of the nineteenth century. Captured French ships were indeed used as models for British warship construction. The reason for the superiority of French vessels was that their design was based on scientific principles, whereas British naval architecture of that time was a rule of thumb affair. Sir James Graham, who as First Lord of the Admiralty abolished the early schools of naval architecture, stated in the year 1861 that his reason for closing the schools was that "there was too much science and too little practical knowledge creeping into the Navy." The new high elastic limit steel gave tensile figures of from 15 tons to 17 tons per square inch, compared with a stress figure of 10 tons to 12 tons for mild steel. The modulus of elasticity for the two steels was the same.

SECTION A.

WIRELESS WAVE PROBLEMS.

Dr. R. L. Smith-Rose contributed to Section A an account of a study of wireless wave fronts by directional methods. He said that all the existing types of wireless direction finders operating by reception of the desired signals, made use of the fact that for a simple wireless wave propagated along the earth's surface the magnetic force was horizontal, and perpendicular to the vertical plane of propagation of the wave. Such direction-finders used in principle a closed loop in a vertical plane capable of being rotated about a vertical axis. A large amount of systematic investigation carried out with such direction finders during the last four years had brought to light many definite facts concerning the behaviour of those instruments in the process of ordinary wireless communication. These facts could be grouped under (1) errors due to local conditions, (2) diurnal variations, (3) land and sea effects and application to navigation, and (4) flat minima and rotating magnetic forces. Methods had been devised for a complete determination of the directions of both magnetic and electric forces, and used to study the propagation of waves under daylight and night conditions.

Dealing with diurnal variations, the author said that on moderate wave lengths, between 450 m. and 2000 m., the variations experienced during the hours of full daylight had an extreme value of about 7 deg., representing a departure of the horizontal magnetic field from its normal direction of less than 4 deg. As sunset was approached those variations increased in frequency and magnitude until from about one hour before sunset to about one hour after sunrise, the apparent direction of arrival of the waves varied rapidly on either side of the true direction over an arc which was often 10 deg. or 20 deg., and might occasionally exceed 90 deg. On the longer waves, of length 2000 m. to 13,000 m., the difference between the effects observed by day and night appeared to be less marked, particularly during the winter months. Within the limits of the investigation so far conducted, no difference between the use of damped and undamped waves or due to varying shapes and dimensions of aerials employed at transmitting stations had been observed, and no consistent evidence had been obtained that the direction in which the transmission was made exercised any influence.

When the transmitting station and the direction finder were so situated that the path of transmission was entirely over land, the difference in variations by day and night became apparent at distances of about 30 miles. When, however, the path of transmission was entirely over sea, the minimum distance for serious variation was increased to about three times the above value. That was very fortunate, as the ranges at which wireless direction finding was required in marine navigation were seldom greater than 50 and never more than 100 miles; and a suitable choice of the land station ensured that that range was entirely over sea. Under such conditions, the great majority, about 95 per cent., of the observed bearings fell within a 2 deg. limit of error, which was found to be adequate for most navigational purposes. When the line of transmission was almost parallel to a coast, there was a liability to errors due to a coastal refraction effect, and it would probably be customary in the future to mark all charts with "arcs of good bearings" for the various land stations used for direction finding. The above facts had been established almost entirely for damped wave transmission on a wave length of 450 m., and there was as yet no definite evidence that they would need modification by the employment of undamped waves or of any other wave lengths within reasonable limits.

Dealing with methods for the complete determination of the direction of the magnetic and electric forces which were described in some detail, the author stated that when these methods were used to delineate the directions of the electric and magnetic forces in wireless waves at times and under conditions which were known to give freedom from interference by night effects and local errors, it was found that the magnetic force was horizontal and at right angles to the direction of propagation. The electric force, however, was found to be nearly, but not quite, vertical, being actually tilted forward by a small amount in the vertical plane of propagation of the wave. It was also found that in that plane the electric force was of slightly elliptically polarised form. That was in exact confirmation of the theoretical prediction of Zenneck as to the modification produced when the wave was propagated over an imperfectly conducting earth instead of over a perfect conductor. In accordance with that theory, the experiments showed that the forward tilt of the electric force increased with a reduction of the wave length employed. The values actually measured in Great Britain ranged from about 0.5 deg. on 6900 m. to nearly 3 deg. on 350 m. wave length. From those angles the effective conductivity of the earth at the wireless frequencies employed could be obtained.

One of the most promising theories of wireless wave propagation over the earth's surface, which had been put forward for the explanation of long-range transmission and the variations experienced in both signal strength and apparent direction of arrival of the waves, implied the reception of one or more waves from the upper atmosphere, in addition to the wave propagated directly along the earth's surface. If the down-coming wave was partially or completely polarised with its magnetic force in a vertical plane, an explanation of the variations of apparent bearings on wireless direction finders was obtained without the necessity of the direction of propagation of the waves departing from the great-circle plane between transmitter and receiver.

It might be thought at first that the detection of the existence of such a down-coming wave would be a comparatively easy matter by determining the directions of the electric and magnetic forces which resulted at the receiver. It must be remembered, however, that with the above value of conductivity the earth's surface would act as a moderately good reflector, and the incidence of a down-coming wave would give rise to a reflected wave which might have an amplitude nearly equal at its maximum to that of the incident wave. The combined effect of the two waves was, briefly, to give a resultant electric force which had no horizontal component, and a resultant magnetic field which had no vertical component. Such a wave therefore became difficult to distinguish from a horizontally propagated wave by directional measurements, since the departures of the directions of the two forces from their normal values was only a residual effect. Indeed, it could be shown theoretically that on the long and moderate wave lengths such departures would be only fractions of a degree, but that on the shorter wave lengths the angles involved might become measurable under certain favourable conditions of phase amplitude and angle of incidence. This had been partly confirmed by experimental observations made during the last eighteen months. Employing the waves from various transmitting stations using wave lengths between 2.6 kiloms. and 12.4 kiloms., the maximum departure of the directions of the electric and magnetic forces from their normal values had been about 1 deg., which was considered to be scarcely greater than the possible error of the apparatus employed. Many of these experiments were carried out at night and for distances of transmission known to give rise to the well-known night effects, these being instanced by variations in apparent bearings ranging up to 23 deg.

On the shorter wave lengths the practical difficulties increased considerably, but some recent measurements made on 385 m. had shown that under suitable night conditions the resultant electric force might depart as much as 12 deg. from the normal "day" value, while the resultant magnetic force might be inclined at 5 deg. to the horizontal. These results appeared to be very promising and to indicate that progress was being made in the right direction. It should, of course, be understood that such measurements alone would not enable the nature of the arriving waves to be completely defined. Experiments were, however, now being carried out at the Radio Research Board's station at Slough, in which these observations were made simultaneously with the measurement of various other parameters of the forces of the arriving waves, the results of which would probably throw light on the problem of the propagation of wireless waves over the earth's surface, which had recently become perhaps the most important scientific subject in wireless research.

SECTION G.

FLYING BOAT DESIGN.

Recent progress in flying boat design was the subject of a contribution by Mr. O. E. Simmonds.

The author said that he would consider separately the development in hydro-dynamic and constructional design. The seaplane had initiated a new branch of hydrodynamics. In the design of the flying boat hull very careful consideration had to be given to static trim. It was most desirable when at rest to keep the centre of buoyancy well forward, so that the flying boat could be treated both when at anchor and when moving at low speed, as if she were a surface craft. Hump resistance was originally a point of prime importance, and presented considerable difficulty, which had to some extent been removed. A decreased resistance had been obtained, due to an improvement in hull lines and a lower power loading, which was the result of a demand for higher performance in flight. The increase of power was reflected in the improved water performance of aircraft. Surface tension must, of course, be reduced to a minimum, and the design must be such that the hull would run steadily on a gradually diminishing planing surface until the speed enabled the wings completely to sustain the aircraft. Porpoising was now abolished, and a well-designed hull would run steadily at such an angle that the wings simultaneously gave their maximum lift. The most important point in the development of the hull had been the all-round improvement of water performance, together with increased strength and ability to ride out heavy seas without any increase in the weight economy figure. Various methods of supporting and stiffening the shell of the boat were in use, but they were all based on some form of transverse frame or hoop, with longitudinals at about 6in. Hulls built in this manner gave long and efficient service, but possessed the disadvantage that they absorbed moisture. In a wooden hull weighing 2000 lb., the soakage in three months would amount to 15 per cent. of the hull weight, or 2 per cent. of the total weight of the aircraft. That fact had been one of the great inducements to substitute metal for wood in hull construction. Duralumin outclassed stainless steel in strength for weight, but in other respects stainless steel had very definite advantages. He would commend the evolution of a light malleable non-corrosive alloy to those metallurgists who had not yet interested themselves in that problem. The trouble which would arise in the case of steel was that the sheets for the skin of the boat would have to be thinner than was practically possible in order to realise the full comparative efficiency figure. The largest successful flying boats yet built weighed about 30,000 lb., and it would probably be necessary to reach the weight of 100,000 lb. before steel could supplant duralumin for hull construction. Some designers considered that by the use of duralumin instead of wood, the hull weight could be reduced by as much as 20 per cent., but it was difficult to obtain reliable comparative figures.

In the case of the superstructure of the flying boat, improvement had been effected in aero-foil characteristics, and in the reduction of parasitic drag. A large variety of aero-foil sections was now available, and the particular section used in any aircraft could be chosen with strict reference to the characteristics of the machine and the requirements in performance. The drag of aero-foil sections had been progressively reduced, and the maximum lift by the utilisation of adjustable slotted leading and trailing edges could be almost doubled. It had been suggested that the principle of the Flettner rotor should be utilised, but considerable difficulties were involved. Another problem to which increasing attention was being paid was the reduction of the movement of the centre of pressure. In the reduction of parasitic drag the utilisation of thicker wing sections had been of the utmost importance. It was left to Dr. Prandtl, of Göttingen University, to show that aero-foils could be designed having twice the relative thickness of the normal thin section of about 10 per cent. camber without loss, and indeed in certain cases with very considerable gain of aerodynamic efficiency. The constructional development of the flying boat was more advanced than that of the hull. Metal construction had received a great deal of consideration. Development had proceeded along two distinct lines. In one method the wing stresses were concentrated in two or more spars, while in the other, the skin of the wing was designed to transmit the load. For a multiplane structure, the separate spar method was to be preferred with built-up spars. The modern flying boat was replete with equipment, and boats of over 30,000 lb. could be fitted with small marine motors for use in case of complete engine failure. Progress would have been slow if by the end of the next decade a boat of 100,000 lb. gross weight had not been built. A commercial machine of that class would be a steel monoplane of about 6000 square feet wing area and 220ft. span. The power units would be housed in engine-rooms built into the thick wing some 30ft. out from the hull, and the output from each room at full revolutions would be some 3000 brake horse-power. The speed would exceed 100 knots, and the boat could undertake flights up to 1500 miles without alighting, carrying 100 passengers. By slightly reducing the number of passengers, therefore, such a boat could fly from Europe to America, with only one stop at the Azores, and accomplish the whole flight within thirty-six hours.

Rectifiers.

No. IX.*

No scientific invention has aroused more general interest than the thermionic valve. As originally devised by Professor Fleming, it had two electrodes and was used exclusively for rectifying feeble currents. Subsequently Dr. de Forest, of America, added a third electrode known as the grid, thereby making the valve capable of amplifying. Here, however, we are only concerned with the valve's rectifying properties, which were practically discovered years ago. In 1883 Edison observed, whilst experimenting with electric lamps, that if a positively charged electrode in the form of a metal plate, were introduced into a lamp bulb—see Fig. 83—current would flow from the heated filament to it, although no current flowed when the electrode was connected, through

* No. VIII. appeared September 11th.

the galvanometer, to the negative end of the filament—as shown on the left of Fig. 83. To this phenomenon Edison appears to have attached little importance. Among those who took an early interest in the so-called "Edison effect," however, and who tried to explain the reason for it, was Professor Fleming, who carried out some interesting investigations, the results of which he communicated to the Royal Society of London in 1889, and the results of a further investigation to the Physical Society of London in 1896.

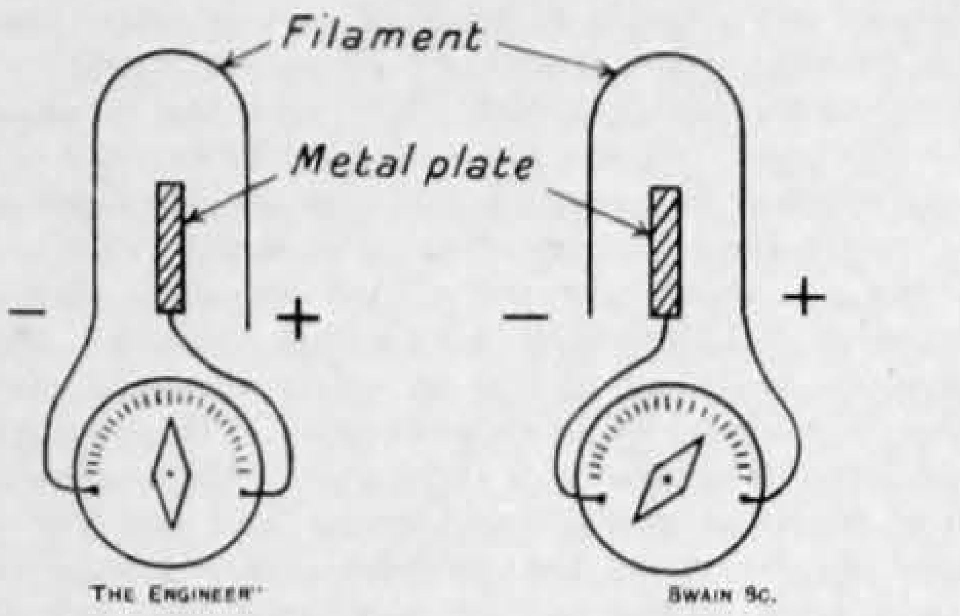


FIG. 83—THE EDISON EFFECT

Elster and Geitel in Germany were also early investigators in this field, but it is not our intention to probe very deeply into history. One of the most significant facts that should be mentioned is that the discovery of the electron in 1897 by Professor J. J. Thomson, and his experimental proof in 1899, that electrons were given off by incandescent carbon filaments removed much difficulty from the path of those who had been trying to understand the cause of the Edison effect. By 1903 Professor O. W.

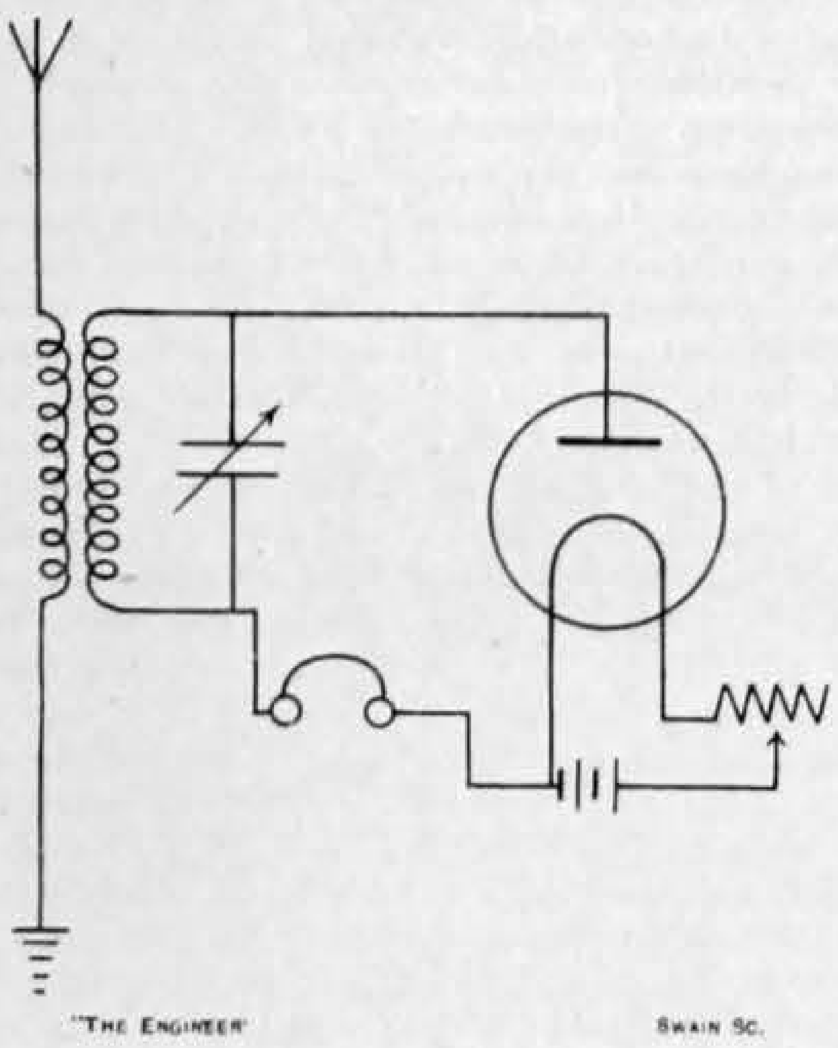


FIG. 84—FLEMING TWO-ELECTRODE VALVE

Richardson had evolved a formula connecting the number of electrons emitted with the temperature of the filament, and in 1904 Professor Fleming invented the two-electrode valve. This was undoubtedly the first attempt to use the thermionic emission from an incandescent filament of metal or carbon, for the purpose of rectifying high-frequency alternating currents, and so to detect the feeble electric oscillations in a wireless telegraph receiving circuit by some form of galvanometer or by a telephone.

Using specially constructed lamps with a metal cylinder surrounding the filament and connected to a wire passing through the glass, as employed for studying the Edison effect, Fleming carried out experiments with a view to discovering whether this arrangement could convert high-frequency alternating current into direct current. It was immediately found that the device would perform this function quite well, and the Fleming two-electrode valve was consequently evolved for wireless receiving purposes. As a detector of signals it proved to be about as sensitive as a crystal, but it had the very marked advantage of being much more stable. As long as the filament was robust enough to stand up to a certain amount of rough handling the valve could be relied upon to operate under circumstances under which a crystal detector would constantly be thrown out of adjustment. The original method of using the Fleming two-electrode valve as a detector on a coupled circuit is shown in Fig. 84.

When positively charged the anode of a two-electrode valve causes the electrons emitted by the heated filament to move across the space between the latter and the anode. In other words, a current flows between the two, but the electron flow cannot occur in the opposite direction. The two-electrode valve, therefore, acts as a rectifier. When a grid is introduced between the anode and filament, the flow of electrons from the latter to the former can be controlled. If the potential of the grid becomes positive with respect to the filament the electron current is increased because the grid potential assists that of the anode, whilst a negative grid potential reduces the flow of electrons from the filament to the anode,

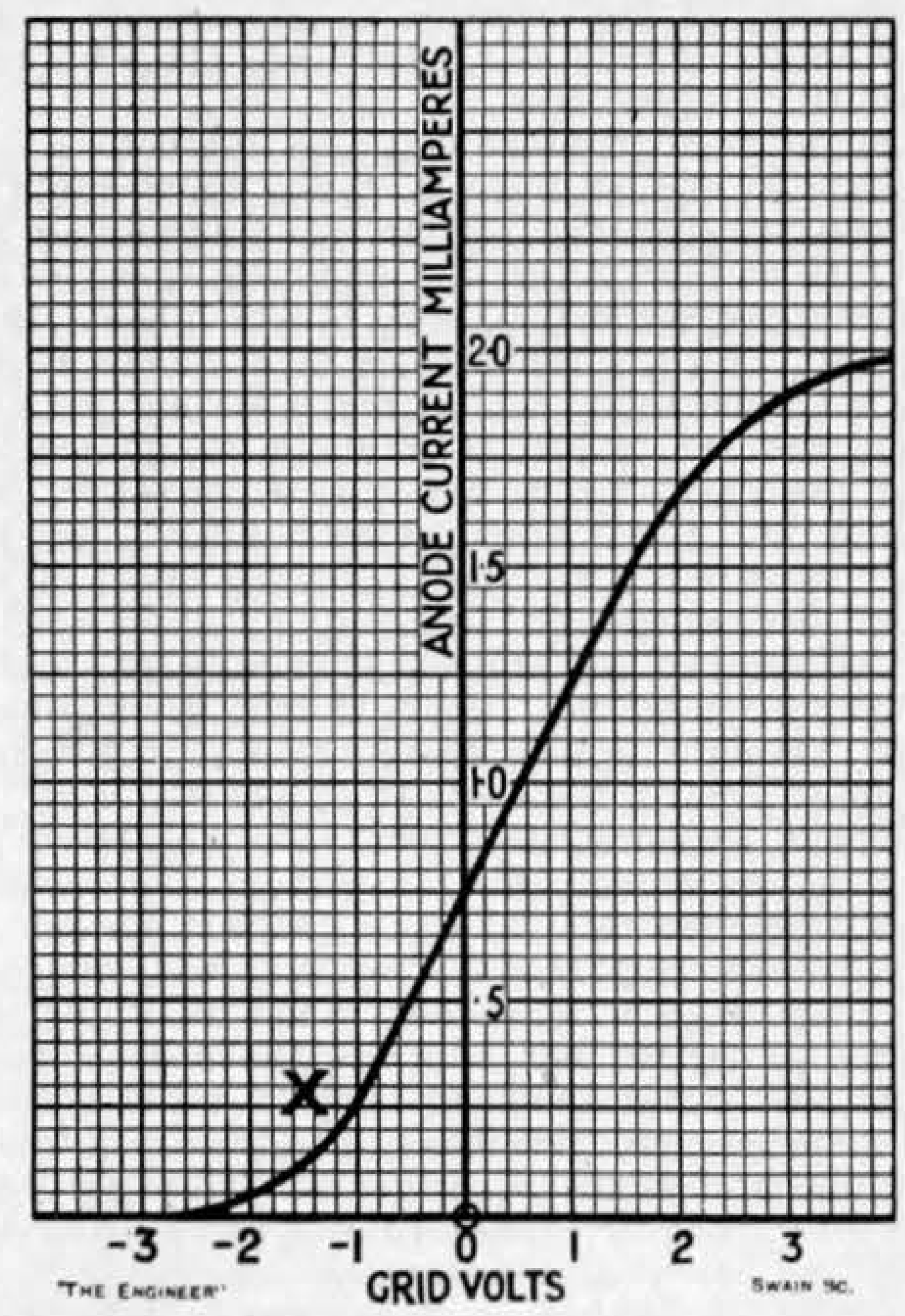


FIG. 85—GRID VOLTS AND ANODE CURRENT

for the grid potential is then in opposition to that of the anode. The grid potential, therefore, controls the anode current—small variations in the grid voltage producing relatively large variations in the anode current, or, in other words, oscillations reaching the grid will produce similar oscillations of much greater amplitude in the anode circuit.

Because of its superior performance the three-electrode valve is now employed on an extensive scale for rectifying received signals, and there are two methods of making it do so. Suppose that by means of a potentiometer the grid potential has been adjusted so that the working part of the valve is at the point X in Fig. 85, and that the half-cycles of the incoming oscillations are alternatively one volt positive and one volt negative. As the characteristic curve above the point X is straight, a positive potential of one volt on the grid will clearly produce a large increase in the plate current. Below the point X, however, the characteristic curve has a sharp bend, with the result that a negative grid potential of one volt will only result in a very small decrease in the plate current. The tops of the waves will, therefore, be responsible for a large increase in the current, whilst the lower parts or troughs produce only small diminutions, and rectification therefore occurs. But in these days this method of rectification is not widely used. A much more common method being the grid leak and condenser or cumulative grid rectification method. Mullin and Turner have dealt very thoroughly with the three-electrode valve as a rectifier,† but it will suffice to give here the usual simple explanation due in the first place, we believe, to Mr. Edwin Armstrong.

† See the *Journal* of the Institution of Electrical Engineers, Vol. LX., page 706.

The function of the small condenser C—Fig. 86—is to insulate the grid so far as the passage of direct-current is concerned, although it does not hinder the passage of the high-frequency currents. When signals arrive at the receiver the grid is subjected to alternate negative and positive potentials, which occur with great rapidity. During the extremely short interval when the grid is positive, the grid current is larger than it is normally—more electrons pass to the grid than is the case when no signals are being received, but during the next short interval, when the grid is negative, no further electrons arrive nor can any escape through the condenser. As the grid leak G L has a resistance of several megohms and the time interval is extremely short, relatively few electrons escape by this path. The net result is that the grid is given a slight negative potential. Each succeeding oscillation adds a further negative charge to the grid, and the negative potential thus acquired by the grid causes a decrease in the anode current. When the signal impulses cease the grid gradually recovers its normal potential; the negative charge draining away through the grid leak in the relatively long quiescent period before the arrival of the next signal. During the succession of high-frequency wave trains, therefore, there will be a corresponding succession of diminutions in the anode current, and these pulsa-

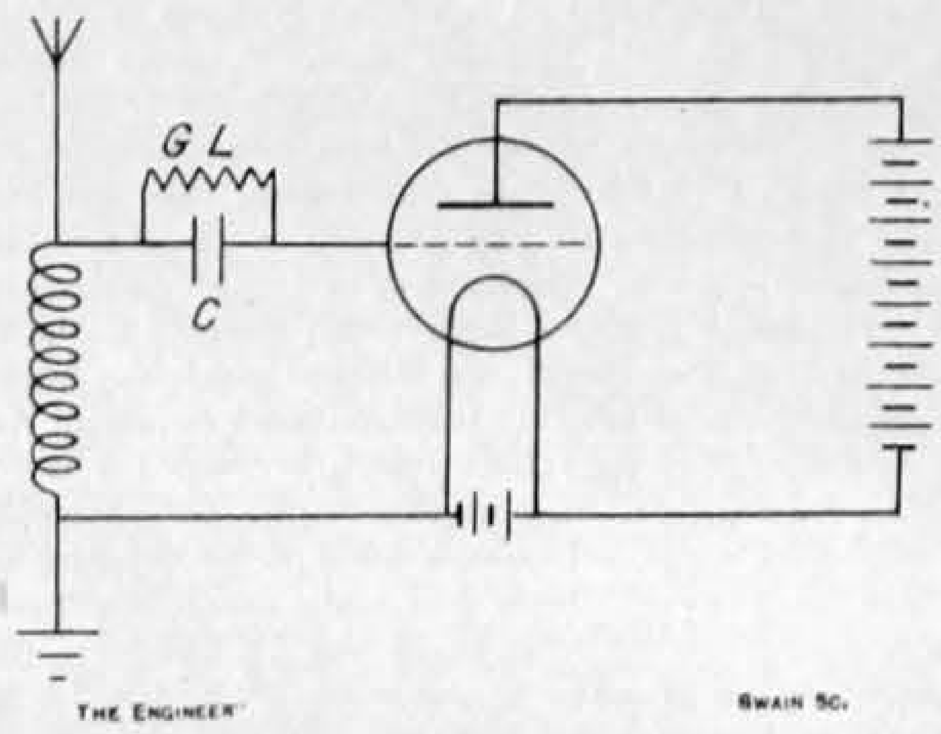
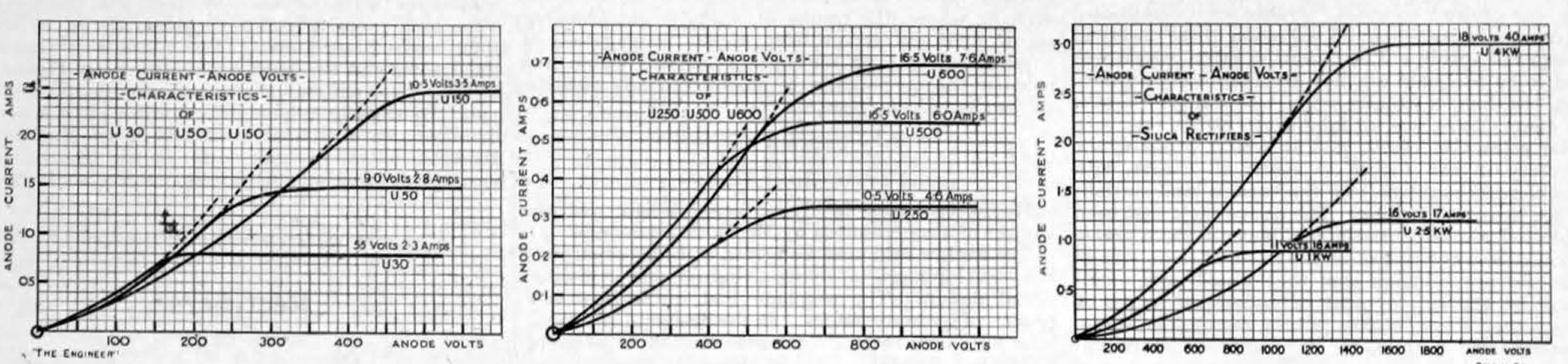


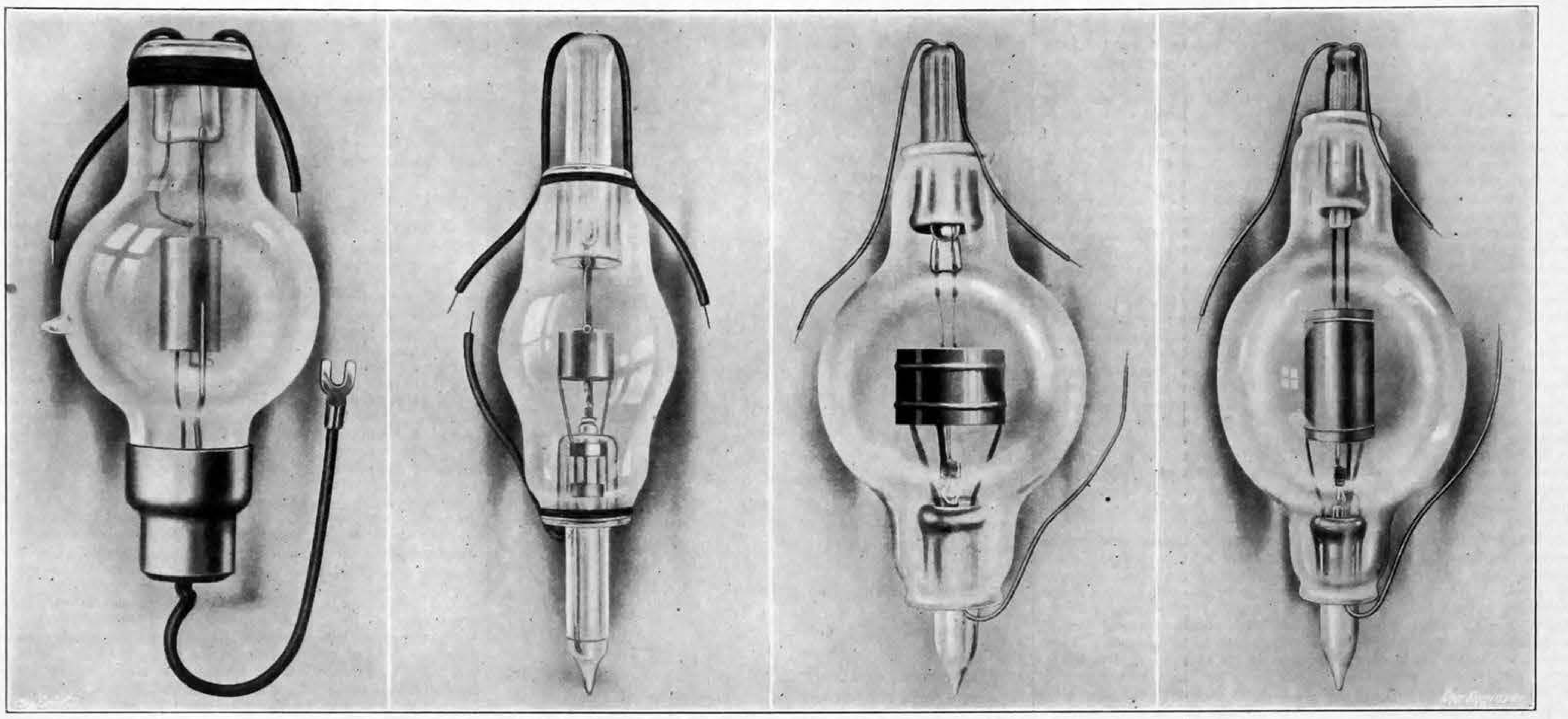
FIG. 86—CUMULATIVE GRID RECTIFICATION

tions make themselves evident in the telephones. This method has certain advantages over the previously described method; its main disadvantage being that a strong atmospheric may charge the grid to such a high potential that it takes an appreciable time for the charge to leak away, and during this time the detector will be insensitive to signals with an amplitude lower than that of the atmospheric.

One of the most convenient methods of obtaining a direct-current supply at high voltages for wireless transmitting purposes is to transform an alternating-current supply to a suitable voltage, and then to rectify it by means of two-electrode valves; the resulting pulsations being smoothed into practically steady direct-current by using chokes and condensers; but it is important to observe that for a given smoothing effect the values of the inductances and capacities vary inversely as the frequency of the alternating-current supply, so that it is advisable to use as high a frequency as is consistent with efficient generation and transformation. The rectifying valves made by the Mullard Radio Valve Company range from valves designed to deal with the lowest powers and voltages possible up to valves capable of passing three ampères electron current at reverse pressures up to 50,000 volts. As already noted, when a heated filament is surrounded by a cylindrical conductor in a vacuum, a current will flow from the filament to the surrounding cylinder if the latter be maintained at a positive potential with respect to the filament. The magnitude of this current depends upon the potential of the anode, its dimensions, and upon the temperature, nature and area of the filament. If the filament conditions and anode dimensions be kept constant, the current will increase rapidly with the anode potential until saturation occurs; that is to say, when the maximum rate of supply of electrons from the filament is reached. A further increase in anode potential will not cause any further increase in anode current, unless the filament temperature be raised, when a second saturation point will be reached at a higher value of anode



FIGS. 87 TO 89—CHARACTERISTIC CURVES OF MULLARD GLASS AND SILICA RECTIFYING VALVES



FIGS. 90 - 93—MULLARD GLASS RECTIFYING VALVES

current corresponding to the increase in filament temperature. When using rectifying valves, therefore, it is important to pay attention to the adjustment of the filament temperature in order to obtain maximum efficiency and long life. If the filament temperature be unduly low the apparent impedance of the rectifier will be high, and as the distribution of potential in the direct-current supply circuit depends on the impedance of the several sections, the potential drop across the rectifier will also be high with corresponding large power dissipation and heating of the anode. If the filament be run at a high temperature with unnecessarily high electron emission, when supplying a light or high impedance load, then the anode will remain cool, but the reduction in the life of the filament will be considerable. Generally the Mullard Radio Valve Company advocates employing a rectifier of such dimensions that under normal working conditions the anode appears dull red, when the filament current is switched off. The most convenient arrangement for supplying the filament current is a transformer with a highly insulated secondary winding, a choke or auto-transformer providing the regulation of the primary voltage. The following table gives the maximum voltages suitable for Mullard rectifying valves :—

	Maximum R.M.S. voltage of transformer double-wave rectification.	Maximum voltage of D.C. supply.
U/30	1,750	1,100
U/50	3,000	1,500
U/150	7,000	4,500
U/250	14,000	9,000
U/500 and U/600	15,000	10,000
U/1 K.W.	20,000	14,000
U/2·5 K.W. and U/4 K.W.	27,500	20,000

Anode current, anode volt characteristic curves for these valves are given in Figs. 87, 88, 89. The U/30 valve—see Fig. 90—which will pass a maximum current of 80 milliampères with a potential drop of 200 volts, requires an input to the filament of 2.3 ampères at 5.5 volts, and is suitable for pressures from the transformer up to 1750 volts, the anode dissipation being strictly limited to 30 watts. The U/50 valve—shown in Fig. 91—is designed to pass .15 ampère at approximately 400 volts, the maximum voltage of the associated circuits being 3000 volts, and the filament consumption 2.8 ampères at 9 volts. The anode will safely dissipate 50 watts. This valve and other high-power Mullard valves made in glass are constructed—under patent No. 158,720/1921—so that the filament can be removed without disturbing the anode or the internal structure of the valve, with the result that the life of the valve is not terminated when the filament burns out. The filament can be renewed by the makers at a cost considerably below that of the original cost of the valve, so that considerable economy is effected. The maximum current which can be passed by the U/150 valve is .25 ampère, with a drop of 500 volts, and the anode will safely dissipate 150 watts. For the full emission of .25 ampère the filament requires 3.5 ampères at 10.5 volts. This valve is suitable for use at alternating current pressures up to 7000 volts, and is capable of supplying direct current to transmitting valves of 250 watts maximum anode dissipation. The U/250 valve—Fig. 92—is designed to dissipate 250 watts at a maximum reverse voltage from the alternating-current supply of 14,000 volts. The maximum emission of .35 ampère, with a voltage drop of 600 volts across the rectifier is given with a filament current of 4.6 ampères and a pressure of 10.5 volts.

The maximum dissipation of the U/500 valve—shown in Fig. 93—is 500 watts, and it may be used on circuits working up to 15,000 volts, the filament current being 6 ampères and the pressure 16.5 volts. The corresponding emission is .55 ampère with a pressure drop of approximately 600 volts. The U/600 valve is the largest glass rectifier made by the Mullard Radio Valve Company, higher power valves capable of dissipating up to 4 kilowatts and passing 3 ampères anode current, having bulbs composed of fused silica. The filaments of these silica valves are renewable, and the valves may be used on circuits of from 20,000 to 50,000 volts. The U/600 glass valve is suitable for rectifying the high-tension supply to all types of glass transmitting valves, and may in some cases be used in conjunction with silica transmitting valves, two or three rectifiers being used in parallel to pass a greater current that .7 ampère, if necessary.

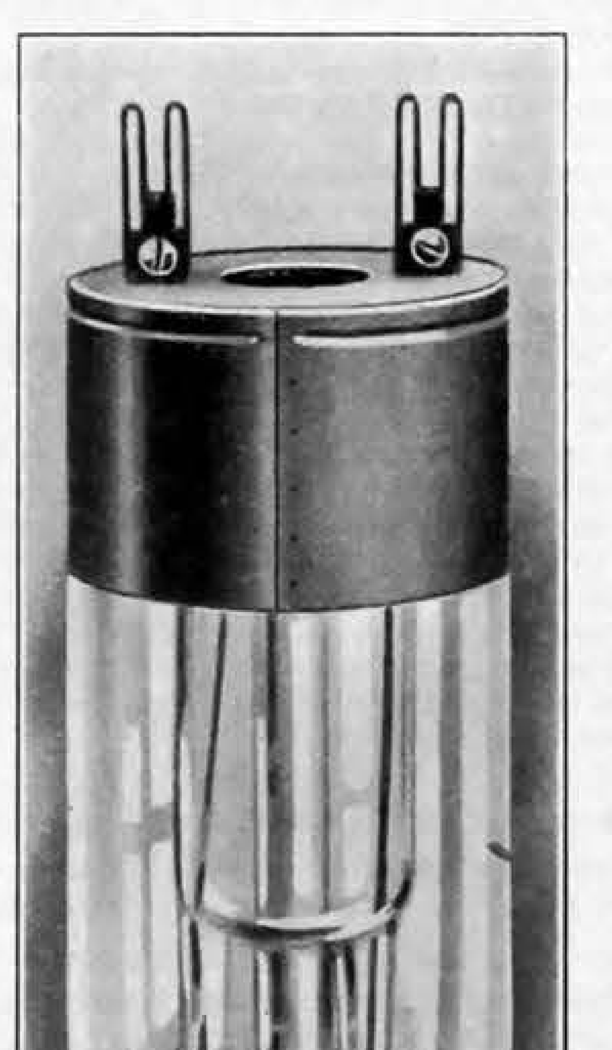


FIG. 94—WATER - COOLED RECTIFIER

Designed to pass a maximum emission current of .9 ampère, the Mullard U/1 K silica rectifying valve has an anode capable of dissipating 1 kilowatt, its filament requiring 18 ampères at 11 volts for the full emission current of .9 ampère. The U/2.5 kilowatt silica valve is capable of dissipating 2.5 kilowatts at the anode, and will pass a maximum emission current of 1.2 ampère. As shown in the above table, it is suitable for rectifying alternating current at a pressure of 27,500 volts. For the full emission current of 1.2 ampère the filament current is 17 ampères at 16 volts. The largest Mullard silica valve —the U/4 K.W.— will dissipate 4 kilowatts at the anode, and will pass a maximum emission current of 3 ampères, the filament taking 40 ampères at 18 volts, and it may be used for supplying any direct-current load of not more than 3 ampères at a maximum transformer pressure of 27,500 R.M.S. volts between the anode and filament. The maximum drop when passing 3 ampères is approximately 1300 volts.

One of the Western Electric Company's water-cooled thermionic rectifying valves, as made at the company's New Southgate works, is shown in Fig. 94. The outer metallic wall serves as the anode, which is water-cooled. This drawn-copper seamless anode is sealed on to a glass bulb, which provides insulation for the filament structure. In accordance with the invention of Mr. Housekeeper, of the Western Electric Company, the open end of the anode is tapered down to a few thousandths of an inch at the edge, with the result that when the seal between the glass and copper is made, the thin copper can take up all variations due to expansion and contraction of the glass. Seals of this type, the makers claim, can be heated from the temperature of liquid air to the melting-point of the glass without risk of cracking. The structure on which the filament is mounted has great rigidity, and is assembled on a re-entrant stem sealed into the bulb, the filament leads being thick copper rods, which pass through copper glass seals. The seal in this case consists of a thin copper disc attached to the rod, the disc being sealed so as to close the end of the glass tube. All the parts of the filament supports, which are likely to attain high temperatures, are made of highly refractory material, whilst the parts that are not liable to be subjected to high temperatures are composed of nickel. The valve is clamped down into the water jacket by means of a split ring, which bears on the flange at the top of the anode. With this arrangement the anode is held rigidly in the water jacket. A water-tight joint is thus provided, and a good electrical connection between the jacket and anode is ensured. Water is fed into the bottom of the jacket, and it exhausts through the top, the tangential arrangement of the inlet and outlet pipes giving a circular motion to the water, which therefore cools the anode in an efficient manner. The water jacket, which is mounted on an insulating stand, is connected to the water supply, and to a drain, by means of long rubber hose pipes, the column of water providing sufficient insulation to enable the anode to be maintained at a pressure of 10,000 volts, without introducing appreciable leakage.‡ The high voltage direct-current supply connection is made on the water jacket. With 1 gallon of cold water per minute it is possible to dissipate safely 10 kilowatts, although the usual dissipation is about 5 kilowatts, including the energy supplied to the filament. The illustration, Fig. 94, shows the valve without its water jacket, and it will, of course, be understood that the filament is inside the anode. The overall length of the valve is 21in., the bulb diameter 3½in., and the anode diameter 2in. The characteristics of the valve are as follows :—

Filament current	41 ampères
Filament pressure	22 volts
Anode pressure	10,000 volts
Normal anode current	·8 to 1 ampère
Maximum anode pressure	20,000 volts

The chief application of these valves is to supply a direct current pressure of 10,000 volts for the operation of the Western Electric Company's 10-kilowatt oscillating water-cooled valves, which, except for the fact that they are, of course, provided with a grid, resemble the company's rectifying valves.

‡ See the *Journal* of the Institution of Electrical Engineers, Vol. LXI., page 816.