Molded Insulating Materials

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MOLDED insulating materials have attained their present importance more because they are molding materials than because they are insulators. As molding materials they provide a new method of manufacture and assembly for telephone-apparatus parts. Large quantities of finished parts of intricate or irregular shapes may be more readily and economically produced by molding than by any other method. Unlike sheet insulating materials, which seldom have other than insulating uses, the molded materials have been frequently adapted for structural rather than insulating needs. Housings and casings—the cover of the new subscriber's set is a conspicuous example—are now molded from insulating materials, which have in many ways proved superior to wood or metals for the purpose.

The earliest molded insulating materials were porcelain and hard rubber. Both are excellent insulators and are still very important as insulating materials, but neither possesses the desirable molding characteristics of the more modern materials. After being molded from clay mixtures, porcelain parts must be fired at temperatures so high as to preclude the possibility of using metal inserts. Nor can parts be made to really close limits without grinding operations such as those performed on protector-block frames. Porcelain is generally used, therefore, where heat resistance or the necessity for minimum fire hazard are major factors. Its main shortcoming is its brittleness.

Parts for which porcelain was unsuited due to its brittleness or due to the necessity for closer limits were molded of hard rubber which readily lent itself to machining after molding. In hard rubber molding, the plastic rubber compound is forced into shape in molds and then vulcanized at temperatures of the order of 300° F. for several hours. The rubber compound has strong corrosive tendencies during vulcanization and therefore is usually molded in soft Muntz-metal or aluminum

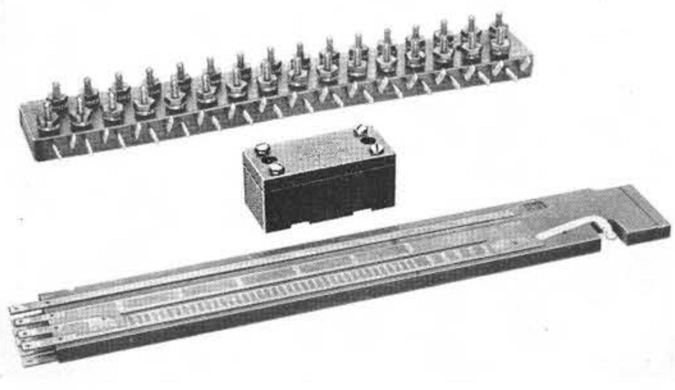


Fig. 1—Typical shellac composition parts with metal inserts embedded during the molding operation

molds. Because of this and the high shrinkage during molding, the process of manufacture is inherently not favorable to the production of completely finished parts, accurate to size and with metal parts molded in place. Though great quantities of sheet hard rubber are used for insulating purposes in the telephone plant, practically the sole use of molded hard rubber compound is in the desk stand receiver case. The case requires vulcanizing for a period of hours and then is completely machined and polished by means of highly-developed special equipment.

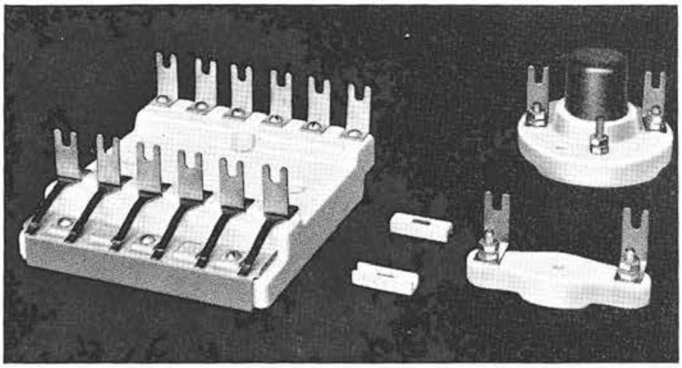


Fig. 2—In these assemblies involving porcelain bases, note how metal parts are attached by screws through molded holes in contrast to metal inserts molded in place

The striking advantages of molding as an advanced method of manufacturing were first emphasized with the introduction of the so-called "composition" materials. Shellac and other gums are used as binders, with the addition of a variety of filling materials such as mica, wood flour, or asbestos, which improve the mechanical properties and at the same time cheapen the mixture. These materials are soft when hot but rigid at ordinary temperatures and are molded by first being softened by heat, then pressed into dies of the required shape and cooled. The molding process in principle is no more complicated than placing a monogrammed seal on an envelope with sealing wax and a signet ring. The part hardens into the required shape merely by the cooling of the mold, and it will again become plastic on reheating to the molding temperature. This lack of heat resistance is a very serious handicap but, in spite of this, the ease and accuracy with which combinations of molded and metal parts may be assembled in one simple and rapid operation has resulted in widespread use of the various compounds of shellac.

In addition to their manufacturing advantages and excellent electrical properties, parts molded of shellac compounds because of the rapidity of molding are comparatively inexpensive. They are quite valuable in their proper place, which is limited by the brittleness and poor heat resistance of the compound. In the telephone plant, shellac-mica compounds are used for assembly and insulation of inserts in such parts as connecting blocks, key buttons and panel type commutators. Until recently the deskstand mouthpiece was also molded of a shellac-mica composition. Another well-known molded shellac product is the familiar phonograph record for which a shellac compound has long been used.

The success of the shellac-molding industry and the obvious need for a cheaper and more heat-resistant gum or resin lent new importance to certain interesting experiments of synthetic

Fig. 3—Familiar handset parts of phenol plastic. All except the handle have molded threads

Phenol plastic molding compounds, like the shellac compositions, consist of a resinous binder combined with a filler. However, the phenol resin possesses a radically new and valuable property in that under the influence of heat the resin undergoes irreversible chemical changes which render it permanently hard, infusible, and practically insoluble in all ordinary solvents. This change occurs at an appreciable rate only at temperatures over about 200° F., and in commercial manufacture of molding materials the varnish or resin binder is brought but part way through this reaction and then mixed with the filling materials and dried. The material in powder form is then ready for molding and may be shipped and stored at ordinary temperatures without change. When this powder is held in a mold under pressures of 1000 to 2000 pounds per square inch at temperatures in the neighborhood of 350° F. it first softens and flows to the shape of the mold. Then under the continued application of heat the chemical reaction proceeds and the material hardens permanently into shape within 1 to 10 minutes, depending upon the size of the piece, type of mold, and other factors. Some cooling before removal from the mold is usually allowed though it is not essential to the molding operation. Cooling before ejection of the part does, however, improve the appearance and prevents warping and possibly blistering in instances where the chemical reaction

chemistry which produced hard resinous substances. Various investigators had been occupied with studies of the product of phenol (carbolic acid) and formaldehyde condensed in the presence of various catalyzers. It remained however, for Dr. Baekeland so to control this reaction as to develop an intermediate varnish-like substance which could be produced on a commercial basis. This material was patented and trade-marked "Bakelite" and molding materials utilizing the new synthetic resin binder came into widespread use under this name. Since the expiration of the original patents, other concerns have entered this field with similar materials advertised under new trade names. Within the Bell System, however, all molding materials using phenol-formaldehyde resins are known, regardless of trade name, as "phenol plastic", a companion name to "phenol fibre"* and "phenol fabric" which are used for laminated sheet materials using the same resins.

* Bell Laboratories Record, *October*, 1927, *p.* 53.

has not been carried to completion.

Phenol plastic is strong, hard, and resists heat to the extent of charring and burning without melting or softening. The compound chiefly used consists of approximately equal parts of phenol resin and wood flour with small amounts of pigments and dyes. Its electrical properties are not so good as those of new hard rubber, but are adequate for any ordinary use and do not deteriorate as do those of rubber. It is not subject to cold flow in the usual sense, though it is subject to slight shrinkage with drying. It has the advantage over metal of not requiring a protecting finish and retains its color and lustre in spite of handling and wear. The telephone user sees it frequently in the external parts of the subscriber's handset, but it is widely used in the telephone plant for a great variety of less conspicuous parts such as jack mountings, non-metallic coil cases, coil spools, and test strips.

It might seem that the phenol plastic materials with their outstandingly desirable properties could fulfill all essentials, but it would indeed be a magical material that would lack nothing in engineering, manufacturing, and cost requirements. Special and peculiar needs frequently are created by the complexities of telephone apparatus. Where, for instance, telephone apparatus is subject to accidental "flash over" — that is, arcs permitted by the accumulation of foreign conducting material on the surface — the insulating property known as "resistance to arcing" is a necessity. This property is indispensable likewise where apparatus must withstand the arc resulting from opening electrical circuits. Conspicuous in the first class is the 1-B test strip and in the second are a variety of interruptive apparatus such as ringing and pulse-machine drums, sequence-switch discs, multiple brushes, and panel-type dial-system commutators, in all of which the insulating properties of the material must not be destroyed by the searing effect of the arcing. Materials which leave a residue of conducting carbon in the path of an arc must be avoided where arcing is a factor.

Hard rubber combines resistance to moderate arcing with excellent frictional and wear characteristics and for complete resistance to severe arcing molded cellulose acetate has been used successfully. Cellulose acetate is, generally speaking, similar to the familiar celluloid (cellulose nitrate) but is free from the peculiarly dangerous fire and toxic fume hazard which makes the older material so undesirable in the telephone plant. Cellulose acetate, though quite expensive, has

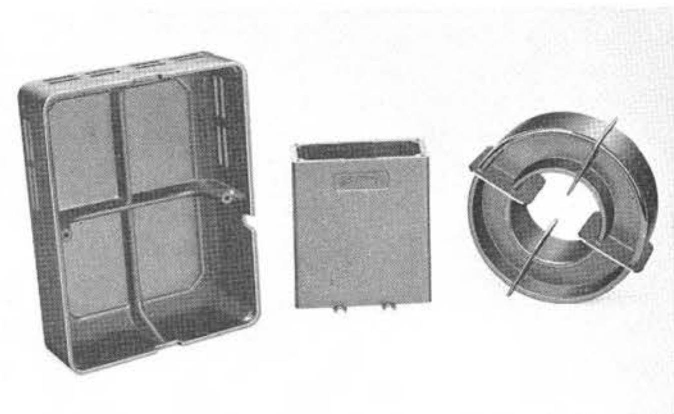


Fig. 4—Cover for small subscriber's set, non-magnetic coil case, and coil core, all large phenol plastic parts

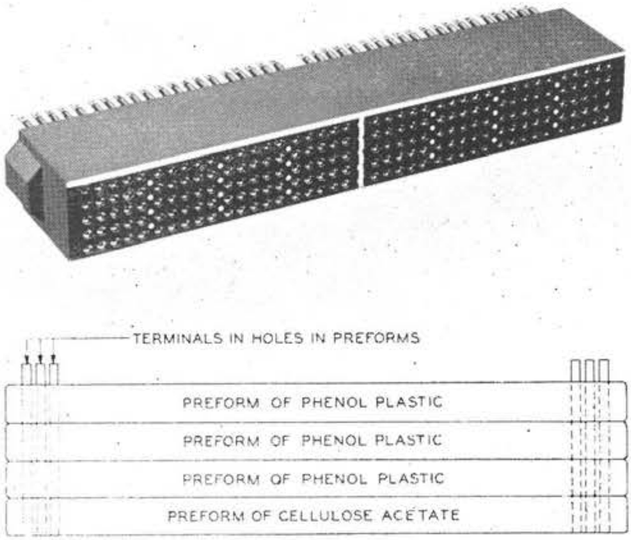


Fig. 5—The 1-C test strip, a difficult molding and engineering problem. It is now molded in one operation of phenol plastic with a veneer of cellulose acetate on the face subject to arcing

been available for some time in the form of flexible transparent sheet and has been used as a substitute for celluloid. Only in recent years has it been produced as a molding powder. It molds at temperatures from 250° F. to 400° F., but no chemical change occurs, and like shellac it can again be softened by heat. When burned by an arc no conducting material is produced and the insulating properties therefore survive any arc not so severe as to actually destroy the apparatus by fire. This valuable property is made use of in the 1-C test strip in which a molded veneer of cellulose acetate is applied where arcing might occur on a body of phenol plastic. This combination of materials is necessary as extensive soldering operations on two hundred closely-set terminals result in a temperature at the back of the part which makes the use of phenol plastic mandatory for the basic structure of the test strip.

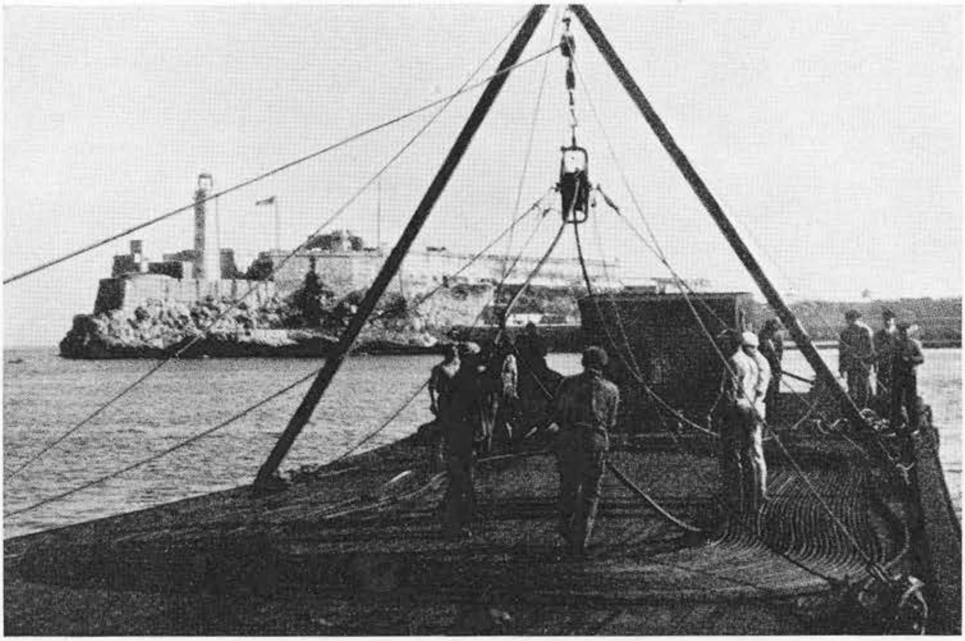
The demand for color in telephone sets creates another special problem. Subscribers' sets at present do not consist entirely of molded parts and since the associated metal parts must in any case be given a surface finish, the demand for color is best met by the use of finishes. With the anticipated extension in the use of molding, this situation may not be permanent.

The use of colors in molded telephone apparatus is an engineering problem of considerable magnitude as our apparatus must have long life and must meet a variety of rigid requirements. The addition of mineral pigments, as is usually necessary for light colors, changes the mechanical properties and even the weight of the material. As a result, very light-colored compounds frequently are found weak and unsatisfactory for our purposes. Many important materials, moreover, are not naturally clear and colorless, or even permanent in color and as a consequence are unsuited for binders in compounding bright or light colors satisfactory for our use. Therefore certain colors may require the selection or development of new materials which must be studied completely from such standpoints as stability or permanence of the material itself as well as from the standpoint of functioning of the apparatus when new.

Casein products, cellulose acetate,

and various new synthetic resin materials may be obtained in a variety of bright and translucent colors, and all must be considered in the search for color. Practically all new materials are investigated as completely as their properties justify in the continuous study of materials necessary to cope with the needs of the Bell System.

Continued familiarity with molding materials and the molding process emphasizes the fact that the most effective use of the process lies in its complete substitution for complicated operations of machining and assembly rather than its use merely as an extension or addition to the older forms of manufacture. Apparatus designed to be produced by the older methods ordinarily will consist of a multiplicity of parts, each individually finished and later assembled with the others. Although substitution, part for part, of molding for machining will result in savings where the individual units are intricate, the really important economies are being achieved by redesign not of a single piece-part but of units of apparatus so that one molded part replaces several machined parts.



The barge used in laying parts of the Key West-Havana cable, under the shadow of Morro Castle, Havana