Plastic Materials in Telephone Use*

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ORGANIC plastics are used extensively in the manufacture of telephone apparatus and equipment. They belong to the class of materials known as insulators but are very often employed not only for their electrical properties but for their unique manufacturing and structural possibilities. Good insulating materials are very important in the telephone field although the voltage and current used are much smaller than in the power field. Progressive improvement in transmission, especially for long distance telephone service, has required that the telephone industry as a whole provide sensitive instruments and that there be a minimum loss of the electrical impulse due to leakage through insulating materials.

Rubber became at one time the most universally used insulating material in telephone apparatus. Where superior insulating properties are required, rubber has been employed not only in the soft vulcanized form as a covering for wire but as hard rubber. Its use was considerably curtailed as a molding material during the period of the world war due to the high price of rubber. This stimulated the substitution of phenol plastics which were found to produce more permanent parts. Although rubber must be classed as an organic plastic, it will not be dealt with here except in passing since it comprises a large field in its own right and quite distinct from that of the synthetic plastics. In recent years rubber has been greatly improved in life, stability, light sensitivity and resistance to cold flow so that its technical uses in the telephone plant are again increasing.

Shellac and asphalt plastics, both natural materials, were among the early important plastics employed in the telephone art. A shellac compound is still the best material for a panel system commutator where there are many long and delicate contact segments and where the principal problem is to obtain accurate location between the insulation and the brass segments together with uniform wear. The low molding temperatures and pressures for the shellac mica compound contribute to the success of the manufacture of this part. (See Fig. 1.)

Other early plastics that have found some limited uses are cellulose

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nitrate and casein. However, the cellulose nitrate plastics were only sparingly employed for telephone construction because of the serious fire hazard. Casein has long been used for key buttons and similar minor applications.

The great expansion of the use of molded plastics in the telephone plant really began with the development of organic materials which had superior manufacturing and structural characteristics over other materials. The newer plastics are of value, therefore, as much from the economies of manufacture as from their superiority over the previously used materials.

Plastics are conventionally divided into two groups: (1) the thermoplastics and (2) the thermosetting plastics. The first, considered as

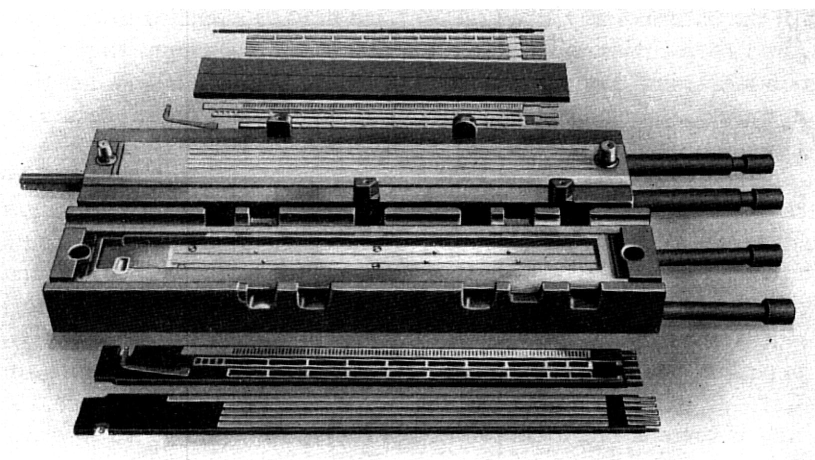

Fig. 1—Panel system commutator (flash type mold).

organic materials, are permanently soluble and fusible as well as fairly rigid at normal or working temperatures and may be deformed under heat and pressure. The second are initially thermoplastic and become insoluble and infusible after a period of time upon application of heat and pressure. These important properties are due to the chemical nature and molecular structure of the materials. All synthetic plastics are polymeric substances, that is, they are the result of a polymerization or condensation from simple organic molecules by linkage of the molecules in fairly definite ways. By a polymerization reaction is meant a reaction in which a more or less considerable number of molecules unite to form larger complexes of the same chemical composition. A condensation reaction on the other hand is one in which molecules join together to give a larger complex but during the reaction there is a separation of a small amount of water, alcohol or some other substance, so that the final chemical composition is not quite the same as at the start.

Those materials which are thermoplastic and readily soluble owe these characteristics to the fact that the molecules are linked essentially in chain-like fashion. The forces holding the chains together are of a secondary valence character, that is, the chains are free to move apart when heat is applied or a solvent is present. Vinyl, acryl and styryl resins are typical thermoplastics and incidentally each is formed from a monomeric material containing the characteristic ethylene grouping $CH_2 = C<$. The properties of synthetic materials of the thermoplastic type vary with the average chain length and distribution, and with the nature of any side groups which may be attached to the main hydrocarbon chains. The materials do not have sharp melting points as do more simple organic substances but soften gradually when they are warmed. Usually on further heating decomposition occurs to the monomeric form before any rapid flow point is reached.

The molecules of thermosetting plastics are initially in chain-like form also, although the chains are generally much shorter in length than those of the thermoplastics. On heating, the material fuses and the chains become cross-linked sufficiently to give a permanent and rigid three-dimensional structure. In the case of a phenol-formaldehyde resin the linkage between chains is directly through CH_2 groups (or according to some investigators through $-O-CH_2$ or $-CH_2-O-CH_2$-groups) and the force necessary to separate the chains is therefore high and of an order equal to that needed to break up any complex organic molecule. Infusibility and inability to go into solution are consequently the prominent characteristics of a phenolic resin in the heat-hardened form. In other materials belonging in this class the cross-linkage may be brought about through oxygen or sulphur atoms though the hardening action sometimes occurs more slowly. Certain oxygen convertible alkyd resins for example are particularly useful as organic finishes because they may be greatly hardened and in this case very much toughened by a baking process, the necessary oxygen for cross-linkage of the polymeric resin being absorbed from the surrounding air.

The properties of the more modern materials including the phenol plastics, the cellulose derivatives and the ethenoid (vinyl, acryl and styryl) type plastics, have yet to be fully evaluated but certain electrical and mechanical characteristics of these materials have already resulted in their adoption to a greater or lesser extent in the telephone plant. Phenol plastics have been employed in the molding of the regular telephone hand set, recent production being in excess of 1,000,000 units per year. Cellulose acetate is widely used in foil form. Plastics in the form of synthetic organic finishes are used for protection, decoration and insulating purposes on apparatus and equipment. For the purpose of discussion, plastics in the telephone plant may be grouped as follows:

1. Molding plastics.
2. Sheet materials (phenol fiber, acetate foil, etc.).
3. Synthetic organic finishes, adhesives and miscellaneous special items.

Objectives of Ideal Telephone Plastics

Telephone apparatus and equipment are not sold as consumption goods but the service rendered by it is sold to the subscriber. Good service means a minimum of breakdown due to replacement of malfunctioning parts, repairs and maintenance. High maintenance costs are inconsistent with the best service at the lowest cost. Uniformly high quality of materials throughout the economic life of the telephone plant is therefore essential.

The molding plastics and sheet materials account for the bulk of the plastics used in the telephone plant and the objectives of these materials are similar enough to permit them to be listed together. There are given below the general and specific properties that must be considered in such materials when they are to be used in the telephone industry. The level of quality demanded in specific properties will obviously depend on the application.

1. General requirements.
    a. Strength, hardness, toughness.
    b. Low density (to decrease mechanical inertia, aid manual use).
    c. Chemical inertness in air, or in contact with other materials.
    d. Resistance to humidity (minimum of swelling and shrinkage with variations of moisture content of the air).
    e. Ability to withstand temperature, heat and cold without too great impairment of strength and shape.
    f. Ability to reproduce die surface accurately and give good appearance to finished part.
    g. Light stability.
    h. Relative non-inflammability.
    i. No odor, no harm to the skin.
    j. Resistance to insect attack.

2. Specific mechanical properties.
    a. Transverse strength.
    b. Impact strength.
    c. Cold flow.
    d. Shrinkage.
    e. Wear resistance.
    f. Machinability.
3. Specific electrical properties.
    a. Insulation resistance
        1. as affected by humidity.
        2. as affected by light.
    b. Dielectric constant.
    c. Power factor.
    d. Dielectric strength.
4. Moldability.
    a. Free flow at moderate temperature and pressure.
    b. Favorable setting characteristics.
    c. Short molding cycle.
    d. No tendency to stick to die.
    e. No abrasion of die surface.
    f. Minimum shrinkage in mold.
    g. Low bulk factor.
5. Economic considerations.
    a. Low density materials preferred.
    b. Cost.
    c. Die life.
    d. Utilization of scrap.
    e. Molding cycle time.
    f. Trimming and finishing characteristics.
    g. Refinishing or maintenance.

The objectives of an ideal plastic in the telephone industry depend upon the use to which the material will be put in the telephone plant. The material may be a structural member, an insulator, or both, and may be in the hands of the public or in a telephone exchange. All of the above requirements need not be met but excellence in a majority of these properties is generally desirable.

The Molding of Telephone Parts

Molding involves consideration of (1) the molding compound (2) the die (3) the press (4) the heating and cooling system (5) method of ejecting part from mold (6) finning and trimming methods. Regardless of the type of plastic, these operations are necessary.

As to the molding compounds, the Bell System obtains from the suppliers whatever materials are needed and this is generally true for the industry. These range from the plain wood flour-filled phenolics to the various thermoplastics depending on the application. Exact compositions are seldom specified in order that the manufacturer be given all possible opportunity to exercise his ingenuity to produce satisfactory quality material.

The die or mold is such an important item in the molding of a material that several points should be emphasized about it. The dies are always expensive. Every part is an individual design problem, involving flow of material in the cavity, use of inserts, opening and closing, the clamping of die parts under high pressures, and alignment. Everything possible must be done to reduce the complication of the die; eliminate inserts if possible, provide generous fillets, ample taper for removal of parts, and facilitate flow of the compound. The Bell System has found it advantageous to make most of its own dies. The conventional boring, milling and hobbing processes are used. Very little success has been had with other methods, such as casting with hard alloys.

In spite of the expensive and time-consuming effort that must be encountered in designing and building a molding die, the finished die when properly used represents one of the most indestructible tools of modern manufacture. The parts are finished, require little or no surface treatment, the dimensions are accurate and sub-assembly operations may already be completed as the part emerges from the die.

The dies used are of the three general types: the open or flash die, the closed or positive die, and the injection die. The open type consists of two parts which come together at a cutting edge or ridge that surrounds both halves of the die. Since this ridge or cutting edge must withstand the full pressure of the press it is usually about one-eighth of an inch wide. Flash dies are all relatively simple, readily loaded, and the charge need not be measured accurately, any excess being forced out as the two halves close until the cutting edges come into contact. Such molds may be used for any molding compound not requiring high pressure and which does not have high die shrinkage. Shellac-mica commutators (Fig. 1) are manufactured by means of a flash die.

The positive type die consists of a plunger and a cavity shaped to produce the finished part. The plunger may aid in shaping the part. Only enough material is placed in the die to make the part. The material may be weighed in separate charges or preformed by a separate operation. The cavity is loaded and the plunger forced down, forming the part. Multiple cavity molds cannot be loaded exactly alike and hence some provision must be made for the escape of excess material, forming a flash that must be subsequently removed. Such dies must be carefully designed so that the fin is located for easy trimming and to provide the best appearance. These multicavity molds are frequently called semi-positive molds to differentiate them from a truly positive mold where there is little flash. A typical telephone part made in a semi-positive mold is the handset handle shown in Fig. 2.

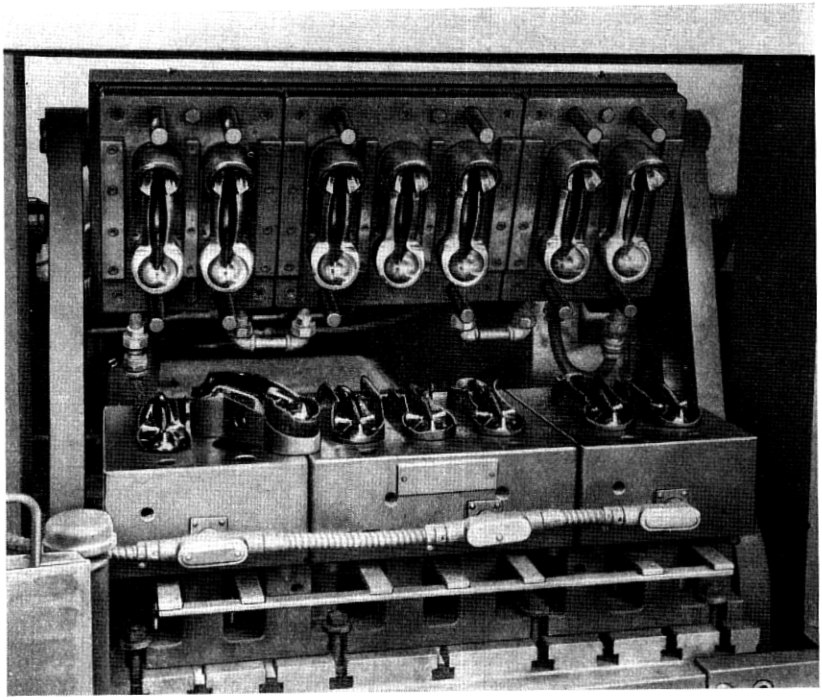

Fig. 2—Mold for handset handle.

The recently developed process of injection molding which consists in forcing plastic material through a nozzle into a completely closed die from an external compression chamber is also being used and promises to alter many of the present operations. Since the opening and the closing of the die are not related to the application of pressure, greater freedom of design is possible. Furthermore, since full pressure is not applied by this method until the die cavity is completely filled with material, the material already in the die tends to support inserts and hold them in their true position. Hence more delicate inserts are possible by this method of manufacture. Since the material is enclosed in an auxiliary pressure chamber and is not exposed to the atmosphere, greater freedom from room dust is possible, rendering this method ideal for colored plastics. A terminal block used to terminate the subscribers telephone cord is made from thermoplastic molded cellulose acetate compounds as shown in Fig. 3.

Finishing and trimming methods are largely determined by the design and the class of service required of a molded part. In the case of the injected cellulose acetate terminal block mentioned above the gates are trimmed off by a simple trimming punch and the scrap is

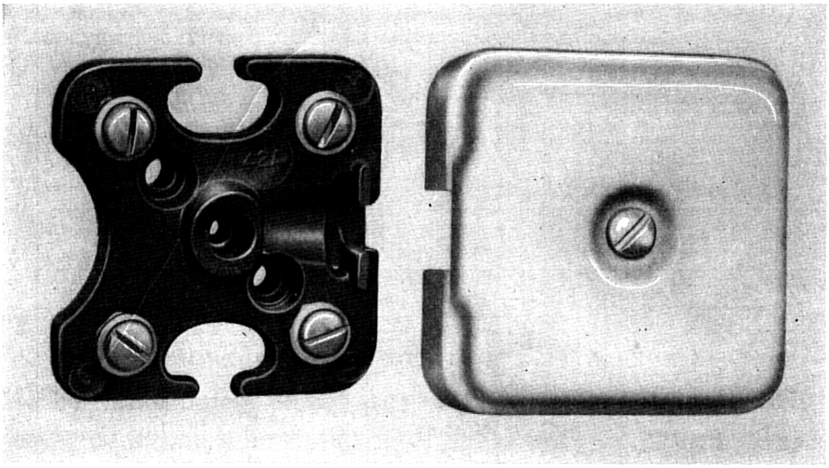

Fig. 3—Terminal block.

reused. This part is covered in service and the appearance of the block is therefore not a major factor.

The telephone handset, since it is in the hands of the public, must be carefully finned for two reasons: (1) to avoid surface roughness and (2) to provide good appearance. The handset handle was originally ground along the fin left by the semi-positive mold and then buffed. The operation was not only expensive but tended to grind off a large portion of the surface of the handle. This removed the resin-rich surface and tended to expose the filler of the phenol plastic molding compound, thus reducing the appearance life of the handle. The more recent product of the Bell System is being grooved along the die parting line. This removes the fin, a minimum of the resin-rich surface and does not detract from the appearance of the handset. Automatic grooving machines were developed for this purpose. Figure 4 shows a grooved handset handle.

It has been found necessary to pay close attention to the design in order that die parting lines, ejector pin marks, gate marks and the like will appear at points where they may be readily eliminated by simple trimming and grooving operations, or where they may be left without objection to appearance or function of the part.

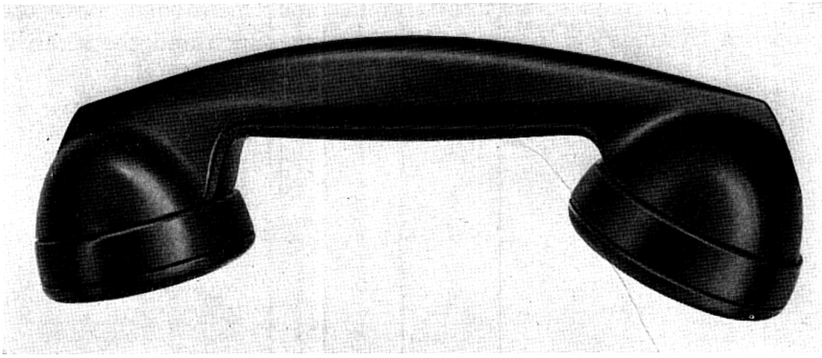

Fig. 4—Grooved handset handle.

General Test Methods and Requirements

The most satisfactory test is one that can be applied to the finished part to measure the ability of that part to perform its function satisfactorily in service. This ideal is seldom realized, not only because of the difficulty of defining the service requirements but of finding tests that are wholly representative of service conditions. It is customary, therefore, to apply a series of tests whose sum total will approach the ideal as nearly as practicable. Molded organic plastic parts are different from parts made from most other materials in that the molding process may modify them and render them quite different from the raw material. In the case of thermosetting compounds this is particularly true.

Tests are in the main applied, therefore, to a molded part of representative specimen of the fabricated material. In the telephone plant the items that are of most importance are strength, both transverse and impact, permanence of form, appearance, effect of moisture and drying on swelling and shrinkage, insulation resistance, electrical breakdown potential, and reaction on adjacent materials. Methods of making all of these tests have been worked out and are supplemented by apparatus tests made on the manufactured product.

There is no known test that will measure completely the quality of a phenol plastic part and it is necessary to resort to the expedient of testing standard bars molded under specified conditions. Five bars are molded in a positive type die as shown in Fig. 5. The step arrangement provides for flow within the die similar in many respects to the molding of actual parts. The test bars provide transverse or flexural strength, impact insulation and cold flow test specimens. The methods used, whenever possible, are those of the American Society for Testing Materials.

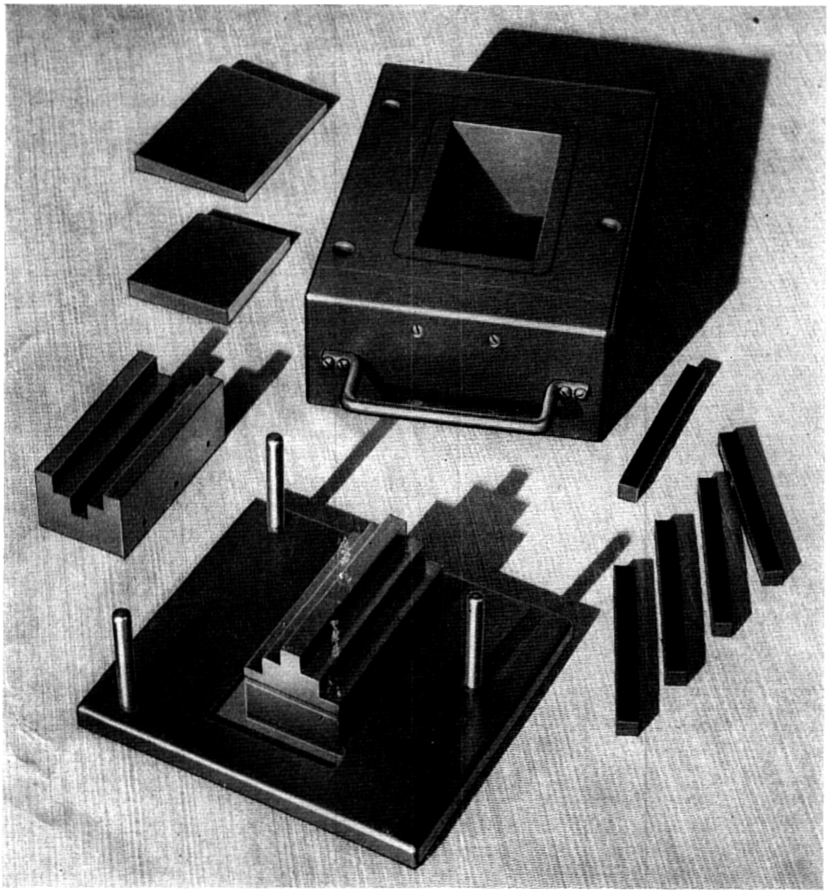

Fig. 5—Specimen mold and bars.

The cold flow test is specially designed to note the distortion of materials which in service are under pressure, such as spring pileups, inserts and apparatus in the form of banks and terminal blocks. The specimen which is ½ × ½ × ½″ in size is first conditioned at 150° F.

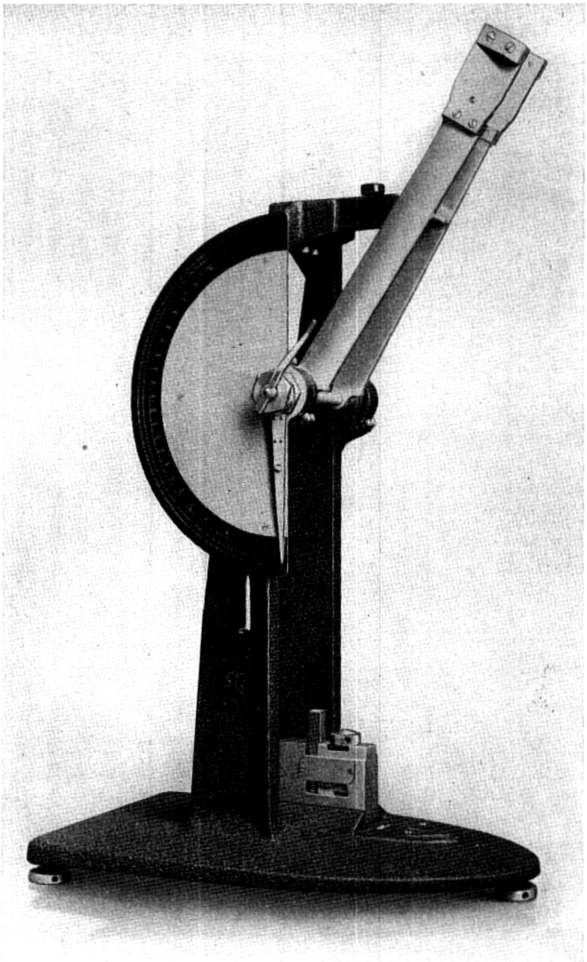

Fig. 6—Impact machine.

for 4 hours and then to 90 per cent R.H. and 85° F. for 68 hours to permit absorption of moisture. It is then held under 4000 lbs. per square inch for 24 hours at 120° F. ± 1° and the percentage change in thickness determined.

Typical Applications of Thermosetting Plastics

Phenol Plastics

A typical phenol plastic telephone part is the handle for the handset. This part is molded in a multiple semi-positive die of the kind described above.

In addition to the laboratory tests on the raw material, samples of the molded handles must withstand a dropping test. After being conditioned, handles representative of a given lot are equipped with transmitters and receivers and dropped down a nearly vertical chute to strike on a steel block. The test is made by dropping first at 36 inches and then increasing the drop in increments of 2″ until the handle breaks.[1] Normal product handles will withstand a drop of 55 inches on a steel block without failure.

The electrical properties of phenol plastic compounds are adequate for most uses in the telephone plant. Two grades are recognized, however, the mechanical and the electrical. Fully 90 per cent of the uses involve the mechanical grades. For certain high-frequency insulation purposes special mica-filled phenol plastics are used in place of the regular wood and cotton filled varieties.

One of the outstanding disadvantages of a phenol plastic is the ease with which it carbonizes on exposure to electrical arcing. For this reason phenol plastic compounds have only a limited use for commutators and similar applications. However, in addition to handsets they have proved of value for mouthpieces, receiver cases, subset housings, non-magnetic coil forms, coil cases, jack mounting blanks and terminal blocks.

Phenol Fiber

Phenol fiber for telephone apparatus is made of alpha cellulose paper, Kraft paper and rag paper by the usual impregnation with a suitable phenol resin varnish and lamination of a number of sheets under heat and pressure. The most important requirement for the paper is that it shall be pure, clean and free from electrolytes. The paper is carefully tested for chlorides, conductivity of water extract and for alcohol soluble materials. Several grades of phenol fiber are necessary to meet the requirements, some of which are largely mechanical and others electrical.

The principal tests for phenol fiber are cold flow and shrinkage, insulation resistance, corrosion tendency, arc resistance, transverse strength and impact. Arc resistance applies to the case where wiping

[1] "The Impact Testing of Plastics," Robert Burns and Walter W. Werring, *Proc. A.S.J.M.*, 19, Vol. 38, 1938.

contacts cause an arc to flash across the surface of the phenol fiber. This is a condition peculiar to telephone apparatus and a special test has been designed which simulates service conditions. An insulator cam (see Figs. 7 and 8) is prepared as the test specimen. The cams are rotated at a speed of 10.5 to 11.5 revolutions per minute. Two metal cams are attached concentrically with each surface of the phenol fiber cam. Attached to a brush that wipes over the cam tensioned to

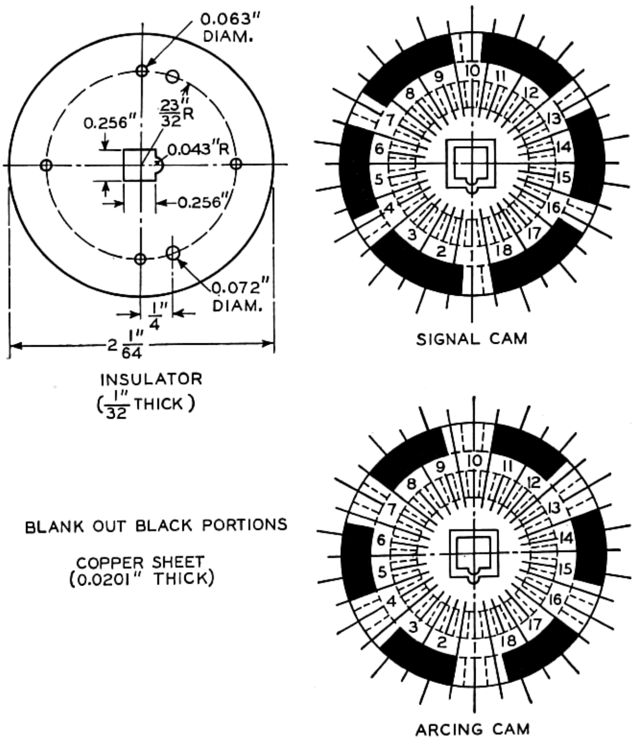

Fig. 7—Arc resistance test cam.

a pressure of 60 grams is a circuit containing 5½ counting relays which supplies a severe inductive load. This is representative of a severe service condition. Failure is indicated when tracking of carbonaceous material shorts a cam segment the distance of 15° or when the 1/32" thick material is punctured, and the test is then stopped automatically. A good grade of fiber will resist over 1,800 revolutions whereas a poor grade will fail in 4 to 100 revolutions.

Phenol Fabric

Phenol fabric is similar to phenol fiber except that it is made with fabric instead of paper. It is generally used for its mechanical strength since its electrical properties are inferior to fiber. Phenol fabric is used in tools where high strength and resistance to impact and bending

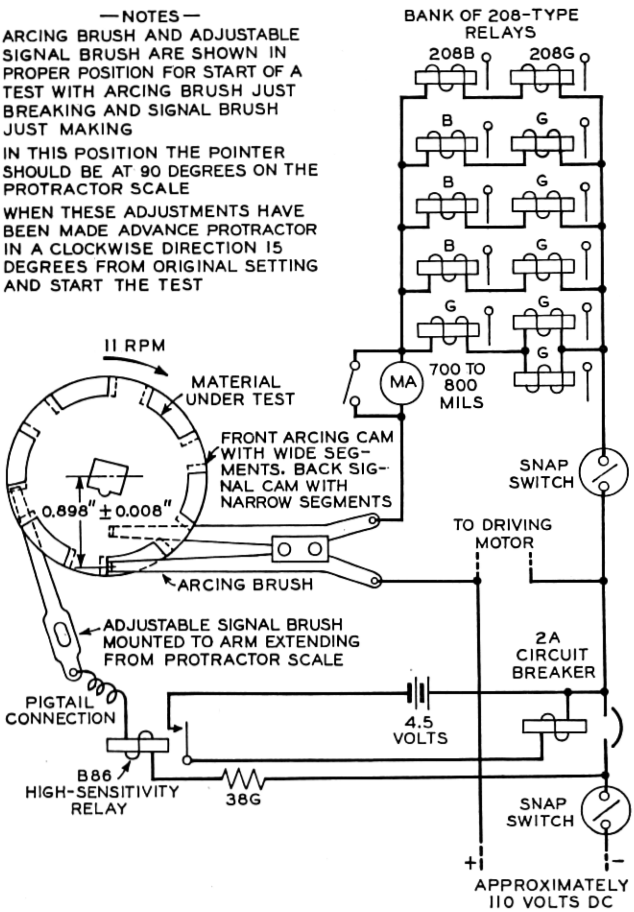

Fig. 8—Circuit for arc resistance test.

are necessary, in terminal plates, cable terminals, gears and in general where phenol fiber does not have suitable structural properties.

Urea-Formaldehyde Plastics

Condensation products made from urea and formaldehyde have attractive possibilities as thermosetting plastics. Relatively lightfast colored parts with porcelain-like surface luster are possible with these materials. The molding cycle is slightly shorter than for phenol plastics and the material at first is somewhat more fluid. Tight molds are therefore necessary in order to get sufficient pressure.

The principal difficulty with urea-formaldehyde plastics has been that on exposure to heating and cooling or humidification and drying cycles, there is a tendency toward cracking, particularly at changes in section and around inserts. Molded into uniform thin sections without inserts they are reasonably satisfactory plastics.

At present there are practically no urea-formaldehyde plastics employed in telephone apparatus because the wide continental climatic conditions and exacting requirements will not permit their use. Recently there have been improvements made from a stability standpoint and it is believed future application may be found for these plastics, particularly in view of their color permanence.

Applications of Thermoplastic Materials

Cellulose Acetate

The principal use of cellulose acetate is for interleaving in coils. Various relay coils are made of layers of cellulose acetate over which a layer of enamel coated copper wire is wound. Layer upon layer of wire and acetate sheet form a coil. These are then assembled on a core and spoolheads attached. One of the phenol fiber spoolheads has a surface coating of cellulose acetate and the winding is pressed against this spoolhead and dipped in acetone. This dissolves or softens the exposed edges of acetate and the whole coil is firmly secured to the spoolhead.

Cellulose acetate is used for this purpose since it is practically inert as regards corrosion of the fine copper wire in contact with it and in this respect it is superior to any known material. It is permanent, reasonably fireproof and has high insulation resistance. Two grades of cellulose acetate sheet are used in telephone practice. These are the window grade used as a window or covering over designations and an electrical grade for coil use. The principal tests for the electrical grade are insulation resistance, shrinkage, and resistance to burning.

The principal use of molding grade of cellulose acetate is for the terminal block (Fig. 3) mentioned above. Here the application is mainly structural since it has more than adequate electrical insulation. Another application for cellulose acetate is a test strip where a surface layer of acetate over phenol plastic avoids carbonization of the latter.

Acrylate Resins

The clear water-white plastics derived from the polymerization of the esters of acrylic and methacrylic acid are at present being used only for windows, viewing lenses on designation strips and other optical uses in telephone apparatus. This is a new plastic and applications will no doubt develop in time, taking advantage not only of color but of the mechanical and electrical properties and insensitivity to moisture.

Vinyl Resins

Vinyl acetate and vinyl chloride polymers and co-polymer products form interesting thermoplastic resins. Their use in communication work has been limited so far to phonograph records, where the resistance of the co-polymer to warping due to humidity and the superior wear resistance of the plastic have been the important factors. The advantage of non-inflammability imparted by chlorine is more than offset by the acidic nature of the fumes given off from vinyl chloride polymers when heated or burned and this has discouraged use of these materials in the telephone plant.

Polystyrene

There have been no important commercial applications for polystyrene as yet in Bell System telephone communication although much experimentation is being carried on with polystyrene plastic. The low electrical losses of this material make it of special interest in high-frequency work but its mechanical properties have not been satisfactory. In Germany and Italy it is reported that polystyrene has been employed as an insulating plastic in various cable structures for experimental and commercial use. However, in this country the spacing insulators for the coaxial cable from New York to Philadelphia have been made of a special grade of hard rubber which has proved to be a tougher material for the purpose.[2]

Synthetic Coatings

An important application of synthetic organic materials in the telephone plant is in the finishes that are put on Bell System apparatus. There are three major reasons why such finishes are needed—(1) for the improvement in appearance of certain fabricated parts, especially the exposed portions of subscriber station apparatus, both in private homes and public places, (2) for the mechanical and chemical protec-

[2] "Systems for Wide-Band Transmission over Coaxial Lines," L. Espenschied and M. E. Strieby, *Bell Sys. Tech. Jour.*, October 1934; and *Elec. Engg.*, Vol. 56, 1937.

tion of the underlying structural material which is usually a metal, and not infrequently, (3) for electrical insulation purposes. Other minor reasons for finishes exist on special apparatus. Many parts are fashioned from such metals as steel, brass, aluminum and zinc alloys. After such practices as punching and die casting the surfaces of these parts are left in an unsightly condition, and furthermore unless protected, they may soon begin to corrode. In certain cases electroplated finishes may be employed to advantage, but organic finishes, because of their low cost and ease of application, find wide use. A good organic finish for telephone apparatus must not only have a lasting decorative value but must also protect the parts against the great variety of conditions to which the apparatus is exposed.

For example, the common black finish which is applied to various parts of subscriber station apparatus, such as the zinc alloy handset mounting, coin collector boxes and metal bell boxes must be sufficiently tough and adherent to withstand perspiration, impact and severe abrasion. Rigorous tests have been applied to find the most durable finishes for such parts. They must maintain their appearance so as to harmonize with the smooth molded black phenol plastic parts. Advantage has been taken of the recent improvements in synthetic resin finishes and a modified alkyd resin vehicle has been employed in the present black enamel. A thorough baking is given to the enamel which results in a more durable finish for telephone apparatus than the former black japan.

There are a number of applications for synthetic finishes where corrosion protection is important from the standpoint of the proper functioning of the apparatus. The aluminum diaphragms in marine and aviation loud speakers and in sound power instruments are protected by a baked finish containing a heat-hardening phenolic resin vehicle into which is incorporated a chemically inhibitive pigment.

The familiar olive-green finish applied to the metal lining of telephone booths is also a synthetic finish. This coating is often subjected to unusual service conditions which only a modern type of finish can withstand. Advantage is also taken of the high initial reflectivity and the retention of light reflection of certain alkyd resins and these are used in the white booth head-lining enamel. Synthetic finishes are generally specified for the finishing of Bell System trucks, etc.

Other applications of finishes include lacquers and wrinkled enamels. A recent interesting development has been the use of ethyl cellulose dipping lacquers to form a continuous, fairly thick, envelope around small telephone parts such as resistances, condensers and the like.

This frequently eliminates a potting operation and provides an excellent mechanical protection for the parts.

The employment of organic coatings for insulation purposes is another important application deserving mention. In general the conditions in the telephone plant are not such as to demand resistance to very high voltages. Millions of feet of copper wire receive a baked clear enamel coating applied in multiple thin coats to assure maximum flexibility and uniformity. Carefully chosen pigmented alkyd baking enamels are used in exchanges as insulating finishes for various hooks, bars and other small parts of the metal framework upon which the exchange wiring is tightly and compactly fastened and from which electrical insulation is needed.

An appreciable amount of clear cellulose acetate lacquer is at present used on switchboard wire. This is applied as a thin coating of a specially plasticized lacquer over a layer of textile insulation, the latter being colored in various ways for ready identification. The requirements of a good lacquer coating material for switchboard wire are chiefly (1) low cost, (2) reasonably good insulation, even under prolonged high humidity conditions such as occur during the summer months in many parts of the country and (3) good transparency so as not to alter the identification colors on the textile serving. Smoothness, flexibility, inflammability and corrosion hazard are other important factors that receive consideration.

A synthetic plastic which has recently found a small but important place in the telephone plant is polybutene. When coated on fabric this plastic has given an excellent membrane material for a new type of handset transmitter. It is dust and moisture-proof, light in weight, flexible and alkali resistant, not impairing in any way the acoustical properties of the instrument.

Synthetic Resins as Adhesives

A growing use for synthetic resins in the telephone plant is in the form of adhesives. The amount of material consumed in this way is not large but the applications are frequently important from the standpoint of the functioning of the apparatus as well as from the economies involved. The older kinds of adhesives such as casein and animal glue are still employed for joining together various large parts (especially wood, as in cabinet work, etc.) but they are brittle and generally unsatisfactory in the assembly of small light parts (metal, phenol fiber, ceramic, etc.) such as go into special communication apparatus.

The trend in the design of most apparatus has been toward smaller lighter parts and at the same time toward more rapid assembly. Synthetic resin adhesives are aiding this trend by avoiding in various places the dependence upon bolts, screws and similar mechanical locking devices. Proprietary resin-cellulosic lacquer adhesives and vinyl and acrylate polymers are proving of value because they give strong tough joints that are affected but little by moisture and are not apt to give trouble from corrosion or growth of mildew. The use of these materials for assembling parts in a thermoplastic manner looks particularly encouraging. When the surfaces which are to be joined are carefully cleaned, then primed with an air-dried coat of a suitable thermoplastic resinous adhesive and finally molded together under heat and pressure, tensile strengths of several tons per square inch are possible between the joined parts. Synthetic resin cements and adhesives are employed in the construction of the handset transmitter, moving coil microphones, loud speakers, switchboard lamps, vacuum tubes and the wood veneer of telephone booths.

Conclusion

Many important applications of plastics have been made in the telephone field. These have sprung from the economies of design, methods of fabrication, as well as from the excellent serviceability of the molded plastic products. It might be well to emphasize again the chief limitations of present day plastics which have prevented wider use. When exposed to outdoor conditions which involve the effect of temperature and sunlight, many plastics, particularly the newer thermoplastic materials, are revealed to be insufficiently permanent for telephone use with respect to the physical and chemical characteristics associated with color, distortion at elevated temperatures, surface deterioration due to action of sunlight and brittleness at moderately low temperatures.

Modern trends in stylized designs make it necessary to take advantage of the molding art in order to achieve good ornamentation. This will probably result in the use of plastics on surfaces exposed to light. The effect of light is not confined to direct sunlight for it has been found that daylight filtered by ordinary window glass for long periods will cause reduction in surface electrical resistance of plastics. In fact, the effect of light seems to be over a rather broad range of the spectrum, becoming intensified as the ultra-violet range is approached.

A few of the new thermoplastics are quite inflammable, a characteristic that will be a serious handicap to their extended use in exchanges and other locations where a fire might disrupt the service of a whole community.

There are still certain weaknesses of organic finishes with respect to impact abrasion, perspiration and moisture penetration, although there have been great advances made in this field in recent years.