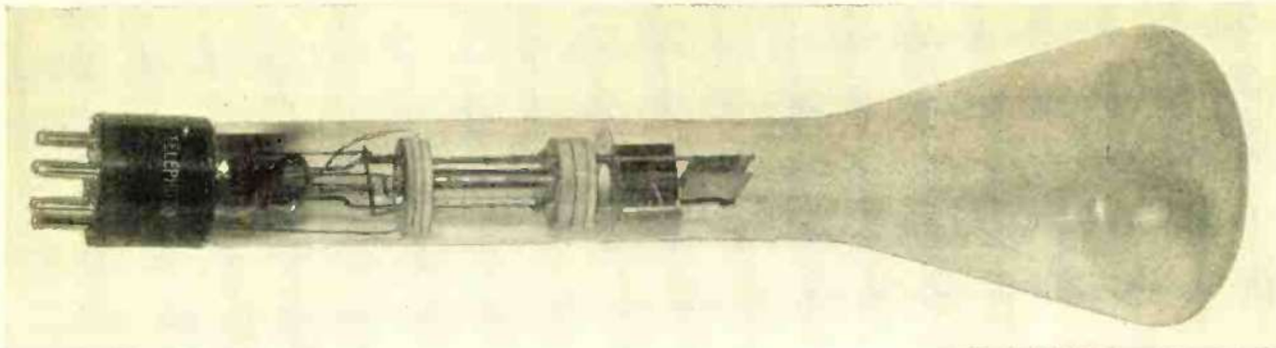


The How and Why of

CATHODE RAY TUBES

For Television and Other Uses

This series of articles will fill a long-felt need for practical construction data on cathode ray equipment. Complete details for making a cathode ray oscilloscope and television equipment will be given and the manifold applications of this equipment discussed

By **John M. Hollywood** *and* **Marshall P. Wilder**

CATHODE ray tubes are essentially devices indicating by means of the movement of a spot of light on a screen, the value of a voltage or current applied to the proper terminals. Unlike the usual meter, the only moving part is a beam of electrons, which has such little inertia that there is practically no time lag between application of a voltage and the movement of the spot of light. The power consumed in moving the beam is practically negligible. The cathode ray tube may also be used as an ammeter by causing the unknown current to flow through coils, and applying the resulting magnetic field to the cathode ray tube; the power required to move the spot of light will then be of about the same value as that required by the ordinary ammeter, but unlike the ordinary instrument, a change in the flow of current will be indicated instantaneously by the movement of the spot. These characteristic features have made cathode ray tubes exceedingly useful for many purposes, and now that relatively inexpensive tubes which give very good performance are commercially available, the next few years will probably see an increasing use of this instrument by all persons interested in electrical measurements.

The electrode structure of the first cathode ray tubes was similar to that illustrated in Figure 1. In these tubes, the electrons were attracted from the cathode to the anode, which was pierced by a small hole. Some of the electrons, now moving with high velocity, would pass through this hole and impinge upon the glass wall (screen) of the tube, where a fluorescent light was produced. It was found that the electrons moved in straight lines unless deflected by a magnetic or electric field.

Until recently, in almost all cathode ray tubes the electron beam was focused to a spot on the screen by introducing a small amount of an inert gas into the tube. Heavy positive ions would be formed and collect along the beam, neutralizing the space charge of the electrons and condensing the beam into a thin line. This method had many objections. To focus the spot, the gas pressure had to be regulated by varying the cathode temperature; and as the tube became older some of the gas would became absorbed so that the cathode temperature had to be raised to dangerous limits, shortening its life. Positive ion bombardment of the cathode also cut short its life.

When deflecting plates were inserted in the tube, to which a voltage could be connected so that the electron beam would be sent in proportion to the voltage, the ionized gas would cause leakage currents to flow between the plates so that the instrument could not be

Cathode Tubes in Television

THE radio public has been hearing and reading much about the wonders of the cathode ray tube, and particularly of its recent application to television experiments which have been going on behind the locked doors of some of the world's leading laboratories. But there has been almost a total lack of authentic and practical information on the cathode ray tubes themselves; and a complete lack of any kind of constructional data on television, laboratory or other apparatus employing these tubes. RADIO NEWS therefore takes pleasure in presenting this series of articles. This first concerns itself primarily with the theory and design of the tube. Subsequent articles will provide detailed data to enable the builder to construct cathode ray equipment at home, including television receivers capable of reproducing images with a degree of fidelity and definition never before possible with home-made apparatus.

—The Editors.

THE EARLIEST TYPE OF CATHODE RAY TUBE

This type of tube provided a beam focused on the screen by the introduction of gas in the tube, making the cathode adjustment critical and behavior erratic

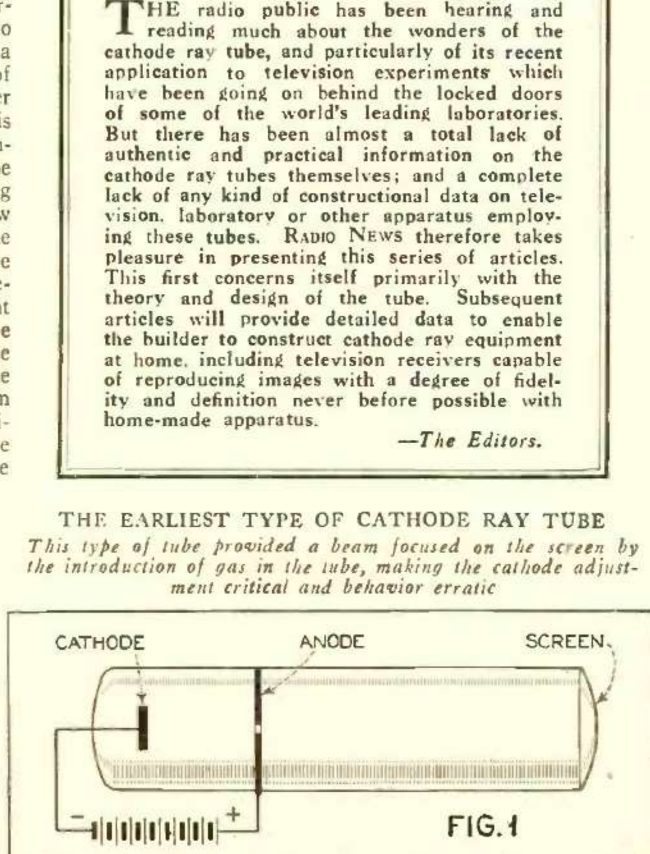


FIG. 1

used as a very high resistance voltmeter. Also, the gas caused non-linearity, that is, the deflection was not proportional to the applied voltage. If high frequencies were applied, the heavy positive ions along the beam could not move rapidly enough to keep the beam focused, and the spot would be blurred. And in addition, gas would cause the screen material to become "burnt" or darkened if a high intensity spot were kept too long in one place.

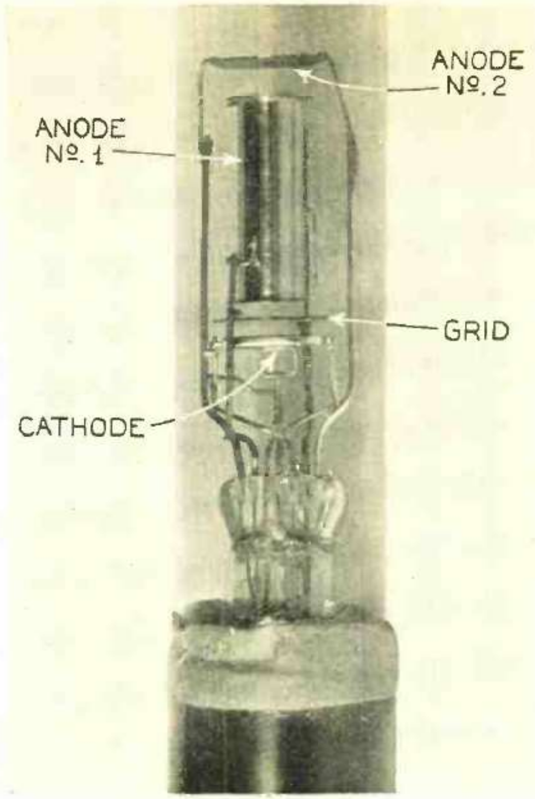
Rogowski of Germany was the next to improve the tube. He added a second anode; a truncated cone the apex of which pointed toward the cathode. For the first time the beam could be focused electrostatically in a high vacuum. The voltages on the two anodes had to be in a definite ratio, which suggested the probability of a general theory of optics for electrons, paralleling light optics.

Static Focusing

Much work has been carried on by independent investigators, our own (Messrs. Wilder and Hollywood are members of the engineering staff of the Telephoto Corporation, manufacturers of cathode ray tubes and apparatus) resulting in charts from which we have been able to determine the voltages and spacing for lenses of any desired focal length. As a result we are able to project the images of our cathode any distance in vacua; to magnify or demagnify; to polarize and refract.

All good camera objectives as well as microscope and projection lenses consist of a series of lenses of different shapes and different kinds of glass, the combination resulting effectively in a simple lens of one focal strength with most of the errors of the corresponding single lens corrected. The same is true in the design of electron lenses. In our studies a four-lens combination was the result of much work along this line and proved, from the viewpoint of simplicity as regards mathematical calculation and focusing potentials, to be the most effective.

The first of our development models employed electrodes supported on wires and glass beads from the press. We found the spot focused exactly as calculated, with a predetermined magnification. Isolantite rings properly machined were finally chosen to support the lenses, deflecting plates and cathode.



AN EXPERIMENTAL MODEL

One of the earlier models developed by the authors, all elements depending upon the glass "press" for support. The final model insured accurate spacing and more rigid support by using isolantite spacers and mounting

Most screens are applied by spraying the fluorescent material in powdered form against a water-glass binder. The first screen materials tried in our experiments were ground up natural Willemite and calcium tungstate. These screens, though very successful proved not to be so brilliant as synthetic Willemite. The screen material adapted is therefore made synthetically, and produces a brilliant soft yellow light, almost white.

Tubes Available

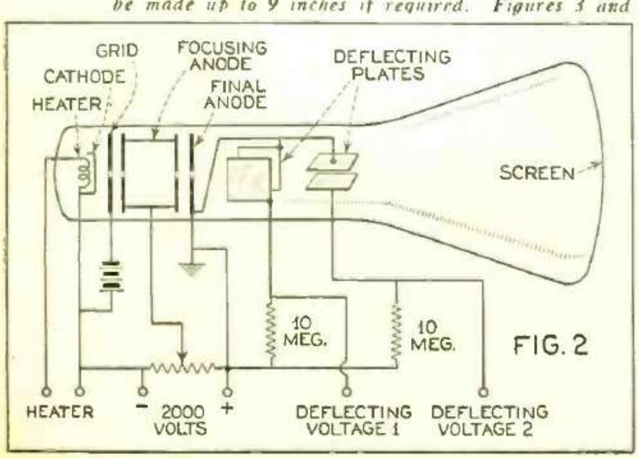
The size of the spot is prearranged and built into the tube in the process of manufacture. The spot size in our type 342G is one millimeter in diameter. The focusing characteristics of our high-vacuum type cathode ray tube remain constant throughout the life of the tube, and over wide ranges of cathode temperature. If a grid is introduced to modulate the light intensity, for instance in television work, modulation has no effect on the focus or the size of the spot, or on its position.

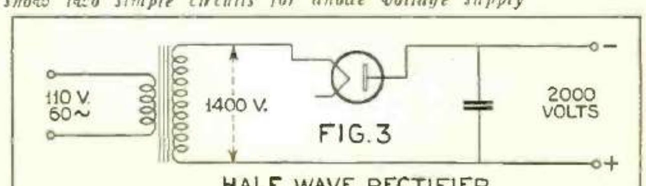
The 342G has a three inch screen and four deflecting plates. Two deflecting plates, one of each pair, are connected inside the tube to the anode, and two are free and brought out to terminals. A modulating grid is also provided. The 343 is the same except for omission of the modulating grid, and the use of four deflecting plates of which three are free and brought out to terminals. These tubes are now available to the public. Others may be manufactured, such as 942G, for instance, which is the same as 342G except for a nine inch screen. All these tubes are of the indirect heater type. The operating voltages are as follows: Heater—2½ volts, 3 amperes; Focusing voltage—½ anode voltage; Max. anode voltage—2000; Negative grid bias—0 to 99 volts.

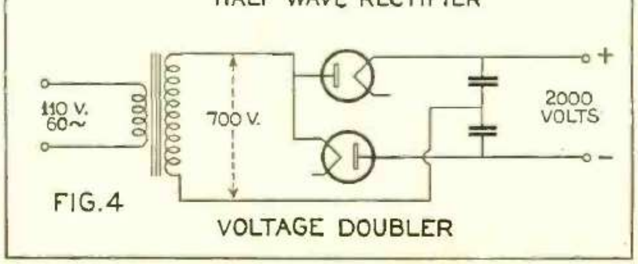
The sensitivity factor of a cathode ray tube may be given as the percentage of the anode voltage necessary for a one inch deflection. The sensitivity factor of the Telephoto tube is about five percent of the anode voltage per inch deflection of the spot for the standard model. With this manner of denoting the sensitivity it is only necessary to know the anode voltage in order to obtain a voltage measurement by measuring

SCHEMATIC PLAN OF THE NEW TUBE AND ITS CIRCUIT

Figure 2. The diagram shows how operating voltages are applied. Voltages to be studied are connected between ground and the terminals marked "Deflection Voltage." The screen on which the image appears is 3 inches in diameter, but can be made up to 9 inches if required. Figures 3 and 4 show two simple circuits for anode voltage supply







the deflection in inches, knowing the sensitivity factor.

Certain power pack assemblies are particularly recommended, such as the half wave rectifier and the voltage doubler types. The former is simple and effective, and the latter is better for obtaining high voltages without using special transformers and condensers. Voltage doublers have the drawback that two rectifier tubes must be used with a separate filament winding for each tube. The current drawn from the power supply is so small that little filtering is required.

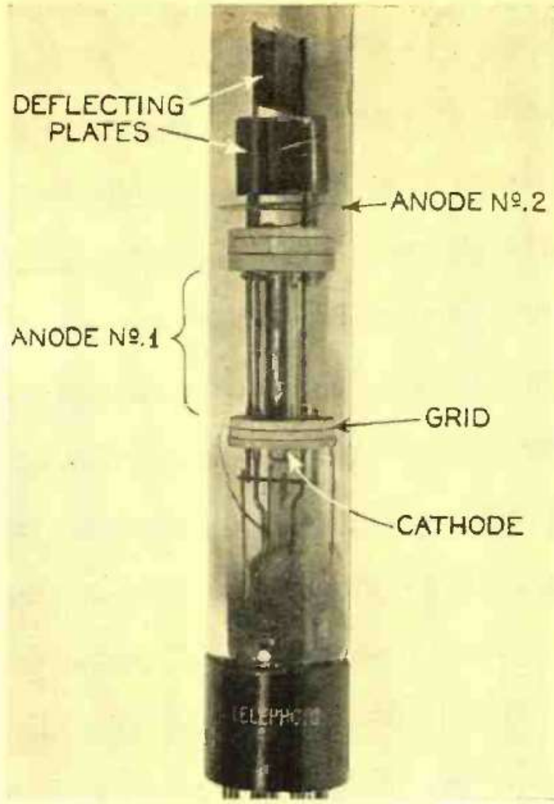
Practical Circuits

In operating these cathode ray tubes, the maximum voltage recommended is 2000 volts, to be applied between cathode and anode. A voltage of half the anode voltage should be applied between the cathode and the focusing electrode, and this should be variable in order to obtain exact focusing. Since some purposes require great brilliance but not much voltage sensitivity, and other purposes demand much sensitivity but not much brilliance, it should be possible to change the anode voltage and focusing voltage simuleaneously over a sufficient range to meet both purposes. Also, in a power supply for the tube, there should be provision for supplying the heater current.

Since the current drawn by the anode and focusing electrode is a fraction of a milliampere, the components of the power supply need not be built for much power, and a small filter will be sufficient. In a later article of this series, exact information will be given for constructing such a power supply from standard parts.

In studying wave forms of periodic voltages or currents, the wave form studied is connected so as to move the spot of light vertically, while some additional means should be provided for moving it across the screen horizontally at a constant rate of speed. If this is done, the wave form of the voltage or current as a function of time will be obtained; but if the horizontal movement is not at a constant speed, the wave form will be distorted; for example, the peaks of a sine wave might be too close together on one end of the screen and too far apart on the other. Also, in order to have the wave pattern stand still on the screen, it is necessary to have the horizontal movement snap back to the start always at the same part of a cycle of the wave form.

Such a "linear time axis" can be provided by means of a "sweep" circuit in which the voltage across a condenser is applied to the horizontal deflecting plates of the cathode-ray tube. A controllable constant current is sent through the condenser, charging it so that the voltage is proportional to the time; the plate



A NEW CATHODE RAY TUBE

A close-up of the stem section of the tube pictured at the head of this article. This tube provides for electron focusing of the beam, the focusing being adjustable to concentrate the beam, forming a sharply defined spot of brilliant light where it strikes the screen. Focusing is accomplished by means of a simple, adjustable external resistor

A HIGHLY EFFECTIVE "SWEEP" CIRCUIT

FIG. 5

THE SAW-TOOTH WAVE FORM OF THE "SWEEP"

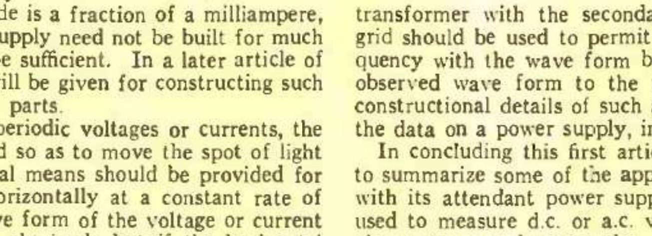


FIG. 6

current of screen-grid or pentode tubes is quite constant over a wide voltage range and may be used for this purpose. A thyratron, which is nothing but a hot-cathode, mercury-vapor rectifier with a control grid, is connected across the condenser, and when the voltage reaches a certain value the thyratron discharges the condenser almost instantly, allowing the cycle to repeat itself. The voltage at which the thyratron discharges is controlled by the grid bias of the thyratron. Such a circuit is shown in Figure 5.

This circuit is really a sort of oscillator, in which the voltage across the condenser has a "saw-tooth" wave form as shown in Figure 6. The amplitude of the voltage can be controlled by the thyratron grid bias, since a negative bias will not permit the condenser to discharge until a high voltage is reached. Increasing the amplitude in this way will also decrease the frequency, since the condenser will take more time to accumulate enough voltage to discharge through the thyratron. The frequency can be controlled independently, though, by changing the constant current or the capacity of the condenser. A smaller condenser will charge faster and increase the frequency; a larger current will charge the condenser faster and increase the frequency. For best results, all three controls should be used in the "linear time axis" or "sweep circuit." A transformer with the secondary in series with the thyratron grid should be used to permit synchronizing the saw-tooth frequency with the wave form being observed, by connecting the observed wave form to the transformer primary. Complete constructional details of such a circuit will be given along with the data on a power supply, in a later article.

In concluding this first article of the series, it is of interest to summarize some of the applications of the cathode-ray tube with its attendant power supply equipment. First, it may be used to measure d.c. or a.c. voltages, including radio frequencies up to several megacycles. Currents, d.c. and a.c., may also be measured. With the addition of a "sweep" circuit, a first-class oscilloscope results and the images of wave forms, transients, etc., appearing on the screen are not only clear and sharp to the eye, but may be readily photographed. Used in this way, the quality of the amplifier may be observed, as may also the modulated output of a transmitter or other modulated r.f. wave form. Frequencies may be exactly compared with a standard. Phase difference between two a.c. voltages may be determined. Curves showing relationship between two electrical quantities such as the grid-voltage-plate-current characteristics of vacuum tubes, hysteresis curves of iron, current against voltage for gaseous (*Continued on page* 313)

adjusting the self-induction of the coil, L, the natural frequency of the string can be brought into resonance with a radio tube oscillator used to generate the operating energy.

[1]G. W. Pierce, Proc. Am. Acad. Arts and Sci. *63*, 1, 1928.
[2]United States Patent 1,113,149.
[3]United States Patent 1,854,025.

Cathode Ray Tubes

(Continued from page 270)

discharge devices, etc., are easily and directly obtained without resorting to the usual, tedious point by point method of plotting.

As a final example of cathode-ray utilization most radio engineers believe that the home television receivers of the future will employ cathode ray tubes. By providing electrical means of making the spot of light scan the entire screen repeatedly in a series of lines, and at the same time varying the intensity of the light according to the output of a television receiver, television images may be received with a perfection depending chiefly on the associated apparatus, without any mechanical moving parts.

In a later article, the more interesting uses of cathode ray tubes will be explained in detail, so that any interested reader may carry out the work with the assistance of the information to be given. As mentioned before, other articles of this series will explain in detail how to construct the associated apparatus necessary to operate a cathode ray tube, and how to use such a tube in the reception of television.

The DX Corner

(Continued from page 284)

ception of the nearer stations in the United States and Europe consistently good. The best of all and the most remarkable is DJC. I have heard stations in Porto Rico, Mexico, France, Great Britain, Spain and Italy. My set is a 3-tube affair used with 'phones. It is battery operated and uses one -32 tube and two -30 tubes. I have also heard police broadcasts, ship-to-shore, airplane, transatlantic telephone and amateur stations."

Report from Kearney, Nebraska

Mr. Floyd Roberts of Kearney, Nebraska, reports that using an Apex 3-tube converter ahead of a 7-tube receiver his Best Bets are VK3ME, GSB, EAQ, HBL, PHI, XDA, XETE as well as most of the stations in the United States and Canada.

A Report from England

Mr. Alan Barber of Bisphan, Blackpool, Lancashire, England, reports that in one evening he recently heard stations: W2XAF, FYA, DJD, DJB, HBL, DJA, HBP, RV59, OXY, W8XK, I2RO, EAQ, GSB, GSF as the best short-wave stations in his locality. He has heard the following American stations on the long waves: KDKA, WTIC, WGY, WJZ, WABC, WPG, WCAU. His receiver is a home-built 3-tube battery operated set.

Best Bets in New Jersey

Mr. Francis Fekel of the Short Wave League, Vineland, New Jersey, states that using a 2-tube home-built set he receives the following stations best: W8XK, DJB, GBU, DBS, W2XE, W1XAL, DJD, GSD, VE9JR, FYA, YVQ, LSX, EAQ, TI4NRH, CT1AA, HBL, W3XAU, W1XAZ, DJA, W2XAF, GSB, VK3ME, VK2ME, HBP, W3XL, YV1BC, W3XAL, W9XF, VE9GW, W9XAA, W8XAL, W3XAU, GSA, DJC, VE9DR.