VACUUM DETECTORS.

IRE Paper by O.B.Moorehead January 16th,1917.

Although the majority of radio engineers arevfamiliar with the use and operation of vacuum 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 reproduction of ide conditions,ie.,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 m/m to .o25 m/m of vacuua,many materials being employed as elements.Various expausts were employed but it was soon found that the use of a gaseous medium introduced considerable difficulty in the matter of accurate reproduction of a desired result.Gasses at pressures ranging from 1 m/m to .oo13 m/m were next experimented with.

I found that a tube containing a platinum filament in an atmosphere of hydrogen at a pressure comparable with one m/m ,gave fair results.Tungsten filaments were then tried in higher vacuua as well as in the so called gaseous medium pressure.It was immediately noticed that conditions could be duplicated as soon as a vacuum above that which allowed a gaseous medium to exist,was obtained.Moreover tungsten was ideal as a filament due not only to its refractory qualities and low volatility but 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.

As the parts are small and complicated,the glass is worked before the blow pipe,after it has been bought in the form of tubes from the glass works.This tubing is obtained by first blowing a bulb,then fusing a iron rod to a point diametrically opposite the blow pipe 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 exhaustionof 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 a uminum plates and copper grids were first selected on account of their electro-chemical relation to the tungsten filament.Later numerous other metals werectried under the same and other conditions of exhaustions and showed widely different operating characteristics.

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

I have eliminated this variation to some extent by subjecting the aluminum plates to a temperature of approximately 600 deg.F. and immersing them in a saturated solution of cyanide of potassium,finally rinsing in alcohol.The copper is subjected to heat until it glows, when it fairly combines with the oxygen to form a black brittle oxide 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 remain very thin but closes the pores of the metal.

The exhaustion of the tubes is the most important operation due to the fact that the low vacuum in 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 produwing a vacuua of .00001 m.m,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 is preferably made of large diameter tubing. A container filled with pento oxide 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 as used as the container fo the elements in the tubular type detector is obtained from the glass works in lengths of six feet with an inside diameter of 7/8" and a wall of1/32 inch thickness. The tube is cutvin lengths of about six inches 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 filamen lead. After the wire is sealed into these stems they must be annealed very carefully. The annealing consists of allowing the temperature to drop very slowly as quickly cooled glass contains 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 causes the stem to xxx 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 diameter large enough 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 inserteh in the prepared tube and the end seals made. A short length of small diameter tubing is attached to the seal at one end of the tube, this bei ing for connection to the pump manifold. The tube is then carefully annealed and is ready for exhaustion.

A number of tubes are sealed on the manifold in the oven and the temperature is gradually increased to 900 deg. F. at which point the pumps are started. The tubes are heated in this manner before the pumps are started so that the air contained in the tubes may conduct the heat to the central elements and drive off the occluded gasses. When the pumps have produced a vacuum of 1 micron, the temperature of the tubes is very gradually raised to 1000 deg. At this point they must be watched very closely as the melting point of this glass varies greatly and should the walls of the tube become soft, the vacuum would suck them in. From one micron the vacuum slowly increases and after about five hours of continuous pumping the tubes are sealed off the manifold and allowed to cool in the oven.

McLeod gauges are used in the measurement of vacuua but I have found that a much more accurate vacuum comparison can be made by using a large induction coil. For this purpose an electrode is sealed to the manifold or at some point in the vacuum line. One terminal of the coil is connected to this electrode and the othe coil terminal connected to the vacuum pump. A calibrated spark gap is used on the coil and when the vacuum is high enough and the residual gasses are properly pumped from the tube a spark will jump from the gap with-

without a glow in the vacuum line or the tubes. The vacuum used in the tubular detector will back down a five inch spark between needle points in air.

Prof. Richardson has shown that when new metals are heated to incandescence they emit positive ions, probably due to the impurities or gases in the metal? I have found that this positive discharge must be eliminated to obtain maximum sensitiveness of the tubular detector and this is accomplished during manufacturing stage by burning the filament on alternating current for about two hours. The tubes that have not been treated in this manner are found to be less sensitive than those in which the positive emanation has been destroyed.

DISCUSSION.

Mr. Sprado- Referring to your last paragraph regarding to the emission of positive ions I gather that this phenomenon is rather transient. If a tube is left idle for quite a period of time, would it recover the power of positive emanation?

Moorehead;-The phenomenon referred to I have noticed to be an emission from fresh wires only and when these wires are heated in a vacuum these positive emissions decay rapidly at first and then more slowly until it finally disappears. This rapid disappearance can be facilitated bybapplying a positive potential to the hot metals. I do not know if it will recuperate when left absolutely idle but it can be revived by burning a fresh wire near it and the old wire being cold. This must be due to a substance which is distilled from one metal to another.

Sprado:-In some research work that I have recently done with the gaseous type of device I have noticed that this power of emitting positive ions can be restored if the plate or filament end of the Audion is held to one terminal of a high tension coil and a luminous discharge be caused to fill the bulb. Do you believe that this rapid decaying of the posiyive emission bears any relation to that phenomenon commonly called Photo-electric fatigu

Moorehead:-It probably does as the photoelectric sensitiveness is not recovered after the surface has rested. Have you ever tried your luminous glow experiment on a plate that shows photoelectric fatigue and ascertained if it regains its sensitiveness.

Sprado:-No I have not. I note that you have experimented with platinum filaments in hydrogen. Did you make any experiments with tungsten in the same or other gasses?

Moorehead:-I have found that tungsten in hydrogen operates very poorly and that exceedingly small amounts of gas cause very great changes in the values of the constants. This applies to all the gases with which I have experimented.

Sprado:-While making the above experiments I had occasion to use different pressures of Argon in your tube. I found that the saturation currents in this gas have the same value as in the higher vacuua. I noted that wh when small quantities of argon were used the attainment of saturation was greatly facilitated due to the action of positive ions formed by impact ionization, in reducing the effect of the mutual repulsion of the electrons. When argon was present in greater quantities the saturation current was considerably higher. Have you any theory regarding this increase in current?

Moorehead:-I presume this was due to ionization by collision of electrons with the argon gas molecules.