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"ELASTOMERIC ENGINEERING MATERIALS USED IN HIGH VOLTAGE DEVICES"

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Abstract

Elastomers can undergo elongation to several hundred times from their original length. Vulcanization of elastomers impart high strength and greater elastic deformation. A Vulcanized rubber is a thermoset polymer as it cannot be reprocessed due to the presence of crosslinks in it. Resilience or bouncling property of elastomers is due to its property of recoverable elastic deformation when it is subjected to loads.

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1. Introduction

Elastomers, also known as rubbers, by virtue of its flexibility, recoverable elastic deformatation and resilience are largely used in high voltage material power system devices. Power grids in transmission and distribution involve the use of elastomers of these transformers, lightning arresters, line insulators and cables are most important. Criteria for choice of such elastomers is decided by their characteristics. The final elastomer product is obtained after the processes of compounding and vulcanization.

ELASTOMER CHARACTERISTICS

Flexibility of elastomers depends on the glass transition temperature (Tg), which is the temperature at which the material passes from glassy state to rubbery state. Flexibility of polymer increases as their Tg decreases. Elastomeric properties of polymers are obtained when the Tg falls below room temperature. Those polymers whose Tg appears above room temperature are thermoplastic. Table 1 shows the Tg of a few common rubbers and plastics.

Table -1 Tg of some common polymers

Name of the Polymer	Tg, C
(A) Rubber	
1. Natural Rubber (Polyisoprene	- 73
2. Polybutadiene Rubber	- 85
3. Styrene Butadiene Rubber	-65
4. Ethylene Propylene Diene Monomer	-56
5. Butyl Rubber	-70
6. Silicone Rubber	-120
7. Chloroprene Rubber (Neoprene)	-50
(B) Rubber Like Material	
1. Polyethylene	-80
2. Plasticized Poly Vinyl Chloride (Flexible)	10
3. Polypropylene	-8
4. Polyurethane Rubber	-23
(C) Thermoplastic	
1. Polyvinyl Chloride (Rigid)	85
2. Polystyrene	100
3. Poly Acrylonitrile	104
4. Nylon 6 (Polycapramide)	50

Determination of Tg is carried out by measuring the change in physical properties such as specific heat, dielectric constant, tan delta, elastic modulus etc over a range of temperature. Tg appears as a second order transition as the temperature of the polymer increases (fig. 1).

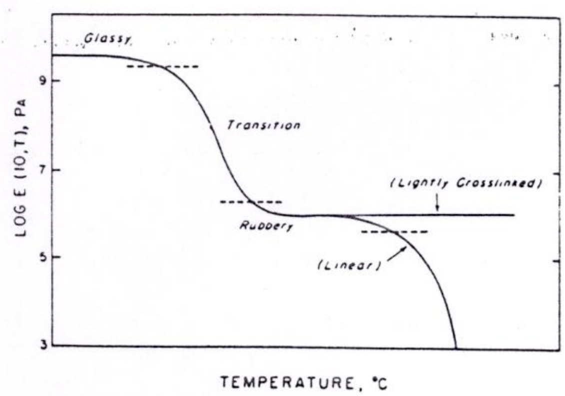


Fig.1 A schematic diagram of modulus versus temperature of polymers

VULCANIZATION OF ELASTOMERS

Elastomers unlike thermoplastics need vulcanization to be made into useful products. Before vulcanization elastomer is compounded with several ingredients. The compounding ingredients are

1. Fillers; these are used to impart strength and other specific properties and to cut down the cost of the rubber compound eg. Carbon black and silica clay, talc, mica cork etc.
2. Coupling agent such as silane and titanate type to improve the chemical bonding between the filler and the rubber.
3. Activator like the combination system of zinc oxide and steraric aicd.
4. Processing aid such as a paraffinic or aromatic oils.
5. Antioxidants of phenolic or amine type.
6. Accelerators like mercaptobenzothiazole, Cyclohexyl benzothiazole sulphenamide etc.
7. Sulphur; this is to crosslink the rubber through sulphide linkages.

RUBBER GASKET FOR TRANSFORMERS

The rubber component in transformer is the oil resistant gasket to provide sealing between the top and the bottom part (fig. 2). The gasket is always in contact with oil. Criteria for choice of rubbers for transformer gasket is (a) oil resistance (b) resistance to dimensional change (c) compressibility and (d) compression set. Two most important elastomers which meet these criteria are nitrile rubber (NBR) and polychloroprene rubber (Neoprene).

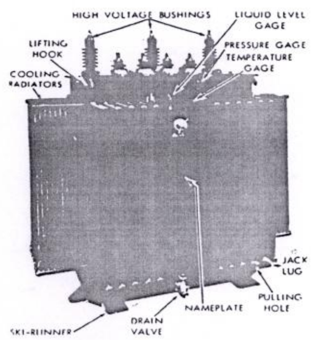


Fig. 2 A transformer

Oil resistant elastomers are structurally elastomeric material with polar characteristics. Nitrile rubber, Polychloroprene rubber, Chlorinated polyethylene, Cholorosulphonated polyethylene, (CSP) Chlorinated PVC, Ethylene Vinyl acetate thermoplastic elastomer and polyester thermoplastic elastomer are the commonly used elastomers for oil resistant applications (1-3).

Oil resistant gasket is an important component for transformers in electric power industry. Gaskets based on NBR is widely accepted in Transformer industry because of its superior oil resistant characteristics to other vulcanized rubbers. Though polychlorprene is also suitable as oil resistant materials it is used only in less volume in transformer industry with the advent of cork filled NBR Vulcanizate which has better high temperature and compression set characteristics in addition to the oil resistance property than the former.

Cork and carbon black are the important fillers used in oil resistant application. Cork filled nitrile rubber vulcanisates have the features of low dimensional change and compression set and high recovery after compression in addition to oil resistance. Table 2 shows the properties of oil resistant cork filled transformer gasket.

Table 2. Properties of oil resistant cork filled transformer gasket .

S. No	Property	Data
1.	Swelling in ASTM No. 3 Oil, (%)	40
2.	Compressibility at $28 Kg/cm^2$, (%)	35-50
3.	Recovery, (%)	80

4.	Compression Set, (%)	85
5.	Dimensional Change, (%)	1.5

RUBBER GASKET FOR LIGHTNING ARRESTERS

Failure of lightning arrestors due to leakage current has become frequent concern to electric utilities (4). Leaky seals of lightning arresters is one of the prime concern which has a direct bearing on the moisture ingress. If moisture is not present in the arrester, the surge would have been harmlessly discharged. Fig.3 shows the path through which moisture can enter the arrester due to leak sealing.

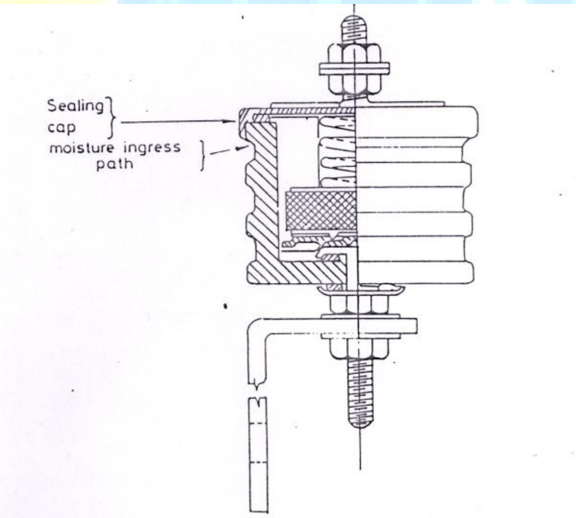


Fig.3 Cross section of lightning arrester

Moisture ingress in lightning arrester can be due to two factors as (a) water absorption of the rubber gasket and (b) untight sealing between porcelain and metallic parts.

Polychoroprene rubber (Neoprene), which is known for its excellent resistance to water absorption is used as the gasket material. However, no through investigations have been conducted to ascertain the mechanism of failure owing to the failure of gasket or to the poor sealing.

POLYMER LINE INSULATORS

Polymer line insulators also known as composite long – rod insulators are becoming widely used for transmission line insulation in situations of high environmental pollution and with tower constructions that require high mechanical strength to the insulators (5). Although ceramic long – rod insulators have achieved a high degree of manufacture as single – piece insulators for HV transmission lines and are also of heavy weight. Polymer line insulators have the advantages of easy handling, breakage reduction, resistance to shock loads, light weight, and low installed cost. A smaller surface area and longer leakage path give these insulators greatly improved power frequency insulation strength under wet and polluted conditions relative to conventional ceramic insulators.

The basic construction of polymer line insulator consists of a core, weathersheds, and metal fittings (fig.4). The core consists of axially aligned glass fibers bonded together by means of an organic resin such as polyester resin. Unprotected rods with end fittings is not suitable for outdoor use at high voltage, as the combination of contamination, moisture, and voltage will result in surface tracking and electrical failure. To protect the core, polymeric weathersheds, compounded for outdoor electrical application and shaped to optimize electrical properties, are placed over the rod between the metal fittings. In some designs, weathersheds are fully moulded onto the core while in others, modular weathersheds are simply slipped onto the core. In the latter designs, a silicone grease or gel is used to fill the space between the sheds and core.

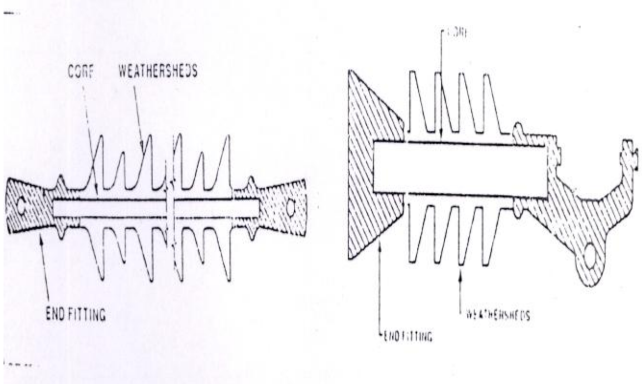
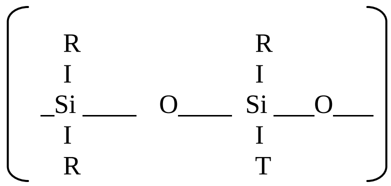


Fig.4 Polymer Line Insulators

EPDM and silicone are the two elastomers preferred for the construction of weathersheds. These elastomers have been proved to withstand excellent performance under polluted, wet and high voltage conditions.

The special suitability of silicone rubber as base material owe its inorganic – organic structure of polysilozanes which gives unique characteristics throughout quite a wide range of temperature and does not allow to split off carbonaceous, non-volataile molecules by local energy inputs such as power arc, UV radiation etc.



Polysiloxane

RTV SILICONE RUBBER COATING FOR CERAMIC INSULATORS

Room temperature vulcanisable (RTV) silicon rubber coating have been developed to overcome problems associated with providing a safe insulation in polluted areas (6-8). Procelain and glass are inert stable materials that can take a substantial amount of arcing without serious surface degradation because of their capacity to withstand the heat of dry band arcing. However, these materials are highly wettable when exposed to wet conditions like fog, rain and dew because of their high surface energy. When these insulators are both contaminated and wet leakage current develops which may lead to flashover which is still considered as the most serious problem of insulation in services.

The most common practice is to maintain a regular insulator washing and cleaning schedule. Most utilities regularly wash insulators to prevent flashover in heavily polluted areas. This practice although effective is quite costly over the long term. Of current interest to utilities are the options of replacing insulators with polymer units having either silicone rubber (SR), ethylene propylene diene monomer (EPDM) rubber or to coat them with a room temperature vulcanisable silicone rubber to prevent water filming.

Where SR, EPR and EPDM insulators are not available to replace porcelain insulators, a coating of RTV silicone rubber applied to the surface of the porcelain is an effective method of enhancing insulator performance.

The coating provides the initial water repellency of the surface thereby preventing leakage current and improving insulating property. This hydrophobic property of the coating causes water to bead up rather than form a continuous film of moisture. However, during transient water filming that is brought about by heavy or prolonged wetting in which the leakage current develops, the use of aluminum trihydrate (ATH) filler prevents the degradation of the material by dry band arcing. The combination of SR and ATH provides an arc resistant elastomers with long term ability to limit leakage current and prevent flashover.

CABLES

Cables consist of polymeric layers of insulation, jacket etc around the conductor (fig.5). Polyvinyl chloride (PVC), Butyl rubber, EPR, EPDM, crosslinked polyethylene (XLPE) are available as insulating materials depending on the voltage rating. Elastomers for jackets are neoprene rubber, PVC, nitrile rubber-PVC blend, Chlorosulphonated polyethylene etc. considerations of manufacturing these layers are influenced by electrical properties, mechanical properties, weather resistance, fire resistance, smoke resistance, radiation resistance and resistance to acid gas generations. The insulation layer for high voltage cable is surrounded by inner and outer semiconducting screens of Crosslinked ethylene copolymers such as ethylene vinyl acetate (EVA) compounded with semiconducting carbon black.

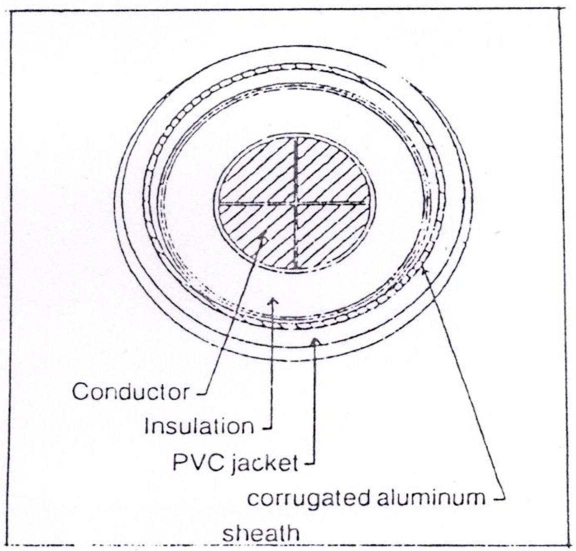


Fig.5 Cross section of cable.

XLPE because of its high dielectric strength, low power factor, low water absorption is the largely used material for the insulation of high voltage cables. In recent studies (9), it has been shown that ethylene propylene rubber is preferred over XLPE at cryogenic temperatures.
EPR and EPDM have wide acceptance in wire and cable applications because of its inherently excellent electrical properties, combined with resistance to ozone, heat, cold and moisture. These are the two insulating elastomers ideal for making cables which are to be exposed to radioactivity.

The ozone resistance of butyl rubber coupled with the moisture resistance of its essentially saturated hydrocarbon structures finds utility as a high quality electrical insulation.

Plasticised PVC is the major volume insulating material for low voltage cables because of its good electrical properties, flexibility and flame resistance. Similarly, it is the largest used material as cable jacket.

Neoprene is the oldest elastomer material of choice for cable jacket because of its resistance to abrasion, oil, flame and PVC have the superior electrical, mechanical and flame properties.

HEAT SHRINKABLE INSULATING POLYMERS

Heat – shrinkable insulating materials are semicrystalline polymers that act like – thermoplastics below the crystalline melt temperature, and like rubbers above it. They can be frozen in an expanded or distorted state by heating, then cooling them under restraint. On reheating, the stretched molecular structure remembers its original size and shape (elastic memory) and attempts to recover it by shrinking (10,11). The most common polymers that are used as the base resin in heat shrinkable electrical components are low density polyethylene (LDPE), linear low density polyethylene (LLDPE), high density polyethylene (HDPE), ethylene copolymers such as ethylene ethyl acrylate (EEA), ethylene vinyl acetate (EVA), ethylene methyl acrylate (EMA), chlorinated polyethylene etc.

Heat shrinkable components are designed by the manufacturers to supply the required wallthickness when installed within the recommended use range. By following the recommended use range, the installer obtains the required mechanical protection, the required electrical insulation thickness, and a sealed interface all with a single component (fig. 6).

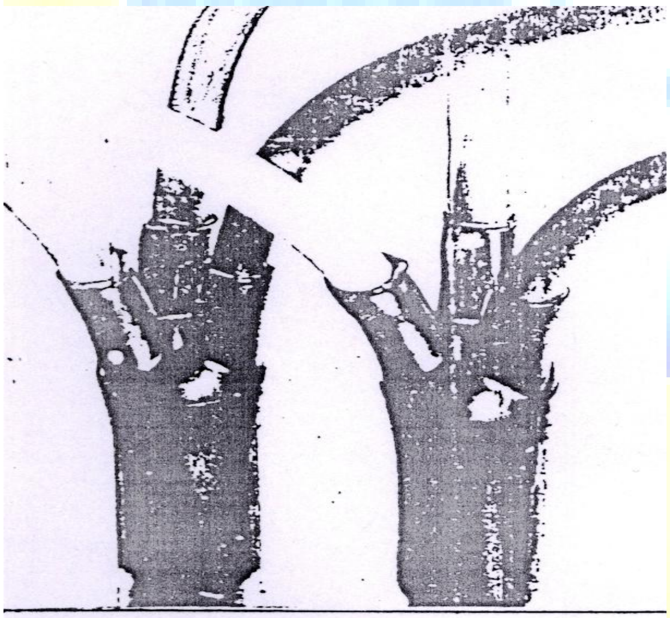


Fig.6 Heat shrinkable polymer Joints

Heat Shrinkable components – in a variety of molded shapes, tubular extrusions, tapes or vaccum formed parts can enhance insulation performace in adverse services environments (11).

CONCLUSION

An outdoor, porcelain, busing insulator is designed with required creepage distance, mechanical strength, and flashover length. However, airborne pollutants from nearby plants or seacoasts can deposit on the surface, thereby degrading its insulation properties periodic washings provides only a temporary restoration of electrical strength (fig 7.). Long term enhancement can be obtained by installing a non-tracking, heat shrinkable polymeric skirt that bonds to the porcelain and extend the creapage distance to protect against pollution induced flashovers.

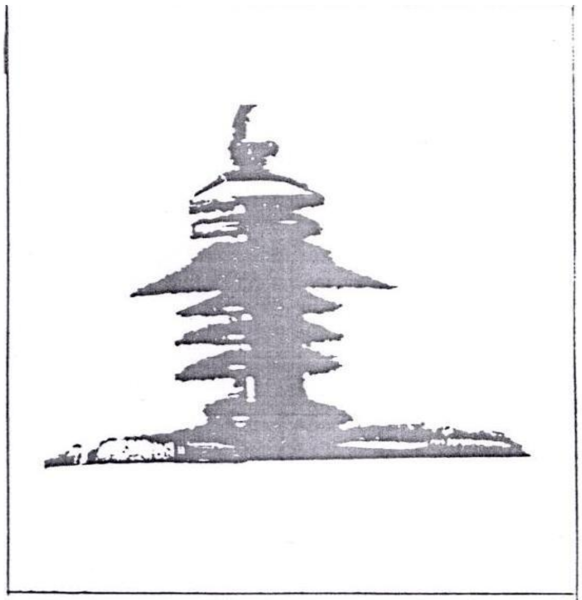


Fig.7 Heat shrinkable polymeric skirt on porcelain insulator to extend creepage distance

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