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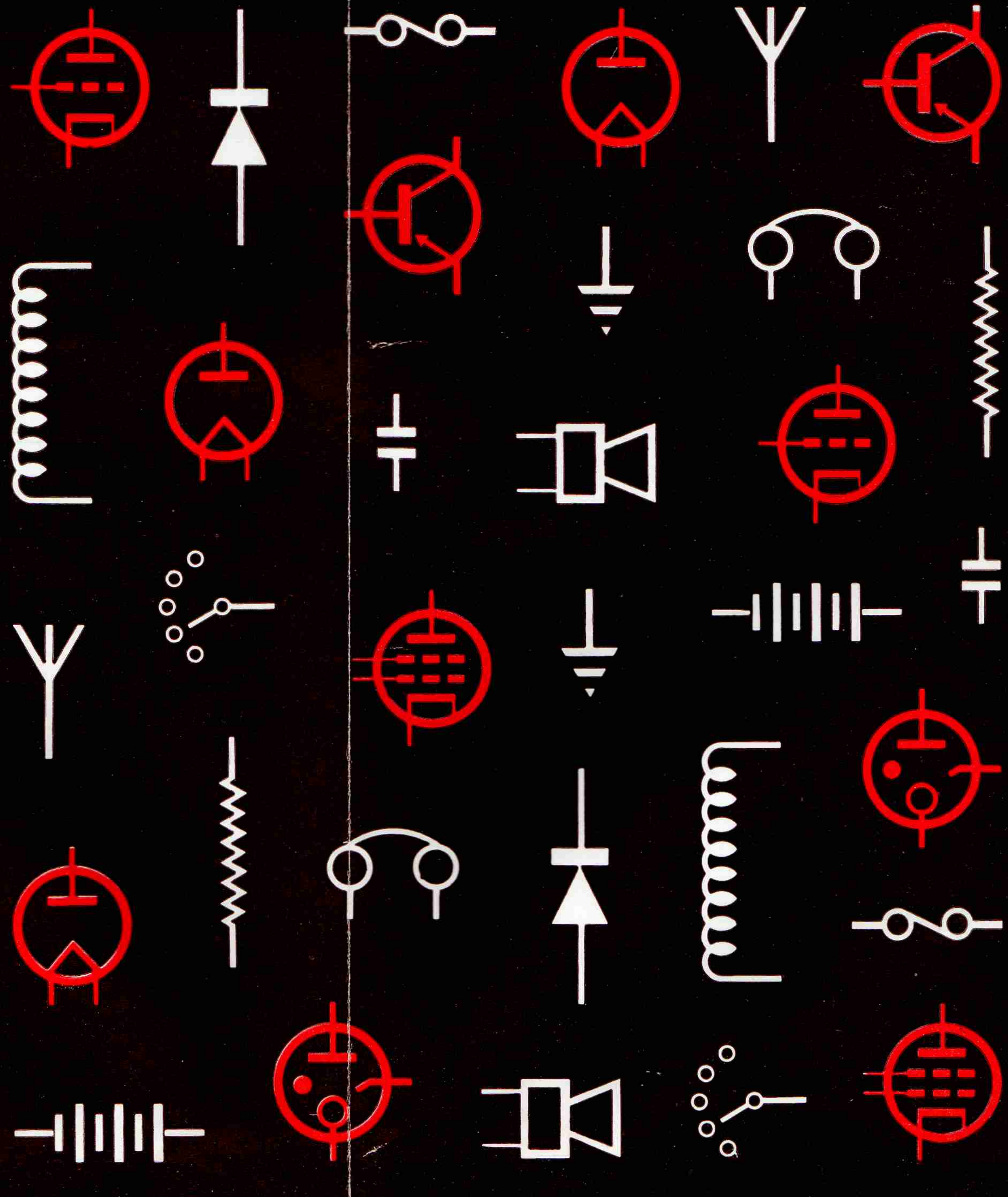

AN AWV PUBLICATION

RADIOTRONICS

Vol. 26, No. 7, 1961

Editor, Bernard J. Simpson

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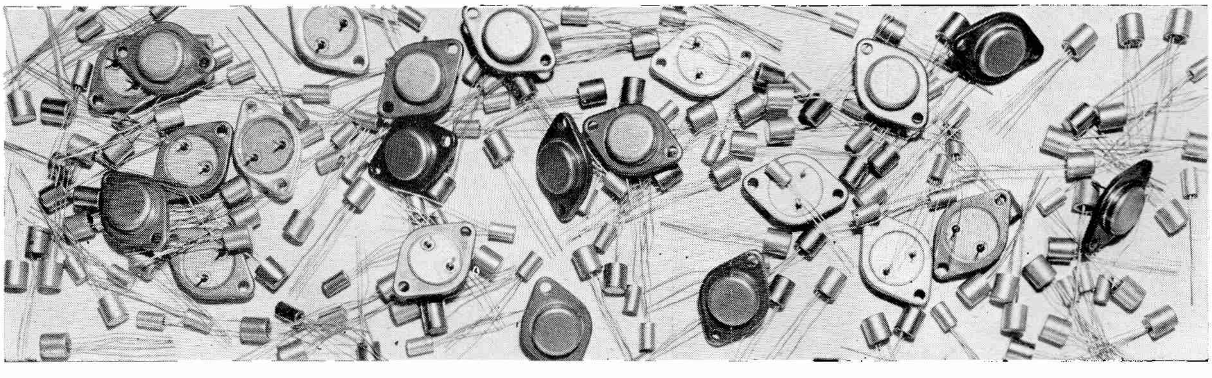
MANUFACTURING THE AWV TRANSISTOR

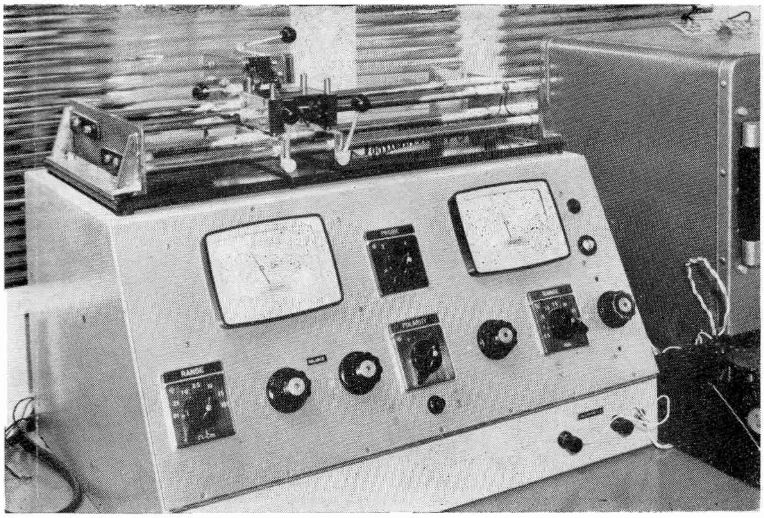
These photographs, taken in the Rydalmere, N.S.W., factory of AWV, show the main processes in the manufacture of the AWV germanium alloyed junction transistor, in step by step operations leading to the final product. In order to ensure that the transistor will meet the demands made upon it, every step in manufacture must be strictly controlled.

The stringent controls employed in the AWV factory fall into two main types. Firstly there is careful examination and testing of all raw materials and components to make sure that no material or parts which are not of the required quality reach the assembly area. Secondly, tight controls and manufacturing limits are imposed on the manufacturing operation, coupled with close inspection and testing at every stage. No transistor or part proceeds to the next operation unless it has been tested and found to comply with the specifications laid down.

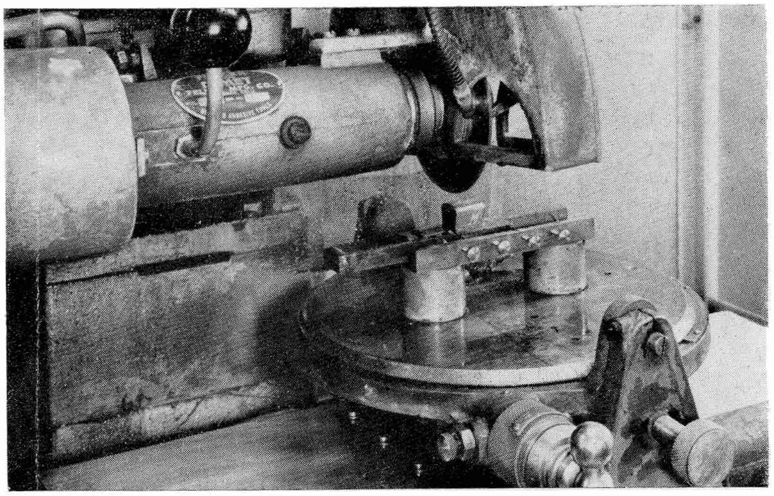
The photographs tell the story of this fascinating operation in a beautiful air-conditioned factory. The comfortable working conditions and the almost clinical cleanliness observed in the illustrations show how no effort has been spared to produce a consistently high-grade and reliable product.



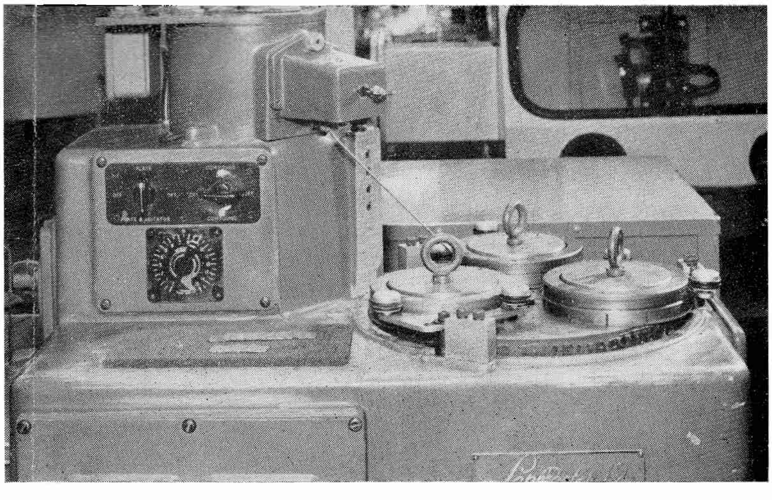
STEP 1: The germanium is received in ingot form, and before it is used in manufacture is subjected to a number of quality checks. Among the qualities tested is the resistivity (the electrical resistance) of the crystal, to check the impurity concentration of the grown crystal. The higher the resistivity, the purer the material.

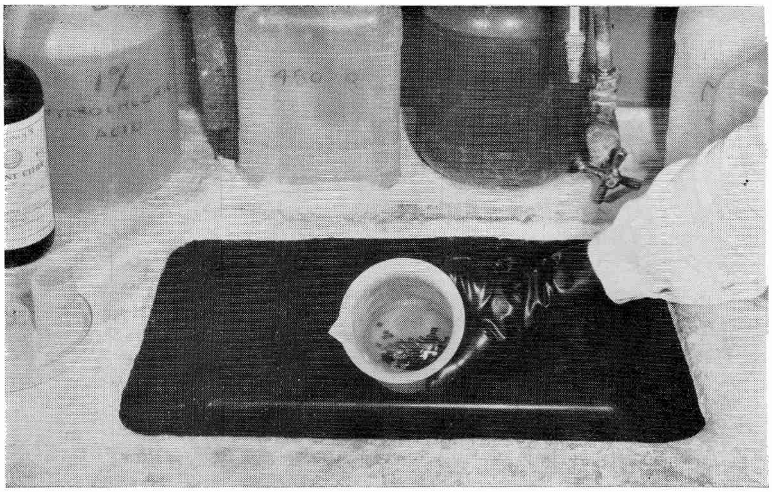


STEP 2: The next stage is to cut the germanium crystal into slices. Great care must be taken in this process, as improper slicing will impair the quality of the transistor. The slicing is done by means of a diamond edged circular saw. The table on which the ingot is held allows minute adjustment of the piece and therefore the angle of cut with reference to the crystal plane. The thickness of a slice is between 10 and 12 thousandths of an inch in a typical case.

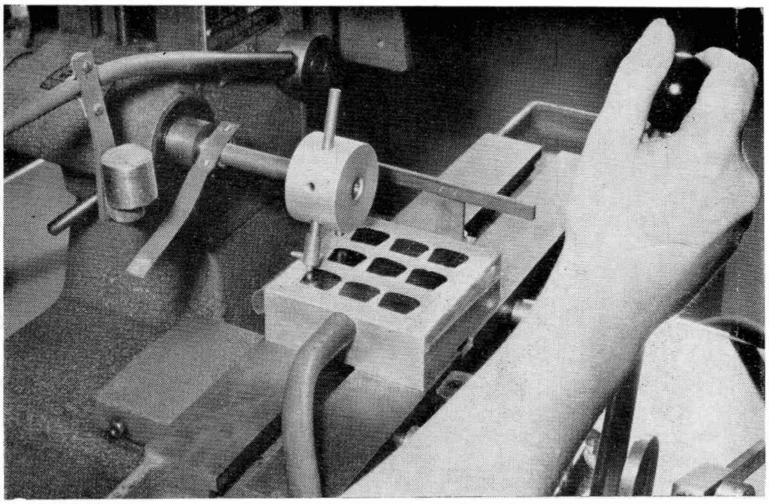


STEP 3: The thickness of the germanium slices must be controlled within fine limits. In order to achieve this, the slices are lapped. This process consists of placing the slices on a rotating table spread with an abrasive compound; here they are lapped or abraded between the lower circular table and the upper orbitally-rotating weighted discs. In addition to reducing the thickness of the slices, this process imparts an extremely fine finish to the slices. Lapped thickness is between 7 and 9 thousandths of an inch in a typical case.

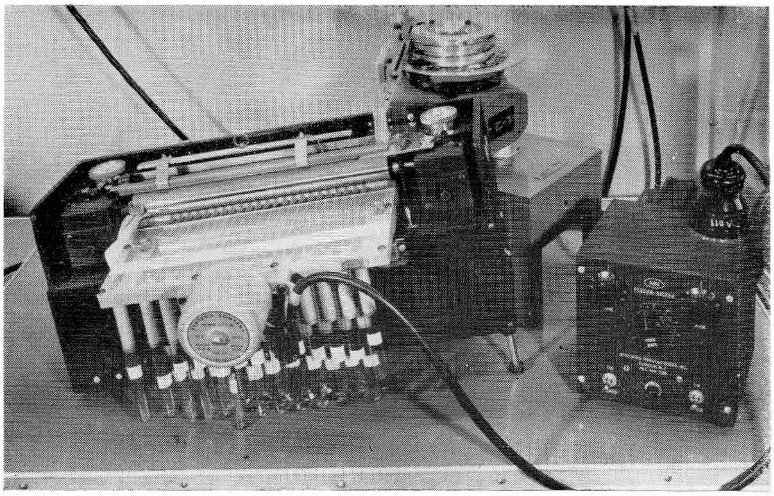




STEP 4: An acid etch is then used to bring the slices to finished thickness. Here the slices are placed in a polyethylene beaker and etched with a solution of hydrofluoric acid. This process facilitates extremely fine control of the thickness and also imparts a high lustre to the slice. The etched thickness is between 35 and 60 ten-thousandths of an inch, depending on the type of transistor being made.



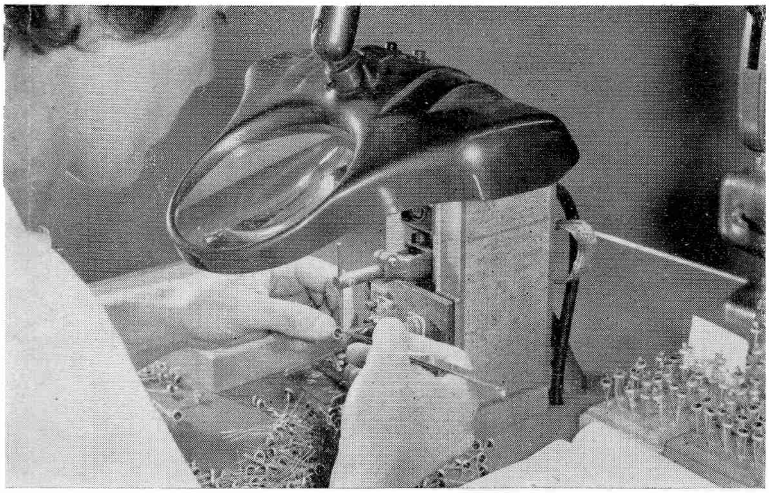
STEP 5: Having reduced the germanium slices to the required thickness, the next step is to cut the slices into the small squares or rectangles, which will eventually form the base region of the transistor. This is done by placing the slices onto a perforated table, where they are firmly held by suction. They are then cut by scribing them with a diamond-tipped tool. Here again, the machine is capable of very fine adjustment.



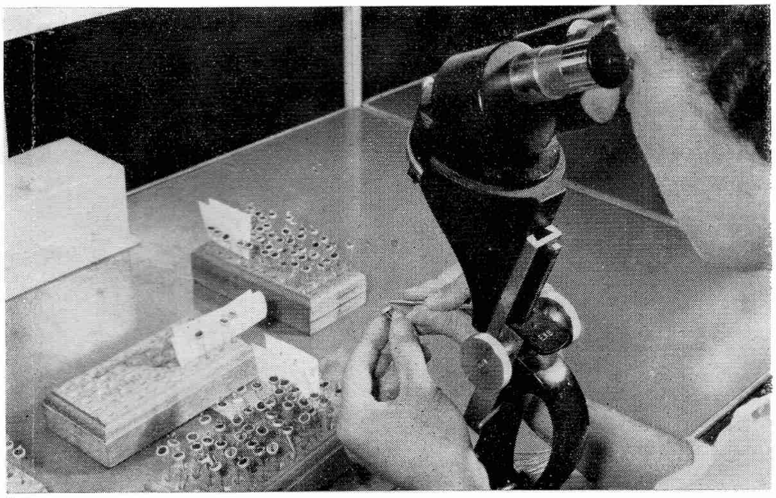
STEP 6: The germanium dice are then measured for thickness by passing them through a roller micrometer. This machine automatically feeds and sorts the dice into thickness groups and collects them in the plastic tubes attached to the front of the machine. Each group is measured to a tolerance of plus or minus 50 millionths of an inch. A typical dice size made is 1/16th of an inch square, by 2 thousandths of an inch thick, a shade thicker than a cigarette paper.

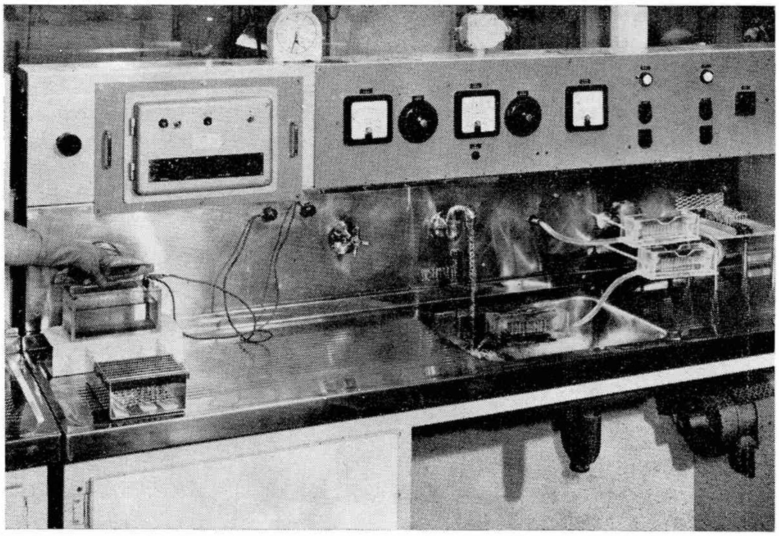
STEP 7: Here the base tab, the germanium dice and the emitter and collector dots are inserted in a graphite jig. The type of emitter and collector dots used determine whether the finished transistor is of p-n-p or n-p-n type. The jigs are placed in a conveyer furnace where the emitter and collector dots alloy with the germanium dice, which at the same time is fused to the base tab.

STEP 8: The base tab assembly is now spot-welded to the stem or transistor base. Two nickel wires 5 thousandths of an inch in diameter are also spot-welded to the stem for connection to the emitter and collector dots. These delicate operations are performed with the aid of a large illuminated magnifier.

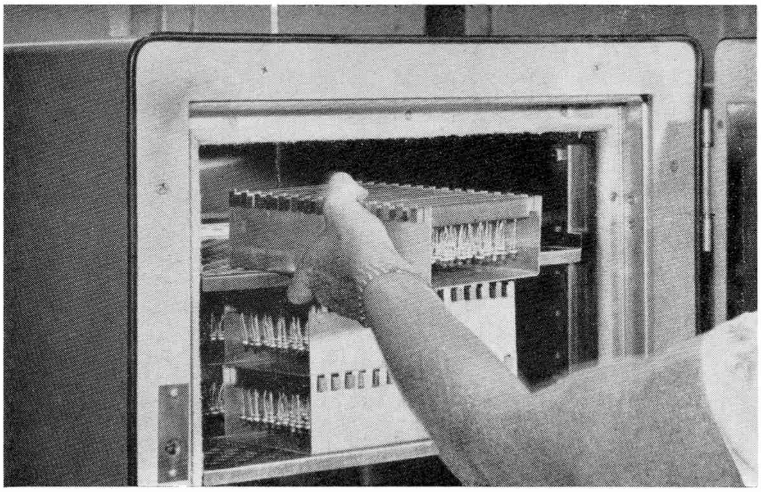


STEP 9: A binocular microscope is used to position the emitter and collector lead wires between the stem leads and the emitter and collector dots of the alloyed germanium dice. This picture is a good example of the almost clinical cleanliness observed throughout the operation.

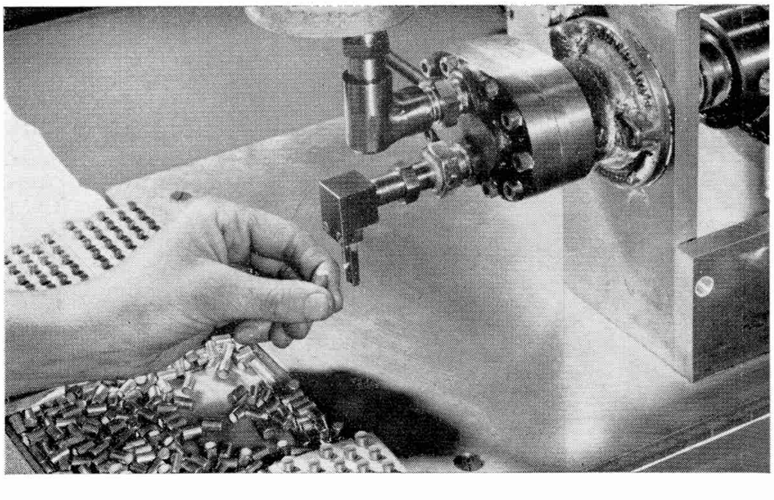




STEP 10: Assembly of the transistor is now complete except for encapsulation. A further acid etch now takes place on the complete assembly to bring the characteristics within the necessary limits. This etch is a delicate operation, and a constant check is kept on the electrical characteristics during the whole time. This etch is followed by a prolonged cascade wash in ultrapure water to remove all traces of the acid, followed by a thorough hot-air drying off.

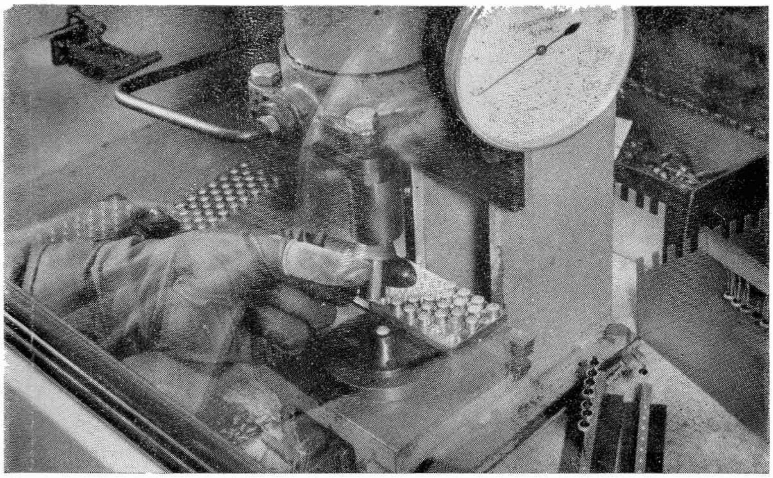


STEP 11: The active regions of the etched transistors are encapsulated in silicone resin and placed in an oven for curing of the resin and stabilization of characteristics. This is done to ensure that the parameters will remain constant and that the completed transistors will have a long and satisfactory life.

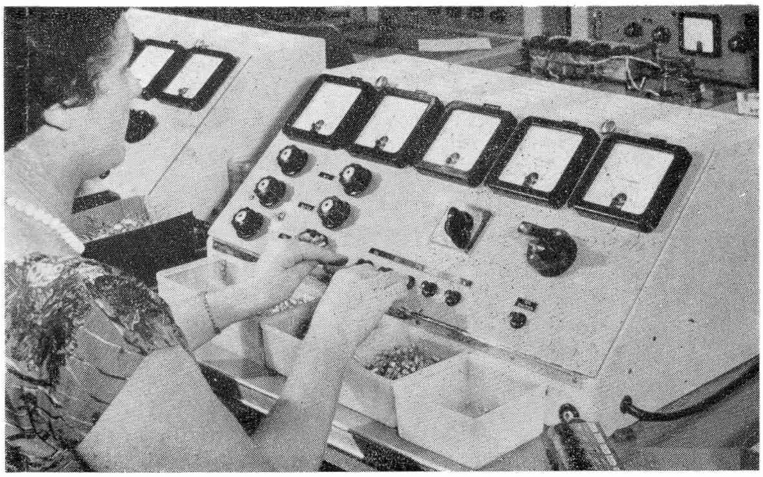


STEP 12: In the operation shown here, the outer cases of the transistors are being filled with a measured quantity of a viscous non-conductive substance. This material acts as a protective coating for the active part of the transistor when finally assembled.

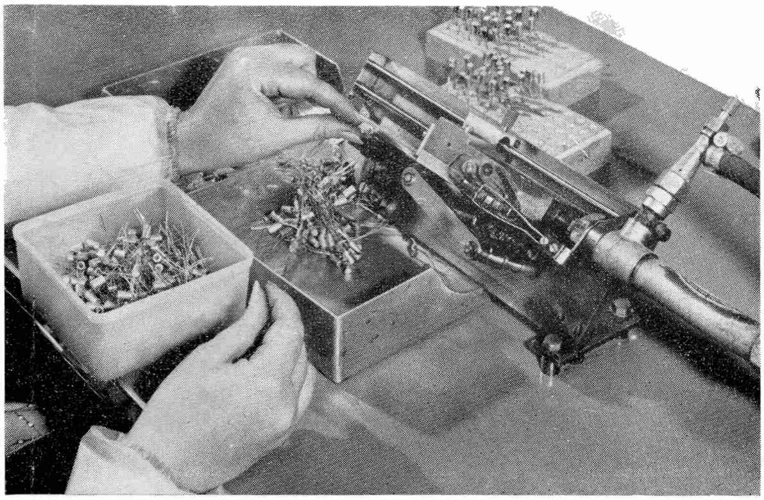
STEP 13: Final assembly of the transistor takes place here, where the stem unit, to which the base tab assembly has been mounted and connected, is hermetically sealed into the outer case. This critical operation is carried out in a controlled and dust-free environment in a glass-fronted and pressurised cabinet. The operator's hands and arms are inserted into long sleeved rubber gloves which form an integral part of the cabinet.



STEP 14: Final testing. Each transistor is carefully tested to ensure that all specifications are met. It is largely upon the standards set here that the production of a high grade and consistent product depend, and rigid limits are laid down. Here also the "family groups" of transistors are sorted by testing routines into groups representing the various commercial type numbers of each group.



STEP 15: When the transistor has passed all tests satisfactorily, it is branded with the well-known AWV monogram and the commercial type number. The branding also includes a manufacturing code for control purposes.



THE "SIAMESE-TWIN" TRANSISTOR

A double transistor which should prove of great value as a power booster in space vehicles and many industrial and consumer devices has been introduced by the Radio Corporation of America. The novel device—incorporating revolutionary "planar" design and construction principles and dubbed "the Siamese Twin" because it combines two identical transistors—is capable of boosting tenfold the voltage of a standard automobile battery and increasing other low-power sources in varying degrees.

Because of its small size, weight and cost, it is expected to find a wide range of uses when it becomes available in the near future. In space vehicles, it could make possible substantial amplification of the voltage from a solar cell to transmit back to earth information on radiation, temperature, atmosphere density and other subjects.

In industry, it could be used in production controls. By converting the heat energy inside a furnace to electrical impulses, it could operate in equipment outside to register temperatures, and in the same way, it would be used in gauging the radiation inside an atomic pile.

This new solid-state device, called a "twin planar" transistor, will be offered initially as a dc chopper amplifier—a device that converts direct current to alternating current, so that it can be easily amplified and then converts the amplified current back to dc. With this transistor, a standard 12-volt automobile battery can be stepped up to 110 volts, the power required to operate many electrical accessories.

Like Siamese twins, the device consists of a two-in-one combination. In this case, two silicon transistors share a common collector — the business-end of a transistor. These twins are united in production and undergo almost identical stress, temperature, environment and other conditions critical to their manufacture. When completed, therefore, they demonstrate a remarkable similarity in electrical and thermal properties and are packaged as a single unit.

Because of the closely matching characteristics, the twin planar can be made to amplify electronic signals, convert them from dc to ac current and back again, regulate their power or flow, subtract one signal from another and amplify the difference (as in a differential amplifier) and do a variety of other useful jobs.

Until now such close matching of characteristics has been achieved by selection — that is, testing out thousands of transistors until two are found that are nearly identical. Not only is this time-consuming and expensive but the match is never as close in all factors as it is in the new twin-planar. Moreover, the twin-planar maintains its match over a wide range of operating points and temperatures which is not usually the case with selections.

Another point is the fact that the twin-planar can take the place of two individual transistors, and thus cut down size and cost of circuits using them. The immense capabilities of the device, plus these other benefits should assure it a significant role in automobiles, military vehicles, laboratory instruments, automatic industrial controls, temperature regulators, air-conditioning units and similar equipment.

This marks RCA's debut in the technology of planar structure, a radically improved technique for building transistors. Essentially, a planar transistor is constructed in such a way that all its electrically active areas are inside the semiconductor crystal from which it is made. Thus, these areas are constantly protected by the 'skin' of the crystal itself even during the manufacturing process.

It's something like building a model ship inside a glass bottle and then plugging the bottle neck permanently. While an extremely precise and demanding process, it leads to a transistor that is inherently rugged, more stable and longer lived.

Valves for High-Power Radio-Frequency Heating

By

P. M. SAWYER, B.Sc.

(English Electric Valve Co. Ltd.)

Considerable amounts of power are sometimes required in radio-frequency heating processes. The valves that have been specially designed for this purpose are capable of delivering an output of 70 Kw or more. The anode dissipation rating may be in the range 6-50 Kw, while the filament consumption varies from 600 w to over 2 Kw. Still larger valves are likely to be developed in the near future.

THE radio-frequency heating generators using vacuum valves can be divided into two classes, (a) induction heaters and (b) dielectric heaters. It was Ferranti and Colby in the later 1800's who put forward the proposal for an induction melting furnace using low-frequency heating; however, it was not until the later 1920's that induction heating began to be used much for brazing, soldering, the out-gassing of metals and metallurgical applications. One of the first applications of induction heating for the out-gassing of metal parts was in the electronic valve industry. The principle of dielectric heating was introduced in the 1800's by Siemens and others as a result of their investigations into dielectrics and insulators, but it was not practically explored until the early 1930's when means became available for obtaining the higher frequencies required.

ADVANTAGES OF INDUCTION AND DIELECTRIC HEATING

Induction Heating

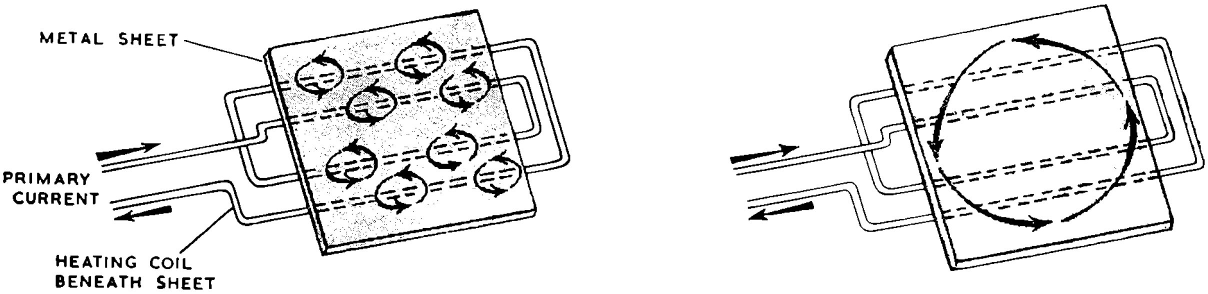
This is carried out by motor generators at frequencies up to 10 Kc and by valve oscillators above this frequency. The lower-frequency generators are used very widely for heating large masses of metal up to a given temperature as in forging work, for at a low frequency the current flows more evenly through the cross-section of the metal whereas a high-frequency current flows more in the surface of the metal. This surface-heating of the metal at high frequency is made use of in surface-hardening techniques. The advantages of high-frequency induction heating over normal methods of heating are well known, and briefly they can be stated as follows:

(i) The current in the work flows in the surface and therefore heats the surface first.

(ii) The transfer of heat energy to the metal occurs at a very rapid rate: this is made possible by the fact that the heat is developed in the metal itself as opposed to heat being transmitted to the metal through its surface.

(iii) Because the heat is developed within the metal itself, the generator coil can be cooled by water and no special lagging is necessary as with a normal furnace.

(iv) No physical contact is required to transfer the electrical energy to the metal as is needed in resistance-type heating. Therefore the energy can be transferred across any non-metallic substance placed between the generator coil and the work. This means that parts can be heated in a vacuum or protective atmosphere, the generator coil being external to the enclosure.



Individual eddy currents

Resultant current

Fig. 1 — The generation of eddy currents in a sheet of metal.

(v) The heating is restricted to the confines of the coil.

(vi) The process lends itself to great adaptability and ease of operation in the production line and requires only semi-skilled labour for operation.

The applications of this type of heating are many and include the surface-hardening of metals, brazing and soldering of metal parts, vacuum-smelting of metals, etc.

Dielectric Heating

The advantage of this class of heater is that it is possible to heat the dielectric uniformly, and therefore the middle of the dielectric is heated as quickly as the outside. This property has enabled the dielectric heater to be of great use in the plywood and wood-glueing industry and also for plastic moulding and food processing. In plastic welding, water-cooled electrodes are used and thus, although the work is evenly heated throughout, the outside is cooled by the electrode and so only the inside is welded.

PRINCIPLE OF OPERATION

Induction Heating

If two electrical circuits are linked magnetically an alternating current flowing in one circuit causes a current to flow in the other circuit. The magnitude of this induced current depends on (a) the ratio of the number of turns in the two circuits, (b) the magnitude of the primary current, and (c) the amount of magnetic linkage between the two circuits. This secondary current can be looked upon as the summation of all the eddy currents which would be set up in a piece of metal placed in an alternating magnetic field, and becomes quite large. The individual eddy currents are quite small and are set up in conductors as a result of the small unit cross-sections of the conductor itself acting as closed electric circuits. Hence sheet metal can be heated in this way as well as rod and tube: see Fig. 1. As the frequency is raised, the eddy-current losses (and therefore the heating effect) increase initially as the square of the frequency because the induced current in the metal varies directly as the frequency. At 10 Kc, however, it varies as the frequency to the power one, and at 500 Kc as the square root of the frequency due to the fact that the depth to which the metal is heated depends upon the square root of the frequency. The optimum frequency of operation for maximum transfer efficiency of energy to the metal depends on the size and nature of the metal to be heated. Generally speaking, the larger the mass to be heated the lower the optimum frequency, and conversely the smaller the mass to be heated the higher the optimum frequency. In practice the induction heaters therefore work in the approximate range 10 Kc-10 Mc.

Dielectric Heating

Much has been written about the principle of operation of dielectric heating, but simplifying the mechanism of operation it may be said that the heating is due to the rapid reversal of polarity of the electrical potential which causes the molecules of the material to be in a constant state of increased unrest, thereby generating heat in the material. It can be seen that higher frequencies are needed here for efficient operation than are needed for induction heating, and generally the dielectric heaters work in the range of 1-100 Mc and higher frequencies are being considered. The power generated in the dielectric increases proportionately to the frequency and proportionately to the square of the voltage across the dielectric. The limit of the voltage is reached at the breakdown voltage of the dielectric, so that just below the breakdown voltage it is necessary to increase the frequency in order to increase the power.

CIRCUIT ARRANGEMENTS

To generate these high-frequency alternating currents for induction and dielectric heating, two methods are available. One is to use a small oscillator driving a power amplifier, which would overcome some of the radio-interference problems associated with rf heating generators, while

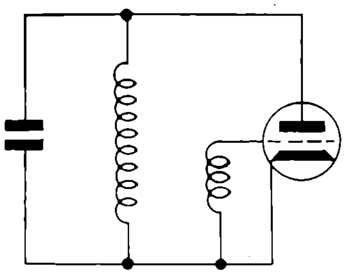


Fig. 2—Tickler-coil circuit.

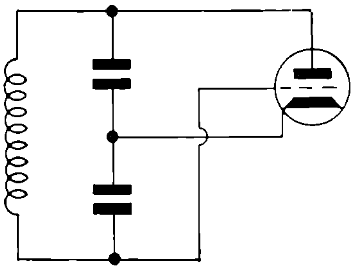


Fig. 3—Colpitts circuit.

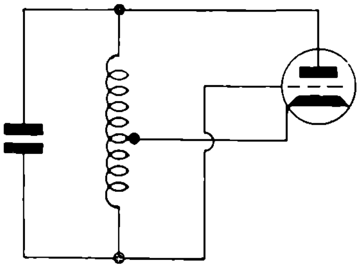


Fig. 4—Hartley circuit.

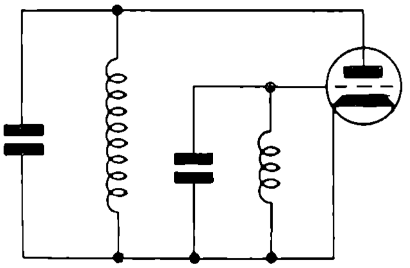


Fig. 5—Tuned-anode/tuned-grid circuit.

the other is to use a power oscillator. The serious practical difficulty that arises in the amplifier method is that with different materials, or as the work is heated, the ouput coupling to the generator alters, and this alters the resonant frequency of the output circuit, which necessitates a retuning of the drive circuit. This presents practical difficulties and a power oscillator is therefore used in which a change in the resonant frequency of the output circuit just alters the frequency of operation of the generator.

Twenty or thirty years ago, quenched-spark oscillators were used, but the interference which they caused was so severe that they were eventually replaced by power-valve oscillators. The circuits in common use today using these power valves are described below.

(a) **Tickler Coil** (Fig. 2). Used because of its simplicity and ease of adjustment, and also because of its comparative cheapness.

(b) **Colpitts** (Fig. 3). Used for induction heating but more widely for dielectric heating. From Fig. 3 it can be seen that the inter-electrode capacitances of the valve are in parallel with the tank-circuit capacitances and thus do not give rise to unwelcome feedback effects at high frequencies as may be the case with the tickler-coil and Hartley circuits.

(c) **Hartley** (Fig. 4). Used widely for induction heating since the conditions for oscillation are not critical and it is not too expensive to build. At higher frequencies, however, the losses in the inductance of the leads tend to make it unsuitable for dielectric heating.

(d) **Tuned-anode/Tuned-grid** (Fig. 5). Used mainly with dielectric heaters.

In induction heaters the output is taken from the generator either by making the work coil part of the tank-circuit inductance or by including a transformer to couple the work coil to the tank-circuit inductance. This latter method has the advantage that a variable transformer coupling can be used to accommodate varying sizes and types of work to be heated.

In the case of dielectric heaters the dielectric to be heated is placed between two metal plates and the resulting capacitor is made part of the tank-circuit capacitance or in some cases it is impedance-matched to the tank circuit capacitance.

VALVE REQUIREMENTS

Generally speaking, a valve used in a radio transmitter is run at a steady power level throughout its life and great care is taken of the valve in regard to running conditions. It is operated well within its limits and long lives are thereby obtained. In the case of valves used in rf heaters the circumstances are rather different; they often have to work in dusty and grimy conditions and are not always carefully handled, and more often than not the valve is run right up to its maximum ratings. It was reported in the U.S.A. that an induction-heating set was examined in a factory by the manufacturer and it was found that the water-pressure switch-trips had been short-circuited. The plant electrician had done this because, when the water was turned on in the shop next door, the drop in water pressure always tripped the set out. The rubber sealing gaskets on the valve anode had to be renewed every 1,000 hours, but this was endured. It is not suggested that such practices are also to be found in this country, but this example serves to illustrate the different attitudes to the valve sometimes adopted by the radio-station engineer and the plant electrician.

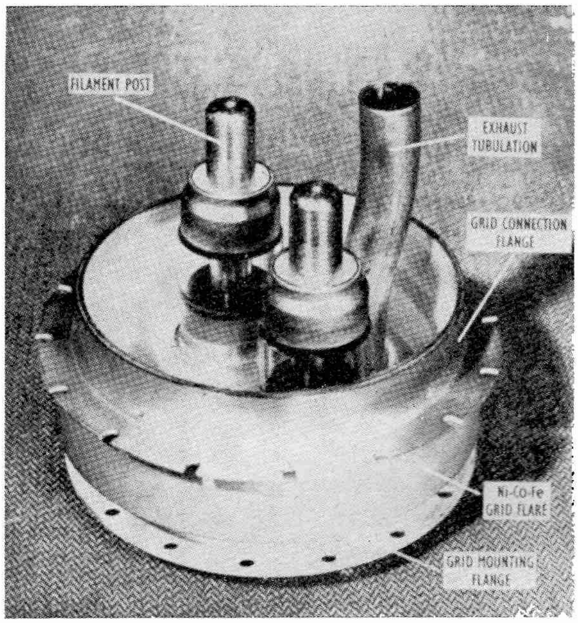


Fig. 6—Metal header.

The valve to be used in these conditions operates with internal temperatures up to 2,000°C, while the pressure must not exceed 10^{-6}mm Hg. A minimum of 5,000 hours' life is expected. The mechanical and physical requirements of the valve are that it shall be vacuum-tight, have strong glass-to-metal seals, be reasonably easy to handle and generally robust. The electrical considerations require the valve to operate at high efficiencies at relatively low anode voltage, to be capable of withstanding momentary overloads without any harm to the valve and to be economical in regard to filament-heating power. In valves intended for high-power operation the power dissipated in the anode necessitates an external anode which can be effectively cooled, and a portion of the envelope is then made of glass so as to insulate the anode from the grid and filament which are mounted on the header, as shown in Fig. 6.

Header

The older type of transmitting valve incorporated a glass basin having copper-to-glass seals, upon which the filament and grid assembly was mounted. The glass tube through which the valve was exhausted was sealed off at the basin. This arrangement made the valve prone to damage in that the small-diameter copper-to-glass seals were not particularly strong and that to the glass seal-off was vulnerable to careless handling. To overcome these difficulties a metal header was developed upon which the valve assembly could be mounted. This is shown in Fig. 6, the main parts being of nickel-iron, copper and nickel-cobalt-iron alloy whose expansion coefficient matches that of the glass used. The parts are brazed together with a silver-copper eutectic solder. Very few leaks are found in the brazed joints, and this method of construction gives a rigid support on which to mount the valve assembly. The Ni-Co-Fe alloy-to-glass seal has a much higher torsional strength than the copper-to-glass seal, and has a high resistance to any bending moment applied at the end of the filament post. The copper filament posts passing through the header are amply sufficient to carry the filament current required by the valve and form a strong support for the filament assembly. In the glass-basin types of valve the grid was often bolted to the basin on two supports only, whereas with this metal header a more rigid fixing is possible with the

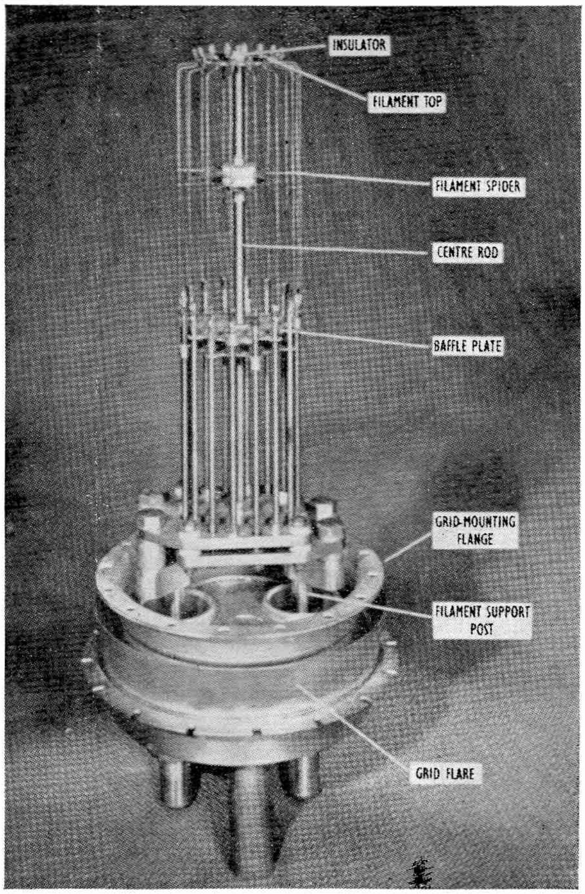


Fig. 7—Modern type of filament assembly used in valves for radio-frequency heating.

grid cone bolted down to the header flange. For higher-frequency use the inside of the header may be copper-plated to reduce the rf loss in the metal surfaces.

Filament

If the valve can be made to operate efficiently at relatively low anode voltages (about 6 Kv), a worthwhile saving can be achieved in the cost of the HT generator and in other factors such as the amount of insulation needed. To meet this requirement the valve must have a high perveance, the perveance G being defined by the equation:—

$$G = \frac{I_k}{(V_g + V_a/\mu)^{3/2}}$$

where I_k = cathode current (i.e. sum of anode and grid current)
V_g = anode voltage
V_a = grid voltage

The perveance can be increased either by reducing the grid/filament spacing or by increasing the amount of electron-emission from the filament. The electron-emission can be increased by using a greater emitting length, or up to a certain point by increasing the number of wires in the filament cage: see Fig. 7. The point is reached where on the one hand the electrode spacing is so close as to cause premature failure due to a grid/filament short-circuit, and on the other hand the filament becomes disproportionately large.

A compromise is therefore necessary and the grid/filament spacing is made as small as possible compatible with a long life for the valve. Therefore, to enable close grid-filament spacings to be realized, the straightness of the filament wires and their position relative to the grid wires must be maintained throughout life. When the filament is heated to its operating temperature of approximately 1,730°C from cold, there is a longitudinal expansion of approximately 0.007 in per inch of filament wire. In the older type valves this was taken up by a sprung filament centre rod: see Fig. 8. Due to the binding of this rod in the insulating bush and also to its warping, several short-life failures resulted. In the more modern type of valve designed for rf heating the filament cage is unsprung and stress-free. It is located centrally at one end to the centre rod by means of an alumina insulating bush. When the filament cage expands in length on heating, the filament top and insulator slide freely over the centre rod, which is made of molybdenum. Due to the slight clearance allowed between the insulator bush and the centre rod and also to the fact that they are made of different materials, the insulator never binds on the centre rod. Occasionally one or more of the filament wires may operate at a slightly different temperature from that of the other wires (e.g. ±50°C) and the resultant differential expansion is taken up in the two right-angled off-sets in the filament wire at the top. If this were not provided there would be a danger of distortion of the wires. To hold the wires correctly in position relatively to each other and to the centre rod, a pair of insulated "spider assemblies" are used half-way along the filament wire. The wire is a sliding fit through a hole in the end of the thin molybdenum spider arm. At the bottom end the wire is clamped and arc-welded to its support rod which is in turn fixed relatively to the other rods and to the centre rod. By this method of holding the filament true at the top, middle and bottom, throughout its life, a distortion-free filament is possible, and thus smaller grid/filament spacings are permissible without the fear of grid/filament short-circuits.

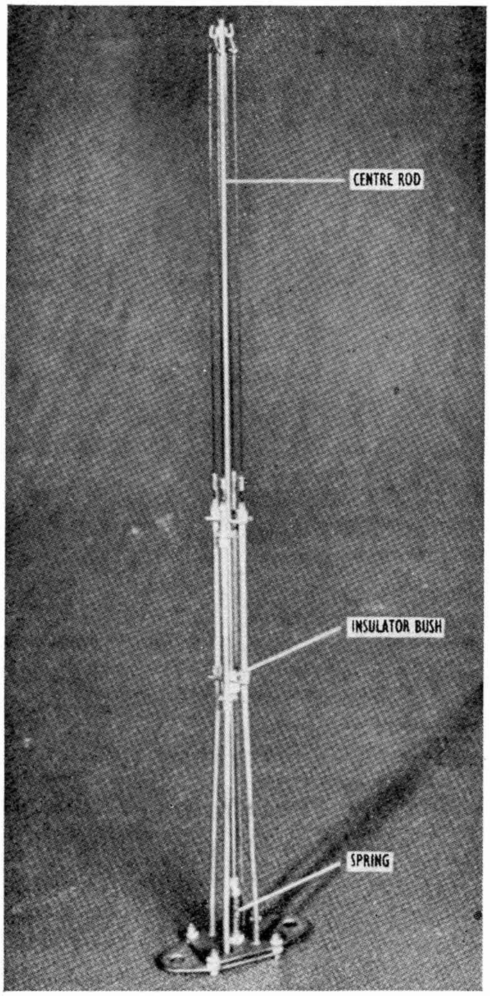


Fig. 8—Old type of transmitting valve filament.

Economy of filament-heating power is attained by using thoriated-tungsten wire, as has been the practice in the later transmitting valves. This operates at 2,000°K. A barium-oxide-coated or dispenser type of cathode cannot satisfactorily be used, mainly because of the undesirable emission from the grid resulting from the evaporation of barium from the cathode and its deposition on the grid. Also there is a certain amount of "back-heating" of the cathode which may cause the cathode to overheat.

Grid

With the close grid/filament spacings that are required for high performance, the grid itself must be rigidly mounted. This is achieved by mounting the grid on a nickel cone by spot-welding techniques and bolting this cone to the header flange shown in Fig. 5. The grid is of the helically wound type with support rods spot-welded to it along its length: see Fig. 9. During the assembly the angular dispositions of the side rods and filament wires are arranged so as to reduce to a minimum the current intercepted by the side rods. A strong construction is ensured by arc-welding the side rods at the top to a molybdenum cap and spot-welding to the nickel cone at the bottom. For the grid winding wire, the lower the temperature at which it will operate for a given grid dissipation, the better it will be as regards grid emission and distortion of the wire. The wire in common use is platinum-clad molybdenum, the thin cladding of platinum serving to reduce grid emission caused by evaporation of thorium from the filament. The maximum safe temperature is reached when the platinum begins to alloy with the molybdenum wire, corresponding to a power dissipation of 10 watts/cm^2. The grid emission at this temperature is 2μa/cm^2.

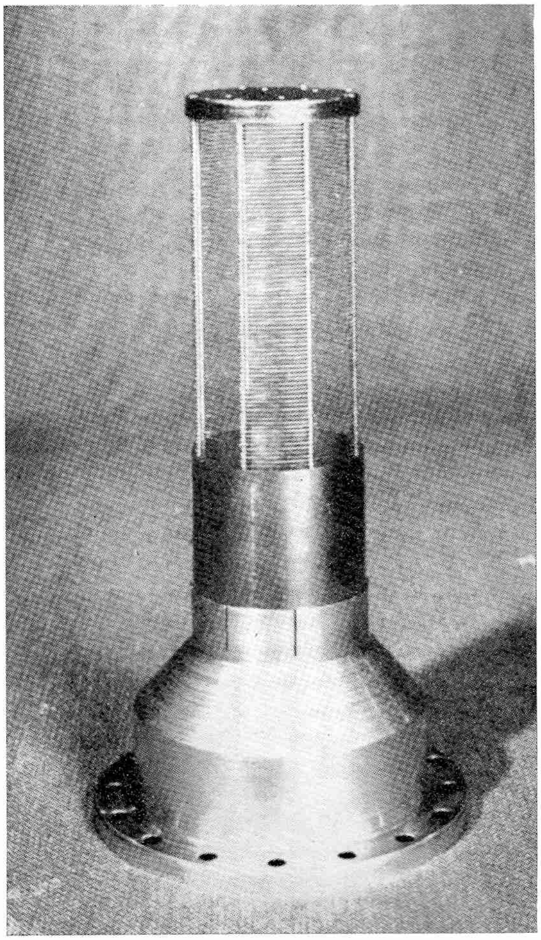


Fig. 9—Grid Assembly.

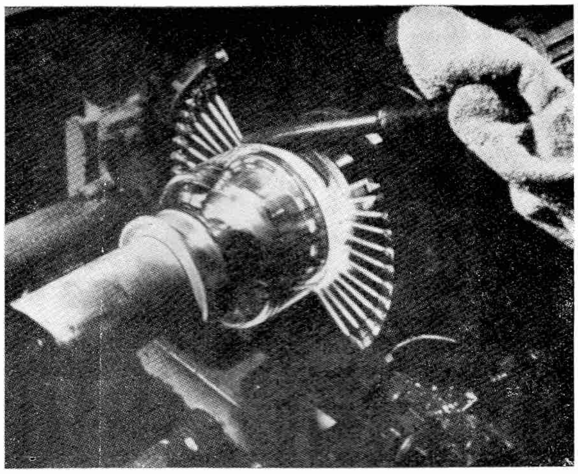


Fig. 10—The sealing-in operation.

Getter

To safeguard against the possibility of the evolution of internal gases due to a flash-arc or a slight softening of the vacuum during storage, a zirconium getter is mounted on the underside of the grid top cap. Under normal operating conditions its temperature will be about 800°C.

Anode

In order to even out local temperature differences that tend to occur at various parts of the anode arising from the focusing effect of the grid side rods and other causes, an anode wall thickness of ⅛-¼ in is used. This provides a sufficiently large heat conductance to equalize the temperature and thus reduce the possibility of local hot-spots and flash-arcs. Also the large heat capacity increases the ability of the anode to withstand momentary overloads.

It might be noted here that in the case of valves operating at a high anode voltage (above about 12 Kv) from a capacitor-smoothed supply, it is desirable to insert a choke between the valve anode and the HT supply. The inductance of the choke limits the rate of rise of anode current and thereby helps to reduce flash-arc troubles. With the recently developed types of valves for rf heating which operate at a relatively low anode voltage (6-8 Kv) and also use an unsmoothed HT supply, flash arcs are encountered very infrequently.

Processing

After sealing the grid/filament assembly to the anode (see Fig. 10) the valve is sealed to a special pumping system and given a long exhaust schedule during which all the parts of the valve are thoroughly outgassed. At the end of the pumping schedule the valve is sealed off the pump by cold-welding the copper exhaust tube by means of hydraulically operated rollers. Valves that are intended for dielectric heating are silver-plated on the outside to reduce the rf losses in the metal surface. Also the copper filament posts are gold-plated to prevent tarnishing.

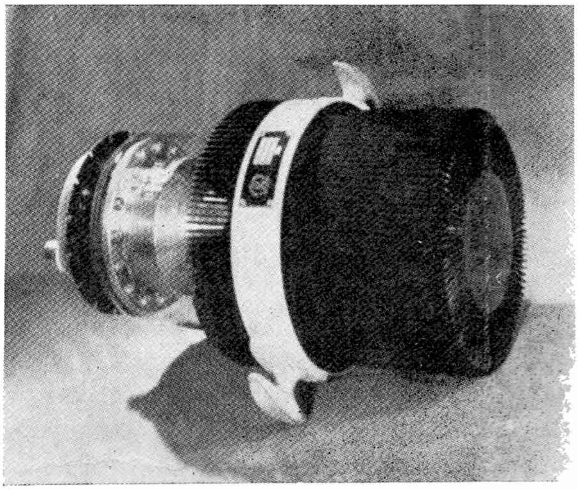


Fig. 11—Air-cooled valve showing finned radiator.

COOLING THE ANODE

Three methods of cooling the anode are described here. All of these are applicable only to the external-anode type of valve, a form of construction which is generally adopted when the amount of power to be dissipated is large. The radiation-cooled type of anode which is mounted internally in the valve is limited by practical considerations to relatively low power-dissipation ratings.

Water Cooling

The anode of a water-cooled valve is sealed by a rubber gasket into a jacket and water at high velocity flows past it. This system of cooling is more compact and therefore requires less space than air cooling: it also permits a slightly higher power dissipation. The temperature-rise of the water through the jacket is limited to 15°C max and the outlet temperature of the water to 65°C max.

In environments where there is a great deal of dust and general grime the water cooling may have additional advantages. However, a certain degree of purity of the water is necessary to avoid scaling on the anode and electrical leakage in the water pipes connected to the anode. This necessitates a closed-circuit system of circulating water of the demineralized type and of course requires the provision of a storage cooling tank, water pump and extra plumbing.

Forced-Air Cooling

In this method the valve anode is soldered into a finned copper radiator and air is blown through the radiator at high velocity. This has the advantage that the cooling medium costs nothing, but entails the need for air ducting and a blower. In operation it may tend to be noisy and this could be a nuisance in any quiet environment. Care too must be taken to provide adequate filtering of the air before it is blown past the radiator fins, since otherwise the narrow gaps between the fins will become blocked with dust. The filters should be periodically inspected for blockage.

In some installations a low-efficiency radiator is used and the air which has passed through the radiator is then used to cool other components in the generator. Here only the high-efficiency radiator is considered. To make the radiator efficient and as small as possible, compatible with high efficiency, the fins need to be specially designed. When air flows along a plane metal fin there is a laminar layer of flow near the fin surface and this laminar layer is a relatively poor conductor of heat compared to a turbulent flow at the surface. A turbulent flow at the surface is achieved by pressing louvres into the copper fin at ¼-in. intervals, down the fin and, at 90° to the line of air flow. The trailing edge of the louvre

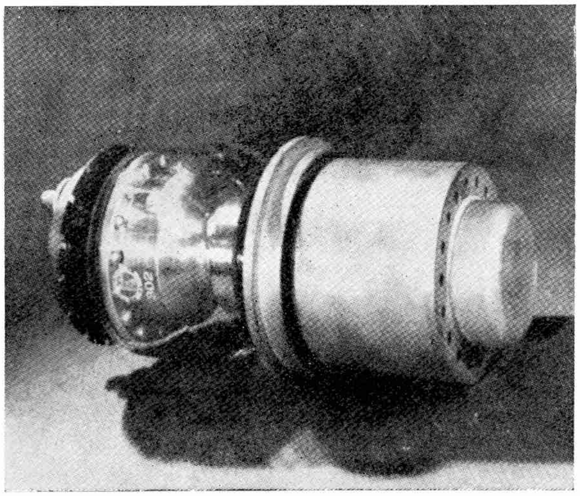


Fig. 12—Vapour-cooled valve showing evaporator block.

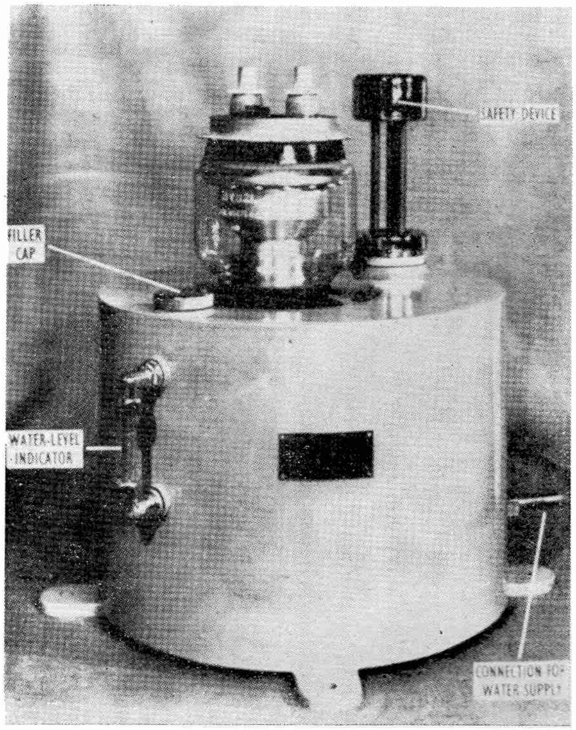


Fig. 13—Boiler-condenser unit.

creates the turbulence necessary for a good heat transfer between the fin and air. To increase the heat transfer the area of the fins can be increased by making the fins wider. However, a point is reached where the fin becomes so wide that the temperature-drop across the fin becomes severe and the outer edge is not effective. Another factor to be considered is the thickness of the fin. As the heat-transfer from a fin depends only slightly on the thickness, it is better to have many relatively thin fins than fewer but thicker fins. The limit of the number of fins usable comes when the air pressure-drop across the radiator during normal operating conditions exceeds 3-4 in water-gauge.

Vapour Cooling

This is a more recent method of cooling the valve anode in which use is made of the fact that heat is required to change water at 100°C into steam at 100°C. The valve is soldered into a special evaporator block which is essentially a thick-walled copper tube with longitudinal holes drilled through the tube around the circumference: see Fig. 12. Water from a reservoir is converted into steam at atmospheric pressure and circulated via a condenser system back to the reservoir as water. The water in the reservoir (or boiler as it is often called) should be of the demineralized type. The condenser may be convection-cooled, forced-air-cooled or water-cooled. If the condenser is water-cooled only a small flow of water is required and this is very much less than that required for normal water-cooling. There are two main variations of cooler design which are (a) the boiler-condenser system (see Fig. 13) and (b) the external condenser system.

The Boiler-Condenser System. The valve soldered into the special evaporator block is seated in the boiler condenser unit, and when the block reaches a sufficient temperature the water in the holes of the evaporator is converted to steam which passes at high velocity up the hole where it is directed to flow on to the condenser tube through which the cooling-water flows. The water level is approximately two-thirds of the way up the evaporator block and wetting of the upper surfaces of the hole is ensured by the "frothing" action of the steam bubbles passing up through the water in the hole. The condensed steam then drips back into the main volume of water. A safe operating temperature for the evaporator block is approximately 110°C. The condenser pipe also acts as a cooling pipe in the water as can be seen in Fig. 14. The maximum allowable water-temperature rise across the condenser is 60°C as compared with the maximum allowable water-temperature rise of 15°C across the water jacket.

This system results in a compact arrangement and affords a useful saving of space.

The External-Condenser System. Here the condenser is external to the boiler and thus a wide choice of both boiler and condenser designs is possible. Rather more space is required for this system and the applications therefore are mainly in the transmitting-valve field.

With both systems a visual indication of the water level in the boiler is provided and there is a safety device which will operate if the pressure rises above a safe limit and causes the release valve to operate or if the water level falls below a safe minimum. The advantages of the vapour-

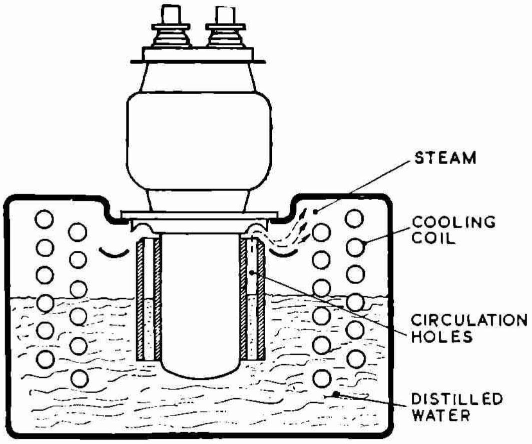


Fig. 14.
Internal arrangement of boiler-condenser unit.

cooling are that the water-flow requirements are much smaller than with the water cooling. Also should the cooling-water supply fail, the valve could still operate for a short period without damage to the valve, although a failure of the water supply would normally cause the trip switches to operate. Compared with the circulating system of water-cooling and the air-cooling method, no water pumps or air blowers are needed in the boiler-condenser system.

Bibliography

1. "Blower Selection for Forced - air - cooled Tubes," by A. G. Nekut, "Electronics" (August 1950), p. 88.
2. "Graphical Determination of Power Amplifier Performance," by R. I. Sarbacher, "Electronics", 15 (December 1942), p. 52.
3. "Industrial High Frequency Power," by E. May (Chapman & Hall, 1949).
4. "Transmitting Valves for Use in Industry," by E. G. Dorgello, "Philips Technical Review", 10 (1958/9), p. 299.
5. "The Design and Operation of High Power Triodes for Radio-frequency Heating," by W. J. Pohl, "Proc. I.E.E.", 104B (1957), No. 16, pp. 410-416.
6. "Induction and Dielectric Heating," by J. W. Cable (Reinhold Publishing Corporation, 1954).
7. "Water and Forced-air Cooling of Vacuum Tubes," by I. E. Mouromtseff, "Proc. I.R.E.", 30 (April 1942), No. 4, p. 190.

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NEW RELEASES

2N705, 2N710, 2N711

The 2N705, 2N710 and 2N711 are high-speed germanium p-n-p mesa transistors. They are designed for critical applications in military and commercial data-processing equipment where exceptional stability of characteristics for reliable performance is a primary consideration. These diffused-base mesa transistors are designed to meet the rigorous testing requirements of MIL-S-19500B and feature the high power-dissipation capability of 150 milliwatts at 25°C, the high minimum beta (h_{FE}) of 25, and a typical alpha-cutoff frequency of 300 Mc. They use the JEDEC TO-18 package.

2N1700, 2N1701, 2N1702, 2N1703

Four new low-cost silicon power transistors for industrial application are announced. These new diffused-junction types—2N1700, 2N1701, 2N1702, 2N1703, are especially useful in dc-to-dc converter, inverter, chopper, voltage-and-current regulator, dc amplifier, servo amplifier, power oscillator, and relay-actuator circuits. Capable of operating at case and/or mounting-flange temperatures from —65° to +200°C, these new low-cost silicon power transistors feature top performance at high temperatures up to 200°C, 75 watts dissipation, and the high collector-to-base voltage rating of 60 volts maximum.

2N1768, 2N1769

The 2N1768, 2N1769 are two new 40-watt n-p-n silicon mesa transistors. These new units utilize a hermetically-sealed package having an offset pedestal-and-stud mounting arrangement for positive heat-sink contact. These new transistors are designed for such applications as dc-to-dc converters, inverters, choppers, voltage and current regulators, dc and servo amplifiers, and relay-actuating circuits. They feature a very low thermal resistance (junction-to-case) of 4.375° C/watt; low saturation resistance of 1 ohm; and top performance at high temperatures up to 200°C.

2050A

The 2050A is a gas-filled thyratron of the tetrode type specially designed for use as a relay tube. It is like the popular 2050 but is constructed in a T-9 bulb for use in compact equipment.

EEV 7038

The 7038 vidicon television pick-up tube has been introduced by EEV to meet the increasing diversity of vidicon applications. This tube is sufficiently comprehensive in design for it to be used in film scanning, studio broadcasting and industrial applications where several specialised tubes have been used previously. The 7038 has a resolution capability of approximately 600 lines in the centre of the faceplate. A uniform photoconductive layer is used as the light sensitive element and this is characterized by a virtually panchromatic response which gives faithful reproduction of flesh tints and provides a picture similar to other pick-up tubes. The EEV 7038 has a sensitivity which permits live pick-up from scenes with 100 to 200 ft-candles of incident illumination, using a lens aperture of f/2.8 to f/4.0. For pictures of broadcast quality a faceplate illumination of 6-15 ft-candles in the highlights is recommended for live scene pick-up and 100 ft-candles for film scanning. Under these operational conditions smearing is negligible and uniformity of the picture is to the highest standards. For industrial applications this highly-sensitive tube may be used with a minimum of 2 ft-candles faceplate illumination with only a slight deterioration in other parameters.

M561

EEV announces that its 80 Kw fixed frequency non-packaged magnetron, the M561, is now in quantity production after exhaustive proving tests. Operating in the marine S-Band, 3040 to 3060 Mc, the magnetron will be notable for reliability and very long operating life. The coaxial output circuit will withstand instantaneous overloads of up to 1 megawatt, and the proving programme, conducted at sea and in the laboratory, has shown that this very conservatively rated and mechanically robust magnetron will be a valuable addition to the English Electric range of special tubes. The M561 has a typical peak power output of 80 Kw at an anode voltage of 13 Kv and a prf of 1000 pps, pulse length 1 microsecond.

7835

The ceramic-metal, super-power valve 7835 is a sturdy, water-cooled triode intended for use as a plate-pulsed rf power amplifier in long-range search radar, particle-accelerator service, and other types of service requiring high peak power output. Full ratings may be applied up to 300 Mc. At 250 Mc the 7835 can provide 5 megawatts of useful peak power output at a duty factor of 0.06 and a pulse duration of 2000 microseconds. With a duty factor of 0.01 and a pulse duration of 25 microseconds, it should provide up to 10 megawatts of useful peak power output at 60,000 peak positive-pulse plate-to-grid volts.

7895

The 7895 is a high-mu nuvistor triode for industrial applications. It has an amplification factor of 64 and is intended for a wide variety of applications in industrial equipment. It is capable of providing high gain with low noise in a wide variety of amplifier applications including: cascode circuits, rf and if stages, "on-off" control circuits, and resistance-coupled amplifier circuits; excellent stability as an oscillator from very low audio frequencies up into the uhf region; and reliable performance in applications such as "on-off" control where long periods of standby operation are required.

7189

The 7189 is a power pentode of the 9-pin miniature type specially useful in push-pull power amplifier circuits of high-fidelity audio equipment. It is particularly useful in combination TV-radio-audio systems where compactness without sacrifice of high-fidelity performance is essential. The 7189 features a maximum plate dissipation of 12 watts and unusually high power sensitivity. Because of the latter feature, it is capable of delivering high power output with small driving voltage. For example, two 7189's in class AB_1 push-pull amplifier service can deliver a maximum-signal power output of 24 watts with a peak driving voltage of only 14.8 volts.

BOOK REVIEWS

Books reviewed in these pages (except AWV publications) are complimentary copies received direct from the publishers. All enquiries for these books should be directed to your local technical booksellers, and not to AWV.

"LEARNING MORSE". Thirteenth edition. H. F. Smith. Iliffe Books Ltd. Size 7¼" x 4⅞". 20 pages.

This newly revised edition will be a helpful guide to all wishing to master the international signal code. The booklet gives methods of learning the code, key manipulation and methods of practice. There are also details and descriptions of equipment, and of an easily constructed transistorised practice set complete with a schematic drawing of the layout and circuits. The International Morse Code is given in full and includes the alphabet, accented letters, numerals, abbreviated numerals, punctuation and other signs in tabulated form. The revised Q code as approved at the Geneva Telecommunication Conference 1959 is included; this comes into operation during 1961. Finally, a series of practice groups and rhythmic groups complete the book.

"PRINCIPLES OF TRANSISTOR CIRCUITS". Second Edition. S. W. Amos. Iliffe Books Ltd. Size 8¾" x 5½". 210 pages, 125 diagrams.

The first edition of this book was favourably reviewed in these pages in October of 1959. This second edition has been enlarged and completely revised. References to obsolete techniques such as the point-contact transistor have been deleted, and the space devoted to new techniques which have become a reality since the first edition was printed, such as the drift transistor, zener diodes and controlled rectifiers.

The bulk of the book is devoted as before to a study of the principles underlying the circuit design of transistorized equipment. A large number of worked examples is included, the mathematics of which is confined to simple algebraic manipulation, in which the order of practical magnitude of the various quantities is accented.

"TELEVISION RECEIVER SERVICING", Volume 1. Second Edition. E. A. W. Spreadbury. Iliffe Books Ltd. Size 8¾" x 5½". 362 pages, 214 illustrations.

This is the second edition of the first volume of a comprehensive book (published in two volumes) written primarily for radio service engineers who wish to obtain a thorough knowledge of television servicing work. It assumes that the reader already has a reasonably good grasp of the principles of radio servicing and it extends this to the more complex circuits and techniques of television.

This new edition has been completely revised, and rewritten where necessary, to include all recent advances in television receivers. Many new drawings are included, and the numbering of the figures has been altered to a decimal system. On many of the diagrams component values have now been added which greatly enhance the value of the circuits.

In the first volume, time-bases and their associated circuits are covered; and it is probably here that more than half the servicing problems likely to be met by the service engineer occur. The second volume deals with all the other sections of a modern receiver, including the video stage, tuning circuits, sound channel and power supplies, and a large section devoted to aerial and signal distribution systems. Being of English origin, this book is naturally oriented towards English circuit practice and of course that country's TV standards.

"ELEMENTS OF ELECTRONICS". Second Edition. H. V. Hickey and W. M. Villines Jr. McGraw-Hill Book Co. Inc. Size 9¼" x 6". 549 pages, with copious illustrations and diagrams.

The object of this book is to offer the reader basic training in elementary electronics, and in that respect it may act as a stepping stone to further and more detailed studies of the subject. The treatment as far as thermionic valves is concerned is very thorough and leaves little to be desired, but it is felt that the treatment of semiconductors is much too thin. The book follows an unusual sequence in dealing with the various matters to be discussed; it is claimed that the methods and sequences used have been employed by the US armed forces for some time with success.

HEART CHECK-UP
by
RADIO

Do heart diseases affect driving proficiency? Since the number of drivers is constantly increasing, this question is of pressing importance now. At present it is being scientifically investigated by two doctors of the Medical Clinic of the Bonn University in the Federal Republic of Germany. Both doctors are employing a medium that can be really considered unique in medical research: radio. In "The Journal for Traffic Medicine, Traffic Psychology and Associated Fields" the two doctors, Dr. H. Hoffman and Dr. W. Reygers, report on their tests, which have not yet been finished.

At various times in the past doctors all over the world have pointed out that certain diseases affecting the circulation of blood to the heart exercise an important influence on fitness for driving. Consequently the regulations of the World Health Organization contain differing instructions for the evaluation of blood pressure diseases, particularly in regard to the danger of a sudden loss of consciousness at the steering-wheel. As the doctors write, such suppositions seem to have been varified by the numerous reports received lately on sudden heart failures at the wheel. But until now sufficiently critical examinations of drivers at the wheel have not been made because the technical conditions were too difficult. For example, how should the complex apparatus required for such examinations and recording of results be accommodated in a car? How should such complicated equipment be protected against vibration?

The two Bonn doctors found a brilliant solution to the problem. Nowadays they transmit the biological values measured in the travelling car-electro-cardiogram, blood pressure, pulse frequency and oxygen content of the blood — via radio to the clinic, where they are immediately registered or stored on a tape recorder. In the same manner the technical data too, such as the vibration of the driver's seat, are transmitted to the clinic.

The measured values to be transmitted and recorded, a difficult proposition in some cases due to their low frequencies, are converted into higher frequencies by means of converter units to facilitate transmission and recording.

The transmitting and receiving equipments, designed by Telefunken engineers, allow the test car a radius of action of more than 30 Km, (18 miles), and within this area the measured values can be reliably received. Since the area in and surrounding Bonn is characterized by dense traffic as well as narrow and wide streets, roads, state highways, open and complicated cross-roads, gradients, etc., almost all conceivable traffic situations required for the purposes of the examination arise within this radius.

Until now 103 trial runs have been made and the two doctors have described the happenings during some of them. The examinations so far show that the blood pressure of drivers suffering from heart trouble changes to a far greater extent than that of other drivers. However, the two doctors stress that after 103 runs it is impossible to give a substantiated and adequate reply to the questions investigated.

Even so, one fact has already been discovered; it is not the high speeds themselves that cause changes in blood pressure. Rather more these fluctuations arise in consequence of the risks experienced, that is to say in dense traffic, frequent bends, side-winds, etc. The risks experienced can arise at a speed of 30 or 40 kilometres per hour (18-25 m.p.h.) in a narrow street with dense traffic from the opposite direction, just as well as at 140 or 170 kilometres per hour (87-105 m.p.h.) in a sports car on the state highway.

(With acknowledgements to Telefunken)


AWV