

The Etelco Bulletin

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Editorial

*The heights by great men reached and kept
Were not achieved by sudden flight,
But they, while their companions slept,
Were toiling upward in the night.*

Longfellow.

PATHWAYS TO PROGRESS

Fundamental changes in the design and character of communication equipment are regulated largely by the economic structure of the service and the industry. However novel or desirable may be an innovation, questions of standardization, capital outlay and interchangeability are but a few of the considerations which impose restrictions on the timing and extent of its introduction. Major phases in the technical progress of telecommunications have therefore been directed in carefully planned stages which have secured adequate periods for their commercial utilization.

In contrast, there are no restrictions of this nature which regulate efforts aimed at the improvement of small details connected with manufacture, performance or design. Taken as a whole, these efforts are of prime importance, for upon them depend the final efficiency and quality of the product. Considerable experience, skill and patience are demanded from those who are engaged in this class of work.

The ultimate aim is, of course, the perfect product, and full credit must be given to those whose unremitting efforts maintain continuous progress toward this ideal, sometimes in the face of repeated failure and often at the cost of much time spent in uneventful routine investigation. It is through such effort that invaluable knowledge and experience is acquired.

Various articles in past Bulletins have revealed the cumulative results of detailed development conducted by the Company's technicians, and in this issue is published a review of the work which has been done in connection with the development of insulating coverings for switchboard wire. This subject is one of considerable importance and our investigations have been continuous over a period of several years during which all aspects of the related problems were closely studied.



New Magneto Telephones Certified for Use in Coal Mines

TYPES N2976 AND N2986

THE main principles of design of magneto telephones developed by the Company for use in coal mines have not materially changed in the last thirty years, but improvements have been made from time to time as a result of experience and advances in technical knowledge. In conformity with this progressive policy, two new telephones have been developed to replace the present standard sets N2974 and N2984.

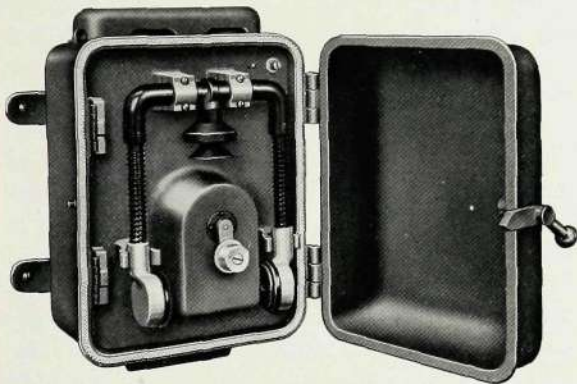


Fig. 1—Telephone N2980 (1921)

The new instruments are coded N2976 and N2986, and, like their respective predecessors, are practically identical except that the former has a hand micro-telephone and the latter a fixed transmitter with separate receivers, consequently, other details of their construction given herein may be regarded as applying to both.

To give some idea of the changes which have been made in the appearance of the ironclad magneto mine telephone over the last thirty years, illustrations of equivalent instruments manufactured in 1921, 1934 and 1950 respectively, are shown in Figs. 1, 2 and 3. Nothing will be gained from a detailed comparison of the telephone in Fig. 1, with those in the other illustrations, but in view of the widespread use and

popularity of the N2984 instrument, it will be compared with its superseding equivalent N2986.

Two of the primary requirements of telephones for use in coal mines are that they shall be capable of withstanding very rough usage and shall be well protected against damage from knocks, falling roof material, etc. This originally led designers to favour a rather too massive construction, with the result that a certain amount of difficulty was created for the installer and the maintenance electrician, owing to the considerable weight and size of the instruments. These points have been borne in mind in the designing of the new sets, as the following comparison reveals:—

Old Type, N2984 :

Weight (w/out batteries)	92 lb.
Approx. dimensions	20 $\frac{3}{4}$ " x 12 $\frac{1}{2}$ " x 10"

New Type, N2986 :

Weight (w/out batteries)	64 lb.
Approx. dimensions	19 $\frac{1}{2}$ " x 11 $\frac{1}{2}$ " x 8"

The reductions have been made without prejudicing the strength, safety or efficiency

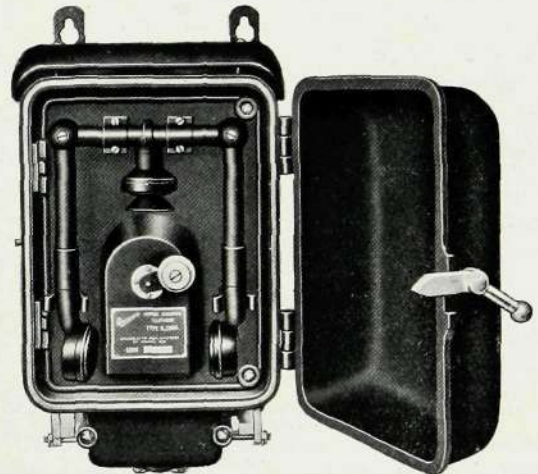


Fig. 2—Telephone N2984 (1934)

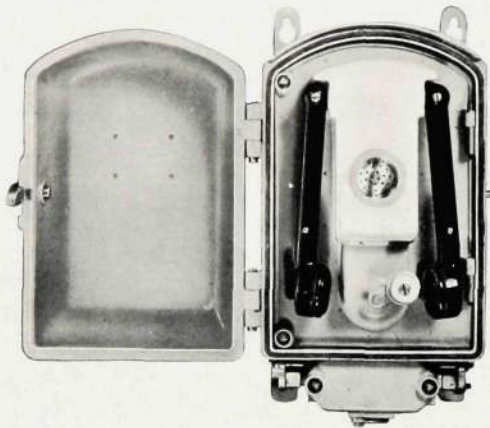


Fig. 3—Telephone N2986 (1950)

of the instruments ; indeed, by using improved types of components and modifying the design, increased speech efficiency has been achieved.

CERTIFICATION.

The new instruments are certified intrinsically safe for use in methane (firedamp) by the Ministry of Fuel and Power Certificate T/TEL/84, dated 3.10.49.

GENERAL CONSTRUCTION.

The construction of the cast iron case-work follows the familiar lines of the earlier sets, consisting of a robust body attached to two vertical wrought iron mounting straps and having an inner and outer door. A cable terminating chamber is screwed to the bottom of the case, and, like the inner door, has special screws to prevent unauthorized interference with the vital parts.

The outer door, fitted with a slam catch, has a flanged edge which presses hard against waxed rope embedded in the grooved front rim of the case, making a weatherproof protection for the speaking equipment and generator crank when the door is shut (Fig. 4).

The interior construction is revealed in Fig. 5 and it will be observed that the whole of the apparatus, with the exception of the batteries and terminals, is mounted on the inner door which is gate-hinged and thus constitutes a comparatively light, removable apparatus unit, when the wires from the

battery chamber have been disconnected at the screw terminals below the ringer. This is a very advantageous innovation from the point of view of the maintenance electrician, as the unit can be readily transferred to the workshop if necessary. In this connection it should be remarked that on omnibus circuits, no break in service between other stations occurs when a telephone apparatus unit is taken from the case.

APPARATUS (N2986 DOUBLE RECEIVER TYPE)

On the inner door, and insulated from it by a moulded bakelite ring, is fixed a modern carbon granule microphone which is protected from damage by a hygienic, domed mouthpiece of perforated stainless steel. Experiments were conducted to determine the position of the microphone and the form of protective device which would give the best results. This involved studies of microphone reaction to speech from persons of different heights and "telephone habits," in order to ascertain the most efficient arrangement for the average user.

The transmitter housing is extended upwards and forms a strong support for the receiver arms pivotted on either side. These move in unison and carry 40-ohm inset receivers set at an angle from the vertical plane in order to provide a more comfortable fitting for the head, while the horizontal distance between them can be varied as necessary. The cast iron cradles formerly used, to protect the receivers from damage when the arms are released from the raised position, are replaced in the new instrument by resilient rubber blocks.

Below the transmitter is the generator crank which has a bearing designed for



Fig. 4—The New Telephone with Door Closed

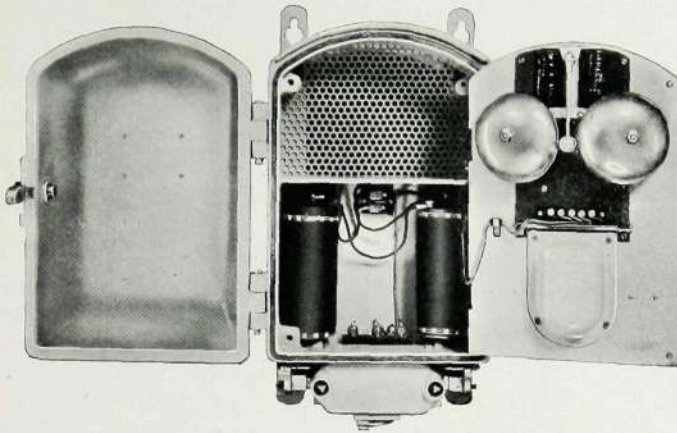


Fig. 5—Interior View

long service and a large aluminium handle.

At the rear of the inner door are two compartments ; the lower one has a domed aluminium cover and contains a modern single-magnet "alnico" generator with a non-inductive shunt across the armature winding, while the upper compartment, shown open in Fig. 6, has a brass cover-plate hinged at the bottom. Mounted on the outside of the plate are a heavy-duty ringer and a 5-way bakelite terminal strip which projects through to form the connecting point for the internal wiring. On the inner face of the plate are an anti-side-tone induction coil, a blocking capacitor, and a safety capacitor for the ringer, while inside the chamber are the transmitter, the receiver switch, and a 2-way bakelite terminal block for the receiver connections which are made in P.V.C. insulated flex threaded down the arms. The switch springs are operated by a cam when the receivers are raised.

The interior of the main case (Fig. 5) is horizontally bisected by a metal wall, the lower portion housing two BSS.397, type DR2, dry batteries, and the terminal blocks. As batteries are liable to cause

corrosion if allowed to become exhausted, their isolation is a desirable feature of the new design. They are supported on projections formed in the casting, so that they will not be affected, should condensation cause water to form in the bottom of the telephone. A similar precaution is taken with the line terminals which project from the terminating chamber through a thick bakelite strip in the battery compartment.

In order that ringing signals shall be clearly audible, the upper section of the case is open at the back, except for a perforated steel plate provided to protect the ringer from damage.

The line terminating chamber, similar to that on N2984, has three entries, one being fitted with a plug and two with glands for armoured cable. Plug and glands are interchangeable so that the external leads can enter the telephone from either side or from below. Glands suitable for $\frac{3}{4}$ " screwed conduit can also be provided.

APPARATUS (N2976, MICRO-TELEPHONE TYPE)

It has been stated that the N2976 type instrument is the same as N2986 except that the twin receivers and fixed transmitter are replaced by a hand micro-telephone.

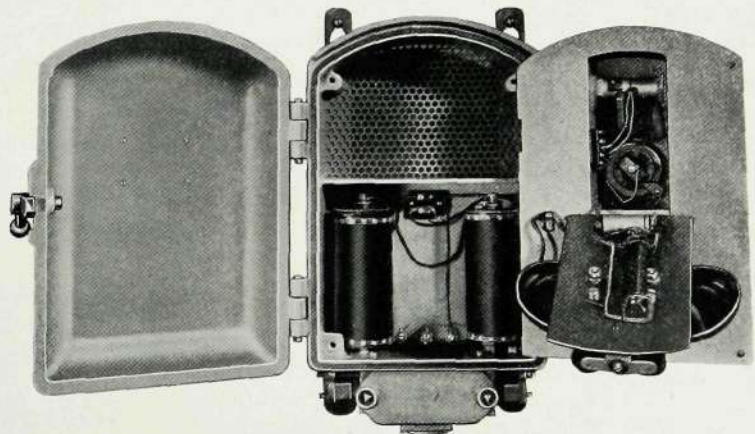


Fig. 6—Interior View with Transmitter Chamber Open

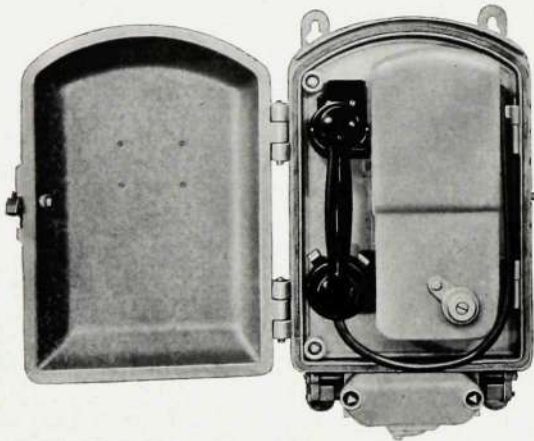


Fig. 7—Telephone N2976

This necessitates some modification of the inner door construction, as may be observed from Fig. 7.

The micro-telephone has been designed to withstand severe handling ; accordingly, the casing is a very strong aluminium alloy casting, as is also the removable mouthpiece which protects the modern inset transmitter. In order to avoid having cold metal in contact with the ear, the inset-type receiver earpiece is made of tough bakelite which projects well above the screwed brass ring clamping it to the diaphragm.

A specially shaped micro-telephone hook, and two phosphor-bronze springs attached to a block fixed on the inner door, behind the transmitter, ensure a secure seating for the handset, while a moulded guard protects the receiver from damage. The micro-telephone switch inside the upper compartment of the door is operated by a lever and spring device and the wired connections to the handset are in the form of a tough, rubber-sheathed cord secured at both ends to prevent strain being placed on the conductors.

PROTECTIVE FINISHES.

In view of the severe conditions under which these telephones are often used,

nothing less than the highest grade finishes were considered suitable, therefore all components, windings, etc., are tropicalized. Steel parts are given a special anti-corrosive zinc plating, and non-ferrous parts are heavily nickelled.

The main casing is rust-proofed and light grey enamelled (in contrast to the black exterior of the N2974/2984 telephones) thereby making the instrument more easily discernible below ground, while the receiver arms on N2986 and the handset on N2976 are finished black.

CIRCUIT DIAGRAM.

A diagram of the wired connections is supplied with every telephone and is in the form illustrated in Fig. 8, which shows the circuit for N2986.

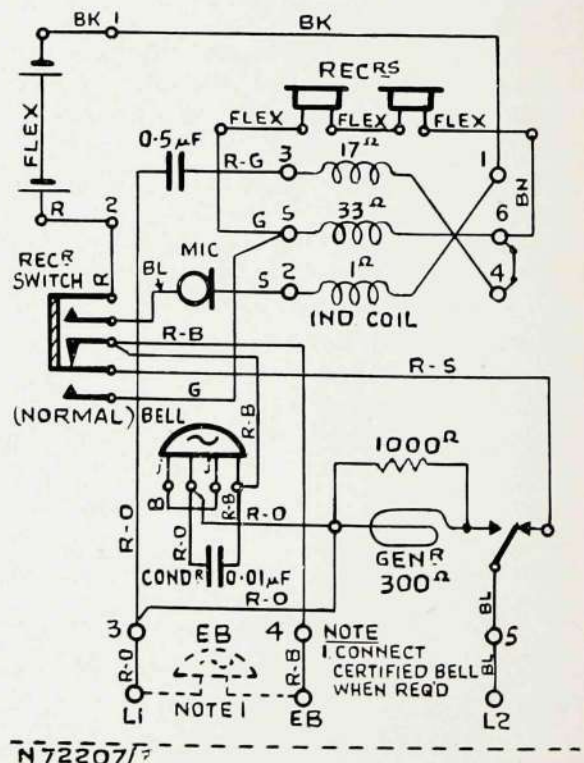


Fig. 8—Case Diagram for Telephone N2986



Development of Plastic Insulated Telephone Switchboard Wires and Cables

RECENT developments in connection with plastic insulated switchboard wires and cables should be considered in relation to the general history of the employment of insulating materials in telecommunication equipment. In the early days of the industry the range of raw materials available was limited. Fibre, wood, ebonite and paper were the main forms of insulation used in the construction of apparatus, while switchboard wires were insulated with natural silk, wool and cotton of ordinary commercial qualities. Technical requirements were not of a high order, as the demands of local battery systems were not stringent. In some instances, however, rubber or enamel insulated wires were necessary to withstand very damp conditions, for it was realized that the use of textiles involved one serious disadvantage—the rapid deterioration of insulating properties under conditions of high, varying humidities which caused almost hourly changes in I.R. values.

The advent of automatic and carrier telephone systems introduced more complex circuits and increased the number of components connected in parallel, while the demand for higher transmission efficiency has been an additional factor which made a progressive policy in the introduction of improved forms of insulation a fundamental requirement.

Continuous efforts are maintained to secure the highest insulation efficiency economically possible with available materials and current designs, and the telephone industry is strongly supported in these efforts by the research and development work of suppliers directly concerned with the manufacture of the basic insulants.

Improvements in connection with plastic moulding materials, laminates, and insulating varnishes, and the introduction of

many new insulating compounds have resulted in the attainment of very high standards in the performance of apparatus in varying atmospheric conditions. In the case of switchboard wires, it has not been possible to achieve, with textile insulating materials alone, the same high standard necessary to meet the stringent conditions imposed, for example, by services requirements and by the rapid development of telecommunication in tropical countries. However, notable improvements in this field have been achieved by the replacement of natural silk and cotton by cellulose acetate, acetylated cotton and other rayons introduced primarily to overcome the shortage of natural silk and the problems associated with the technical control of this variable product.

Textiles may be classified in two groups :

- (a) Those named above, which are applied direct to the conductor as the first lappings and which provide the basic insulation. These materials are usually undyed so that insulation hazards associated with dyeing processes are avoided.
- (b) Those which form the outer lapping or braiding and provide colour identification and mechanical protection.

Washed and purified cottons are used on switchboard wires but in the case of cables, or where resistance to fire is required, wool is preferred, except for tropical use when it is subject to insect attack.

Textile insulating materials are the subjects of intensive research, continuous efforts being maintained to improve efficiency, thus their characteristics are widely known and abundant references to their technical properties are available. The results of the investigations have been of great practical value.



Textile covered wires have proved eminently suitable as far as cable forming, stripping and soldering are concerned and an outstanding advantage is that they facilitate the provision of comprehensive colour identification schemes. Although technical requirements have become stringent, textile insulated wires give long and satisfactory service under the normal conditions experienced in telephone exchanges installed in temperate climates, or wherever suitable arrangements can be made for efficient heating and ventilation, but this does not necessarily apply to equipment located in industrial areas. Textile insulated wires are not suitable for severe service conditions where high humidities prevail, so that enamelled and textile covered wires have been widely used. The insulation efficiency is maintained almost entirely by the enamel coating, while the textile lappings provide mechanical protection and colour identification. The most satisfactory results are achieved by enamel coatings of $\cdot 004''$ thickness. In more favourable circumstances $\cdot 001''$ may be adequate.

The basic electrical properties of enamel and textile-insulated wires are shown in the following table :

INSULATION RESISTANCE AND BREAKDOWN VALUE OF ENAMELLED AND TEXTILE INSULATED SWITCHBOARD WIRES.

Description of Insulation.	Break-down Volts.	Radial Thickness of Insulation in Mils.	Volts per Mil of Total Insulant.	Insulation Resistance in Megohms per Mile. Twin 1" Lay. Normal Room Temperature & Humidity (65°F—60% R.H.).
25 SWG—Single silk and single cotton. Waxed.	1380	10	138	50 megohms
23 SWG—Double rayon and single cotton. Waxed.	1600	10·5	152	100 megohms
25 SWG—Single acetylated cotton and acetylated cotton braided. Waxed.	1600	15	107	250 megohms
25 SWG—1 mil enamel, double silk and single cotton. Waxed.	5300	10	530	200 megohms
25 SWG—1 mil enamel, single acetylated cotton and acetylated cotton braided. Waxed.	3300	10·7	308	250 megohms
23 SWG—2 mils enamel, double rayon and single cotton. Waxed.	7200	12·8	562	300 megohms
23 SWG—2 mils enamel, double silk and single acetylated cotton. Waxed.	5800	10	550	400 megohms

The efficiency of all insulating materials is influenced by the conditions in which they will be used, and when selecting them, the climate, the location of the particular building, and the existence, or otherwise, of adequate air conditioning plant must be taken into consideration. The development of improved types of insulants for wire is based on expert knowledge of the problems created by the diverse conditions experienced in service, which, together with other factors affecting efficiency, will now be considered.

MAIN CONDITIONAL FACTORS.

Humidity.

Organic materials absorb moisture at differing rates when exposed to a humid atmosphere or when in contact with water. Plastic insulating materials of many types absorb extremely minute amounts over long periods ; for example, in the case of polythene and polystyrene the amounts are negligible for all practical purposes. On the other hand, animal and vegetable textile fibres rapidly absorb considerable proportions of moisture from the atmosphere (Fig. 1), and this has a tremendous effect on insulation resistance, as revealed in

Fig. 2. The range of humidities indicated may be experienced in this country in poorly heated buildings or where the equipment is exposed. In many overseas countries, high humidities are accompanied by sudden atmospheric changes which cause the condensation of moisture and rapid acceleration of the amount absorbed.⁽¹⁾ It follows, therefore, that under adverse conditions of humidity all textile insulants become relatively ineffective, and,

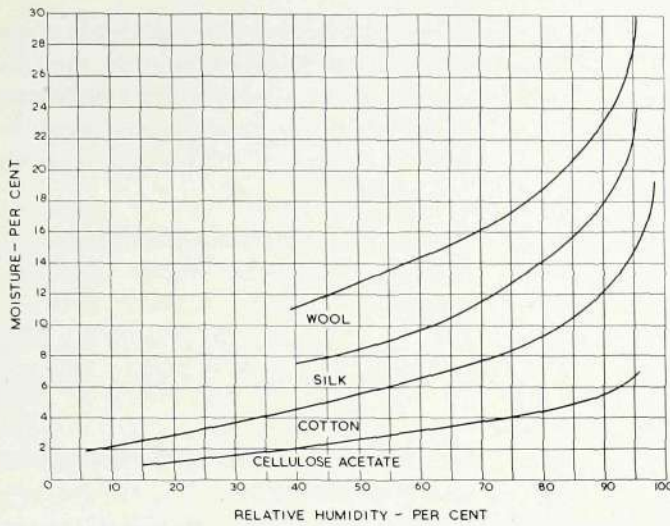


Fig. 1—Relation of Moisture Content of Textiles to Relative Humidity

whilst opinions vary as to the safe maximum humidity to which they should be submitted for long periods, it can be stated that, approximately, this should not exceed 70% R.H. at a temperature of 70°F. It is therefore important that one of the principal objectives of development should be the maintenance of insulation under high humidities. Reference has already been made to the improvement achieved in this respect by the use of enamel insulated textile covered wires, and the comparative efficiencies of the standard types are shown in Fig. 3.

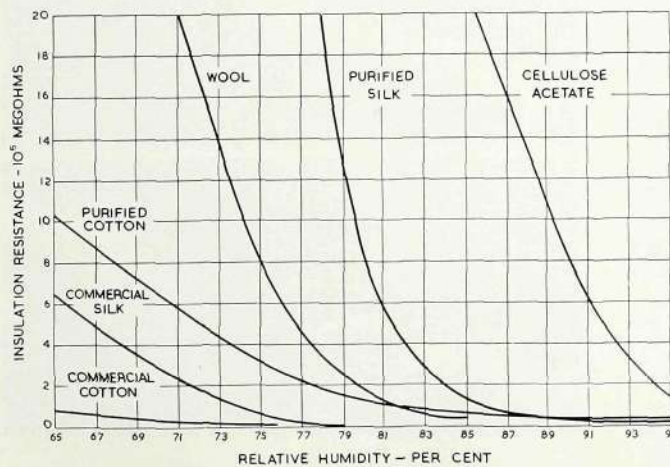


Fig. 2—Insulation Resistance of $\frac{1}{2}$ inch Lengths of Textile Threads as Influenced by the R.H. of Atmosphere

Purity of Materials.

The initial purity of materials has an important bearing on insulation efficiency and, in the case of textile coverings, present day specifications cannot be met unless great care is taken to ensure that the proportion of inorganic salts present is very small. Apart from these deleterious substances which invariably exist in the natural animal or vegetable fibres, manufacturing and dyeing processes involve treatment with chemicals the residues of which may degrade insulation. Synthetic fibres and certain types of plastic compounds originate from manufacturing processes which generally enable the necessary

degree of purity to be maintained, but cotton, wool and rayon must be subjected to thorough washing processes in order to attain this degree. Impurities which form electrolytes may be acids, alkalis or neutral salts, and the amount of these substances present in the moisture content of the textiles determines its electrical conductivity and, therefore, the efficiency of the insulation. The sulphate and chloride contents of a number of different textiles are given in the following table :—

Textile.	.SO ₄	.Cl.
Cotton	0.05%	0.03%
Rayon	Very faint trace	0.015%
Pure silk	0.08%	0.025%
Cotton (red)	0.015%	0.005%
Cotton (blue)	0.02%	0.008%

P.O. Specification M.109.D includes a convenient method of assessing the electrolyte content of textiles by measurement of the specific conductivity of aqueous extracts and also states the maximum permissible values, which are as follows :—

Material.	Max. Specific Conductivity at 25°C Micromhos.
Soft cotton	100
Mercerized cotton	100
Acetylated soft cotton	100
Acetylated mercerized cotton	100
Natural silk	100
Woollen or worsted	100
Cellulose acetate rayon	100
Regenerated cellulose	100

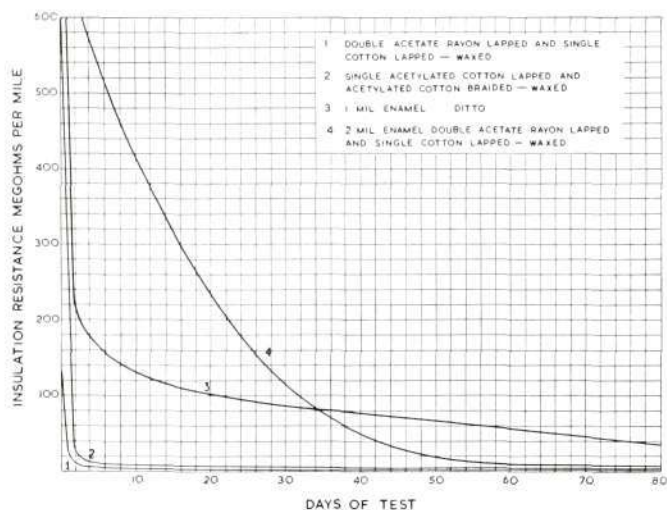


Fig. 3—Fall in Insulation Resistance of Twisted Pairs Subjected to 95% R.H. at 60 F.

The allowable maximum fatty content, in the form of residual quantities of spinning lubricants, are also specified in M.109D.

Standing Potentials and Surge Voltages.

In the early days of public telephone systems the standing voltage imposed on the equipment was of the order of 3V and that used for signalling was derived from low wattage hand driven magnetos. This, while imposing functional limitations on these very simple systems, permitted the use of insulating materials of very low efficiency, such as wood. Magneto systems were followed by central battery signalling, later by central battery, and finally by the present automatic systems. Concurrently with these developments the d.c. voltage was increased. The growth in size, and the complexity of individual exchanges, combined with the intricacies of trunk working have made it imperative for the insulation resistance for each component to be considerably improved, but other factors also must be taken into account. Today the maximum nominal working voltage to earth on B.P.O. automatic telephone systems is 50V. d.c. and 90V. a.c. 16.6 c.p.s., thus there is a standing peak voltage between conductors of almost 180V., and a maximum of 127V. above earth.

These, however, are not the highest stresses to which insulants may be subjected, as, with certain conditions of working on auto/manual switchboards, peaks of 1600V. have been recorded.

From the foregoing statements it follows that the three essential objectives are :—

- (a) Adequate insulation values to meet normal circuit requirements.
- (b) Ability to withstand momentary peak voltages.
- (c) Freedom from electrolytic corrosion over long periods, particularly where wires have standing potentials.

With regard to (c), the factors to be taken into consideration are the specific conductivity of the textiles and the prevailing humidity. In severe conditions where humidity persists for long periods at 95% R.H., all textiles are liable to electrolytic corrosion. This problem has been thoroughly investigated in our laboratory and a

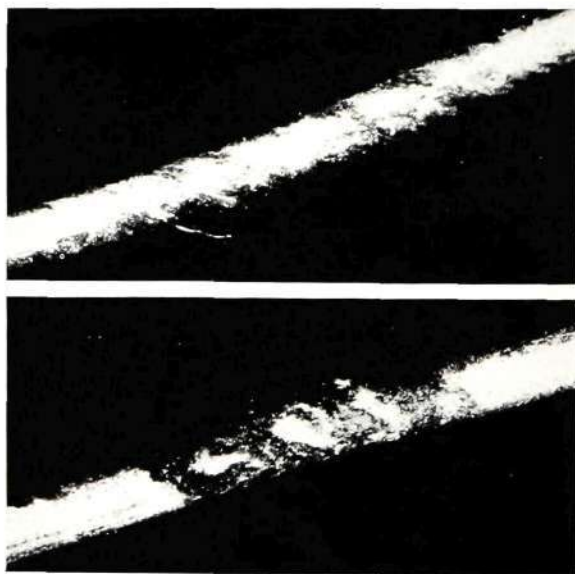


Fig. 4—Micrographs Showing Electrolytic Corrosion on Wires which were Textile Insulated



very extensive range of impregnated and unimpregnated wires have been submitted to tests.

With standing potentials of 24V. at 90% R.H., 65°F, it was confirmed that cotton insulated wires showed large areas of corrosion, affecting from 50% to 90% of the surface of the conductor, after a period of four months. Rayons of various types had corrosion areas of 5% to 50% under similar conditions. The micrographs in Fig. 4 show that in each case the action closely follows the spiral form of the lapping at the points where the textiles are in close contact with the conductor. These experiments confirm that it is not possible, at present, to eliminate the liability of wire to electrolytic corrosion with textile insulants alone, and that a continuous covering of enamel or plastic is essential for tropical or other severe conditions.

Temperature.

It is difficult to consider the influence of temperature on switchboard wire and insulating materials without taking into account prevailing humidities. Obviously, with the higher temperatures experienced in tropical countries the effects of moist conditions are much more marked, as the following figures illustrate :—

Temperature	60°F.	90°F.
Relative humidity	90%	90%
Moisture content/cu. ft.	5.1 grains	13.2 grains

It will be seen that at 90°F. the moisture content is about $2\frac{1}{2}$ times that at 60°F. It is important that switchboard wires should have good insulation, not only at high temperatures and humidities but also when subjected to temperature changes which result in the condensation of moisture.⁽²⁾

Most organic insulating materials are adversely affected by rises in temperature alone, the resistivity decreasing as temperature increases. In the case of plastic insulation the effect of temperature is distinct and materials used for switchboard

wire insulation must be carefully selected so that the necessary resistance value can be maintained at service temperatures.

Liability to Mould Growth.

In the untreated condition most textiles are subject to mould growths, and the consequences may be extremely serious because of the physical and electrical deterioration which follows. Cotton is particularly susceptible, and its insulating properties are liable to complete failure when conditions are favourable to mould growth.

Impregnating waxes do not give adequate protection and it is therefore necessary to introduce fungicides which inhibit mould growth. There are many types available and small quantities can be incorporated in textile fibres, plastics, or impregnating materials. It is incorrect to assume that mould growth is a serious matter only in tropical countries, for many instances have been noted in temperate climates, as a result of poor ventilation. The resistance to mould attack can be determined by spraying the material with an aqueous suspension of several types of mould spores, followed by incubation at 32°C, 95% R.H. After 28 days there should be no visible sign of growth. This method of testing is detailed in various government specifications.

Insect Attack.

Textiles are subject to attack by many types of insects and their larvae, while rodents constitute another menace. Ants and termites have caused serious damage to installations overseas. It is extremely difficult to treat textile insulated wires in order to render them immune to these forms of attack and there is growing evidence that polyvinyl chloride insulated wires will form the best solution to this problem.

Thermal Effects.

Telephone multiple cables and switchboard wire forms may comprise some



hundreds of individually insulated conductors bunched closely together, and if any one conductor becomes slightly heated by electric current there is a certain amount of evaporation of the moisture present in the covering. This may result in condensation in adjoining wire coverings and an increase in their moisture content. Heavy waxing or the impregnation of cable forms may accentuate these effects because the moisture is confined and is not readily released to atmosphere. It is necessary to consider these points when evaluating insulating materials and to provide a factor of safety to meet humidities higher than those which prevail in the atmosphere. Plastic insulated wiring has an extremely low moisture content and is therefore influenced by thermal reaction to a very small degree; furthermore, as there is no need to impregnate the forms, free ventilation is maintained.

Atmospheric Contamination.

Reference has already been made to the rapid absorption of atmospheric moisture by textiles and the importance of the maintenance of a high degree of chemical purity. It is obvious that if the atmosphere is polluted by chemical substances, these will also be absorbed, thus reducing the efficiency of the insulation and increasing the liability to electrolytic corrosion. In industrial areas, products of combustion introduce into the local atmosphere traces of sulphur oxides and ammonia compounds, while chemical factories and other process plants may emit many more impurities.

This matter has been studied very closely in this country since 1912 when an advisory committee on atmospheric pollution was appointed under the control of the Meteorological Office. The work was taken over in 1927 by the Department of Scientific and Industrial Research and is now continued by the Atmospheric Pollution Research Committee of the Fuel Research Board. A large number of reports have been published as a result of their work in many parts of the country. In some places

the quantities of atmospheric impurities are low, the proportion of ammonia and sulphur (SO_3) each being of the order of 0.01 mg/cubic metre, but in certain industrial areas, proportions are much higher and SO_3 contents up to 9 mg/cubic metre have been reported. In coastal areas it is possible that a certain amount of chloride may be introduced into the atmosphere from the sea, in fact, as much as 36 lbs. of sodium chloride per acre is deposited in some regions, and in any case, the chloride content of textile insulants is usually found to be higher than in inland locations.

Organic substances may absorb up to 0.7 mg of sulphur oxides per day per 100 sq. cm. of surface exposed, and as textile filaments present a very large surface area in relation to that of the conductor, high absorption rates are frequently recorded. Conductivity measurements of the aqueous extracts reveal increases of impurities which result from atmospheric exposure. For example, initial conductivity values of the order of 70 micromhos, for some textiles, may increase to 350 micromhos over a period of ten years in an industrial town, and to 150 micromhos in more favourable conditions. The reduction of insulation values which accompany this is considerable.

Atmospheric pollution may, in certain circumstances, result in considerable degradation of the strength of textile fibres. Investigations indicate that this may be caused by sulphur oxides and traces of other inorganic acids. It would appear that wax impregnation does not retard to any appreciable extent the absorption of atmospheric impurities, the resistance to which is, without doubt, one of the most important objectives in the development of switchboard wire insulants.

Dirt and Dust Deposits.

One of the principal causes of the deterioration of telephone equipment is the deposition of dust from the atmosphere.⁽³⁾



Dust and dirt are highly contaminated with conducting substances which promote surface leakage and generally reduce insulation resistance. In main exchange equipment it is possible to minimize the effect by the provision of suitable air filtering units which, however, do not eliminate dust deposition but rather reduce the rate of this inevitable process.

Dust deposited from industrial atmospheres has a very high conductivity, which in the aqueous extract may be as much as 1500 micromhos, and a substantial sulphate content of up to 5%. Ammonia salts are also present in appreciable quantities.

In tropical countries dirt deposits may support mould growth, although the switchboard wire covering may not do so, while in coastal areas high proportions of salt cause even greater deterioration. Dirt on waxed cable-forms rapidly masks the identifying colours, and its adhesion to the somewhat sticky surface eliminates the possibility of cleaning. This fact is emphasized by the appearance of the partially cleaned cable-form on the extreme right of the coloured illustration. Our experimental work proves that chemical substances contained in the dust permeate through the textile insulation. Obviously, a smooth polished surface such as plastic insulated wires and lacquered textile insulants possess, is much to be preferred. Coverings of this type have three advantages :—

- (1) They can be readily cleaned. (See cable form second from right in the coloured illustration).
- (2) The colours are permanently recognizable.
- (3) Initial I.R. values are maintained.

Incidental Contamination.

Elaborate precautions are taken in the telephone industry to prevent the contamination of covered wires during manufacture and assembly, a very high standard of cleanliness being maintained at all stages. Nevertheless, the possibility of occasional

contamination cannot be dismissed, and cases are met where faults have been caused through condensation from new buildings, or through contact with perspiration. In other instances, corrosion has resulted from the presence of vermin. High resistance to all types of chemical action is therefore most desirable for all forms of wire insulation, and non-absorbent materials are necessary to secure this feature.

FUNDAMENTALS OF SWITCHBOARD WIRE DEVELOPMENT.

Switchboard wire development is based on :—

- (a) The maintenance of technical progress to provide the best textiles for service under reasonably favourable conditions.
- (b) The development of insulation which will satisfactorily withstand stringent conditions of service and the other adverse factors which have been described.

As it is not possible to forecast with accuracy the ultimate service conditions in any particular instance, the preferred course is to provide the types of covered wires which are satisfactory under all circumstances, assuming that the cost is permissible. This policy would achieve a greater measure of standardization—always a desirable objective—while increasing the factors of safety. The latter point is particularly important in securing standardization in countries having wide variations in climatic conditions.

It has been stated that a continuous form of insulation covering is essential for maximum efficiency, and modern extruded plastics are now regarded as the main field for development. The group of flexible plastics available include natural and synthetic rubber, polythene, and polyvinyl chloride (polymers or co-polymers). P.V.C. is relatively non-inflammable and is, therefore, preferred for telecommunication wiring, where the prevention of fire is a matter of prime importance, also this class of



covering eliminates the absorption problems which are always associated with the large surface areas and capillaries presented by textiles.

While continuous insulation is given by enamel coatings, difficulties with soldering and the possibility of pinholes are problems which are very difficult to overcome. Wires which are only textile lapped and lacquered provide the smooth, polished finish which is desirable but they do not provide high insulation resistance under humid conditions.

P.V.C. Wire Insulating Compounds.

P.V.C. compounds are primarily based on vinyl chloride acetate, co-polymer resins. Special grades have been developed for electrical purposes as distinct from other types which are manufactured for a wide variety of commercial uses. The P.V.C. resins are suitably plasticized in order to obtain the degree of flexibility required, and other modifications to the extrusion compounds maintain chemical stability during the covering processes, when the material is subjected to considerable heat. Features which P.V.C. compounds possess in common are as follows :—

- (1) They are chemically inactive and are resistant to acids, alkalis, and salts.
- (2) No oxidation occurs through exposure to the atmosphere.
- (3) Moisture absorption is extremely low and consequently insulation values are maintained after prolonged exposure to moisture.
- (4) The compounds do not support combustion.
- (5) They will not support mould growth and are not attacked by insects or their larvae.
- (6) High fundamental electrical properties are maintained as regards insulation value and breakdown voltage.

Government Department Electrical Specification No. 18 stipulates the P.V.C.

compounds which are used for dielectric insulation and sheathing in the following classes :—

1. General purpose insulant.
2. General purpose sheath.
3. Arctic sheath.
4. Non-migratory sheath.

The compounds are used very extensively throughout the electrical industry and wide experience has been gained under varying conditions in all parts of the world. It must be admitted that the early types of compounds possessed certain weaknesses which, however, have now been eliminated, also it has been found that some types of plasticizers are liable to migration under d.c. potentials and they have been discarded. Extensive research has proved that the plasticizers now employed are stable under these conditions and do not cause stickiness after long periods.

The stability of dioctyl phthalate is fully recognized, whereas many esters of fatty acids are known to have caused difficulty and their use has been discontinued. Similarly, certain aromatic petroleum residues previously employed as extenders are known to sweat out from P.V.C. compounds and these, again, should not be used in any formulation for switchboard wires.

Selection of P.V.C. Compounds.

Manufacturers and users of P.V.C. compounds agree that it is necessary to study very closely the selection of suitable materials for specific types of wires, and to adjust the technical properties of the plastic in order to comply with the appropriate specification, and other requirements assessed from performance evaluation tests made on the completed wire. The Company has, therefore, pursued a policy of close collaboration with P.V.C. manufacturers, and joint technical resources have been utilized to develop grades of insulating materials which are prepared specifically for telephone switchboard wires, principally in the range of 20—25 SWG.



In formulating these compounds the following physical properties are regarded as essential :—

- (1) The thickness of insulation must comply with existing standards so that no wiring accommodation problems are introduced.
- (2) Possibilities of cold flow under pressure must be eliminated.
- (3) There must be no tendency for insulation to "run back" when joints are soldered.
- (4) Stripping of the wire, prior to soldering, must be a simple operation.
- (5) An insulation resistance of at least 100 megohms per mile is desirable at normal temperatures, and must be maintained when the wiring is exposed to prolonged high humidity.
- (6) Proof voltage figures should be such as to ensure that the insulation will withstand peak stresses with a reasonable factor of safety under severe conditions of service.

These points are additional to the accepted fundamental properties of P.V.C.

A compound which satisfies these requirements possesses the following general characteristics :—

- † Volume resistivity (ohm-cm³) at 20°C :
Not less than 5×10^{14} .
- † Volume resistivity (ohms-cm³) at 60°C :
Not less than 5×10^{11} .
- † Power factor at 20°C : 5—7%.
- † Specific inductive capacity at 20°C :
3.5—5.0.
- † Stress at 100% elongation : 3,000-3,400 p.s.i.
- † Ultimate tensile strength : 3,900-4,300 p.s.i.
- † Elongation : 200-250%.
- † Cold Bend : Below -40°C.
- † Cold Flex : -15°C.
- † Specific gravity : 1.41.
- † Hardness (B.S. 903) : Approx. 10.

† Tested according to G.D.E.S. No. 18 (1945) on samples moulded at 170°C.

‡ The cold flex figure gives an indication of the stiffness of the compound and is the temperature at which a force of 580 gm-cms is required to twist the specimen through 200° of arc.

P.V.C. INSULATED, TEXTILE LAPPED AND LACQUERED WIRES.

P.V.C. extrusion compounds can be obtained in a variety of plain colours which can be combined in various ways to give an extensive colour range. Pigmentation may have considerable influence on the electrical properties of the compounds, as particular colours give differing volume resistivities; special care is therefore essential in the selection of the colouring matter employed. An alternative method of obtaining a colour coding scheme is by the application of a thin textile lapping over white P.V.C., a combination which provides efficient insulation and enables existing identification schemes, which may consist of up to 108 colour codes, to be maintained. A high tensile, fine filament lapping is necessary for this purpose so that overall diameters are not unduly increased. Fortisan, a regenerated cellulose rayon, is particularly suitable in these respects; furthermore, it has a low rate of moisture absorption, a high degree of chemical purity, and a smooth polished finish when coated with cellulose acetate lacquer.

There is no doubt that some of the present applications in the telephone industry for switchboard wires insulated with P.V.C. alone, will be maintained; however, apart from the wide colour range, outer textile lappings give the following added advantages :—

- (1) An additional safeguard is provided against the "run back" of P.V.C. during soldering, as the lapping process introduces a slight degree of compression so that if the P.V.C. softens temporarily, as a result of local heating, there is no tendency to shrink, even with the softer types.
- (2) On sharp bends and with heavy cable forms P.V.C., insulation is liable to deform or flow, and in some cases the insulation thickness may be reduced. The rigid textile lapping arrests cold flow under stress, partly as a result of distribution of pressure but principally



because of its non-thermo-plastic nature.

- (3) The outer textile coverings can be modified to give varying degrees of mechanical protection, for example, many conditions of wiring involve considerable manipulation with pliers in order to make acute bends in confined spaces, and double lappings or braiding over the P.V.C. may be preferable in these cases.
- (4) The compactness of the wire forms for telephone switchboards, automatic racks and instruments involves special soldering problems. When soldering is in progress the iron is sometimes in close proximity to adjoining wires which are, therefore, subjected to temporary radiant heat. The non-thermo-plastic textile lappings again prevent any damage or deformation of the P.V.C. which may be momentarily softened by the soldering iron.

It is essential that the outer textile coverings should be treated so that the fibres are made secure and a smooth, hard polished surface results. Cellulose acetate lacquer coatings provide an excellent solution to this problem,⁽⁴⁾ the films having good electrical and mechanical properties and being very stable. The lacquers may be based on widely differing formulations which must be adjusted to suit the characteristics of the particular type of wire concerned. Long experience in the manufacture of cellulose acetate cable lacquers has enabled the Company to produce a special type for the final treatment of P.V.C. and textile-covered wires. In addition to providing the necessary smooth and hard finish, it incorporates a fungicide which inhibits mould growth, while improved flame retarding properties are conferred by special plasticizers. Other advantages, to which reference has already been made, are :—

- (1) The wires are clean in handling during manufacture and storage.

- (2) The textile colours are maintained in a bright and easily recognizable form.
- (3) Dust and dirt do not adhere to the surface, in fact cable forms can be cleaned readily by wiping or brushing.
- (4) Clean neat edges are presented at stripped wire ends and soldered joints.

Specifications and Tests for P.V.C. Insulated, Textile Lapped and Lacquered Switchboard Wires.

In view of the continued development of P.V.C. insulating compounds, current government and other official specifications for the above type of wire may be subject to review ; however, as a matter of interest, typical examples of some of the stipulated requirements are given :—

- (1) Minimum insulation resistance, 100 megohms per mile, measured in air at a temperature of 15°C to 25°C.
- (2) Minimum insulation resistance, 50 megohms per yard, measured in air at 70°C.
- (3) Minimum insulation resistance, 20,000 megohms per yard, immersed in water at a temperature of 15°C to 25°C.
- (4) To withstand 1,000 volts a.c. for 15 minutes after 12 hours immersion in water.

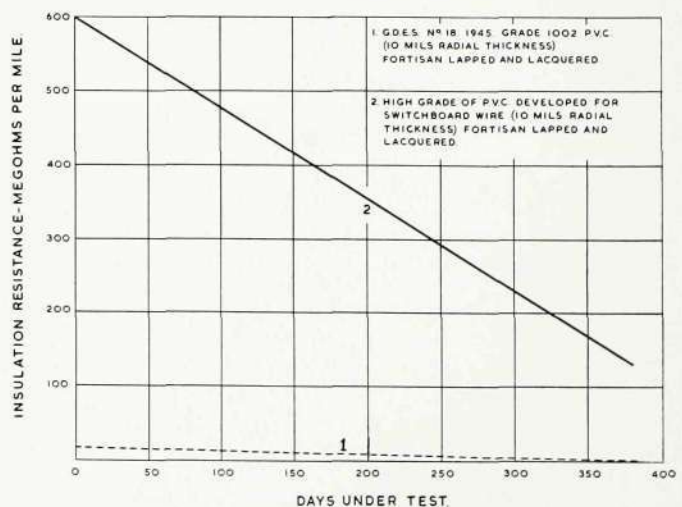


Fig. 5—Fall in Insulation Resistance of Twisted Pairs Subjected to 95% R.H. at 60°F.



It is essential that the general stability and the efficiency of the insulation of switchboard wires should be maintained during the life of the equipment and to ensure this they are subjected to life tests and field trials under various conditions. Extended tests are generally preferred to short accelerated ones, and some examples of the former which are undertaken continuously in the Company's laboratories, are described below :—

Insulation Values Under Prolonged Exposure to High Humidity at Normal Temperatures.

Coils of wire are conditioned in a cabinet which provides a uniform relative humidity of 95% at normal temperatures (60°F—65°F), and test periods extend up to one year, insulation resistance values being taken at regular intervals. A typical example in Fig. 5 shows how these values, at 500 volts d.c., are maintained at a high level in the case of the improved type of compound.

Prolonged Water Immersion at Normal Temperatures.

The maintenance of the initial insulation resistance after the wire has been immersed in water for a long period is a remarkable feature of P.V.C. compounds, and the special grade developed for switchboard wires gives outstanding results. The curves in Fig. 6 are representative of tests made over a period of several months and indicate the average values recorded.

Effects of Atmospheric Pollution.

Reference has already been made to the rapid absorption of atmospheric impurities by textile insulants, and the resistance of P.V.C. insulated wires to polluted atmospheres has been confirmed in our laboratories by a series of exposure tests. Samples of wires were exposed to flue gas of the following composition :—

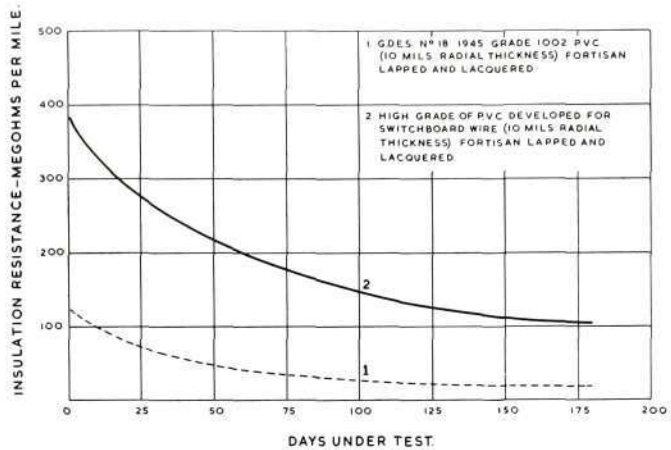


Fig. 6—Fall in Insulation Resistance of Single Wire Immersed in Water at 60°-65°F.

Oxygen	9.1 to 10.2% by volume
Carbon dioxide	7.9 to 9.0% by volume
Carbon monoxide	1.4%
Sulphur trioxide	24.6 m.grms/m ³
Hydrochloric acid	5.29 m.grms/m ³

The results of a 6-months test are tabulated below :—

Description.	Initial Insulation Resistance in Megohms per Mile at 65°F.	Insulation Resistance in Megohms per Mile After 6 Months in Flue Gas Atmosphere at 65°F.
High-grade P.V.C., Fortisan lapped and lacquered, developed for switchboard wire	275	6.72
G.D.E.S. No. 18-1945, grade 1002 P.V.C., Fortisan lapped and lacquered.	12	1.05
Double rayon lapped, single cotton lapped and waxed.	430	0.0005
Single acetylated cotton lapped, acetylated cotton braided and waxed.	2580	0.0008
1-mil enamel, double rayon lapped, and single cotton lapped and waxed.	2060	0.224
2-mil enamel, double rayon lapped, single cotton lapped and waxed.	2450	3.96

P.V.C. insulated wires give a generous factor of safety over the normal specification figures, as shown by the breakdown voltages tabulated below :—



BREAKDOWN VOLTAGES OF P.V.C. INSULATED SWITCHBOARD WIRES.

Type.	No.	.036" tinned copper wire.			.020" tinned copper wire.		
		Break-down volts.	Volts per mil.	Approximate radial thickness of insulation. Mils.	Break-down volts.	Volts per mil.	Approximate radial thickness of insulation. Mils.
Plain P.V.C.	1	18 KV	1310	13.75	12.5 KV	1300	9.6
	2	22 KV	1465	15	11 KV	1135	9.68
	3	21 KV	1510	13.9	13 KV	1340	9.7
	4	21 KV	1510	13.9	15 KV	1530	9.8
P.V.C., Fortisan lapped and lacquered	1	18 KV	1110	16.2	17 KV	1480	11.5
	2	20 KV	1180	16.95	18 KV	1550	11.6
	3	19 KV	1160	16.4	14 KV	1170	12
	4	21.5 KV	1300	16.5	18 KV	1460	12.3

"I am directed to advise you that tests were again carried out during March on the two switchboards wired with the above type of wire (i.e. 23 S.W.G. tinned Cu, P.V.C. insulated, textile lapped and lacquered—Ed.). The insulation resistance was in all cases found to be infinity and the

Insulation Resistance at High Temperatures Under Water.

It is interesting to note that after the initial reduction in insulation resistance resulting from temperature rise, the resistance increases with time, as illustrated by the two graphs Figs. 7 and 8.

Other long term tests have been conducted to confirm that the wires are not liable to electrolytic corrosion, and pairs carrying d.c. potentials of 50V for periods of up to one year in humid atmospheres show no evidence of corrosion or of plasticizer migration.

P.V.C. insulated lapped and lacquered wire was first used on the Company's equipment in 1946, after some years of experimental work, and a number of friends overseas were invited to report on its efficiency under service conditions. Much favourable comment has been made and the reports have formed a valuable supplement to the life tests which have been described. We quote an extract from a report from Malaya on cable forms which have been in service for three years in temperatures of up to 90°F with 95% relative humidity.

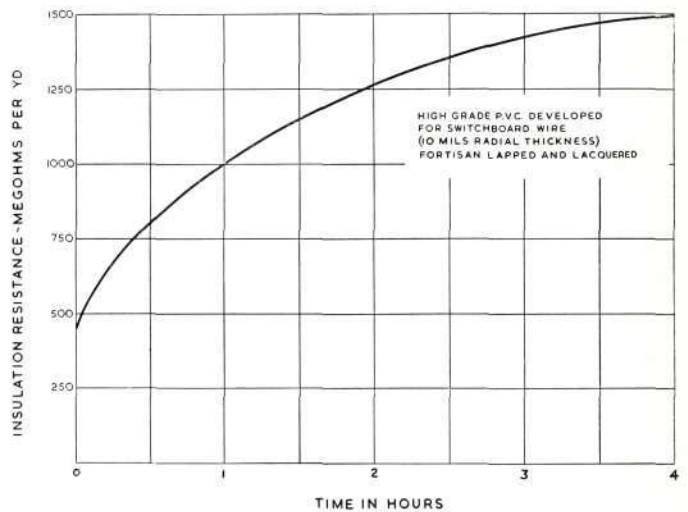


Fig. 7—Insulation Resistance of Single Wire Immersed in Water at 57°C (135°F.)

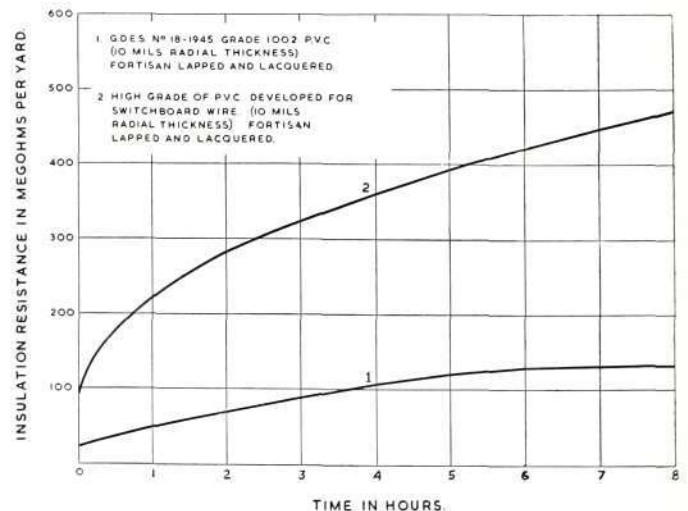
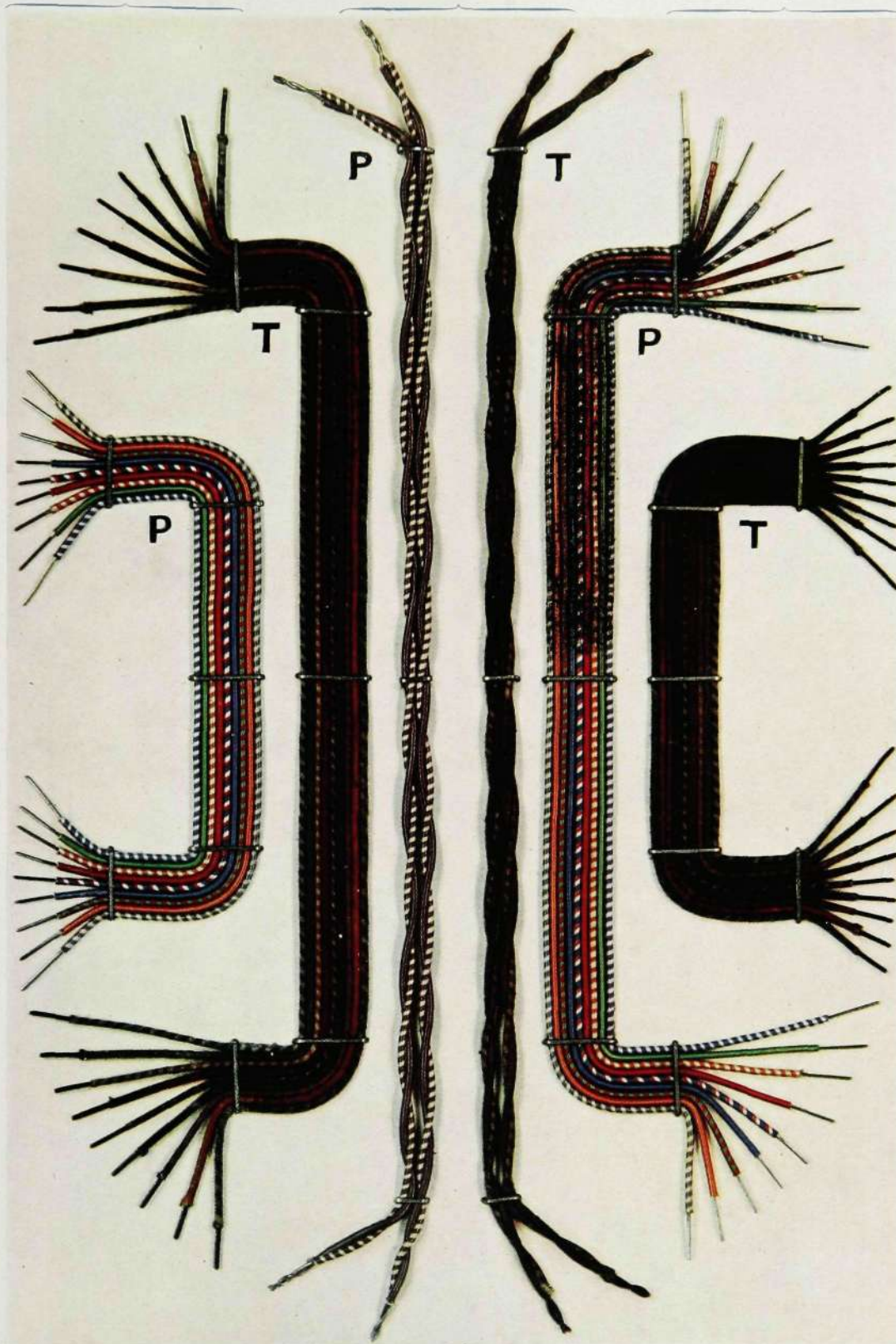


Fig. 8—Insulation Resistance of Single Wire Immersed in Water at 70°C (158°F.)

Unused
condition

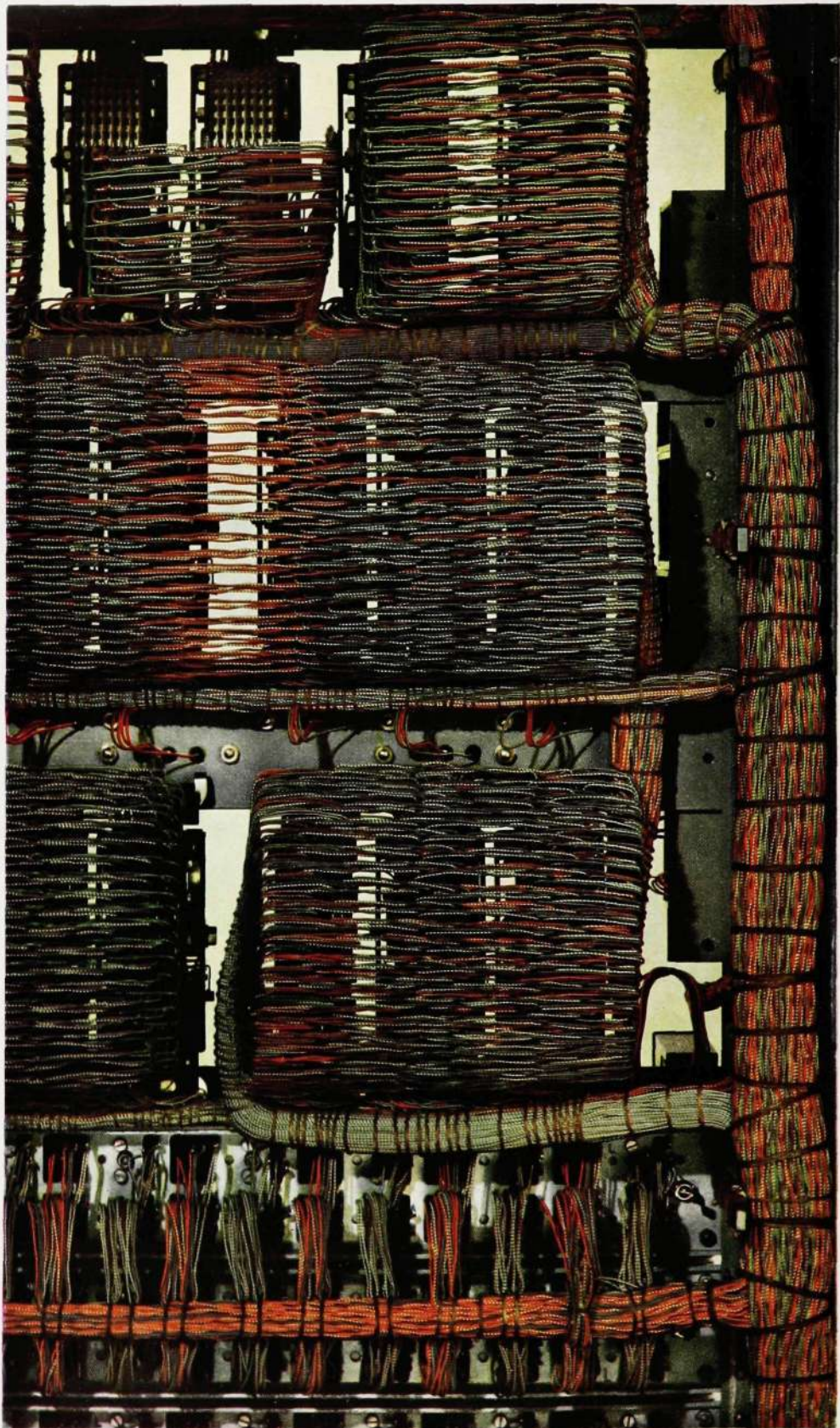
After twelve months
exposure in humid
conditions

Partially cleaned after
exposure in dusty
atmosphere



$P =$ 23 S.W.G. TINNED COPPER WIRE, P.V.C. INSULATED, TEXTILE LAPPED & LACQUERED $T =$ 23 S.W.G. TINNED COPPER WIRE, ENAMELLED, TEXTILE LAPPED & WAXED

Illustration Showing the Brilliance and Permanence of Colours and Resistance
of Insulated Wires "P", Compared with "T" above.



Part of a P. A. X. Equipment Rack Wired with 23 S. W. G. Tinned Copper Wire P.V.C. Insulated, Textile Lapped and Lacquered.

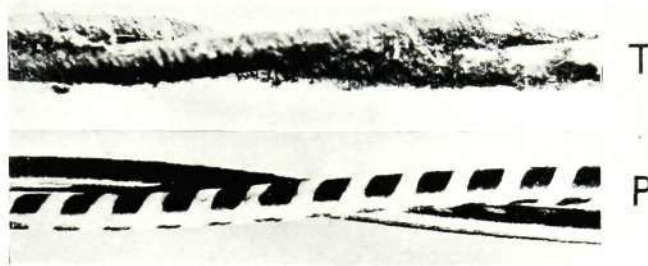


Fig. 9—23 S.W.G. Insulated Wire Magnified to Show Effects of 12 months Exposure in Adverse Conditions

T=Enamel and textile insulated, textile lapped and waxed
P=P.V.C. insulated, textile lapped and lacquered.

testing officer reports that the wiring is still in excellent condition, and that its cleanliness is remarkable, as dust can very easily be removed from the surface of the forms."

Previous reports from the same location confirmed entire freedom from mould growth or insect attack under conditions which create serious problems in connection with textiles.

The two wire forms in the centre of the coloured illustration, and the magnified portions of forms shown in Fig. 9, indicate the comparative efficiencies of the two types of insulation under adverse conditions of humidity. It will be seen that the P.V.C. insulated, textile lapped and lacquered wire has retained its original appearance and properties, while the waxed textile insulation has been badly discoloured by mould growth.

The use of the new type of switchboard wire has been approved by many of our

principal customers both at home and overseas and its application is steadily expanding. An example of its use is shown on the coloured insert which illustrates part of the wiring side of a 50-line P.A.X. unit. The brilliance of the identifying colours and the neat appearance are particularly noticeable.

New types of plastic insulated wires are being examined and evaluated by the Company and there is no doubt that these will result in further advances in the efficiency of tele-communication wiring in the future.

REFERENCES.

- (1) *Special reference to humidities and other characteristics of tropical climates are dealt with in detail in a paper presented to the I.E.E. "The development and design of Colonial Telecommunication Systems and Plant" C. Lawton and V. H. Winslow—July, 1946.*
- (2) *"Electrical Engineering Problems in the Tropics," by R. Allen I.E.E. Journal, Installations Section, December 11th, 1947.*
- (3) *"Telephone equipment for the Tropics," by Sir Norman Frome, C.I.E., D.F.C., M.Sc.—I.E.E. paper, September, 1949.*
- (4) *"Cellulose Acetate Treatment for Textile Insulations," Bell Technical Journal" Volume 11, 1932—E. V. Wood, D. R. Broste.*



A New Frequency Meter

THERE are various ways of measuring frequency, e.g. by the Lissajou figure method,⁽¹⁾ the use of an oscilloscope with a calibrated time scale, the utilization of various types of frequency dependent networks,⁽²⁾ and by the counter valve method in which an electronic gate is opened for a definite period and the number of cycles passing through it counted electronically.^{(3) (4)}

The meter described in this article is in the last-named category and although the principle used is not new, the introduction of a new type of cold cathode counter valve has enabled a more simple and compact instrument to be designed than was possible with hard valve binary and ring type counters.

The meter was designed for laboratory use and is of an experimental nature ; however, it has shown that it is possible to evolve a means of measuring low audio frequencies to a high degree of accuracy at reasonable cost.

An indication of the economy achieved is revealed by the fact that commercially available types of decade counters utilize a minimum of eight valves per decade and at least four indicating lamps or one moving coil voltmeter, whereas in the meter here described, the equipment per decade comprises one valve pulse amplifier

and a gas-filled counter valve^{(5) (6) (7) (8)} or "dekatron". The higher speed dekatrons used are limited to a maximum of 2,000 c/s and are not yet commercially available ; however, for the purpose for which the instrument was designed, i.e. the laboratory and factory testing of the frequency of vibrators to close limits, the range is adequate.

GENERAL PRINCIPLE AND DESCRIPTION.

The principle of the instrument may be explained by reference to the block schematic diagram, Fig. 1. The frequency reference source is a 1 kc/s crystal controlled oscillator the accuracy of which is better than 0.01% over a normal ambient temperature range. The output from the oscillator is applied to a phase-splitter and amplifier and then to a series of dekatron dividing stages. These are used in preference to multi-vibrator dividers, requiring no adjustment and being independent of normal supply voltage variations.

The standard frequency of 1,000 c/s is divided down to obtain pulses at pulse repetition frequencies (p.r.f.) of one per second and one per ten seconds. These pulses are applied to the gate circuit which remains inoperative until the "count" key K1, (Fig. 2) is depressed, when, upon receiving a pulse from the previous stage it is switched to the condition where the

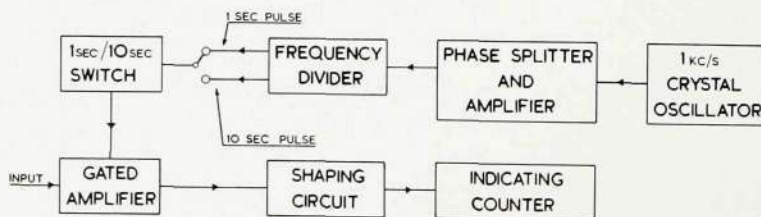


Fig. 1—Block Schematic of Frequency Meter

gate amplifier passes the signal under test to the pulse shaping circuit. The next pulse arriving at the gate circuit restores the *status quo*, and thus the electronic gate is opened for a period of one or ten seconds as selected by the frequency multiplier switch S4. During this period the amplified signal under test is fed to the shaping circuit, which provides pulses of suitable shape and amplitude for operating the first of another series of dekatron counters.

This second series, the indicating counter of Fig. 1, is brought to zero by the operation of the "reset" key K2 of Figs. 2 and 3. It will be seen from Fig. 2, that the indicating counter valves are positioned so that the glow is visible from the front of the instrument.

Without any special attempt at miniaturization, the instrument has been made reasonably compact, being 19" x 19" x 12" and weighing 48 lb.

PERFORMANCE.

From the foregoing description it will be appreciated that the operation of the instrument is extremely simple. The frequency range is 15-1,500 c/s and the minimum operating voltage is 10V peak to peak. For vibrator work a 15V d.c. supply is provided, and may be chopped by the contacts of the vibrator under test, the resulting square wave output being used to operate the instrument. The lower frequency limit is determined by the time constant of the

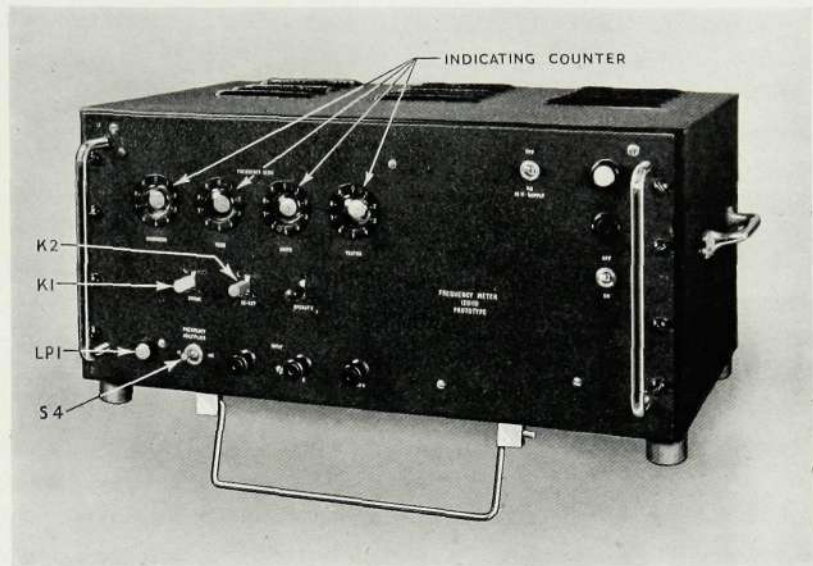


Fig. 2—The New Frequency Meter

R/C coupling of the gate amplifier and may be extended to zero provided that the latter is d.c. coupled.

The accuracy of the instrument is determined largely by the phase of the input waveform at the instants when the gate opens and closes, and as the pulse shaping circuit, a bi-stable multivibrator, does not operate exactly at the moment when the input waveform crosses the zero potential line, but at points either side of the latter, it is estimated that the maximum error to be expected, which is additive to the last digit displayed, is within the limits +1.0 and -1.3. In practice the positive error is reduced to +0.5, a fact which is possibly explained by the particular nature of the first and last input pulses to the counter. These are not only of variable width, but are distorted by the R/C coupling networks. Other factors affecting accuracy, such as the frequency of the 1,000 c/s crystal oscillator, are found in practice to be of a lower order than those mentioned above.

CRYSTAL OSCILLATOR, AMPLIFIER AND PHASE SPLITTER.

The frequency reference source is a crystal controlled oscillator of conventional design, with a sinusoidal output voltage of 3.5V at a frequency of 1,000 c/s $\pm 0.01\%$.

Its output is amplified, then applied to a phase changing network to obtain two sinusoidal voltages of equal amplitude, one lagging 60° in phase behind the other. Each signal is then amplified by two separate R/C coupled amplifiers and applied to the second and first guide electrodes, respectively, of the first dekatron, so that these electrodes become successively negative with respect to the cathode, causing the glow to transfer from one cathode to the next, in turn.

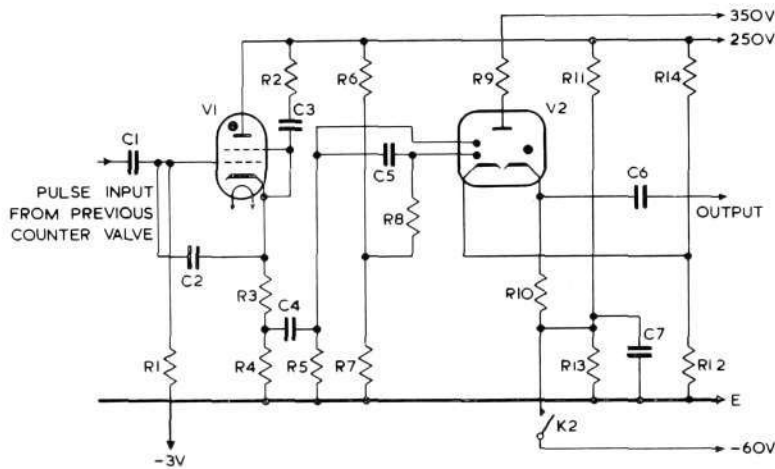


Fig. 3—Dekatron Coupling Circuit

FREQUENCY DIVIDER.

The frequency divider consists of four dekatrons, each of which provides output pulses at a recurrence frequency of one-tenth of that of the driving pulses; thus at the outputs of the third and fourth dekatrons, pulses are obtained every one second and every ten seconds respectively. A convenient method of coupling successive

dekatrons is by means of a gas filled tetrode (Fig. 3). The pulse from the previous counter is applied via the differentiating circuit R1/C1, to the grid of the gas filled tetrode V1. The valve is connected as a relaxation oscillator, the standing negative bias on the grid being sufficient to prevent the valve from striking. When this grid potential is raised by the incoming positive pulse, the thyatron commences to oscillate in the conventional manner; however, before more than one cycle is completed the potential at the grid of V1 is restored to its normal value and the thyatron stage becomes, in effect, a pulse amplifier producing a large steep-fronted positive pulse. The output of V1 is fed via the potentiometer R3/R4 and an R/C coupling R5/C4 to guide 2 of the dekatron V2. It is also

coupled to guide 1 via a differentiating circuit R8/C5. The static potentials existing on the guides and cathodes are shown in Fig. 4.

The glow rests on the electrode which at any particular moment has the largest negative potential with respect to the anode, and will normally be on guide 2. On the arrival of a positive pulse at both guide electrodes, the glow transfers to the cathode and as the voltage on guide 1 decays at a greater rate than that on guide 2, the glow moves successively on to these electrodes; consequently a train of pulses moves the glow round the valve at a rate determined by the input p.r.f.

Following the dividing counter is a further gas filled tetrode pulse amplifier

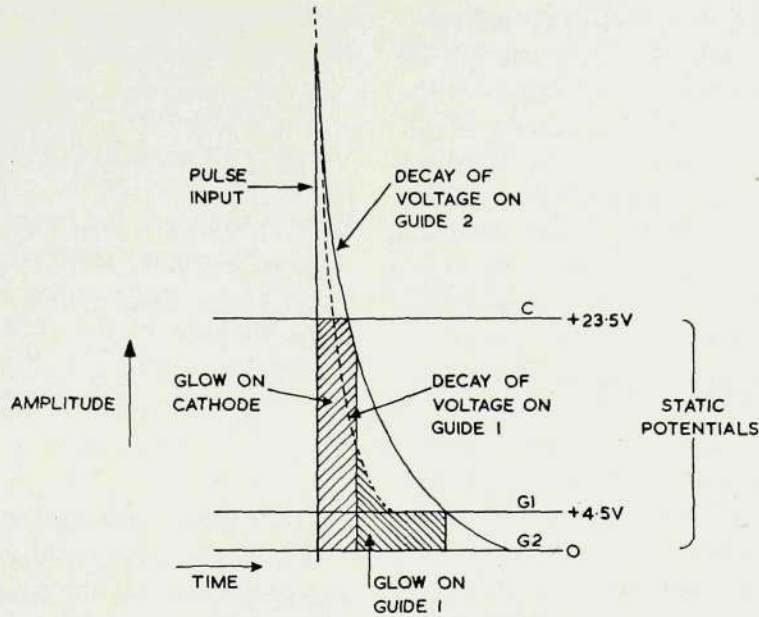


Fig. 4

which provides pulses of sufficient amplitude to operate the switch circuit. The input is selected by the frequency multiplier switch S4, (Fig. 2) so that the gate amplifier is made to pass the input signal for a period of one or ten seconds as required.

1 SEC./10 SEC. SWITCH AND GATE.

The switch circuit and gate are shown in Fig. 5 and consist of a gate amplifier V1 and two Eccles - Jordan trigger circuits V2/V3 and V4a/V4b. The operation of these circuits is as follows :—

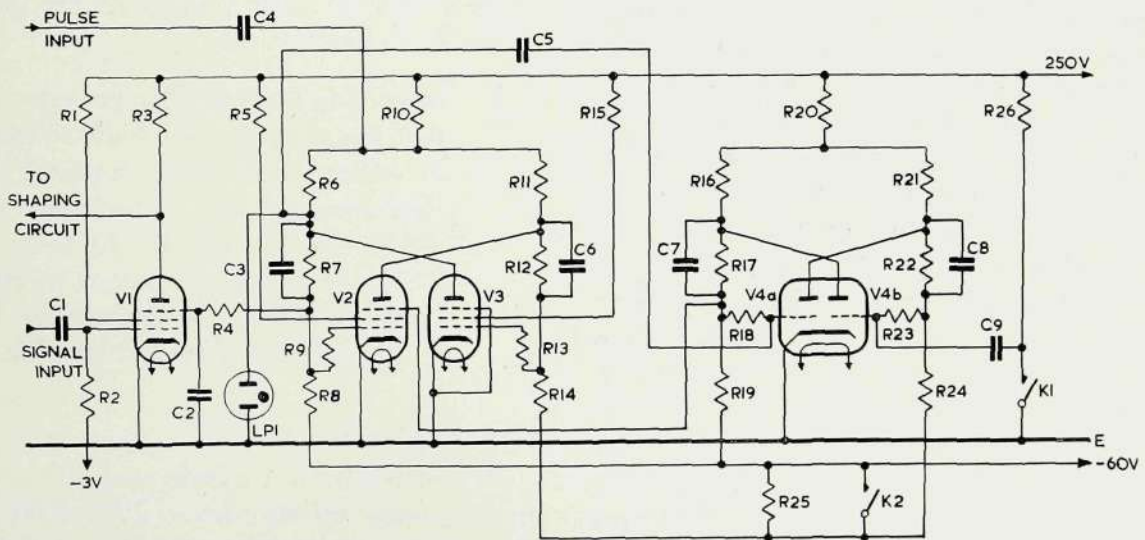


Fig. 5 1 sec/10 sec. Switch and Gate Circuit



The short suppressor grid base pentode V1 has sufficient negative suppressor grid bias to prevent anode current flowing, the bias being obtained from the control grid of V2. The trigger pair V2/V3 is held by the suppressor grid of V2 in such a manner that V2 passes no anode current. This trigger pair is operated in a conventional manner, negative pulses being injected into both anode circuits. While the circuit is unbalanced these will, of course, have no effect. The negative voltage on the suppressor grid of V2 causing the unbalance, is obtained from the grid of V4a, one of the valves forming the second trigger pair V4a/V4b. This pair is in turn biased by the operation of the reset key K2 (Figs. 2 and 5) which momentarily raises the potential at the grid of V4b and causes this valve to pass current.

When the contacts of the count key K1 are closed, a negative pulse is applied to the grid of V4b, switching the trigger pair V4a/V4b, so that the grid of V4a is raised in potential by an amount which is sufficient to restore balance in the trigger pair V2/V3, thus making it capable of responding to the first negative pulse arriving at the anodes. This pulse switches V2/V3 to the condition where the control grid of V2 and the suppressor grid of V1 are raised in potential. The latter valve then passes anode current, and the incoming signal is amplified and applied to the shaping circuit; simultaneously the voltage at the anode of V3 is increased and the neon lamp LP1 strikes, indicating that a count is taking place. The next negative pulse arriving at the anodes of V2 and V3 restores these valves to their original condition, causing the anode current of V1 to cease and at the same time transmitting, via C5, a negative pulse to the grid of V4a. This in turn restores the second trigger pair V4a/V4b to its original

condition so that subsequent pulses have no effect on V2 and V3.

A small capacitor C2 is connected between the suppressor grid of V1 and earth, in order to by-pass to earth any stray positive triggering pulses fed to the suppressor grid. This removes any chance of spurious counts due to extraneous pulses being fed via the gate amplifier to the shaping circuit. No appreciable error in the period of the opening of the gate is introduced by this capacitor.

PULSE SHAPER AND INDICATING COUNTER.

The pulse shaper which follows the gate amplifier provides the first dekatron of the dividing counter with a waveform of definite shape, and comprises a bi-stable multivibrator giving a square wave output of some hundred volts peak amplitude. (The method of operating the dekatron from square pulses has been described elsewhere.⁽⁵⁾) The following three dekatrons are coupled in a manner similar to that used in the dividing counter. It is important in this case that the guides of each dekatron be connected in such a way that the glow moves in a clockwise direction.

N.B.—A notable feature of these valves is that the glow may be made to move in either direction as required, by interchanging the connections to guide 1 and guide 2. In order to bring the dekatron to zero, a large negative voltage is applied to the output cathode via K2 (Figs. 2 & 3).

POWER SUPPLIES.

For operation over a wide range of mains input voltage variations, i.e. 215V-255V, it is necessary to stabilize the h.t. voltages to the gate circuit and the indicating



counters. In view of the small h.t. currents required, this is easily accomplished by the use of suitable gas-filled stabilizing valves. Unstabilized voltages of +350V and +250V are also provided for the oscillator, amplifier and dividing counter. Four unstabilized negative voltage rails of -120V, -60V, -9V and -3V are obtained by means of a potential divider chain placed across the -120V supply. The total power consumption is 135 watts, approximately half of which is required for valve heating.

CONCLUSION.

With improved circuitry and taking advantage of developments in counter valve design, it should be possible to reduce the cost of this type of frequency measuring equipment. Moreover, as new dekatrons with higher top speeds become available, instruments having a wider range than the one described will, no doubt, be designed. Present research seems to indicate that it will be possible to cover the whole audio frequency range.

It appears improbable at the moment that the dekatron will completely oust the hard valve counter from this type of apparatus, but it is evident, even at this early stage of its development, that the new valve is capable of forming the basis of several novel and useful devices.

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Acceptance Testing at Automatic Telephone Exchanges

AUTOMATIC telephone exchange equipment comprises a very large number of parts, many of which are designed to inter-work mechanically and electrically within fine limits ; it is therefore manifestly important that every item should be subjected to meticulous inspection and testing at every phase of manufacture and assembly.

Some of the facilities available in our Beeston factory for this purpose have been described in Bulletin articles from time to time, also details of methods used to inspect raw materials before the commencement of manufacture.

In continuance of these efforts which are made to eliminate faults and to ensure the efficiency of the equipment in service, it is further subjected to comprehensive testing and inspection during and after installation in the exchange building, by both the Company's and the customer's staffs.

"Acceptance Testing" is a term used to cover the inspections and tests made on site. It comprises "provisional acceptance" and "call through" tests, and it is not until these have been satisfactorily completed that the equipment is put into service.

Considerable numbers of the exchange equipments manufactured by the Company are for the British Post Office and this article is descriptive of the work carried out on this type of contract, but the general procedure outlined can be accepted as being applicable to any of our public automatic exchange equipments.

At a later stage it will be noticed that it is the practice of the B.P.O. engineers to inter-spere special tests with our own, and where reference is made to these it should be clearly understood that work of this nature at other than P.O. exchanges becomes the responsibility of the Company's staff.

As the installation proceeds, sections of the equipment are checked and handed over for P.O. testing and provisional acceptance. The tests can be classified in five groups (a) to (e) as follows, and are usually made in the order listed. The call through test (C.T.T.) is additional and for convenience can be designated (f).

<i>Test Group</i>	<i>Check Made.</i>
(a) 1	Position, alignment and rigidity of frames, racks, etc.
(b) 2	Insulation of cables and wires.
(b) 3	Continuity of cables and wires (excepting selector bank multiples).
(c) 4	Selector bank multiple continuity.
(d) 5	Relay and selector mechanism adjustment.
(e) 6	Functional.
(e) 7	Routining.
(e) 8	Transmission.
(e) 9	Lubrication.

Special tests conducted by the P.O., and previously mentioned, include a check on coil resistances, which is carried out at any convenient time before (d) above, and a check on the insulation of apparatus, which can be made as conditions allow. Tests in groups (a) and (b) are normally made during the constructional period.

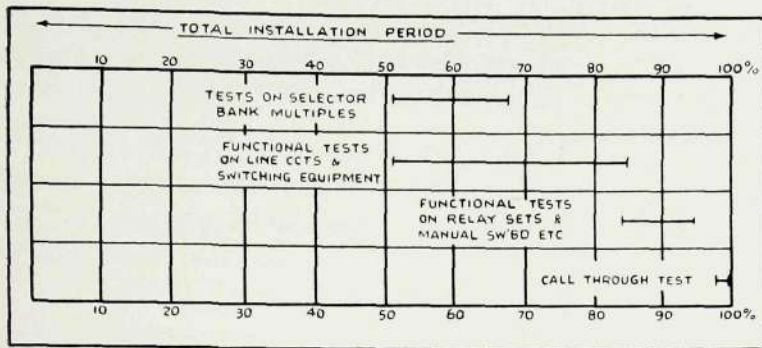


Fig. 1—Relationship of Testing to Total Installation Time

The actual procedure for obtaining provisional acceptance of equipment is as follows :—

When a particular frame, rack, suite of racks or a suitable group of apparatus has been passed by the Company's staff through one of the tests listed, an "acceptance note" is submitted to the P.O. Clerk of Works. This note is a request to inspect the equipment specified, e.g. "final selector racks Nos. 1 to 5 for cabling and wiring".

The P.O. inspection and/or test having been completed, the note is returned, either signed to signify acceptance or with a request to clear the faults indicated, in which case the appropriate action is taken and the equipment re-submitted.

It can usually be assumed that equipment tests, i.e. groups (c) to (f) occupy 40% to 50% of the total installation period for the average contract, as shown typically in Fig. 1.

There can be an overlap between the completion of the constructional period and the start of testing ; for example, wiring can be in progress on miscellaneous circuits while tests are being made on items of main equipment, the amount of overlap being controlled by the extent to which the respective groups are directly

associated, and by the size of the exchange.

The relative percentages of the testing period allocated to the various sections of the equipment in a typical director exchange

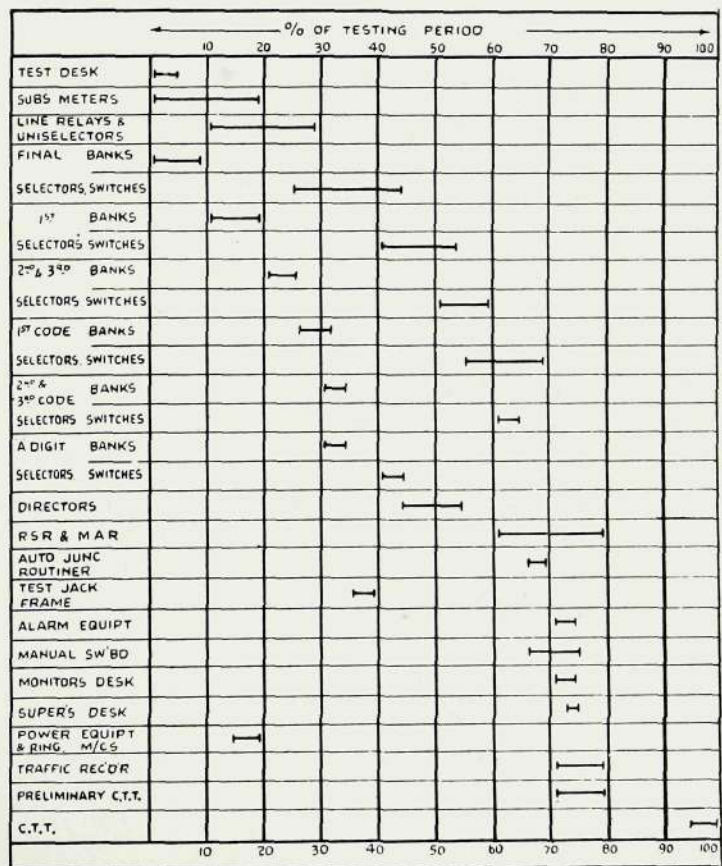


Fig. 2—Typical Testing Programme for 2000-line Director Exchange



of 2000 lines are shown diagrammatically in Fig. 2 which also indicates the sequence usually followed.

Automatic routiners are not listed as their functional tests are carried out in conjunction with those on the associated main apparatus.

Referring to the list of tests previously given, it will be appreciated that all are not applicable to every section of the equipment, as will be perceived by comparing Fig. 3 with Fig. 4, the former listing those scheduled by the P.O. for the manual switchboard and the latter for selector racks. At the left-hand side of each list are references to the main test groups, while certain items are dealt with as part of the normal installation (*) or factory (‡) procedure.

A comprehensive range of apparatus is provided by the Company to enable the staff to carry out the tests made before submitting equipment for acceptance. This includes test boxes which, in the majority of cases, are similar to, or perform similar functions to those of the P.O. The main aim is to submit the apparatus to conditions more severe than, or at least equal to, those experienced in service, but it is not within the scope of this article to give full details; however, the following brief descriptions may be of interest.

TESTER FOR SUBSCRIBERS' METERS.

This is semi-automatic in action and transmits a train of ten impulses to the

meter, facilities being provided in the circuit for checking the impulsing output before the test box is brought into use.

TESTER FOR SUBSCRIBERS' LINE CIRCUITS.

The equipment tests each pair of L and K relays, the associated uniselector, the multiple, and outlets to the trunk distri-

Test Group (a)	INSPECTION FOR LOCATION, ALIGNMENT AND RIGIDITY.
*	INSPECTION FOR LOCATION OF EQUIPMENT.
(b)	EXAMINATION OF CABLING AND WIRING FOR DRY JOINTS, COLOUR SCHEME AND NEATNESS. MULTIPLE TO BE INSPECTED AFTER EACH LAYER IS PLACED IN POSITION.
*	INSULATION OF FUSE PANELS AND ASSOCIATED WIRING. (SEE NOTE 1).
‡	RESISTANCE CHECK OF RESISTORS AND RELAY COILS. (SEE NOTE 2).
*	CONTINUITY TEST OF SWITCHBOARD MULTIPLES (INCLUDING CABLES TO I.D.F.) AFTER EACH FIVE LAYERS HAVE BEEN PASSED FOR CONTINUITY.
(d)	ADJUSTMENT CHECK OF RELAYS.
(e)	FUNCTIONAL TESTS OF CORD AND POSITION CIRCUITS, CHARGEABLE TIME CLOCKS AND MISC. CIRCUITS.
(e)	TRANSMISSION TESTS. (SEE NOTE 3).
	FINAL MISCELLANEOUS INSPECTION.
NOTES.	
1. Can be made at a convenient time by arrangement with Contractor.	
2. Can be made at any convenient time prior to Adjustment and Functional Tests.	
3. If more convenient can be made before Functional Tests.	

Fig. 3—Schedule of P.O. Acceptance Tests for Sleeve Control Manual Switchboard

bution frame. It is semi-automatic in action and circuits are tested in pairs, the change-over from one pair to another being effected by moving the connecting clips along the I.D.F. or the shelf incoming connection strip. Fault indication is given by the failure of check lamps to glow. Facilities are provided to change over from one circuit of the pair to the other, to apply continuous tests to any circuit, to check the



critical adjustment of relays in the box before use, and to restore the testing equipment to its original position ready for the next cycle.

The procedure is as follows :—
One selector is jacked into the first bank in the multiple and the other into the last bank, thus enabling both banks and the interconnecting multiple to be checked, after which the selector is moved from the first to the second bank and the cycle of tests is repeated. This procedure is followed until all banks and the complete multiple have been tested for continuity, reversals, and short-circuited pairs.

When a fault is encountered, the selectors stop and the position of the wipers in the bank is revealed by the glowing of one of a series of lamps on the test box. Should the fault be a short circuit, a special lamp indication is given.

On P.O. contracts the actual equipment selectors are jacked into their respective positions before the Department's bank tests commence, and although at this early stage the switches have not been subjected to our functional tests on site, they should be in working order, with wipers adjusted into the banks.

Test Group	
(a)	INSPECTION FOR LOCATION, ALIGNMENT AND RIGIDITY.
*	INSPECTION FOR LOCATION OF EQUIPMENT (EXCEPT SELECTORS), BUS BARS AND MISCELLANEOUS ITEMS. INSULATION OF CABLES.
(b)	EXAMINATION OF CABLING AND WIRING FOR DRY JOINTS, COLOUR SCHEME AND NEATNESS.
*	INSULATION TESTS OF FUSE PANELS AND ASSOCIATED WIRING. (SEE NOTE 1).
‡	RESISTANCE CHECK OF RESISTORS, MAGNET AND RELAY COILS. (SEE NOTE 2).
*	CONTINUITY OF WIRING NOT COVERED BY BANK TESTS.
(c)	MULTIPLE BANK WIRING, SHELF AND RACK TIES AND TAILS.
(d)	ADJUSTMENT CHECK OF RELAYS AND SELECTORS.
(e)	FUNCTIONAL TEST.
(e)	TRANSMISSION TEST.
	INSULATION TESTS OF SELECTORS AFTER COMPLETION OF INCOMING GRADING.
(e)	FUNCTIONAL TESTS OF MISCELLANEOUS SELECTORS, SIGNALS AND ALARMS.
	FINAL MISCELLANEOUS INSPECTION.
(e)	LUBRICATION OF SELECTOR MECHANISMS.
	MISCELLANEOUS TESTS PRELIMINARY TO CALL THROUGH TEST.
(f)	CALL THROUGH TEST.

NOTES.
1. Can be made at a convenient time by arrangement with Contractor prior to Jumpering and Grading.
2. Can be made at any convenient time prior to Adjustment and Functional Tests.

Fig. 4—Schedule of P.O. Acceptance Tests for Selector Rack

TESTING SELECTOR BANK MULTIPLES.

The equipment consists of a test box and a variety of special test selectors which are used in pairs suitable for the type of rack concerned. The testing of each bank is semi-automatic, the vertical stepping of the selectors being controlled by a key and dial while the rotary movement is automatic.

TESTER FOR GROUP, NUMERICAL, CODE, AND "A" DIGIT SELECTORS.

This equipment is manually operated, keys being used to test the vertical and rotary movements of the mechanism, the efficiency of the impulsing relay and other miscellaneous relay functions, and the various tones applicable to the type of circuit concerned.



The operation of the selector is checked under normal, long line and leak conditions and indication of its correct functioning is given by the glowing of appropriately designated lamps. During the tests a visual inspection is made to ensure that there is no excessive sparking at relay contacts and that the selector steps with a positive, clean action.

TESTER FOR FINAL SELECTORS.

This is semi-automatic, i.e. certain tests are automatically applied in the periods between the manual operation of keys used to effect the complete cycle. The correct functioning of the selector is indicated by a uniselector which stops at pre-determined positions in accordance with the particular test being applied. The uniselector is inside the test box which has an observation window so that the operator can check the position of the switch by inspection of the index wheel.

The tests applied are similar to those for selectors of other types.

TESTER FOR MANUAL SWITCHBOARD.

Switchboard testing is performed manually by means of the test box keys and those used for normal operating on the positions, visual indication of the correct functioning of the circuits being given by the glowing of lamps on the tester and switchboard.

The main features checked are summarized below under the four sections into which the relevant instructions are divided :

(a) *Cord and Position Circuits.*

Sleeve circuit control conditions, engaged test, supervisory signals, cord circuit continuity and the functioning of the telephone, dialling, ringing and coupling circuits.

(b) *Time Checks with Lamp Display.*

Operation of the lamp display panel, and the periods at which the "pip-pip" tone is given.

(c) *Chargeable Time Clocks.*

Functioning of the clocks and the periods at which the associated tone is given.

(d) *Miscellaneous Circuits.*

Under this heading are grouped all miscellaneous tests.

Although not specifically mentioned above, the jack and lamp multiples and cabling to the I.D.F., together with any associated apparatus are also checked.

TESTERS FOR RELAY SETS.

There are two types of test box in this category, both being manually operated by means of keys and having fault indicating lamps. One is used for sleeve control, and the other for miscellaneous, relay sets.

AUTOMATIC ROUTINERS.

The automatic routiner is, in effect, a test rack forming part of the permanent exchange equipment and is capable of applying a cycle of tests either continuously to one particular circuit or successively to a group of circuits without the assistance of a testing officer, once routining has been started.

When a fault is found, the routiner stops and an alarm is given. The particular circuit under test and the nature of the fault are indicated by means of glowing lamps.

Automatic routiners are primarily intended for maintenance purposes but are also used by the P.O. for section functional tests (in the case of selectors, a separate



check on impulsing conditions is first made) and for routining the apparatus in the period between the section and call through tests.

Circuits for which routiners have been designed include all classes of selectors, also directors, outgoing junctions, repeaters, etc. but, excepting directors, they are not normally supplied where there are only small quantities of equipment to be tested. On the other hand, in large exchanges there may be more than one for the same class of circuit.

WORKING TESTS.

This term is used to define the tests made without the assistance of special equipment, as, for example, on test desk, miscellaneous apparatus and alarm and signal circuits which are checked by simulating the conditions experienced in normal working.

POWER PLANT TESTING.

(a) *Ringling Machines and Equipment.*

Tests are applied to verify machine speed, the periodicities of pulses and tones, also the volume of the tones and the functioning of equipment associated with the automatic changeover from the supply-driven to the battery-driven machine on mains failure.

(b) *Batteries.*

It is usually the responsibility of the battery supplier's representative, under the nominal supervision of the Company's staff, to see that the batteries are satisfactory and of the correct output.

(c) *Battery Charging Equipment.*

Tests of the efficiency of motor-generators, or alternatively, rectifiers, are made at the maker's works and it is generally only necessary on the site to check on

polarity, speed, vibration, 25% overload, insulation and temperature in the case of machines, and polarity, output, regulation, insulation and temperature in the case of rectifiers. The associated control apparatus and indicating instruments on the power board are also checked.

PREPARATION FOR THE C.T.T.

When all sectional and miscellaneous tests have been completed and equipment has been provisionally accepted, the switching mechanisms are lubricated. At this stage, the cross-connections on the distribution frames and all grading will have been done so that the whole exchange is ready for the call through test, but before this commences it is the practice of the P.O. engineers to make a series of preliminary checks which include :—

- (1) The proving of all cross connections on the distribution frames.
- (2) A "live line" test on each subscriber's line circuit.
- (3) Verification that NU tone is connected to all spare numbers.
- (4) Tests on junction access equipment.
- (5) A comparison of the gradings with the charts.
- (6) Transmission and overhearing tests.
- (7) Verification that the quality and volume of the various tones conform with the requirements.
- (8) Inspection at the alarm equipment rack to ensure that ringing current and tone and pulse supplies are correctly distributed, also that impulse machines and the associated circuits are in order.



CALL-THROUGH TEST.

This is an operational check which brings into use, at least once, all the subscribers and switching equipment and all junction circuits. It requires the presence, at each rack or suite of racks, of a number of staff whose duties, depending upon their location, include :—originating calls, observing the operation and release of each selector used during a call and then “engaging” that particular switch so that the next one in the group is seized for the following call, and checking from the grading chart that the correct selector is brought into use.

The efficiency of the equipment is judged by the number of faults which occur, a small percentage being allowed ; if, however, this is exceeded, the equipment is rejected and the whole of the particular section may have to be re-tested after correction, with a consequent repetition of the C.T.T.

When the specified standard of efficiency has been met, external tests are made by the Department to check that the exchange equipment functions properly when connected to the subscribers’ telephones and distant exchanges, after which it is usually subjected to special “traffic” tests before being considered completely satisfactory for transfer to service.

CHANGE-OVER OPERATIONS.

The procedure of acceptance testing has been outlined sufficiently to indicate the extent of the precautions taken to ensure the

efficient working of automatic exchange equipment, and although “change over” operations do not come within the category of testing, a brief reference to them is a suitable conclusion to the subject.

It is assumed that all work on the external lines and at the subscribers’ premises has been finished by the time installation of the exchange equipment is completed.

At the conclusion of exchange testing, all circuits are “live” as far as the main distribution frame where they are isolated from the external lines by insulating wedges inserted in the arrester mounting test springs.

Unless the exchange serves a completely new telephone area, means must be provided at the existing old exchange for “cutting out” the original equipment. This is done by removing the heat coils from the M.D.F. arrester mountings, the arrangements being such as to enable the equipment to be disconnected in groups.

Simultaneously with the removal of these heat coils, the insulating wedges at the new exchange are withdrawn so that there is minimum interference with the telephone service.

The change over having been completed, the subscribers’ and junction circuits are again tested and any temporary cabling in the external line network is removed and the plant made good where necessary.