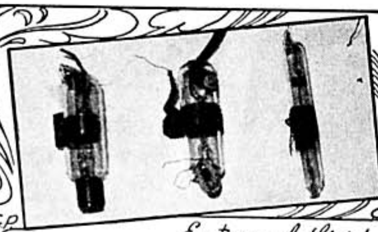
Thomas A. Edison

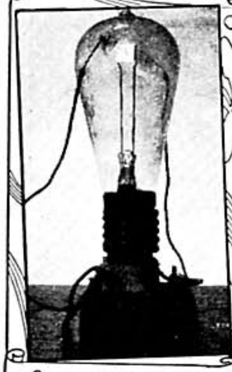
De Forest Audion with Double Plate ~1912.

Double-Filament Audiotron.- About 1914.



External-Grid Experimental Tubes,-1915.

FLEMING'S



Edisons Incandescent Lamp with Plate Element. Responsible for Discovery of Edison Effect.

THE "glow lamp oscillation detector" is the heart of your radio set—for that is what Dr. J. A. Fleming, of London, christened the vacuum tube when he adapted it to radio use.

Generally considered the pioneer in the tube field, Fleming in reality was merely one of a long succession of experimenters. It was his good fortune that thought was being devoted to wireless communication when he achieved his laboratory triumph.

1725 TO 1905

The basis of the vacuum tube was laid down in 1725, when Dufay discovered that if one of two spheres was heated, a current-carrying path was formed between them. About 150 years later, Guthrie proved that if an iron ball, insulated, was brought to a red heat, it would still retain a negative electrical charge, but not a positive one, and 7 years afterward, in 1880, Elster and Geitel added a plate to an incandescent lamp. They noticed the *valve effect* by 1889!

Approximately half-way between the two latter dates (or in 1883), the Edison Effect—flow of current from heated filament to positively-charged electrode in a partially-evacuated tube—had been noted. Sir William Crookes had also conducted his experiments and shown that "corpuscles" (small particles of electricity, now called *electrons)* could be made to flow between 2 electrodes connected to a source of electricity (such as a Wimshurst machine), when the air between these electrodes was evacuated. The electrodes were sealed in either end of an elongated glass tube, now called a "Crookes' tube".

In 1883, as a result of his association with the Edison Electric Company of America, Fleming began his experiments; in 1897 Thompson published the results of a research into the conductivity of gases; and in 1905 Fleming (by that time with the Marconi Co., in England) patented his "glow lamp oscillation detector or oscillation valve", for he had found its valve (i.e., one-way) effect, and knew that it would function as a rectifier.

INTRODUCING "MR. GRID"

For a time, due to their insensitivity to weak impulses, these tubes or "valves" met with scientific interest but public apathy. Even when, in 1907, de Forest added the 3rd element, or grid, there was not much commercial activity in producing the audion for two reasons. The Marconi Company of England, which owned the Fleming valve patent, claimed an infringement since they asserted the de Forest tube to be a Fleming valve with a grid interposed. The basic patent was, therefore, Marconi's and de Forest could not make the tubes.

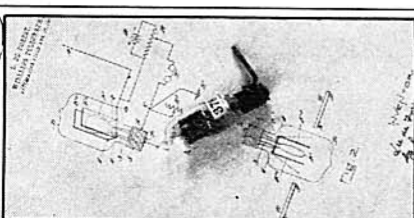
Also, since de Forest owned the audion patent, Marconi could not make the audion, and hence the audion situation reached a stalemate! The second reason was that the crystal detectors developed in the same year were far cheaper, and the results nearly as good as the audion.

The reason for the old audion's efficiency not excelling the crystal detector by proportions comparative to later years, was because so little was known of the precise phenomena which took place and the attendant need for very special precautions in manufacturing the tube. The early audion was very "soft" or gassy, and any plate voltage above (about) 30 volts would cause it to turn blue (gas ionization) and make the tube inoperative. Further additional plate voltage would result in complete destruction of the tube. With such low plate voltage plus the interference offered to the electron flow by the gas molecules, it was no wonder that the audion was only a mite better than the crystal detector. Hugo Gernsback's E. I. Co. was the first to sell audions to the public in 1911.

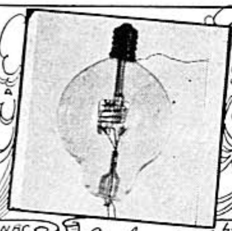
By this time the *diode* (2-element) and *triode* (3-element) tubes had undergone considerable analysis, and out of the analyses had come—and gone, thank goodness—many weird and fearsome designs. One of the most intriguing of these was the "external element" —either the plate, or the grid, as the case might be; numerous variations were tried and, in the final analysis, discarded, by many experimenters, including, Hugo Gernsback.

Fleming Valves or 2-Element Tubes,-1903-7

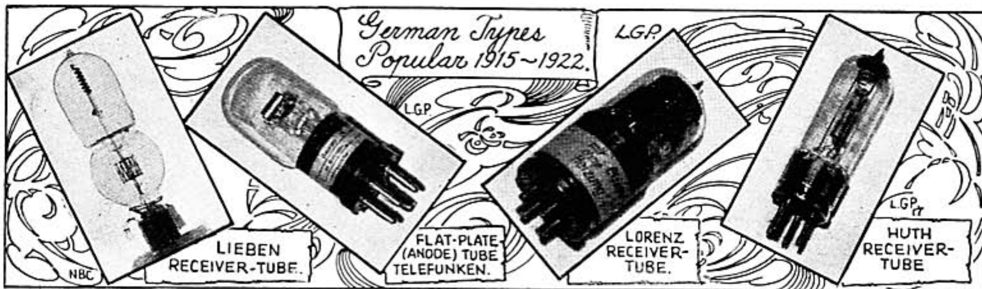
First de Forest Audion- about 1908



Replica of de Forest's Patent Application on Third Element Tube-1907.



Early de Forest Audion-1909.



VALVE AND UP


Sir Ambrose Fleming.

The general idea was to effect operation even through the glass wall of the tube; it worked, too, as real "old-timers" well recall!

HIGH-VACUUM TUBES

All these defects were eventually overcome as a result of Langmuir's researches into high-vacuum lamps (1912-1913) at the G. E. laboratories, and (almost simultaneously) Arnold's work in the same field for the Western Electric Company, a subsidiary of the American Telephone and Telegraph Company. While Langmuir's work was a result of incandescent lamp problems (although his discoveries affected the whole field of vacuum bulbs), Arnold's research was more directly centered about the audion—since de Forest had offered the tube to the A. T. & T. Co. in 1912, and they undertook to improve it for repeater (amplifier) operation for long-distance telephone communication.

In 1914, as a result of the A. T. & T. Co.'s work, the de Forest triodes were first used successfully in sending telephone messages from one side of the continent to the other and in the following year, in telephony from Arlington, Va., to both Paris and Honolulu.

The World War, of course, spurred activity in communications as well as in other fields, and while only gaseous or "soft" tubes had been available before, so-called "hard" tubes made especially for the Navy somehow got out to the public towards the end of and just after the war. Their superior operation and efficiency as compared to the old audion, resulted in a great demand, by amateurs, for good "hard"-vacuum tubes.

As a result of this demand for tubes by amateurs, we find numerous manufacturers entering this field in 1916-1919 and marketing their products—patents or no patents! Those first tubes will remain indelibly impressed on the memory of every old-timer. The "Moorhead", the "Electron-Relay", and the "Audiotron"—first with its double filament (in case one burned out), then later with a single filament, the various types of de Forest tubes—long tube-shaped (type T) and spherical, as well as the Western Electric-made VT-1, VT-21 and VT-2. When used in regenerative circuits with about 22½ volts for the plate—nothing that was ever made before for detection could touch them. Then, one day in 1920, the newly-formed Radio Corp. of America, with patent privileges retained from the old Marconi Company of America, began to make the Marconi VT tube and warn other companies that it was infringing on its Fleming patent.

THE "UV" SERIES

In 1921, RCA released the UV 200 (detector) and UV 201 (amplifier), both triodes with brass shells known as the UV base, and incorporating a filament that required one ampere at 5 volts for operation. Previously, during July, 1920, the General Electric Company (which was manufacturing the tubes for RCA) made arrangements with the American Telephone and Telegraph Company, owners of the de Forest 3-element audion patent, so that by an exchange of radio patent privileges each was allowed to make tubes without fear of litigation. Shortly afterwards, the UV 201A (thoriated filament) tube was developed and released, a far better tube than the old 201 in many respects, especially since the filament only consumed one-fourth of an ampere and hence materially reduced the drain on the "A" battery.

Many of the early tubes had oxide-coated tungsten filaments, and operated at low brilliancy—such were, for example, the WD11's, the 200 and 201. Meanwhile the laboratories had been experimenting with thorium, and found it to be an efficient emitter of electrons. Consequently, in 1922, tubes with filaments both coated and impregnated with thorium (200A and 201A) came into general use.

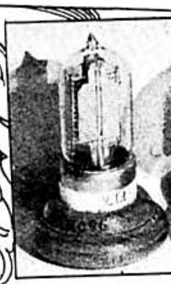
CONTEMPORARY DEVELOPMENTS

A digression here may not be amiss. These early tubes were high in cost as compared with tubes of today; they were not especially durable, and were easily damaged by being operated at too great a filament potential. Also, despite the ever-expanding facilities for tube


German Types – 1915–1922.


Audiotron in "holder" 1916.

Dr. Lee de Forest DeF.



Western Electric VT1-1917. BTL.

Moorehead Detector-1918. BTL.

LGP. Early G.E. Tube About 1919

FLEMING'S

LGP. Bartley Tube — about 1919.

LGP. Electron Relay (Moorehead)-1920-'22.

LGP. R.C.A WD11 Dry-Battery Tube.—About 1921.

manufacturing by the G. E. Company and Westinghouse (which were also manufacturing the tubes for RCA by this time), the supply could not keep up with the tremendous demand which was caused by amazing sales of receivers and parts as a result of the growth of broadcasting. Therefore, there sprang into being a new industry—*the rebuilding of radio tubes;* new filaments inserted for a dollar or two. Usually the repaired tubes had imperfect vacuum, but no one seemed to mind. At the same time, *tube reactivators* were put on sale for public use. These devices served to "boil" new thorium out of the wire at a high filament temperature, then "bake" it fast to the surface of the filament at a temperature only slightly higher than that used for normal operation. No plate potential was applied during this process.

The next advance was the low-current tube —the 199 (1922), which used only 60 milliamperes of filament current. This was important to fans who had to buy drycell "A" batteries or have storage "A's" recharged. After that, we find the trend going back to "soft" or gassy tubes for detection purposes. The 200A is an example, as well as the Donle sodium-vapor detector tube made by Connecticut Tel. & Tel. Co.

1926—POWER TUBES AND RECTIFIERS

In 1926, the early power tubes, such as the 120, the 112 and the 171 came into use. These afforded greater undistorted output and hence better reproduction than was formerly possible. The 210 and 250, usually used with a lighting-line filament and plate supply, soon followed.

The *"B"-eliminator* became popular in 1926, and as a rectifier the 80-type (filament) tube and Raytheon BH (helium-filamentless) or "cold" tube shared honors, although the latter tube is now practically unheard-of. All these types up to this date were known as *direct-heater* tubes.

1927—CATHODE-TYPE "INDIRECT-HEATER" TUBES

Then came 1927, with increased interest in A.C. all-electric sets, and we find the 226 and 227 tubes released by the tube manufacturers.

The 226 is a tube whose filament is slow to respond to the cyclic changes of alternating current, and, therefore, could be connected across an A.C. supply of 1.5 volts without causing hum.

The 227 employs a *cathode,* and is known as an *indirectly-heated* tube and for that reason was perfect for A.C. heater operation. Soon other A.C. tube models were produced, and the battery-operated tubes were pushed out of the radio picture, save for use in locations where electric mains were not available.

1928—SCREEN-GRID TUBES

In 1928, the *screen-grid tube* was released, type 224 for A.C. sets and 222 for D.C. sets. These tubes had tremendous amplifying power (as compared to old triodes) as well as inherently lower internal tube capacity.

The screen-grid tube did away with the necessity for neutralizing R.F. stages, and resulted in a more stable and sensitive receiver. In fact the amplification of this screen-grid tube was so great that local stations were tuned-in sometimes interfering with each other, sometimes so that they could not be "turned-down" soft enough. Special dual volume control circuits were necessary, as well as local-distance switches to reduce the antenna signal to the set on local stations.

The defect was known as "cross-modulation" and worried engineers no little, until 1931 when *variable-mu* tubes such as the '35 and '51 (by this time it had become the custom to use an apostrophe ['], later dropped, in place of the first of a tube's 3 code numbers) were released along with a *power pentode*—the '47 tube.

PENTODES

The new power tube was more sensitive and could be satisfactorily driven by the output of an average detector stage and still give higher power output.

In 1933, *multi-purpose tubes* were released such as the 2A7, 58, 2B7, 55, etc., to be followed shortly by similar tubes *but with heaters re-*

Early R.C.A Tube Type UV201-1921. LGP.

Atlantic Radio Supply Detector and Oscillator-1927. BTL.

Myers Cartridge-Type Tube, RAC-3 -About 1922-'24. LGP.

215A-"Peanut" Det.-Amp.-1921-'22. B.T.L.

First "Peanut" Tube, With External Plate About 1922. RDW.

RCA UV201A Thoriated-Filament Tube ~1922. LGP

De Forest DV3 Triode About 1923. LGP

Dr. Vladimir Zworykin RCA

VALVE AND UP

quiring 6.3 volts instead of 2.5 volts. The 6A7, 78, 6B7, etc., are examples. Also, in this year, the *acorn tubes* were developed as a result of research in the ultra-highfrequency field.

1935—METAL TUBES

The final stage in the development of tubes, to date, is the now famous *metal tubes*, and the *secondary emission* tubes. In theory, the metal tubes are a marked improvement over the glass tubes, since they are smaller, entirely shielded and, therefore, better for efficient, stable circuit operation. The "secondary emission" type of tube, in its most advanced design, is perhaps best represented by the *electron multiplier* introduced in the winter of 1935-'36 (See *Radio-Craft*, Jan. 1936, pg. 391.); its design makes possible a gain of several millions (i.e., amplification about equivalent to that of 6 or more ordinary tubes). The "electron multiplier" tube makes possible heretofore unattainable results in the field of television. All in all, the vacuum tube development from Fleming's early diode has been more than satisfactory, and in no small measure responsible for the great improvement in the operation of present-day radio receivers.

CONTEMPORARY DEVELOPMENTS

All vacuum tube developments, however, were not along "receiving tube" lines only. In the early part of the 1930's we find tube manufacturers considerably interested in various other applications of "electronics", as a consequence of which numerous strange types and special-purpose tubes have been developed. Their continuous research into the problems relating to tube operation and production made the evolution of special tubes designed for a specific though relatively foreign application, comparatively simple.

Specific types, with which we are now all familiar, are the various types of photocells—including the caesium and the miniature RCA types 922-923; the cathode-ray, of which we now have various sizes ranging from a 1-inch in diameter screen to 10 inches; the electron-ray tuning indicator tube; the "iconoscope", a special tube for television pick-up purposes; the beam-power tube, used essentially in high-power amplifiers for obtaining tremendous power outputs; improved-efficiency transmitting tubes, by using graphite or carbon anodes for reducing plate losses due to the tremendous heating of this element when operated at maximum ratings. Also, concerning transmitting tubes, the improved construction of present types enables more stable and improved operation on higher frequencies.

Apace with these developments, we find improvements made in rectifier tubes—in some, the inclusion of mercury vapor which ionizes when the filament becomes heated and thus aids the conduction or flow of electrons between plate and filament. In addition, special types of thyratrons have been developed for inverter equipment, the release of which has done much towards solving many special problems in industrial fields.

It is perhaps best that mention be made here of special tubes *still in the laboratory and in the process of being developed*, the release of these tubes pending the solution of some problems which retard their efficiency and hence application in the radio and electronic fields. These tubes are of the "cold-cathode" variety, no filament or heater being employed although, it must be emphasized that no immediate promise for their future release to the public is in sight.

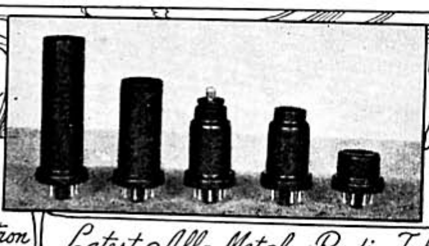
Due to lack of space we have not been able to discuss *transmitter-tube* developments. In general, though, they have paralleled the development of receiving tubes; and, in fact, almost all the low-power transmitting tubes, for many years, were taken from the field of receiving-type tubes. *Public address* and *electronics*, two newer applicational fields, tell the same story; only within the last 3 or 4 years has there been any evidence of other than regular radio receiving tubes being applied to these fields. But the march is on! Today, it is estimated that there is an approximate total (radio receiving and transmitting, public address, and electronics general and special-service) of about 500 types of tubes; tomorrow?—!

RDW. Schickerling Novel-Construction Triode.-About 1924.

RDW. Conn. Tel. & Tel. Sodium Detector Tube.-About 1924.

LGP. Helium Rectifier; 250 ma. Output-for "A" Eliminators-About 1925-6.

BDL. Newest and Possibly Future Radio Tube. The Electron Multiplier-1938.



Latest All-Metal Radio Tubes 1935. GE.

RDW. Kellogg (Also McCullough). A.C.-Filament Tube. About 1926.