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Panclimatization of Telephone Equipment

FOR many years, the Company has maintained a high reputation for the manufacture of telephone equipment designed to give long and efficient service under tropical or adverse climatic conditions. Investigation, development and tests are carried out continually by a section of the process engineering department, a specially equipped laboratory providing the apparatus necessary for accelerated and other tests. Fig. 1 is an example of one of the methods used for accelerating the effects of weather on panels having various protective finishes.

Fig. 1—Accelerated Weathering of Specimen Panels

New materials, processes, and designs are examined so that their performance and durability can be assessed under various climatic conditions which are simulated by humidity cabinets, refrigeration, salt spray, "Weather-Ometer" etc. Provision is also made so that the effects of dust and chemical corrosion can be investigated. Telephone engineers will appreciate that it is not wise to rely wholly on accelerated tests; these are therefore supplemented by field trials under actual service conditions in many parts of the world. In this connection, the reports and assistance given by friends overseas and their representatives in this country are of great value and are gratefully acknowledged. Reference should also be made to the close collaboration which exists with the suppliers of raw materials, the joint study of various problems being of great assistance to progress.

In recent years many new materials and processes have been developed in the fields of insulating materials, plastics, ferrous and non-ferrous metals and protective finishes. The Beeston factory has already applied a large number of these innovations, with considerable advantage, while a progressive future for further developments is also assured. It may be considered that the increased provision of air conditioning for telephone exchanges in tropical or humid climates may render this work less vital, but it must be remembered that the period for shipment and installation has also to be considered, while lower maintenance costs, longer life, and reduced fault liability are constant objectives. This point, no doubt, prompts overseas telephone engineers to express the view that the highest practicable standards are the most desirable and economical in the long run. In the case of subscribers' and P.B.X. equipment, it is wise, of course, to provide against the most severe conditions which may be anticipated.

The production of telephone equipment for service in the tropics requires close attention to detail and precise technical control during manufacture. The following are the most important categories for consideration :—

1. The selection of raw materials and components suitable for use under humid conditions, at relatively high temperatures.
2. The selection and application of protective finishes which are adequate not only for the severe service conditions, but which will comply with the fundamental requirements of the apparatus.
3. The provision of features of design which provide for resistance to moisture ingress or for improved insulation.
4. Special processes, e.g., coil and wire impregnation, treatment of insulators, sealing methods.
5. Packing and wrapping methods designed to give protection during shipment and storage.

In addition to the above, consideration must be given to the liability of materials to support mould growth and, if necessary, treatment with fungicides to eliminate this possibility. Considerable attention has been directed to this matter in recent years, as a result of which knowledge of preventative materials and processes has developed rapidly.

The possibility of accelerated corrosion resulting from contact of dissimilar materials is another important consideration. The selection of metals employed, electro-plating or sealing by various organic compounds are the methods used to ensure freedom from faults due to this cause.

Fig. 2—Control and Testing of Electro-plating Solutions and Deposits

Valuable guidance is given in the Inter-Services specifications on the above matters, supplementing the manufacturer's specialized and local knowledge.

It will be seen from the foregoing that the tropicalization of telephone equipment chiefly involves careful attention to detail. Most of this work is not spectacular, taken individually, but the collective results are of great importance.

The scope of this article does not permit a full account of the methods employed for the tropicalization of various classes of equipment at the Beeston factory, however, some examples can be quoted to show the means which have been adopted and which are securing increasingly high standards as follows :—

Protective Finishes.

The electro-plating department is fully equipped to apply all types of commercial finishes. Modern plant and processes are controlled by the departmental laboratory, part of which can be seen in Fig. 2. Each batch of work is checked for thickness of deposit, a reasonable factor of safety being maintained over specified minimum thicknesses. Throwing power and uniformity are matters which receive particular attention. Electro deposits are improved by additional processes; e.g., by chromate passivating on zinc and cadmium, or where applicable, by subsequent coatings of stoved pigmented or clear lacquer. Anti-corrosion solution treatment is applied where lacquering or enamelling is not permissible.

Fig. 3—Parts being fed on to the Conveyor of the Infra-Red Dryer

In the enamelling department, high grade alkyd stoving enamels are used almost exclusively. These materials have a high protective value, combined with permanence of colour and outstanding flexibility and adhesion. Infra-red and conveyor ovens, Fig. 3, ensure precise stoving times and temperatures. A typical treatment for parts made from mild steel may be quoted: Pre-treatment consists of cleaning, followed by surface phosphatizing; a rust-inhibiting iron oxide-zinc chromate stoving enamel is then applied, after which the parts are given coats of stoving enamel in grey or other specified colour. This finish gives prolonged protection under the most adverse conditions of humidity and temperature. Incipient rusting does not develop below the enamel finish because of the thorough preparation and priming.

As an additional means of promoting development and of checking protective finishes, routine tests are carried out on apparatus after assembly, in a tropical test cabinet, (Fig. 4). These tests are more informative than when applied to the individual piece parts, as the effects of contact potentials and capillary spaces are revealed.

INSULATION.

The maintenance of high electrical insulation under tropical conditions is a subject which demands unremitting attention and embraces a wide field in industrial technology. A considerable number of specialized processes have been developed by the Company, two of the most important being those applied to springsets and coil impregnation. A brief description of these processes will no doubt be of interest.

For springsets on keys, relays, switches, etc., insulators are manufactured from highest grade S.R.B.P. sheet. These insulators are cleaned and baked after machining to remove traces of moisture or volatile matter ; they are then uniformly coated with special phenolic resin-based varnish, so that all cut edges are sealed, and are finally baked at 300°F. After assembly, the springsets are immersed in a low temperature baking synthetic resin insulating varnish, the arrangements during this process ensuring that the soldered connections and contact areas remain clean. Repeated dipping provides a complete seal. These treatments result in a considerable increase in insulation values under damp conditions. Other advantages are, mechanical security after frequent changes in temperature, and elimination of troubles due to dust, these being achieved through the filling of capillary spaces by the dip varnish and the formation of continuous films over the insulators and metal parts. In some cases, e.g., for relay springsets additional varnish sealing is provided by wet assembly methods.

Fig. 4—Components undergoing Tropical Humidity Tests

Similar meticulous care is observed with coil impregnation processes. The coil formers are first coated with varnish prior to the application of insulating materials and winding. Double impregnation and baking, followed by a final coat of heavy sealing varnish provides higher resistance to moisture ingress. In the case of double wound coils the first windings are impregnated separately, as an additional process. The impregnating materials are used for enamel and textile covered wires, being specially suited to both types of coverings, and all materials employed are selected and tested for chemical purity. A section of the laboratory used in the control and investigation of organic finishes is shown in Fig. 5. Long and satisfactory service in tropical countries has fully justified the additional care and effort which have been made.

In the field of plastics, developments have been particularly noteworthy. Earlier types of plastics have been improved and extended in range while completely new products open additional possibilities. Moulding technique provides almost unlimited facilities for the economical production of complex forms and shapes, a very useful feature for the design of tropical components. An example of this is the production of moulded bobbins for transformers, iron cored relays, indicators, ringers, buzzers, etc., illustrated in Figs. 6 and 7. End cheeks and core insulation are continuously formed by plastic moulding in phenolic resin material. Improved insulation results under humid conditions, and capillary spaces, which exist with built up coil formers, are avoided. The precise and uniform diameters also ensure superior windings. Arrangements are being made for full scale production of these formers.

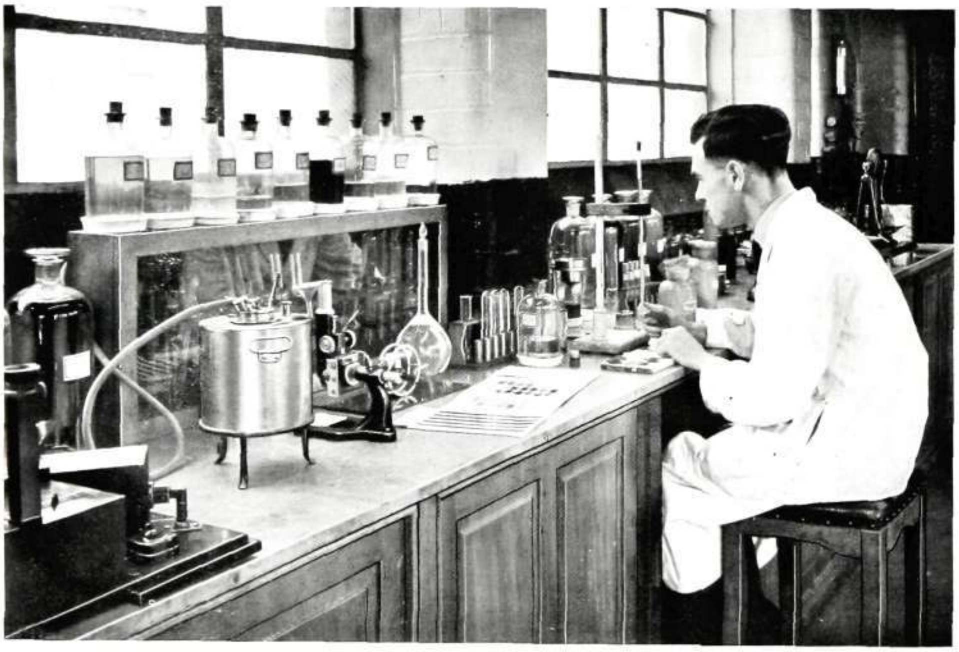


Fig. 5—Part of the Organic Finishes Laboratory

Materials.

Progress in engineering design and performance goes hand in hand with developments in raw materials. Ferrous and nonferrous metals, timbers, insulating materials, plastics, and textiles are continually offering technical advancement, many new properties being particularly valuable for tropical equipment. Developments with raw materials are therefore closely followed and investigated at the Beeston factory and are applied whenever there is advantage to be gained.

Arrestor blocks are produced from plastic bonded conducting materials. Freedom from dusting and porosity, and chemical purity are some of the advantages which result in these arrestors being specially recommended for tropical service.

In connection with the use of metals, many special applications have been developed ; for example, certain parts of telephone components such as uniselector and two motion switches, switchboard plugs etc., are subject to heavy duty and wear in service. Stainless steels and corrosion resisting metals are frequently applied as the most satisfactory materials to withstand these conditions.

coats of cellulose acetate lacquer giving a smooth hard finish. Briefly, the advantages of this wire are :—

1. High insulation under very moist conditions.
2. Freedom from electrolytic and chemical corrosion.
3. High breakdown voltage under moist conditions.
4. Bright colours which can be readily identified.
5. Permanent cleanliness owing to the fact that cable forms need not be waxed and therefore do not pick up atmospheric dirt, dust or polution.

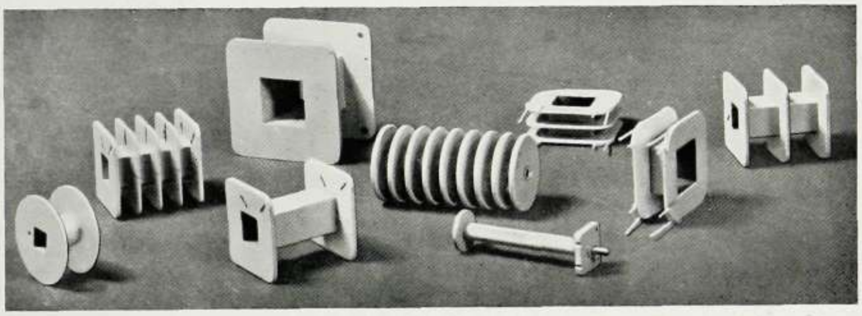


Fig. 6—Typical Completely Moulded Plastics Formers used on Tropical Equipment

SWITCHBOARD WIRES.

Enamel and textile insulated wires have been used widely for tropical equipment for many years but these are now being strongly challenged by plastic (P.V.C.) insulated wires. Still further technical advantage is provided by the plastic-textile insulated wires which are being used by the Company as an alternative for severe service conditions. The full description of this wire is " P.V.C. insulated, rayon lapped and lacquered wire ". Polyvinyl chloride is the main insulant, the properties of which are enhanced by a tight rayon lap with final

6. The lacquer includes a fungicide so that the wire does not support mould growth.
7. The lapping and lacquering eliminates the possibility of cold flow and other forms of ageing.

Developments are continuing with various types of plastic insulated wire.

PACKING.

Warehouse facilities have been increased by the provision of a number of modern processes specially designed for tropical equipment. These include the use of heat sealed metallic laminated foils, impregnation and dip-immersion sealing, and various dessicants. Much progress has been achieved in the construction of packing cases, which are now largely manufactured from moisture and weatherproof plywood. These cases are strongly reinforced by strips and battens, all joints being secured by synthetic resin adhesives in addition to normal mechanical methods. Internal corners are sealed with bitumen material and lids are also made watertight by means of flexible compounds. The result is that the cases possess great mechanical strength and resistance to handling shocks, and remain watertight even under complete water immersion tests.

Much valuable experience was gained during the recent war in connection with materials, protective finishes and packing, not only in respect of new substances and processes but also with regard to the efficiency of familiar, previously accepted standards under extraordinary conditions such as were experienced, for instance, in the far East where equipment was often floated from ship to shore in heavy seas for lack of proper landing facilities and where it was sometimes used for long periods with very little or no natural protection from the elements.

Knowledge thus gained was pooled by the allied countries and concerted efforts were made to overcome these conditions, with considerable success.

The necessity for changing some of the protective finishes and processes was due to the compulsory use of war-time substitute materials, nevertheless all these developments have greatly assisted the investigations which are being continuously made by the Company to find the best material and the best treatment, consistent with reasonable economy in cost, for every component manufactured.

Fig. 7—Iron-cored Coil Formers with Moulded Insulation

It will be appreciated that the foregoing account of some of our activities in this direction can be only of a general nature as the field of investigation is very wide, but it is hoped that some important projects which are at present in the development stage may be described in detail in future issues of the Bulletin.

Inspection Without Gauges, by the Optical Projection Method

IMPROVEMENTS in the Company's production methods in recent years, resulting in increased output, have necessitated the speeding-up of inspection by the employment of optical projectors instead of gauges, for certain classes of work.

An optical projector is an instrument by means of which a magnified image of a work piece or tool is formed on a screen and compared against an enlarged layout or master drawing of the same magnification. Any dimensional error or departure from the true form can be measured by means of a scale or micrometer, and for quantity inspection, a system of broken lines giving the specified work tolerance shows at a glance whether the work piece is within the desired limits. Following are some of the purposes for which the instrument can be be used :—

1. The checking of formed components by projection against an enlarged master drawing.

2. The inspection of small toothed parts such as gears, pinions, ratchet wheels, etc., where gauging by other means is difficult and slow.

3. For checking milling hobs, gear hobs, milling cutters, form cutters, broaches etc., to very fine limits of accuracy, both during manufacture and use.

4. The measurement and inspection of screw threads, both external and internal.

5. Work which cannot be dealt with by direct projection, such as surface markings and scales.

The main details of a projector are the light source, the collimator, the projection lens, the work stage, and the screen. (Fig. 1.)

The projection lens is the most important part of the instrument, and must be capable of forming an image which is exactly similar to the object.

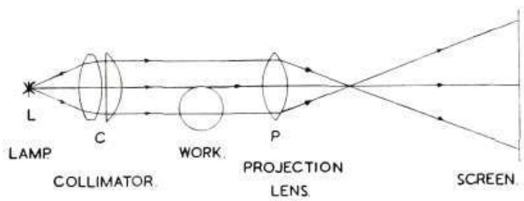


Fig. 1—Schematic Arrangement of the Optical Projector

The area of the object under observation and the size of the image formed, is governed by the magnification of the projection lens. Lenses of X10, X15, X25, X50 and X100 magnification are generally used, and the field of view, for example, of an X10 lens fitted to a type of projector commonly used is 1·4 x 1·1 inches. These dimensions decrease in direct proportion for the other lenses.

The screen is opaque except when the image is projected on to the underside of the screen in which case a transparent plate is used in conjunction with a special master layout drawn on good quality paper or a specially prepared material such as "Kodatrace".

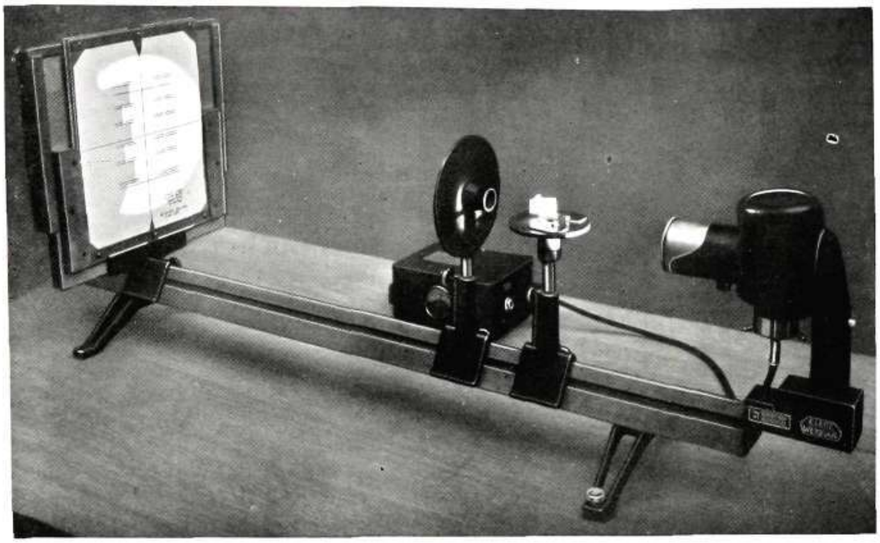


Fig. 2—Horizontal Projector, with Relay Buffer Block under Examination

jector, whereby the position of the steps (the number of which may vary from one to four depending on the type of block) possibly eight dimensions in all, may be checked simultaneously. Using the type of projector illustrated in Fig. 2, the image is thrown on to an opaque screen upon which is drawn a series of lines representing the work limits, all dimensions being given from the flat base marked X - X in Fig. 2A.

The main essentials of an opaque screen are that it should possess a high reflecting power and must have a flat grey or white surface.

Having briefly described the projector some examples of its use can be illustrated.

The relay, as used in automatic telephone exchanges, etc., is a mechanism manufactured by the Company in great quantities and is a delicate and sensitive piece of apparatus. Its efficiency depends largely upon the very accurate making and positioning of its various parts, one of which is the buffer block, a moulded unit with a step formation for controlling the pressure of the contact springs.

The buffer block is a piece part which is ideal for inspection on a horizontal pro-

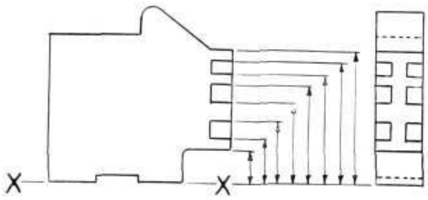


Fig. 2A—Dimensions of Steps to be Checked by method shown in Fig. 2

The piecepart is mounted on a circular stage with a flat upper surface and is located by means of two plates suitably positioned at an angle to allow the passage of light, from the collimator, only over the edges of the steps, thereby reducing the risk of distortion.

For certain types of buffer blocks this arrangement is essential as the steps are formed only on the sides and leave a central web. The drawing is correctly positioned by means of a setting line which is at a convenient distance relative to the base line or upper surface of the work stage, and as this line is drawn to a round figure, say, ·500 inches, a standard slip gauge may be used as a setting piece.

Large quantities of buffer blocks have been inspected by this method which has proved very satisfactory as compared with the usual type of stepped gauge. In operation the step gauge was found to be slow and inconclusive, thereby necessitating the lengthy process of actually measuring quantities of buffer blocks at frequent intervals by means of a height gauge.

The value of optical projection is further demonstrated by a study of Fig. 3, which illustrates the inspection of another type of product, i.e., part of a switch mechanism.

The two-motion selector so extensively used in automatic telephone exchanges must be efficient and reliable (as indeed must any piece of apparatus employed in the vital service of telecommunication) and its action involves the vertical and rotary movement of contact springs attached to a movable shaft.

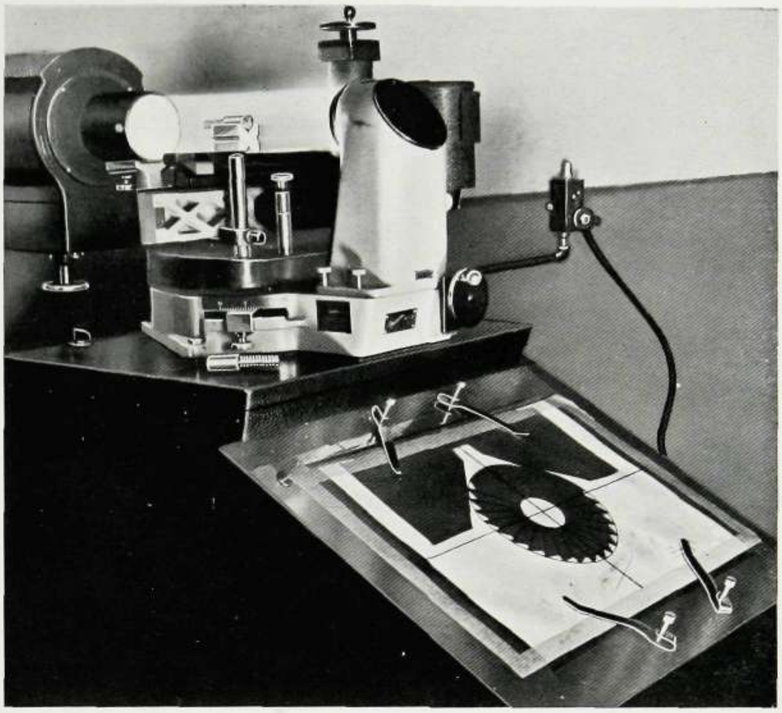


Fig. 3—Inspection of Teeth on a 2-motion Selector Shaft

The correct positioning of these springs is of paramount importance and is effected by the engagement of a ratchet with teeth formed on the periphery of the shaft. It will be appreciated that extreme accuracy is essential in the locating and cutting of these teeth and also, that to check them by means of gauges requires great care and a considerable amount of time ; with the optical projector, however, inspection can be carried out with greater accuracy in much less time. In Fig. 3, examination of the form and angular position of the teeth controlling the rotary movement is shown. Simple enlargers are generally used for production inspection, and as the component under test is longer than the average, correct positioning is essential since the tooth face (owing to its length) must lie perfectly parallel with the light beam in order to reduce interference to a minimum. For this reason, use is made of a universal projector, which, having a flat, horizontal, rectangular work stage in the same plane as the light beam, enables the component to be mounted in a standard V block set to the square edge of the stage, and from the well-defined projected image thereby attained, any error in pitch or form of the teeth may be immediately noted.

This type of universal projector is invaluable where a variety of formed milling cutters and other tools have to be manufactured to a high degree of accuracy, and when direct projection is impossible a system of surface illumination brings most problems within its scope.

Owing to the increasingly high standard of manufacturing accuracy demanded by the telephone industry, optical projection as a means of inspection is eminently successful and leads to a greatly increased output whilst saving the cost and maintenance of gauges.

A Single Channel, Open Wire Music Channel System

THE transmission of a music programme over open wires presents certain difficulties which are not as readily overcome as in the case of a voice frequency or physical circuit.

Unwanted low frequency currents are induced in the open wires from adjacent circuits, power cables and other sources which give rise to noise over the audio band, and since the music programme requires a much larger dynamic range, it cannot tolerate as high a noise level as the voice frequency circuit.

The physical, V.F. telegraph and 3-channel circuits on open wires occupy that part of the frequency spectrum from zero to 33 kc/s. Since the music programme requires a band width of approximately 8 kc/s it is not conveniently fitted in at these low frequencies, neither is it desirable to do so due to the line noise which is present.

The music programme is therefore modulated by a carrier frequency of 42·5 kc/s and by means of a suitable band pass filter the lower sideband of 34 to 42·47 kc/s is selected and transmitted to line whilst the upper sideband and the carrier frequency are suppressed.

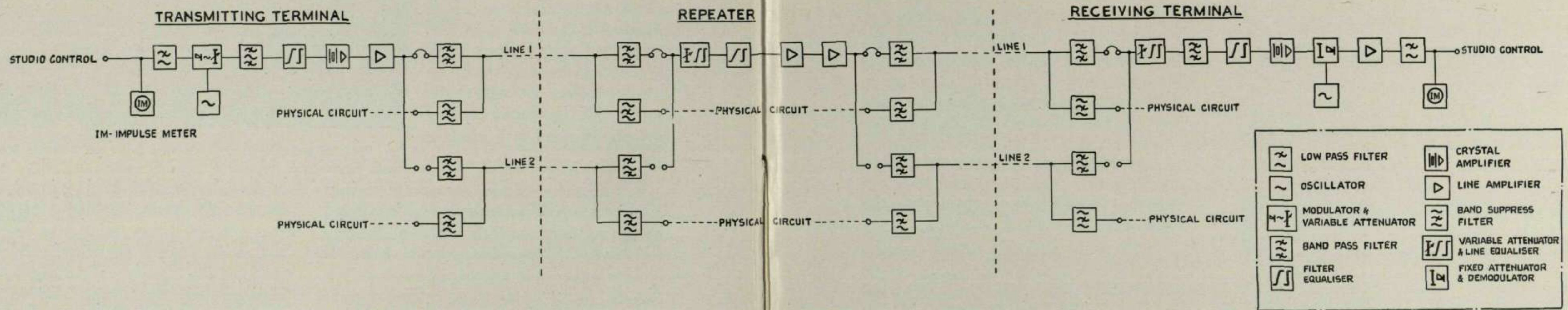


Fig. 1—Block Schematic of Single Channel, Open Wire Music Channel with Repeater

The demodulated audio frequencies of a music programme must not vary from the original audio frequencies by more than a few cycles per second, otherwise, as is well known, distortion will result. It is therefore desirable that the carrier frequency of the receiving terminal should be synchronized with that of the transmitting terminal and for this purpose a 34 kc/s pilot frequency is transmitted to line. This pilot frequency is also used to give an indication of level changes due to varying line conditions.

The schematic arrangement of a single channel open wire music channel system with repeater is shown in Fig. 1.

THE TRANSMITTING TERMINAL.

It will be seen that the audio frequency input to the system from studio control passes through a low-pass filter which is known as the music band filter. This has a cut-off frequency of 8·5 kc/s—the frequency of the pilot before modulation.

The audio band now passes into the modulator together with the 8·5 kc/s pilot frequency from the frequency generating equipment. The carrier frequency of 42·5 kc/s for the modulator is also provided by the frequency generating equipment. This modulator is of the conventional ring type which by suitable adjustment will give a a high degree of carrier suppression, however, due to the ageing of the rectifiers, this cannot be maintained, therefore further carrier leak suppression is provided in the crystal pre-amplifier. A special phase shift network is incorporated to give additional suppression, up to 100 c/s from the carrier frequency, of the unwanted sideband. Mounted on the modulator panel is a variable attenuator—calibrated in 1db. steps—used to control the level of the output to line, and a reactive network which compensates for the increase in attenuation at the band edges of the modulator band filter. This filter, which follows the modulator, selects the lower sideband and offers high attenuation to the upper sideband.

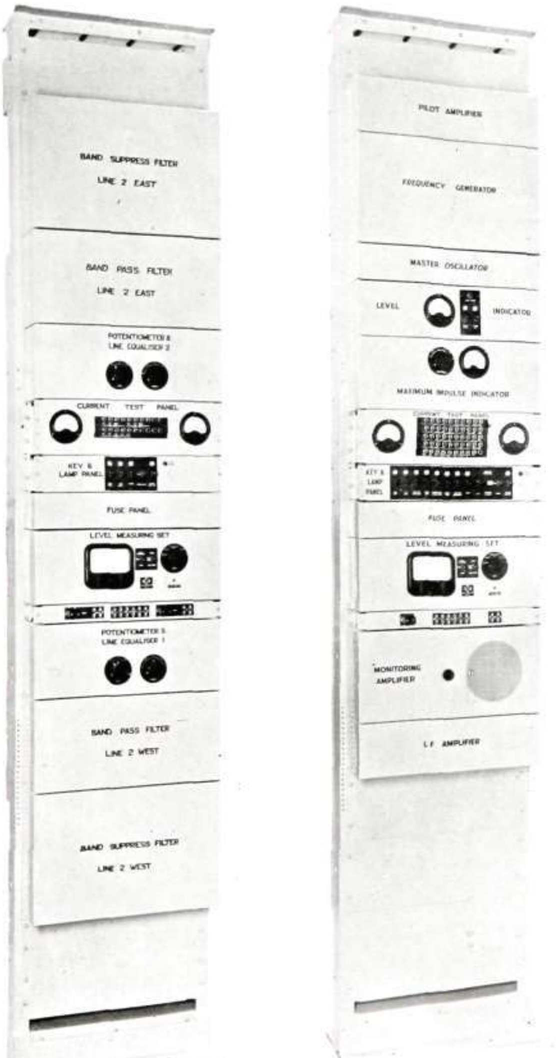
At this point an equalizer is introduced to compensate for the increase in attenuation at the band edges of the band-pass filter through which the sideband is fed to line.

The level of the side-band is now restored to approximately zero level by the crystal pre-amplifier, in the input circuit of which is a crystal bridge network resonating at 42·5 kc/s and giving a minimum carrier suppression of 50 db.

The sideband next passes into the line amplifier where the level is raised by approximately 28 db giving the necessary power amplification for line transmission. It is then fed via the " U " link panel through the band-pass filter and out to line. Here the physical and 3-channel circuits are superposed on the line via the band-suppress filter.

The Repeater.

The input from line to the repeater enters a filter set comprising a band-pass filter and a band-suppress filter, similar to those on the transmitting and receiving terminals.



Repeater Terminal

Fig. 2—Rack Equipment for Single Channel, Open Wire Music Channel with Repeater

This filter set segregates the music channel from the physical and 3-channel circuits.

The music channel sideband is fed through the " U " link panel to the variable attenuator and line equalizer panel. The variable attenuator is calibrated in steps of 1 db. over a range of 20 db. and gives control of the output level from the repeater. The line equalizer consists of a number of reactive networks selected by a rotary switch to compensate for the prevailing frequency-attenuation characteristics of the line.

At this stage a filter equalizer is introduced to equalize for the input and output band-pass filters on the repeater, after which two line amplifiers connected in tandem provide the gain necessary to raise the level of the sideband for transmission to line, each amplifier having a gain of approximately 28 db.

The sideband is now fed out to line via the " U " link panel and filter set where it combines once again with the physical and 3-channel circuits.

The Receiving Terminal.

The input from line to the receiving terminal enters the filter set, and the music channel sideband, once more separated from the physical and 3-channel circuits, passes via the " U " link panel to the variable attenuator and line equalizer, which, as in the case of the repeater, gives facilities for the compensation of the frequency-attenuation characteristics of the line and control of the sideband level.

Following the line equalizer are, respectively, the modulator band filter, the filter equalizer and the crystal pre-amplifier, as in the transmitting terminal. At this point the pilot frequency of 34 kc/s is amplified by the pilot amplifier and is used to synchronize the frequency generating equipment. The output from the crystal pre-amplifier then enters the demodulator, which is of the conventional ring type, and the music programme is restored to its original audio-frequency band. The 42·5 kc/s carrier frequency for the demodulator is provided by a frequency generating equipment similar to that of the transmitting terminal.

After demodulation the level of the audio band is raised by the low frequency amplifier so that it may be fed out to studio control at approximately zero level. The gain of this amplifier is variable in steps of 1 db. from 20 to 50 db. Before being fed out to studio control the audio band passes through the music band filter which offers high attenuation to the demodulated pilot frequency.

FREQUENCY GENERATING EQUIPMENT.

On the transmitting terminal a lamp-stabilized crystal oscillator provides a fundamental frequency of 85 kc/s for the control of a frequency dividing network on the frequency generator panel from which are derived the 42·5 kc/s carrier and the 8·5 kc/s pilot frequencies. On the receiving terminal the frequency generator is controlled by the 34 kc/s pilot frequency.

MONITORING EQUIPMENT.

The terminal bays are fitted with monitoring amplifiers which by means of a single key operation may be used to monitor the music programme at either audio or high frequency points in the circuit.

In order to give visual indication of the overloading of the system by peak impulses a maximum impulse indicator is permanently connected across the studio control termination.

A level indicator panel is fitted to monitor the received pilot level and should this level change by more than ±2 db. an alarm is given.

SPECIAL FEATURES.

This system is unidirectional but reversible and a simple key operation will effect the changeover of a terminal from transmit to receive. A similar key operation reverses the direction of transmission through the repeater.

The apparatus is panel mounted on standard racks 8 ft. 6 ins. high (Fig. 2) and each panel is connected into the main bay wiring via a plug and jack which have been specially designed to eliminate risk of contact faults and to facilitate the removal of individual panels for servicing.

The individual valve power supply is checked from a centrally situated test panel on each bay by the simple operation of push button keys, and anode currents and filament voltages are read directly on associated instruments.

All suitable points in the circuit where level measurements may be desirable are connected directly to a test jack field where the level measuring set may be plugged in.

POWER SUPPLIES.

This system has been designed to operate from the standard repeater station power supplies.

Development of the Microphone

IN the expansion and development of telephony it has long been recognized that a great deal of the loss of intelligibility, and distortion of the characteristics of the human voice during any telephone conversation is due to a large extent to the inferior performance of the carbon granule type of microphone, and modern standards demand that continued attention be directed to the attempt to effect improvements in this direction. It is obvious that any development carried out must involve the minimum sacrifice of sensitivity, and the question of cost of production must be continually borne in mind.

The microphone is a device actuated by power in an acoustic system, and delivering power to an electric system, and of the many forms of microphone in use today the only one suitable for ordinary line telephony is the carbon microphone which depends for its operation upon the varying resistance of carbon contacts. For the pressures encountered in speech the essential for efficient operation is that the resistance must be critical to very small changes in the position of the microphone diaphragm.

The fact that the carbon microphone is almost universal in its application to line telephony is due to its high sensitivity, and until quite recently the need for this degree of sensitivity has been of paramount importance, having far greater value than a uniform response over a wide range of frequency. Considering the advances made in telephony and the means available for upgrading speech volume on long line circuits, it may be said that the need for the very high sensitivity of the microphone, important as it is, may be subordinated to some extent in an endeavour to obtain a measure of equalization, or in other words, to improve the frequency response.

The microphone occupies a unique position in any telephone system because the success or failure of the system is judged by its performance. To be entirely successful, a conversation should be continued smoothly and without interruption and preferably in such a manner that the participants are not immediately conscious of any intervening apparatus.

Development of the microphone has been very slow, modifications of the original solid back type (White 1890) being still in use by some administrations, and from the

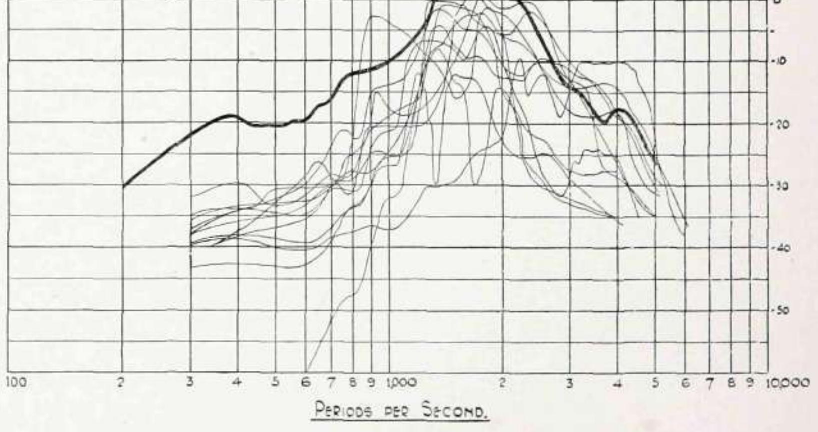


Fig. 1—Frequency Response Curves of Various Types of Microphone

aspect of volume efficiency the actual increase is of the order of 4 to 6 db. over a period of about 30 years. It is apparent that, unless some revolutionary new principle is evolved as the result of the work in a wide field of investigation, the maximum volume efficiency for the loose contact type of carbon microphone has been achieved.

Practically all microphones used in ordinary line telephony systems have pronounced peak frequencies which are in general somewhere near the average speech frequency, 1000-1200 c.p.s. Fig. 1 is a reproduction of a " nest of curves " showing the frequency response of a number of microphones of different manufacture. These characteristics, determined at the laboratory of the C.C.I. in Paris, illustrate the incidence of the " peak " and the general similarity of performance. The curve in heavy line is the response of the N.7742A microphone manufactured at Beeston.

The position of this peak in the audio spectrum determines to a large extent the characteristic " pitch " of the microphone, and the harmonics generated by the varying frequencies and sound pressures produced by the person speaking, influence the intelligibility. It is apparent therefore that with types of microphone having frequency responses as shown by the curves, the intelligibility varies with the character of the voice actuating the microphone, e.g. a quiet non-resonant voice will be the most pleasing and natural, whilst a powerful resonant voice gives rise to what may be termed " blasting," and intelligibility is adversely affected.

The articulation efficiency of a microphone is affected by many factors, some of which can be varied by methods of design, but there are a few, such as " room noises " and " line noises " of many kinds over which the designer has no control. As microphone development is being considered, only those features which can be modified by design will be taken into account.

In the development of a microphone the factors to be taken into consideration, all of which have inter-related effects, are in general, as follows :—

Effective stiffness of diaphragm.

Effective mass of diaphragm.

Effective mass of granular charge.

Effective stiffness of granules.

Effective stiffness due to enclosures, air, etc.

Effects due to mass and stiffness of case.

The values involved may be laid out in an equivalent circuit, mass being represented by inductance and the stiffness by capacitance. Calculations may be made around any set of values to give a reasonably good approximation, but a great deal of experimental work and a series of lengthy tests have to be carried out, since any slight change in resistance or in any of the features quoted above will affect the final result.

In addition, the carbon granules have certain inherent defects or disadvantages which must be taken into account, these are briefly :—

Packing — which seriously affects output.

Breathing — a cyclic distortion resulting from " packing " and " unpacking ".

Heating — resulting from the passage of current.

Frying — Generated with the passing of current.

Ageing — Deterioration of efficiency with the passage of time.

Resistance — The average ohmic resistance in the speaking condition.

It will be appreciated that any change in the design of a microphone involves the detailed investigation of all the foregoing factors and is a long-term task.

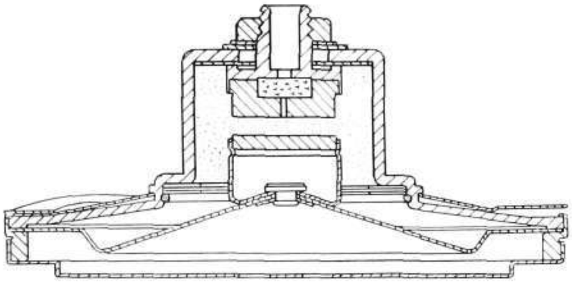


Fig. 2—Sectional View of Microphone Inset N.7752

The production of the carbon granules is a carefully controlled laboratory process; primarily the dependence upon a natural form of raw material—the highest grade anthracite—is at present an indisputable necessity. The selection of the material for the hard, shiny, short grained, non-porous portions is tedious but very important. This precedes the processing which involves preliminary crushing, sifting to size, extraction of dust, roasting to drive off unwanted volatile matter and to obtain the correct resistance characteristics, final sieving to size, removal of "flats" or "slivers" and treatment to remove all magnetic particles.

For the maintenance of microphone efficiency, every batch of granules produced is subject to close control and careful test before final issue to the assembly shop for actual microphone production.

In considering the design of the granule chamber, attention must be given to the size and shape of the chamber and the disposition of the electrodes; the ideal chamber is probably that where the fall of the carbon granules in any position of the microphone results in the same pressure being exercised on the electrodes and between the granules, but it appears at present that there is little possibility of this condition being satisfied. The semi-spherical chamber appears to be a satisfactory compromise and this has been embodied in the N.7750 and N.7753A types of microphone, in which pressures exerted in all directions are nearly equal, except when the microphone is held face downwards. The complete immersion of both electrodes in the mass of carbon granules is a necessary feature which effectively prevents any possibility of a complete disconnection with the microphone held in any position.

The closure to the carbon chamber may be carried out in several ways; the two best known methods are:—(1) To arrange the closure so that an electrode system affixed to the main diaphragm may move freely through a hole in the centre of the closure (Fig. 2, section N.7752). This method has two main disadvantages:—if the hole through the closure disc or discs is very slightly too large some of the granules may escape into the outer case, on the other hand, if the hole is too small it will exercise a restraining effect on the diaphragm system with the consequent loss of efficiency. (2) The chamber may be completely closed by a diaphragm of mica or other suitable material which is rigidly fixed to the main diaphragm, thus forming a definite closure effectively sealing the granule chamber.

By arranging this form of closure to have a definite mass and stiffness, a counter resonance is produced, acting against the natural resonance of the main diaphragm and resulting in improved intelligibility; a step in the direction of equalization which is a very desirable feature. Fig. 3, N.7753A, shows a section of microphone embodying this feature.

Concerning method (2), doubts from a technical point of view have been expressed regarding the completely closed, hermetically sealed chamber. Long experience satisfies the opinion that there are no serious disadvantages; changes of atmospheric pressure at the diaphragm are of a relatively low order with normal variations in barometric pressure, and the slight damping which may be experienced can, with suitable design of carbon granule chamber and diaphragm type closure, be arranged to give advantages in the direction of an improvement in articulation.

Attention has also been directed to the question of insulation coating within the granule chamber. This was a coating of hard stoving enamel on the inside of the chamber and metal electrode mounts. Occasional troubles were experienced due to the hard carbon granules piercing the enamel, causing a large increase in microphone noise and eventual short circuit of the microphone. A composite construction of the case was evolved and has proved to be a definite improvement (Fig. 3).

The trend in the development of the N.7753A microphone has been to provide a component that will give satisfactory service in tropical climates and in situations where moist conditions prevail. Even in normal temperature surroundings any microphone is subject to the impact of moisture; it is desirable therefore that the so-called tropical type be adopted as standard.

Developments in the matter of finishes have been made in collaboration with the Services and conditions have been satisfied where the microphones have passed the most severe tropical tests, including the subjection to intensive salt spray for extended periods. This experience has been used to advantage in the production of microphones.

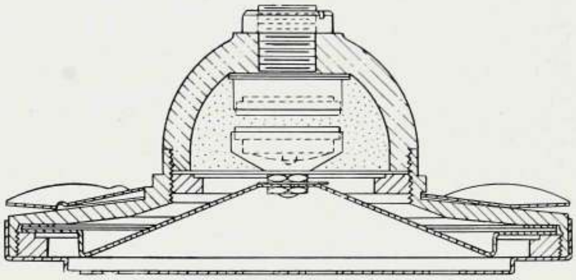


Fig. 3—Sectional View of Microphone Inset N.7753A

The N.7753A type of microphone is interchangeable with the N.7752 (P.O. No. 13) in practically every case and no circuit modification is necessary. It may be used in local battery type instrument circuits, and on heavy C.B. systems, also by modifying the granule charge to have a higher resistance, it can be used on the low current exchange feeding systems of the condenser relay type having high resistance feeding coils.

The N.7742A type may also be utilized in the same conditions but owing to its smaller dimensions it is not interchangeable with N.7752 or N.7753A.

Gate Circuits for Voice Frequency Switching

THE problems of voice frequency switching are continually under consideration in the Company's laboratory, and in this article an endeavour is made to set out in generalized terms typical problems and the approach to their solution, without going into details of any specific requirement or application.

There are many telephone switching arrangements which include devices whose function is to permit or obstruct the passage of speech signals in a particular circuit. In automatic telephony, as it is known to-day, this operation is carried out by a series of relays whose function is to interact in such a way as to keep the talking circuits disconnected from the interconnecting devices until step - by - step switching is completed, so that switching or impulsing noises are excluded from the subscribers' circuits. At the switching speeds employed in automatic telephony, the ordinary telephone relay offers a simple and satisfactory solution to this problem.

In certain types of circuit, however, it is essential to be able to perform this switching action more rapidly, so that no loss occurs of syllables or initial consonants when the speech sounds themselves are used to initiate the switching action. An example of this type of voice frequency switching is to be found in the echo suppressors fitted to long repeatered audio trunk circuits. In these a signal travelling in one direction, must, for the duration of the signal, so interrupt the circuit in the opposite direction that any echo is attenuated to a level such as not to be apparent to the person speaking.

A similar situation arises in the design of amplified loudspeaking telephones. To avoid howling due to microphone-loudspeaker acoustic interaction, either the amplification used must be restricted to a very small amount, in which case the device can hardly be a loudspeaking telephone, or some circuit must be incorporated which will effectively allow speech to pass only in one direction at a time. In some systems which are in commercial use, this is effected by incorporating a push-to-talk key which performs the required switching directly. To be able to eliminate manual operation, recourse must be had to a voice-operated switching circuit, and if this is not to cause loss of initial consonants, it must operate very much more rapidly than the ordinary telephone relay. A considerable increase in switching speed is possible with a telegraph-type high-speed relay, and the operating speed of this class of relay can be still further increased if a carefully adjusted driving circuit is employed to produce a rapid build-up of magnetization, but in the most favourable circumstances it is difficult to reduce the operate and release lags to much below one millisecond. There is, under development, a new high-speed relay having an operating time of less than 0·1 milli-second which can be still further reduced by driving the relay from a pentode valve with a suitable pulse-shaping network, and it seems that it will be possible to reduce the transit time to the order of 20 micro-seconds. With this operating speed it should be easily possible to construct a relay-controlled loudspeaking telephone and investigation into this matter is being conducted.

To obtain still faster switching it is necessary to employ an electronic arrangement. By simple analogue with the control of, say, pedestrian traffic, this type of circuit is commonly referred to as a " gate " circuit, and it is with the performance and application of gate circuits that this article is mainly concerned.

The increased operating speed which is possible with these gating circuits is only obtained at the cost of a considerable increase in circuit complexity over simple relay switching, and in addition to this change of circuitry, several other requirements must be satisfied in the design of the gate : for example, in the " open " state it must not introduce any distortion into the signal passing through it, and in the "closed" state there must be no leakage of signal through the stage either by imperfect cutting-off or through stray capacity.

Additional conditions, whose fulfilment imposes mutually conflicting circuit requirements, are that the gate must have high switching speed, but must not introduce spurious pulses or transients due to rapid changes of current within the stage at the instant of switching.

A number of practical arrangements for gate circuits have been produced, some of which will now be described, with particular reference to those likely to have uses in the sphere of telecommunications.

One of the simplest possible gate circuits consists of a conventional single-valve amplifier, as shown in Figure 1, with provision for injecting an auxiliary control voltage into the grid circuit.

If the control voltage is made zero, the stage will operate in the normal way as an amplifier. If a control voltage is applied, of the polarity indicated, and large enough to produce complete plate-current cut-off in the stage, the amplication of the stage will drop to zero : by removing this control voltage the stage will resume normal working.

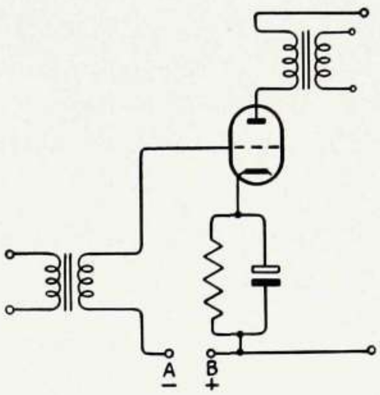


Fig. 1—Amplifier used as Gate Circuit.

While the stage is working as an amplifier, the steady plate-current produces a certain amount of magnetization of the output transformer core, and on cutting off the plate-current, the sudden collapse of this magnetic field will induce a transient voltage in the secondary of the transformer. In a similar way, the sudden build-up to the normal steady magnetic field will induce a transient during the switching-on process.

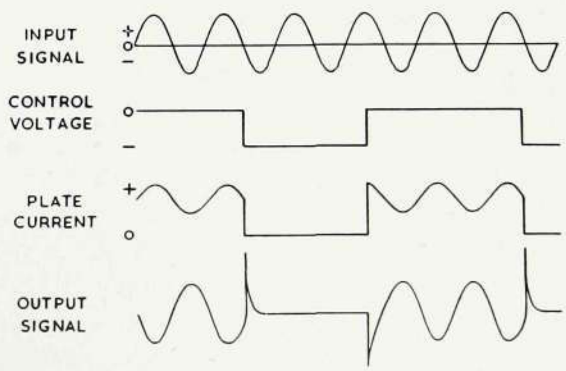


Fig. 2—Waveforms of the Gate Circuits during Switching

If, for example, such a gate circuit was used for keying a tone source, the action and the waveforms of the various voltages and currents would be similar to those shown in Figure 2.

In addition to the desired tone wavetrains, the output also contains transient impulses larger than the normal output, and which occur at the onset and cessation of the tone signals. These transient impulses would be heard as extremely objectionable " clicks ", and, due to their large amplitude, might well produce momentary overloading, and consequently, still further distortion in subsequent amplifier or repeater equipment.

An alternative arrangement, shown in Figure 3, in which the control voltage is applied to the suppressor grid of a pentode valve, has the same limitations as the circuit of Figure 1, but has the convenient feature of having the signal and control voltages applied to separate grids.

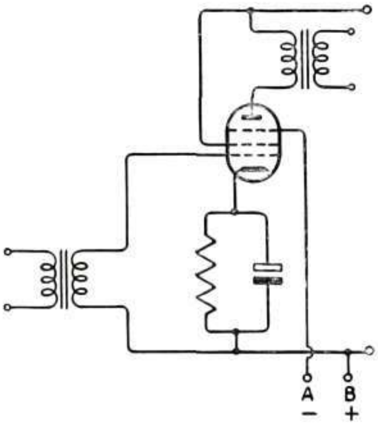


Fig. 3—Suppressor-gated Pentode Amplifier

The separation of control and signal voltage input points which is possible in the suppressor-gated amplifier stage is particularly convenient in some applications where, for example, the signal input is derived from a source such as a filter or a long line having appreciable reflection properties. If an attempt is made to superpose the control voltage on such a source, the high self-capacity of the source will prevent a rapid change of control voltage and will delay the switching action. In all probability there will also be internal reflections of the sharp edge of the control voltage which might well lead to irregular gating. Both these difficulties are overcome by the use of suppressor-gating, but no improvement is obtained in the transients which occur as unwanted by-products exactly as in the circuit of Figure 1. As the transient impulses arise from the sudden collapse and build-up of the steady magnetic field in the output transformer, an output free from transient impulses could be obtained from a circuit arrangement which balances out this steady field without itself introducing transient impulses. It has been found that this balancing action is most readily obtained from a push-pull stage, Figure 4.

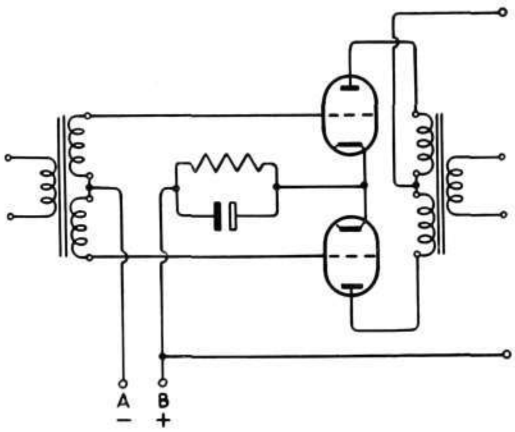


Fig. 4—Push-pull Gate Stage.

The action of each valve is the same as the stage shown in Figure 1, but as they are connected in push-pull, there will be no output transients due to steady magnetization of the output transformer if the valves have equal standing plate-currents and similarly shaped characteristics. This condition of balance can be maintained to an extent sufficient to give substantially clickless keying without undue difficulty.

In exactly the same way as the circuit of Figure 1 was modified to that of Figure 3, by substituting a pentode with the control voltage applied to the suppressor grid, so the push-pull arrangement of Figure 4 can be changed to that of Figure 5.

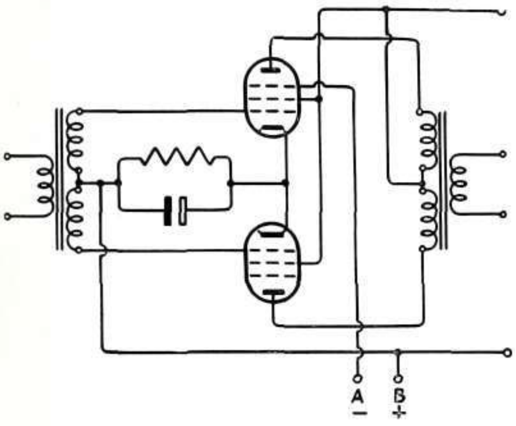


Fig. 5—Push-pull Suppressor-gated Amplifier

In this form, the gated amplifier is finding increasing application in many branches of electronic and telecommunications engineering; so much so, that valves have been made available with suppressor-grid characteristics specially designed for this type of application.

A preliminary survey which is being made of the properties of this type of circuit tends to show that it may prove particularly suitable for use in loud-speaking telephones, as it is possible to obtain operate and release " lags " of the order of a few micro-seconds very easily, and this would be amply fast to avoid the loss even of sibilant consonants.

For the sake of completeness, reference must also be made to a device which although not strictly a gate, has properties which make it very suitable for many gate-type circuit applications : this is the copper-oxide rectifier. The characteristics of such a rectifier are shown diagrammatically in Figure 6, and it can be seen that the effective resistance can be varied over a wide range by changing the applied steady voltage.

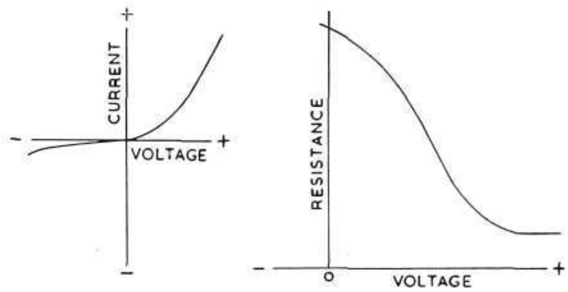


Fig. 6—Metal Rectifier Characteristics

If such a rectifier is incorporated into an attenuator, the effective attenuation can be varied by altering the " polarizing " voltage applied to the rectifier. It is desirable to keep the overall impedance of the attenuator as constant as possible, and this leads to the circuit shown in Figure 7.

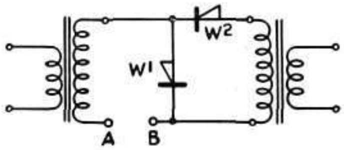


Fig. 7—Variable Attenuator employing Metal Rectifiers

If the control voltage is applied in such a direction as to make A positive with respect to B, then the rectifier W1 will be biassed into the low-resistance state, thus giving high effective attenuation to the network. If the polarity of the control voltage is reversed, the rectifier W1 will become high resistance, W2 will become low resistance, and the network will have low effective attenuation. Exactly as in the case of the valve gate circuit, better performance and greater freedom from switching noises can be obtained by using a balanced or push-pull arrangement, such as is shown in Figure 8.

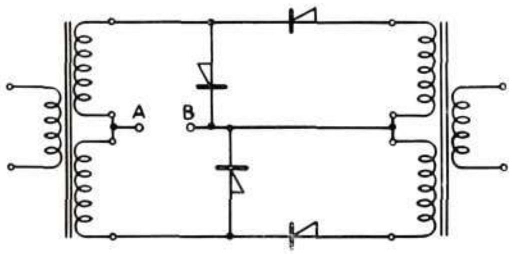


Fig. 8—Typical Metal Rectifier Attenuator

This arrangement has been used commercially in a number of applications: one of these is the echo suppressors fitted to long audio trunk circuits. For this purpose, two such networks are used, one in each direction of transmission, with the control voltage circuit so arranged that a signal in one path produces a control voltage on the attenuator in the opposite path, of polarity such as to bias the attenuator almost to cut-off, thus lessening the effect of any far-end reflections.

Another application, so far only in the laboratory stage, is in the system for a loudspeaking telephone, shown in Figure 9.

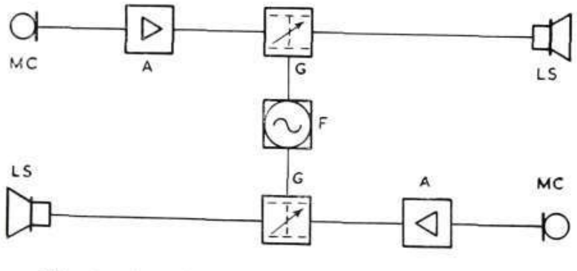


Fig. 9—Gated Loud-speaking Telephone

Each speech path consists of a microphone MC, an amplifier A, a metal rectifier gate circuit G, and a loudspeaker LS. In addition there is an oscillator F, which supplies out-of-phase control voltages to the two gates. In this way, each path conducts alternately, and the switching frequency can be varied by altering the frequency of oscillator F. It was found that no acoustic feedback occurred in the arrangement, but a number of other effects were encountered. If the chopping frequency is low (below audible frequency), there is a gargling sound superposed on speech, tending to reduce intelligibility; on the other hand the circuit is completely stable and can be used to give relatively high amplification without feedback (compare "quenching" in a super-regenerative receiver). Using a supersonic chopping frequency there is no distortion of speech sounds, but the effective amplification which can be used is appreciably less than that which is possible with the low frequency chopping arrangement. The overall performance of the circuit is still much better than if no chopping were used, however, and it is possible that it may prove valuable for some applications (for example, a time-division multiplex arrangement for telemetering, using a number of gate circuits operated successively).

From the above brief survey, it can be seen that a great deal of work has already been done in this class of circuit, and much more remains to be done: but sufficient information has already been gathered to show that it is not altogether improbable to envisage much of the telephone exchange switching of the future being carried out by some form or another of gate circuit of a basically electronic character.