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RECOGNITION OF THE TECHNICIAN

An important factor in most branches of applied science is the work of the technician upon whose ability the usefulness or efficiency of engineering equipment may finally depend. The extent to which such skill merits professional recognition is largely dependent upon the product or service, and for this reason it is impossible to make a general rule on the place of the technician in the engineering profession.

Industrial development is creating an ever increasing demand for personnel trained in *practical* application. The moral case for professional recognition rests on the ability of the technician to understand engineering technique; for this purpose he requires the collaboration of the engineer in this training and practice.

This phase of industrial change is the responsibility of the engineering profession and therefore, in its relation to radio, the concern of the Institution.

When the Institution was founded there was the greatest difficulty in obtaining recognition of the need for *any form* of training in radio engineering, and whilst it is not claimed that we have even now achieved finality, opportunity for training now exists which was very much decried less than 20 years ago.

The Institution has always recognized the need for suitably trained craftsmen or mechanics. Thus in 1930 the Institution first held an examination in radio service work which finally gained the support of the Radio Industry Council and subsequently led to the formation of the Radio Trades Examination Board. The Institution can therefore claim some credit for the schemes of training now available for and the recognition given to radio mechanics.

It is obvious, therefore, that by diligence in study and experience the radio mechanic can obtain advancement by working on more elaborate scientific equipment than he had opportunity for in the pre-war era. It has been argued that the immediate opportunity for more responsible work demands ability beyond that normally expected of a mechanic yet not requiring the status and training of an engineer.

Such may be the broad definition of a technician. The Institution's close interest in the general question of the education and training of craftsmen has already been demonstrated and justifies the enquiry as to how the Institution can help the technician.

The first consideration must be the content of recognized examination courses. Statistics show that only a small number of students take a Higher National Certificate, and this suggests that the level of the Ordinary Certificate is about the standard of those students who expect to remain as technicians.

Certainly there cannot be any confusion with, or alteration to, the present requirements for acknowledgment of the qualified engineer which result in admission to corporate membership of the Institution. Nor can there be alteration in the graduate class of the Institution which represents the younger engineer who has completed the technical and theoretical qualifications which when finally coupled with the required experience will also qualify for corporate membership. Apart from the traditional viewpoint of engineering institutions, therefore, the problem bristles with difficulty, but the Council has already recognized the need for fairly facing the problem and will very shortly present its recommendations to the membership without whose approval no alteration can, of course, be made in the constitution of the Institution.

THE DESIGN AND CHARACTERISTICS OF MARINE RADAR EQUIPMENT*

by

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A paper read before the Scottish Section on the 12th January, the Merseyside Section on the 2nd February, the North-Western Section on the 3rd February, and the London Section on the 17th March.

1. Summary

Radar techniques devised during the war, mainly for Service applications, are now being applied to commercial transport by air and sea. This paper considers the application of radar to coastwise navigation and collision warning in the Mercantile Marine.

After an introductory discussion of the problems involved in fitting the use of radar into the framework of existing navigational practice, a comparison is drawn between the available information under varying conditions from visual observations and from the use of radar, and methods of presenting the radar information to the operator are described.

In Section 3, " Design Considerations of an Equipment," it is shown that little freedom of choice is available to the designer, in so far as the radar performance is rigidly limited in nearly every direction by certain fundamental requirements and parameters, and the derivation of the main constants of the equipment is demonstrated.

In the final section an examination is made of the results obtained from a typical marine radar equipment.

2. The Nature of the Problem

The navigation of ships by direct observation of the land is a process which has undergone a long period of development. To-day, charts of great accuracy and detail are available and the navigator, by visual observations of his surroundings and comparison of his observations with a chart, can safely guide his ship, avoiding the dangers of the land and collision with other ships.

Direct visual navigation is convenient and safe if visibility is adequate but, in conditions of poor visibility, fog, or even darkness, the method may fail partially or completely.

At the same time it is to be noted that the mariner is able to judge how deficient is the visibility at any time and exercise caution accordingly.

The aim of the radar is to free the mariner from the restrictions of poor visibility without introducing any additional causes of risk.

In considering the application of radar to marine navigation it is also essential to remember that the radar information should be in a form applicable to the procedures developed for visual navigation in which the navigator has proficiency and confidence.

The requirements of a system, therefore, are :—

Firstly, it should give, under all conditions of weather likely to be encountered, the full information of the ship's surroundings normally available to the eye under optimum conditions.

Secondly, it should give clear indication of impaired efficiency.

Thirdly, it should give additional or improved information where this may help navigation.

It is interesting to consider how far these requirements can be met.

The Nature of the Information

The information available to the eye comprises the bearing and approximate range of surrounding objects, their elevation plan, colour and texture. Of these, the last three are not available from the radar presentation.

The bearing resolution of the eye in good daylight is some 1 to 2 minutes of arc, and such resolution cannot be approached by radar, the best resolution of present ship-borne equipment being about 1°.

It should be noted, however, that the radar resolution is of the same order of accuracy as that to which the ship's course is known, so that the true bearing of an object is not obtainable

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U.D.C. No. 621.396.932.

with appreciably greater accuracy by visual means than by radar.

The loss of detail resulting from the use of 1° beam is probably the most obvious deficiency of the radar picture. Experience indicates, however, that the resolution obtained is sufficient for close water navigation. An improvement in angular resolution would, nevertheless, make the presentation far more informative.

The plan presentation obtainable by radar is, in general, a far clearer indication of the disposition of the ship's surroundings than can be obtained by direct observation.

The range-estimating accuracy of the unaided eye is, by comparison with the ± 1 per cent. realizable with normal radar equipment, extremely poor—at best ± 10 per cent. The radar navigator will, therefore, tend to replace the normal position fix obtained by the intersection of bearing lines on two known objects by one obtained from the intersection of two range circles, although, for many purposes, the range and relative bearing given by the radar on one known object will give a sufficiently accurate fix when the heading of the ship is added in.

The Estimation of Visibility

Even under daylight conditions the extent of visibility in the presence of haze or fog is extremely difficult to estimate. In a region with which he is familiar the navigator may perhaps expect to estimate this distance with an accuracy of ± 50 per cent., but in an unfamiliar region it is easy to misjudge by a factor of 3 or 4.

This best estimate of ± 50 per cent. can be shown to correspond to an uncertainty of at least 7 db in the radar overall performance. A change of this magnitude in the system performance can be detected by fairly simple monitoring equipment which will be discussed later.

The Range Obtainable

If sufficient transmitted power is available the range of a radar operating on a suitable wavelength will extend somewhat beyond the optical horizon. Thus, the range obtainable will be not less than the maximum obtainable by visual observation from the aerial position.

Since, from the foregoing, it seems likely that radar information can be adequate in respect of completeness and trustworthiness for position fixing with respect to known objects and for general close water navigation, it is interesting to consider how the operational requirements and the fundamental limitations of radar technique together determine the equipment specification.

The Choice of a Display Scheme

At the present time radar is regarded by the marine operator only as an aid and adjunct to the classical procedures. On this account the radar information must be so presented as to permit use of the charts and procedures already in use.

This major consideration has resulted in the almost universal adoption of the P.P.I. type of display because :—

Firstly, the displayed information forms a plan or map of the area and, as such, may readily be used in conjunction with a chart to give a complete picture of the ship's surroundings ;

Secondly, ranges and bearings may be readily obtained and transferred to ordinary charts.

The generation of the P.P.I. display is as follows :[1]

A radial linear scan is arranged to rotate in synchronism with the aerial.

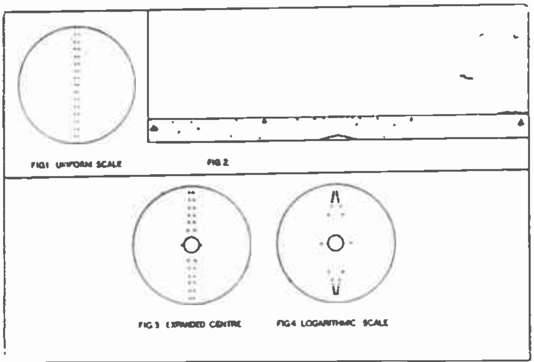
The scan commences outwards from the origin at the centre of the tube at the instant that the transmitter emits a pulse.

The echo returned from any object is arranged to brighten the spot so that the object appears as a bright dot on a radius making an angle with a reference radius corresponding to the bearing of the object relative to the ship's heading line and at a distance from the tube centre directly proportional to the range of the object from the ship.

If the number of radial time bases per revolution exceeds $\frac{360}{\theta}$ when θ = horizontal beam width, then all objects around the aerial will be illuminated each revolution.

A complete plan of the ship's surroundings is thus built up.

For medium-range navigation the simple P.P.I. presentation is quite adequate. When, however, the radar is to be used to set a course down a narrow buoyed channel, the radar impression of the situation on a simple P.P.I. differs markedly from that given by direct vision.



Figs. 1-4.

This effect arises because the simple P.P.I. gives a true plan of the area so that the displayed distance between a pair of buoys is equal at the centre and periphery of the display. (Fig. 1.)

The eye near sea level registers the angle subtended by each pair of buoys so that the effect of perspective is produced. (Fig. 2.)

A more realistic impression under these circumstances may be obtained by using an expanded centre to the display.

In this presentation the zero range point is expanded into a circle of a diameter equivalent to 200-300 yds.

The bearing of any object relative to the ship's head remains accurate but the azimuth distances are increased in the area near the zero range. The displayed picture then appears as Fig. 3.

Such a presentation more nearly approaches the effect of visual observation and facilitates the setting of the line representing the ship's head between pairs of buoys.

This facility is normally only required on the shortest range and is arranged either by an extra switch position or a spring-loaded key.

It has sometimes been suggested that the open centre P.P.I. would be further improved by use of a logarithmic range scale.[2] It is felt, however, that although the display might resemble more closely a perspective view, such a display could introduce a hazard. This view is held because one would observe an approaching object perhaps half-way down the scale from the periphery when, in fact, only a small fraction of the range in use remained in which avoiding action might be taken. (Fig. 4.)

The Use of " A " Type Display

The " A " type display, in which range and signal amplitude are displayed by horizontal and vertical deflection of an unmodulated beam, has been widely used in naval fire control equipment as a precision range display.

By means of various expanded scale techniques a range discrimination of ±25 yds in 50,000 is obtainable.[3]

As, however, this operation requires the aerial to be held stationary and in alignment with the target whose range is being measured, the simultaneous operation of a P.P.I. and " A " type range display from a single aerial is impossible. An " A " type oscilloscope is normally installed as a secondary display to monitor the equipment waveforms.

This type of display is also extremely convenient for measurement of echo-box response time and for precision tuning of the receiver with the aerial stationary.

3. Design Considerations of an Equipment

(*a*) *The Choice of a Wavelength*

As has been stated, radar vision at present is markedly inferior to direct viewing in respect of azimuth resolution, so that improvement in this respect is a prime aim of the design. This deficiency arises from the method of collection of the radar data, that is, by scanning the area viewed with a fanlike beam. The horizontal width of this beam at any point represents the smallest unit available to build up the picture in azimuth.

From geometrical considerations the minimum beam-width obtainable from any given size of aerial is proportional to the wavelength used so that, on this account, the shortest wavelength for which commercial valves are available would be chosen. This is at present about 1 cm.

At this frequency the conventional scanner of 6 ft aperture would produce a beam of about ·4° between ½-power points.[4] A picture of this azimuth resolution would represent an enormous improvement upon those customarily obtained, that is, from 1·2° beams.

It is necessary, however, to consider the operation of the equipment in the presence of rain, hail and snow.

In general, under these conditions, two effects are observed :—

(1) A portion of the outgoing energy is returned by scattered reflection to the aerial and appears as a random illumination of the screen.

(2) A further portion of the energy is absorbed by water particles in the atmosphere.

Now the relative importance of these effects depends upon the range and bearing of the precipitating area with respect to the target. If the target lies within the precipitating area the first effect will limit the range obtainable regardless of transmitted power. The energy returned from the water particles will cause an illumination similar in texture to that caused by noise, which, in the limit, will obscure the target. It is also clear that no improvement can be obtained by increased transmitted power since the ratio

$$\frac{\text{Power returned from water particles}}{\text{Power returned from target}}$$

will be determined by their relative scattering cross-sections.

It is a little difficult to derive a precise value for the above ratio, since the scattering cross-section of a rain-storm depends not simply upon the rate of rainfall but upon the number and size of the drops and the operating wavelength.

Only by assuming a much simplified set of conditions, therefore, can this reflecting power be related to the rate of precipitation, which is the quantity ordinarily measured.

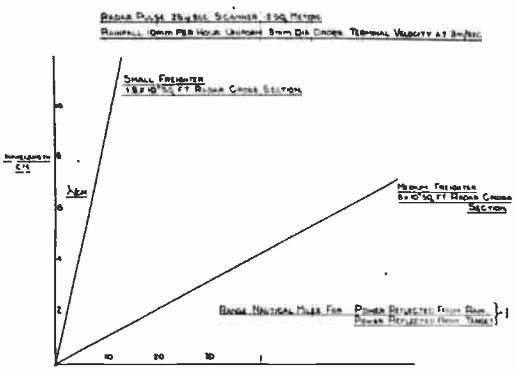


Fig. 5.

It is, however, useful to consider such a simplified state in order to obtain some idea of the magnitude of the effect and its dependence upon operating wavelength.

The ranges at which the power reflected from the rain equals that from the target have been plotted against wavelength for the following simplified conditions.

Target :

(1) Medium freighter (2) Small freighter

Radar :

·25 μsec pulse 1·2° beam

Rainfall :

Heavy rain. 10 mm/hour, in uniform drops 3 mm diameter having a terminal velocity 3 metres/sec.

It is clear from this graph that use of 1 cm wavelength would restrict the use of the equipment under conditions likely to be encountered fairly frequently, but that performance at 3 cm and longer wavelengths is not seriously restricted.

If the target lies beyond a precipitating area so that the incident and reflected waves pass through the falling rain, the serious effect is the attenuation of the target signal resulting from losses in the water particles. The screen illumination by scatter appears upon the screen at shorter ranges and does not, in itself, obscure the target.

This effect, which is equivalent to a deterioration of the receiver signal/noise ratio, can be offset by increased transmitted power.

Such increase is, however, extremely expensive, so that the propagation loss must be most carefully considered.

The loss in db per mile has been shown to be approximately proportional to the rate of precipitation and, inversely, to the square of the wavelength.[5] If the loss in db per mile is plotted against frequency for heavy rain 10 mm per hour, it is clear that serious attenuation will arise at frequencies below 3 cm. (Fig. 6.)

At wavelengths greater than 5 cm, however, the effect is not likely to be serious, particularly as extremely heavy rainfall does not, in general, occur at the same instant over a very wide area.

If the water in the atmosphere is in the form of fog, then the attenuation is more strictly proportional to water content and, inversely, to wavelength squared.

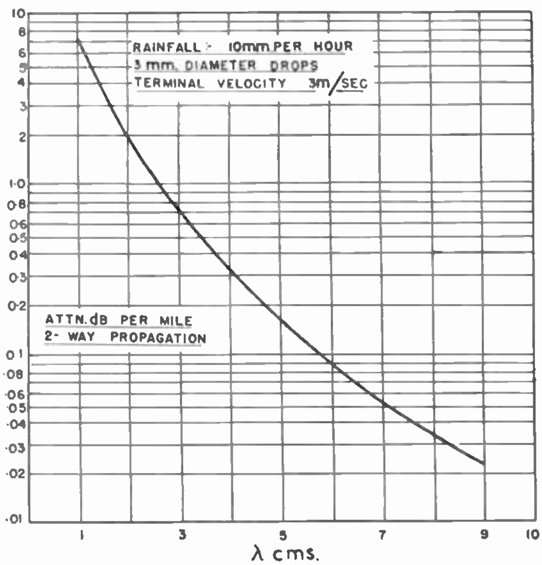


Fig. 6.

On this somewhat more accurate basis a graph has been constructed for operating wavelength 1-10 cm. showing the range at which

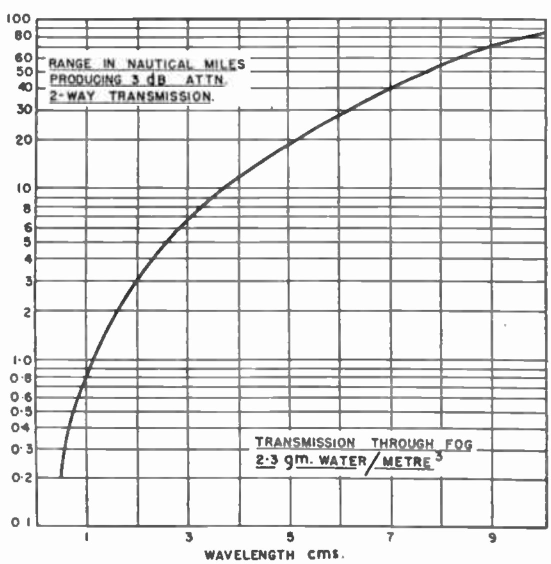


Fig. 7.

the power returned from the target is reduced to 50 per cent. of the clear weather value under conditions of fog sufficiently dense to restrict direct visibility to about 100 ft.

The great advantage of radar vision in fog, compared with direct vision, is clearly shown, but, again, a wavelength greater than 3 cm is necessary if the maximum range of the equipment is not to be appreciably reduced under these conditions.

Bottom Lobe Angle and Low Angle Cover

When a seaborne target is illuminated by a horizontally polarized radar beam, the energy arrives by both a direct and a reflected path. Now the wave undergoes a phase reversal upon reflection so that these two components, which are nearly equal, tend to cancel. By simple geometry it is evident that the phase difference between the two routes is

$$4\pi \frac{h_a}{\lambda} + \varphi$$

where $\theta = \frac{h_t}{r}$ = angle of elevation of target

h_a = height of radar aerial

h_t = height of target

λ = wavelength

r = range

φ = phase shift at reflecting surface, which, for shallow angles of incidence on a water surface, may be taken as π. The coefficient of reflection at such angles may be taken as unity.

Hence, maximum signals are received when :

$$\frac{4h_a h_t}{\lambda r} = 1, 3, 5 \ldots\ldots$$

A graph has been prepared showing the relationship between low angle coverage and the quantity $\frac{h_a}{\lambda}$. From this it is evident that the signal from a small object of effective height 10 ft, e.g., a reflector on a small buoy, at 5 miles will be -3 db on the free space signal when $\frac{h_a}{\lambda} \simeq 200$. This corresponds to a scanner height of 20 ft at

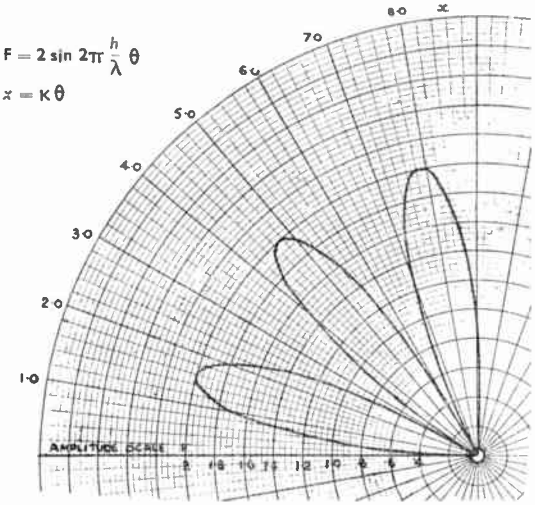


Fig. 8.

3 cm or 67 ft at 10 cm. The comparable loss at 10 cm for a scanner height of 20 ft is 20 db which would, in itself, greatly reduce the value of the equipment as an aid to close water navigation.

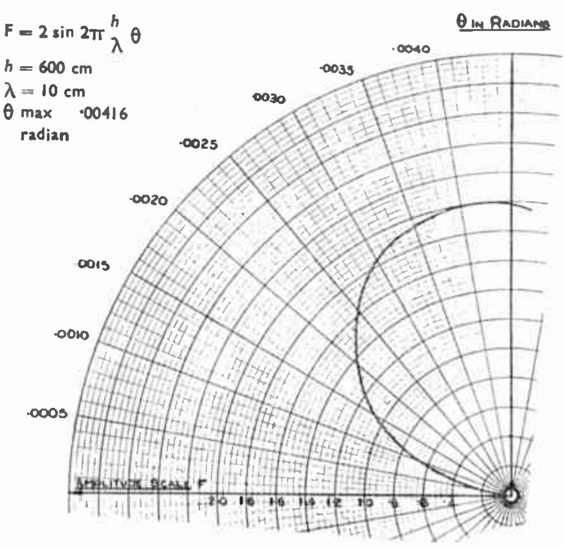


Fig. 9.

The optimum operating wavelength, therefore, will be dependent upon the size of the vessel in which the equipment will be fitted. For an equipment which is to serve vessels down to perhaps 150 tons, the limitations as to scanner size and height will necessitate use of 3 cm wavelength, and the limitations due to attenuation and scatter must be accepted.

Where the installation permits, a longer wavelength should be used with a larger scanner mounted at a sufficient height.

The valves at present available tend to cover either 3 cm or 10 cm as a result of wartime concentration on these bands. It would, however, seem that 5 cm would produce an optimum compromise for the larger type of vessel.

(*b*) *The "Overall Test"*

When a marine radar equipment is used in calm open waters there will be no target returns and this condition presents two difficulties :

(1) It is not self-evident that the equipment is functioning normally.

(2) There are no echoes by reference to which the equipment may be adjusted.

The function of an overall test device under these conditions is to enable :

(1) The overall efficiency of the equipment to be accurately estimated.

(2) The tuning controls to be adjusted.

A commonly used form of overall test is the echo box.[6, 7]

This is a low decrement cavity resonator which should be coupled to the equipment via the scanner and complete waveguide system. The operation is as follows :—

During the transmitter pulse energy is received by the echo box, which is resonant at transmitter frequency. The energy level in the box at the end of the pulse is proportional to the energy content of the pulse. This energy is then re-radiated so that the level in the box falls exponentially.

A portion of the re-radiated energy is returned to the receiver and appears as illumination of the tube. The amplitude of the received signal at time T after the end of the transmitted pulse is :

$k.P.e^{-\frac{T}{t_c}}$ when k = constant proportional to coupling between box and equipment

P = energy in the pulse

$t_c = \frac{Q}{\omega}$ for the cavity

$\omega = 2\pi \times$ frequency.

The signal received from the echo box will thus diminish exponentially with time, and the period which elapses before this signal falls below visibility will be given by :

$$T = t_c \log_e \frac{kP}{G_R}$$ where G_R is the received power necessary to produce a visible signal.

Now for any particular equipment the relative value of P/G_R, which may conveniently be expressed in db, is a measure of the constancy of the overall performance. Thus, the time T for which the echo signal remains visible is directly proportional to the overall performance in db of the system.

In practice, the design of the echo box and the presentation of the signals produced are a matter of some difficulty.

It has previously been stated that changes in overall performance of 7 db should be clearly displayed. If the change in performance is made to produce a change of 1·2 microsecond in echo time, there will occur a change of 1 cm in echo length when a 1 mile trace 10 cm long is in use. A change of 1 cm is approximately the minimum easily observable when the indeterminate nature of the echo line at the point where echo falls below noise is considered. For this discrimination, then, t_c is ·8 microsecond,

hence $Q = 50{,}000$ when $\omega = 6{\cdot}28 \times 10^{10}$.

Such a cavity must therefore be very accurately adjusted to transmitter frequency and, in practice, the tuning is generally swept continuously over the band in which the transmitter may be expected to emit. If, then, the box is fixed to the ship's structure and energized by the rotating scanner, echoes will be produced only when illumination by the scanner coincides with correct tuning of the box. The probability of this is low, so that the echo line tends to be weak and the coincidences irregular.

The echo line produced, however, appears on a fixed azimuth, and this can be chosen to fall within a blank sector on the display, such as that caused by a funnel shadow.

If no blank sector exists naturally, as in certain motor ships, then a small screen should be fitted aft of the aerial.

This necessity arises because, with the type of box commonly used the echo line cannot be made to extend much beyond 2,000 yds whilst, in rough water, sea clutter may extend beyond 5,000 yds, thereby obscuring the echo-box line.

Two distinct types of echo box may be used :

(1) Cylindrical cavity single mode box. These resonators are precisely designed and provide maximum Q for a given volume.

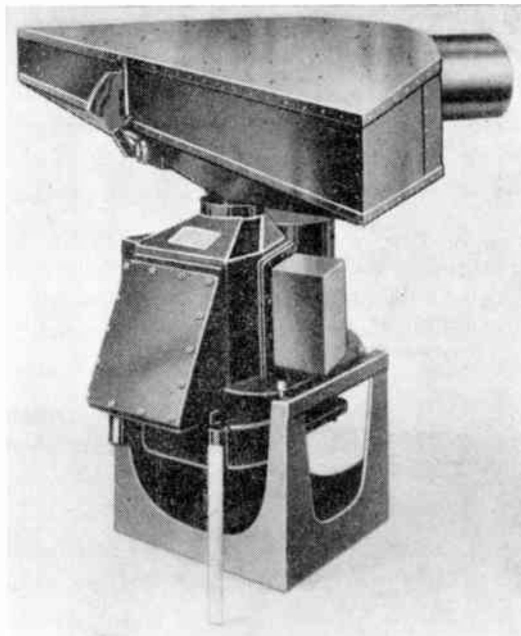


Fig. 10.

(2) Cubical box of sides about 10 λ. Such boxes are the subject chiefly of empirical design but offer the important advantage that, because of the numerous modes possible in such a cavity, one or more invariably fall within the spectrum emitted by the magnetron. An echo by which the receiver may be tuned is thus produced without the necessity of first tuning the box.

Typical boxes of the two types are shown.

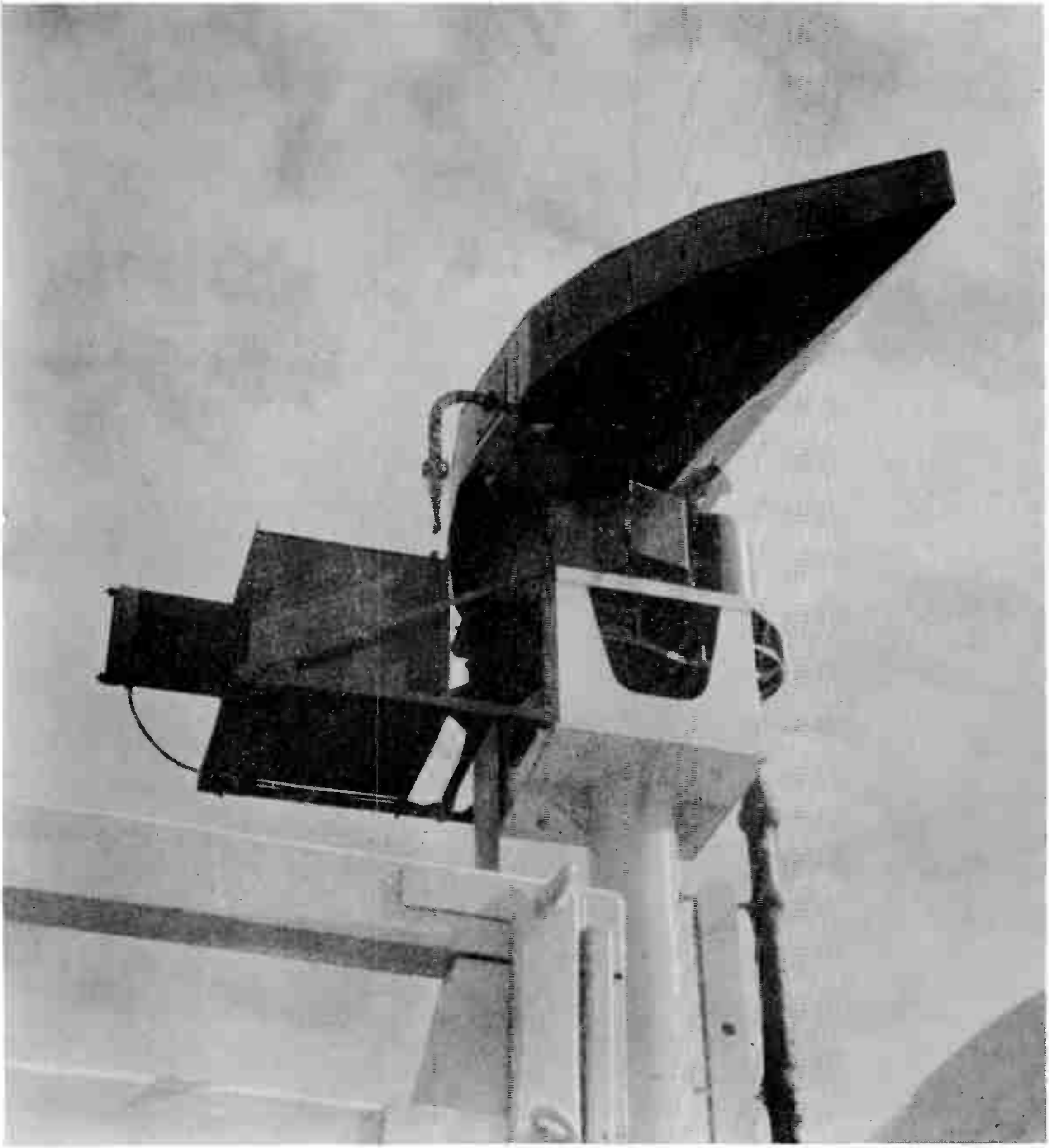


Fig. 11.

Whichever design is chosen, the interior must be maintained perfectly clean and dry, as considerable loss of Q results from any moisture or internal corrosion.

(c) *The Design of the Aerial*

At the frequencies normally used for marine radar, the aerial generally consists of a source illuminating a parabolic reflector to provide a beam having differing directivity in azimuth and elevation. The polarization is horizontal.

Since the horizontal beam width represents the smallest unit available to build up the picture in azimuth, it is important to reduce this quantity to a minimum. For this reason the aperture of the mirror will be made as large as may be accommodated. It can be shown that, for any aperture, maximum directivity is obtained with uniform illumination of the mirror.

Under these conditions the angular separation of the half-power points is given by :[8]

$$\theta = \frac{51\,\lambda}{D}$$

where θ = separation between $\frac{1}{2}$-power points in degrees.

λ = wavelength

D = aperture of mirror

An aerial designed for maximum directivity in this manner is, however, unsatisfactory for the following reason.

If a single target is illuminated by a rotating aerial having a polar diagram of the general form shown in the upper half of Fig. 12, then multiple images on a common range and on bearings making angles relative to the main beam image corresponding to the side lobe angles will be observed.

Such false images from large targets may easily be stronger than the main images from buoys and other small objects unless the side lobe radiation is reduced to a very low level.

For the case of uniform illumination the largest side lobe will be $-13{\cdot}4$ db. It is, however, possible to reduce this to about -23 db by varying the illumination across the aperture in a half-sinusoidal distribution. This has the effect of broadening the main lobe, and θ is then approximately equal to $71\,\frac{\lambda}{D}$.

The vertical diagram is chosen so that the illumination of the target is not lost when the vessel rolls or pitches. The half-power points are thus designed to subtend 20°-25°.

Although this arrangement is fairly satisfactory, there are several disadvantages. Firstly, much of the transmitted power is lost. If the scanner were stabilized in roll and pitch it would not be necessary to radiate above the horizontal, so that a two-fold increase in effective power would be obtained.[9]

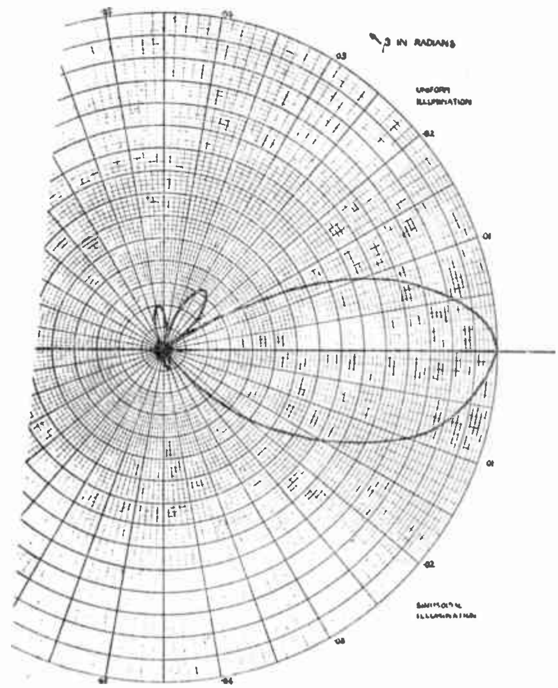


Fig. 12.

The pattern in the lower half could also be made to compensate partially for the fourth-power relation between range and echo power by directing the greater part of the energy nearly horizontally, thus further increasing the effective power on long-range targets.

There is a further disadvantage of radiation above the horizontal which is not related to power loss. Because of the two-dimensional presentation, if a surface target is under observation and there are rain clouds at the same range and bearing, the returns from these clouds lie over the target on the tube and tend to obscure it, although the direct path between aerial and target may be entirely free from rain. This effect is seldom serious but is considered to be undesirable.

There are, therefore, advantages in scanner stabilization but, because of complexity and weight, the system has not, so far, been used on merchant ships.

(*d*) *The Design of the Indicator*

The function of the indicator is to convert the radar responses into a display by means of which the navigation of the vessel may be facilitated.

The details of the design must, firstly, meet the navigational requirements, and, secondly, comply with the conditions imposed by the remainder of the equipment.

The navigational necessities, in order of importance, are considered to be :

- Convenience for use with standard charts.
- Adequate resolution for close water navigation.
- Correct screen characteristics.

(i) *Range Scales*

When a P.P.I. is to be used for general navigation it is most desirable that the area displayed shall approximate to that on the chart in use at the time. As, however, charts are not, in general, drawn to fixed scales, a P.P.I. of continuously variable scale would be required to obtain exact correspondence. Because change of P.P.I. scale usually involves a simultaneous change in other parameters it is, however, usual to use a series of pre-set ranges, to which may be added a fine control when exact correspondence is required.

For close water navigation an open scale is a necessity and a maximum range of some 1 to 1·5 mile is generally chosen.

Further scale expansion will not appreciably increase the resolution because the minimum pulse width which may conveniently be used (that is, approximately ·2 microsecond) in itself occupies 2·5 × spot width on a one-mile trace. It is also considered that the use of a display of shorter range would itself introduce a hazard in that insufficient warning of objects of high relative velocity would be obtained.

The longest range incorporated will be based upon an estimate of the probability of receiving echoes at maximum range.

In conditions of normal propagation the anticipated maximum range will approximate to optical, and this may simply be shown to be :

$1{\cdot}07\,(\sqrt{h_a} + \sqrt{h_t})$ nautical miles when h is in feet.

For an aerial at 100 ft, which is representative of an installation in a large vessel, the maximum range will be $10{\cdot}7 + 1{\cdot}07\sqrt{h_t}$ miles, so that a target, to be visible at 30 miles, must be 325 ft in height.

It is not, therefore, very profitable to extend the maximum displayed range greatly beyond 30 nautical miles.

The range 1-30 miles is conveniently covered in four ranges, 1-3-10-30.

If the installation is to be used in regions where long periods of super-refractive propagation may be anticipated, as have been reported from the Great Lakes, the extension of the maximum displayed range is worth considering, but such propagation is, by its nature, inconsistent and reliance thereon unsafe.

(ii) *Resolution*

The resolution of the system in range will, in the limit, be determined either by the finite size of the tube spot or by the transmitted pulse width. On any range it is desirable to make both limits operate equally.

In the tubes in general use, some 150 spots may be resolved along a radius so that the displayed pulse length should be given by

$$\frac{\text{duration of range trace}}{150}$$

The signal section of the indicator must therefore pass a pulse of approximately (0·08 × range scale in miles) microseconds.

The resolution in azimuth of the tube itself clearly varies along the trace and is approximately :

$$\cdot 38\ \frac{\text{distance from tube centre}}{\text{radius of tube}}\ \text{degrees.}$$

The resolution at the periphery on this basis is ·38° so that the restrictions imposed by the 1° aerial beam width limit azimuth resolution over the outer 60 per cent. of the trace.

Any considerations such as these above relate to well-focused spots, and it is necessary to devise limiting arrangements so that strong signals do not de-focus the tube. The resolution obtained operationally will depend considerably upon the design of these circuits and their correct adjustment.

(iii) *Choice of Screen Characteristics*

It is by means of the cathode ray tube screen that the radar electrical information is finally rendered visible so that the properties of this medium are extremely important.

The principal characteristics for P.P.I. purposes are :

Brilliance

Integrating properties

Image persistence.

Because the display may be mounted upon the bridge of a ship, the highest obtainable brilliance is required. The tubes at present available are insufficiently brilliant to permit operation in normal daylight and, for this reason, a visor must be used.

Now the collection of information by a radar set is a sequential operation, the surroundings of the vessel being scanned in a cycle of about 2 seconds. In order that a complete picture of the area may be displayed it is necessary that the images persist upon the screen for at least this period. This result may be obtained by use of a double-layer screen.

A double screen consists of an outer layer of long persistence phosphor over which is deposited a layer of short persistence material having a high efficiency of conversion of energy of bombardment into blue light. This phosphor is irradiated by the beam directly. The emitted light excites the long persistence screen which retains the image for a considerable period. Because the excitation of the long persistence material tends to build up over a period equal to several times the pulse duration, such screens discriminate in favour of signals which recur at the same screen position over several pulses against random signals such as are caused by receiver noise.

Now the number of hits on any point target will be given by :

$$\frac{\text{No. of transmitter pulses per unit time}}{\text{No. of scanner revolutions per unit time}} \times \frac{\text{beam width in degrees}}{360}$$

and these parameters are determined by the following considerations :

The maximum usable pulse repetition may be determined by the limit of transmitter valve dissipation. The interval between pulses may also not be less than the time taken for an echo to be returned from the farthest object capable of producing a visible signal on the screen.

This restriction is imposed in order that returns from one transmitted pulse shall not appear on the displayed trace appropriate to the following pulse, and so produce false images.

On this account a maximum repetition of about 1·5 kc/s is normally chosen. Any object, to give a false image, must then be distant 54 miles, and any considerable return at this range is unlikely.

The aerial rotation rate is fixed by the necessity of obtaining fresh information as frequently as possible, particularly when objects of high relative velocity are under observation at short ranges.

If, for example, two vessels pass at 300 ft with relative velocity 30 knots, the trace of the target vessel will degenerate into a series of dots separated 20° in azimuth when scanner speed is 30 r.p.m., so that it is unsafe to utilize lower aerial speeds.

A repetition of 1·5 kc/s, an aerial speed of 30 r.p.m., and a beam width 1°, will give 8 hits on a point target each revolution. It can be shown that the signal power required to produce a visible return is reduced by approximately $\sqrt{\text{number of hits}}$, so that the screen build-up characteristic will substantially improve the effective signal/noise ratio under these circumstances.[10]

The persistence of the screen must be sufficient to maintain an adequate image over a period of one scanner revolution but should not be greatly in excess of this in order that, when a change of range or course is made, the screen shall clear as quickly as possible.

Ideally, then, the screen brightness would remain sensibly constant over a period of about

2 seconds and then fall rapidly to zero, as indicated by the ideal rectangular characteristic of Fig. 13.

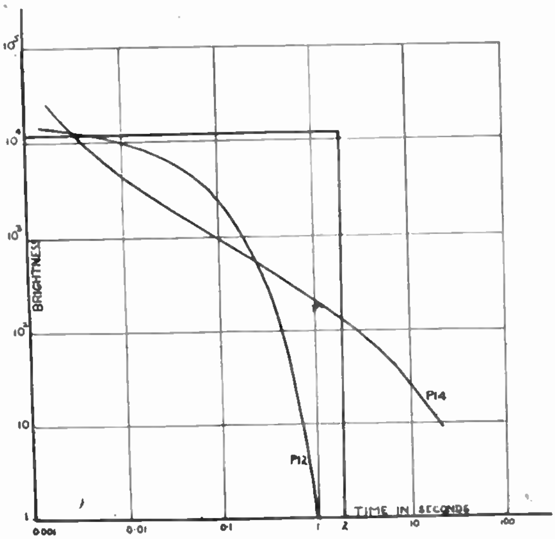


Fig. 13.

The double-layer screen is somewhat unsatisfactory in this respect since the decay characteristic is of the form of curve P14 of Fig. 13. When viewed by the eye, which has an approximately logarithmic appreciation of brightness, such a screen clears at a uniform rate so that the unwanted picture persists at a low level for an objectionally long period.

The single-layer fluoride screen having a characteristic similar to Fig. 13, curve P12, more clearly approaches the ideal.

Such screens at present suffer from a somewhat shorter life than conventional double layer types, but their superior performance is considered to justify the more frequent replacement involved.

(iv) " *Chart Comparison* " *Display*

When the display is used in conjunction with a chart, it is convenient to stabilize the picture in azimuth. True bearings may then be read from a fixed scale despite changes in ship's heading. When the picture can be stabilized it is convenient operationally to superimpose an image of the display upon the chart. This procedure enables a radar picture, which may show only isolated topographical details, to be identified with a chart displaying complete information. This process is also most useful in distinguishing ships from navigational marks on the display.

Because of the inelegance of the technique, optical superposition has not been widely used in merchant ships. It is considered that, when a separate chart room display is to be fitted, it should provide this facility.

(*e*) *The Transmitter and Receiver*

The purpose of the receiver is to convert the centimetric energy received from a target into video frequency energy to modulate the display tube.

Now the power returned from a target in free space may be shown to be :[11]

$$P = P_t \frac{G}{4\pi r^2} \frac{A\alpha}{4\pi r^2}$$

where P_t = transmitted power

G = power gain of aerial during transmission

r = range

A = " radar cross-section " of target

α = effective aerial aperture during reception.

Under operational conditions the value of returned power obtained from this relation is modified by two factors :

(1) The term $16 \sin^4 \dfrac{2\pi h_a h_t}{\lambda r}$ discussed earlier, arising from the modification of scanner vertical polar diagram due to reflections from the sea.

(2) A further correction to factor 1, due to variation in h_a and h_t to allow for the earth's curvature.

Figure 14 shows the relation between received and transmitted power as a function of range, the straight line representing the free space value where P is inversely proportional to r^4, and the curve representing the free space value as modified by the two correcting factors. The figure relates to a typical 3 cm marine radar with a scanner at 40 ft above sea level, and the target considered is a 3 ft corner reflector at a height of 10 ft above sea level.

The breaks in the curve cover the ranges at which the target, considered as a point, lies within the minima of the lobed vertical polar diagram, as at ranges of about 1,350 and 2,700 yds a point target would give zero return. The computation of the actual return from a target of finite size in these regions is impracticable.

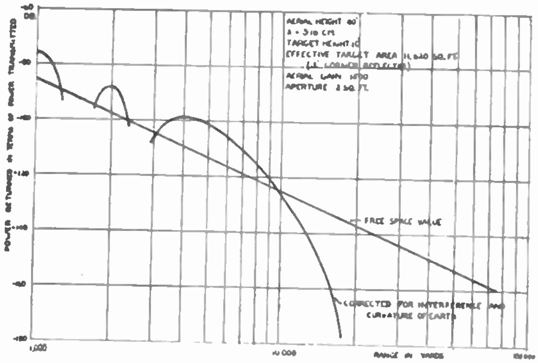


Fig. 14.

It will be seen that, up to a range of some 8,000 yds, P remains approximately proportional to $1/r^4$ but that beyond this range (i.e. when the angle $\frac{2\pi h_a h_t}{\lambda_t}$ is small), P becomes proportional to $1/r^8$ with a further reduction due to diminished effective aerial and target height.

On such a target it is therefore unprofitable to attempt to increase range beyond this point by increase of transmitter power as, if the latter be increased 10 times, the resulting increase in range is only 25 per cent.

Consideration of such curves for a variety of targets leads to the conclusion that a transmitter power of some 160 db above the minimum acceptable received signal represents the economic limit.

The minimum acceptable received signal is determined primarily by receiver noise, although some variation arises from consideration of the number of transmitted pulses reflected from the target during each revolution of the scanner.

To pass a pulse length of ·2 μs with low distortion a receiver bandwidth of 10 Mc/s is required, and if the noise is considered to be generated entirely in the input circuit of the receiver, its minimum value (kT.δf) is -134 db relative to one watt. Practical receivers, due to imperfect matching, high " noise-temperature " of the crystal detector, etc., fall short of this ideal by a factor of 15 db or more, giving a noise power input of -119 db relative to one watt.

The transmitter power required to give unity signal/noise ratio at the extreme range desired is therefore +41 db on one watt, or about 10 kW, and normal practice is to use an output between this value and 50 kW, the higher values giving some measure of compensation for attenuation in waveguide systems and loss of signal strength due to rain.

(*f*) *Receiver Gain Law*

It is operationally desirable that the displayed signal from a given target shall be characteristic of that target, regardless of its range. It is apparent from Fig. 14 that this requirement cannot be met over the entire range of visibility of a target, and it is customary to compromise by varying the gain of the receiver with time in such a way that the gain is proportional to $(\text{range})^4$. Thus, taking the conditions of Fig. 14 as an example, a sensibly constant displayed echo from the target considered would be obtained at all ranges up to about 8,000 yds, the variations being due to scanner lobing and earth's curvature effects. It is evidently not possible to correct for these owing to their dependence on target height. This gain variation has a further advantage in that reflections from the surface of the sea, which are most serious at short ranges, are also reduced to a sensibly constant level, so that saturation of the display by sea returns at short range may be avoided.

It has been suggested that the latter object may alternatively be achieved by the use of a logarithmic receiver[1];[2] i.e. one in which output is a linear function of log (input signal power) but it will be seen that, although the use of such a receiver considerably reduces the range of signal amplitudes to be handled by the display, the amplitude of a given target echo is dependent on range.

4. The Nature of the Results

A series of photographs of the display at a shore station, using a virtually standard marine equipment, is reproduced in Figs. 15-19. This station is situated at Seacombe Ferry on the west bank of the Mersey, and a reproduction of the chart showing the area covered by the radar is given in Fig. 20.

Fig. 15.

In Fig. 15, the picture with normal operational adjustment of the controls is shown, the range covered being approximately 1¼ miles radius. The large signals in the river represent ships, and a number of the smaller ones may be identified from the chart as buoys, the remainder being small boats. The elongated trails are caused by movements of shipping during an exposure of one minute.

Fig. 16.

Figure 16 shows the same area, with the receiver gain considerably higher, showing a patch of sea-clutter up-river from the stage. It may be noted that clutter is usually greatest on the windward side, owing to the characteristic steep-sided wave shape in this direction.

Farther up the river is a large vessel, showing side lobes at a narrow angle to the main beam, while on both sides of the station may be seen strong false echoes due to side lobes returned from large buildings directly across the river from the station.

Fig. 17.

At an intermediate gain setting, Fig. 17 shows the display on a range of three miles, and a similar photograph taken during a rain-storm is shown in Fig. 18. Areas of heavy rain may be seen over the Liverpool bank of the river and inshore on the same bank.

A comparison of Fig. 19, with a maximum range of ¾ mile, with Fig. 15, shows that no improvement in resolution results from such an increase in scale, although, in this instance, the use of the larger scale is justified by the easing of strain on the operator, as fast-moving vessels are not encountered in this area during periods of low visibility.

Fig. 18.

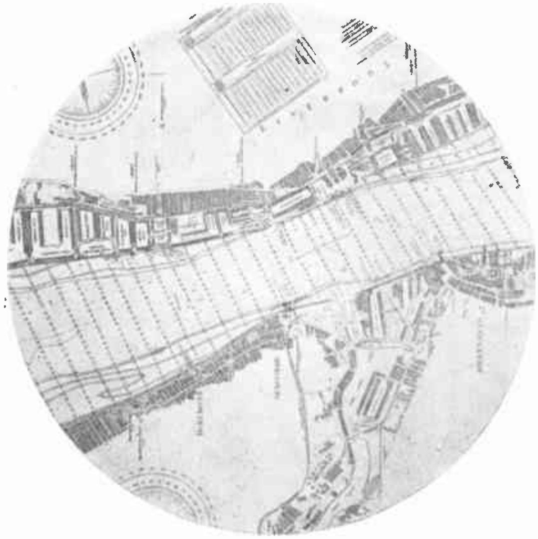


Fig. 20.

It will be observed from these photographs that the landing stage near the station, at a range of some 60 yds, is clearly visible and, in general, a minimum range of less than 50 yds may be obtained with a transmitted pulse length of ·2 microsecond, and small targets separated by considerably less than this distance may be consistently resolved.

Fig. 19.

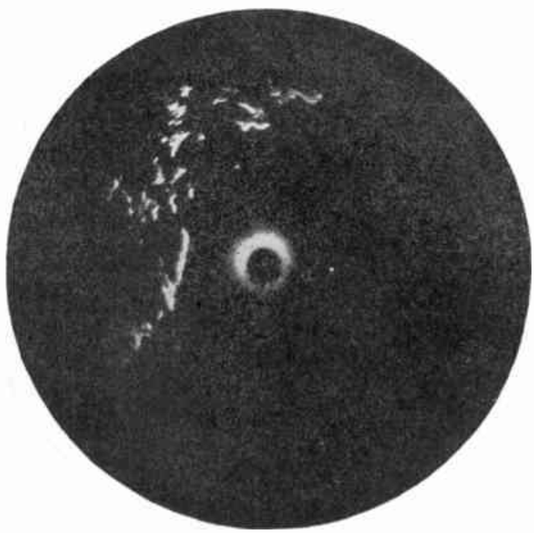


Fig. 21.

Fig. 22.

Fig. 24.

Figs. 21-31 show the performance of an equipment installed in a ship approaching St. John, New Brunswick.

Figs. 21-24 are of the 12-mile range. The wind may be seen to be offshore and the approach to the harbour can be traced.

Fig. 23.

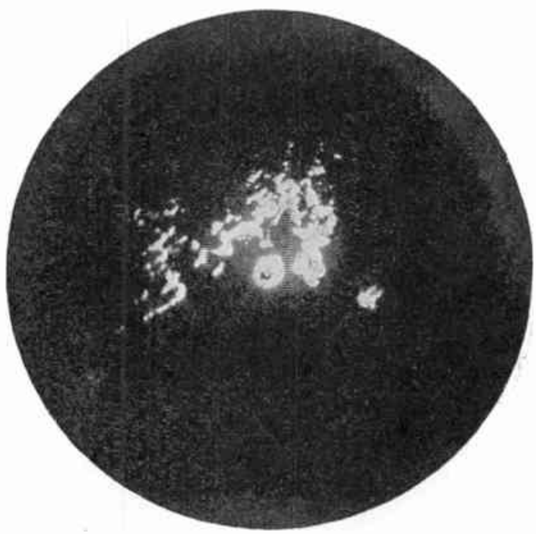


Fig. 25.

Fig. 26.

Fig. 27.

Figs. 26-30 are of the 3-mile range and show entry into the outer harbour and the passing of a small island to port. The quiet water to leeward of the island is clearly shown (Fig. 29). Small craft are shown in the bay to port and the jetty and approach buoys are indicated ahead.

Fig. 28.

Fig. 29.

Fig. 30.

Fig. 31 is of the 1 mile range and shows the effect of ship motion during the period of the exposure. This effect is, however, considerably less objectionable to the normal eye than appears from the photograph.

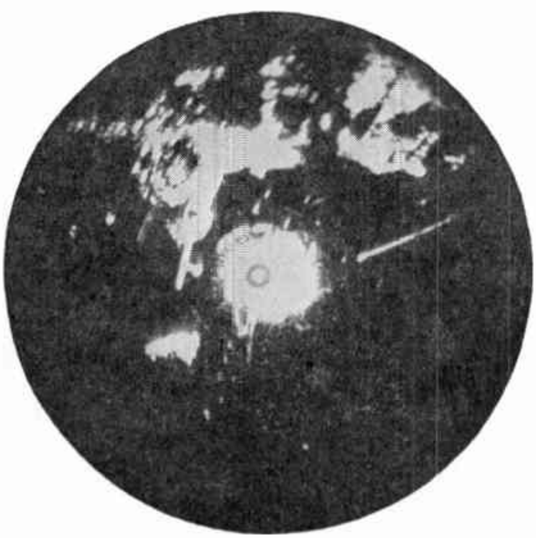


Fig. 31.

The performances at longer ranges are summarized in the following table, which relates to a 3 cm radar with a scanner mounted about 50 ft above sea level :

Target	*Detected at*
Small boat (30 ft long)	2 miles
Second class buoy	2½ miles
Fishing smack (80 ft)	3 miles
200-ton ship	6 miles
5,000-ton ship	12 miles

Steep coastline or hill inland, at optical range.

It is evident from consideration of these results that, in radar, a tool of real utility has been added to those previously available to the marine navigator.

5. Acknowledgment

The paper is based on work carried out for Cossor Radar, Limited, to whose directors the authors are grateful for permission to publish the paper.

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TRANSFERS AND ELECTIONS TO MEMBERSHIP

Subsequent to the publication of the list of elections to membership which appeared in the May issue of the Journal, a meeting of the Membership Committee was held on April 28th, 1949. Nine proposals for direct election to Graduate or higher grade of membership were considered, and twenty-one proposals for transfer to Graduate or higher grade of membership.

The following list of elections was approved by the General Council: seven for direct election to Graduate or higher grade of membership, and fourteen for transfer to Graduate or higher grade of membership.

Direct Elections to Associate-Member

BROWN, Leonard James — Pakistan
FURNISS, Joseph James — Nairobi, Kenya
VAN RYN, Bernard — Cardiff

Direct Election to Associate

BIRCH, John Yardley, Flt./Lt. — Leeds
*CULLIS, Harry Ernest, B.Sc. — Wotton-under-Edge, Glos.

Direct Election to Graduate

KARPLUS, Heinz Berthold, B.Sc. — London, E.9
NICKSON, Noel Francis — Hale

Transfer from Associate to Associate-Member

DENNY, William Guy Cecil — Johannesburg
FAIRFAX, Osmond Maurice — Singapore

* *Reinstatement.*

Transfer from Associate to Graduate

CURRIE, John Andrew — Birmingham

Transfer from Graduate to Associate

de BEER, Baron Christian — London, N.W.7

Transfer from Student to Associate

ALLEN, Edwin Paul Reeve — Braintree
BENNETT, Sydney George — Hayes
SPRING, Alfred Laurence — Ruislip, Mddx.

Transfer from Student to Graduate

BRISTER, John Arthur — Leigh-on-Sea
CHESTER, Alan Sydney — Blackpool
HOLMES, Peter William — Seven Kings, Essex
JONES, Evan Haydn, B.Sc. — London, W.12
RAO, Laxminarayan P. — Belgaum, India
SANGAMESWAR, Venkitachal T. — Wadakanchery, India
WHITEHEAD, Geoffrey — Blackpool

STUDENTSHIP REGISTRATIONS

In addition to the list of Studentship Registrations published in the May issue of the Journal, the following twenty-eigh studentshipt proposals were dealt with at the meeting of the Membership Committee held on April 28th, 1949, and these have now been approved by Council :—

BHANU RAJA, K. C. B.Sc. — Madras
BROWN, William Trevor — Dorking, Surrey
BULLEY, Frank Noel — Croydon
CHAND, Satish, B.Sc. — Simla, India
CHAPMAN, Derrick James Kenneth — Ludlow, Shropshire
CONESA, Raphael, Ph.D., M.A. — Bombay
CRORIE, William Douglas — West Lothian
GAYNOR, Alan Roger — Liverpool
GOKHALE, Narayan Ramchandra, B.Sc. — Poona
HASAN, Syed Shafi-ul, B.A. — Bareilly, India
HATELY, John Norman — Paisley
JONES, Dennis — Shrewsbury
KARANJIA, Keki Framji — Bombay
LILLEY, Robert James Hartley — Invercargill, N.Z.
MANECKJI, M. J. B. — Bombay
MENSAH-BROWN, Joseph Paschal — Cambridge
MURTHY, V. Sathya, B.Sc. — Bangalore, India
NAEF, Edward Albert — London, S.W.20
ORSMOND, Douglas William — Swindon, Wilts
PRABAKAR, Parakal, B.Sc. — Madras
RAJEN, Chittoor Thyaga — Chittoor, India
ROBINSON, Kenneth Robert — Weymouth
SATHYANARAYANA, Iyer K. — Madras
SKINNER, Leonard Malcolm — London, E.10
TIMMINS, Walter Bryson Bradley — Toronto, Canada
UBAID-UR-RAHMAN — Lahore, Pakistan
VAIDYANATHAN, Ganesa, B.Sc. — Anathandara-puram, India
YU, Fleming Iu Kan — Hong Kong

MICRO WAVE TELEVISION LINK

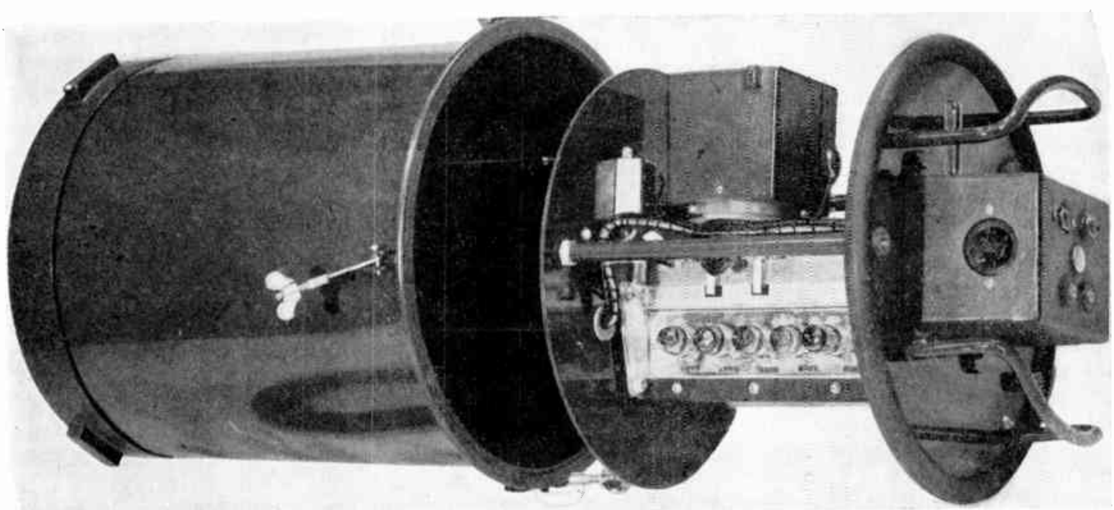
B.B.C. Engineers in collaboration with British Manufacturers are at present engaged on the development of light-weight equipment for television outside broadcasts. Some of the equipment which has been produced is shown in the two illustrations.

The transmitter uses a klystron oscillator operating at a frequency of 6,500-7,100 Mc/s (about 4·5 cm). An output of 100 mW is obtained, and the 6 ft. paraboloid aerial system gives a gain of 40 db.

Transmission direct to Alexandra Palace has proved completely free from interference over a distance of 7 miles and it is expected to increase the range to 20 miles without trouble. For greater distances micro wave relay circuits may be employed.

The aim of the equipment is to extend the scope of outside broadcast operations and to increase the speed with which the equipment can be set up, so that events of exceptional topical interest can be televised. The transmitting and receiving apparatus, being light and easy to carry, marks an important advance on the apparatus used for this purpose before the war.

Micro wave radio link transmitter and wave guide.



4½ cm transmitter.

ELECTRONIC EQUIPMENT FOR THE PRODUCTION ENGINEER

A report of the discussion meeting held between the Institution and the Institution of Production Engineers of February 17th, 1949, at the Royal Empire Society, London, W.C.2.

The President of the Institution of Production Engineers (**Mr. F. P. Laurens**) opened the meeting by referring to the fact that this was the first joint meeting of the I.P.E. and the Brit. I.R.E. The interest shown in the meeting was evinced by the packed assembly.

The Chairman of the Brit.I.R.E. Council (**Mr. J. L. Thompson**) opened the proceedings with the following contribution :

Prior to 1939 the industrial application of electronic principles, save in the most elementary forms, was confined almost entirely to the radio industry.

To industry generally, radio engineering was synonymous with entertainment, and it had not appreciated (and it had not been made aware of) the enormous versatility of this new branch of radio engineering. Much has happened in these past ten years to change this state of affairs.

All of us here are familiar with the part that was played during the war by radar and the several navigational aids based on radar principles, such as Gee. All of us here are familiar, if only in name, with George—the automatic pilot.

These complex electronic devices developed and perfected during the war are now in everyday use on the air lines and shipping lines of the world. Operating under extremes of temperature and humidity they have proved their complete reliability, and the manufacturing techniques developed to meet these stringent operational requirements have been applied to industrial equipments.

Obviously, electronic devices have their limitations, but their field of application is a wide one, and within that field they can perform certain functions more quickly, more reliably and much more efficiently than many of the methods at present in use. Especially is this the case where quality control and inspection is concerned. These important and essential operations are largely dependent upon the human element with all the known weaknesses of that element. Electronic devices can perform even the most complex of these operations without any preliminary training, without either physical or psychological fatigue, without any cessation in hourly output, and without that most dangerous of all human attributes (at least so far as these operations are concerned), the power to philosophize—to pass border-line cases. Such devices can be set to operate within precise limits and to give either aural, visual or mechanical indication when these limits are exceeded, be those limits in terms of colour, shade or density, time or speed, rotation or vibration, temperature or humidity, physical size or shape, continuity or interruption of flow, silence or noise, compression or expansion, force or weight, or changes in the chemical or metallurgical composition of a body or substance.

To the industrial chemist, one of the most important factors to be controlled is hydrogen-ion concentration, the degree of which affects such diverse processes as the preparation of photographic emulsions, the manufacture of jams and jellies, the refining of sugar, the colour brilliance of pigments and the sterilization of food.

In the manufacturing control of such products as paints, dyes, inks, glues and beer, it is essential to compare continually the shade of colour of the product with previously set standards.

With the old visual method there was always the danger of personal error when so matching colours, and optical fatigue was a serious factor in routine matching. With electronic devices employing photo-electric cells these sources of error and fatigue have been completely eliminated.

The photo-electric cell has many other applications in industry. Electrically sensitive to differences in illumination, brought about by the actual or partial interruption of an incident light beam, or by changes in the colour or texture of a reflecting medium, it can, by means of suitable equipment, supply sufficient power to operate warning lights, bells, counters, etc., or to control automatically electric motors or heavy machinery.

Sands, clays and dusts can be graded either for colour or grain size—factors of vital importance in the manufacture of ceramic, pottery, face or toilet powders. Products can be sorted and counted either by means of their physical shape or by the colour of the labels or codes on the packages containing them.

Machinery, doors, escalators, alarms, etc., can be operated by the passage of persons, articles, traffic and the like between the light source and the cell. By photo-electric means it is also possible to control the temperature of electric furnaces to an incredibly high degree of accuracy.

Another powerful weapon that electronics has given to industry is the cathode ray oscilloscope. With this device it is possible to examine both transient and recurrent phenomena of all types. A stationary picture of a recurrent phenomenon can be viewed on the screen of the tube even though its actual duration be only one-millionth of a second.

For transient phenomena, cameras are used to take either single shot or continuous film records of the event, which can then be examined and analysed later. Examples of such applications are waveform analysis of A.C. and D.C. voltages and current, the test and inspection of circuit breakers and relays for contact "bounce," and the performance of alternators and motors of all types. Used in conjunction with electrically sensitive pressure pick-ups the oscilloscope is extensively used by the automobile and aircraft industries for the performance testing of all types of internal combustion engines. Acceleration, velocity or vibration can also be detected and measured by employing pick-ups electrically sensitive to these quantities.

The rate of gain or loss of watches can be translated on the screen of the cathode ray tube as a spot of light which will move either clockwise or counter clockwise depending upon whether the movement is gaining or losing. Correct timing adjustment is therefore a matter of minutes rather than hours.

Camera shutters can be accurately adjusted and timed and the muzzle velocity of shells and bullets measured.

Now that our doctors have all been nationalized we can perhaps regard medicine as being in need of production aids and time-saving devices. The cathode ray oscilloscope is widely used for the investigation of cardiac troubles.

Perhaps the most extensive single electronic application is found in the ubiquitous "traffic lights," certain of which are now fitted with electronic control so that the light changes are automatically varied according to the volume of traffic in each direction and the road carrying the greater flow receives the greater "Green" or "Go" time.

Timing control devices are not limited to traffic control or to the operation of lights. Electric welders may be controlled, both for the duration of weld and the amount of current passed, and in all cases where a timing device is required for timing operations of less than, say, 1 sec, the electronic timer shows a considerably improved degree of accuracy over the former mechanical types. Electronic micrometers, comparators and gauges are available to measure accurately to limits of 0·0001 inch irrespective of the size of the object to be measured. These devices are not delicate laboratory instruments requiring skilled handling, but sturdy and robust, designed for use by relatively unskilled personnel under shop conditions. Suitably adapted, they can be used to measure the quality and straightness of bore of gun and rifle barrels, cylinder bores and the like.

Electric motors can be started, synchronized, regulated in speed (with negligible loss of power) and reversed and stopped (if necessary, without over-run), by electronic means.

Torque and the control of torque can be transmitted electrically without any mechanical linkage and the remote equipment so driven will accurately follow the movements of the driving mechanisms. Such remote equipments are not limited to one; any number of like equipments can be made slaves to a master mechanism.

The mercury vapour discharge tube, another electronic product, is perhaps more familiar to many as the "sun ray lamp," and as such is widely used by the medical profession. It has, however, many applications other than medical. In conjunction with suitable electronic timing and switching circuits it can provide a source of high intensity stroboscopic light. By this means it is possible to determine accurately the speeds of rotating mechanisms and visually to reduce the speed of rotation of such mechanisms until they seem to be stationary or revolving at very low speeds. The stresses or deformations in bodies revolving at high speed can then be visually examined or photographed.

By means of a screen coated with nickel oxide the visible light from such lamps can be completely filtered and only the ultra-violet rays (invisible to the human eye) allowed to pass. Under the influence of these rays certain inks, whether visible or invisible, can, among many other physical items, be made to fluoresce strongly.

This phenomenon has been utilized by certain laundries for the sorting of articles prior to despatch. The tiny code marks previously sewn on to such articles are replaced by bold marks with inks invisible to the eye but which, under the influence of ultra-violet rays, become clearly visible. Sorting time is obviously much decreased and the possibility of wrong sorting eliminated. Paper, rubber, linen, silk, and cellulose products, to name only a few, can be inspected for texture and quality or for the presence of flaws or impurities by this same phenomenon of fluorescence.

It is also used for detecting forgeries in bank notes and rare foreign stamps.

The X-ray tube has many functions other than medical. The homogeneity of plastic mouldings, the detection of flaws and blow-holes in castings and of foreign bodies in foodstuffs are applications in common usage.

X-ray diffraction has done much to assist chemical and metallurgical research and analysis. The electron microscope, which is a very special form of cathode ray tube, is opening up entirely new possibilities of research and development in these same fields.

The application of electronics to industry is not, however, limited to quantity control and inspection, although that field offers great scope. Radio heating, for example, has opened up entirely new possibilities in the manufacture of such diverse articles as plywoods and plastics, and in the hardening of machine tools and gears.

Electronic heating, unlike any other form of heating, does not depend upon conduction to transmit heat through a body but produces such heat by agitation of the molecular structure of that body. Temperature, area of heating, uniformity of heating and depth of penetration are all under complete control.

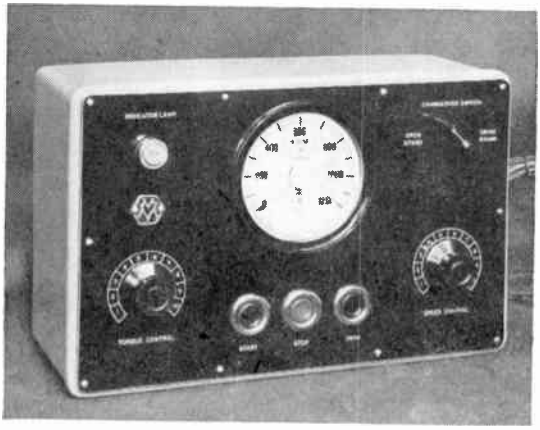
Now from this very broad outline of the applications of electronics to industry, you will appreciate that no man can possibly hope to put himself forward as an expert in all these branches, and although any one engineer may have and, in fact, should have, a general picture of what has been done and what can be done, he will, of necessity, tend to specialize on a particular group of electronic devices, although, of course, any one device may have applications to many industries.

For the next contribution the chairman called on **Mr. S. A. Ghalib.**

Machine Tool Drives

For various types of machining operations wide range of speed control is required. Probably the most extensive use of electronic control is in this field.

Almost invariably armature control is used, but in some special cases field control is employed. For the range of motors, ¼ h.p. to 25 h.p. thyratrons or small mercury arc rectifiers provide the necessary power. Electronic control of the "grids" gives infinitely variable speed control often referred to as "stepless control" from creep speeds up to the maximum speed. The speed can be preset and maintained constant against variations in the supply voltage and loading.



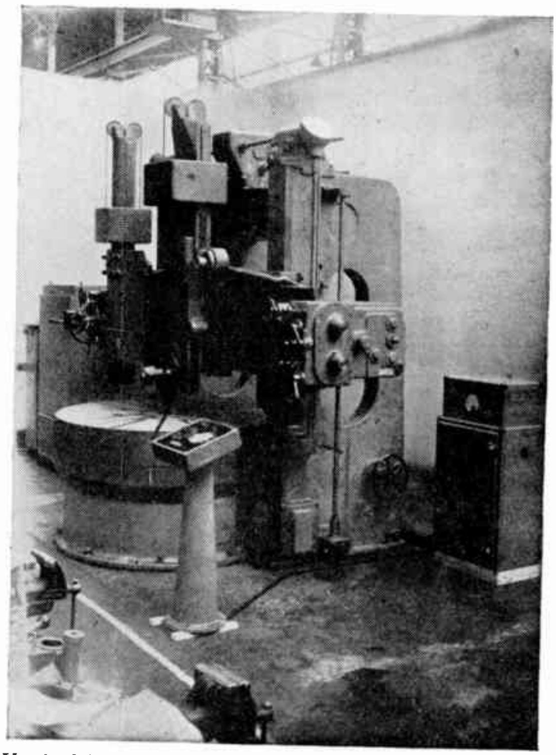
A typical control station including adjustment of motor torque.

A current limiting device prevents the motor from being overloaded above a predetermined value under all conditions of starting and running. On lathes where it is desired to maintain a constant cutting speed, a potentiometer is driven by the feed screw, so that the position of the potentiometer arm corresponds to the position of the cutting head, and therefore to the instantaneous cutting radius. The output of the potentiometer is arranged to be inversely proportional to the radius. As the speed of the motor has to be varied inversely as the radius in order to maintain constant cutting speed, the output of the potentiometer is fed into the amplifier and controls the speed of the motor directly. The potentiometer is driven through a slipping clutch and is fitted with a knob and dial graduated in inches of radius. When the job is first set up, the potentiometer is adjusted to correspond to the initial cutting radius. The

A typical control station.

operation thereafter is entirely automatic. In order to prevent the motor speed from exceeding the maximum designed figure when the cutting radius is reduced to a small value, the clutch is arranged to slip below a predetermined radius.

A few words on the rating of electrical apparatus may not be out of place at this point. Motors and electronic power units, such as thyratrons and mercury arc rectifiers, are rated to carry a certain current continuously. The torque of a shunt motor is proportional to the armature current. It follows, therefore, that shunt motors are rated at a certain torque, which fixes the frame size. The h.p. delivered then depends entirely on the speed. If constant h.p. is required over wide speed range, then the motor frame size is fixed by the minimum speed. This motor would of course be capable of delivering many times the h.p. required, at the maximum speed. The practical meaning of this,



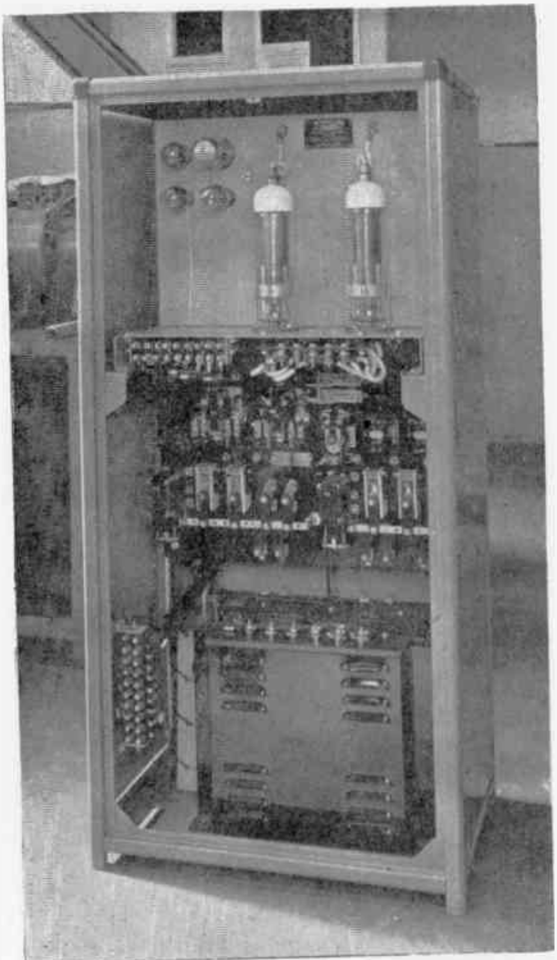
Vertical boring mill with constant cutting speed device.

is that the size of the motor and the power unit is large for apparently small h.p.

Ideally, constant h.p. should be obtained by a variable gear ratio and a constant speed motor. In practice, the best compromise is to use a number of pre-selective gear ratios, and a limited range of speed control.

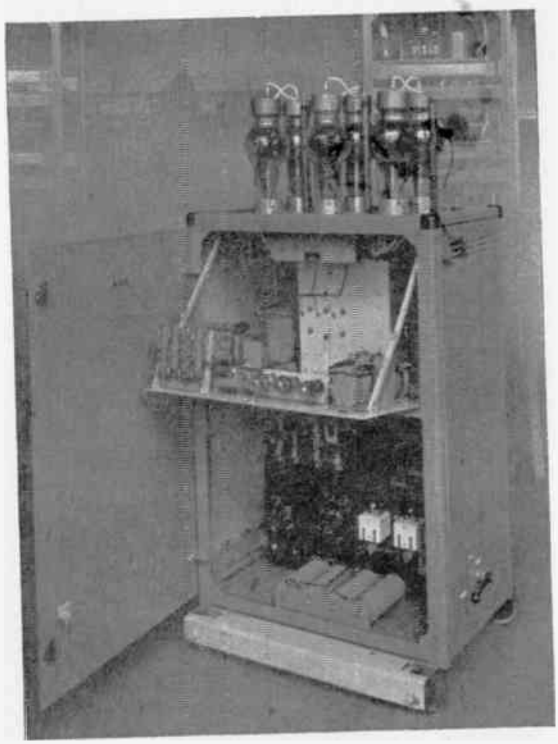
Copying Attachment for Lathes (Profile Cutter)

Automatic machining of even the most complicated profiles can be carried out by fitting two motors to control the longitudinal and crosswise motions. An electromagnetic "head" with a stylus is rigidly connected to the cross



Typical control cubicle for 3 h.p. motor.

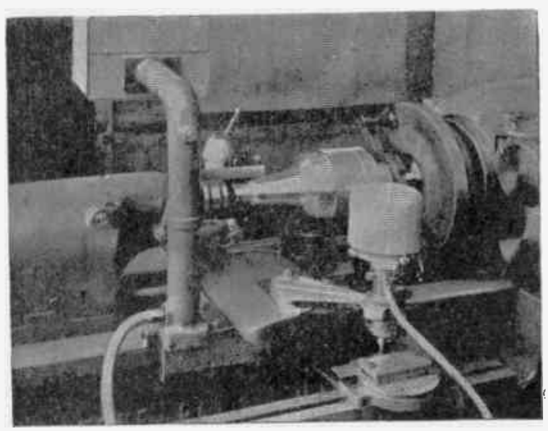
slide of the saddle. The "head" has two electromagnetic displacement sensitive devices, effectively at right angles and parallel to the motions of the tool carriage. The operation of the stylus alters the inductance of each electromagnetic device by an amount proportional to its resolved movement, in that plane. A template of the section to be machined is fixed in a position so that the stylus can be in contact



Typical control cubicle for 25 h.p. motor, top cover removed to show thyratrons and amplifier panel hinged out.

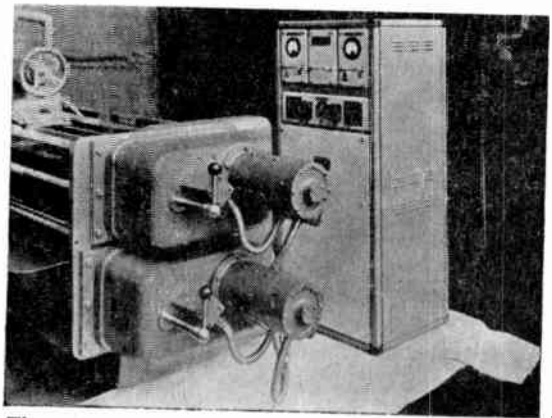
with it during the machining operation. The motors are fitted with split field windings and are controlled by "hard" valves.

Normally, when the stylus is not deflected, the motors are stationary. To commence the operation, voltages are applied to the two



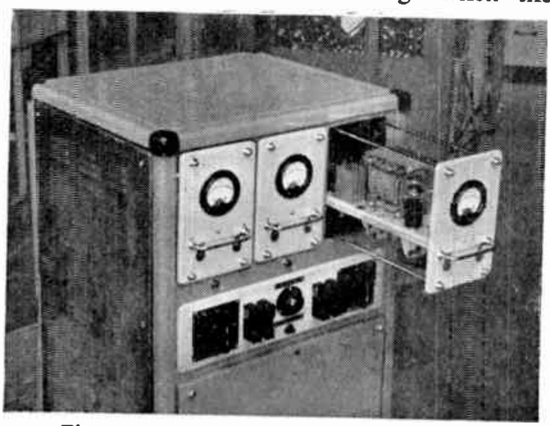
Lathe fitted with two-motion automatic copying attachment.

amplifiers. The motors then run at speeds proportional to the respective bias voltages. This is ensured by fitting tacho-generators to the motors, and by feeding the generator voltage into the amplifier, in opposition to the bias voltage. The motors therefore run up to the



The motor and gear box and the electronic cubicle for two-motion copying attachment.

speed at which the tacho-generator voltage is very nearly equal to the bias voltage. The stylus then runs into the template in a direction determined by the ratio of the bias voltages, until it is deflected sufficiently to produce a voltage equal to the bias voltage when the



Electronic cubicle showing amplifier chassis.

corresponding motor comes to rest. If the shape of the template at the point at which the stylus runs into it is at right angles to the direction of motion, then the deflection of the stylus, resolved into the planes of motion, will simultaneously wipe out the two bias voltages, and both motors would come to rest. This condition must be avoided, by setting the ratio of the bias voltages and hence the direction of initial motion, in such a way as to ensure movement of the stylus along the profile of the template. Unless the equipment is fitted with fully automatic control, the bias voltages have to be adjusted manually wherever there is a sharp change in the curvature of the template. Automatic biasing is obtained from the ratio of the two signals from the " head." This ratio is a measure of the slope of the template at the point of contact with the stylus, and is converted into two bias voltages which are automatically added to the preset voltages in the two motions.

As the cutting tool is rigidly fixed in relation to the follower head it reproduces the profile of the template, and the accuracy obtained in practice is well within ·001 in. By fitting a potentiometer to the crosswise movement of the tool carriage, a voltage proportional to the cutting radius can be obtained. This voltage can then be used to obtain constant cutting speed by controlling the speed of the main work head motor.

The Chairman then called on **Mr. J. A. Sargrove** :

In the opening remarks, Mr. Langham Thompson made the point that electronics embraces too wide a field for one engineer to become a specialist in all phases of the art. Consequently it will be found that some specialize in the communication applications, others in electro-medical appliances, motor control metallurgical equipment, instrumentation, and so on.

Sargrove Electronics Ltd. operate in quite a narrow segment of the electronic field and we are interested in industrial control problems, which can be summarized under the four broad headings :—

(*a*) Process control.
(*b*) Quality maintenance.
(*c*) High-speed automatic gauging and testing.
(*d*) High-speed counting and batching.

Process controls cover devices for the perception of the article, control of the process by information fed into the unit by the perception units, and actuation by electrical, mechanical, pneumatic or hydraulic means.

Perception may be achieved by means of

(*a*) a photo-cell for sensing the objects or even gases by their physical presence, by their colour, or by their heat ;

(*b*) a chemical reactor may replace the photo-cell for many problems, as for instance, where the device has to be humidity conscious, or where a chemical condition is required to initiate the process ;

(*c*) a thermal device for application where temperature is an important factor ;

(*d*) a radio frequency field is widely used when the objects being controlled can be monitored by the changes they cause to a mean capacitance ;

(*e*) a microphone diaphragm, for applications where sound or pressure are reliable means of perception ;

(*f*) the simplest "perceptor," a plain electrical contact, which is to be preferred where the objects have sufficient mass and where the desired speed of operation is comparatively low.

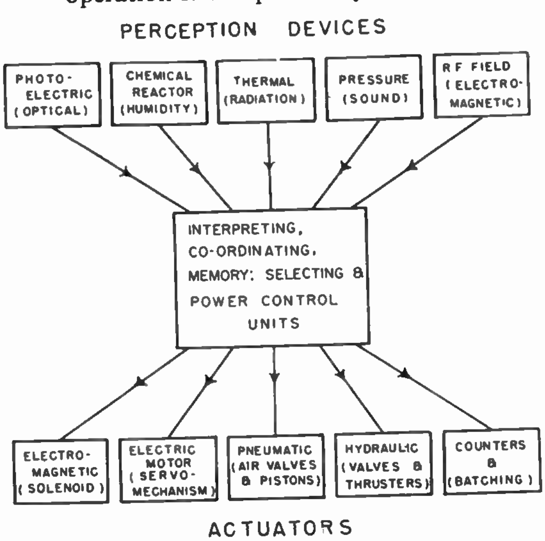


Fig. 1. Basic conception of electronic process control.

Control units are designed to take signals from one or more of these perception heads, co-ordinate all the information and control the processes in the correct sequence, by energizing the means of actuation.

Actuation of the process can be by any desired method. The control unit can be designed to operate electrical, mechanical, hydraulic or pneumatic devices, gas valves or fuel supplies.

Figure 2 is a diagrammatic representation of a

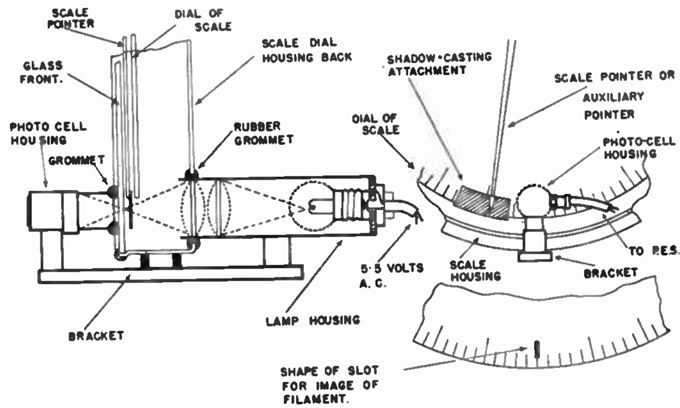


Fig. 2. Simple photo-electric automatic weighing control.

single perception unit, in this case a barrier layer cell with a light source and optical system, applied to a scale mechanism for an automatic weighing operation. Here the lenses cause the

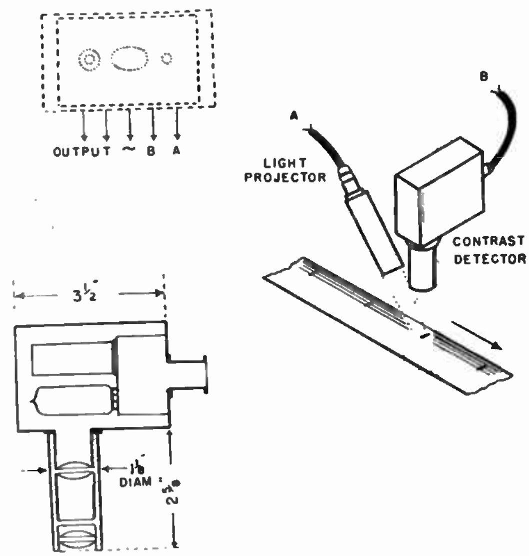


Fig. 3. Contrast detector used for printing registration.

light beam to cross over, and at this point a mask with a very narrow aperture is inserted. Beyond the mask, the light beam broadens out and

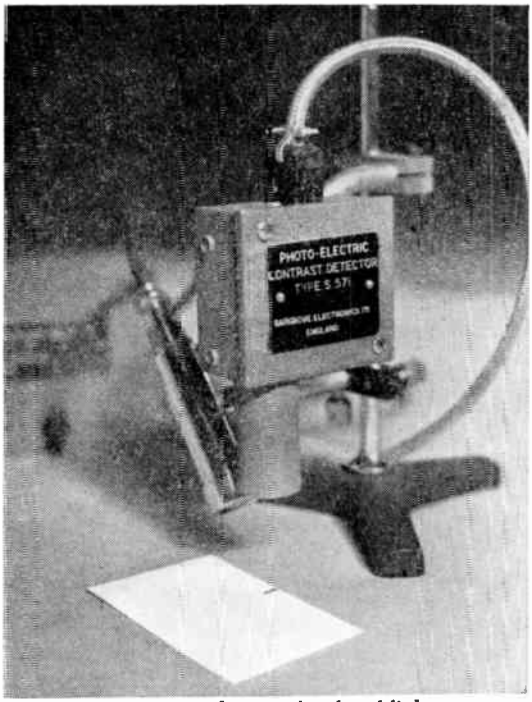


Fig. 4. Contrast detector head and light source.

covers the active area of the cell. A shutter is fixed on the scale needle to block the light beam when the weight of the materials being handled reaches the preselected value, and the hopper or other methods of filling the sacks or containers is shut off. Such a device is used for filling bags

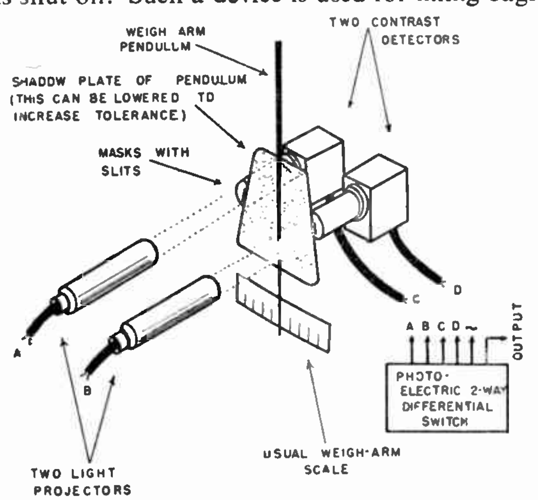


Fig. 5. Photo-electric overload and underload weigh arm control used on ore conveyor.

of grain, flour or cement, or filling oil drums by weight.

Figure 3 shows diagrammatically a contrast detector head, which contains its own optical system, masks and filters, emissure photo-electric cell, and head amplifier which makes it possible to use the device at some distance from the control unit. The light source is mounted alongside the detector head, and in the example depicted the cell is operating off register marks on a paper strip. This arrangement has wide applications in industry for registration in printing, packing, folding and wrapping machines, for indexing in colour printing on paper or fabric, or perceiving, inspecting and counting small objects at high speed.

Figure 4 shows an actual contact detector head which measures only $1\frac{1}{2}$ in $\times$ $2\frac{1}{2}$ in $\times$ $3\frac{1}{2}$ in,

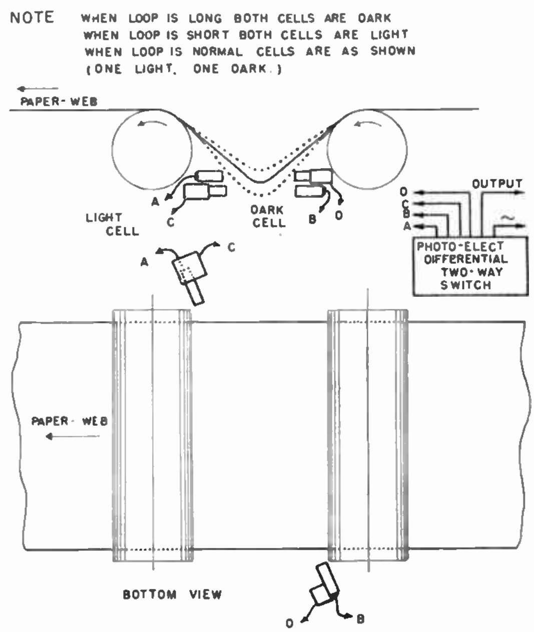


Fig. 6. Paper loop slack plus or minus control.

which permits the device to be fitted into a machine where space is limited.

Figure 5 demonstrates a method of using two perception units for a weigh-arm application, where it might be desirable to maintain the flow of coal, ore, and other minerals on a moving conveyor belt. Here, the weigh-arm pendulum has a shadow plate which blocks either one cell or the other, and operates a reversing electric motor, clutches, or solenoids, as desired. The working tolerance is adjusted by altering the position of the shadow plate up or down on the weigh-arm pendulum.

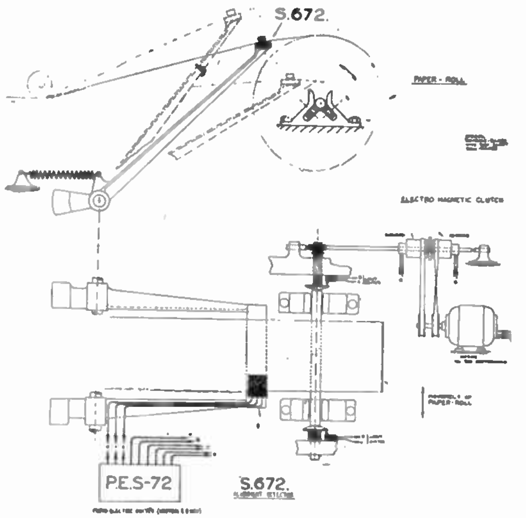


Fig. 7a. Paper edge alignment.

Figure 6.—This double perception unit has very many applications, notably, maintaining loops of paper or fabric where it is desirable to remove tension from a web in printing, indexing or collating in multiple processes.

Figure 7.—Double perception units are used here to control and maintain the lateral position of a moving web of paper or fabric. When conditions are correct, one cell is in darkness and the other in light. Deviations of just a few thousandths of an inch are sufficient to actuate the means of correction, which may be electrical or pneumatic. This diagram shows a continuously running correction motor, and the

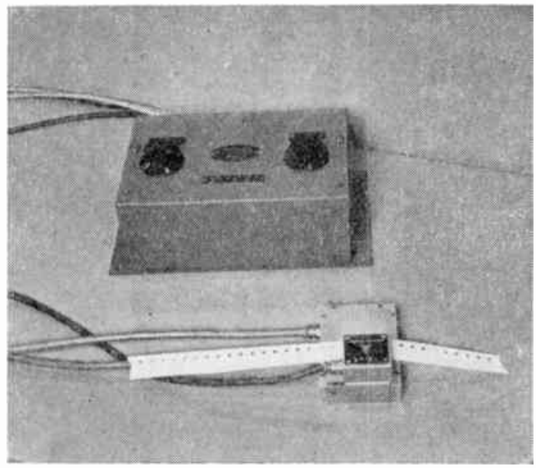


Fig. 7b. Small unit is the head to be mounted in machine: main unit on adjacent wall.

photo-cell systems controlling clutches to move a paper roll in the direction necessary to maintain the position of the web.

Figure 8 shows an equipment which does not contain a valve at all, but is nevertheless electronic since barrier layer photo-cells are employed in this thread monitor. The problem here

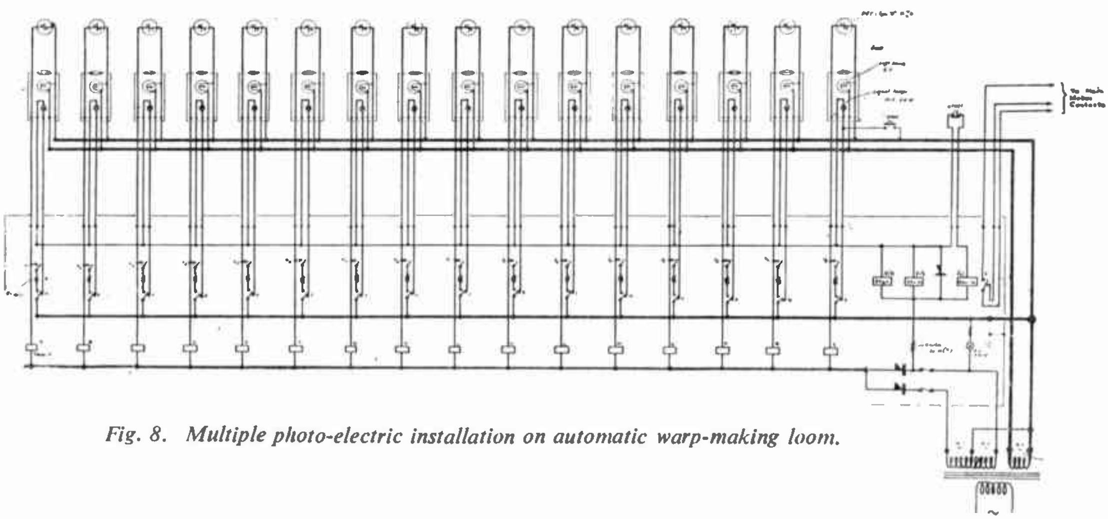


Fig. 8. Multiple photo-electric installation on automatic warp-making loom.

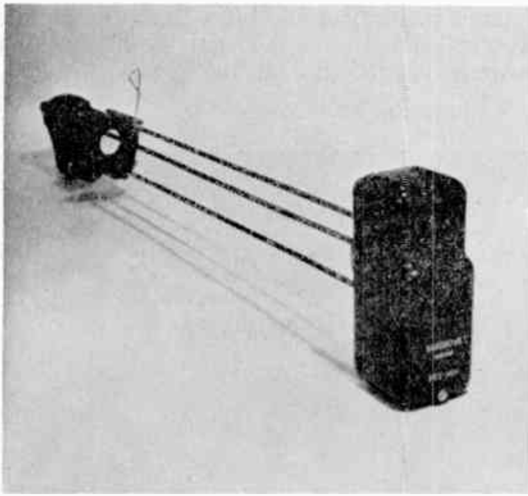


Fig. 9. One photo-electric element of loom, comprising photo-cell, shutter, projector and signal. (Up to 100 shutters can be mounted on one unit.)

was to monitor 2,000 threads in a loom. This was achieved by arranging for a very light flag to interrupt a light beam when a thread broke ; for convenience sake, each unit monitors 50 threads simultaneously. When a thread breaks, the loom shuts down and a visual warning lamp indicates in which block the break has occurred. The " flags " are made so very light that this method of monitoring can be used on the finer threads where electrical methods cannot be employed without danger of the purely electrical device itself breaking the threads.

Figure 9 shows the layout of just one thread monitor unit, with one flag attachment in position. The box houses the cell, relay and warning lamp, the light source being fitted at the far end.

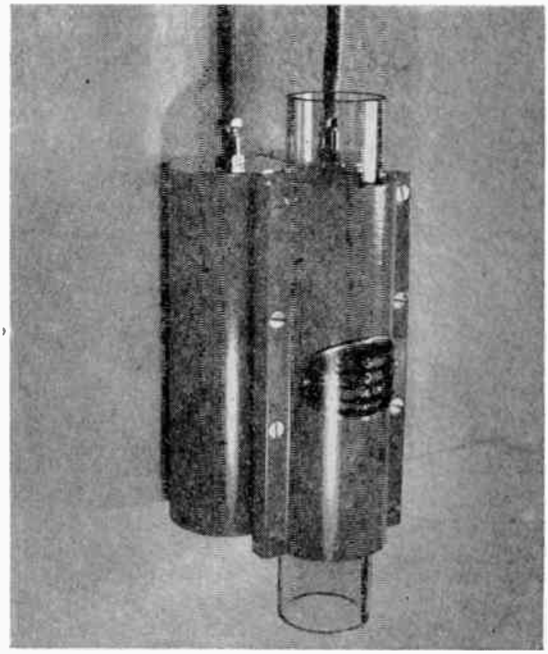


Fig. 11. Nephoscope—Turbidity monitor.

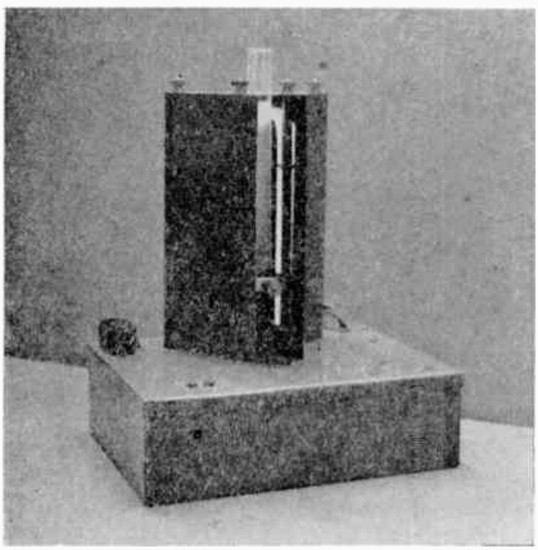


Fig. 10. Laboratory precipitation monitor.

Figure 10 is a photograph of a laboratory model precipitation monitor. This device can be preset to give warning, either audible or visual, when precipitation, or the reverse, occurs. Alternatively, it can operate an electrical device, timer or recording meter.

Figure 11.—Nephoscope ; turbidity monitor. In very many industrial processes, changes in liquids from a clear to a turbid state, or the reverse action, have to be very carefully watched and controlled to ensure a satisfactory result in the particular production process. For instance, in a filtration process the forerunnings are usually cloudy and gradually become clear. The instrument shown can be used either to indicate when this state is reached, or to operate an electrically actuated valve to divert this clear filtrate to its proper receiving tank. No personal

judgment is necessary to decide when a satisfactory degree of clarity is achieved, and processes can be repeated with a very much greater uniformity in the ultimate results. Conversely, it is of the greatest assistance to know as soon as possible when a clear filtrate begins to become cloudy for any reason, for example, when a filter paper breaks. The Nephoscope can prevent the accidental admission of cloudy filtrate which could easily ruin a very large bulk of clear filtrate.

There is a very large number of precipitation processes where it is useful to know if the pigment has settled satisfactorily, and how far down a closed or obscured tank this has occurred. In other processes in which two or more products are heated together until they change from a cloudy to a clear state, at which point the heat treatment is stopped, the Sargrove Nephoscope can be employed to control the heat treatment directly by constant reference to the state of turbidity and dispenses with the necessity for withdrawing samples at frequent intervals for visual examination. This positive means of monitoring and controlling a process by the incidence of turbidity, or the change to clear liquid, is a matter of the greatest importance to the chemical industry and in the preparation of food products, where mistakes can not only impair the quality of the finished product, but also add to the final cost by increasing the processing time and the power consumed during the process, or by the waste of raw materials if they are spoilt beyond recovery.

The instrument has also been specially designed to detect opalescence in a fluid and to operate the means of controlling a process to give immediate warning that a change has occurred, to actuate electrically the next operation, or to pass or reject the liquid from the system. There is a number of solvent power laboratory tests which are based upon the development of turbidity, now performed by crude visual methods, but which could be improved greatly by the introduction of this equipment. Further, this device might be applied to special forms of analytical technique.

The Nephoscope is basically a photo-electric switching device with an optical system specially developed to detect particles of solid matter suspended in a fluid.

The liquid to be controlled is passed through a large diameter glass tube about which the sensing head is mounted, and an intense light beam is directed through the liquid.

A photo-cell is so arranged that it responds to

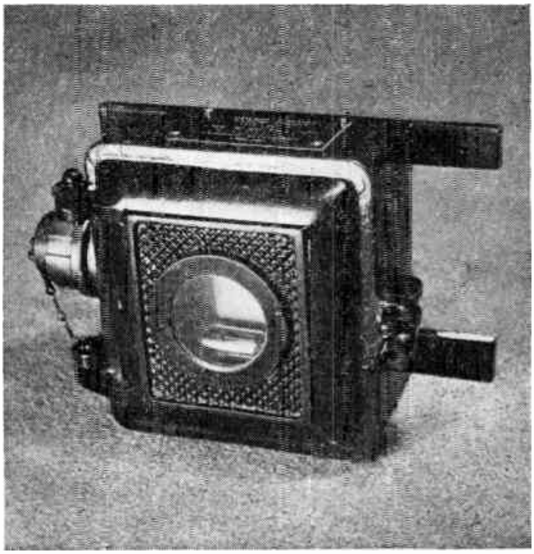


Fig. 12. Daylight monitor—automatic lighting switch.

the light scattered by any suspended particles of matter, and after amplification operates a switch controlling a circuit breaker, electric motor, or electrical actuator, such as a magnetic liquid breaker. Sensitivity is of such a high order that the apparatus will respond to a change from a clear state to a turbidity of one part in 100,000 by volume. The operating point is adjustable

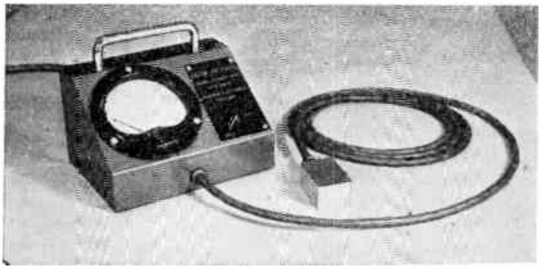


Fig. 13. Dermometer—skin thickness measuring device.

and can be preset to the desired degree. This unit can be mounted remote from the sensing head, provided that the distance is not excessive, for example, it may be fitted on an adjacent wall.

Figure 12.—The primary purpose of this device is the automatic control of street or factory lights. The unit is operated by failing or increasing light and can thus be used for switching on at dawn or dusk. The apparatus should be mounted outside buildings and in such a position that direct sunlight cannot fall on the photo-cell, that is to say, the window should face north for locations north of the Equator. A sensitivity control under the lid varies the lower and higher light levels at which the unit operates and a deliberate delay of 15 seconds has been arranged as a safeguard against false operation.

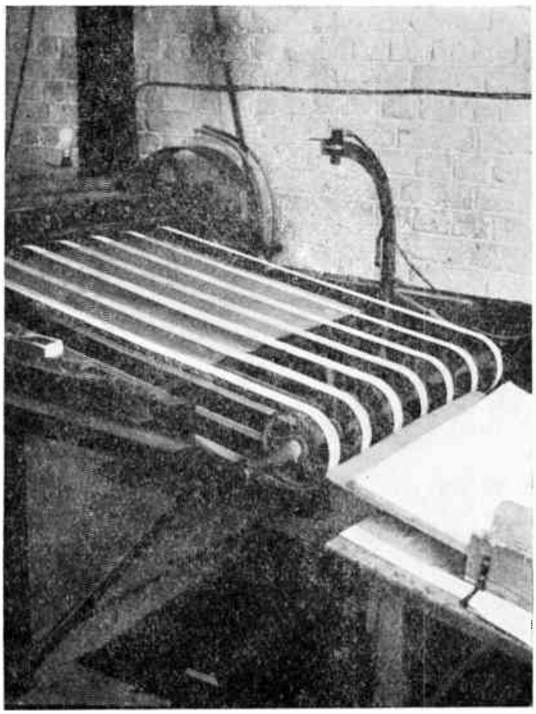


Fig. 14. Photo-electric paper guillotine.

Figure 13.—This is a type of apparatus for measuring the thickness of paint or enamel on sheet metal. The sensing head is an electro-magnetic device and the thickness of the film can be read off directly in thousandths of an inch.

Figure 14 shows a photo-electric device in use controlling a guillotine for continuously cutting off paper to exact lengths.

Fig. 15 is an electronically controlled guillotine, parting fabic labels from the roll by reference to a mark printed into the design on the label.

Figure 16 is another simple application of photo-electronics, in this case counting magazines by reference to the actual magazines being delivered from the machines and not by counting revolutions of a roller which would count in the absence of paper.

Process controls include maintaining the correct conditions to ensure a satisfactory result, which may involve temperature control, humidity control, machine or tool speed, gas or liquid pressures, or the correct supply of ingredients in the correct proportions for a given process. It is a principle in the design of equipment to ensure that all process control units not only give warning when all the conditions for a satisfactory result are not present, or when there is

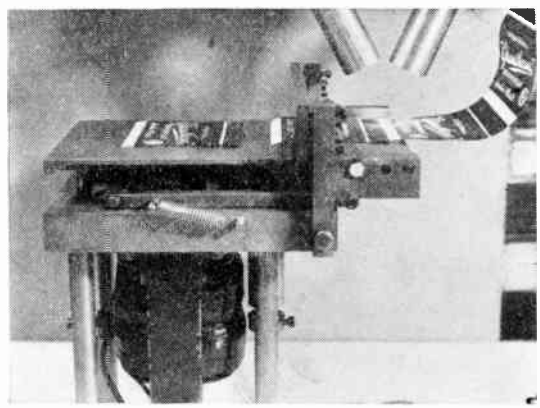


Fig. 15. Photo-electric register operated guillotine for cutting fabric.

a departure from the preset standards, but also if the electronic devices themselves develop a fault. In this manner electronic controls also monitor themselves.

An example of increased output together with a reduction in scrap is typified by a complete electronically controlled automatic unit being developed for cutting off extruded plastic rods from multiple extrusion heads and counting the total output delivered. When these rods are cut normally, it has been found that, for a variety of reasons, diameters of the extruded plastic in its uncured state are distorted, lengths vary widely and much time and material is wasted when the finished product has to be ground down to a lower standard size.

The completed outfit will have an automatic " dose-ing " device to maintain the correct level of material in the hoppers, and will include temperature control of the extrusion heads. The extruded uncured rods will be conveyed on a continuous belt in water, the rods measured individually and cut off to a precise length, and the total number of rods cut off will be continuously displayed. It is anticipated that the saving in material, on the basis of scrap now produced by manual labour, will pay for the development and construction of the complete installation in less than a year.

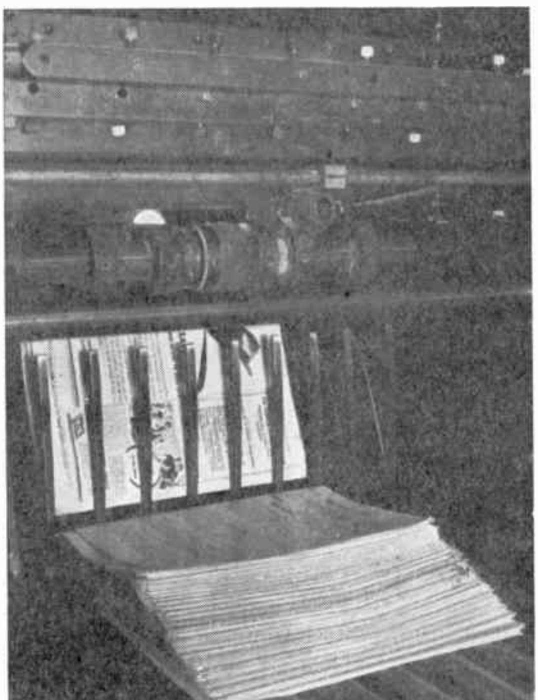


Fig. 16. Counting printed matter photo-electrically by perception of actual product.

The next example is one where electronics has been successful in carrying out an operation which was impracticable by purely mechanical means.

The problem was to cut a continuous strip of pastry into equal strips as it emerged from an automatic bakery. The complication was that

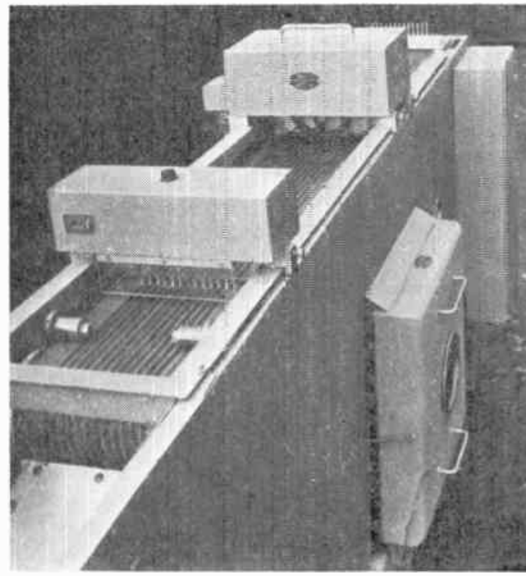


Fig. 17. Electronically operated guillotines on multiple extrusion of plastics.

the speed at which the pastry travelled varied considerably and was dependent upon many random factors, such as ambient conditions, oven temperatures, ingredients and so on.

For this purpose an electronically controlled web severing device has been developed and constructed, the speed of operation being governed by the actual speed of the web. In fact, the operation depends upon the presence of the pastry, and the undamaged condition of the web. In this case, a considerable saving in

Fig. 18. Electronically operated web severing machine mounted on band conveyor.

actual labour has been achieved, and the installations will have paid for themselves on this basis within a short period of time.

The purely mechanical automatic plant has achieved such a high rate of perfection that such items as screws, nuts, ball bearings and so on can be produced at a rate that outstrips inspection, testing, counting and batching operations. Labour taken up on these operations is often very much greater than that expended on the actual production of the article. Further, the automatic machine alone continues at its high rate of output, whether it is turning out a satisfactory job or whether it is producing scrap.

The human agency is still too largely employed simply to watch that conditions remain correct and that limits are being maintained. Too often much time has elapsed before the fault comes to light, during which time the good articles have been contaminated with some faulty ones, and these must be laboriously and expensively removed. Electronics offer a means of continuous high-speed automatic inspecting, counting, gauging and batching with a capacity to match the most prolific automatic machine. Such electronic inspection devices continuously monitor the operation of the machine by reference to the article being processed at each stage of manufacture, give warning at the instant of any departure from pre-selected standards, and stop the machine until the fault is rectified. These devices look at each individual item, prevent the machine from continuing to make scrap and prevent the contamination of good articles.

Magnetic counters have long been used, but for many applications they are unreliable at anything but slow speed and the numbered wheels are difficult to read. Very high-speed electronic counters exist for laboratory work and are now extensively used for particle counting in atomic research. These equipments are too complex for industrial use and usually the information is displayed in the complicated binary system.

Another example is an industrial electronic counting-batching equipment, simplified in design and robust in construction, and displaying the information in the decimal system or in dozens and grosses. This high-speed counting and batching equipment can handle, with unerring precision, thousands of items per minute and, for all practical purposes, the speed of operation is limited only by the speed at which the articles can be fed in, or by the speed at which the gate separating the batches can be moved. Clearly this equipment can make inroads into non-productive labour now engaged upon these operations, and carry out the work with an accuracy and persistence impossible by any other means.

Equipment is also available for the control of machine tools ; safety devices for large drop hammers ; shuttle monitors not only inspecting the shuttle after each excursion but also anticipating the thread running out ; flame control in metallizing processes ; paper or cloth web control to limits within $\pm 0{\cdot}5$ mm.

These examples taken at random will serve to illustrate the versatility of electronics. Without electronic control the productivity of an automatic machine or plant is limited by all the well-known shortcomings of human control necessary to co-ordinate the feed of material, monitor the process, maintain quality and inspect the output. These limitations can be removed by the applications of electronics, which is a new and flexible tool in the hands of the production engineer. Many devices exist which can be fitted as an adjunct to existing plant and machinery but, undoubtedly, the optimum benefit will be attained when the electronic and mechanical engineer co-operate to produce a production unit with " built-in consciousness " capable of continuous operation to the full capacity of the mechanical components.

Further contributions :

At the invitation of the Chairman, **Dr. H. A. Thomas,** of the National Physical Laboratory, referred to his wide experience in stimulating wider interest in electronic technique by his visits to factories throughout the country and by his lectures on the subject.

Dr. Thomas stated that one of the commonest criticisms encountered was that the practical man had little confidence in electronic equipment because it contained valves, which were not, it was alleged, robust and reliable. A few examples would disprove that view.

First of all, there was the mass of evidence collected during the war of radio equipment of every possible type, which successfully withstood the most appalling conditions, and rarely gave trouble. There were now submarine repeaters under the ocean, complete with valves in the electronic equipment, which had to stay under the sea for years.

During the war hundreds of radio-sounding balloons containing valves were launched. On many occasions the equipment had failed, and the apparatus had fallen from heights of 2,000 to 3,000 feet, it being necessary later to dig it out of the ground: although most of the coils, condensers and switches were compressed, the valves were rarely, if ever, broken.

Another point of criticism from production engineers was that the equipment looked like a wireless set. This was often due to poor engineering technique, and every effort should be made to get away from a mass of soldered connections, which were always a source of weakness.

It was essential that those who were going actively into the electronic field should have a sound engineering and scientific training. There were far too many enthusiasts who knew something about radio and who took the view that this automatically enabled them to become good electronic engineers. It did not.

It was most important to realize that there was no point in performing some function electronically if it could be done as well by other means, and Dr. Thomas illustrated this by several examples.

In his opinion, the best way of furthering the cause of electronics was, first of all, by using electronics only when there was no alternative method available, or by proving that the electronic method was the better one. Secondly, sound engineering principles should always be adopted, and finally electronic devices should not be pushed unnecessarily in fields in which their applicability was a little dubious. There were so many thousands of problems where there was no better alternative than an electronic aid and where this new branch of science could achieve great results.

Professor H. F. Trewman: Production engineers had a lot of problems, of which they might or might not be conscious, and the electronic engineers perhaps had the solution to those problems—if only they knew what they were. The problem seemed to be how was the electronic engineer to be made aware of industry's methods, e.g. the sequence timing of spot welding machines?

Secondly, the development of any solution to a problem was going to involve development charges, and production engineers knew only too well that those costs were liable to be very heavy indeed. Therefore, it did appear to indicate the advisability of holding joint meetings such as the one being held that evening. He ventured to suggest, therefore, that perhaps every two months the authorities interested in production engineering, as such, and the authorities interested in electronic engineering, as such, might get together and exchange their ideas. Even if it were a matter of pooling financial resources in order to get results, it would be an end which would ultimately benefit everybody.

Mr. Elliot: It would appear that electronics had a particular use in connection with the problem of following a complicated profile in turning, but the problem which many production engineers came up against concerned the turning of a small simple profile with a number of pieces of several diameters. A device was being used in which the information was compiled in the form of punch cards. They gave several diameters, the lengths over which they were held and the number of cuts and the depth. It would be interesting to know whether such equipment had been developed in this country.

Mr. S. A. Ghalib: He did not think he could answer the question because he did not know of such equipment. Two-motion control was rather a special case, and in 85 per cent to 90 per cent of the cases a single-motion control met all the requirements.

Mr. Munro: Could Mr. Thompson elaborate a little on the methods of measuring loads in fine threads? He did mention it earlier, but the speaker did not gather whether it was in connection with strain gauges.

Mr. J. L. Thompson: The measurement was effected by means of a strain gauge torque meter whereby a very sensitive cantilever was arranged. If a cantilever were mounted together with fixed strain gauges, and if the end of the cantilever were used as one of the thread guides, then any strain coming back on the thread would deflect the cantilever and it would be made extremely sensitive. The restraint exercised by the cantilever could be reduced to the order of a few milligrammes if necessary.

Mr. Gravitt : How did the power factor of an A.C. mercury rectifier or thyratron compare with that provided by an induction motor?

Mr. S. A. Ghalib : The power factor was really a function of the speed. At the top speed the thyratron or mercury rectifier was fired fairly early in the cycle, and the power factor was very good—probably of the order of 0·9. At lower speeds, however, the power factor fell to something of the order of ½. If the power factor were important, then the solution was to use a tap on the transformer so that even at the lower voltages the rectifiers fired early in the cycle.

Mr. F. W. Atkin : During the war he was responsible for the maintenance of a lot of radio equipment. It was not industrial equipment, but it still used valves. One lot of large valves of 250 watts after being in use for 18,000 hours had been tested and found to be satisfactory; they had then been placed back in use for three years in apparatus which, in some cases, was working 24 hours a day. There were also many smaller valves in the equipment, and they had lives, running 24 hours a day, of four years. Even then, on testing, they were found still to be within the manufacturer's tolerance ; in other words, they would have passed as new valves.

With regard to the rating of valves, in his view electronic engineers very often tended to take the manufacturer's rating of a valve and work right up to it. That was definitely a mistake in electronic equipment where reliability was essential.

Mr. J. L. Thompson : With wartime equipment it was a case of do something and do it quickly. Equipment was made to work for a limited period, and many sets of equipment costing hundreds of pounds had to fulfil a specific function and then finish. Scrap did not matter ; life did not matter. The problem was to get it done and done quickly. Of course, industrial equipments were different. No industrial equipment should be engineered in a hurry.

He thought one could say that all the valves which were in use were running well within their ratings ; in fact, far below their ratings. Another point was that it was not a case simply of taking hold of any old valve and checking it. Each valve was given the same check and that check was made after a number of valves had had a test run for about 100 hours. At the end of that time, any valves which were likely to give trouble would show up, and the number was usually very small.

Mr. J. A. Sargrove : In his experience, with any equipment using many valves it was advisable to have such equipment designed with two power switches, one for H.T. equipment and the other for filaments. If the filaments on valves could be left alight day and night, the valves would last much longer than if the equipment were left off. Tungsten, which was used for heaters of cathodes, crystallized into peculiar shapes and at a certain temperature it would maintain a given geometrical form.

Another point which members of the Post Office engineering branch had discovered was that with equipment using many valves, when they reached a life of 10,000 to 15,000 hours one valve failed, it was advisable to change all the valves, because in that way failures occurring at random intervals could be avoided.

Mr. H. J. Tyrell-Gramann : Electronic equipment might work satisfactorily for several years and then break down through a perfectly normal fault. Since servicing or repairing might cause dissatisfaction, the merits of unit production should be borne in mind. The exchange of units enabled faulty equipment to be replaced without the delay caused by servicing.

In heavy engineering the cause of a breakdown was usually immediately apparent ; in electronic equipment it was frequently not visible, which sometimes led to suspicion of the apparatus. Splitting up the apparatus into easily replaceable units would do much to dispel the suspicion when breakdown did occur.

Breakdowns were frequently caused by the failure of the connection between the apparatus and the power supply. The only satisfactory solution was to fit tough cables connected by some form of armoured plug.

Mr. J. E. Hill, Chairman of the Council of the Institution of Production Engineers, moved the vote of thanks to the speakers, which was received with acclamation.

NOTICES

Obituary

Council regrets to record the death, after a lengthy illness, of Mr. Kenneth Stanley Marsh, of Southport, Lancashire.

As a Registered Student of the Institution, Mr. Marsh was successful in the 1938 Graduateship Examination, and in October 1939 qualified for transfer to Associate Membership. The whole of his professional life was spent in Liverpool and Lancashire. He was only 40 years of age when he died and he leaves a widow and two children.

A domestic accident caused the death of Major Ernest Hargreaves (Associate Member) whilst serving with the Intelligence Branch of the Army of Occupation in Germany.

Major Hargreaves was elected an Associate Member in 1944 and entered the Army immediately after leaving school. He was only 38 years of age and leaves a widow and three children to whom Council has expressed sympathy.

Edison Swan Electric Company, Limited.

Mr. T. Hands, O.B.E., formerly General Manager—Valves, has been appointed Director of Manufacture of the Edison Swan Electric Company, Ltd. Mr. E. Yeoman Robinson has been appointed Chief Engineer and Manager—Valves.

Errata

The following corrections should be added to the paper "**The Co-ordination of Circuit Requirements, Valve Characteristics and Electrode Design,**" by **I. A. Harris (A.M.)** (No. 4, Vol IX, April, 1949) :—

Eqn. (11b), right hand side. For ρ read ρ^2.

Eqn. (40). The third factor of the second term should be inverted.

Page 135, following Fig. 10. For $<$ read $>$.

Page 139. The index of c should be positive in eqn. (51a) and negative in eqn. (52b).

Page 141. Ref. 6. For L. A. Moxan read L. A. Moxon.

Ref. 13. For 1949 read 1939. Ref. 14. For 1932 read 1923.

In addition the following diagrams were omitted :—

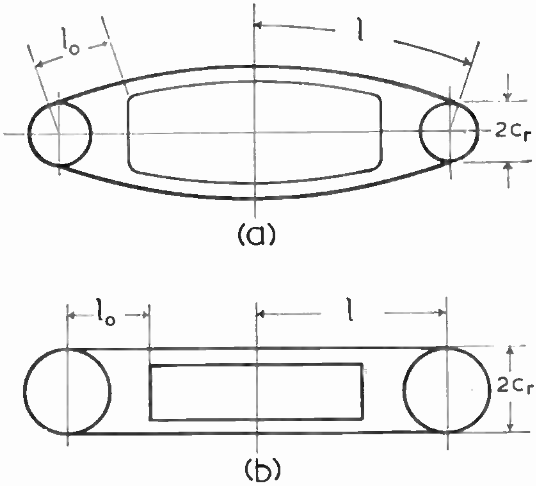


Fig. 11.—Parameters of the cathode-grid structure.

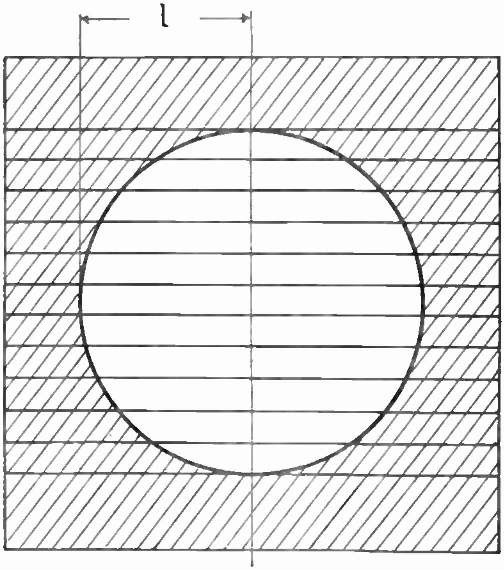


Fig. 12.—Grid structure of disc-seal valve.

Climatic and Durability Tests for Radio Components

A specification describing the general conditions and procedure for durability testing of components for electronic equipment has been drawn up by the Technical Specification Committee of the Radio Industry Council. The specification, No. RIC/11, covers approximately the same ground as the Inter-Services specification No. RC.S/11 : it is a private specification, published for the use of the radio industry, and has not yet reached the stage of consideration by the British Standards Institution.

Copies of the specification, price 1s., can be obtained from the Radio Industry Council, 59 Russell Square, London, W.C.1.

Mond Nickel Fellowships Committee

The Mond Nickel Fellowships Committee invites applications for five Fellowships of £750 tenable for one year. These fellowships are primarily intended to enable those with University degrees engaged on metallurgy to obtain further training in the subject. They are also designed to attract persons qualified in other sciences into the field of metallurgy, in order to alleviate the shortage of qualified metallurgists available to industry.

Full particulars may be obtained from The Secretary, Mond Nickel Fellowships Committee, 4 Grosvenor Gardens, London, S.W.1.

Physical Society Exhibition

The Physical Society's 33rd Annual Exhibition of Instruments and Apparatus was held from April 5th to 9th at Imperial College, South Kensington. This exhibition has now established itself as an annual landmark, and the 140 stands contained a wealth of ingenuity and experience.

The exhibition covered a wide field, including every branch of physics in its scope, but the importance of electronics in it was outstanding. Besides numerous exhibits of electronic measuring instruments, many applications of electronics in other branches of science were in evidence, showing the ever-increasing importance of this subject in science and industry.

1948 Indexes

There is a shortage of 1948 indexes at the Institution. We shall therefore be grateful if anyone who has no further use for his copy will kindly return it. It will be of great value in making up bound volumes.

New Equipment for B.B.C. Television Service

In accordance with the policy of the B.B.C. the television service is being re-equipped with post-war apparatus as the equipment becomes available.

On May 2nd, two new equipments for televising films were used for the first time. One set was manufactured by Cinema Television, Ltd., and the other by E.M.I., Ltd.

On April 30th, one of the television cameras used at the Cup Final was fitted with a Zoom lens. This enables the camera to choose any part of the scene and gradually magnify it to obtain a closeup view. To the viewer it appears as if the camera is moving towards the scene.

This particular lens was invented by H. Hopkins, B.Sc., Ph.D. Although lenses have been made and used before in America and England, this lens works on an entirely different principle and is more optically efficient.

Naval Short Service Commissions

It has been recently announced by the Admiralty that short service commissions are now being offered in the Navy's electrical branch which has been previously restricted to R.N.V.R. officers.

Candidates must have a degree or diploma in electrical engineering or science or be Graduate Members of the Institution of Electrical Engineers, or of the British Institution of Radio Engineers, or have passed examinations recognized by these bodies as qualification for Graduate Membership.

Further details are available from The Director, Naval Electrical Department, Admiralty, Queen Anne's Mansions, S.W.1.

Publishers Request

Pitman and Sons are proposing to commission two new text books for which authors are required.

The first will cover the whole field of telecommunications and will be divided into a number of sections. Authors are required for two of these which deal with :—

(1) Dry battery design and applications.

(2) Transformer and coil design for radio equipment

The second book will cover the syllabus of the new City and Guilds Radio Amateur's Examination.

Any members who are interested are asked to communicate with the Librarian.

BOOK REVIEWS

Radio Fundamentals: Prof. A. L. Albert. McGraw-Hill Publishing Co. 1948. pp. 595 + vii. Price 27s.

The sequence of this book is arranged well, taking the reader through a number of important principles to final application in the form of receivers, transmitters and antennas. The section on resistors is particularly pleasing, since the treatment of these is so often sketchy. The diagrams are excellent, and numerous illustrative problems are included. Although there are several corrections which can be made in further editions, the book is first class in its sphere, and can be confidently recommended to students in the first stages of radio engineering.

J. R. M.

Microwave Magnetrons : Edited by G. B. Collins. M.I.T. Radiation Laboratory Series. McGraw-Hill Publishing Co. 1948. pp. 806 + xviii. Price 54s.

The magnetrons described in this book are almost exclusively of the type invented by J. T. Randall and H. S. H. Boot at Birmingham University in May, 1940.

The first chapter contains an elementary introduction to magnetrons, and the remainder of the book is divided into five specialized parts, respectively entitled : Resonant Systems, Analysis of Operation, Design, Tuning and Stabilization and Practice.

The first two of these parts develop a mathematical theory of the magnetron, commencing with detailed discussions of unstrapped, rising sun and strapped resonant systems using electromagnetic field theory and circuit analysis by matrix methods. This is followed by an analysis of the electronic mechanism by which oscillations are generated, including elegant expositions of the theories of Brillouin, Hartree and Bunemann. If the reader overlooks the statement that " our understanding of the electronic processes is largely of a qualitative nature," he will gain the mistaken impression that present-day magnetron theory is adequate or even complete.

The subsequent chapters describe qualitatively the behaviour of the magnetron as a circuit element, viewed from the output feeder and from the pulser, and discuss starting phenomena and noise. There is little reference to the previous mathematical theory.

Later chapters concerned with construction and measurements describe numerous techniques specially applicable to magnetrons. The final chapter describes in detail more than a dozen typical magnetrons.

The book collects together a wealth of information invaluable to the magnetron designer. There are, however, occasional typographical errors, and it is to be hoped that, at least, those in the design formulae will be eliminated from later editions.

R. D.

Velocity Modulated Thermionic Tubes : A. H. W. Beck. Cambridge University Press. 1948. pp. 180 + x. Price 15s.

This is the latest volume of the Cambridge University Press Modern Radio Technique Series. An introductory chapter on the physical principles of velocity-modulation tubes is followed by a discussion of resonant cavities and of the methods used in calculating their characteristic frequencies. Chapter 3 contains a detailed consideration of the interaction between the electric field and the electron beam in a klystron and leads to a short survey of electron optics as applied to heavy current beams.

The fundamental theorems developed in the foregoing chapters are used in concise but adequate analyses of velocity-modulation amplifiers, klystron and reflex klystron oscillators, and a few other miscellaneous types of velocity-modulation tubes. The final chapter, in contrast to the rest of the book, is severely practical, dealing with the materials and processes used in the manufacture of klystrons and similar valves. Appendices are devoted to the travelling wave tube and to a sample of the calculation required in designing a high-powered klystron.

The book contains a lot of information not previously available in a collected form, and it will be a very valuable work of reference for those concerned with centimetre-wave radio or radar. It is written in a direct and economical style, making few concessions to the reader's unfamiliarity with the subject, and it is not a book for the elementary student.

J. M. A. L.