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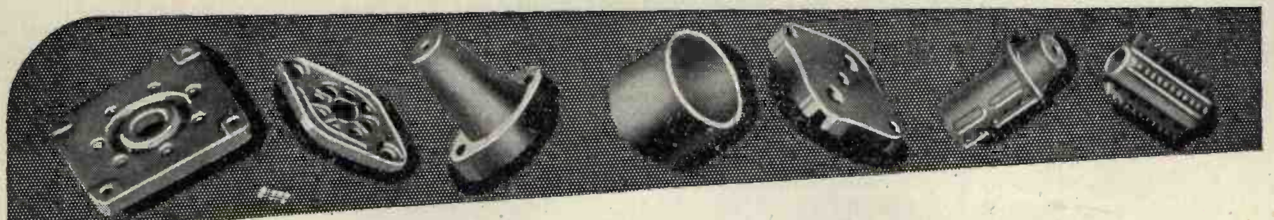

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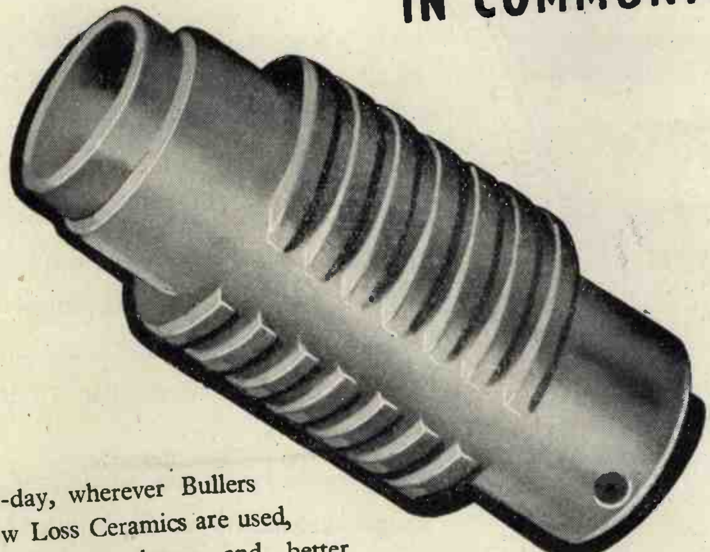

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CONTENTS


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Planned Research

SHOULD scientific research be centrally planned? Dr. J. R. Baker (of the Department of Zoology, Oxford University) thinks not, and his fellow members of the Society for Freedom in Science agree with him.

In a recently published book* he sets out his views at some length and in an entertaining style. There are two fundamental reasons, in his opinion, why science cannot be comprehensively planned. Firstly, the obvious one that scientists are not, and cannot be replaced by, crude machines. Secondly, and more important, discoveries often come by way of a surprise and not as a result of meticulous attention to a plan; for the end of a research cannot be envisaged when the plan is being made.

" It is not the slave to a plan, but the person with a mind that is prepared for the unexpected, who becomes the great discoverer "—and this argument is supported by numbers of instances from the lives of past and present scientists.

Dr. Baker draws a clear distinction between science, the acquisition of as complete a knowledge as possible of the material universe, and technology, which serves man's material needs directly.

The magnification of technology at the expense of science is deplored. In science, every discovery is of permanent value, but technological discoveries are often ephemeral. In Dr. Baker's view " If science disappeared and only technology remained, knowledge would be a hotch-potch instead of an ordered system. . . ."

This is called " an astonishing statement " by *The Scientific Worker*† in which a critique of Dr. Baker's book and views appears. He is denounced as an " Anti-Planner " and his book as revealing an out-of-date conception of the world to-day.

A great deal seems to depend on the precise definition of the word " planned ". The critique referred to quotes as an example of successful planned research the work of Langmuir in improving the emission of thermionic cathodes.

Surely this is not the " planned research " referred to by Dr. Baker. No worker undertakes research without a coherent plan in his mind as to the rough course it will take. Dr. Langmuir undertook the research with a definite aim, but it is exceedingly improbable that it was planned *for* him. And the aim of Dr. Baker's book (if it has been interpreted correctly) is not to attack method or system in research but rather to attack those who would give scientists " assignments," to use an expressive term.

Dr. Baker is not the only one who is uneasy about the future of scientific research. Dr. C. Kellogg in a paper on " Scientists and Machinery of State "§ says, " In the area of his special competence the scientist must determine how his skill and technique can be used to best advantage in helping to serve the common problem."

The Association of Scientific Workers states in concluding its note that it is working for freedom *for* Science not only freedom *in* Science, and that if the freedom they are working for comes to pass, there will be no need for the Anti-Planners to insist on choosing their own research.

" In their own field of endeavour they will be part of a vast flood of discovery, and will realise how fully the end of scientific knowledge is the service of humanity."

The distinction between two prepositions is subtle and may leave the reader wondering in what way the Association's views differ from those of the Society for Freedom in Science, as they undoubtedly do.

In the meantime, Dr. Baker has been invited to state his opinions in a short article (p. 147) and the columns of this Journal are equally open to supporters of the other side.

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* " The Scientific Life " (Allen and Unwin)

† (The Journal of the Association of Scientific Workers) July, 1942.

§ " The Scientific Monthly," July, 1942.

Some Aspects of Radio Valve Manufacture

By T. F. B. HALL and A. H. HOWE*

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 mandrel, and the speed at which the tube leaves the mandrel. Combined with the pulling mechanism is a cutting device, for separating the tubing into lengths of approximately 4 ft., which is a convenient size for handling in subsequent operations. The cutting is carried out by a chisel edged carborundum block mounted on a belt having the same length as that of the glass sticks, and which travels at the same rate and in the same direction as the tube. The belt is set at a slight angle to the glass tube so that a cross rubbing action takes place between the cutter and the tube whilst the two are in contact.

The glass tubing produced by the method which has just been described is used in the making of the valve foot or pinch (Fig. 1). The lengths of tubing are inserted vertically into a flanging machine, fitted with a number of revolving chucks mounted on a small circular table, which is indexed at regular intervals of time. At the first two or three stationary positions of the table, the bottom end of each tube is heated by gas burners until it becomes plastic. Whilst in this condition a spinning tool is brought into contact with the tubes, which are flanged outwards (Fig. 1/6). In the next two positions the flanged tube is cut to length by heating at the required distance above the flange and parted off by two rotating bevelled circular knives, one on the inside and the other on the outside. On the last position the chucks are opened, allowing the length of tube to fall on to a length setting plate ready for the cycle of operations to be repeated.

The flanged tubes are now transferred via a sloping chute to a horizontal circular slotted table, and in

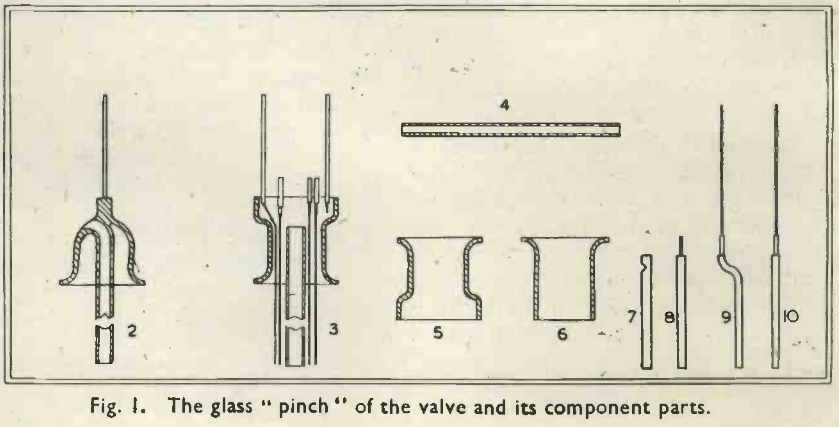

Fig. 1. The glass "pinch" of the valve and its component parts.

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*The M. O. Valve Co., Ltd.

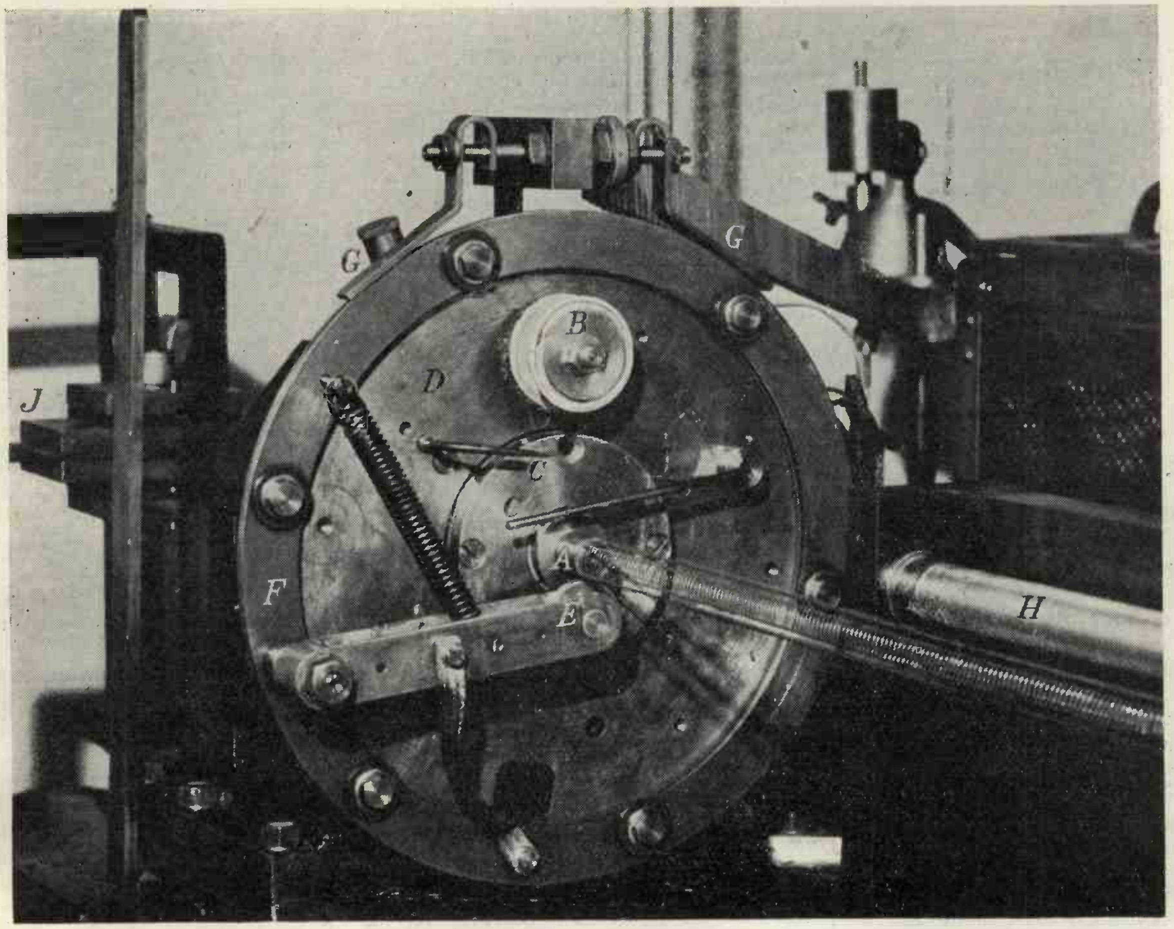

Fig. 5. Close-up of the grid winding machine showing grid wound in a continuous length.

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

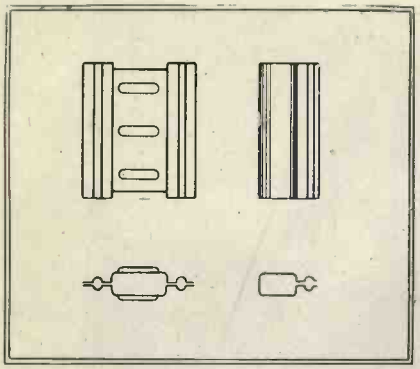

Fig. 2. Various one-piece and two-piece anode pressings.

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.

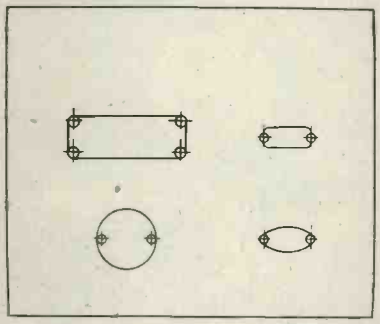

Fig. 3. Cross sections of various types of grid.

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.

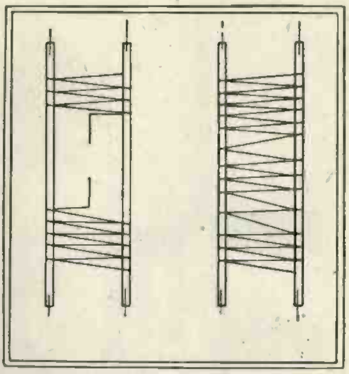

Fig. 4. Grids wound with constant and variable pitch.

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.

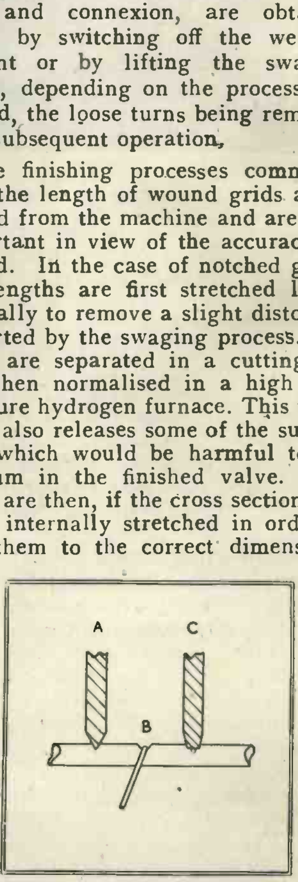

Fig. 6. Stages in the manufacture of notched grids.

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

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.

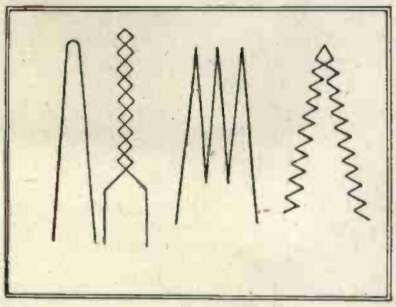

Fig. 7. Types of filaments and heaters.

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.

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

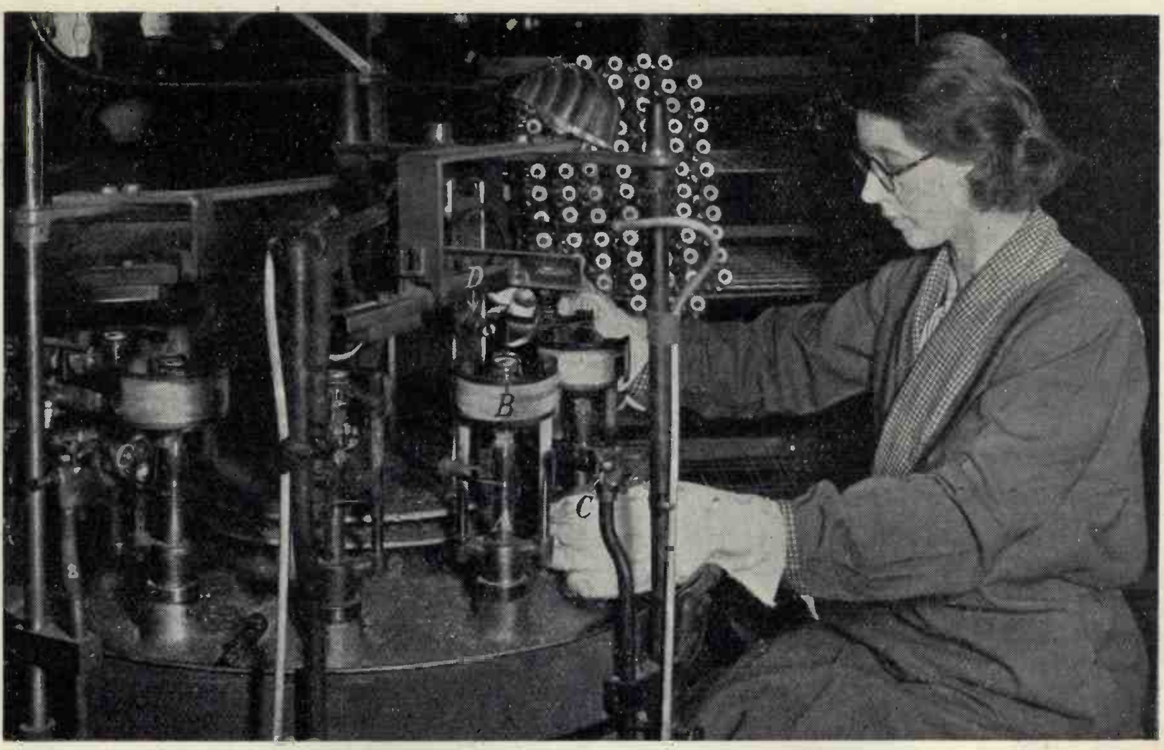

Fig. 9. A view of the automatic sealing-in machine.

loaded into the respective slots or grooves in the jig and the pinch, complete with the bottom mica assembled, is now offered up to the jig and the respective electrode leads fed through the holes in the bottom mica. The electrodes are now welded to the respective pinch supporting wires and the barrel jig withdrawn.

The welding operation itself calls for little comment. The spot welders are usually fitted with 1 kVA or 2 kVA step-down transformers and are of light construction, fitted with a spring-controlled make and break mechanism. In some cases special current controlling devices are fitted where extra delicate work is called for. The accurate use of these small welders is well within the capacity of the average woman worker and most of them are able to carry out this operation with a high degree of efficiency. Naturally, the avoidance of damage or distortion to the various electrodes during assembly is one of the things which call for most attention during this operation, particularly as much time and money has been spent in previous operations in making these electrodes to accurate sizes. Other allied problems have to be dealt with, such as the avoidance of contamination of the material surface by greasy hands, and the associated difficulty of avoidance or at any rate dispersal of small particles of fluff or lint, which ultimately give rise to extraneous noises in the finished valve.

Sealing-In

The electrode system, when mounted on the glass stem, is now ready for enclosing in the surrounding glass envelope or bulb. This operation, known as sealing-in, is carried out on the machine shown in Fig. 9. This consists of a number of rotating heads each having a central pin (A) into which the exhaust tube of the mounted seal is inserted. The bulb (B) is now fed into position open end downwards over the mounted seal. It is held in position by a chuck, in such a manner that it completely covers the mounted seal and the lower or open end extends for some distance below the opened out or flanged part of the seal. The machine which is power indexed now starts to rotate and in the first position " soft " fires impinge on the neck or lower part of the bulb at a point almost opposite the flanged out part of the seal. The machine continues to index through other positions, where other " harder " fires are brought into play at the same point. It is perhaps necessary to give an explanation of the term " soft " and " hard " fires. It is essential in working glass to raise the temperature slowly till the plastic stage is reached, in order to avoid thermal shock and the resultant cracking. Correspondingly the glass must not be allowed to cool suddenly after the operation is completed. In order to ensure that there is no sudden increase or decrease in the temperature gradient curve, the fires used are arranged so that in the initial stages they give a low heat output (usually by limiting the amount of gas flow and at the same time cutting down the air supply to a very low figure—this gives a " soft " flame). Correspondingly the latter stages consist of fiercer or hotter fires with a greatly increased air pressure, resulting in a " hard " fire. After the completion of the sealing-in operation the temperatures are again slowly lowered. With the increase of temperature the neck of the bulb starts to melt and in so doing the glass shrinks on to the flange at the bottom of the pinch and a lip near the top of the seal support pin, as the lower part of the bulb drops down under its own weight. An airtight joint is thus made between the bulb and the pinch, and the only connexion between the interior of the bulb and the atmosphere is now via the exhaust or stem tube. The sealing-in operation can perhaps be more readily followed by examination of Fig. 10 where view (1) shows the bulb prior to the application of heat, (2) after the bulb has shrunk on to the glass flange and pin and (3) where the neck has been separated from the bulb. This is accomplished by blowing a jet of air from a series of small holes in the pin above the lip which punctures the hot glass between the flange and the lip so that it is quickly melted away.

Pumping

The basic principle underlying the pumping operation is to drive out the occluded gases from the electrodes of the valve and also from the glass bulb in the shortest possible time. The gases occluded in the electrodes have been previously reduced to a minimum by cooking, either in a vacuum or in an atmosphere of hydrogen. Certain precautions are also taken in the smelting stage of the metals used to reduce the gas content. Very low pressures, by ordinary standards of comparison, are obtained by means of microscopic mechanical clearances in the rotary exhaust pumps sealed by oil, which has been treated under vacuum to remove the more volatile components. A good double stage oil pump, one stage of which is shown diagrammatically in Fig. 12, is capable of reaching a pressure of 1/10 of a micron (0.0001 mm. of mercury). Actually, the pressure in the exhausted valve is considerably above this figure, owing to unavoidable losses due to the multiplicity of rubber joints, leakage across the lapped surfaces of the machine valve, the restriction imposed by the small bore exhaust tube and the progressively slower rate of exhausting, which takes place as the lower pressures are reached. Some manufacturers prefer mercury vapour diffusion pumps backed by a single stage oil pump. This arrangement has a higher rate of exhausting but requires more maintenance.

In actual practice a pump machine shown diagrammatically in Fig. 11 consists of a number of such units, coupled by a multipoint central rotary valve to the various positions in a circular manifold, which support the valves to be exhausted. The exhausting process consists of inserting the glass exhaust stem of the valve into one of the rubber connecting tubes of the pump manifold and opening up the control tap to the pump system. The machine indexes and the valves being pumped then move forward under the pump oven which is heated at an average temperature of 450° C. By this means the bulk of the occluded gas is driven from the glass bulb—water vapour is readily removed by this treatment in considerable quantity. The electrodes of the valve are then heated up by a current induced from a high frequency source. This liberates gas from the electrodes and heats the cathode to decompose the carbonates in its sprayed coating. At this stage it is usual to reheat the electrodes to disperse any gas which they may have absorbed during the heating of the cathode. The final vacuum on the pump is usually obtained by liberating a " getter " or chemical composition to effect the final clean up of the remaining residual gases. The " getter" employed varies, but usually consists of barium or magnesium or a varying percentage of each.

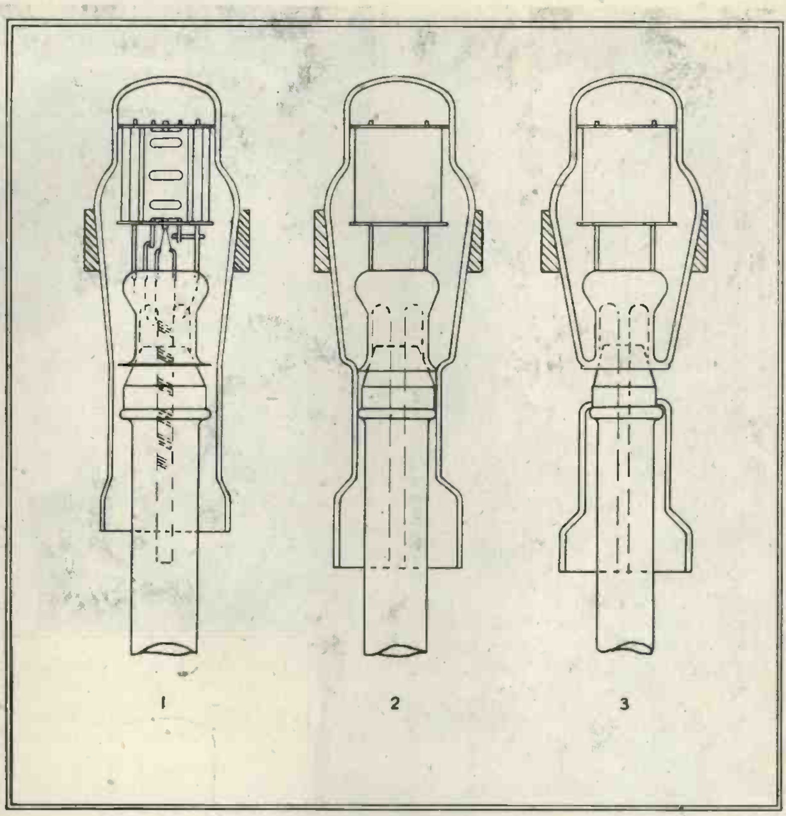

Fig. 10. Showing the stages in the sealing-in operation.

With the completion of the pumping schedule the valve is sealed off by melting the exhaust stem to a small pip.

A typical pumping machine is shown in Fig. 13, which shows (A) one of the rubber valve connexion housings built into the circular water cooled manifold (B), (C) the oven for baking the bulbs, (D) one of the high frequency coils, (E) the sealing off device, and (F) the delivery chute to the capping machine.

Capping

The fixing of the cap to the glass bulb is by no means such a simple operation as it appears at first sight. It is an unfortunate fact that most of the quick hot treatment cements available require a heat treatment temperature, which is very close to the blistering point of the bakelite material of the cap and great care has to be taken in selecting a suitable capping cement, which usually consists of a bakelite or shellac base with a suitable filler. The cement is fed into the cap in a semi-plastic state, and the copper leads from the valve are threaded into the respective pins in the cap, the lower part of the bulb is then introduced into the cap and is now in contact with the cement. The valve, complete with cap, is then inserted into a rotary machine and passes through an oven, thus drying out the carrier in the cement and forming the bond between the glass and the cap. Modern practice usually includes the use of centring devices, for ensuring that the cap and bulb are reasonably aligned. After the capping operation the surplus copper wires are cut off and the leads soldered to the pins in the cap.

Activation and Ageing

The full emission of the valve is not developed directly it comes off the pump, but by running the cathode at a temperature which requires careful control, with suitable potentials on the other electrodes for a specified time, further activation takes place, and the valve is stabilised from the point of view of the remaining small quantities of gas left behind.

Testing

The final operation in the manufacture of a valve is testing. The number of tests to be applied is governed by the type of valve being tested, but all valves have some tests in common.

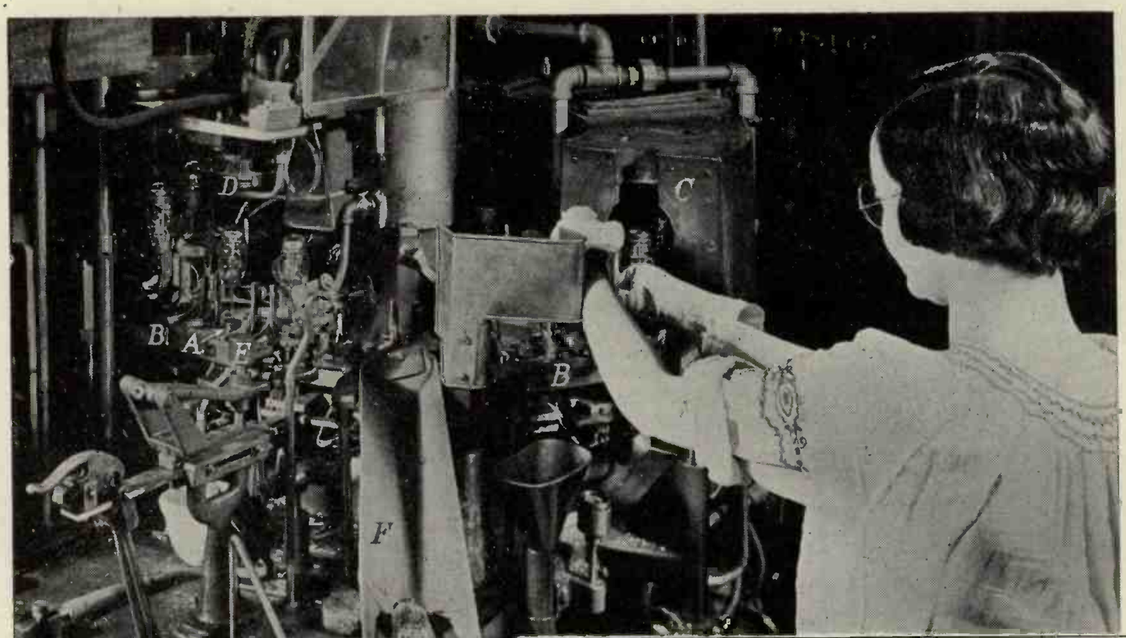

Fig. 13. Automatic rotary exhausting machine.

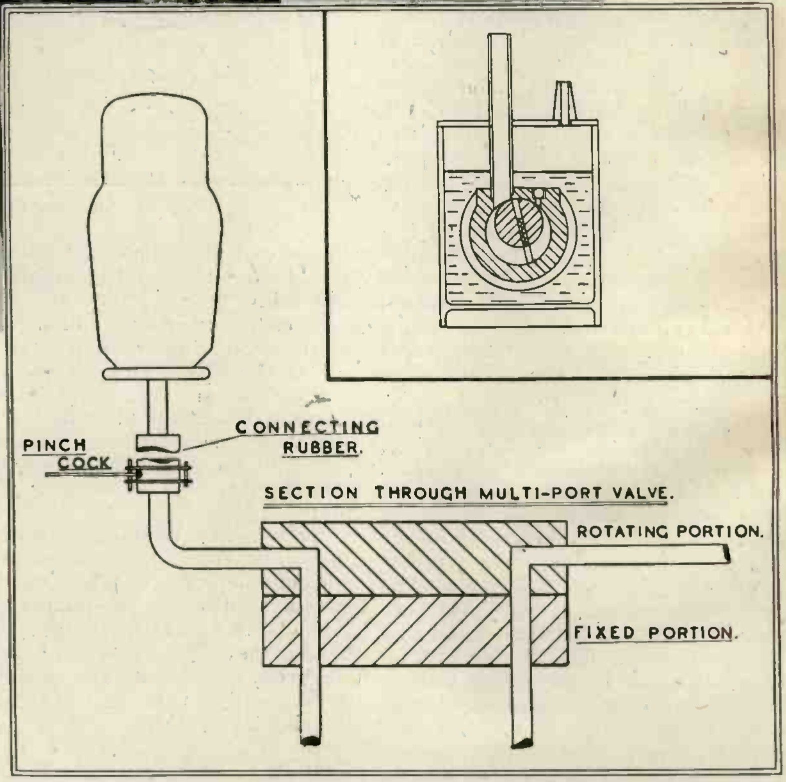

Fig. 11. Diagrammatic layout of exhausting machine.
Fig. 12. (Inset) Section through rotary oil pump.

The ones usually applied are :—

(1) *Filament Rating.*

Either the filament voltage is fixed and the filament current read, or vice versa.

(2) *Anode Current.*

The anode current is recorded, with a fixed potential on the anode and grid, usually at the working point.

(3) *Negative Grid Current or "Backlash."*

A potential is applied to the anode and the heater/cathode or filament circuit run under normal conditions, and with a low negative potential applied to the grid the negative grid current is recorded. This reading will give an indication of the gas pressure of the valve under test.

(4) *Other Applied Tests.*

According to the type of valve and its particular application to circuit use, other tests are made such as power output in the case of the output valve, and conversion conductance in the case of frequency changers. In addition to these tests it is usual to test each valve for microphonic properties, or other noises which may be indicative of loose fitting or badly joined electrodes.

Conclusion

From the foregoing it can be gathered that although valve manufacture has now developed on an extensive scale, the maintenance of characteristics, and satisfactory life performance, are problems which call for very close inspection of the electrode construction and all the subsequent valve manufacturing processes right up to the final testing.

The Scientist and the Community

By JOHN R. BAKER, M.A., D.Sc. (Oxon.)

APART from the application of science to practical affairs, there are two main reasons why science is necessarily a social activity. First, the subject of a scientist's research must be influenced by the subjects which others have investigated. Secondly, the need for objective proofs of his discoveries presupposes the interest of others. Investigators influence one another sometimes in conversation or by lectures, but more usually through the medium of print. It often happens that great discoverers are people to whom social life is unattractive. They are engaged on a social undertaking, but some degree of solitude is usually necessary if they are to find out things that will interest others.

Great discoverers are attracted by great problems, and they measure a discovery not by its immediate effect in providing the material wants of man, but by quite a different criterion. They consider a discovery great if it links together many facts not previously known to be related. Such discoveries often bring enormous material benefits to mankind in unexpected ways, but the urge which made the discovery possible was the urge to know more and to help others to know more.

Science and Industry

Much remains to be learnt about the conditions necessary for the origin, both in pre-history and in individual development, of the urge to discovery. Hypotheses can be put forward to account for the evolutionary origin of the urge, but for the present it is possible to be certain only of this—that it is the prime requisite in a research worker. Certainly the urge does not arise as a direct result of manual labour, as some political thinkers would have us believe. Only those whose real interest is the establishment of a particular political view can deceive themselves into thinking that modern science is the product of material human needs.

Five of the greatest geniuses of physics and chemistry were the sons of a blacksmith, a candle-maker, an operative weaver, a cloth-dresser and a bricklayer; but it was not manual labour which directed their attention to the properties of matter. Faraday, for instance, was directed to that subject not by the iron of his father's forge nor by the physical materials of the books which he bound, but by the contents of those books. Franklin found life among his father's candles so distasteful that he left it to become a printer's apprentice and thus reached the world of culture, like Faraday, through books. (Physics itself presented itself to him much later in life, in the shape of a travelling lecturer). Dalton's genius was able to fructify not because he was driven forward by a consuming passion to study the woollen materials which gave his father a scanty livelihood, but because a Mr. Elihu Robinson noticed and stimulated the boy's desire to study and improve his mind. Priestley's thoughts were not turned to the study of materials by contact with the family cloth-dressing business. It was to his aunt, not to cloth, that he was indebted for the possibility of developing his talent. It was she who encouraged him in youth and brought him into contact with people of culture and liberal thought. That Gauss was able to develop his genius was due to the far-sighted encouragement of the Duke of Brunswick, not to any congenital desire to probe into the ultimate composition of his father's bricks.

The pretence that the handling of materials in crafts and industry is a mainspring of science is false, and nothing less than flat contradiction meets the case when the Vice-President of the United States remarks that "Modern science is a by-product and an essential part of the people's revolution." It is, on the contrary, a direct product of men of genius and talent. The "common man," upon whom it is nowadays so fashionable to fawn, has played almost no part in its development. The history of science shows convincingly that it is not industry that makes science, but science that makes industry and much besides. Manual labour is involved in scientific research as it is in playing the piano, but the manual labour of industry is no more the source of scientific discovery than of musical composition.

That geniuses have risen from very poor circumstances does not prove that manual labour produces genius, but only that genius is remarkably independent of social status. It is not the devotion of a man's life to material human wants that results in great discoveries. The very reverse is true. Ampère deliberately took up the study of physics as an escape from mundane affairs, when the execution of his father by the French revolutionaries had weakened his feeling of kinship with human society. That his genius was able to benefit humanity in such a remarkable degree both intellectually and practically was due to his deliberate retreat into matters transcending those of everyday life.

Much is written nowadays about the social relations of science, and it is insisted that all scientific research should be directed towards satisfying the material needs of man. This insistence is short-sighted. During the war scientific research must indeed mostly be devoted to practical affairs, but in times of peace such a policy would be disastrous. To use Dr. L. E. Sutton's phrase, it would mean that we were living on capital. Great discoverers are often not concerned with immediately practical affairs. Some of the greatest modern scientific geniuses, like Bohr, Dirac, Einstein, Moseley, Planck and Schrödinger have concerned themselves mostly with matters which have not yet affected the material welfare of man. That welfare may be (and probably will be) revolutionised by their work, but we do not yet see exactly how. Their work has a tremendous cultural value whether practical applications come or not. It would be nothing less than a disaster if the introduction of totalitarian methods into scientific life were to prevent men of this calibre from allowing their genius to manifest itself.

Scientific Method in Political Discussion

Science has a great potential social function beyond the obvious one of forming the only secure basis for technology. Scientists can make, if they will, a tremendous contribution to human welfare. They can make that contribution not by attending to the modern parrot-cries about the social relations of science or throwing themselves into the violent stress of party politics, but by a very different and much more congenial process. They can introduce scientific method and habits into the problems of human relationships.

At present, those scientists who have become most politically conscious have unfortunately set a bad example by leaving behind scientific method when they enter the political arena and adopting the worst of the practices which make politics disreputable. It is, perhaps, scarcely necessary to stress the radical difference between the truly scientific and the ordinary political atmosphere. The degraded nature of political life is so much taken for granted, that most people scarcely bother to reflect seriously on the subject. A few months ago a weekly journal intended for intellectuals published a letter from a man who told how he enjoyed watching his dog kill a rat, because that was what he would like to do to those with whom he disagreed politically. This is, of course, rather an extreme example, but it exemplifies the kind of thing that tends to be taken for granted by readers of political journals. We should be startled out of our wits if we found a comparable public display of hate in *Electronic Engineering*. In science we resolve our disagreements in another way.

One of the greatest social functions of science, then, is to inculcate scientific virtues into the field of human relationships, so that at last no one will seek to influence political opinion in any direction by falsehood, exaggeration, hate (a very infectious emotion), sarcasm, contempt, argument by analogy, use of misleading similes and metaphors, imputation of low motives, repetition of slogans, or any rhetorical device that would not be approved in a scientific paper. These devices for affecting opinion are as much used in some political journals intended for intellectuals, as in the popular Press; and it will be an uphill task to revolutionise the conduct of political argument.

The slogan that economic liberty is more important than liberty of speech is current among those who harp upon what they imagine to be the only social function of science. The logical fallacy involved in the slogan need not detain us, but it is significant to note that in twentieth-century Britain liberty of speech can still be challenged. It is regrettable that even certain scientists are prepared to discard this most important element of the only technique known to man for arriving at demonstrable truth. A valuable social function of science would be to spread ever more widely those methods that have made science great, and to combat those which have caused the low status of politics.

Freedom of Enquiry

Freedom of speech is, of course, not in itself a sufficient freedom for the research worker in pure science: there must also be freedom of inquiry. Every scientist with the talents of an original investigator knows better than anyone else how his own personality can best be used in the expansion of the bounds of knowledge. He knows his own deficiencies as well as his strong points, and he knows that no one else has exactly the same qualities and interests as himself. He applies himself to the problems which he is fitted to solve. This process, repeated over and over again in the persons of all the original investigators in the world, results in the attempt being made to cover the whole field of science, so far as it is possible to cover it in the existing state of knowledge. Every time a scientific dictator or planning committee decides that an original scientific investigator is to undertake a stated piece of research, the plan which includes him necessarily excludes him from the work which he would have done had he been free. Those who speak enthusiastically of the central planning of science should reflect seriously on the gaps which their policy would make in the expanding front of science, and on the waste of material involved in confining an original mind in a mental strait-jacket. Anyone who has ever known an originally-minded investigator is aware that one might as well try to plan the activities of a volcano or a musical composer as his.

Faraday did not stay long within the narrow confines of a plan to improve glass. When pressed to continue this work, Faraday wrote some memorable words in answer. He said that as he had been obliged " to devote the whole of my spare time to the experiments [on glass] already described, and consequently to resign the pursuit of such philosophical inquiries as suggested themselves to my own mind, I would wish, under present circumstances, to lay the glass aside for a while that I may enjoy the pleasure of working out my own thoughts on other subjects." Never has a planner been told more courteously or more effectively exactly where he gets off. Instead of improving glass, Faraday went on to the researches in pure science which made him one of the greatest investigators the world has ever known, and which resolutionised industry at the same time.

Those who consider that the subject-matter of scientific research should be centrally planned almost seem to think of scientists as a flock of sheep, whose individual temperaments and interests are not important. Like Francis Bacon, they imagine that they have a method of making scientific progress automatic, a method which " nearly levels all wits and intellects." Wits can be levelled, it is true, by totalitarian methods; but the levelling will all be downwards, and can only be achieved by the strangling of genius and talent.

There is a place in science for the talented but unoriginal investigator who works happily and well under the direction of others. There are certain fields in science which are suitable for these men, who should not be persuaded to undertake original work if their own special aptitudes are best satisfied in a directed team. These men serve science well, and damage will only be done if their interests are made to transcend those of the original investigator, so that funds and facilities are lavished on plans, while free science is slowly starved. Planning can co-exist with free science, provided that freedom is not confined to established genius. Genius cannot manifest itself *in vacuo*. Einstein has become what he is not only because of his intrinsic merit, but also because of the co-existence of others who made a milieu in which his genius could flourish. Had he lived a thousand years ago, or spent all his life in a modern totalitarian country, it is unlikely that he would have made such enormous contributions to knowledge. Original and independent investigators who are much less than geniuses not only make a very large total contribution to knowledge themselves, but also help to provide an environment which favours the manifestation of genius.

In the period of reconstruction after the war, the parrot-cry of planning is likely to drown the sober conversation of those who are working to make a better world. It is to be hoped that the needs of original and independent minds, of all grades up to genius itself, will not be forgotten.

A Sound Suggestion

NOT long ago the question of terminology for ultra-high frequencies was being discussed on both sides of the Atlantic, and at a conference of American professors it was solemnly decided to refer to the ultra-ultra-high frequencies as U.H.F.I.—Ultra High Frequency Indeed.

Dr. Lee de Forest suggested in a letter to our contemporary *Electronics*, that the next step would be " Goodness! Ultra-High Frequency Indeed!, pronounced abbreviatedly G.U.H.F.I., or plain Goofy.

A far more logical suggestion is made by B. C. Fleming-Williams in a letter to the Editor of *The Wireless Engineer*. He proposes that the whole frequency spectrum should be divided up into a number of bands defined in the following manner.

If a frequency is expressed in cycles per second, it will lie in a band whose number is equal to the logarithm of the frequency to base 10. The band number is therefore given by expressing the frequency as a number between 1 and 10 multiplied by a power of ten, and using that power as the band number.

For example 50 Mc/s is 5×10^7 c/s, and the band number is 7.

It is pointed out that the present terminology does not correspond to the band numbers exactly, but this should not present difficulty. The system can also be extended widely, light waves being associated with band 14.

Wave Analysis

Part I — General Review

By K. BOURNE*

THE term wave is commonly used in a very wide sense, to cover almost anything from a heat wave to the probability waves of modern physics, but it can be generally taken as representing the variation of some quantity with regard to time or space. The variation of an electric current or potential difference with time will be called the waveform of the quantity concerned, and in accordance with the above will be taken in a very general sense, *i.e.*, it will not necessarily be periodic or even continuous. Only the analysis of electrical waveforms will be directly considered, but this limitation is not severe; variations of other kinds which come within the frequency range that can be handled in current electrical technique, can be translated into electrical variations and dealt with by the standard methods described below. This applies particularly to acoustic and physiological phenomena. Thus any variation with time of an electric current or potential, however produced, comes within the field of wave-analysis.

Analysis in the broad sense implies the separation into component parts of the primary subject of investigation, but leaves the form of the components to be decided by considerations of practical use. Now, in a large variety of physical phenomena, it is found that the reaction to an applied force is in direct linear relation to the displacement thus caused. This condition ensures that the free oscillations and favoured modes of vibration of such a system will be simple harmonic. Thus in the analysis of waveforms, it is always understood that analysis into simple harmonic components is required. It would in fact be very difficult to analyse a wave into other than simple harmonic components, and moreover, this analysis has a very sound mathematical basis in Fourier's Theorem and the general theory of Fourier Series. Thus, the problem of wave analysis is: given an arbitrary waveform, determine its simple harmonic components in phase, frequency and amplitude.

Types of Waves Considered

It is convenient to divide the waveforms which occur in electrical circuits into four different classes: these are:

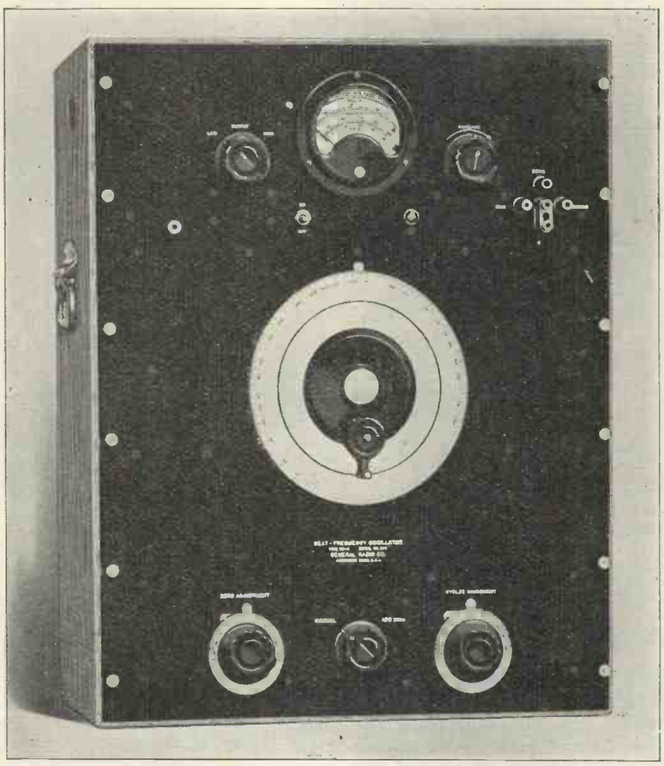

Fig. 5. General Radio Wave analyser for the measurement of individual periodic components of a complex voltage wave, having amplitudes between 30 microvolts and 300 volts and frequencies between 20 c/s and 16,500 c/s.

By courtesy of Messrs. Claude Lyons Ltd.

(a) Periodic, single.
(b) Periodic, multiple.
(c) Non-recurrent, continuous.
(d) Transients.

Expanding this classification, class (a) comprises waves of one well defined fundamental period, but of arbitrary waveform, *i.e.*, a fundamental tone with harmonic overtones. These are of frequent occurrence, tones from most musical instruments, A.C. waveforms from alternators (and ripples on D.C.), oscillator outputs, to mention only a few. It is frequently necessary to determine the components to a high order of accuracy and since very small amounts may be important, considerabe sensitivity is also needed.

Class (b) includes those waveforms which are the sum of two or more periodic functions whose fundamental frequencies do not bear an integral relation to each other. Thus combinations of several tones, a wanted tone and an interfering tone, modulation products, etc., are in this class. In many cases, selectivity and sensitivity of a very high order are required in the analysis.

Waveforms in class (c) are those which, while continuing indefinitely, are not periodic. There is a considerable gradation in this class, from such cases as a pianoforte, the sound of which consists largely of fundamental and harmonic overtones, but which also produces a certain amount of percussive noise, to industrial noises which may be largely random, speech and music with tones of changing period and accompanying non-periodic sounds, and resistance noise which is wholly random.

Class (d) includes "transients," *i.e.*, tones or impulses that exist only for a very short time, or sudden changes in level, frequency or phase of a continuous tone.

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* Post Office Research Station.

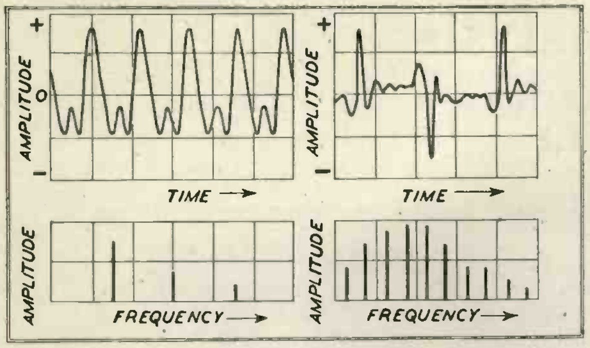

Fig. 1. Waveform and spectrum of Class (a) waves.

Some typical curves of class (a) are shown, with their analyses, in Fig. 1, whilst Figs. 2 and 4 give similar examples of classes (b) to (d).

Classes (a) and (b) are considered as steady-state conditions, and the spectra of their waveforms will be a series of values for the fundamental and harmonics, *i.e.,* line spectra. Class (c) is normally considered as a steady-state condition for the time of the analysis, in this case, the characteristics (band-width, build-up time, etc.) of the analyser are of very considerable importance, and the results may be difficult to interpret. In general, the spectrum will be partly line, partly continuous. In the case of class (d), the difficulty is intensified, and many methods are not applicable to this class, though excellent for classes (a) and (b). Fortunately, the accuracy required is in general, much less; however, the results must be carefully considered in connexion with the instrument used, and the use to which they will be put. The spectrum will be continuous and in general, infinite.

Methods of Measurement

General Considerations.

The requirements to be met by an instrument or method for wave analysis vary over a very wide range, according to the purpose of the analysis. Normally, no great accuracy in the determination of frequency is required; in the case of waveforms (c) and (d) it is not justified by the general circumstances of their production, and the use to which the analysis will be put. In the case of waves (a) and (b) numerous methods for the determination of the frequencies involved already exist, of all degrees of accuracy—and in very many cases, the frequencies involved are already known, and all that is required is an approximate indication of their place in the spectrum being investigated. The determination of the phases of the components is not easy even with class (a) waves, and no attempt is normally made to determine phases in the cases of (c) and (d) (where little significance can be attached to phase). However, the phase of a component is but rarely required.

The main purpose of the analysis is normally to obtain the amplitudes of the component waves, and it is to this end that most of the design features are directed. There are conflicting requirements, however, of accuracy, rapidity, and ease of operation, not to mention portability and cost. It is convenient here to indicate a broad division in methods, between those which give a quick recorded spectrum or show it on an oscillograph so that it can if necessary be photographed, and the methods which require a setting for each component, or each frequency band. This division corresponds quite closely to that between classes (c) and (d), and classes (a) and (b), *i.e.,* between continuous and line spectra. The applications of the first group of methods are chiefly to acoustics; of the second, to electrical phenomena.

The general advantages of the first group are fairly obviously speed and convenience; speed becoming a necessity in the case of short duration sounds, or any other quickly changing effects. In contradistinction, the second group of methods are relatively slow and laborious when applied to the explanation of an extensive spectrum, but very much more accurate and flexible. They allow of the singling out of individual components and their observation while conditions are changing; very high accuracy can be obtained by the use of substitution methods; and the whole procedure is more easily followed and the performance more easily estimated. They are, however, of little use with short duration and quickly changing phenomena.

Classification.

The varied and diverse methods which have been used to meet the requirements of particular problems can be grouped under seven main heads. These are :—

1. Graphical methods.
2. Resonance methods.
3. Filter methods.
4. Bridge methods.
5. Heterodyne methods.
6. Stroboscopic and mechanical methods.
7. Diffractive and optical methods.

Some idea of the uses and limitations of these methods is given below, before the more specific treatment in a later section.

The first of these methods depends upon the delineation of the waveform, by oscillographic means on film or coated strip, or by successive readings using a Joubert contact, and its subsequent analysis by standard methods into the Fourier components. These include " schedule " methods, Henrici analysers, planimeters and integraphs. The sensitivity and accuracy are limited by mechanical or computational accuracy, and by the preliminary oscillographic or plotting process, and the method is lengthy and somewhat laborious. It is, however, applicable to all classes of waveforms, giving frequency, amplitude and phase. The actual time spent in recording the waveform may be very short, moreover, which somewhat compensates the length of time required to analyse the results. That it is a far from perfect method, though, is shown by the fact that it has been thought worth while to adopt the reverse process in some cases, and transform a curve into electrical variations to effect its Fourier analysis.

The second method isolates the components of the wave in turn, so that they can be separately measured. It is, strictly speaking, only applicable to waves in classes (a) and (b) (exceptionally, class (c) when components of approximately steady frequency exist). It is sufficiently indicated by saying that it is a " tuned circuit " arrangement. It is a simple and obvious method, and in most respects both flexible and powerful, leading itself to the design of simple or of more involved apparatus as the requirements

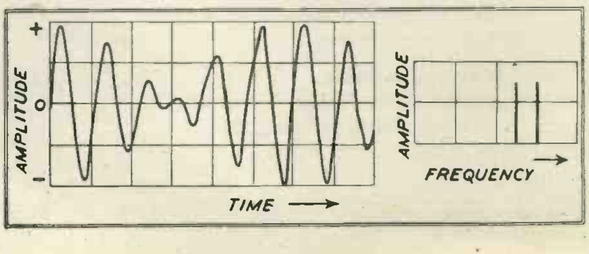

Fig. 2. Waveform and spectrum of Class (b) waves.

dictate, and very useful in combination with other methods. It normally gives ample selectivity for waves of class (a), but often not enough for class (b). It is, of course, in common use in wave-meters and radio sets, which can be easily made to serve as analysers, using a substitution method. The method indicates frequency with very considerable accuracy, amplitude with accuracy equal to any other method, but is not able to indicate phase (except indirectly, with much additional apparatus and using a substitution method).

The third arrangement is very similar to the second, but the emphasis is on the analysis into bands of frequencies, not into single components. Thus it cannot analyse class (a) and (b) waves unless the components are well spaced, but it can give the continuous spectra of classes (c) and (d) (though it must again be emphasised that the build-up time in the filters and indicating instrument and the general question of their response to transient impulses, must be considered in interpreting the results obtained.) The method is thus suited to the estimation of the power distribution over the spectrum of music, speech or noise, mechanical vibration, or electrical interference with communication or broadcast channels. In this connexion, it can evidently be used with class (a) and (b) waveforms, to integrate their effect over a band of frequencies. It is also very suitable for testing purposes using predetermined testing frequencies (*i.e.,* testing amplifiers and any other equipment, for harmonic production or intermodulation), where the amplitudes of certain products alone are required, or perhaps only the sum of all harmonics produced. As regards frequency, the method is seen to give no indication beyond the limits set by the filter band-widths; as to phase, it is similarly placed to the resonance method.

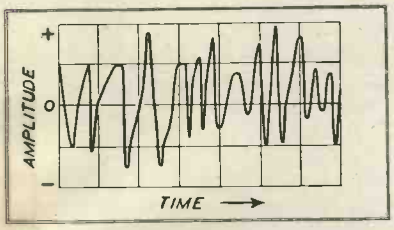

Fig. 3. Waveform of Class (c) wave.

The fourth method, the use of a bridge network, is obviously suited for only a limited range of requirements, practically, those where the comparison of a single wanted tone with the sum of all other components is all the indication needed. Thus, used with class (a) (b) and (c) waves, a bridge method will evaluate the proportion of unwanted harmonics, intermodulation or noise present (with some uncertainty as to conditions immediately adjacent to the frequency of balance), but cannot present a detailed analysis of the waveform. It may be of use, however, to eliminate a strong fundamental or other component before proceeding with further analysis by other means. There is an interesting method, using, as it were, an inversion of the bridge characteristics, by including the bridge in the feedback circuit of an inverse feedback amplifier thus obtaining a tuned amplifier of very desirable characteristics; this gives results as outlined above under the head of Resonance.

The heterodyne method is well known; briefly, it changes the frequency of a component or a frequency band in the spectrum of the waveform being analysed, bringing it to a predetermined frequency, where the component or band is selected and amplified as required. This is also known as the "exploring-note" method. It has evident advantages in that constant sensitivity and band-width are directly obtained without having a large number of variable components, and it is extremely flexible in selectivity and frequency range covered. The constant band-width may not be advantageous in some respects, since it makes for poor selection at low frequencies and very critical adjustments (and long build-up time) at high frequencies. For waveforms of class (a) and (b) also to a considerable extent class (c) the method is very widely employed, and is almost indispensable in many cases. The frequency accuracy is not necessarily lower than that of the resonance method, and the amplitude accuracy is equally good; the same situation applies as regards phase, *i.e.,* difficult to measure, needing additional apparatus. The apparatus is not necessarily complicated (*e.g.,* in the "dynamometer method") but has a tendency to elaborate set-ups (with correspondingly increased accuracy, ease of operation, or range); it always requires an external or internal oscillator, however, and thus power supplies must be provided: an important point when portability, size and cost are in consideration.

The stroboscopic method, translating the electric waveform into light variations which illumine a stroboscopic disk, marked in black and white sectors and of which the speed can be varied, gives the phases of the components of Class (a) and (b) waves to a moderate degree of accuracy in a very direct fashion, also their frequencies, but no clear indication of the amplitudes. It is thus of very little use alone. Another mechanical method, commutator rectification, gives accurate indication of amplitude, frequency and phase, but is only suitable for low frequencies.

The diffractive method, using acoustic waves in air, and a diffraction grating, with a microphone to explore the resulting spectrum, is particularly adapted to class (c) and (d) waveforms as encountered in acoustics, giving a very rapid record of frequency and amplitude, of sufficient accuracy for all the cases in which it is likely to be useful.

There are several optical methods, using film recording by one or other of the available systems. One or two of these use the film as a diffracting medium, deriving the spectrum from the diffraction bands produced; another ingenious method effects the Fourier analysis of the recorded curve by multiplication (through super-position of a second film) by the appropriate sine and cosine functions, and electrical integration of the result. The method is only applicable to class (a) waveforms, but for these gives surprisingly accurate results; frequency, amplitude, and phase are determined.

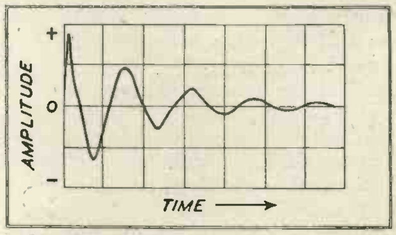

Fig. 4. Waveform of Class (d) wave.

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Pender and McIlwain: *Electrical Engineers Handbook*, Vol. II.

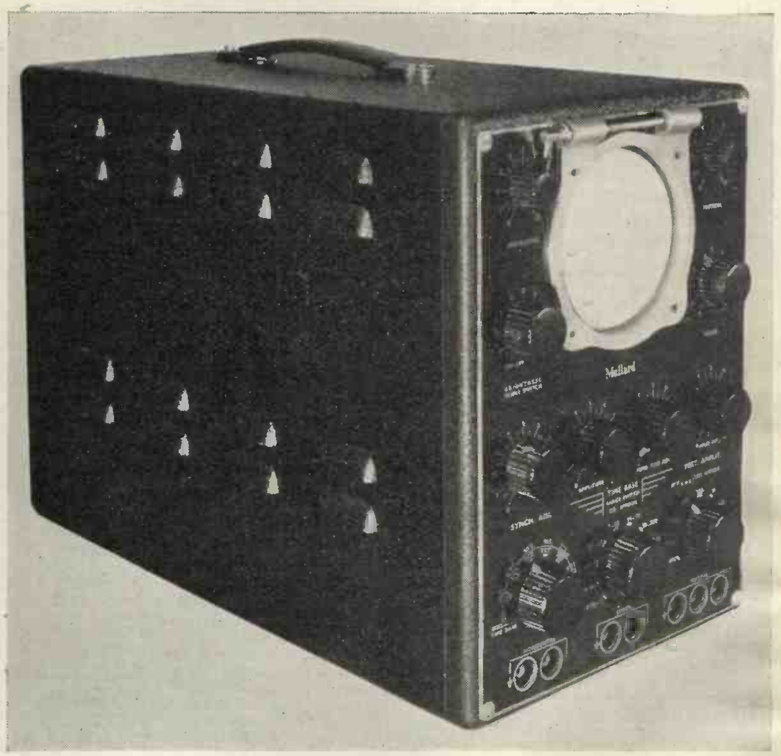
Hall: *Journal of Acous. Soc. of America*, 8. 4, April 1937.

Barnard: *Electrical Communication*, 16. 2, October, 1937.

The
Mullard Oscillograph
Type GM.3156

THE Mullard Oscillograph, of which a photograph appears on this page, is a portable laboratory instrument possessing several features which will appeal to the electro-physiologist and workers on vibration studies. The chief among these are a linear time base capable of very low speeds of traverse, with provision for single-stroke sweeps, and a high gain amplifier with level response from 0.1 to 10,000 c/s.

Thus it is particularly suitable for recording slow speed transient impulses such as cardiograms or nerve action potentials in addition to the waveforms met in the audio-frequency range.



The following is the specification:

Mains input, 100-150 V. and 200-250 V. 50 c/s.
Power consumption, 60 watts approx.
Final anode potential, 1,000 V.
Vertical deflexion sensitivity approx., 10 V.$_{rms}$/cm.
Vertical deflexion sensitivity approx., 30 V.$_{dc}$/cm.
Horizontal deflexion sensitivity approx., 12 V.$_{rms}$/cm.
Horizontal deflexion sensitivity approx., 36 V.$_{dc}$/cm.
Amplifier response (2 db loss), 0.1-10,000 c/s.
Amplifier sensitivity (max. gain), 1 mV.$_{rms}$/cm.
Max. input volts to attenuator, 250 V. peak.
Input resistance using attenuator:
  10,000 mV/cm.-10 mV/cm., 2 megohms approx.
  3 mV/cm., 1.2 megohm.
  1 mV/cm., 00.4 megohm.
High impedance input, 2 μF and 2.2 megohms.
Time base frequency range, 0.25-2,000 c/s.
Valves (*Mullard Types*).
Amplifier—4 H.F. Pentodes EF36.
Time Base—1 H.F. Pentode EF36 and 1 Gas-filled Triode EC50.
Power Supplies—1 Half-wave Rectifier HVR2, 1 Full-wave Rectifier AZ31, 2 Neon Voltage Stabilisers 4687.
Cathode Ray Tube—1 4 in. Tube A41-G4 or 1 "Intensifier" Tube.

Vertical Amplifier

The vertical deflexion amplifier consists of a two-stage push-pull amplifier using pentode valves with resistance capacity coupling. A voltage amplification of approximately 10,000 is provided with a frequency response flat within 2 db from 0.1 c/s to 10,000 c/s. The supply to the screening grids of the first pair of valves is stabilised by the two neon stabilisers V10 and V11 (*See* diagram).

The sensitivity of the amplifier may be adjusted in steps of 3 : 1 by means of the *Attenuator Switch A*3, while continuously variable control at each setting of A3 is given by the *Amplitude Control R*6 with which is coupled the Switch A5. The figures against each position of the attenuator switch indicate approximately the sensitivity in millivolts per cm. trace height when the fine control R6 is fully clockwise.

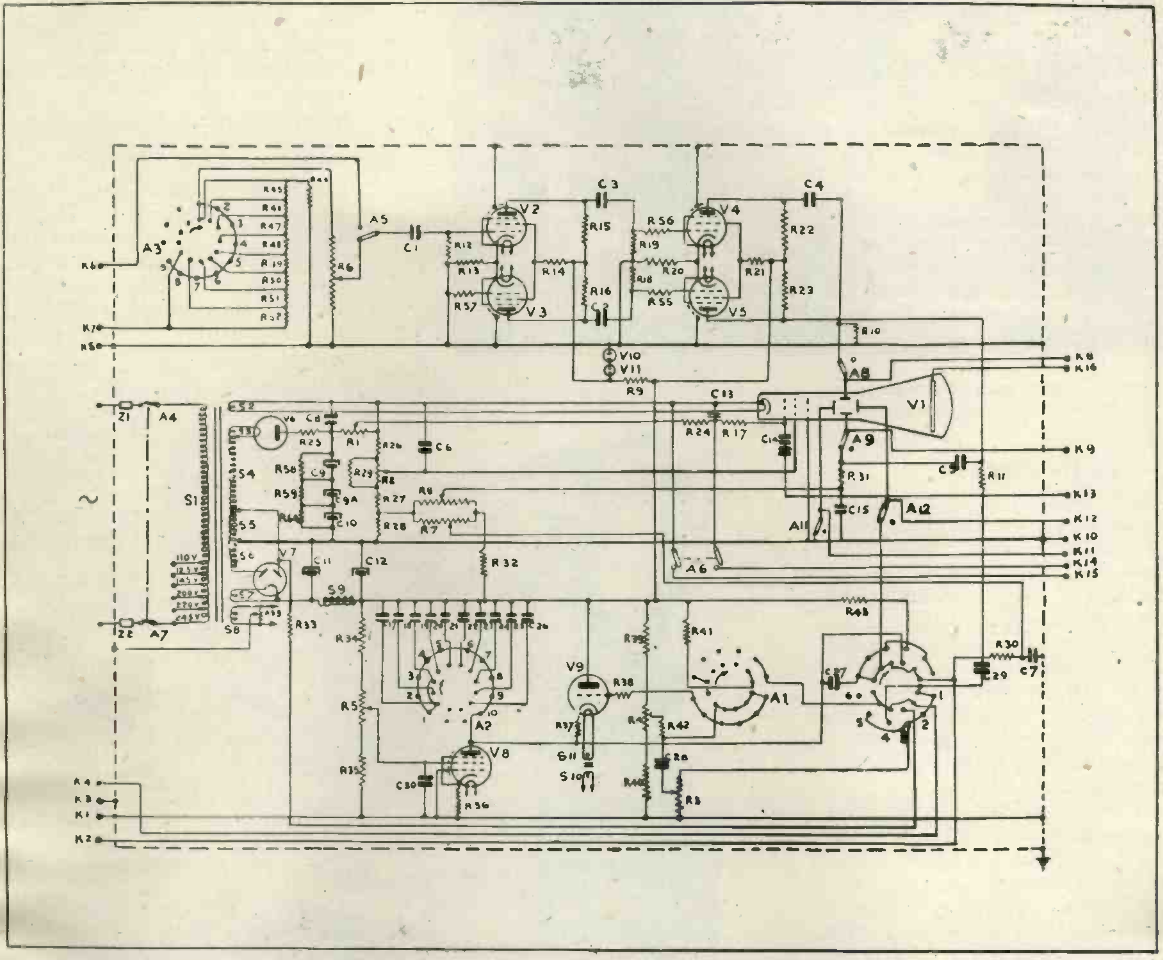
Should the first valve become overloaded by the application of too high an input voltage, the image will be displaced vertically and will not return for a number of seconds. It should also be noted that when observing an alternating voltage superimposed on a steady potential, any adjustment of attenuator or fine gain controls will produce a temporary vertical shift of the image.

Time Base Circuits

The Time Base Control Switch A1, provides a number of ways of controlling the operation of the time base, as under:—

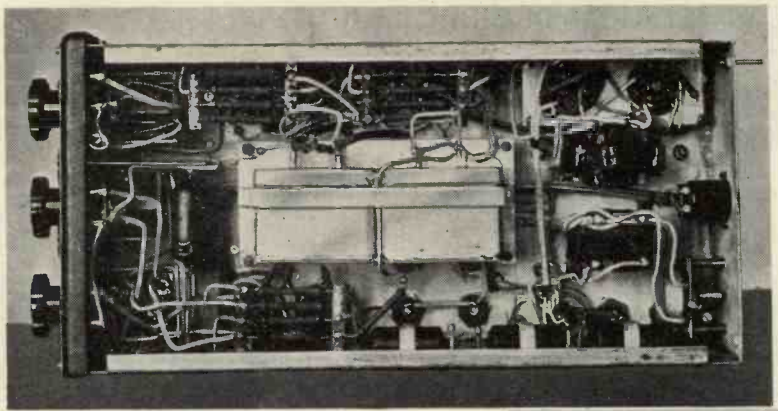
Position	*Time Base*	*Synchronising*
1	Internal	Derived from vertical deflexion amplifier.
2	Internal	Derived from an external source.
3	Internal	Derived from 50 c/s mains.
4	External	A synchronising signal of 25 volts derived from the vertical deflexion amplifier can be taken out from sockets on the front panel. The load impedance must not be less than 0.5 megohm.
5	Internal	By means of a mechanical contact breaker (V9 fires at "break.")
6	Single stroke	(*See* next paragraph). (p. 154).

CIRCUIT OF MULLARD OSCILLOGRAPH



COMPONENT VALUES

R1		50,000	ohms	R30	1 W.	2.2	megohms	R60	1 W.	1	megohm
R2		0.5	megohm	R31	1 W.	2.2	megohms				
R3		0.5	megohm	R32	1 W.	0.22	megohm	C1		2	μF
R4		0.2	megohm	R33	1 W.	4.7	megohms	C2		2	μF
R5		0.2	megohm	R34	1 W.	0.1	megohm	C3		2	μF
R6		0.5	megohm	R35	0.5 W.	10,000	ohms	C4		2	μF
R7		0.5	megohm	R36	0.5 W.	820	ohms	C5		2	μF
R8		0.5	megohm	R37	1 W.	1,000	ohms	C6		0.47	μF
R9	5 W.	10,000	ohms	R38	0.5 W.	0.22	megohm	C7		0.47	μF
R10	1 W.	2.2	megohms	R39	1 W.	0.1	megohm	C8		0.47	μF
R11	1 W.	0.22	megohm	R40	1 W.	10,000	ohms	C9		16	μF
R12	1 W.	2.2	megohms	R41	1 W.	0.33	megohm	C9A		16	μF
R13	0.5 W.	330	ohms	R42	0.5 W.	0.22	megohm	C10		16	μF
R14	1 W.	0.1	megohm	R43	1 W.	4,700	ohms	C11		32	μF
R15	1 W.	47,000	ohms	R44	0.5 W.	200	ohms	C12		64	μF
R16	1 W.	47,000	ohms	R45	0.5 W.	400	ohms	C13		0.47	μF
R17	0.5 W.	10,000	ohms	R46	0.5 W.	1,400	ohms	C14		23,500	μμF
R18	0.5 W.	2.2	megohms	R47	0.5 W.	4,000	ohms	C15		0.47	μF
R19	0.5 W.	2.2	megohms	R48	0.5 W.	15,000	ohms	C17		4	μF
R20	0.5 W.	270	ohms	R49	0.5 W.	47,000	ohms	C18		2	μF
R21	1 W.	0.15	megohm	R50	0.5 W.	0.27	megohm	C19		1.4	μF
R22	1 W.	47,000	ohms	R51	0.5 W.	0.86	megohm	C20		0.47	μF
R23	1 W.	47,000	ohms	R52	0.5 W.	0.86	megohm	C21		0.22	μF
R24	1 W.	0.47	megohm	R53		2,000	ohms	C22		0.1	μF
R25	1 W.	15,000	ohms	R55	0.25 W.	47	ohms	C23		47,000	μμF
R26	1 W.	82,000	ohms	R56	0.25 W.	47	ohms	C24		18,000	μμF
R27	1 W.	0.22	megohm	R57	0.5 W.	47	ohms	C25		8,200	μμF
R28	1 W.	0.15	megohm	R58	1 W.	1	megohm	C26		5,600	μμF
R29	1 W.	0.47	megohm	R59	1 W.	1	megohm	C27		4	μF



View of underneath of chassis showing sub-assembly of components.

Single Stroke Time Base

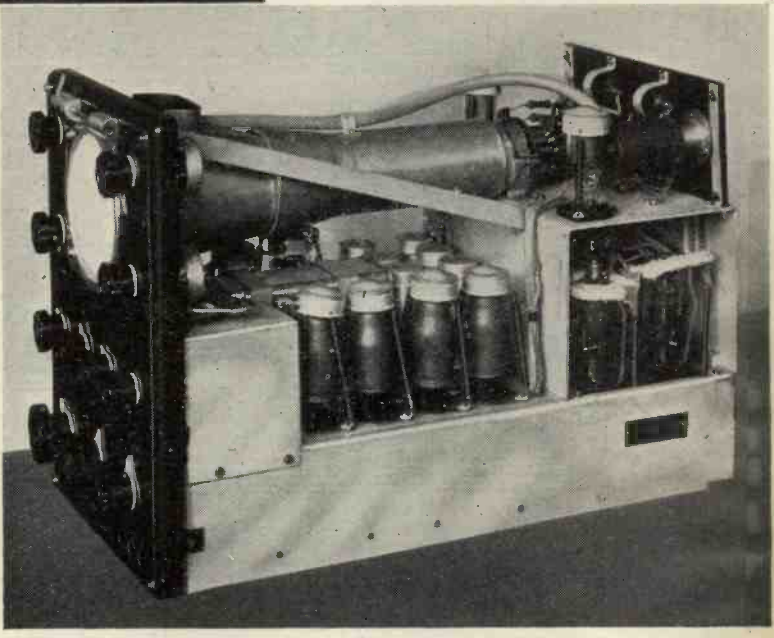
For observation of non-recurrent phenomena or for photographic recording, the time base can be controlled so that it starts from the left of the screen at a given time, makes one complete traverse and then comes to rest off the screen. This is effected by setting the control switch A1 to position 6. When this is done, the spot slowly moves to the middle of the screen, and it is first necessary to move it to the left of the screen by means of the horizontal shift control.

The effect of setting A1 to position 6 is to return the grid of V9 to the main H.T. line via R41, thus maintaining the condenser C17-C26 in a discharged condition. The junction of R41 and R38 is also connected to the synchronising socket K4.

Upon short-circuiting sockets K4 and K3 the grid of V9 is connected to earth and the valve ceases to conduct. The condenser C17-C26 then charges up in the normal manner through V8 and continues to do so until socket K4 is freed again, when it is discharged through V9 and the spot flies back to the left. It is thus necessary to short-circuit K4 and K3 for the duration of the phenomenon under observation.

Grid Modulation and Beam Suppression

In order to obtain a time scale when photographing a non-recurrent phenomenon in conjuction with the single stroke time base, it is convenient to modulate the grid of the cathode-ray tube at a frequency n cycles per second, so that the trace appears as a dotted line, the time interval between successive dots being $1/n$ seconds. To do this, the modulating frequency, which should have an amplitude not less than 5 V. rms. is applied between sockets K13 and K10 (earth), after which the brightness control R1 is adjusted to give the best results.



Oscillograph with cover removed. The transformers are in the screened compartment at the back. Valves are held in position by spring tensioned caps. The lay-out is clean and all components easily accessible.

If it is required at times to work with the camera shutter open, in order to prevent the horizontal time base from fogging the film, it is necessary to suppress the beam except while the phenomenon to be recorded is actually occurring. When the switch A6 is in the right hand position, sockets K14 and K15 are connected respectively to grid and cathode of the cathode-ray tube. To suppress the beam, a 45 volt battery is connected with its negative pole to K14 and its positive pole to K15. Breaking this external circuit will restore the beam to the intensity previously set by adjustment of R1.

Intensifier Tube

Provision is made in the GM. 3,156 oscillograph for the use of a special intensifier cathode-ray tube. This type of tube possesses an extra accelerating electrode between deflector plates and screen and gives a picture of sufficient brilliance for projection purposes. The extra electrode is brought out to a contact at the top of the tube and the accelerating potential (1,000-5,000 V.) is applied via a socket at the back of the instrument.

Valves

The valves used in the GM. 3,156 have an extremely long life and it is unlikely that any trouble will be experienced. It sometimes happens that heavy vibration may cause a slight vertical deflexion of the trace. If this should occur the first amplifier valve V2 is the most probable source of the trouble, and it should be interchanged with one of the other valves of the same type.

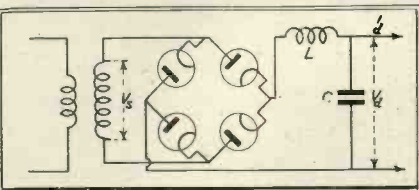
Non-linearity of the time base, if not due to too much synchronising will most probably be due to deterioration of V8, while lack of amplitude of the time base indicates a faulty EC50 (V9).

The potentiometer R53 is located at the bottom right-hand corner of the chassis and is used to balance out the last traces of hum from the heater supply. It is preset at the factory and is unlikely to require adjustment, but if after replacement of a valve, hum is noticeable with the gain control R6 at minimum (not in the " off " position) R53 should be adjusted with a screw driver to the position giving minimum hum.

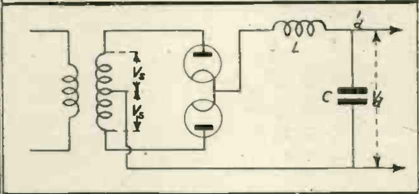
DATA SHEETS XXXIV-XXXVI.

Rectifier Circuits with Choke Input Filters.

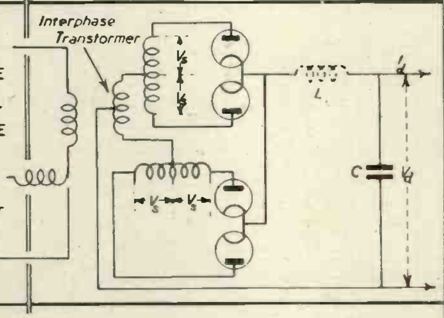
① SINGLE PHASE FULL WAVE BRIDGE (*Three Heater Windings*)



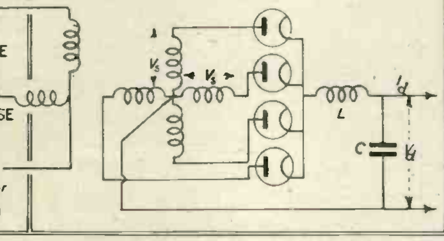
② SINGLE-PHASE FULL-WAVE or BI-PHASE (*One Heater Winding*)



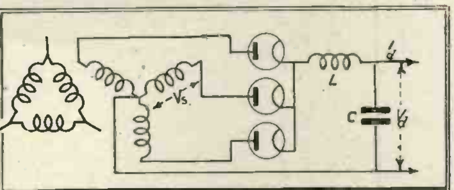
③ TWO PHASE PARALLEL FULL WAVE (*One Heater Winding*)



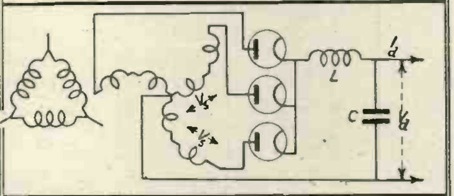
④ TWO-PHASE FULL-WAVE or 1/4-PHASE (*One Heater Winding*)



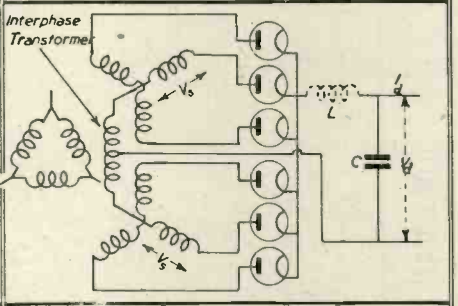
⑤ THREE-PHASE HALF-WAVE Y (*One Heater Winding*)



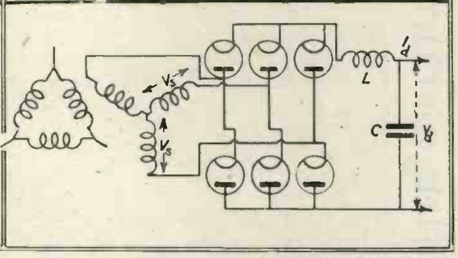
⑥ THREE-PHASE HALF-WAVE INTERPHASE Y (*One Heater Winding*)



⑦ THREE PHASE PARALLEL HALF WAVE or DOUBLE Y (*One Heater Winding*)



⑧ THREE PHASE FULL WAVE BRIDGE (*Four Heater Windings*)



THE properties of rectifier circuits have been tabulated in one form or another on a number of occasions. Before any real benefit can be derived from such information it is however essential to appreciate the limitations implied, if not always stated, that make such tabulation possible.

Rectifier circuits can be divided into two general types:—

1. Condenser Input Filter, where the rectifiers are connected directly to the reservoir condenser.
2. Choke Input Filter where a high inductance choke is interposed between the rectifiers and the reservoir condenser in order to maintain as constant a charging current as possible.

The first type which is used extensively in low power applications such of broadcast receiver H.T. supplies, cannot unfortunately be represented in a general table owing to its very complex relations. Some of its properties will, however, be dealt with later in the series.

The properties of the second type can, however, be calculated accurately under certain limiting assumptions, which are that (a) the transformer losses and reactances, (b) rectifier volt-drop and (c) choke volt-drop are all neglected and that (d) the choke has a sufficiently high inductance in order to maintain the output current constant. $(L \rightarrow \infty)$.

The effect of (c) can usually be estimated, and while the assumption (b) is not generally justifiable in the case of high vacuum rectifiers, it is admissible for reasonably high voltage supplies employing mercury vapour rectifiers.

The provision of a choke with a sufficiently high inductance to approximate clause (d) is feasible in practice in the case of multi-phase systems having a high fundamental ripple frequency of small amplitude. While two circuits (1) and (2) widely used with single phase supplies have been included in the table for comparative purposes, the provision of a choke delivering a constant charging current with mains frequencies of the order of 50 c./s. will in these instances be normally impracticable.

The case of the half wave single phase rectifier is not included as owing to D.C. component core saturation and completely impracticable choke required it is only used in low current condenser input systems.

The following notes will assist the use of the Data Sheet No. 34.

Utilisation Factor of the primary or secondary is the ratio of the D.C. volt-amps delivered to the load to the R.M.S. volt-amps taken by the windings, in the case of the primary it is also the power-factor of the system. The mean utilisation factor gives an indication of relative transformer size.

In the case of both circuits (2) and (8) two rectifiers are operating in series. Circuit (6) eliminates the D.C. core saturation of circuit (5). Though each winding has a voltage of 0.494 V_d due to the phase difference, the voltage of the two windings in series is still 0.855 V_d.

RECTIFIER CIRCUIT DATA

	CIRCUIT (Reference Numbers correspond with those on previous page.)	Single Phase Full Wave Bridge.	Single Phase Full Wave or Biphase.	Two Phase Parallel Full Wave.	Two Phase Full Wave or Quarter-phase	Three Phase Half Wave.	Three Phase Half Wave Inter-phase Y.	Three Phase Parallel Half-Wave or Double Y.	Three Phase Full Wave Bridge.
RECTIFIER DATA.	REFERENCE No.	1	2	3	4	5	6	7	8
	No. of Rectifiers	4	2	4	4	3	3	6	6
	Current per Rectifier : Mean ...	0.5 I_d	0.5 I_d	0.25 I_d	0.25 I_d	0.333 I_d	0.333 I_d	0.167 I_d	0.333 I_d
	Current per Rectifier : Peak ...	I_d	I_d	0.5 I_d	I_d	I_d	I_d	0.5 I_d	I_d
	Current per Rectifier : R.M.S ...	0.707 I_d	0.707 I_d	0.354 I_d	0.5 I_d	0.577 I_d	0.577 I_d	0.289 I_d	0.577 I_d
	Peak Inverse Voltage per Rectifier	1.57 V_d 1.41 V_s	3.14 V_d 2.83 V_s	3.14 V_d 2.83 V_s	2.22 V_d 2.83 V_s	2.09 V_d 2.45 V_s	2.09 V_d 2.45 V_s	2.42 V_d 2.83 V_s	1.05 V_d 2.45 V_s
SMOOTHING DATA.	Frequency and Peak Amplitude of Ripple for :								
	Fundamental	2 f .667 V_d	2 f .667 V_d	4 f .133 V_d	4 f .133 V_d	3 f .25 V_d	3 f .25 V_d	6 f .057 V_d	6 f .057 V_d
	2nd Harmonic	4 f .133 V_d	4 f .133 V_d	8 f .032 V_d	8 f .032 V_d	6 f .057 V_d	6 f .057 V_d	12 f .014 V_d	12 f .014 V_d
	3rd Harmonic	6 f .057 V_d	6 f .057 V_d	12 f .014 V_d	12 f .014 V_d	9 f .025 V_d	9 f .025 V_d	18 f .006 V_d	18 f .006 V_d
TRANSFORMER DATA.	R.M.S. Secondary Volts per leg. (V_s) ...	1.11 V_d	1.11 V_d	1.11 V_d	0.785 V_d	0.855 V_d	2 (0.494) V_d	0.855 V_d	0.427 V_d
	R.M.S. Secondary Current per leg ...	I_d	0.707 I_d	0.354 I_d	0. 5 I_d	0.577 I_d	0.577 I_d	0.289 I_d	0.816 I_d
	Secondary Volt-Amps (total)	1.11 $V_d I_d$	1.57 $V_d I_d$	1.57 $V_d I_d$	1.57 $V_d I_d$	1.48 $V_d I_d$	1.71 $V_d I_d$	1.48 $V_d I_d$	1.05 $V_d I_d$
	R.M.S. Primary Volts per leg	1.11 V_d/n	1.11 V_d/n	1.11 V_d/n	0.785 V_d/n	0.855 V_d/n	0.855 V_d/n	0.855 V_d/n	0.428 V_d/n
	R.M.S. Primary Current per leg ...	nI_d	nI_d	0.5 nI_d	0.707 nI_d	0.471 nI_d	0.471 nI_d	0.408 nI_d	0.816 nI_d
	Primary Volt-Amps. (total)	1.11 $V_d I_d$	1.11 $V_d I_d$	1.11 $V_d I_d$	1.11 $V_d I_d$	1.21 $V_d I_d$	1.21 $V_d I_d$	1.05 $V_d I_d$	1.05 $V_d I_d$
	Mean Rating (V.A.)	1.11 $V_d I_d$	1.34 $V_d I_d$	1.34 $V_d I_d$	1.34 $V_d I_d$	1.35 $V_d I_d$	1.46 $V_d I_d$	1.27 $V_d I_d$†	1.05 $V_d I_d$
	Utilisation Factor : Primary	0.9	0.9	0.9	0.9	0.827	0.827	0.955	0.955
	Utilisation Factor : Secondary ...	0.9	0.637	0.637	0.637	0.675	0.585	0.675	0.955
	Utilisation Factor : Mean	0.9	0.746	0.746	0.746	0.744	0.685	0.79†	0.955
	Line Current (r.m.s.)	nI_d	nI_d	0.707 nI_d	nI_d	0.816 nI_d	0.816 nI_d	0.707 nI_d	1.41 nI_d

Notes.

n = **No. of phases.**
f = **Mains Supply frequency. (c/s).**
I_d = **D.C. Load Current.**
V_d = **D.C. Load Volts.**
V_s = **Secondary Volts (r.m.s.) per leg.**

INTER-PHASE TRANSFORMER DATA.

Frequency	3 f
Equivalent 3f volts r.m.s. per winding (approx).	0.177 V_d
Peak volts per winding	0.303 V_d
Volt Amps (total) at Frequency 3f (approx.)	0.177 $V_d I_d$
Equivalent Rating Volt Amps. at frequency f (approx.)	0.06 $V_d I_d$

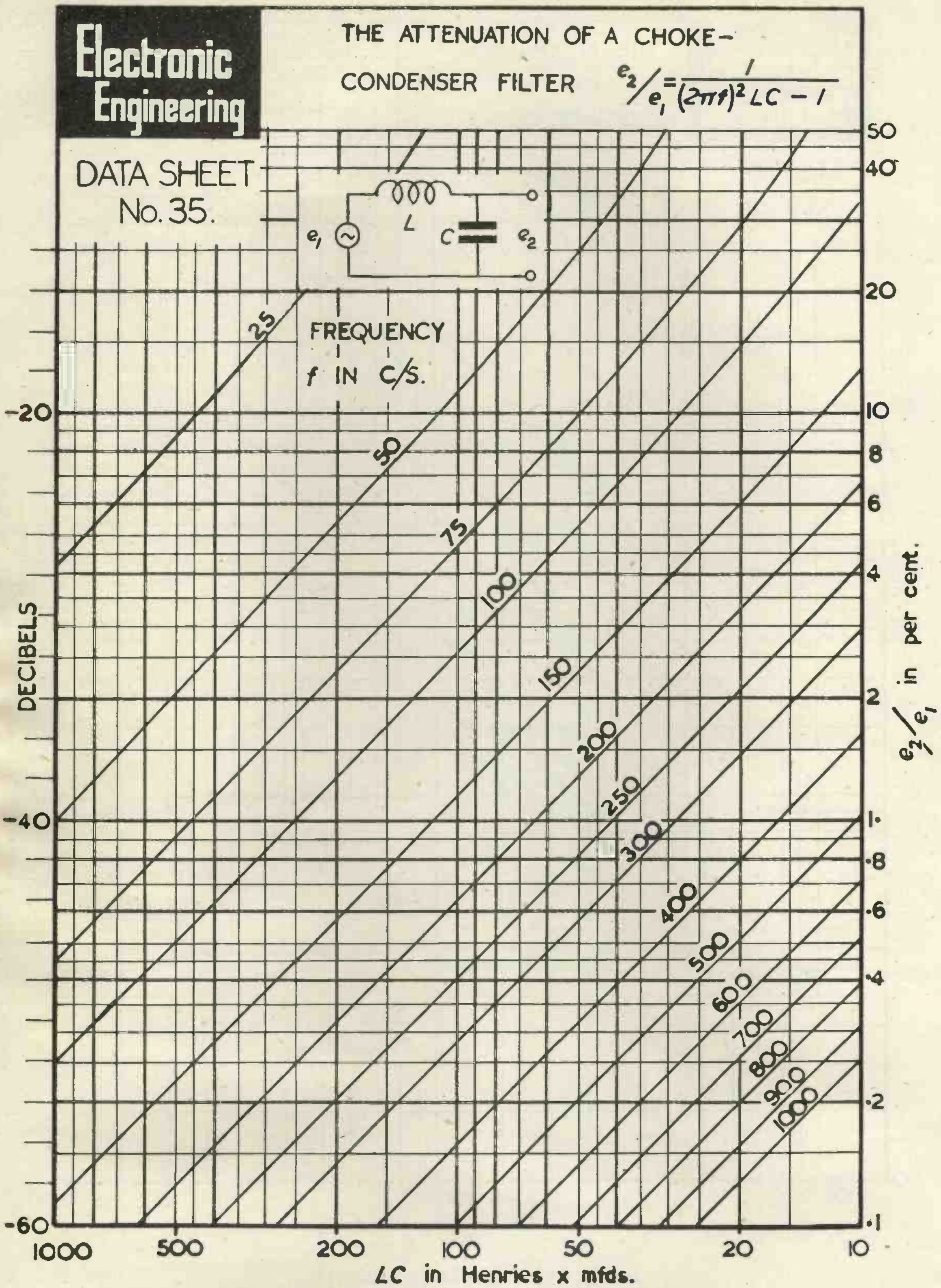
† Excluding power taken by interphase transformer. With this loss included the Mean Rating and Mean Utilisation Factor become 1.33 $V_d I_d$ and 0.753 respectively.

Electronic Engineering

DATA SHEET No. 35.

THE ATTENUATION OF A CHOKE-CONDENSER FILTER

$$e_2/e_1 = \frac{1}{(2\pi f)^2 LC - 1}$$



Example in the use of Data Sheet 35.

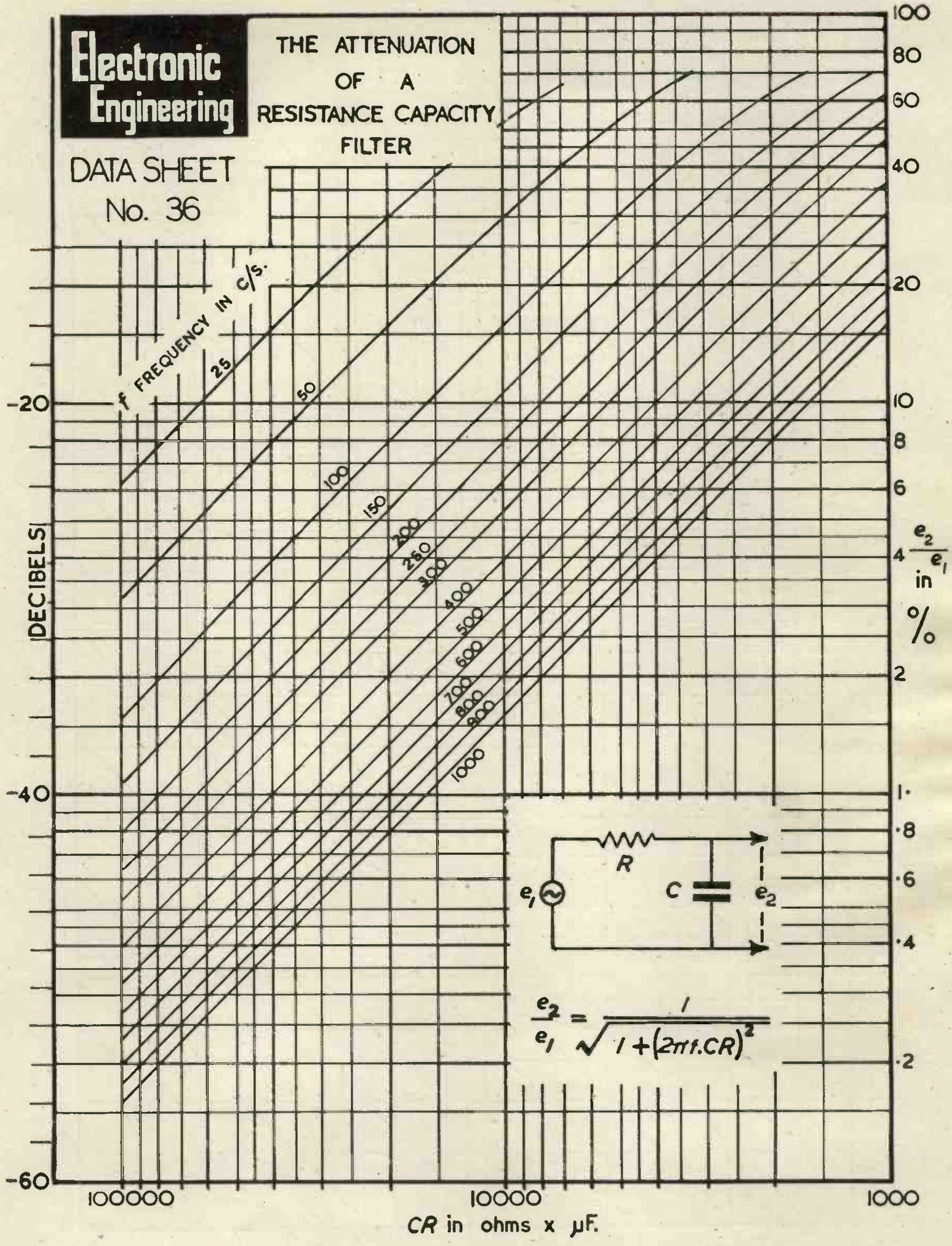
The LC product to give an attenuation of –40 db. (1% of the original amplitude) at 100 c/s is 250 H x μF., e.g. 8 μF. and 40 henries approximately.

To extend the frequency scale to any desired degree, multiply the curve markings by " m " and divide the LC scale by " m^2." The vertical scale values are unaltered. Thus the LC product to give the same attenuation at 1,000 c/s is 2.5 H x μF.

Electronic Engineering

DATA SHEET No. 36

THE ATTENUATION OF A RESISTANCE CAPACITY FILTER

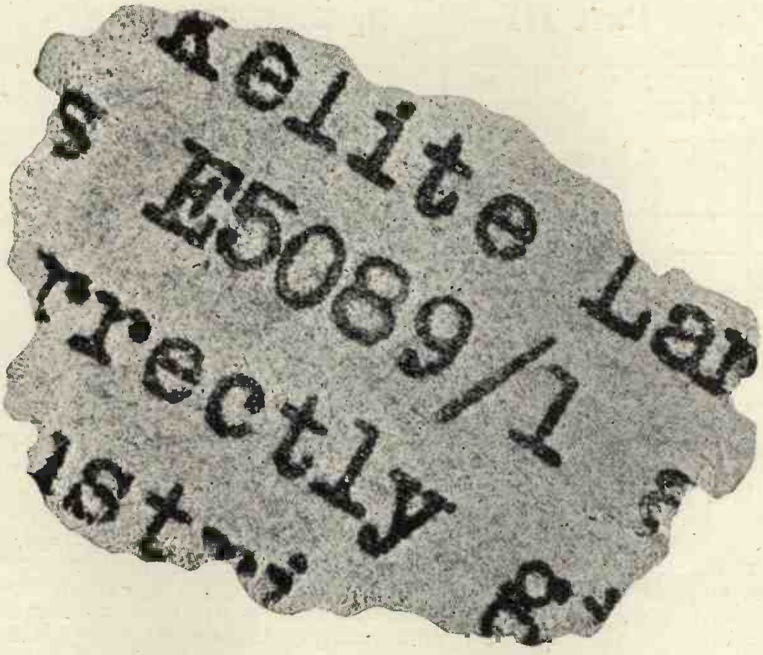


$$\frac{e_2}{e_1} = \frac{1}{\sqrt{1+(2\pi f.CR)^2}}$$

Example in the use of Data Sheet 36.

The values of CR to give an attenuation of -40 db. (1% of the original amplitude) at 400 c/s is 40,000 ohms x μF.

To extend the frequency scale to any desired degree, multiply the curve markings by " m " and divide the CR scale by " m " The vertical scale values are unaltered.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Practical Notes on Receiver Design

Part III— By G. T. CLACK

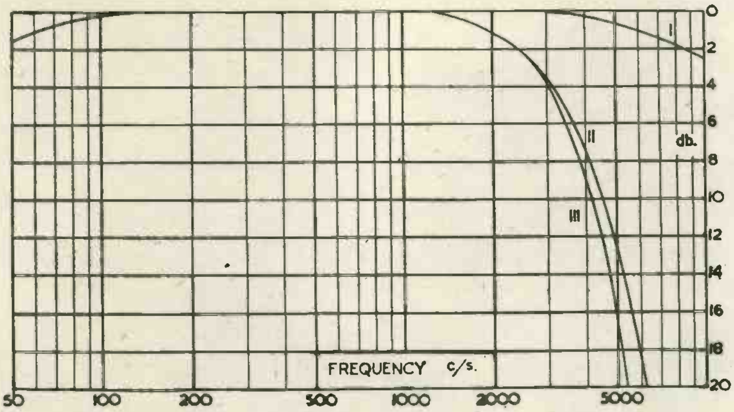

Fig. 25. Curves of loss in various stages: (I) at diode anode (II) at f.c. grid (III) overall response.

R.F. Response

THE combination of the R.F. and I.F. circuits discussed previously produced, at 1,000 kc/s., a measured overall attenuation of 16.5 db. at 5,000 c/s. at the diode load. The aerial circuit accounted for 3.5 db., the I.F.s for 12 db., and the diode circuit a further 1 db.

A measured drop of 1 db. below 100 c/s. was found to be due to the diode load constants and is of small importance compared with the average audio-amplifier response at frequencies below 100 c/s. In Fig. 25, the curves indicate the db. loss occurring in each of the various stages, where Curve I is for an A.F. measurement at the diode anode, II is for a modulated I.F. measurement at the grid of the frequency changer, and III the overall response with the aerial circuit tuned to 1,000 kc/s.

The drop in response at 5,000 c/s. may seem severe, but is necessary for distant reception. For local station reception, the bandwidth can be increased as the field strength ratio to that of a comparatively weak adjacent channel signal is extremely high and the subsequent decrease in receiver sensitivity due to A.V.C. and use of the manual A.F. control reduces the likelihood of any interference. As mentioned earlier, expensive receivers normally incorporate some form of variable bandwidth control to suit local signal conditions, but with the smaller type of receiver such an adjustment is not included. If improved response is desired without excessive modification of the circuit, the simplest method is to employ some form of switching to either shunt resistances across the tuned circuits or to overcouple one or more circuits. (Fig. 26).

An improvement of 8-10 db. at 5,000 c/s. can be obtained by overcoupling (a) the first I.F. transformer with a decrease in overall receiver sensitivity of not more than 3/1. If the shunt resistance method (b) is more convenient, the values can be from 50-100,000 ohms for the aerial circuit, and 0.05 to 0.25 megohms for the I.F. transformers. A compromise between bandwidth and sensitivity must be considered in some cases as the advantage of improved response may be marred by a large reduction in sensitivity and possibly a decreased signal to noise ratio.

Diode Detectors

Nowadays the I.F. input applied to the 2nd detector of a superheterodyne is comparatively high and as a result the diode has practically superseded almost every form of detector in view of its ability to handle higher inputs, high modulation levels with less distortion, and its ready adaptation to A.V.C. circuits.

The basic circuit is shown in Fig. 27 where *C.R.* represents the diode load and the I.F. transformer as the supply source. The applied voltage (A) swings the diode anode alternatively positive and negative, and with *R* only in circuit the diode conducts on the positive half cycles, producing a unidirectional pulsating current flow (B) around the external circuit. With the addition of *C* across *R*, the conduction takes place only on the extreme positive peaks (C) of the input voltage. The reason for this is that the external anode current flow from A to K during conduction produces a charge in *C* which builds up during the time the positive half cycle of the supply is rising to its peak value. When this peak is passed and the falling supply voltage becomes equal to that across *C*, the voltage across A and K becomes zero, conduction ceases and the condenser commences to discharge through *R*. The time constant *C.R.* determines how much the potential across *C* falls before it is recharged by the next anode current pulse, which occurs as soon as the input voltage commences to exceed the negative potential across *C.R.*

The existence of a negative potential at the anode due to the accumulated charge in the condenser can be illustrated as in Fig. 28 where (A) is the applied I.F. voltage, (B) is the charging current that flows during conduction on the positive peaks, and (C) is for a steady condition reached when the discharge through *R* is replaced by the succeeding anode current pulses. If only *C* were in circuit, it would charge up to a negative value, at A, equal to the peak value of the input voltage and further conduction would cease, but with *R* in shunt, the anode current charges the

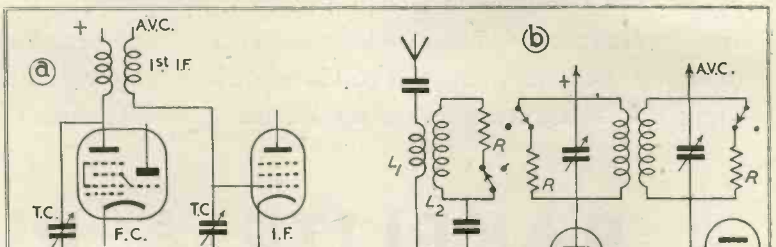

Fig. 26. Improvement in band width by (a) overcoupling the first I.F. transformers or (b) by shunting the tuned circuit.

condenser to a potential just below that of the peak input. The diode then conducts only during the period when the input voltage exceeds the condenser charge, thus making the anode positive with respect to K.

A diode under no signal conditions will have a negative potential at the anode under working conditions by virtue of a small number of high velocity electrons that pass through the space charge around the cathode and reach the anode despite the absence of a positive potential. The E_aI_a characteristic of a diode is depicted in Fig. 32, where the space current through R will set up a potential of -0.55 volts at the diode anode at zero input voltage.

The curvature at the bottom end will introduce distortion at low R.F. inputs and/or high modulation levels.

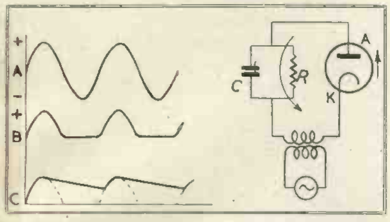

Fig. 27. Basic diode circuit and its action.

In Fig. 29 the lack of proportionality between input and output voltage as a result of the curved characteristic towards zero input is shown for inputs of 1.0 and 2.0 volts peak I.F. input at 465 kc/s, with estimated modulation depths of 50 per cent. and 80 per cent. respectively.

The conclusion drawn from this is that with low signal voltages distortion occurs when the modulation cycle swings over the non-linear part of the I_a curve, whereas with higher inputs it becomes less in proportion to the total length of the modulation swing thus permitting deeper modulation with reduced distortion. Distortion due to non-linearity of the I_aE_a characteristic decreases when R is made high in comparison with the diode anode resistance (Fig. 30) and by keeping the I.F. input above 2 volts peak; the usual recommended input being in the order of about 10 volts. Furthermore, detection efficiency increases with R (or C) as with low values the charge in C falls rapidly during the non-conducting period, causing the diode to conduct for a much longer time which in turn increases the damping across the preceeding circuit. The aim is then to keep R as large as possible, consistent with good modulation response, so that the conduction time is kept to a minimum.

In the previous section dealing with the damping of the I.F. transformer by the signal diode, it was given approximately as 0.1 megohm. This would be the case for low inputs when the curvature of the diode characteristic produces a lower value of detection efficiency. As input resistance is given as $R/2\eta$ where $R = R_{10} + R_{11}$ (Fig. 31) and η = detection efficiency, it is clear that a reduction in input resistance occurs when the signal varies about 0-1.0 volt. For higher inputs the efficiency increases and under normal operating conditions, with an input to the diode circuit greater than 2 volts peak, the input resistance can be considered as one-half of the load resistance, $R_{10} + R_{11}$.

A.C. Loading

The distortion due to non-linearity will be found to be small in practice as with most receivers both R and E_a input are kept high. The most likely source of distortion originates in the diode loading as with the addition of C_{11} R_{12} in shunt with R_{11} the A.C. impedance of the circuit is decreased with the result that at high modulation levels the diode ceases to conduct.

This is due to the superposed modulation current reaching a value equal in magnitude to the D.C. anode current produced by the carrier, and is illustrated by the point at which the A.C. load line intersects the current axis in Fig. 32. For such conditions the maximum degree of modulation that can be rectified without distortion is given as

$$\%M = \frac{R_{ac}}{R_{dc}}$$

where R_{ac} is the circuit impedance to the modulation frequencies and R_{dc} is the D.C. resistance offered to the rectified current.

It will be seen from Fig. 28 that the rectified voltage across R contains a fair amount of I.F. ripple which must be filtered out before the signal reaches the A.F. stages in order to avoid premature overloading of the 1st A.F. stage and possibly feedback. This is readily achieved by decoupling the diode load as indicated in Fig. 31. The total D.C. load is then $R_{10} + R_{11}$, the A.F. output being reduced by the factor $R_{11}(R_{10} + R_{11})$ as a result of the voltage drop across R_{10}. An increase in the A.C. impedance of the circuit also takes place as the shunt circuit R_{11} C_{11} is across a smaller proportion of the D.C. load.

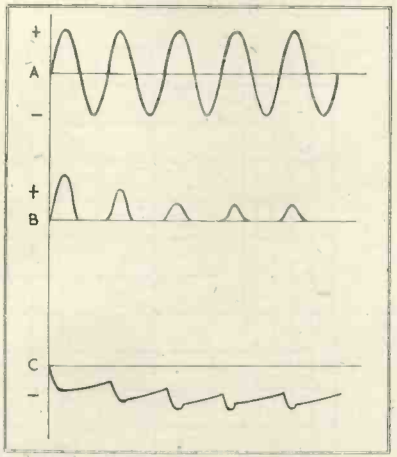

Fig. 28. Showing how the accumulated charge on C produces a negative potential at A.

The curves in Fig. 32 are for a typical diode and give the rectified carrier volts at the anode for various inputs. The procedure to follow when estimating the maximum degree of modulation that a circuit such as in Fig. 31 can handle without serious distortion, is to draw a load line which is represented by POQ (in this case $R_{10} + R_{11} = 0.75$ megohms). If the operating point is 7 volts peak, the diode current is 8.5 microamps, and the D.C. voltage at the anode is 6.4 volts. As the input voltage will swing above and below 7.0 volts when modulated, it will be seen that for a 100 per cent. modulated carrier the D.C. anode voltage will move from O to P to Q and back to O during every modulation cycle. Across R_{10} R_{11} will exist a voltage which is a copy of the input modulation with negligible distortion provided that the capacitance in the diode circuit introduces no parallel reactance path, i.e., the impedance offered to either the modulation component or the D.C. current being equal. With $C_{11}R_{12}$ connected across R_{11} omitting the effect of C_9, C_{10} the A.C. load line is shown by MON which has a slope corresponding to the effective A.C. impedance.

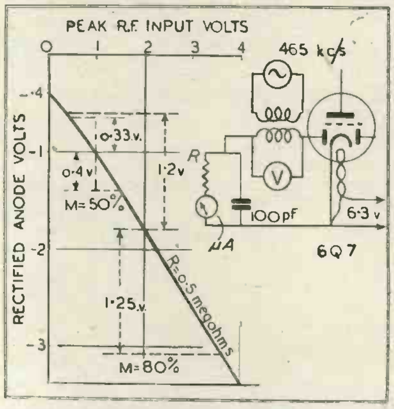

Fig. 29. Effect of curved diode characteristic on low signal voltages.

$$R_{10} + \left(\frac{R_{11}\,R_{12}}{R_{11} + R_{12}}\right) = 0.5 \text{ megohms.}$$

Using the values as in Fig. 31 the estimated limit of modulation with low distortion is 67 per cent., but under measured conditions at 5,000 c/s. it was found to be in the order of

79 per cent. This may be due to the combined effect of C_9 C_{10} and the discrimination offered by the I.F. circuits to higher modulation frequencies.

If R_{12} is increased to 5 megohms the modulation handling capacity of the diode circuit would increase to 93 per cent., but valve manufacturers set a limit to the amount of resistance that can be connected in the grid circuit of a valve (varying between 1-2 megohms) and as R_{12} is in the grid of the A.F. triode V_3, the recommended limit for the particular valve should not be exceeded. The values normally used in a practical circuit are given in Fig. 31 where R_{10} can be 0.01 to 0.25 meg; R_{11} 0.25 to 0.5 meg; R_{12} 0.5 to 2 meg. The condensers C_9 C_{10} are invariably found to be about 100 pF. and C_{11} from 0.001 to 0.01 μF. The rectification efficiency can be ascertained by taking a series of measurements as shown by the E_aI_a curves in Fig. 32 or by measuring the unmodulated peak input and output D.C. volts under working conditions using suitable measuring instruments.

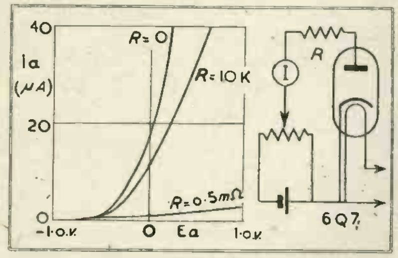

Fig. 30. Showing distortion reduced by increase of *R* in diode circuit.

A.V.C.

On the M.W. band changes in field strength at the receiving aerial vary widely except for very local stations and may rise or fall in value from 10 to 100 times or more, especially during the period before and after sunset. These changes in field strength are normally slow, taking place over minutes or more, and superposed upon this may be found quick deep fades that are not shorter than 3-5 seconds. With high power long-wave transmissions the field strength is invariably consistent night and day; any fading that is present takes the form of very small changes over long periods.

On the S.W. band, however, conditions are extremely variable, the average level of field strength rising or falling over very short periods, in addition to which is experienced very sudden fades sometimes occurring in less than one second. It seems then, for a receiver covering the long, medium and S.W. bands, the time constant of C_{18}, C_{19}, R_5, R_6 (Fig. 31) should be arranged to cope with fading on the S.W. band as with the medium- and long-wave bands the fading is very much slower.

In Fig. 31 is illustrated the circuit of a combined 2nd detector, A.V.C. and 1st A.F. stage as would be used in a conventional 4-valve superheterodyne. Most receivers use separate diodes for A.V.C. and signal rectification in order to obtain the maximum efficiency as the operation of both from a single diode would considerably reduce the A.C. impedance of the signal circuit. For the values illustrated, but assuming the A.V.C. circuit connected to the junction of R_{10}, R_{11}, the highest degree of modulation that could be rectified without distortion is 50 per cent. To improve this it would be necessary to decrease the DC/AC ratio by lowering $R_{10} + R_{11}$ which in turn decreases the input resistance and detector efficiency of the circuit.

Using a separate diode as shown, the load of the A.V.C. circuit across the primary of the 2nd I.F. transformer can be assumed to be equal to R_5, R_6, R_7 in shunt, and decreases to half this value once the signal voltage applied to the anode is sufficient to exceed the delay voltage and conduction occurs. The operation during rectification has already been discussed; one item of importance is the time constant of the A.V.C. circuit. The diode load consists of R_7, which is usually in the order of 1 megohm and the D.C. voltage across the condensers $C_{18}C_{19}$ after the initial charging period is a little less than the peak I.F. voltage applied to the anode. R_5 and R_6 with C_{18} and C_{19} function as decoupling circuits to attenuate I.F. and L.F. components, also to avoid coupling between the grid circuit and V_1 and V_2. The cathode is positive with respect to the earth line by virtue of the anode current through the triode section of the valve which provides a voltage drop across R_{14}. The diode anode is then at the zero potential as far as the earth line is concerned, but 3v. negative with respect to the cathode. No conduction takes place until the peak I.F. voltage across anode and cathode exceeds the delay of −3 volts, which ensures that the maximum receiver sensitivity is available for weak signals.

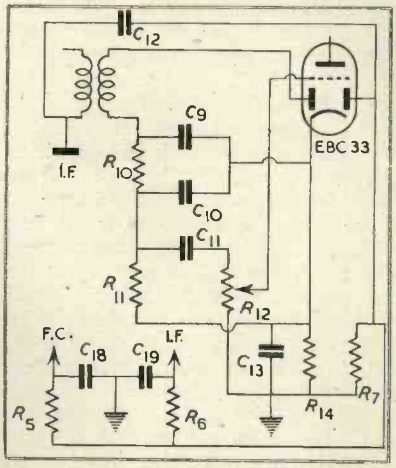

Fig. 31. Filtering I.F. ripple by decoupling diode load.

R_5, R_6 & R_7	1 megohm.	C_9 & C_{10}	100 pF.
R_{10}	0.25 ,,	C_{11}	0.01 μF.
R_{11}	0.5 ,,	C_{18} & C_{19}	0.1 μF.
R_{12}	0.5 ,,		
R_{14}	1,000 ohms.		

The circuit $C_{18}C_{19}R_5R_6$ requires a certain time to charge and discharge and if this takes place within 0.5 seconds the A.V.C. circuit should compensate for average receiving conditions. An approximation for the time constant of such a circuit is given as *C.R.* seconds, where *C* and *R* are in microfarads and megohms.

The charging time will consist of the sum of the time constants for each resistance and condenser, i.e., for the values in Fig. 31 it will be $R_5C_{18} + R_6C_{19} = 0.2$ seconds. R_7 must be included during the discharge period as it is common to both controlled circuits, then the time taken will be

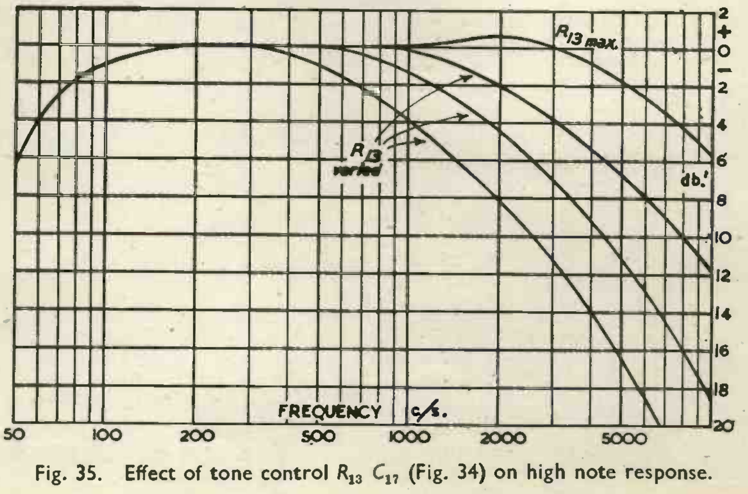

Fig. 35. Effect of tone control R_{13} C_{17} (Fig. 34) on high note response.

Circuit of Receiver discussed in text

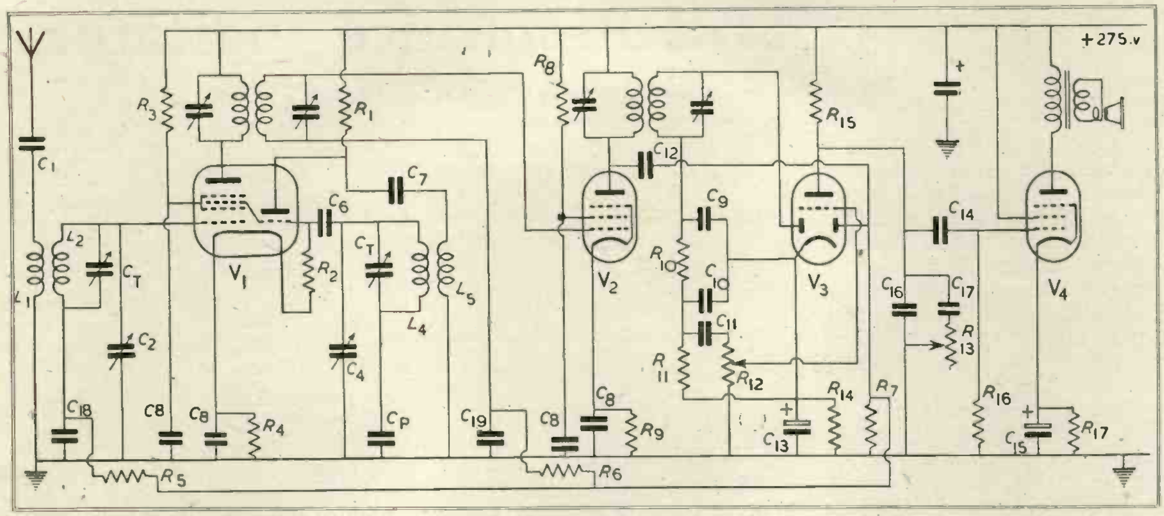

Fig. 34.

R_1	40,000 ohms.	R_6	1.0 megohm.	R_{11}	0.5 megohm	R_{16}	0.5 megohm	C_4	500 pF	C_9	100 pF	C_{14}	0.01 μF
R_2	40,000 ,,	R_7	1.0 ,,	R_{12}	0.5 ,,	R_{17}	200 ohms	C_P	Padder	C_{10}	100 pF	C_{15}	50 ,,
R_3	100,000 ,,	R_8	100,000 ohms.	R_{13}	0.5 ,,	C_1	50 pF	C_6	50 pF	C_{11}	0.01 μF	C_{16}	0.001 ,,
R_4	100 ,,	R_9	300 ,,	R_{14}	1,000 ohms	C_2	500 pF	C_7	500 pF	C_{12}	50 pF	C_{17}	0.02 ,,
R_5	1.0 megohm.	R_{10}	0.25 megohm	R_{15}	50,000 ,,	C_T	Trimmers	C_8	0.1 μF	C_{13}	25 μF	C_{18}	0.1 ,,

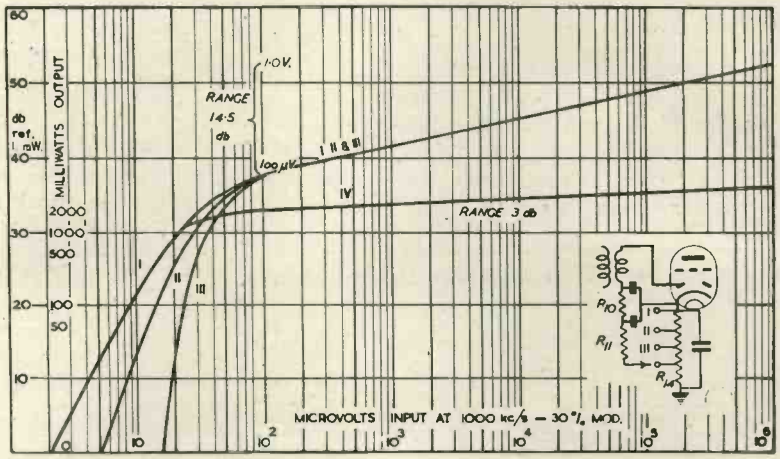

Fig. 33. A.V.C. characteristics. (I) for two controlled stages of conventional receiver with —3v. delay. (II) as (I) but with —1.0 v. at signal diode. (III) with —1.5 v. (IV) is the same as (I) but with A.V.C. also applied to the 1st A.F. stage.

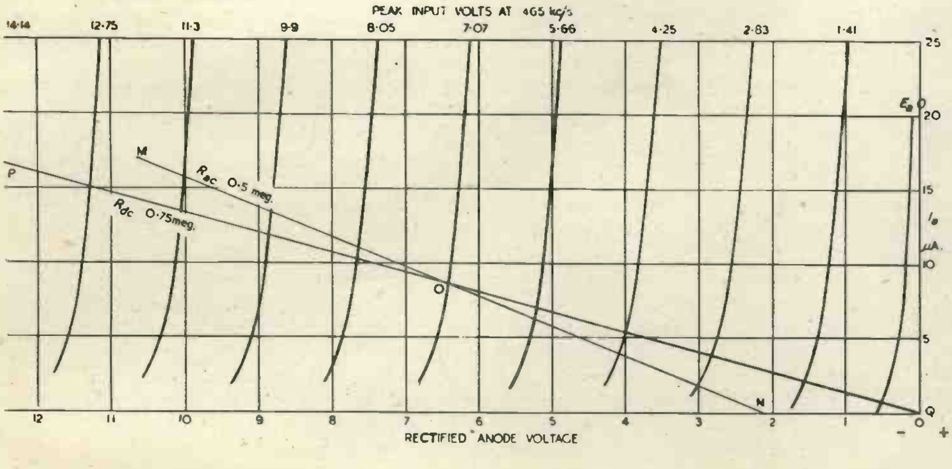

Fig. 32. Curves of rectified output v. input for typical diode.

The Magic Eye as a Resonance Indicator

By J. M. A. LENIHAN, M.Sc., A.Inst.P.[*]

THE cathode-ray tuning indicator, or magic-eye valve, originally developed for radio receivers has a number of applications in the laboratory. Its advantages as a balance indicator in bridge measurements are well known and it has been used in valve voltmeters of the slide-back type. The purpose of this note is to mention another and very obvious use, which does not appear to have been recorded hitherto.

Many measurements at radio frequencies are made by a substitution method in which a resonant circuit, including a variable standard inductance or capacitance, is disturbed by the addition of an unknown inductance or capacitance and restored to resonance by an alteration of the standard. The amount of this alteration is equal to the value of the unknown. There are several other experimental methods in which an indication of resonance is required, although the actual voltage across the resonant circuit need not be known. For cases such as these, the magic eye is an excellent indicator and a suitable circuit is shown in Fig. 1. Variable negative bias is applied to the grid of the triode portion of the valve by means of a rheostat in the cathode lead. It is advantageous not to include the customary by-pass condenser here for the following reason. The signal voltage undergoes two phase-reversals, one in each part of the valve, and as the target current is much larger than the anode current the alternating P.D. set up across the bias resistor is in phase with the input, thus producing regeneration and increasing the effectiveness of the amplifier section. At a certain value of the bias (−7 volts for the 6E5 valve used by the writer) the eye closes, and if a greater bias is applied the two halves of the pattern will overlap.

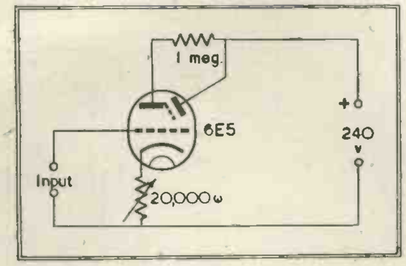

Fig. 1.

Operation

If the input terminals are connected across a condenser forming part of a resonant circuit, the triode section of the valve functions as an anode-bend rectifier and the anode current increases. This leads to a decrease in the target current and part of the negative bias is neutralised, with the result that the eye opens out. The maximum opening of the eye indicates resonance. The instrument is most easily used when the bias is adjusted so that the eye is closed at frequencies off resonance and just opens at resonance.

Performance

A 6E5[†] valve was found to give an adequate indication of resonance at frequencies up to 15 Mc/s, though at the higher frequencies the sensitivity was greatly reduced. The input capacitance of the valve measured at − 7 volts bias was $9 \mu\mu F$, and the shunting effect of this capacitance limits the useful range to frequencies below about 5 Mc/s. At that frequency resonance was well defined with an input of 0.5 volts r.m.s. It will be seen from these figures that the device described has characteristics better than those of a valve voltmeter of comparable cost and convenience, though its use is limited to the operations described in the second paragraph above.

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[*] University of Durham (King's College, Newcastle upon Tyne).

[†] Valves of the remote cut-off type, such as 6N5, 6G5, and several others, require a much larger negative bias to close the eye, and are not so satisfactory as the sharp cut-off type.

Practical Notes on Receiver Design—*continued.*

$C_{18}(R_5+R_7)+C_{19}(R_6+R_7)=0.4$ seconds. The time constant should not be too rapid otherwise the A.V.C. circuit will respond to changes in rectified volts across R_7 due to modulation.

The values of R_5R_6 are determined by the maximum rated resistance that can be introduced into the grid circuit of a valve. In most cases, this value is limited to 2 megohms in which R_7 must be included. In this case, both controlled valves have a total of 2 megohms between grid and cathode.

The method of measuring A.V.C. to ascertain its effectiveness has already been outlined.[*] The average control slope (Curve I, Fig. 33) for two stages in a conventional receiver is about 5.7 : 1 or 14 db. change in power output for 80 db. change in input signal at the aerial socket.

The delay voltage should be sufficient to allow the A.F. stages to load fully before A.V.C. takes control, an average figure would be about 2-3 volts, which is conveniently obtained from R_{14} in the cathode circuit.

An improved characteristic is obtained by using the A.V.C. to control the A.F. gain when the valve employed is the usual double-diode-triode, but the triode has variable-mu characteristics which permits the application of bias to control the amplification. The improvement is obvious, an effective slope of 26.5 : 1 or 3 db. rise in output for 80 db. change in input signal. The amount of A.V.C. applied should be adjusted to compromise between control slope and distortion as the curvature of the triode characteristics at high input levels is liable to introduce distortion.

If some form of interstation noise suppression is employed together with R.F. and A.F. A.V.C., the overall control characteristic is one approaching the ideal except that the maximum sensitivity of the receiver is never available unless some form of switching is introduced. The circuit in Fig. 33 shows a simple method of biasing the signal diode to accept only comparatively strong signals. The curves show the result of : (I) normal A.V.C. curve for 2 R.F. stages—delay −3v. at A.V.C. diode anode, (II) same as (I), but with -1.0 volt at signal diode (III) with -1.5 volt at signal diode (IV) same as (I) but with A.V.C. also applied to the 1st A.F. stage. The disadvantage of biasing the signal diode is that when the signal voltage applied to the diode circuit is just sufficient to overcome the delay, serious distortion is evident. To avoid this, it becomes necessary to employ some form of mechanical or electronic circuit to remove the bias at the signal diode once the transmission is received, otherwise in the event of a reduction in field strength, the signal will become distorted and possibly disappear every time it falls below a critical value determined by the suppression bias across R_{14}.

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[*] *Electronic Engineering,* No. 164. Vol. XIV, pp. 452-454, Oct. 1941.

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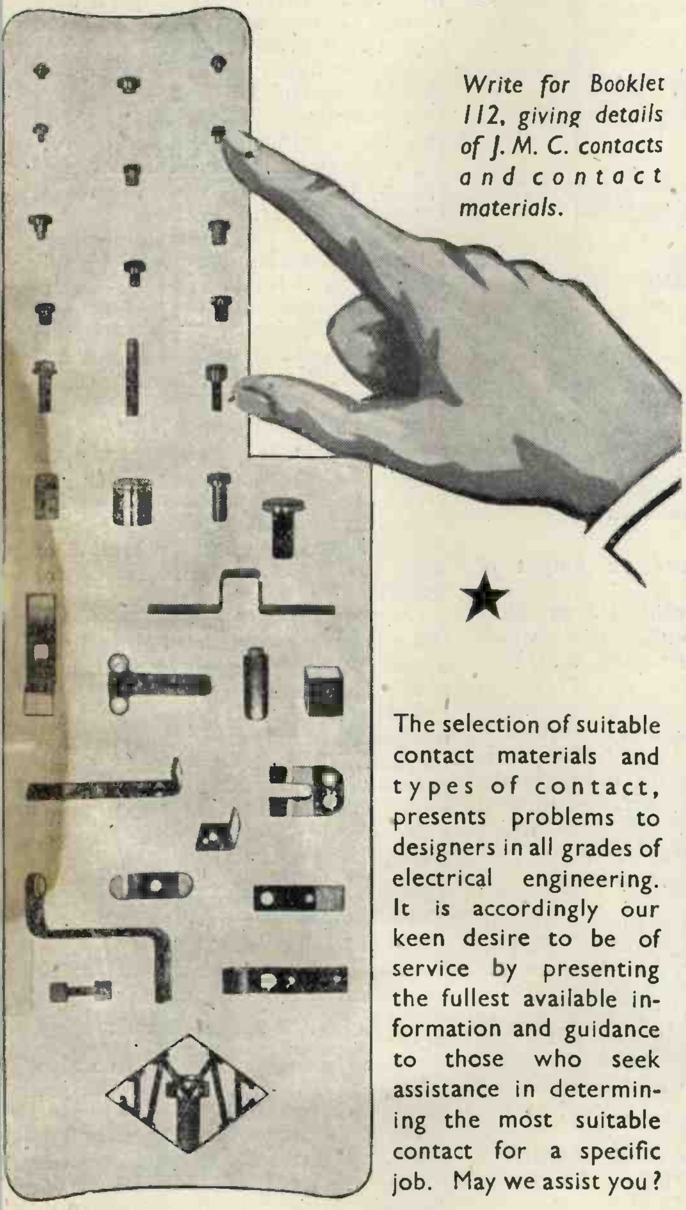

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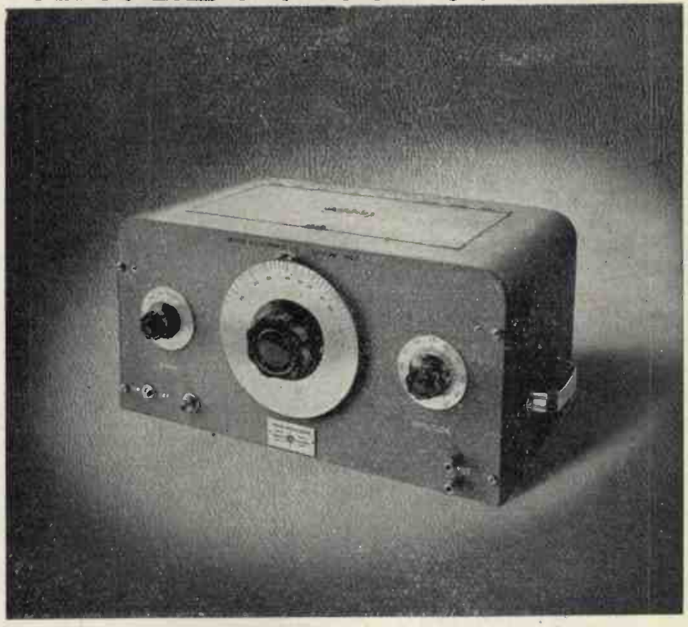

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Electronics in Medicine and Surgery

Part II— By A. W. LAY, F.Inst.P., A.M.I.E.E.

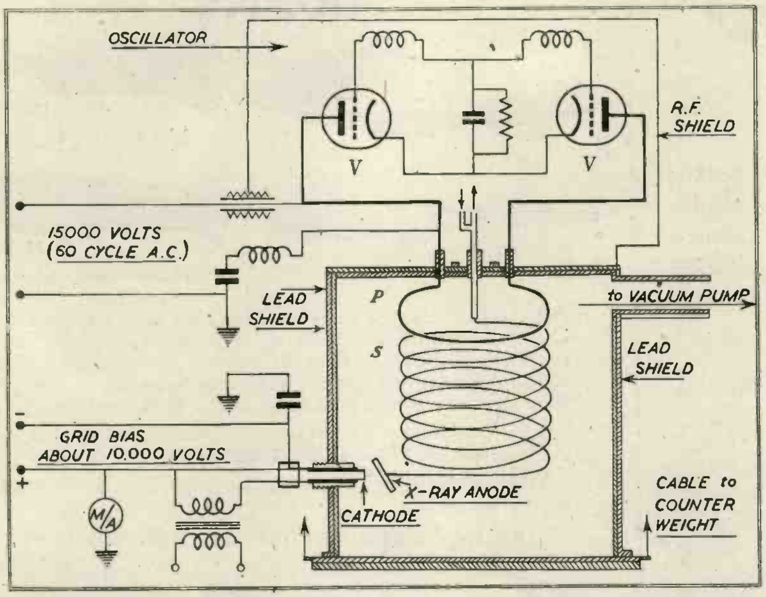

Fig. 1. Diagrammatic sketch and circuit of the Sloan H. F. Resonance Transformer.

In the application of the discoveries in the field of nuclear physics and high voltage X-rays to biological and medical research several types of accelerator have been developed for providing high velocity particles with which to bombard the nuclei of atoms—a practice popularly known as " atom smashing." These accelerators take several forms, but space permits of mentioning only a few, which by their nature are of particular interest.

It does not follow that those which are not fully described are less worthy of attention, but that they may be on the borderline between electric power engineering and electronics.

One of the types of apparatus used for the production of ions accelerated to 700 kV. and upwards, is the Impulse Generator. In this system a number of condensers are charged in parallel and then discharged in series. The period of the active impulse is of the order of 2×10^{-6} seconds, and particles accelerated up to 3 MV. have been obtained from this apparatus.*

By connecting four transformers in series, each of which is capable of giving 250 kV., an output of 250 μA at 1.0 MV. has been obtained by this system, which is due to Lauritsen[1] and other workers.

Condenser-Rectifier Voltage Multiplier[2]

In their original work on disintegration of atomic nuclei Cockcroft and Walton used this type of equipment to produce highly accelerated particles. They obtained an output of 200 μA at 700 kV.

As the name implies, the principle used is voltage multiplication, which is achieved by rectifying and then charging condensers 60 times per second.

It may be of interest to state that the circuit due to these investigators forms the basis of the electrical design of the 1.0 MV. X-ray equipment at St. Bartholomew's Hospital, which will be referred to again later.

Van de Graaff's Electrostatic Generator

This is an electrostatic machine in which electric charges are sprayed on to belts which convey them to the proximity of two large spheres, which are thus charged by influence to opposite polarity. These belts are made of a continuous band of insulating material, and travel at speeds of the order of 4,000 or 5,000 feet per minute.

Van de Graaff has obtained voltages up to 5.0 MV. under laboratory conditions.

This type of generator is being improved by using the remarkable insulating properties of the gaseous form of (CCl_2F_2) which is known as " Freon," and is a better insulator than transformer oil.

A typical installation of this equipment is that which is used at the Huntingdon Memorial Hospital at Boston (U.S.A.) where 1.0 MV. X-rays are used for research on, and the treatment of cancer.

Sloan High Frequency Resonance Transformer

The title of this apparatus explains its nature. It is used mostly for high voltage X-ray work. The essential circuit is shown in Fig. 1.

The oscillator valves V are of special construction and self-rectifying. They are capable of dealing with 200 kilowatts of energy and of producing radio frequency currents of 6×10^6 c/s. in the primary P of the resonance transformer.

P consists of $\frac{3}{4}$ turns of stout copper tube, and the secondary winding S is of 14 turns of smaller tubing. When these circuits are tuned to resonance a potential of about 800 kV. is developed across the ends of S. One end of this is earthed, and to the other end (H.T. end) is attached the anode of the X-ray generator. Opposite to this X-ray target is the heated cathode which is biased to about 10,000 volts. This prevents the flow of electrons from the cathode to the anode until the latter has reached a positive potential of approximately the peak value of 800 kV.

Owing to the high frequency of these peak potentials the voltage arcoss the X-ray target and cathode is nearly constant.

This type of H.T. generator is very compact, and offers the advantage that the E.H.T. winding and X-ray generator is housed in a protective tank. A window is, of course, provided for the X-ray beam to emerge, with any necessary filtering.

Low Frequency Resonance Transformer

The principle on which this type of H.T. apparatus works is also explained by the title. In the centre of this transformer an X-ray tube is mounted co-axially with the winding. This is contained in a steel tank into which " Freon " is compressed to 40 lb. per square inch for insulation.

The transformer primary winding consists of flat copper strips, and the secondary of 120 thin flat sections of fine wire which are spaced apart to facilitate ventilation.

This secondary winding is proportioned to make its natural period of oscillation match that of the supply (180 c/s.). This frequency is obtained by introducing a frequency tripling device, trebling the supply frequency of 60 c/s. (U.S.A.).

Voltages up to 1.2 MV. have been produced by this system for working an X-ray tube of special design, which contains accelerating electrodes. These

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* M = mega (10^6)

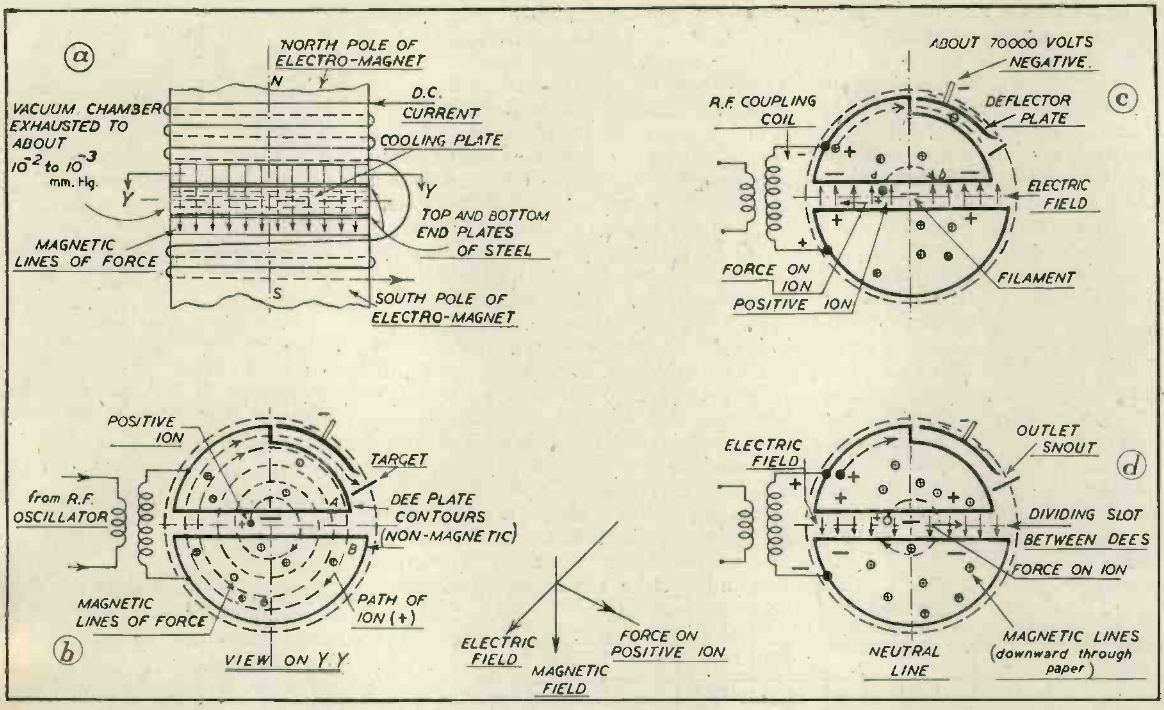


Fig 2. The Cyclotron. Four drawings to illustrate the layout and path of the ions under the electrical and magnetic forces applied.

are tapped progressively along the secondary of the transformer. Currents up to 9.0 milliamps have been drawn from the system.

Magnetic Accelerator or Cyclotron

The pioneer work of Cockcroft, Walton[3], Lawrence[4], and others in their investigations on atomic nuclei prepared the background from which grew the necessity for improved equipment capable of accelerating particles to potential energies of upwards of 5 million volts.

This is because heavy radioactive elements have nuclei which are unstable, but which are surrounded by an intense electrical barrier which must be pierced by high velocity projectiles before nuclear disintegration can be accomplished.

The accelerators already mentioned did excellent service, and still do, when the maximum potentials required did not exceed 2 or 3 MV., but when the research workers sought "other worlds to conquer" the problem of generating much higher voltages arose.

This was solved in an ingenious manner by E. O. Lawrence and his group of workers, at the University of California, when they created the Cyclotron.

At this stage it will be convenient to consider briefly a few of the factors which enhance the probability of a bombarding projectile penetrating the potential barrier around heavy nuclei.

It has been shown by Gamow[5] that when an atom of atomic number Z is bombarded by a particle of mass m, and of atomic number N, the probability P of the particle striking the nucleus of the atom is given by the expression:

$$P = \epsilon\left(-\frac{2\pi Z\sqrt{mN}e^2}{h\sqrt{E}}\right) \quad \ldots \quad (1)$$

In this formula E is the energy of the particle, Ne is charge, h Planck's constants, e is in e.m.us. ϵ symbolises the exponential function.

From this equation it is indicated that the probability of a particle passing through the potential barrier increases as the product $\sqrt{mN}$, decreases. In other words it is an advantage to use light particles rather than heavy ones as projectiles.

The cyclotron is a prolific source of high potential light particles, such as protons, deuterons, alpha particles, and neutrons—depending upon the nature of the gas which is ionised. For example: if helium is ionised alpha particles are produced, deuterons from deuterium, or protons from hydrogen.

The creation of the cyclotron is regarded as one of the greatest advances in the development of multi-million volt generators, and most probably it holds the future for equipment of this nature.

Fundamentally Lawrence's invention depends upon the acceleration of ions under the combined influence of electric and magnetic fields. These are arranged to be active at right angles and well known physical laws may therefore be applied. Fig. 2 indicates the form and disposition of the active material through which the physical force operates.

The cyclotron is composed of a powerful electro-magnet which is capable of producing a magnetic field of the order of 1.5×10^4 Oersteds between the pole faces, spaced several inches apart.

This magnet is energised by about 4×10^5 ampere-turns of which the current component is from 100 to 200 amperes provided by a motor-generator.

Typical dimensions of the electro magnet for an equipment of moderate power are: pole pieces 100 cms. dia. tapered to 90 cms. at the pole faces; weight (with coils) 45 tons, magnetic field intensity 18,000 Oersteds within a radius of 38 cms.

In the air gap between the pole-pieces is mounted a pump-maintained vacuum chamber of flat cylindrical form, a cooling plate at the top protecting it from destruction by bombardment. The gas to be ionised is introduced into this chamber.

Within this enclosure are mounted two hollow plates of "D" shape (called "dees.") They are insulated from the vacuum chamber, which is at earth potential, by pyrex supports which must be strong mechanically as they will be intensely stressed by the operating forces.

A rectangular space across the diameter of the chamber separates the dees from one another and they are coupled to a balanced radio frequency oscillator insulated from earth.

The thick line in the centre of Fig. 2b represents the source of electrons, which is usually a hair-pin filament heated by h.f. current of 2×10^5 c/s. to avoid deformation when it is subjected to the intense working stresses. A negative bias of about 1,000 volts to earth is applied to the filament structure, which is mounted on a movable arm. By this means the emitted electron beam is adjusted to be nearer to one dee than it is to the other.

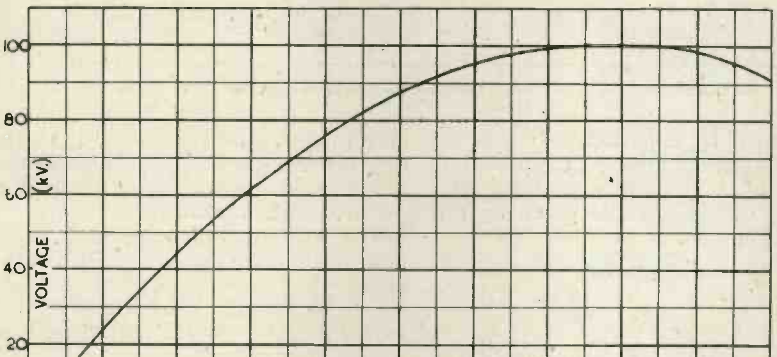
Between the filament and the space between the dees is mounted a shield into which is cut a rectangular slot, shown diagrammatically in Fig. 3.

For many purposes an arc source of ions is sometimes more satisfactory than one which depends upon the emission of electrons from a heated filament, but we are here concerned with the latter.

From Fig. 2c it will be seen that the top dee is cut away around the periphery, and a thick line is drawn in this space. This represents the deflector plate, which is biased to between 5×10^4 and 1×10^5 volts negative with respect to earth. The function of this plate is to direct the emergent beam of ionised particles to the target chamber, which is indicated by the thick line normal to the direction of the beam. The element which is to be bombarded is mounted in the target chamber which is provided with a vacuum gate, to facilitate its isolation from the main vacuum chamber. This is maintained at a pressure of 10^{-2} to 10^{-3} mm. of mercury, and into which the gas to be ionised is introduced.

For high intensity bombardments an aluminium window about 0.0025 cms. thick is provided.

Owing to the intense concentration of the energy of the emergent beam on the target and through the window a cooling system maintains these at a safe temperature.



Figs. 4 and 5.

Fig. 4 (lower curve.) Height of an electron above the filament as a function of the phase of the dee voltage. Fig. 5 (upper curve). The voltage between dees at the phase indicated on the lower graph. An electron starting at zero phase (*chain line*) oscillates about the position of the upper dee edge. An electron emitted at an initial phase of 1.0 radian (*full line*) oscillates back and forth across the median plane and finally returns to the filament after the dee voltage has dropped below the valve it had when the electron was emitted. Electrons starting after an initial phase of $\pi/2$ radians (*dotted line*) cross directly to the cooling plate (*after Wilson*).

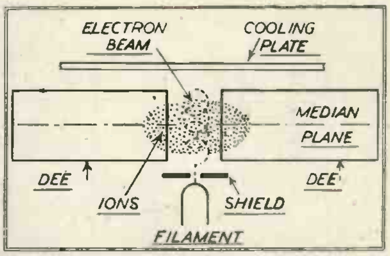


Fig. 3. Formation of the ions in the centre of the cyclotron.

The " snout " of the vacuum chamber is free to expand and is made of molybdenum on account of its high melting point, as this runs hot when bombarded by some of the stray ions.

Creation of Ions

Suppose that a certain gas, say helium, is introduced into the vacuum chamber. This, when doubly ionised, will produce alpha particles.

Now if electrons are emitted by the filament, but for the negative bias they would tend to cloud around the filament under the shield and form a space charge.

The bias expels them up through the slot in the shield and they now come under the combined influence of the oscillating electric fields of the dees and the unidirectional magnetic field. These fields are at right angles to one another as indicated in Figs. 2a and 2c.

A full analysis of the behaviour of the electrons as they oscillate in the space between the dees would involve differential equations to deal with the variables, but a picture of what happens has been presented by R. R. Wilson.[6]

This is illustrated in Figs. 4 and 5 from which it will be seen that under the combined influence of the electric and magnetic forces the electrons spiral up and down the magnetic lines in a mode which is dependent on the phase of the potential wave on the near dee at the instant the electron is emitted from the filament.

The potential energy of the electron after passing through the shield will therefore be a function of the electric field which is oscillating at the frequency of the r.f. generator. It will also depend upon its position in the space between the dees—since these are hollow. (Fig. 3).

Looking into the dees, the shape of the electric field will be approximately rectangular in form, as delineated by the edges of the plates. In this region the field will be of the greatest intensity, but will not be sharply defined owing to the effect of edge distortion.

We can assume the main electric field to be across the upper and lower edges of the dees and that this is at right angles to the vertical magnetic field as indicated in Figs. 2a and 2b.

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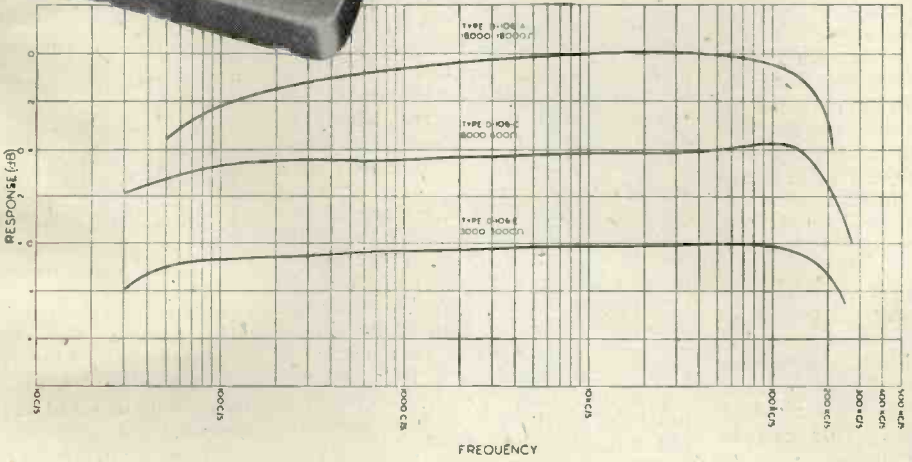

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The effect of the magnetic force will be to constrain the electrons to follow a cycloidal path in a plane perpendicular to the field, whilst a varying vertical component of force will be introduced by the electric field. Consequently the path of the electron in the dee space will be in the form of a helix.

It can be shown that the diameter of this is about 2×10^{-4} cms. which indicates that a pencil of electrons spirals up and down between the dees.

Assuming increasing positive potential of the near dee as the electrons enter the dee field, they will be accelerated upwards and we may equate the potential and kinetic energies thus:

$$eV = \tfrac{1}{2}mv \qquad \ldots \quad (2)$$

These will be transformed from one to the other as the electron oscillates up and down, and the energy will be spent in the process of ionising the gas molecules by impact for which purpose this electron beam is produced.

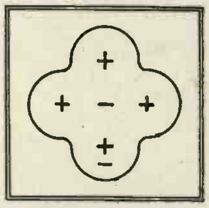

Fig. 6. Diagram of alpha particle.

Referring to Fig. 4, due to Wilson,[4] it will be seen that electrons which leave their source when the near dee is at decreasing positive potential spiral up past the upper edge of the near dee and are lost in the cooling plate.

The probable explanation is that they shoot up past this edge by virtue of the kinetic energy to which they have been accelerated by this dee edge, but as the positive potential of this is increasing, by the time that the electron has shot a little distance past the dee the potential has fallen to a value insufficient to attract the electrons back into the field, and they therefore continue to spiral upwards to the cooling plate.

If, however, the dee is at an increasing positive potential at the instant of emission then it will be kept within the field until several oscillations have been performed when the potential is again insufficient to keep the electron within the dee space. This can be reasoned out as indicated.

The effect of these oscillations is to increase the intensity of ionisation in the space around the electron beam. This will be most intense in the region of the median plane as indicated in Fig. 8.

It can be shown that the average velocity of an electron in a direction perpendicular to the electric and magnetic fields depends upon the ratio of V/H, and as V will diminish near the median plane the effect will be to slow up the electrons in this region, but they will still retain sufficient energy to ionise the gas molecules.

This provides an ion current of about 10 to 15 milliamps if the emission current is 0.3 amperes; but of these ions available only a small percentage, depending upon the nature of the gas, are usefully accelerated.

Fig. 6 illustrates the electrical composition of an alpha particle, as a result of double ionisation of helium from which it will be observed that it carries an electric charge of 2 positive units. Its mass is 6.64×10^{-24} grams, or four times that of the hydrogen atom.

We can now follow the course of the particle whilst it is under the influence of the accelerating forces.

Referring to Fig. 2c, and applying Fleming's Left Hand Rule to the force on this positive ion, the force acting upon it will be towards the left if the potential of the upper dee is negative, but before being drawn into the dees the ion will describe several initial cycloidal paths in the space between the dees.

After these initial excursions it will be attracted into the dees (if the cyclotron is in tune) at the instant when the potential between the dees is at a maximum, of the order of 1.8×10^5 volts peak for the two as shown at (a) in Fig. 7.

Whilst it is practically free of electric force in the hollow dee the magnetic force will be active in constraining the ion to a cycloidal path.

Now if the time taken for the semicircular path (a b) on Fig. 2c is exactly the same as that of half a period, $T/2$, of the high frequency field then the particle will emerge from the upper dee at the instant when the lower dee has assumed maximum negative potential as indicated at c in Fig. 7.

The particle will therefore be accelerated across the gap into the lower dee plate and describe a cycloid of greater radius until it emerges again and is thus attracted to the upper dee which by now is again at maximum negative potential. This cycle of events is repeated many times according to the geometry of the cyclotron until the particles have been accelerated to the desired voltage.

They then emerge tangentially to the final cycloidal path when they are directed by the deflector plate on to the target.

The final energy of the particle is given as

$$W = e\frac{H\omega}{2c}R^2 \qquad \ldots \quad (3)$$

where H is in e.m.u.s and R is the final radius of the path in cms.

Considering now the factors which govern the motion of the particle we have:

$$Hev = \frac{Mv^2}{r} \qquad \ldots \quad (4)$$

where r is the radius of curve of the path at any instant and H is the strength of the magnetic field in Oersteds.

The other symbols have the significance already ascribed. At any instant we may equate the kinetic energy of the accelerated ion against the equivalent potential difference V through which it has been raised. Thus

$$eV = \tfrac{1}{2}mv^2 \qquad \ldots \quad (5)$$

From equation (4) $v = \dfrac{Her}{m}$

$$\therefore \; v^2 = \frac{H^2e^2r^2}{m^2} \qquad (6)$$

substituting this for v in equation (5) we have

$$eV = \tfrac{1}{2}m\frac{e^2H^2r^2}{m^2}$$

and hence $V = \tfrac{1}{2}H^2r^2\,(e/m)$ (7)

In this equation H and e are in e.m.u.s and therefore to convert to the practical units of the Oersted and the volt we divide H and e by c and 10^8 respectively, with the result that

$$V \text{ volts} = H^2r^2\frac{e}{m}(1.667 \times 10^{-19}) \quad (8)$$

When the ion emerges from the cyclotron r becomes R, the radius of the final cycloid, if this, the magnetic field, and the mass of the particle are known the final voltage can be calculated from this equation.

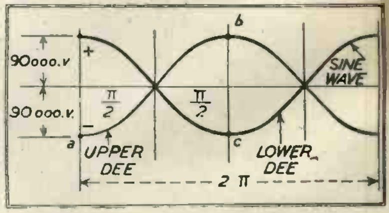

Fig. 7. Voltage changes on the dees.

If the charge e carried by the ion is also known the energy can be evaluated from equation (5) from which the final velocity v of the ion may be calculated if the mass m is known.

Then, knowing v, the effect of relativity may be determined.

The value of H and frequency f of the r.f. oscillator is also required before we have the general design basis for the accelerator.

If ω is the angular velocity, then

$$\omega r = v \qquad \ldots \quad (9)$$

and from (4)

$$\omega = \frac{He}{mc} \qquad \ldots \quad (10)$$

if H is in Oersteds, also

$$\omega = 2\pi/T \qquad \ldots \quad (11)$$

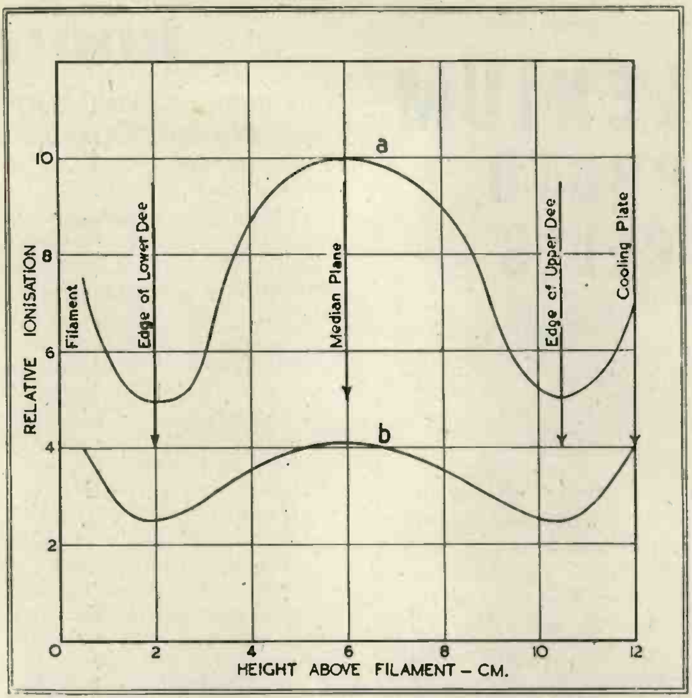

Fig. 8. Relative ionizing power of an electron plotted as a function of its height above the filament. Curve (a) is for a typical oscillating electron emitted when the phase is above 0.3 radian. Curve (b) is for an electron emitted when the phase is about 2.0 radian, i.e. one which crosses directly to the cooling plate (*After Wilson*).

or the frequency $f = \dfrac{1}{T} = \dfrac{\omega}{2\pi}$. Substituting for ω from equation (10) we have

$$f = \frac{He}{2\pi mc} \quad \ldots \quad (12)$$

This indicates that the frequency of the oscillator and the strength of the magnetic field are directly proportional.

Equation 10 shows that the angular velocity ω of the ion is independent of the radius of its path r and also of its linear velocity v.

As a general example we suppose that the frequency of the oscillator is 1×10^7 c/s. or 30 metres, wavelength, and that an alpha particle is to be accelerated. This will carry two units e of positive charge, that is $4.8 \times 10^{-10} \times 2$, by taking a mean value of the latest determinations of e. Similarly its mass is 6.64×10^{-24} grams. Then from equation (12)

$$H = \frac{2\pi fmc}{2e} = 13{,}030 \text{ Oersteds} \quad (13)$$

Let the final radius of the path of the ion be, for example, 50 cms; this will be R instead of r in equation (8) by means of which we can evaluate V, therefore by substituting the known values, we have

$$V = 10.23 \times 10^6 \text{ volts} \quad \ldots \quad (14)$$

The energy of the single ion on emergence may now be calculated, this is eV, where these are in e.m.u.s and as the ion carries two positive units, that is $1.6 \times 10^{-20} \times 2$ e.m.u.s. Therefore

$$10.23 \times 10^6 \times 10^8 \times 3.2 \times 10^{-20}$$
$$= 3.273 \times 10^{-5} \text{ ergs.}$$

This may, for convenience, be converted to electron volts as indicated in an earlier article, and hence

$$\text{The energy} = \frac{3.273 \times 10^{-5}}{1.59 \times 10^{-12}}$$
$$= 2.058 \times 10^7 \text{ electron volts.}$$

This may be checked by deriving and using equation (3).

From equation (4) we have $\omega = He/mc$ and as $v = r\omega$ by substitution

$$v^2 = \frac{H^2e^2r^2}{m^2c^2} \quad \ldots \quad (15)$$

equation (4) also gives $m = He/\omega c$ and hence

$$\tfrac{1}{2}mv^2 = \tfrac{1}{2}\frac{He}{\omega c} \times r^2\omega^2 = \tfrac{1}{2}\frac{He\omega r^2}{c} \quad (16)$$

We are concerned with final R = 50 cms.

By substituting the values already known we get:

$$\text{energy} = 3.274 \times 10^{-5} \text{ ergs}$$
$$= 2.058 \times 10^7 \text{ electron volts as before.}$$

It will be of interest to find the effect of relativity on the mass of the ion which will now be travelling at a high velocity. To find v we use equation (5) this gives

$$v = \sqrt{\frac{2eV}{m}} \quad \text{therefore}$$

$$v = 4.439 \times 10^9 \text{ cm/sec.}$$

From the relativity equation already given

$$m_e = \frac{m_0}{\sqrt{1 - \dfrac{v^2}{c^2}}} \quad \text{and hence}$$

$$m_e = \frac{6.64 \times 10^{-24}}{\sqrt{1 - \dfrac{(4.4 \times 10^9)^2}{(3 \times 10)^2}}}$$
$$= 6.715 \times 10^{-24} \text{ grams}$$

and the increase in mass is therefore 1.13 per cent., which is sufficient to throw the ion out of resonance unless compensation is made.

A full mathematical analysis would account for the difference between the quantity of ions available at the source and that contained by the emergent beam.[7] This would involve focusing, shape of magnetic poles, creeping of the ions, and several other subsidiary factors[8 9] which cannot be taken into consideration here, and only brief mention can be made of the r.f. oscillator. This is usually of orthodox push-pull type which must be stabilised for frequency and output. It will be obvious that the output of the order of 50 kW. must be carefully balanced.

Wavelengths between 20 and 30 metres permit of a convenient design for the electromagnet of the cyclotron. A frequency stability of one part in 10,000 is desirable and this is usually accomplished by using a quarter-wave resonant line in the grid circuits, in preference to crystal technique, of which the Q is found to vary at these wavelengths.

A ripple of more than 3 per cent. cannot be tolerated on the D.C. supply.

The oscillator is generally coupled to the dees of the cyclotron through quarter wave concentric lines.

This type of accelerator offers great potentialities of which we have sucn examples as the 50 million volt cyclotron projected at Moscow before the war, and the 100 million volt equipment, weighing 4,000 tons under construction in the U.S.A.

Devices for the control of the beam, also for the regulation of the magnet current were being developed, and new sources of ions were being investigated.

In 1939 about thirty cyclotrons were in operation in various parts of the world, two of these were in this country.

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BOOK REVIEWS

Elementary Mathematics for Wireless Operators

2nd. Edition. W. E. Crook. 74 pp. 42 figs. (Pitman & Sons, 3/6 net).

This is a companion book to the author's "Handbook for Wireless Operators" and having been twice reprinted has now gone to a second edition.

A section on arithmetic has been added together with a number of examples at the end of each chapter.

The remainder of the book covers elementary algebra, geometry, trigonometry and mechanics in a concise and pleasantly colloquial style which should soften the "dryness" of the formulæ to the beginner.

A suggestion to the author: Instead of saying "The index ^{3} means that the number is to be multiplied by itself *twice*," why not say "The index ^{3} means that 3 of the numbers are to be multiplied together, *e.g.*, $4^3 = 4 \times 4 \times 4$. It should be easier to remember.

Radio Handbook Supplement

Edited by J. Clarricoats. (Radio Society of Gt. Britain). 2/6 net.

This is a war-time publication intended to bridge the gap between the current edition of the Amateur Radio Handbook and a future third edition.

In addition to radio mathematics and fundamental principles, the book deals with the Cathode-Ray Oscillograph and Direction Finding. One of the most interesting chapters is that on "The Service Operators Vade Mecum" which originally appeared as a series of articles in the T. & R. Bulletin.

A well-produced book which should have a large sale among service technicians.

Wave Guides

H. R. L. Lamont. 102 pp. (Methuen's Monographs on Physical Subjects, 4/- net).

The present rapid advance in Microwave technique makes it essential for every radio engineer to make himself familiar with the theory of wave guides and resonant chambers. A great deal has been written on the subject in recent years and will be found scattered in foreign periodicals, mostly American. Mr. Lamont is to be thanked for providing us with this little volume which is a compact statement of the present position of the subject.

The book is written primarily for the physicist and a reasonably good knowledge of mathematics is presupposed, however, this and a working knowledge of electromagnetic theory is essential for the proper understanding of the subject.

The radio engineer who is familiar with aerial theory and the propagation of waves will find little trouble in reading this book. Unfortunately, the majority of radio engineers have seldom had use for Maxwell's Field Equations and the reviewer would advise them to read the second part of Pierce's "Electric Oscillations and Electric Waves" before tackling this monograph. If this book is not available a companion volume in the present monograph series "Electromagnetic Waves" by F. W. G. White should be absorbed.

The book is divided into six chapters covering the theory and properties of wave guides for the transmission of waves, and as resonators and radiators. A good bibliography of all the most important articles on the subject is included as a guide for further reading. It is, however, a great pity that a different system of suffixing the different types of guided waves has been employed from that generally adopted in American literature on the subject. C.L.H.

Radiology Physics

J. K. Robertson, 245 pp. and appendix 188 figs. (Chapman and Hall, 18s, net.)

This book is mainly intended for the medical student and radiologist, and serves to give an outline of the physical principles involved in X-ray practice. It is based on a course of lectures to second year students at the Queen's University, Canada, at which the author is Professor of Physics.

The first chapter deals with the principles of alternating currents, leading on to the production and measurement of high voltage, cathode rays, and finally to X-ray tubes and associated apparatus. Radioactivity and artificial radioactivity are also covered, together with H.F. apparatus for diathermy—altogether a comprehensive course.

The electronic engineer will probably find many of the author's explanations unsatisfying in the earlier part of the book, and the wording at times borders on the "loose" side.

On p. 10 there is a slip in the experimental determination of the reactance of a 1.0 mfd. condenser which is checked by calculation on the next page to be 265 ohms at 60 c./s.!

In the description of X-ray apparatus and circuits the book covers the field well, and radio engineers, who can afford to ignore the opening part of the book, will find useful information about a subject with which they are unfamiliar.

Preserving the D.C. Level in Oscillograph Amplifiers

By A. W. RUSSELL*

IT frequently occurs in practice that one wishes to study with a cathode ray oscillograph phenomena of low frequency, or phenomena in which the mean level (i.e., the D.C. value) is of importance. This demands a D.C. amplifier with direct coupling on to the deflector plates of the cathode-ray tube, an instrument which is not available commercially and which requires considerable time and experience to construct. In cases where the job does not justify the expenditure of so much time and money it is possible to obtain much useful information from a normal oscillograph incorporating a resistance-capacity-coupled amplifier, using one of the popular H.T. vibrators as an interrupter. In this way, a steady voltage is converted into a square topped wave of the natural frequency of the vibrator (90-110 cycles/sec.) while any alternating component appears superimposed on the flat tops of the waves. Such a waveform can be handled by almost any oscillograph amplifier.

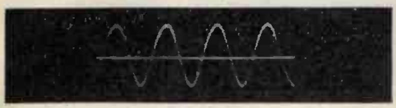

Fig. 2a.

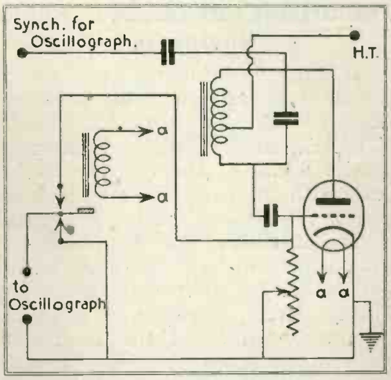

Fig. 2.

In the normal way, the driving coil of the vibrator is fed from a D.C. supply with an auxiliary interrupter contact, and sparking at these contacts may give rise to interference which will be visible on the oscillograph. This may be overcome by disconnecting the driving contacts and feeding the driving coil with 50 cycle current. If the natural frequency of the vibrating system should be sufficiently different from 100 c/s. to prevent proper operation, it can be adjusted quite simply by a slight bending of the fixed outer contacts.

The schematic diagram Fig. 1 shows the application of the device to the study of the conditions obtaining at the grid of a back coupled L.F. oscillator (frequency 1,000 c/s. approx.). A variable grid leak is used to control the amplitude of the oscillations. Figs. 2a and 2b are oscillograms photographed from the screen of a Mullard GM.3156 cathode-ray oscillograph, and in each case the straight line represents zero grid potential. Fig. 2a was obtained when the grid leak was only just large enough to maintain oscillation. It will be seen that the grid voltage is sinusoidal and symmetrical about zero potential. Fig. 2b was obtained with a high value of grid leak. The wave form is no longer sinusoidal and the mean D.C. potential has changed as the grid is now biased negatively on its own grid current.

Fig. 2b.

Suitable vibrators can be obtained from Messrs. Wright & Weaire, who very kindly supplied those used in these experiments.

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* Mullard Wireless Service Co.

NOTES FROM THE INDUSTRY

Multicore Solders, Ltd.

In order to conserve supplies of tin it has been necessary for solder manufacturers to supply new tin-lead alloys containing a lower percentage of tin than hitherto.

The use of cored solder in lead-rich alloys (in which a maximum of 45 per cent. tin is permitted) has introduced a number of problems in soldering processes, particularly of electrical equipment. Information on how to overcome these difficulties, and recommendations for the requisite bit temperatures of soldering equipment, are contained in Reference Sheet 2 issued by Multicore Solders, Ltd., manufacturers of the well-known Ersin Multicore solder wire.

Copies may be obtained free of charge by firms engaged on Government contracts, on application to the head offices of Multicore Solders, Limited, at Bush House, London, W.C.2.

Radio Reference Data

Messrs. Standard Telephones, Ltd., have just issued a useful booklet of Reference Data for Radio Engineers. Originally compiled for the use of their own staff, they have decided to make the data available to a wider circle, and a limited number of copies are available for bona fide radio engineers at a cost of 2s. plus postage.

In addition to the usual tables of mathematical functions and conversion factors there is information on approved cables for aircraft wiring, wave propagation, noise units and acoustics, from which it will be seen that the field covered is wide and useful.

Applications should be addressed to the Publicity Dept., Messrs. Standard Telephones & Cables, Ltd., Connaught House, Aldwych, W.C.2.

Electrodes for Welding

Messrs. Compound Electro Metals, Ltd., have specialised in the production of metal alloys by the powder metallurgy method and their catalogue gives some interesting figures on the effects of adding certain elements to copper in regard to hardness and conductivity.

Copelmet, a copper-tungsten compound, is particularly recommended for spot-welding electrodes and is supplied in one case as a small insert in a copper shank, forming a highly efficient and durable electrode tip.

Useful reference tables and a heat colour chart are included in the catalogue, which can be obtained on application to the Company's head office at 42 Pall Mall, S.W.1.

The British Institution of Radio Engineers

Sir Louis Sterling has been elected president of the Institution in succession to C. C. Garrard, Ph.D., M.I.E.E., M.Brit.I.R.E. The presidential address, which is expected to deal with registration of engineers, will be read before the London section of the institution on September 25. This meeting will be held at the Federation of British Industries, 21 Tothill Street, Westminster, S.W.1.

Representatives of the Institution, the Scottish Radio Retailers' Association and the Radio and Television Retailers' Association met on Tuesday August 18 to discuss and arrange the holding of a National Certificate in Radio Servicing. The examination will replace the existing Brit. I.R.E. Radio Servicing Certificate, but the Institution will continue to be responsible for holding the examination, the passing of which will be recognised by the Trade Associations.

The meeting will also discuss the desirability of forming a separate association for radio service men.

Polytechnic Kinematograph Course

The two-year course in kinematography, held in conjunction with the British Kinematograph Society at the Polytechnic, Regent Street, commences the session in September, and a limited number of applications for enrolment is now invited.

The Institution of Electronics

A lecture meeting will be held on Friday, September 11, 1942, at the Reynolds Hall, College of Technology, Manchester, at 7 p.m., on "Short Wave Radio Apparatus for Medical Purposes" by R. G. B. Gwyer, M.A., A.M.I.E.E., A.I.Mech.E. (Member). The chair will be taken by Dr. James A. Darbyshire, M.Sc., Ph.D., F.Inst.P. (President). Application for tickets should be made to A. H. Hayes, Hon. General Secretary, 64 Winifred Road, Coulsdon, Surrey.

British Standards Institution

A new British Standard Specification (No. 1044) which has just been issued deals comprehensively with the dimensional standardisation of all of the common types of gauges, including ring gauges, gap gauges and both solid plug gauges and plug gauges of the renewable end type as developed in America and now commonly used in this country.

Copies of the Specification may be obtained price 5s. 6d. each.

Radio Industries Club

At the luncheon held on July 29 an address was given by Mr. S. Rostovsky, editor of the *Soviet War News* and a member of the Soviet Embassy.

The theme was "Radio Propaganda in the Front Line on the Eastern Front," and Mr. Rostovsky described how powerful amplifying apparatus was taken to the fighting front and put into use there. In this way Nazi soldiers are told about the heavy raids on their home cities and also urged to surrender to the Russians. The method had proved most successful in many cases.

Capt. H. de A. Donisthorpe of the Valve Department of the General Electric Company is giving a tour of lectures to the Services on "The Romance of Radio."

The lecture traces the evolution of radio from the early days of Marine Wireless Telegraphy to modern day broadcasting with special reference to the wireless valve.

American Radio Manufacturers' Association

Mr. R. C. Cosgrove, vice-president and general manager, Manufacturing Division, the Crosley Corporation, has been re-elected as a director of the Radio Manufacturers' Association.

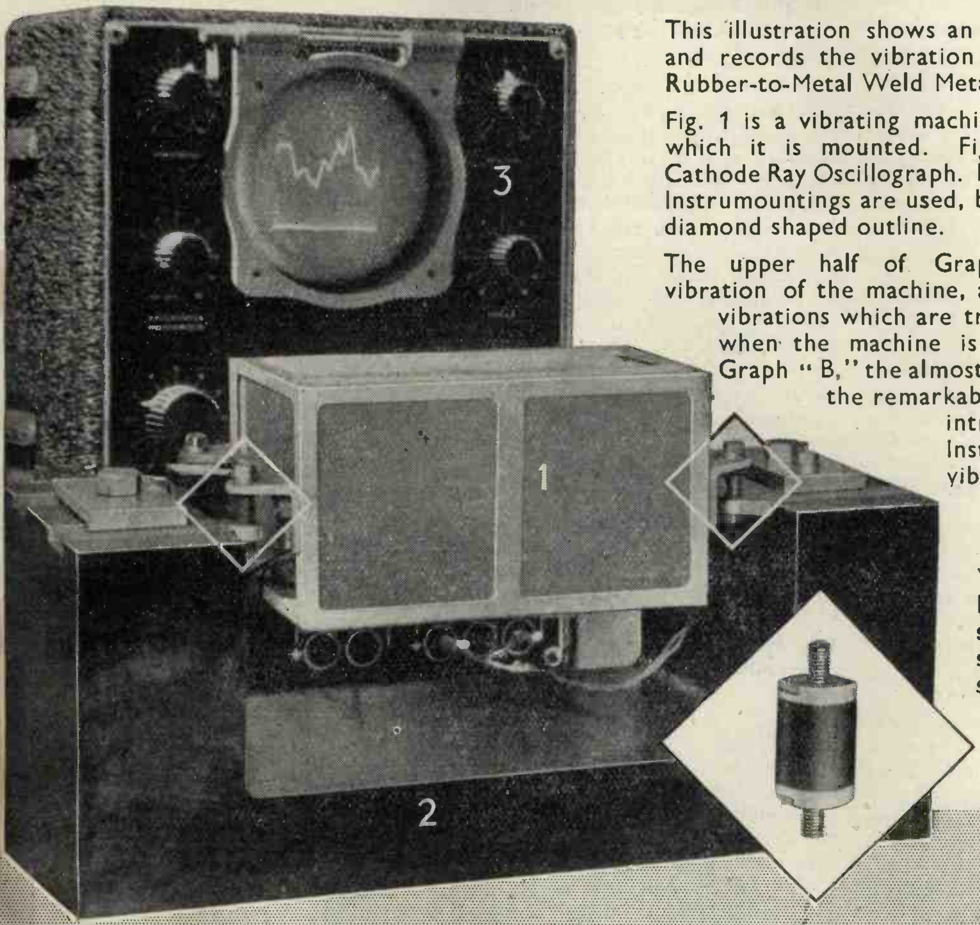
Mr. Cosgrove was first elected to the directorate of the RMA in June, 1941, and has been active in the affairs of the association for some time.

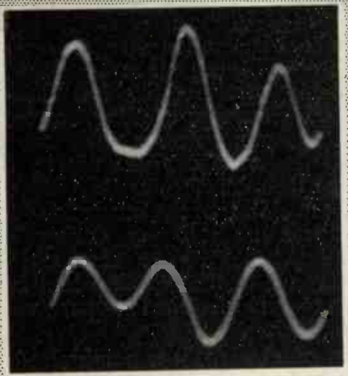
New Packing Method for Valves and C.R. Tubes

A revolutionary new principle of packing radio valves which, if utilised by the valve industry, will result in major contributions to the war effort in shipping space, material, handling and warehousing savings, has been developed by the manufacturers of RCA radio valves.

To extend the value of the new packing principle more quickly, RCA has granted patent rights to the new type cartons to other valve manufacturers. In addition, other valve manufacturers have been shown factory routines that have been developed to make the most efficient use of the new process.

In handling receiving valves alone, savings of 30 per cent. in material were found to have been achieved by the new methods. Factory handling efficiency has been stepped up 20 per cent., loss by breakage has been materially reduced, as has the need for storage space. It is now possible to pack 647,500 valves of a given type into a single boxcar, an increase of nearly 100 per cent. in capacity.





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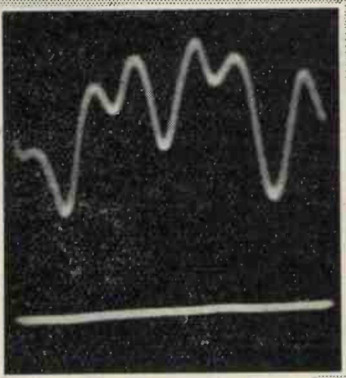

"B" WITH METALASTIK.

ABSTRACTS OF ELECTRONIC LITERATURE

CIRCUITS

Frequency Division without Free Oscillation

(*D.G. Tucker and H. J. Marchant*)

A system of frequency division is described which does not involve locked oscillators; very constant phase relations are obtained and the production of an output frequency is dependent on the presence of the input frequency.

—*P.O.E.E. Jour.,* Vol 35, Part 2 (1942), page 62.

A Voltage Stabiliser for a D.C. Generator

(*W. M. Schwarz*)

A simple stabiliser for a cyclotron magnet is described, which stabilises the voltage across the magnet within one part in 2,000. It acts as a variable resistance in parallel with the generator field, which remains shunt connected to the armature.

—*Rev. Sci. Inst.,* Vol. 13, No. 5, page 213.

Emission-Regulating Circuit for an Ionization Gauge

(*R. B. Nelson and A. K. King*)

A description is given of the design and operation of a circuit employing gas-filled tetrodes to maintain constant electron emission in an ionisation gauge by controlling the filament temperature. Performance data is given to show that variations in the electron emission due to fluctuations in line voltage or changes in the pressure in the ionisation gauge have been to a large extent eliminated.

—*Rev. Sci. Inst.,* Vol. 13, No. 5, page 215.

A Carrier-Frequency Heterodyne Oscillator

(*K. W. Bourne*)

A carrier frequency heterodyne oscillator is described having a frequency range 50 c/s to 170 kc/s and developed on similar lines to the earlier Ryall-Sullivan oscillator.

—*P.O.E.E. Jour.,* Vol. 35, Part 2 (1942), page 65.

ELECTRO-MEDICAL

Hearing Aid Design

(*I. Kamen*)

A survey of various common types of deafness, with statements of how they may be overcome by appropriate hearing aids. The design of a modern, compact hearing aid is given.

—*Electronics,* Vol. 15, No. 7 (1942), page 32.

MEASUREMENT

Power-Circuit Instruments for the Higher Range of Audio Frequencies

(*L. J. Lunas and P. MacGahan*)

The extended use of frequencies in the range 900 to 12,000 cycles to induction furnaces, etc., introduces problems of measurement due to high coil reactances and eddy losses which are relatively unimportant at other frequencies. Thermal instruments used for communication purposes at audio frequencies are unsuitable for power equipment because of their small overload capacity and slow response. The types of instruments best suited for measurement of current, voltage, true power, wattless power and power factor at these frequencies and special arrangements for reducing their errors are discussed. An elementary diagram of instrument connexions for a typical installation is shown. In conclusion, the special requirements of instrument calibration for this frequency range are considered.

—*Supplt. to El. Engg.,* December, 1941, page 1,230.*

The Measurement of the Loss Coefficients of Magnetic Dust Core Materials

(*V. G. Welsby*)

The author describes a method by which the losses in a toroidal dust-cored coil may be measured and those associated with the winding eliminated to allow the loss coefficients of the core material to be determined.

—*P.O.E.E. Jour.,* Vol. 35, Part 2 (1942), page 46.

Direct Pen Recording of Galvanometer Deflexions

(*D. J. Pompeo and C. J. Penther*)

An instrument is described which records directly the deflexions of a light beam pointer without recourse to photographic development processes. The recording is easily accomplished at pen speeds of 12.7 cm. per second across 25 cm. of chart without "hunting" taking place. The pen follows the light beam from an external galvanometer by mounting a double cathode photo-cell on the pen carriage so that both move as a unit. By means of valve amplifiers operating a reversible motor, the pen carriage moves to the left when the light beam deflects to the left on to the left photo-cell cathode, and to the right when the right photo-cell cathode is exposed.

A movement of the light beam as small as 0.1 mm. causes a corresponding movement of the pen.

The instrument has been satisfactorily used, with considerable saving in time, for recording current-voltage curves in polarographic analysis, for obtaining infra-red absorption curves, and for recording ion currents in mass spectrographic work.

—*Rev. Sci. Inst.,* Vol. 13, No. 5, page 218.

THEORY

Characteristic Impedance of Parallel Wires in Rectangular Troughs

(*S. Frankel*)

The method of conformal transformation and the method of images are employed jointly to deduce the characteristic impedance of a balanced two-conductor transmission line and of a balanced three-conductor transmission line symmetrically surrounded by perfect, rectangular, earthed, conducting surfaces. It is assumed that (1) the wires are of circular cross-section, of diameter small compared to the distance between them and small compared to the distance from the wire to any side of the surrounding surface and (2) the wires are perfect conductors.

—*Proc. I.R.E.,* Vol. 30, No. 4 (1942), page 182.

INDUSTRY

Properties and Characteristics of Formex Wire

(*Curtin*)

The initial dielectric strength of Formex wire which has a coating of a synthetic resin of the polyvinyl acetal type, is much the same as that of conventional enamelled wire, the essential difference lying in the fact that Formex wire retains its dielectric strength during winding, assembly, etc. The main properties of the wire, methods used for determining these properties and various tests for proving the ability of the insulation film to maintain its integrity during harsh treatment similar to that which it undergoes in the winding and manufacture of electrical apparatus are described.

In conclusion, it is emphasised that the superior properties of Formex wire enable long-needed changes in manufacturing procedure and apparatus design to be made.

—*G.E. Review,* May, 1942, page 285.*

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* Supplied by the courtesy of Metropolitan-Vickers, Ltd., Trafford Park, Manchester.

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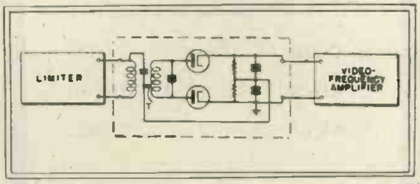
PATENTS RECORD

The information and illustrations on this page are given with the permission of the Controller of H.M. Stationery Office. Complete copies of the Specifications can be obtained from the Patent Office, 25, Southampton Buildings, London, W.C.2, price 1s. each.

TELEVISION

Suppression of Interference in F.M. Television Images

It is known that undesired signals are most objectionable when they are primarily effective in the region of the black shade value of the reproduced image. Frequency-modulation receivers are equally subject to disturbing reproduction of spurious noise components in the black region of the reproduced image. This patent provides a means for translating the derived voltages in the detector so that components of the received signal, having a frequency corresponding to a black shade value, are always detected within a portion of the operating range of the detector over which it is substantially less responsive to undesired signals. By adjustments of the tap T the output characteristic of the detector may be made substantially asymmetrical with respect to the mean carrier frequency. The circuit is adjusted by means of the tap T so that the balance point of the detector coincides with the carrier-signal frequency corresponding to the black shade value of the transmitted image.—*Patent No.* 546,323. *Hazeltine Corp.* (*Assignees of J. C. Wilson*).



C.R. Tube Screens

A method of forming a fluorescent layer on a support which includes heating a mixture of hydrogen sulphide and oxygen and depositing sulphur produced by the combustion upon the support to form a binding layer of the fluorescent material. The proportion of hydrogen sulphide to oxygen in the mixture is not less than one to one.—*Patent No.* 546,216, *Electrical Research Products.*

Sound Reproduction

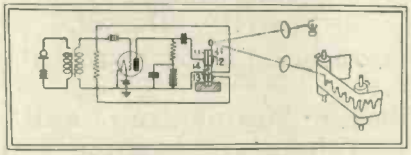
A system for reproducing recorded sounds from a localised reproducer and automatically reproducing the same sounds from separated reproducers. The automatic method is under the control of means synchronised with the sound record.—*Patent No.* 546,077. *Radio Corporation of America.*

CIRCUITS

Negative Feedback in Piezoelectric Crystals

The invention takes advantage of the fact that a piezoelectric motor may be made to serve also as a piezoelectric generator. In other words, a piezoelectric device connected to the output circuit of an amplifier may be used to develop an entirely distinct e.m.f. which is proportional to the actual displacement obtained from the piezoelectric crystal.

The use of electromechanical devices constructed from elements of Rochelle salt or other piezoelectric materials for such purposes as oscillographs, recorders, loud speakers, etc., has been handicapped by the fact that such piezoelectric devices have a non-linear operating characteristic. Among the reasons for this are the hysteresis of the piezoelectric material and the variation of dielectric constant, etc.



In the patent, electrodes 11 and 12 are associated with a piezoelectric relay unit having two sets of electrodes or coatings. A second smaller set, 13, 14, from which the feedback energy is taken to the input of the amplifier, is mounted on the same piezoelectric plates, but insulated from the electrode 11 and 12 in order to function independently.

In operation, if the temperature increases and the piezoelectric efficiency of the material falls off, there will be a small electromotive force generated between plates 13 and 14 and therefore a lower reverse e.m.f. will be applied to the grid and the amplification of the valve will correspondingly rise.

For complete stability of feedback amplifiers against singing, it may be necessary to use a suitable network in the feedback path connected between the coatings or electrodes 13 and 14 and the amplifier input circuit. As the piezoelectric crystal has not only a natural resonance response frequency, but also third and higher harmonic response frequencies it is necessary to take these into account in the design of the network.—*Patent No.* 546,182. *Electrical Research Products.*

A circuit for stabilising the frequency of an oscillation generator modulated in frequency by a reactance valve which receives modulation energy on a control grid. Part of the oscillator output is tapped off and beats with the output of a constant frequency, *e.g.*, a crystal controlled oscillator. The resulting variable frequency is passed through an amplitude limiter to a rectifier by a reactance, to distinguish between wave energy of the beat frequency and that of other frequencies. The output of the rectifier is applied through time constant elements to another control grid of the reactance valve.—*Patent No.* 546,168. *Marconi's Wireless Telegraph Co.* (*Assignees of J. L. Hathaway*).

MEASUREMENT

Measuring Quality and Quantity of X-radiation by C.R. Tube Indication[*]

Two antimony-caesium vacuum photo-electric cells are each connected in a circuit comprising in series the photo-cell, a battery, and a resistance to which a condenser is connected in parallel by a suitable switch. The voltages across the two resistances are applied respectively to two pairs of deflector plates in a C.R. Tube. In front of each photo-cell, a fluorescent screen, of the zinc-sulphide type, *e.g.*, a Levy-West visual-fluorescent screen, is interposed in the path of the X-rays to be measured. A copper or aluminium screen is also interposed in the path of the X-rays to the fluorescent screen of one of the two systems. The tube screen is marked with a number of straight parameter lines passing at different angles through the intersection of the two axes (which is the point corresponding to the undeflected beam). Each line corresponds to a predetermined ratio of the deflexions caused by the filtered and unfiltered X-rays respectively. The harder the X-rays to be measured, the greater will be the ratio of deflexions, so that the hardness of the X-rays, expressed for example by their half-layer value or the KV figure, can be indicated as a parameter at each line of the scale.—*Patent No.* 546,095, *R. H. Herz.*

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[*] See also *Brit. Jour. Radiology*, April 1942, page 110.—Ed.

U.I.C

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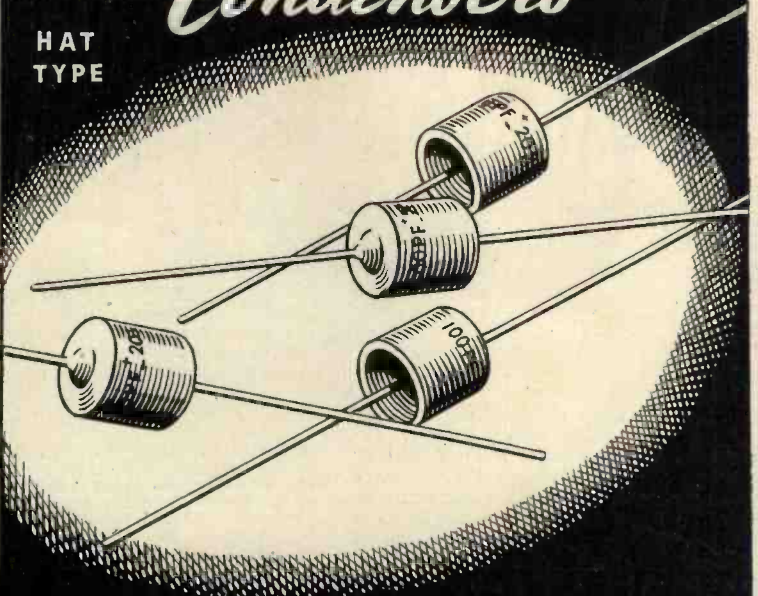

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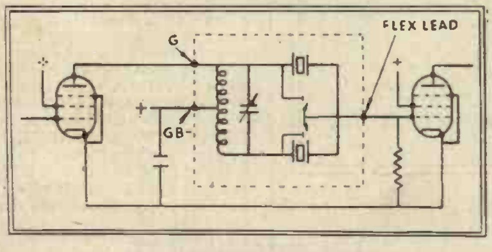

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Aerovox 40 mfd. 200 volt Condensers, for Midget Receiver, at	6/6
Aerovox 32 mfd. × 32 mfd. 175 volts Condenser, for Midget Receiver, at	6/6
Dubilier .1 mfd. 6,000 volt working condenser; at	6/-
First grade N.S.F. Tubular Condensers, .1 and .01 mfd. 350 volts ... each	6d.

INTERVALVE TRANSFORMERS

I.F. 465 Kc. square can type	6/-
I.F. 465 Kc. small cylindrical	4/-
Low frequency small shrouded, 3.1 ratio, 3/6 ; heavier type	5/-

VALVE HOLDERS

American Octal chassis mounting (Paxolin)	4d.
Ceramic (Amphenol) 5-pin, U.S.A. ...	2/-
Ceramic 4 and 5, British	1/-
Side Contact Valve Holder, for E series valves	6d.

MISCELLANEOUS ITEMS

Push Back Insulated Flex (single), doz. yds.	1/-
Resistance Cord for A.C./D.C. Receivers, 100 ohms., per ft. per ft.	2/-
Flexible Couplers for ¼in. shaft rubber insulation, each	4d.
80 ohm. Concentric Cable (½in. diam.), maximum length 150 ft., per ft.	8d.
Collapsible Microphone Stands ...	42/-
Highest quality Moving Coil Microphone, with transformer ...	£5 5s. 0d.
Potentiometers and volume controls—all usual values from stock	4/6
Midget type Centralab	5/6
Phillips Loudspeaker 8½in. P.M. 3.5 ohms. speech coil	17/6
45 volt Burgess High Tension Batteries, heavy duty	14/8

Additional charge of 1s. for postage and packing on orders below 10s.

WEBB'S *Radio*

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