EPOXY RESINS

And some of their applications in the electronics industry

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The technique of protecting components by enveloping them in a "block" or film of moisture-resistant material was in use long before the development of the present-day potting or casting resins. For many years, components such as capacitors have been encapsulated in wax or bitumen, while transformers and other wound components have been impregnated using vacuum or dipping methods.

These processes, however, give very little mechanical protection to the components. Moreover, should any local overheating occur, thermoplastic materials such as wax and bitumen will melt and drain away. Another method is to hermetically seal components in a metal can, the leads being made through glass-metal seals, which are subsequently soldered. This method, however, is expensive.

Epoxy resins, introduced to this country about 18 years ago, have brought new concepts of design to the electrical and electronics industries and the ease with which intricate high performance components can now be formed with these resins has given a new freedom to design engineers.

APPLICATIONS

Probably the most well known use of epoxy resins is as adhesives and they are widely used as such in the electronic and electrical industries. Gramophone rotors are bonded to shafts, ceramic insulators are bonded to metal, nickel iron laminations are bonded together to form stators, etc. They are also used to bond the lids of car batteries and to bond iron powder in the manufacture of iron dust cores.

A wirewound resistor receiving a coating of epoxy resin by the fluidised bed technique

CIRCUIT BOARDS

When reinforced with, for example, glass cloth, epoxy resins can be formed into structures having a high strength-to-weight ratio, excellent electrical properties over a wide range of temperatures, great dimensional stability under varying conditions, and good chemical resistance, etc. Pre-impregnated sheets of epoxy glass cloth, pressure moulded to form printed circuit boards, are rapidly supplanting conventional s.r.b.p. ("Paxolin") in high quality equipment.

CHOICE OF INGREDIENTS

Chemically the resins are derived from epichlorhydrin and diphenylol propane. By varying the ingredients and certain phases of the manufacturing process a series of resins may be produced ranging from rather viscous liquids to hard solids. In the uncured state the resins are thermoplastic with poor mechanical strength. They are converted into hard, tough and substantially infusible materials of high molecular weight, by reaction with a suitable hardener. A wide range of chemical hardeners may be employed and since the hardener takes part in the reaction, the properties of the cured product are not only affected by the type of resin selected, but also markedly by the type of hardener employed.

Some epoxy resin and hardener mixtures will cure at room temperature, while others require processing at elevated temperatures. The ratio of hardener to resin in each case is fixed within narrow limits and departure from the optimum ratio entails loss in performance. The choice of hardener can affect the application viscosity of the mixture, the pot-life and the rate of cure. In general, therefore, pot-life and rate of cure can be varied only by choice of hardener, and not by change of resin : hardener ratio. There are, however, some formulations in which a small and variable addition of an accelerator may be used to adjust the pot-life and cure time of a slow acting resin-hardener system.

FILLING AND COLOURING

The many combinations and permutations of the several basic epoxy resins and the greater number of hardeners can be extended by even further modifications. The viscosity may be reduced by solvents, plasticisers, and diluents. Some diluents and plasticisers are reactive and can be combined into the final cured product. Diluents and plasticisers reduce viscosity or impart resilience at the expense of strength at elevated temperatures. Inert fillers may be added to the epoxy resin systems for opacity, cheapness, to improve hardness, wear resistance, thermal conductivity, electrical and mechanical properties, to increase viscosity or reduce the co-efficient of expansion or possible exothermic reaction.

Commonly used fillers are silica, mica, chalk, asbestos, glass, and synthetic fibres, etc. Epoxy resins can be dyed, pigmented and pastes of colouring matter dispersed in liquid epoxy resin are available.

Although the number of possible combinations of resin, hardener, plasticiser, filler, and dyestuff is very great and the number of possible applications is equally large, resin formulations for specific purposes are commercially available. At the same time, the ingredient resins and hardeners are available for those who prefer to exercise wider choice or to derive their own formulations.

EPOXY POWDERS

Although much of the early work with epoxy resins in the electrical and electronic industries involved the use of liquid epoxy resins, more recent techniques make use of the resin systems in powder form.

Epoxy moulding powders consist essentially of a partially cured resin-hardener mixture in powder form. In use they are very free-flowing and may be easily moulded round delicate inserts, while thin sections of resin may be moulded round large metal inserts without difficulty. They cure rapidly on the application of heat and pressure with negligible after-shrinkage. As with other forms of epoxy resin, the absence of volatile matter during the curing operation is of particular value.

The moulding powders have a shelf life of some months and are usually stored at temperatures below 25 degrees C. After processing, they possess high insulation strength, excellent dimensional stability, good heat resistance, low water absorption, and good resistance to tracking. They maintain their dimensional stability at elevated temperatures and in adverse climates.

Epoxy moulding powders have been widely adopted for the fabrication of bobbins, relay bases and connectors, and for the protection and insulation of transformers, silicon diodes, ferrite cores, and metal film resistors.

FLUIDISED BED COATING

In the fluidised bed coating technique the powder, based on an epoxy resin system, is placed in a container with a porous base plate. Air is passed through the plate which causes the powder to become fluid. The component requiring protection is pre-heated and placed in the powder which becomes molten with the heat and adheres to the component. The time of immersion in the powder and the pre-heat temperature of the component determines the thickness of the coating. Subsequent cure may or may not be required depending upon the resin system used. By suitable masking techniques, the protective or insulating film can be placed where required, as for example, in the slots of rotors, eliminating the need for slot liners. The absence of solvents, as may be present in normal coating systems, leads to the elimination of solvent bubbling and solvent entrapment during processing, etc.

Apart from application by the fluidised bed technique, powders can be applied by electrostatic spraying techniques or by processes involving the advantages of both techniques.

"E-PAK" TECHNIQUES

A technique recently introduced to the U.K. and particularly applicable to the packaging of diodes and transistors uses moulded cases and pre-formed pellets of epoxy resin, appropriate in shape and size to the component being protected. As supplied the pellets are dry, non-toxic, and easy to handle. Cure temperature, viscosity, and other physical properties may be varied to meet the requirements of productivity. As in the case of moulding powders and fluidised bed powders, etc., the epoxy pellet in the "E-Pak" process, as it is called, is not fully cured and under the influence of heat it melts, fills the moulded housing containing the components, then sets to form a high strength solid.

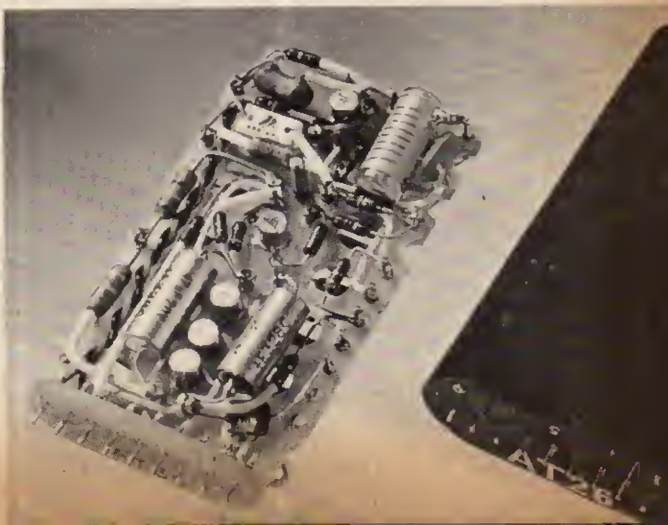
LIQUID RESINS

In the same way that an electronic component can be dipped into a fluidised bed powder, it may be protected by dipping into a liquid epoxy resin system. In this case, however, the component is usually at room temperature. The liquid epoxy resin system is formulated to give a thixotropic characteristic so that the resin will not flow from the component during cure. Where the specified requirements are not too high, this system probably offers the cheapest method of encapsulation. It is necessary, however, to take steps to ensure control over the thickness of the coating, since, should this vary, variable performance under high humidity may be obtained and there may also be a tendency for the thinner coatings to crack at low temperatures.

Liquid resin epoxy systems are, however, normally employed by pouring the fluid uncured mixtures into moulds of metal, plaster, plastic or other material by simple gravity casting techniques. Indeed, the term

(right) Rank Pullin amplifier-transmitter units before and after encapsulation

(below) An epoxy cased transistor from the Mullard "Lockfit" range



"casting" is normally employed to describe the general process, although it usually implies the production of an insulating or insulated component where the mechanical as well as the electrical properties of the material are important.

Potting, or encapsulation, implies the complete envelopment and embedment of a component or device in a protective mass of the resin, the object being not only to insulate, but also to protect the article being potted against vibration, shock, dust, ingress of moisture, chemical attack, insects, and other environmental hazards. It will be appreciated that such a technique gives a consistent resin thickness around the component being protected.

The basic casting methods are common to both the electronic and heavy electrical industries, but the products are usually different. Resins used for encapsulating electronic devices are usually designed to cure at low temperatures, for obvious reasons.

MECHANICAL REQUIREMENTS

In the case of magnetic materials, which are highly sensitive to pressure, such as some high permeability steels, it is often necessary to exclude contact with the encapsulation resin by making the core external to the casting, or by means of certain more specialised methods. Metal components can be enclosed within the cured epoxy resins, providing that the differences in thermal co-efficient of expansion are considered.

Both thermal contraction and the curing shrinkage may be further reduced by extending the resin mixtures with inert mineral fillers such as silica, mica, slate, and chalk, etc. The use of fillers also reduces possible exotherm, increases the thermal conductivity and reduces the cost. Fillers are invariably used in the production of large castings.

An automatic dispenser is used by Telegraph Condenser Co. for epoxy sealing of capacitors

Pye of Cambridge use epoxy adhesives to bond the two halves of ferrite pot cores for telephone equipment

Liquid epoxy resin systems may be used to complete the existing closure, made of metal or insulating material, with which a component has been surrounded, by casting the epoxy resin in the container. For example, components may be placed in metal cans and sealed with a layer of epoxy resin and by this technique the need for relatively expensive sealed outlet bushings may be eliminated.

Certain other liquid epoxy resin systems are specially designed for impregnation. The usual technique is the straightforward vacuum impregnation used in industry, although when considered necessary, vacuum may be followed by pressure.

For the impregnation of windings of electrical machines, such as motors, dynamos, and syncros, liquid epoxy resin may be employed in the trickle impregnation process. Here the wound armatures or stators are exposed, while rotating, to a trickle of freshly prepared solvent-free epoxy resin mixture, for a fixed time at a constant temperature and at an appropriate angle. When the winding is completely filled with the epoxy resin, rotation is continued at a controlled temperature in the horizontal plane until the resin has gelled. Heat treatment may follow.

SOLUTIONS

Solutions of epoxy resins are also employed for impregnation and have advantages over more traditional systems. For example, they are used for the impregnation and bonding of "C-cores", where their adhesive properties are valuable.

Another major application of epoxy resins is their use in surface coatings. Epoxy based primers and finishes find wide application for the protection of refrigerators, washing machines, and the housings of many items of electrical and electronic equipment. ★