THE

RADIO REVIEW

A MONTHLY RECORD OF SCIENTIFIC PROGRESS IN RADIOTELEGRAPHY AND TELEPHONY

VOL. II NOVEMBER, 1921 No. 11

Editor:
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Editorial.

Poulsen Arcs with Shunt Condensers.—Professor P. O. Pedersen has published a paper in the *Proceedings of the Institute of Radio Engineers* for June under the somewhat misleading title of "On the Poulsen Arc in Coupled Circuits." In this paper he does not deal with coupled circuits in general, but only with one special circuit arrangement which one might hesitate to refer to as a coupled circuit. It is none the less a very important arrangement because it has been used in a number of the large arc transmitting stations. In these stations it is customary to insert the arc between the antenna and the earth, so that the antenna and its loading coil constitute the oscillatory circuit across the arc without any intermediate closed oscillatory circuit. To avoid a short-circuit of the direct current in case any part of the aerial is accidentally earthed it is customary to insert a large series condenser in the earth connection. Now it has been found that a condenser connected as a shunt either across the arc or across the arc and the series condenser gives an increased output. It might be suspected that the increased antenna current was due to harmonics but it is claimed that this is not so, and that the signals are actually strengthened by this arrangement. Professor Pedersen compared the measured values of the currents in the arc, antenna, and shunt circuit with those calculated on the assumption that the arc acted as a simple source of alternating current of a single frequency. Considerable differences were found and Professor Pedersen shows that these are due to the fact that the shunt and series condensers and the arc form an oscillatory circuit of high frequency which is set oscillating every time the arc strikes and that this oscillatory current is superimposed upon the normal arc current causing the arc to be wholly or partially extinguished once or twice at the beginning of the cycle. Professor Pedersen points out that although the antenna current for a given arc current may be increased, it necessitates a higher supply voltage for the arc and it increases the wavelength. The increased efficiency will be due to some extent to the latter effect. He states that the increased efficiency was only obtained at the cost of steadiness and that in his opinion the advantages gained by the device are not of any great value. It would be of interest to learn whether in any practical case an increased efficiency or output has been obtained by the use of a shunt condenser without sacrificing steadiness or purity of the emitted wave. **[3728]**

The Action of the Grid Leak in the Audion Detector.*

By Professor G. W. O. HOWE, D.Sc., M.I.E.E.

There is much haziness in many of the descriptions given in text-books and articles of the action of the grid condenser and grid leak when a triode is used for reception in the manner originally introduced by de Forest and often referred to as the audion method of reception. Fig. 1 shows the connections under consideration with the source of high-frequency signals represented by an alternator in the grid circuit. In Fig. 2 the curve represents the grid characteristic, that is, the current flowing in the grid circuit plotted against the P.D. between the grid and the negative terminal of the filament. The line OL is drawn at an angle θ to the vertical such that the tangent of this angle is equal to the leak resistance R. This line cuts the curve at P.

When no alternating E.M.F. acts in the grid circuit, the grid assumes the steady negative potential OA and the current AP flows from filament to grid through the external circuit. Since the tangent of the angle θ between the line OL and the vertical is equal to the value R of the grid leak, OA represents the P.D. across the grid leak and AP the current through it.

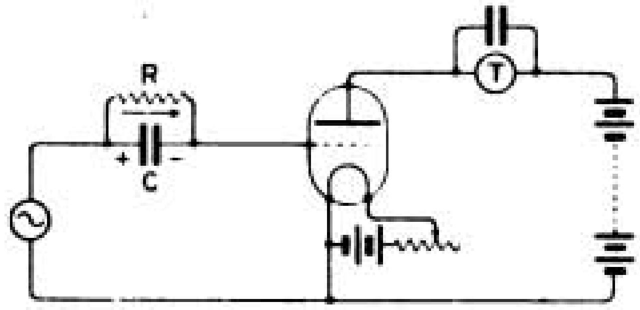

FIG. 1.

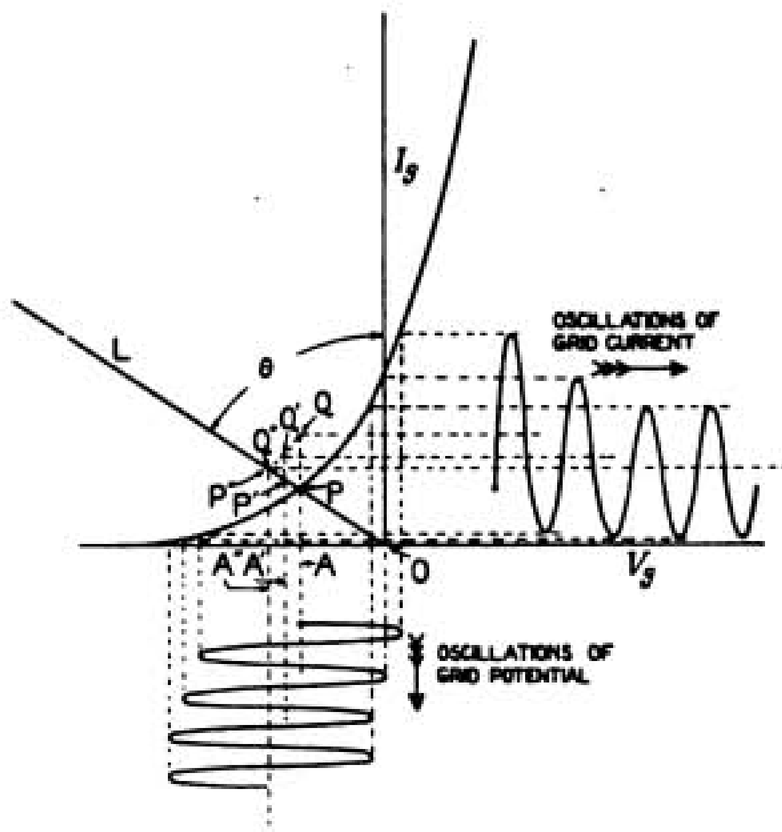

FIG. 2.

If now an alternating E.M.F. be introduced into the grid circuit, the grid potential begins to oscillate symmetrically on either side of the point A, but because of the curvature of the characteristic the mean grid current is increased to AQ. Since the mean P.D. across R is still OA, the mean current through R is still AP, hence the difference PQ must pass into the condenser, increasing its P.D. from OA say to OA′. This causes the mean current through the leak to increase to A′P′. The next oscillation of grid potential takes place about A′ instead of A and the grid current reaches a lower maximum, and

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* Received for publication February 17th, 1921.

has a lower mean value, say Q′. The difference between A′Q′ and A′P′ must pass into the condenser and increase its P.D. say to A″. This will cause the mean current through the leak to increase still further to A″P″; it will also cause the succeeding oscillation of grid potential to move over a lower part of the curve and thus lower the mean grid current to Q″. This goes on until the curve QQ′Q″ meets the line OL, that is, until the decreasing mean grid current equals the increasing mean leak current; when this point is reached the condenser gets no further charge. The increased negative potential of the grid causes a fall in the anode current which affects the diaphragm of the telephone receiver.

It is seen that when a signal is being received, although the grid potential becomes more negative, the mean grid current as read on a milli-ammeter inserted in the grid circuit is increased, viz., from AP to A″Q″ in Fig. 2.

The effect of the signal on the anode current depends on the steepness and curvature of the anode current characteristic which we have not shown. There are two separate effects, one due to the displacement of the mean grid potential from A to A″ causing a fall of anode current and the other due to the oscillation of grid potential causing a certain amount of rectification of the anode current depending on the curvature of the anode current characteristic. On the upper bend these effects are in the same direction but on the lower bend they are in opposition.

Note on a Four-electrode Thermionic Vacuum Tube.*

By H. J. VAN DER BIJL, M.A., Ph.D.

In a recent issue of the Radio Review † an article appeared by Professor Fleming on what he calls "A Four-electrode Thermionic Detector for Damped and Undamped Electric Oscillations of High or Low Frequency." As was pointed out in the editorial notes of the same issue, this type of tube originated with Majorana in 1912. In 1914 I made investigations on this type of tube, and while I did not find it to be as satisfactory a detector as the audion, which had at that time already been well developed, Fleming's publication has revived a certain amount of interest in this tube, especially his suggestion to use it as an A.C. ammeter and for the purpose of indicating small differences of potential in A.C. bridges. It may therefore not be out of place to give a brief discussion on a few points regarding the operation of this type of tube, which are apparently not well known.

Fleming states that "the peculiar property of this thermionic detector is that if a small difference of potential whether of high or low frequency is set up between the potential plates the thermionic current passing between the filament and the collecting plates at once falls to an extent determined by this potential difference." This effect, which was also observed by Majorana,

* Received July 25th, 1921.
† Radio Review, 2, p. 38, January, 1921.

is to be expected. It is well known that in an audion the control electrode need not have the form of a grid placed between the filament and the anode, although this is usually the preferred form, but could be a plate or wire placed anywhere in the neighbourhood of the filament. Consequently, two control electrodes placed symmetrically with respect to the filament and anode, as in the tube shown by Fleming, would have equal effects on the emission current. The result is that when the tube is connected in a circuit in such a way that the one control electrode becomes as much positive as the other one becomes simultaneously negative, the resultant effect on the current to the anode would be *nil*, if there were no other influences. What actually happens, however, is that when one control electrode, say P_1, becomes positive, it attracts electrons and therefore acquires a negative charge. During the following half cycle the other control electrode, P_2, attracts electrons. The result is that both electrodes acquire a negative charge and this causes the reduction in the electron current to the anode which has been observed. But with the circuit shown by Fleming the electrons, having once entered the control electrodes P_1 and P_2, have no way of escaping from the system comprising these electrodes and the input circuit connected to them (assuming the vacuum and insulation to be perfect).

Fleming states that he had not yet determined the effect of a slight reduction in the vacuum. The effect of gas on the behaviour of this type of tube is known. If the vacuum in the tube and the insulation between the terminals were perfect and the air dry, this tube would become inoperative as a radio detector, for the reason that since the negative charge accumulating on the control electrodes cannot leak away, the anode current cannot return to its normal value on the cessation of a train of incoming oscillations. The case is very similar to that of an audion operating with a blocking condenser in the grid circuit. Unless there is collision ionisation in the audion or the blocking condenser is leaky or is bridged with a high resistance, to enable the negative charge accumulating on the grid gradually to leak off, the tube becomes inoperative. If the tube contained a small amount of gas the positive ions formed by collision ionisation would neutralise the negative charge on the control electrodes, as is well known to be the case with an audion containing a small amount of gas and operating with a blocking condenser in the grid circuit. Of course, when oscillations are impressed on the input circuit, the rate of accumulation of negative charge must at first exceed the rate of neutralisation, but this latter rate must be sufficiently large to enable the control electrodes to discharge themselves between successive trains of oscillations.

But it is not possible to rely on the presence of gas when the tube is to be used for quantitative measurements, because it is extremely difficult to keep the pressure of a small amount of gas in the tube constant, and unless this is done, the rate of formation of positive ions and therefore also the rate of neutralisation of the negative charge on the control electrodes would not be constant, thus making the reduction in the anode current erratic.

The best way is to provide for the neutralisation of the negative charge on the control electrodes. This can be done by using an inert vapour in the tube in thermal equilibrium with the parent substance, for example, mercury, which is kept at a constant temperature. This would insure constant pressure of the vapour and therefore consistent behaviour of the tube. Or again, the neutralisation can be provided for by connecting a suitable point of the input circuit through a high resistance to the filament, the circuit being so arranged that the two control electrodes assume under the influence of the impressed oscillations, equal and opposite potentials with respect to the filament.

The similarity between the four-electrode tube and the audion operating with a blocking condenser in the grid circuit will be apparent. But there are certain differences which are interesting, although perhaps not of great importance. In the audion the accumulation of negative charge on the grid takes place during alternate half periods, while in the four-electrode tube this happens every half period. In the audion the anode current fluctuates with a frequency equal to that of the impressed oscillations, the mean value of the anode current being lower than the steady D.C. value. In the four-electrode tube the anode current also fluctuates, although not as much as in the audion, but the fluctuations have a fundamental frequency twice that of the impressed oscillations, and, provided that the control electrodes be made as effective as the grid in the audion, the reduction in the anode current would be somewhat greater. This is due to the counteracting effect of the two control electrodes as far as the direct action on the anode current of the potentials impressed on them is concerned. If the four-electrode tube has any advantage over the audion in this respect it is doubtful if it would be sufficiently great to warrant the complication of a fourth electrode. It may be well to point out that the operation of the audion with a condenser in the grid circuit is improved by operating the audion, as is now frequently done, with the grid maintained at a steady positive potential with respect to the filament, of such value as to operate on that part of the grid-current—grid-potential characteristic where the curvature is greatest, and with the anode potential and filament current so adjusted as to operate on the upper part of the anode-current—grid-potential characteristic where it becomes concave towards the voltage axis. The necessary steady positive potential on the grid can be maintained simply by connecting the input circuit to the positive end of the filament.

As regards the using of vacuum tubes for measuring small potential differences in A.C. bridges, I presume it is known that the audion has been used successfully for such purposes. (See, for example, Fig. 109 on p. 213 of my book on " The Thermionic Vacuum Tube." *) Whether or not the four-electrode tube would work better than, or even as well as the audion in such circuits is something which has yet to be established. In any case, it is risky to have floating electrodes, that is, electrodes whose potentials cannot definitely be controlled, in a vacuum tube, and unless provision is made for neutralising, whenever necessary, the negative charge accumulating on the control electrodes, the four-electrode tube could hardly be relied upon as a measuring instrument.

* H. J. van der Bijl. "The Thermionic Vacuum Tube." (New York: *McGraw-Hill Book Co., Inc.* London: *McGraw-Hill Publishing Co., Ltd.* 1921.)

Radiotelegraphy in the Dutch East Indies.

The August number of the organ of the Dutch Colonial Defence Society,* which Society has been established "to promote by all means at its disposal, every measure that will strengthen the economic and military position of the Dutch Indies," is devoted to a historical review of the development of radio-telegraphic communication between the Dutch Indies and Holland and an account of the present position. It is a very important document both from the political and technical points of view and we feel sure that the following abstracts from it will prove of interest to our readers :—

"It is the object of the present essay to make widely known the grand work performed by the officials and engineers of the Dutch East Indian Postal, Telegraphic and Telephonic Service. The Dutch nation has reason to be proud of these men, who, sure of future success, carried through their plans in spite of a thwarting bureaucracy and of administrative pettiness. The Indië Weerbaar Society cannot think of a better way to honour Mr. Pop, Dr. de Groot and their collaborators, than by devoting a special number of its organ to the work they have achieved and spreading it broadcast all over the world."

Plans for a wireless chain have existed for many years. The van der Bilt scheme worked out in conjunction with the Marconi Company proposed intermediate stations in Tripoli, Italian Somaliland and Ceylon, but it was hoped later to do without the last named and thus be entirely free from British control and have their means of radio-communication in the hands of countries belonging to a different group to Britain who controlled the cables. The action of Italy in the war proved "how vain it is to count on political constellations for projects of this kind." The war made the carrying out of the van der Bilt—Marconi scheme impossible and also proved that strategically it would have been an absolute failure.

Another rival scheme known as the Moens scheme was coupled with the Telefunken Company, the proposed route being Nauen—Sayville—Curaçao—German South Seas—Java. This scheme did not survive its rival.

Careful experiments were made during 1913 and 1914 at several experimental stations in the East Indies, the results of which led Dr. de Groot who was in charge at Situbondo to propound his theory that night transmission was relatively easy between points separated by multiples of 3,000 km, a very promising theory, seeing that the distance to Holland was 12,000 km.

Since that time de Groot's energies have been concentrated on the attainment of direct communication between the Indies and the Motherland. His theory received some support from the fact that de Haas received signals at night from Nauen, a distance of 9,000 km, with a contact detector without amplifiers, the antenna power being 100 kW and the wavelength 5 km. In December 1916 de Groot returned from Europe and America with new receiving apparatus and reception from the large European stations was

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* *Orgaan van de Vereeniging "Indië Weerbaar,"* 4, pp. 4—44, August, 1921.

obtained with fair regularity. They were spurred on to these developments by the fear which proved only too well founded, that the Allies would impose a telegraphic blockade.

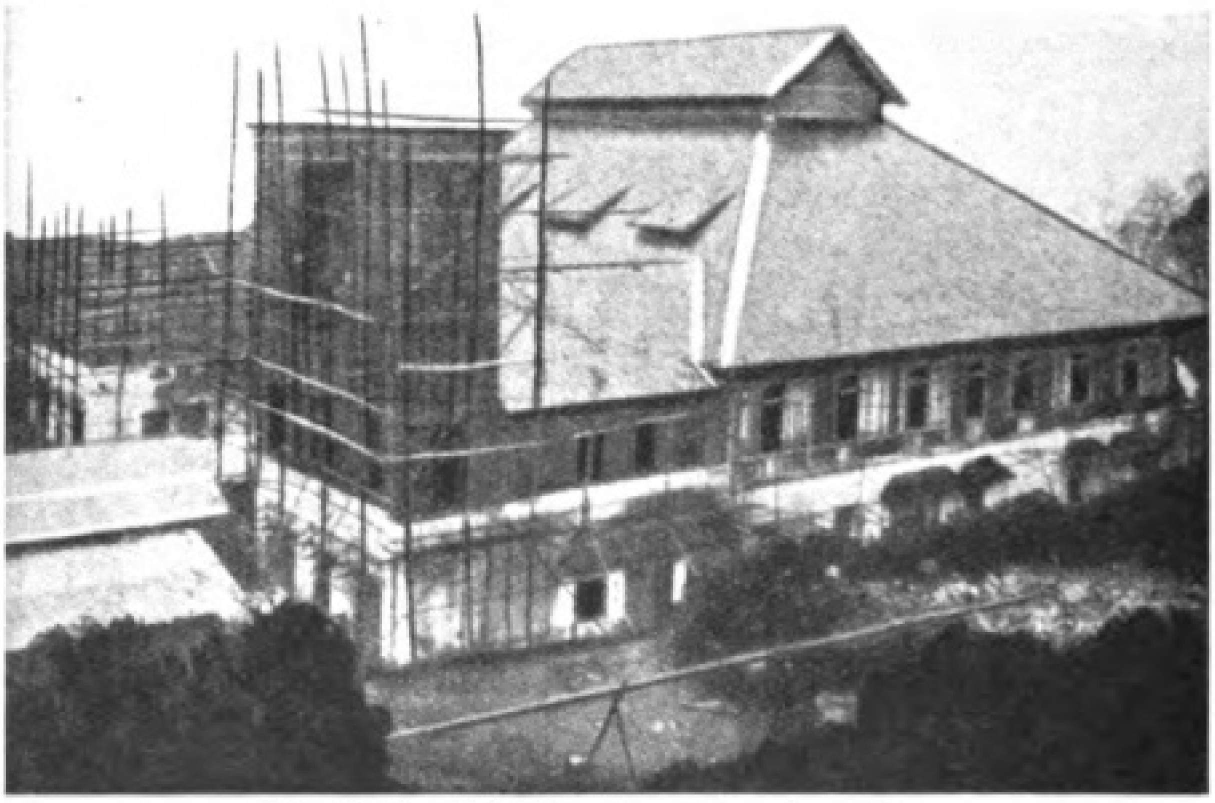
"Meanwhile it was clear that reliable means of communication especially in war time must take years to construct owing to the large power-plant required and that it could therefore be of little use during the war. This led to the thought of temporary communication by way of neutral intermediate stations, *e.g.* Honolulu and neutral America, whence it was so much easier to communicate with Holland than from Java. The preliminaries had been arranged by Dr. de Groot during his journey through America with the

Location of the Station.

naval authorities. When, however, shortly afterwards, before the arrival of the American transmitter, it was proved by the reception tests, with how little energy, comparatively speaking, the distance between Holland and Java could be spanned at night time, *provided short waves were used*, the colonial authorities changed their minds and chose Holland instead of America for their object, the more so as uninterrupted communication with America had meanwhile been obtained in another way.

"The American transmitter arrived here in August, 1917. . . . During the period between the ordering and the receiving of the transmitter, the balloon idea was abandoned as a more felicitous mastless solution had been found in the shape of an aerial across a mountain gorge, consisting of an aerial suspended from steel hawsers connecting the mountain tops around the gorge, the station being at the bottom. . . . It afterwards proved itself superior to the highest mast aerial.

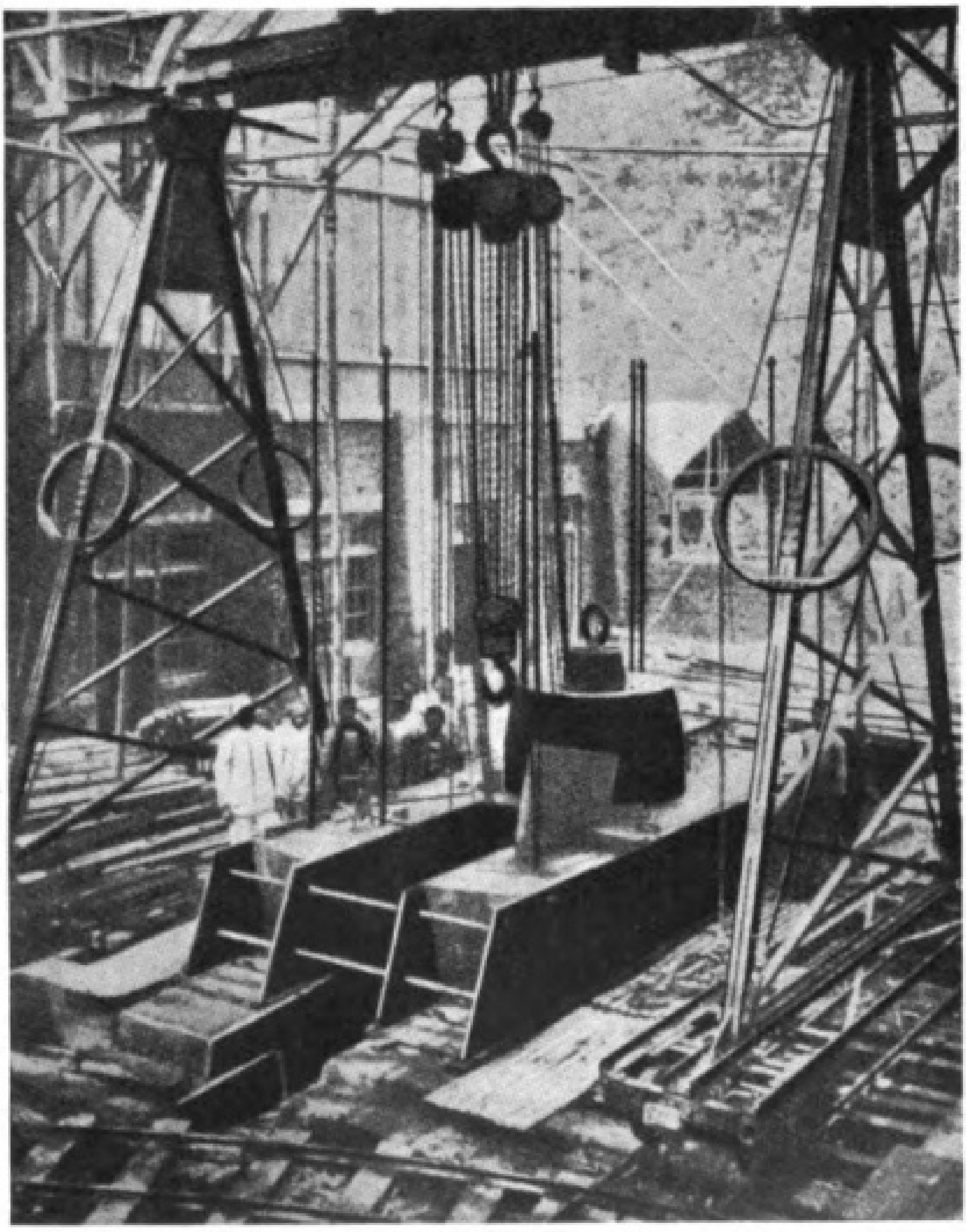
"A suitable gorge was found 9 km from the main road with steep walls 900 metres high. . . . Within a few months there arose in a clearing a large cabin, representing the station which was to be the first to span the world, with a dynamo borrowed from the Batavia Tramway Company driven by an aeroplane motor lent by the army [supplying a 100 kW arc]. . . . Holland was called up from November 1917 onward and experiments afterwards proved beyond doubt that even then *at the beginning of the telegraphic blockade* one-sided communication might have been established if something had been done on the other side *to make communication possible.* But practically



The Station Buildings in course of erection.

speaking Holland did *nothing*. . . . The station had been constructed on definite lines, did its work excellently well, but called in vain a whole year long *because no one on the other side moved a finger to rescue us from our isolation* . . . and if, by the middle of 1919 it was possible to speak of a first temporary communication between Holland and its East Indian possessions, this is entirely owing to the fact that a proper receiver was built in Java and sent to Holland; else another year would have been wasted."

"Instead of pushing forward the construction of a Dutch transmitting and receiving station the home authorities sent out a second temporary transmitter. The said transmitter of Telefunken manufacture possessed indeed double the primary energy of the Governmental transmitter, but was, owing to its injudicious equipment (only one mast 120 metres high and one single *long* wave) decidedly inferior to the one already in action, especially at nights, the only part of the twenty-four hours when communication with slight means was possible. The transmitter was of the so-called high-frequency generator type which only acts correctly in the case of an extremely constant line frequency and voltage, which, however, was unsuitable for this kind of work on account of the hand-regulated water-wheels which are used as prime-movers."

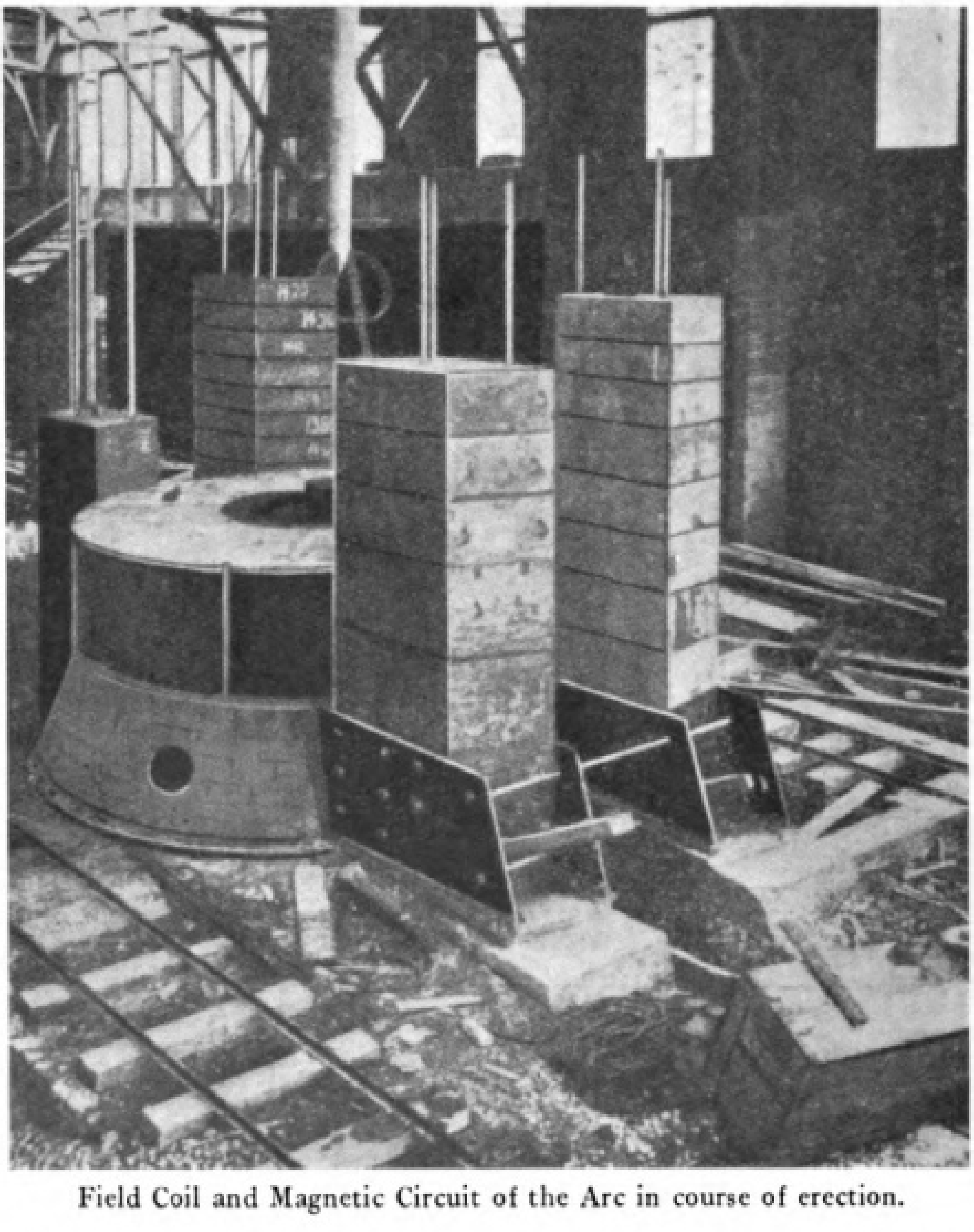


The Foundations for the Magnetic Circuit of the Arc.

"The first Bandung station owing to its larger permanent aerial was heard from five to ten times louder than the Telefunken station even when using *long waves*."

"Of course, the station also has points in its favour. Thus it is thoroughly reliable. Its drawback, however, is typical of all Telefunken stations supplied in this country, viz. far too little energy compared to the distance to be spanned."

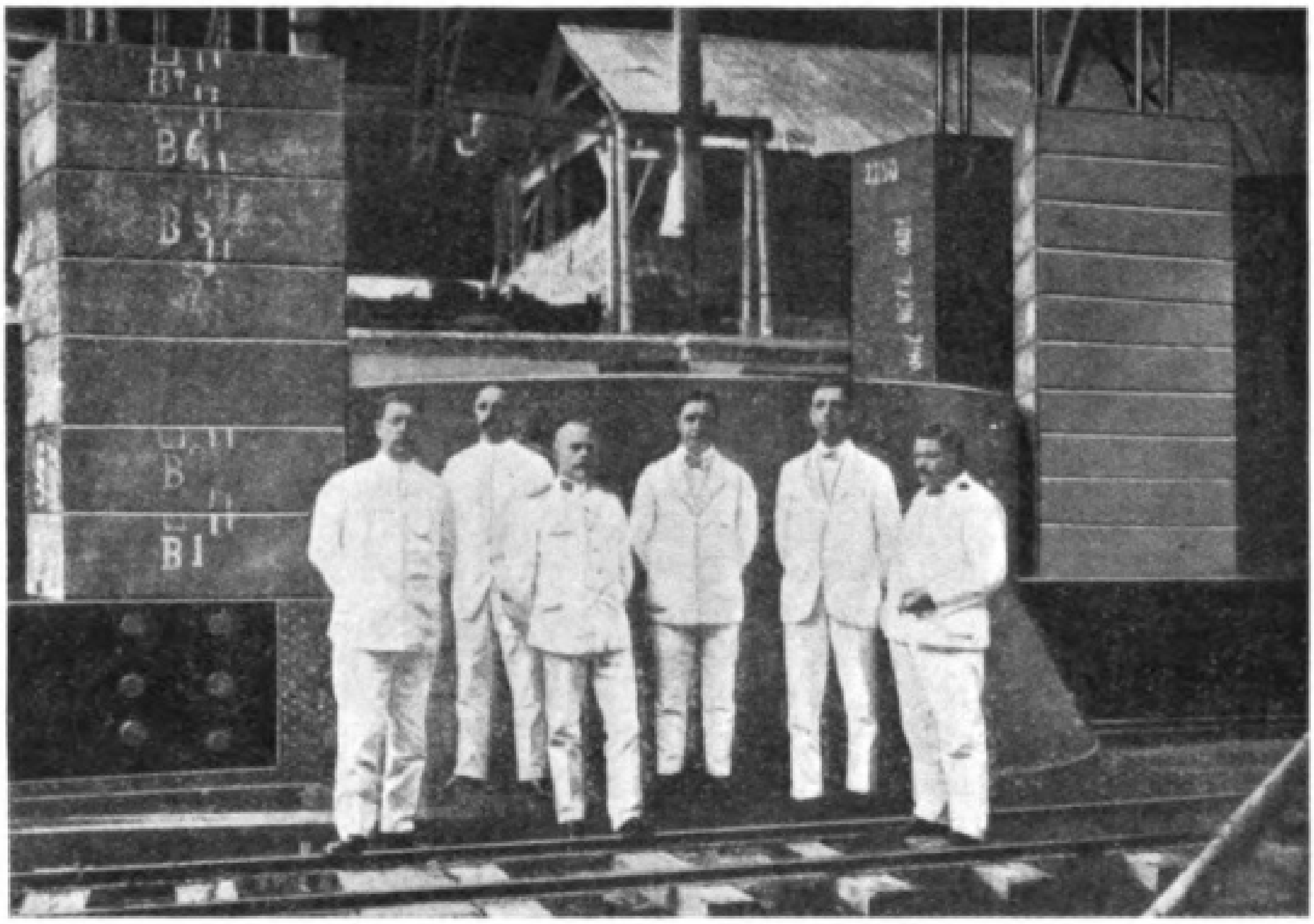
"Unfortunately it must be added that *during the war* the Government station was of no more practical use for communication with Holland than its rival. This was not our fault. Communication was established as soon as a receiver had been sent out to Holland. Communication was naturally faulty, audibility varied as is also the case in the East when receiving the large European stations. For really satisfactory communication the



Field Coil and Magnetic Circuit of the Arc in course of erection.

transmitter is from ten to twenty times too weak. But results have proved that its range is greater than that of any existing station, greater therefore than Nauen and of the permanent Telefunken station now in course of construction in Holland. This means that communication with the East Indies will become worse than the results in the reverse direction with temporary means up to now."

"Although the projects for—and the work on behalf of—the permanent station were being pushed forward, it was tried at the same time to perfect the temporary station as much as possible. Thus the arc transmitter built for 100 kW output at long waves, was rebuilt in such a way as to be now capable of taking 165 to 320 kW according to the length of the wave employed. The combined aeroplane motor and tramway dynamo could only supply 65 kW. . . . As soon as a road had been made a twenty-year-old water turbine obtained from the Ketahoen Mining Company in liquidation was set up and was ready for action in August 1918. It originally drove the tramway dynamo and afterwards a more powerful dynamo giving 165 kW at 1,100 volts obtained from Japan, which still constitutes one of the principal



Side view of Arc Magnetic Circuit and Tank for Field Coil.

sources of energy for communication with Holland and Honolulu. As a second source of power connection with the Bandung city mains was obtained in July 1919 by means of a 25,000 volt three-phase overhead transmission line 35 km long and used to drive the 100 kW General Electric Company motor generator which arrived in December 1918. By combining these sources it became possible to supply the arc for long waves in the daytime up to 240 kW. A 200 kW motor generator purchased in Japan has now been set up in the new permanent station and a second turbine installation has been put up lower down the river. This plant generates 2,200 volt three-phase current which is conducted to the new station where a motor generator also purchased in Japan converts it into a direct current of 165 kW output. The wooden hydraulic pressure pipes had to be imported from Australia.

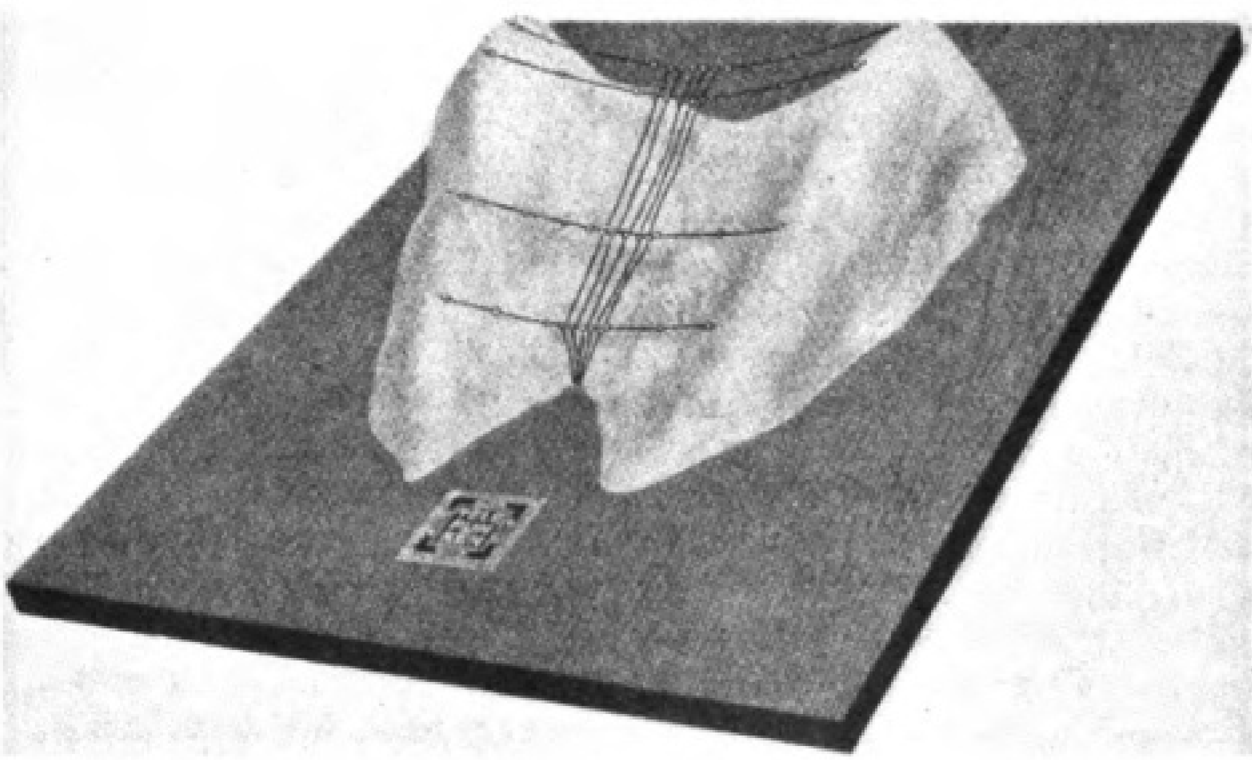
"As to the aerial, considerable improvements were introduced by replacing the original one which gave great satisfaction in the case of short waves (with 6 km wave the Antipodes had been reached), but could not be charged with more than 150 kW, by a much larger permanent aerial which constituted the first part of the permanent station. This aerial was ready in July 1919 and allowed the arc to be supplied with from 240 to 320 kW for long waves and as a result Java immediately got into touch with the colonial-built receiving station at Blaricum in Holland."

"As the permanent aerial in Java is already in position and the colonial receiving station in Holland has systematically collected data for over a year, it has for some time been possible to calculate with fair accuracy the energy required, the result being that the colonial transmitting aerial, to be powerful enough for reasonably accurate *commercial* intercourse, requires 1,200 to 1,800 kW swinging in it, *i.e.* three to four and a half times that of the most powerful European stations such as Bordeaux, etc. The arc input has therefore to be taken as high as 2,400 to 3,600 kW and the aerial will then be charged to the utmost voltage for which effective insulation is possible."

"The *power* having been determined, the *choice of system* was the next important point. Every large European country has as a matter of fact in the immediate neighbourhood of the Dutch frontiers enormously strong transmitter stations, producing in the receiving telephones of Dutch stations sounds so strong that the weak signals from the East Indies can never hope to compete with them, however strong the transmitting station over here is made. The only way to baffle such a disturbing station is to choose another wavelength. The disturbing station will try to follow suit, to resume its disturbing activity and it becomes a trial of skill between the operators. For this reason all military stations have a system which makes it possible to change the wavelengths rapidly and frequently. The *only system* which can do this in the case of very powerful stations is the *Poulsen system* with which the temporary Government station in the colony has consequently been fitted. Stations of the high frequency generator type, especially those with frequency multipliers such as characterise the Telefunken system, are absolutely unsuited for this kind of work."

"That the impracticability of the high-frequency generator for this kind of wireless communication is not a purely theoretical personal opinion appears from the fact that Blaricum reported soon after communication had been established that disturbances were regular with the following waves: 5, 6, 8, 10, 11, 12, 13, 14 km so that only waves of 7, 9 and 15 km remained practicable. The colonial Poulsen station had no difficulty in immediately using these waves; the temporary Telefunken station fitted with one invariable wave, could not do so, was interrupted beyond the hope of ever re-establishing communication and had to give it up. These were *accidental* disturbances in times of peace, which shows what would happen in war time."

"The Colonial Telegraphic Department therefore decided on a Poulsen arc transmitter installation with an input of 2,400 to 3,600 kW. Basing himself on the necessary working data obtained from the temporary arc-lamp transmitter, Dr. de Groot undertook to design and have built in the colony a 2,400 to 3,600 kW arc-lamp transmitter, a transmitter two to three times as large as the world's largest (at Bordeaux) and construction was started in 1918. The manufacture of the giant arc involved the casting and working of 260 tons of cast and sheet iron in the Dutch Indies, delivery being adversely influenced by the fact that the parts must not be heavier than 6 tons with a view to the uphill transport, whilst by far the greater number of castings which were manufactured in the State railway shops at Bandung



A Scale Model of the Aerial System which is to be slung between the mountains on each side of the valley.

and Madioen which have a limited casting capacity only weighed from 1 to 2 tons, which necessitated a good deal of planing and involved extremely difficult constructions to build up the very heavy arc out of so many small parts. The winding of the magnet alone required 20 tons of copper; the bronze arc chamber which is being manufactured at the naval dockyard at Surabaya weighs nearly 6 tons. The *magnet system* two cores of which weigh 25 tons each and are moved by hydraulic power is rapidly approaching completion and only the *arc chamber* is still in course of construction so that the transmitter will before long be quite ready."

"The two motor generators of 800 to 1,200 kW on the D.C. side have now arrived from America. There are, however, foundations for two more such motor generators in order to increase the power to 3,600 kW with one set in reserve. There are also spare foundations for a second 2,400 to 3,600 kW arc transmitter in case one is needed.

"A special hydrogen generator supplies the necessary gas for the Poulsen arcs in order to keep these clean and in perfect working order."

"The walls of the station are of brick to a height of 4 metres and thence of teak wood with a view to earthquakes and high-frequency losses."

"We might end our description here were it not that a second station, standing cheek by jowl to the colonial one, is in course of construction. It is a Telefunken transmitter of the size of the one at Nauen, sent out to us by the Colonial Office in Holland quite independent of the colonial project. This Telefunken transmitter which is a copy of the one now being built in Holland, is indeed being installed at the company's risk, so that it is officially possible to refuse accepting the station if it fails to give satisfaction for commercial purposes. We must leave it to the reader's fancy to decide, in how far it will be possible to refuse an installation costing millions of money because it does not come up to the stipulated requirements. It will be impossible to blame the station for being useless for our purpose on account of the system itself. Its lack of suppleness in wavelength was known or might have been known if proper inquiries had been made."

"Hence the station has been designed as one whole with the Government station at the special request of the Telefunken Company and is to use the same aerial. It will prove an excellent reserve station in times of peace owing to the reliability which characterises the system. But during a great part of the year it will prove too weak for commercial communication with Holland. At times, however, when this work will have to be left to the more powerful Government station, it can be used for smaller distances (Japan, China, etc.). In times of war it will be doomed to silence."

"On the Dutch side the chances for regular communication are much less favourable. They are now building on the Veluwe moors a transmitting station equal in size to the Telefunken station here, but with a far inferior aerial. Although, therefore, the arguments for using the system in Holland are not so serious as here, a station not stronger than the one at Nauen, of which we have known the receiving results for years, will prove much too weak to be a worthy partner of the Government station at Malabar in commercial intercourse."

Carborundum and its Rectification Effect.*

By H. M. DOWSETT, M.I.E.E., F.Inst.P.

In the present paper it is intended to examine the chemical and physical nature of carborundum ; to describe those conditions which must be satisfied in order to produce the most reliable and best form of carborundum detector ;

* Received July 29th, 1921.

to give the results of a number of experiments designed to elucidate the nature of the rectification effect; to suggest a theory for this effect in carborundum and to give the results of its application to the voltage-current characteristic; and finally, to describe a model of the carborundum molecule which would have the properties required to bring about the reactions described.

(1) Carborundum is a resistance furnace product of a crystalline nature made from the raw materials sand, coke, sawdust, and salt packed round a core of granular carbon and heated to a temperature of from 3,500° F. to 4,000° F.

It is supplied in irregular blocks about 3 inches to 4 inches square and from 1½ inches to 4 inches thick which although composed mainly of silicon carbide, SiC,—to the extent of 85 per cent. to about 97 per cent.—vary considerably in the chemical composition of the remainder, in crystal structure, electrical behaviour, density, hardness and colour. Each block in itself is, however, fairly consistent in its qualities, which suggests that these qualities depend to a large extent on the position in the furnace where the block was formed, and the temperature to which it was subjected. In what follows the base of the block refers to the less crystalline part which has been attached to the wall or floor of the furnace.

(2) In order to grade the crystal according to its capacity to rectify weak currents a small piece is chipped from each block, a good electrical contact over a wide area is made at one part of it which is then known as the base of the crystal, and a good electrical contact is also made at an edge or point on the crystal which is found by trial to rectify the current, and is referred to as the point of the crystal.

The current-voltage characteristic of the sample is then taken in the usual way.

The varieties are found to classify into five distinct groups :—

(*a*) A close packed light green crystal which is free from dust. It is full of irregular but parallel fissures normal to the base of the block. The lowest potential difference at which a rectified current will flow through it is obtained when the base of the crystal is connected to the positive pole of the battery. It is therefore known as positive crystal.

It has very few neutral conducting points and no negative. Compared with other grades of carborundum its resistance when suitably mounted is low.

(*b*) A close packed steel-grey crystal inclined to be dusty and graphitic. This also has fissures. Some of its sensitive points react like positive crystal, some like negative, but all have high resistance characteristics This variety has the least number of neutral conducting points.

The steel-grey crystal sometimes merges into the light green.

(*c*) A looser packed dark grey crystal and a black crystal, with the usual fissures. These varieties are predominantly negative but very occasionally a high resistance positive point can be found. There are always many neutral conducting points.

(*d*) A brittle multicoloured crystal with a colour basis of dark green, dark grey, or black, and having fissures. Electrically there are two distinct varieties which have this same appearance. One of them is decidedly positive, has a low resistance and many neutral conducting points, the other is negative, but is a poor rectifier, has a high resistance and very few neutral conducting points.

(*e*) A close packed grey or black crystal, sometimes multicoloured on the surface of the block and with no fissures. It conducts but it does not rectify.

(3) A spectroscopic and chemical analysis shows that the principal impurity is iron which varies from **3** per cent. to **8** per cent., the best positive and negative crystal in a recent analysis having least iron.

There is a little aluminium present in all varieties.

There are heavy traces of magnesium and calcium in the green, sodium is present in the multicoloured and black non-rectifying crystal, but the black negative except for the iron appears to contain the least amount of other elements than carbon and silicon. It contains however a certain amount of free carbon and free silica which are not present in the positive green.

(4) Carborundum has been classified by Baumhauer in the tourmalin group.

Under a high power microscope the crystals in all blocks having fissures are seen to be massed irregularly but with a strong tendency to layer parallel to the base of the block and at right angles thereto, that is along the length of the fissures. The crystals parallel to the base are small but fairly regular in shape, those parallel to the fissures are long and irregular.

The green positive crystal has the appearance of hexagonal and rhombohedral slabs, the black negative of hexagonal flakes, the relative thicknesses under a magnification of **36** diameters being comparable to green window glass and a sheet of paper.

The greater thickness of the green positive crystal accounts for its greater mechanical robustness.

The colouration of the multicoloured blocks is seen to be due to interference effects in the top crystal layers which appear to be partially destroyed or fused as the crystal has lost all definition.

It is said to be caused by the oxidisation of the impurities in carborundum when a furnace is opened before being allowed to cool.

The black conducting and non-rectifying blocks having no fissures show masses of irregular crystals more nearly related to the negative variety than the positive, but having no definite arrangement, with veins of spongy coke-like material in which occasional single crystals are embedded.

Fissures are produced by the escape towards the centre of the furnace of the gases of combustion, their absence indicates that the blocks were in a position whence the gases and light vapours could not escape, and the presence of the coke, of sodium as mentioned in section **(3)**, and the neutral conducting quality of the material are thereby explained.

Apart from acting as channels for purifying the material the fissures as already pointed out give a structural grain to the block, and this is accompanied by an electrical grain as rectification takes place normal to the base and neutral conduction at right angles thereto. The fissures also provide the space necessary for the growth of perfect crystal edges and faces without which the rectification effect cannot be demonstrated.

The microscope shows that the neutral conducting points in green positive crystal are badly fractured crystal edges, but in black negative crystal they are more often faults where the growth of the crystal has been interrupted by the presence of some impurity.

(5) The influence which the nature of the contact of wide area has on the characteristic of the crystal is shown by the series of curves Fig. 1.

A green positive carborundum crystal was first mounted in solder, search was made for its most sensitive point contact, and the characteristic was taken with a steel plate on this contact.

The solder was then melted off the end of the crystal which was next plunged into molten brass and allowed to set.

This brass-tipped crystal was afterwards mounted in solder in the standard brass cup, its most sensitive point was found and a second characteristic was taken. These operations were repeated with steel. Platinum was also tried but in this case no suitable junction could be obtained.

Fig. 2 gives the characteristics of a positive crystal B tipped successively with brass, copper and steel, and of a negative crystal A tipped successively with steel and tungsten.

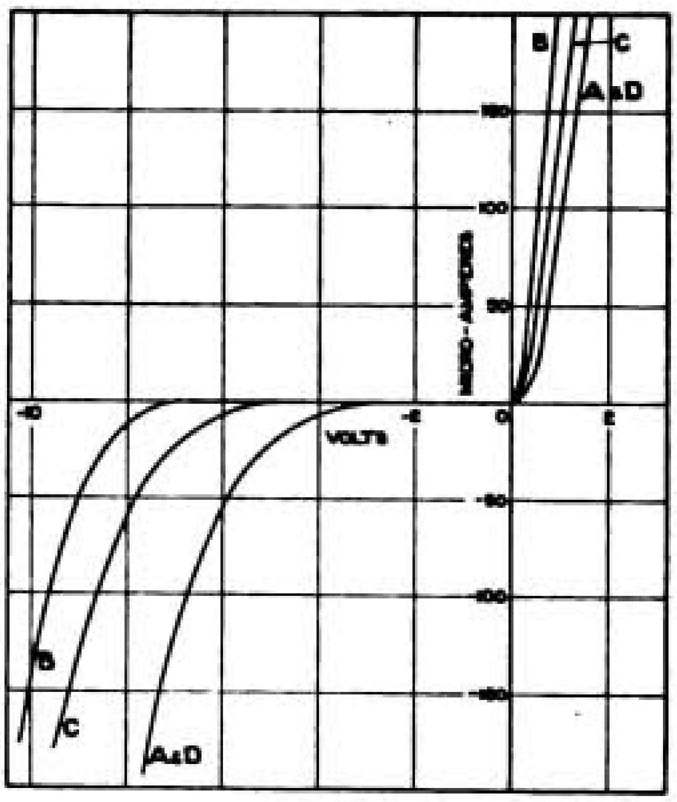


FIG. 1.—Characteristic Curves showing Influence of Nature of the Contact.

Curve A = Mounted in solder.
Curve B = Steel tipped.
Curve C = Brass tipped.
Curve D = Again mounted in solder.

TELEPHONE SHUNTS.

A and D = 120 ohms.
B = 20 ohms.
C = 20 ohms.

The author found that if suitable care were taken of the point of the crystal it was possible to use these metals one after the other on the same crystal and then on returning to solder to obtain a repetition of the first characteristic without any difficulty.

The face of the carborundum on which the contact of wide area was made was undoubtedly altered by these changes without altering the characteristic. The quality of the contact therefore appeared to be of much greater importance than the loss or fracture of a small amount of crystal. The internal resistance of the crystal excluding the rectifying point and in comparison with the resistance of the contact of wide area must therefore be assumed to be very low. There are other facts which have a bearing on this question which will be stated later.

The characteristics obtained show that the best results are given by steel and tungsten, the metals which melt at the highest temperatures and nearest to the temperature at which carborundum is formed or changes its state. Also it is probable that steel when molten has a stronger affinity for carborundum than other metals owing to the iron and carbon contained in the crystal itself. And again as steel and tungsten are among the hardest metals,

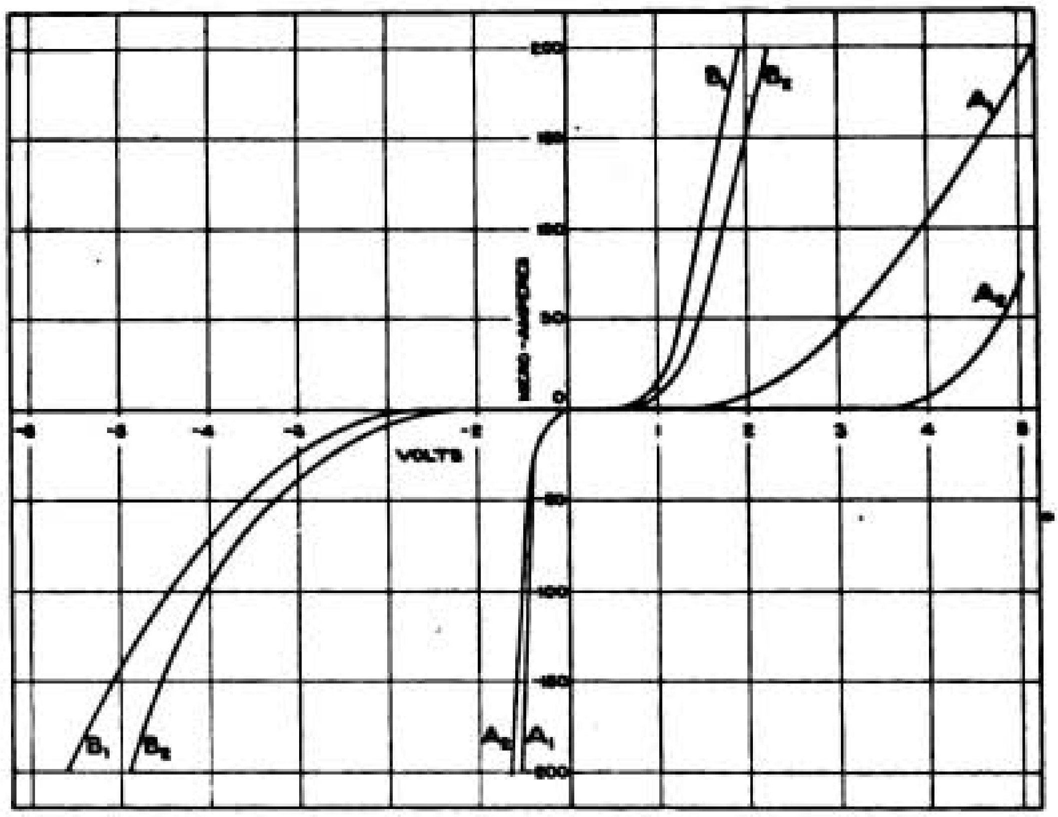


FIG. 2.—Characteristic Curves showing Influence of Nature of the Contact with Positive and Negative Crystal.

Curve A_1 = Steel tipped negative crystal.
Curve A_2 = Tungsten tipped negative crystal.
Curve B_1 = Steel tipped positive crystal.
Curve B_2 = Brass and copper tipped positive crystals.

on cooling from these higher temperatures the pressure exercised by contraction must be much greater in their case than with copper, brass or solder.

This pressure can operate in two ways, first by improving the actual electrical contact, and second by mechanically fracturing the outer crystal layers, which, as shown in section (4), will produce or extend the neutral conducting area.

The improvement which results from steel tipping is in general less marked but still appreciable when applied to black negative crystal. In this variety the neutral conducting points are more numerous and are mainly caused by impurities, and it is possible that solder makes a better electrical contact to these impurities than to carborundum itself.

(6) From a commercial point of view the principal improvement which resulted from the steel-tipping process was that about 85 per cent. to 90 per cent. of the raw crystal supplied by the Niagara Falls Company could be employed for rectifying purposes instead of the usual 20 per cent. or 25 per cent. if the crystals were simply mounted in plain solder.

The increase was almost entirely made up of the hard green positive variety which has a much greater contact resistance to solder than has the dark grey or black negative variety, so much so that crystals of this type which prove to be of comparatively low resistance when steel tipped, commencing to rectify with a steep characteristic when only a fraction of a volt is applied, when mounted in plain solder may show no current in either direction when two volts positive or negative is applied, or may give a high resistance characteristic unsuitable for use in practice.

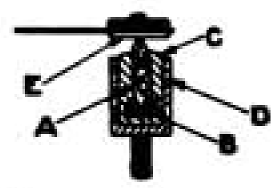


FIG. 3.—Arrangement of Crystal and Contact.

The crystal detectors under the observation of the author are made entirely from green positive or black negative carborundum the two most suitable varieties, and are constructed as shown in Fig. 3 where A is a crystal chip tipped with steel at B, and set in solder C, in a brass cup D, which is painted red if the crystal is positive and black if the crystal is negative.

The steel plate mounted on a strip spring which makes contact with the rectifying point of the crystal is shown at E and is usually set to exert a pressure of 400 to 500 grammes, or roughly 1 lb.

The official test for such a detector is that it shall pass a current of at least

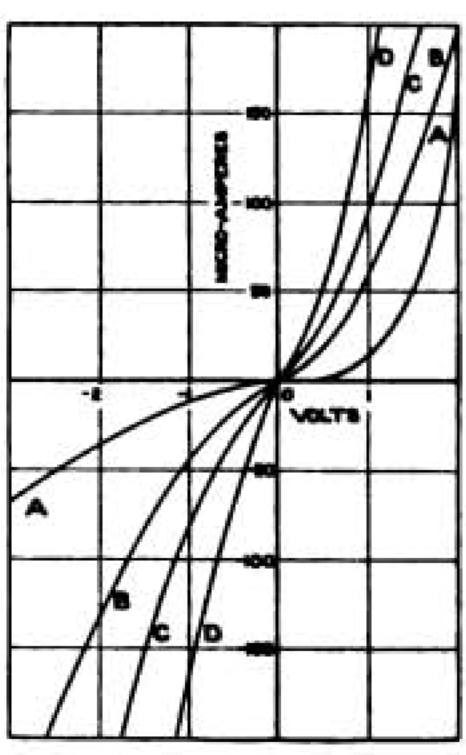


FIG. 4A.—Crystal mounted in Solder only.

TELEPHONE SHUNTS.

A = 20 ohms.
B = 40 ohms.
C = > 200 ohms.
D = No signals.

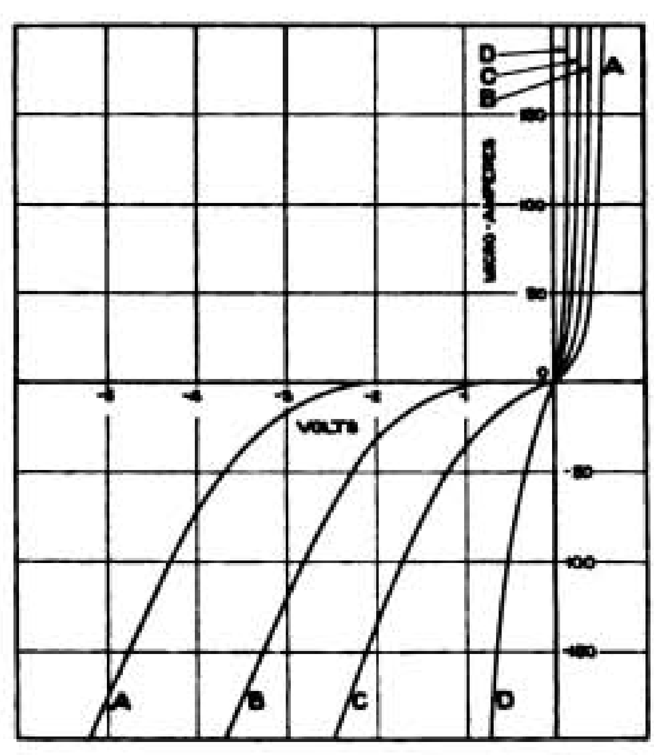


FIG. 4B.—Crystal Steel Tipped and mounted in Solder.

TELEPHONE SHUNTS.

A = 20 ohms.
B = 40 ohms.
C = 120 ohms.
D = > 200 ohms.

CHARACTERISTIC CURVES SHOWING EFFECT OF CONTACT AREA.

Curves A = Steel contact.
Curves B = Mercury just touching.
Curves C = Contact immersed 1 mm. in mercury.
Curves D = Contact immersed 3 mm.

UU 2

250 microamps when 2 volts are applied to it in one direction but no current whatever when the same voltage is applied in the opposite direction, and it is also compared for sensitivity on signals against a standard.

(7) The metal used for the strip spring making contact to the point of the crystal does not appear to be a matter of great importance provided the strip presents a plain undented surface.

The best results are obtained when the area of contact is as small as possible, but with an abrasive material like carborundum the crystal point will scratch and enter deeper into brass than into steel so that for this reason the harder metal is to be preferred.

The effect of extending the area of contact is illustrated in the series of characteristics of Fig. 4. A steel plate contact as shown by curves AA has a higher resistance than a mercury contact which is just touching the crystal point, but the sensitivity with the steel is greater than with the mercury.

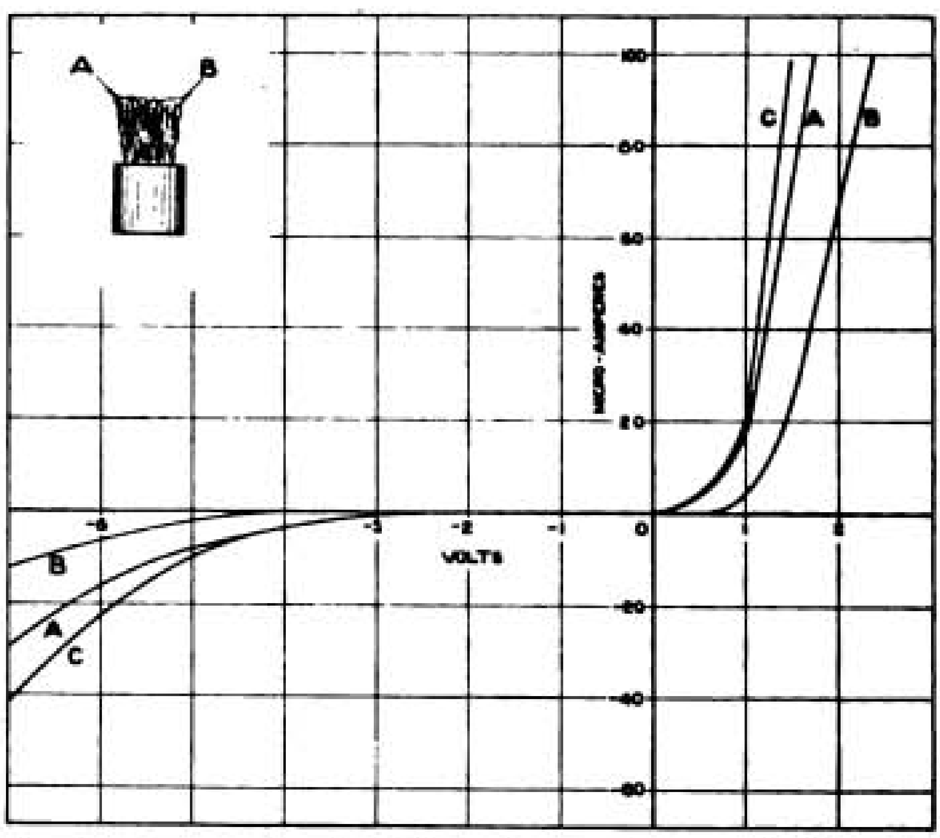


FIG. 5.—Curves showing Effect of using Contacts in Parallel.

Curve.	Point of Contact.	Sensitivity : Telephone Shunt.
A	A	100 ohms.
B	B	120 ohms.
C	A and B in parallel.	100 ohms.

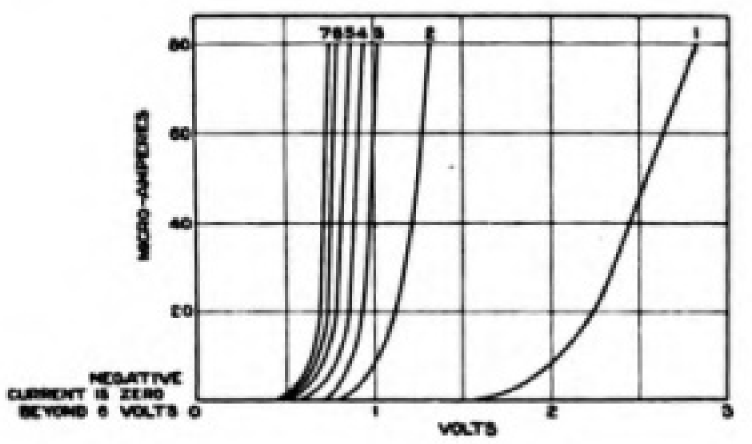
As the area of contact of the mercury is increased the detector resistance falls but so does its sensitivity.

The effect of increasing the number of point contacts is also illustrated in Fig. 5.

Contact B offers a higher resistance and is less sensitive than contact A.

If the two are connected in parallel the total resistance is less than either and the sensitivity is that of the lowest.

This is a case of selected points but with a broad mercury contact, no such selection could be exercised.



Curve.	Pressure. Grammes.	Sensitivity : Telephone Shunt. Ohms.
1	Light contact.	100
2	100	85
3	200	80
4	400	80
5	600	80
6	800	80
7	1,000	80

Average pressure = 453 grammes = 1 lb.

FIG. 6A.—Effect of Contact Pressure on High-resistance Positive Crystal.

(8) The effect of contact pressure at the crystal point is shown in the series of curves Figs. 6A, 6B, 6C, and 6D.

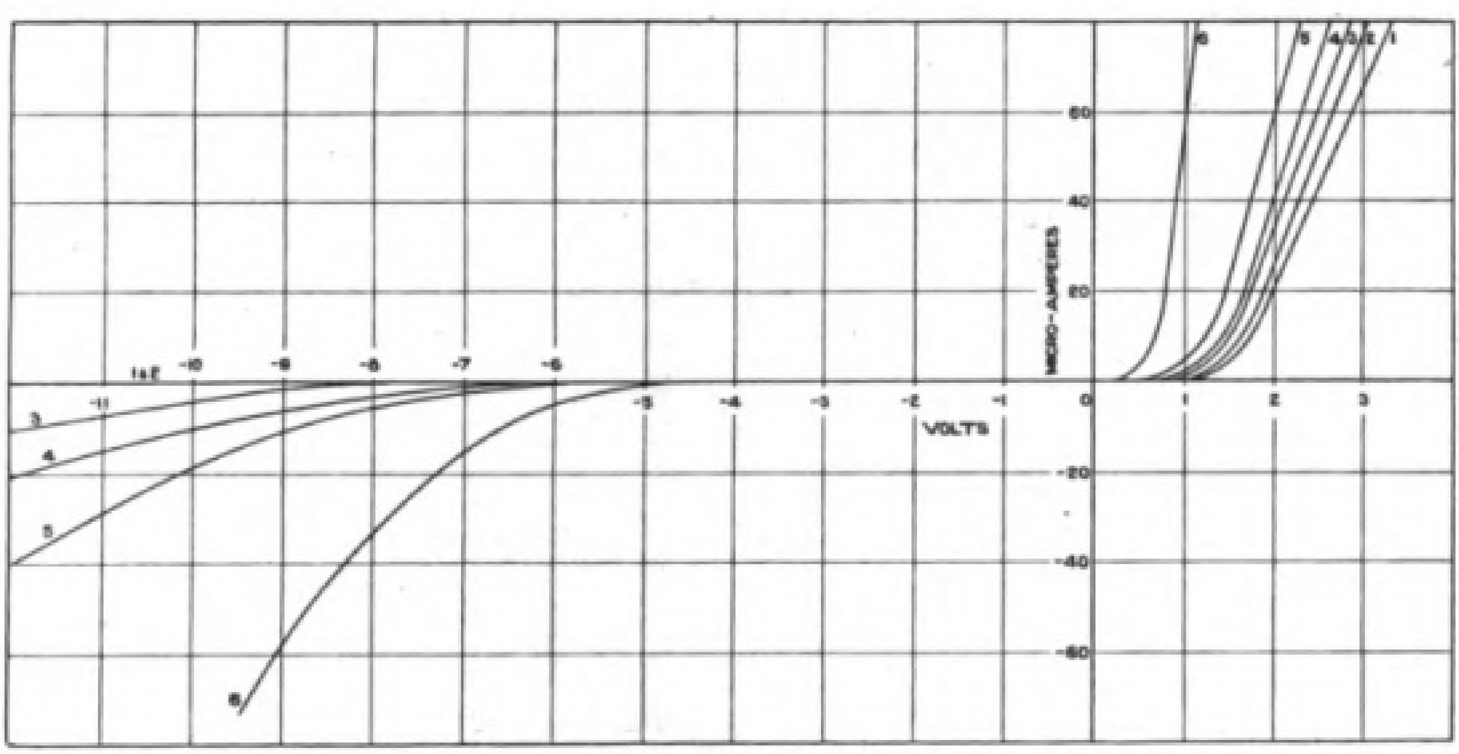


FIG. 6B.—Effect of Contact Pressure on Low-resistance Positive Crystal.

Curve.	Pressure. Grammes.	Sensitivity : Telephone Shunt. Ohms.
1	Light contact.	100
2	100	100
3	200	95
4	300	95
5	400	95
6	2,500	80

Average pressure = 453 grammes = 1 lb.

In Fig. 6A the pressure applied to a high-resistance positive crystal was increased from a light contact up to 1,000 grammes. This caused a corresponding fall in the effective resistance and the potential at which the current appeared, but the sensitivity of the crystal as a detector only increased slightly up to 200 grammes pressure and then remained constant up to a pressure of 1,000 grammes.

Fig. 6B refers to a positive crystal of lower resistance. Similar effects were noticed but it was possible to take the pressure up to 2,500 grammes with a 20 per cent. improvement in sensitivity.

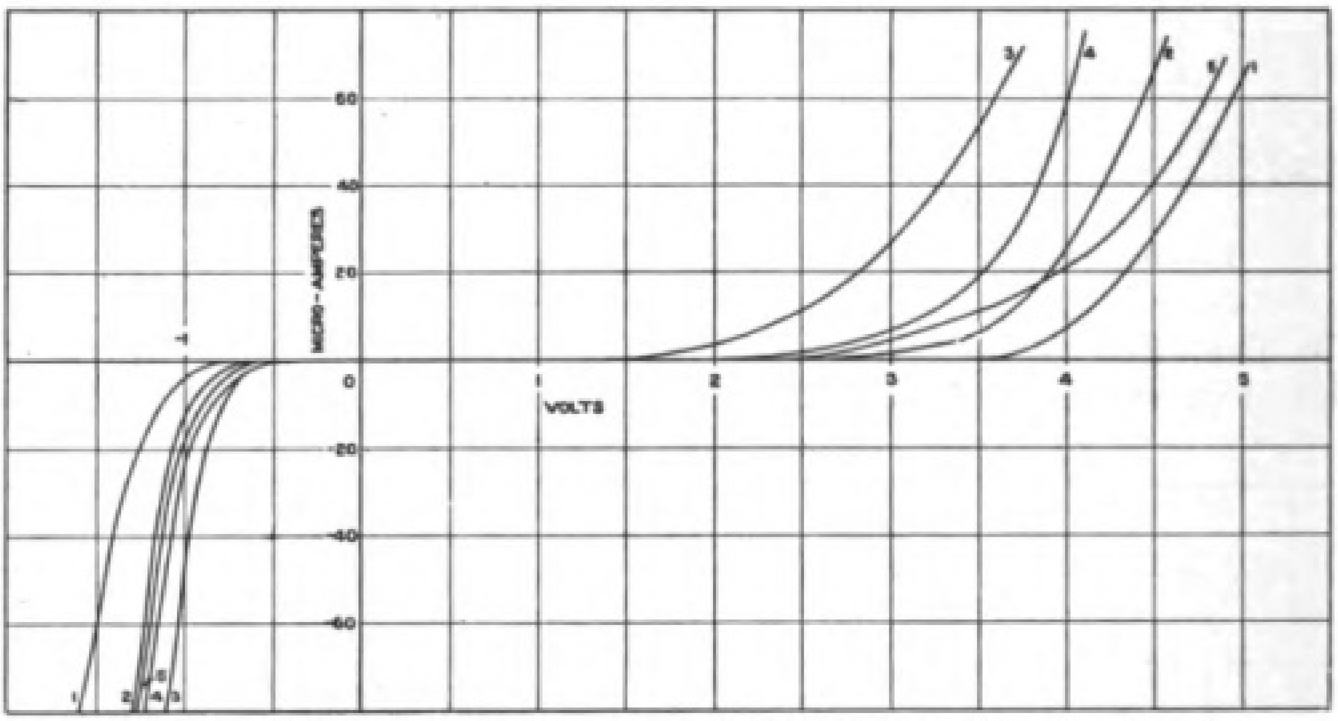


FIG. 6C.—Effect of Contact Pressure on High-resistance Negative Crystal.

Curve.	Pressure. Grammes.	Sensitivity : Telephone Shunt. Ohms.
1	Light contact.	100
2	100	95
3	200	95
4	300	95
5	400	95

Average pressure = 453 grammes = 1 lb.

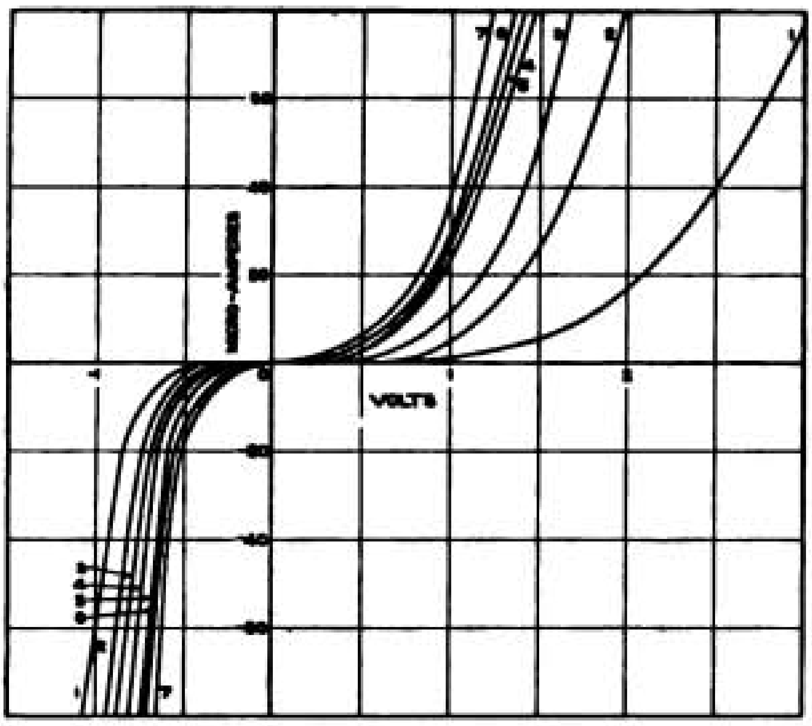
In Fig. 6C a negative crystal of fairly high resistance showed a small improvement in conductivity up to 200 grammes and then fell off again as the pressure was increased up to 400 grammes. Its sensitivity remained constant above 100 grammes.

Finally in Fig. 6D a negative crystal of a lower resistance improved steadily in conductivity but not in sensitivity as a detector.

These results show that the contact pressure is not critical. It need only be sufficient therefore to make the adjustment insensitive to local vibration.

At the working pressure of 400 to 500 grammes the results just quoted show that the sensitivity has practically reached a constant value.

(9) The effect of pressure applied to a neutral point on the resistance of a crystal measured from the neutral point to the steel-tipped base is shown in Figs. 7A and 7B.



Curve.	Pressure. Grammes.	Sensitivity: Telephone Shunt. Ohms.
1	Light contact.	100
2	100	100
3	250	100
4	500	100
5	750	100
6	1,000	100
7	2,500	100

Average pressure = 453 grammes = 1 lb.

Fig. 6D.—Effect of Contact Pressure on Negative Crystal of Lower Resistance.

The plots in Fig. 7A were obtained when using a green positive crystal, the neutral point being provided by a jagged crystal edge. In this case a change of pressure from 100 grammes to 2,500 grammes lowered the resistance from 5,000 ohms to 500 ohms.

The plots in Fig. 7B were obtained when using a black negative crystal the neutral point being provided by foreign matter in a fault in the crystal. In this case the resistance was 6,250 ohms for a pressure of 100 grammes, it started to fall and then rose as the pressure was increased and finally fell again, being 550 ohms when the pressure reached 2,500 grammes.

It was found that this irregular decrease and increase with pressure was a permanent feature of this point on the crystal.

One is likely to conclude from these results that the improvement noted from steel tipping can be explained by the great contact pressure exercised by the shrinking of the steel when cooling, but it will be made clear later that this cannot be the complete explanation.

(10) Having thus determined the conditions of contact at the base and point of a crystal chip which must be satisfied in order to obtain consistent results, it is of interest to show how the characteristic of a crystal block alters in proceeding from the part which has been attached to the furnace wall,—the base,—to the part which has been nearest the furnace core,—the top of the block.

For this purpose some of the thickest blocks obtainable were selected, sample chips were taken from different levels, they were mounted in the standard manner and were then tested in the usual way.

Figs. 8A and 8B for green positive carborundum show that the rectification

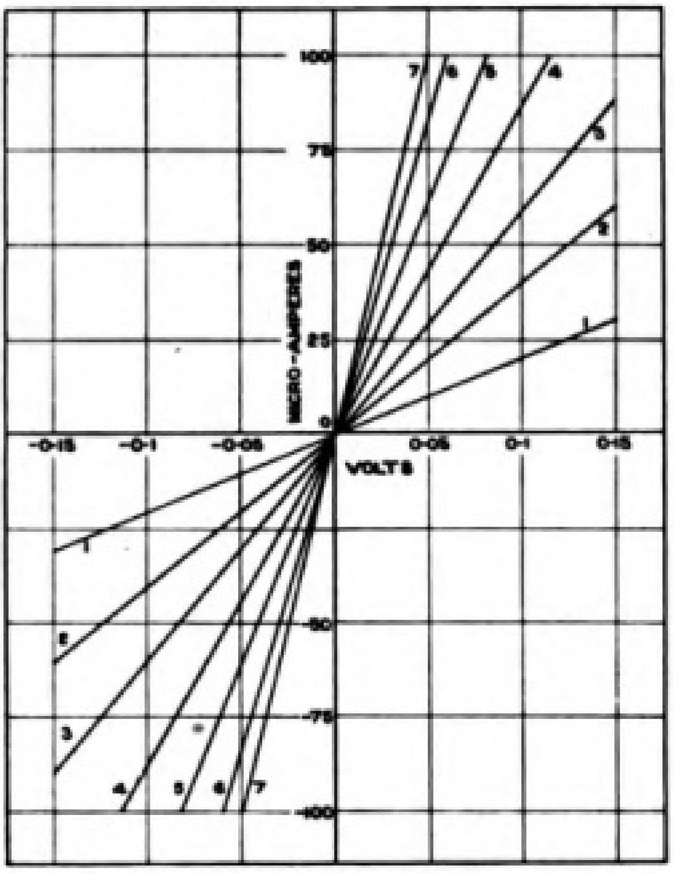


FIG. 7A.—Green Positive Crystal.

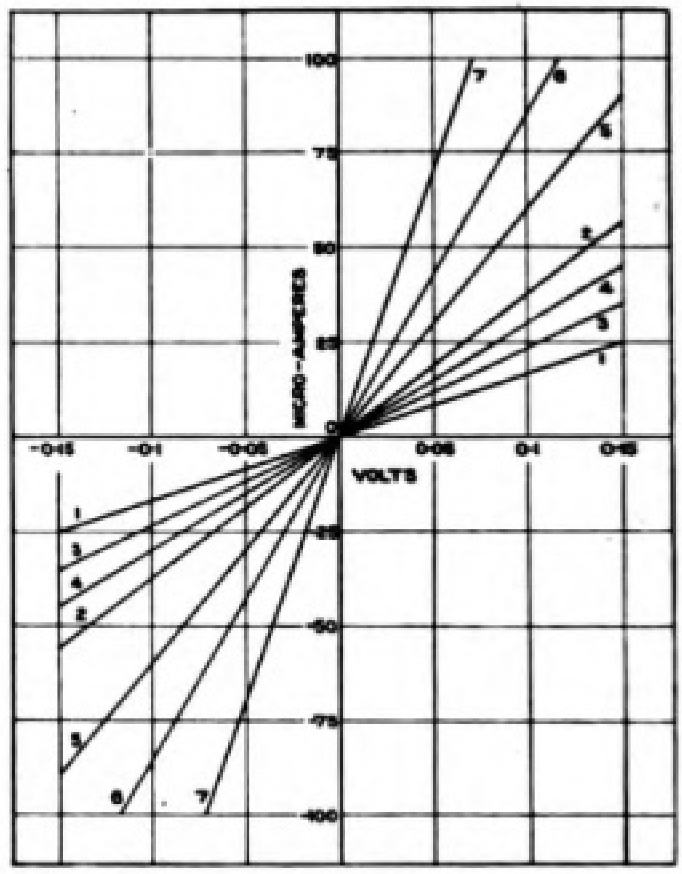


FIG. 7B.—Black Negative Crystal.

EFFECT OF PRESSURE APPLIED TO A NEUTRAL POINT ON THE CRYSTAL.

Curve.	Pressure.		
	Grammes.	Lbs.	Ozs.
1	100	—	3·53
2	250	—	8·82
3	500	1	1·64
4	1,000	2	3·28
5	1,500	3	4·92
6	2,000	4	6·56
7	2,500	5	8·20

effect and the resistance are greatest at the base of the block and least at the top, and Figs. 9A and 9B for negative crystal show the same effect.

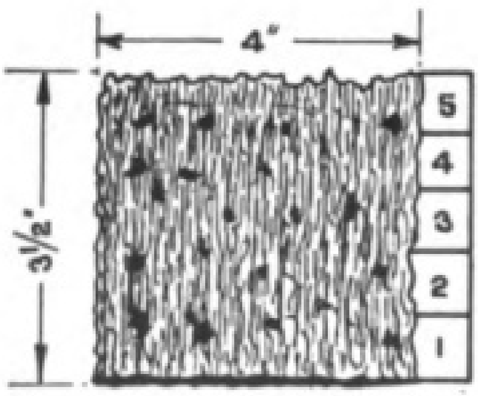


FIG. 8A.—Section of Block of Positive Carborundum.

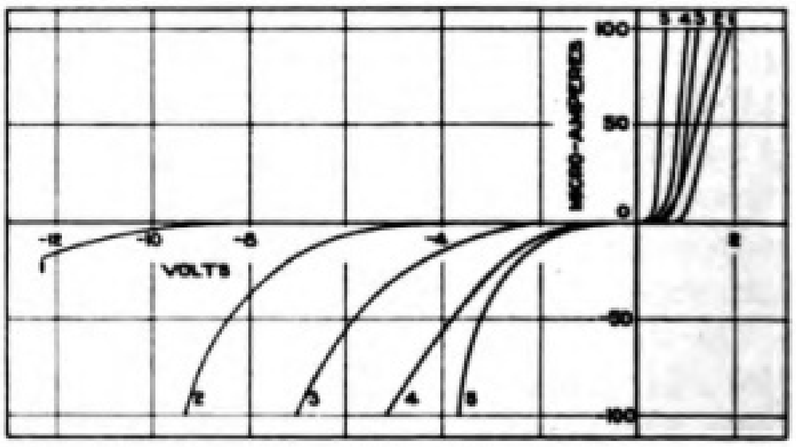


FIG. 8B.—Variation of Rectification Effect with Position in Block (Positive Crystals).

The best detector crystal in each case, however, is usually obtained from the position of the second layer.

The sense of the rectification is the same throughout the whole block, and, as shown in Fig. 9B, does not depend on which end is made the point and which the base. The degree of rectification does depend on this in the lower layers but not in the top.

The base of the negative block has an amorphous coke-like nature, and if the top of the first layer is steel tipped usually only neutral conducting points can be found on the bottom. The top of the first layer is composed of small crystals and the top of the sixth layer of large crystals.

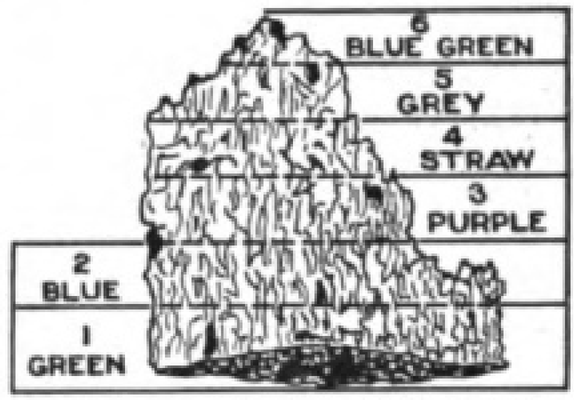


Fig. 9A.—Section of Block of Negative Carborundum.

Practically all the crystals in the block are faulty; they grow one out of the other or one group out of another group, and where they are thus grafted together they conduct. With the possible exception of some parts of the first layer active rectification can only take place at the surface point contact, as any interior point contacts are short circuited by the surrounding grafted crystals.

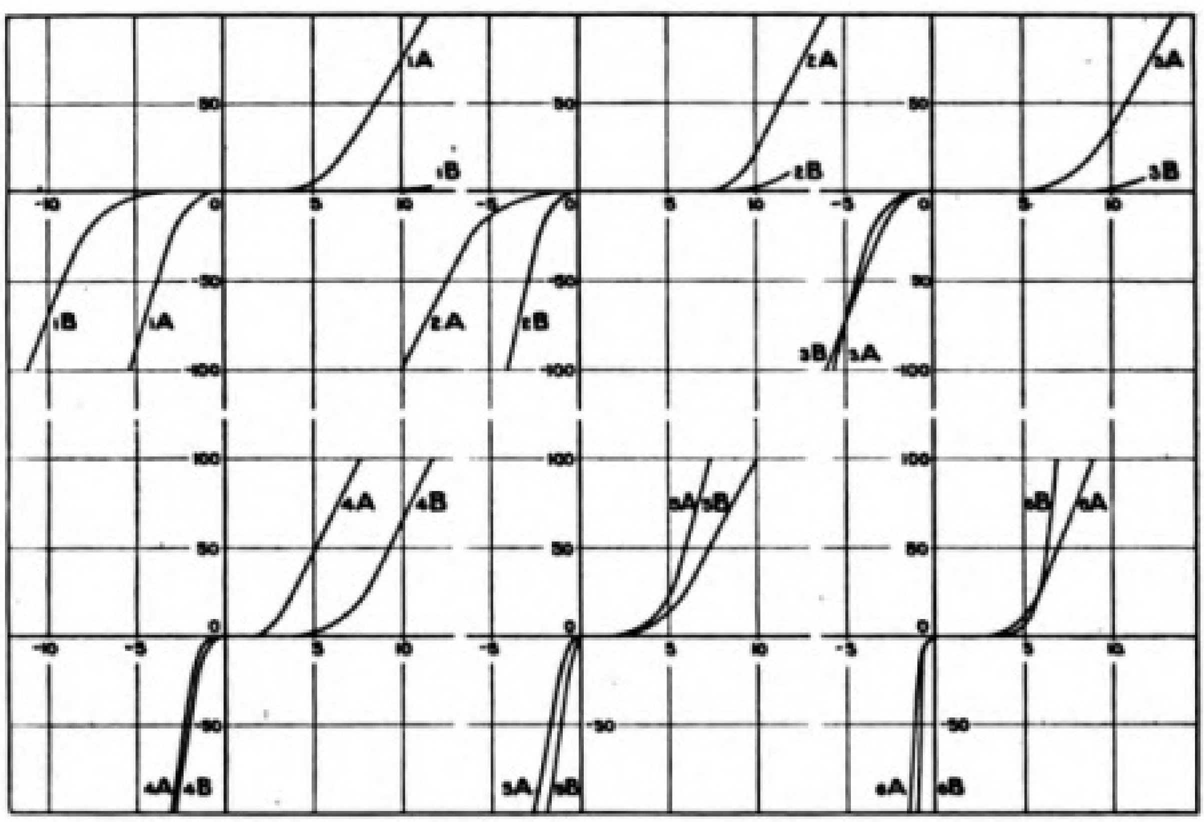


Fig. 9B.—Variation of Rectification Effect with Position in Block (Negative Crystals).

Curves A = Crystal base nearest to top of block.
Curves B = Crystal base nearest to base of block.

Note: The numbering of these curves corresponds with the sections numbered in Fig. 9A.

The degree of rectification and the effective resistance of the crystal chip would appear therefore to be dependent inversely on the size of the surface crystal to which the point contact is made.

The effect of chemically cleansing the crystal surface of oxides, either by heating in fused borax, or by boiling the samples in a mixture of nitric and hydrofluoric acid, and then in a mixture of nitric acid and potassium chlorate, is to produce an extraordinary consistency in the characteristics of all samples from the same layer, but the difference between the characteristics of one layer and another is not affected.

(11) What influence has the air at the point contact on the rectification effect ?

A standard carborundum and steel plate detector after being adjusted was mounted in a glass chamber which could be exhausted of air. Its characteristic was taken and its maximum sensitivity was measured by the shunted telephone method at different air pressures.

It was found that for air pressures from normal down to 0·00001 mm of mercury at constant temperature there was no change in the characteristic or in the sensitivity of the crystal.

The conclusion is that with carborundum and with the normal spring contact pressure on the crystal point, the air at the point plays a negligible part in the rectification effect, which must therefore be due to a reaction in the thickness of the crystal itself.

(12) The influence of temperature is considerable.

The chamber containing the detector was heated in steps from 19° C. to 100° C.

The characteristic became progressively steeper and the sensitivity of the detector increased until at 100° C. the telephone shunt resistance was half that required at 19° C. to give the same audibility.

This indicates that a carborundum crystal detector employed in the tropics will give better results than when it is used in temperate latitudes.

At 100° C. a variation of air pressure from 760 mm to 0·00001 mm made no difference to the behaviour of the detector.

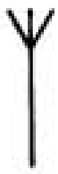
A test was made to find out whether the change in the characteristic with temperature was due to a thermo-electric effect at the contact. For this purpose a D'Arsonval type of galvanometer capable of detecting an E.M.F. of 0·00025 volt was employed. The detector enclosed in the glass containing vessel was heated up to 140° C. but no deflection was obtained.

(To be concluded.)

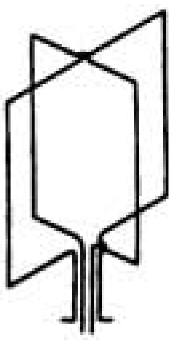
Graphical Symbols for Radio Diagrams.

The interpretation of circuit diagrams used in explanation of radio apparatus is considerably simplified if standardised symbols are always used in their preparation. For some time past we have adhered as far as possible in the RADIO REVIEW to a uniform scheme of such symbols, but in view of the increased interest that has recently been taken in this subject we are setting out in the following pages a list of the most important symbols that are at present being used, or that are proposed for use in the RADIO REVIEW. These have been compiled so as to be in agreement as far as practicable with the symbols that are most commonly employed in British, American, French, German, and Italian radio literature, keeping in mind the necessity for both clearness and ease of drawing. An alternative is shown for the three-electrode thermionic valve.

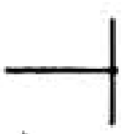
Comments as to the merits or demerits of these suggested symbols will be welcomed from readers, with any suggestions as to additions or other changes which might make this list more complete and useful.

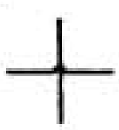
 Aerial—Elevated.

 Aerial—Horizontal or Buried.

 Aerial—Directional.

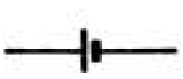
 Terminal.

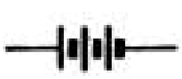
 Connection — Electrical Joint.

 Bridge—Crossing.

 Earth.

 Counterpoise.

 Cell. (The long thin stroke represents the Positive Terminal.)

 Battery—L.T.

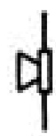
 Battery—H.T.

 Condenser—Large, Audio Frequency.

 Condenser—Fixed Radio Frequency.

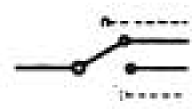
 Condenser — Variable (continuously) Radio Frequency.

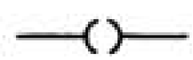
 Telephones.

 Microphone — Telephone Transmitter.

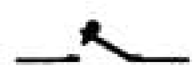
 Fuse.

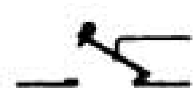
 Switch—Single-way.

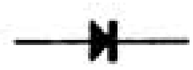
 Switch—Multi-way.

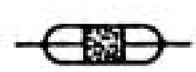
 Switch—Plug.

 Plug.

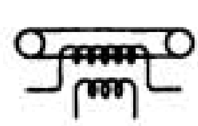
 Key—Morse Tapping.

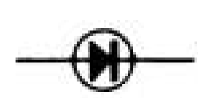
 Key—Morse, Back Contact.

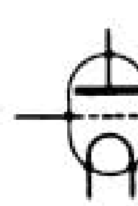
 Detector—Crystal.

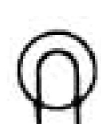
 Coherer.

 Tikker.

 Detector—Magnetic.

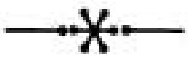
 Rectifier. (Electron Current Flow assumed from Point to Plate.)

 Valve—Tube Thermionic. (Alternative — 1.)

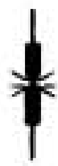
 Lamp—Bulb Electric, Filament.

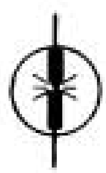

Spark Gap—Open.

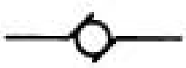

Spark Gap—Quenched.

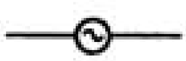

Spark Gap—Rotary, Synchronous.

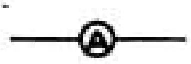

Spark Gap — Rotary, Asynchronous.

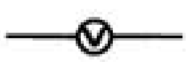

Arc—Open.

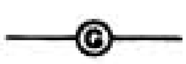

Arc—Enclosed.

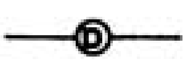

Generator—D.C.

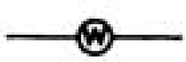

Generator—Alternating.

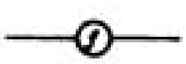

Ammeter.

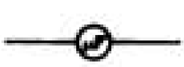

Voltmeter.

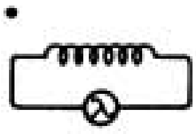

Galvanometer.

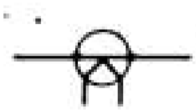

Decremeter.


Wattmeter.


Frequencymeter.


Microfaradmeter.


Wavemeter.

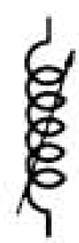

Thermoammeter.

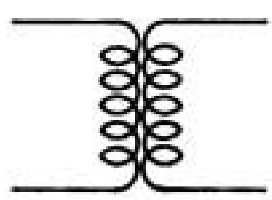

Resistance—Fixed.

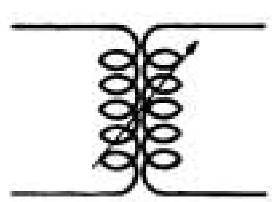

Resistance—Variable.

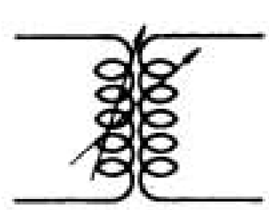

Potentiometer Resistance.

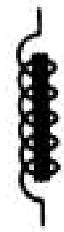

Inductance.


Inductance—Variable.

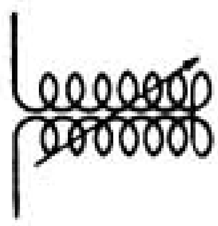

Coupling—Inductive.


Coupling—Inductive, Variable.

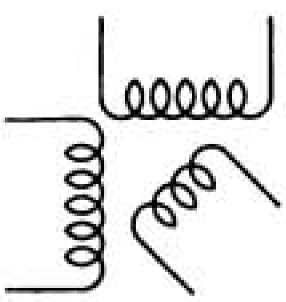

Coupling — Inductive, Variable, one Inductance variable.



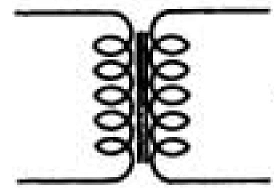
Choke Coil—Iron Core.



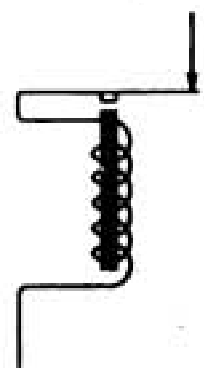
Variometer.



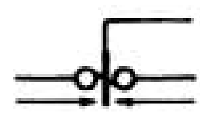
Radiogoniometer.



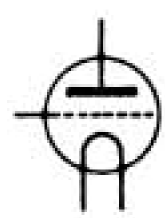
Transformer—Iron Core.



Vibrator—Buzzer Make and Break.



Relay.



(Alternative — 2.) Valve —Tube Thermionic.

Notes.

WIRELESS TELEPHONY ON THE "QUEST."—Sir Ernest Shackleton's expedition on the *Quest* has been fitted out with wireless telephone apparatus in addition to its regular wireless equipment. Two 100 watt "Y.B." type Marconi C.W. and telephone sets have been fitted, one being for base work on land. The Avro aeroplane which is being taken has also been fitted with a similar set. **[4305]**

ANNUAL CONVENTION.—The first Annual American Radio Relay League Convention was held in Chicago between August 30th and September 3rd. Many important papers on the subject of radio work were read and discussed. **[4163]**

DAMAGE TO ARLINGTON RADIO STATION.—In a recent severe electrical storm the U.S. Naval Radio Station at Arlington was struck by lightning and had temporarily to suspend operations. The interruption however was of short duration. **[4003]**

A new Weights and Measures Law has been passed in Japan rendering compulsory the use of the metric system. The complete change-over from the existing system is to be effected in all works, schools, Government offices, etc., in a period not exceeding five years. **[3147]**

It has been stated in the House of Commons in reply to inquiries that no alteration is contemplated in the existing rules with respect to wireless "watchers" on ships. **[3029]**

THE SHIPPING, ENGINEERING AND MACHINERY EXHIBITION which was held at Olympia, London, W., between September 7th and 28th, included several items of radiotelegraphic interest exhibited by various manufacturers. Particular mention may be made of the apparatus exhibited by the Radio Communication Co., Ltd. (marine spark and arc installations); the R.M. Radio Co., Ltd. (see RADIO REVIEW, 2, pp. 172—179 for illustrated description); H. Hamilton Wilson (motor driven interrupter type of transmitters, high-tension condensers, and a complete ½ kW set); the British Thomson-Houston Co. (portable wireless receiving apparatus); F. O. Read & Co. (amateur wireless apparatus and components); S. G. Brown (telephones). **[4241]**

Two New Negative Resistance Devices for Use in Wireless Telegraphy.*

By JOHN SCOTT-TAGGART,

Chief of the Patent Department, and Research Engineer, Radio Communication Co., Ltd.

The paper opens with a short account of the uses of negative resistances, the chief being the production of continuous oscillations for use in wireless telegraphy. The author then describes two new thermionic valve devices by means of which negative resistance characteristics may be obtained. The first device, termed the "Negatron," was produced in September, 1919 (*British Patent* 166260). The principle on which it works is briefly as follows: A thermionic valve is arranged having two flat anodes one on each side of a filament. Each anode is connected through an anode battery to the filament so that the electrons emitted by the filament, when it is heated to incandescence, are distributed fairly equally between the two anodes. A control electrode, which may be a flat grid, is also arranged within the valve between the filament and one of the anodes. This latter anode will be called the "diversion anode," while the first one will be called the "main anode." If we suitably arrange the relationship between the electron emission and the anode voltages, we may make the total of the anode currents approximately equal to the electron emission. In other words, a saturation effect is obtained. Under these conditions, if we make the grid more positive with respect to the filament we shall divert electrons from the main anode to the diversion anode, with a consequent reduction of the current flowing in the main anode circuit. In the negatron, as preferably used, the main anode is connected to the grid so that when the main anode voltage is increased the grid potential is increased, electrons are diverted from the main anode, and the main anode current decreases. Hence the negative resistance effect.

Theory of Action of the Negatron.—Fig. 1 illustrates the negatron valve itself. The anode on the left is the main anode (usually small), while the anode on the right is the diversion anode. Between the filament and the diversion anode is a flat openwork grid. A tubular valve with four-pin cap is preferred, the connection to the main anode being taken to the metal portion of the valve cap. A metal spring on the holder presses against and makes electrical contact with this metal portion.

FIG. 1.

The action of the negatron will be best understood if reference is made to Fig. 2, which shows a negatron connected up in one way so as to possess negative resistance characteristics. Between the anode A_1 and the filament F is a battery B_2 and two terminals I, N. Between these terminals a milli-ammeter may, for the time being, be connected. The anode is connected through a battery B_3 to the grid G. This battery is merely connected in this position to keep the grid at a suitable potential which is preferably slightly negative. If G were connected directly to A_1, G would have a high positive potential with respect to F. Between F and the diversion anode A_2 is a second battery B_2'. Both B_2 and B_2' are usually of about 60 volts, but their values are not very important provided that the current supplied to the filament F may be adjusted to produce the saturation effect.

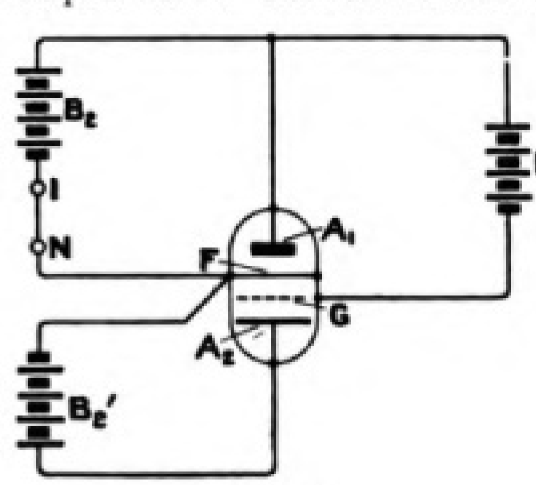


FIG. 2.

Let us now see what will happen if we increase the voltage of B_2. We should normally expect the current to A_1 to increase, but as the potential of A_1 increases so does that of the grid G. Since G becomes more positive, the current

* Abstract of papers read before Section G of the British Association at Edinburgh on Tuesday, September 13th, 1921.

to A_2 will increase, and this increase could be measured by connecting a second milliammeter in the A_2 anode circuit. This method of varying (by altering the space charge) the current to A_2 is, of course, well known, as it has been used in ordinary valves since Lee de Forest first introduced the grid. The important fact to notice, however, is that, if the current to A_2 increases, the electrons which go to A_2 must come from those which would have gone to the anode A_1. There is, therefore, a diversion of electrons. If the A_2 anode current increases, the A_1 anode current must decrease, and conversely. Similarly, a decrease of the A_1 anode current would always be accompanied by an increase of the A_2 anode current, and conversely. This effect is conditional on the existence of saturation in the valve. Since by increasing the potential of the main anode A_1 we have diverted electron current to the anode A_2, the main anode current decreases. There are now two effects which govern the A_1 anode current. The increase in the A_1 anode potential tends to increase the A_1 anode current; the diversion effect, however, tends to decrease the A_1 anode current. The diversion effect greatly outweighs the other, and the result is a decrease in the main anode current consequent on an increase of the main anode potential; the converse also applies. A decrease of the main anode potential makes the grid G more negative and decreases the current to A_2; the A_1 anode current consequently increases. In this way, the negatron acts as a negative resistance.

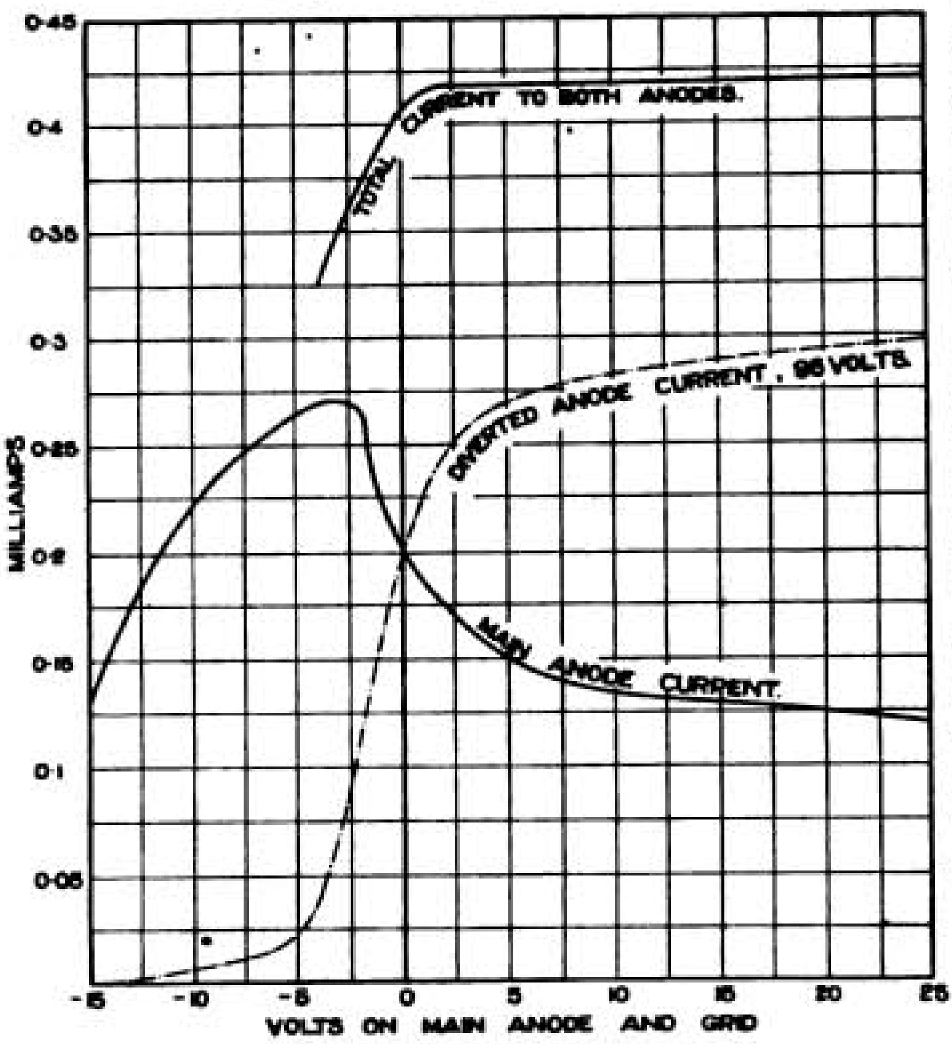


FIG. 3.
(Main anode datum = + 95 V.)

The negatron, as described, works only when the saturation effect is obtained. For this reason, a filament current rheostat is desirable and the current through the filament is adjusted until the negative resistance effect is obtained. If the filament be too bright, there will be no "robbing" action; there will always be a plentiful supply of electrons around the filament and an increase of grid potential would increase the A_2 anode current and the additional electrons would come from the source round the filament and not from amongst those which would have gone to the main anode A_1. The A_1 anode current would therefore be unaffected and no negative resistance effect would be obtained.

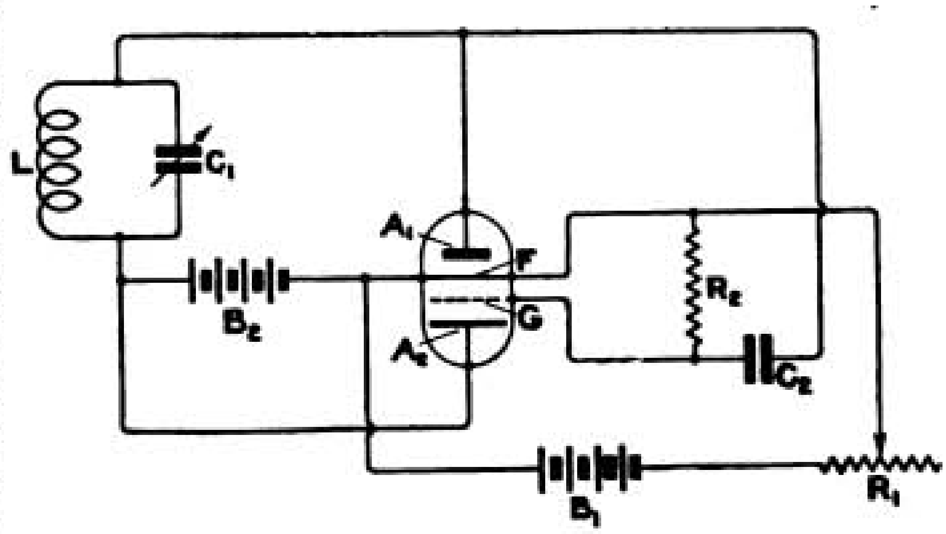


FIG. 4.

Characteristic Curves of the Negatron.—The above explanation is borne out by characteristic curves obtained with the negatron, three of which curves are shown in Fig. 3. The thick line shows the main anode current. The top thin curve shows the sum of the two anode currents. The broken line represents the diversion anode current. Since the grid is always kept in the neighbourhood of zero volts, the grid current is almost zero. The grid is usually kept slightly negative, so that the grid current is zero. If this were not so, the grid current would add itself to the main anode current and the negative resistance slope would be less steep.

The curves of Fig. 3 bring out very clearly the "robbing" action which the negatron utilises. The top curve shows that the negative resistance effect is obtained while the valve is saturated. Since the total current remains constant and the diversion anode current increases (due to the control electrode potential rising) the main anode current must of necessity decrease, and this is shown by the thick line curve which slopes downwards. The main anode current decreases to the left of the peak because the saturation effect is non-existent (as proved by the top curve) and the decreasing grid potential produces an increasing space charge between filament and main anode which decreases the main anode circuit. The curve is, of course, only used along its downward sloping portion and oscillations will only be produced when the main anode and grid potentials are at suitable values. In practice, the grid potential is usually slightly negative and no grid voltage adjustment is necessary.

Applications of the Negatron.—To recount the applications of the negatron would take up too much space; they are as numerous and varied as those of the dynatron (which, of course, works on an essentially different principle). The main use of it is as a generator of continuous oscillations for the transmission or reception of continuous waves. It may be used for receiving spark signals by reducing the effect of positive resistance. As a local oscillator it is exceedingly convenient as it will oscillate on all ranges from 600 m to 20,000 m (the usual commercial range) without any complicated switching arrangements. The circuit arrangements which have been found most convenient are shown in Fig. 4. These are the same as those in Fig. 2, except that the two batteries are replaced by a single one B_2 of about 60 volts. The main anode is connected through a leaky grid condenser C_2 to the grid G, a resistance R_2 being connected across grid and filament. This leaky grid condenser merely replaces the battery B_3 of Fig. 2 for the purpose of avoiding a high positive grid potential. The filament F is heated by current from the 6-volt accumulator B_1 through the rheostat R_1, of about 7 ohms resistance. This rheostat is adjusted until continuous oscillations are produced in the oscillatory circuit L C_1. It is to be noted that the diversion anode circuit plays no other part in the circuit than as a path round which electrons are shunted. The A_2 anode current produces no effect whatever on the oscillatory circuit L C_1. If this anode were disconnected, the circuit would not, of course, oscillate even if there were plenty of electrons because the phases of the grid potentials would be exactly opposite to those necessary to produce oscillations. As it is, the grid, over (and beyond) the working range, does not control the main anode current in any way, when the A_2 anode is disconnected.

FIG. 5.

Fig. 5 is a photograph of a commercial negatron oscillator designed for use as a local oscillator for beat reception. The circuit arrangements are similar to those of Fig. 4. A metal plate is preferably connected to a point along the inductance. This metal plate increases the strength of the oscillations induced in the receiver and it is preferably not connected at the end of L because this tends somewhat to damp out the oscillations on short wavelengths. With regard to the design of this model, the author desires to acknowledge the work of Mr. Norman Lea, chiefly in designing the final dimensions of the valve electrodes to give the best results, and that of Messrs. Ree and Bainbridge-Bell in obtaining curves and designing the constants of the oscillatory circuit.

Before concluding, it will be of interest, no doubt, to demonstrate by means of curves the fact that the negatron only oscillates over a given range of filament current. Fig. 6 shows a series of characteristic curves. Main anode current curves are given for different values of filament current. The negative resistance effect disappears completely when the filament current is above 0·575 ampere. Likewise, it disappears, for another reason, when the filament current is very small. An oscillatory circuit will oscillate provided conditions are such as to come within the shaded area, and no difficulty is experienced in practice through the limited range of filament brightness.

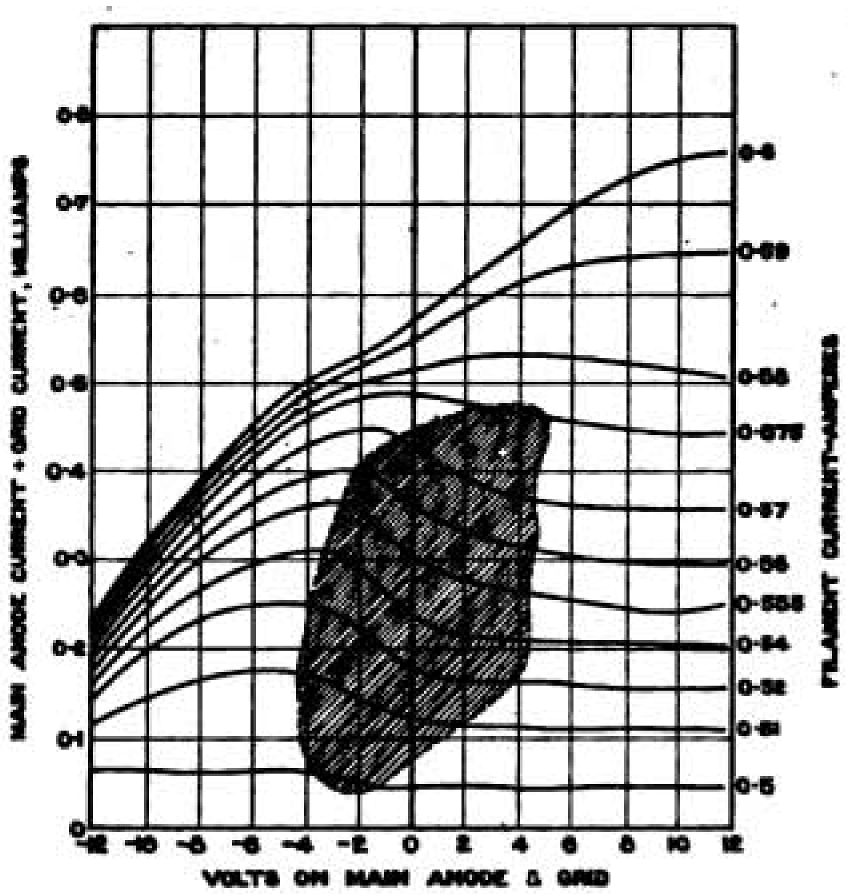


FIG. 6.
(Main anode datum = + 60 V.)

The second negative resistance device, which may be termed a "Biotron," employs two ordinary three-electrode valves, one acting as a conductor of current and the other as a phase-reverser. The valve V_1 (Fig. 7) is the conductor of current from the battery B_2'. Let us imagine an ammeter included across the terminals I N. If the E.M.F. of B_2' were increased we should expect the anode current to be increased. The opposite effect is obtained, however, by arranging that the increase in the anode voltage of V_1 increases the potential of the grid of the valve V_2. The normal potential of this grid is kept near zero by a battery B_3. In the anode circuit of V_2 is an anode battery B_2 and a resistance R. When the grid of V_2 becomes positive, the anode current through R increases, making the grid of V_1 more negative. The battery B_3' keeps the grid of V_1 at a suitable normal potential near zero. By increasing B_2' we therefore have two effects: One is a tendency to produce an increase of anode current by increasing the anode potential; the other is a tendency to decrease the anode current by making the grid more negative. This latter effect greatly outweighs the former, so that the anode current decreases and a negative-resistance characteristic is obtained. If the voltage of B_2' be decreased the converse effect takes place. The circuit, the resistance of which is to be decreased, is normally connected across I N. This static negative - resistance device can produce a very steep negative characteristic. The curve, moreover, is straight. This par-

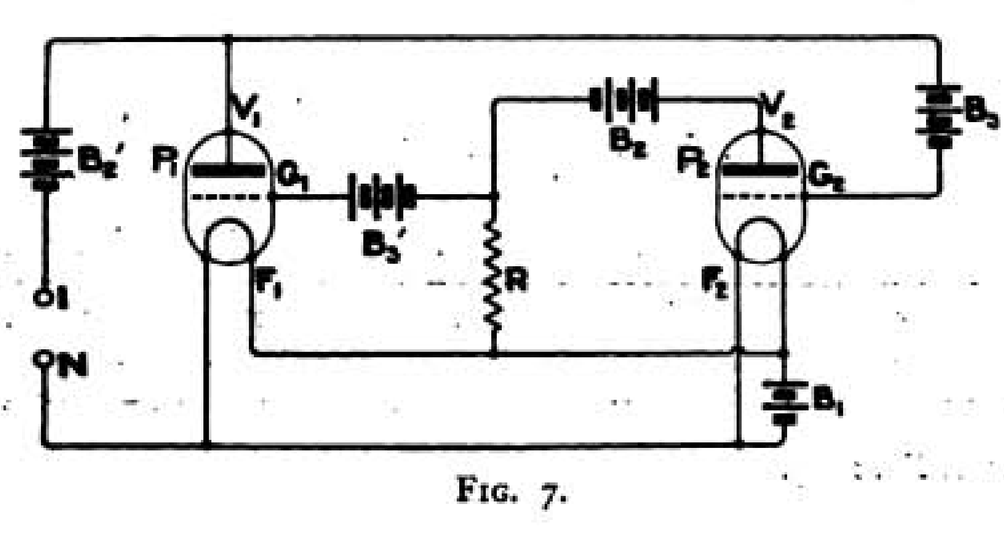


FIG. 7.

ticular negative resistance bears, at first glance, a certain resemblance to other resistance coupled arrangements, but as far as operation is concerned this is not the case. The arrangement shown in the diagram is perfectly stable. There is no building-up or retroactive action, as in the devices using two anode resistances. In the diagram the "negative-resistance current" does not itself produce any further change in any of the grid potentials. This is not the case with the arrangements the author is thinking of wherein the negative-resistance current passes through a resistance and produces a building-up action. The arrangement is described more fully in *British Patent* 152693 (July 25th, 1919).

Review of Radio Literature.

1. Abstracts of Articles and Patents.*

(C.) Arc Apparatus.

2562. **P. O. Pedersen.** On the Poulsen Arc in Coupled Circuits. (*Proceedings of the Institute of Radio Engineers*, 9, pp. 228—242, June, 1921.)

A mathematical and experimental investigation of the circuit shown in Fig. 1. The results seem to point to the fact that the advantages of applying the shunt circuit (C_1) are not of any great value. (See also p. 569 in this issue.)

2563. **O. C. Roos.** Electromagnetic Wave Transmission System. (*U.S. Patent* 1369281, November 4th, 1918. Patent granted February, 22nd, 1921.)

(F.) Thermionic Valves, and Valve Apparatus.

(4) DESIGN AND CONSTRUCTION OF VALVES.

2564. **J. Niedholt.** An Amplifier for Weak Alternating Currents. (*German Patent* 316408, April 4th, 1917. Patent granted November 25th, 1919. *Jahrbuch Zeitschrift für drahtlose Telegraphie*, 17, pp. 153—154, February, 1921—Abstract.)

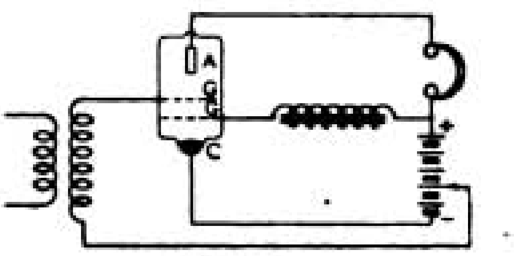


FIG. 2.

A discharge tube filled with one of the rare gases, with a cathode (C) of a substance which has a small cathode-fall in the particular gas. The anode (A) and grids (GG) are connected as shown in Fig. 2.

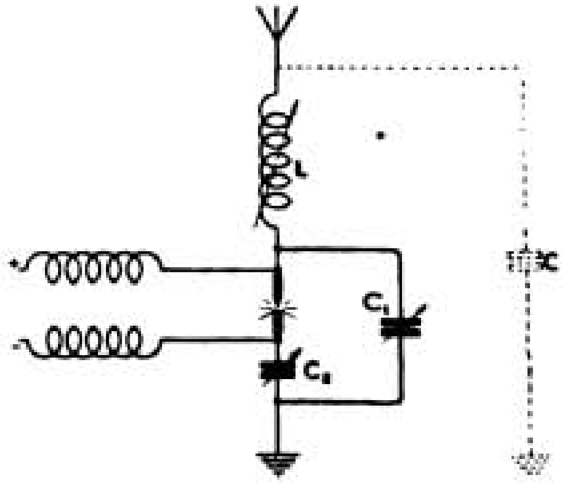


FIG. 1.

2565. **Miss M. Taylor.** Note on the Low Frequency Voltage Factor of an Oscillating Triode. (*Electrician*, 87, pp. 205—206. August 12th, 1921.)

Reference is made to a recent paper by Professor Eccles and Miss Leyshon,† in which the

* Particulars of the U.S.A. Patents abstracted in this section have been supplied by Mr. John B. Brady, Patent Lawyer, Ouray Building, Washington, D.C., U.S.A.; and those of the French Patents by Messrs. J. E. Raworth & Moss, Patent Agents, 75, Victoria Street, London, S.W.

† See RADIO REVIEW Abstract No. 2649.

voltage factor of a thermionic valve was defined as the change in the anode voltage required to maintain the anode current constant when unit additional E.M.F. is applied between the grid and the filament. This article describes experimental determinations of the voltage factor as defined above in the case of a valve actually generating high frequency oscillations. It is found that in certain circumstances the voltage factor may be much greater than its value when the valve is not oscillating. The results obtained assist in elucidating the action of the auto-heterodyne receiver.

2566. **W. C. Heraeus.** Metals for Vacuum Tube. (*British Patent* 144690, June 9th, 1920. Convention date April 18th, 1918. Patent accepted May 19th, 1921.)

An addition to *British Patent* 138648, describing means for freeing the electrodes of vacuum tubes from the occluded gases.

2567. **H. L. Crowther** and **W. Makower.** Thermionic Valves. (*British Patent* 161115, February 2nd, 1920. Patent accepted April 7th, 1921. *Engineer*, 131, p. 557, May 20th, 1921—Abstract.)

To heat the filament of a thermionic valve it is connected to a low resistance coil inside the bulb, which is excited by induction from a high-frequency current circulating in a coil outside the glass. Alternatively the currents may similarly be induced in a cylindrical cathode.

2568. **Société Anonyme pour l'Exploitation des procédés M. Leblanc-Vickers.** Thermionic Valves; Converting Electric Currents. (*British Patent* 161157, January 24th, 1921. Convention date April 2nd, 1920. Patent not yet accepted.)

Describes the construction of a valve for rectification or oscillation generation.

2569. **S. Loewe.** Thermionic Valves. (*British Patent* 149193, July 12th, 1920. Convention date July 9th, 1918. Patent not yet accepted.)

The cathode of a thermionic valve is made of considerable superficial area, and is rendered incandescent by electric bombardment by giving it a positive potential with respect to an adjacent auxiliary cathode which may comprise a filament heated by a current. The main cathode preferably encloses the auxiliary one.

2570. **S. Loewe** [E. F. Huth Gesellschaft]. Thermionic Valves. (*British Patent* 149210, July 12th, 1920. Convention date March 8th, 1917. Patent not yet accepted.)

Two or more sets of electrodes for use as amplifiers, detectors or oscillation generators are mounted in a single tube.

2571. **K. Rottgardt** and **S. Loewe** [E. F. Huth Gesellschaft]. Thermionic Valves. (*British Patent* 149211, July 12th, 1920. Convention date July 31st, 1919. Patent not yet accepted.)

A thermionic valve has a filament cathode and one or more controlling electrodes so shaped or arranged that the resulting field due to them is uniform in spite of the drop of potential along the cathode, or if preferred the non-uniformity of field due to this cause may be increased, for instance in a valve for use as a detector.

2572. **L. Bischoff** and **S. Loewe** [E. F. Huth Gesellschaft]. Thermionic Valves. (*British Patent* 149238, July 12th, 1920. Convention date March 1st, 1919. Patent not yet accepted.)

Deals with the expulsion of occluded gases from the anodes of valves.

2573. **J. Scott-Taggart.** Thermionic Valves. (*British Patent* 159920, November 6th, 1919. Patent accepted March 7th, 1921.)

For securing the electrode supports of a three-electrode valve U-shaped wires are sealed into the glass stem or walls of the tube and bent down over the electrode supports.

2574. **H. L. Crowther** and **W. Makower.** Thermionic Valve Construction. (*British Patent* 159955, December 4th, 1919. Patent accepted March 4th, 1921.)

During exhaustion of the bulb one or more of the electrodes may be heated by H.F. currents induced from a coil placed outside the tube.

2575. **A. M. Sarnmark.** Thermionic Valves. (*British Patent* 156760, January 7th, 1921. Convention date December 1st, 1919. Patent not yet accepted.)

The valve for oscillation generation is arranged to be simultaneously used as a signalling lamp for visual signalling.

2576. **L. A. McDougald.** Thermionic Valves. (*British Patent* 158011, July 28th, 1919. Patent accepted February 3rd, 1921.)

In a valve for use as a continuous-wave generator for wireless signalling, the anode, or a plate to which the anode is attached, forms part of the wall of a glass bulb, and of a glass reservoir containing cooling liquid, the anode and the reservoir being connected by fusion with the bulb.

2577. **S. R. Mullard.** Thermionic Valves. (*British Patent* 158720, November 14th, 1919. Patent accepted February 14th, 1921.)

Deals with an arrangement of sealing tube or support for the valve electrodes such that the electrodes may be readily replaced, while at the same time a long leakage path is provided between the electrode supports. (See also pp. 537—544 in last issue.)

2578. **Gesellschaft für drahtlose Telegraphie.** Electric Discharge Apparatus. (*British Patent* 147441, July 7th, 1920. Convention date January 29th, 1918. Patent not yet accepted.)

A cathode for a "cathode tube" is formed of a metal of the alkaline-earth group such as calcium or magnesium. The tube may contain hydrogen or one of the rare gases.

2579. **Gesellschaft für drahtlose Telegraphie.** Thermionic Valves. (*British Patent* 147443, July 7th, 1920. Convention date October 10th, 1918. Patent not yet accepted.)

In a valve for use as an oscillation generator the cathode is heated by discharge from an auxiliary filament cathode placed behind it, a high potential being maintained between the cathodes.

2580. **Gesellschaft für drahtlose Telegraphie.** Thermionic Valve Apparatus. (*British Patent* 147463, July 7th, 1920. Convention date February 9th, 1915. Patent not yet accepted.)

Relates to the use of an alkaline metal or alloy for the cathode of a thermionic amplifying tube.

2581. **I. Langmuir** [British Thomson-Houston Co.]. Thermionic Valves. (*British Patent* 147616, July 8th, 1920. Convention date October 16th, 1913. Patent not yet accepted.)

A hard three-electrode tube of the "pliotron" type.

2582. **H. St. J. de A. Donisthorpe.** Thermionic Valves. (*British Patent* 162338, December 23rd, 1919. Patent accepted. *Engineer*, 131, p. 631, June 10th, 1920—Abstract.)

A valve in which the grid and plate are in the form of hollow hemispheres enclosing the loop filament. Greater rigidity is claimed. (See RADIO REVIEW, 2, p. 431, August, 1921, for illustration of this valve.)

2583. **A. K. Macrorie, C. L. Fortescue, G. B. Bryan** and **H. Morris-Airey.** Thermionic Valves. (*British Patent* 162367, January 23rd, 1920. Patent accepted April 25th, 1921.)

A transmitting valve with a metal casing forming the anode, provided with a pump for maintaining the vacuum and arranged for easy opening to renew the electrodes. The metal container may be artificially cooled.

2584. **G. Seibt.** Thermionic Valves. (*British Patent* 147043, July 6th, 1920. Convention date October 24th, 1913. Patent not yet accepted.)

Relates to a valve having a double cone-shaped grid to which the incoming oscillations are applied. The arrangement is similar to that sketched on p. 1, January, 1921, RADIO REVIEW. A slotted plate anode may be used having the slots in line with the spaces between the teeth of the comb-like grids.

2585. **E. F. Huth.** Thermionic Valves. (*British Patent* 148314, July 9th, 1920. Convention date March 30th, 1918. Patent not yet accepted.)

Relates to the introduction of small quantities of gas or vapour (such as ether) during exhaustion, so as to increase the normal anode current.

2586. **O. Kruh.** Sealing Electric Conductors in Glass Vessels. (*British Patent* 148522, July 10th, 1920. Convention date January 15th, 1919. Patent not yet accepted.)

2587. **Gesellschaft für drahtlose Telegraphie.** Thermionic Valves. (*British Patent* 148525, July 10th, 1920. Convention date April 30th, 1919. Patent not yet accepted.)

Deals with the structural design of the valve to secure the generation of oscillations with the minimum of reaction coupling.

2588. **Electrische Gluhlampenfabrik Watt Akt. Gesellschaft.** Vacuum Tubes. (*British Patent* 152617, October 16th, 1920. Convention date October 18th, 1919. Patent not yet accepted.)

Relates to special means of sealing the electrodes into glass.

2589. **A. K. Macrorie** and **H. Morris-Airey.** Thermionic Valves. (*British Patent* 162773, February 2nd, 1920. Patent accepted May 2nd, 1921.)

Two- or three-electrode valves have an additional anode, preferably in the form of a grid, and connected externally to the main anode through an energy-absorbing resistance or similar device. The heating of the main anode is thus reduced.

2590. **E. R. Stoekle.** Thermionic Valves. (*British Patent* 146357, July 2nd, 1920. Convention date June 13th, 1917. Patent not yet accepted.)

Relates to thermionic valves in which the cathode is heated by an auxiliary electronic bombardment.

2591. **R. A. Weagant** [Radio Corporation, U.S.A.]. Thermionic Valves. (*British Patent* 146529, July 5th, 1920. Convention date April 5th, 1915. Patent not yet accepted.)

Relates to a thermionic valve in which the control member is outside the glass.

2592. **R. A. Weagant** [Radio Corporation, U.S.A.]. Thermionic Valves. (*British Patent* 146531, July 5th, 1920. Convention date April 5th, 1915. Patent not yet accepted.)

A thermionic valve with an external control electrode is provided in addition with a disconnected interior grid.

2593. **R. A. Weagant** [Radio Corporation, U.S.A.]. Thermionic Valves. (*British Patent* 146533, July 5th, 1920. Convention date April 2nd, 1915. Patent not yet accepted.)

Relates to connection schemes for a thermionic valve with external grid. (See two preceding Abstracts.)

2594. **Naamlooze Vennootschap Philips Gloeiloeilampenfabrieken**; **M. G. Holst** and **E. Oosterhuis.** Valve Construction. (*French Patent* 507519, December 18th, 1919. Published September 17th, 1920.)

The specification describes an anode for a thermionic oscillation generator. The anode is made hollow so that the inside is accessible from without. Water and gas may be passed through the interior and during exhaustion a heater may be inserted to expel the gases. See also *British Patent* 137281 (RADIO REVIEW Abstract No. 797, September, 1920).

2595. **R. A. Weagant** [Radio Corporation, U.S.A.]. Thermionic Valves. (*British Patent* 146537, July 5th, 1920. Convention date March 10th, 1917. Patent not yet accepted.)

Constructional details for a valve with external control electrode.

2596. **R. A. Weagant** [Radio Corporation, U.S.A.]. Thermionic Valves. (*British Patent* 146538, July 5th, 1920. Convention date March 10th, 1917. Patent not yet accepted.)

Relates to a guard ring construction to remove static charges from the glass bulb.

2597. **R. A. Weagant** [Radio Corporation, U.S.A.]. Thermionic Valve Construction (*British Patent* 146539, July 5th, 1920. Convention date February 1st, 1916. Patent not yet accepted.)

2598. **R. A. Weagant** [Radio Corporation, U.S.A.]. Thermionic Valves. (*British Patent* 146540, July 5th, 1920. Convention date February 1st, 1916. Patent not yet accepted.)

Relates to a Fleming two-electrode valve with a connection to the hottest point on the filament.

2599. **Siemens** and **Halske Akt. Gesellschaft.** Thermionic Valves. (*British Patent* 145421, June 17th, 1920. Convention date May 31st, 1916. Patent not yet accepted.)

A thermionic valve has an incandescent cathode, a grid, an anode, and an openwork electrode interposed between the grid and the anode and maintained at a constant potential lower than that of the anode.

2600. **J. Scott-Taggart.** Thermionic Valves. (*British Patent* 146708, June 20th, 1919. Patent accepted July 15th, 1920.)

Relates to a double anode rectifying valve in which the two anodes have opposite polarities at any given instant.

2601. Wireless Inventions. (*Journal of Commerce*, June 29th, 1921.)
An account of a demonstration by **R. M. Radio, Ltd.**, of a new pattern of triode valve having a hemispherical anode and grid.*

2602. **L. Duverger.** Electric Signalling and Transmission Systems. (*British Patent* 157385, January 10th, 1921. Convention date February 16th, 1918. Patent not yet accepted.)
A method of transmitting telephone or power currents over a single wire without an earth return. A device termed an "absorbing apparatus" is employed, consisting of a metal tube containing an oxide-coated filament and a grid. Gas may be passed through the tube by appropriate stopcocks.

2603. **O. Durdle** [General Electric Co., London]. Thermionic Valves. (*British Patent* 156411, January 2nd, 1920. Patent accepted January 13th, 1921.)
The support for the loop of a valve filament is made of steatite, as it is stated that this material does not occlude gases.

2604. **C. F. Trippe** [General Electric Co., London]. Thermionic Valves. (*British Patent* 151462, September 12th, 1919. Patent accepted September 30th, 1920.)
Relates to caps for valves.

2605. **E. Schaeffer** [Franklin Industrie Gesellschaft]. Vacuum Tubes. (*British Patents* 153002 and 153003, October 25th, 1920. Convention dates August 26th and October 24th, 1919. Patents not yet accepted.)
A construction for vacuum tubes, applicable to thermionic valves, in which one of the electrodes is in the form of a conducting liquid on the outside of the glass or other container.

2606. **J. Scott-Taggart.** Thermionic Valves. (*British Patent* 154364, September 8th, 1919. Patent accepted December 2nd, 1920.)
To reduce the space charge in a valve an element of perforated metal work is mounted inside the anode and connected to it.

2607. **W. Kossel.** Thermionic Valves. (*British Patent* 147856, July 9th, 1920. Convention date December 23rd, 1916. Patent not yet accepted.)
A magnetic field is used for controlling the discharge in a thermionic valve. The magnet may be sealed inside the bulb.

2608. **O. Kruh.** Sealing Electric Conductors through Glass. (*British Patent* 148127, July 9th, 1920. Convention date July 6th, 1917. Patent not yet accepted.)

2609. **I. Langmuir** [British Thomson-Houston Co.]. Electron Discharge Devices. (*British Patent* 148130, July 9th, 1920. Convention date June 6th, 1914. Patent not yet accepted.)
The anode of a thermionic valve is deposited on the bulb by vaporisation of the metal in a vacuum.

2610. **I. Langmuir** [British Thomson-Houston Co.]. Electron Discharge Devices. (*British Patent* 148132, July 9th, 1920. Convention date October 28th, 1915. Patent not yet accepted.)
The filament of the valve is made of thorium, and potassium or other alkali metal is placed in the tube to prevent oxidation of the thorium.

2611. **W. Kossel.** Electron Discharge Apparatus. (*British Patent* 148184, July 9th, 1920. Convention date March 1st, 1917. Patent not yet accepted.)
Relates to a valve in which the cathode is heated by auxiliary ionic bombardment.

2612. **J. Marsten.** The Efficient Design of Vacuum Tube Telegraph and Telephone Sets. (*Radio News*, 2, pp. 870—871, June, 1921; pp. 23 and 48—59, July, 1921.)
Some data is given for the design of the circuits to obtain the most efficient operation.

2613. **General Electric Company, U.S.A.** [British Thomson-Houston Co., Ltd.]. Thermionic Valves. (*British Patent* 163745, January 12th, 1920. Patent accepted May 12th, 1921.)
A two-electrode thermionic valve, which may or may not contain gas, having a "negative

* See also RADIO REVIEW Abstract No. 2582.

resistance," the current between the electrodes varying inversely as the potential applied thereto. The characteristic curve is as shown in Fig. 3.

2614. **S. S. Torissi.** A New Cathode for Vacuum Tubes. (*Wireless Age*, 8, p. 23, August, 1921.)

The proposed cathode consists of a nickel cylinder heated by an internal filament.

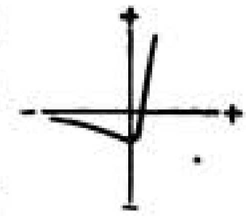


FIG. 3.

2615. **J. B. Pratt** [General Electric Company]. Degasifying Process for Valves. (*U.S. Patent* 1374679, March 15th, 1920. Patent granted April 12th, 1921.)

(5) TESTS AND MEASUREMENTS ON VALVES AND VALVE CIRCUITS.

2616. **Gesellschaft für drahtlose Telegraphie.** Valve Vacuum Tester. (*German Patent* 316448, February 14th, 1918.)

A circuit for measuring the positive ionisation in a valve. The grid is made positive with respect to the filament while the usual anode battery is reversed. The positive ions are detected by means of a galvanometer in the anode circuit.

2617. **F. Holborn.** New Experiments with the Dynatron. (*Telegraphen- und Fernsprech-Technik*, 10, pp. 1—10, January—February; pp. 17—22, March, 1921.)

An oscillographic investigation of an ordinary three-electrode valve used as a dynatron to maintain oscillations of a frequency of 20 cycles per second. The static dynatron characteristics of the valves are also given and the dynamic results are found to agree with the static. The distortion of the anode current at each limit of its amplitude is studied for various conditions. The gradual building up of an oscillation is shown on oscillograph films both for the dynatron circuit and for the ordinary back-coupled valve circuit.

2618. **L. Hartshorne** and **E. S. Keeping.** Notes on Vacuum Tubes used as Detectors of Electric Oscillations. (*Proceedings of the Physical Society of London*, 33, pp. 249—258, June 15th, 1921. *Chemical News*, 122, pp. 259—260, June 3rd, 1921—Abstract; *Nature*, 107, pp. 445—446, June 2nd, 1921—Abstract.)

Describes experiments on neon-filled tubes used as detectors in aircraft wireless sets.

2619. **F. F. Martens.** Alternating Current Measurements on Amplifying Valves. (*Zeitschrift für Physik*, 4, pp. 437—440, 1921.)

A.C. methods of determining the internal resistance R_i and the amplification ratio $1/D$ have been described by Barkhausen, Miller and Schottky, but these all assume zero grid current; this assumption is not made in the present methods, which are A.C. bridge methods.

Fig. 4 shows the connections for finding D and Fig. 5 those for finding R_i. When silence is obtained in the telephone receiver T it is shown that in Fig. 4 $D = l/r$, and in Fig. 5 $R_i = \frac{1+D}{D} \cdot \frac{l}{r} \cdot R$.

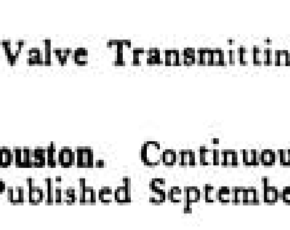


FIG. 4. FIG. 5.

2620. **H. de A. Donisthorpe.** The Testing of Thermionic Triodes. (*Model Engineer*, 45, pp. 119—120, August 11th, 1921.)

Describes insulation, backlash and other tests on valves.

(6) APPLICATION OF VALVES TO OSCILLATION GENERATION (including Valve Transmitting Apparatus).

2621. **Société Française pour l'Exploitation des Procédés Thomson-Houston.** Continuous Wave Transmitter. (*French Patent* 506986, May 14th, 1919. Published September 2nd, 1920.)

The inductances of the plate and grid circuits of a vacuum tube oscillation generator are connected in series in the aerial circuit whereby the aerial-earth capacity forms an electrostatic coupling between the plate and grid circuits. The amplitude of the oscillations may be controlled by applying potential variations of audible frequency to the grid, such variations being amplified by the tube and returned to the grid circuit by a transformer. See also *British Patent* 127325 (RADIO REVIEW Abstract No. 13, October, 1919).

2622. **Gesellschaft für drahtlose Telegraphie.** Short Wave Generator. (*German Patent* 305063, October 21st, 1917. Patent granted January 29th, 1920. *Jahrbuch Zeitschrift für drahtlose Telegraphie*, 16, p. 309, October, 1920—Abstract.)

A generator (see Fig. 6) in which the internal capacities of the valve are used as coupling.

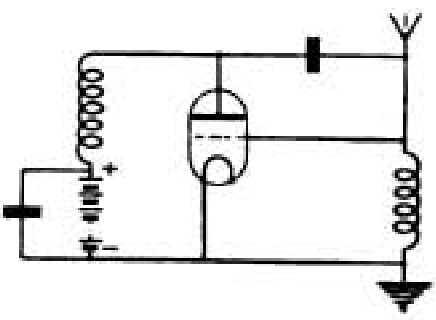


Fig. 6.

2623. **H. G. Möller.** The Theory of the Phase Reversal in Coupled Oscillatory Valve Circuits. (*Jahrbuch Zeitschrift für drahtlose Telegraphie*, 16, pp. 402—431, December, 1920. *Radioélectricité*, 2, p. 130, August, 1921—Abstract.)

A mathematical and experimental investigation of the phenomena observed when an oscillatory circuit is coupled to the oscillatory anode circuit and the frequency of the former varied through the resonance value. The method of treatment is that of the "phase-balance," *i.e.* if a current in the anode circuit produces by reaction through the back-coupling and grid an anode current lagging behind the assumed initial current, the frequency will decrease and *vice versâ* until a balance is obtained. A simple graphical method is evolved for determining the amplitude and frequency-resonance curves. The values of the critical coupling are calculated for various values of damping and frequency; the frequency-resonance curve and the position of the reversal point are determined by calculation and the results compared with the experimental results. Good agreement is found.

2624. **L. A. Hazeltine.** Valve Oscillators for Radio Transmitters. (*Proceedings of the Radio Club of America*, 1, pp. 2—10, October, 1920. *Q.S.T.*, 4, pp. 5—8, October, and pp. 15—19, November, 1920.)

Paper read before the Radio Club of America. Various arrangements of oscillating valve are discussed together with a consideration of the mode of operation of such transmitters from the characteristic curve of the valves. The circuit designed for best operation is also given and the paper concludes with an arrangement of polyphase oscillators.

2625. Self-rectifying C. W. Sets. (*Q.S.T.*, 4, pp. 7—10, December, 1921.)

A description is given of valve transmitting sets for operation on A.C. using one or both half-waves of the A.C. supply. Some particulars are given as to constructional details of a 500 watt set built on these lines.

2626. **Société Indépendante de Télégraphie sans Fil.** Wireless Transmitting and Receiving Apparatus. (*British Patent* 153553, May 4th, 1920; Convention date May 5th, 1919. Patent not yet accepted.)

In a valve oscillation generator a relay valve is used to couple the variations of the plate potential of the oscillating valves back to their grids. By slight alterations of the connections the arrangement can alternatively be used as a receiver.

2627. **W. Hyndman.** Short Wave Radio Vacuum Tube Transmitter and Regenerative Reception with Two-Step Audio-Frequency Amplifier. (*Radio News*, 2, p. 693, April, 1921.)

2628. **J. Marsten.** The Use of A.C. Potential with Vacuum Tube Transmitters. (*Radio News*, 2, pp. 604—605, March, 1921. *Radioélectricité*, 2, p. 13D, August, 1921.)

After summarising some of the usual buzzer methods of radiating interrupted C.W. the author discusses the advantages to be obtained by operating the transmitting valve on an alternating current supply.

2629. **Compagnie Française pour l'Exploitation des Procédés Thomson-Houston.** Continuous Wave Transmitter. (*French Patent* 507651, December 23rd, 1919. Published September 21st, 1920.) Also **I. Langmuir** [British Thomson-Houston Co.]. (*British Patent* 144647, June 7th, 1920. Convention date October 29th, 1913. Patent not yet accepted.)

The specification describes arrangements for the production of oscillations of any frequency from direct current or alternating current, by employing an electron discharge tube in which the grid-filament and anode-filament circuits are coupled by external electro-magnetic or electrostatic couplings or by the capacity between the electrodes. Several examples of arrangements are given.

2630. **L. M. Clausing.** Interrupted Continuous Waves from 60 Cycle Current. (*Q.S.T.*, 4, pp. 5—6, February, 1921.)

A commutator arrangement is described for interrupting the power supply to a valve transmitter, the energy being derived from 60 cycle A.C. mains.

2631. **F. Harms.** Triode Oscillation Generators with Coupled Oscillatory Circuits. (*Jahrbuch Zeitschrift für drahtlose Telegraphie*, 17, p. 218, March, 1921.)

A correction to the article with the above title. See Radio Review, 2, pp. 313—322, June, 1921, and footnote on p. 315.

2632. **K. Heegner.** Valve Transmitters with Coupled Oscillatory Circuits. (*Archiv für Elektrotechnik*, 9, pp. 127—152, 1920. *Jahrbuch Zeitschrift für drahtlose Telegraphie*, 17, pp. 133—137, February, 1921—Abstract.)

An abstract by the author of his Jena dissertation of July, 1919. It is an analytical investigation of the valve transmitter with coupled oscillatory circuits.

2633. **Gesellschaft für drahtlose Telegraphie.** Thermionic Oscillation Generators. (*British Patent* 148991, July 12th, 1920. Convention date August 7th, 1917. Patent not yet accepted.)

In methods of generating oscillations with thermionic valves, the aerial is coupled with the grid oscillatory circuit in such a way that the latter is uninfluenced by the varying factors of the former. Suggested arrangements for this purpose are indicated in Fig. 7.

2634. **W. H. Eccles** and **F. W. Jordan.** Thermionic Valve Oscillation Generators. (*British Patent* 149018, March 20th, 1918. Patent accepted August 12th, 1920.)

Deals with the use of the valves in parallel for generating oscillations. For description of the arrangements see Radio Review, 1, pp. 80—83, November, 1919.

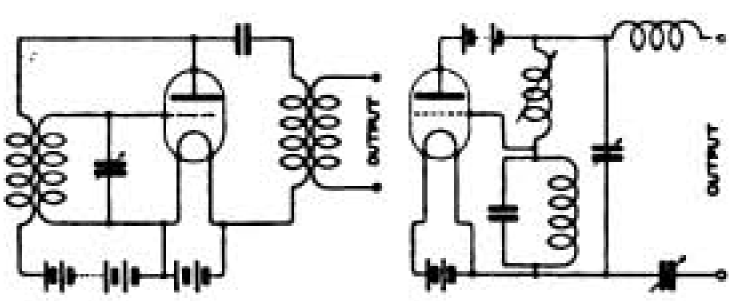


Fig. 7.

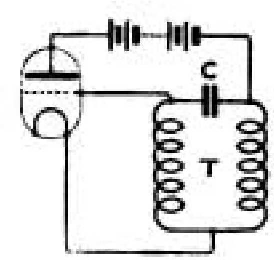


Fig. 8.

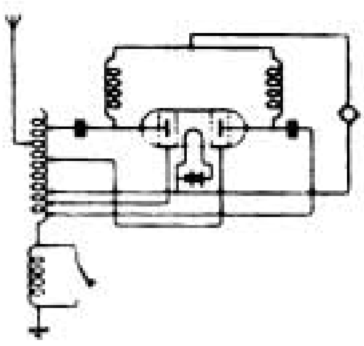


Fig. 9.

2635. **W. Heller** [E. F. Huth Gesellschaft]. Thermionic Valve Oscillation Generators. (*British Patent* 149192, July 12th, 1920. Convention date July 17th, 1918. Patent not yet accepted.)

Describes a number of arrangements of the circuits of thermionic valves for generating or amplifying H.F. oscillations.

2636. **S. Loewe** [E. F. Huth Gesellschaft]. Producing Electric Oscillations. (*British Patent* 149195, July 12th, 1920. Convention date July 16th, 1917. Patent not yet accepted.)

An arrangement of valve oscillator particularly adapted to the production of short waves. See Fig. 8. The coils T may if desired be in the form of an autotransformer. For reception the circuit joined by T and C may be detuned to produce beats, the receiving circuit being coupled to T.

2637. **C. L. Farrand** [Radio Corporation of America]. Radio Transmitter. (*U.S. Patent* 1385818, June 14th, 1919. Patent granted July 26th, 1921.)

A vacuum tube is arranged with a plurality of external control members outside of the tube connected in separate circuits. Oscillations are produced in the several circuits and energise the antenna system (Fig. 9).

2638. **V. J. F. Bouchardon.** Generator of High-frequency Oscillations for Wireless Telegraphy. (*U.S. Patent* 1373710, October 24th, 1919. Patent granted April 5th, 1921.)

See corresponding *British Patent* 135464 (Radio Review Abstract No. 409, June, 1920) and *French Patent* 493222 (Radio Review Abstract No. 107, January, 1920).

(G.) Transmitter Control or Modulation.

2639. **F. Ware** [Ware Radio Inc.]. Cut-in System of Radio Telegraphy. (*U.S. Patent* 1379144, February 8th, 1918. Patent granted May 24th, 1921.)

2640. **C. R. Englund** [American Telephone and Telegraph Company]. Radiotelephony. (*U.S. Patent* 1258548. Re-issue No. 15089, March 3rd, 1920. Re-issue granted April 19th, 1921.)

2641. **H. D. Arnold** [Western Electric Company]. Power Modulator for Radio-Transmission. (*U.S. Patent* 1375481, August 23rd, 1915. Patent granted April 19th, 1921.)

2642. **D. G. McCaa** [Assigned one-half to C. D. Ehret]. Transmitting Apparatus. (*U.S. Patent* 1382206, May 10th, 1920. Patent granted June 28th, 1921.)

Transmitting apparatus, for radiotelephony in which the high-frequency energy is not present in the antennæ and ground system until the microphone is operated. The carrier frequency oscillations are generated by vacuum tube and controlled by a microphone such that instantly the voice or sound waves cease at the microphone the high-frequency energy ceases in the antenna system and similarly instantly sound waves or speech are initiated and continued at the microphone oscillations are present in the antenna system and vary in accordance with the speech.

2643. **R. A. Heising** [Western Electric Company]. Power Modulator for Radio Transmission. (*U.S. Patent* 1383807, September 21st, 1915. Patent granted July 5th, 1921.)

The modulation of the total high-frequency power is obtained by varying the impedance of a vacuum tube placed in the antenna circuit. In order to permit the passage of both halves of the high-frequency oscillations the system is made symmetrical by using two vacuum tube impedances, suitably connected, or by using a single vacuum tube impedance containing additional elements which render the circuit symmetrical.

2644. **E. F. W. Alexanderson** [General Electric Company]. Method of and Apparatus for Producing and Distributing Electric Current Waves of Radio Frequency. (*U.S. Patent* 1386830, August 5th, 1915. Patent granted August 9th, 1921.)

Two sources of radio frequency circuits are impressed upon the transmitting aerial, so that their resultant only is radiated.

2645. **H. E. Shreeve** [Western Electric Company]. Signalling System. (*U.S. Patent* 1378982, September 17th, 1918. Patent granted May 24th, 1921.)

(H.) Radio Receiving Apparatus.

2646. **J. Kunz** [Board of Trustees of the University of Illinois]. Photo-electric Cell, Method and Means for Making the Same. (*U.S. Patent* 1381474, August 24th, 1918. Patent granted June 14th, 1921.)

2647. **T. W. Case.** Radio Receiver. (*U.S. Patent* 1379167, February 20th, 1918. Patent granted May 24th, 1921.)

2648. **C. Bardeloni.** Device for Receiving Radio Telegraphic and Radio Telephonic Signals. (*U.S. Patent* 1381692, April 12th, 1919. Patent granted June 14th, 1921.)

2649. **W. H. Eccles. and Miss W. A. Leyshon.** Some Thermionic Tube Circuits for Relaying and Measuring. (*Journal of the Institution of Electrical Engineers*, 59, pp. 433—438, April, 1921; *Electrical Review*, 88, p. 354, March 18th, 1921; *Technical Review*, 9, p. 111, May 17th, 1921—Abstract; *Electrician*, 86, pp. 754—755, June 17th, 1921—Abstract.)

Paper read before the Wireless Section of the Institution of Electrical Engineers and discussion. See Radio Review, 2, pp. 169—170, April, 1921, for abstract of paper.

2650. **A. W. Hull** [General Electric Company]. Wireless Receiving System. (*U.S. Patent* 1387986, March 10th, 1917. Patent granted August 16th, 1921.)

Wireless receiving system, employing a negative resistance device connected to the radio frequency receiving circuit for reducing the damping thereof. The negative resistance device is connected to the oscillating circuit in such a way as to compensate for the positive resistance of the circuit reducing the damping factor and increasing the maximum possible amplification of the oscillations in the circuit.

2651. **R. V. L. Hartley** [Western Electric Company]. Receiving Apparatus for Wave Signalling. (*U.S. Patent* 1387262, September 30th, 1915. Patent granted August 9th, 1921.)

Receiving apparatus for wave-signalling, which may be readily changed to receive telephonic and telegraphic signals either with or without the heterodyne. A local generator at the receiver may be cut in or removed from the circuit to permit reception by means of the heterodyne or by straight rectification and amplification of the signals.

2652. **R. E. Hall** [Hall Research Corporation]. Method of and Means for Translating Energy Variations. (*U.S. Patent* 1378345, May 31st, 1919. Patent granted May 17th, 1921.)

(K.) Aerials and Earthing Systems.

2653. **S. C. Hooper** and **G. H. Clark.** Radio Receiving Antenna. (*U.S. Patent* 1379262, September 16th, 1919. Patent granted May 24th, 1921.)

2654. **H. H. Beverage** [General Electric Company]. Radio Receiving System. (*U.S. Patent* 1381089, April 10th, 1920. Patent granted June 7th, 1921.)

2655. **E. T. Jones.** Underground or Underwater Antenna System. (*U.S. Patent* 1372658, April 11th, 1919. Patent granted March 22nd, 1921.)

See Radio Review Abstract No. 378, May, 1920.

2656. **E. C. Hanson.** Underground Loop Antenna. (*U.S. Patent* 1373612, March 19th, 1919. Patent granted April 5th, 1921.)

2657. **A. A. Hall.** Wireless Signalling Apparatus. (*U.S. Patent* 1384523, November 1st, 1919. Patent granted July 12th, 1921.)

Wireless signalling apparatus, comprising an oscillating vacuum tube transmitter wherein the oscillatory circuit is completed through a portion of the earth. See corresponding *French* and *British Patents* (Radio Review Abstract No. 1700, April, 1921).

2658. **J. H. Rogers.** Radio Signalling System. (*U.S. Patent* 1387736, May 2nd, 1917. Patent granted August 16th, 1921.)

Radio signalling system for operation aboard submarine vessels. An antennæ is employed, comprising horizontal wires disposed entirely within the metallic hull of the vessel with a metallic screen enclosing the antennæ throughout their length.

2659. **E. F. W. Alexanderson** [General Electric Company]. Radio Receiving System. (*U.S. Patent* 1375992, April 18th, 1919. Patent granted April 26th, 1921.)

2660. **H. H. Beverage** [General Electric Company]. Radio Receiving System. (*U.S. Patent* 1381089, April 10th, 1920. Patent granted June 7th, 1921.)

A horizontal and aperiodic antenna extending in a direction parallel to the direction of transmission of the signals to be received is used. The antenna is constructed with distributed capacity, inductance and resistance of such values that the currents produced therein by the desired signals increase progressively from the end of the antenna nearest the transmitting station to a maximum at the farthest end from the transmitting station at which the receiver is connected.

(P.) High-frequency Circuits and Measurements.

2661. **E. T. Turney.** Inductances. (*U.S. Patent* 1372850, April 1st, 1920. Patent granted March 29th, 1921.)

2662. **J. S. E. Townsend.** Variometer. (*U.S. Patent* 1376592, April 10th, 1918. Patent granted May 3rd, 1921.)

2663. **A. M. Curtis** [Western Electric Company]. Construction of Reaction Coils. (*U.S. Patent* 1367734, August 16th, 1917. Patent granted February 8th, 1921.)

2664. **C. D. Tuska.** Condenser. (*U.S. Patent* 1371061, March 29th, 1918. Patent granted March 8th, 1921.)

2665. **H. W. Hitchcock** [American Telephone and Telegraph Company]. Electrical Measuring Apparatus. (*U.S. Patent* 1373504, September 11th, 1918. Patent granted April 5th, 1921.)

2666. **E. Thompson** [General Electric Company]. Condenser. (*U.S. Patent* 1375982, November 16th, 1916. Patent granted April 26th, 1921.)

2667. **F. Kratz** [American Bosch Magneto Corporation]. Electrical Condenser and Method of Making It. (*U.S. Patent* 1385379, January 26th, 1917. Patent granted July 26th, 1921.)

Electrical condenser and method of making it. The condenser is constructed upon an oval core with alternate bands of foil and dielectric wound thereon, the individual bands having laterally projecting edge portions lying flat against the opposite sides of the condenser to form side terminals.

(U.) Miscellaneous Methods of Communication.

2668. **T. W. Case.** Radiant Energy Signalling System. (*U.S. Patent* 1379166, January 22nd, 1918. Patent granted May 24th, 1921.)

2669. **R. A. Fessenden** [Submarine Signal Company]. Method and Apparatus for Signalling and otherwise Utilising Radiant Impulses. (*U.S. Patent* 1384014, January 14th, 1918. Patent granted July 5th, 1921.)

Method and apparatus for signalling and otherwise utilising radiant impulses, in which a tetrahedron collector, having three joining faces at right angles to each other and another surface in proximity to the tetrahedron is employed whereby the incidence of radiant energy on the tetrahedron may be determined. The system employs light waves, heat waves, ultra-violet waves, X-rays, Hertzian waves, or sound waves.

2670. **L. Bell** and **N. Marshall.** Method of and Apparatus for Utilisation of Observable Radiations. (*U.S. Patent* 1385657, February 1st, 1919. Patent granted July 26th, 1921.)

Method of and apparatus for utilisation of observable radiations. Signalling is conducted by use of invisible light rays by forming a directive beam of rays between 400 $\mu\mu$ and 350 $\mu\mu$ wavelength and by collecting the rays for observation on a fluorescent medium.

2671. **N. Marshall** and **L. Bell.** Method of and Apparatus for Utilisation of Observable Radiations. (*U.S. Patent* 1385696, February 1st, 1919. Patent granted July 26th, 1921.)

Method and apparatus for utilisation of observable radiations. A combined transmitting and receiving apparatus is provided for communication by light rays, comprising at the receiver an observing objective lense and an eye piece and fluorescent medium acted upon by invisible rays; and at the transmitter a projector of rays.

2672. **W. G. Ziegler.** Submarine Wireless System. (*U.S. Patent* 1382590, January 3rd, 1920. Patent granted June 21st, 1921.)

Submarine wireless system, operating at low frequencies. The patent discloses a particular form of transmitting and receiving apparatus.

2673. **W. W. Macfarlane.** System of Communication. (*U.S. Patent* 1370333, May 15th, 1919. Patent granted March 1st, 1921.)

2. Books.

PRINCIPLES OF RADIO COMMUNICATION. By J. H. Morecroft (Assistant Professor of Electrical Engineering, Columbia University), assisted by A. Pinto and W. A. Curry. (New York: *John Wiley & Sons, Inc.* London: *Chapman and Hall, Ltd.*, 1921. Pp. x + 935. 9" × 6". Price 45*s.* net.)

Although the literature of wireless telegraphy (or Radio, as our American friends prefer to call it) has become quite voluminous in recent years, the development of the subject has never failed to outstrip its literature, so that there is ample room for a modern treatise of the character of this work, viz., a general text-book for the use of both students and wireless engineers.

Time was when books on wireless telegraphy generally began with what purported to be an explanation of the ether (from which the student might sometimes learn that it was both imponderable and luminiferous) and it is symptomatic of the times that the present author plunges at once into a discussion on electrons and gives no more than a passing reference to the elastic properties of the medium. In these circumstances a brief description of the physical experiments upon which the theory rests would not have been out of place, though no fault can be found with the way the electron is treated. In this treatment the presence of a positive charge is rightly dealt with as the absence of negative electrons, just as cold is the absence of heat; but the statement (p. 8) " the smallest positive charge is an atom of matter from which an electron has been removed " (which would be equally true if a gramme was substituted for an atom) might lead the student to suppose that he had met the positive nucleus.

Throughout the book the author has dealt fully with the various electrical problems that arise, not shunning or overdoing their mathematical treatment on the one hand, nor failing to give a physical concept of each equation on the other. But the mathematical treatment is not always equally detailed. For example in Chapter IV. the derivation of Kelvin's equation for the current produced by the discharge of a condenser is given in full (though it is inaccurate to describe the substitution of ε^{mt} for i in the solution of a linear differential equation of the second order as an " intelligent guess "), while later on in the same chapter (p. 221) we are told that a damped sine may be integrated by standard methods, and are given the solution forthwith. It might be useful to the student, as well as to the engineer seeking to refresh his memory, to be at least reminded that the sine must be split up into exponentials.

Vacuum tubes are very well treated in Chapter VI., which should prove very useful to all interested in the subject, though the hydraulic model of the three-electrode valve (p. 386) is not nearly as good as the model exhibited by Mr. Gossling at the meeting of the Wireless Section of the Institution of Electrical Engineers on June 23rd, 1920.

Continuous wave telegraphy and radiotelephony are also very well treated in Chapters VII. and VIII. respectively.

A chapter which is conspicuous by its absence from a work of this nature is that generally entitled " Historical," but the author is no doubt wise in avoiding everything of a controversial character and in giving no grounds for an accusation of bias.

The figures and printing are good, and the small errors inseparable from a first edition not too numerous, while with the exception of " neighbor " and " center " the spelling is English.

Taken altogether the book fulfils its title and should prove valuable to every one engaged in wireless telegraphy.

J. S. V. P.

Correspondence.

THE FOUR FUNCTIONAL PARAMETERS OF THE TRIODE AS EXTENDED TO THE "MAGNETRON."

To the Editor of the " Radio Review."

Sir,—In French Patent No. 512295 of April 15th, 1916, as well as in an article which appeared on page 280, volume 78, of the *Electrician* for 1916, the writer has introduced the four well-known functional parameters of the triode, $\frac{\partial i_p}{\partial v_p}, \frac{\partial i_p}{\partial v_g}, \frac{\partial i_g}{\partial v_g}, \frac{\partial i_g}{\partial v_p}$, the use of which has become classic.

It has recently occurred to the author to ascertain what became of these four parameters with reference to the vacuum tube designated by Mr. A. W. Hull under the name of " magnetron " (see *Proceedings of the American Institute of Electrical Engineers*, September, 1921), and in which the electrostatic grid control of the electron stream is replaced by an outside coil producing a magnetic field.

This particular tube, in which it is necessary to superimpose a permanent field to the controlling field in order to obtain practical results, has already been described as detector, amplifier and generator in the French Patent No. 503935, 1917, of Messrs. Bouchardon and Lesage.

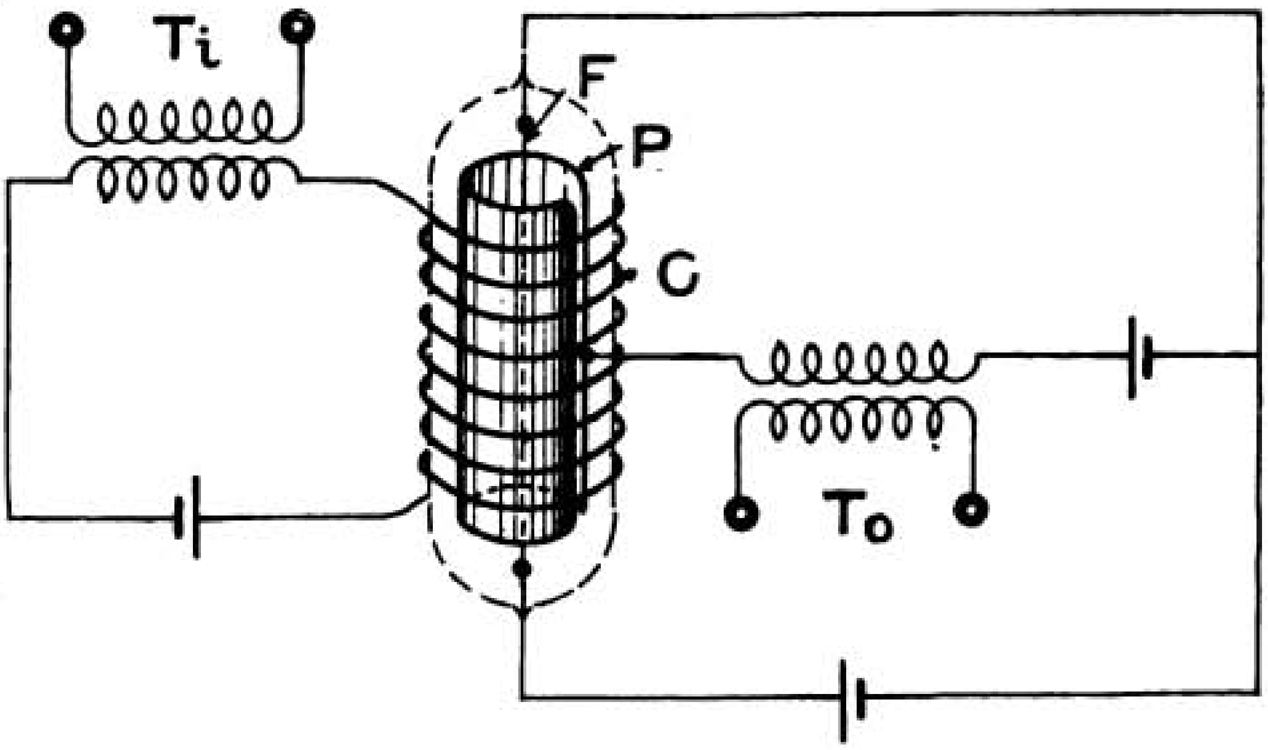


FIG. 1.

The magnetron, as represented in Fig. 1, comprises an axial filament, F, a cylindrical anode, P, and an outside coil, C, which is traversed by the current to be amplified and a permanent direct current. Fig. 1 illustrates the input transformer, T_i, and the output transformer, T_0.

The anode current, i_p, is a function of the anode potential, v_p, and of the total current, i, which traverses the coil, C. We have $i_p = F(v_p, i)$, whence there results two parameters for the plate current,

$\frac{\partial i_p}{\partial v_p}, \frac{\partial i_p}{\partial i}$, similar to those of the triode.

But the method of deriving *two* parameters for the control circuit is not readily apparent. They nevertheless exist. If we consider the case of the triode with an electrostatic grid, the fourth parameter, $\frac{\partial i_g}{\partial v_p}$, generally approximates zero. From a theoretical point of view, however, this parameter is of great importance, for it defines the possible reaction of the plate circuit upon the grid circuit.

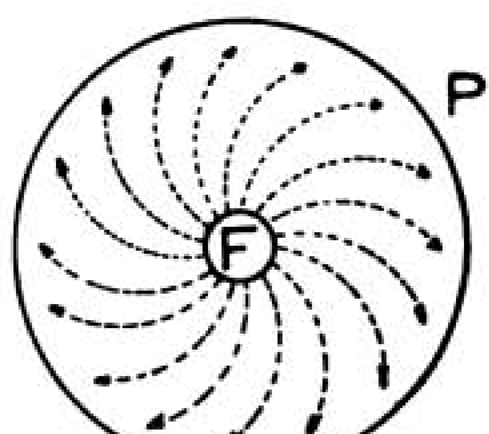


FIG. 2.

Might there also be a similar reaction of the plate circuit upon that of the coil, C, in the case of the magnetron? In fact, there might be one. While the electrons are being whirled around the filament, as shown in Fig. 2, they tend to produce a magnetic field parallel to the axis of the filament and consequently that of the coil, C, and the flux embraced by the latter actually includes the flux produced by that field. In this case, the magnetic flux, ϕ, embraced by the coil, C, is at once a function of i and v_p. We have $\phi = f(i, v_p)$, whence two new parameters for the control circuit: $\frac{\partial \phi}{\partial i}, \frac{\partial \phi}{\partial v_p}$.

Let us designate the four parameters of the magnetron by symbols which recall their dimensions, as follows :—

$$\frac{\partial i_p}{\partial v_p} = \frac{1}{r_p} \quad \text{(Conductance).} \qquad \frac{\partial \phi}{\partial i} = l \quad \text{(Self-induction).}$$

$$\frac{\partial i_p}{\partial i} = k \quad \text{(Numerical coefficient).} \qquad \frac{\partial \phi}{\partial v_p} = t \quad \text{(Time).}$$

Let us consider the actual values of these parameters for values, v_{p_0}, i_{p_0}, ϕ_0, i_0, in the neighbourhood of which the device is supposed to work, and let us imagine that we superimpose on the continuous current, i_0, by means of the transformer, T_i, a weak current $j \sin \omega t$ to be amplified. To determine the amplified alternating electromotive forces and currents, $V \sin \omega t$, $J \sin \omega t$, and the alternating flux, $\psi \sin \omega t$, embraced by the coil, C, we shall have, when supposing that the anode circuit includes, through a transformer, T_0, of ratio 1, an external resistance R, the following equations :—

$$\begin{cases} J = \dfrac{V}{r_p} + kj \\ \psi = lj + tV \\ V + JR = 0. \end{cases}$$

These equations correspond to :—

$$\begin{cases} J = \dfrac{kr_p}{r_p + R} j \\ V = -\dfrac{kr_p R}{r_p + R} j \\ \psi = \left(l - \dfrac{tkr_p R}{r_p + R}\right) j. \end{cases}$$

Knowing $\psi \sin \omega t$ and the resistance r, of the coil, C, it is easy to compute the potential difference at the terminals of the coil, C, and to calculate all the deducible matter concerning amplification and generation.

MARIUS LATOUR.

Paris,
October 4th, 1921.

TRIODE CHARACTERISTICS WITH HIGH GRID POTENTIAL.

To the Editor of the "Radio Review."

SIR,—The explanation given by Mr. Appleton in the September RADIO REVIEW of a certain type of grid current curve is of very great interest but is open to criticism. Grid curves of this type (Fig. 1) appear only to occur when the space current is temperature limited and are always associated with an anode current of the form shown in Fig. 1. It has been found that provided the electron emission from the filament is ample both grid and anode current curves are of the form shown in Fig. 2, neither showing any abnormality at the point where $V_a = V_g$.

It is difficult to see why in the first case there should be a considerable emission of electrons having high initial velocities and in the second case apparently no secondary emission.

It is possible, however, to account for this type of grid curve without postulating secondary emission. Since when it occurs the space current is temperature limited it can be assumed that the electrostatic field of the valve is not greatly affected by the space charge.

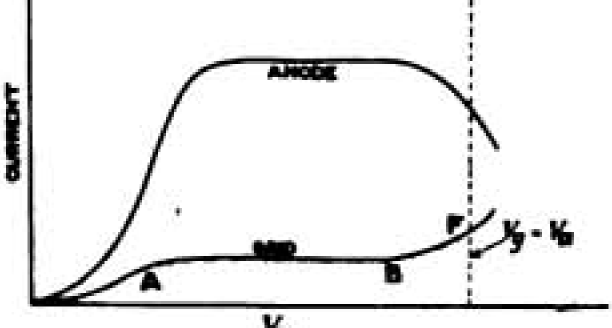


FIG. 1.

It can be shown from the ordinary electrostatic theory of the cylindrical valve that the expression for the charge per unit length of the grid contains a factor

$$\left(V_g - V_a \cdot \frac{\log \dfrac{d'}{d_f}}{\log \dfrac{d_a}{d_f}} \right)$$

where d_a = anode diameter.
d' = grid diameter.
d_f = filament diameter.

and is otherwise independent of V_a and V_g. In most cylindrical valves $\log \frac{d'}{d_f} \Big/ \log \frac{d_a}{d_f}$ is equal to 0·8 or 0·9.

It follows therefore that this point $V_g = 0{\cdot}8\ V_a$ is a transition point where the electrostatic field changes from the type of Fig. 3 to that of Fig. 4.

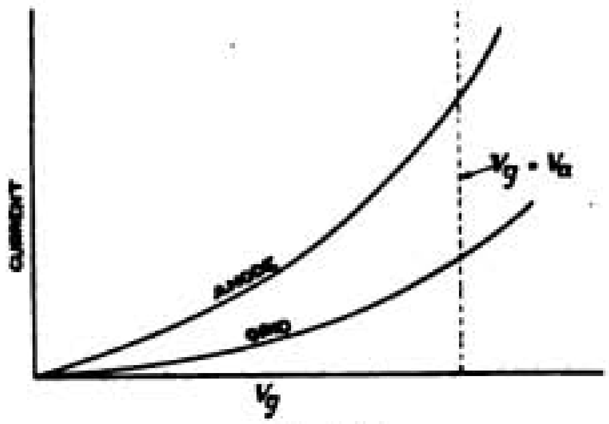


FIG. 2.

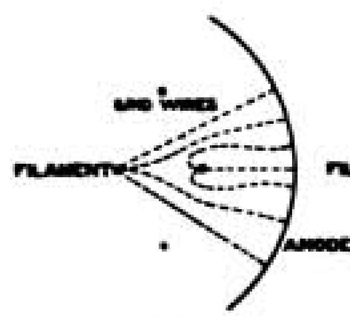


FIG. 3.

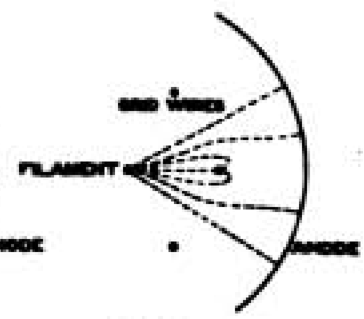


FIG. 4.

The charge on the grid is negative until $V_g = 0{\cdot}8\ V_a$ and therefore up to this value of V_g the grid is actually repelling electrons, the grid current being due to mechanical obstruction of electrons which have attained considerable radial velocities before approaching the neighbourhood of the grid wires. It will be found experimentally as might be expected that the fraction of the space current going to the grid is nearly equal to the fraction of the grid cylinder surface obscured by wires. Above the point $V_g = 0{\cdot}8\ V_a$ the grid is attracting electrons and the grid current naturally increases at the expense of the anode current.

It has been found experimentally that the point B when the grid current curve begins to rise steeply occurs approximately at $V_g = 0{\cdot}8\ V_a$ over the range of receiving valve anode voltages.

The question of secondary emission from the anode might of course be attacked experimentally by comparing the watts received by the anode with the product of the anode current and volts but the difficulties would probably be serious.

A. C. BARTLETT.

The Research Laboratories of the General Electric Co.,
London.
September 27th, 1921.

ERRATA.

Page 550, *Abstract No.* 2441, *the second reference should read: Radioélectricité*, 1, p. 147D June, 1921.

Page 561 *Abstract No.* 2547, *title should read:* "The Effect of a Uniform Magnetic Field on the Motion of Electrons between Coaxial Cylinders."

Page 531, in the first line of equation (15) for $E^2\lambda$ read $F^2\lambda$.

Page 533, in the 6th and 7th lines of par. 9 the values of H should be $3{\cdot}7 \times 10^{-10}$ and $1{\cdot}1 \times 10^{-10}$ respectively.