THE MANUFACTURE OF VACUUM DETECTORS*

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Altho the majority of radio engineers are familiar with the use and operation of vacuum tube detectors, a brief description of their manufacture may be interesting.

In the early experimental work on this type of device, we strove to produce a detector which would combine maximum operating efficiency with inexpensive manufacture. The next point considered was the production of desirable conditions, i.e.; tubes that possessed oscillating characteristics, tubes that were exceptional detectors, and tubes that displayed both qualities. The third consideration was the production of a device easily handled and shipped without disturbing the adjustment of the elements and damaging the filaments.

Tubes and bulbs of various shapes and sizes were tried using a gaseous medium ranging from one millimeter to 0.025 millimeters of vacuum, many materials being employed as elements. Various exhausts were applied but it was soon found that the employment of a gaseous medium introduced considerable difficulty in the matter of accurate reproduction of a desired result. Gases at pressures ranging from one millimeter to 0.0013 millimeters were next experimented with.

I found that a tube containing a platinum filament in an atmosphere of hydrogen, at pressures comparable with one millimeter, gave fair results. Tungsten filaments were then tried in higher vacua as well as at the so-called "gaseous medium" pressure. It was immediately noticed that conditions could be duplicated as soon as vacua above that which allowed a "gaseous medium" to exist, were obtained. Moreover, tungsten was ideal as a filament not only because of its refractory qualities and low volatility but also because it acts as a purifying agent by attacking any traces of residual gases that may remain in the tube and forming compounds which are then volatilized on the walls of the tubes.

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As the parts are small and complicated, the glass is worked before the blowpipe, after it has been brought into the form of tubes by the glass works. This tubing is obtained by first blowing a bulb, then fusing an iron rod to a point diametrically opposite the blowpipe and rapidly separating the two points of attachment from each other.

Various grades of glass were experimented with, and a mixture containing a high percentage of lead and a small quantity of silicic acid was found to be the easiest to work and produced a detector of maximum sensitiveness when used in conjunction with the aluminum plate and copper grid. In the selection of the glass to be used, the devitrification of the glass had to be considered, as during exhaustion of the tubes it is necessary to subject them to a temperature near the point of softening and nearly all glasses, when maintained at this temperature for any length of time, have a tendency to separate out into the crystalline state.

There has been considerable discussion regarding the elements in this type of device and I may say that aluminum plates and copper grids were first selected on account of their electro-chemical relation to the tungsten filament. Later, numerous other metals were tried under the same and other conditions of exhaustion and showed widely different operating characteristics.

The selection of metals for the elements is very difficult, as a slight difference in either the copper or aluminum changes the whole system of exhaust. For instance, copper and aluminum purchased from one factory will require a certain degree of applied temperature during the evacuation, while another factory lot of the same weight and size will require an entirely different exhaust.

I have eliminated this variation to some extent by subjecting the aluminum plates to a temperature of approximately 600 degrees Fahrenheit (315° C.), immersing them in a saturated solution of cyanide of potassium, and finally rinsing in alcohol. The copper is subjected to heat until it glows, when it combines with the oxygen of the air to form a black, brittle oxid which breaks off in scales and exposes the underlying metal which is of rose red color. It is then placed in a current of moist air and becomes covered with a layer of oxygen compounds, which remains very thin but closes the pores of the metal.

The exhaustion of the tubes is the most important operation because of the fact that the low vacuum of the round bulb nickel element audion which permits of gas conduction is not used in the tubular "electron relay," wherein all gas phenomena must be eliminated.

To produce the high vacuum necessary, I have found that a Gaede mercury pump capable of producing a vacuum of 0.00001 millimeter, backed by a piston pump, such as the Geryck type, is the most satisfactory method of evacuation.

The manifold to which the tubes to be exhausted are attached and the vacuum line connecting the manifold to the pumps are preferably made of large diameter tubing. A container filled with pentoxid of phosphorus is connected in the vacuum line between the pump and the manifold. The manifold is contained in an oven heated by gas and arranged so that the tubes during exhaustion may be heated to high temperatures.

The lead glass tubing, used as the container for the elements in the tubular type detector, is obtained from the glass works in lengths of 6 feet (2 m.) with an inside diameter of 0.875 inch (2.2 cm.) and a wall of 0.032 inch (0.7 mm.) thickness. This tube is cut in lengths of about 6 inches (15 cm.) and one end is drawn down to a point. Two stems are made of glass tubing similar to those used in an incandescent lamp, one stem contains the grid and two filament leads and the other contains the plate connection and one filament lead. After the wire is sealed into these stems, they must be annealed very carefully. The annealing consists in allowing the temperature to drop very slowly, since quickly cooled glass is subject to internal strains which arise in the following manner: In rapid cooling, a low temperature is soon established at the surface and the outermost layer solidifies while the interior tends to contract, thereby exerting a pressure on the outer layer which is directed inwards. This may cause the stem to crack.

After the stems are annealed, the grid is wound to the proper diameter and the filament is clamped onto the two leads. The plate is mounted on the other stem and the two stems are then connected together by means of the filament. Final adjustment of the plate and grid is then made. The spacing between the elements is not very critical in this type of device, but it is best to wind the grid to a large enough diameter so that it will strike the plate rather than the filament when the tube is jarred.

After adjustment on the plate and grid has been made, the assembly is inserted into the prepared tubes and the end seals made. A short length of small diameter tubing is attached to the seal at one end of the tube, this being for connection to