RADIOTRONICS

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RADIOTRONICS

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By the way—

We are pleased to report that Mr. Eric Watkinson, author of "Universal Coil Winding" which appeared in Radiotronics No. 146, has been approached by the British Institute of Radio Engineers for permission to reprint his most informative article in their journal.

This month's front cover shows mercury-vapour rectifier valves undergoing ageing treatment. Each valve is operated in this test for a length of time sufficient to stabilize its electrical characteristics.

In view of the large number of enquiries received from readers concerning the theory and operation of phototubes, we have devoted the major portion of the March issue to this subject. Included with this issue is a pamphlet describing and illustrating the Cintel range of phototubes for which this company has been appointed an Australian agent. It will be noted that these phototubes which are made in England and are therefore available without the expenditure of dollars are identical replacements for popular U.S. types.

On page 41 of our February issue "Audio-Frequency Applications of Type 6BE6" appeared as Circuit Laboratory Report No. 5 when actually it should have been listed as Report No. 6.

Noted

About the time this issue is in the hands of our subscribers we will have available a new, enlarged Characteristics Chart available at 1/6 per copy. Full details and an application form will be included in the next issue.

Subscribers are asked to check their address as stencilled on the Radiotronics envelope and advise us immediately if found incorrect. Changes of address should also be advised promptly.

Should a subscriber fail to receive an issue for any reason, this should be brought to our notice as soon as possible. Due to the limited printing of each issue, supplies of back numbers cannot be guaranteed more than a few months after publication.

Editor:
Ian C. Hansen,
Member I.R.E. (U.S.A.).

Asst. Editor:
R. Ainsworth, A.S.T.C.,
A.M.I.R.E. (Aust.).

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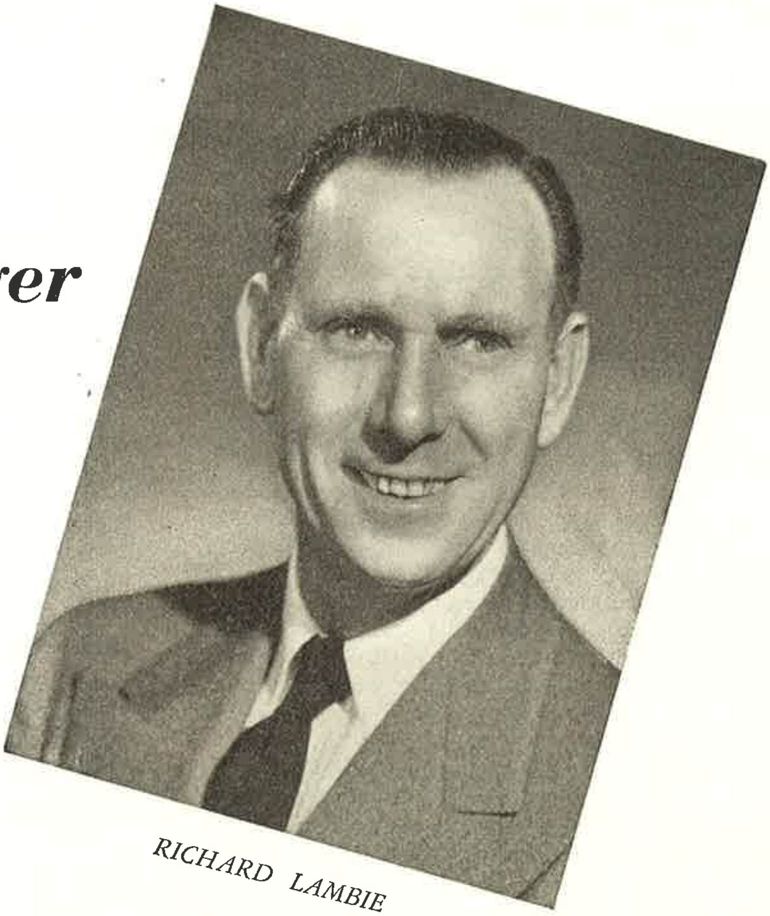
New Manager

For A.W.V.



RICHARD LAMBIE

On January 1st this year, Mr. Richard Lambie was appointed Manager of Amalgamated Wireless Valve Company.

Prior to his arrival in Australia in 1925, Mr. Lambie, who hails from North of the Border, was with Vickers Ltd. at their Crayford plant in Kent. He was selected by them after some months to be a member of the first group of apprentices to be trained by Vickers at Crayford.

After being initially employed by the Gramophone Company in N.S.W. until their amalgamation with Columbia, he joined the staff of Westinghouse Rosebery Pty. Ltd.

Mr. Lambie's part in the development of the radio valve industry in Australia has been a prominent one. He joined Amalgamated Wireless Valve Company in 1933 and superintended the design and layout of the present Valve Works installed at Ashfield in 1942, at which time he was Acting Works Manager, and later appointed Works Manager.

During the war years he supervised the development and manufacture of Klystron and Magnetron valves for Radar, and the quantity production of transmitting valves, together with the manufacture of the millions of receiving valves required by the Armed Forces.

Following Mr. Lambie's return from a visit to the United States in 1944, the first manufacture of miniature valves commenced.

Mr. Lambie recently returned from a business tour of U.S.A. and Europe.

Circuit Laboratory Report **Number 7**

A.V.C. Characteristics

A.V.C. curves presented with Radiotron receiver descriptions are now drawn in a manner similar to that recommended by M. G. Scroggie in "Wireless World", May 4, 1939, and in Radio Laboratory Handbook, Second Edition. The readings are obtained by turning the volume control of the receiver to maximum, setting the generator output to 1μV, modulated to a depth of 30%, at the desired frequency and accurately tuning the receiver to it. The receiver power output is then noted and the input increased by suitable small steps, recording the output at each step until it reaches say one quarter of the rated power output of the receiver. The volume control of the receiver is then turned back 10 db and the input increased again in steps until the output reaches its previous maximum, when the volume control is again retarded by the same amount. This process is repeated until the whole characteristic has been plotted.

A convenient output power range for most a.c. receivers is between 50 mW and 500 mW if this range is available on one scale of the output meter. When plotting the results, the alteration of the volume control setting in db is added to the indicated power output so that a continuous curve of output versus input results.

The noise curve is plotted in the same way except that the input to the receiver is unmodulated and usually it is not necessary to alter the volume control setting from its maximum position. A more sensitive scale on the output meter may be needed as noise decreases with increasing signals.

Small increments of input such as 1, 2, 5, and 10 times should be used to avoid undue rounding-off of the a.v.c. characteristic. Some signal generators have stepped output switches giving approximately 10 db. increments per step. These steps are suitable for most design work, but an accurate curve needs at least one more step per decade.

One precaution which is necessary is the retuning of the receiver for maximum output as the signal input is increased on receivers in which the oscillator frequency is affected by the signal input.

Analysis of a.v.c. curve

A description of the Radiotron Receiver RD34, using a 6A8-G converter and 6AR7-GT reflex i-f and a-f amplifier appeared in Radiotronics 144. Figure 1 is the a.v.c. curve of the receiver and, in common with most other a.v.c. characteristics, it can be conveniently divided into three main sections.

Small-signal input

The low-input section of the curve is the part over which a.v.c. is not operating due to insufficient a.v.c. voltage being developed, or to the use of a.v.c. delay. In this section output is approximately proportional to input; for example, in Figure 1 an increase of signal from 4μV to 10μV, i.e. 8 db, increases the output from zero to 9 db (reasons for the output increasing more rapidly than the input are given below). In Figure 1 the small signal section of the curve extends from 1μV to approximately 50 μV.

In some a.v.c. curves this first section is apparently missing. When this occurs the receiver is a very sensitive one and an input of 1 μV, at which the curve begins, generates sufficient a.v.c. voltage to keep the output approximately flat. In an extreme case the noise in the input stage of the receiver may be high enough to operate the a.v.c., and although this provides a very flat a.v.c. characteristic right from the origin, it has the disadvantage (at least in commercial A-M receiver designs) of limiting the signal-handling capacity of the receiver at high inputs.

Medium-signal input

The medium-signal section of the curve is the part covering the range of inputs from the beginning of a.v.c. control to the beginning of i-f overload; that is, from say 50 μV to 200,000 μV in Figure 1. This section of the curve does not necessarily have the same slope throughout, firstly because a variation in bias applied to one or more of the controlled valves may not give a proportional variation in sensitivity. This applies particularly to some types of converters, and in Figure 1 the shape of the curve between 1 mV and 10 mV is mainly due to the shape of the conversion conductance vs. control-grid bias characteristic of the 6A8G.

The second reason for a variation in curvature is that different valves may not have the same a.v.c. voltages applied to them. For example, in a receiver with simple a.v.c. applied to the i-f stage the r-f stage may have a.v.c. control delayed until a large input is reached, and in this case the a.v.c. curve will have an almost flat section above the input at which the r-f stage is controlled. Alternatively, one valve may have only a small fraction of the generated a.v.c. voltage applied to it so that the control does not become effective until a high input is reached. An example of this is seen in Figure 1, in which the 6A8-G a.v.c. begins to take effect at about 50 μV, but control of the 6AR7-GT is negligible below about 5000 μV. It is to observe

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Contributed by the Circuit Design Laboratory, Valve Works, Ashfield

these changes of slope that small increments of input are used, and for the same reason an a.v.c. curve should pass through each of the points plotted without any smoothing-out of the resultant characteristic.

Large signal-input

The high input section of the curve is the part in which the overload characteristic is shown. Overloading usually causes modulation rise (see Radiotronics 78), and the increased slope of the curve is noticeable in most cases before distortion, due to overloading, becomes severe. For example, in Figure 1 the rise at 0.5 volt input is obvious, but referring to the text of the receiver description, the distortion measured at this input is only 3.7% (some cancellation of distortion occurred in this receiver, but not enough to affect the order of the result).

Nevertheless, distortion due to overloading can occur without modulation rise appearing on the a.v.c. characteristic, and some receivers show overloading by a flattening of the curve. The measurement of distortion at large inputs cannot be dispensed with merely because the a.v.c. characteristic appears satisfactory.

Modulation depth

Because the a.v.c. curve is drawn with 30% modulation of the input signal, whereas actual broadcast station modulation levels vary considerably, the a.v.c. curve can only give an approximate idea of receiver performance. A curve drawn with 60% modulation starts from the same point at zero input, rises until it reaches a level 6 db above the 30% modulation curve, and follows this curve, 6 db above it, until overloading begins, which is at a smaller input than on the 30% curve, because of the larger plate voltage excursion of the last i-f amplifier. As a check on this overloading it is advisable to measure distortion with simultaneous high signal inputs and high modulation levels during receiver development.

From the point of view of obtaining sufficient a-f output from small signals the use of 30% modulation gives a conservative indication of receiver performance, because the modulation of broadcasting stations consistently exceeds this value. However, to make provision for the worst conditions liable to be met, it is advisable to have the a.v.c. characteristic reaching full a-f output as soon as possible with 30% modulation of the signal.

Significance of a.v.c. curves

A large amount of information about the receiver in question can be obtained from further analysis of an a.v.c. and noise curve, more, probably, than from any other receiver characteristic. The information includes:

1. The rate of change of output vs. input over the whole useable range of input signals.
2. The sensitivity of the receiver for any output within the capabilities of the output valve.
3. The theoretical output (ignoring overload in the output stage) for any signal input.

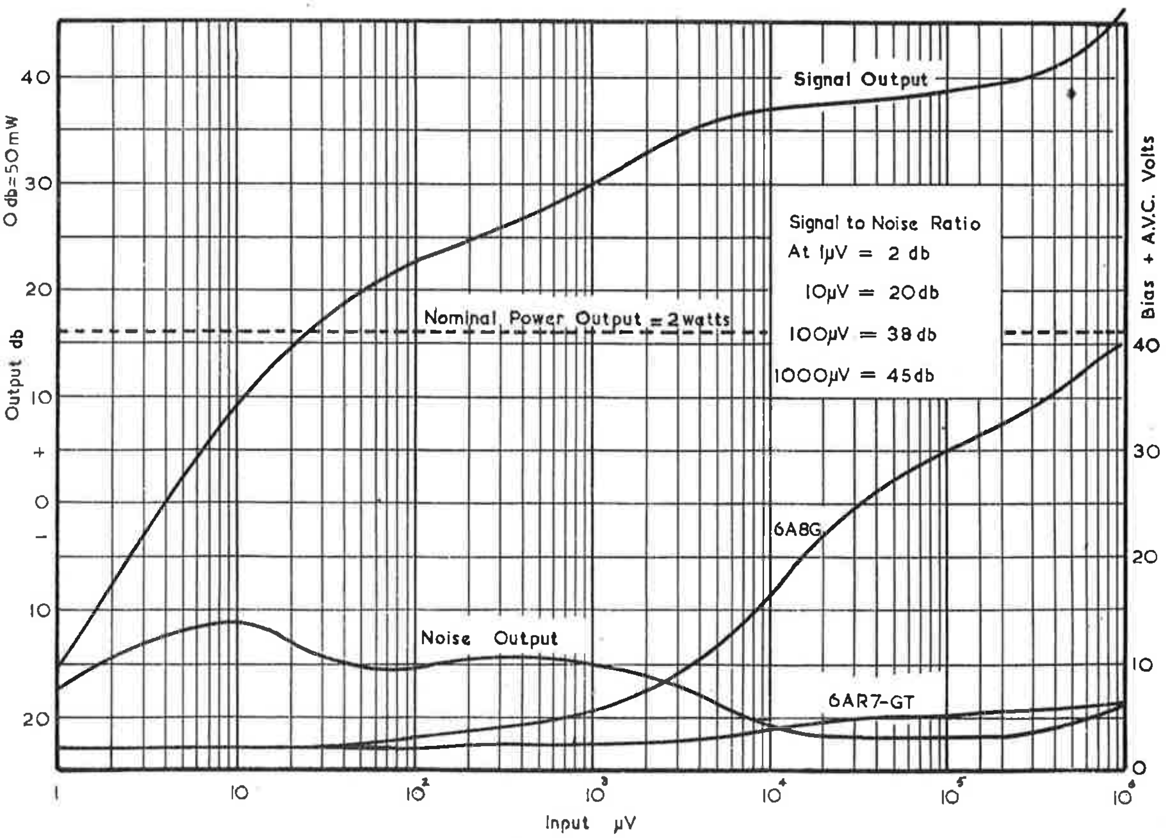

Fig. 1. Curves of signal and noise output and a.v.c. voltages vs. signal input voltage.

4. The volume control setting for a given output at any specified signal input.
5. The signal-to-noise ratio for any input.
6. The rate of increase of signal-to-noise ratio with increase of input.
7. The incidence of modulation hum with high signal inputs.
8. An indication of the range of inputs which the receiver will handle satisfactorily.
9. An indication of under-biasing of any controlled valve if this occurs.

Amplification of the above points follows below:

1. Rate of change of output vs. input

Scroggie's method has important advantages over the previous method of feeding a large signal into the receiver, adjusting the output to say half the maximum output and noting the fall in output as the input is decreased.

The main advantage is the additional accuracy available at small signal inputs because of the greater output being measured and because residual hum in the receiver is not a major part of the output as it may be in the older system.

Another advantage is that instead of using some arbitrary maximum input the input can be increased until the receiver is obviously overloading, or discontinued as soon as overloading occurs.

A point of interest with regard to the rate of change of output versus input is that a completely flat characteristic, although usually considered ideal, is not necessarily the most satisfactory for a sensitive commercial A-M receiver. With such a characteristic, interstation noise is much more objectionable than in a receiver having a curve with a steep slope below say 500 μV. If the a.v.c. is reasonably flat (an increase in output of from 2 to 4 db per decade of input) above this input, variations in volume of local stations will be due as much to variations in average modulation levels as to difference in signal strengths.

2. Receiver sensitivity

When output is plotted in db with standard output (50 mW) taken as 0 db the sensitivity of the receiver is, of course, the input voltage at which the a.v.c. curve crosses the 0 db line, e.g., in Fig. 1 the receiver sensitivity is 4μV.

However, if sensitivity for 500 mW output is required, this is obtained at the point at which the a.v.c. curve crosses the + 10 db line, about 11 μV in Fig. 1.

The desirability of drawing a line across the graph to represent the nominal a-f output of the receiver is evident in that if the a.v.c. curve flattens before crossing this line, so that a large signal input is needed to reach it, the receiver will not deliver full a-f output from stations providing smaller inputs. In such a case a smaller fraction of the developed a.v.c. voltage should be applied to the controlled valves or a.v.c. delay should be used.

On the other hand, if the a.v.c. characteristic crosses the maximum a-f output line and still goes on rising rapidly for say 20 db or more, this is an indication that the a-f output stage can be easily overloaded and that the top 20 db or so of volume control movement will probably never be used, unless the receiver is sometimes operated on very weak stations. If the receiver has delayed a.v.c. a reduction in the amount of delay is desirable, so that the a.v.c. begins to operate as soon as the a-f output valve is driven to full output. If there is no a.v.c. delay the shape of the a.v.c. curve is an indication of excessive a-f gain.

3. Receiver output

In a similar manner the receiver output for any input can be obtained from the curve. For example, in Fig. 1, a 20 μV input gives an output of about 14.5 db above 50 mW, or 1.4 watts.

Receivers with forward-acting a.v.c. (i.e. a.v.c. which is applied to a stage after the a.v.c. detector) sometimes have an a.v.c. characteristic which falls with increasing input at high levels. Reflex receivers with three valves and a rectifier are susceptible to this effect, because the a-f gain of the reflex stage is usually controlled by a.v.c. The a.v.c. characteristic of these sets should be checked to see that the a-f output at high inputs does not fall below the maximum undistorted output of the a-f output valve, and preferably has at least 6 db of a-f overloading in reserve.

4. Volume control setting

The a.v.c. characteristic as drawn shows the output with the volume control set to maximum. If the receiver on which the characteristic of Figure 1 was drawn were tuned to a 1000 μV signal and delivered on a-f output of 500 mW, the volume control would have been adjusted 20 db down from its maximum setting. This is known, because with the control at maximum the receiver would deliver 30 db above 50 mW, i.e., 50 watts (assuming no a-f overload). As the output is only 10 db above 50 mW the volume control has been turned down 20 db.

This type of information can be useful when frequency compensation is being applied to a tap on the volume control to compensate for scale distortion.

5. Signal-to-noise ratio for any input

The signal-to-noise ratio for any input can be obtained by subtracting the level of the signal-output curve from that of the noise-output curve. For example, from Fig. 1 the signal-to-noise ratio of the RD34 receiver at 5 μV input is 14.5 db [+ 2.5 db – (–12 db)]. This figure, obtained at an input at which a.v.c. is not operating gives an indication of the performance of the input stage, i.e., aerial coil and mixer valve, from the point of view of noise.

6. Rate of increase of signal-to-noise ratio

Commercial A-M receivers are rarely if ever used with a signal input of 5 or 10 μV, so that the signal-to-noise ratio at this level is only important if the ratio improves at the maximum possible rate as

(Continued on page 59)

Photoelectric Phenomena

By C. D. Prater

It was Heinrich Herz, the discoverer of radio waves, who made the first observation of photoelectric phenomena. By photoelectric phenomena is meant the effect of light on some component of an electrical system.

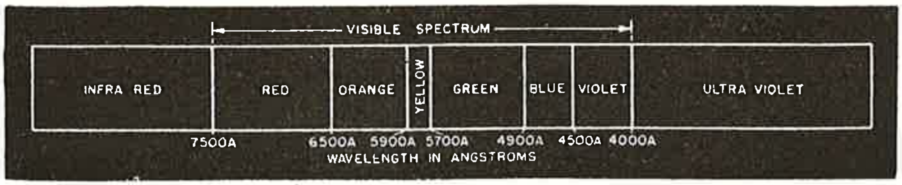

Fig. 1. The visible region of the light spectrum, including infra-red and ultra-violet.

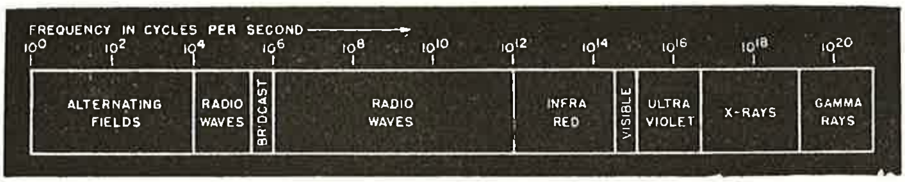

Fig. 2. The entire radiant energy spectrum from the lowest audio frequency to the gamma rays.

Light is an electro-magnetic radiation just as radio waves are, but it is much shorter in wave length. The color of light depends upon the wave length. The wave length of red light is approximately 8×10^{-5} cm. and violet light is approximately 4×10^{-5} cm. Red light is the longest wave length, and violet light is the shortest wave length the eye can detect. The wave lengths for different colours are shown in Fig. 1.

It is convenient to use a smaller unit than the centimetre in measuring the wave length. The unit used is the Angstrom which is 10^{-8} cm. Red light would then be 8000 A and violet light would be 4000 A. The relationship between the various radiations can be readily seen.

The complete electro-magnetic spectrum is shown in Fig. 2 with the frequencies given. The frequency is related to the wave length by the formula

$$f = \frac{c}{\lambda}$$

where c is the velocity of light, λ is the wave length, and f is the frequency. In the first part of the spectrum with a frequency vibration from 10^{0} to 10^{4} are the electro-magnetic radiations given out by alternating currents of audio frequencies in a wire. The region of frequency from 10^{4} to above 10^{12} are the familiar radio waves. The position of the broadcast band is shown. From about 10^{12} to 7.5×10^{14} are the infra-red radiations. These include what is commonly known as heat radiations. Then comes the very narrow region which comprises the visible range. To the right of the visible range up to a frequency of about 5×10^{16} is the ultra-violet. The regions from 5×10^{16} to 10^{19} are X-rays. Above them are the gamma rays given off by radium. The region of the visible spectrum and a small part of the ultra-violet and infra-red adjacent to it will be of interest in the study of study of photoelectric phenomena. The boundaries between the various regions indicated are not sharp but overlap.

If the amount of radiation corresponding to a given wave length given off by a hot tungsten filament is plotted against the wave length, a curve like that shown in Fig. 3 will be obtained when the filament is 2600° C. It can be seen that the maximum amount of energy is radiated in the near infra-red region at about 9000 A. This placement of maximum energy is of great interest in the application of photoelectric devices since often the amount of energy which they can collect in a very short time is of great importance because it determines the amount of amplification necessary. Most photocells are more sensitive in the ultra-violet and are not sensitive in the infra-red at all. The question might be asked could a light not be made which would give the maximum in the ultra-violet or the near ultra-violet.

Since the easiest source of light is a hot body such as the hot tungsten wire mentioned above, it will be well to examine this source first. The maxi-

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mum temperature that can be obtained is determined by the vapor pressure of the metal at that temperature since this determines how soon the filament will burn out by evaporation of the metal. The short time maximum temperature is determined by the melting point of the metal. The best metal from all points of view is tungsten which has a maximum operation of about 3000° C., but the life of the filament is short at this temperature. The maximum in energy is moved towards the visible by this increase in temperature but only by a relatively small amount. The maximum is still about 9000 A. So the search must be in another direction. The question is asked is there not some other material, which although it operates at a lower temperature will give a better placed maximum. The most perfect radiator is an absolutely black body. The radiation curve for it is shown in Fig. 3 above that of tungsten at the same temperature. It will be seen that the maximum is in the same region of the spectrum. The conclusion is that when the intensity is small either photocells must be used which are sensitive in the infra-red or a lamp which radiates great intensities in the ultra-violet must be found.

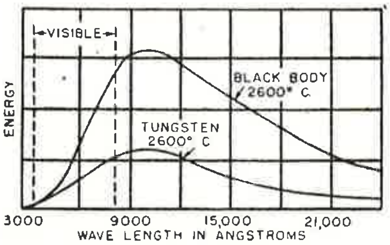


Fig. 3. (left). Energy curves for two hot bodies.

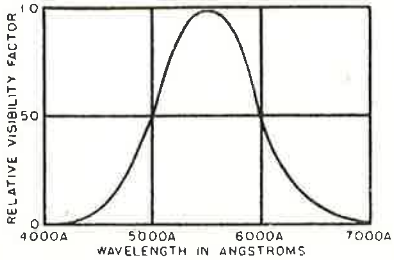


Fig. 4. (right). Sensitivity curve for the human eye.

If the gas discharges are examined, it will be found that one of them the mercury arc, gives large amounts of ultra-violet. The use of ultra-violet has a serious drawback in that all the glass parts must be made from quartz or some special glass which is transparent to ultra-violet. Ordinary glass is opaque to ultra-violet. The mercury arc is not as convenient mechanically as the tungsten lamp as a source of radiation. Gas discharge lamps have been developed in recent years which have good efficiency of radiation in the visible region of the spectrum.

The visual sensitivity curve of the human eye is shown in Fig. 4. It will be of interest later to compare the sensitivity of various photocells with this. Often a photocell is required which "sees" things as nearly as possible as they are seen by the eye.

The standard for measurement of luminous intensity of a source of radiation is the candle power. The intensity of illumination is measured in foot-candles. This is the intensity on a screen placed 1 foot from a source of 1 candle power. The amount of light falling on each square foot of this screen is called 1 lumen. The amount of light falling on a square foot varies as the square of the distance from the source. For instance, the amount of light falling on a square foot of a screen placed two feet away from a 1 candle power source will be ¼ as much as for a screen placed 1 foot away. The comparison of intensity of a source is made visually and therefore the units above will correspond to different energy measured in watts for different parts of the spectrum because of the variation of visual sensitivity of the eye shown in Fig. 4.

Photoelectric effects can be divided into three major classes; photoemissive effects, photovoltaic effects, and photoconductive effects. All of these effects depend on the freeing of electrons from atoms in a substance under the action of light. The first represents an actual liberation of an electron into space as in thermal emission of electrons; in the second the electron takes part in chemical and physical changes to produce an electro-motive force; and the third is the change of electrical resistance of a semi-conductor by the liberation of electrons in the semi-conductor. The first to be considered, and the most important practically is the photoemissive effect.

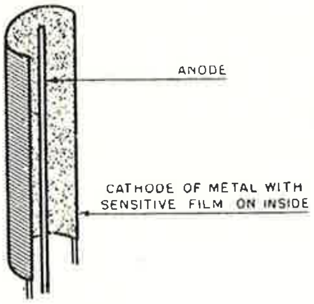


Fig. 5. Construction of a photoelectric cell.

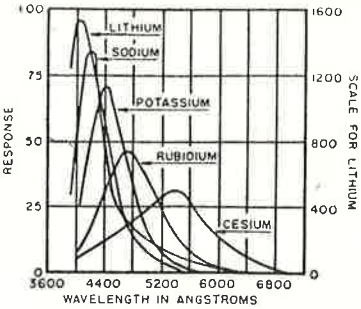


Fig. 6A. Colour curves for alkali metals.

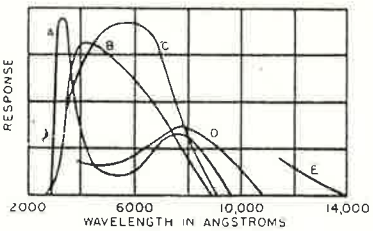
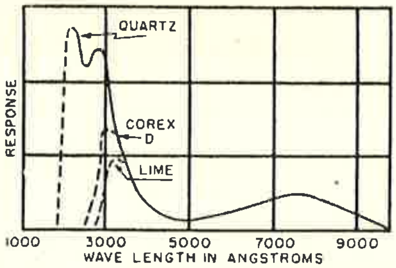


Fig. 6B. Colour curves for caesium oxide cells.

If the surface of a metal is irradiated with light of sufficiently high frequency it will be found to emit electrons. It will be found that there will be a frequency below which no electrons will be emitted. This is called the threshold frequency, and it depends upon the work necessary to remove one electron from the metal and is the same, in certain instances, as the work function met with in thermionic emission.

There are two laws of photoelectric action which came out of the early work with photoemissive effects. They are: (1) the number of electrons released per unit time at a photoelectric surface is directly proportional to the intensity of the light fall on it, and (2) the maximum energy of electrons released at a photoelectric surface is independent of the intensity of incident light but is directly proportional to the frequency of the light. These two laws made the scientist change his concept of light. The light here behaves as if it were discrete particles of energy, each with the same energy striking the photoelectric surface and knocking the electrons from it. The number of such particles striking the surface, i.e., the intensity of the beam would determine the number of electrons released which corresponds to the first law. The energy that these particles have to impart to the electron will determine the maximum velocity with which the electrons are liberated. There will be an energy below which no electrons can be removed from the surface because of the work required to remove the electrons. Not all of the electrons come out with the same velocity, but they come out all possible values of velocity below the maximum because the electrons come from various depths in the metal and have to make their way up through the metal after they are released by the light and therefore lose energy. These light particles are called "quanta".

Fig. 7.
Response of glass in the ultra-violet.



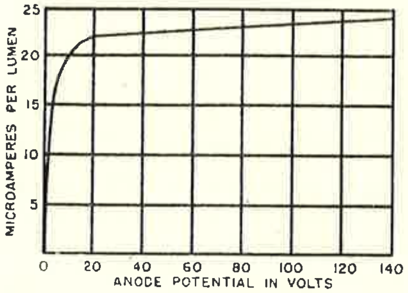


Fig. 8.
Current voltage curve of a photocell.

Einstein was the first to show that photoelectric effects could be accounted for in this way. He gave an equation which now bears his name, $\frac{1}{2}mv^2 = hf+P$ where m is the mass of the electron, v is the velocity, h is a constant known as Planck's constant, f is the frequency of the light and P is the work that must be done on the electron to remove it from the metal. The quantity $\frac{1}{2}mv^2$ will be recognized as the kinetic energy which the electron possesses. If this equation is restricted just to those electrons which come off with a maximum velocity, the P will be determined by the same work function as in thermionic emission. For P, hf_0 can be substituted, where f_0 is the threshold frequency of the metal. This equation includes both of the laws of photoelectric emission.

The threshold frequency for most common substances lies up in the ultra-violet, and since the cell needs to be sensitive to visible radiation at least, if not all the way down into the infra-red a substance is needed with as low a work function as possible. This is the same problem that was met in thermionic emission. It is somewhat simplified in this case because the electrode does not need to be heated and this makes possible its use of a substance with a high vapor pressure. More stable films can also be formed. The best photoelectric emitters are then, as for thermionic emitters, the alkali metals and the alkali earth metals in this order, calcium, lithium, strontium, sodium, barium, potassium, rubidium and caesium, going from the poorest to the best. Of these only the last five are used in photoelectric cells. If a film of one of these metals is deposited on a surface of the oxide of that metal which in turn is deposited on a base metal, the work function will be lowered still further. Caesium-caesiumoxide-silver is a good example of this and is one that is used to a great extent to-day. They are called caesium-oxide cells.

In the practical construction of photoelectric cells, the metal may be deposited directly on the glass envelope or may be deposited on the half cylinder cathode, as shown in Fig. 5. The anode is a small rod placed in the centre of the bulb. The cathode is illuminated either through the side of the half cylinder left open or through an uncovered portion of the bulb walls when the bulb wall itself is covered.

The color sensitivity curves for five alkali metals are given in Fig. 6a. It will be noted that the maximum response of caesium lies in the middle of the visible range. If a cell is made from sodium or potassium and a hydrogen glow discharge is made between the coating and the anode, the sensitivity of these cells can be raised 100 times over their initial value. Caesium is the only alkali metal which is not affected appreciably by glowing in hydrogen. The explanation of this increase in sensitivity is probably that a composite film is formed like the caesium-caesiumoxide-silver films. Sulphur can be used in much the same way on potassium and sodium. Sometimes organic dyes are used to stain the surface of the film to increase the sensitivity to longer wave lengths in much the same way these dyes are used in sensitive photographic emulsions for longer wave lengths. The caesium-oxide cells are of interest as an illustration of the differences in cells due to slightly different methods of treatment in making. These curves are shown in Fig. 6b. The curve C is a good approximation to the visual sensitivity curve shown in Fig. 4. The curve D would represent a good cell to use with a tungsten filament lamp for such applications as sound pictures. Caesium-oxide cells can be made by special processes which have sensitivity in the infra-red in the region of 12,000 A.

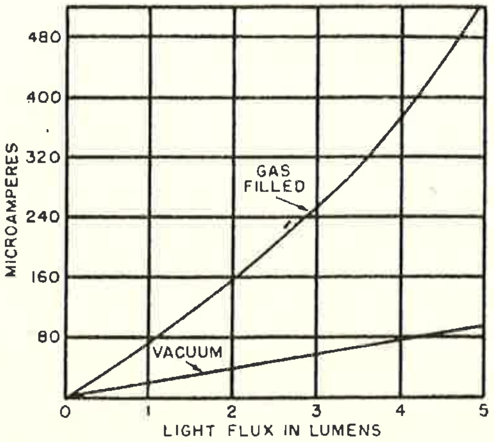


Fig. 9. Photocell illumination curves.

Cells which have sensitivity in the ultra-violet are no problem since ordinary metals as well as caesium-oxide cells can be used if a glass which is transparent to ultra-violet is used for the bulb. The color curve for a caesium-oxide cell is shown in Fig. 7. The dashed curves represent the cut-off by the different types of glass. The region of fall in the curve about 5000 A is not well understood. The sensitivity of hydrogenated potassium cells is about 0.2 microamperes per lumen, that of caesium cells about 2 microamperes per lumen. Experimental caesium-oxide cells with a sensitivity of as high as 50 to 65 microamperes per lumen have been made. A typical caesium-oxide cell has a sensitivity of about 10 microamperes per lumen.

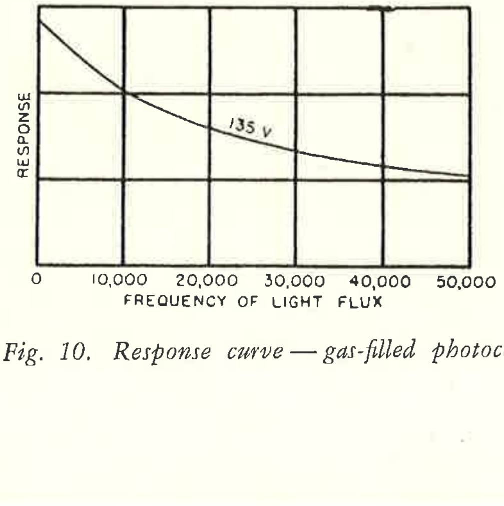


Fig. 10. Response curve — gas-filled photocell.

If the sensitive film is located in a high vacuum, the phenomena that are observed are in many ways similar to those observed in high vacuum thermionic tubes. There is a space charge limited region and an emission limited region just as in the case of a high vacuum tube as can be seen in Fig. 8. Photoelectric cells are operated in the emission limited regions rather than in the space charge limited regions as thermionic vacuum tubes are for the obvious reason that changes in the emission are what are to be followed. This causes the high vacuum photocells to have a linear response with light flux. The dynamic characteristics of a vacuum photoelectric cell are flat because there is no time lag in the emission of the electrons. By dynamic response is meant the ability of the photoelectric cell to follow variations in light intensity exactly.

Since the output of vacuum photocells is so small and consequently has to be amplified so much, gas photocells are made. These gas photocells are filled with one of the inert gases so that the sensitive film will not react with the gas. This gas is usually argon. Gas photoelectric cells behave in much the same way that gas-filled thermionic tubes behave. A typical current-illuminator curve for a gas-filled photocell is shown in Fig. 9. The increase of amplification obtained in a gas-filled cell over the vacuum cell can be seen by comparing the two curves shown in Fig. 9. The current illumination curve for a gas-filled cell is not quite linear and the dynamic response curve is not at all flat but falls off with increase in frequency as can be seen in Fig. 10.

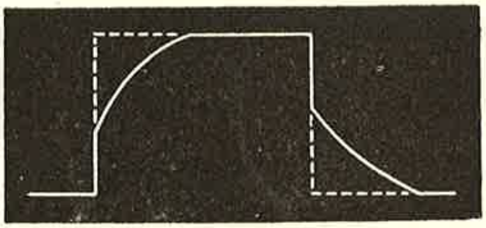


Fig. 11. Distortion of a square light pulse.

This causes non-linear frequency amplification. There is a distortion of the wave form at high frequencies or with square pulses as can be seen in Fig. 11. The dotted lines show the square light pulse applied to the photocell, and the heavy lines show the output wave form of the photoelectric cells. This is caused by the time it takes the electrons to build maximum ionization in the gas to deionize at the end of the light pulse. A typical circuit for the use of a gas or a vacuum photoelectric cell is shown in Fig. 12. Amplification is necessary since the only apparatus that even a gas-filled photoelectric cell will operate is a galvanometer. Since the photoemissive cell produces a current, and the thermionic amplifier requires a voltage, a high resistance must be used in the input stage in order to produce a voltage drop great enough to amplify.

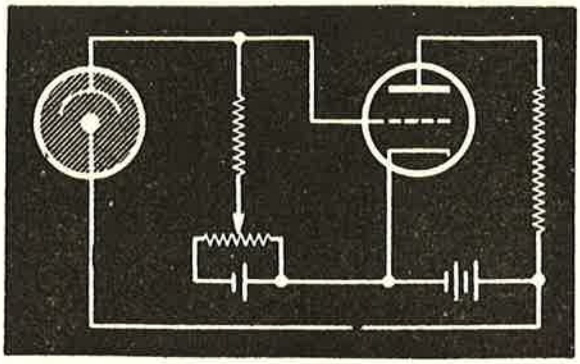


Fig. 12. Typical photo-electric cell circuit.

One of the most important uses of photoelectric cells is in the sound reproduction in motion pictures. The sound is recorded on a very small strip at the side of the motion picture film by two different methods (1) the variable density method in which the density in this area varies as the sound varies and (2) the variable area method in which the area occupied by a region of constant density is varied. The source of light which passes through this film is usually a tungsten filament lamp. A vacuum photocell or a gas photocell with a properly corrected amplifier is used.

A. V. C. CHARACTERISTICS

(Continued from page 54)

the input is increased Under normal conditions an increase of 20 db in input cannot give an increase of more than 20 db in signal-to-noise ratio. However, because increasing the bias of a valve increases its noise resistance a larger input to a receiver does not always produce an equivalent improvement in signal-to-noise ratio when a.v.c. is operating on the first valve. This makes the rate of increase of signal-to-noise ratio with signal an important measurement in a receiver and it is immediately available from the a.v.c. curve. For example, in Fig. 1 the ratio is tabulated for 1, 10, 100 and 1000 μV, and it will be seen that for the first two 20 db increments in signal level an 18 db improvement in signal-to-noise ratio is obtained. The ratio should improve as rapidly as possible until it reaches at least 40 db, and preferably 45 db.

The noise curve in Fig. 1 is not a typical one owing to the presence of modulation hum. A more normal noise curve would fall progressively from 10 μV as the a.v.c. voltage became effective until it flattened out at a level representing residual hum from the receiver or the signal generator rather than random noise generated in the first stage of the receiver.

7. Modulation hum

Many receivers show modulation hum by an increase in the level of the noise curve with large signals. This is not necessarily a fault if the hum is far enough below the level of the output due to modulation, but the curve serves a useful purpose in drawing attention to it.

8. Overload

As mentioned previously, overloading of the receiver is indicated by upward curving of the a.v.c. characteristic caused by modulation rise. However, other effects, such as a flattening of the curve or a decrease in output may occur.

9. Diode linearity and under-biased valves

As the input voltage in Fig. 1 is increased from 1 μV to 4 μV, i.e., 12 db, the output increases 15 db. This would be impossible if the receiver had a linear input-output characteristic, as would be expected before the a.v.c. control starts. However, a diode needs a certain minimum signal input before linear operation is obtained. This input is not supplied to it in the receiver RD34 until the signal applied to the aerial terminal is about 10 μV, so that at lower inputs the output decreases more rapidly than the input, due to decreasing diode detection efficiency.

Another condition under which output increases more rapidly than input occurs when the bias on a controlled valve is less than that which gives maximum gain. The characteristic then rises normally over the part of the curve for which the a.v.c. is inoperative, but has a steep upward tilt as soon as a small amount of a.v.c. voltage increases the bias on the controlled valve to that which gives maximum gain. The characteristic is normal at higher inputs.

Precautions

There are two types of receiver in which the information deduced from a.v.c curves obtained as above will be subject to error.

In a receiver having negative feedback applied to the cold end of the volume control to reduce hum progressively as the arm approaches the minimum setting, the ratio of residual hum to signal will be better than indicated by the curves, provided that residual receiver hum is the output plotted on the "noise" curve. This is not a serious effect, because the indicated result is worse than the true performance, and in any case the final criterion for satisfactory hum is usually a listening test.

Receivers having diode biasing of the first a-f amplifier should not have a.v.c. curves drawn by the method described above. The alteration of the volume control in steps alters the amount of a.v.c. applied to the a-f amplifier, and at large inputs the output which is presumed to be that which would be obtained with the volume control at maximum (and hence with full audio a.v.c) is actually the output which is obtained with only a small fraction of the developed a.v.c. applied to the a-f stage.

In view of the very small number of receivers using diode biasing this is not considered to be a serious drawback to the method.

Phototube Characteristics

By Alan M. Glover

Radio Corporation of America, Lancaster, Pennsylvania.

1. Introduction

The first large scale use of commercial phototubes occurred in the motion picture industry with the advent of sound film. The reliable performance of sensitive phototubes in this field gradually encouraged others to make use of the devices and since the middle thirties there has been a rapidly widening market for industrial controls and instrumentation employing phototubes. The paper-making and printing industry was perhaps the next to make large-scale use of the tubes, chiefly for registry; another of the early applications was in safety devices on power presses. These latter applications were likely to be of the on-off type which requires the least refinement in the phototube characteristics. In recent years scientific instruments of a highly complex nature have been marketed in increasing numbers. Spectrophotometers, spectrographs, and other devices which require a much closer control of the phototube characteristics are becoming more common. One such instrument employs twenty-one multiplier phototubes each assigned to the measurement of the intensity of one spectral line for impurity control. A very recent application which bids fair to make use of considerable numbers is the scintillation counter which may become a large-scale competitor of the Geiger-Mueller counter for the detection, identification, and measurement of nuclear radiations and also for the measurement of ultra-violet and X-rays.

2. Classes of phototubes

Phototubes may be most readily classified by the spectral sensitivity of the surface which they contain. In recent years a wide variety of surface types has become available, the two most important of which are:

S-1 Caesium-silver-oxygen
(includes envelope transmission)
S-4 Caesium-antimony
(includes envelope transmission)

Spectral sensitivity curves for these two surfaces are shown in Fig. 1. These curves are shown on an equal energy basis. Response to any given light source will, of course, be weighted by the spectral distribution of the light source. The problem presented to the manufacturer by the S-1 type is illustrated in Fig. 2. Control of the spectral sensitivity is fortunately much better than indicated by the possibilities of Fig. 2, but variations exist of a much wider order than in the S-4 type.

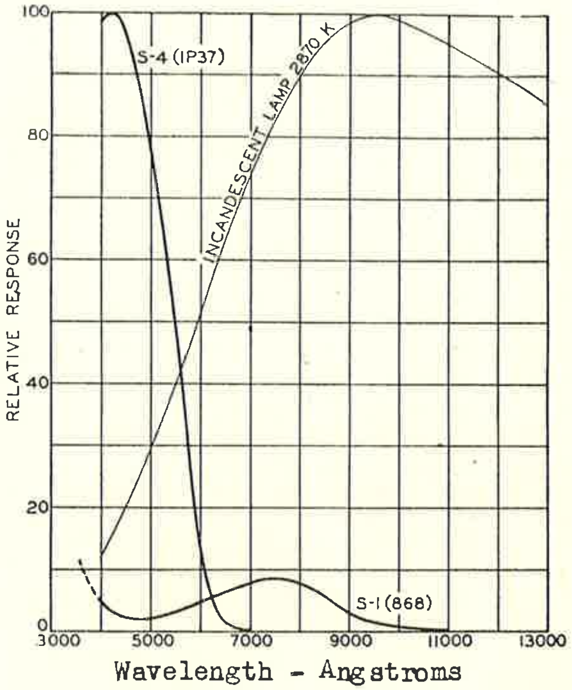


Fig. 1. Spectral response of S-1 and S-4 phototubes.

It is often suggested that the manufacturer publish data showing the range of the spectral sensitivity curves. Unfortunately as Fig. 2 shows, it is difficult to do this. The shape of the curves may vary widely. Such a condition makes it impossible to show the curves on a limit or range basis. As a degree of control it has been decided to show the range in the position of the major spectral maximum as the tubes are most commonly processed for maximum infrared sensitivity.

Since the furnishing of the spectral curve on a 100% basis is hopelessly impractical because of cost, filter data may be resorted to as a means of control either on a 100% basis or on a design basis. A table

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showing limits agreed to by the industry which will be published as JETEC (Joint Electron Tube Engineering Council of NEMA and RMA) Data is shown in Table 1. The limits appear wide and may be further narrowed as experience is gained. The extent of the problem is clearly evident from the data.

Table 1.
PER CENT RESPONSE OF PHOTOTUBE
Having Spectral Characteristics Identified by Symbol.

Corning Filter No.	S1	S3	S4	S7	S8
5113	0.05–2.5	1–4	2–15	0.2–1	1.5–6
3384 & 9780	1.5–8	9–35	15–40	8–15	15–45
3482 & 5850	40–75	3–32	0–1	32–55	1–6
2540	2–40	0–1	0–0.1	0.5–10	0–0.1

In addition to those shown in the table, other standardized surfaces which may be mentioned briefly are:

S-5 Ultra violet (Cs-Sb in 9741 glass)
S-6 Ultra violet (Sodium).

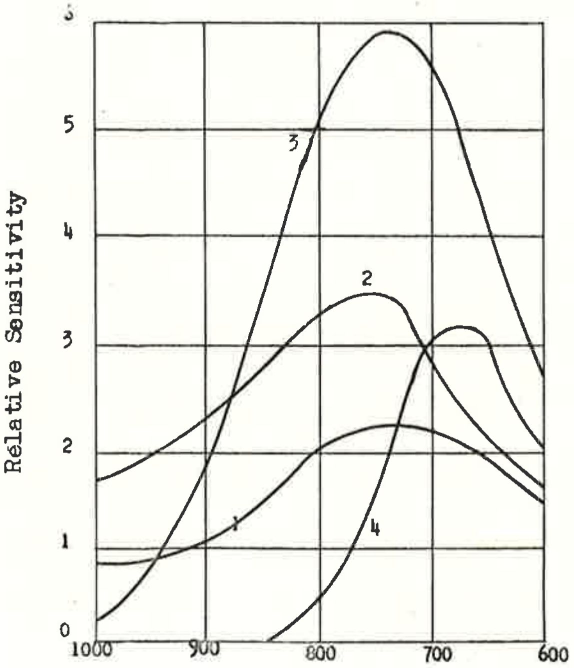

Fig. 2. Several spectral distribution curves of S-1 type phototubes. C. H. Prescott Jr. and M. J. Kelly, Bell Syst. Tech. J. 11.334 (1932).

3. Fatigue and stability

The chemical surfaces which are most sensitive for the photoemissive effect contain highly active elements such as caesium; in some cases also the uppermost surface layer is believed to be only monomolecular in thickness. For a number of reasons the photosensitivity is subject to fatigue with use. The magnitude of this effect varies with the severity of the operating conditions, and indeed differs considerably from one surface to another.

The S-1 type, in high vacuum, is much more subject to fatigue than the S-4 type which is remarkably stable, and if the nature of the light source available permits, the S-4 type should obviously be used. This is not yet generally appreciated by industry.

Fatigue of the S-1 surface with use is a function of a number of variables the chief of which is current density. The cause is believed to be a polarization or migration phenomenon since the sensitivity is almost always recoverable with storage treatment, with exposure to infrared radiation, or to moderately high temperatures. A non-recoverable loss in sensitivity may occur if the tube is subjected to excessive light energy so as to cause volatilization of the surface, and also in the case of gas-filled tubes there is the possibility of sputtering of the cathode surface by the positive ions. Recovery on standing of the S-1 surface, even though used in a gas-filled type, is still marked, however. Thus intermittency in use is an important factor. An example is encountered in sound-film service.

Early efforts to employ the caesium-antimony or S-4 surface in gas-filled tubes were unsuccessful but more recently a number of tubes have appeared on the market in which adequate stability has been achieved by special treatment as shown in Fig. 3. The stability is of the same order as that of the S-1 type.

In gas-filled types the positive ions acquire energy as a function of the applied voltage so that limitation of voltage is necessary for this reason as well as to limit regenerative amplification accompanied by gas breakdown. The industry is attempting to reach an agreement on maximum ratings which will state permissible current densities as a function of anode voltage for the various spectral types. Reference should be made to a paper by S. Pakswer[1] who summarized data available on this subject.

The phototube rating sheets are being expanded to give the user more idea of the capabilities of the tubes. In addition to the maximum average current rating, a rating is being established for peak cathode current density. This value determines the instantaneous capabilities of the tube, and gives more latitude to the user who contemplates the operation of the tube in intermittent duty. To be strictly correct, a maximum averaging time must be set up to accompany the peak and average ratings. This figure will probably be of the order of 30 secs.

4. Multiplier phototubes

The use of electron multiplier phototubes has developed widely since the end of the war. As the

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[1] S. Pakswer, "Factors Influencing the Life of Phototubes with S-1 and S-4 Response". Electronic Industries and Electronic Instrumentation, Vol. 1, No. 9, pp. 6-7, September, 1947.

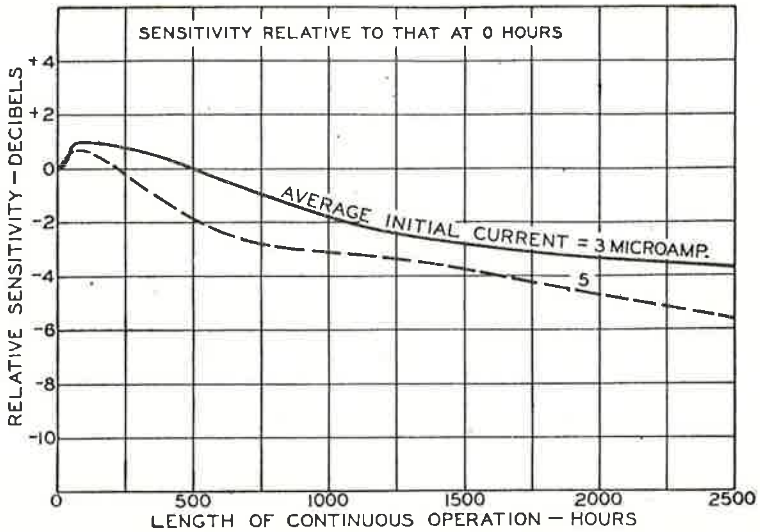


Fig. 3. Life data on 1P37.

user, and the manufacturer have learned more about the limitations of the multipliers more reliable operation has become possible. I doubt whether anyone would seriously consider designing a photoelectric spectrometer to-day which was not based on multiplier phototubes.

The limitations encountered in the use of multipliers are (1) spread in output due to the large variation in gain of the multi-stage secondary-emission amplifier (2) objectionable fatigue at current levels in the order of 1 milliampere. Many conservative designs employ an output current of the order of 10 to 100 microamperes. (3) Tube geometry limits the size of the light spot.

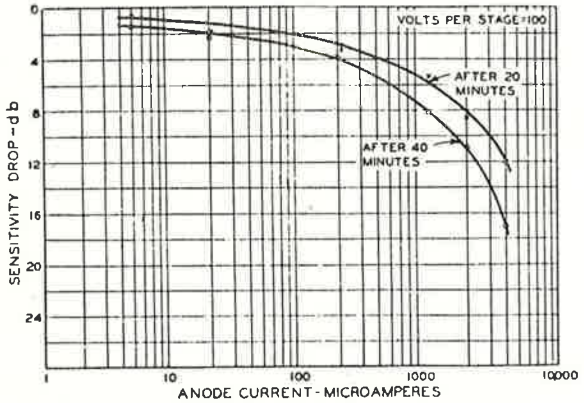


Fig. 4. Sensitivity loss in type 931-A.

The spread in output sensitivity may be of the order of one hundred or more between tubes. Fortunately this spread is not as difficult to handle as might be supposed. A change in the value of the voltage applied to the multiplier stages of 25% will accommodate a 10 to 1 spread in sensitivity. Such control thereby presumes the use of a well-regulated voltage supply controllable in output over a two-to-one range. Regulation of the order of one part in 10,000 is readily obtained by the use of voltage regulator tubes, or high-vacuum tube and regulator.

Fatigue may be subdivided into two parts, the first of which may be considered as a positive or negative change in output which is due to further distribution of the alkali metal employed in processing the tube. Such fatigue is usually irreversible. However, a decrease (with subsequent increase) on standing which is a function of output current occurs repetitively on intermittent use of the tubes. To our best knowledge this fatigue shown in Fig. 4 is so characteristic that the only reliable cure is to operate the tube at as low an output current as is required to hold the effect within the tolerable limit. Since this limit may vary widely from one application to another, the maximum current rating of the tube was set at a higher figure such as would be perfectly satisfactory in a pulse type or normally-off type of application. As experience has been gained articles have appeared advising users of the tubes on their limitations.

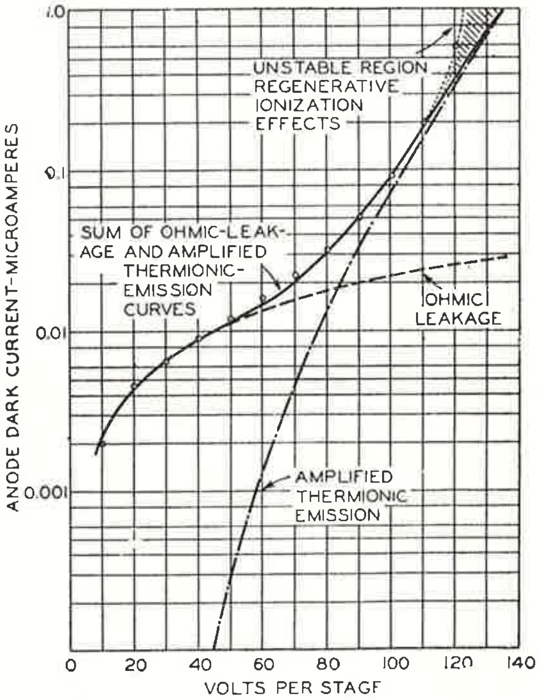


Fig. 5. Dark current in multiplier phototubes.

Most of such articles have appeared in the Journal of the Optical Society of America whose files should be consulted by anyone interested.

The geometrical limitation was not apparent in use of the multipliers in such applications as spectroscopy which employ collimated light beams. However, for nucleonic scintillation counters in which the light available is gathered from an extended source, a tube has been designed employing a large end-on type of cathode. Such a tube would also be useful to the industrial designer of X-ray thickness gauges. The larger area cathode immediately raises the problem of thermionic background current, however, so that the multiplier ratings and characteristics must specify such background as a maximum under the given rating conditions. The increase in light-gathering power must be sufficient to outweigh the objectionable increase in dark current.

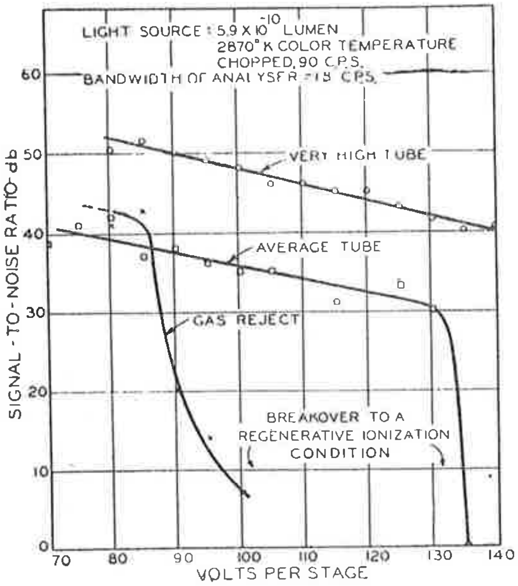
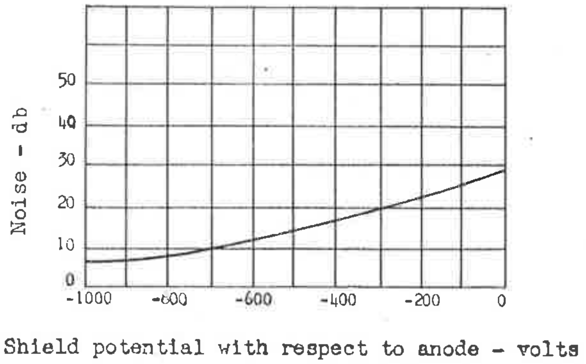


Fig. 6. Sample signal-to-noise curves for RCA multiplier phototubes.

In all photoelectric circuitry, the advantages of a.c. amplification are becoming increasingly apparent. If a modulated light source is employed the d.c. dark current background of the tube becomes unimportant since it is not coupled with the signal. A small-packaged, long life, and vibration-free light chopper would be much sought after by the control and instrumentation industry. There are occasional applications in which it is inconvenient or impossible to interpose a light chopper. In this case the background current of the photoelectric tube is the ultimate limitation to the user. Since this background is largely thermionic, or thin film leakage path in nature, refrigeration of the tube usually is well worthwhile although inconvenient in many cases. In many cases operation of the tubes at reduced voltages will result in a marked increase in signal/noise ratio because of the decrease in regeneration due to ion feedback.

Fig. 5[2] shows the contribution of the three important factors to the dark current of a multiplier phototube, namely: (1) ohmic leakage, (2) thermionic emission, and (3) regenerative residual gas ionization. The degree to which the latter can be almost completely eliminated is shown in Fig. 6 which indicates that by reduction of the overall voltage, a point is reached at which the signal/noise ratio improves markedly. The tube is, of course, normally rated so as to put voltage outside of the rating, but conservative operation would allow considerable safety factor.



Multiplier phototube type 1P21.
Amplifier bandwidth = 1.8 cps.
Volts/Stage = 100.
Load resistance = 0.1 megohm.
Volts between dynode No. 9 and anode = 100
Noise reference level = 1 microvolt.
Anode grounded.

Fig. 7. Noise reduction in multiplier phototubes by external shield in contact with glass envelope.

Over the past decade the characteristics of phototubes have been improved considerably. The S-4 surface has been a remarkable contribution for sensitivity; the multiplier has opened up a number of new fields of application. There always remains the possibility however that improved results can be obtained by the user with the current product. A striking example of this is shown in Fig. 7 in which the effect of eliminating glass-wall charges by metallic shielding is shown for the 1P21 multiplier.

A ten-fold reduction in noise background can be accomplished in many cases by this simple expedient. No doubt as this ingenious group develops further photoelectric applications, other discoveries of this nature will occur which will serve to expand the usefulness of photoelectric tubes.

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[2] R. W. Engstrom, J.O.S.A., Vol. 37, No. 6, 420-431, June, 1947.

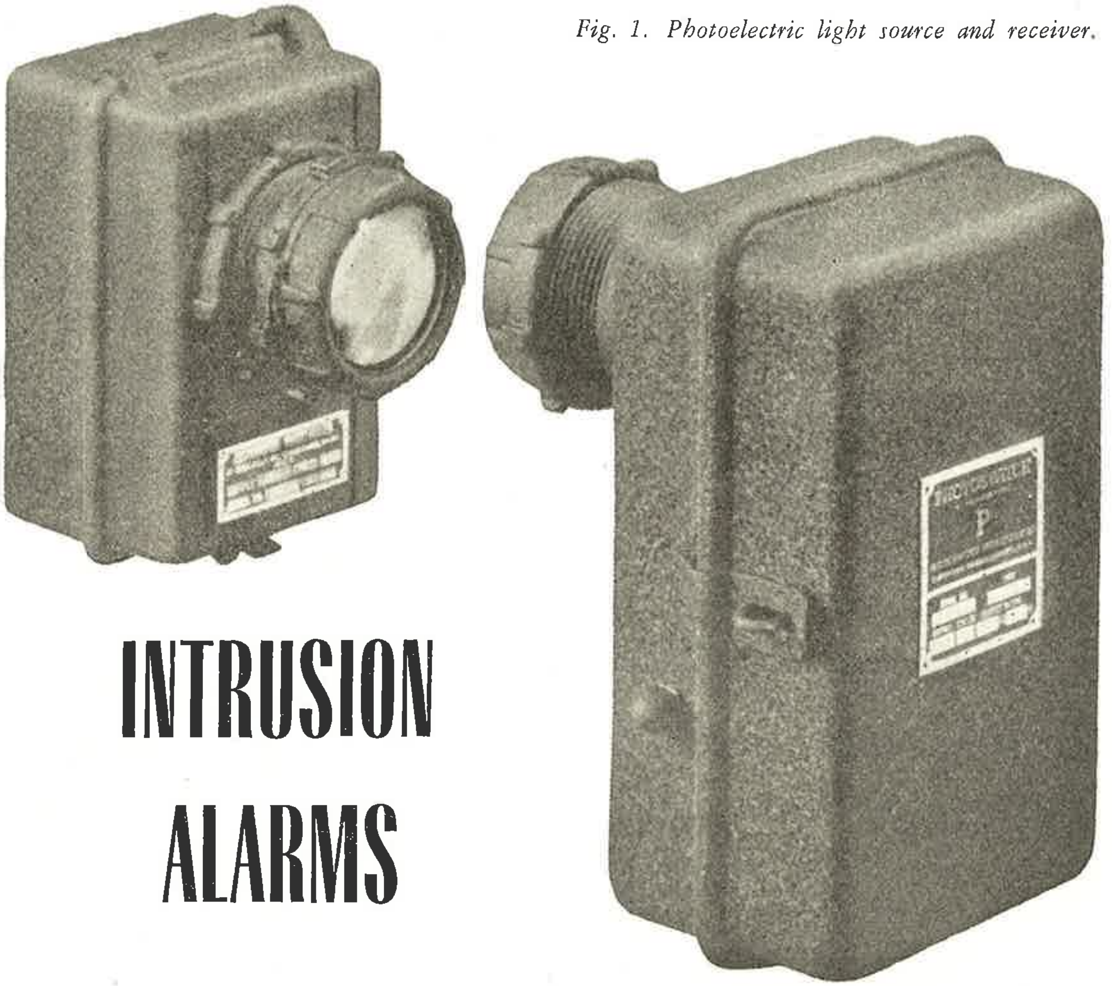

Fig. 1. Photoelectric light source and receiver.

INTRUSION ALARMS

By Clark E. Jackson

Electronics has stepped forward to guard home and factory against the intruder and his subversive activities. Electronic alarms operate tirelessly and are quick to respond. Installed and maintained properly, these devices which are not new to radio men possess none of the human tendencies toward distraction, inattention, and absenteeism. Nor do they need to "knock off" after an eight-hour shift. They function equally well alone or in conjunction with human watchmen.

In this article, we present descriptive material concerning a selected number of alarm devices which have earned recognition for alertness and long unattended service. We call attention to these circuits and systems, which are not our invention at all, with the hope that they will be useful to industrial technicians having charge of factory safety, home owners desiring to protect their premises from intrusion, and free-lance radio men and electricians desiring to build and install these alarms.

Types of alarms

Electrical and electronic intrusion alarms in regular use are generally to be found classified in one of the following groups: (1) Electric-eye systems, (2) Capacity-operated vacuum-tube relays, and (3) Directly-operated d.c. systems which depend upon light-pressure switch mechanisms for actuation. There are numerous other categories; however, a number of the unlisted types, while exceedingly clever in action, are at present so experimental in nature as unfortunately to rate the term "gadgets". The ingenious electrical reader will, in reviewing the systems described in this article, think readily of elaborations or simplifications of the schemes shown and will be reminded of applications other than those given.

The photocell or electric-eye type of burglar alarm is perhaps best known to the general public, chiefly because of the wide application and enormous publicity this method of operation has received. However elaborate the photocell system may be made, the fundamental operating scheme remains substantially unchanged — a light source, such as an incan-

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descent electric lamp of proper size directs a light beam upon the face of a photocell located some distance away. Currents generated by action of the luminous energy on the cell may then be utilized, either directly or through a vacuum-tube amplifier, to actuate a relay when the light beam is interrupted, as by the passage of an intruder across the beam. The relay in turn sets off a bell, horn, light, or other appropriate alarm to attract attention of the proper authorities.

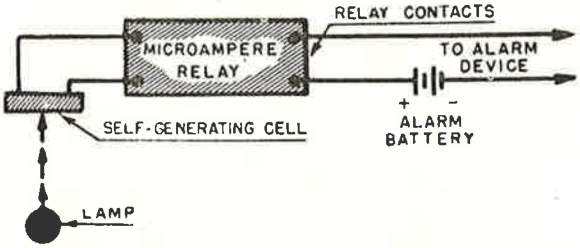

Fig. 2. Simple photocell circuit.

The manner in which the feeble light-generated currents from the photocell are utilized for turning on the alarm marks the difference between the various practical systems. Some of these systems will be more readily applicable to a particular installation than will others, this being a matter to be decided by the authorities in charge of the installation.

The simplest of all cells is the self-generating photocell. This type of unit delivers currents directly from the action of light and requires no polarizing battery or power supply for its operation. Figure 1 shows a rugged photocell alarm unit which is manufactured for industrial application. The light source is contained in one of the heavy metal housings, while the photocell occupies the other. Both light house and cell house are provided with glass or plastic windows, as will be seen from the photographs. This feature is particularly desirable since it prevents damage either to the lamp or the cell. In some outdoor installations where there is likelihood of fogging or soiling of the windows, the latter are provided with automatically-operated wipers of the windshield type.

Figure 2 shows the simplest possible photo-electrically-operated intrusion alarm. The lamp directs a light beam upon the face of the distantly-located self-generating cell. The tiny currents generated by this cell are then fed into a low-current d.c. relay which is designed to close on currents of a few microamperes. The "work" contacts of this relay close a local circuit consisting of a battery (or other appropriate power source) and the alarm device which may be a bell, siren, annunciator, or similar device.

The type of relay recommended for this alarm is one that is normally open. Interruption of the light beam will then cause this relay to close, thereby setting off the alarm signal.

Figure 4 shows a vacuum-tube circuit for utilizing a photocell of either the self-generating or voltage-polarized type (insert battery at X, Fig. 4, when cell is not of the self-generating type). Here, a larger-sized relay may be employed than in the previous circuit — one drawing several milliamperes. The relay is arranged in a four-arm resistance bridge circuit in the plate circuit of the tube, the tube plate resistance being one of these arms. With no current coming into the circuit from the cell, the system is balanced by adjusting *R*4. At balance, no current flows through the relay and its contacts are closed. When a light falls on the cell, the latter generates a current which by flowing through *R*1 sets up a voltage which is applied to the tube grid. The application of this voltage to the grid changes the value of the tube plate resistance, thereby unbalancing the bridge, and current flows through the relay opening the contacts. By choosing a relay with its contacts normally closed, the relay will be held open as long as the light beam impinges upon the photocell. But as soon as the light beam is interrupted, the plate-circuit bridge becomes balanced, current ceases to flow through the relay, and the relay arm is released to close the contacts and ring a local alarm circuit.

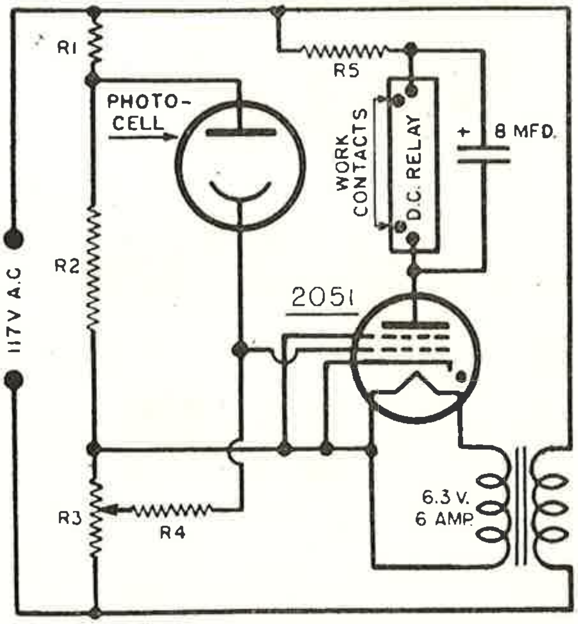

Fig. 3. A.C. operated photocell unit.

Vacuum-type photocell.
R_1 — *0*
R_2 — *20,000 ohm 1w.*
R_3 — *1,000 ohm 1w.*
R_4 — *5 megohms 1w.*
R_5 — *See text*
Gas-type photocell.
R_1 — *10,000 ohm 1w.*
R_2 — *9,000 ohm 1w.*
R_3, R_4, R_5 — *Same as above.*

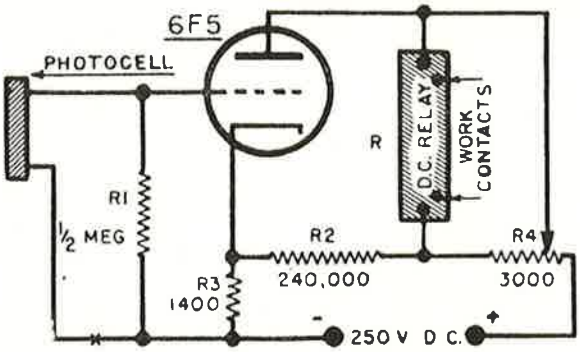

Fig. 4. Single stage photocell amplifier.

Figure 3 shows a circuit that makes use of a gaseous type tube. Due to the relatively high plate (anode) current with this type of tube, it becomes possible to use directly a relay of larger size than employed in the foregoing circuits. This relay may be rated as high as 25 milliamperes.

When set up this circuit is adjusted "in darkness" (e.g., without a light beam). The contact on *R*3 is set to a point where the plate current just ceases to flow and the relay closes. When a light beam is subsequently applied, cell current flows through resistor *R*4 producing a voltage drop which reduces the negative potential already on the grid of the 2051 tube. This results in the flow of plate current and the actuation of the relay. Resistor *R*5 is set, after adjustment of *R*3, to limit the plate current through the relay to a value within the maximum current rating of the relay.

An added advantage of this circuit, which is due to RCA, is the fact that all operating potentials are a.c. and are obtained directly from the power line without a rectifier-type of power supply. Either vacuum- or gaseous-type photocells may be employed in the circuit.

In any installation where the photocell currents are too feeble to actuate a relay or relay-tube directly, due to remoteness of the light source, a conventional d.c. amplifier employing two or more vacuum tubes may be inserted between the cell and the relay or relay-tube. This applies to any type of cell or relay system.

A complete line-operated system is illustrated in Figure 5 in another RCA circuit. In this arrangement, up to 30 milliamperes d.c. are available for relay operation and vacuum, rather than gaseous tubes are employed. A Type 919 photocell indicated in the input portion of the circuit actuates the grid of the small input pentode. The tubes recommended are 6SJ7 and 25A6 or their equivalents. The voltage divider resistor, shown between the two tubes, supplies both filament and plate potentials to the two tubes, no transformers being required. All the taps along this resistor (a high wattage bleeder type resistor with ring clips), except tap B, are to be adjusted, with the aid of a high-resistance-input d.c. voltmeter, to give the recommended cathode and screen voltages for the 6SJ7 and recommended screen voltage for the 25A6.

Multi-station alarm operation

Most buildings needing automatic alarm protection have several vulnerable points, such as doors, windows, aisles, etc., to guard. Obviously, it is convenient to install a photocell pickup at each of these points and to connect them all to an alarm system at a central guard room. In many cases this is done by the simple expedient of connecting the various pickup stations to the central point by wire lines. However, the running of such special lines becomes a sizeable task, to say nothing of the expense in sprawling buildings.

Where separate lines cannot be run to advantage, the writer recommends the employment of a carrier-current or "wired wireless" system for communication of the pickup station alarm impulses to the central watch room. Figure 7 illustrates one such pickup station, operating by feeding the radio wave into the regular power lines. These systems may be operated at low radio-frequency power at any selected frequency between 50 and 1000 kilocycles with excellent results. Each station may be set permanently, fixed-tune fashion, on its own operating frequency. Simple receivers, one for each station frequency, operate in the watch room from waves coming over the power lines.

The simple r-f oscillator comprising the transmitter at the pickup station (see Figure 7) is provided simply with two terminals for closing its B-plus circuit. The filaments are kept running continuously at all stations with low current consump-

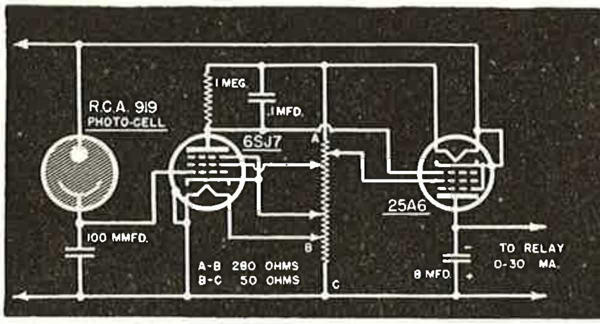

Fig. 5. Photocell operating 0–30 mA relay.

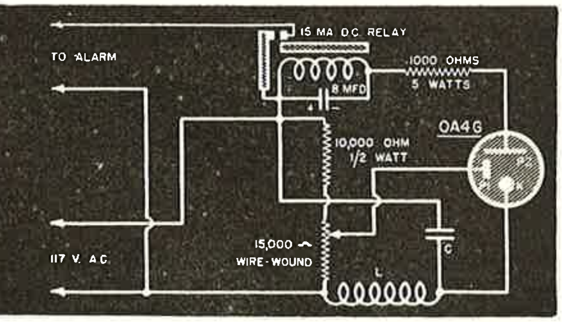

Fig. 6. Circuit diagram for carrier-current receiver.

tion and little impairment of tube life. The oscillator B-plus circuit is closed by the photocell relay, throwing the oscillator into operation and actuating the station signal by way of wired-radio back at the watch room.

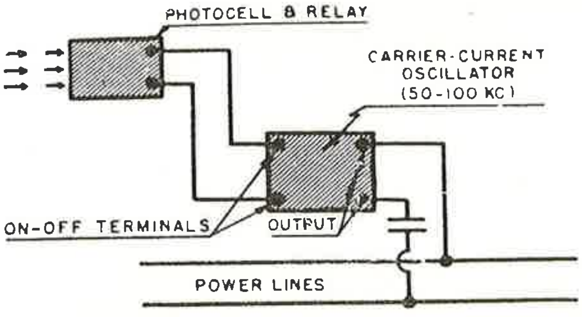

Fig. 7. Carrier-current oscillator.

A typical receiving station is shown in Figure 6. This circuit makes use of the type 0A4-G gaseous tube which has no filament and thus needs no filament transformer. Coil *L* and condenser *C* are chosen in value so as to be resonant at the frequency of the pickup station to which it is to be tuned. When the cold-cathode receiving circuit is placed into service, the line voltage is continuously applied to the tube anode P_1. The carrier voltage drop across coil *L* is applied in series with the cathode and P_1, increasing the negative bias across the tube. The starter-anode discharge is then initiated in turn initiating the main discharge in the tube and closing the relay.

The adjustment of the 15,000-ohm potentiometer is very important. This resistor is set at a point where the 0A4-G just "fires", and then the setting is reduced until the discharge is just extinguished. The latter point is correct for continuous operation.

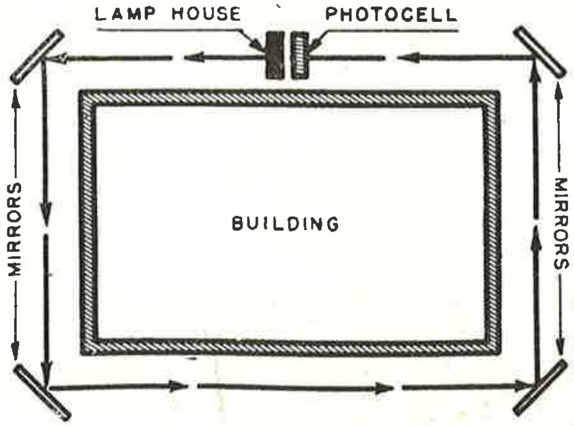

Fig. 8. Photocell guarded building.

Special light-alarm arrangements

From time to time, we learn of attempts to cover a wide area with the minimum of light-alarm protection equipment. Figure 8 shows one scheme rather widely used industrially. Here, a single photocell and lamp-house provide protection against intrusion along any door or window at a particular level all around a building. Mirrors placed at an angle at each corner of the building reflect the light beam, causing it to travel along all four sides of the building. The only "blind spot" is directly in the space occupied by the lamp-house and photocell, but this is an area of only a few square inches, being equal to the size of the two units. Further safety, over and above that provided by the thinness of the instrument housings might be obtained by placing the units along a "dead" portion of the coverage area, i.e., at a point where there are no points of entry into the building.

Obviously, the success of any photoelectric alarm system depends upon inability of the intruder to see the light beam and to escape it by stepping over or crawling under it, or to pinch-hit for the beam with his own flash-light. The scheme illustrated in Figure 10 aims to make the system more foolproof by covering as much area as possible at a point on entry, making it difficult, if not impossible to evade the light beam which is reflected successively by a number of mirrors. Lamphouse, mirrors, and photocell may be concealed by recessing each of these units into the woodwork of the door or window frame and covering them with thick glass windows.

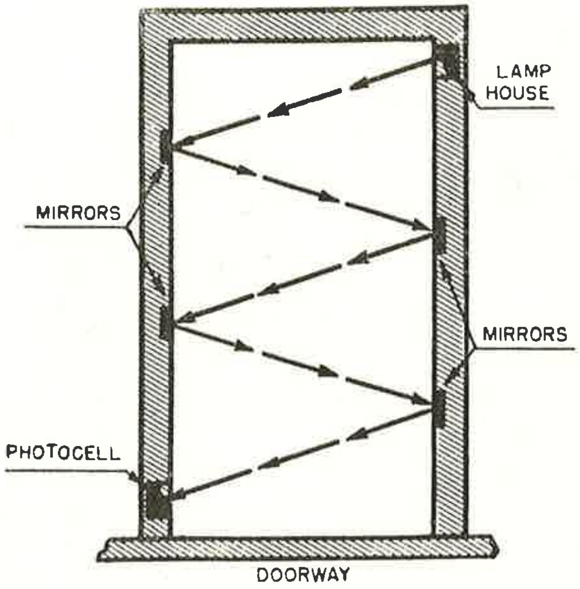

Fig. 10. Doorway protected by photocell.

Another alternative consists in obtaining special photocells which have very high sensitivity and are thus capable of operating under action of a light beam too faint to be discerned readily. Or special photocells with increased response in the ultra-violet or infra-red regions might be employed.

Capacity-operated relay

Especially useful because of its foolproof qualities and the possibility of its complete concealment, is

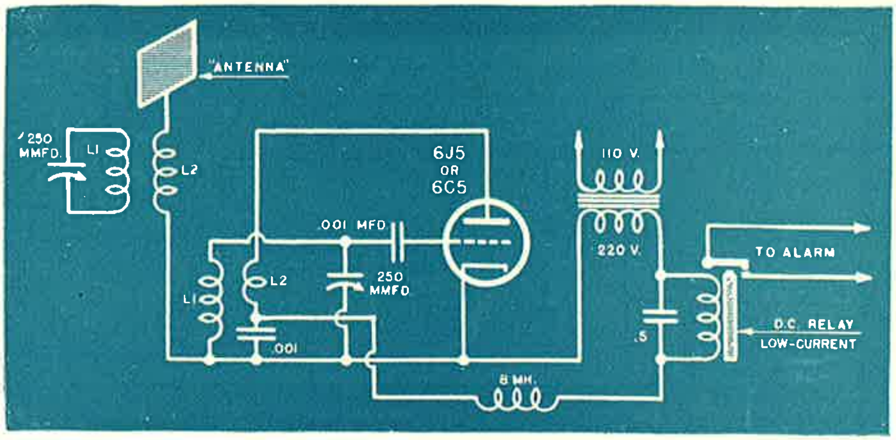

Fig. 9. Schematic diagram of capacity type alarm unit.

the capacity-operated intrusion alarm. With this system in operation, there are no light beams or other visible media with which the clever mind of the intruder may reckon. The mere presence of his body sets off the alarm.

A typical capacity-operated relay is shown in Figure 9, as one of the numerous circuits now in operation. This arrangement is a hypersensitive oscillator of the blocked-grid type. Relay action is obtained whenever a nearby conductive body moves close to the sensitive plate labelled "antenna" in Figure 9. This antenna may be a metallic plate of any size. It might consist of a square of metal screen or metal gauze hidden under a rug. Or it might be a grid of wires concealed within the woodwork of a door or window frame. Likewise, the antenna might actually be a piece of secret machinery which is to be guarded.

A simple triode, such as a 6C5, 6J5, or even a 117-volt type with screen and plate tied together is employed without grid leak. No rectifier tube is required, the instrument operating directly from the power line. The coupled coils *L*1 and *L*2 are ordinary t.r.f. broadcast coils. And the condensers connected in parallel with them are set so that the circuit is just on the verge of oscillation. Any small additional capacitance, such as that introduced by a body approaching the sensitive plate antenna, will be sufficient to spill the circuit over into oscillation and close the plate-circuit relay.

Success of the circuit is due to absence of a grid leak. On each positive half-cycle of excitation, the grid collects electrons; and since there is no grid resistor path for these electrons, the negative charge they produce on the grid soon reaches a value sufficient to cut off the plate current.

Like the photocell pickup station described earlier, a number of capacity-relay pickup stations may be installed at strategic points about a building and their impulses may be piped to a central watch room either over direct wires or by means of wired radio.

Capacity-operated relays may be adjusted for such sensitivity that they will operate alarms positively when an approaching body is several feet distant.

New Publications

"TELEVISION RECEIVING EQUIPMENT" by W. T. Cocking, M.I.E.E., 3rd edition. Published for "Wireless World" by Iliffe and Sons Limited, on December 6th, 1950. Size 8¾" x 5½" (D8vo). 375 pages with 284 diagrams and photographs. Cloth bound with jacket.

Probably no branch of modern engineering is developing so rapidly as television; its technique advances steadily almost from month to month. This important book, now in its third edition, has become known to television engineers the world over as an authentic and comprehensive guide to British practice. The Author, Editor of the "Wireless Engineer", and well-known also to readers of "Wireless World" has revised the work thoroughly and brought it in line with the very latest developments.

The book assumes a fair knowledge of ordinary sound radio technique on the part of the reader, for without this grounding he will make little headway in the study of television. After explaining the fundamentals of the subject, it goes on to deal with practical details of receiver design. The text is largely non-mathematical in treatment, but mathematical matter of particular value to the designer has been collated and appears in appendices.

Apart from the exhaustive and lucid description of each stage of the normal television receiver, details of special circuits are included, and there are additional chapters devoted to faults and their remedies and to servicing modern sets. Another chapter of outstanding interest discusses the problem of obtaining selectivity, an increasingly important matter with the expansion of the B.B.C. service and the adoption of vestigial-sideband transmission.

Our copy received with the compliments of the publishers.