History of the Vacuum Tube

Experimental tubes: commentary on the development of significant phototubes and camera tubes, Tesla and ballast tubes

PART V

by Robert G. Middleton

All types of vacuum tubes go through an experimental or developmental stage before they are finalized. Experimental tubes are generally unbased, and the exhaust tip is exposed. Although Ediswan incandescent lamps were based in 1905, the first Fleming valves were unbased. The final production version of the Fleming valve was provided with a bayonet-type base. Comparatively recent experimental tubes often look similar to commercial Audiotron tubes, which were unbased. For example, one experimental triode appears similar to the DeForest Audiotron (Fig. 1).

Fig. 1 An experimental triode.

Fig. 2 An experimental Pliotron oscillation detector tube with two anodes, circa 1917.

Another experimental tube employed a single filament, single grid, and two separate anodes (Figs. 2 and 3). Each of the anodes consisted of a zig-zag section of wire. A later version of this tube was provided with a Shaw base (Fig. 4). In this production design, the two anodes were connected together, and the exhaust tip was placed at the top of the tube, in accordance with 1920 practice. An experimental transmitting tube of the same era was a triode with comparatively large elements for dissipation of appreciable power (Fig. 5).

Fig. 4 Shaw-based version of the experimental triode.

Phototubes and Camera Tubes

Phototubes were used in the 1930's with scanning-disk television transmitters (Fig. 6). There were various early forms of the phototube (Fig. 7). In 1887, a physicist named Hallwachs observed that a negatively charged zinc plate with a polished surface emits electrons when ultraviolet light strikes the zinc. This is termed the photoelectric effect. A photoelectric tube commonly consists of a glass envelope with an extremely thin film of cesium or similar metal deposited on the inner surface of the glass (Figs. 8 and 9). This constitutes the cathode, which emits electrons when struck by light rays. These electrons are captured by a positively charged anode, which consists of a section of wire.

Some phototubes were opaque except for a "window" opposite the cathode (Fig. 10). Both "hard" and "soft" phototubes were utilized. Those with appreciable residual gas were more sensitive and could be operated at low light levels. However, the highly evacuated phototubes were more stable and had a faster response time. Smaller sized phototubes were used in talking-picture machines (Fig. 11).

In the 1930's, phototubes were progressively displaced by various types of camera tubes. The advantages of a camera tube were in elimination of scanning disks and in the greatly increased quality of picture detail that could be transmitted and reproduced. One of the earliest camera tubes was the first Farnsworth image-dissector camera tube (Fig. 12). The image to be scanned is focused on a photoemissive cathode surface. The anode at the opposite end of the tube has a positive potential, which attracts the emitted electrons. This electronic image is focused by the electromagnetic coils A and

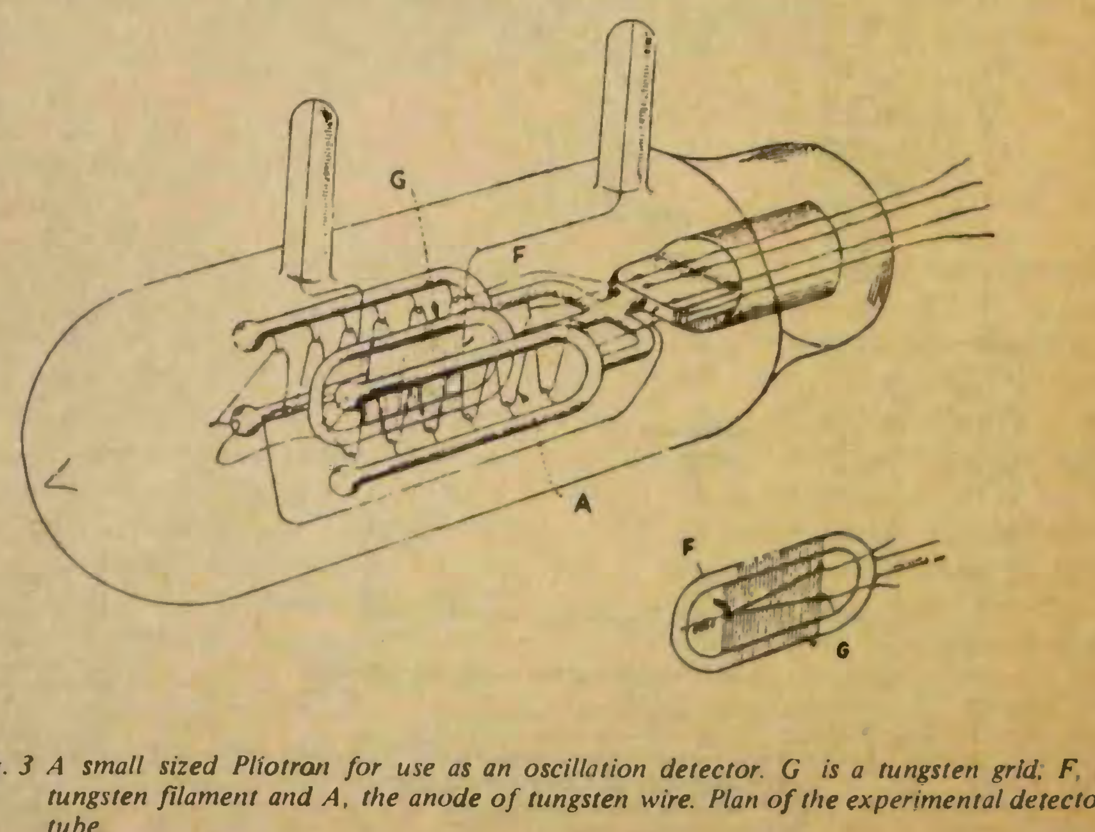

Fig. 3 A small sized Pliotron for use as an oscillation detector. G is a tungsten grid; F, a tungsten filament and A, the anode of tungsten wire. Plan of the experimental detector tube.

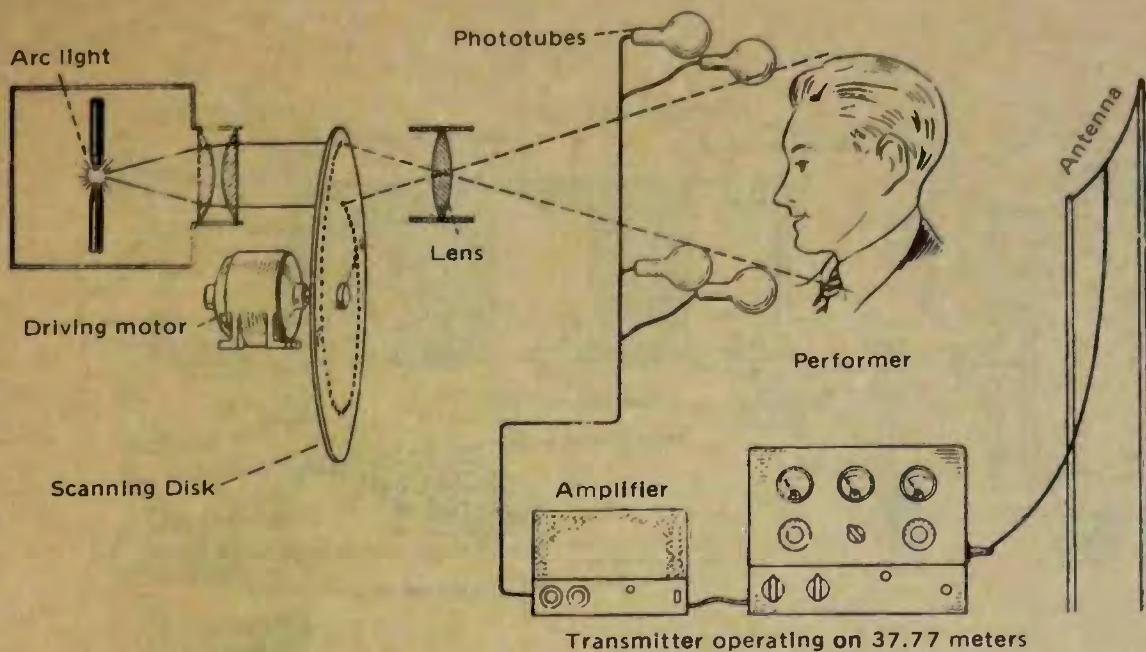

Fig. 6 Plan of a 1930 scanning-disk television transmitter.

Fig. 5 Experimental transmitting triode.

Fig. 7 A phototube used in an early scanning-disk television transmitter.

Fig. 9 Another early type of phototube.

Fig. 10 A phototube with a "window" envelope.

A[1]. Deflection coils B and B[1] move the electronic image back-and-forth, so that it is scanned by the anode aperture. Another pair of deflection çoils is provided to move the electronic image up and down.

In this same era, another type of camera tube called the iconoscope was being developed by RCA (Figs. 13 and 14). A mosaic electrode is employed, designed for high electron emission. It is formed by deposit of myriads of tiny silver globules on a sheet of mica. These globules are photo-sensitized with cesium, and each globule constitutes a tiny photoelectric cell. An electron gun and beam-deflecting system are mounted in the neck of the iconoscope. Electrons emitted by the globules are attracted to the silver coating inside the tube, which operates as the anode, or collector.

Emitted electrons will leave a charge deficiency on the mosaic, which in effect produces a tiny capacitor charge with respect to the backing plate. The function of the cathode electron beam is to discharge these globules in a scanned order. In turn, the potential between the backing plate and the collector varies in the scanned order, and a video signal appears across resistor R. The chief advantage of this iconoscope design was improved sensitivity, compared with the image-dissector tube.

A later version of the Farnsworth camera tube employs a photo-island grid upon which the image is focused after passing through the transparent anode at the end of the tube (Fig. 15). This grid had approximately 160,000 holes per square inch in a thin nickel plate. One side was coated with a dielectric material upon which were

Fig. 8 Construction of a phototube.

deposited many photosensitive "islands." In turn, the image focused upon this photoemissive surface established an electrical potential image. The electron beam from the gun struck the surface of the nickel plate, liberating secondary electrons. These secondary electrons constituted a virtual cathode source, and were drawn through the tiny holes of the mesh. The charge distribution over the mesh produced grid action, and determined the number of electrons that were emitted at a given point to proceed to the electron multiplier. This tube had the advantage of higher sensitivity than the iconoscope.

Next, the Zworykin image iconoscope was developed (Fig. 16). The image to be televised was focused upon the photoelectric cathode near the end of the tube. In turn, an electronic image was emitted from the opposite surface of the cathode. This image was focused by suitable means on the mosaic at the other end of the tube. Secondary elec-

Fig. 11 A small phototube, used in talking-picture machines.

trons from the globules were carried off by the anode coating, and a charge distribution was thus established between the mosaic and the backing plate. Secondary emission represented electron multiplication and an increase in sensitivity.

The image orthicon is a later development of the foregoing camera tube (Figs. 17 and 18). It is a storage type camera tube and has very high sensitivity compared with the iconoscope. Photoemissive response is increased by using a conducting photosensitive sur-

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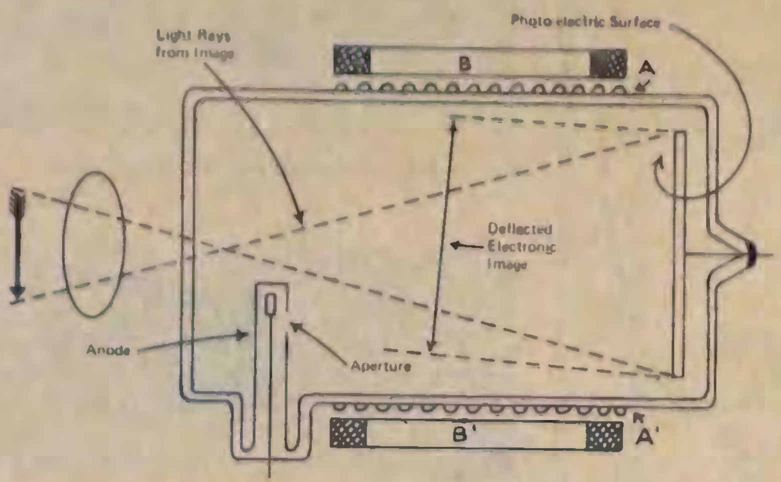

Fig. 12 Plan of the first Farnsworth image-dissector camera tube.

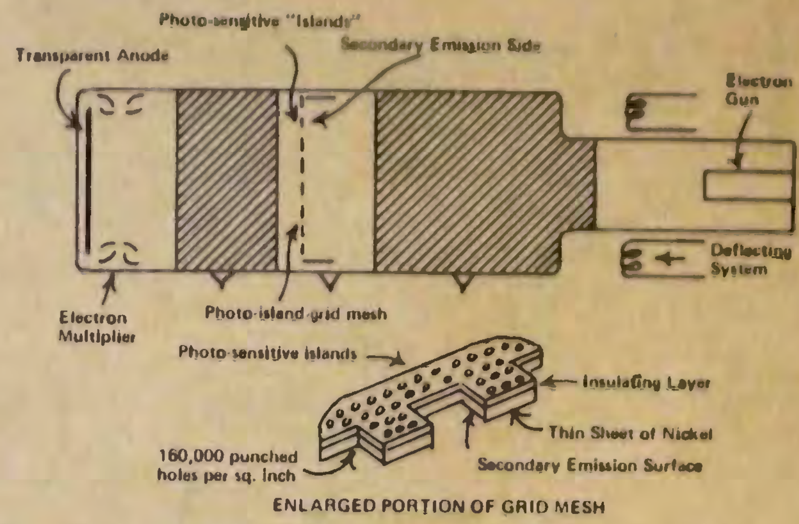

Fig. 15 A later version of the Farnsworth camera tube.

HISTORY OF THE VACUUM TUBE

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face. Secondary emission, with its undesirable side effects, is eliminated by scanning with a low-velocity electron beam. Finally, the signal-to-noise ratio is improved by utilizing a photomultiplier section. The light rays are focused on one side of the photocathode, and photoemission takes place from the opposite side. Scanning is accomplished on a separate plate called the target electrode. The video signal is produced by the electron beam that returns from the target and which moves toward the cathode from which the electrons were emitted.

A light image is focused on the transparent photocathode. Emitted electrons are accelerated toward the target by grid No. 6. The target is a thin glass disk with a fine mesh screen on the photocathode side. Secondary electrons are emitted, which are collected by the wire mesh. Emitted electrons from the photocathode side of the target set up a positive charge. Next, the rear side of the target is scanned by a low-intensity electron beam. Grid No. 4 is a focus grid, and grid No. 5 slows down the electrons. Some of the beam electrons neutralize the charge on the glass target, and the remainder return to dynode No. 1. This is the first stage of the electron-multiplier section, which provides a gain of approximately 500 times.

Another type of camera tube was called the vidicon (Figs. 19 and 20). It is smaller than an image orthicon, but has good performance. It comprises an electron gun, a grid No. 3 beam-focusing electrode, a grid No. 4 fine-mesh screen, and a target. An electron gun is provided, consisting of a cathode, grid No. 1 control grid, and grid No. 2 accelerating grid. The electron gun provides a low-velocity electron beam which is focused in part by grid No. 3. The target employs a transparent conducting film on the inner surface of the face-plate. A point on the photoconductive layer becomes slightly conductive when exposed to light.

Grid No. 4 sets up a decelerating field. Since the photoconductive layer is positive, it collects electrons when scanned by the beam. However, as the surface potential rises, arriving electrons are turned back. Thus a charge distribution is produced on the scanned surface, and its discharge through an external circuit from target to cathode produces the video signal. Vidicon tubes are widely used in closed-circuit TV cameras (Fig. 21). They also find considerable application in TV station operations.

Because the image-dissector tube produced a very weak output signal in its original form, Farnsworth developed an electron-multiplier tube, which he termed a multipactor. This type of tube is called a photomultiplier today (Figs. 22

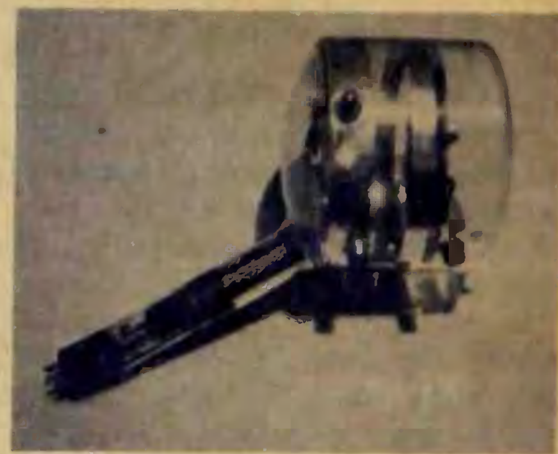

Fig. 13 A Zworykin iconoscope camera tube.

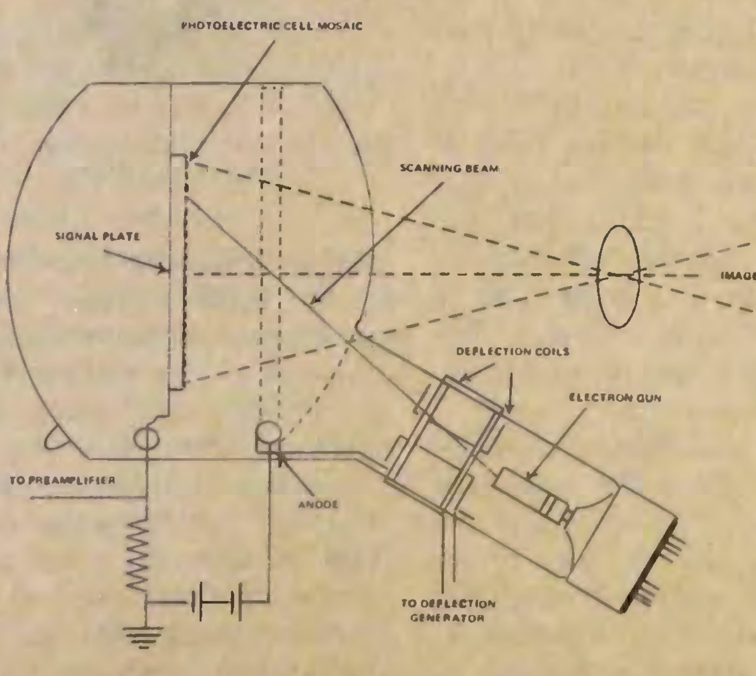

Fig. 14 Plan of an iconoscope.

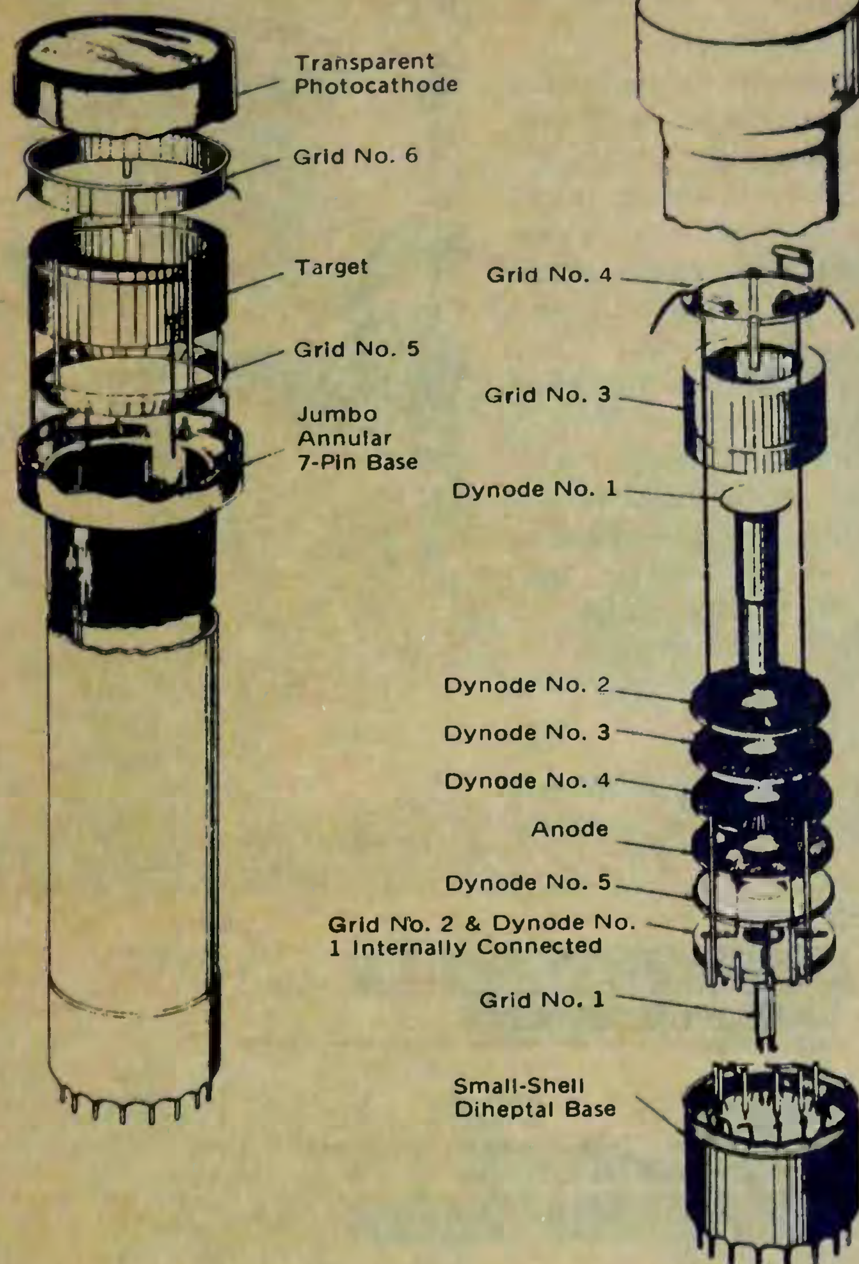

Fig. 18 Construction of an image orthicon tube.

Fig. 17 An image orthicon tube.

Fig. 19 Appearance of a vidicon camera tube.

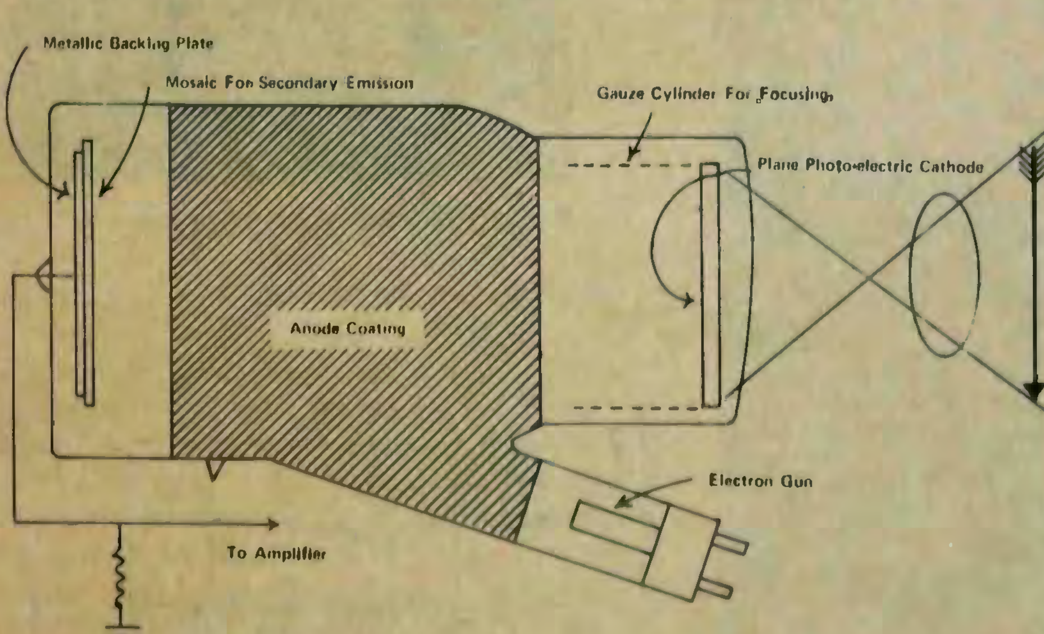

Fig. 16 Plan of the image iconoscope.

and 23). Basically, it is a phototube with electrodes arranged to produce secondary emission and build up weak electron currents. Light that strikes the photocathode causes electron emission. These electrons are attracted to the first dynode, which has a positive potential. Secondary electrons are emitted, and the process continues until final collection by the anode. An amplification of 60,000 times is typical.

Tesla Tubes

Among unusual and ephemeral tubes was the Tesla tube (Fig. 24). This was a gas tube with one electrode. It was energized from a Tesla coil connected between the tube and ground. Corona discharge took place from the electrode inside the tube, due to stray capacitance. In turn the tube glowed (typically a purple color). If the operator brought his finger near the glass envelope of the tube, sufficient capacitive current would flow to produce a small spark discharge. Tesla tubes were made in many forms, and were used chiefly in popular electrotherapeutic devices in the 1920's. These units were called violet-ray machines.

Tesla tubes were also used in ozone generators (Fig. 25). These were elongated tubes, suggestive of Geissler tubes. However, each tube had only one electrode. When energized from a Tesla coil, the tubes glowed. One set of tubes glowed orange, and the other set glowed purple. The ozone was actually produced by corona discharge, and the Tesla tubes merely added a spectacular appearance to the generator. The ozone

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Fig. 22 A modern photomultiplier tube.

Fig. 24 A Tesla tube.

was employed as an air deodorizer and purifier and was also supposed to benefit respiratory ailments.

Ballast Tubes

The filament current for early vacuum tubes was controlled manually with a rheostat. However, in the later 1920's automatic current control was introduced to simplify the operation of radio receivers. The first device used for current stabilization was the ballast tube, also called a barretter (Figs. 26 and 27). It consisted simply of an iron-wire spiral in an atmosphere of hydrogen. Because of the large temperature coefficient of iron, practical current stabilization resulted. Barretters were also designed which operated in air; however, their response time to a voltage change was slower than for hydrogen barretters.

Photo Courtesy Ampex Corp.

Fig. 21 A closed-circuit TV camera that uses a vidicon tube.

Fig. 26 Example of a barretter, or ballast tube.

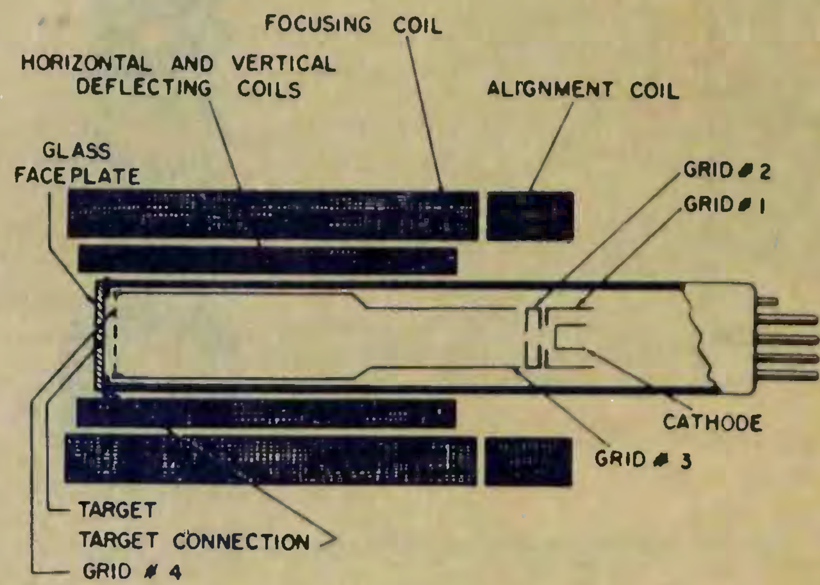

Fig. 20 Construction of a vidicon camera tube.

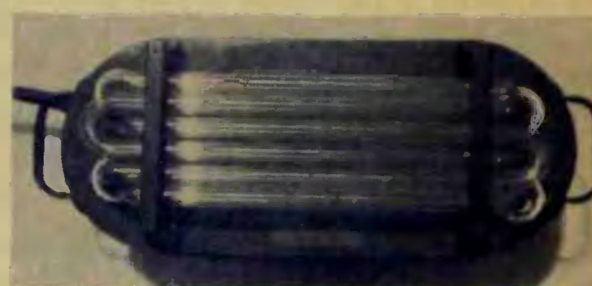

Fig. 25 Tesla tubes in an ozone generator.

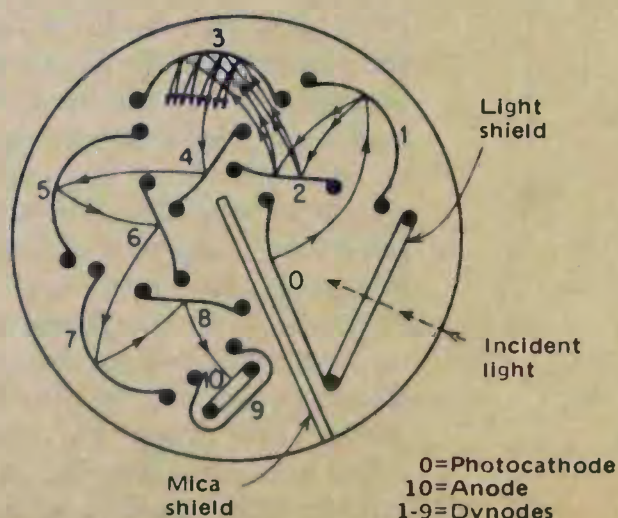

Fig. 23 Plan of a photomultiplier tube.

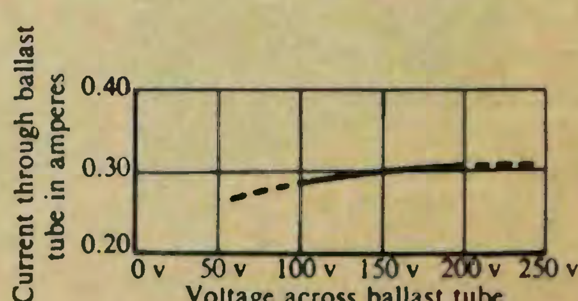

Fig. 27 Typical E-I characteristic for a barretter.

FROM AN ALBUM T.M.

PICTORIAL HISTORY OF ELECTRONICS

Courtesy Zenith Radio

"HELLO AMERICA" were the first words heard in 1924 on this early Zenith radio rig by Hiram Percy Maxim, former president of the American Radio Relay League. He is shown in this photo published in April, 1924 by Popular Science magazine with his 1922 model 1R Zenith tuner, bottom right, and the 2M two stage amplifier, bottom left. Both sets carried the Chicago Radio Laboratory name – the predecessor name to Zenith Radio Corporation.

This history-making picture is the first television broadcast in Chicago on March 30, 1939, which was conducted by Zenith Radio Corporation on an experimental basis. The telecast was received 18 miles from the TV transmitter. Engineers at station W9XZV pictured here include: (from left), WLS Chief Engineer, Tommy Rowe; Howard Black; Reggie Cross; and J. E. Brown, Zenith television engineer. Rusty Gill is kneeling in front.

Courtesy Zenith Radio

In 1956 Zenith introduced this unusual method of remote control tuning – the Flash-Matic system. It operated with a flash of light to turn the set on and off and change channels. It was advertised to "shoot off long, annoying commercials while picture stays on the screen." Earlier, Zenith had introduced its "Lazy Bones" remote control system which changed TV channels in any direction utilizing a hand-held control device connected to the television set by wire. In 1957 Zenith introduced to the industry its Space Command remote control tuning system utilizing high frequency sound.

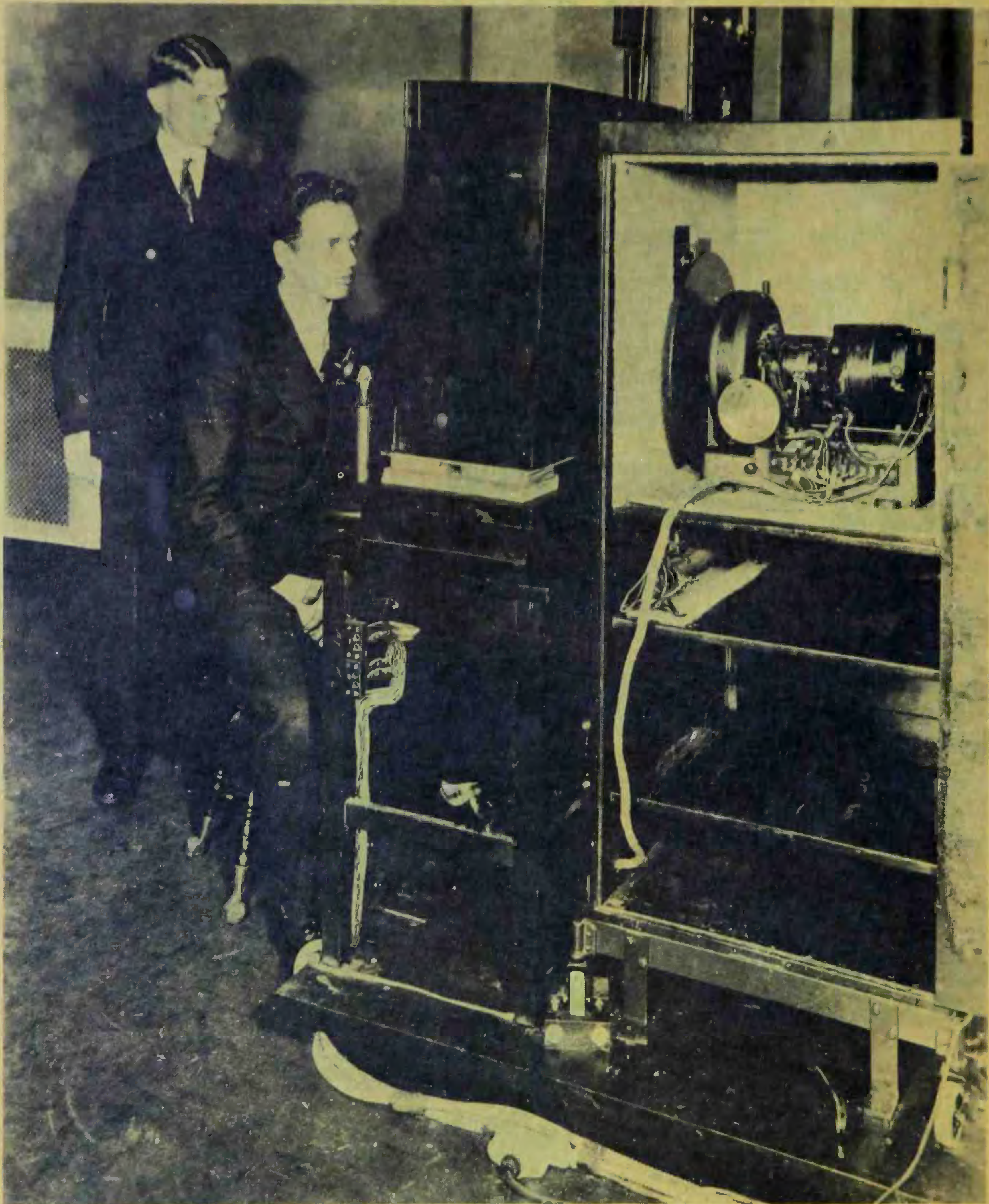

Photo Courtesy Bell Telephone Laboratories

TWO OF TV'S PIONEERS John R. Hefele, seated, and Frank Gray (both retired) were two of an estimated 200 Bell Telephone Laboratories scientists, engineers, and technicians whose work contributed to the success of the first U.S. demonstration of intercity television which took place 45 years ago. Many research problems involving this television transmission and other apparatus were solved under the direction of Dr. Gray.