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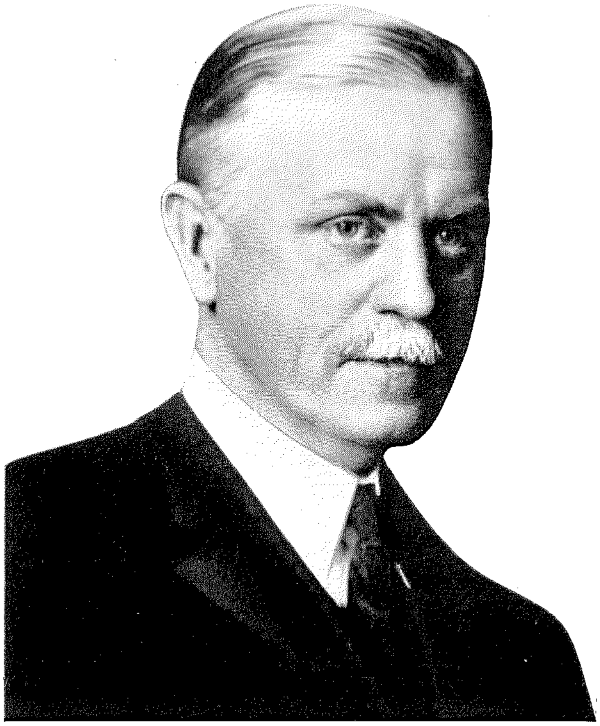

James L. McQuarrie
1867—1939

Public Address System at the Thirty-Fourth International Eucharistic Congress

Budapest, May 22-29, 1938

By G. A. DE CZEGLÉDY, A.M.I.R.E.,

Chief Engineer, Standard Electric Company Limited, Budapest, Hungary

INTERNATIONAL Eucharistic Congresses rank amongst the outstanding events in the Catholic world of modern times. It is thus natural that early recognition was given to the importance of communicating sermons and other items on the Congress programmes to the largest possible number of Catholics and others not within the fold of the Church of Rome.

In connection with previous Congresses,[1] the problem of utilizing loudspeaker systems, capable of reproducing the proceedings faithfully for the benefit of multitudes, both at the Congresses themselves and at distant points, was extensively studied. As on previous occasions, it is an undoubted fact that the elaborate public address and transmission systems evolved for the Budapest International Eucharistic Congress contributed to an important degree to its overwhelming success.

Since modern loudspeakers and power amplifiers have attained a high level of perfection, sound effects covering a wide range could be reproduced in a highly natural manner. Great care was needed to ensure the highest

[1] See references at end of this article.

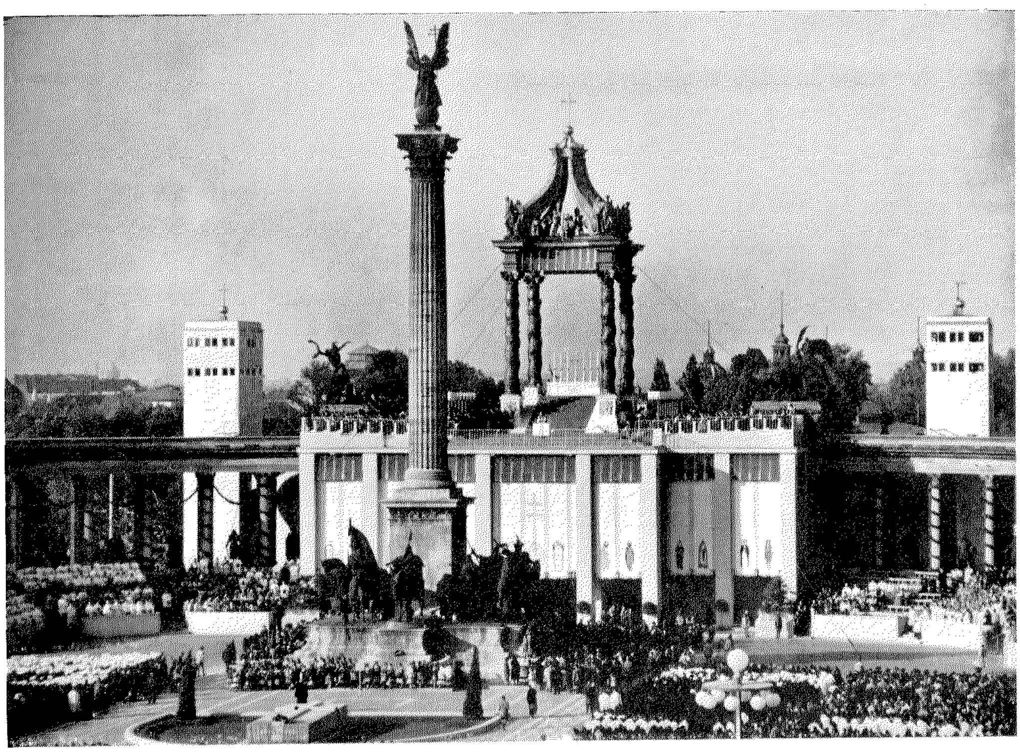

Fig. 1—Main Altar at Heroes' Square.

Fig. 2—Papal Legate, Cardinal Secretary of State Pacelli (now His Holiness, Pope Pius XII) before the Microphone.

possible quality in transmissions from the microphones to the power amplifier stages of the loudspeakers.

Standard Electric Company Limited, Budapest, handled all transmission and sound engineering problems and was officially responsible for the success of the sound transmissions during the Congress. In addition to part of the loudspeakers and power amplifiers, Standard furnished all microphones and pre-amplifiers required in connection with mixers and volume indicators, as well as the distribution amplifiers.

The outstanding Congress events, attracting the largest multitudes ever congregated in Budapest, took place at Heroes' Square, at St. Stephen's Cathedral, at the Congress Hall and at the Vigado (Concert Hall). A prominent Congress feature was the Boat Procession of the Holy Eucharist on the Danube, when public address systems arrayed on both banks of the river transmitted the programme to the vast crowds aligned on its shores in devout adoration.

Additional loudspeakers and power amplifiers were placed along the streets, the former on fixed poles, lamps, etc., and the latter in wooden booths. The booths were inter-connected by a cable network which the Postal Administration placed at the disposal of the Congress. Telephone exchanges, in most cases, served as the distribution points of this network, over which the output of the microphone groups,

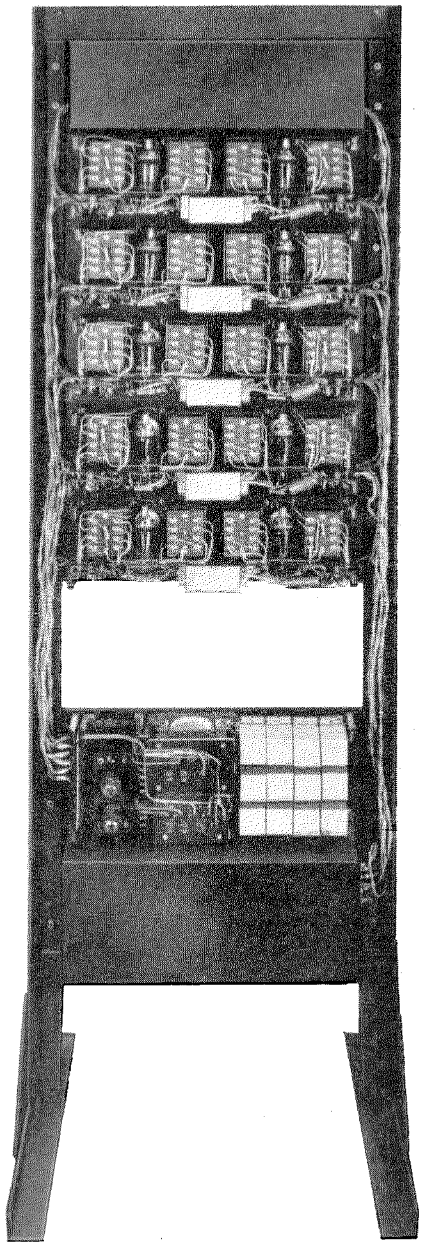

Fig. 3—Group of Distribution Amplifiers.

adequately amplified and equalized, could be faithfully transmitted.

At Heroes' Square, a sort of terrace was erected for the Princes of the Church, headed by the Papal Legate, Cardinal Secretary of State Pacelli (now His Holiness, Pope Pius XII). The Main Altar stood in the centre of the terrace. The orchestra and choir were on the street level between the Millenary Memorial Column and the Altar (Figs. 1 and 2).

All sound effects, from orchestra and choir, and from terrace and Altar, were transmitted true to life. Eight microphone lines, consisting of shielded rubber cables 25 to 30 m in length, were utilized, terminating in jacks at the Altar terrace and in a socket at the Millenary Column. It was accordingly possible to place the microphones at any desired spot within the area, thus providing great flexibility in the selection of combinations of microphones and loud speakers—a prerequisite in view of the rapid and varied programme sequences.

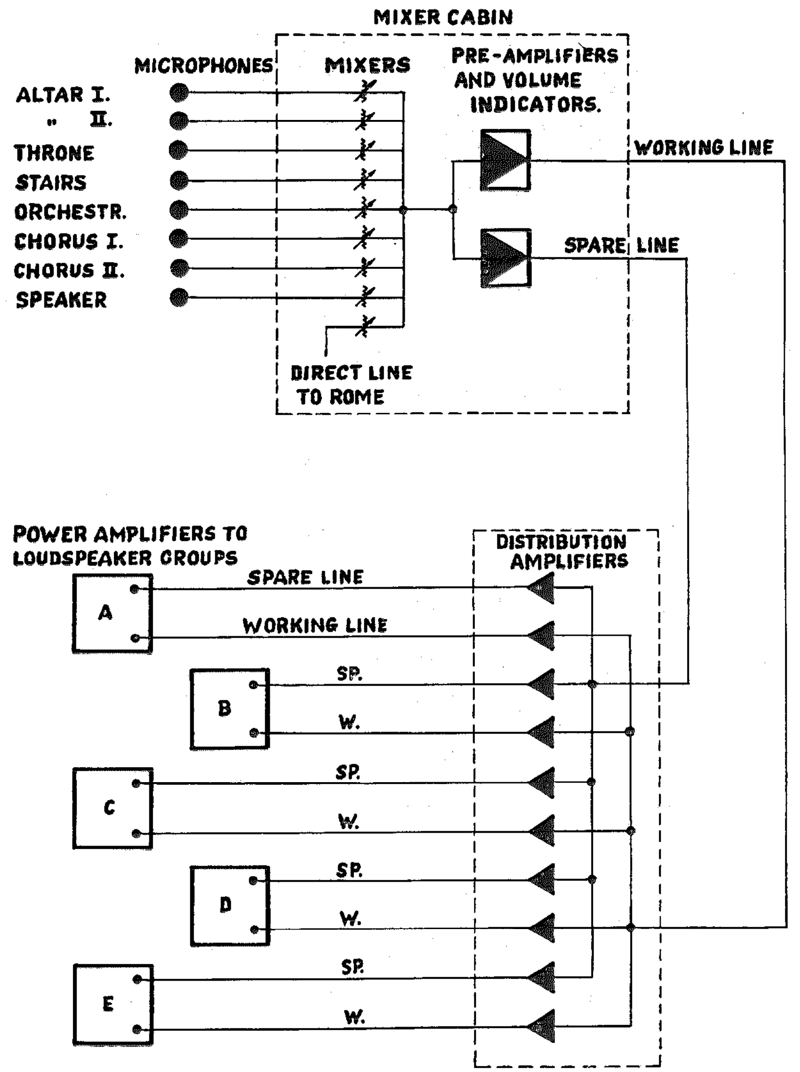

Fig. 4—Block Schematic of Transmission System at Heroes' Square and Surrounding Area.

The shielded pair microphone cables were concentrated at a cabin in the monitoring tower, to the right of the Main Altar. This cabin housed the microphone mixers and amplifiers; from it, all transmissions were controlled.

Each microphone was associated with a mixer-potentiometer, the output of which was connected to a microphone pre-amplifier. The mixers served special purposes; for example, when orchestra and choir programmes were transmitted, the different microphones were set by means of the mixers to appropriate sound volume. Further, with the same mixers, microphones could be connected or disconnected without the slightest noise. The main function of the mixers, however, was to give suitable musical colouring to the various sound effects.

The Pontifical High Mass, from the point of view of transmission, presented the most difficult problems. Microphones were arranged with special regard to naturalness of the sound reproduction: one each in front and behind the Altar; one on the first step of the stairway to the Altar proper; another on the Throne of the Papal Legate; and two in the orchestra and choir. At the rehearsal, the choir of 1 200 was regrouped in view of the predominance of soprano voices. This choir was supplemented by a Gregorian choir formed by 500 seminarists and the Schola Cantorum Sabariensis. The latter rendered individual programme numbers which required an additional microphone.

The allocution of the Holy Father made a profound impression on the vast multitude that attended the Pontifical High Mass. It was transmitted from the summer residence of the Popes in Castel Guandolfo near Rome over several hundred kilometres of telephone line. Inasmuch as the sound volume of the Pope's address could not be ascertained in advance, an adjustable mixer-potentiometer was kept in readiness for practically instantaneous connection to the loudspeaker system.

The microphone and amplifier system used at Heroes' Square and its environs is shown in Fig. 4. The whole system was designed with due regard to the principle constantly emphasized in connection with the Congress, viz., reliability of performance. Microphones and mixers were connected in parallel to the two pre-amplifiers. From their output terminals, independent leads were run to the distributing system.

In order to increase the effectiveness of the system, distribution amplifiers were employed where signals had to be divided between several groups of power amplifiers and loudspeakers. Individual loudspeaker and power amplifier groups were thus entirely independent; also, a possible short circuit occurring in any one group would not cause disturbance elsewhere.

The distribution amplifiers (Fig. 3) were located in the cellar of a building adjacent to Heroes' Square. They were provided in duplicate, as were also the connections to loudspeakers and their associated amplifiers. Transmission could thus be effected over two independent channels; and, in the event of failure of a loudspeaker group, the necessary switching could be effected without special instructions to the personnel on point duty. Five loudspeaker-amplifier groups (Fig. 4) were utilized at Heroes' Square.

The nine mixers and the microphone preamplifiers (Fig. 5) were placed in a small cabin in the tower near the Altar. From this tower the Altar was clearly visible, so that the sound-engineer could easily follow the ceremonies.

Compared with open air transmissions, indoor transmissions involved fewer problems.

According to the occasion, three to five microphones were used in the Congress Hall. In the Vigado and at St. Stephen's Cathedral, only two microphones were needed; and mixing and pre-amplification arrangements were similar

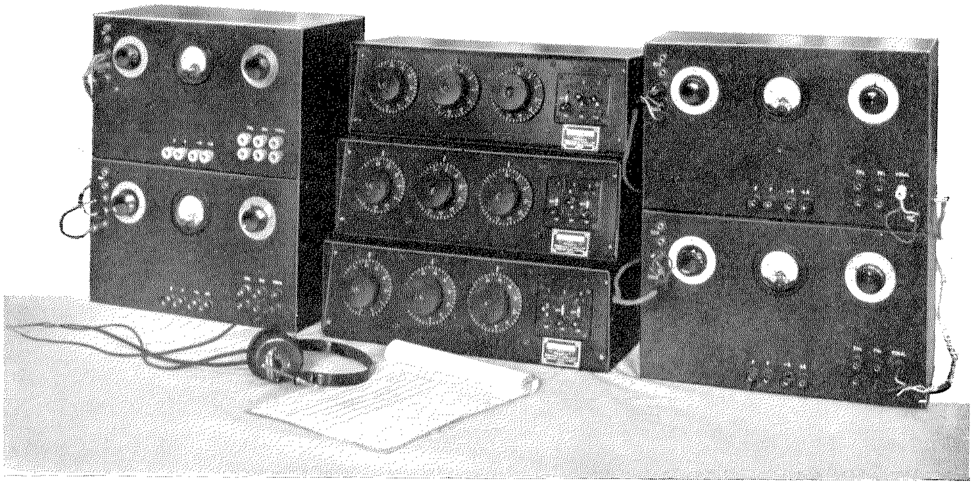

Fig. 5—Mixers and Pre-amplifiers at Heroes' Square.

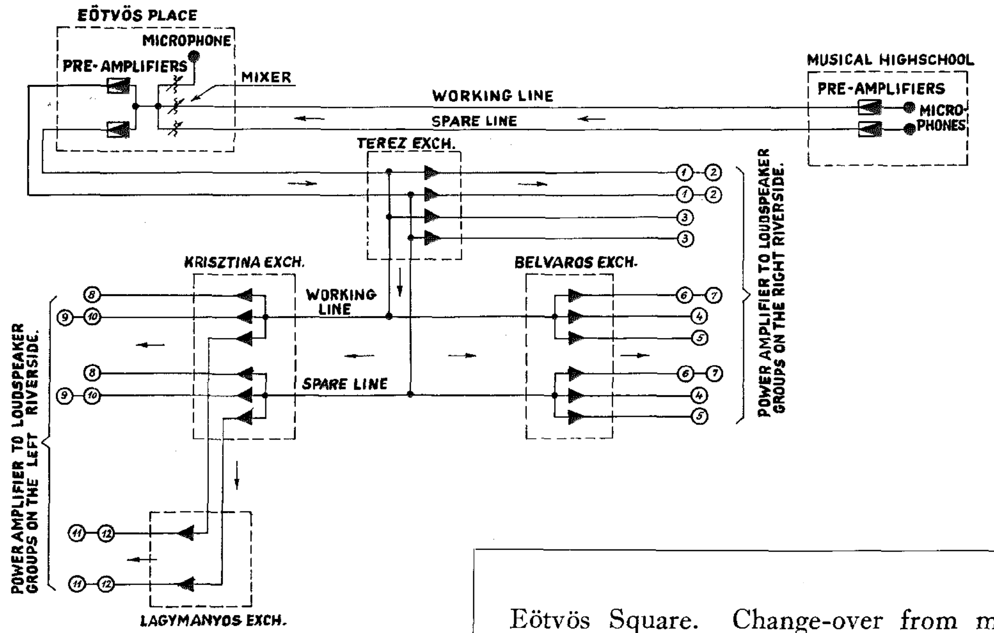

Fig. 6—*Block Schematic of the Transmission System for the Eucharistic Boat Procession.*

to those described, except that no distribution amplifiers were employed inasmuch as the microphone system was required to supply only one loudspeaker group.

From the viewpoint of technique and performance, the Danube Procession of the Holy Eucharist is perhaps unique in the history of public address systems.

The loudspeakers were placed along the river banks : in Buda, along the right shore from the Technical High School to Margaret Bridge ; and, in Pest, along the left shore from Francis Joseph Bridge to Margaret Bridge. For the feeding of the necessary loudspeakers, five and seven power amplifier groups were used in Buda and in Pest, respectively.

Announcements were made in various languages from Eötvös Square to the public arrayed on both shores. Transmission of the features of the Procession alternated with religious songs, conveyed from the Musical High School where two microphones and their associated pre-amplifiers were located. Transmissions took place over telephone lines to Eötvös Square. Change-over from music to speech, and vice versa, as well as mixing, were accomplished at the latter point.

The resulting speech currents were passed through distribution amplifiers located at the Teréz, Belváros, Krisztina and Lágymányos automatic exchanges to the five and seven loudspeaker groups, respectively, along the river banks. A schematic and plan of the system are shown in Figs. 6 and 7.

For transmission the telephone network was used, the Postal Administration taking special precautions to assign the most suitable circuits. The attenuation of all line sections had been previously measured and, on the basis of the results thus obtained, the frequency response curves of the line sections were equalized between 30 and 6 000 cycles by means of distribution amplifiers located at the individual exchanges.

As a result of this detailed and conscientious effort, the frequency response curve of even the longest line sections never deviated more than 2 decibels from a medium frequency value. This good performance was, of course, of utmost importance in achieving high quality transmission. Safety of operation was increased in this instance also by the provision of a spare network (Fig. 6).

Inasmuch as the Choir Master listened to the

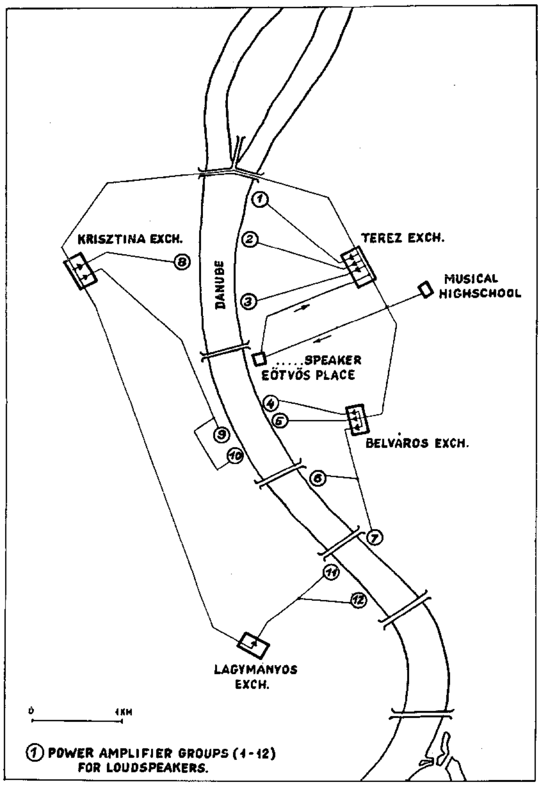

Fig. 7—Simplified Map of the Transmission System for the Eucharistic Boat Procession.

speeches transmitted from Eötvös Square with the aid of a radio receiving set, the Choir renderings were timed with the greatest precision.

By means of the distribution amplifiers located at the four telephone exchanges, the volume of the individual loudspeaker-amplifier groups could be adjusted so that the loudspeakers mounted on the right river bank could not be heard on the left, and vice versa. Since the weather was calm, transmissions were not disturbed by atmospheric effects.

Brief comments on the characteristics of the equipments herein described may be of interest :

The microphones were of the Standard electrodynamic type, No. 4017-A. They afford the great advantage that their noise level is negligibly low ; they are not sensitive to shaking, humidity, heat, etc., and they do not require battery supply voltage. The level supplied by the microphones was −82 decibels at normal sound pressure.

The mixers were the so-called "H" type balanced potentiometers, the output impedance of which is constant regardless of the degree of adjustment.

The microphone pre-amplifying circuit gave a maximum gain of 100 db. The frequency characteristic between 30 and 12 000 p : s showed a deviation of only one decibel, a result due to negative feed-back. The amplifier also contained a volume indicator circuit, by means of which the volume could be checked accurately and adjusted accordingly.

The distribution amplifier also contained negative feed-back, the maximum gain being 20 db. and giving approximately 300 mW into a 600-ohm impedance without noticeable distortion. Its frequency characteristic could be adjusted between 30 and 8 000 p : s for the purpose of line equalization.

The Eucharistic Congress sound system, including all equipment and apparatus components utilized, was of impressively high quality and admirably adapted to the requirements imposed. That the transmission of the programme was most satisfactory in every respect was due largely to the painstaking effort devoted to the solution of the many constituent transmission and sound-engineering problems presented. A further important factor contributing to the successful consummation of this outstanding sound reproduction project was the fine co-operation of the Hungarian Postal Administration, the clergy and those in charge of the musical programmes of the Congress.

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Ultra-Short Wave Oscillators*

By D. H. BLACK, Ph.D., M.Sc., F.Inst.P., F.P.S.,
Standard Telephones and Cables, Limited, London, England

The various types of valve oscillators for obtaining ultra-high frequencies are briefly outlined, and the limitations of negative grid oscillators enumerated and discussed. Some practical examples are described together with methods of operation. An interesting oscillatory circuit in which a number of valves can be connected enables comparatively large powers to be obtained if required.

FOR a number of years many investigators have been working on the problem of obtaining electro-magnetic oscillators of higher and higher frequencies and of making these oscillators deliver larger power outputs. Extremely high frequencies have been obtained using special forms of spark generators but at the present time some form of electron discharge tube is almost universally used for the generation of these oscillations. The oscillators forming the subject of this paper use thermionic valves of the so-called negative grid type, but before describing some recent work on this subject other types of oscillators will be considered.

Ultra-high frequency oscillators using thermionic valves may be divided into four main groups:

(1) Negative grid valves,
(2) Positive grid valves,
(3) Magnetrons,
(4) Miscellaneous.

POSITIVE GRID VALVES

Oscillators of the positive grid type are usually referred to as Barkhausen oscillators and have been known for some considerable time together with the somewhat similar Gill-Morrell oscillators. In its simplified form the valve used to generate the oscillations is of the triode type. The grid has a positive D.C. potential applied to it, while the anode is usually maintained at a negative potential. Electrons emitted from the cathode oscillate rapidly between the anode and the cathode before finally coming to rest on the grid. These oscillating electrons induce currents in the grid and, by suitable coupling circuits, these induced currents may be made to deliver power to the external circuit. The power is either taken off between the grid and the cathode, or between grid and anode; but, in one specialized form developed by A. G. Clavier of Les Laboratoires, Le Matérial Téléphonique, Paris, the oscillations are built up in a helical grid and the power taken from the two ends of the grid. The frequencies obtainable from this type of valve are very high, 6 000 megacycles per second having been attained, but the output powers are very small. It should be remembered, however, that a commercial system[1] using valves of the Clavier type has been in operation between England and France since 1931. This operates at a frequency of approximately 1 750 megacycles per second; a view of the type of valve used is shown in Fig. 1.

MAGNETRONS

The use of magnetrons to produce high frequency oscillations is too well known to make it necessary to describe them in any detail. Where the highest powers at very high frequencies are required, the magnetron is in a class by itself and considerable ingenuity has been shown in developing small high performance valves of this sort. It does, however, suffer from one very serious disadvantage. Owing to the fact that the oscillation frequency is dependent upon the anode voltage it is very difficult to modulate the output from the valve, especially if a wide modulation bandwidth is required. A system of so-called "pulse" modulation has been applied to magnetrons with some success but only for comparatively narrow bands.

*Paper delivered at the Emporium Section of the Institute of Radio Engineers, 31st January, 1939.

[1] "Production and Utilization of Micro-Rays," *Electrical Communication*, July, 1933.

MISCELLANEOUS OSCILLATORS

A number of other methods for generating ultra-high frequency oscillations have been proposed from time to time. It is quite possible that some new method which will supersede all existing methods may be developed in the future, and indeed some of the methods already proposed show considerable promise. All that is intended here is to recognise that other methods of generating these oscillations have been proposed.

NEGATIVE GRID OSCILLATORS

The term negative grid oscillators arises from the fact that the D.C. potential applied to the grid is usually negative, as distinct from the positive potential applied to the grid in valves operating as Barkhausen oscillators. The use of triodes in oscillators of this type dates back to the early days of thermionic valves. At first the frequencies involved were seldom higher than a few megacycles per second; but, at the present time, frequencies of 70 megacycles per second are in common use, and the indications are that frequencies up to 750 megacycles per second will find extensive application for certain classes of work. Frequencies as high as these have been produced by means of negative grid triodes and still higher frequencies will no doubt be obtainable in the future, 3 000 Mc/s having already been attained experimentally.

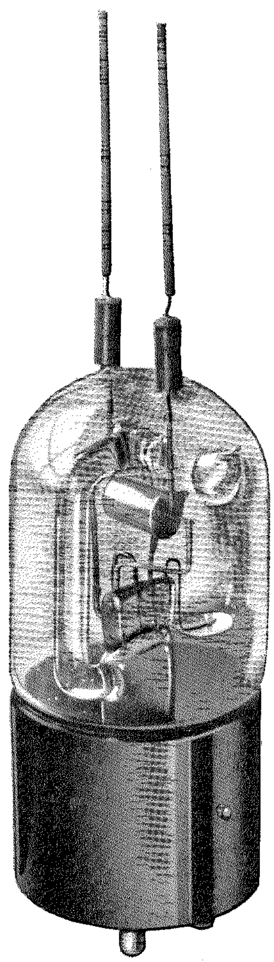


Fig. 1—4036-*A Micro-Ray Valve.*

FEATURES LIMITING THE OPERATION OF VALVES AT ULTRA-HIGH FREQUENCIES

In considering the possible behaviour of a triode at very high frequencies a number of limiting factors arise. Some of these factors affect the operation of the valves at normal radio frequencies, but others do not have any marked effect until the ultra-high frequencies are approached. The principal factors to be considered are as follows:

(1) Maximum available emission from the cathode;
(2) Maximum anode dissipation;
(3) Grid emission;
(4) Dielectric losses in the envelope and insulators;
(5) Inductance of the valve leads;
(6) Capacities between the electrodes;
(7) Transit time of the electrons between cathode and grid.

The first three of the limitations also enter into the design of valves for operation at normal frequencies but they have a much more marked and, in some ways, a different effect on valves for operation at ultra-high frequencies. Some of the limitations mentioned above are interconnected, e.g., (1) and (6), and (5) and (7); and some of these relationships will be considered hereinafter. Before doing so, however, it will be advantageous to consider each limitation separately.

(1) It is obvious that if a valve is to deliver power, certain peak emissions must be obtainable from the cathode. The total emission available is proportional to the area of the

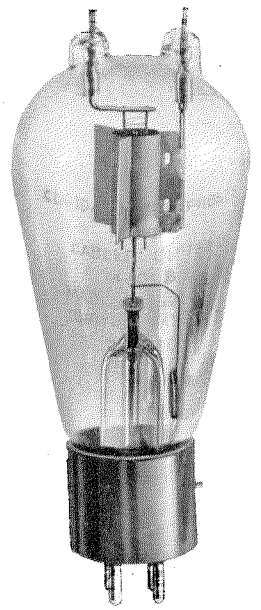


Fig. 2—4304-*B Valve* (*S.T. & C.*).

cathode and the emission per unit area. Without considering the reasons for the moment, it is fairly obvious that valves for operation at high frequencies must be small; hence the area of the cathode must be small and the total available emission from the cathode is limited. Consequently, the cathode must operate with as high an emission per unit area as possible. It is therefore customary to run the cathode of ultra-high frequency valves at higher than normal temperatures, even at the cost of reduced life. Pure tungsten and thoriated tungsten filaments are both used; and, later in this paper, some results obtained with oxide-coated cathodes will be described.

(2) Similar restrictions apply to the anode of the valve. As the frequency of the operation of a valve is pushed towards the limit, the efficiency decreases rapidly and a large proportion of the input power is dissipated by the anode; as in the case of the cathode, the anode must be of small dimensions and it is a common practice to run the anode at a considerably higher rating than the normal.

(3) In any valve oscillator grid emission may be the cause of a considerable amount of trouble. For a grid to emit electrons it must increase in temperature; its rise in temperature is due to the heat generated by the flow of electrons to it and by the absorption of heat from the cathode and the anode. Any tendency for the grid to emit is greatly increased if active material from the cathode becomes deposited on it. This is particularly noticeable where oxide-coated cathodes are used. It can be counteracted to a certain extent by constructing the grids from materials such as manganese-nickel alloys, or by coating them with certain substances which decrease the tendency for emission to take place. It has been observed that in valves having oxide-coated cathodes the tendency for grid emission to take place increases as the frequency of operation increases. A number of explanations to account for this phenomenon has been put forward, but they are of a somewhat speculative nature and need not be considered here.

(4) Inasmuch as dielectric losses in most insulating materials increase rapidly with frequency, care must be taken to keep these losses to a minimum by the use of low loss insulating materials. In valves intended for operation at the highest frequencies, the only insulating material used is that of the hard glass envelope.

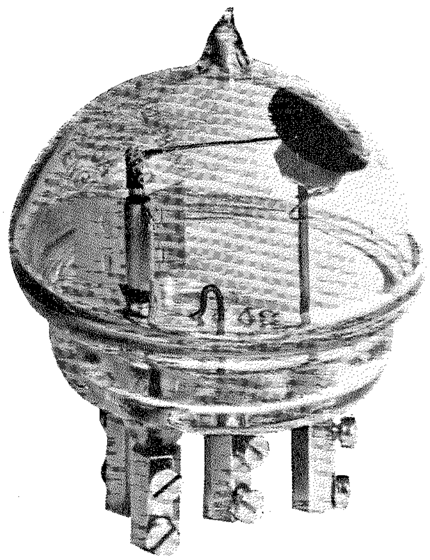


Fig. 3—4316-*A Valve* (*S.T. & C.*).

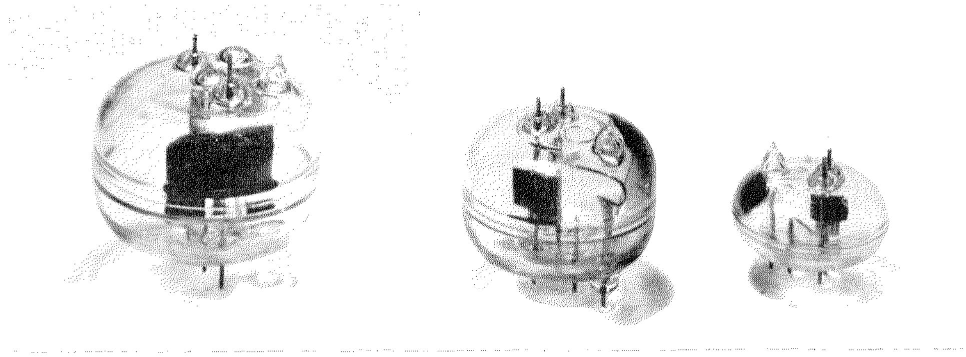


Fig. 4—Double Lead Ultra-short Wave Valves (Bell Telephone Laboratories).

(5) The inductance of the connecting leads to the electrodes is also of great importance in these valves. Every effort is made to keep these leads as short as possible.

(6) The frequency of an oscillatory circuit is given by the equation

$$f = \frac{1}{2\pi}\sqrt{\frac{1}{LC}},$$

where L is the inductance and C the capacity of the circuit. Assuming for the moment that L remains fixed, it is obvious that there is a definite limit imposed on the frequency which can be obtained from a valve because of the capacities between the electrodes. In order to obtain high frequencies the inter-electrode capacities must be small. As will be seen later, this means that the actual dimensions of the valve must be reduced as the frequency is increased, thus limiting the power which can be obtained.

(7) In valves operated at frequencies of 60 Mc/s or less, the time which an electron takes to travel from the cathode to the anode is usually negligible as compared with the time of one complete oscillation. As the frequencies are increased this transit time does not remain negligible but may be the limiting factor determining the upper frequency limit at which the valve will operate. It is generally accepted that it is the transit time between cathode and grid which is of the greatest importance since the field acting on the electrons is lower in this region than in that between the grid and anode. It is also agreed that the limiting transit time is one-half the period of one complete oscillation.

INTERDEPENDENCE OF LIMITING CONDITIONS

The various factors which limit the frequency at which a valve can be operated have been mentioned above. Each one considered separately might be improved fairly easily. For instance a tungsten filament could be run at a high temperature in order to obtain a high emission, or the spacings between the electrodes could be increased in order to decrease the inter-electrode capacities. Unfortunately nearly all the limitations are interdependent, the only exceptions being dielectric losses and, possibly, inductance of the leads. It may therefore be of interest to consider some of these relationships in a general way.

Consider first the cathode. One cannot obtain a high value of total emission by increasing the size of the cathode since this will increase the size of the grid and anode, and so increase the capacities unless the electrode spacings are also increased; but this cannot be done. As has been seen, the capacities must be kept to a low value. Increase in cathode temperature is quite a common method of increasing the emission but, quite apart from shortened life, there is a definite limit to which this can be carried. Increasing the temperature of the cathode increases the temperature of the grid, so that, if the cathode be of the thoriated tungsten or oxide-coated type, active material will be deposited on the grid at an increased rate, consequently increasing the grid emission.

Increased emission, if used to its fullest extent, means increased power to be dissipated on the anode ; and, as in the case of the cathode, the size of the anode cannot be increased without increasing the capacities except at the expense of the electrode spacings. If the distances between the electrodes be increased, the inter-electrode capacities will be decreased but, as a result, the mutual conductance of the valve will be decreased and the electron transit time increased. As has been pointed out, this latter effect may set a definite frequency limit on the valve.

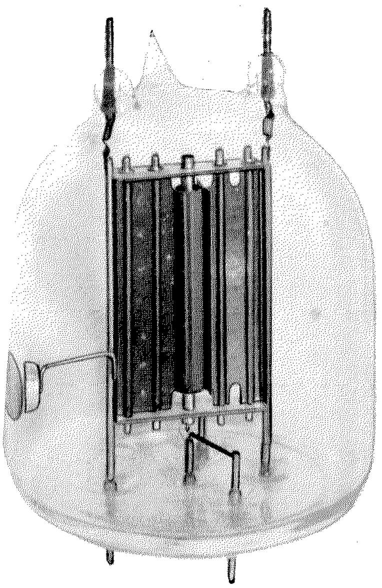


Fig. 5—*LS*.486 *Valve.*

Thus it is seen that, in order to keep both the capacities and the transit time to the low values required, the electrodes must be of decreasing size as the frequency of operation is increased. In order to obtain maximum dissipation, the anode of such valves is usually provided with ribs and the surface roughened in order to improve its radiation properties. Carbon is frequently used for the anodes owing to its extremely good properties in this respect. Grids are also provided with cooling fins in order to keep their temperature, and hence their emission, down to a minimum.

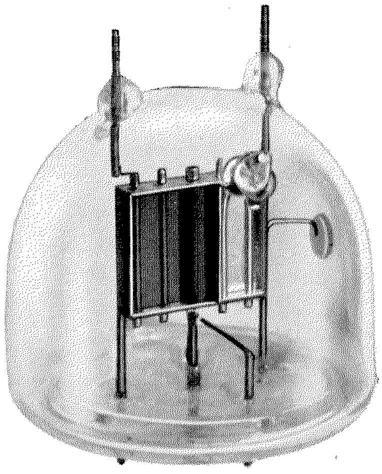


Fig. 6—*LS*.445 *Valve.*

It has been suggested that the necessary short transit time might be attained by operating a valve with high potentials, thus allowing the requirements of close inter-electrode spacing to be relaxed somewhat or permit higher frequencies with a certain electrode spacing. High anode voltages, and the resulting high grid voltages, can be of assistance in some cases, but they do not offer a complete solution of the problem. If the inter-electrode spacing is fixed, it is at once evident that the application of high potentials entails increased space current, and thus the total emission from the cathode sets the limit to the magnitude of the potential which can be applied. If the frequency of operation is fixed and attempts are made to increase the power handling capacity of the valve by increasing the inter-electrode spacings, then the same limitation is again encountered, although not to such a marked extent.

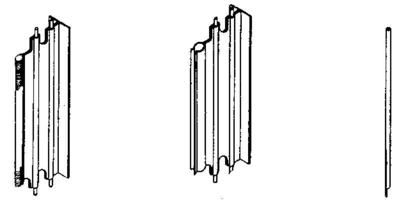


Fig. 7—*Structural Details of the LS*.486 *Valve of Fig.* 5.

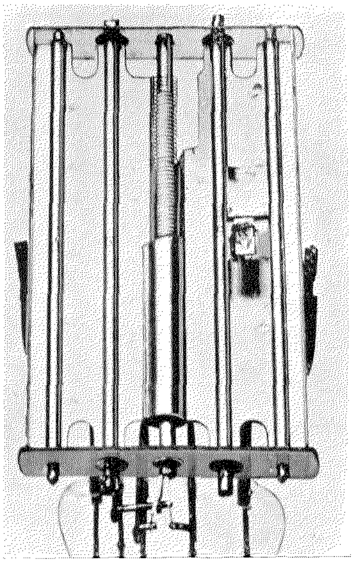


Fig. 8—Structural Details of the LS.445 Valve of Fig. 6.

To sum up, then, we find that valves intended for operation at ultra-high frequencies have a number of inherent limiting characteristics which do not affect their operation at normal frequencies. These limitations are largely interconnected and the resulting valve must have the following characteristics :

(1) High cathode emission per unit area ;
(2) High anode dissipation per unit area ;
(3) Low temperature grids ;
(4) Small electrodes and inter-electrode spacings ;
(5) Short straight leads ;
(6) Minimum of insulating material.

VALVE TYPES

A number of valves which have been specially designed for ultra-high frequency operation are shown in the accompanying illustrations. The first two were designed in the Bell Telephone Laboratories, Inc., and are referred to in the U.S.A. as the 304-B (Fig. 2) and the 316-A (Fig. 3).

The same valves manufactured in England are referred to as the 4304-B and the 4316-A. In both these valves it will be noticed that the leads to anode and grid are kept as short as conveniently possible and both electrodes are supported from the leads. These valves have been very successful, the 316-A type having a higher frequency limit of operation than any other valve on the market. It will oscillate at 750 Mc/s although the output at this frequency is very small. Approximately 8 watts can be obtained from it at 300 Mc/s. The 304-B will deliver approximately 55 watts at 100 Mc/s, 15 watts at 300 Mc/s, and has an upper frequency limit in the neighbourhood of 350 Mc/s.

Fig. 4 shows three valves which have also been developed by the Bell Laboratories. They all differ from conventional triodes in that the anode and the grid each have two leads, one at each end of the bulb. The advantage of these double leads will be mentioned later. These valves also have finned grids to lessen any tendencies to grid emission ; and the filaments are of thoriated tungsten run at a somewhat higher temperature than the normal.

Figs. 5 and 6 show two double lead triodes which have been developed by Standard Telephones and Cables, Limited, London.

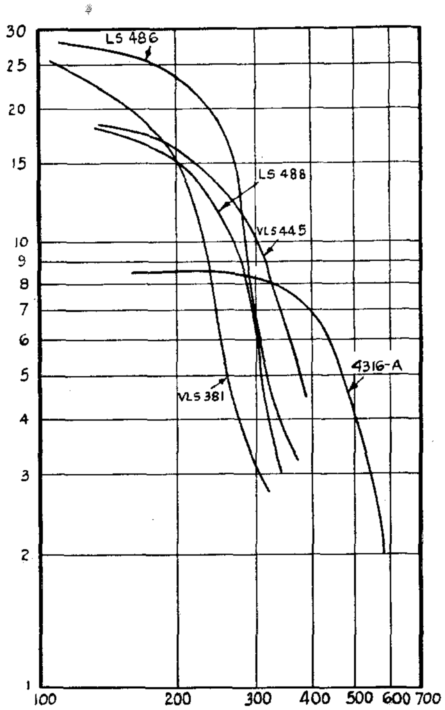


Fig. 9—Relationship between output and frequency for some indirectly heated Valves, and a 4316-A Valve.

These valves are similar to the Bell Laboratories valves in that they have double leads to grid and anode, and the grid is provided with a fin. Figs. 7 and 8 illustrate details of the structures. Their principle of construction, known as "micromesh," was developed by Standard Telephones and Cables, Limited, some years ago and was applied to high mutual conductance triodes for radio receivers. Each turn of the grid is welded to the cooling fin and consequently keeps much cooler than the turns of a conventional type grid. The grids used in the Bell Laboratories valves differ in form but they have adopted the same principles. The Standard valves differ from the others in that they have indirectly heated cathodes of the oxide-coated type. Such cathodes run at a much lower temperature than the tungsten or thoriated tungsten type and provide a comparatively high value of total emission.

METHODS OF OPERATION

At frequencies up to 150, or even 200 megacycles, more or less conventional oscillatory circuits may be used. That is to say the inductance is in the form of a coil which is tuned by a condenser. As these high frequencies are approached, however, the sizes of the coils and condensers become very small, and the inductance and capacity of the connecting leads to the valve become of increasing importance. As the frequency is raised, increasing difficulty arises through losses in the insulators used. After considerable study of the various possibilities, Standard Telephones and Cables, Ltd., has adopted the so-called "Linear" oscillator as being the most efficient and convenient for frequencies above 200 Mc/s ; and the remainder of this paper deals with some of the results obtained with the valves illustrated above, together with some developments arising out of the work done.

In the linear oscillator the oscillatory circuit proper consists of a length of transmission line. In its simplest form the transmission line consists of two parallel rods connected directly to the anode and grid pins. If the line is open-ended its length is between a quarter and a half of a wavelength. The line may be closed with a condenser in order to decrease the frequency without using a long line ; but for the most

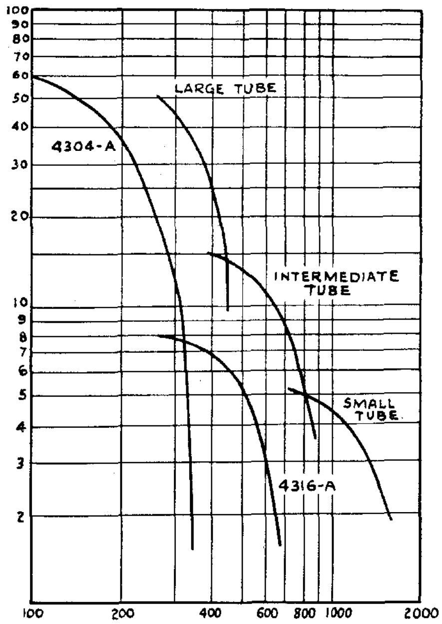


Fig. 10—*Relationship between Output and Frequency for Bell Laboratories' Double-ended Valves and for the* 4316-*A and* 4304-*A Valves.*

efficient operation the open-ended line is recommended. It is also necessary to tune the cathode to obtain the most efficient operation. This is conveniently effected by connecting the cathode to the centre of a coaxial transmission line the effective length of which can be varied. This line usually consists of a length of copper tubing with a copper rod along its axis, and having a moveable plunger sliding on the copper rod and making contact with the tubing. In the case of valves having indirectly heated cathodes, only one such tuning device is needed ; but in filamentary type valves one is required for each leg of the filament. The external supplies are connected to the valve through small chokes, and in the case of the anode and the grid these are conveniently connected at the nodal points of the transmission line. The load into which the output works can be connected across the rods at a point depending upon its impedance.

Reduced to its simplest terms the oscillatory circuit consists of two parallel wires terminated at one end by a system, the valve, consisting of a lumped capacity and inductance. The frequency is determined by the length of the transmission line, a voltage anti-node occurring at the open end of the line and a voltage node one quarter of a wavelength from the open end. The length of line on the other side of the node, together with the inductance and capacity of the valve, constitute an equivalent quarter wavelength, the end of the electrode system remote from the line possibly forming another voltage anti-node. As the length of the line is reduced the valve oscillates at increasing frequencies and the nodal point enters the valve envelope, eventually entering the electrode system itself in some circumstances.

As mentioned above, a voltage anti-node is possibly formed at the end of the electrode system remote from the point where the transmission line is joined to it. If such is the case, one might consider the possibility of placing a second electrode system against this and taking a similar transmission line out on the opposite side. This becomes, in effect, the double lead type of valve, examples of which have already been shown. From the above reasoning one would expect a double lead valve with a double linear oscillator system, at a particular frequency,

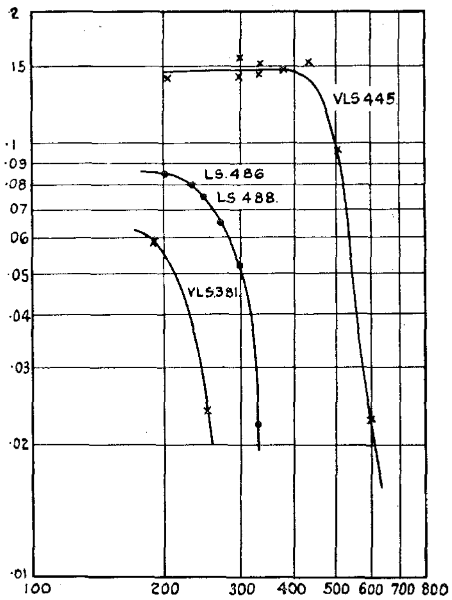


Fig. 11—*Relationship between Equivalent Capacity and Frequency for the Indirectly Heated Valves.*

to have twice the output of a single lead valve. In Fig. 9 the output versus the frequency characteristics of four valves are shown together with that of a 4316-A valve for comparison purposes. The valves all have the same interelectrode spacings but differ in the following manner: VLS.381 is a single lead valve; LS.486 is a double lead valve having the same electrode length; LS.488 is a single lead valve having half the electrode length of LS.486; and VLS.445 is a double lead valve having the same electrode length as LS.488. These curves do not bear out the above conclusions very well since one would expect LS.486 to have twice the output of LS.488 at all frequencies; but it must be remembered that the output obtainable depends on a number of factors and that these results are taken on a few experimental valves. The curves do, however, show the general superiority of the double lead valves, since it will be seen that while VLS.381 and LS.486 have approximately the same output at the lower frequencies, LS.486 has a higher output at the higher frequencies. The same thing is true of LS.488 and VLS.445. Fig. 10 shows similar curves for the Bell Laboratories' valves.

From the results obtained with the four valves illustrated in Fig. 9, it was found that when the length of the transmission line was plotted against the wavelength a series of parallel straight lines was obtained which could be represented by the formula

$$l = \frac{\lambda}{3} - k, \quad \ldots\ldots\ldots\ldots\ldots(1)$$

where l is the length of the transmission line, λ the wavelength and k a constant which varied from valve to valve and which depended upon the point from which the length of the line was measured.

If the origin of measurement was taken as the point at which the leads joined the electrode system, the values of k for the four valves in question were:

VLS.381	−9
LS.486	−7
LS.488	−7
VLS.445	−4.

Thus it is seen that the double lead LS.486 gave the same results as the single lead LS.488 of half the length. Since the distance from the

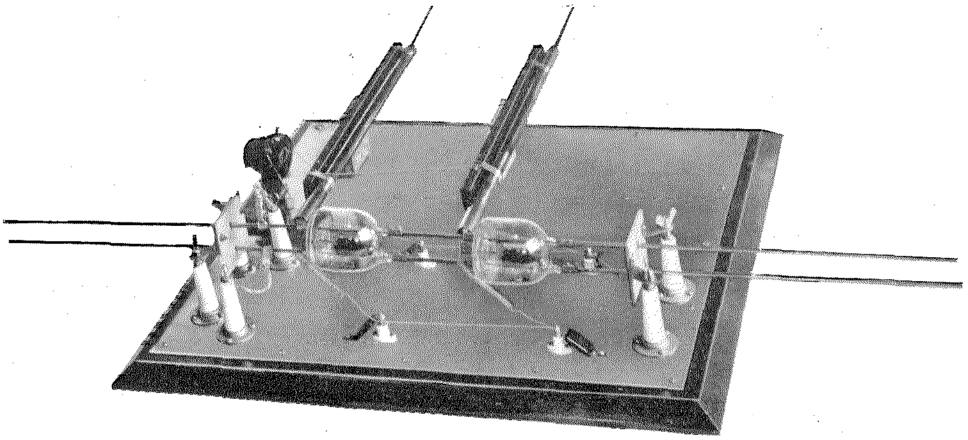


Fig. 12—*Double Valve Oscillator.*

open end of the line to the nodal point is $\frac{\lambda}{4}$, the distance between the nodal point and the electrode system (x) is given by:

$$x = \frac{\lambda}{3} - k - \frac{\lambda}{4}$$

$$= \frac{\lambda}{12} - k. \qquad \ldots\ldots\ldots\ldots(2)$$

Thus when $\lambda = 12k$ the nodal point reaches right to the electrode structure. The fact that wavelengths shorter than this value have been measured shows that in some cases the node is situated inside the electrode structure.

If the electrode system of the valve could be replaced by a fixed inductance and a fixed capacity then one should expect the length of the transmission line to be proportional to $\frac{\lambda}{4}$. The fact that this is not the case indicates that either the inductance or the capacity of the valves changes with frequency. It is well known that the capacity of a valve varies with frequency and it is reasonable to assume that the inductance remains fixed. In the valves in question the inductance is small compared with the capacity and can be neglected to a first approximation. It is then interesting to see how the capacity of the valve must change with frequency in order that equation (1) may be satisfied.

In all measurements referred to, the grid-anode transmission line consisted of two parallel copper rods $\frac{3}{16}$ in. in diameter and $1\frac{1}{8}$ in. between centres. For a parallel wire system the impedance of propagation along the line, $Z_\rho \left(= \sqrt{\frac{L}{C}}\right)$ is given by

$$Z_\rho = 276 \log_{10} \frac{b}{a}, \qquad \ldots\ldots\ldots\ldots(3)$$

where b is the distance between centres and a is the radius of the rods. For the system used, the value of Z_ρ was approximately 300 ohms. Assuming the transmission line to be resistanceless, the impedance of an open-ended line Z is given by the expression:

$$Z = -jZ_\rho \cot\left(\frac{2\pi l}{\lambda}\right) \ldots\ldots\ldots\ldots(4)$$

If this is tuned by a capacity C then Z must also equal $\frac{1}{jwC}$ and therefore

$$-j\, Z_p \cot\left(\frac{2\pi l}{\lambda}\right) = \frac{1}{jwC}$$

$$\text{or } C = \frac{\tan\left(\frac{2\pi l}{\lambda}\right)}{wZ_\rho}, \qquad \ldots\ldots\ldots\ldots\ldots(5)$$

where $w = 2\pi f$, f being the frequency $\left(= \frac{3.10^{10}}{\lambda}\right)$.

Thus for the valve VLS.381 the value of C is given by:

$$C = 0.018\,\lambda \tan\left(60 + \frac{3\,240}{\lambda}\right) \quad \ldots\ldots\ldots(6)$$

Similarly, expressions may be found for the capacities of the other three valves; but it must be remembered that the values of C

obtained for the double-ended valves will only represent half the actual capacity, since each of these are regarded as forming two complete oscillator systems, placed back to back as it were. The fact that the relationship between l and λ for the double lead LS.486 valve is identical with that for the single lead LS.488 having half the electrode length lends very strong support to this assumption. In Fig. 11 values of $\frac{1}{C}$ are plotted against frequency and it can be seen that they follow the same general trend as the output versus frequency curves for these valves.

MULTIPLE OPERATION

An added advantage of these double lead valves is that they can be connected in multiple. With the double lead linear oscillators, nodal points are usually situated a short distance outside each end of the valve. If the parallel rods forming one side of the double linear oscillator are removed and another valve of the same kind is connected to the first valve with rods whose length is twice the distance from the envelope to a nodal point, a two-valve linear oscillator is formed. The rods which were removed from the first valve are of course connected to the second pair of leads of the second valve. Such an oscillator operates at the same frequency as the single valve type and gives double the output. Fig. 12 shows an example. The coaxial lines for tuning the cathodes should be noticed. Thus we have an oscillator consisting of a transmission line with valves situated at voltage anti-nodes and separated by one electrical half wavelength. Owing to the lumped capacities of the valves the physical distance between them is shorter than one half wavelength.

Such a multiple oscillator is not limited to two valves. Three valves, giving three times the output of a single valve have been operated successfully; and there seems to be no reason why the system should not be extended to greater numbers of valves. This would appear to be a very useful method of obtaining comparatively large outputs at ultra-high frequencies. Furthermore, it is not necessary to space the valves one electrical half wavelength apart since they may be spaced at multiples of half a wavelength. This latter arrangement is essential when operating at frequencies approaching the upper limit of the valves; for in this case the nodal points are situated inside the valve envelope and it becomes impossible to space the valves one electrical half wavelength apart. Using three LS.486 valves, an output of over 50 watts at 250 megacycles can be obtained with an applied anode potential of not more than 400 volts.

It is not considered that the results obtained from the indirectly heated cathode valves described above represent the limit of what can be effected with this type of structure. The indications at present are that all these valves have an upper frequency limit which is determined by the valve capacity and not by the transit time. Consequently it is hoped that the frequency limit may be extended by changing the electrode dimensions. While these valves do not give the same performance as the Bell Laboratories' valves, it should be remembered that they have the following advantages:

(1) Indirectly heated cathodes giving greater simplicity in the circuits;
(2) Lower cathode wattage;
(3) Lower anode potentials (in general);
(4) Simpler to manufacture.

Ultra-Short Wave Police Radio Telephone Installations in Oslo and Stockholm

By G. WEIDER, M.N.I.F.,

Standard Telefon og Kabelfabrik A/S., Oslo, Norway

GENERAL

WITH the extensive introduction of motor cars and vehicles in police services, wire telephone and signal box systems no longer afford the efficiency and rapidity required for communication purposes. Radio, on the contrary, offers an ideal medium for meeting the highly important requirements of a flexible and rapid communication system between the cars and the police stations. Large areas thus can be controlled practically instantaneously and the cars directed to spots where " something is happening."

Two types of radio systems are available for police services:

Short wave	120–190 m
Ultra-short wave ..	7– 10 m .

Both may be adapted to one- or two-way communication, either telephonic or telegraphic.

In cities and municipal or suburban areas covering maximum ranges of 15 to 20 km, the ultra-short wave system is preferable in nearly all cases. In rural areas, due to the restricted range of ultra-short waves, short wave working is usually more suitable.

In cities and densely populated areas, the application of short waves in two-way police communication is not usually desirable for the following reasons:

(1) The existence of dead spots when receiving. They are not so frequent with ultra-short waves due to their reflection from buildings and other structures along the streets.

(2) Relatively high transmitter output, both for cars and headquarters required.

(3) Difficulty in obtaining an efficient car transmitting antenna, especially for radiation while the car is in motion. (In the case of ultra-short waves and a quarter-wave vertical radiator, the length of the antenna is two to three metres.)

(4) Interference with broadcasting services and with other police stations.

(5) Static from atmospheric disturbances. Ultra-short waves, on the other hand, are more sensitive to disturbances from car ignition systems.

For two-way communication between cars and stations, ultra-short waves offer the best facilities within a local area. In view of the possibility of immediate and positive acceptance of a call, the two-way system is nearly always favoured. In the case of cities such as London or New York, where the number of cars calling simultaneously may be great, the introduction of the two-way system may present difficulties.

Since radio telegraphy necessitates the employment of special operators, telephonic working is generally preferred. The latter also permits police officers, who are not often expert telegraphists, to communicate directly with the cars without the intervention of a third person. Because of the reliability and high quality of the equipment to be described, the possibility

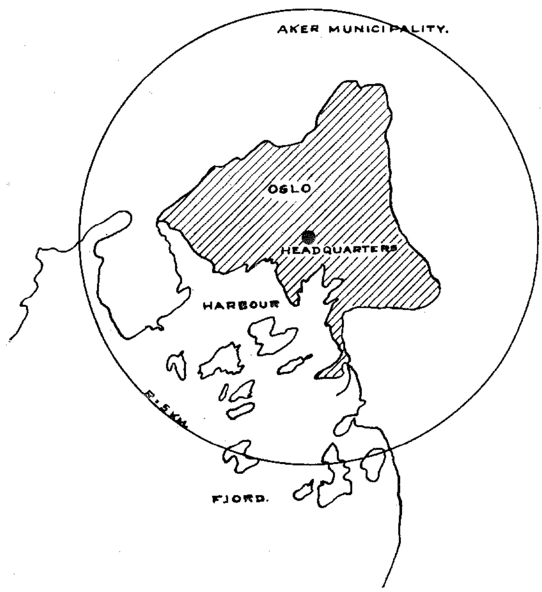


Fig. 1—Map of Oslo and its Suburbs.

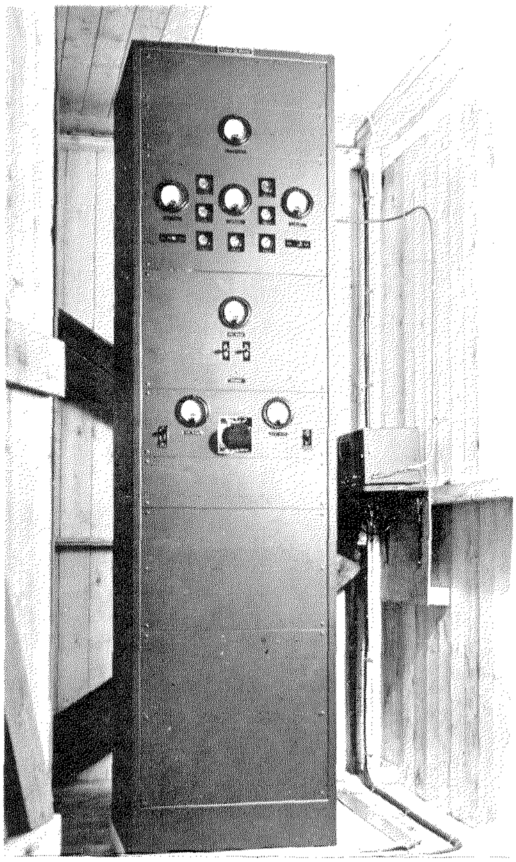


Fig. 2—Headquarters Transmitter and Receiver.

of a call " being lost " is reduced. Secrecy, if required, can be obtained by the use of a simple code, but its importance is considerably reduced by the speed and efficiency of the radio system.

Police radio equipment must be specially designed, and contain high quality components in order to meet the exacting service requirements. In addition to obtaining the best possible electrical characteristics, consideration of the unfavourable working conditions imposed on the mobile equipment shows that great care in mechanical construction is required. Rigidity of construction sufficient to withstand the effects of shock and vibration, ease of installation, adaptability of the apparatus to various types of cars, accessibility of components, and simplicity of operation are all of major importance. Further, the power supply must be economically designed and preferably obtained from the car battery.

A high degree of reliability is of vital importance inasmuch as a breakdown may involve serious consequences. The equipment is operated mainly by personnel not expert in radio matters, and it should not, in fact, be necessary for them to know anything about radio. The characteristics of the apparatus, moreover, should be such as to engender confidence on the part of the user equal to that of the ordinary telephone subscriber in his subset.

THE OSLO POLICE INSTALLATION

The Oslo Police have carried out trials with radio communication systems since 1931, but it was not until the end of 1936 and the beginning of 1937, when tests were made with ultra-short waves, that satisfactory results were obtained. Experiments confirmed that, with short waves, it was not possible to avoid the existence of several dead spots within the city. In April, 1937, Western Electric ultra-short wave equipment was demonstrated to the Oslo Police and, for the first time in Scandinavia, two-way ultra-short wave communication between cars and headquarters was carried out. After the Police had tested the equipment thoroughly, an order was placed with Standard Telefon og Kabelfabrik A/S., comprising:

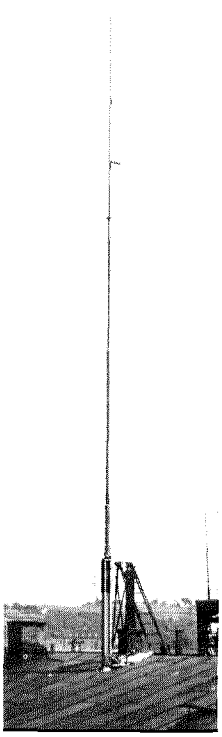


Fig. 3—Headquarters J-type Antenna.

For Headquarters:

1—No. 16-B transmitter, 50 watts,

1—No. 19-A superheterodyne receiver,

Fig. 4—Radio Telephone Switchboard Room at Headquarters.

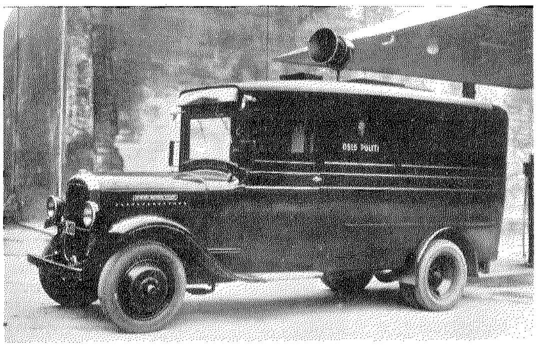


Fig. 5.A.—Transport Car.

Fig. 5.B.—Receiver and Control Unit in Transport Car.

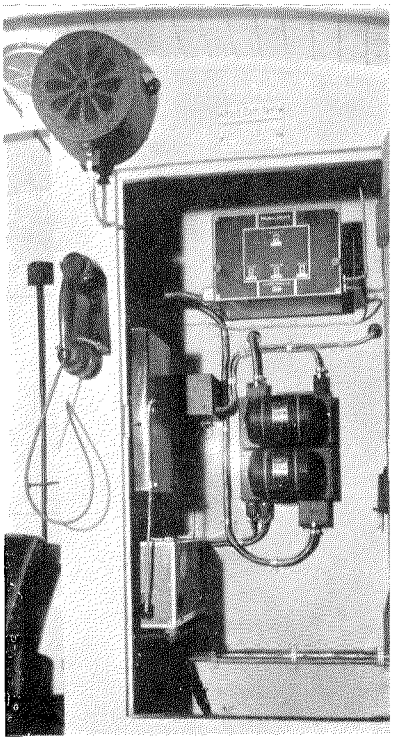


Fig. 5.C.—Transmitter, Power Units and Public Address Equipment in Transport Car.

aerial and control equipment.

For Four Patrol Cars:

4—No. 18-E superheterodyne receivers.

For Harbour Boat and Transport Car:

2—No. 211-A equipments including:
No. 18-A transmitter, 5 watts, and
No. 18-E receiver.

Subsequently, 211-A equipments for four patrol cars were delivered. When a new patrol car is being provided by the police, it is not now considered complete unless radio equipment has been installed. Following on the successful results obtained with the Oslo system, seven No. 211-A car equipments also were furnished to the Government Police.

The wavelength range of the transmitters and receivers is 10 to 7.14 m (30 000 to 42 000 kc/s). The operating wavelength in Oslo is 8.086 m (37 100 kc/s). The oscillator circuit of the transmitters is crystal controlled, the crystals being cut for 1/6 or 1/4 of the carrier frequency. The beating oscillator circuit of the headquarters' receiver is crystal controlled, the crystal oscillating on 11 083.33 kc/s.

The headquarters building is situated as shown in Fig. 1. It is located on a low hill and its height is approximately 25 m to the top of the roof. The transmitter and receiver, illustrated in Fig. 2, are installed on the top floor. The output of the transmitter and the input of the receiver are connected via 3/8 in. coaxial transmission lines to a relay, which connects the transmitter and the receiver, respectively, to a 7/8 in. coaxial transmission line leading to the antenna, illustrated in Fig.3.

The antenna is a vertical J-type dipole and is supported by a 15 m steel tube mast, $4\frac{1}{2}$ in. in diameter at the base and 2 in. at the top. Because of their possible absorption of radiated energy, metal guys are not used. The mast is supported at the base by two $5\frac{1}{2}$ in. × $2\frac{1}{2}$ in. × 6 m channel irons, passing through the roof of the building and resting on two 9 in. × 9 in. floor timbers. While in the horizontal position, the antenna was mounted on the mast and transmission line connections made. The mast was then raised to the vertical position by means of a shaft fixed between the channel irons. This process greatly simplifies inspection of the antenna system.

The transmission line, at the base of the mast, is connected by means of a special weatherproof demountable coupling to the down lead to the antenna relay mounted in the transmitter-receiver room. Transmission line connections must be made with great care in order that the insulation resistance between the inner and outer conductors can be maintained above 10 Megohms.

The transmitter and receiver are operated from the telephone switchboard room (Fig. 4) located on the ground floor.

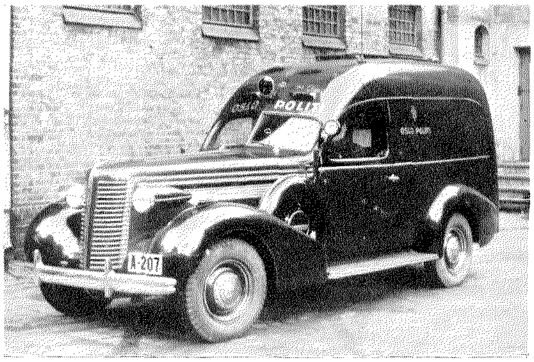


Fig. 6.A.—Patrol Car.

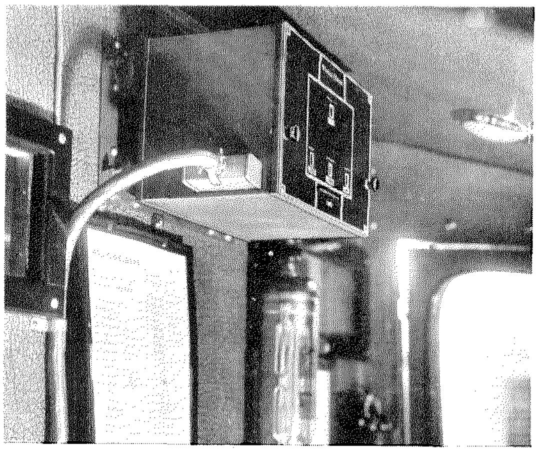


Fig. 6.B.—Transmitter in Patrol Car.

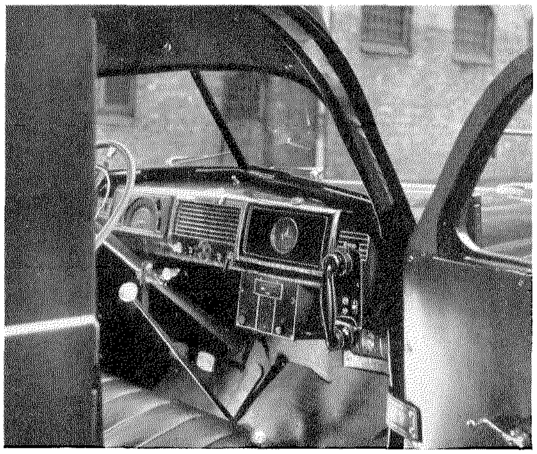


Fig. 6.C.—Receiver, Control Unit and Power Units in Patrol Car.

Fig. 7—Transmitter and Power Units in a Government Police Car.

The control equipment includes a control box with switches, ammeter, microphone hummer, microtelephone and amplifier with loudspeaker. On the table beside the control apparatus is a map of the city ; a wall panel with removeable numbered cards indicates the cars in service and the districts being patrolled.

A switch on the control box puts the equipment in the stand-by and receiving condition, i.e.,

(1) The receiver is made alive and connected via the antenna relay to the transmission line ;

(2) Filament voltage is applied to the transmitter valves and, after about 30 sec., the operation of a time delay relay permits the application of plate voltage and grid bias.

An incoming call will then be heard from the loudspeaker, which may be switched off and conversation carried on with the handset. By means of a key, the " CODAN " circuit of the receiver, which will be referred to later, can be switched in or out.

The equipment operates from a 220-volt, single phase, 50-cycle A.C. supply. In the stand-by position the reading of an ammeter on the control panel is approximately 2.5 amps., corresponding to a power consumption of 500 W with a power factor of 0.9.

By throwing another switch, plate voltage is applied to the transmitter valves, the antenna relay disconnecting the receiver from the transmission line and connecting the latter to the transmitter (the receiver input and output being short-circuited). The previously mentioned ammeter reading is then 6.5 amps., corresponding to a power consumption of 1.3 kW with a power factor of 0.9. When modulating the carrier, either with a 1 000-cycle tone produced by a microphone hummer or with speech, the needle of the ammeter follows the modulation periods. This simple arrangement provides adequate means for control of the equipment.

The lay-out of the apparatus in the cars may vary, depending on the type of car and space available. The No. 211-A automobile equipment consists of :

No. 18-A transmitter,
No. 18-E receiver with separate loudspeaker,
Control unit with microtelephone,
Power unit for transmitter,
Power unit for receiver,
Antenna,
Cables, sockets and plugs.

The equipment meets all the specified requirements. Shockproof mountings are used throughout. The components are of small dimensions, the transmitter being 18 cm high, 28 cm wide and 17 cm deep ; the receiver is of the same dimensions with exception of the width, which is 23 cm. The equipment is very flexible. All cables are connected to the transmitter, receiver and power units by means of plugs and sockets, allowing quick dismantling of the apparatus for inspection and replacement. A car may be furnished initially with receiving

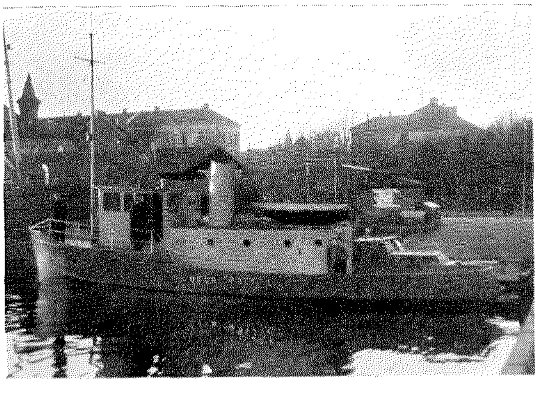


Fig. 8—Police Harbour Boat.

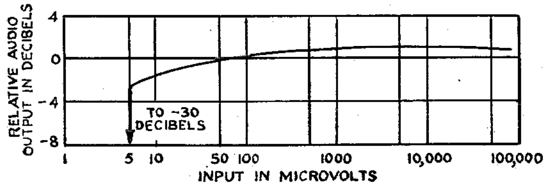


Fig. 9—Receiver Characteristics with " CODAN " and Automatic Volume Control.

equipment only, in which case the later addition of transmitter and accessory equipment does not make any of the equipment superfluous. The transmitter and power units may be mounted where most convenient, but the receiver and control unit with microtelephone must, obviously, be located within the range of the operator. The power units are driven from the car battery, the total current drain being 10 amps. in the stand-by position and 20 amps. when transmitting.

Fig. 5 illustrates the installation in a transport car having a capacity of 20 patrolmen. This car is also used as " mobile headquarters " in connection with public meetings, demonstrations, etc. Loudspeaker and microtelephone are duplicated, with one set in the chauffeur's and one in the passengers' compartment. The car is also equipped with a Standard public address system for transmitting messages to large crowds.

Fig. 6 shows an installation in one of the new patrol cars. Both transmitter and receiver are mounted below the dashboard.

Fig. 7 gives details of the installation in one of the cars of the Government Police. The transmitter with the power units is mounted on a framework in the trunk compartment which also houses the car battery. The control unit and microtelephone are placed on the dashboard, below which the receiver and loudspeaker are arranged. All cabling between the front and rear of the car is run in a copper tube placed under the car chassis. With this arrangement a practical cabling scheme is achieved without the necessity of modifying the body of the car.

In order to eliminate noise generated by the car ignition system, suppressor resistances are connected between the plugs and conductors, or special screened plugs are utilized. A suppressor resistance also is connected to the distributor and a condenser is inserted between the terminals of the dynamo.

The antenna consists of a flexible steel rod of quarter wavelength, supported by a bracket and connected by means of a special cable or a coaxial transmission line to the antenna transfer relay mounted in the transmitter. To obtain correct matching and thus reduce losses, the transmission line is cut to a length dependent on the wavelength. The use of a vertical antenna is desirable because of its higher radiation efficiency. On cars where the transmitter is housed in the trunk compartment, the antenna is mounted on the trunk in order to keep down the distance between the transmitter and the antenna.

Fig. 8 is a view of the police harbour boat. The antenna is mounted on the top of the mast and the radio equipment in the pilot house.

The operation of the equipment is very simple. By turning the combined switch and volume control on the front panel, the receiver is alive within 30 sec. During patrol service the receiver is in continuous operation. A switch on the control unit starts the transmitter

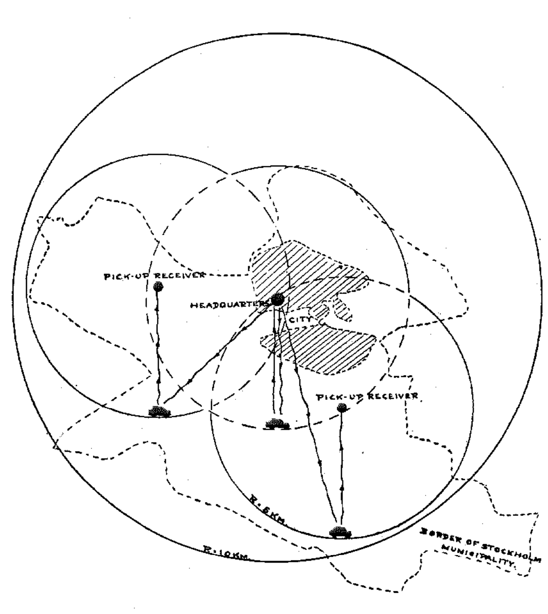


Fig. 10—Stockholm Police District.

power unit; by means of a switch on the microtelephone handle, plate and screen grid voltages are applied to the transmitter—an arrangement which reduces the battery drain to a minimum. The press-to-talk switch also controls the antenna transfer relay and incorporates a receiver cut-off device.

The circuits of the transmitters and receivers are of modern design with efficient types of valves. The crystal controlled oscillators ensure high carrier frequency stability, and the characteristics of the equipment are above normal for commercial radio equipment. Due to the high noise level, the low antenna height on the cars, and the restricted carrier power of the car transmitters, high quality is essential for establishing satisfactory two-way communication.

To describe details of the electrical construction of the apparatus, regarding which information has previously been published, would be beyond the scope of the present article. Mention of some special features of the car receiver, however, may be of interest.

Due to their semi-optical character, the waves radiated from the stationary transmitter are subject to reflections from building walls and other structures and reach the car antennae from many directions. In some cases, the phase relationship of the waves is such that they will reinforce each other; in others, they tend to neutralize, resulting in very low field strengths. Signal strength thus will vary rapidly and widely while a car is moving along a street. Receivers, therefore, are equipped with a quick acting automatic volume control (AVC). For an increase in the signal strength from 5 to 100 000 microvolts, the change in the audio output will be less than 3 db.

Ordinarily, the AVC, during silent periods, would cause amplification of the ignition noise to a level which would be annoying to the operators and which might lead to false calls. To avoid this difficulty, a " CODAN " circuit (" carrier operated device anti noise ") is utilized. Hence, when no signals, or signals below a certain level, are being received, a neon tube shunts the grid of the output valve in the receiver, thus silencing the loudspeaker. The " CODAN " generally is adjusted to function on an input signal up to 5 microvolts. This represents the minimum useful carrier level and is below the average noise level. Fig. 9 indicates the combined working of the AVC and the

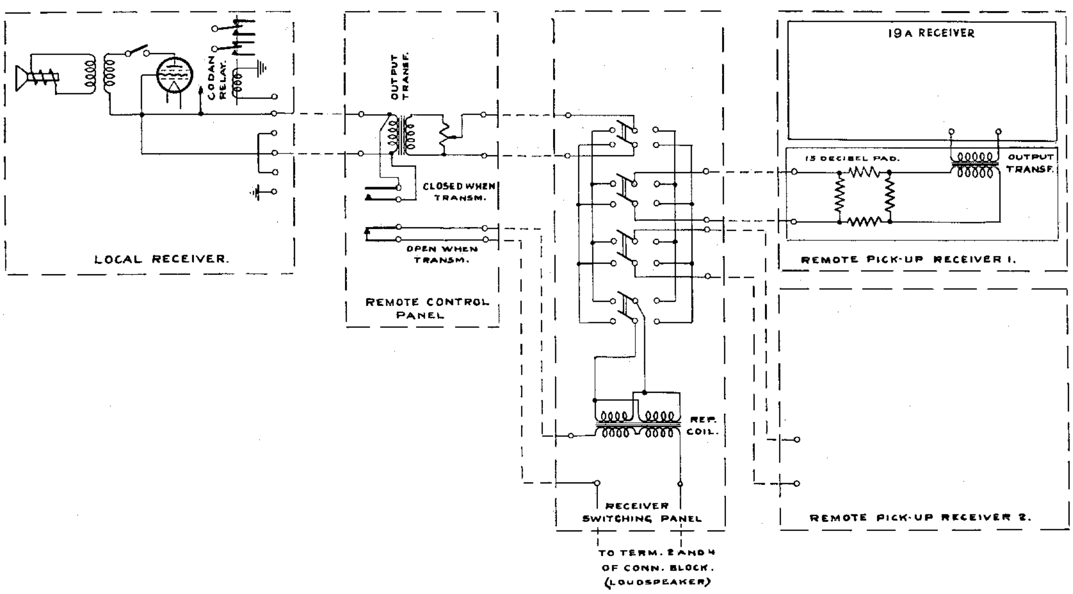


Fig. 11—Connection of Local Receiver and Two Remote Pick-up Receivers.

" CODAN." By means of a potentiometer it is possible to adjust the operating level for the " CODAN " which, by means of a switch, may be disconnected. At great distances from headquarters the low field strength level may necessitate switching off the " CODAN " device, but in the outskirts of the city the noise is generally not disturbing.

A noise suppression circuit, recently developed, will increase the range of the receivers. This circuit will be introduced in the present receivers in Oslo and also in Stockholm.

At headquarters reception is disturbed by ignition systems, electric motors, electromedical apparatus, etc. It appears, however, that satisfactory reception with the " CODAN " in operation is possible from the entire area served by the Police. From 5 p.m. to 7 a.m., noise is not very disturbing with the "CODAN" switched off. All noise sources in the building are compensated; it was, however, rather difficult to trace the origin of a very annoying interference, the level of which increased with the height above ground. By means of a noise-detector, this noise was found to reach the building over a pair of the telephone lines connecting headquarters with the telephone signal boxes in the city and terminating at a mast on the roof of the building. A choke coil in series with the line, and a shunt condenser inserted at the distant end, cured the trouble.

The radio system, which has been in service since October, 1937, has operated without a single breakdown, thus proving the sturdiness of its design, particularly in the case of the mobile equipment. The service conditions imposed obviously are rather severe; for instance, the harbour boat receiver with power unit is in continuous operation, night and day. Maintenance work, notwithstanding, consists essentially in the replacement of valves and brushes. When a car transmitter or receiver becomes faulty, it is immediately replaced by a spare, the replacement taking less than one minute. The defective apparatus is then inspected by the police in their workshop, first by checking the valves with a valve tester. At regular intervals the aerial current of the car transmitters is measured in order to determine the emission of the valves, and stationary transmitter meter readings are taken weekly.

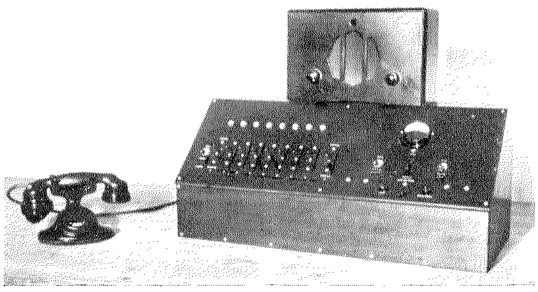


Fig. 12—Headquarters Control Equipment.

THE STOCKHOLM POLICE INSTALLATION

A commission from the Stockholm Police visited Oslo in March, 1938, to study its police radio system. Subsequently, Standard Telefon- og Kabelfabrik A/S received an order from Stockholm for a similar type of equipment, comprising:

For Headquarters:
1—No. 16-B transmitter, 50 watts,
1—No. 19-A receiver,
Antenna and remote control equipment.

For Two Remote Pick-up Receiver Stations:
2—No. 19-A receivers.

For Two Patrol Cars:
2—No. 211-A equipments, including:
No. 18-A transmitter, 5 watts,
No. 18-E receiver.

After the present system has been thoroughly tried out, it is the intention to furnish six or eight additional cars with radio equipment.

The carrier frequency is 31.9 kc/s. The transmitters and stationary receivers are crystal controlled.

Compared with the installation in Oslo, the Stockholm system differs principally with respect to:

(1) Remote pick-up receivers,
(2) Operation and control,
(3) Connection of radio telephone subscribers,
(4) Coaxial antenna at headquarters.

The police district consists, as indicated in Fig. 10, of the city itself (600 000 inhabitants) and its suburbs (200 000). The main transmitter and receiver are housed on the top floor

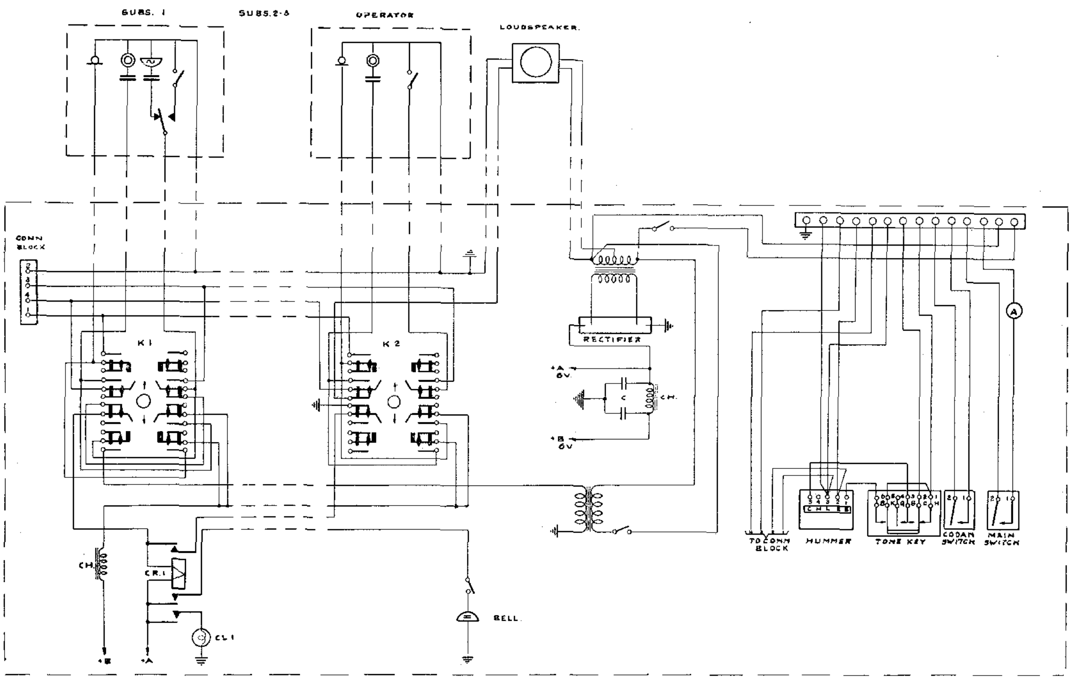


Fig. 13—*Control Box Circuit Schematic.*

of the police building, the antenna being about 70 m above the street level and the control equipment on the ground floor.

Anticipating a maximum range for the car transmitter of 5 km, two remote pick-up receivers have been foreseen, located as shown in Fig. 10. Since the southern section of the district is rather rocky, a relay receiver would in any case be required. These receivers are unattended and their output is connected to headquarters through output transformers and pads via telephone lines.

As will be seen from Fig. 11, each line terminates at headquarters at a double-pole double-throw switch by which the remote pick-up receivers may be linked to a common bus-bar for connection through an impedance matching repeating coil to an amplifier and loudspeaker. With this type of coil, a maximum of six remote lines may be connected.

The local receiver is connected via an output transformer in the remote control panel of the transmitter and a D.P.D.T. switch to the bus-bars of the remote receivers. By means of switches mounted on a wall panel in the operator's room at headquarters, each receiver may be connected and individually tested. The secondary side of the repeating coil is wired via a relay contact in the remote control panel to the loudspeaker. When transmitting, this relay contact disconnects the loudspeaker and another relay contact short-circuits the output of the local receiver.

At the remote points quarter-wave vertical antennae are used, supported by 8 m steel tube masts mounted on the roofs of the buildings housing the receivers : $\frac{3}{8}$ in. coaxial transmission lines connect the aerials to the receivers.

The aim has been to simplify operation in order to obtain the greatest possible conformity with usual telephone practice. In the cars microphone hummers have been mounted, a 1 000-cycle tone-modulated signal in the loudspeaker announcing an incoming call. On starting a conversation, the loudspeaker may be switched off, either by a separate switch on the control desk at headquarters and on the car loudspeakers, or by means of contacts in the switchhook of the operator's subset.

Control and operation at headquarters is

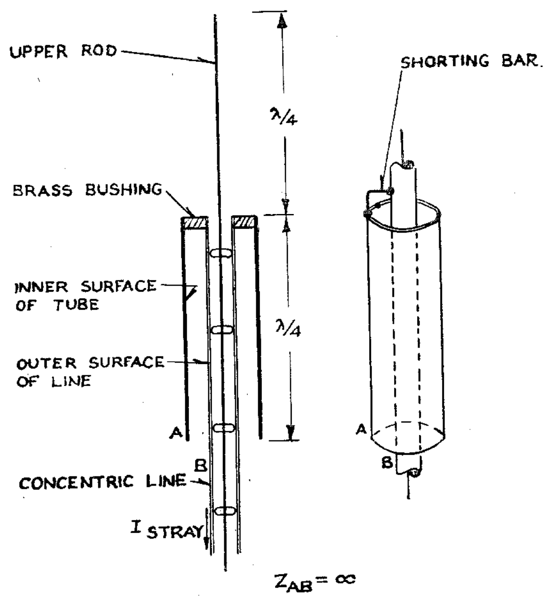


Fig. 14—*Coaxial Type Antenna.*

accomplished from a control box (Figs. 12 and 13). On the right side of the control box panel, the controls for the operation of the transmitter and receiver are grouped. A main switch on the panel serves to place the equipment in the stand-by and receiving position. In this position, reduced filament voltage is applied to the transmitter valves, thereby increasing the life of the valves. By pressing a key on the microtelephone handle, the antenna transmission line is transferred to the transmitter, the receiver output is short-circuited, the loudspeaker is disconnected, and plate and full filament voltages are applied to the transmitter valves, resulting in the emission of carrier frequency energy. The 1 000-cycle "attention" signal is sent out by pressing a non-locking key on the control box panel; by means of another key, the "CODAN" circuit of the receiver may be connected.

The left side of the control box contains apparatus required for the connection of eight radio telephone subscribers to the system in order that communication may be established from certain offices within the building (e.g., that of the police chief) to the cars. The radio subscriber set in appearance resembles the usual C.B. subset, employing the same type of microtelephone as the operator's. Corresponding to each subscriber, a key and a signal lamp are included on the control box panel.

To transfer an incoming call to one of the subscribers, the operator throws the respective key to the "local" position and presses a button on the panel, whereupon 50-cycle current operates the bell of the radio subset. The subscriber removes his microtelephone and may be advised by the operator regarding the call. When the operator now throws the key of the subscriber in the "radio" position, the subscriber receives directly from the car and may answer by pressing the key on the microtelephone handle. The conversation may be heard by the operator through the loudspeaker, which is wire-connected to the operator's subset when his key is in the middle position. The ammeter on the control panel for measuring the current drain also gives an indication as to whether or not a conversation is in progress.

A subscriber desiring a radio connection depresses the microtelephone key momentarily and his call is indicated on the control box by a ringing signal and by the flashing of a lamp corresponding to each individual subscriber. The operator's throwing of the subscriber's key into the position marked " radio " places the latter " on the carrier."

At headquarters, a coaxial type antenna, recently developed by the Bell Telephone Laboratories, Inc., is used.

It will be appreciated that the most efficient antenna is one giving off no high angle radiation. With the J-type antenna construction previously used in ultra-short wave police working, where the transmission line is mounted alongside the supporting pole, the system acts somewhat like a long antenna due to excitation of the supporting pole and the outside surface of the transmission line, resulting in partial high angle radiation. The coaxial type of antenna is free from such reactions.

Referring to Fig. 14, the coaxial antenna is a centre-fed vertical dipole consisting of a rod and the outer surface of a 3 in. tube, both of quarter wavelength. A $\frac{7}{8}$ in. concentric transmission line running inside a 2 in. supporting tube connects the upper rod to the transmitter output. Due to the high impedance across the lower end of the 3 in. tube section and the transmission line, the stray pole current is reduced to a minimum. A maximum radiation in the horizontal direction is thus obtained, and is of course of vital importance in its effect on the transmission range.

This new antenna compared to the J-type is said to give a gain of about 6 db. in field strength for the same power input. In other words, the range of a 50-watt transmitter with the new antenna is approximately equivalent to a 200-watt transmitter with the J-type antenna. The present J-type antenna in Oslo will shortly be replaced by the coaxial type.

For Stockholm the new antenna is arranged to mount on the top of a 45 m guyed steel tube mast placed on a balcony of the building. The length of the transmission line to the transmitter is about 60 m.

The car equipments and remote receivers have been installed and tested with satisfactory results. The car installations are similar to those of Fig. 7.

The installation of the equipment at headquarters was completed during April, 1939. The ranges obtained during the first tests were better than had been expected. This result, no doubt, is due to the satisfactory location of the transmitter and the adoption of the coaxial type of antenna placed at a great height.

View of one side of the Bell Telephone Manufacturing Company's stand at the Brussels Fair, March 12th to March 26th, 1939, showing the exhibit of the remote control of street lighting and multi-service system.

R-6 Automatic System

By F. GOHOREL, Technical Manager, and R. LAFON, Engineer,

Compagnie des Téléphones Thomson-Houston, Paris, France

EDITOR'S NOTE.—*Automatic telephone systems employing single motion switches or uni-selectors are now well-known. Such systems are characterized by the use of common control circuits, resulting in a minimum of equipment being held in use during the period of conversation.*

The R-6 system is a single motion switch system designed primarily for step-by-step areas and employs a single motion switch with a step-by-step drive. In this respect the R-6 system is similar to the Bypath system. The well-known 7-D Rotary system is also a single motion switch system but is designed on Rotary principles with power drive switches.*

INTRODUCTION

THE R-6 automatic telephone system, developed and completed in the laboratories and workshops of the Compagnie des Téléphones Thomson-Houston, has made great strides since 1923, the date of its origin.

The first public network equipped with this system was the Neunkirchen (Sarre) system, which consisted of a central exchange and two sub-exchanges placed in operation at the end of 1927. The importance of the R-6 system did not at that time escape the engineers of the French Postes Télégraphes et Téléphones ; an automatic switchboard intended for the town of Troyes had been ordered by way of experiment and was cut over at the beginning of 1928. The results obtained from the beginning were remarkable in every way, in particular in so far as the quality of the service was concerned. The P.T.T., moreover, considering the low cost of the new system in the establishment of telephone exchanges, modified its plans involving the installation of manual exchanges in the towns of Nîmes and Épinal and, in 1928, substituted two R-6 automatic exchanges.

They were successful from the moment they were placed in operation. The P.T.T. consequently decided on the generalized application of the system in the provinces, and entered into an agreement with the Compagnie des Téléphones Thomson-Houston under which the French Government reserved the right to have R-6 automatic exchanges set up for its own needs by French manufacturers in accordance with the design requirements of C.T.T.-H.

There are at present 140 R-6 automatic urban exchanges equipped for from 50 to 10 000 lines, totalling 180 000 lines either in service or in course of installation. By adding the rural semi-automatic and the private branch exchanges (136 000 and 35 000 lines, respectively), it will be seen that, within ten years of its existence, the R-6 system has provided 350 000 lines of the networks of France, Algeria and the French Colonies.

The maps, Figs. 1A and 1B, show the large regional zones and centres equipped with R-6 automatic exchanges (excluding semi-automatic rural equipment, which is not considered in the present article). The reasons for this rapid development are due to the fundamental principle on which the system is based.

SELECTOR FUNDAMENTALS

A selector, in any automatic telephone system, should fulfil two distinct functions :

(*a*) A " control selection " function, which consists in selecting a group of lines under control, directly or indirectly, from the calling station ;

* " A Controlled Single Motion Switch System Operating in the London Area," by J. H. E. Baker and E. P. G. Wright, *Electrical Communication*, July, 1933.

(*b*) A function of "free selection," which consists in finding a free line in a group thus chosen.

The first of these operations is accomplished by the calling station in conjunction with the connecting line to the exchange. The control from the calling station is effected by means of a dial resulting in electrical interruption of the connecting line in rapid sequence. These connecting lines may possess widely different characteristics, depending on the quality of insulation and the distance which separates the subscriber from the exchange. Since the current impulses produced by the dial may be considerably distorted when they reach the exchange, it is necessary that they be received on devices which respond rapidly to these impulses; that is, devices possessing minimum inertia and, consequently, small dimensions.*

* The same reasoning applies to register systems when the impulse transmission on the interconnecting lines between exchanges is considered.

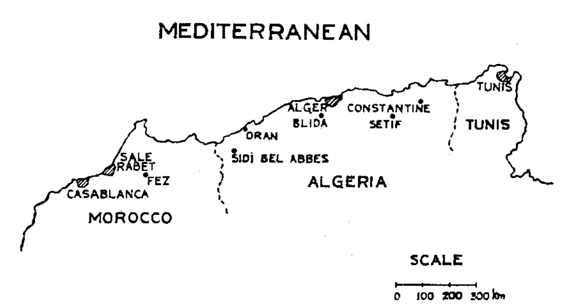


Fig. 1-B—Regional Zones and Centres in North Africa equipped with the R-6 Automatic System.

The function of free selection, on the contrary, is purely local and depends solely on the actual conditions at the telephone exchange.

In accordance with the theory of probabilities, moreover, the number of components necessary at the exchange decreases as the extent of the groups in which they are distributed increases. Differently stated, the larger the number of lines to which a selector has access in a single group, the smaller the number of necessary components. Taking into consideration the possible economic realizations of the selector, it is advantageous for the field which it explores to be as large as possible. Accordingly, it follows that a selector should:

(1) Be small, in order to fulfil satisfactorily the function of controlled selection;

(2) Be large, in order to fulfil satisfactorily the function of free selection.

Combined on the same mechanical member, these two functions, which impose contrary requirements, can produce only a far from ideal

Fig. 1-A—Regional Zones and Centres in France equipped with the R-6 Automatic System.

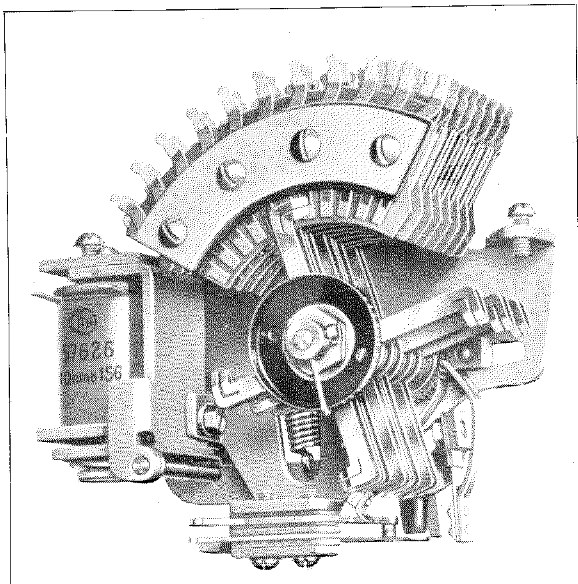


Fig. 2—Eleven Point Rotary Switch.

compromise. The use of two distinct members, each as far as practicable suitable to its particular functions, however, leads to a far more rational solution. This has been adopted in the R-6 system, in which each selector consists of two distinct components:

(*a*) A receiving switch controlled by the subscriber, termed the control switch, of low inertia (Fig. 2) and high velocity (the period of time for the attraction of the armature and that of its release is under 3 milliseconds);

(*b*) A uni-directional line-finder of adequate dimensions to ensure reliable choosing of the wanted line from groups of 50, 100, 150 or 200 lines (Fig. 3).

If the part played by a selector in a telephone connection be considered, it will be found that it is two-fold:

(*a*) The first, very complex but of short duration, is to establish the communication;

(*b*) The second, which is much longer but also much simpler, is to maintain the connection until the communication is completed.

The operation of controlled selection taking place entirely during (*a*), the operating period of the control switch utilized in the R-6 system for establishing the communication is very low in relation to the non-operating holding time of the selector. The separation of the two members, involved in the operation of controlled selection and of free selection, has made it possible to employ a single control switch to obtain controlled selection of several selectors (from 6 to 20).

In associating with the common control switch the complex components which are utilized only during the short period during which a connection is established, and restricting the selector itself to the two or three relays necessary for the maintenance of the established communication and for the momentary connection of the selector to the control switch, it has been

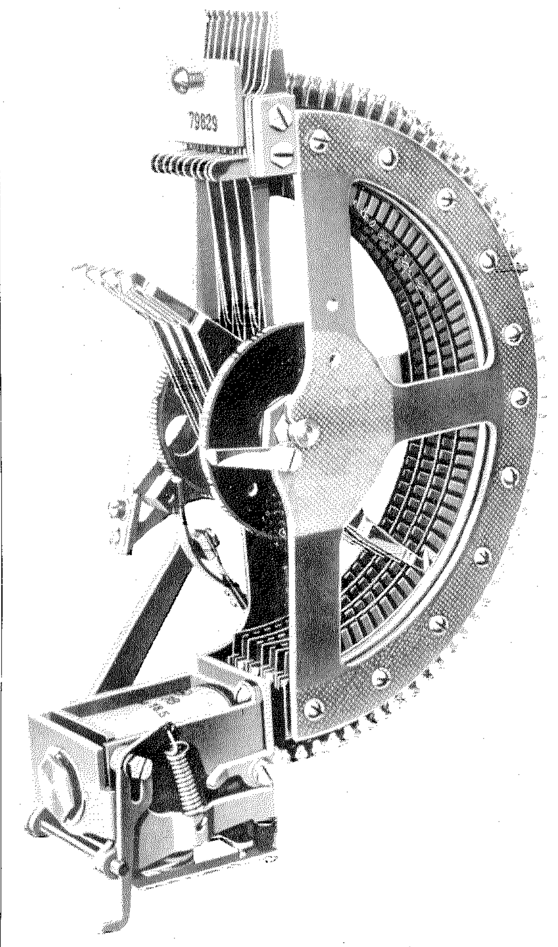


Fig. 3—R-6 Automatic Switch—51 Point Rotary Switch.

possible to economize considerably in components without in any manner degrading the characteristics of the R-6 system.

An R-6 automatic exchange, consequently, consists of an association of simple line-finders and some directive devices, viz., the control switches. An evident analogy is presented by a well organized enterprise in which a small

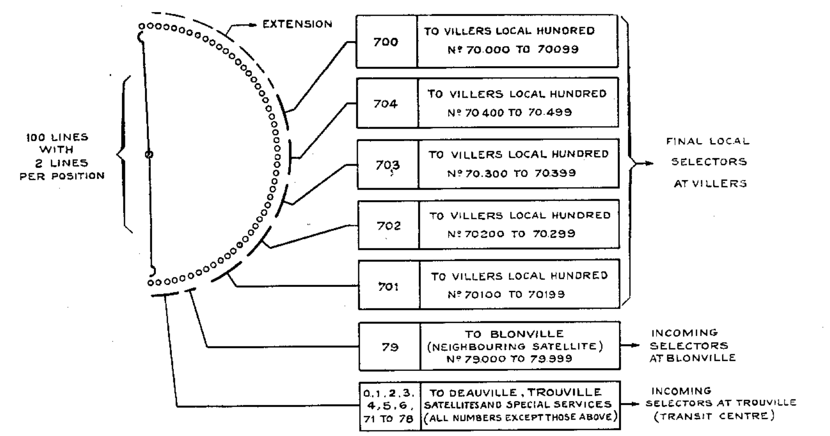


Fig. 5—Lines Grouping on the First Selector Banks, "Villers" Satellite (Deauville Area).

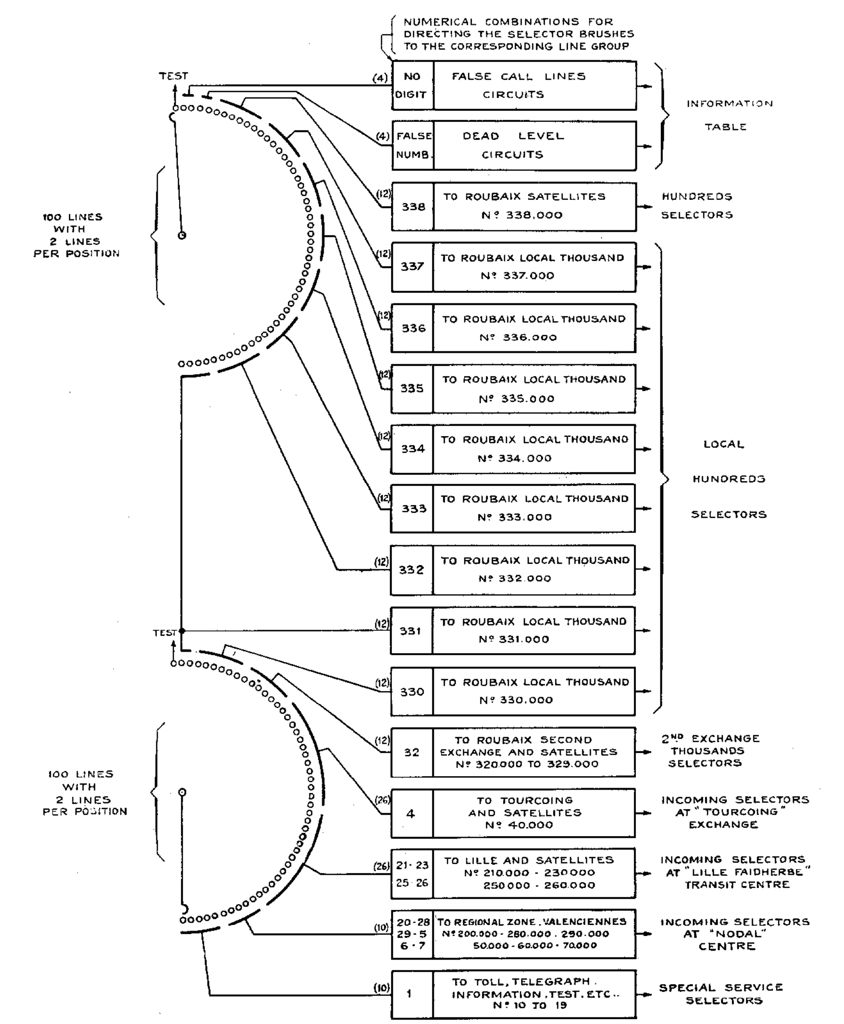


Fig. 4—Lines Grouping on the First Selector Banks, "Roubaix" Exchange.

number of expert individuals control a number of workmen from whom only simple, routine operations are required.

PERFORMANCE

The performance of the R-6 system has vindicated the conception which formed its basis.

In the R-6 system with direct control (that is, selectors controlled directly by the subscriber), operation for normal adjustment is satisfactory on lines with loop resistance varying from 0 to 1 800 ohms and with insulation between wires ranging from infinity to 3 600 ohms, representing outside limits met with in practice.

In a network comprising a number of exchanges, the R-6 system employs neither repeaters nor impulse

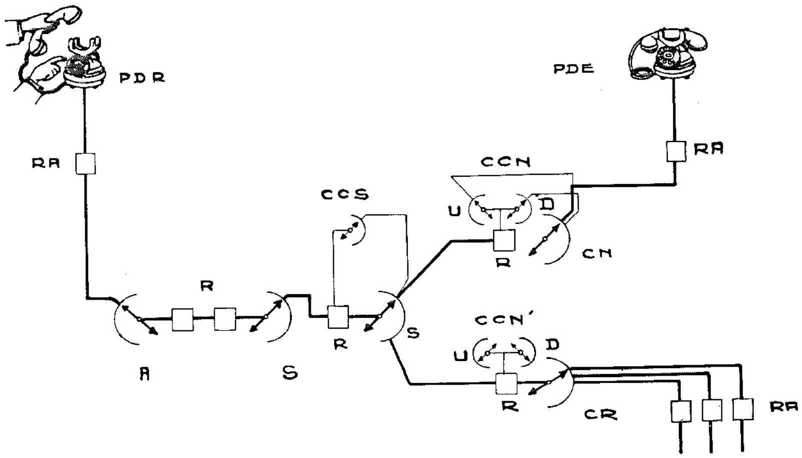


Fig. 6—Simplified Junction Diagram in the R-6 System.

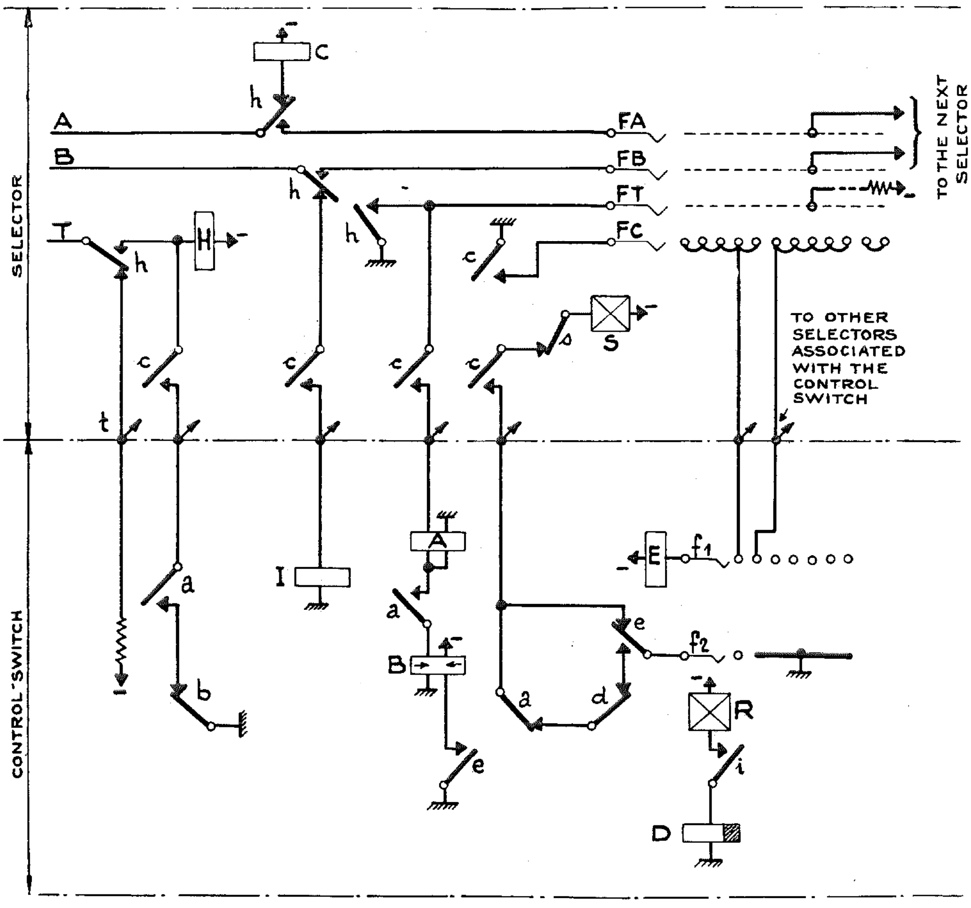


Fig. 7—R-6 Selector Simplified Circuit Schematic.

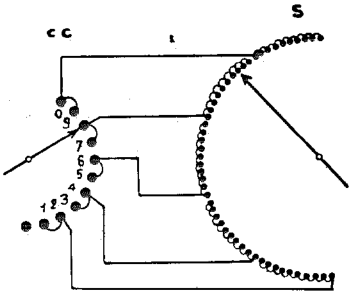


Fig. 8

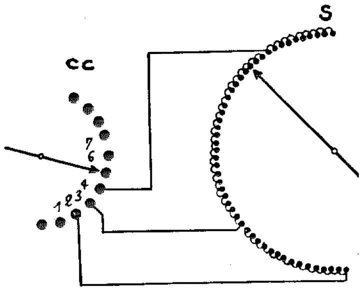


Fig. 9

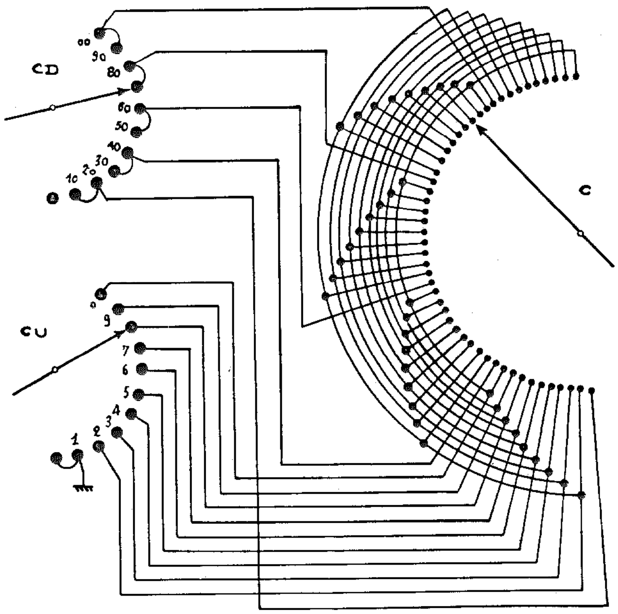


Fig. 10

Figs. 8, 9, 10—*Principles of Connections Between Selectors and Control Switches.*

correctors on the junction lines between exchanges, even if these be of considerable length. In the Lille network, for example, the impulses pass up to five exchanges (20 km of line) without repeaters and without attaining the limit of operation. The automatic Casablanca — Rabat connection, enabling a subscriber of one sub-exchange of the Casablanca central exchange to call a subscriber of the Rabat sub-exchange (linked by underground cable 94 km in length and with 50-cycle A.C. dialling), has been in satisfactory operation for six years without any impulse corrector.

The use, for free selection, of a selector with uni-directional movement, eliminates the disadvantage of the distribution of lines by levels and makes it possible to arrange the groups of lines following on one another, whilst varying their number and importance. It follows that a low traffic direction (towards a small capacity sub-exchange, for example), may have available only four or five lines on the selector bank, whilst a heavy traffic direction (towards P.B.X. groups or public exchange) may be served by groups of 20 or 30 lines. Similarly, a central exchange of 2 000 lines capacity may be equipped with first selectors having access by 20 groups of lines to the final selectors, thus eliminating one selection stage without the necessity of translating the called subscribers' numbers.

In practice, arrangement in variable groups has proved of great advantage in numerous cases, notably:

(*a*) In networks with several central exchanges, where it has been possible to decrease the number of junction lines between exchanges without recourse to any additional device (such as secondary line switches) or to avoid increasing the capacity of the selector bank (see Fig. 4, which represents the grouping of the lines on the first selector bank in the Roubaix exchange);

(*b*) In sub-exchanges, where a single selector is used to reach the central exchange, neighbouring sub-exchanges and local subscriber groups (see Fig. 5, which represents the grouping of lines on the selector bank in the "Villers" sub-exchange at Deauville).

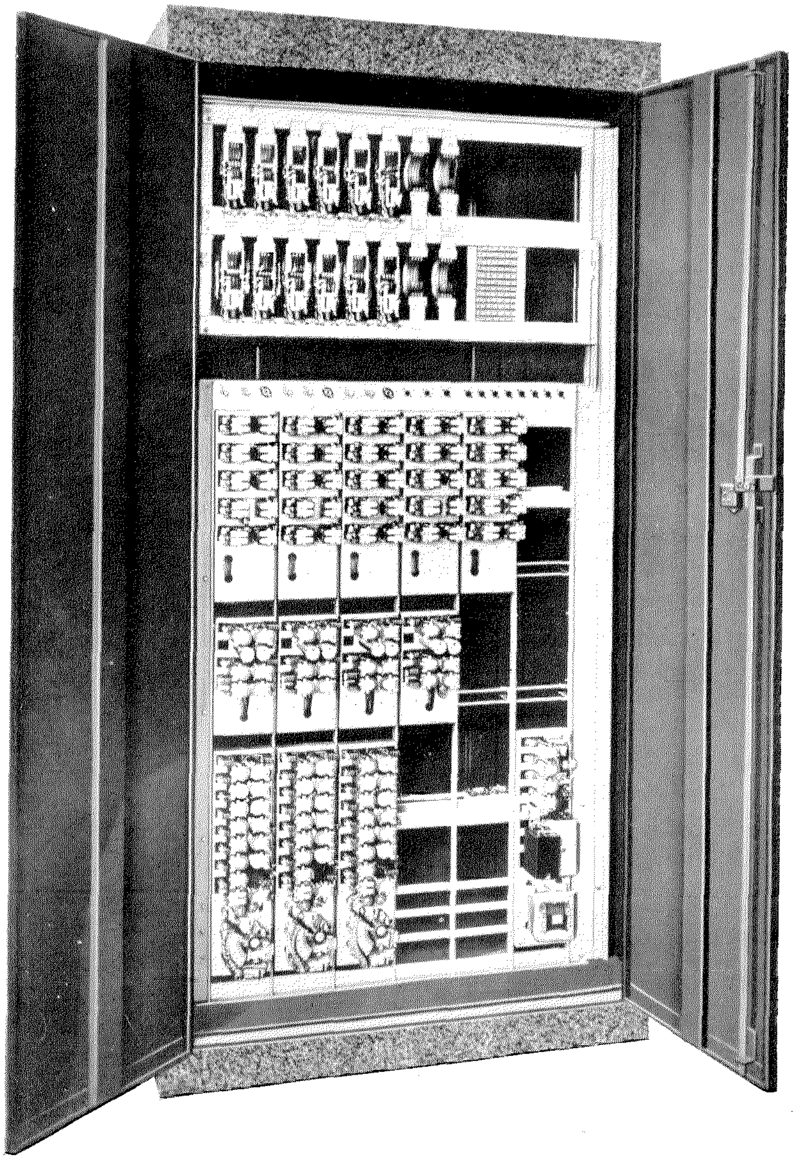


Fig. 11—*P.A.B.X. Unit Type* 49-*D.*

Finally, due to simplification of the components as a result of their specialized application to each of the two functions of the selector, and also to the very delicate operations which the control switches are capable of

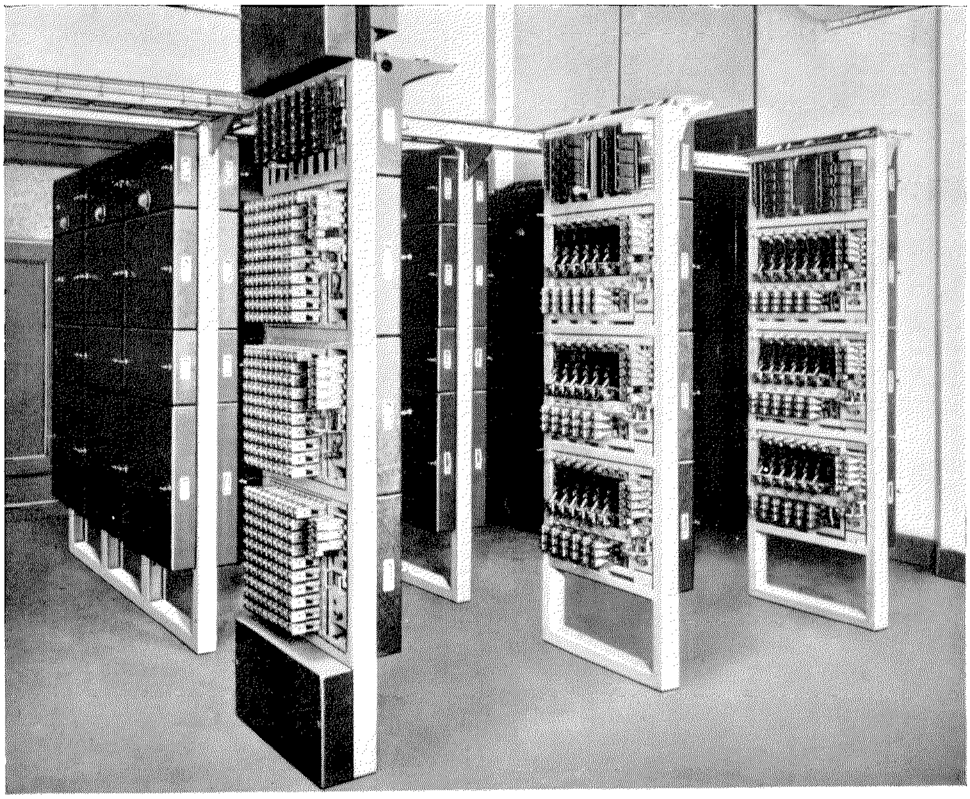


Fig. 12—*P.A.B.X. Installation in the R*-6 *System.*

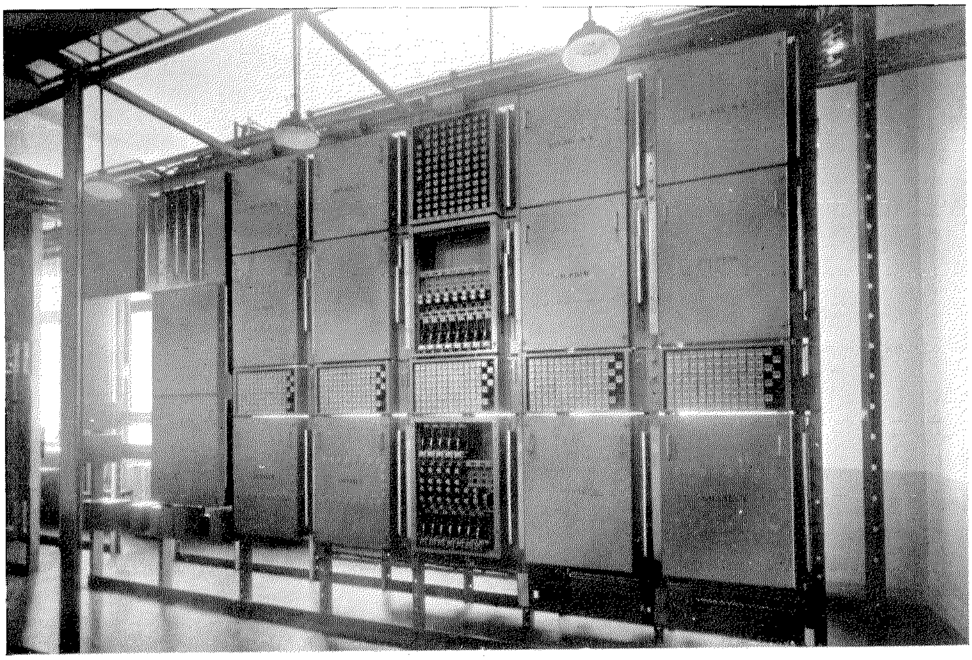


Fig. 13—*R*-6 *Automatic Telephone Exchange, La Baule—First Line-finders and Connectors Bays.*

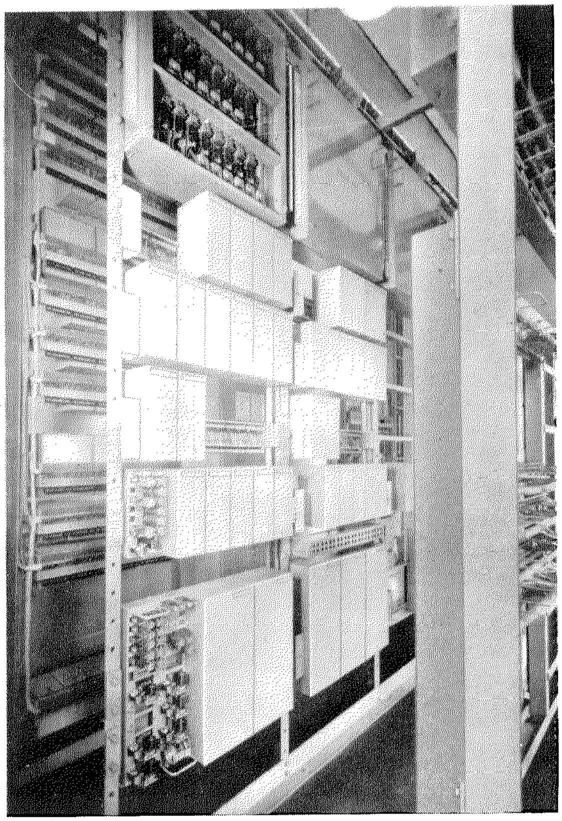


Fig. 14—*R*-6 *Automatic Telephone Exchange—La Baule—Registers and First Selectors.*

performing, low maintenance expenditure and high grade service should be expected from the R-6 system. Experience has confirmed these anticipations. In exchanges which have been in operation seven, eight and nine years and which have been maintained by a small staff, the percentages of faults vary from 0.1% to 0.15%.

METHOD OF OPERATION AND CIRCUIT DESCRIPTION

The general arrangement of the components and their interconnection is shown in Fig. 6 for the simple case of an exchange capable of dealing with 1 000 subscribers.

The operation of an installation of this kind is as follows :

The calling subscriber lifts his receiver (*PDR*) and thereby places a calling-line finder *A* in operation through the medium of the calling relay *RA*. Simultaneously, the finder of the selector *S*, associated with the finder *A*, finds the free first selector *S* associated with a disengaged control switch *CCS*. When this double finding has been completed, the calling subscriber is connected to the first selector *S* and receives the audible dialling tone. The sending of the first digit by means of the calling dial operates the switch *CCS*, which is advanced by a number of steps equal to the number sent (3, for example). The brushes of the selector *S*, as will shortly be described, are directed to the first line of the called group (that is, a group of lines connected to the final selectors of the third hundred) ; and then, in this group, to a disengaged final selector *CN*, associated with a free control circuit *CCN*.

The calling subscriber is then connected to the final selector. The tens digit (2 for example), which is received on switch *D*, and the units digit (8 for example), which is received on switch *U*, are successively transmitted. The switch *D* directs the brushes of the final selector *CN* to the first line of the second tens digit, and the switch *U* then directs them to the eighth unit of the second tens digit, that is, to the dialled line 328.

If the desired subscriber has several lines (as indicated on the final selector *CR*) the finding of a free line is automatically effected by the

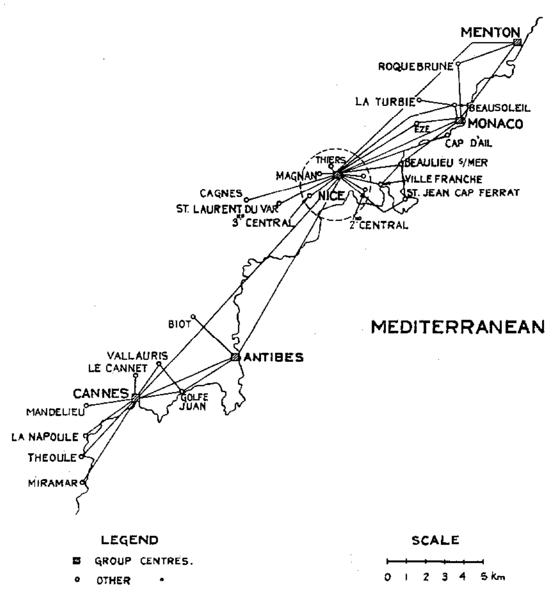


Fig. 15—*Automatic Regional Network of the Côte d'Azur.*

final selector, the brushes of which continue to rotate until they come to a disengaged line. It will be noted that the number of lines grouped under the same numeral is restricted only by the capacity of the selector and not by level limitations as in the case of selectors with contacts arranged by levels.

For simplification, the switches D and U have been shown separately; in practice, however, a single switch receives the tens and units digit impulses. The arrival of the final selector on the tens group of the lines (in which the wanted line is included) is effected in the interval of reception of the two digits.

A circuit schematic of an R-6 selector is indicated in Fig. 7. In general, it functions as follows:

When the selector is engaged for the establishment of communication, "earth" potential is placed on the wire T of the engaged selector and also on the wires T of the momentarily occupied selectors associated with the same control switch (the point t being common to all the associated selectors). The relay C is energized and the current impulses produced by the dial operate the relay I which, in turn, acts on the electro-magnet R of the control switch. This latter advances the brushes f_1 and f_2 by a number of contacts equal to that of the impulses received by the relay; that is, equal to the digits sent by the dial. As soon as the brushes f_1 and f_2 have left their rest position, the electro-magnet S of the selector operates; its movement is controlled by the contact e which opens under the action of the relay E when the brush FC makes a contact connected with the brush f_1 to the relay E; that is, when the brushes of the selector reach the first line of the group marked by the control switch.

During the reception of the current impulses, the slow acting relay D remains in the operated position. When all the impulses have been received the relay D releases, and another circuit operating the brushes of the selectors is closed by the contact d and controlled by the contact a, dependent on the test relay A. The test brush FT of the selector explores the group of lines required and when a free line is found in this group (a line characterized by a "battery" potential on the wire T), the relay A is energized and stops the movement of the brushes of the selector. Relay A supplies current to one of the windings of the low resistance, differentially wound relay B, which is normally energized. If the test potential is suitable and if two selectors do not arrive at the same time on the same line, the currents in the two windings of relay B neutralize each other. The relay B then releases its armature and through its contact b causes the operation of the connecting relay H. The latter establishes the connection of the selector in question to the called line, earths its test wire and opens the circuit of the relay C, which, in turn, disconnects the selector from the control switch. The latter thus becomes available for other calls, as do also the other associated selectors.

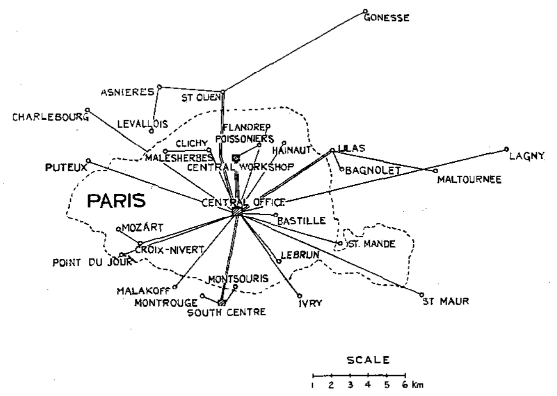


Fig. 16—Private Telephone Network of the "Société des Transports en Commun de la Région Parisienne" with Automatic R-6 Registers.

As will have been seen, it is through the brush FC and the contacts which it explores that the orientation of the selector brushes takes place. Hence, by the grouping of these contacts, arrangements on the selector bank can be obtained of groups of lines which are variable in number and importance.

Figs. 8, 9 and 10 illustrate examples of the connection between the control switch and the selector.

Fig. 8 shows a selector with ten equal groups of lines and two sets of brushes; one series explores the groups of even lines and the other, the groups of odd lines. It should be noted that, in systems with direct control, the necessity of obtaining an orientation of the selector before beginning the succeeding operation of the dial means that, as a rule, two sets of brushes must be arranged on each selector with a view to reducing the time of selection by half.

Fig. 9 represents a selector serving only three groups of lines of different importance, and utilizing one or more sets of brushes. The selection of a free line in the latter case takes place on several lines simultaneously.

Fig. 10 illustrates a final selector with two sets of brushes : one for even tens, the other for odd tens.

Equipment and installations of the R-6 system are illustrated in Figs. 11 to 14 inclusive.

R-6 REGISTER SYSTEM

From the above it is seen that the selector impulses are received on rotating low inertia switches, which operate reliably even when the impulses are much distorted. If the sole purpose of registers were to transmit perfectly correct impulses to the selectors, it would be unneccessary to provide such devices in R-6 exchanges. Actually, in numerous cases registers have not been included in the R-6 exchanges.

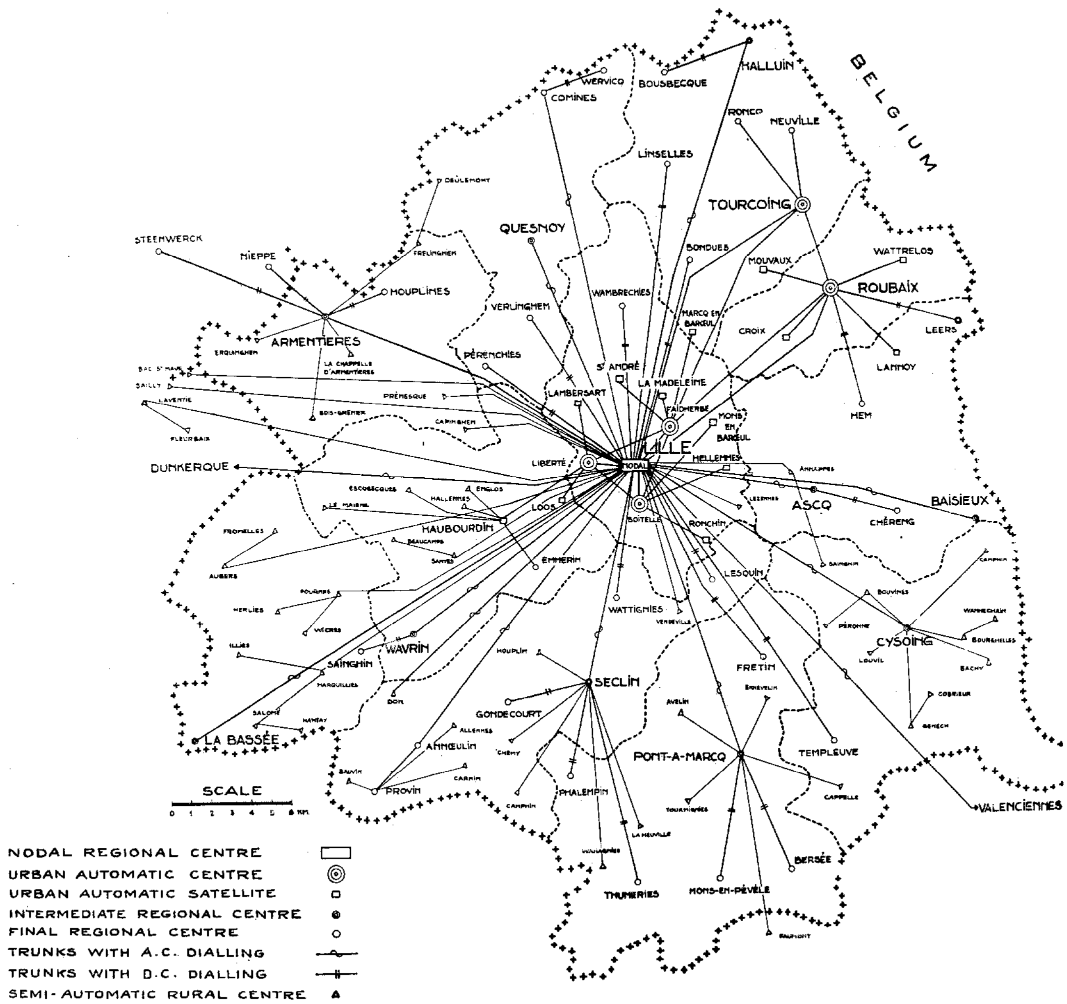


Fig. 17—*Lille-Roubaix-Tourcoing Telephone Network.*

As a result of the tendency to group in increasingly extensive networks large numbers of exchanges, between which interconnections and tariff arrangements are becoming more and more complex, C.T.T.-H. engineers envisaged the application of registers when the R-6 system was originally developed.

Study of this subject has shown that, far from imposing any complication, the introduction of registers in the R-6 system permits simplifications of selectors and, in many cases, results in appreciable economy.

It is interesting to note that, in a register system, the time factor does not operate as rigorously as in a direct control system. In the latter case, the orientation period of a selector should as a rule be proportional to the number of impulses received, and selection should be sufficiently rapid to be completed before the sending of the following digit.

In the R-6 register system these two restrictions do not apply. It, therefore, becomes possible to employ selectors without a fixed normal or home position and with only a single set of brushes. (In the R-6 direct control system, the selectors, in general, should include several sets of brushes, functioning from a fixed normal or home position.) The introduction of registers thus evidently makes it practicable considerably to simplify the selectors and the associated control switches.

Moreover, the facility of directing R-6 selectors to the same group of lines by numerically different combinations, and to other groups of lines by numerical combinations comprising a different number of digits—when associated with the additional possibilities afforded by the registers—provides great flexibility in the disposition of the selecting stages and junction lines between exchanges.

These advantages have led to the utilization of registers in the majority of public networks which have been installed since 1930. The very complex network of the Côte d'Azur (Fig. 15) may be cited as an example. Despite its extent, the calling numbers contain only 5 digits. Mention may also be made of the Lille-Roubaix-Tourcoing network (Fig. 17).

In certain very large private installations the use of registers has been found especially advantageous. Fig. 16 illustrates the private automatic network of the "Société des Transports en Commun de la Région Parisienne," comprising 30 R-6 automatic exchanges with capacities varying from 15 to 300 stations and extending over Paris and its suburbs. The same 4-digit calling numbers are used regardless of the point of origin of a call.

CONCLUSION

Due to space limitations, the varied and numerous applications of the R-6 system cannot be described. They embrace large urban exchanges, extensive regional networks, rural exchanges, and long distance automatic interconnections including P.A.B.X.'s. In every case, the R-6 system has provided a simple solution to the increasingly complex problems daily confronting communication engineers.

James Lawrence McQuarrie

1867—1939

JAMES LAWRENCE McQUARRIE, who advanced to the top of the technical phase of the telephone business in a career of fifty years, died on March 1st at Vineyard Haven, Massachusetts, at the age of 71. Mr. McQuarrie was Vice-President and General Technical Director of the International Telephone and Telegraph Corporation and of International Standard Electric Corporation when he retired from active duty on July 1st, 1932, which was approximately his fiftieth anniversary in the telephone business. He had more than 100 patents to his credit in the electrical field.

Mr. McQuarrie started as a telephone operator at Bath, Maine, in 1882, with one of the ancestor Bell System companies. He demonstrated an outstanding aptitude for the technical end of the telephone business, and in 1894 the Western Electric Company engaged him to work on common battery switchboard development. He contributed substantially to the development and design of the common battery manual multiple switchboard and was appointed Assistant Chief Engineer of the Western Electric Company in 1903. It is interesting to note that while with the Western Electric Company Mr. McQuarrie had much to do with the development of the automatic central office switching system (panel type) which replaced the common battery manual system in many exchanges of the Bell System.

As a result of outstanding successes in the telephone development field in Europe and the Far East, Mr. McQuarrie was appointed Chief Engineer of the International Western Electric Company on January 1st, 1925, and when the properties of International Western Electric were purchased by International Telephone and Telegraph Corporation in October 1925, and the International Standard Electric was organized, Mr. McQuarrie was elected a Vice-President of International Telephone and Telegraph Corporation, appointed Chief Engineer and later General Technical Director. In this position from 1926–1932 he supervised the organizing of new research and development activities in Europe and established the technical standards of I. T. & T. manufacturing companies and telephone operating systems in many countries.

He spent considerable time in Japan and for his very important part in the development of telephony in Japan, he was awarded the Order of the Rising Sun by the Emperor.

He also covered many other parts of the world in his travels on behalf of telephone improvement and wherever he went he won many friends. He was a Fellow of the American Institute of Electrical Engineers, and was a great favourite in Bell System and I. T. & T. circles in the United States. His popularity in Europe is well known, and he had the affection as well as the respect of telephone leaders in many countries.

At a meeting of the Board of Directors of the International Standard Electric Corporation, held on March 23rd, 1939, the following resolution was passed:

> "RESOLVED, That the Directors of this International Standard Electric Corporation adopt as their own the above statement read by their Chairman outlining the career of their friend Mr. McQuarrie and that they record their deep sorrow for the death of one whose great technical knowledge, wise business judgment together with his upright character and keen sense of humour won for him the admiration and affection of his many friends and associates to whom he has long been known as the 'Chief,' and they direct that a copy of these minutes be engrossed and handed to Mrs. McQuarrie as a mark of their affection for her husband and their sorrow for his passing."

James Lawrence McQuarrie—An Appreciation

By F. B. JEWETT

ALL of us have experienced the shock of finding our first judgment of men wrong. Sometimes those whom we have rated highly on initial association have turned out to have feet of clay or only a polished veneer masking an absence of ability. Sometimes those who have made a poor impression disclose later and on closer acquaintanceship hidden abilities and sterling traits of character.

Occasionally our first appraisal turns out to be a correct one. When it has been an adverse one the thing is usually a mere incident of life, although sometimes fate decrees a long association which is a continual tribulation. On rare occasions, however, this first appraisal of ability and character is both favourable and correct, and in making it you have achieved one of the great satisfactions of life—the discovery of a dependable friend and associate.

In my relations with James L. McQuarrie I had one of these rare satisfactions.

When I first met him thirty-five years ago he had already made an international reputation for creative ability in the telephone field despite the fact that he was still a comparatively young man. I shall never forget the impression which that first meeting made on me. It was the impression of an extraordinarily able and entirely honest man; of a kindly thoughtful human being who stated his beliefs modestly without bombast and maintained them against attack without rancour. It was an impression which neither time nor circumstance has caused me to alter.

From the day of that first meeting until the day of his death I have cherished him as one of my close friends. For much of the time we were intimately associated in a common undertaking and while in later years our paths diverged somewhat, the feeling of trust and security in his counsel and advice never altered.

His was a life grounded in inherent ability and high character schooled in the austerity and kindliness which is the hallmark of all that is best in the tradition of New England. With such qualities it is small wonder that he commanded the loyal support of his associates, and this without any conscious effort on his part to command. He did not know how to do a dishonourable thing.

Nor were his qualities and his influence confined to the sector of his professional and business life. For many years now I have known him in his island home at Vineyard Haven, Martha's Vineyard. To one raised in a shipbuilding family on the coast of Maine in the heyday of sailing ships it was foreordained that he should seek a seafaring community, first for vacations and later as a permanent abode in well-earned retirement. He knew and loved those who had salt on their clothes—they instinctively knew and valued his qualities as no others could. I suppose they took pleasure in the credit for achievements in the busy places of the world which he brought to his adopted island home. What they valued most, however, was the simple sincerity of the man who, without effort or any trace of affectation, fitted into the daily life of the community.

In his death Vineyard Haven has lost one of its substantial citizens; the world of electrical communication one of its distinguished men; his family a beloved husband and father, and many of us a never-to-be-replaced friend.

The Bucharest-Ploesti Toll Cable

By A. C. NANO,
Toll Lines and Transmission Engineer,
Societatea Anonimă Română de Telefoane, Bucharest, Rumania

IN December, 1938, the Societatea Anonimă Română de Telefoane, a subsidiary of the International Telephone and Telegraph Corporation and the holder of the concession for operating the Rumanian telephone system, took the first step toward transferring its extensive long-distance telephone network from open-wire to underground cable. The first section of cable, which has been installed, extends from Bucharest northward to Ploesti, the junction point of the major long-distance leads serving the north-east and the north-west portions of Rumania. As explained later, this cable will be extended to Brasov and to Buzau in 1939 and, eventually, other open-wire routes probably will be replaced by cables.

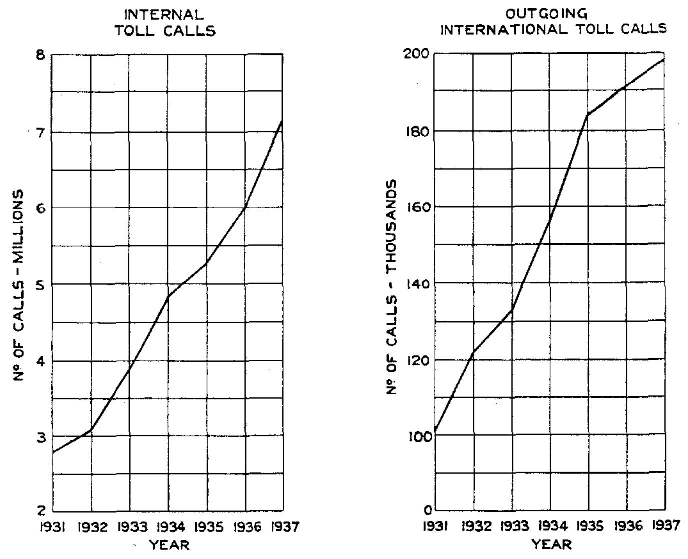


Fig. 1—Rumanian Toll Traffic Growth.

It has been possible, in the past, to care for the rapidly growing Rumanian long-distance telephone development by building open-wire leads of modern construction with single- and three-channel "Standard" carrier systems superimposed. The use of open-wire and carrier to care for the initial growth of long-distance demand in Rumania was dictated by numerous economic and practical considerations, foremost among which were :

(*a*) Necessity for providing immediately general long-distance relief over nearly the whole country ;

(*b*) Uncertainties regarding the possible long-distance demand during and following the general conversion of the local service in the major cities to automatic ;

(*c*) Advent of the new carrier-on-cable art.

An immediate cable programme covering the whole country was impracticable because of the extent of the territories involved (some 316 000 sq. km containing 1 308 telephone offices). On the other hand, by applying open-wire carrier systems to existing lines and by constructing new open-wire lines specially transposed for complete carrier working, it was possible to obtain a large number of new circuits with minimum delay and to distribute them over the whole country.

Simultaneously with these improvements on the long-distance lines, a programme of modernization was carried out in the local areas. Experience in Rumania, as in many European and other countries, soon proved that a latent demand for telephone service existed and could be developed by the provision of modern facilities. The long-distance traffic demand, in fact, as indicated in Fig. 1, grew so rapidly that accurate forecasts of future requirements became extremely difficult. A year or two after the telephone system was taken over by the Societatea Anonimă Română de Telefoane, it became apparent, nevertheless, that a cable would shortly prove the most logical and economical means of providing the necessary circuits over the main route north from Bucharest to Ploesti and from thence to points north-west and north-east, as indicated in Fig. 2.

By 1934 the necessity for placing cable over the above-mentioned routes in the immediate future was clearly evident; and, from traffic statistics obtained and commercial surveys made during the four years the company had been operating the telephone system, sufficiently accurate information had become available to make possible the preparation of a logical cable programme. Carrier-on-cable, especially the 12-channel type of system, moreover, had been considerably clarified both as to its technical and economic features. The extensive reconstruction work done on these routes up to 1934, furthermore, made it practicable to apply still more carrier to the open-wire circuits and thus postpone major reconstruction work until 1938–1939, at the end of which period the newer crystal filter 12-channel type system with its broader band and improved performance was expected to be ready. All general open-wire construction on these routes, except that incidental to the application of the carrier necessary to cater for the 1935–1938 traffic growth, therefore, was cancelled and cables engineered for installation during 1938 and 1939 in accordance with Fig. 2.

Joint studies carried out by the Societatea

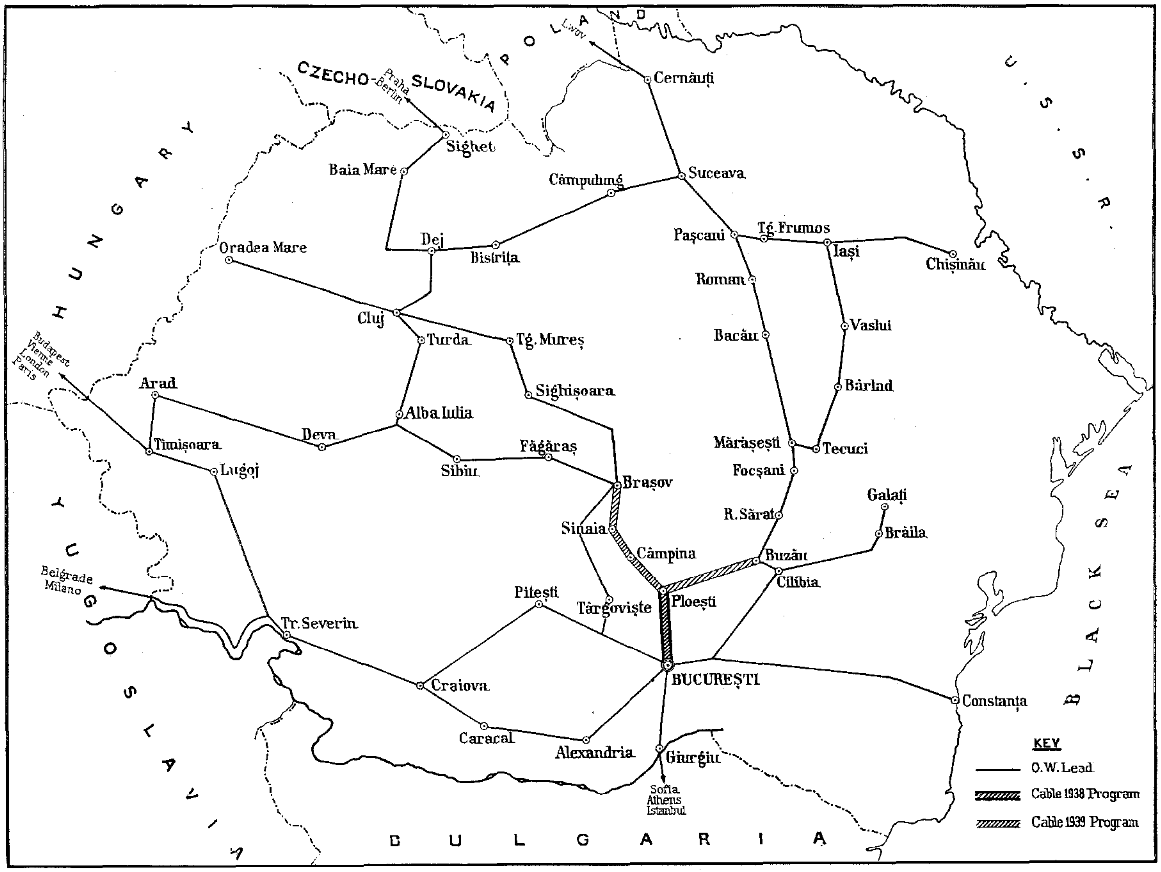


Fig. 2—Rumanian Telephone Network.

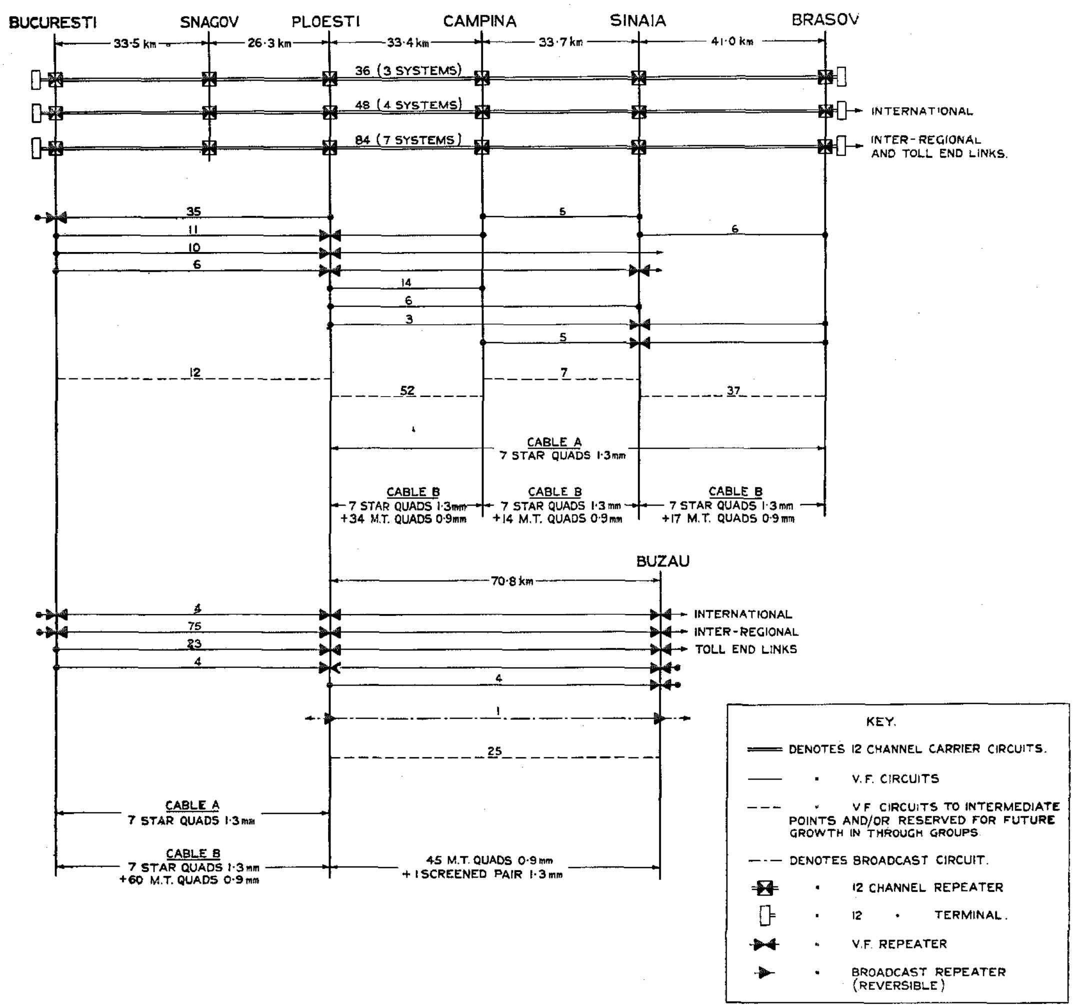


Fig. 3—Circuit Allocation over the Bucharest–Ploesti–Brasov Route.

Anonimă Română de Telefoane and the International Standard Electric Corporation resulted in the cable design of Fig. 3 which shows the circuits required over the Bucharest—Ploesti—Brasov route. They may be divided into two main groups:

(1) Circuits from Bucharest to Brasov and beyond, including a group of international circuits, for which it was found that the most economical construction would be provided by 12-channel carrier systems on non-loaded cable circuits, with carrier terminals at Bucharest and Brasov, and intermediate carrier frequency repeaters at Snagov, Ploesti, Campina and Sinaia (Figs. 2 and 3). Seven star quads of 1.3 mm conductors were required for the "Go" and seven for the "Return" direction, providing a total of 168 channels between Bucharest and Brasov.

(2) Circuits for relatively short-distance traffic between the various points on the cable route, or for circuits to towns connected to these points over open-wire routes. For this group, two-wire 0.9 mm loaded cable circuits employing the well-known multiple-twin construction were chosen as the most economical, two-wire repeaters

being planned at Bucharest, Ploesti, Sinaia and Brasov. It was decided to lay-up the voice frequency two-wire quads around one of the groups of 7-star quads required for carrier working. Between Bucharest and Brasov there will therefore be two cables, one containing 7-star quads 1.3 mm, used exclusively for 12-channel carrier working, and the other comprising 7-star quads in the centre with from one to three layers of 0.9 mm multiple twin quads around them. Over certain sections of the route, two similar cables might have been used, each containing 12-channel quads and voice frequency two-wire quads; for example (between Bucharest and Ploesti), two cables each containing 7-star quads for carrier and 34 multiple twin quads for two-wire voice frequency circuits. However, because of conditions existing at the time the cables were engineered, it appeared preferable, from a noise point of view, to use two different types of cables. Noise interference into the carrier circuits may arise from ringing or speech currents on the voice frequency circuits or from the power supply at the repeater stations; also, where open-wire extensions are connected to the cable, the open-wire lines may pick up carrier frequency noise from various sources and transfer it via crosstalk paths to the carrier circuits.

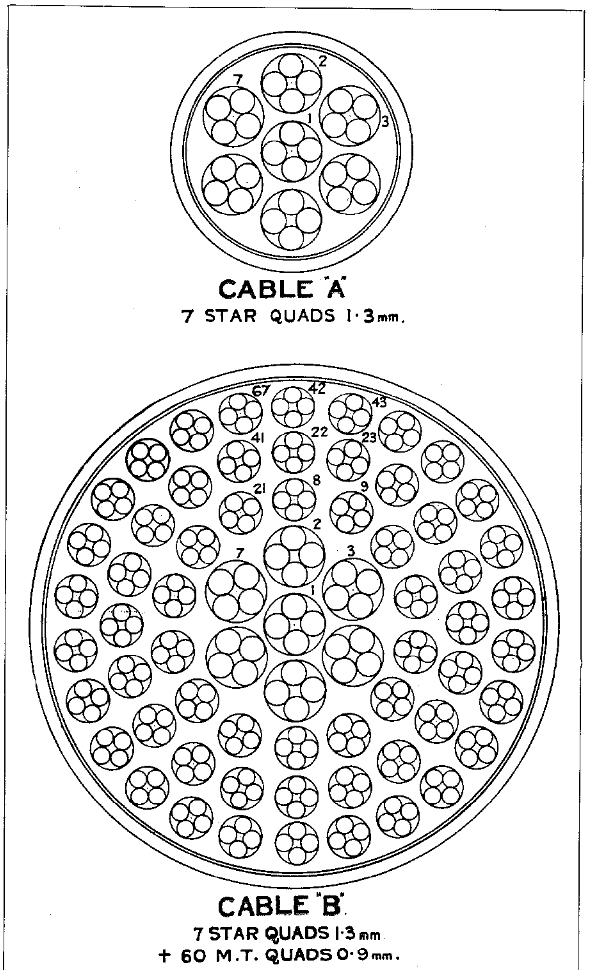


Fig. 4—Target Diagrams of Cables.

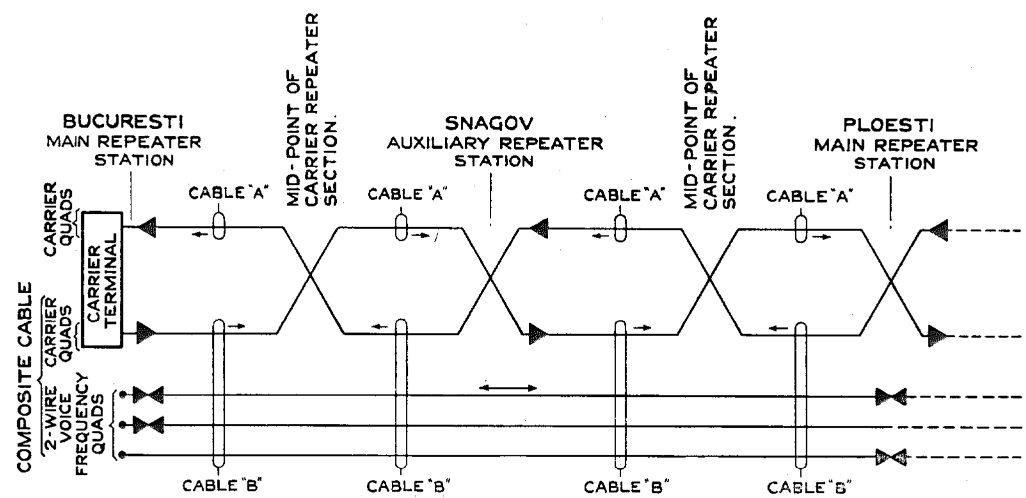
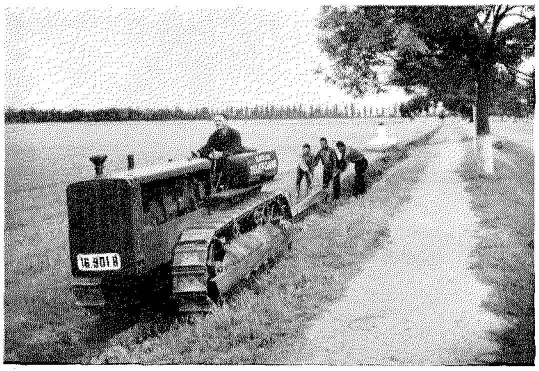
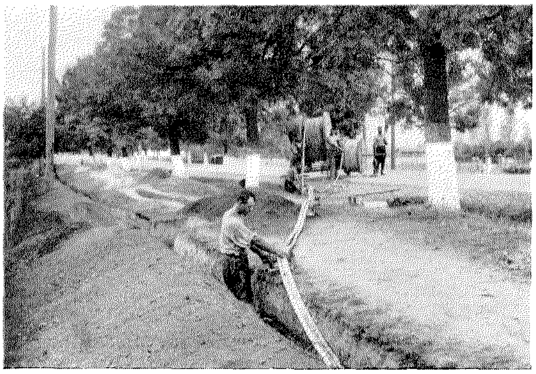


Fig. 5—Method of Transposing Cables.



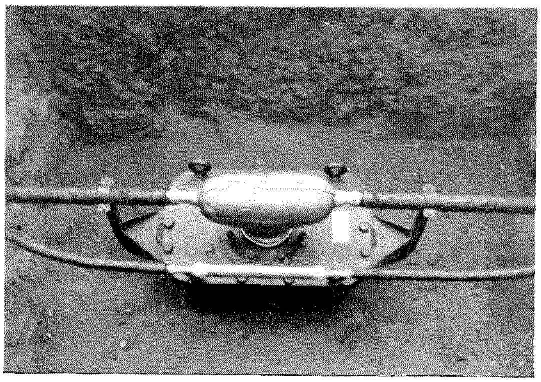
Trenching with Tractor-drawn Plough.



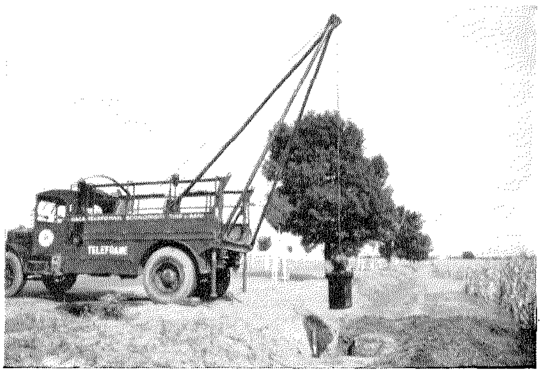
Pulling-in the Two Armoured Cables.

Noise is, of course, only serious if it occurs at a point of low power level on the carrier circuits. By reserving one cable solely for carrier working, and placing all the voice frequency circuits in the other cable, it is possible to separate the low level ends of the carrier quads from the voice frequency quads. This is accomplished by crossing over the carrier quads from the composite to the simple cable, and vice versa, at the mid-point of the carrier repeater section, as shown in Fig. 5. From this figure it is clear that, where the carrier and the voice frequency circuits are in the same cable, the former are at a high power level. The schematic also indicates the method of transposing the carrier quads from one cable to the other at the carrier repeater stations. This transposition, in addition to improving the noise conditions, as already mentioned, breaks the indirect crosstalk path which would otherwise exist from output to input of the carrier repeaters via the voice frequency quads.

The general design and lay-ups selected are indicated in Fig. 3. An interesting feature of the cable design is illustrated by the Sinaia-Brasov section where, in order to realize the practical advantages of locating the 12-channel repeater stations in existing central office buildings, it was necessary to cater for an



Loading Coil Case in Position and Jointed. The joints are protected by cast iron protection boxes. The smaller cable by-passing the loading coil case is the 7-star quad carrier cable.

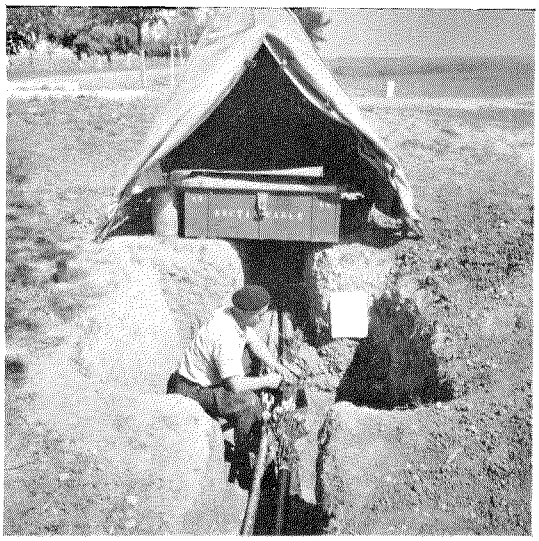


Placing Loading Coil Case in Position. The loading coil case contains 60 units (i.e., 120 side circuit and 60 phantom coils) for loading the 60 voice frequency multiple twin quads. It weighs approximately 700 kg (14 cwt.).

abnormally long repeater section by the provision of a lower capacity cable.

After the first section of the cable from Bucharest to Ploesti was put into service in 1938, it was possible not only to meet all demands resulting from near-term traffic growth via this most heavily loaded route in Rumania but, also, by temporarily utilizing voice frequency circuits ultimately reserved for short-haul circuits, to provide all circuits, both long-haul and short-haul, required in this section. Moreover, the carrier terminals originally located in Bucharest were transferred to Ploesti, thus making possible the abandonment of all open-wire lines in this section. A similar procedure will be adopted in the cases of the two later sections, i.e., Ploesti—Buzau and Ploesti—Brasov, which will be installed in 1939. Furthermore, during the early part of 1940, when the Bucharest-Brasov cable section will have been completed, 12-channel equipment will be installed and all existing open-wire and carrier circuits will be transferred to the cable, thus making it possible to abandon all open-wire leads over these sections and to utilize elsewhere the open-wire carrier equipment involved in order to provide for growth in long-distance traffic in other parts of the country.

The installation of the Bucharest-Ploesti portion of the cable was started on June 15th, 1938, and was completed on November 1st of that year. Installation was done by the Societatea Anonimă Română de Telefoane under the supervision of the International Standard Electric Corporation. The cables were armoured and laid directly in the earth except where duct routes were available in the towns. An interesting feature of the trenching was the use of a tractor-drawn plough. Where soil free from obstructions was encountered, it was possible by ploughing over a length three or four times to obtain a trench 50 cm wide and 50 to 70 cm deep with practically no hand digging, the only hand operations necessary being the cleaning out of loose dirt and levelling off the bottom. Both cables were pulled into the trench simultaneously, as shown in the (unnumbered) photographic reproductions, which give a rather good indication of the methods and equipment used during installation.



Jointing Work in Progress.

Details of the electrical characteristics of the cable have not been included in this article inasmuch as the 12-channel circuits, which are of most interest, will not be placed in service prior to the end of 1939. After their completion, it is planned to publish information on their characteristics.

Some Industrial Applications of Selenium Rectifiers

By S. V. C. SCRUBY and H. E. GIROZ,

Le Matériel Téléphonique, Paris, France

DURING the past few years the technical characteristics of selenium rectifiers have resulted in the development of numerous applications in various branches of industry and improvements in the construction of complete equipments incorporating rectifying elements.

The major advantages of selenium rectifiers over earlier types of dry rectifiers are as follows :

(1) High permissible working temperature (up to 85° C.),
(2) High current density (up to 180 mA/cm² with cooling fins),
(3) High permissible reverse voltage (up to 15 volts D.C.),
(4) Contact pressure not critical,
(5) Small size and weight compared to power output,
(6) High efficiency.

The technique of these rectifying elements is now definitely established, although further progress doubtless will be achieved in the future. At present, attention is mainly directed to research in connection with supply and regulation circuits, and to the improved design of complete rectifying units containing not only the rectifying elements themselves, but also supply transformers, inductances (with or without saturation windings), filters, control, and automatic protection devices, etc.

The experience of recent years shows that the selenium element characteristics are particularly suitable for industrial uses involving heavy currents, for example, in electro-plating applications, where several thousand amperes are required.

Descriptions of various applications have been previously published.* The purpose of the present article is to present supplementary information concerning high power equipment for industrial applications and, particularly, to describe equipments with which sufficient experience has been gained to permit a certain degree of standardisation.

AUTOMOBILE BATTERY CHARGERS

In so far as single battery rectifiers (for private customers or small garages) are concerned, the power output required from the charging equipment is relatively small. Considerably larger outputs are required for garages where it is necessary to charge several batteries simultaneously either in series or in parallel. The power ratings adopted by Le Matériel Téléphonique for different models of this type of equipment, shown on the following table, correspond approximately to the requirements of the automobile industry :

Type :	Volts	Amps.	Watts
Model 3005 (Junior)	6 12	3 1.5	18
(Tourist)	6 12	5 2.5	30
(Small Garage)	6 12	10 5	60
(Truck)	6/12 24	10 5	120
(Large Garage)	6/12 18/24	20 10	240

The description given herein is limited to that of the model, "Large Garage," since the other models may be considered as simplifications or reductions thereof.

* "*The Selenium Rectifier,*" by Dr. Erich Kipphan, *Electrical Communication,* July, 1937. "*Dry Rectifiers for Repeater Station Power Supply,*" by H. Jacot and M. Frey, *Electrical Communication,* July, 1937. "*Der Selen Trockengleichrichter,*" by W. Hofer, *Schweizerische Technischen Zeitschrift,* Vol. XII, No. 35/36, 1937.

The equipment and its circuit diagram are shown in Figs. 1 and 2, respectively. The rectifier consists of the two bridge-connected units which can be coupled, by means of a shifting fuse system, either in series (for 24 or 18-volt battery charging) or in parallel (for 12 or 6-volt battery charging).

Two groups of elements are mounted on cooling fins and fixed on the frame of the mains transformer. A robust and compact block is thus obtained, suitable for wiring before the block is housed in the case. This unit is shown in Fig. 3.

On the front panel are mounted an ammeter and a volt-meter, both of the moving coil type, a multi-position fuse (on the primary of the transformer) to permit choice of the correct mains supply tap, two automatic fuses (used also for 6/12-volt voltage shifting) and a mains switch in the primary circuit of the transformer.

The transformer has high leakage in order to limit the short-circuit current to a value which can be safely carried by the transformer and elements during the time required for the operation of the protective fuse.

It is to be noted that in the case of automobile battery charging rectifiers, there is the possibility of polarity reversal when the connections are made by a customer. It is necessary, therefore, to provide a protective device in the D.C. circuit, since in case of reversed polarity, even if the equipment be disconnected from the A.C. supply, the battery is short-circuited through the elements and both may be damaged. This protective device consists of two units readily adaptable to the rectifier spindles and provided with a resetting knob such that, once operated, the circuit remains open as long as this knob is not depressed. The heat control element is ordinarily a bi-metallic plate.

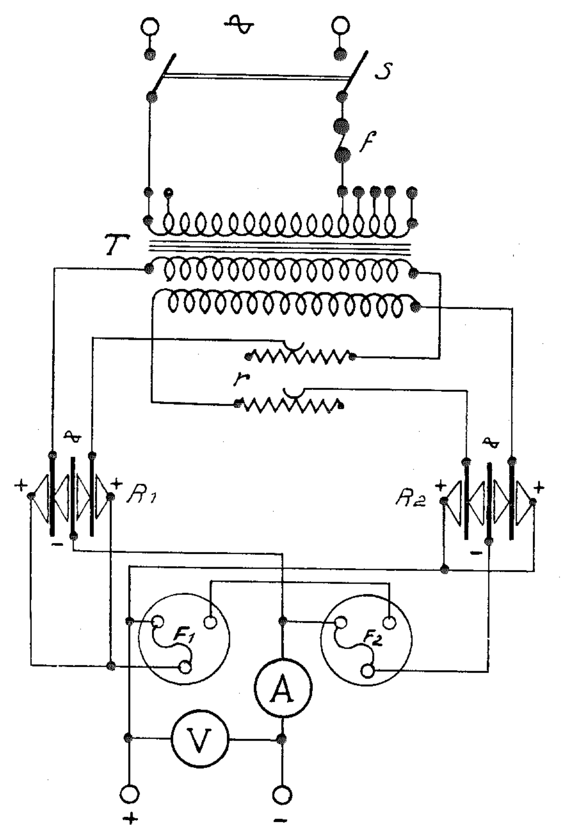


Fig. 2—Circuit of "Large Garage" Selenium Rectifier.

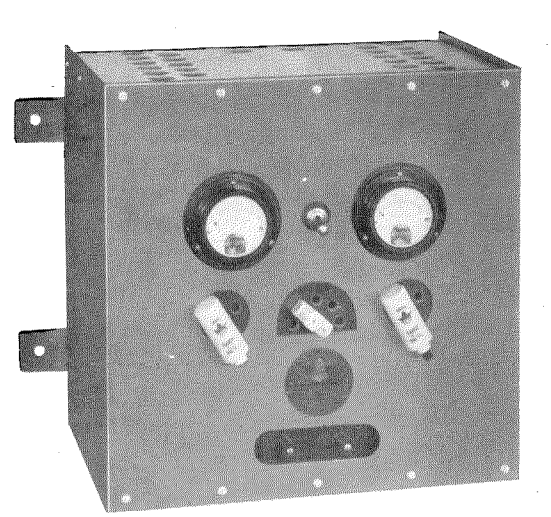


Fig. 1—" Large Garage " Selenium Rectifier.

CINE ARC RECTIFIERS

With the advent of copper-plated carbons and automatic carbon feed in modern cine projector arcs, the applied voltage between carbons is notably lower than that required in earlier projector arcs fitted with ordinary carbons. Furthermore, with automatic feeding, arc stability requirements are less stringent.

Cine arc rectifier output depends on the carbons used. The following table indicates the normal powers required for various carbon sizes :

Negative carbon diameter	Positive carbon diameter	Output
5 mm	6 mm	30 to 40 amps.
6 mm	7 mm	40 to 50 amps.
7 mm	8 mm	50 to 65 amps.

The voltage between carbons is almost independent of the arc current and in fact depends chiefly upon the distance between the carbons.

The distance having a fixed value, based on the best optical performance, the voltage between carbons is therefore practically fixed at an average value of about 35 volts. Nevertheless, it is advantageous to provide an adjustment capable of supplying the arc with voltages ranging from 30 to 40 volts.

Since the best working conditions of 112 mm selenium discs with cooling fins occur at 15 amps. output per element, three standard units have been made available, delivering 30, 45 or 60 amps. at 30 to 40 volts, and consisting, respectively, of 2, 3 or 4 standard elements. The three-phase rectifier, which is the type most commonly used, provides current sufficiently rectified to make further D.C. filtering unnecessary. This unit has an average efficiency of about 70%, compared with an efficiency of 55% to 60% normally achieved with rotary converters.

Cine arc rectifiers must fulfil the three following major requirements :

(1) Safely carry the short-circuit current during the spark over which occurs when the arc is struck ;

(2) Be as compact as possible in floor space requirements inasmuch as they must be installed near the projector and inside a cabin of small dimensions ;

(3) Work in a high ambient temperature reaching, in some cases, 45° C.

Figs. 4 and 5 show, respectively, front and rear views of a 3-phase, 35 volts, 60 amps. rectifier for projector supply. Fig. 4 shows the control wheel of the main commutator which is connected to the primary taps and provides adjustment of the arc current.

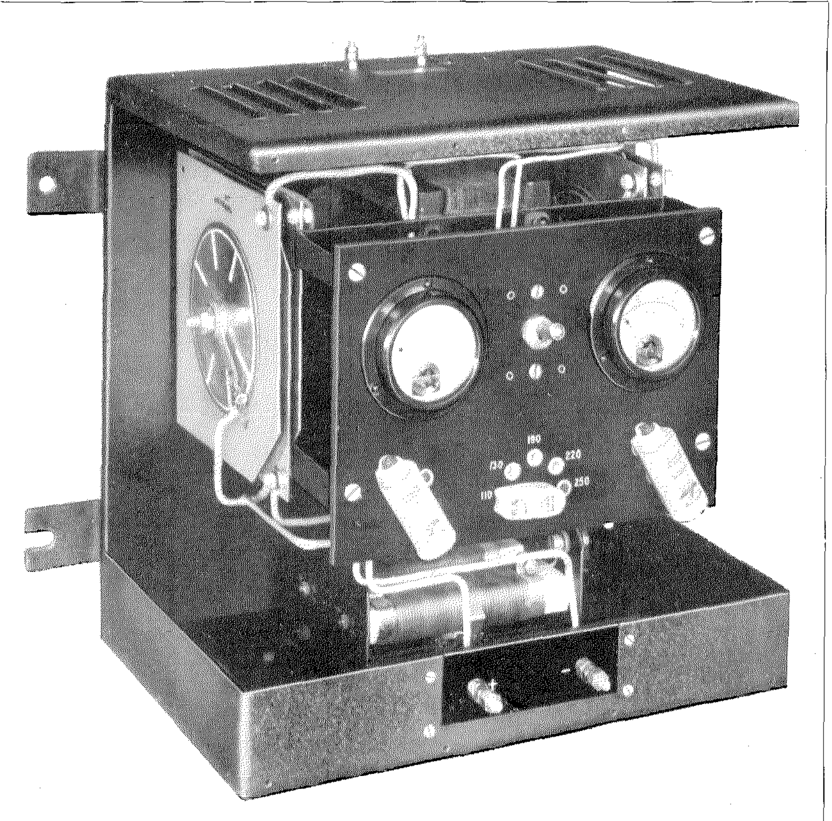


Fig. 3—Selenium Rectifier "Unit" for "Large Garage" Rectifier.

The design of the equipment has been much simplified by the provision of a combined switch-fuse. The use of switches or contactors on an apparatus which must be short-circuited to be put in service would be rather unsafe.

The ability of the selenium element to operate efficiently under temperature conditions which would be dangerous to other types of dry rectifiers makes it particularly suitable for the above application. In fact, artificial or fan cooling is not required. It is merely necessary to design the housing with special care. A narrow high shape is recommended, without any side ventilation and with

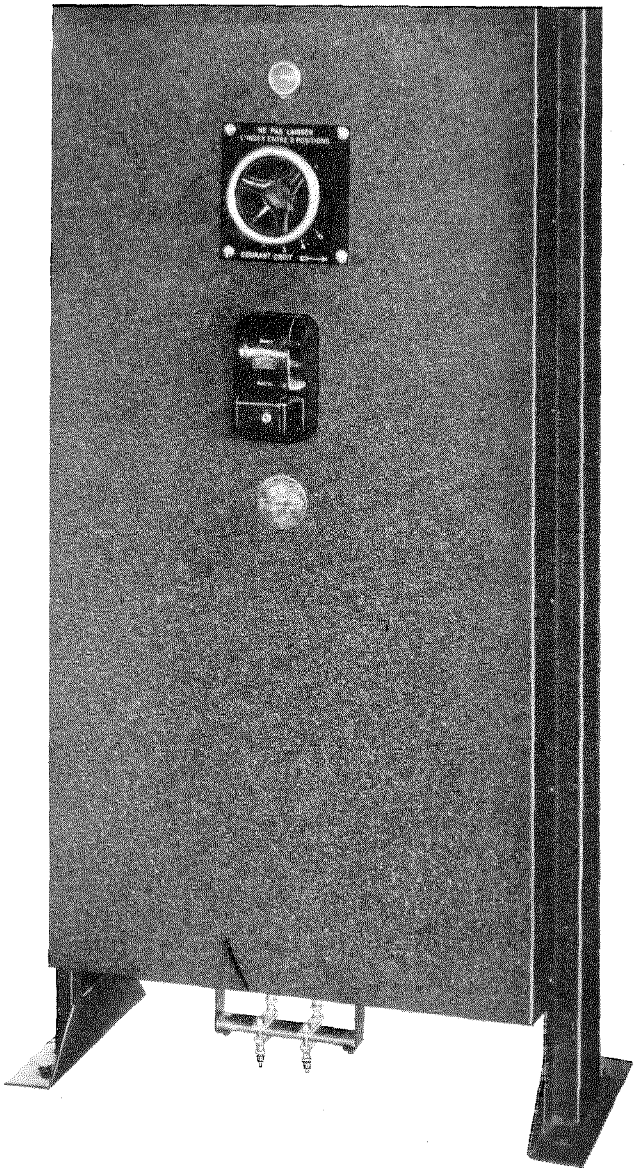


Fig. 4—Selenium Rectifier for Projector Supply (Front View).

large apertures provided at the top and the bottom. The rectifying elements are superimposed to permit the use of a housing of minimum cross-section.

Under such conditions it has been found that the working temperature of the rectifying elements is notably less than that obtained when all the elements are fitted in the same horizontal plane inside a casing of wide section and reduced height. The selenium rectifiers for projector arc supply, in fact, are the only dry rectifiers ensuring entirely safe service inside the projection cabin without the use of artificial ventilation, which is indispensable with other types of rectifiers. Moreover, from the standpoint of reduced floor space requirements, the narrow high shape is ideal.

ELECTRIC VEHICLE BATTERY CHARGERS

Battery requirements for electric vehicles vary according to the type of vehicle and type of battery employed. Commoner specifications are :

(*a*) For small electric trolleys, batteries with 15 to 18 cells, 165 to 230 amps. hr.

(*b*) For trucks, tractors, etc., batteries with 24 to 44 cells, 200 to 500 amps. hr.

The above characteristics apply to lead batteries. For "nickel-iron" batteries, the most usual characteristics are :

(*a*) For small electric trolleys, batteries with 24 to 30 cells, 165 to 225 amps. hr.

(*b*) For trucks, tractors, etc., batteries with 38 to 70 cells, 200 to 500 amps. hr.

Consequently, rectifiers designed for electric vehicles or truck battery charging must be capable of delivering about 30 to 100 amperes at 30 to 90 volts, approximately.

All standard charging equipments are provided with an automatic cut-out device which automatically switches off the charger as soon as charging is finished.

Electric vehicles are usually equipped with an ampere-hour-meter, the needle of which rotates in one direction during the charge and in the opposite direction during the discharge. In order to allow for battery loss, a correction is applied in the following manner : the meter needle operates a contact (closing or opening, according to construction) which in turn actuates the automatic cut-out device, as explained below, as soon as the battery has been charged up to a predetermined number of ampere-hours, equal to the amount delivered during normal service plus the battery loss.

A rectifier wiring diagram of this type is illustrated in Fig. 6, the ampere-hour-meter having a closing contact. The dotted lines correspond to parts fitted on the vehicle, i.e., battery, ampere-hour-meter and polarized plug. The latter consists of two main plugs and, in addition, an auxiliary low current plug for connection to the ampere-hour-meter auxiliary contact.

To start charging, the sequence is as follows:

The rotary switch designated "Manual Charge," "Stop," and "Automatic Charge" is placed in position 3 corresponding to "automatic charge." The plug connected to the charging leads terminating at the truck is inserted in the corresponding rectifier jack. Under these conditions, if the ampere-hour-meter has a closing contact (i.e., at the end of the charge, the ampere-hour-meter closes a contact), the coil circuit of the end-charge relay (b) is opened at the beginning of the charge and its contact closed. Consequently, the locking coil of the main contactor is connected to the battery and the contactor is switched on. Further, as soon as the plug is inserted in the main supply jack, the main contactor (c) closes and connects the rectifier to the A.C. mains and the battery. On the main contactor, a complementary opening contact is provided and designed to insert, after locking, a current limiting resistance in series with the contactor locking coil.

When the charging is finished (i.e., after the ampere-hour-meter indicates that the necessary quantity has been delivered to the battery), the closure contact of the meter operates; the end-charge relay coil (b) is then operated, its contact opened, and the contactor locking coil circuit cut out. The contactor opens and stops the charge.

If, instead of automatic charging, manual charging is desired, the rotary switch is placed in position 1 ("Manual Charge"). Under these conditions, the insertion of the charge leads plug starts the charge. The

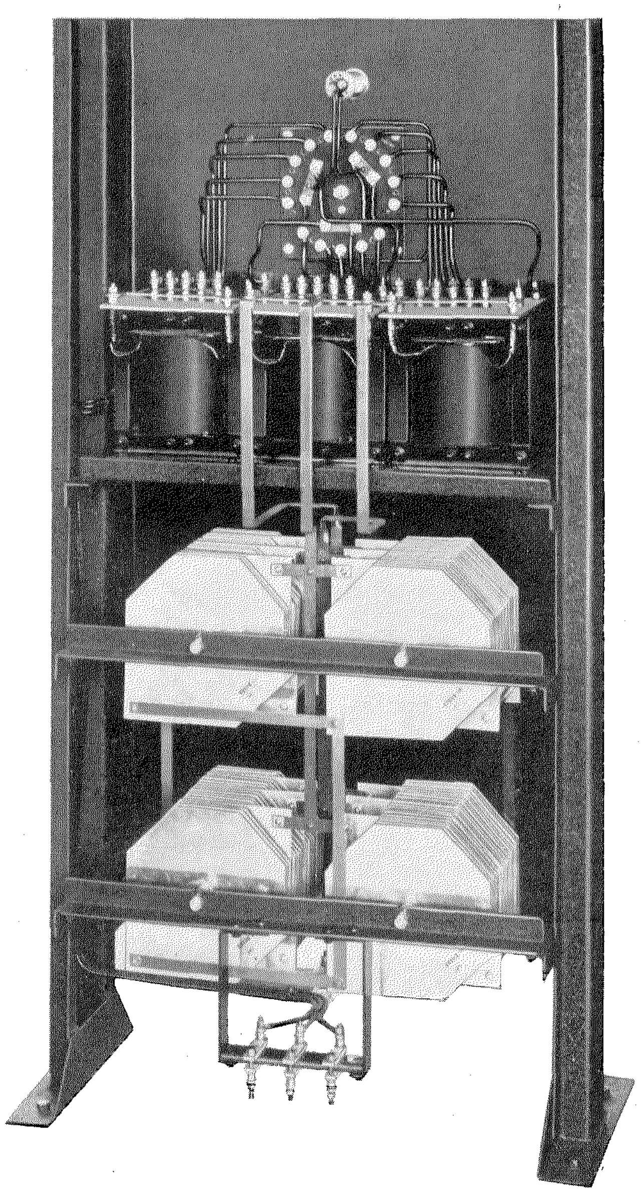


Fig. 5—Selenium Rectifier for Projector Supply with Cover Removed (Rear View).

charging can be stopped at any moment by turning the rotary switch to position 2 ("Stop"), thereby operating the end-charge relay.

Electric vehicle battery chargers must be designed so as to satisfy the requirements of the battery maker. For a given battery, current and voltage at the end (I_1, U_1) and at the beginning (I_2, U_2) of the charge are known. Thus, assuming that the volt-ampere characteristic is a straight line between the two points I_1, U_1 and I_2, U_2, the slope of this characteristic is determined. Generally, the voltage drop in the elements is not sufficient to obtain the desired slope, so it is necessary to increase it by the addition of a substantial inductive drop obtained by the insertion of self-inductances between the transformer secondary winding and the elements. The volt-ampere characteristic of the system, transformer + regulating chokes (assuming a sinusoidal A.C. current, which is only approximately true), is an ellipse.

Fig. 8 illustrates the volt-ampere characteristic of the whole rectifier :

Curve 1—is the elliptic volt-ampere characteristic of the system, transformer + regulating chokes. The co-ordinates are the D.C. current and voltage values corresponding to the secondary A.C. current and voltage, i.e., the curve represents the characteristic which would be obtained if there were no voltage drop in the rectifying elements ;

Curve 2—gives the voltage drop in the elements ;

Curve 3—is obtained by subtracting the corresponding ordinates of 1 and 2 and gives the resultant characteristic, passing through the points I_1, U_1 and I_2, U_2.

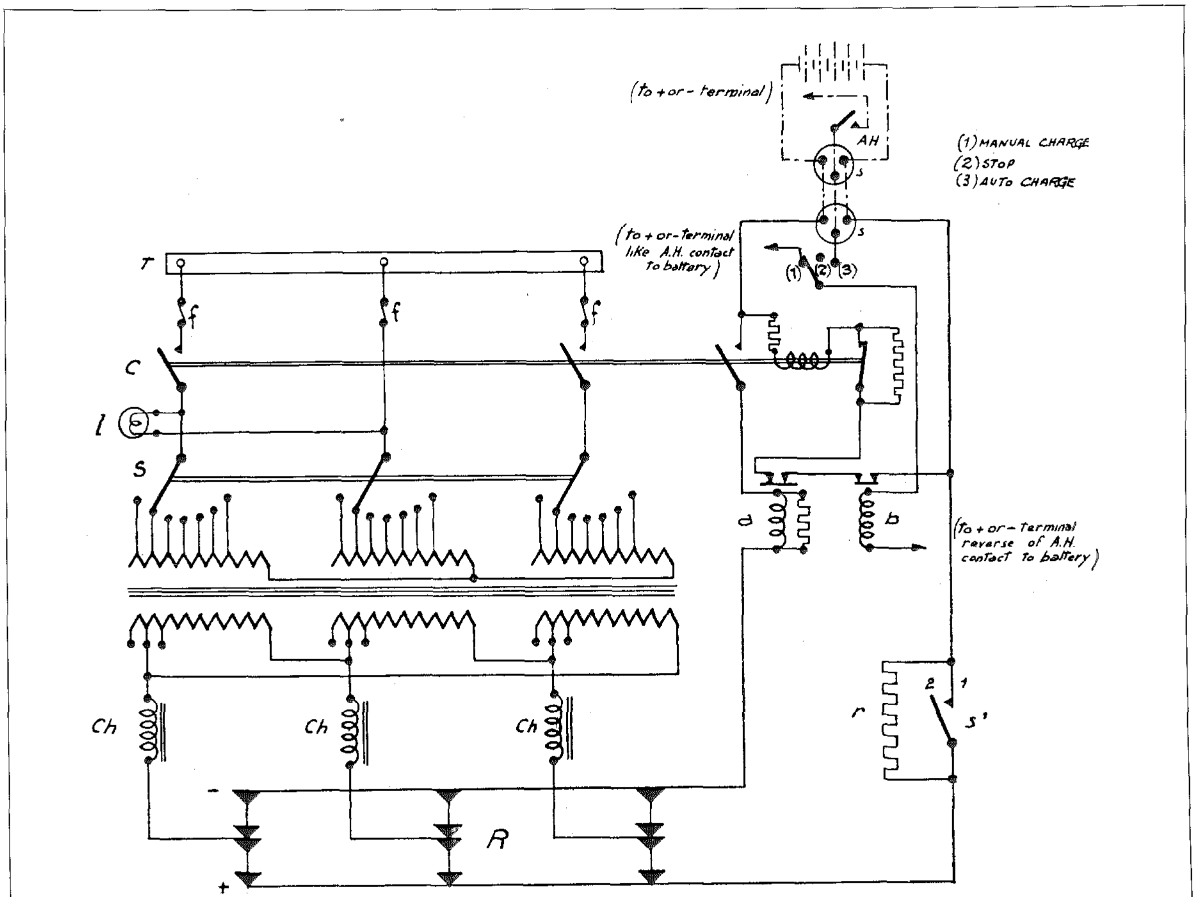


Fig. 6—Circuit of Electric Vehicle Battery Charger.

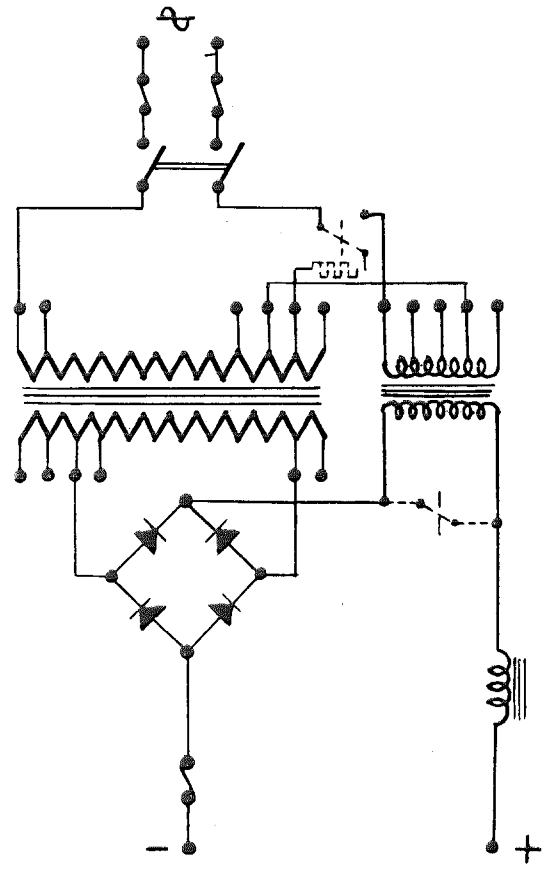


Fig. 7—Rectifier Circuit for Floating Battery Supply.

In addition to the regulating chokes and to the apparatus for automatic or manual charging, the following are provided :

3 fuses on the primary side for protection in case of failure of the maximum current (overload) relay provided on the D.C. side ;

1 three-pole seven-position switch connected to three groups of 7 taps on primary phases. This switch allows the rectifier to work with seven different and parallel characteristics. The requirements of battery manufacturers who prefer a choice of several charging rates, rather than a fixed charging rate, is thus met ;

1 maximum current relay connected in the D.C. circuit designed to open the main switch if the charging current should reach a value dangerous to the selenium elements. In particular, it protects these elements against a short-circuit due to accidental polarity reversal of the leads connecting the rectifier to the vehicle battery. This operation cannot be effected by the maximum current relay connected in the A.C. side ;

1 resistance for the tapered charge. During normal battery charging this resistance is short-circuited by means of a switch. In order to obtain a tapered charge, the switch is opened enabling the rectifier to charge the battery at a low rate.

The primary is usually "star" and the secondary "delta" connected. This arrangement reduces the current intensity in the secondary windings. The rectifier elements are connected in the 3-phase bridge arrangement.

Cases are frequently encountered in practice where the ampere-hour-meter has an opening instead of a closing contact. The circuit in this case is identical to that above described, with the exception that the end-charge relay is normally under current during the charging period ; its release causes the main switch to operate and stop the charge.

ARC WELDING RECTIFIERS

There is some analogy between the working conditions of these rectifiers and those for cine projector supply rectifiers, since both types are designed to feed an arc between two conducting electrodes.

In both cases short-circuit operation (arc-striking) must be considered as normal rather than accidental ; this condition, however, occurs much more frequently in arc-welding than in projector supply. It is necessary, therefore, to devise supply and regulation in a manner such that the ratio, short-circuit current/normal current, is as low as possible. To attain this result, the rectifier has a high potential drop, the natural drop of potential of the elements being increased by the addition of a substantial inductive drop obtained either by the insertion of self-inductance on the A.C. side, or by the presence of high leakage coils inserted between

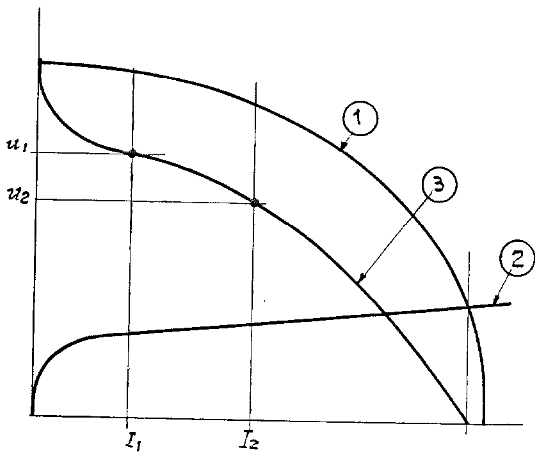


Fig. 8—Volt-Ampere Characteristic of Arc Welding Rectifier.

the mains transformer primary and secondary windings.

The theory of the regulating chokes has been explained above in connection with electric vehicle battery chargers. But due to the necessity of a low value of the ratio, short-circuit-current/welding current, these regulating self-inductances are of higher value.

The volt-ampere characteristic must satisfy the following conditions :

(1) Starting voltage (no load) : 55 volts ;
(2) Working voltage (welding load) : 25 volts ;
(3) Short-circuit-current/maximum welding current :—1 : 10 to 1 : 12.

Various welding current control devices have been proposed such as : transformers with variable leakage, regulating chokes with taps connected to a commutator and regulating chokes with saturation windings.

The maximum current output (from 50 to 320 amps.) of an arc welding rectifier depends on the size of the electrodes (diameters from 1 to 12 mm).

RECTIFIERS FOR TELEPHONE EXCHANGE SYSTEMS

One of the essential features of this type of rectifier, designed either for operation with floating battery or for direct supply, is the provision of a regulation device with saturation winding coils provided principally in order to give the rectifier a compound characteristic.

(a) Installation with Floating Battery

These equipments must meet the following conditions : under normal operation, the rectifier must carry the major part of the load required by the external circuit and provide an additional small current (maintenance current) for continuously maintaining the battery on floating charge. In case of main power supply failure when the battery is called on to carry the load, the rectifier must be capable of progressively restoring the battery to its initial state of full charge after the power supply is re-established.

(b) Installation for Direct Supply

The circuit of such an equipment is different from that indicated above, in that it is provided with a filter designed to reduce the A.C. component in the output to the required value.

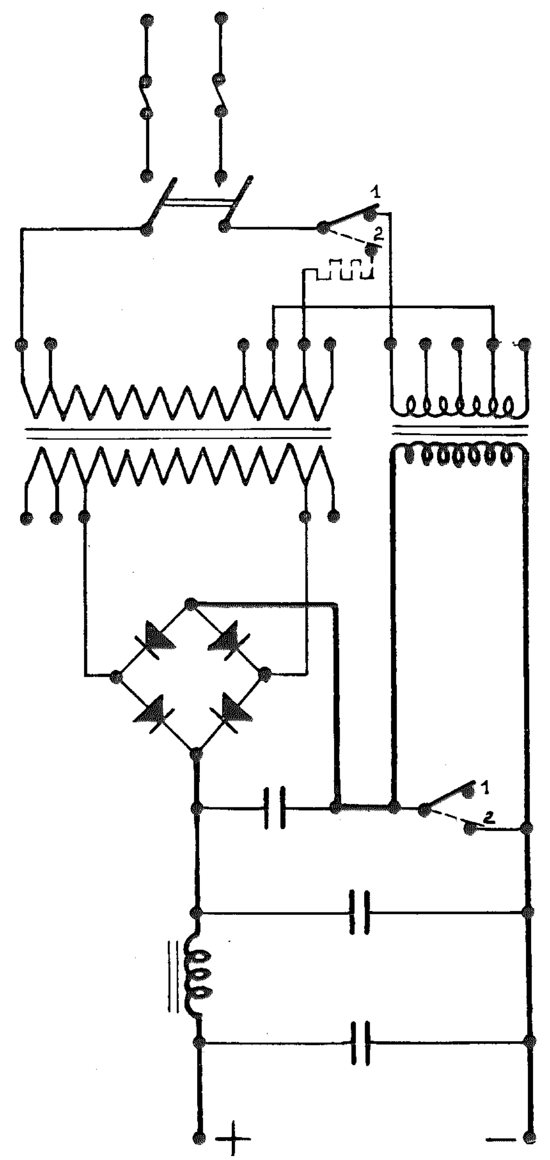


Fig. 9—Rectifier Circuit for Direct Supply to Telephone Equipment.

Figs. 7 and 9 show the circuit diagrams for the two types of telephone supply systems mentioned.

The chief difficulty with regulating systems using saturation coils lies in the fact that stable operation can be obtained only if the mains power supply is sufficiently constant. Assuming

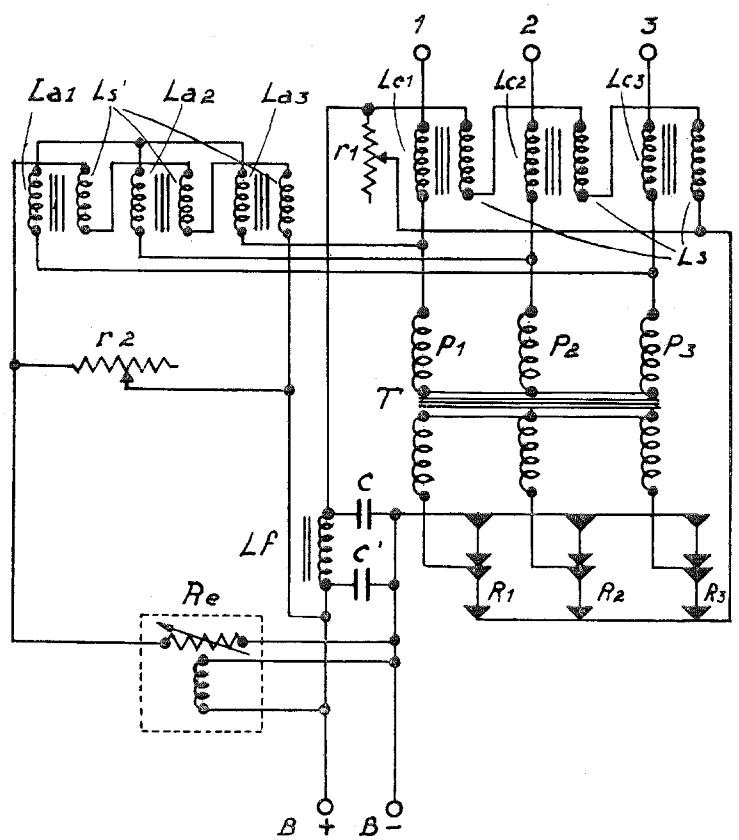


Fig. 10—Schematic of Rectifier "Superregulation" Circuit.

that the mains power supply increases, the rectified voltage tends to rise, thereby causing the output to increase. Further, any enlarged output, by increasing the compound coil saturation, tends also to increase the alternating voltage applied to the rectifier. In other words, the operation is unstable owing to mains voltage variations.

The term "superregulation" has been applied to devices designed to maintain at a constant value the rectifier D.C. voltage, not only for any load, but also for large mains supply voltage variations. The function of such a device will be understood by reference to the circuit schematic of Fig. 10, applying to three-phase operation.

Referring to the circuit, Lc_1, Lc_2 and Lc_3 are the compound coils, the saturation winding L_s being in series with the external circuit. La_1, La_2 and La_3 are termed pre-loading coils with the saturation winding Ls' in parallel with the external circuit; the current in this coil is controlled by means of a quick acting regulator *Re*, influenced by the rectified voltage. The compound coils Lc_1, Lc_2 and Lc_3 are used to maintain the rectified voltage constant in terms of the load, in accordance with the usual method already described. The pre-loading coils La_1, La_2 and La_3 enable the load variation compensation initiated by the compound coils to be completed, and also provide compensation for power supply voltage variation.

This compensation is effected in the following manner:

Assuming that the mains voltage tends to increase, there results a rectified D.C. voltage increase, which must be kept at a minimum. The increase of the rectified D.C. voltage actuates the regulator *Re*, decreasing its variable resistance, the regulator being connected in series with the saturation winding Ls' of the pre-loading coils. Under these conditions, the pre-loading coil saturation current increases and the current, for the major part wattless, absorbed by these coils, also increases.

Since this current flows through the compound coils, there is an increase in potential drop in these coils compensating for the mains voltage increase and tending to maintain constant the voltage applied to the primary of the rectifier supply transformer.

CONCLUSION

From the favourable reception accorded these higher power selenium rectifiers in the field, rapid development of additional industrial applications may be confidently expected.

A Long Distance Automatic Teleprinter Exchange with Manual Priority Services

London & North Eastern Railway Teleprinter Network

By G. A. M. HYDE, B.A.,

Standard Telephones and Cables, Limited, London, England

INTRODUCTION

AN automatic Teleprinter System offering unique facilities, designed and manufactured by Standard Telephones and Cables, Limited, is now being installed on the London & North Eastern Railway, at Liverpool Street Station, London. The system is designed to interconnect stations in the Southern Area of the Railway's network. A point-to-point teleprinter system has been in operation in the Northern Area for some time past; its successful performance led to the decision to provide an automatic exchange for the Southern Area, inasmuch as it was felt that such an automatic exchange would speed up the service still further and effect economies in operation.

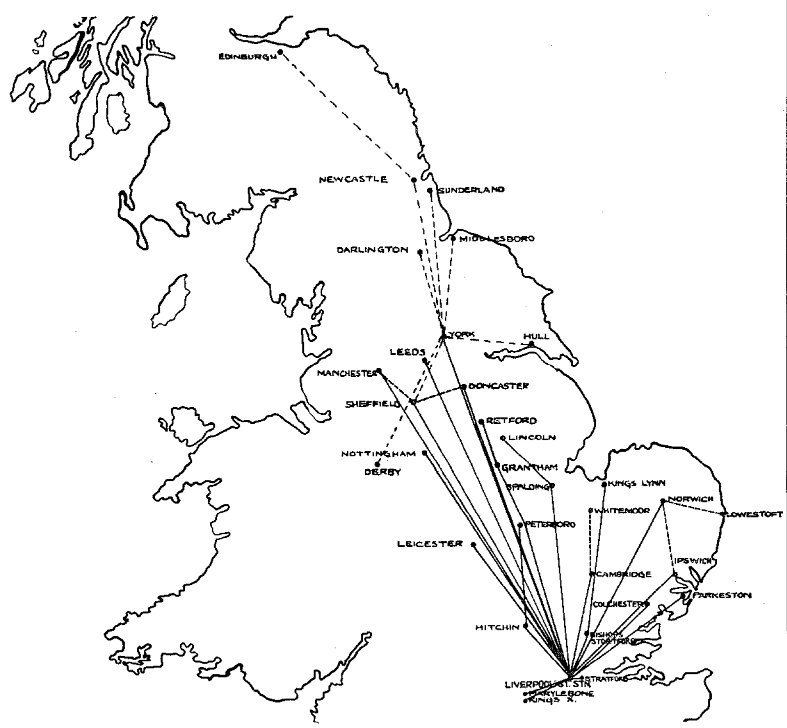


Fig. 1—L.N.E.R. Teleprinter Network shewing Long Distance Connections.

The map (Fig. 1) shows the relationship of the exchange to the Railway's communication network. The dotted lines are those working on a point-to-point basis, and the full lines represent stations connected to the automatic system at Liverpool Street. The automatic network is connected to the point-to-point network by an extension to York, which is the Headquarters of the point-to-point system. Messages may, therefore, be exchanged between the two areas via York Station.

REQUIREMENTS AFFECTING DESIGN

The problems encountered at the outset were the very high traffic and the limited line plant available. Railway communication, moreover, is made up of urgent and non-urgent traffic; urgent traffic, such as danger messages and train control messages, must always have immediate preference over all other forms of traffic. Some means of trunk offering, therefore, had to be incorporated in the exchange to handle this type of traffic. While automatic schemes of trunk offering were considered and are possible, it was felt that such a facility might be abused by out-station operators. It was agreed,

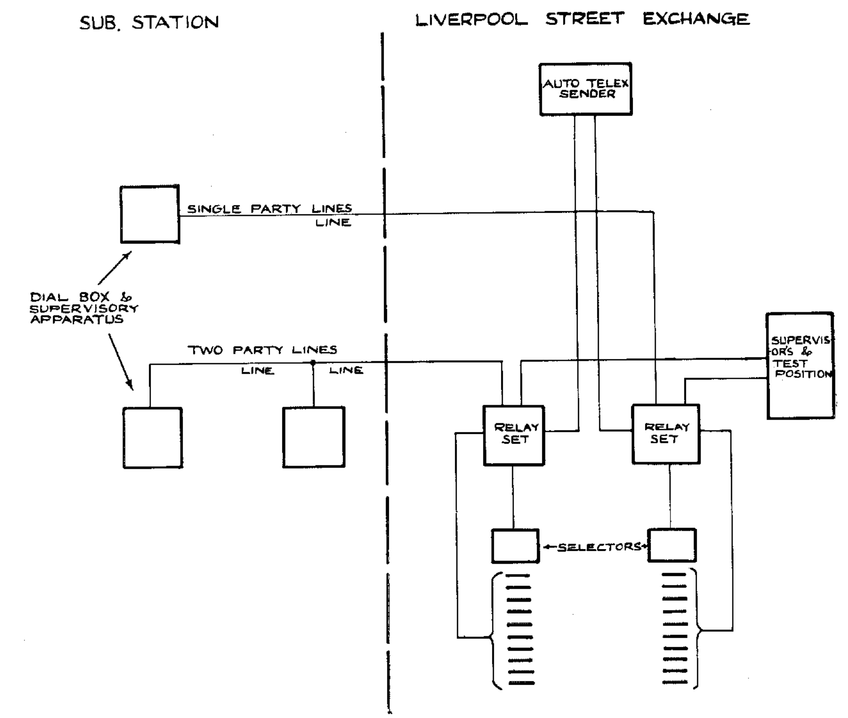
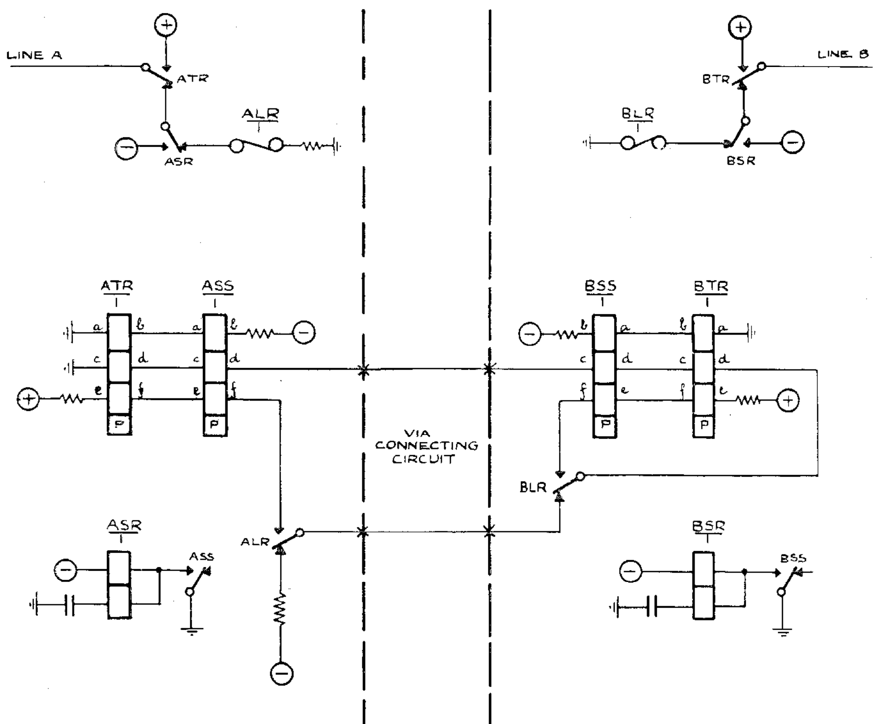


Fig. 2—Switching Scheme, Liverpool Street Teleprinter Exchange.



NOTES:-
WINDINGS a-b USED FOR SLIGHT PERMANENT MARKING BIAS
WINDINGS c-d AND e-f ARE EQUAL AND OPPOSITE IN EFFECT

Fig. 3—Skeleton Connections for Switched-simplex Repeater—Liverpool Street Teleprinter Exchange.

therefore, that all trunk offering of urgent messages should be carried out by a central supervisor who would have means for entering any existing communication. The system adopted ultimately may be compared with a Private Automatic Branch Telephone Exchange where local connections are obtained automatically, and exchange traffic is handled by an attendant, the attendant having means of entering established automatic connections for the purpose of offering urgent calls.

The line plant available for the initial installation consisted of open wire earth return circuits, some of which were superposed on telephone channels. This required the development of a switched-simplex repeater as repetition would be required at Liverpool Street in order to keep the overall distortion within reasonable limits. Switched-simplex operation was adopted because duplex operation was ruled out owing to the very large variation in line leakance. The system, as now designed, is capable of operation with line insulation as low as 1 000 ohms.

Owing to the very high traffic on all lines, it was decided to provide each extension on the system with a selector. The ultimate capacity of the exchange is 80 lines, of which 34 are equipped initially. In order still further to ease the busy hour peaks, arrangements are included for reperforation and automatic retransmission of messages from Liverpool Street.

SWITCHING SCHEME

Fig. 2 is a schematic of the switching scheme at Liverpool Street. The party lines shown are arranged for selective calling and, when intercommunicating with one another, the supervisor at Liverpool Street may offer urgent connections as in the case of single party circuits.

Subscribers' lines terminate at the exchange on a side-stable polarised relay. This relay repeats the impulses received from the line to repeating relays associated with the line termination and selector circuit. These repeating relays form a complete switched-simplex repeater when connected through to a similar unit on the wanted party's circuit. When not connected through, they are used for dialling and for communication with the supervisor, who obtains direct association with any line by means of a line key associated with each subscriber.

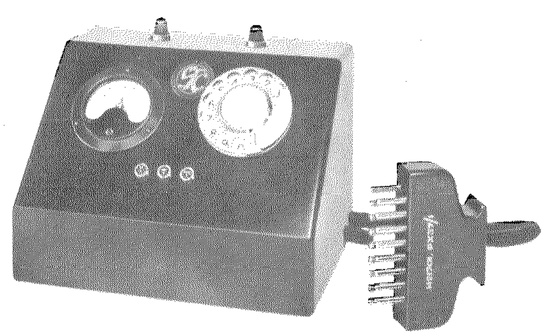


Fig. 4—Dialling Unit.

Fig. 3 shows two elements of the repeating circuit at the exchange when connected together. The orientation of the relays, when the circuit is the calling or called circuit, is performed by telephone switching relays associated with them.

Subscribers may obtain direct access to one another by dialling the appropriate two-digit number. A group of teleprinters at Liverpool Street is required for the transmission and reception of Liverpool Street traffic; this group is reached by dialling the single digit 9, the selector being arranged to hunt over the busy machines and connect the calling party to the first free machine.

The supervisor at Liverpool Street is obtained at all times by the transmission of a special signal from the teleprinter itself. This signal is generated by a cam and springs driven by the same mechanism as the "answer-back" device. Origination of the signal is accomplished by the subscriber pressing a key on his dial box; this trips the "answer-back" drum and switches over the line from the regular transmitting contacts to the special supervisory springs. This special signal consists of two long spaces of about 750 milliseconds each, separated by a short mark of 50 milliseconds, and concluded with a mark. It is, in fact, the signal used for release repeated after 50 milliseconds. As this signal may be used to call in the supervisor during a connection, special relays are provided at the substation to erase it when received.

OUTSTATION EQUIPMENT

The equipment at an outstation (waystation) is illustrated by Figs. 4 to 6, inclusive, showing a dialling unit and an apparatus rack containing line relay and supervisory relays. The teleprinter is started up automatically and is stopped on receipt of the "clear" signal. In the case of single line stations, the equipment is decreased by the five telephone relays otherwise required to count the pre-calling code required for selection.

AUTO TELEX SENDER

Supervisory indications from the exchange, such as "busy," "unobtainable," etc., are generated by a special automatic telex sender.

If a subscriber dials a busy number, the word "busy" is automatically printed back on his machine and his selector is re-set so that he may dial another party, should he so desire, without first clearing the previous set-up. If the dialled number be unobtainable, the abbreviation "UNOB" is printed on the calling party's machine. If the wanted party is free, the telex sender sends out the code required to trip the "answer-back" device on the distant party's machine, whereupon the number called is printed back on the calling party's machine as a check and indication that he has been connected through.

A machine of similar character has been used before for the generation of teleprinter signals ; but, in the present case, owing to the nature of the lines and the absolute necessity of keeping distortion to a minimum, special precautions had to be taken in order that the telex sender would transmit perfect signals. This result has been achieved by the incorporation of a cleaning-up device, a full description of which will be published later.

In addition to generating the teleprinter signals, the telex sender provides interrupted earth and timed impulses for the operation of time delay alarms.

SUPERVISOR'S AND TESTING POSITION

Fig. 7 shows a view of the supervisor's desk, which includes a test position to enable the speed and distortion of the remote teleprinters to be measured from Liverpool Street. Facilities are also provided, on the testing position, for checking the speed of the out-station dials, and for making exhaustive routine tests on the automatic equipment at Liverpool Street.

SUBSCRIBER TO SUBSCRIBER CONNECTION

Connection between subscribers is effected by dialling the number of the wanted party.

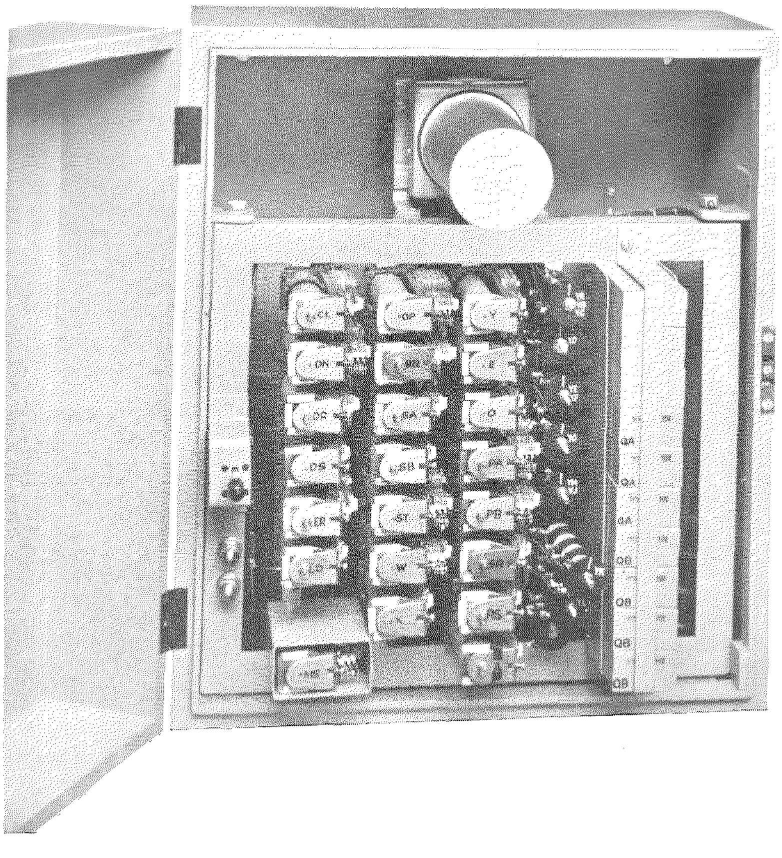


Fig. 5—Apparatus Cabinet with Cover Open.

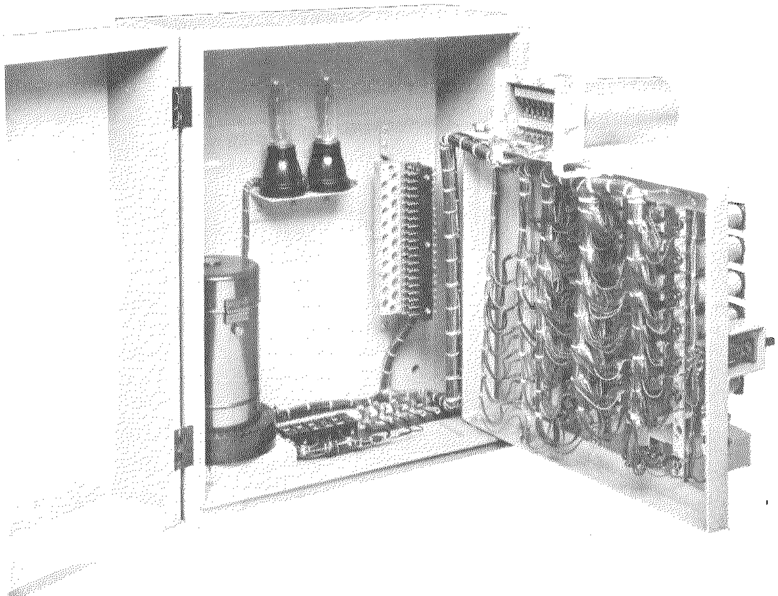


Fig. 6—Apparatus Cabinet, showing Accessibility of Components.

No pre-dialling operation is required since, in this installation, each line has its own selector. If the wanted party is free, communication may commence as soon as his number has been automatically printed back on the calling party's machine. On originating a call, the red lamp on the dial box lights. On the incoming side, both the red and green lamps light in order to indicate to the operators the type of call that has been set up. A centre-zero milliammeter is incorporated in the dial box because of the type of operation, namely, switched-simplex, and the fact that, if the line should become disconnected during communication, printing of the home record would continue. The milliammeter, therefore, is provided as a visual indication of the line condition.

Operating instructions will provide for the originating subscriber transmitting the " Who are you ? " signal at the end of each message. This is desirable as a check that the connected teleprinter is still functioning correctly.

SUBSCRIBER TO SUPERVISOR

The subscriber calls the supervisor directly by pressing the OPK key on the dial box. This starts up the teleprinter which sends out the signal required for calling in the supervisor. On the supervisor's position there is a "calling" and "engaged" lamp, together with a line key, associated with each subscriber. The calling lamp will flash and the supervisor answers by operating the line key and printing to the calling subscriber.

Should the supervisor wish to communicate with a subscriber, he operates the line key and momentarily presses a calling key on the position circuit : this sends out the code to trip the "answer back" drum on the wanted party's machine. The supervisor may then attract the attention of the operator at the outstation by pressing the bell key on the teleprinter, causing a buzzer in the dial box to operate until the wanted party answers or the supervisor abandons the call.

CALLING IN OF SUPERVISOR

On an established connection, either party may call in the supervisor by pressing the OPK key on the dial box : the calling signal is sent out by the teleprinter and the calling lamp flashes on the supervisor's position. The supervisor enters the connection by operating a line key associated with the calling lamp. In this condition he inserts a repeating relay in series with the repeating relays associated with the calling and called parties ; he may print simultaneously to both parties and he also receives a copy of a message transmitted by either party. The supervisor, at his discretion, may withdraw from the connection.

OFFERING OF URGENT CALLS

Should a subscriber wish to send an urgent message to an engaged party, he may call in the supervisor by operating the OPK key in the dial box. The supervisor, on ascertaining the requirements and at his discretion, may offer the call to the engaged party. He may do so by operating the line key associated with the wanted party, whereupon he is connected in, and, at a suitable opportunity, may attract the attention of both parties by operating the bell key.

When the supervisor enters an established connection in this way, he does not mutilate the signals being transmitted. As simplex working is used, the supervisor, however, must await a suitable opportunity before transmitting as otherwise the communication in progress would be interfered with. The supervisor then offers the urgent call to the wanted party, who may accept the new call immediately or ask the supervisor to wait until the existing communication is concluded.

In the first case, the supervisor may transfer the wanted party to the urgent calling party by pressing the transfer key on his position circuit. In the second case, he may leave the urgent calling party "camped" on the wanted party's circuit, and the wanted party will be connected to the urgent calling party directly he releases from his existing connection. In this case the supervisor need not remain in circuit as the switching is performed automatically. When the wanted party is connected to the calling party in either of the above cases, the wanted party's number is automatically printed back on the urgent calling party's machine as an indication that the circuit is available.

REPERFORATORS AND AUTO SENDERS

Facilities are provided on the exchange equipment for introducing a reperforator on a circuit adjacent to a "busy" subscriber. If this subscriber be engaged when called by another party, the calling party's selector will automatically hunt on to a free reperforator and the word "PERF" will be printed back on his machine. The calling party may then leave his message on the reperforator if he so desires. Subsequently, the tape from the reperforator is passed through an automatic sender. This automatic sender is under the control of an operator at Liverpool Street, who may dial the sender on to any station desired, thus providing for the transmission of non-urgent routine messages from Liverpool Street during the slack hours of the night.

PRINTING OF FALSE CHARACTERS

In teleprinter exchange systems where a long space signal is transmitted for supervisory purposes, there is a possibility of false characters being printed on the connected teleprinters unless the teleprinter used is of a

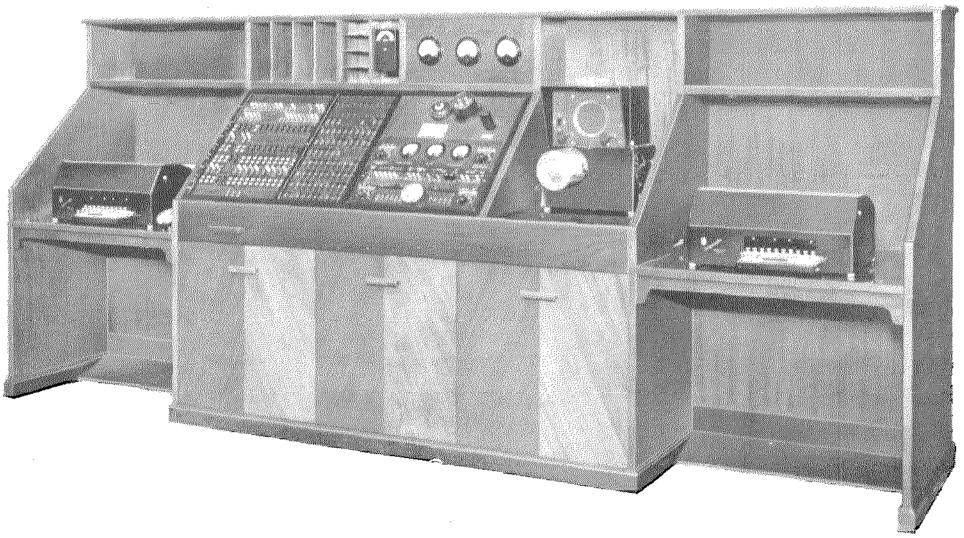
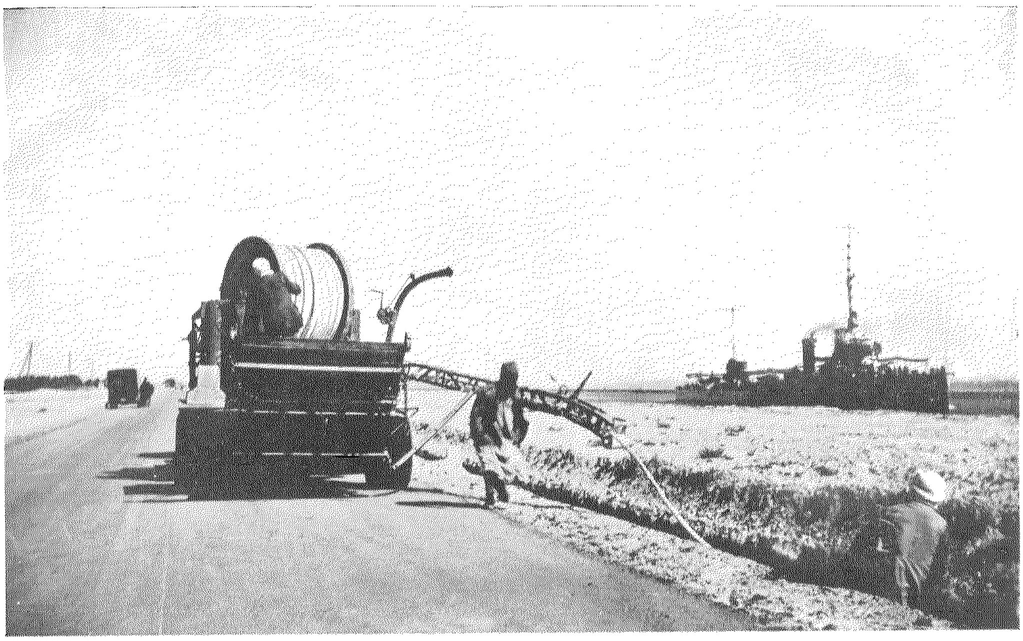


Fig. 7—Supervisor's Desk with Test Position incorporated.

type in which five space signals stop subsequent release of the single revolution clutch. On the 7-A Creed teleprinter, used in the system described herein, the printing mechanism is not so arranged, and thus the transmission of the release signal and the signal used for calling in the supervisor would, unless special precautions were taken, print false characters at both ends of the circuit.

The Railway Administration considered this highly undesirable. An addition, therefore, was made to the Creed teleprinter and to the substations circuit in order that the release and supervising signals would not print a false character. Inasmuch as the printing of the false character depends on the timing of the mark signal in its relationship with the position of the controlling cam in the teleprinter, the operation of a relay ensures that the mark signal will not be fed to the teleprinter until the teleprinter cam is in the "stop" position. Subsequent revolution of the clutch is prevented and no character is printed.

[The facilities and circuits incorporated in this system will be described in greater detail in a subsequent article.]



SUEZ CANAL CABLE

This loaded and armoured cable was supplied by Lignes Télégraphiques et Téléphoniques, France, and Standard Telephones and Cables, Limited, London. It was laid alongside the Canal from Port Said to Suez, a distance of approximately 180 km, and was put into service in 1938.

The Eiffel Tower Television Transmitter

By S. MALLEIN,

Ingénieur des Postes et Télégraphes Chargé du Service de la Télévision de l'Administration Française des Postes Télégraphes et Téléphones

and

G. RABUTEAU,

Le Matériel Téléphonique, Paris, France

INTRODUCTION

TO meet the requirements of modern television systems, the French Post Office (P.T.T.), towards the end of 1936, gave consideration to replacing the 10 kW equipment* used for broadcasting 180 line television images by an equipment suitable for transmitting images of high definition. During 1937, comparative tests of various scanning systems were conducted, and an order was placed with Le Matériel Téléphonique for the realization of a 30 kW peak power television transmitter to be installed at the foot of the Eiffel Tower.

The programme adopted in March, 1937, for the erection of the new television station included an experimental period during which the peak power of a temporary equipment was to be progressively raised from 7.5 to 30 kW.

A building for housing the new equipment was erected under the supervision of the P.T.T. Installation of the provisional equipment manufactured by Le Matériel Téléphonique was started in July, 1937, and experimental transmissions, with a 7.5 kW peak power and a 2 Mc/s bandwidth, were commenced in September, 1937.

The peak power was gradually raised to 25 kW in December, 1937. On April 8th, 1938, the transmitter was inaugurated by the P.T.T. Minister, Mr. Lebas. A provisional antenna was used at the top of the Tower.

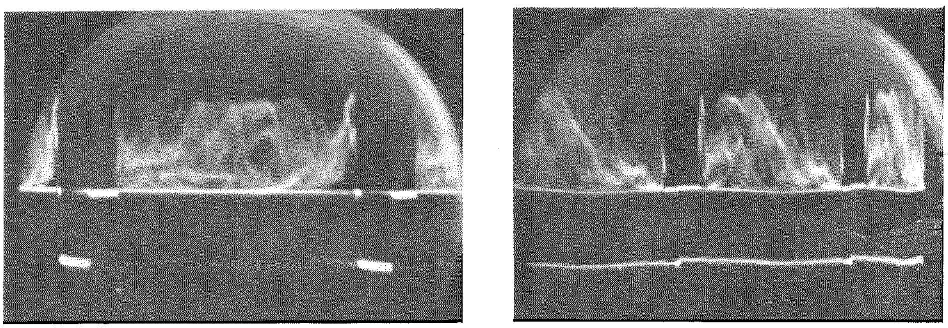


Fig. 1—Line and Image Signals as produced by the Studio Camera.

Regular transmissions, at 25 kW peak power, five days a week, were then started. The plans called for replacing the provisional by the final equipment, with a nominal power of 30 kW, towards the end of 1938.

Regular transmissions were discontinued during December, 1938, to permit replacing the provisional equipment. During this period a temporary 1.5 kW peak power television trans-

* In service since the latter part of 1935.

mitter, installed by Le Matériel Téléphonique, was operated in the P.T.T. offices at Rue de Grenelle, Paris. The antenna used was installed at the top of a 70 metre mast supporting the antenna of the oldest French broadcasting (Paris P.T.T.) station.

The new television transmitter has been in service since December 25th, 1938. Final adjustments were made during January and February, and official acceptance tests by the P.T.T. Commission were completed by March 15th, 1939.

Studio and film transmissions are being made five days a week from the P.T.T. Studio at Rue de Grenelle, located 2.5 km from the transmitter. The signals are conveyed to the transmitter by means of a coaxial cable and a terminal equipment furnished by Le Matériel Téléphonique.

RADIATED WAVE FORM

The carrier frequency of the Eiffel Tower television transmitter is 46 Mc/s. The transmitter radiates signals comprising both sidebands, extending to 3 Mc/s each side of the carrier frequency.

The polarity of transmission is positive, i.e., a white image raises the transmitter power to the peak value. The latter is actually 35 kW, whilst the nominal peak power of the transmitter is 30 kW.

The French television standard, which is to remain in force up to July, 1941, calls for 25 complete pictures per second, each picture containing between 440 and 455 total lines. These lines are interlaced so that the frame and flicker frequency is 50 per second.

The lines are scanned left to right when looking at the picture received. The line frequency is comprised between 440 × 25 and 455 × 25, i.e., 11 000 c/s and 11 375 c/s.

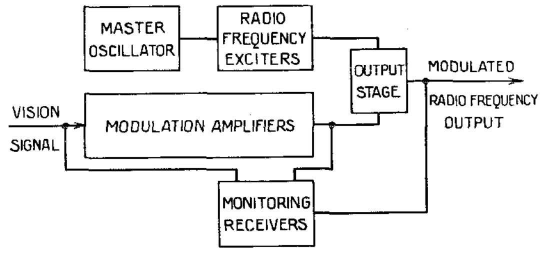


Fig. 2—Block Schematic of the Vision Transmitter.

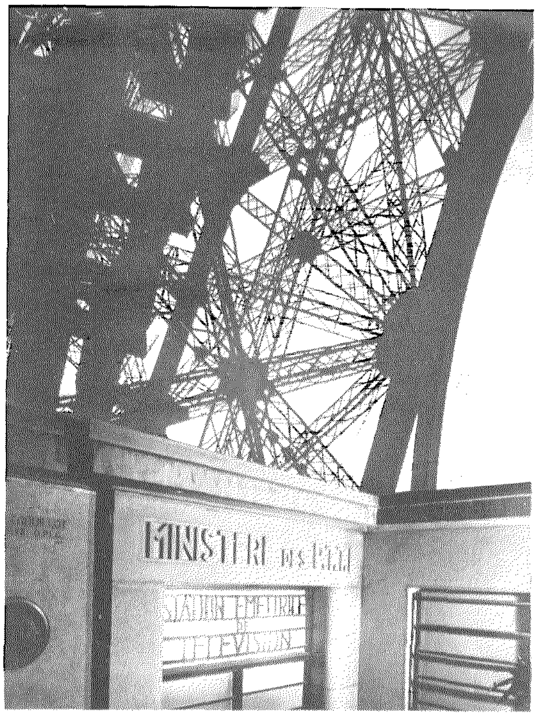


Fig. 3—Main Entrance to the Eiffel Tower Television Transmitter.

The frame frequency is 50 per second, frame-scanning being made from top to bottom of the picture received.

The aspect ratio, i.e., the width versus height ratio of the image, is $\frac{5}{4}$.

The line and frame synchronizing signals extend downwards so as to reduce the carrier level to zero. The duration of the line synchronizing signal is 18% of the total scanning time of one line (a ± 2% tolerance is allowed).

The shape of the frame synchronizing signals is not entirely specified in the French P.T.T. standard. It is stated that suppression of the vision signals must occur during at least 15 lines per $\frac{1}{2}$ image, i.e., about 7% of the scanning time of the complete image.

The maximum amplitude of the high frequency signals capable of being radiated by the transmitter is taken as a reference level, i.e., 100%. Signals with an amplitude between 0 and 30% are used exclusively for synchronization ; tolerances of 27% to 33% for the upper

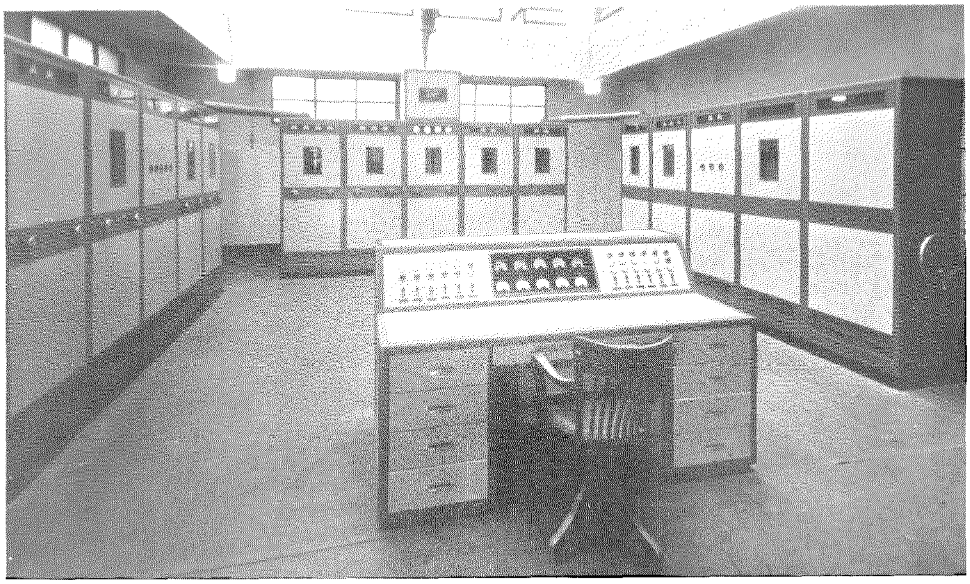


Fig. 4—The Transmitter Room of the Eiffel Tower Television Transmitter.

portion of the synchronizing pulses, and 5% for the lower portion, are allowed. Signals of amplitude between 30% and 100% are used for the transmission of the vision signals proper.

VISION PICKUP EQUIPMENT

Since the inauguration of the transmitter in April, 1938, an iconoscope and its associated equipment, supplied by Compagnie Française Thomson-Houston, has been used for the transmission of studio programmes.

The equipment supplied by the Compagnie Française Thomson-Houston, generally speaking, is similar to that used in the London television system and produces signals having the same wave form except that the number of lines per image is 455 rather than 405 as in London. This wave form meets the requirements of the French P.T.T. television standard. Fig. 1 is a reproduction of an oscillogram of the line and image signals produced by the Compagnie Française Thomson-Houston equipment.

Film transmissions employ scanning equipment furnished by "Radio Industrie." The wave form of the signals produced by this equipment accords with the French standard, but the signals used for frame synchronization differ appreciably from those of the Compagnie Française Thomson - Houston equipment. During a period equivalent to 10 line impulses, the signal amplitude is kept steady at 30%. Interlacing is performed by line impulses instead of using impulses having a frequency twice that of the line as in the Marconi-E.M.I. wave form.

The adoption of a common wave form for studio and film transmissions is under consideration by the French P.T.T.

PRINCIPLE OF OPERATION OF THE VISION TRANSMITTER (FIG. 2)

The 46 Mc/s carrier frequency of the transmitter is generated by a crystal-controlled master oscillator using screen grid valves. The master oscillator is followed by a radio frequency exciter delivering 5 kW drive to the penultimate stage of the transmitter. The exciter units employ triodes in push-pull.

The penultimate stage of the transmitter is an inverted amplifier working without balancing condensers and delivering a 20 kW drive into the transmitter output stage. The latter is of the inverted amplifier type, also without balancing condensers—an essential feature for obtaining the bandwidth required.

The output stage is grid modulated from the final stage of the modulator which is connected directly to the grids of the output stage of the transmitter. The output stage of the modulator is arranged to maintain the modulation depth of the transmitter constant.

The transmitter output is fed into a symmetrical output circuit. The latter is coupled by two short lengths of coaxial line to a matching transformer which adapts the impedance of the output circuit to that of the antenna feeder.

The antenna consists of eight vertical push-pull dipoles, each comprising two vertical, half-wavelength frames. The radiating elements are equally spaced around the upper part of the Eiffel Tower.

The aerials are centre-fed from quarter-wave transmission line sections connected to four matching transformers projecting through the windows of the Tower beacon, which has been dismantled to permit installation of the antenna system. A junction box placed in the centre of the Tower connects the coaxial cable coming from the transmitter to the matching transformers and houses the compensating network used for flattening the antenna characteristic.

The station is entirely A.C. operated. Rotating machinery is used only for the cooling system. The filaments of the valves are either fed from raw A.C. (single or 3-phase) or from D.C. from an individual dry rectifier associated with each stage. Grid bias and plate voltages are obtained by means of dry rectifiers or from hot cathode mercury vapour rectifiers.

Provision is made for the complete control and monitoring of the wave form of the signals at various points in the equipment, and also for examining the incoming and the transmitted images.

TRANSMITTER BUILDING

Fig. 3 shows a view of the main entrance to the Eiffel Tower television transmitter. The building houses the sound transmitter, the vision transmitter and the receiving end of the terminal equipment of the coaxial cable conveying the vision signals from the studio.

The space available for the building was greatly restricted due to the importance of not

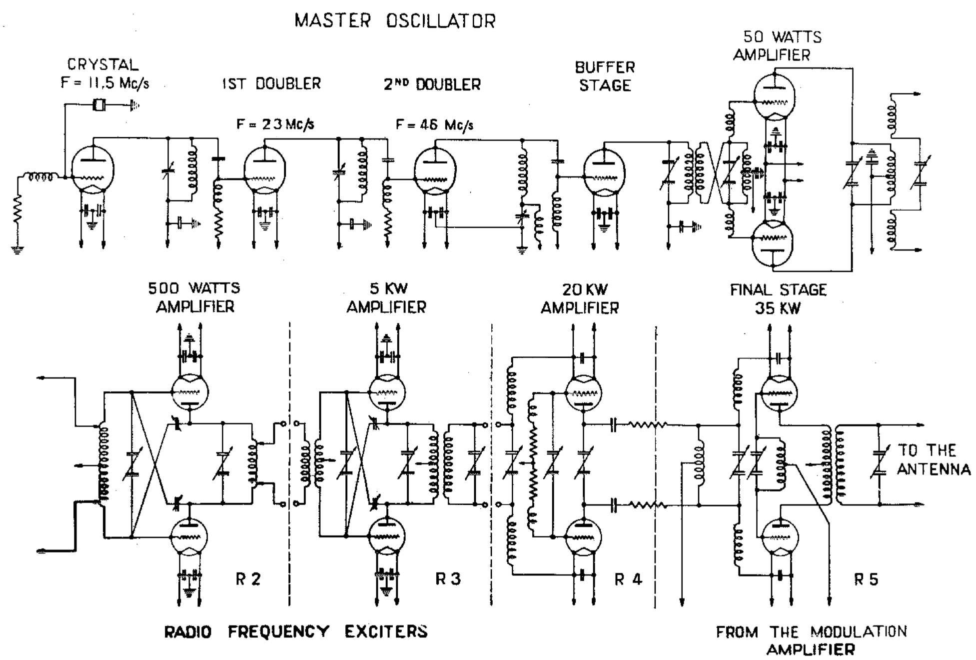


Fig. 5—Schematic of the Radio Frequency Amplifiers.

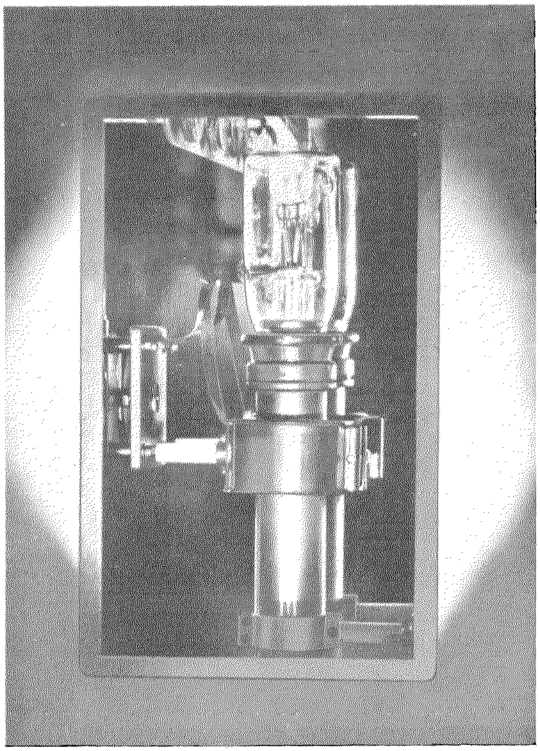


Fig. 6—View through the Window of the Pre-penultimate Radio Frequency Amplifier.

encroaching unduly on the gardens surrounding the Eiffel Tower. The vision transmitter and the terminal equipment occupy rooms of the following dimensions :

Television transmitter proper ..	120 sq. metres
High tension room	20 ,, ,,
Water-cooling plant	30 ,, ,,
Terminal and monitoring equipment	20 ,, ,, .

It will be evident that the space occupied is extremely small, particularly when it is considered that the vision transmitter equipment takes from the mains an input of 260 kVA. Equipment of unusually compact design was consequently necessary.

Fig. 4 is a view of the vision transmitter room. The high frequency exciters and the modulation amplifier are on left and right, respectively. The control desk is in the centre.

RADIO FREQUENCY UNITS

A schematic of the radio frequency portion of the transmitter is shown in Fig. 5.

The R.1 unit contains the master oscillator delivering an output power of 50 watts at 46 Mc/s. The crystal-controlled master oscillator includes a Y-cut crystal keeping the frequency constant within ± 50 parts in a million.

The fundamental frequency of the crystal is 3.83 Mc/s, but it operates on its third partial, i.e., it delivers directly a frequency of 11.5 Mc/s. The oscillator is followed by two doublers for raising the frequency to the carrier frequency of 46 Mc/s.

A one-valve buffer-stage followed by a push-pull amplifier increases the output power of the master oscillator to 50 watts.

The next unit, designated as R.2, is a push-pull amplifier with two air-cooled, type 3016-B, triodes, which deliver an output power of 500 watts. The drive from the master oscillator is applied on the grid of these two triodes by means of a parallel tuned circuit, balancing condensers being cross-connected between grid and plate of the two triodes. The output circuit

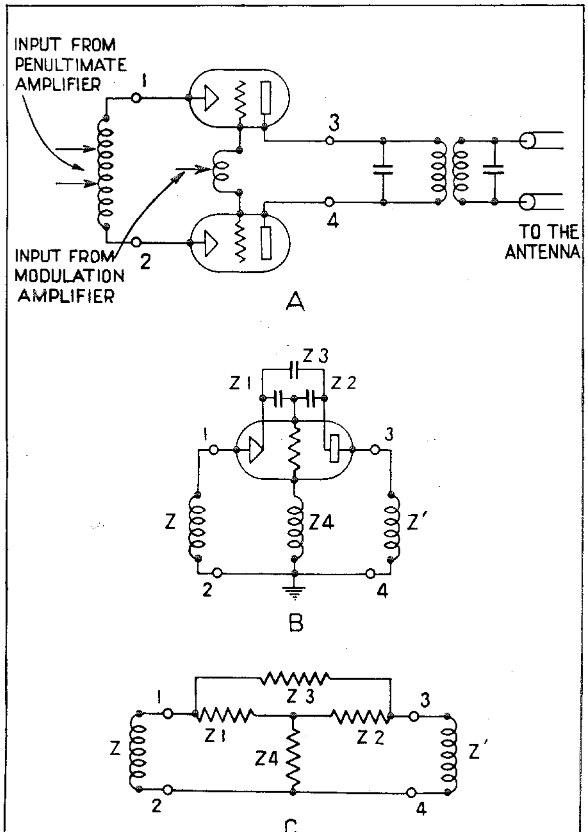


Fig. 7—Fundamental Circuit of the Output Stage of the Vision Transmitter.

is a parallel tuned circuit directly connected to the succeeding stage.

The master oscillator and the first amplifier circuit employ air-cooled valves exclusively and include all necessary filament, grid bias and anode voltage supplies, obtained from dry rectifiers operating from 220-volt, 3-phase, 50-cycle mains.

The following unit, the pre-penultimate stage of the transmitter, contains two water-cooled, type 3073-A valves connected in a push-pull circuit, similar to that of the preceding unit.

Fig. 6 shows a view, through the window of the pre-penultimate unit, of the two water-cooled triodes and of the balancing condensers surrounding the water jackets. These latter extend to the bottom of the bay and form the anode circuit of the unit. An adjustable short-circuiting device is used for tuning the plate circuit. This unit, as well as the other units of

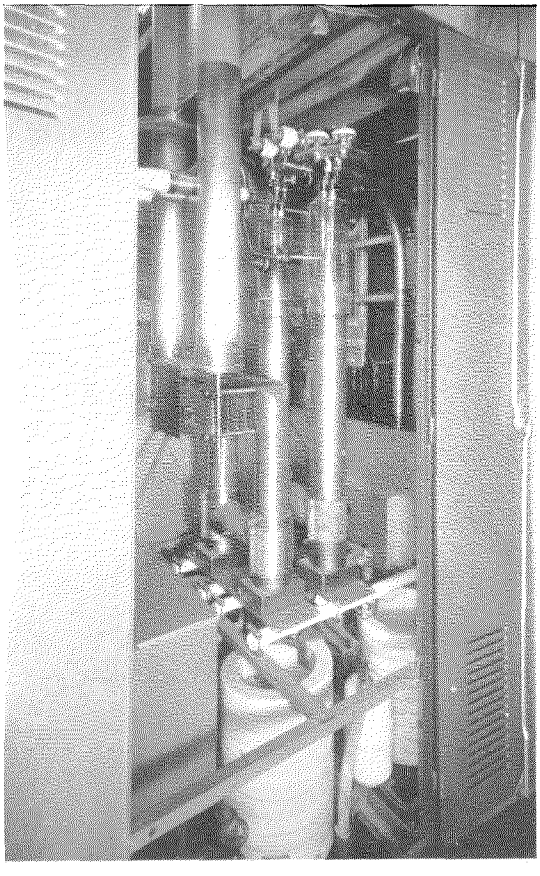


Fig. 8—Rear View of Output Stage (doors open) of the Vision Transmitter.

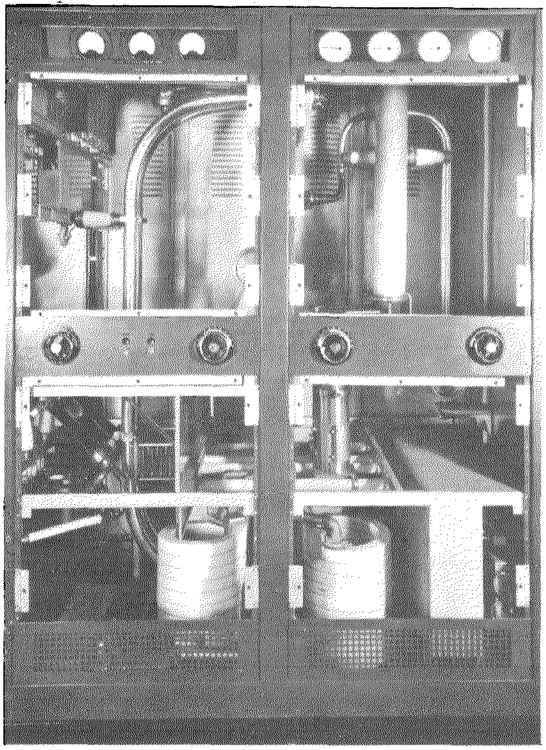


Fig. 9—Front View of the Output Stage (front panels removed) of the Vision Transmitter.

the transmitter, is built in a standard steel cabinet.

The penultimate amplifier also contains two water-cooled valves in push-pull. These are of the type 3081-A, a more powerful type than those in the pre-penultimate unit. In the penultimate amplifier the drive is applied to the filaments, rather than to the grids of the valves as in the preceding stages.

The penultimate high frequency amplifier is coupled to the final stage of the vision transmitter through two water-cooled resistances. This unusual method of coupling is due to the necessity of maintaining the load on the penultimate amplifier fairly constant over the band of modulation frequencies required, as well as to provide a sufficiently damped circuit in parallel with the input circuit of the final stage.

OUTPUT STAGE OF THE TRANSMITTER

The output stage of the vision transmitter uses two water-cooled triodes, type 3084-A. Their characteristics are as follows :

Filament voltage 3-phase A.C. (between terminals).. ..	10.5 volts

Filament current (per terminal)	123	amps.
Filament emission	18	amps.
Amplification factor	25	
Slope	7.5	mA/V
Maximum anode dissipation ..	30	kW
Grid anode capacity	23.5	μμF
Grid filament capacity ..	25.5	,,
Anode filament capacity ..	6.5	,,
Nominal waterflow	50	litres per minute
Overall length	64	cm
Maximum diameter	13	cm.

As mentioned previously, the output stage of the vision transmitter is of the so-called "inverted amplifier" type, i.e., the radio frequency drive is applied to the filaments rather than to the grids of the valves. Modulation is applied to the grids of the valves and the output circuit is coupled to the plate circuit.

A simplified schematic of the output stage is given in Fig. 7-A. The inverted amplifier, as used in this transmitter, does not require balancing condensers which, for television purposes, constitutes a big advantage over other more conventional circuits. The two valves used in the output stage of the vision transmitter are connected in push-pull. For simplification, only half of the circuit is given in Fig. 7-B.

Fig. 7-C shows more conventionally the fundamental circuit of the output stage. The reason why balancing condensers are not required for the inverted amplifiers will be apparent from consideration of this figure.

In any amplifier the ideal condition to be fulfilled with regard to balancing is that, when the drive is applied between the input terminals, no voltage should appear across the output terminals. In Fig. 7-C, this means that any voltage at carrier or sideband frequencies applied between terminals 1 and 2 must not produce any voltage between terminals 3 and 4. Selection of the impedance Z4 in Fig. 7-C (i.e., the impedance between the grids of the valves), accordingly, must be consistent with the formula :

$$Z_4 = \frac{-Z_1 Z_2}{Z_1 + Z_2 + Z_3}.$$

Experience and calculation both prove that this condition is fulfilled when a small inductance is present between the grids. For valves of the type used and for operation at 46 Mc/s, the inductance of the grid leads is higher than that required for balancing the circuit, and it has been found necessary to connect the grid terminals of the two valves by a condenser reducing the grid-to-grid inductance, including that of the grid leads, to the value required for the balance.

The immediate advantage of this arrangement is that the effective plate-to-plate capacity of the output amplifier is only about 50% of the grid-to-plate capacity of one valve plus a small increment due to the other bridge components.

The effective plate-to-plate capacity of an inverted amplifier, balanced according to the method described above, is only about 60% of the plate-to-plate capacity of an amplifier using similar valves in the conventional circuit and fitted with balancing condensers.

Furthermore, with an amplifier using equivalent valves in the conventional manner, the physical lengths of the arms of the funda-

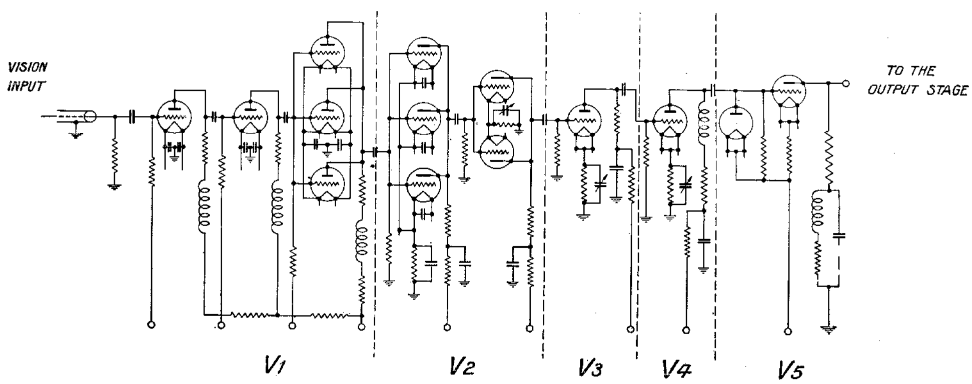


Fig. 10—Schematic of the Modulation Amplifiers.

mental bridge would not be negligible with respect to the wavelength. It would thus be difficult to maintain the balance of the bridge over the whole of the sideband frequencies.

On the other hand, with a properly dimensioned inverted amplifier, the reactions which result from the operation of the valves tend to maintain the balance of the fundamental circuit of Fig. 7-C over the entire range of the sideband frequencies.

In the inverted amplifier, the grid-filament portion of the valves is common to both the input and output circuits. Hence, electrons flowing between filaments and grids produce a voltage in the filament circuit *which opposes* the drive, i.e., a negative feedback is produced in opposition to the drive.

As will be seen from Fig. 8, except for a very small adjustable condenser, no plate condenser is used and nearly the whole of the circulating current of the plate circuit passes through the inter-electrode grid-plate capacity of the valves and returns through the grid circuit. The grid-to-grid impedance is adjusted to be equivalent to a positive reactance and the circulating plate current, between the grids, produces a voltage which adds to the effect of the drive ; in other words, a positive feedback adds to the drive. These two reactions (negative feedback in the filament circuit, and positive feedback due to the grid-to-grid inductance) would completely upset the operation of the output stage at carrier and sideband frequencies if one were much *larger* than the other. However, it has been found possible, by careful design of the filament, grid and plate circuits, to make the resultant of these two effects fairly constant over the band of frequencies required, and to utilize only a small amount of negative feedback. This renders the output stage perfectly stable during modulation peaks, and also tends to keep the harmonic distortion at a very low value.

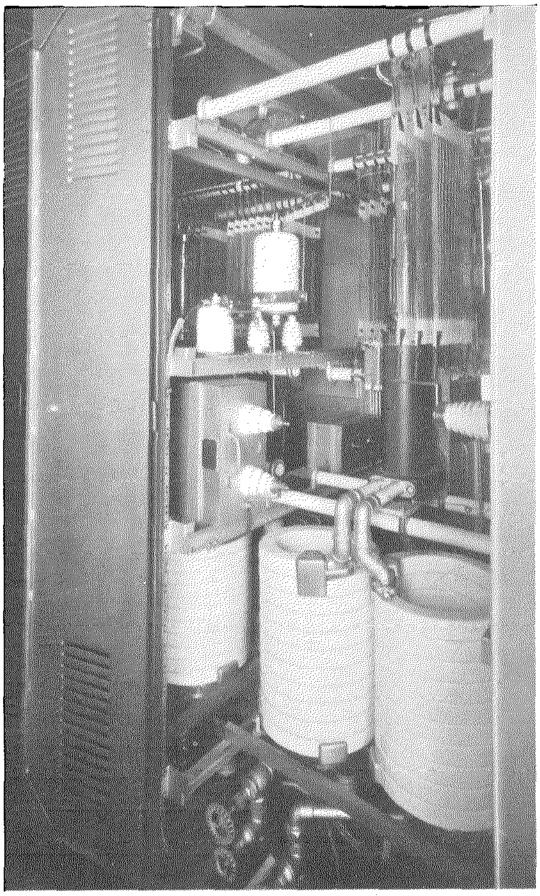


Fig. 11—Back View of the Output Stage of the Modulator (doors open).

Neither a condenser nor an inductance is connected directly between the filaments, the circuit being tuned by means of a condenser connected at the end of the quarter-wave matching transformer remote from the filaments.

To balance the output stage, a capacity is required between the grid terminals of the valves. A condenser, if used, should be capable of carrying the full plate tank current, about 35 amps. RMS for 100% amplitude. For this current, its overall dimensions and capacity to earth necessarily would be rather large, representing an important load for the output stage of the modulation amplifier. To minimize the capacity to earth of the grid circuit, an equivalent network consisting of a quarter-wave transmission line with its far end terminated by an adjustable choke coil is used in place of a condenser. The mid-point of the inductance is connected to the output stage of the modulation amplifier.

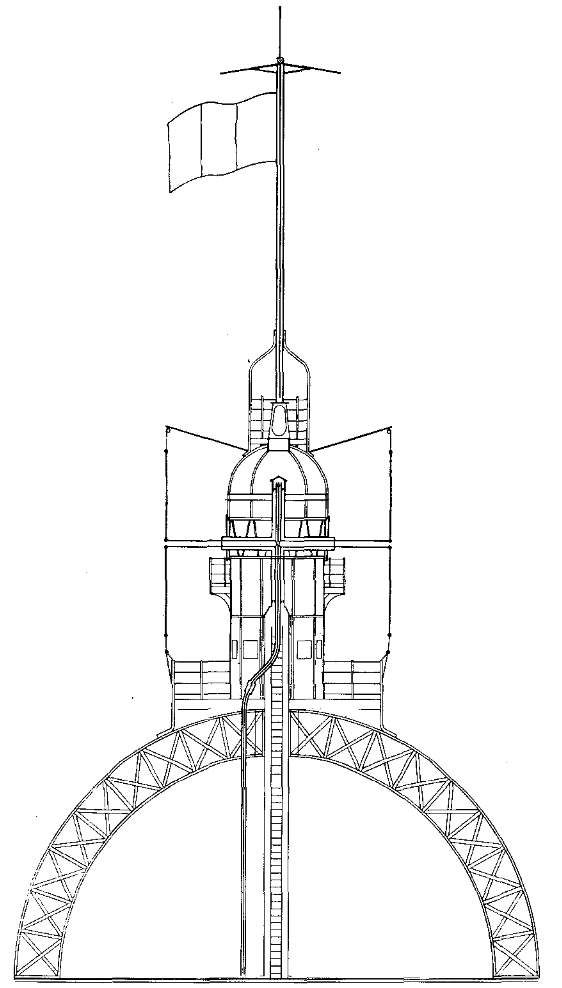


Fig. 12—Outline Sketch of Aerials: The sound antenna is at the top of the flag pole; the vision antenna surrounds the top part of the Tower a few metres below the bottom of the flag pole.

The output circuit is a parallel-tuned circuit made with copper pipes of the same dimensions as the water jackets of the valves. The step-down ratio of the output circuit reduces the impedance to about 500 ohms.

The output circuit is connected through quarter wavelength transformers to the inner conductors of a pair of coaxial cables joining the output stage to a junction box which terminates the coaxial cable feeding the antenna.

The junction box, placed on the roof of the transmitter building and about 15 metres away from the output stage, consists of an adjustable quarter-wave transformer matching the impedance of the antenna feeder, i.e., 60 ohms, to that of the two coaxial lines to the transmitter, i.e., 175 ohms. This transformer can be connected either to the outgoing feeder or to an artificial load for test purposes.

MODULATION AMPLIFIERS

The modulation amplifier is illustrated schematically in Fig. 10. It is arranged to work from an input level, for white images, of 4 volts peak. The input impedance of the first amplifier is equal to the characteristic impedance of the coaxial cable feeding the vision signal into the modulation amplifier, i.e., 100 ohms.

In the first two units of the modulation amplifier, air-cooled triodes are used; the three last units contain water-cooled triodes, type 3053-A.

The characteristics of the type 3053-A triode are as follows:

Filament voltage	19.5 volts
Filament current	67 amps.
Filament emission	7 amps.
Amplification factor	6.5
Slope	7.8 mA/V
Maximum anode dissipation	20 kW
Grid anode capacity	40.5 $\mu\mu$F
Anode filament capacity	3.5 ,,
Grid filament capacity	36.5 ,,
Overall length	75 cm
Maximum diameter	10.5 cm.

The various valves used are operated as Class A resistance-capacity coupled amplifiers. Correction in the upper part of the video frequency band is obtained by shunting the cathode resistances, either wholly or partially,

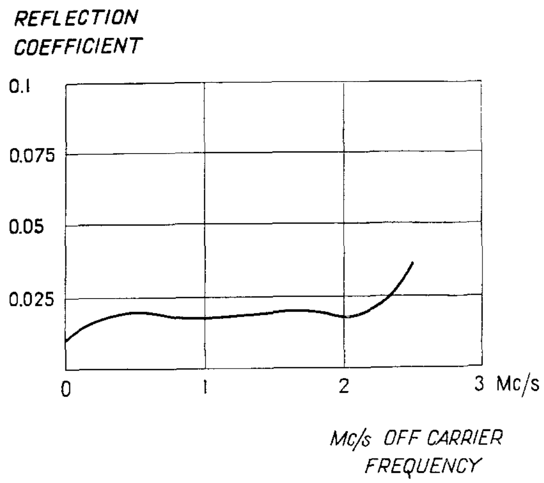


Fig. 13—Reflection Coefficient of the Vision Antenna.

with correcting condensers, thus reducing the amount of negative feedback at the higher frequencies.

The plate resistances in the low power stages are wound so as to be as non-inductive as possible. For the medium and high power stages, resistances of the mat type are used, wound on an asbestos support.

As previously mentioned, the wave form of signals meeting French television standards is such that amplitudes below 30% are used exclusively for synchronization, whilst amplitudes between 30% and 100% are reserved for transmission of the vision signals proper.

Another requirement of the French television standards calls for the amplitude of the high frequency signals radiated by the transmitter being less than 5% of the full amplitude during transmission of synchronization signals. To meet this condition with the various types of vision signals which might be obtained within the limits of the French television standard, it was found necessary to take as a reference the only factor common to all systems, i.e., suppressions of the carrier during the transmission of the synchronization pulses. Consequently, the output stage of the modulation amplifier and the final stage of the transmitter were arranged for invariable and complete modulation of the transmitter during transmission of the synchronization pulses.

This constant depth of modulation is obtained (as also in broadcast transmitters operating on the well-known " floating carrier " system) by means of a diode connected between filament and grid of the output valve in the modulation amplifier (see Fig. 10). The circuit arrangement is such that the amplitude of the carrier of the transmitter is adjusted in terms of the vision signal to be transmitted.

Suitable operation of the constant modulation depth system is only possible if the output stages of the modulation amplifier and of the transmitter are directly coupled and arranged to pass correctly a frequency band extending down to zero. Since it is not possible to realize rectifiers and associated smoothing circuits with an internal impedance sufficiently low for frequencies down to zero, a special correcting network is provided in the anode circuit of the output stage of the modulation amplifier. This network opposes the detrimental effect of the rectifier impedance at low frequencies.

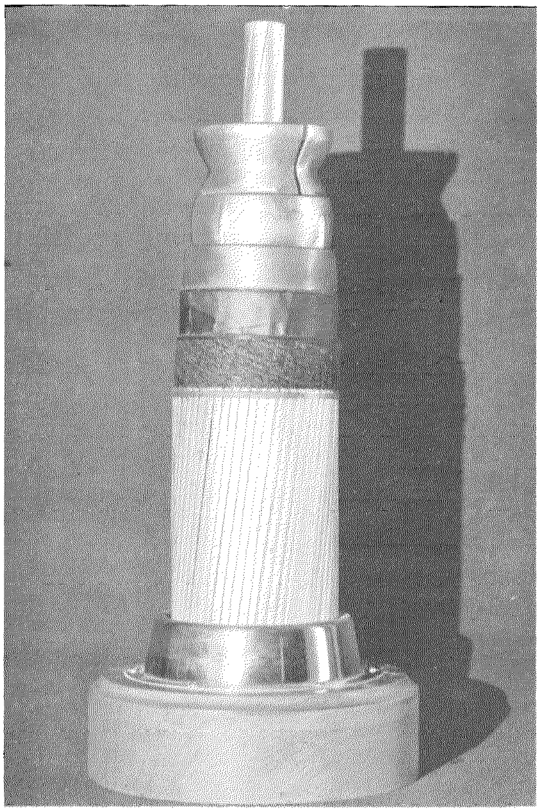


Fig. 14—A Section of the Semi-flexible Coaxial Cable used to feed the Antenna.

To permit the direct connection of the modulation amplifier to the grids of the final stage of the transmitter, the filament of the last modulation valve is insulated from earth and must withstand the full D.C. voltage of the high tension rectifier, the positive terminal of which is at earth potential.

Fig. 11 shows a rear view of the output stage of the modulation amplifier with doors open. At the upper part of the unit the filament and plate resistances are supported by steatite rods. The lay-out of the unit is arranged to minimize the capacity to earth of the various components. The lower part of the bay contains porcelain coils for the water-cooling of the valve.

The operating conditions of the output stage of the modulation amplifier are as follows :

Plate impedance : 1 400 ohms, increasing to 2 600 ohms for D.C.
Plate current corresponding to white : 1 amp.
Plate current corresponding to the cut-off of the transmitter : 2.85 amps.

The filaments of the valves in the modulation amplifiers are D.C. fed from selenium rectifiers. The rectifier capacities to earth are kept to a minimum so as to reduce their effect on the correcting condensers in parallel with the cathode resistances.

The control desk in the centre of the transmitter room facilitates the operation of the equipment. It includes a meter panel for checking the high tension rectifier currents and voltages.

In addition to the door contacts (providing electrical security), a mechanical interlocking system is used for preventing the doors of the various cubicles from being opened unless the high tension busbars have been earthed.

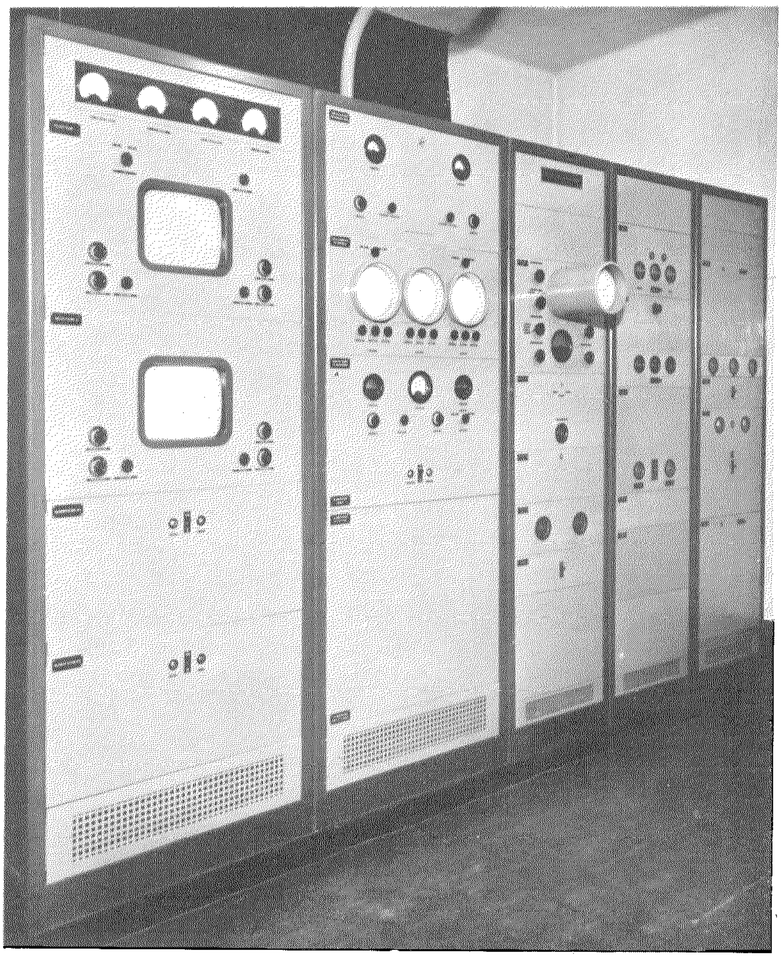


Fig. 15—Front View of the Monitoring Equipment.

ANTENNA SYSTEM

Fig. 12 shows the disposition of the antenna at the top of the Eiffel Tower. The antenna consists of eight vertical push-pull dipoles, each formed by two vertical frames one-half wavelength long. The aerials, as stated above, are centre fed by means of quarter-wave transmission line sections connected to four matching transformers projecting from the antenna equalizer box through the windows of the Tower beacon. The distance of the eight antenna elements from the centre of the Tower is approximately one-half wave. To prevent an unbalancing effect due to the balcony at the top of the Tower, a screen of copper wires, equivalent to a conducting cylinder about one-half wavelength in diameter, covers the whole of the upper part of the structure.

The coaxial cable coming from the bottom of the Tower ends in the antenna equalizer box, which is a cylinder one-half wavelength long. The cable from the transmitter is fed into the lower half of the box, whilst opposite it, projecting from the top of the box, is a quarter-wave short-circuited section of a coaxial line.

The outer conductor of the cable from the transmitter is connected to the inner conductor of this compensating element, whilst the outer conductor of the compensating element is connected to the inner conductor of the coaxial cable from the transmitter. The body of the box itself and the outer surface of the outer conductor of the coaxial cable, as well as of the compensating section, also constitute quarter-wave short-circuited coaxial lines in parallel with the antenna.

The characteristic impedance of these concentric lines is chosen so as to compensate the impedance variation of the antenna system over the range of frequencies required for the transmissions of the sidebands, and also to obtain a correct energy transfer into the antenna which, with respect to the frame of the Tower, is a symmetrical network, whilst the coaxial

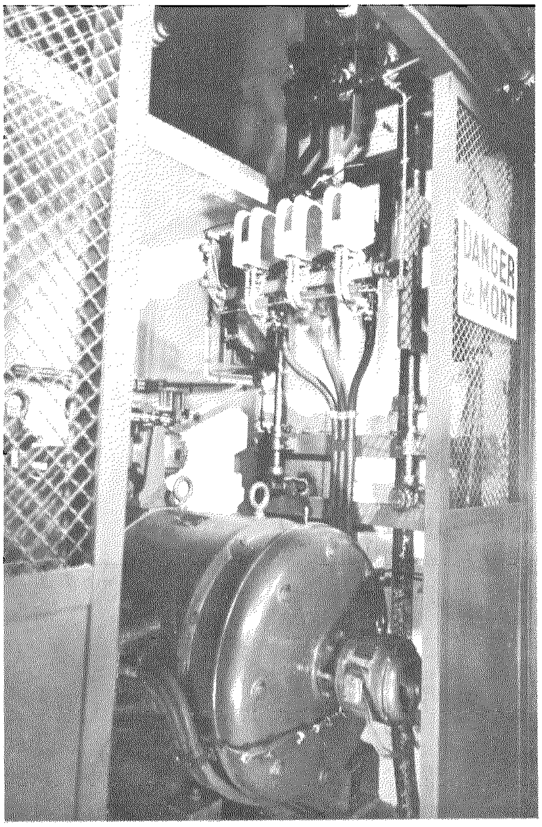


Fig. 16—*Incoming Power Supply Cubicle.*

cable from the transmitter has its outer conductor grounded to the frame.

The characteristic impedance of the four matching transformers (contained in the four arms extending from the antenna equalizer box through the windows of the upper part of the Tower), is adjustable by means of movable flanges fixed inside the arms.

Outside the Tower, quarter-wave short-circuited open wire lines are connected across

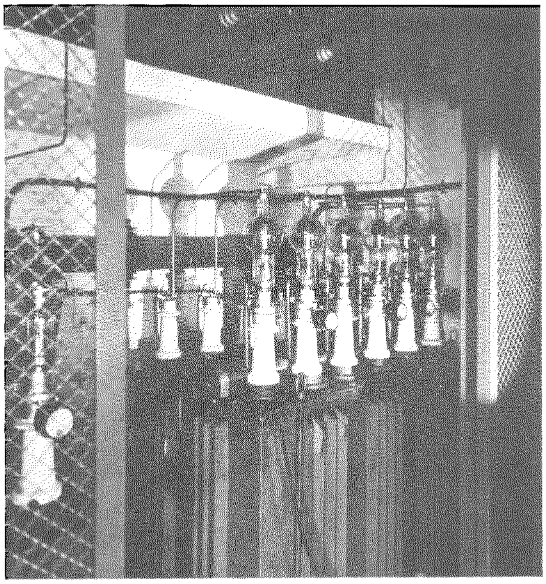


Fig. 17—*One of the Hot Cathode Mercury Vapour Rectifier Units supplying the High Tension to the Power Stages of the Transmitter.*

the terminals of the matching transformers. Their characteristic impedance can be varied by inserting adjustable shields between conductors.

Fig. 13 shows the reflection coefficient of the antenna, i.e., the amplitude of the wave reflected into the cable feeding the antenna, due to mismatching of the antenna at the carrier or sideband frequencies.

Fig. 14 illustrates a section of the coaxial cable used to join the transmitter to the antenna. This cable, manufactured by the Allgemeine Elektricitäts-Gesellschaft, is of the semi-flexible type. Its characteristics are as follows :

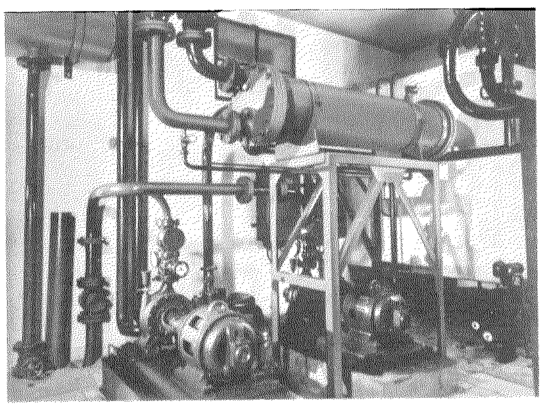


Fig. 18—*Water Cooling Plant.*

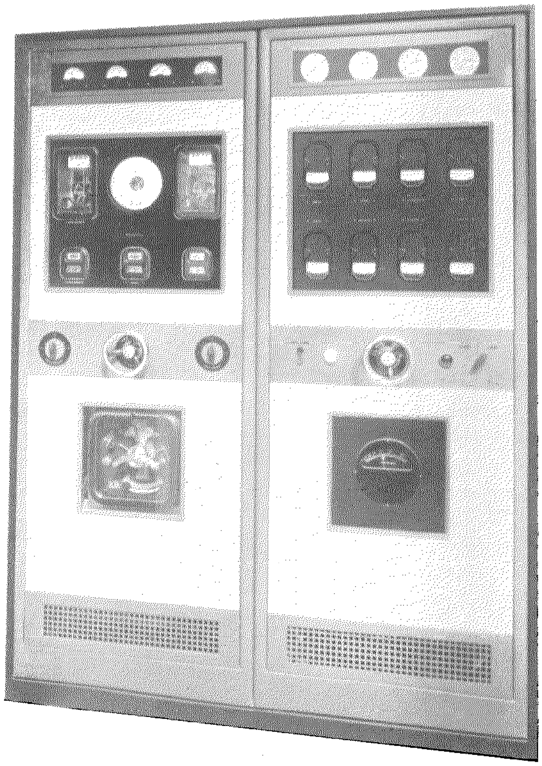


Fig. 19—Power and Water Control Board.

Diameter of the inner conductor	28 mm
Inner diameter of the outer conductor	94 mm
Spacing of insulators	304 mm
Outer diameter including armouring wires..	128 mm
Weight	30.5 kg per m
Characteristic impedance ..	60 ohms
Attenuation at 40 Mc/s	0.36 db. per 100 m
Attenuation at 50 Mc/s	0.42 db. per 100 m.

The cable has been installed in six sections, each joined by elements similar to those constituting the cable. The total length of the cable between the transmitter and the antenna is about 360 m which, for the carrier frequency of 46 Mc/s, corresponds to an attenuation of 1.41 db., i.e., an efficiency of 72%.

MONITORING EQUIPMENT

Extensive monitoring facilities are provided. Fig. 15 shows the monitoring units, which are installed in the same room as the terminal equipment of the cable bringing the vision signals from the studio.

The monitoring equipment receives incoming and outgoing signals and also signals from a cathode-coupled valve picking up the signals at the output of the modulation amplifier. The rectified outgoing signal is obtained from a diode rectifier coupled to the antenna feeder, this detector being provided with two separate cathode-coupled output valves.

A switching panel enables the incoming and outgoing signals to be applied to either of two cathode ray oscillographs or to either of two monitoring television receivers, thus providing means for comparing input and output wave forms at either line or frame frequency, or input and output images. Input potentiometers enable the level of both signals to be adjusted to the same value to facilitate comparison.

Provision is made to modulate the transmitter with sine wave signals produced by a signal generator covering a frequency range from a few cycles up to 4 Mc/s.

When using sine wave signals, switches on the monitoring cathode-ray oscillographs enable the modulation depth and the phase distortion of the transmitter to be measured directly by applying the input video frequency signal to the horizontal plates of the cathode ray tubes, and the modulated radio frequency signal or the detected radio frequency signal to the vertical plates.

POWER AND WATER EQUIPMENTS

Except for the pumps used in the water circulation system no rotating machines are employed. The various power and water equipments are respectively assembled in two separate rooms. The power room consists of concrete cubicles closed at the front by sliding doors, interlocked with earthed switches. Fig. 16 is a view of the incoming power supply cubicle. The station is fed from 500-volt, 3-phase, 50-cycle mains. An induction regulator controlled by a relay maintains the supply voltage constant. The low power stages are fed by 220-volt, 3-phase A.C. through a step-down transformer. Filaments of the radio frequency exciters and of the output stage are A.C. fed, using Scott-connected transformers for the exciter valves and 3-phase A.C. for the valves of the output stage of the transmitter. The various valves of the modulation amplifiers are fed by D.C. from individual dry rectifiers.

All the units using air-cooled valves include their own high tension rectifiers, whilst all the units using water-cooled valves obtain their

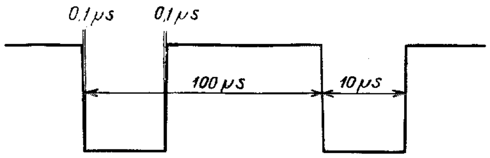


Fig. 20—*Square-wave Signal used for the Alignment of the Equipment.*

high tension supplies from hot cathode mercury vapour rectifiers. The several hot cathode mercury vapour rectifiers are enclosed in two cubicles of the power room ; Fig. 17 shows a view of the high tension rectifier of the output stage of the modulation amplifier. Separate rectifiers are used for all units equipped with water-cooled valves in order to avoid undesirable couplings. The hot cathode mercury vapour rectifiers are of the so-called tank type in which the rectifier valves are mounted on top of the transformer bushings, the transformer tank containing in addition to the high tension transformer, the filament transformers and the smoothing choke coils. The smoothing condensers are assembled above the rectifier in concrete cubicles. Off-load taps and star-delta switches enable the output voltage of the rectifiers to be varied while testing the transmitter. Each hot cathode mercury vapour rectifier has its individual contactor rack which, in addition to the contactors of the rectifier, contains the contactors controlling the filaments of the water-cooled valves.

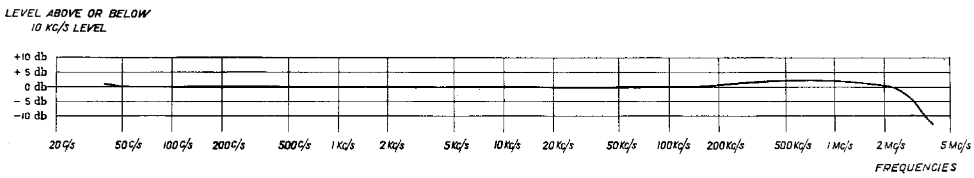


Fig. 21—*Overall Frequency Response Curve of the Vision Transmitter.*

Switching of the filament and of the high tension supplies is performed in two steps, the first step inserting a resistance, whilst the second step short-circuits this resistance.

The water-cooling of the valves is effected by distilled water in a closed circulation system, the distilled water being cooled by water-to-water cooling.

Two pumps, each capable of 600 litres per minute flow, are used, one as a spare to the other. The water system is designed to handle a 200 kW dissipation. Fig. 18 shows the water cooling plant. The incoming power supply and the water system are controlled from a power and water control board (Fig. 19), whilst the various filament and high tension circuits are controlled from the control desk visible in Fig. 4.

ADJUSTMENT OF THE TRANSMITTER

The adjustment of the modulation amplifiers consists mainly in setting the correcting condensers in parallel with the feedback resistances to their optimum value. With properly proportioned components, this adjustment is relatively simple, but checking signals should be available.

Most of the alignment work was done with the signal shown in Fig. 20. The most difficult problem connected with the modulation amplifiers was the elimination of all irregularities resulting from the various high tension supplies, wiring, cables and by-pass condensers. Any spurious resonance up to 4 Mc/s must be carefully avoided. It was, for example, necessary to terminate all lead-covered high tension cables connecting the rectifier room to the transmitter room by their characteristic impedances.

The determination of appropriate impedances

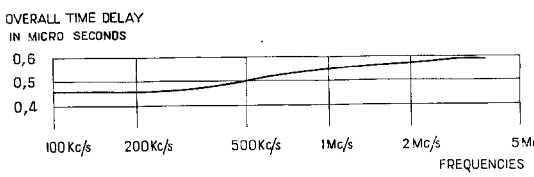


Fig. 22—*Overall Time Delay Curve of the Vision Transmitter.*

of filament, grid, and plate circuits of the output stage of the transmitter for obtaining the correct band-width presented a special problem. Experimental and theoretical work was carried on simultaneously. When these impedances are determined, the adjustment of the output stage is extremely simple.

Proper setting of the grid circuit is done first with the filament cold, the correct setting being such as to prevent coupling between the filament and plate circuits with both the latter tuned to resonance. When the filaments are hot and the high tension is applied, a slight modification in the setting of the grid circuit is required. The final setting is obtained when the high frequency drive from the penultimate stage is prevented from passing into the output circuit, the filament and plate circuits being tuned to resonance and the output stage biassed to cut-off. Final settings of the filament and plate circuits depart slightly from the resonance points ; they are arranged for obtaining both a good frequency response curve and minimum phase distortion.

Since the output stage works into a low plate impedance and very effective damping is provided between the penultimate and output stages, the setting of the final amplifier is almost completely independent of slight changes in the filament and plate circuit tuning or in the valve characteristics. The substitution of valves with characteristics within reasonable manufacturing limits does not necessitate readjustment of the penultimate or output stages.

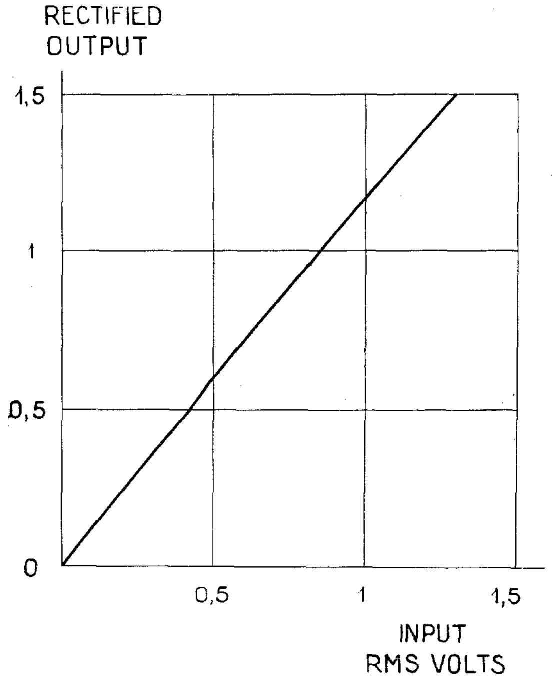


Fig. 23—Amplitude Response Curve at 10 kc/s.

PERFORMANCE

The measurements necessary for checking the operation of a television transmitter are far more numerous and complex than those ordinarily required for the acceptance tests of broadcast transmitters. The bandwidth, in the case of the Eiffel Tower television transmitter, covers 6 Mc/s (3 Mc/s both sides of the carrier frequency) and is 300 times greater than that of broadcast transmitters. In broadcast transmitters, moreover, it is almost always possible to connect measuring gear on each circuit ; in a television transmitter, it is nearly always impossible. Special coupling circuits must be provided or, alternatively, the input impedance of the measuring equipment must be high in comparison with that of the circuit to be checked. The use of measuring equipment of high input impedance is, however, extremely difficult in the vicinity of a powerful U.S.W. transmitter.

Up to now, it has not been normal practice to measure phase distortion in broadcast transmitters, but such measurement is essential in television transmitters. For broadcast transmitters, measurements are nearly always made with sine waves ; for television transmitters, the particular shape of the vision signal must be taken into consideration and, for some of the measurements, special signals are required.

In broadcast transmitters the effect of sudden variations of the power supply voltage is relatively unimportant or not transmitted by the equipment. In television transmitters, on the contrary, any amplitude change in the power supply voltage is immediately visible in the image, even if the level of the interference is 30 db. below the image level.

For the alignment and acceptance tests of the Eiffel Tower television transmitter, most of the necessary measuring equipment had to be developed. It includes :

Wide-band video amplifier for television monitoring ;
Modulation meter for television transmitter ;
Square wave signal generator for television monitoring ;
1, 10, 100, 1 000 kc filters for harmonic content measurement ;
U.S.W. standing wave measuring set on open-wire line ;
U.S.W. standing wave measuring set on coaxial line ;
Open-wire line parallel current measuring unit for U.S.W. ;
40 to 50 Mc/s variable frequency oscillator ;
Screened U.S.W. transformer for measurements on coaxial cables.

For making measurements with sufficient accuracy, the measuring equipment was developed with characteristics appreciably better than those of the transmitter ; in fact, most of it meets the following guarantee :

Frequency response curve within 0.5 db. for a frequency band extending up to 3 Mc/s ;
Harmonic distortion less than 1% ;
Frequency response of monitoring receivers within 1 db. up to 3 Mc/s.

The performance of the vision transmitter as a whole is such that a frequency band of 3 Mc/s is transmitted without appreciable distortion.

The overall frequency fidelity of the transmitter at 50% modulation is as follows :

Modulation Frequencies	*db. gain or loss over 10 kc/s level*
50 c/s	+ 2 db.
1 Mc/s	+ 2.1
1.5 ,,	+ 1.2
2 ,,	+ 0.5
2.5 ,,	— 1.7
3 ,,	— 4.5
3.5 ,,	— 9.8
4 ,,	— 12.5.

These results are reproduced in Fig. 21, which shows the overall frequency response curve of the transmitter.

The overall time delay varies from 0.46 microsecond at 100 kc/s to a maximum of 0.59 microsecond at 2.7 Mc/s ; i.e., a maximum variation of 0.13 microsecond. Fig. 22 shows the variation in time delay from 100 kc/s up to 4 Mc/s. For frequencies below 10 kc/s the phase shift is not appreciable.

The harmonic contents measured at 80% modulation are :

Modulation frequency in kc/s	*Harmonic Contents*
1	1.8%
10	2.1%
80	2.1%
900	3.15%.

The curve of Fig. 23 gives the amplitude response of the transmitter at 10 kc/s. As will be seen from this curve, practically no visible amplitude distortion occurs at 10 kc/s.

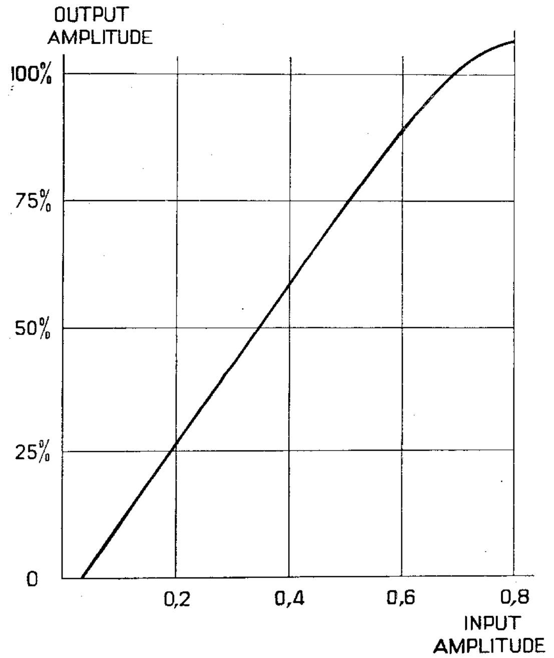


Fig. 24—Operation of the "Constant Modulation Depth" Regulator.

To meet the requirements of the French television standard the transmitter, as mentioned above, is operated under a "floating carrier system." The performance of the latter system is indicated in Fig. 24, which gives the amplitude of the radio frequency output of the transmitter in terms of the amplitude of the square-wave signal, shown in Fig. 20, applied to the input terminals of the modulation amplifier.

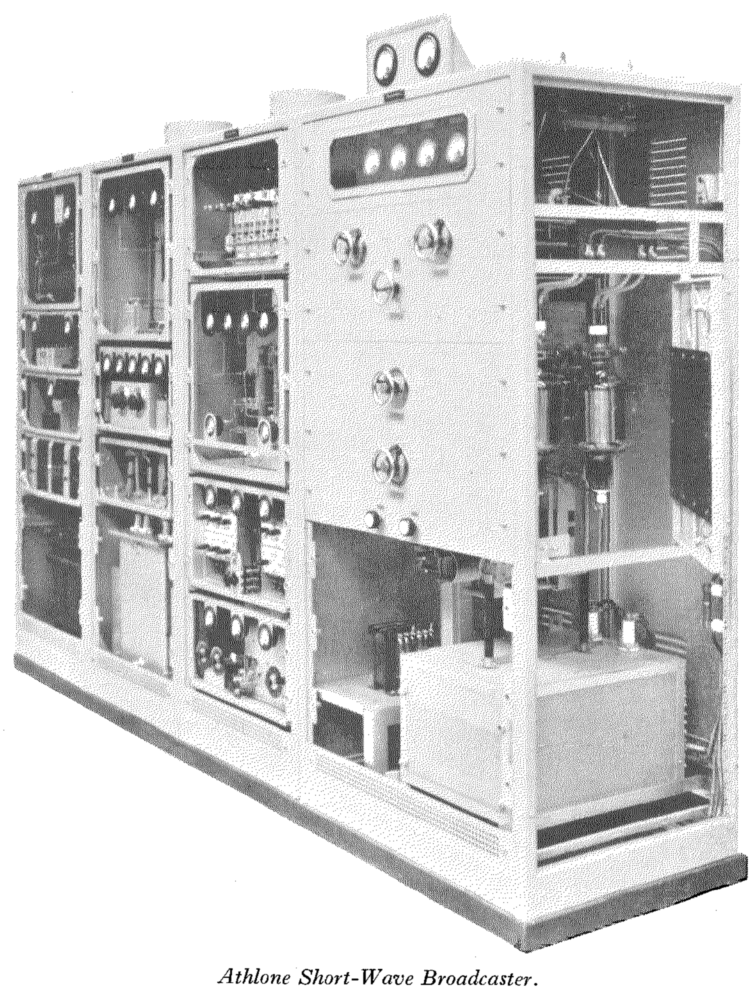
For an output of 35 kW, the overall power consumption of the transmitter is 233 kW with a power factor of 0.92. When not transmitting signals, the output power of the transmitter falls to zero and the power consumption to 140 kW. For an image of average brightness which, according to the French television standard, corresponds to an amplitude of about 65% of the peak amplitude required for a white image, the power consumption is about 200 kW.

Recent Telecommunication Developments of Interest

Athlone Short-Wave Broadcaster.—Standard Telephones and Cables, Limited, London, recently completed the installation at Athlone of a central short-wave Broadcasting Transmitter to the order of the Irish Post Office. This transmitter has been installed initially for a power of 1–1.5 kW, but the design is such as to facilitate future extension, as circumstances warrant, up to the highest powers used in short-wave broadcasting.

Basically the transmitter is similar in design to the low power stages of the two 50 kW "Standard" short-wave Broadcasting Transmitters used by the British Broadcasting Corporation at Daventry for the Empire Broadcasting Services. High efficiency Class "B" modulation is used, giving maximum economy in power consumption, a distortion content less than 4 % at 90 % modulation, and an overall frequency response characteristic level to within ± 1 db. between 30 and 10 000 p : s.

Although this type of equipment is normally designed for crystal controlled operation, the special requirements for the Athlone station were met by a high stability variable frequency master-oscillator. The transmitter is arranged to operate over the whole range from 15 to 80 metres.



Athlone Short-Wave Broadcaster.

All power supplies are taken from A.C. mains through transformers and rectifiers, no rotating machinery whatsoever being used. The power supply apparatus is built into a cabinet of the same design as the transmitter proper, and is lined up with the transmitter cabinets.

Reports received during the short time the transmitter has been on the air show that the transmissions have been at times satisfactorily received in places as far distant as Newfoundland, South Africa, Italy, Portugal and many towns throughout the United States of America.

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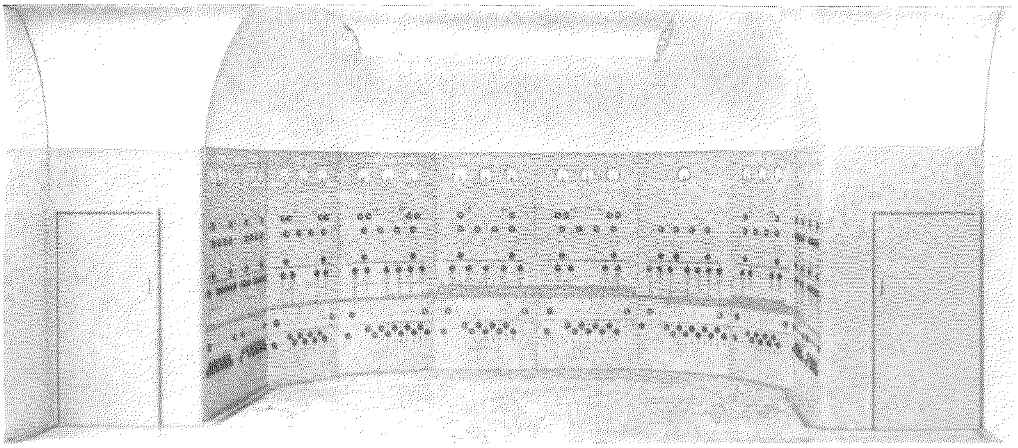
High Power Broadcaster for Bangkok.—The new 100 kW medium wave broadcasting transmitter and studio equipment for the Siamese Administration, ordered from Standard Telephones and



Scale Model of proposed Control Room for the London Passenger Transport Board's Northern Extension.

Cables, Limited, London, will employ the high efficiency Class "B" system of modulation which is used in the Empire Broadcasting Station at Daventry as well as in the four latest medium wave British stations at Stagshaw, Aberdeen, Start Point and Bristol, and also at Kaunas, Lithuania, and Melnik, Czechoslovakia. In order to increase the fading-free area of the transmitter, the station will be equipped with a Blaw-Knox vertical radiator, 640 feet in height.

The new transmitter building will be located 15 km from the new studios to which it will be joined by a programme cable. The studio building will house eight studios of various types. The studio amplifiers, employing the latest feed-back circuits, will be similar to those used for the new Copenhagen Broadcasting House and the Swiss Studios at Basle, Zurich and Lugano.

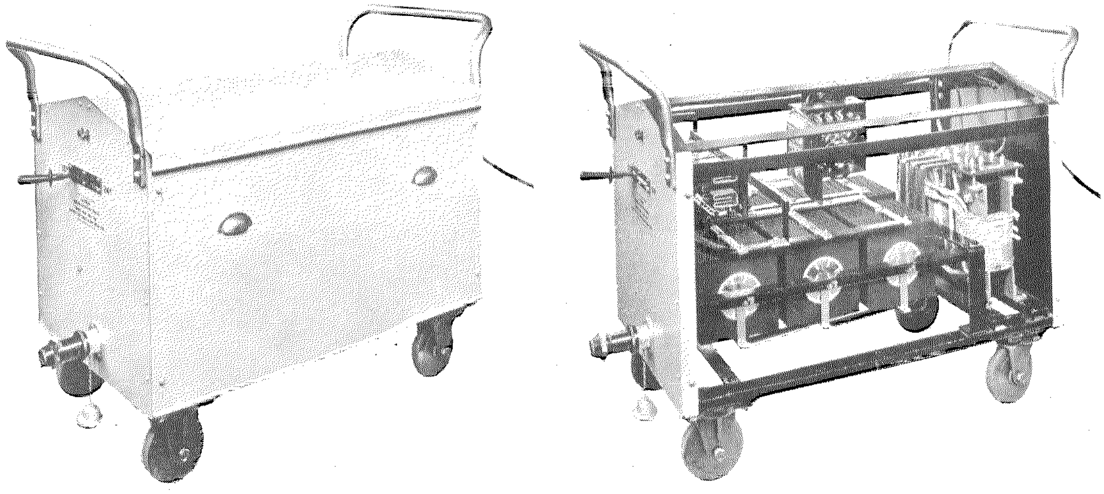
The whole system will be placed in service in the early part of 1940.

● ● ●

Remote Control of Power Stations.—The application of telephone technique and telephone type apparatus is making great advancement in the control circuits of heavy electrical engineering equipment in many countries. One recent instance is an order received by Standard Telephones and Cables, Limited, London, as sub-contractors to the English Electric Co., Stafford, for the supply of remote control, indication and telemetering equipment for ten substations on the new extension of the London Passenger Transport Board's underground railway from Highgate over the London & North Eastern Railway Company's lines to High Barnet and Edgware.

The equipment covers the remote operation and indication of upwards of 260 circuit breakers, and telemetering of the load on 18 machines as well as of D.C. bus-bar voltages and air pressures at each substation. All of these functions are effected from the control point over one pair of telephone wires to each substation.

Radio-telephone Installation in the Douglas (Isle of Man) Lifeboat.



Portable Rectifier Unit.

Lifeboat Radio Telephone.—The Royal National Lifeboat Institution's lifeboat *Manchester and Salford*, stationed at Douglas, Isle of Man, is the latest of a number of these boats to be fitted with radio telephone equipment by the International Marine Radio Company, Limited, London. Although these equipments are only required to provide short distance communication between the boats and their shore stations, or with ships in distress, the Douglas boat, in sea trials to test the new installation, successfully carried on a two-way radio telephone conversation with the London *Daily Telegraph* via the Post Office radio station at Seaforth, nearly 70 miles away, and 200 miles of land line. It is understood that this was the first occasion on which a lifeboat at sea spoke to an ordinary telephone subscriber. The illustration on page 399 shows the I.M.R.C. apparatus installed in the fore-cabin of the Douglas lifeboat. The aerial runs between the main and mizzen masts, and is erected simultaneously with the hauling up of the masts after the boat takes the water.

• • •

Portable Rectifier Unit.—For starting airplane engines, a unit has been designed by Standard Telephones and Cables, Limited, London, to operate from a 400/440 volt 3-phase A.C. supply and to give an output either of 12 volts at 300 amps. or 24 volts at 150 amps. on a short-time rating. Two banks of selenium rectifiers are arranged to be connected in series or parallel according to the voltage required. A second unit rated at 24 volts, 300 amps. continuously, or 700 amps. intermittently, is available for starting Diesel omnibus engines.

ERRATUM

Electrical Communication, Vol. 17, No. 3, January, 1939, "Electrical Communication in 1938":
Page 215, first paragraph, lines seven and eight: "a few hundred microseconds" should read "a few hundredths of a microsecond."

Licensee Companies

Bell Telephone Manufacturing Company .... *Antwerp*
Branches : Brussels
Bell Telephone Manufacturing Company .... *Berne*
Bell Telephone Manufacturing Company .... *The Hague*

China Electric Company, Limited .... *Shanghai*
Branches : Hongkong, Tientsin, Canton, Kunming.

Compagnie des Téléphones Thomson-Houston .... *Paris*

Compañía Radio Aerea Maritima Española .... *Madrid*

Compañía Standard Electric Argentina .... *Buenos Aires*

Creed and Company, Limited .... *Croydon (England)*

Fabbrica Apparecchiature per Comunicazione Elettriche .... *Milan*
Branch : Rome.

International Marine Radio Company, Limited .... *London*

Jugoslavian Standard Electric Company, Limited .... *Belgrade*

Kolster-Brandes, Limited .... *Sidcup (England)*

Le Matériel Téléphonique .... *Paris*

C. Lorenz, A.G. .... *Berlin-Tempelhof*

Mix & Genest Aktiengesellschaft .... *Berlin-Schöneberg*

Nippon Denki Kabushiki Kaisha .... *Tokyo*
Branches : Osaka ; Dalny (Dairen, Manchuria) ; Taihoku (Formosa).

Société Anonyme les Téléimprimeurs .... *Paris*

Standard Electric Aktieselskab .... *Copenhagen*

Standard Electric Company w Polsce Ska z O. O. .... *Warsaw*

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