Some Aspects of Radio Valve Manufacture

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Many users of wireless valves, whether for domestic or scientific purposes, can have little or no conception of the many interesting manufacturing problems which have confronted the technical and production engineers of the Industry in producing the modern valve.

In contrast to the general run of precision engineering, which deals with solid pieces of metal which can be readily machined and finished to fine limits of accuracy, the valve engineer has to produce and assemble a wide variety of thin sheet metal and wire components many of which are extremely fragile and require very careful handling to avoid distortion. The wireless valve is an electrical device which depends on extremely accurate spacing of the various electrodes, and it will not be difficult to appreciate that any mechanical distortion will materially increase the effect of the small manufacturing tolerances allowed and largely control the uniformity of the finished product.

The special electrode materials in general use are tungsten, molybdenum, pure nickel, various alloys of nickel with manganese, aluminium or magnesium etc., and have been chosen, not on account of their easy working properties, but for their ability to withstand high temperatures and their general freedom from impurities. A high standard of inspection, both dimensional and analytical, has been set by valve manufacturers on all the various raw materials employed to ensure that the necessary quality is maintained. Uniformity of raw materials is essential for the smooth running of intricate machinery, and to permit strict adherence to approved manufacturing processes.

Another interesting point is that many of the processes are peculiar to the industry and require special plant which, in the majority of cases, is designed and constructed by the manufacturers themselves.

Component Manufacture

In spite of its small size a wireless valve can have as many as thirty or forty separate parts depending on the purpose it has to fulfil. These parts are generally produced by each valve manufacturer to his own design and in order to exercise the necessary degree of control.

The glass bulbs are produced on automatic machines where the quantities are sufficiently large to justify a large hourly production. A vacuum operated device is provided on these machines to collect from a tank of molten glass the correct amount for each bulb, which is then blown by compressed air to the required shape in split moulds. The bulbs are then ejected from the moulds and passed through an annealing furnace to remove internal strains. The hourly rate of production is about 3,500 to 6,000 bulbs per hour, depending on the type of machine. Where the quantities are small it is more convenient to have the bulbs produced by glass blowers, but of course, it is not possible to maintain the same degree of uniformity by this method.

Except in the case of metal valves glass tubing is used for the electrode assembly foundation and also for the exhaust tube. This tubing is produced on a machine in which a stream of molten glass is allowed to fall on to a sloping cylindrical mandrel. As the mandrel slowly rotates the glass becomes deposited as a thick film, which slides down the nose from which it passes on to a series of rollers mounted on the floor of a long shed. A jet of air, emerging from the nose of the mandrel, prevents the tube from collapsing until it has cooled sufficiently to retain its circular cross section. At the end of the rollers is a mechanism for pulling the tubing along at a steady rate, varying from 200 to 300 ft. or more per minute depending on the size of the tubing. The diameter and wall thickness of the tube are adjusted by varying the rate of flow from the furnace, the diameter of the mandr and the speed at which the tube lea the mandrel. Combined with the pu ing mechanism is a cutting device, separating the tubing into lengths approximately 4 ft., which is a co venient size for handling in sub quent operations. The cutting is ca ried out by a chisel edged carbor dum block mounted on a belt havi the same length as that of the gl sticks, and which travels at the sa rate and in the same direction as th tube. The belt is set at a slight ang to the glass tube so that a cross ru bing action takes place between th cutter and the tube whilst the two a in contact.

The glass tubing produced by th method which has just been describ is used in the making of the valve fo or pinch (Fig. 1). The lengths of tu ing are inserted vertically into a fla ing machine, fitted with a number revolving chucks mounted on a sma circular table, which is indexed at r gular intervals of time. At the fi two or three stationary positions of t table, the bottom end of each tube heated by gas burners until it becom plastic. Whilst in this condition spinning tool is brought into conta with the tubes, which are flanged o wards (Fig. 1/6). In the next two p tions the flanged tube is cut to leng by heating at the required distan above the flange and parted off by t rotating bevelled circular knives, on the inside and the other on the o side. On the last position the chu are opened, allowing the length tube to fall on to a length setting pl ready for the cycle of operations to repeated.

The flanged tubes are now tr ferred via a sloping chute to a ho zontal circular slotted table, and

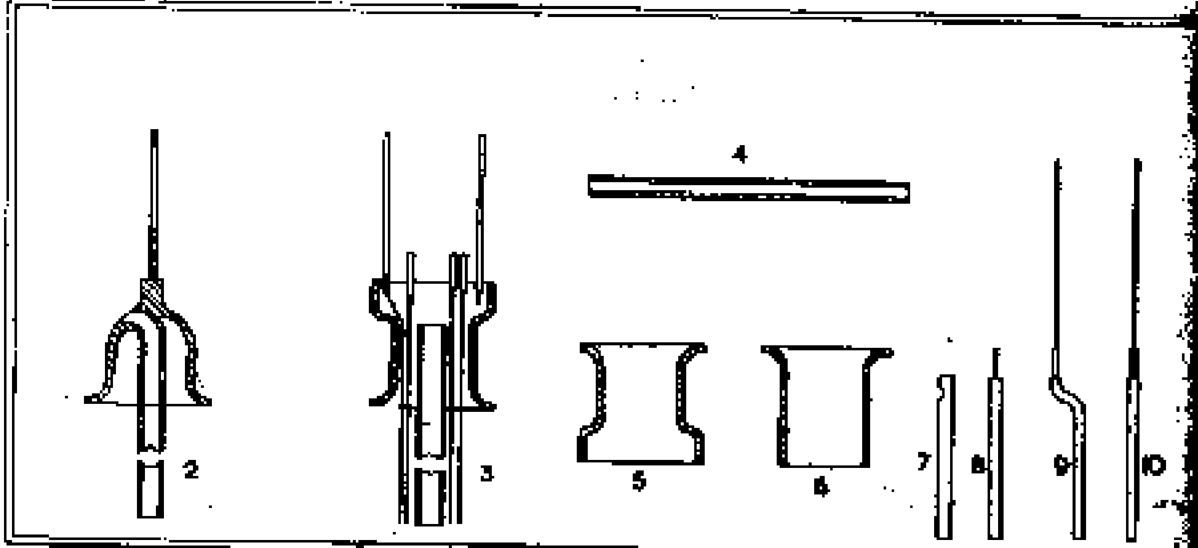

Fig. 1. The glass "pinch" of the valve and its component parts.

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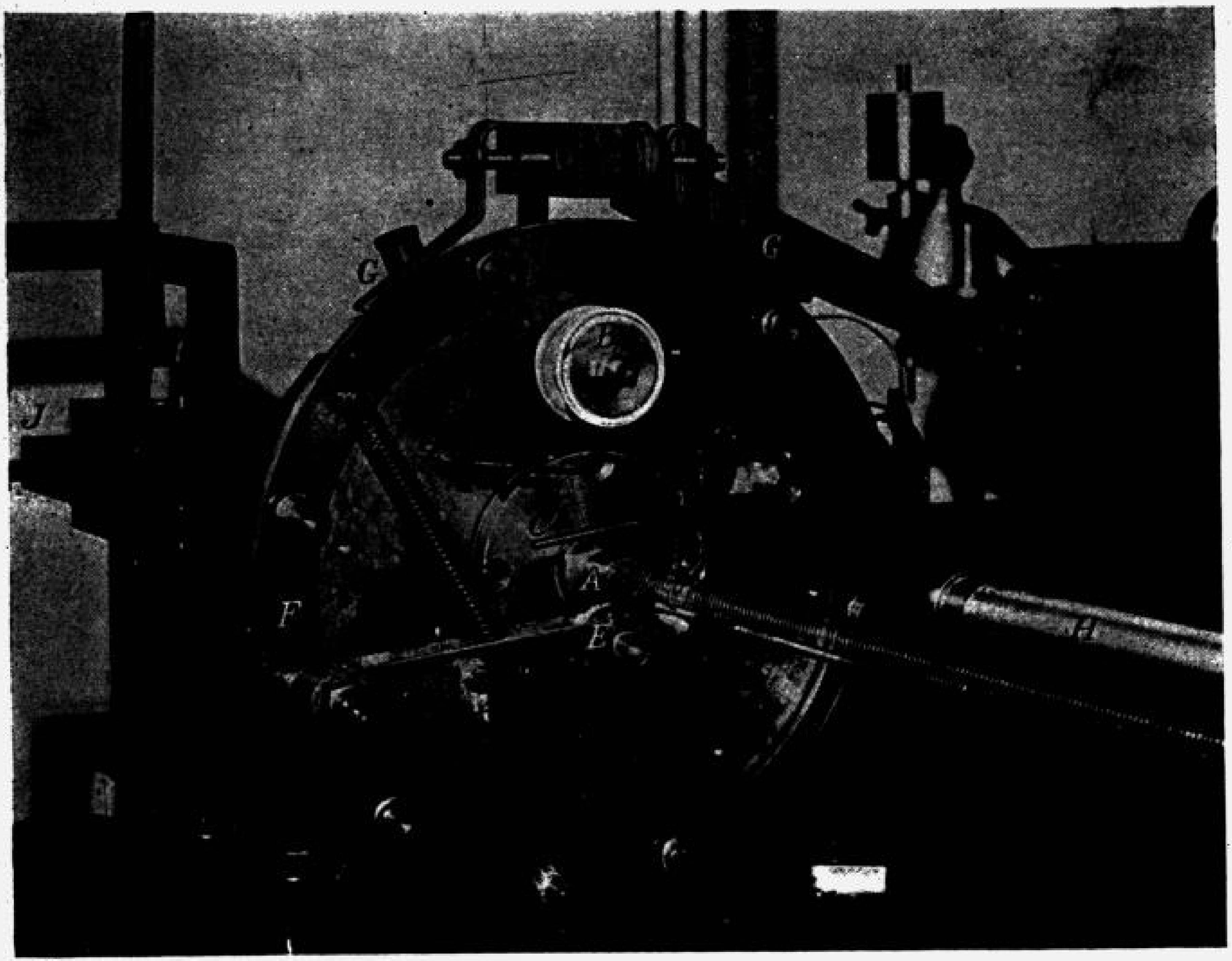

Fig. 5. Close-up of the grid winding machine showing grid wound in a continuous length.

order that they can be supported by the flange, are inverted during their passage down the chute. The table is indexed so that each slot receives a flanged tube, which is heated at the bottom end until it becomes plastic. At a suitable position a pair of blades, similar to a glove stretcher, are inserted and the tube stretched to the shape shown in Fig. 1/5. This operation is necessary in those cases where the two outer electrode lead wires are spaced at a greater distance than the internal diameter of the tube.

The lead wires, which not only support the various electrodes, but provide electrical connexion to them, are in most cases composite in nature. In Fig. 1/10 is shown a three-piece lead comprising (a) an electrode support, usually nickel, (b) a short length of alloy wire which is fused into the tube to form a vacuum tight joint, and (c) an external copper connector. When a very wide spacing is required between the outer supports, the nickel component is pre-formed as in Fig. 1/9. In those cases where an electrode is supported by two wires, one of them does not have an external copper connexion and is made with either a short length of alloy wire (Fig. 1/8), or with a nick (Fig. 1/7), to hold it securely in the glass.

The foot or pinch is made by inserting the lead wires, nickel downwards, into holes drilled in a heat resisting die block. The glass flange and exhaust tube (Fig. 1/4) are supported in Fig. 1/3, *i.e.*, with the welded joints of each of the lead wires lying within the flattened zone of Fig. 1/5. Whilst thus aligned the die block and jaws are indexed through a number of graduated fires to reduce the thermal shock to the glass, which gradually becomes plastic and flows around the lead wires. At this stage a pair of jaws compress the glass firmly around the wires and complete the seal. The inner end of the exhaust tube is now embedded in the pressed portion of the flange tube, and, in order to provide a free passage for exhausting the valve, a jet of air is directed into the outer end, whilst at the same time small gas burners keep the upper surface of the pressed portion in a plastic state. The air pressure in the exhaust tube forces a passage through the wall as shown in Fig. 1/2, which is a view taken at right angles to Fig. 1/3. The final pinch is then thoroughly annealed to prevent glass cracks. The conventional type of pinch-making machine may have from twelve to twenty-four heads, and production varies from 200 to 400 pinches per hour according to type. As a final operation, and depending on the layout of the various electrodes, the lead wires are trimmed and bent to the required shape as for example in Fig. 8.

The metal components can be divided roughly into two groups, *i.e.*, sheet metal pressings, and those made from wire or strip.

Those falling into the first group consist of anodes, beam plates, shields, contact caps etc.:

Anodes are generally two-piece pressings, or single piece as in Fig. 2.

Shields and other pressings in general use are too diverse to describe in detail, but represent general press work technique, except that the thin material used and the accuracy required calls for the highest skill in tool making. It will no doubt have been noticed that some of these are made in bright metal and others in black. Black or carbonised material permits the use of smaller components

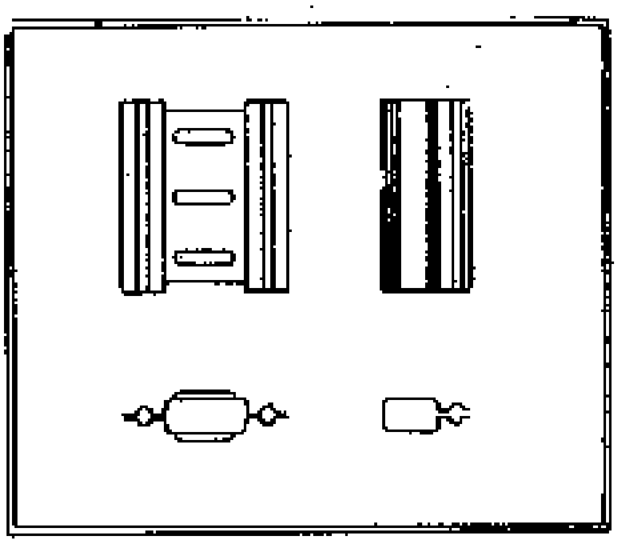

Fig. 2. Various one-piece and two-piece anode pressings.

for a given wattage dissipation on account of its improved heat radiating properties, a very useful factor in view of the modern tendency towards a reduction in the overall size of valves. A large variety of formed wire and strip components are required for clamping, supporting and connecting purposes. These are produced on automatic machines where the quantities required are large, otherwise it is more economical to construct simple hand operated jigs, which do not require careful setting up.

Depending on the function which it has to fulfil, a valve, unless it is a diode, may have from one to six separate grids. The grids are usually the most critical component parts of a valve and it is proposed to deal with their manufacture in some detail.

A grid normally consists of a helix of fine wire attached to one or more longitudinal support rods and may, according to requirements, have one of the various cross sections shown in Fig. 3. The helix pitch in the majority of cases is constant and can vary from 8 turns per inch to nearly 200 turns per inch. In certain cases of high frequency valves used in manual or automatic volume control circuits, the pitch is increased in the centre portion as shown in Fig. 4 (right).

The two methods of attaching the grid wires to the supports in general use are by resistance welding or by a mechanical process of notching and swaging, the latter being in effect a caulking process. In certain older types of transmitting valves the supports are laced to the grid turns by means of a fine binding wire, mainly because the art of welding together two molybdenum wires had not been developed when these types were introduced. Welding by high speed machines is really only practicable when the small diameter winding wire has a higher melting point than that of the supporting wires, so that with the increasing use of materials such as nichrome, manganese nickel, etc., which are considerably cheaper than molybdenum, the use of this process has diminished in recent years. The notching and swaging process provides unlimited scope in the choice of materials; a considerable boon to the valve designer.

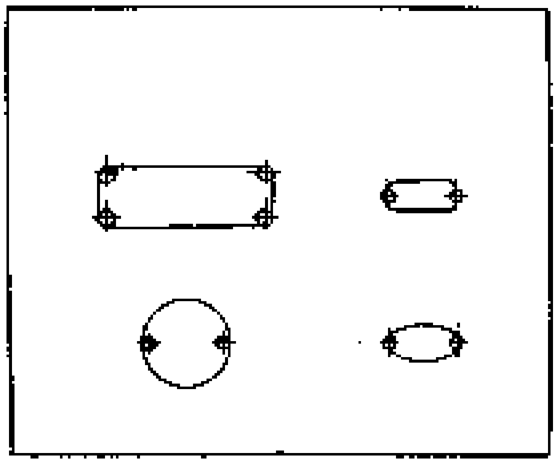

Fig. 3. Cross sections of various types of grid.

Irrespective of the process employed, the basic principle of the winding machine, one type of which is shown in Fig. 5, is that of a screw-cutting lathe. A short mandrel (A) of the required cross section, with longitudinal grooves to accommodate the support wires, is mounted in a non-rotating holder inside the hollow main spindle through which pass the support wires, fed from spools carried in an external cradle. The support wires are adjusted in the initial set up to project beyond the nose of the mandrel and are gripped by a suitable clamp mounted on the slide rest, which is traversed by a lead screw (H) driven by a train of gears to give the required pitch. A face plate (D) mounted on the spindle carries both a spool of winding wire (B) and a spring loaded welding roller (E), which is connected by brushes (G) contacting an insulated ring (F) on the face plate, to the low voltage secondary winding of a single phase transformer. As the face plate revolves around the stationary mandrel, the wire is drawn off the spool over guides (C) and welded to the grid support wires. The machine is now stopped when the slide reaches the end of the machine bed and the length of wound grid severed close to the mandrel, the slide traversed back to the starting point and the clamp reconnected to the support wires.

In the notching and swaging process, shown diagrammatically in Fig. 6 stages A, B and C, the cycle of operations is very similar, except that a rigidly supported sharp-edged circular cutter, which is free to revolve, is substituted for the welding roller. This cutter makes a succession of notches in each of the support wires as they are drawn across the mandrel, and into these the winding wire is laid. A square-edged spring-loaded roller hammers or caulks the material of the support wire around the winding wire, and secures it firmly in position.

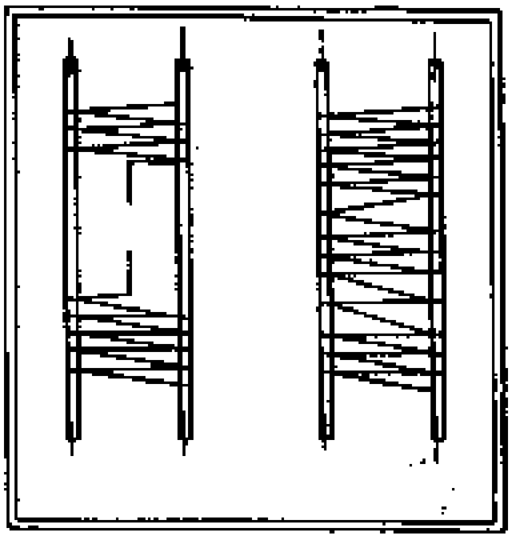

Fig. 4. Grids wound with constant and variable pitch.

The projecting ends of the grid support wires which are required for location and connexion, are obtained either by switching off the welding current or by lifting the swaging roller, depending on the process employed, the loose turns being removed in a subsequent operation.

The finishing processes commence with the length of wound grids as removed from the machine and are very important in view of the accuracy required. In the case of notched grids, the lengths are first stretched longitudinally to remove a slight distortion imparted by the swaging process. The grids are separated in a cutting-tool and then normalised in a high temperature hydrogen furnace. This treatment also releases some of the surface gas, which would be harmful to the vacuum in the finished valve. The grids are then, if the cross section permits, internally stretched in order to size them to the correct dimensions.

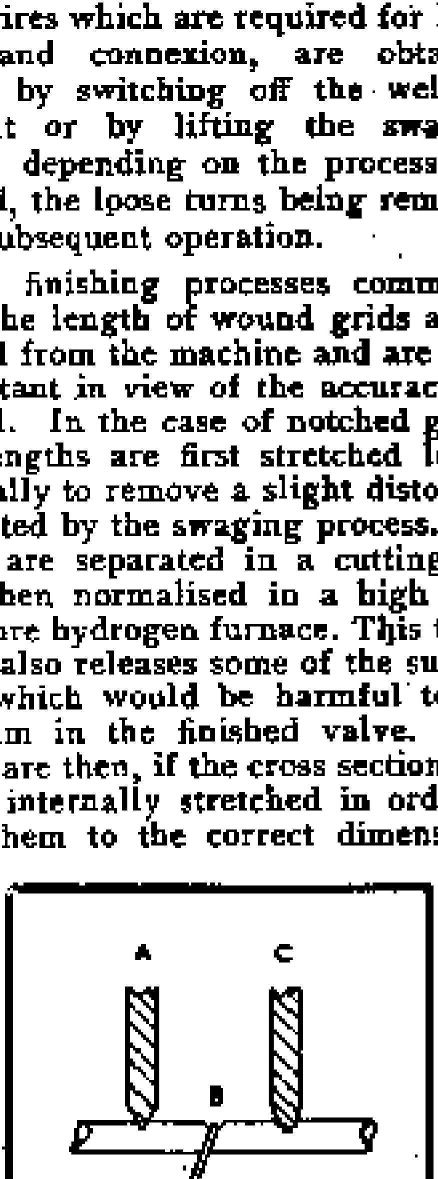

Fig. 6. Stages in the manufacture of notched grids.

All grids have to be gauged across the minor axis in "Go" and "Not Go" gauges. The normal limits imposed for the most critical grids are of the order of ±0.3 mm. (±.0012 in.) and in certain cases the limits may be even smaller. As previously pointed out these limits are large in comparison with accepted standards of precision engineering, but it is necessary to bear in mind the fact that, in the known art of wire drawing, variations in the temper of various successive batches exist, and these affect grid making considerably. When one considers that grids may be made in batches of say 10,000, and that anything up to 15 or 20 spools of wire may be required for this quantity, the possibility of variation is very apparent and frequent adjustments are necessary to maintain uniformity in the product.

Cathodes and Heaters

The cathode, of which there are two distinct types, namely, directly and indirectly heated, is coated with electron emitting chemicals which only become active when raised to a temperature of the order of 700/800° C.

The first consists of a length of wire or strip usually formed into one or more "vees" (See Fig. 7/1 and 7/3), the ends of which are clamped or welded to two lead wires in the pinch, the bottoms of the intermediate loops, if any, are secured to dummy lead wires while the tops are supported by helical or cantilever springs to hold the system taut and to compensate for expansion and contraction. The emissive coating is applied to the wire or strip by passing it at a steady rate through a series of baths with intermediate drying ovens; the coating thickness, which is critical, being maintained by careful control of the viscosity of the chemical suspensions in the baths.

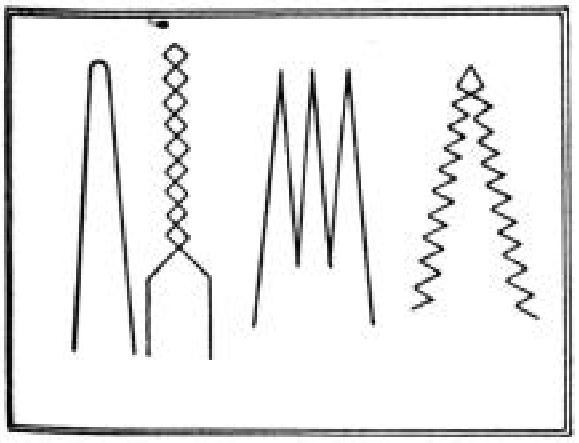

Fig. 7. Types of filaments and heaters.

In the indirectly heated type the cathode consists of a thin wall seamless or lock-seam folded cylindrical or elliptical nickel tube, whilst rectangular cathodes are usually formed up from thin strips of metal. The emissive coating is applied in the form of a fine spray directed on to a row of cathodes mounted in a jig, specially designed to control the length of the coated portion. The thickness is controlled by weighing samples in the coated and uncoated state. In order to activate the cathode coating, an insulated heater of tungsten or molybdenum-tungsten alloy wire is inserted into the interior. The transfer of heat is relatively slow, hence the time lag which is encountered in starting up with valves of this type. The insulating medium in this case is pure alumina, which is likewise applied by a spray gun to batches of heaters mounted in special jigs.

The coated heaters, which may assume any of the shapes shown in Fig. 7 are inserted into small bore alumina tubes and sintered at a high temperature (1,450-1,750° C.) in an atmosphere of hydrogen to remove impurities and to consolidate or sinter the coating.

Fig. 8. Photograph of a barrel jig used in electrode assembly.

The Mounting of the Electrode on to the Stem

The assembly of the various components on to the supporting stem or pinch is an operation calling for extreme care in order to ensure that the relative clearances between the various electrodes are maintained within the desired limits set to ensure that the required electrical characteristics of the finished valve are obtained. On this account it is usual to anchor the various grids, anodes and cathode systems in accurately pierced mica spacers before completing the operation of welding the electrode supports to the respective lead wires on the pinch.

In the more complicated types of valves the use of assembly aids or jigs is often resorted to. As previously mentioned, in the more complicated types assembly jigs are used and the barrel jig shown in Fig. 8 is probably the best example of this type. The various electrodes are