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# Recent developments in cathode ray tubes and associated apparatus†

By Allen B. DuMont

THE past year has seen a growing interest on the part of engineers in the use of cathode ray tubes for all types of analytical measurements and also for numerous industrial applications. In order to make the cathode ray tube generally more useful it was felt that the life could be considerably improved as well as the uniformity of the tubes. Furthermore any increase in the brilliancy of the spot obtained would facilitate their use in a number of applications. The use of these tubes commercially calls for a tube which is rugged mechanically and which can be operated from equipment which is reasonably foolproof as to adjustment. In this paper it is proposed to discuss the essential characteristics of the cathode ray tubes as well as the essential equipment necessary to operate them.

### Tube Characteristics

The requirements of tubes used for oscillograph and allied work may be summarized as follows:

1. They should reproduce with fidelity the observed wave.
2. The threshold effect should be at a minimum.
3. They should give a brilliant spot on the fluorescent screen.
4. The spot should be regular in shape over the entire screen.
5. It should be possible to focus the spot to any desired size.
6. Maximum sensitivity is desirable.
7. There should be a minimum current across the deflection plates.
8. The trace should not blur at high frequencies.

Although special uses may call for more attention to one or more of the preceding requirements if these are met a satisfactory tube for general use will be obtained. Before going into detail on these various points it might be well to mention that experience has shown that a number of screen sizes were necessary. Fig. 1 shows cathode ray tubes having 2, 3, 5, 7, and 9 inch screens. In order to simplify classification of these various tubes it was decided to designate each tube by a two-number combination the first number representing the diameter of the fluorescent screen and the second numeral the number of deflection plates in the tube. Hence a tube with a 3-inch screen and four deflection plates is known as a type 34 tube and one with a 9-inch screen and no deflection plates is given the type number 90.

### Fidelity of Observed Wave

In order to obtain fidelity in the observed wave the deflection plates of each pair should be parallel to each other and the same size. Each pair of deflection plates should be at right angles to one another. The leads supporting the deflection plates should be so positioned that they do not exert any appreciable deflection on the beam. The distance between each pair of deflection plates should be calculated so that the sensitivity is the same along the X and Y axis. This can be obtained by the use of the following formula:

$$h = \frac{ElL}{2E_a d}$$

where

h = Deflection in cm.

E = Volts difference between the deflection plates.

$E_a$ = Accelerating electrode volts.

l = Length of deflection plates in cm.

d = Distance between deflection plates in cm.

L = Length from center of deflection plates to screen in cm.

Hence by having a slightly greater separation between the lower deflection plates than the upper plates the same sensitivity can be obtained along both axes. It is also important that the

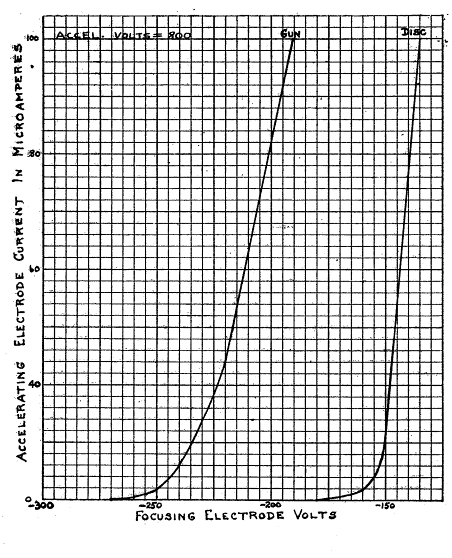
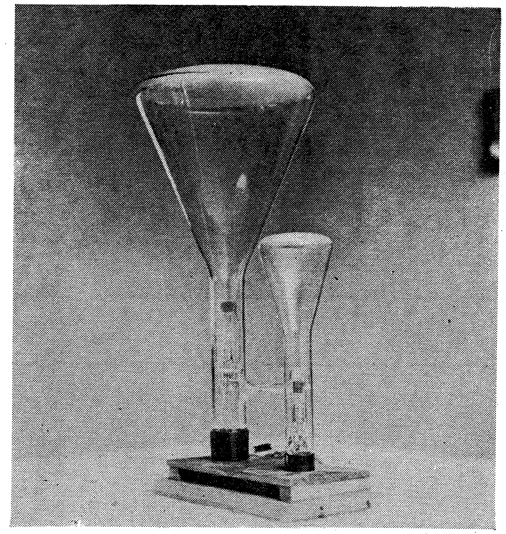



Fig. 3. Focusing electrode bias.

†*Presented before the Radio Club of America, January 18, 1933.*

screen be smooth and have the same radius of curvature as that of a sphere having its center at the top of the accelerating electrode. In designing the mount which would accomplish the desired results a number of tests showed that by using a suitable mounting jig and assemblying all the elements from a common press greater accuracy could be obtained than by taking the connections out separately from the side of the envelope. In the first case after the mount was assembled it could be sealed in without disturbing the elements while in the second case too much responsibility is put upon the glass blower to line up the various elements. Fig. 2 shows tubes with a three and a nine inch screen using this design.

Fig. 2.



## Brilliance of Spot

The brilliance of the spot is determined by a number of factors. Among these are the chemical composition and particle size of the fluorescent screen used. Willemite and calcium tungstate are the two most commonly used salts. The former gives a green color which is probably the best for visual work while the calcium tungstate gives a blue color which is better for photographic work. By using a screen composed of a mixture of these two salts a very satisfactory screen can be obtained which is good for both visual and photographic work. At low accelerating electrode potentials the screen gives a light green color which changes to a white as the accelerating electrode voltage is increased. With the developments in films the importance of the special screen for photographic work is considerably reduced and we have found that by using verichrome film better results can be obtained using a combination screen, than when using calcium tungstate and the older type films which were quite sensitive in the ultra-violet region but not so sensitive to the longer wavelengths. Generally speaking, the larger the particle size of the salt the more brilliant the spot but, of course, a balance has to be worked out between brilliance and the permissible coarseness or texture of the screen. Some other salts tried with some success are calcium fluoride, phosphorescent calcium sulphate and phosphorescent calcium tungstate. In connection with a particular application calling for the development of a time delay salt we have been able to work out a screen which gives a white spot of from two to three times the brilliancy of any of the screens mentioned. This particular screen is satisfactory for any of the present uses and in addition will retain the trace for as long as one minute and a half after all voltages have been removed when used in a darkened hood or room. However, the spot is so intense that the phosphorescence does not bother the tube when used for any oscillograph application. The phosphorescence itself is bright enough to be readily seen. Another important factor effecting briliancy is the design of the accelerating electrode. One of the simplest and most effective accelerating electrodes is a disc with a hole in the center placed between the focusing electrode and the bottom set of deflection plates at right angles to the direction of the beam. If the hole is sufficiently large practically the entire beam passes through it and a sharp, well defined spot of excellent brilliancy can be obtained. An accelerating electrode consisting of a cap with a small diameter gun attached to it has proven useful when an extremely fine trace is desired. This construction, however, does not allow all the electrons in the beam to pass through it, a number being masked off by the cap. The first construction mentioned normally has a current to the accelerating electrode of approximately 30 microamperes, while the last mentioned construction has a current of about 50 microamperes to give the

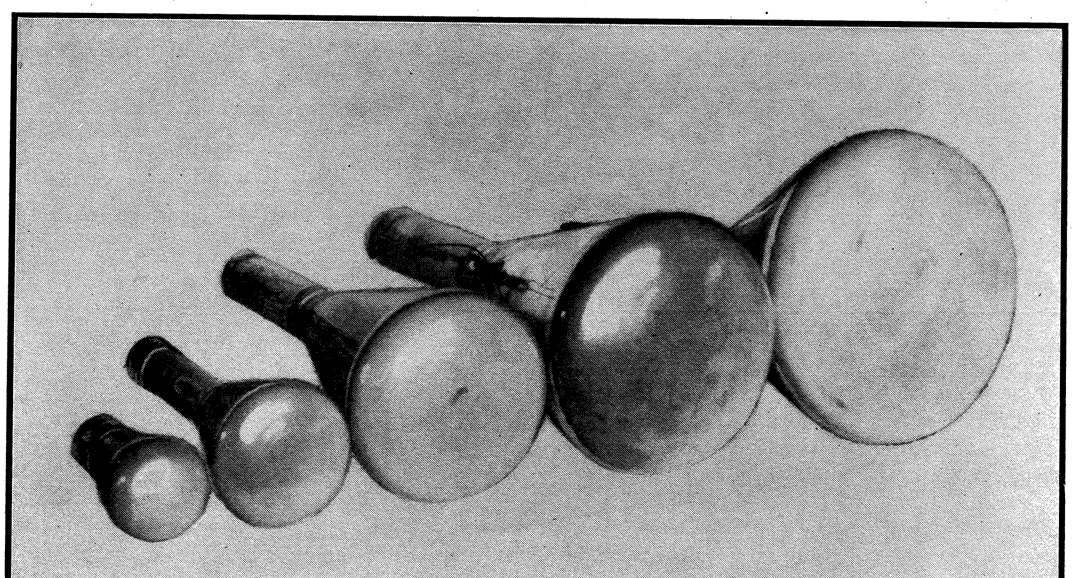


Fig. 1.

same brilliancy. The characteristic curve of accelerating electrode current versus focusing electrode bias for the two constructions mentioned is shown in Fig. 3. These curves were taken on a type 34 tube with an accelerating voltage of 800. The amount of air or gas in a cathode ray tube also has much to do with the intensity of the spot. Tubes with a considerable amount of gas give a poorly defined spot and low brilliance. The factors discussed assume that the accelerating electrode voltage was the same in all cases. As this is increased the intensity increases approximately proportionally to the square of the accelerating voltage, since the fluorescent action depends upon the velocity of impact of the electrons onto the fluorescent screen.

## Focus

The design of the filament, the shape of the focusing electrode and the pressure inside the envelope are the main points to be considered in connection with focusing the beam of electrons to a point. The spot obtained is the same shape as that of the coated or active part of the filament. The three elements of the cathode ray tube, namely, the filament, focusing electrode and acclerating electrode concerned with the generation, focusing and acceleration of the electrons combine to act in a manner quite similar to that of a pin-hole camera. Hence it is possible to obtain a round spot, a square spot or a spot of any shape depending upon the design of the filament. With reference to the filament the ideal condition is to use a point source of electrons although it is possible to use a large area filament or cathode and concentrate or mask off a portion of the beam to obtain a fine spot. For oscillograph work the focusing electrode is usually in the form of a cylinder surrounding the filament. Fig. 4 shows how the beam may be concentrated by increasing the bias on this electrode. Fig. 5 is a curve on a type 34 tube which shows the bias necessary to obtain a sharp spot at various accelerating electrode voltages. The function of gas in the tube is twofold. It provides a path for the charge to leak off the fluorescent screen and it also causes the beam to converge as it approaches the screen. Fig. 6 shows this effect. Fig. 7 shows the beam spread out by the application of an a-c. voltage to the lower set of deflection plates. While on the subject of focusing it might be worthwhile to mention a few things which can affect the sharpness of the spot in ordinary operation.

1. Filament current too high causes halo around spot.
2. Insufficient bias to focusing electrode causes halo around spot.
3. Filament current too low causes large weak spot.
4. Too high a bias on focusing electrode causes large weak spot.
5. A-C. ripple in accelerating electrode voltage supply causes radial line instead of spot as beam is moved from normal center position.
6. Unshielded stray fields cause distortion of spot.

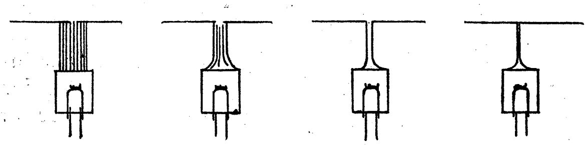


Fig. 4.

## Effect of Gas

Although a certain amount of gas is useful as previously explained, if the pressure exceeds a few microns certain undesirable characteristics come into play. Too high a gas pressure increases the current across the deflection plates. It also limits the frequency at which the tube can be operated. In practice it has been found possible by careful regulation of gas pressure to extend the upper limit of frequency to well over 4 megacycles without having the trace become blurred due to the lateral speed of the beam moving faster than does the ionized gas. Another effect of too high gas pressure is the increase to objectionable proportions of the so-called "threshold effect." That is, the deflection produced by small voltages applied to the deflection plates is not at as great a rate as when higher voltages are applied. Fig. 8 shows the current across the deflection plates versus the deflecting potential, and Fig. 9 shows the curve of beam deflection versus the deflecting potentials. These were taken on a type 34 tube operating with 800 volts on the accelerating electrode.

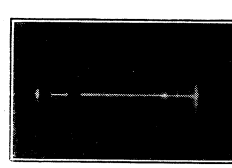


Fig. 6. Function of gas.

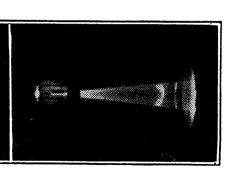


Fig. 7. Beam spread cut by application of voltage to lower plates.

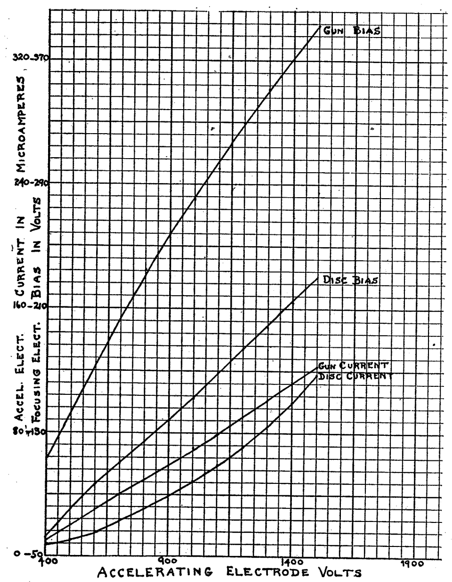



Fig. 5. Curve of type 34 tube, showing bias necessary to obtain a sharp spot at various accelerating electrode voltages.

## General

The life of cathode ray tubes has been somewhat of a problem although a large number of tests to determine just what factors determine life have shown that it is entirely practical to design and build these tubes so that consistent and satisfactory life can be obtained when they are operated in suitable equipment. The two major problems have been deterioration of the filament coating by bombardment, and a gradual change in pressure in the tube either caused by the clean-up action of the high voltage or by the liberation of gas from the elements of the tube. The first problem can be eliminated by correct design of the electrodes to reduce positive ion bombardment to a minimum and at the same time use a coating which mechanically withstands this bombardment. The second problem has also been solved by the application of proven vacuum tube exhaust technique.

Because of the wide and dissimilar applications of the cathode ray tube it was soon apparent that no one tube would answer all requirements. To date four different screen sizes have been standardized, namely tubes with 2, 3, 5 and 9 inch screens. The 2 inch screen type is useful for moving film recording where only one set of deflection plates is used, and a number of these can also be used in certain applications to do similar work to the multi-string oscillograph. The three inch screen size type 34, is an economical tube suitable for factory measurements, industrial applications and general laboratory work. The intensity at a given accelerating voltage is somewhat better than the 5 or 9 inch types and because of this, with a given intensity of spot the sensitivity, is approximately the same as with the larger screen types. The larger screen types of necessity must have a longer L value and the slowing up of the beam in the additional distance from the accelerating electrode to the screen accounts for this.

The 5 inch type is mainly used for laboratory determinations where a larger trace is necessary. Certain applications where the tube is used for time interval determinations also require a larger trace. The 9 inch tube has its main use for demonstration purposes although several applications require its exceptionally large screen.

All of the types mentioned can be operated interchangeably from a standard power supply and the prongs of the base fit into a standard six prong socket. The filaments of all tubes consume 1.3 amperes at .6 volt, and heat up in three seconds.

## Associated Equipment

In order to realize the full possibilities of the cathode ray tube when used for oscillograph work, it is necessary to provide a power supply which will supply all the required voltages and which is easily adjustable to accommodate the tube to the optimum conditions under test. Although for many applications this is all that is required, a sweep circuit to provide a linear time axis is extremely useful for the accurate study of waveforms and other periodic phenomena. Fig. 10 shows a complete power supply and sweep circuit unit. The power supply being contained in the case nearest the shielded cathode ray tube holder, the sweep circuit contained in the other case.

In Fig. 11 is shown the diagram for the power supply unit. Provision is made for adjusting and checking the filament current. The voltage to the focusing electrode is continuously variable to control the size of the spot, and the voltage to the accelerating electrode is also continuously variable to control the brilliance of the spot. However, when using voltages on the accelerating electrode, over 1,500, this arrangement is not very practical, and separate rectifiers supply the voltages to the focusing and accelerating electrodes.

The sweep circuit as shown in Fig. 12 provides a linear time axis which may be made to sweep from one to 5,000 cycles per second. The power supply contained in this unit furnishes all the necessary voltages for the sweep circuit except the bias voltage of the mercury vapor discharge tube which is obtained from a standard 4½ volt C battery. The linear sweep frequency is obtained by charging a condenser through a constant-current device. The actual device used is a screen-grid tube operated with the plate voltage well above the screen voltage so that the plate volts versus plate current curve is practically flat over the working region. This arrangement secures not only ease of control (varying grid bias) but also comparative freedom from line voltage variation. The "quick return" discharge is obtained by means of a mercury vapor discharge tube. The use of this tube permits controllable amplitude and ideal synchronization. The unit has the following controls:

1. Position control. A potentiometer arrangement enables the figure to be centered on the screen and moved to any desired position.

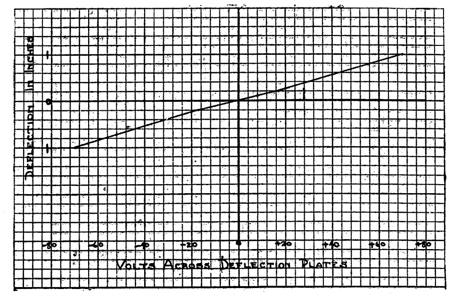



Fig. 9. Beam deflection versus deflection potentials.

2. Amplitude control. The mercury vapor discharge tube flashes at an anode voltage determined by the bias on the grid of this tube. This control varies the grid bias.

3. Frequency control. A fine, and a rough frequency control are provided. The rough control selects one of five condensers for the plate circuit of the screen-grid tube. The fine adjustment is obtained by varying the bias of the screen-grid tube.

4. Synchronization control. A suitable portion of the voltage of the wave under investigation is fed to the grid of the mercury vapor discharge tube by means of a variable resistance, causing the tube to trip in step with the frequency of the wave under investigation. When this voltage is strictly recurrent a locked or stationary picture is obtained. This control can also be used for tripping a single traverse to record transient phenomena.

It is possible to combine these two units and obtain both the voltage for the cathode ray tube and sweep circuit from one common power supply. However, in this case it is not practical to use as high voltages on the cathode ray tube as with the separate units. Fig. 13 shows one of these combination units. Its main value lies in its portability and it is very satisfactory for all types of visual observations, the limited accelerating voltage, however, somewhat restricts its use for high speed photographic recording.

## Classification of Applications of the Cathode Ray Tube

The applications of the cathode ray tube may be roughly grouped into three classifications.

1. Applications requiring a time base.
2. Applications not requiring a time base.
3. Applications requiring some independent base other than time.

The applications requiring a time base comprise the general study of waveform. Across one pair of plates is placed a time base potential. This is such as to cause the spot to move forward and backward over a straight line in a known manner. Across the

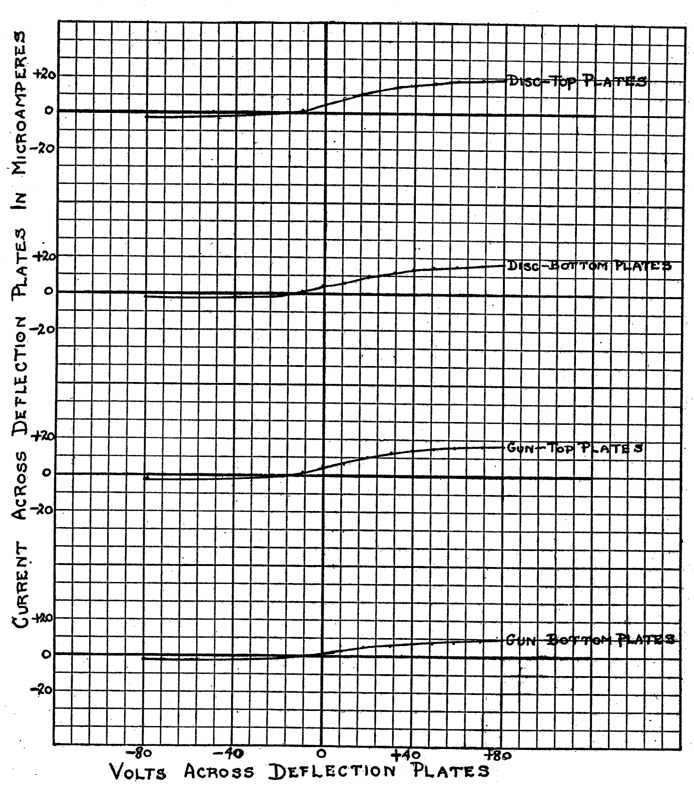



Fig. 8. Current across deflection plates versus deflecting potential.

other pair of plates the voltage under investigation is applied. For some purposes a convenient time base is provided by the 60-cycle mains, but more generally the time base makes its excursion at a uniform speed and then restores rapidly. The apparatus described provides this type of a time base.

When the time base is linear the picture or figure that appears is the wave shape of the voltage examined. With a non-linear time base the wave shape is distorted, but if only the middle portion of a sinusoidal time base is used, this distortion is not particularly bad. The method of investigation of wave shape against a time base applies equally to transient as well as periodic phenomena.

Some periodic phenomena which may be studied are:

Waveform studies on alternators, transformers, ripple on d-c. supplies (generators and rectifiers).

Waveform studies of tube oscillators and amplifiers.

Measurement of percentage modulation.

The transient phenomena possible to study include:

Making and breaking of circuits, current and voltage waveforms.

Study of electric sparks.

Static or local interference.

Physiological phenomena such as heart beats or nerve response.

Measurement of explosive and acoustical pressures.

A hybrid case lying between the two groups is the study of the waveform of speech and music and also the case where the voltage takes the form of modulated r-f. In the latter case if the time base is set for observing the lower frequencies the r-f. waveform will be so congested as to give the appearance of a solid figure. The fine structure of this, however, can be seen by speeding up the time base.

## Use of Time Delay Screen

With the new time delay screen it is also possible to readily measure time intervals without the use of a moving film camera. A suitable timing pulse is put across one pair of plates and the focusing voltage biased so no spot is seen. The device or wave to be measured is then connected so that at each impulse the focus bias is decreased so that the spot shows and remains on the screen for about one minute. Hence, the distance between the spots can be measured and the time between pulses determined. In some cases it is desired to measure the time at which certain waves reach given devices and the shape of the wave identified. In this case the voltage of the wave is placed across the other set of deflection plates and the time interval is determined in the same manner as previously.

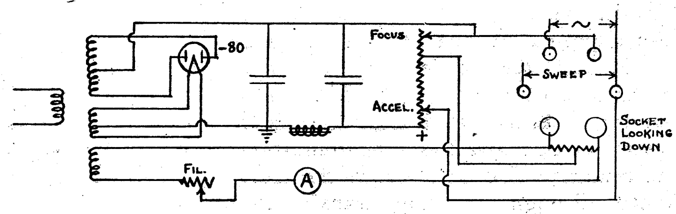



Fig. 11. Diagram of power supply.

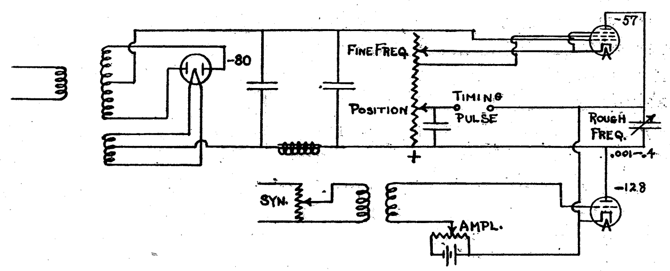



Fig. 12. Diagram of sweep circuit.

Another use of the time delay screen is for comparison of given figures. It is possible to put one figure on the screen and then another one over it or in any desired position. With ordinary fluorescent screens it is impossible to see the wave shape of phenomena occuring at rates below approximately one-sixteenth of a second. The time delay screen allows heart beats to be visualized as well as starting curves of motors, etc. In the study of high-speed transient phenomena the present practice is to photograph the transient, as the eye is not able to retain an impression long enough to arrive at conclusions. The time delay screen permits these to be readily observed.

## Applications Not Requiring a Time Base

The applications not requiring a time base include the investigation of current and/or voltage relationships in electrical circuits, wherein both pairs of plates derive their deflecting voltages from the circuit itself. Some examples are:

Observation of tube characteristics either static, dynamic or oscillating.

Comparison of input and output of amplifiers and transformers.

Studies of phase relationship.

Properties of dielectric and magnetic materials.

Radio direction finding.

Frequency comparisons.

Studies of modulation and detection including maintenance and fault-finding on radio transmitters.

Monitoring on radio broadcasting, talking motion picture and phonograph recording.

Voltmeter with extraordinary h-f. range.

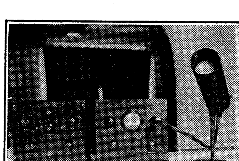


Fig. 10. Power supply and sweep circuit unit.

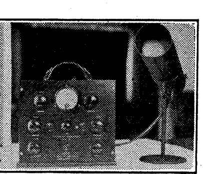


Fig. 13. Combination, portable set.

## Applications Requiring Some Independent Time Base

Certain applications arise in which a base deflection is required which is not provided by the circuit under investigation and is not a simple time base. Such cases arise whenever it is necessary to graph an electrical quantity against a variable, other than time, and which is not directly obtainable from the circuit itself. The most important variable is frequency. For example, it might be required to make the oscillograph show the frequency response curve of, say, a band-pass filter. We would need first an oscillator of variable frequency and constant output, or at any rate we would need to know the output as a function of the frequency. The output from the filter would be applied to one pair of plates. To the other pair we would have to apply a voltage representing frequency to some known scale; a matter which could be arranged either mechanically or electrically.

## Photographic Recording

The methods commonly used to record waves or figures drawn by the cathode ray tube may be classified into two general classes. The first method is to use an ordinary camera, focus it on the screen of the tube and expose the film. The time of exposure depends upon the brilliance of the trace, the size of the figure and the rate of movement of the spot. This method is satisfactory for stationary figures or for recurring phenomena. Fig. 14-A is a photograph taken showing an a-c. wave across one set of deflection plates. Fig. 14-B shows the trace caused by an a-c. voltage on each set of plates, the voltages being out of phase. Fig. 14-C is the same but with a greater phase difference between the two voltages. These were taken with a standard

Graflex camera using Verichrome film. An exposure of one half second was used with the accelerating electrode voltage only 500 volts. Fig. 15-A shows an a-c. wave as traced using the linear sweep circuit and the synchronization adjustment. Fig. 15-B shows the same wave through a cheap transformer. These were also time exposures of the same length of time. By increasing the voltage to the accelerating electrode it is possible to photograph in considerably less time. For instance, with 2,000 volts on this electrode successful photographs were taken in one thirtieth of a second with an F11 opening of 16 cycles of a 1,000 wave covering an area on the screen approximately 2½ square inches.

The second method for photographic recording is mainly used for non-recurring phenomena. The wave is applied across one set of deflection plates and the spot is focused onto a moving film which supplies the time axis.

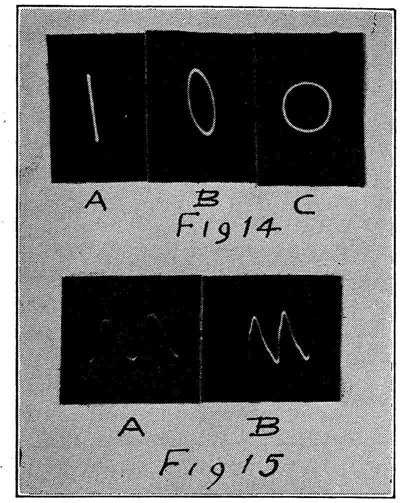



**Fig. 14.**
A. A-C. wave across one set of deflecting plates.
B. Trace of a-c. voltage on each set of plates.
C. Same as 14B, but with greater phase difference between the two voltages.

**Fig. 15.**
A. A-C. wave using linear sweep circuit and synchronization adjustment.
B. Same as 15A, but through a cheap transformer.

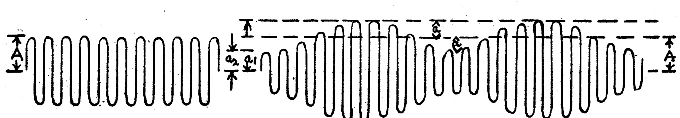


Fig 16 Fig 17

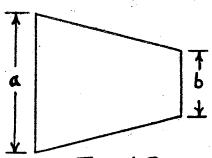



Fig 18

Figs. 16, 17 and 18.

## Some Present and Future Applications Checking Percentage Modulation

The cathode ray tube lends itself very nicely to modulation studies and the determination of the percentage modulation of a transmitter. This determination may either be made with or without a sweep circuit. In the first case a constant amplitude and frequency signal is used to modulate the transmitter. The sweep circuit is then adjusted so that the modulated r-f. wave applied across one set of plates is stationary, and synchronized on the screen of the tube. Percentage modulation is the ratio, expressed in per cent, of the amplitude of a sinusoidal modulating signal wave to the amplitude of the carrier wave. This is illustrated in the following figures. Fig. 16 shows the unmodulated radio-frequency carrier wave, having an amplitude of A. Fig. 17 shows the same carrier wave, modulated at audio-frequency which results in a maximum amplitude of $a_1$ and a minimum amplitude of $a_2$. The percentage modulation is then

$$\frac{a_1 - a_2}{2A} \text{ X } 100.$$

This is equivalent to considering the envelope as an alternating current having an amplitude of (a) superposed on the carrier of amplitude A, as shown in Fig. 17. The per cent modulation is then

$$\frac{a}{A} \text{ X } 100.$$

The modulation becomes 100 per cent when the amplitude $a_2$ becomes zero, that is when the amplitude of the audio-frequency wave (a) becomes equal to that of the carrier A.

The second method which does not use a sweep circuit has one disadvantage in that any phase shifting makes determinations rather difficult. In this method the modulating voltage (a-f.) is put on one pair of plates, and the modulated r-f. across the other pair; then, provided no phase shift occurs, the resulting figure should be a solid trapezium; at least the sloping sides of this figure should be linear so long as the modulation is linear. Fig. 18 shows the shape of the figure. Where

$$\text{Percentage modulation} = \frac{a - b}{a + b} \text{ X } 100.$$

With undistorted, complete modulation, the resulting figure is an isosceles triangle. Any distortion of the modulating wave which occurs between the grid of the modulator tube and the antenna output will be indicated by the converging boundary lines of the pattern.

With the standard cathode ray tube it is somewhat difficult to check accurately the percentage modulation during regular programs unless photographs are taken. However, with the time delay screen patterns may be studied by using a quick acting switch to sample the trace.

### Cathautograph

The cathautograph is an interesting and useful application of the cathode ray tube for the transmission of intelligence either in printed or written form. The electron beam is controlled by a suitable transmitting apparatus which causes the spot to move in any desired direction for any desired dis-

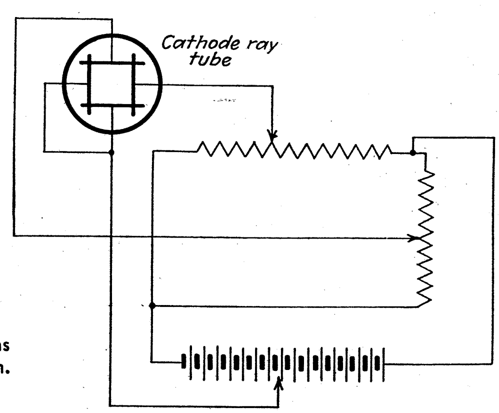



Fig. 19. Connections of the cathautograph.

tance on the screen. If a standard cathode ray screen were used the operation of the transmitting apparatus would cause the spot to move around but it would be impossible to tell what was being written. However, with the special screen previously mentioned which, instead of having a decay period of a fractional part of a second, has a decay period of around a minute, a line can be drawn the same as with a pencil. At present some ten words can be seen on the fluorescent screen of the cathode ray tube at one time. As the eleventh word is being written the first word has faded out.

The transmitting system consists of a pencil or stylus which is connected with two resistances so that as the pencil is moved a voltage is picked off the resistances which is proportional to the movement of the pencil. The receiver consists of a standard cathode ray tube with two pairs of deflection plates having the time delay screen. Fig. 19 shows the connections used and Fig. 20 is a sample of the writing as it appeared on the screen of a 3-inch tube. A suitable shielded stand or holder supports the tube. The voltage picked off one resistance is applied across one pair of plates and the voltage picked off the other resistance is applied across the second pair of deflection plates.

Provision has been made so that when the pencil of the transmitter is brought into writing position the receiver at the distant station is set into operation, which requires less than two seconds. A buzzer signal is also operated at the distant station. Provision has been made so that when the pencil is lifted from the paper the spot is turned off eliminating traces between the words. The complete apparatus is shown in Fig. 21.

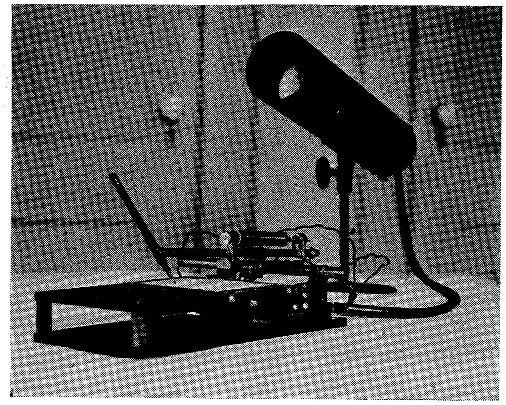


Fig. 21. Cathautograph. Complete apparatus.

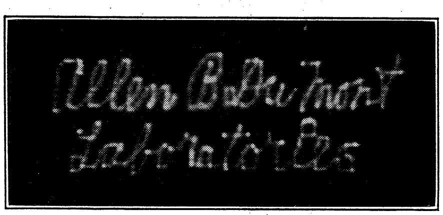



Fig. 20. Specimen of cathautograph writing.

The cathautograph may be operated over radio circuits by modulating two separate tones on a single carrier. At the receiver each tone is rectified and used to operate a set of deflection plates.

Some of the applications which suggest themselves are communications between airplanes and ground stations, communication between small vessels at sea (not carrying a licensed operator) and land stations, office intercommunication, and communication between distant offices, communication between police department and radio equipped cars, noiseless instructions to broadcast artists, Chinese or Japanese communication circuits and also for advertising displays.

### Depth Measurements

By rotating the beam in a circle at a known rate and sending out an impulse at a predetermined time the echo can be made to appear as either a spot or a radial line along the circumference of the circle. A suitable scale will indicate the depth. Using cathode ray tubes for this purpose it is economical to place repeaters at any desired point in the ship. Due to the fact that there is no inertia to the system it is also possible to use these tubes to detect extremely small differences in time such as might be useful in a radio altimeter, etc.

### Radio Compass

For a long time the use of the cathode ray tube for this purpose has been experimented with. One suggested method was to use two large fixed loops at right angles to each other and feed the voltage from each loop to a set of deflection plates. Hence, if the common deflection plate lead was periodically interrupted a line would be drawn on the screen of the tube pointing directly toward the sending station. So far, because of the extreme sensitivity of the cathode ray tube which is required, no great success has been obtained. However, if the signal from the loops is amplified and then fed into the tube, the problem is simplified, providing the apparatus is so designed that each amplifier gives exactly the same overall gain. Recent developments along this line appear to be practical and there is a good possibility that the tube may become a valuable aid in this field. The advantage over the present radio compass would be that it could be left on continuously and would constantly indicate the location of the sending station. Furthermore the device would indicate a group of stations when they were within range, each being distinguished by its respective time interval.

# Book Review

*"RADIO SERVICING COURSE." By Alfred A. Ghirardi and Bertram M. Freed. Published by the Radio Technical Publishing Co., New York City,* 1932. *Price* $1.50. (192 *pp.*—121 *illustrations—cloth*).

THIS text has been prepared primarily to provide the reader with a general explanation of the fundamentals of routine practice employed in radio servicing. It is co-authored by the author of the *Radio Physics Course* and embodies many of the instructive features employed in that volume; for which reason the text may be easily digested by the novice.

The entire problem has been presented in a logical manner; the authors first considering the basic principles of this profession and progressing by order of related sequence to an explanation of the purpose and application of servicing equipment. The contents are arranged so that this book may serve as a text for individual or group study. With the terminative study of each chapter, the student may test his assimilation of each section by answering review questions chosen to cover the most important problems of his study.

Each chapter considers practical topics for discussion, each type of equipment under study being presented with a concise explanation of its principle of operation, application, and value to the radiotrician in his work. The treatment is semi-technical and no use is made of mathematics, save in the explanation of simple formulae. Circuit diagrams have been rendered useful by including the electrical constants of each component constituting the unit. This provides the reader with full details on the construction of numerous aides such as analyzers, oscillators, tube checkers, etc. A liberal use of photographic illustrations also assists in the elucidation of the accompanying text.

The *"Course"* consists of nine chapters; the first of which is introductory, serving as a preface in presenting the following study. Chapter two reviews the principle of operation and expounds the construction of useful electrical measuring instruments employed in circuit testing. In the third chapter a further discussion of simple testing aids and procedures are outlined with a view of their practical use in actual service work. The use of the set analyzer is explained in the succeeding chapter wherein a brief description is also given of popular commercial set testers. Constructional data is included for the making of several practical analyzers for the benefit of those interested in building their own equipment.

"Trouble shooting the receiver" is the title of the fifth chapter outlining the preliminary procedures of radio servicing with practical interpretation of common troubles; their general symptoms, analyzation and elimination. The value of the test oscillator in aligning and neutralizing receivers is next dealt with. Following in order, the subject of interference and noise elimination is discussed as well as the purpose for and use of the tube checker. The last chapter is devoted to varied useful data of value to the prospective radiotrician.

The *"Course"* will prove to be a valuable guide for those contemplating entering the radio service profession.—*Reviewed by Louis F. B. Carini.*

# FORUM

THE development of any art, such as radio communication, may be divided into three periods. During the early years, the workers in the new art are busy discovering what the problems are and in getting them clearly stated. Then comes the period during which several solutions for each of the problems are brought forward. The final period is devoted to finding out which of the many solutions is best.

The radio art is 35 years old, and broadcasting is over 12 years old. A great many problems have been solved in a great many ways, and some of the early solutions have already been discarded. But there are, even today, a good many questions which have not been answered. There are many choices still to be made, many solutions to be examined and approved or discarded, and there is the question as to whether even the best solution of any one of the problems, is adequate.

The Radio Club of America includes in its membership many of the oldest and ablest workers in the radio field. Many of these men have worked through all the years of development and research that have brought the radio mechanism to its present state. They bring to its problems a point of view born of experience.

But among the younger members there is the vision of new problems to be solved, and the determination to find better answers for the old problems. They view each new task in the light of the latest technical advances in mathematical analysis and laboratory investigation.

The Forum is a place where these men meet for discussion and an adequate exchange of ideas and opinion. Each month, a question, not yet definitely settled, is proposed and analyzed, and although no record is kept, each participant leaves with one problem much clearer in his mind than it was before. There is no attempt to settle a question, and no vote is taken. The only rule is that each man must confine himself to the question being discussed.

Come to the meetings, listen to the paper, and then participate in the Forum. If there is a particular problem on which you would like to have the ideas and opinions of other radio men, send the question in.

R. H. LANGLEY, Chairman,
Forum Committee.