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MBM Consult

2-component polyurethane electrical potting compounds

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2-component polyurethane electrical potting compounds

MBM-Consult has been selling electrical potting compounds from polyurethane for many years for the potting of transformers, cable joints, magnets, capacitors and various electronics for low, medium and high voltage.

In recent years polyurethane potting compounds have been widely used as a substitute for epoxy and polyester potting compounds.

Polyurethane potting compounds are characterised by their good physical, mechanical and electrical properties, they are hydrolysis, chemical and ageing resistant. They are tough and adhere well to components and materials.

Contents

Introduction

Electrical potting compound is used in the electrical and electronic industries for encapsulation.

For encapsulation, the components are placed in a plastic or metal potting box, whereupon the potting compound is poured in and round the components, curing to form solid polyurethane. The box becomes part of the finished product.

Casting is carried out similarly, but in a mould. After curing, the mould is removed and the potting compound acts as a box.

Electrical potting compound is used for protection and insulation

- against moisture and corrosion
- against electrical short circuiting
- against mechanical and electrical faults
- against heat, cold and mechanical influence (e.g. vibration)

and for

- fixing and assembly of components
- achieving a fire protection class (e.g. UL94V0)
- concealing components
- discharging heat

Electrical potting compound is used widely for almost all potting purposes, among others for

- Transformers
- Capacitors
- Magnet coils
- Cable joints
- Starting coils
- Circuit boards
- Ignition coils
- Insulators
- Primer charges
- Various small components

Special advantages of polyurethane

For potting purposes polyurethane is often compared with epoxy-based products. Polyester, acrylate, polybutadiene and silicone are also used to a lesser extent.

Because 2-component polyurethane products vary from soft, flexible materials to very hard, solid products, it is difficult to make direct comparisons between polyurethane and epoxy products. The properties which the users appreciate in the polyurethane potting compounds are:

- Good electrical properties
- More solid, non-brittle types
- Curing even at low temperatures
- Rapid final curing, particularly under heat (50°C)
- Flexible qualities
- Low exotherm
- Low shrinkage
- Good adhesion
- Low water absorption
- Chemical resistance
- Low water vapour permeability
- Problem-free repairs (potting of PUR to PUR)
- Good safety conditions
- No odour problems

Composition of polyurethane electrical potting compound

Polyurethane electrical potting compound consists of a base resin and an isocyanate curing agent (MDI). Before potting, the two components are mixed in the correct proportions. After mixing, a chemical reaction (curing) begins, giving a homogeneous polyurethane potting compound as the end product.

The base contains polyols, filling material, catalyst and various additives (e.g. to prevent settling, foaming, air bubbles, or to improve flow properties, etc.).

Electrical potting compound is a fluid, pour able liquid which does not normally contain solvents (approx. 100% solid matter).

Some of the functions of the individual components are described below:

Component	Function
Polyols, castor oil	A hard or soft, flexible potting compound is obtained, depending on the polyol types. Hard types are more hydrolysis resistant than the soft types, and normally have higher heat resistance and better chemical resistance.
Filling agents	Improve thermal conductivity, as well as tensile/compressive strength, reduce shrinkage. Give better impact resistance, increased stiffness and better heat resistance. Increase fire resistance.
Additives	May be liquid or solid. Used to provide fire retardant properties and prevent spreading of flames. Prevent foaming and sedimentation, and provide improved flow properties.
Catalysts	Used to adjust pot life and curingtime.

Definition of properties

In order to meet the requirements, which are often stringent, an electrical potting compound must exhibit a wide range of properties. These may be divided into 5 main groups.

1. Physical properties

2. Mechanical properties

3. Thermal properties

4. Electrical properties

5. Other properties

1. Physical properties

Property	Unit	Definition
Density	g/cm³ kg/m³	Expresses the weight of the compound per unit of volume
Viscosity (dynamic)	mPa·s (millipascal - seconds)	Expresses the ability of the liquid to flow. High viscosity = viscous liquid 1 poise = 100 cps =100 mPa·s 1 mPa • s = 1 cps Dynamic viscosity always refers to a measuring method, spindle, spindle speed and temperature
Shrinkage	%	Expresses, in percent, the linear contraction or curing
Weight loss	%	Expresses the weight loss in per cent after storage for one month at a given high temperature, e.g. 120°C.
Solids content	%	The non-volatile portion left after 2 hours, for example, at 105°C in a thin coat.

2. Mechanical properties

Property	Unit	Definition
Tensile strength	N/mm²	Intrinsic strength of the material when pulled apart, expressed in N/mm² (often indicated in kg/cm²) 1 N/mm² = 10 kg/cm²
Elongation at rupture	%	The elongation of the material at fracture when stretched, in per cent of the initial length. Example: 1 cm of material is stretched to 2 cm = 100% elongation.
Hardness	Shore A Shore D	Scale for soft and flexible materials. Scale for semi-flexible to hard materials. Expresses the resistance of materials to penetration of a needle of which design and shape are defined according to the unit type.

3. Thermal properties

Property	Unit	Definition
Thermal conductivity	W/(m•K)	Expresses the ability of the material to conduct heat. 1 kcal = 4.2 kJ (kilojoule) 1 kcal/(m•h•°C) = 1. 17 W/(m•K) Example: 0.5 kcal/(m•h•°C) = 2.1 kJ/(m•h•°C) = 0.58 W/(m•K)
Coefficient of linear expansion	μm/(m•K)	Expresses the expansion of the material when the temperature rises.
Martens value	°C	Expresses the highest temperature at which the material is dimensionally stable under the influence of a certain pressure.
Heat class	The letters A-E-B-F-H-C	Expresses the maximum temperature which the material is able to tolerate continuously A = 100°C E = 120°C B = 130°C F = 150°C H = 180°C C = > 180°C

4. Electrical properties

Property	Unit	Definition
Volume resistivity	Teraohm (Ω)•cm (1 teraohm = 1×10^{12} ohm)	Expresses the resistance of the material to conducting an electric current through the material.
Surface resistivity	Teraohm (Ω) (1 teraohm = 1×10^{12} ohm)	Expresses the resistance of the material to spark over on the surface
Dielectric strength	kV/mm	Expresses the ability of the material to resist electrical disruptive discharge resulting in Short-circuiting.
Tracking resistance	KA scale	Expresses the resistance of the material to creeping currents or tracks. (Discharges to the surface and tracks burning down into the surface). KA 3A = Poor KA 313 = Acceptable KA 3C = Good
Dielectric constant (epsilon)	ε_r	Expresses the dielectric constant of the material.
Dissipation factor	$\tan \delta \cdot 10^{-3}$	Expresses the loss factor of the material, i.e. the energy losses to the potting compound of variable magnetic fields. Epsilon and tangent delta have only little significance at low frequencies, e.g. for variable transformers and power supply units. At higher frequencies (radio, TV, radar) the values for epsilon and tangent delta are more significant and should be as low as possible.

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5. Other properties

Property	Unit	Definition
Pot life	minutes	States the time during which the potting compound changes from liquid to solid form.
Application time	minutes	States the time during which the potting compound is liquid and gives optimum use (normally half the pot life).
Exotherm	°C	Maximum temperature is reached during potting at the centre of the electrical potting compound.
Water absorption	% (percentage by weight)	Expresses the ability of the material to absorb water. Measured in per cent by weight of water absorbed in proportion to the mass of the dry material.
Fire protection class	Fire retardant/self-extinguishing	Measured according to UL standard.

It is difficult to give general rules as to the properties electrical potting compounds should have because this depends on the purposes for which they are to be used.

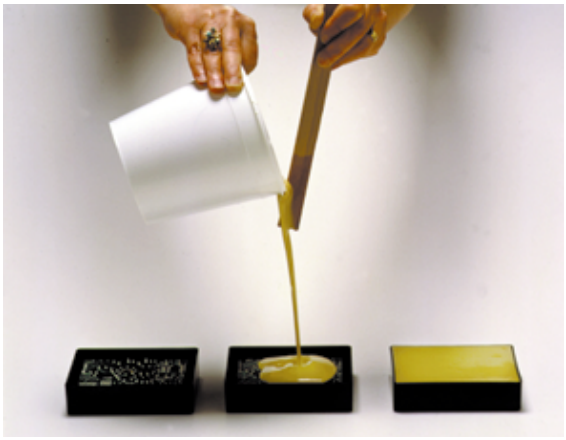
Therefore the requirements for a transformer are not the same as those for an insulator. However, there are minimum requirements for certain properties, namely
• The flow properties must be good.
• The coefficient of linear expansion should be as low as possible.
• The heat classification should be as high as possible. Minimum class A.
• The volume resistivity should be as high as possible. Minimum 10^{10} ohms • cm.
• The water absorption should be as low as possible.

Mixing and dosing

Mixing by hand

A simple method of potting components is as follows.

The components are placed in a plastic or metal box. The calculated quantity of curing agent and base is weighed in a polyethylene container. The curing agent is poured in first, followed by the base. The mixture is agitated until it has assumed a homogeneous colour. Avoid stirring too much air into the mixture. The mixture is then allowed to stand for a few minutes to release most of the air stirred in. The potting compound is poured into the box up to the required level, then placed in a suitable position for curing. Alternatively, the calculated quantity of potting compound can be poured into the box before the components are inserted, thereby effectively replacing the air.



Dosing from a bottle or disposable polyethylene syringe is very useful for smaller objects and series.

Mechanical mixing and dosing

A considerable saving in labour and a degree of automation can be achieved by using a 2-component mixer. Such a mixer consists of two separate containers one for the base and one for the curing agent. The mixing takes place either dynamically or with a static mixer, and the mixed potting compound can be dosed through a nozzle. Some machines can be programmed to dose a predetermined quantity of potting compound, e.g. to a transformer moving past on a conveyor belt. On certain types of machines a third container is required to flush out the system, thereby avoiding curing in the mixer and nozzles. Some machines can be pre-programmed to clean the mixer head with cleaning fluid if the machine has not been in use for some time - often half the pot life.

Keramax A/S 1900 Cleaning Liquid may be used for polyurethane. This cleaning liquid is unclassified and less environmentally harmful than acetone, methylene chloride, etc.

Vacuum

Keramax A/S polyurethane electrical potting compounds are vacuum-treated when supplied.

Air contained in the mixture of the 2-component polyurethane and air trapped during potting may have a very negative effect on the flow of the resin and on the final properties of the encapsulated objects. Furthermore expansion and/or contraction of air bubbles and air cavities due to large variations of temperature can cause fissures, cracks and adhesion breaks.

Air may be trapped in the potting compound in different ways:

a) During production of the base part
When this process is finished, the air is evacuated.

b) During mixing of the two components
This is often the case when the base part and curing agent are mixed by hand. Therefore Keramax A/S recommends the use of automatic dosage and mixing machines to reduce the risk of air getting into the mixture.

c) During potting
Two major causes:

1. The components are so designed that air can be trapped underneath them.
2. The potting compound flows too fast or is not applied from the bottom resulting in blocking of air escape.

Vacuum during potting
In special cases it is recommended to pot under vacuum conditions or after potting to establish vacuum, i.e. when optimum penetration is required e.g. for encapsulation of electronic components exposed to large and sudden variations of temperature. This procedure is frequently combined with preheating of the base part and the curing agent in order to lower the viscosity of the mixture.

Curing and potting techniques

Curing often takes place at room temperature in 5-6 hours, or overnight, depending on the pot life and temperature of the compound. If faster curing is required, the components can be heated to approx. 50°C before potting is carried out. In this case the following advantages are achieved:

- Better penetration, because the potting compound becomes thinner as a result of heating
- Drying of the components reduces the moisture problems
- Fewer bubbles on the surface
- Faster curing
- If heating continues, curing takes place very quickly

If the components are designed so that air can be trapped underneath them, it may be the case that the air bubbles are released at such a late stage that they do not burst on the partially cured surface of the potting compound. If a gas flame or hot air is applied to the surface, the bubbles will burst, and a smooth surface is obtained.

With polyurethane electrical potting compound, several potting operations can take place. On the first occasion the potting compound is poured in until it reaches just above the components, after which it is allowed to cure completely or partially. A thin layer is then poured over the first layer to cover any air bubbles and to give a flat, smooth surface. With polyurethane electrical potting compound, perfect adhesion is achieved between the two layers.

Potting should not normally be carried out at temperatures below 18°C. The potting compound becomes thicker and cures more slowly at lower temperatures, which presents a risk of absorption of moisture that may result in foaming problems.

Heat treatment and catalyst

To reduce the production time it is best to accelerate curing. This can be achieved as follows:

1. Heat treatment

The potted unit is cured in a furnace at 50°C, for example. This shortens the curing time to approx. 1/4 of the normal time, depending on how quickly the heat is transferred.

2. Heating the components

When the components are heated to 50°C very fast curing is achieved, with better penetration, which improves the quality.

3. Heating the base

Heating the base compound to approx. 30°C shortens the pot life and curing time by about half. The electrical potting compound becomes thinner, which gives better penetration. Make sure that there is good ventilation around the potting point.
N. B. This method is not suitable for potting compounds with a short pot life.

4. Catalyst

Curing can also be accelerated by adding a catalyst to the electrical potting compound, but this also shortens the pot life. The exotherm increases in pro portion to the reduction in pot life, and the flow properties are impaired.

Adhesion

If any of the materials in the potted unit require particularly good adhesion, they must be prepared for bonding. They should be cleaned with solvents and/ or abrated, and possibly sandblasted. Always keep objects to be potted free from dust and grease, and never use hygroscopic water-based products.

Inspection and faultfinding

The use of an electrical potting compound is generally free of problems, but it is recommended that the quality of each mixture is inspected by pouring a couple of cm in a plastic cup and, after curing, comparing with earlier samples.

Faultfinding, electrical potting compound

Problem	Cause	Remedy
Cured electrical potting compound too soft or too hard and brittle.	1. Too little or too much curing agent. 2. Settlement in base compound.	1. Weigh the quantity carefully. 2. Stir the base com- pound before use.
The potting compound or the mixture is too thick. The pot life is too long. Slow curing.	Too low a temperature	All materials should remain at 20-25°C during pouring.
The potting com- pound and mixture are too thin. The pot life is too short.	Too high a temperature.	All materials should remain at 20-25°C during pouring.
Foam during pouring or foam bubbles on the surface.	1. The base compound has absorbed moisture. 2. One or more of the components poured in contain water/ moisture.	1 . Keep the container closed. 2. Dry the component in a furnace before potting, or pot in two operations. Never pot (pour) in cold boxes.
Soft or liquid areas on the cured potting	The base compound and curing agent are not sufficiently mixed.	Carefully mix for at least 1 min. Scrape the sides clean/remix. Pour from the mixing container to the potting container. Inspect the mixing machine.

Safety

Keramax A/S base compound consists of polyols, filling material and additives, which are not subject to marking regulations.

The curing agent is liquid MDI (methylene diphenyl diisocyanate) with low volatility, i.e. a low vapour pressure. MDI is classified as harmful to health, and must be handled according to the regulations regarding Curing plastics.

The following applies to the handling of curing agent and mixed product:

Apply protective cream or wear protective gloves of the disposable type. Provide for good ventilation.

May cause sensitisation if inhaled and by skin contact. Harmful concentrations may be formed in the air, particularly during heating, spraying or dusting.

Skin contact: Wipe off, wash with soap and water.

Splashing in eyes: Rinse with large quantities of water.

Inhalation: Fresh air and rest. Call a doctor in case of breathing difficulties.

Conclusion

Electrical potting compounds are used to a large extent for encapsulation of different electrical and electronic components for use indoors, outdoors and underground.

They protect against moisture and mechanical loading and discharges heat from the components.

Electrical potting compounds are tough products with very low shrinkage and good chemical resistance.

With the correct equipment for 2-component dispensing, problem-free potting can be carried out.