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Vacuum Tubes The Hard Way

Building Home-made Tubes

BY SAM DIAZ PUMARA*, ex-LU2DII

My interest in vacuum tubes dates back forty years to when I was a boy not yet ten years old, in Buenos Aires, Argentina. My father had just brought home a WD11 tube, for which he had paid $24, to replace a burned out tube in his regenerative receiver. My interest and enthusiasm for tubes mounted as I was able to examine the old WD11. Right then, I promised myself that I would someday build my own tubes. Seventeen years later I made my first one — a very, very primitive thing — for I did not have the necessary equipment or the materials.

Today I have the equipment I need. That which I could not buy I have built myself. I am able, therefore, to build many types of tubes and rebuild tubes of various sizes and types.

My avocation has fascinated many persons who believe that if one can produce workable radio tubes with high vacuum in one's own home, the process must be relatively easy. When one has the necessary equipment and knowledge of materials and techniques, some of the problems of building tubes are solved. Even so, the process is not as easy as it appears.

The Problem of Vacuum

Consider the fact that a high vacuum pump connected to a chamber and pumping continuously would never be able to remove all molecules of gas from the chamber. Although it is impossible to produce a perfect vacuum with today's equipment, science is always progressing and bettering systems. It is now possible to produce vacuums up to and over 10^{-14} of a millimeter, but a vacuum of 10^{-9} or 10^{-10} is considered excellent. The higher the vacuum produced, the greater the difficulty in finding instruments sensitive enough to measure the molecules of remaining gas.

After the envelope is blown and the internal parts of the tube are constructed, one must produce and maintain a good vacuum for the lifetime of the tube. All further processes are directed to this end.

A major part of this problem is to extract occluded gases from the various parts of the tube. Generally the tube parts are submitted to an intense heat treatment in vacuum chambers for this purpose. After the tube is mounted in its glass envelope, the whole unit is submitted to a temperature of nearly 500 degrees Centigrade for hard glass bulbs, such as Pyrex. Soft glass, such as lead and soda glass, require a temperature of almost 400 degrees Centigrade. This amount of heat will extract gases from the tube parts, as well as much of the water vapor that is always present on the surface of glass. The entire operation is performed with the high vacuum pumps working and the process may last from one to several hours, depending upon the size of the tubes.

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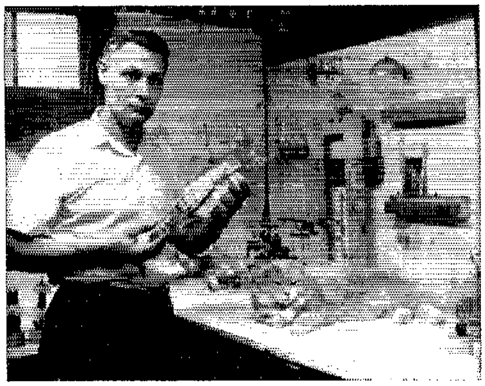
The author and a view of the vacuum shop where the tubes are constructed and evacuated.



The author holding a tube envelope and anode for a 2 kw. transmitting triode. Some of the apparatus used for making the tubes can be seen in the background. Observing the goings-on from table-top level is Rica.

When the vacuum has reached 10^{-6} millimeters or more, it is time to heat the elements of the tube with an r.f. generator or by electronic bombardment. The latter is used in my workshop.

With the filaments lighted, high voltage is gradually applied to the plate until the anode of the tube begins to show color. This operation must be conducted with extreme care because gas begins to leave the element and the tube may arc, melting the electrodes. Therefore, the heating must be very gradual and the results constantly observed on the vacuum gauge. Eventually, at the end of the heating process, the anode is glowing brightly and the highest possible vacuum is achieved. The next step is to fire a small barium getter which helps to maintain vacuum throughout the life of the tube.

In my basement vacuum shop three pumps are used. A mechanical oil pump, producing a vacuum better then 10^{-2} millimeters, is connected to a second pump of the diffusion type, with two stages. The high vacuum pump is a three-stage oil pump. With these three pumps it is possible to obtain vacuums of nearly 10^{-8} millimeters, which is more than sufficient for my purpose.

All glass seals used in the tubes which I build and repair are made with tungsten metal and uranium glass which assure a perfect hermetic seal even though the tubes in operation are submitted to great differences of temperature.

Filaments

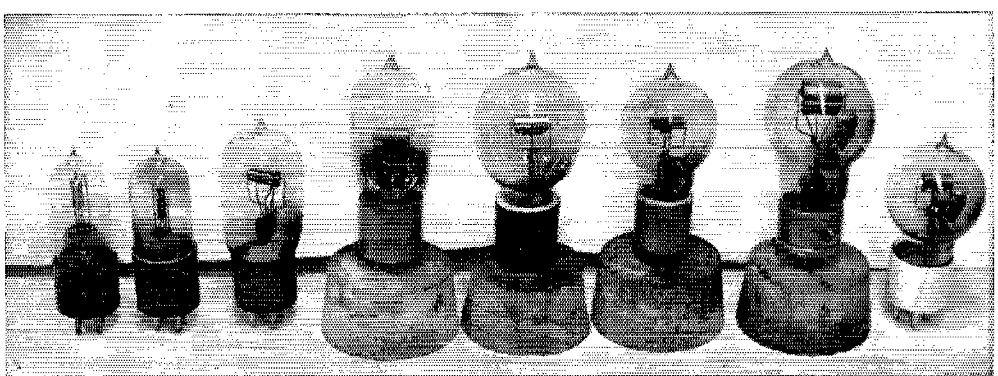
Most of the filaments used in my tubes are tungsten and thoriated tungsten. For small tubes, where the filament consumption is low, fine thoriated wire is preferred. This wire is also indicated for restoration of old-fashioned tubes used in antique equipment.

Pure tungsten filaments are interesting in that they are not easily poisoned by gases in the envelope and thus the vacuum required in the tube is not so great. However, tungsten filaments require relatively higher current for producing electron emission. As a bonus, they will last from 2000 to 3000 hours, all the while giving excellent service. In tubes with tungsten filaments, the elements have to be spaced farther apart and larger envelopes are required, due to the great generation of heat produced by these filaments.

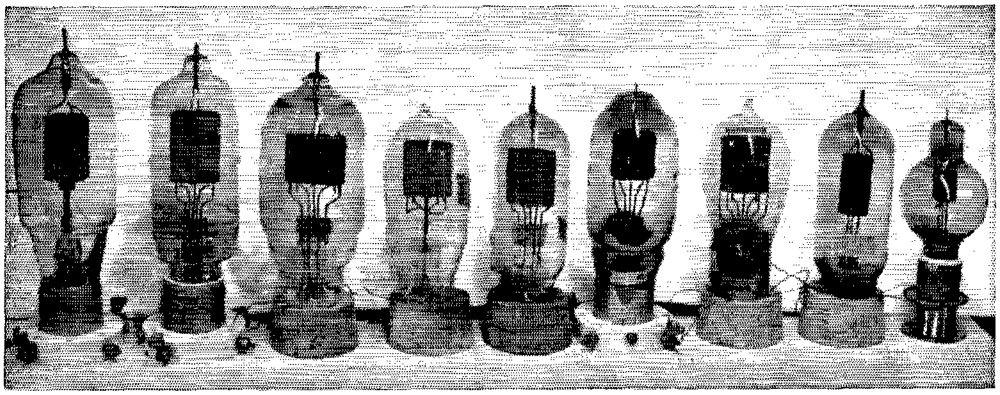
Thoriated filaments on the other hand have the advantage of emitting more electrons at lower currents but they have to be used in the highest possible vacuum in a very well cleaned-out tube, otherwise they are easily poisoned by even the smallest trace of gas.

Barium and strontium filaments are not as good for my purposes as the tungsten and thoriated tungsten. Barium and strontium are the best emitters but they contain a great deal of gas which prolongs the pumping time of the tube, and if filaments of these types are not made evenly, hot spots will develop. These hot spots shorten the life of the tube and produce unstable operation.

The thoriated filaments must be activated when the tube is about to be finished. Activation is accomplished by applying three times the normal filament voltage for a period of a few seconds. This procedure produces a temperature of about 2800 degrees Kelvin and the thoria in



Some of the hand-made receiving tubes. From left to right are two WD12 tubes, a German tube, two British "R" tubes and two French tubes of the 1920's. Bases are salvaged from commercially made tubes.



Transmitting tubes made in the basement workshop. Tubes 1, 2, 3, 6, 7 and 8 from the left have thoriated tungsten filaments; others have pure tungsten filaments.

the wire is diffused to the surface of the filament where it forms a layer. After many thousands of hours the thoria will be consumed and the tube is rendered useless.

If the tube is thus made useless, it is sometimes possible to use it as a pure tungsten filament tube, if additional voltage is applied to the filament. However, in many cases, the spacing of the tube elements is so small that the grid will get too hot and start emitting.

Other Elements

All the tube parts are welded by my home-made spot welding machine. The metals used include molybdenum, nickel, tantalum, stainless steel, and copper. Molybdenum is excellent for great strength, but it is a difficult metal to weld. For this reason, in big tube structures where anodes are working at high temperatures, it is best to rivet the molybdenum. If the anode is working at low temperatures, it can be welded easily to nickel.

Filaments are welded to nickel wires three or four times the thickness of the tungsten filament. This avoids excessive vaporization and assures better conductivity. The recommended procedure is to bolt them, but this is costly and takes extra time.

Grids for my tubes are made on a mandrel of copper utilizing two wires of nickel of approximately 70 mils, depending upon the size of the tube to be built. The grid may be round or oval. It is made by coiling the nickel wire, of approximately 10 to 15 mils diameter with enough spaced turns to cover the two transversal nickel wires. If the tube is going to use much power, the thin nickel wire is replaced by molybdenum or tungsten.

The Envelope

The anode is generally sealed in the upper part of the bulb, becoming self-supporting. If the envelope or bulb is made of Pyrex glass, a piece of uranium glass will have to be welded to the element-supporting tunsten rod. The uranium glass will closely match the coefficient of expansion of the tungsten as well as the Pyrex glass of the bulb. If the tube is Nonex glass, which is used extensively in commercial tubes, the tungsten can be welded directly to the glass. Nonex requires a high oxidizing flame. Otherwise, the glass turns dark. Nonex is a very good glass to work on the glass lathe since the flame doesn't touch the glass continuously in the same spot and discoloration does not appear.

For small receiving tubes, the best glass to use is either soda or lead glass, with the sealing wire being Dumet or copper-clad wire. This glass requires careful annealing, much more so than Pyrex glass, if cracks are not to appear. Small tubes can be made in Pyrex, but working with this glass requires an oxygen cylinder and a special valve, both of which I have in my shop.

Other people may think I'm a nut about vacuum tubes and maybe I am. My happiest hours, however, are spent during evenings and weekends when I can go down to my basement workshop and build tubes. My thanks to Mr. Carl Volz, Jr., who took the photographs used in this article. QST

Strays

The International One Sixty Society is a newly-formed group of 160-meter enthusiasts aimed at promotion of common interests, agreement on mode usage between a.m., sideband and c.w., exchange of technical data, etc. Dues are $2; a bi-monthly news letter will be published. Address the acting director, Ike Kerschner, RD 1, Box 254, Telford, Penna.

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K9BRI has a problem. Bugs congregate around the main tuning dial opening. Presumably some of the spray repellants would mar the finish. Any BRIght ideas?