

It has been reported[7] that "an interesting feature of the VR105 and many other tubes is the fact that the temperature coefficients of running voltage are of opposite sign for deviations above and below room temperature." Bache and the author have recently measured[8] the temperature coefficients of several tubes of 14 different types as the ambient temperature was varied from 21°C down to 2°C to see whether this change of sign of temperature coefficient is observed in general or if it is a characteristic of certain tubes only. For 11 types of tube out of the 14 examined the running voltage increased as the temperature was reduced below room temperature. This might be expected since all these tubes had previously shown negative temperature coefficients[3]. These 11 types of tube are: CV1070, 85A1, 85A2, NT2, CV188, KD60, QS83/3, CV284, G120/1B, CV45 and S130. With the other 3 types, namely, CV71, VR105 and VR150, some, but not all, show the change of sign of temperature coefficient. These 3 types are the only ones previously reported to have shown positive temperature coefficients. An attempt has been made to explain the reasons for these results[8] since this has not been done before.

Little work has been done in the past on variations in running voltage with time for intermittent, rather than continuous, operation. Apart from the high-stability tubes using the 85A1 manufacturing technique, most others seem to have rather unpleasant characteristics showing noticeable changes during resting periods. Some typical characteristics of S130 type tubes run for various intermittent cycles at currents of 50mA are shown in Fig. 2. These forms of characteristic are not uncommon with glow-discharge tubes.

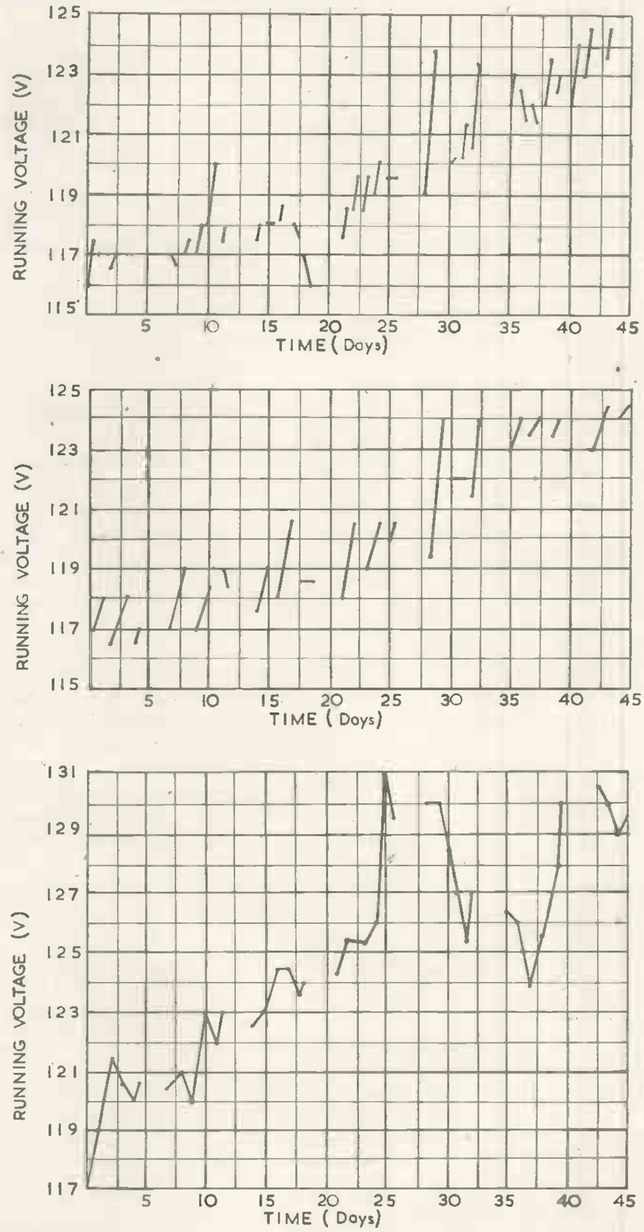


**Fig. 2. Typical characteristic of an S130 glow-discharge tube for intermittent operation**

*The lines indicate when the tube was operating at a current of 50mA. In the top diagram the tube was on for seven hours and off for 17 hours each day for five days a week. In the centre diagram the tube went through two cycles of 24 hours on 24 hours off followed by seven hours on each week. In the lower diagram the tube was on for the first 103 hours of each week. All tubes were new at the beginning of the test.*

Bache and the author[9,10,11] have investigated, in considerable detail, the peak-noise and mean-noise characteristics of many types of glow-discharge tube. Until this work was carried out very little information was available on noise characteristics of tubes. A few tube specifications quote a single value for the noise voltage but many specifications make no mention of noise characteristics. From the published results, the variations in noise with tube current, from tube to tube of similar or different designs, from operation to operation with a single tube, with life or with the effective load can be determined. The most important point seems to be that the noise characteristics of all tubes, at any stage in their life, follow the same general form, i.e., the noise increases with decreasing tube current. The noise increases rapidly as the region of minimum current is approached.

An interesting article on the current fluctuations in a direct-current gas-discharge plasma has been published by Parzen and Goldstein[12].

Information on several German glow-discharge tubes has been tabulated by Schumacher[13] and their current-voltage characteristics plotted.

Andrew[14] has drawn attention to the considerable increase of A.C. impedance of glow-discharge tubes with frequency and he mentions some interesting measurements on 7475 and 85A1 tubes over the frequency range 50 to 20 000c/s. Some typical resistance/frequency and inductance/frequency characteristics of a particular type of tube have also been given, and briefly commented on by Hunt[15].

Miles[16] has illustrated how families of curves for various tube types can be used for quick solutions of voltage-regulator tube circuit-design problems.

Kiryluk[17] has tried using a dynamic test for selecting good glow-discharge tubes for use in stabilized power supplies. This test not only reveals hysteresis, discontinuities and A.C. resistance of a tube but also permits a rapid determination of the best operating point for each tube individually. Kiryluk[17] has given a description of his dynamic-test circuit together with some typical traces obtained by the method.

Jacobs and Martin[18] have studied the role of cathode temperature in the glow-discharge of argon, neon, neon-argon mixtures and mercury-vapour/argon mixtures in the hope that some of the causes of the variations in the characteristics of glow-discharge tubes would be revealed. They examined the following as a function of cathode temperature and gas pressure, (a) striking voltage, (b) running voltage, (c) current density, (d) minimum current required to sustain the discharge. In all cases the cathodes were oxide-coated ones.

The following conclusions are drawn for tubes, without mercury vapour, for cathode temperatures between 300 and 750°K:—

(a) The striking voltage falls with increasing cathode temperature.

(b) The running voltage rises with increasing cathode temperature. For argon and mercury vapour the running voltage falls with increasing cathode temperature.

(c) The current density in the glow discharge decreases with increasing cathode temperature.

(d) The minimum current for sustaining a glow discharge decreases with increasing cathode temperature but rises with increasing pressure.

(e) The current density in the glow discharge varies approximately linearly with pressure.

(f) The running voltage rises very slightly at the lower pressures.

In a short article by Rudolph[19] a simple circuit is presented for predetermining the reliability of glow-discharge tube performance.

## Normal Cathode Fall in Neon for Various Cathode Materials

Further to the work which was carried out on the glow-discharge in neon with a plate-type molybdenum cathode, which led to the production of the high-stability tube type 85A1, Penning and Moubis[20] have now applied the same method to a number of other cathode materials. They publish figures for what they call the normal cathode fall $V_n$. The definition of normal cathode fall is given by Engel and Steenbeck[21] as the minimum voltage of the glow discharge between large parallel plates when the distance between the plates is varied. The value given by this definition is equal to the minimum voltage of the discharge between parallel plates when the current is changed, provided there is no anode voltage drop. Also, the anode shape is not very important. Penning and Moubis have, therefore, determined the minimum voltage, $V_{min}$, between a plate cathode and a rod anode. Values of $V_{min}$ thus obtained are, at the most, a few volts only different from $V_n$. Some of the metals used were only available in rod form and thus a correction had to be applied to bring the value to that for a plate cathode. It might be expected that $V_n$ should be independent of pressure[22] but this is not true for neon. Jurriaanse[23] has found for a molybdenum cathode that as the pressure is increased from 13 to 120mm of mercury $V_n$ decreases from 111 to 101V. Thus Penning and Moubis have reduced all their results to a pressure of 40mm of mercury. Table 1 shows the results obtained. $V_{min}$ represents the mean of the minimum discharge voltages in each case and $\triangle V$ is the estimated uncertainty. It is assumed that $V_n$ for the special pressure and cathode shape used is equal to the measured value of $V_{min}$. Table 1 is believed to represent $V_n$ for pure cathode materials in pure neon at a pressure of 40mm of mercury. Even for a pure metal $V_n$ may change somewhat with the surface condition. It was found difficult to obtain reproducible results with copper and silver and exceedingly difficult with carbon.

Attempts have been made many times to find a correlation between $V_n$ and some fundamental property of the cathode material. Güntherschulze[24] found that $V_n$ in neon could be represented by $V_n = c\phi$, where $\phi$ is the work

TABLE 1

Values of minimum discharge voltage $V_{min}$ and normal cathode fall $V_n$ (reduced to plate cathode and a pressure of 40mm mercury)

| MATERIAL | CATHODE | | PRESSURE (MM OF MERCURY) | $V_{min}$ (VOLTS) | $\triangle V$ (VOLTS) | CORRECTIONS (VOLTS) | | $V_n$ (VOLTS) FOR 40 MM PRESSURE AND A PLATE CATHODE |
|---|---|---|---|---|---|---|---|---|
| | SHAPE | DIAM. (MM) | | | | SHAPE | PRESSURE | |
| Carbon | — | — | 20 | 200 | ±20 | — | — | 195 |
| Silicon | Rod | 1·8 | 40 | 142 | ± 5 | −5 | — | 137 |
| Titanium | Plate | — | 20 | 116 | + 2 | — | −3 | 113 |
| Vanadium | ,, | — | 40 | 118 | ± 3 | — | — | 118 |
| Chromium | ,, | — | 40 | 123 | ± 5 | — | — | 123 |
| Iron | Rod | 1·5 | 20 | 137 | +10−2 | −4 | −4 | 129 |
| Nickel | ,, | 2·0 | 20 | 145 | ± 2 | −5 | −4 | 136 |
| Copper | ,, | 3·7 | 20 | 156 | ± 5 | −3 | −5 | 148 |
| Zirconium | Plate | — | 40 | 104 | ± 3 | — | — | 104 |
| Niobium | ,, | — | 40 | 106 | ± 3 | — | — | 106 |
| Molybdenum | ,, | — | 40 | 107 | ± 2 | — | — | 107 |
| | ,, | — | 20 | 111 | ± 2 | — | — | |
| Rhodium | ,, | — | 40 | 124 | ± 3 | — | — | 124 |
| Silver | Rod | 2·3 | 20 | 152 | ± 5 | −5 | −4 | 143 |
| Hafnium | ,, | 2·0 | 40 | 108 | ± 2 | −3 | — | 105 |
| Tantalum | Plate | — | 20 | 109 | ± 3 | — | −3 | 106 |
| Tungsten | ,, | — | 20 | 114 | ± 2 | — | −3 | 111 |
| Thorium | ,, | — | 20 | 115 | ± 3 | — | −3 | 112 |

function of the metal and $c$ is a constant. Penning and Moubis find large deviations from this relation.

STABILOVOLT CHARACTERISTICS

Some information has now been collected on the variations in the characteristics of the four-gap stabilovolts types STV280/40 and STV280/80. Some idea of the spread in running voltages from tube to tube for these types can be seen from Table 2. Voltage/time curves for a typical tube of each type taken over a period of three hours are shown in Figs. 3 and 4. The results of tests on striking voltages of a batch of 110 type STV280/80 tubes are shown in Fig. 5. Fig. 5(a) shows the number of tubes

TABLE 2

**Running-voltage limits for stabilovolts types STV 280/40 and STV 280/80. The figures for STV 280/40 refer to a current of 30mA and those for STV 280/80 to a current of 40mA and are taken after a 15-minute ageing period at these currents**

| | RUNNING VOLTAGES (V) | | | |
|---|---|---|---|---|
| | TUBE TYPE S.T.V. 280/40 | | TUBE TYPE 280/80 | |
| ELECTRODES | MIN. | MAX. | MIN. | MAX. |
| A4—C | 266 | 294 | 266 | 294 |
| A3—C | 183 | 236 | 189 | 231 |
| A2—C | 121 | 162 | 126 | 153 |
| A1—C | 60 | 80 | 60 | 80 |

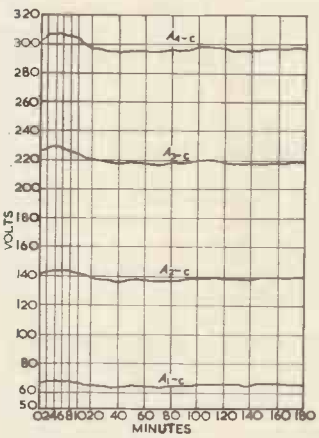


Fig. 3. Typical voltage/time characteristic of a stabilovolt type STV280/40 over a period of three hours

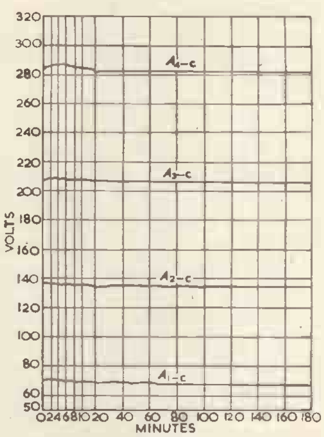


Fig. 4. Typical voltage/time characteristic of a stabilovolt type STV280/80

which struck at the particular voltages in the range and Fig. 5(b) shows groups of tubes referred to discrete striking voltages to give an impression of the shape of the curve.

It is understood that some manufacturers are working on multi-electrode cold-cathode tubes with 85A1 type technique. These will, no doubt, show big improvements in the variations of the characteristics from tube to tube and with life.

STABILOVOLTS IN PARALLEL

It is interesting to see that Harvison[25] has used two STV280/80 stabilovolts in parallel to provide high-current output. He gives a circuit diagram, with typical component values, for an output of 280V at 120mA.

## Corona Voltage-Regulator Tubes

A corona discharge between coaxial cylinders offers a means of stabilizing voltages at currents below 1mA and is probably well known now in principle. These tubes stabilize at voltages higher than the normal glow-discharge tubes. A good deal of information on such tubes can be found in the literature[26-36].

The subject has been studied for a good many years by the Naval Research Laboratory, Washington, and some early results on their work were given by Friedman and Kaiser[28] and a more detailed account of the theory and performance of corona tubes by Blifford, Arnold and Friedman[29]. Lichtman[27] has reviewed all the Naval Research Laboratory work and has given examples of the constructional features and performance characteristics of

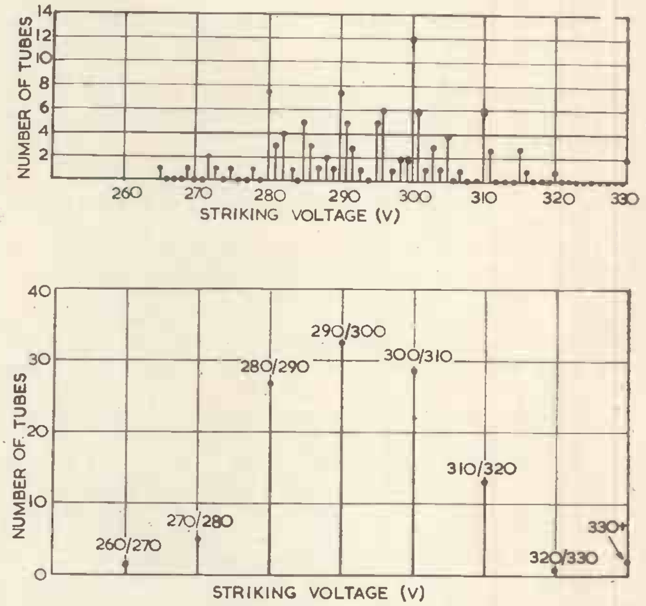


Fig. 5. Striking voltage characteristics of 110 stabilovolts type STV280/80 (*Voltages measured between $A_4$ and cathode.*)

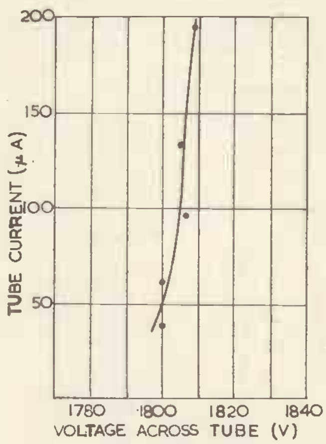


Fig. 6. Characteristic of subminiature corona tube

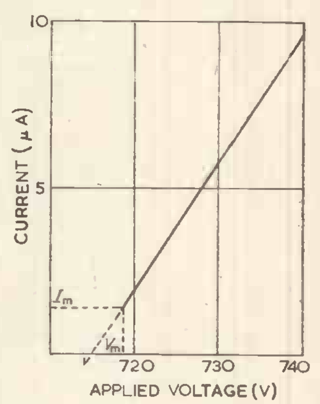


Fig. 7. Typical corona-discharge characteristic

some typical tubes. He points out that laboratory models have been made in a large number of sizes, using various electrode materials, gas fillings and types of construction. Tubes having cathode cylinders as large as 3ft in length and 0·5ft in diameter have been used for operating 40 000V X-ray equipment and subminiature sizes for voltages up to 2 000V have also been constructed. One subminiature tube uses a cathode of chrome-iron 3/16in long and $\frac{1}{8}$in diameter. Its maximum diameter is 3/16in and its overall length is less than 1in. This tube stabilizes at about 1 800V with currents up to 200μA. The performance obtained for such a tube is shown in Fig. 6.

Lichtman[27] has presented a good account of some of the theoretical aspects of corona discharges. A typical discharge characteristic is shown in Fig. 7 for a pair of coaxial cylinders in a gas filling consisting of a wire anode and a comparatively large-diameter cathode. With no external ionizing radiation the current through the gas will be initially small. On raising the voltage a critical value $V_m$ is reached, which is sharply defined, where a self-sustained corona is obtained. Here a luminous sheath appears round the anode and the current is now of the order of microamperes. On increasing the applied voltage further the current increases continuously until the gap breaks into a complete glow.

The reciprocal of the slope of the characteristic of Fig. 7 has resistance dimensions ($r$). If the characteristic is straight the following expression holds: —

$$V = v + rI \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

where $V$ is the tube voltage when passing a current $I$ and $r$ and $v$ are constants.

The corona-tube circuit for voltage stabilization is similar to that for a normal glow-discharge tube (i.e. a resistor is included in series with the tube) and can be analysed in the same way. The effects of tube dimensions and gas filling on the constants $r$ and $v$ of Equation (1) have been worked out by Werner[37] and Loeb[38] and the results have been given by Lichtman[27].

Lichtman[27] has also given some other interesting data on corona tubes. The influence of temperature on the operation of a commercial 700V tube is shown in Fig. 8. Such a tube, he states, has a useful life much greater than 1 000 hours at a current of 50$\mu$A. But he gives no definite figures for the life nor does he state how, or whether, the operating current affects life. Apparently, such a tube is suitable for use over an ambient temperature range of −50°C to +75°C.

For good performance the tube elements should be in coaxial alignment. Eccentricity in anode centring or non-parallelism of cylinder axes both prevent a uniformly-distributed discharge over the surface of the anode. This may result in sharp discontinuities in the characteristics and rise of slope resistance of the voltage-current curve.

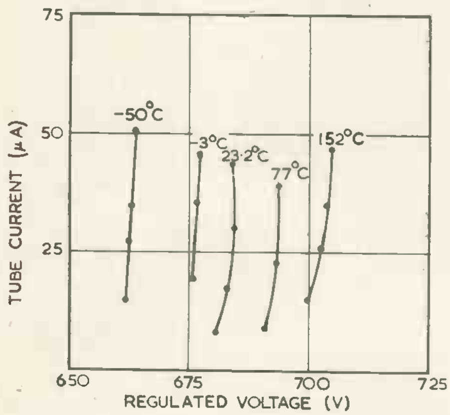


**Fig. 8. Influence of temperature on the discharge characteristic of a corona tube**

Corona regulators, like normal glow-discharge tubes, can be used in series to give multiple voltages or higher voltages than can be obtained from a single tube. Naturally, in such cases, if their current ranges are different, they must overlap in the region where they are to be used.

Corona tubes can act as voltage-reference elements for thermionic-valve stabilizers in the same manner as ordinary glow-discharge tubes, but they take small current.

The characteristics of two American subminiature corona tubes, types 5841 and 5950, as specified[39] by The Victoreen Instrument Co., are given in Table 3. These may be compared with glow-discharge-tube specifications.

**TABLE 3**

**Characteristics of two American subminiature corona tubes**

| TUBE TYPE | STRIKING VOLTAGE ($V$) (MAX.) | RUNNING VOLTAGE ($V$) | CURRENT RANGE ($\mu$A) | REGULATION OVER CURRENT RANGE (%) (MAX.) | LIFE |
|---|---|---|---|---|---|
| 5841 | 930 | 900±15 | 2—50 | 1·5 | 1000 hours minimum |
| 5950 | 730 | 700±15 | 2—50 | 1·5 | Unlimited by use |

Corona tubes are now available in this country. There is a complete range of tubes operating at voltages to match the various types of G.M. tubes in general use. Articles dealing with British corona tubes have been written by Shelton and Wade[33], by Holton and Sharpe[34] and by Smith and the author[36].

An excellent description of corona tubes has been given recently by Shelton and Wade[33]. The work they report was undertaken because a need arose for stabilizing voltage supplies to low voltage (400V) G.M. counter tubes. Two types of construction are briefly described and mention is made of some of the development work which had to be carried out. Curves of the stabilizing voltage against gas-filling pressure which are given illustrate the differences which can arise from the choice of the filling. Other curves shown are: —

(a) Stabilizing voltage when the anode diameter, cathode length and tube current are held constant and the cathode diameter and gas pressure are varied.

(b) Stabilizing voltage for fixed cathode diameter, cathode length and tube current while the anode diameter and gas pressure are varied.

(c) The incremental resistance (i.e. the slope of the voltage-current curve of the tube) against pressure for various cathode and anode diameters.

It is concluded that the stabilizing voltage increases with gas pressure, cathode diameter and anode diameter. The incremental resistance increases with gas pressure and cathode diameter but decreases as the anode diameter increases. It is interesting to note that Shelton and Wade have found that asymmetry of the cylindrical electrode structure has little effect on the stabilizing voltage.

They have also investigated the life of corona tubes. Four tubes were put on shelf test and another four on continuous operation life test. During the shelf test, of about three months' duration, the voltage of one tube remained constant, the voltage of another tube increased by 5V and the voltages of the remaining two fell by 4V and 3V respectively. The voltages of the tubes placed on life test fell rapidly during the first 300 hours and considerable work was done to improve the life characteristics. The work was successful and led to the production of tubes with lives greatly in excess of 1 000 hours.

Holton and Sharpe[34] have outlined the requirements of E.H.T. supplies for use with proportional counters employed for radioactive assay work and have described a supply, using corona tubes, which has the required characteristics. The supply gives three stabilized voltages, namely 1 000V, 1 600V and 2 400V. For an input voltage of 230V ± 25V the output voltage is 2 400V ± 4V. For a change in temperature of the power-supply unit from 20°C to 40°C the output voltage changes by 3V.

Smith and the author[36] have studied the variations in the characteristics of six, 500V, corona tubes. Variations of striking voltage and running voltage from tube to tube have been recorded and the effects of ambient-temperature changes and of excess current on the tube characteristics have been noted. Running-voltage drifts have been observed during the first 1 200 hours of life and the properties of tubes run with reversed polarity have been discussed.

The work of Saha, Chandersekhara and Sundaresen[40] is of interest and should be mentioned in this section. They have produced a voltage stabilizer for the range 600/2 000V (current about 100$\mu$A) which is effected with the help of gas ionization in an air-discharge tube of variable

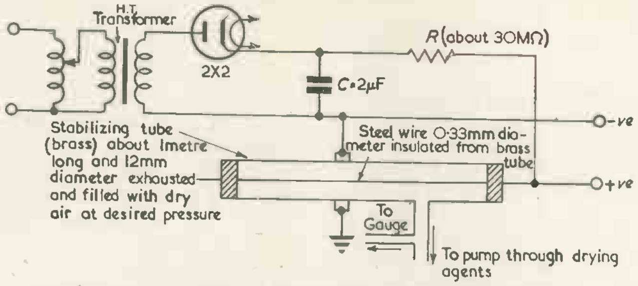


Fig. 9. Stabilizer using an air-discharge tube of variable pressure

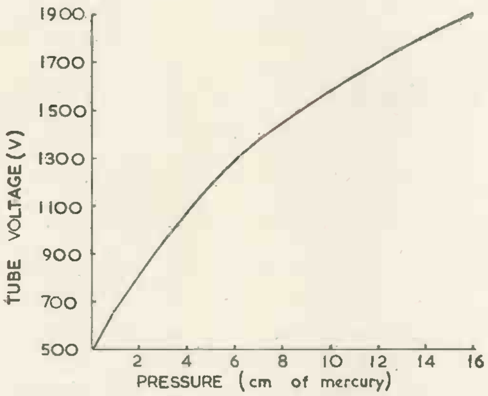


Fig. 10. Air-discharge tube voltage/pressure characteristics

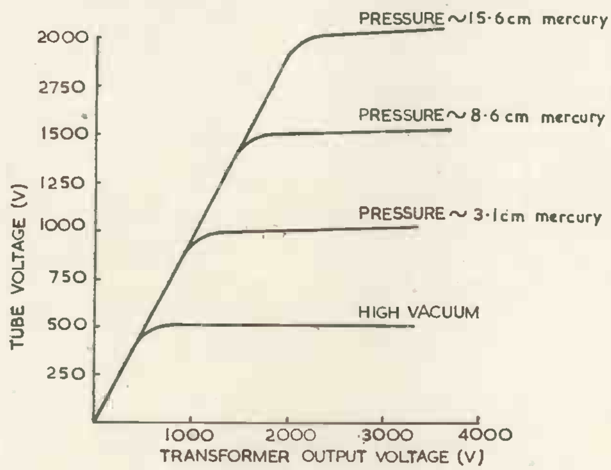


Fig. 11. Air-discharge tube characteristics

pressure. Their circuit arrangement is shown in Fig. 9. The action of this circuit is as follows. If the output voltage of the transformer is raised from its lowest value the voltage drop across the discharge tube also increases. At a certain voltage, depending on the pressure inside the tube, the voltage becomes constant for a wide range of transformer output voltage. The stabilized voltage increases with pressure as shown in Fig. 10. At a given pressure the constant voltage is due to the fact that a rise of transformer output voltage produces a higher tube current which gives a larger voltage drop across resistor $R$ thus compensating for the transformer voltage increase.

The voltage across the tube for various pressures is shown as a function of the rectified transformer output voltage in Fig. 11. At the points where stabilization begins spontaneous flunctuations of tube voltage, for a fixed transformer output voltage, are found but are not shown on Fig. 11.

At a stabilized voltage of 1 500V a variation of about 2·5 per cent is observed when the transformer output voltage is varied from 2 000 to 3 500V.

*(To be continued)*

## REFERENCES

Apart from the references quoted in the text which are given below an additional list of references will be given for further reading. This additional list contains a number of interesting articles which, although not all recent, have been found useful by the author since the publication of "Voltage Stabilizers."


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# Power Supply for Multi-Speed Record Players

By Lt.-Col. C. A. Henn-Collins, M.I.E.E.

THERE is a dearth of suitable equipment for the reproduction of long playing records where the mains supply is direct current. The problem exists, too, where the supply is alternating and the frequency is not standard, or where the frequency stability is bad.

If D.C. is available then it will be found that many readily available D.C. operated record players intended for 78 R.P.M. service are not satisfactory when used with speed reduction type turntables for slow speed records. The slightly uneven torque due to varying armature currents produces audible modulation which is very unpleasant.

In this case an obvious solution is to use a rather costly rotary convertor. Apart from the cost, the frequency stability of conventional types is poor. There are, too, the well-known problems of suppressing the acoustic and electric noise. Recent U.S.A. literature has described special types claiming excellent frequency stability and various vibratory convertors are marketed in this country. However, either moving or vibratory mechanisms have a worse maintenance liability than purely static devices using components common to domestic radio equipment.

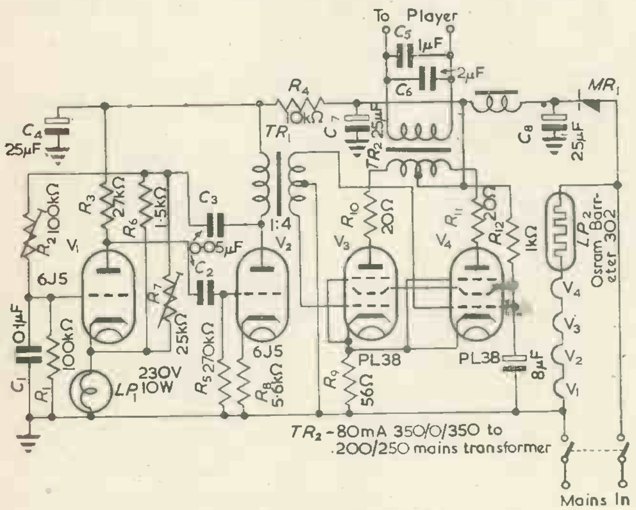


Fig. 1. The complete circuit

When the A.C. supply frequency is unsuitable the problem has often been insoluble. Most popularly available record players for domestic use have synchronous and not governed induction type motors.

These considerations have led to the design of an A.C./D.C. operated static power source for multi-speed record players.

The solution adopted by the author is to use a Wien bridge oscillator stabilized by a high degree of feedback to excite a push-pull amplifier using a pair of high gain pentodes. The tubes chosen were designed as line scan amplifiers in A.C./D.C. television receivers. The unit is powered by a conventional half-wave rectifier and filter, while the heaters are supplied through a barretter.

Fig. 1 shows the circuit diagram. It is easy to assemble, cheaper than rotary and vibratory convertors and produces no noise or interference whatever. It is suitable for any mains voltage from 200V upwards, A.C. or D.C. without adjustment. It possesses excellent frequency stability.

$R_1$, $C_1$, $R_2$ and $C_3$ are the controlling elements of the Wien bridge, while $R_{6,7}$ and $LP_1$ constitute the feedback path. As the frequency range required is fixed it is not necessary to vary more than one element in the bridge. Adjustment to the desired frequency is made by varying $R_2$. The variable resistors $R_2$ and $R_7$ have detents fitted on their spindles to prevent fortuitous movement. With the component values chosen the oscillator will run at any chosen frequency between 40 and 70c/s or higher. If desired, $R_2$ can be adjusted to enable $33\frac{1}{3}$ R.P.M. players to be used to play 45 R.P.M. records.

The feedback should be set up so that the peak voltage across $T_1$ is approximately 4·5V. If suitable equipment is not available to set this, adjust the feedback until the output voltage to the player motor begins to fall heavily.

The amplifier is designed so that no trouble will ensue if no load is connected. This is important with record changers with automatic stop switches. $R_9$ provides upwards of 7V bias and the series resistor in the screen supply, $R_{12}$, drops the voltage to about 100V when the load is off, so preventing the permissible screen dissipation being exceeded.

If more output is required than this circuit arrangement allows then the screens can be connected direct to the H.T. line. It is then necessary to provide a dummy load when the player is disconnected. The output transformer shown is a standard domestic radio set mains transformer. The common ratio chosen gives adequate matching by connecting the player motor in the 110V condition. The motor circuit should be tuned by means of the capacitors $C_5$ and $C_6$. Depending on the make of record player series or parallel tuning may be best.

The power supply calls for two comments only. Ample smoothing is required of the supply to the oscillator pair, or they will lock on the mains hum or a sub-multiple of it. Secondly the selenium rectifier provides H.T. instantly and until the cathodes warm up the voltage will rise on A.C. supplies to the peak value. Therefore the electrolytic capacitors must be appropriately rated.

The unit performs excellently and will operate satisfactorily any record player having suitable low wattage synchronous motors. The frequency stability is about 1 part in $10^4$.


## USING THE TELEVISOR WITH WIDE-ANGLE C.R.T's.

Now that large screen wide-angle cathode-ray tubes are available for the home constructor, many owners of the ELECTRONIC ENGINEERING Home Built Televisor will want to modify their receivers to use these later type tubes.

An eight-page leaflet giving full details of the modifications required is now available, price 1s. post free, from:—

The Circulation Department,
ELECTRONIC ENGINEERING,
28 Essex Street, London, W.C.2.

# Notes from the Industry

**Premiums for Technical Writing.** The Radio Industry Council, organization of the manufacturers in all branches of the industry, announces six further awards of premiums for technical writing. Full awards of 25 guineas were made to:

P. H. Parkin, B.Sc., A.M.I.E.E., and P. H. Taylor, A.M.I.E.E., for an article in *Wireless World*, February-March, 1952, on "Speech Reinforcement in St. Paul's Cathedral." Mr. Parkin is principal scientific officer in charge of acoustics and insulation at the Building Research Station, Garston, Watford. Mr. Taylor is technical director of Pamphonic Reproducers, Ltd.

T. Somerville, B.Sc., M.I.E.E., F.Inst.P., head of the Electro Acoustics Group of the Engineering Research Department, BBC, and C. L. S. Gilford, M.Sc., F.Inst.P., head of the acoustics section of the Group, for an article in the *BBC Quarterly*, Spring, 1952, on "Composite Cathode Ray Oscillograph Displays of Acoustic Phenomena and their Interpretation."

J. A. Jenkins, M.A., M.Inst.P., and R. A. Chippendale, B.Sc., for an article in ELECTRONIC ENGINEERING, July, 1952, on "Some New Image Convertor Tubes." Mr. Jenkins is in charge of the photo-electric division of the Mullard Vacuum Physics Research Laboratories, and Mr. Chippendale is his chief assistant.

W. R. Stamp, on the staff of the Admiralty Research Laboratory, Teddington, for an article in *Discovery*, September, 1952, on "Underwater Television."

Ex gratia awards of £10 each were made to T. W. Bennington, who is engaged on ionospheric and short-wave propagation work in the Research Department, BBC, for an article in the *Wireless World*, January, 1952, on "Propagation of VHF via Sporadic E"; and to G. N. Patchett, Ph.D., B.Sc., A.M.I.E.E., M.I.R.E., A.M.Brit.I.R.E., head of the Electrical Engineering Department of Bradford Technical College, for an article in the *Wireless World*, July-August, 1952, on "Faulty Interlacing."

The new awards will be presented at a luncheon of the Public Relations Committee of the Radio Industry Council at the Cafe Royal, Regent Street, W.1, on Thursday, April 9.

**Marconi's Wireless Telegraph Co., Ltd.**, have created a new post of General Works Manager of all works and model shops of the company. It will be filled by Mr. Robert Telford, A.M.I.E.E., who was formerly assistant to the General Manager. Mr. J. P. Wykes, A.M.I.E.E., will continue as Works Manager of the Chelmsford Works, and Mr. E. B Greenwood, A.M.I.E.E., has been appointed Works Manager of a self-contained factory now being built at Basildon New Town, Essex.

**U.S.A. Radio Buyers to visit R.E.C.M.F. Exhibition.** Mr. Leonard Carduner, President of the British Industries Corporation of New York, who are the U.S.A. distributors for Garrard Record Changers and Ersin Multicore Solder, is making arrangements to fly over a party of important American radio buyers for the R.E.C.M.F. Exhibition.

**Journal of the Audio Engineering Society.** This is a new American issue for the publication of papers on broadcast audio equipment, recording and reproduction of sound and music and related subjects. Inquiries should be addressed to the Editor, P.O. Box 12, Old Chelsea Station, New York 11, N.Y.

**Television Test Transmissions.** Until June 1 the BBC's morning test transmissions for the trade will be extended by one hour, and will run from 10 a.m. to 1 p.m. continuously on weekdays. The extra hour's transmission from 12 noon will consist of a picture of Test Card C with 440c/s tone on the sound channel. The BBC is now also able to give details of the temporary low-power television station to be installed near Brighton which will be in service before the Coronation and is intended to improve reception in the populated districts of Brighton, Hove, Worthing, and Shoreham-by-Sea, where reception from Alexandra Palace is at present unreliable.

**The Eighth Annual Electronics Exhibition** organized by the North-Western Branch of the Institution of Electronics will be held at the College of Technology, Sackville Street, Manchester, from July 15-21. A series of lectures and film shows on electronic subjects will also be presented. All inquiries should be addressed to the Honorary Exhibitions Secretary, Mr. W. Birtwistle, 17 Blackwater Street, Rochdale, Lancs.

**The Plessey Company, Ltd.** have appointed Mr. L. W. D. Sharp, M.A.(Cantab), A.M.I.E.E., to be Chief Engineer, Components Division. Mr. Sharp has, for the last two years, been Chief Radio Engineer, Telecommunications Division, engaged in the development of radio equipment for mobile applications and for ground-to-air and fixed link communication.

**Wolf Electric Tools, Ltd.** are opening a new office and service depot at Leeds to replace the previous service depot at 2 Park Square, Leeds, which has become inadequate to handle increasing business. The new premises are at 405 York Road, Leeds 9, and are under the direction of Mr. D. S. Powell.

**R.E.C.M.F. EXHIBITION**

**"Electronic Engineering" will be represented at the R.E.C.M.F. Exhibition to be held at Grosvenor House, Park Lane, London, W.1, from April 14 to 16 inclusive. The Stand number will be 102.**

**Marconi's Wireless Telegraph Company** announce that the Canadian Broadcasting Corporation has ordered British television transmitting equipment for Ottawa. This will be the third station in a network the Corporation is planning to build across the country, of which the Toronto and Montreal stations have been working since September last. Ottawa will have a 5-kilowatt vision transmitter and a 3-kilowatt sound transmitter, with all associated monitoring and control equipment. The new station is due for completion in the autumn.

Orders for transmitter and studio equipment for broadcasting extensions in Nigeria, Kenya, Uganda, Tanganyika and the Gold Coast have also been received by Marconi's from the Crown Agents for the Colonies.

**The Glass Manufacturers' Federation** announce that Mr. C. E. Weeden has been appointed Publicity Officer to the Federation which was founded in 1926, and which is the central Trade Association for the British Glass Industry.

**A Television Outside Broadcast Unit** for the West of England and Wales based at Whitchurch, near Bristol, now enables events and ceremonies taking place in Wales and the West to be brought within range of the television cameras and broadcast from the national television network.

**The Radio Communication and Electronic Engineering Association** have announced a change in their constitution empowering the Council to introduce a new class of associate membership which the Chairman, Mr. K. S. Davies, expects will appeal alike to the small company as well as to the larger concern having a limited interest in this field.

**The Scientific Instrument Manufacturers' Association** are able to supply a limited number of copies of the proceedings of their first convention to bona fide instrument makers who are not members of the Association. Application should be made to the Secretary at 20 Queen Anne Street, London, W.1.

**South East London Technical College Department of Electrical Engineering** are giving a course of six lectures on Electric Strain Gauges. The lectures will take place on Thursday evenings from April 16 to May 12, inclusive. The syllabus will cover methods of experimental stress analysis, types of wire gauge, forming characteristics, methods of manufacture, sensitivity, temperature effect, fixing techniques, etc. The fee for the course is 17s. 6d. and application should be made as soon as possible to the Head of the Department of Electrical Engineering, South East London Technical College, Lewisham Way, London, S.E.4.

**Errata.** The title of the article which appeared on page 110 of our March issue should have read "Visual Method for the Determination of Electrolytic Conductivity."

On page 124 of our March issue we referred, in our description of the new civil aviation communications centre, to radio-teletype machines. This should have been radio-teleprinters, and we have been asked to point out that the word Teletype is the registered trade mark of the Teletype Corporation.

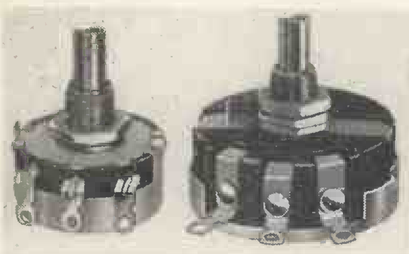
# R.E.C.M.F. EXHIBITION PREVIEW

*A description of selected exhibits at the Exhibition of the Radio and Electronics Component Manufacturers Federation to be held in the Grand Hall, Grosvenor House, Park Lane, London, W.1. from April 14 - 16.*

*(Figures in parenthesis refer to Stand Numbers.)*

**A.B. Metal Products, Ltd. (64)**

"CLAROSTAT" controls and resistors are now being manufactured under licence in this country by AB Metal Products, Ltd., and will be exhibited on this stand. Typical examples of this range are illustrated below.



The following new components will also be on view:—

1. The A.B. "H" Type Switch with ceramic insulation.
2. The A.B. "H" Type Switch in a miniature version both with S.R.B.P. and ceramic insulation.
3. A Programme Switch Unit for use in Relay and Wired Radio.

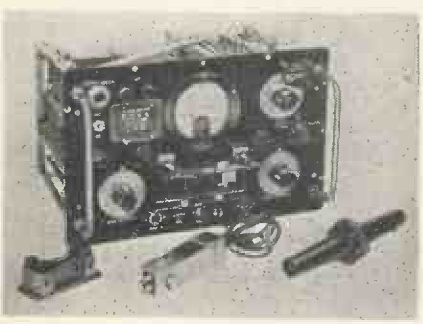
**A.B. Metal Products, Ltd.,**
**16 Berkeley Street,**
**London, W.1.**

**Avo (105)**

THE principal new exhibit of this firm will be the Electronic Multimeter, which is illustrated below. This instrument is basically a highly stable balanced valve D.C. millivoltmeter having a full scale sensitivity of 250mV, with a R.F. diode head, decade R.F. amplifier, voltage multipliers, shunts and a valve stabilized power supply.

Ninety-five ranges are included in the instrument which complies with Inter Services Specifications K114 and RCS. 1 000. Voltage measurements from 250 mV to 10kV can be made at D.C., A.C., and low radio frequencies. Radio frequencies up to 250Mc/s are covered by the use of the diode head.

All D.C. ranges are of reversible polarity with respect to earth and a single zero setting serves for all ranges. The movement is automatically protected against overload.



Another new instrument is the AVO Power Factor and Wattage Unit. This unit, which is the same size as the Avometer, comprises two parts: the main assembly, which contains the power factor computor, controls and leads, and the lid on the inside of which the wattage and kVA computor is mounted.

The unit is intended for use with commercial A.C. supplies from well below 100V to 450V. From readings taken on the Avometer used in association with the unit, power factor and A.C. power can be determined in single phase and balanced or unbalanced two or three phase circuits, provided the current remains constant for two or three seconds, and is of normal sinusoidal waveform. Unbalanced two or three phase power can be determined as the sum of the powers in the separate phases.

**Automatic Coil Winder and Electrical Equipment Co., Ltd.,**
**Winder House,**
**Douglas Street,**
**London, S.W.1.**

**Cosmocord (59)**

A NEW range of complete Acos pick-ups and pick-up cartridges will be shown by Cosmoscord, Ltd. Of particular interest will be new pick-ups and cartridges capable of tracking the latest types of microgroove records. This new development has been necessitated by the introduction of records capable of playing up to 30 minutes per side with greatly reduced groove dimensions and the extension of the dynamic range by nearly 100 per cent.

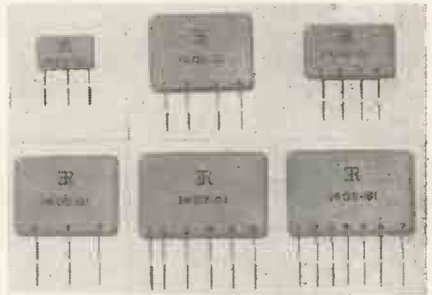
There will be an improved range of hearing aid microphones giving an increase in the performance-to-size ratio.

**Cosmocord, Ltd.,**
**Enfield, Middx.**

**Erie (26)**

ERIE isolators have been developed primarily to meet the urgent demand for a capacitor for mains isolation at aerial sockets and at other similar danger points in radio and television receivers. They are the first ceramic capacitors to provide such a means of safety in a size compatible with the present-day trend towards miniaturization, and they are the only capacitors produced to date, which comply with the recommendations of BS.415.

Two types are available, namely, CD6P/100 capacitance 470pF ± 20 per cent and CD9P/101, capacitance 1 800pF +80 per cent −20 per cent, both half-potted in low loss durable mouldings. The CD9P/100, is ideal for suppressing television interference caused by small



domestic motors for which application they also comply with BS.613.

A range of high voltage disk ceramic capacitors will also be exhibited. These capacitors are intended primarily for the suppression of interference by the small electric motors used in vacuum cleaners, hair dryers and shavers.

Printed circuits which have recently been developed by Erie will make their first appearance on this stand. Five types are immediately available comprising three forms of coupling circuits and two filter circuits. These are illustrated above at approximately half-size. The largest printed circuit contains five capacitors and three resistors.

**Erie Resistor, Ltd.,**
**The Hyde,**
**London, N.W.9.**

**Ferranti, (37)**

ON this stand is exhibited a wide range of small transformers and chokes. These are designed to meet the requirements of electronic and light cur-

rent equipment manufacturers, and are produced in Edinburgh.

The "Pentland" series of transformers and chokes is a range of resin cast components designed to meet, at low cost, the stringent requirements of Interservices Specification RCS. 214 and are being exhibited this year for the first time. They are completely hermetically sealed in a block of resin which provides a robust unit capable of reliable operation through wide ranges of ambient temperatures and under extreme climatic conditions. This method of construction enables units to be made smaller and lighter than conventionally cased units; the greatest savings are apparent in high voltage applications.

An extensive range of valves and cathode-ray tubes including several new types for industrial and domestic use, from the Electronics Department., Moston, will also be on show.

**Ferranti, Ltd., Hollinwood, Lancashire.**

### G.E.C. (100)

MANY new items will be included in the display of valves, cathode-ray tubes and other electronic devices to be shown on this stand.

In addition to the current ranges of valves there will be a new "Quiet A.F. Pentode" suitable as a first stage valve in high gain amplifiers and a new high slope R.F. pentode with characteristics eminently suited to video amplification. A series of indirectly heated sub-miniature valves and two new G.M. halogen quenched counter tubes will also make their first appearance.

Three new high voltage germanium diodes have been introduced and a new transistor will be a key exhibit.

Among the cathode-ray tubes there is to be a 14in all glass rectangular television tube and a 12in circular tube with a flat face. The latter uses a 6.3 volt 0·3 amp heater, which makes it suitable for A.C. or D.C. television receivers.

**The General Electric Company, Ltd., Magnet House, Kingsway, W.C.2.**

### Goodmans (31)

ONE section of this stand will be given over to the display of the Vibration Instruments manufactured by the Special Products Division of this company for use in fatigue testing, biological research, calibration of acelerometers, etc.

Model 8/600 Vibration Generator illustrated above is a recent addition to this range and has been designed for vibration testing of heavy components or complete assemblies.

The principle details of this generator are:—

Stroke, 1in. total excursion.
Frequency range, up to 3kc/s.
Weight of moving system, 6lb.
Total weight, 4cwt.

The unit can be fitted with a built-in air blower, a switch to give a high or low impedance armature coil, and a pick-up unit for monitoring the amplitude and waveform of the vibratory motion.

On the stand also will be exhibited

amplifiers for driving the vibration generators.

**Goodmans' Industries, Ltd., Axiom Works, Wembley, Middx.**

### Hallam, Sleigh and Cheston (85)

THE range of Widney-Dorlec Components has recently been extended to 4 basic gauges.

The new sizes are the "Heavy Gauge" which is particularly useful for large cubicles and rack mounted equipment, and the "Miniature Gauge" which, as its name suggests, is intended for small cases.

The "Miniature Gauge" is of novel construction and a complete departure from the Widney-Dorlec Cabinet System as it has been known in the past. Fully radiused cabinets can be quickly assembled by spot welding, and this system should be invaluable for production use.

The range of telescopic mountings manufactured by this firm have also been extended and include the new Admiralty roller bearing type, which is being specified for all new development work by the Services. A miniature slide suitable for radiogram and unit chassis is also displayed.

**Hallam, Sleigh and Cheston, Ltd., Technical Sales Office, 299 New King's Road, London, S.W.6.**

### Hellerman, Ltd. (71)

A RANGE of pressure and waterproof bungs has recently been introduced by Hellerman, Ltd. These components, which are now widely used by both the aircraft and electrical industries are made from a thermoplastic and act as a seal between one or more cables and a bulkhead junction box, instrument case or the like.

The bung consists of a PVC plug with a number of holes running through it from the wide end; across the narrow end there is a thin diaphragm of PVC over the holes. The purpose of the diaphragm is to maintain a pressure seal even though the holes of the bung are not all filled with cables.

The waterproofing bung is very like the pressure bung except that the wide end has a brim on it. A cone-shaped ferrule is supplied to fit over the bung, giving greater compression and increasing the waterproof seal on the cables. The assembly is then held on to the plug by the standard coupling nut. The bung also provides a cordgrip which takes the strain of any tension on the cables.

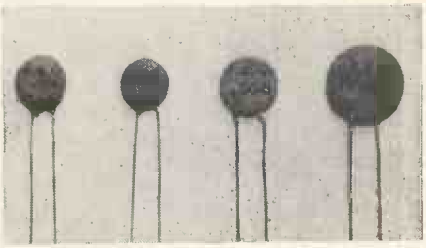
**Hellerman, Ltd., Tinsley Lane, Crawley, Sussex.**

### L.E.M. (44)

NEW high permittivity disk capacitors manufactured by this firm are illustrated in the photograph below.

These capacitors are made in a range from 0·001$\mu$F to 0·005$\mu$F and have been specially developed for by-pass and decoupling uses on television and V.H.F. frequencies.

Another new capacitor is the type 1106. This is a sub-miniature silvered mica capacitor 11 × 6mm in size with a capacitance range from 10-1 500pF at 350V D.C. working. This small capacitor has a close temperature co-efficient of 30



parts per million per °C. and is suitable for operation from −70°C. to 100°C. under H2 conditions.

**London Electrical Mfg. Co., Ltd., Beavor Lane, Hammersmith, London, W.6.**

### Marconi Instruments, Ltd. (96)

SIX instruments from the wide range of test equipment produced by this company will be exhibited. Among these will be the Output Power Meter TF893, illustrated below.

This is a wide range audio power meter for measurements on receivers, amplifiers, etc., and covers 20$\mu$W to 10W

with a frequency characteristic flat from 50c/s to 25kc/s. The input impedance is adjustable between 2·5Ω and 20 000Ω in forty-eight steps for balanced inputs—and a similar number for unbalanced at one-quarter the impedance—consequently the instrument is ideal for optimum load matching. Two important design features play a great part in this meter's performance over so wide a range of impedance. First, the use of a resistance network to select the significant figures of the input impedance value and second, decade multiplication of impedance by a transformer with a wound-strip core of anistropic alloy.

**Marconi Instruments, Ltd.,**
**St. Albans, Herts.**

**Mullard (20, 115, 120)**

SHOWN for the first time will be an entirely new range of miniature 25mA valves for use in all-dry battery portable receivers. The range includes an R.F.


pentode; a frequency changer; a diode pentode; an output pentode; and a new form of tuning indicator, the DM70.

Also to be shown for the first time will be two 10mA flat sub-miniature valves, the DF64 voltage amplifier pentode and the DL64 output pentode. These valves, which are among the smallest of their class in the world, have been specially developed for use in hearing aids. These valves have been designed with satisfactory low-voltage operation in mind, using the newer-type 15-volt H.T. batteries.

Another interesting exhibit will be a new range of all-glass valves on the novel (9-pin) base, specially developed for use in high-quality amplifying equipments—audio amplifiers; sound-on-film apparatus; magnetic recorders, etc. Prominent among these valves is the voltage amplifying pentode EF86. This is primarily intended for use in high-gain, R.C. coupled A.F. voltage amplifying stages, and is characterized by extremely low noise, low hum and freedom from microphony. Other valves in this new Mullard range include the ECC81, ECC82 and ECC83 double-triodes; the high-sensitivity output pentode EL84 and the EZ80 full wave, indirectly-heated rectifier.

Of interest to designers of television equipment will be two germanium crystal diodes, the OA60 intended for use as a video signal detector, and the OA61, which finds important uses as a D.C. restorer or synchronizing pulse clipper. Both these crystals are of robust construction and have been designed to withstand heavy shocks. They have a nominal shunt capacitance of 1·00pF and can be used between ambient temperature limits of −50°C. to +60°C.

Also of interest to designers of television receivers will be the 17in. rectangular, long-life television picture tube, MW43-64. A feature of this new tube is the incorporation of a new design of electron gun that ensures uniform focusing over the whole screen. The tube also has a grey glass face, which enables pictures of extremely good contrast and low glare to be obtained, even under conditions of normal room lighting. A metal-coned version of the MW43-64 will also be exhibited. This is the MW43-43.

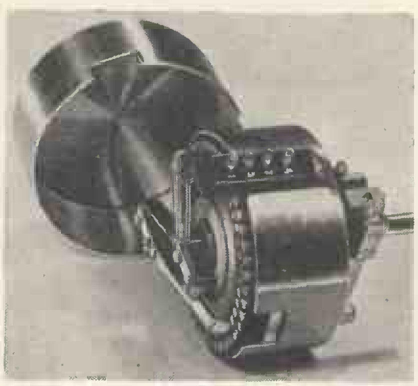
A valve that should prove of value to designers of telecommunication equipment is the QQVO3-20 R.F. double tetrode, which is illustrated on the left. Built in the butterfly construction, this valve can be used in conventional circuits at frequencies up to and well in excess of 600Mc/s, and it has been specially designed to operate at high efficiency with low drive power. This valve is specially suitable for use in airborne and mobile telecommunications equipment.

Other new valves and electron tubes to be shown will include an inert gas-filled half-wave rectifier 3B28 for use in high-voltage rectifier circuits; a 12in. radar display tube MF31-95, a flash tube LSD24 having an anode rating of only 1 000 volts.

**Mullard, Ltd.,**
**Century House,**
**Shaftesbury Avenue,**
**London, W.C.2.**

**Painton (24)**

A NUMBER of new components will be displayed on this stand, including the following:—A Midget Attenuator (Type M) which is a 21 step instrument of only $1\frac{1}{8}$in. diameter with a scale indicator built into the control knob; and a



type BM Fader, a new miniature rotary instrument having provision for a 40-step Bridge "T" network. This fader is illustrated at the foot of the previous column.

Also displayed will be a modified version of the 2-watt wirewound potentiometer, Type CV2, incorporating a new dust cover to protect the winding and a split-collet spindle-locking device for the preset version.

Augmenting the range of wirewound and high stability Carbon Resistors, are Wirewound Resistors for specialized applications, including a limiting resistor (501 395) for jet-engine starter motors, and a 400 watt resistor (P5009F) capable of withstanding voltage impulses of 150kV.

**Painton and Co., Ltd.,**
**Kingsthorpe,**
**Northampton.**

**Rola Celestion, Ltd. (36)**

AMONG the new exhibits on this stand will be a Truvox "Minor" re-entrant P.A. Speaker, which is illustrated above. This speaker has a frequency range of 400c/s to 9kc/s with a handling capacity of 3 watts, and can be supplied with or without line transformer.

Other new speakers in the Rola Celestion range include a B25 $2\frac{1}{2}$in. square, a B35 $3\frac{1}{2}$in square and a J61 10in × 7in elliptical type.

**Rola Celestion, Ltd.,**
**Ferry Works,**
**Thames Ditton, Surrey.**

**Salford Electrical Instruments, Ltd. (49)**

ONE of the most recent advances in powder core technique will be shown on the stand in the form of a new Gecalloy micro-powder magnet for television tube focusing.

Another aspect of powder core applications will be the display of all the transformer and other cores needed for a television receiver. In addition, the latest range of Gecalloy toroidal cores with plastic coatings and the new miniature types will be on show.

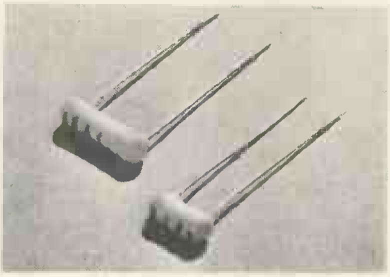
For the first time a precision frequency measuring equipment used for quartz crystal calibration will be shown, accompanied by a new version of the quartz crystal activity test set.

**Salford Electrical Instruments, Ltd.,**
**Peel Works,**
**Salford, 3.**

**Stability Radio (33)**

TUBULAR Ceramic Capacitors are being introduced by Stability Radio Components, Ltd. Two sizes with dimensions of 0·2in. × 0·45in. and

0·2in. × 0·7in. are manufactured in a range of dielectric materials. One of the outstanding features of these capacitors is their thermo-setting dip-coating which makes them truly insulated. The coating is heat resistant and will not be damaged by contact with a soldering iron.



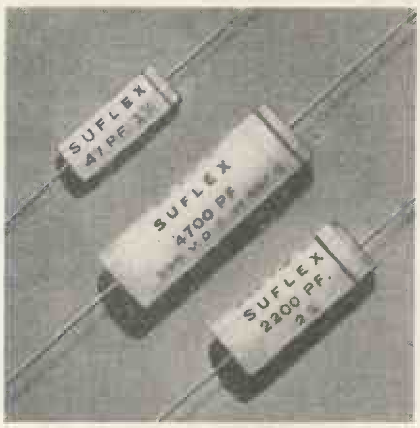
It withstands a test voltage of 1 500V D.C. and allows close mounting to points of different potentials. The good insulation properties are fully maintained after prolonged humidity cycling.

Another feature of these capacitors, which are illustrated above, is the consistency of their electrical characteristics.

**Stability Radio Components, Ltd.,**
**Woodford Avenue,**
**London, E.18**

**Suflex, Ltd. (8)**

A NEW range of Polystyrene Capacitors have been developed by Suflex, Limited, to overcome the difficulties in obtaining high grade mica at reasonable cost. The high insulation resistance, excellent stability and low power factor make these capacitors eminently suitable for the most critical applications.




Hitherto the low operating temperature of polystyrene capacitors has been a serious limitation. This has been overcome by Suflex, who rate their capacitors at +85°C. for continuous operation, and which have in fact been granted Type Approval by R.C.S.C. on their range to Joint Service Category 40/85 (−40°C. +85°C.).

The present range at 500V D.C. working covers 33pF to 4 700pF at tolerances of ±2 per cent and ±10 per cent. Some idea of the very modest space requirements of these capacitors is conveyed by the fact that the largest measures only 10 × 32mm. and the smallest 6 × 18mm.

**Suflex, Ltd.,**
**35 Baker Street,**
**London, W.1.**

**Swift Levick (107)**

ANISOTROPIC permanent magnets for loudspeakers, television focusing, microphones, radar and electrical instrument use will be exhibited by this company.

The latest permanent magnet material known as "Calumax" will be demonstrated. This material has the following average magnetic properties.

$B_{min}$ 13 000 gauss.
$H$ 740 oersted.
$BH_{max}$ 6·8 m.g.o.

The energy product of this material is 30-40 per cent greater than hitherto available commercially.

**Swift Levick and Sons, Ltd.,**
**Clarence Steel Works,**
**Sheffield.**

**T.C.C. (48)**

THE main theme of the T.C.C. stand will be the introduction of a range of completely new capacitors. Among these is the tantalum electrolytic capacitor, which has been designed to work over a temperature range of −50°C. to 100°C. Two important properties of this new capacitor are its increased shelf life and the substantially neutral electrolyte which it contains. Other features are the high insulation resistance and a low power factor.

At the present moment the only capacitor of this type in an 8μF 100V D.C. working.

A high voltage paper dielectric smoothing capacitor for use with the E.H.T. supplies for the largest cathode ray tubes has also been developed. This capacitor employs a special construction comprising a moulded case, stud mounting and a flexible connexion.

Illustrated above is a 500pF capacitor of this type for operation at 21kV at 60°C.

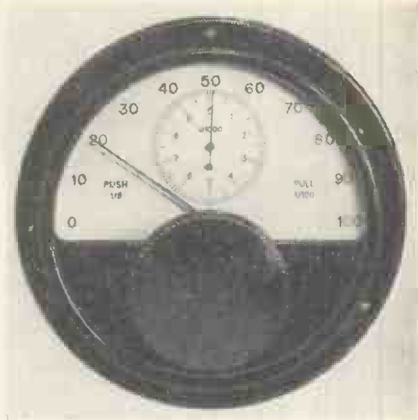
Other new capacitors include subminiature electrolytic capacitors for use in hearing aids and high voltage ceramic capacitors for line time-base circuits.

**The Telegraph Condenser Co., Ltd.,**
**North Acton,**
**London, W.3.**

**Transradio (90)**

TO the range of air-spaced articulated COAX RF cables manufactured by Transradio have been added two new types, A5 and A55. These cables are designed for use as heavy duty R.F. Transmission Lines combining low attenuation and high loading with greater flexibility and low weight.

Characteristics of the cables are as




follows:—

| | | A5T | A55T |
|---|---|---|---|
| Capacitance (pF/ft) | .. .. | 16 | 23 |
| Attenuation (db/100ft) | 1Mc/s | 0·035 | 0·04 |
| | 600Mc/s | 1·6 | 2·0 |
| Loading (kW) | 1Mc/s .. .. | 48 | 48 |
| Characteristic impedance (ohms) | | 72 | 51 |
| | 600Mc/s .. .. | 0·6 | 0·4 |

Illustrated above is the recently developed "micro dual" precision two-speed rotary drive which will also be on display.

Axial displacement of the knob allows either speed ratio to be selected with no observable backlash on either range.

The main drive is by split and spring-loaded gears with automatic take-up of any wear or play between the primary and secondary drives.

**Transradio, Ltd.,**
**138A Cromwell Road,**
**London, S.W.7.**

**Westinghouse (23)**

EXHIBITED for the first time will be a selection of new power and sealed miniature high voltage low current rectifiers specially designed for Service requirements, and a range of newly developed units for television anode supplies.

These developments will be backed by a very comprehensive display of current ranges of rectifiers that will include types suitable for operation at 70°C. in power and magnetic amplifier circuits and units Type Approved to RCL.241. Sealed 16 and 36 tubular types, instrument rectifiers and "Westectors," and H.T. units for radio receivers, will be shown, together with a range of Germanium crystals and a new aluminium based lightweight rectifier for aircraft power supplies.

**Westinghouse Brake and Signal Co., Ltd.,**
**York Way,**
**King's Cross,**
**London, N.1.**

**Wimbledon Engineering (81)**

IN addition to the extensive range of standard and heavy duty vibrators and standard duty power units, a new miniature vibrator weighing under 1oz and having an operating frequency of 400c/s will be exhibited. This vibrator is 1in. diameter by 2¼in. long. This unit will be available in 6 and 12 volts, and is of non-synchronous, shunt drive type.

**Wimbledon Engineering Co., Ltd.,**
**Garth Road,**
**Lower Morden,**
**Surrey.**

# LETTERS TO THE EDITOR

*(We do not hold ourselves responsible for the opinions of our correspondents)*

### Distortion and Gramophone Reproduction

DEAR SIR,—With reference to the article by Mr. M. L. Gayford in the January, 1953, issue of ELECTRONIC ENGINEERING, I should like to mention that I made an approximate analysis of the effects of longitudinal tip movement some eighteen months ago. My analysis has the admitted defect of neglecting the effect of friction between stylus tip and groove wall; nevertheless, it may be of some interest. My study shows that longitudinal motion results in a small change in the amplitude of the fundamental output voltage with the addition of a third harmonic component. In evaluating the distortion produced, in terms of the pick-up parameters and groove modulation, four equations result, each applicable to one of the four possible combinations of mass and compliance control for both lateral and longitudinal motion, as shown in the Table. $M$ and $C$ represent mass and compliance respectively, measured at the stylus tip, with a subscript $y$ or $x$ to denote whether the quantity is measured in the lateral ($y$) or the longitudinal ($x$) direction. In addition $f$ = modulation frequency (sinusoidal), $a$ = modulation amplitude and $V$ = groove linear velocity.

Referring to Mr. Gayford's Fig. 7 these equatons would be applicable as follows: below 600c/s—equation 2; between 600c/s and 1 500c/s—equation 1; above 1 500c/s—equation 3. The longitudinal resonant frequency has been taken from Fig. 7 to be about 3 000c/s. The longitudinal oscillation is at twice the modulation frequency so that the mode of control for this direction changes over at a signal frequency of about 1 500c/s and distortion will, as suggested by your contributor, rise to a maximum at this frequency.

I think Mr. Gayford's explanation of the mechanism by which the stylus may lose contact with the groove wall (or walls) needs clarification. As I see it, the importance of the pinch effect is that it causes the stylus to undulate vertically at a frequency of twice the modulation frequency. If this undulation frequency exceeds the effective resonant frequency of the vibratory system (reckoned vertically) then the vertical motion becomes mass controlled and, following a groove constriction or "pinch," the groove "falls away" faster than can be followed by the stylus tip. The actual frequency above which this effect takes place will be influenced by such factors as the static downward pressure at the stylus tip, the recorded amplitude and frequency, the groove linear velocity and the tip radius.

Yours faithfully,

R. W. BAYLIFF,

Old Coulsdon, Surrey.

| | | Lateral Motion ($y$): Mass Controlled | Lateral Motion ($y$): Compliance Controlled |
|---|---|---|---|
| Longitudinal Motion ($x$) | Compliance Controlled | Equation 1<br>Percentage 3rd harmonic<br>$= \frac{M_y C_x f^4 a^2}{V^2} \times 1{\cdot}16 \times 10^5$ | Equation 2<br>Percentage 3rd harmonic<br>$= \frac{C_x f^2 a^2}{C_y V^2} \times 3 \times 10^3$ |
| | Mass Controlled | Equation 3<br>Percentage 3rd harmonic<br>$= \frac{M_y f^2 a^2}{M_x V^2} \times 738$ | Equation 4<br>Percentage 3rd harmonic<br>$= \frac{0{\cdot}19\ a^2}{C_y M_x V^2}$ |

**The author replies:**

DEAR SIR,—Mr. R. W. Bayliff's comments are of interest.

Rabinow and Codier* gave a tentative theory covering the effects of longitudinal stylus movement, and indicate that the calculation of the distortion products is somewhat complicated. I should be glad to see Mr. Bayliff's derivation of his formulæ.

A full analysis of the factors causing the stylus to leave the groove would be too lengthy for a short general article. The pinch effect is one of the factors and should be considered in conjunction with the appropriate co-existing lateral forces. In the case of "hill and dale" recording it is true that the stylus will not follow properly as the groove "falls away" unless there is sufficient vertical force available from gravitational or compliant sources to give it the appropriate acceleration.

Yours faithfully,

M. L. GAYFORD,

Standard Telephones & Cables, Ltd.

* RABINOW, J., CODIER, E. Phonograph Needle Drag Distortion. *J. Acoust. Soc. Amer.* 24. 216 (1952).

### A D.C. Phototube Circuit with A.C. Modulation

DEAR SIR,—Many improvisations have been made to enable A.C. amplification to follow control by a photocell. Of these the most common are those employing a light-chopper, modulated light source, or the application of A.C. directly to the photocell electrode.

These methods possess disadvantages in their application from a practical viewpoint, or in their operation, and it is therefore proposed to describe a simple method of modulation. The circuit is shown in Fig. 1.

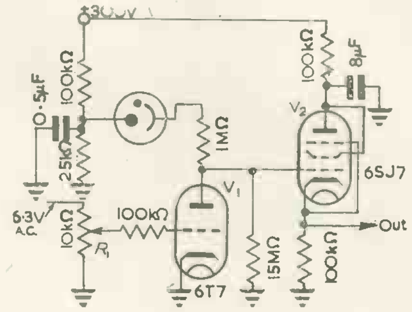



**Fig. 1. The circuit described**

The photocell has a D.C. potential applied to its anode. When light is on the photocell, positive-going pulses appear at the cathode of $V_2$. When the light is cut off from the photocell no signal appears at the cathode of $V_2$. We therefore have a simple on/off control of pulses by a photocell. (See Fig. 2.)

Without $V_1$ and its associated components, the circuit would be the conventional photocell and cathode-follower $V_2$. The addition of $V_1$ causes the circuit to operate in the following manner.

The grid of $V_1$ is fed with approximately 1V at 50c/s A.C. When there is light on the photocell a voltage exists at the anode of $V_1$ and $V_1$ therefore acts as a variable impedance under the influence of its grid voltage. During the negative period of this voltage the impedance represented by $V_1$ rises, causing a positive pulse to appear at the grid and cathode of $V_2$. During the positive excursion of the modulating voltage, the grid of $V_1$ draws current and has a smaller and opposite effect on the impedance of $V_1$, causing the base line of the pulse to be shifted in a slightly negative direction.

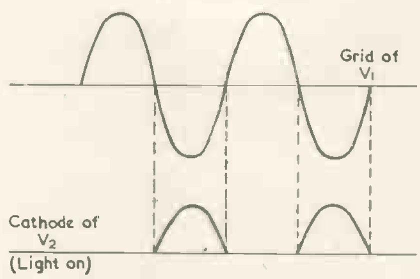



**Fig. 2. Waveforms of circuit in Fig. 1**

When light is absent from the photocell little or no voltage is present at the anode of $V_1$ and the grid modulation is therefore ineffective.

With the light beam absent from the photocell $R_1$ is adjusted so that the pulses are just suppressed at the cathode of $V_2$.

In cases where there exists considerable ambient light, effective cancellation may be obtained by passing the pulses through a positively backed-off diode

(Fig. 3). Adjustment is made by placing $R_2$ at the zero voltage then adjusting $R_1$ so that pulses appear with the actuating light on the photocell, and finally adjusting $R_2$ to cancel ambient light only.

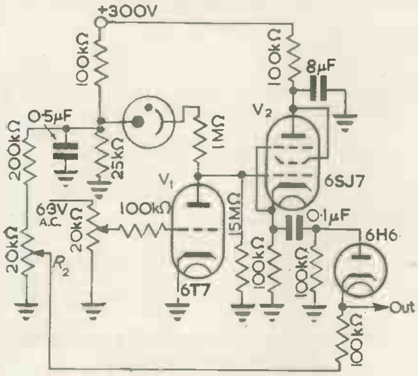



**Fig. 3. Use of backed-off diode**

The circuit was developed in the Industrial Development Department, Canterbury University College, and thanks are due to the Director, Mr. T. R. Pollard, for his encouragement.

Yours faithfully,
W. V. Dromgoole,
Canterbury University College,
Christchurch,
New Zealand.

## D.C. Relays

Dear Sir,—My attention has been drawn to some statements made in an article by Mr. N. E. Hyde, having the above title, in your January issue. As these statements are without foundation and, to the uninitiated, must seem to reflect most unfavourably on the relays made by the Telephone Manufacturing Co., Ltd., under the Patents granted to me, you will perhaps allow me space for a reply.

Under the heading "Polarized Relays" it is stated—"The Carpenter and the Shipton relays each have a half-bridge magnetic circuit, the Ericsson relay has a full-bridge circuit. The half-bridge suffers from shunting of the operating flux by the polarizing system and special steps have to be taken to introduce high reluctances into the polarizing system to reduce this effect."

I devised what Mr. Hyde calls the half-bridge magnetic circuit before 1928 and it is broadly covered by my British Patent No. 315 496 which still has some years to run, the High Court having twice extended it. This is the basic Patent under which I licensed the Telephone Manufacturing Co. in 1940 and under the German equivalent of which I licensed Messrs. Siemens & Halske in 1934.

Now as regards the versions of the relay manufactured by the Telephone Manufacturing Co. to my designs, the "special steps" referred to by Mr. Hyde that have to be taken to avoid the shunting away of signal flux through the polarizing system are, in fact, inevitably taken if the polarizing magnets are made of modern magnetic material whose incremental permeability is, of course, exceedingly low. That in fact the polarizing magnets do not shunt any detectable flux away from the working gap is shown by the fact that measurements of the magnetic leakage as between the flux generated at the centre of the reversals coil core and that reaching the working face of the armature, show no measurable difference whatever whether the magnets are in place on the relay or not.

In the case of the relay manufactured by Siemens & Halske under my Patent but to their own design, of which the Shipton Relay is very largely a copy, the undesired shunting of the signal flux is avoided by carrying the polarizing flux from the single magnet to the pole pieces through a pair of saturated magnetic bolts. This arrangement, however, while perfectly effective, leads to a somewhat more bulky relay than the design used by Telephone Manufacturing Co.

The article continues "In the case of the first mentioned relay two magnets are used in a way conducive to magnet deterioration." This statement is without foundation and it is a matter of some surprise to me that Mr. Hyde should be so irresponsible as to make a wholly baseless and damaging assertion of this nature. Anyone taking the trouble to understand the magnetic circuit employed will appreciate that while two magnets are arranged with like poles facing one another, there exists the comparatively low reluctance path presented by the armature to screen each magnet from the other.

In fact the two magnets are merely supplying flux in parallel to a comparatively low reluctance circuit and no deterioration whatever has been detected in the strength of the magnets even after they have been employed on relays for a period of years.

Any weakening of the magnets in a relay designed on modern lines would become apparent in a very short time for the following reasons.

The moving-iron armature of a polarized relay of the type under discussion is subject to magnetic forces tending to draw it to one pole or the other, and these forces may profitably be regarded as a negative stiffness acting on the armature. Unless compensated in some way this negative stiffness would result in a relay having unnecessarily large contact pressures and therefore a low sensitivity. It is therefore necessary to mount the armature on a spring or springs having a positive stiffness of the same order as the negative magnetic stiffness. The nett stiffness of the armature as measured is, of course, the algebraic sum of these two figures. In an each-side stable relay (that is one in which the armature will remain on the contact on which it was last put) the magnetic stiffness is made greater than the spring stiffness so that the nett stiffness is negative—that is, the armature is in unstable equilibrium.

In a centre-stable relay however (that is, one in which the armature remains approximately centrally between the two side contacts in the absence of a signal, and only makes contact on one side or the other when current is applied to the coil) the spring stiffness must clearly exceed that of the magnet system.

Now should there be progressive deterioration of the magnets as implied in Mr. Hyde's article, an each-side stable relay would become steadily more sensitive and ultimately centre-stable, while a relay initially centre-stable would become steadily less sensitive with the passage of time.

Now in point of fact these things do not happen, the magnets being extremely stable.

It is, I think, pertinent to remark that, of the relays manufactured in this country by my licensees, the Telephone Manufacturing Co., the Type 4 relay has been standardized by the British Post Office, the Types 3 and 5 by Cable & Wireless and the Type 3 by the Australian Post Office. In addition large numbers of Type 5 have been bought by the Dutch Post Office and by some hundred or more commercial firms, many of the highest standing.

The total number of relays made under the Patents granted to me now greatly exceeds the million mark and the demand continues; this would seem to disprove the faults suggested by your contributor. This must not be taken to mean that I am implying that the relays designed by me have no faults. In all highly sensitive relays there is a tendency to bias change, which corresponds to zero drift in sensitive galvanometers, and the more sensitive the relay the less stable is it likely to be. The result of this bias change, which is more marked in relays exposed to wide temperature variations, is to make it essential so to design the circuits supplying the operating current as to make the latter several times the bare minimum which will just operate the relay, and my licensees inform all users of the factor of safety appropriate to the circumstances.

The problem of stability is, of course, the more acute as the instrument is made smaller and some models of the Miniature Type 5 relay have proved insufficiently stable for some types of use but, as the result of some years of investigation, the causes of this are now known. They are mechanical not magnetic, and a redesigned relay embodying these improvements is going into production and will, it is hoped, be shown at the next R.E.C.M.F. Exhibition.

Faithfully yours,
R. E. H. Carpenter,
Telephone Manufacturing Co., Ltd.

**The author replies:**

Dear Sir,—With reference to Mr. Carpenter's letter which you sent to me I would only hasten to say that my intention was not to give an unfavourable impression of any particular relay discussed in the article.

Yours faithfully,
Norman E. Hyde,
British Joint Services Mission,
New Jersey.

*Correspondents have written discussing the various parameters governing the performance of Polarized Relays and notably that of sensitivity. These comments are not germane to the article which dealt with alleged magnetic defects.*—Editor.

# BOOK REVIEWS

## Radio Antenna Engineering

**By Edmund A. Laport. 563 pp., 343 figs. Royal 8vo. McGraw-Hill Publishing Co., Ltd. Price 76s. 6d.**

MR. LAPORT has for many years been designing not only aerial systems, but also complete radio transmitting installations for all purposes. In consequence, he is able to put both engineering and economic considerations in proper proportion. His book incorporates his wide experience and specialized knowledge in an eminently useful form. It is limited to low-frequency, medium-frequency and high-frequency aerials with their transmission lines and impedance-matching networks, and it ignores completely the other world of frequencies above 30Mc/s; division at this point is convenient since it means in effect that all "wire" aerials are included.

The chapter on transmitting aerials for low-frequency communications is particularly valuable since the number of such installations is quite small and hardly increases with time, so that there is little opportunity for fresh designs, and real danger that the valuable and sometimes costly experiences of the earlier designers would be lost for ever.

The next chapter is concerned with medium-frequency broadcasting aerials, and, recognizing that the design of the aerial itself is linked with the performance expected from it, instructions are included for estimating the corresponding field-strength coverage. A large part of this chapter is devoted to M.F. directional aerial systems.

In the chapter on high-frequency aerials both dipole arrays and travelling-wave aerials are treated. Sections are included on the synthesis of array patterns, and on the derivation of special current distributions for side-lobe suppression; for rhombics, a graphical method is described for approximating the complete radiation pattern over a frequency range. Information for high-frequency propagation calculations is included in this chapter.

The remaining three chapters deal with radio-frequency transmission lines, the graphical synthesis of impedance-matching networks, and logarithmic-potential theory. This last chapter is closely related to the one on radio frequency transmission lines, a subject in which Mr. Laport has specialized. It is all the more surprising to find some rather extraordinary muddling in some of the characteristic-impedance expressions. For example, on page 382, it is quite obvious that the calculations for k of a 3-wire transmission line cannot have been derived from the formula given and inspection shows that the denominator should have been

$\log_{10} 2h^2/a\rho$ instead of $\log_{10} 2h/a$

Again, on page 389 the calculated values for the type XI transmission line cannot have been derived from the formula. Reference to item 28 of the bibliography reveals the fact that the calculations have been taken from Brown's original article, with a $\rho$-value of 0·081in. and with Brown's notation, which differs from Laport's in using "a" as the side of the ground-wire square instead of its half-diagonal, and "b" as the high-potential wire-spacing instead of one-half of this value. Discoveries of this sort unfortunately weaken the reader's confidence, and make the reviewer wary!

There are a few other obvious discrepancies, which while they should not occur in a book of this standard, do not detract from its utility. In the list of symbols on page 11 $\mu$ is omitted, although it is employed on the same page. On page 27, G is suddenly used without definition for conductance while, on the immediately preceding pages it is the length in electrical degrees of an aerial. On page 369, "f" is defined only as "frequency", although in equation No. 15 on the same page it must mean the frequency for a fall to $1/\sqrt{2}$ of the peak impedance or admittance magnitude. On the same page equation No. 16 has "C" instead of "c". There are one or two printer's errors (on page 218 there are two different unhappy attempts to spell the word "intelligibility"), and hyphens are used or omitted with light-hearted abandon; among the odd-looking results of these omissions are "cleanup" on page 198, and "interisland" on page 214. On page 302 there is a reference to a "node" in a radiation pattern instead of a "null".

A more substantial complaint is that in a few instances Mr. Laport fails to give information which one feels entitled to expect. In chapter I, after several references to the subject of sleet-melting (=de-icing), there is no indication as to the amount of power required for this purpose. On page 450 in discussing dissipative transmission lines, there is no suggestion as to the values of $\mu$ appropriate for this purpose with available materials. In other cases, one has the impression that space requirements have forced the ruthless truncation of an exposition to the extent that what remains is of little practical use; the section 2.18 on the direct synthesis of an array for a specified pattern is an example.

On page 37 it is stated that "In the case of telegraphic on-off keying . . . a long series of symmetrical side-frequencies . . . is required for distortionless transmission". The operative word is "distortionless", and Mr. Laport is undoubtedly correct. However, very many error-free transmissions are made, although the signal-elements may be distorted, with circuits of which the bandwidth is only sufficient to pass the side-frequencies corresponding to the fundamental dot-frequency and its third harmonic. This is tacitly admitted by Mr. Laport on page 38, although he does not show the connexion between this and his previous statement.

These are minor faults in an excellent work. High on the credit side is the very large number of photographic illustrations of all phases of aerial construction. There are very full bibliographies at the end of each chapter, with a general bibliography at the end of the book; these are notable in listing many English and European contributions to aerial literature. The book is well indexed, although one omission was observed, and there is an excusable misspelling of a Scottish name.

With the hope that there will be very careful revisions of future editions, the book can be recommended as a valuable text-book and source of practical information for those engaged on the design and construction of aerials.

C. GILLAM

## Alternating Current Wave-forms Theory and Practice

**By Phillip Kemp. 406 pp., 100 figs. Demy 8vo. Chapman & Hall Ltd. 1952. Price 50s.**

MR. KEMP is well known for his writings on the subject of wave-forms.

The book under review was first published in 1934 under the title Theory of Alternating Current Wave-forms. In the present edition it has been revised considerably and extended by three new chapters dealing with harmonics in transformers, flux-waves and alternating current windings.

The number of figures and diagrams has been more than doubled and are a great aid in discussing this difficult subject. Mr. Kemp makes full use of graphical methods of solving numerical problems in harmonics, including rectified currents.

The effects of magnetic saturation are well studied both in transformer cores and three-phase machine field systems. This is followed up in the chapter on A.C. windings in order to derive the E.M.F's in windings of typical form. This chapter ends with a description of the effect of armature reaction on salient pole and cylindrical rotor flux wave-forms.

Various methods of harmonic analysis, including that of the author, are fully dealt with in the last chapter. The bibliography has been brought up to date.

This book can be easily understood given a knowledge of mathematics of second year degree standard and will be very helpful to electrical engineers.

H. M. CLARKE

## Lighting in Industry

**154 pp., 85 figs. Demy 8vo. British Electrical Development Association. Price 9s.**

THIS book is the second volume in the Association's "Electricity and Productivity" series, and deals with many of the questions which confront works managers and executives in industry. There are seven chapters on these lighting problems and chapter II gives a detailed account of the method of conducting a lighting survey, which would enable factory managements to survey their own factories to see whether the lighting is effective, and used efficiently. Other valuable features of the book include a method of determining the most economical fittings cleaning programme, and a method of fluorescent lamp replacement.

## The Use of Radar at Sea

**Edited by Capt. F. J. Wylie, R.N. (Ret.). 279 pp., 52 figs. Royal 8vo. Hollis & Carter. Price 30s.**

In the reviewer's experience, when a book is assembled from sections written by different specialist authors, the resulting variation of style from chapter to chapter is a small price to pay for the ring of authority which the specialist authorship gives; the present book is no exception. Written under the auspices of the newly-founded Institute of Navigation, it provides a valuable guide for the sea-going radar operator, for the navigator and captain, and in fact for anyone concerned with the operation of marine radar.

It is not suggested that the work in itself is entirely complete since there are many fundamental questions to be answered—not a few of them being set out in the final chapter, i.e., Chapter 17, which discusses the future of radar as well as the future Radar. It is the thoughts and ideas that this book will stimulate among the users of radar, that will be most valuable in the advancement of the science and the consequent further safety of those who may need to rely upon it. The inherent possibilities of such a principle as radar cannot possibly be fully explored without a tremendous amount of operational experience. This emphasizes the keynote of one of the later chapters, i.e. the importance of keeping a log of the radar at sea. Only so, can a clear picture be obtained of the navigational advantages and hazards in the use of radar.

It is gratifying to find that this book does not suffer from a fault prevalent among many of its type, i.e., a tendency to waste the first few chapters in an introduction to the fundamentals of electricity, when there are plenty of suitable books already published, and in all probability the prospective reader would have at least one in his possession. What little this book does cover of such elementary work is relegated to the appendices. Chapter 1 very rightly commences the study by dealing directly with the principles and general characteristics of radar, followed by chapters on the equipment itself, its operational controls, and the factors affecting the propagation of the energy into the atmosphere and the formation and characteristics of the echoes obtained by reflection of this energy from objects.

An old proverb "it is an ill wind that blows nobody any good," may be aptly applied to the use of radar in meteorology since the very factors which make it useful in this study are those which limit its performance in other fields. Chapter 5 presents a very instructive review of these factors although the emphasis is on the ill effects rather than the good.

Possible errors of radar, or at least the possible misinterpretations of the display, are enumerated. A complete chapter is given to the interpretation of the display and is presented extremely well; it is well illustrated with some actual photographs of P.P.I. traces. These are correlated with the topography of the area in which the picture was recorded and must have represented many hours tedious work. In fact the illustrations throughout the book are very commendable and represent considerable thought and effort on the part of the authors.

The difficulties of navigation using a two dimensional screen, as compared to sighting with the help of both colour and stereoscopic effects, are no doubt enormous, but are not necessarily insuperable. Apart from the possible improvements in displays, the appreciation of the technique might, in itself lead to satisfactory results. The change of emphasis from one form of navigation that has been established so successfully in good ambient conditions for so many years, to another, would of necessity be slow, and it must be shown that the new method is completely reliable. Present rules of the sea are instinctive to most mariners and in such crises as pending collisions simplicity is essential. Use of radar in this connexion and its relation to sighting is a controversy which forms the subject of another chapter in this mine of information.

Ramark and Racon, the ancillaries of radar, have their relative advantages and disadvantages weighed against one another. The use of one or the other can provide a considerable improvement in the reliability of radar in coastal navigation and hence can be extremely important to the future of radar.

Maintenance of the set and its efficient operation are subjects of chapters which deserve the close attention of those directly connected with the actual equipment. Belying the title of the book, there is a very interesting chapter on shore based radar showing how its efficient operation can be completely interwoven with the normal harbour routine and how it can raise the safety and utility of a port.

Chapter 16, in which circuits and components of radar are discussed, could have been omitted, but nevertheless is well written and the information is pertinent even if it could be found elsewhere.

A series of appendices provide some very useful information, especially Appendix 7—a short glossary of terms which will be helpful to the less initiated in the reading and understanding of the book.

In conclusion, it is good to find that in these days of high publishing costs the price of a work of this size with such an excellent presentation has been kept down to 30s.

J. W. R. Griffiths

## Sub-Station Practice

**By T. H. Carr. 467 pp., 321 figs. Demy 8vo. 2nd Edition. Chapman & Hall Ltd. Price 55s.**

THIS is the book on the subject, and is inclusive of the structural and mechanical design, electrical layout, individual items of equipment, operation, management and control. The chief application is to engineers concerned primarily with sub-stations, but the many works electrical engineers, where sub-stations are included in their orbit will also find the book indispensable. Both theory and practice are equally well treated, based on many years practical experience. This edition is well revised in all major aspects, but a few minor points are omitted, such as the addition of selenium metal rectifiers which tend to replace copper-oxide. The terminology is mainly correct but in some cases "capacitance" is given as "capacity" where it is not easy to see if current-carrying capacity or capacitance is intended.

E. H. W. Banner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# Meetings This Month

## THE BRITISH INSTITUTION OF RADIO ENGINEERS

Date: April 8. Time: 6.30 p.m.
Held at: The London School of Hygiene and Tropical Medicine. Keppel Street, London, W.C.1.
Lecture: Lens Aerials for Centimetric Wavelengths.
By: Lt.-Col. J. P. A. Martindale, B.A., A.M.Brit.I.R.E.

**North-Eastern Section**

Date: April 8. Time: 6 p.m.
Held at: The Institute of Mining and Mechanical Engineers, Neville Hall, Westgate Road, Newcastle-upon-Tyne.
Annual General Meeting followed by a demonstration of Stereophonic Reproduction.

**Scottish Section**

Date: April 9. Time: 7 p.m.
Held at: The Institute of Engineers and Shipbuilders, Glasgow.
Lecture: Remote Control Devices and Servo-mechanisms.
By: A. E. W. Hibbitt.

## THE INSTITUTION OF ELECTRICAL ENGINEERS

All London meetings, unless otherwise stated, will be held at the Institution, commencing at 5.30 p.m.

Date: April 9.
Lecture: Special Effects for Television Studio Productions.
By: A. M. Spooner, B.Sc.(Eng.), and T. Worswick, M.Sc.
Date: April 23.
The Forty-fourth Kelvin Lecture: The Dilemma of Lord Kelvin.
By: Professor P. I. Dee, C.B.E., M.A., F.R.S.

**Radio Section**

Date: April 13.
Discussion: The Relative Merits of Broad-Band Transmission by Beam, Cable and Waveguide.
Opened by: E. C. H. Organ, O.B.E.
Date: April 22.
Lecture: An Investigation of the Characteristics of Cylindrical Surface Waves.
By: Professor H. M. Barlow, Ph.D., B.Sc.(Eng.), and A. E. Karbowiak.

**Measurements Section**

Date: April 14.
Four Lectures:
(1) Digital Computers at Manchester University.
By: T. Kilburn, M.A., Ph.D., G. C. Tothill, M.A., M.Sc., D. B. G. Edwards, M.Sc., and B. W. Pollard, M.A.
(2) The Construction and Operation of the Manchester University Computer.
By: B. W. Pollard, M.A., and K. Lonsdale, B.Sc.Tech.
(3) Universal High-Speed Digital Computers: A Decimal Storage System.
By: T. Kilburn, M.A., Ph.D., and G. Ord, M.Sc.
(4) Recent Advances in Cathode-Ray Tube Storage.
By: Professor F. C. Williams, O.B.E., D.Sc., D.Phil., F.R.S., T. Kilburn, M.A., Ph.D., G. N. W. Litting, B.Sc., D. B. G. Edwards, M.Sc., and G. R. Hoffman, B.Sc.

**North-Eastern Centre**

Date: April 13. Time: 6.15 p.m.
Held at: The Station Hotel, Newcastle-on-Tyne.
Annual General Meeting and Conversazione.
Date: April 21. Time: 7 p.m.
Faraday Lecture: Light from the Dark Ages, or the Evolution of Electricity Supply.
By: A. R. Cooper.

**North-Western Centre**

Date: April 14. Time: 6.15 p.m.
Held at: The Engineers' Club, Albert Square, Manchester.
Lecture: The London-Birmingham Television-Cable System.
By: T. Kilvington, B.Sc.(Eng.), F. J. M. Laver and H. Stanesby.

## INSTITUTION OF ELECTRONICS

Date: April 24. Time: 7 p.m.
Held at: The College of Technology, Manchester.
Lecture: Present Technique of Colour Television.
By: J. A. Darbyshire, M.Sc., Ph.D., F.Inst.P., A.M.I.E.

## THE TELEVISION SOCIETY

Date: April 9. Time: 7 p.m.
Held at: The Cinematograph Exhibitors' Association, 164 Shaftesbury Avenue, London, W.C.2.
Lecture: Aspects of Television Programme Planning.
By: Cecil Madden, M.B.E.

# Recent British Standards

**British Standard for Lateral-cut Gramophone Records and Direct Recordings. (B.S.1928:1953)**

The British Standard for lateral-cut gramophone records and direct recordings is the first British Standard to deal with some of the requirements for disk recording or reproduction of sound by electro-mechanical processes.

The standard specifies the important dimensional features of the types of gramophone record generally available (78 and 33⅓ R.P.M.) and also deals with direct recordings on, for example, lacquer disks.

Requirements governing the recording characteristics, change-over frequency and the information that should appear on the label, are given, together with notes on the most suitable dimensions of reproducing styli and diameters of turntable centre pins. The price of this standard is 2s. 6d.

**British Standard for Aluminium Filler Alloys for Brazing. (B.S.1942:1953.)**

This new British Standard is complementary to B.S.1723, "Brazing" and to B.S.1845, "Filler alloys for brazing (silver solders and brazing solders)."

The standard covers four types of aluminium alloy suitable for brazing a number of alloys complying with the series of British Standards for aluminium and aluminium alloys, namely B.S.s 1470 to 1477, and 1490.

Chemical composition and limits of impurities together with the form of material are specified, and the approximate melting ranges are given for information. Copies of this standard cost 2s. 6d.

**British Standard for Synthetic-Resin Bonded Paper Insulating Tubes (Rectangular Cross Section) for Electrical Power Circuits up to 1 000 volts. (B.S.1885:1952).**

A standard setting out the minimum requirements for synthetic-resin bonded paper rectangular tubes for use on electrical power circuits up to 1 000 volts has been published recently. The new standard. B.S.1885, is an addition to the published series dealing with insulating material and, apart from the voltage limitation, is complementary to B.S.1314 (1946) which covered circular tubes of similar material.

The new specification deals with two types of rectangular tube intended for electrical insulating purposes with direct-current, and with alternating-current up to 100c/s. The internal side dimensions of the tubes specified range from ¼in. up to 6in. with wall thicknesses of from 1/32in. to ⅛in. Electrical and mechanical properties are specified, together with the tolerances on dimensions. Methods of test, including the preparation and conditioning of specimens prior to test, are fully described in appendices. The price of this standard is 2s. 6d.

# Publications Received

PLESSEY E.H.T. CONCENTRIC CONNECTORS is an attractively produced catalogue on the demountable and moulded types of connectors. It also details wiring demountable types, panel units, cable units, bulkhead connectors and protective caps for these new E.H.T. connectors. The booklet has many useful diagrams, including a complete schedule of assemblies, demountable plugs and sockets. The Plessey Company Limited, Ilford, Essex.

GLASEF (P.T.F.E.) AIRCRAFT WIRING CABLES is a brochure giving data of the new single-core aircraft wiring cables, which are capable of continuous service at temperatures up to 250°C, and are particularly suitable for use in the high-temperature regions of jet aircraft. Information on the high energy ignition cable is also included. This cable is supplied for jet engine igniter leads to withstand the increasingly severe operating conditions imposed by the latest types of jet engines. British Insulated Callender's Cables Limited, Norfolk House, Norfolk Street, London, W.C.2. (Reference No. 319).

THE NIMONIC ALLOYS is a revised edition of a general publication giving detailed properties of these high-temperature materials. It includes short notes on Nimonic 80A, and also on Nimonic 95 which is the latest published addition to the series of creep-tested wrought alloys, together with general description of Nimonic DS and Nimonic DT which are modifications of Nimonic D introduced recently. Free copies of the booklet are available from Henry Wiggin & Co., Ltd., Wiggin Street, Birmingham, 16.

THE SPECIALIZED FILM is a booklet on the use of motion pictures in industry and commerce. It contains preliminary information, including costs of production, on the use of films by industry for training, demonstration or sales purposes. The booklet may be obtained free, on mentioning this journal, from Kinocrat Film Unit, Kinocrat House, Cromwell Road, London, S.W.7.

EDISWAN STABILIZED POWER SUPPLY UNIT is a brochure describing the Type R.1103 stabilized power supply unit. This is one of a range of Ediswan units providing highly stabilized supplies at relatively low cost. It is designed to meet the requirements of a general purpose supply of D.C. power for laboratories, test bays, etc., and supplies a higher voltage and current than the Ediswan unit type R.1095. The Edison Swan Electric Company, Ltd., 155 Charing Cross Road, London, W.C.2.

CONCERNING A CAREER is a booklet published by The Marconi International Marine Communication Company, Limited, and its purpose is to give in brief and condensed form some details of a career as a radio officer in the British Merchant Navy. Further details will be provided on application to The Marconi International Marine Communication Company, Limited, Marconi House, Strand, London, W.C.2, or Siemens Brothers & Company, Limited, Woolwich, London, S.E.18.

MULTICORE SOLDERS is a technical summary of the Ersin multicore solder and describes its various features and uses. Copies of the leaflet are available free of charge from Multicore Solders Ltd., Hemel Hempstead, under reference M.52.

SOLARTRON TECHNICAL BULLETINS are now available on new regulated power supplies, laboratory amplifier, video amplifier, pulse generator, and wide range oscillator. The bulletins give useful information on these models, including circuit details and specifications. Solartron Laboratory Instruments Ltd., 22 High Street, Kingston-on-Thames.

OSRAM LAMPS IN THE MAKING is a new booklet issued by the General Electric Co. Ltd., Magnet House, Kingsway, London, W.C.2, on the production of light bulbs and tubes. The stages of production are described and illustrated for both the filament lamp and the fluorescent tube. In the case of the filament lamp the story starts with sintering tungsten, and continues through coiling the filament, the making of the bulbs, assembly, etc., to the packing and inspection of the completed lamps. For the fluorescent lamps, the account describes the fluorescent powders, the glass envelopes, coating the tubes, the cathodes used, pumping, capping and ageing, and inspection.