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MANUFACTURE OF VALVES BY MACHINERY

By T. F. B. HALL AND A. H. HOWE, The M.O. Valve Co. Ltd., London

INTRODUCTION

FOR some considerable time manufacturers of vacuum tubes and radio valves in particular have been employing automatic and semi-automatic machinery for the manufacture of their products. This has been done for two main reasons, first to reduce the cost of production, and secondly to achieve a greater uniformity of product than is possible with hand methods of manufacture.

The progress made in both these directions during recent years has been considerable, and while fresh avenues are constantly being explored, certain types of machines have, for the time being, come into general use in the industry and some of these will be described briefly in this article.

With this object in view the subject-matter that follows has been divided into the following sections: manufacture of component parts; assembly of component parts; processing of assembled valves; methods of testing in general use.

MANUFACTURE OF COMPONENT PARTS

The choice of materials suitable for the respective role of each part is a most important consideration. Material specifications are prepared with great care so as to control purity and, what is more important as far as our immediate subject is concerned, the correct physical properties to suit automatic processes. These are determined often by prolonged investigations and can only be enforced by a rigid check of all batches of material prior to acceptance.

The principal components of a valve consist of the following items: pressed sheet metal parts; grids; cathodes and mica spacers; wire and strip supports and connexions; heaters and filaments; the glass components (bulb and pinch).

PRESSED SHEET METAL PARTS

A wide variety of pressings are required for the complete range of valves in common use to-day. Many of these however are not suitable, from the point of view of design or potential demand, for manufacture on automatic machines. Where this is possible anodes are produced on multi-slide machines, which on being fed with a suitable size of metal strip cut off the correct length of material, emboss or rib the blank for ultimate strength and wrap it round a former of the desired cross section, finally seaming or cleating the joint prior to ejection. These machines work at rates of 3000–6000 per hour, depending on individual parts, and are very accurate in operation.

For small quantity production or because of other considerations anodes are generally blanked at the rate of 10,000–12,000 per hour on power presses equipped with roll feed attachments, and then formed to the required shape on screw or pendulum presses. When desired these two operations can be combined with a considerable reduction in manufacturing cost.

Circular shields with shallow skirts and of complicated cross section can, when the quantity justifies the expense, be produced on multiple eyelet presses. Some of these components require as many as eight operations, the machine being provided with sets of feed fingers which move the component to successive positions until it emerges completed at the rate of 4000 or more per hour.

Again for small quantity production or on the introduction of a new component, separate operations afford the cheapest and quickest means of commencing production. To facilitate setting up and where the quality of tool justifies the additional expense, the tools should be mounted in pillar die sets as the accurate alignment obtained increases the effective life considerably.

Wire and strip supports and connexions

A large proportion of the wire strip supports and connexions lend themselves to rapid production on automatic forming machines of which a useful range is available as products of specialist firms. Sometimes however valve manufacturers consider it worth while to construct special single purpose machines for the production of components required in very large quantities. The design of these machines follows conventional lines, and there is therefore little to be gained by discussing them at length.

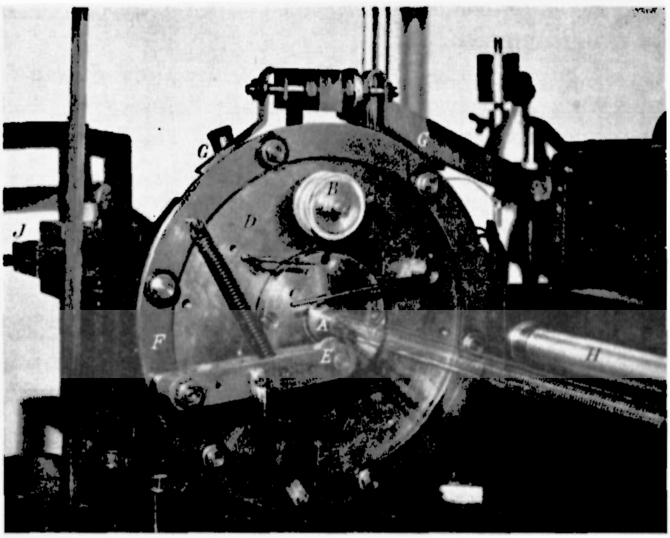

Fig. 1. Automatic grid welding machine

Grids

A grid of conventional design consists of a coil of fine wire attached to one or more longitudinal supporting members either by welding or by "notching and peening", which latter can best be described as a caulking process.

The first method is of particular value where the melting point of the fine wire is considerably higher than that of the supporting members or side rods as they are frequently described. The notching method can be accomplished with a wider range of materials, but the side rods should not be too hard otherwise loose turns will result.

In both methods a mandrel of suitable cross section with locating grooves for the side rods is rotated by suitable means, the winding wire being fed on to it through a quill or guide from a spool, a tension device being provided to ensure uniform winding. The pitch of the winding is controlled by the rate at which the side rods are drawn through the grooves in the mandrel, and is determined by a lead screw driven through a chain of gear wheels to permit variation at will. Fig. 1 shows an automatic winding and welding machine for large grids. In this case, for reasons dictated by design, the mandrel A remains stationary and the wire is taken from spool B over suitable guides C so that it is wrapped round the mandrel when the face plate D is rotated. A welding roller E is mounted on an insulated ring F attached to the same face plate so as to follow closely behind the wire feed, the welding current supplied by a low voltage stepdown transformer and fed to the insulated ring *F* by the brushes *G*, being switched on and off by a cam operated make and break contact system. A pair of clamping jaws mounted on a sliding block, which engages with the lead screw *H*, grip the side rods of the grid, thus forming a helix of the desired pitch when the lead screw is rotated. The adjustable friction plates *J* guide and straighten the side rods and keep them in a state of tension during the winding operation. When a length of grids has been wound it is cut off and the clamps reconnected to the free ends of the side rods and the process repeated.

Fig. 2 shows part of a conventional notching machine. Two circular rollers which are carried in trunnion bearings will be noticed, the upper one *A* being ground to a sharp edge and adjusted to cut a series of notches in the side rods as the mandrel rotates. The peening or caulking roller *B* is mounted below and slightly to the right and adjusted to hammer the side rod material over the top of the grid wire which is fed on to the mandrel between the two rollers. A hollow spindle carried in a bearing at the centre of the machine is rotated in unison with the mandrel, a nut, split to permit disengagement, attached to the right-hand extremity engages with a fixed lead screw causing it to travel along the screw and away from the mandrel as it rotates. A clamp at the left extremity grips the side rods causing the grids to be wound to the same pitch as that of the lead screw. The pitch can be altered by a change of lead screw or by rotating a standard lead screw at various speeds in the same or a contrary direction to the hollow spindle mentioned above. A grid of variable pitch can be wound by superimposing a lateral movement to the lead screw through the agency of a cam of suitable design, a second cam changes the position of the peening roller to suit the irregular spacing of the notches in the side rods.

This type of machine winds a predetermined number of grids in a length *C* and then stops, allowing the operator to sever them by a suitable cutter *D*. The split nut is opened and the sleeve traversed back to the starting point so as to engage with the partially wound grid on the mandrel.

The bare ends of the grid side rods (which are required for location and connexion purposes) are produced by switching off the welding current in the case of a welding machine or by lifting the peening roller of the notching machine for the required number of turns. This enables the surplus wire to be unravelled from the grid. Some forms of machines provide a quick skip between grids to reduce the wire wastage and to increase machine efficiency.

The grids have now to undergo further treatment before they are ready for use. Those wound on the welding machine described above are first cut to length, then sized or shaped to adjust the cross section and finally gauged and inspected, but those produced on the notching machine require additional processes. The lengths are first stretched longitudinally to remove any distortion imparted by the peening operation and are then cut into individual grids and the surplus wire removed. The grids are then sized and gauged as previously mentioned.

The technique of grid manufacture has advanced considerably during recent years and pitches of the order of 200 turns per inch can be wound with great accuracy. The minor axis is the most important dimension and this (in one case) is as small as 0·035 in. and held to a tolerance of plus or minus 0·0005 in. To ensure uniformity under such conditions machines have to be maintained in first class order and replacement tools made with great accuracy.

Heaters and cathodes

The emitting source of a thermionic valve consists, in the case of a valve made for battery operation, of a filament usually of nickel or tungsten coated with a mixture of barium and strontium oxides.

In the case of a valve designed for mains operation the cathode consists of a nickel tube on which the emissive coating is sprayed—usually from a hand-operated gun. A filament located inside the tube at the assembly stage forms the source of heat required to raise the cathode to emissive temperature and usually consists of a tungsten wire in either spiral or V-formation coated with an alumina composition to insulate the heater from the inside of the cathode tube. The alumina is sprayed on to the heater and is usually sintered or fired at a very high temperature to ensure adhesion of the coating before insertion of the heater into the cathode.

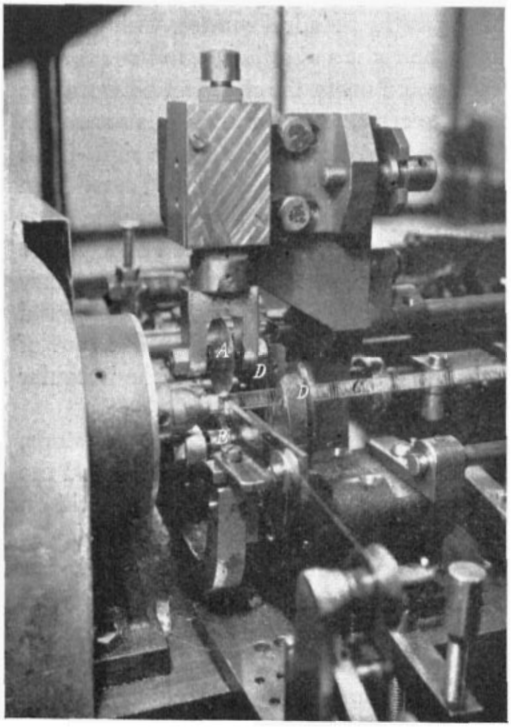

Fig. 2. Automatic grid notching machine

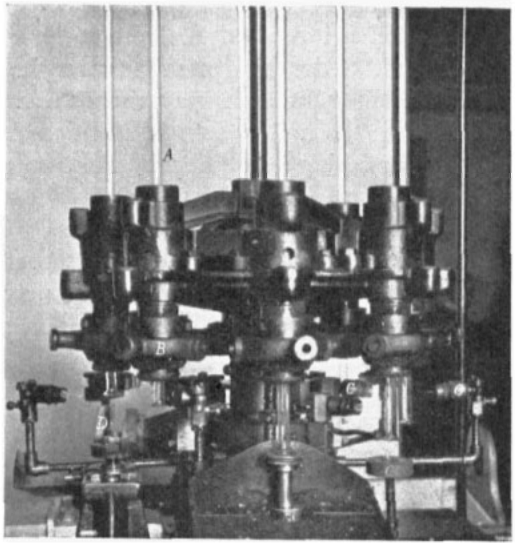

Fig. 3. Hot cut flange making machine

Mica spacers

It is the general practice to support the various electrodes of a valve in mica spacers, which are anchored to two or more supporting members projecting from the glass pinch. Suitable apertures are pierced in these spacers to receive the various components and these have to be produced to very small tolerances. These apertures are carefully proportioned to facilitate assembly and yet to provide an accurate location: a reasonable fit to avoid noisy valves in operation being essential. The top spacer is usually provided with small projecting teeth which are a push fit in the dome of the bulb to secure a cushioned suspension for the electrode system. Sometimes metal "snubbers" or springs are cleated into the spacer to perform the same function.

Mica spacers are specialized products, and are usually purchased from mica dealers trimmed and pierced ready for use.

Manufacture of the pinch or support tube

The valve electrodes, the manufacture of which has now been described, are mounted on supporting pinch and the mechanism of building up this support calls for some attention.

It consists primarily of an outer tube, which is cut on an automatic machine which in addition forms a bell mouth opening at one end. Fig. 3 shows the long tubes of glass *A* which are held in the chucks *B* and supported at the upper end by a circular cage and fed forward by gravity on to a fixed stop when the chucks are opened at the correct moment. The first index positions are allocated to preliminary warming of the glass by the gas flames *C* as slow raising and lowering of the temperature is essential to avoid breakage in all glass working operations. When the end of the glass tube is sufficiently hot and plastic a rotating metal tool *D* is brought in contact with the hot rotating glass and the bell mouth is produced by the spinning action of *D* which is slowly raised to a horizontal position. The length of the tube and the diameter of the bell mouth or flange can be controlled by machine adjustment, the flanged tube being cut off the lengths of tubing by internal and external circular knives.

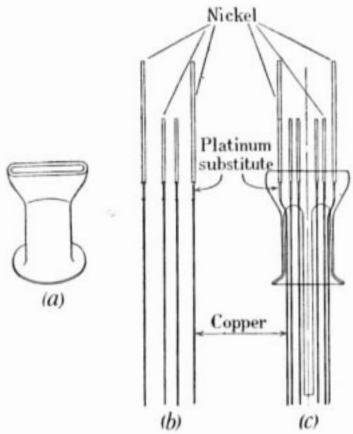

Fig. 4. Stages in the manufacture of the pinch or electrode support tube

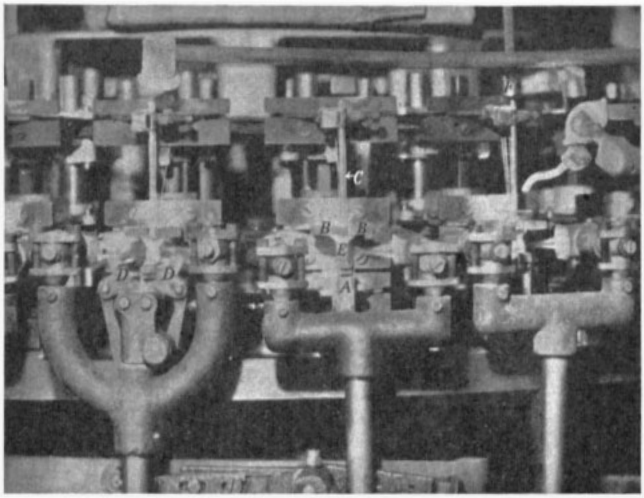

Fig. 5. Pinch-making machine

In many cases, in order to facilitate the subsequent pinch manufacture, the other end of the flanged tube is opened into a flat channel by the automatic insertion of a spear-shaped tool in a subsidiary mechanism attached to the flange making machine. The opened flange now presents the appearance shown in Fig. 4 (*a*).

The wires which perform the double function of supporting the various electrodes inside the bulb and making the electrical connexion to the pins of the cap are composite in make up. It is common practice for the supports inside the bulb to be made of nickel and the outer connecting wire to consist of copper. In order to secure a permanent vacuum tight joint, the interconnecting link between the nickel support and the copper wire must consist of a material which has approximately the same coefficient of expansion and contraction as the glass over a wide working range. Such a material as pure platinum possesses the characteristics required, but the high cost of this material has lead to the development of a substitute in the form of nickel-steel wire coated with copper. The plating of the nickel-steel core is carried out in the rod stage and the outer covering of copper is preserved throughout the subsequent drawing operations. The actual joints between the nickel, platinum substitute and copper wires are made on an automatic welding machine fed with continuous lengths of wire.

The next operation is the manufacture of the pinch or support tube; this consists of welding the joined supporting wires into the opened flanged tube in such a manner as to give a vacuum tight seal. The joined wires Fig. 4 (*b*) are fed into their respective holes in the die blocks A of the pinch-making machine (Fig. 5) and the flanged tube is held in position by two flat jaws B so as to locate it slightly above the surface of the die block and with the centre portion (platinum substitute) of the joined wire approximately in the centre of the flat opened end of the flanged glass tube. In the centre of this arrangement a length of small diameter glass tube C is inserted for the purpose of securing an exhaust outlet through which the valve is to be pumped at a later operation. In the first few index positions gas flames impinge on the lower end of the flanged tube and gradually the glass becomes plastic. When in subsequent positions the glass is hot enough a pair of "hammers" or pinching blocks D move forward and press the molten glass round the leading-in wires—at the same time the inner exhaust tube is joined to the pinch itself.

In the next position after the withdrawal of the pinching hammers the surface of the now flat and formed pinch E is heated up again to its melting point and in the following position a jet of air from nozzle F is directed down the centre exhaust stem causing a swelling out of the glass at the point of juncture with the outer flanged tube. This bursts almost immediately and forms the exhaust outlet for pumping. After subsequent slow cooling down and annealing the pinch is withdrawn from the machine and presents the appearance shown in Fig. 4 (c). In many cases the nickel support wires have to be trimmed to a given length or bent at various angles to suit the individual type of mount; this is done as a separate operation by special tools designed for this purpose.

Electrode assembly

This is almost exclusively carried out by female labour and calls for considerable dexterity on account of the small size and comparative fragility of the components which have to be handled. Owing to diversity of design, which must of necessity exist, the assembly of each type of valve is a problem which must be solved by joint collaboration between the design and production engineers.

The glass pinch with its lead wires is the basic foundation for all assemblies and in the majority of valves the assembly is commenced at a datum line near the pinch, which is usually a mica spacer anchored by metal clips attached to the outer support wires. The various grids and cathode, in the case of a mains valve, are inserted into this spacer individually, or collectively by the aid of a special jig which is described below. The anode is then secured to the appropriate supporting wires and finally the top mica spacer is placed in position. In the case of directly heated valves a fine wire emissively-coated is employed and this must be attached to its supports in the pinch as a preliminary step.

Spotwelding is almost universally employed for bonding together the various metal parts of an assembly and for making connexions. Each operator is provided with a small welder fed by a stepdown transformer, which is usually equipped with an automatic current controlling device where delicate connexions have to be made.

A wide variety of assembly jigs and aids are provided to expedite the work of assembly and to avoid damage through handling of the electrodes. One such jig (Fig. 6) is provided with a number of concentric formers to support the various electrodes, those intended for the grids being provided with grooves to accommodate the side rods. The jig, after being loaded with a complement of electrodes, is guided on to the pinch and all the locating members of the electrodes are inserted simultaneously into the bottom spacer. The jig is withdrawn after the electrodes have been welded to their respective pinch supporting wires, and the assembly is completed as described above.

Simple types of valves with a limited number of electrodes can be assembled without the aid of jigs quite satisfactorily, as the latter are expensive to construct owing to the accuracy demanded and are dispensed with if circumstances permit. In special cases the electrodes are assembled into a separate unit which is later welded to the pinch supports, but this is largely dictated by the design.

Assembly of the mounted system into the bulb or sealing in

The mounted seal is held in position on a central pin *A* on the head of a sealing-in machine shown in Fig. 7 and the glass bulb *B* placed in position with the open end downwards completely covering the mounted seal. The whole head now starts to rotate and gas flames *C* are directed against the neck of the bulb at a position almost corresponding with the belled-out portion of the flanged tube inside. The machine indexes to positions where the gas flames become sufficiently hot to melt the neck of the bulb and fuse it on to the rim of

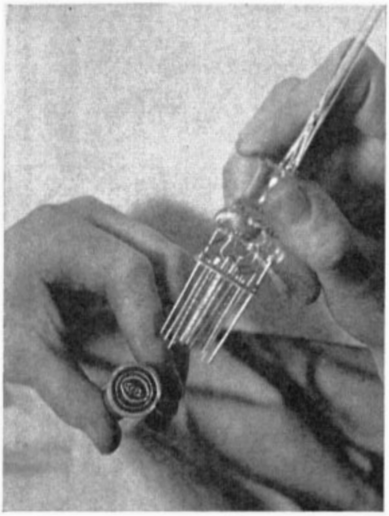

Fig. 6. Typical assembly jig

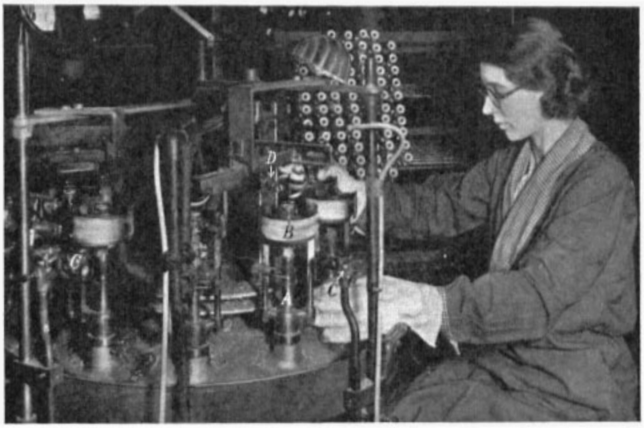

Fig. 7. Sealing-in machine

the glass flange of the pinch thus making an air tight joint. At this stage, then, the only connexion between the inside of the bulb and the outer atmosphere is through the centre exhaust tube.

It should be mentioned that many valves have a connecting wire at the top of the bulb. This joint is made in a somewhat similar manner on the same machine when required by the gas flame *D*.

Exhausting or pumping

The sealed-in valve is now connected to the rotating exhaust machine or pump, Fig. 8, by the insertion of the centre stem tube in a rubber connexion housed in the tube *A* which is mounted in the water-cooled manifold *B* of the pump. In the first few index positions of the machine air is exhausted from the bulb by rotary oil pumps without any external heating, but in subsequent positions the valves, still connected to the exhaust system, pass through a gas heated oven *C* for the purpose of liberating occluded gases from the glass bulb. In order to remove gas from the filament or heater a suitable potential is applied to it to raise it to incandescence in certain positions during the exhausting process and this varies with each type of filament or heater. The other electrodes (anode, grids, screen, etc.) are heated up during pumping by the application of a high frequency current which is induced into the electrodes themselves by means of a series of coils one of which is visible at *D*. These register outside the bulbs of the valves during the latter stages of exhausting and are automatically located in position and withdrawn when the operation is complete by a cam which is an integral part of the machine mechanism.

The last traces of gas are removed by the heating up (by the transference of inductive current) of a small cup which contains a chemical composition known as a "getter". This usually consists of a barium and/or magnesium compound which when heated effects a spontaneous clean up of the residual gases.

In the last position of the pump the central exhaust stem of the bulb is sealed off with two small gas flames attached to a mechanically operated tipping off device *E*. A valve which has just been exhausted is seen sliding down a delivery shute *F*.

The exhaust machine described is capable of dealing with between 300 and 600 valves per hour.

Capping

After exhaust the capping operation is carried out by the threading of the copper leading out wires (of the pinch or electrode support) into the respective metal pins in the bakelite base or cap. The inside of the bakelite base is partly filled with a special cement and the base is then fixed to the bulb by a baking process. To ensure uniformity of baking the valves are inserted into a rotating machine which carries them through a circular oven of suitable cross section, the temperature of which is accurately controlled. With the soldering of the copper leads to the pins of the cap the valve is now ready for seasoning and testing.

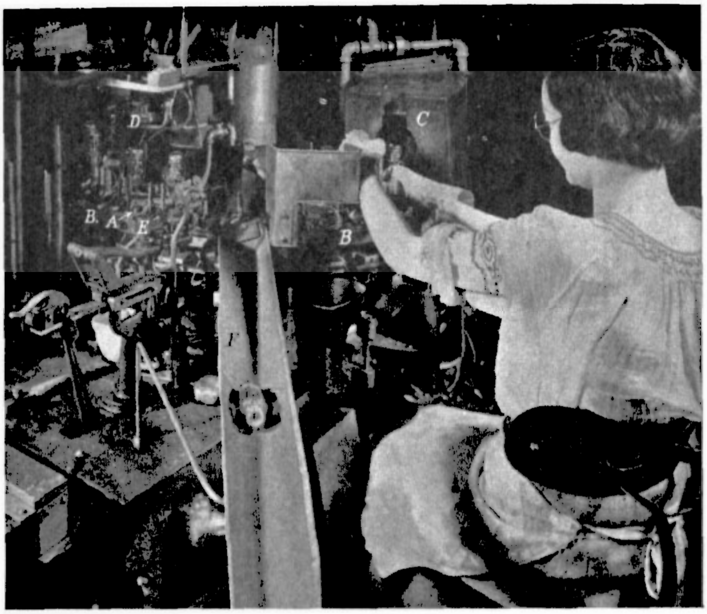

Fig. 8. 24-head automatic exhaust machine

Seasoning

With the completion of exhaustion the filament (in the case of battery valves) or the cathode (in mains operated valves) is not in a state of complete activation and this state is brought about by the application of different potentials to the respective electrodes with the cathode running at a temperature of the order of 900° C. The exact nature of the schedule is dependent on the type and function of the valve.

Due to extreme diversity of types and fluctuating demand automatic seasoning and ageing machines are giving way to the use of stationary racks which are more economical and adaptable to these conditions.

Testing

Apart from the tests which are naturally common to all types of valves such as for filament current, anode current and negative grid current, which latter is taken as an indication of the vacuum in the valve, there are many others which are applied to special types, such as the conversion conductance test for frequency changer valves and the power output test on power amplifying valves.

Under these conditions it is again natural that automatic machinery could not be considered an economical proposition although such equipment is not beyond the ingenuity of the designer.

A typical test set up consists of the warming rack equipment for the testing of "shorts" or interconnexion between electrodes, the noise test amplifier and finally the static characteristic test table.

Quality control and despatch

In order to safeguard the quality of the finished product it is customary for manufacturers to impose a general over-riding check on the product before despatch and this is carried out by a department which is usually operated under a control which is separate from the factory manufacturing engineers.

Conclusion

It is hoped that the foregoing notes have done something to justify the title of "The Manufacture of Valves by Machinery", but it must be pointed out that although considerable progress has taken place in the mechanization of valve manufacture since the laboratory stage of some twenty years ago, limitation in this direction still comes by way of increasing diversity and complexity of types. This limitation must be considered to be unfortunate not only from the point of view of obtaining a cheaper product but also in light of the evidence that valves having a longer average life and smaller characteristic spread are more readily obtained by mechanized methods of production.

A "HARD" VALVE ELECTRONIC RELAY SWITCH

By W. K. CLOTHIER, B.Sc., B.E., University of Sydney, Australia

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ABSTRACT. A two-circuit electronic relay switch is described which uses "hard" valves exclusively. Certain disadvantages of the more commonly used thyratron circuits are thus avoided. The switching frequency may be controlled over the range 15 to 13,000 cyc./sec., and the electronic relay switch is therefore suitable for use with either steady state voltages or transients of low natural frequency.

Introduction

An electronic relay switch may be briefly defined as an electronic device for the simultaneous delineation of two or more voltage waves on the screen of a cathode-ray oscillograph. Descriptions of various types of electronic relay switch have been published from time to time (1), and, in general, the thyratron has been used as an essential circuit element.

Circuits employing thyratrons usually have a number of drawbacks which are: (1) the useful frequency range is limited by the deionization time of the thyratrons; (2) many circuits employing thyratrons require priming in order to ensure correct operation; (3) the circuits are frequently critical with respect to voltage and component values; (4) a warming-up period is usually necessary in order to comply with the thyratron manufacturer's specifications. An attempt has been made to devise an electronic relay switch in which the thyratron is not used.

Description of switch

The electronic relay switch is a two-circuit switch using hard valves exclusively; also, the switching frequency may be made sufficiently high to allow the photographic recording of transients, provided their natural frequency is lower than several hundred cycles per second.