# HUBBELL'S PROPRIETARY ESP™ ENHANCED SILICONE POLYMER EXPLAINED

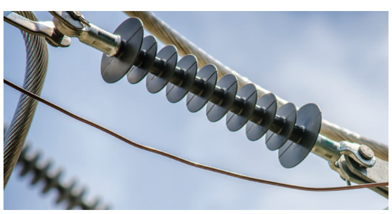
HUBBELL POWER SYSTEMS, INC. | AIKEN, SC

## SUMMARY

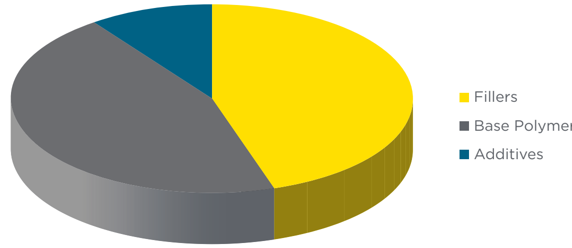

Polymer compounds used for insulator housing are integral to the life of the insulator. The housing made of polymer is key to protect the critical fiberglass rod of the insulator from the environment while providing electrical insulation. These polymer compounds are made up of multiple ingredients, and it is a common misconception that the base polymer is the only defining factor in a polymer material. Additives and fillers can enhance or strengthen the base polymer's characteristics in compounds suitable for electrical insulation. It is important to highlight Hubbell Power Systems' decades of polymer research and development as we discuss ESP™ enhanced silicone polymer material. Hubbell's proprietary *ESP* polymer blend is a reliable housing material for many high voltage applications, including polymer insulators.


## INTRODUCTION

As increased grid reliability is matched with elevated consumer expectations, utilities are held to higher power quality standards. The requirement for uninterrupted power compels electrical component manufacturers to provide products that stand the test of time. Insulator manufacturers must develop products that withstand harsh conditions over decades. An insulator is primarily a mechanical device that supports a conductor and prevents current flow to ground. The mechanical component of a composite insulator is the fiberglass rod. The polymer housing protects the fiberglass rod core from many environmental influences which would cause the insulator to fail if the housing is breached. Therefore, the life of the insulator directly correlates to the durability, quality, and life expectancy of the polymer.



Although most polymers in electrical equipment are labeled by their base polymer, there are many additional ingredients that are combined to deliver the desired properties. The performance of the polymer material is defined by the compounding of ingredients and the manufacturer's processing and design for the final polymer insulator. Ohio Brass, traditionally a porcelain manufacturer, began developing polymer materials suitable for use in high voltage applications in the 1960's. Hubbell Power Systems acquired Ohio Brass in 1978. The evolution of these efforts resulted in Hubbell's proprietary *ESP* brand blend of ethylene propylene diene monomer (EPDM) and silicone.




**[ Figure 1 ]** Typical Composition of a Polymer Compound [7]

## COMPONENTS OF A RELIABLE COMPOUND

Compounds suitable for electrical insulation can consist of 10 or more ingredients which can be broken down to three major categories, shown in Figure 1. These include the base polymer, making up 30%-40% of the total compound, fillers which can make up as much as 50% of the total compound, and then active additives. Compounding an elastomer with fillers and additives is critical to achieve the desired results for a given application. The components are carefully selected to enhance field performance as well as manufacturability. [7]

## BASE POLYMER

The base polymer that makes up a compound is called an elastomer. Silicone and EPDM are commonly identified as base polymers for insulator housings. Selection of the base compound is only the first step in designing a reliable polymer compound for electrical applications. *ESP* polymer uses a combination of EPDM and silicone to form the base that makes up about 40% of the total compound.

## FILLERS

Fillers are used to support the base elastomer of a compound and typically make up 40-50% of a compound. There are two types of fillers, classified as reinforcing and extending. Reinforcing fillers can improve tensile strength, modulus, tear strength and abrasion resistance of a compound. An extending filler is a loading or non-reinforcing material used to enhance desirable properties such as electrical characteristics and flammability resistance.

Alumina Trihydrate (ATH, or Hydrated Alumina) acts as an extending filler in *ESP* polymer, which further improves the compound's already good electrical characteristics. As an additional benefit, when the ATH is overheated it goes through an endothermic reaction in which it rehydrates to release water. This leaves behind the inorganic component but, in the process, cools the surface and makes it more resistant to damage due to dry band arcing on its surface.

## ADDITIVES

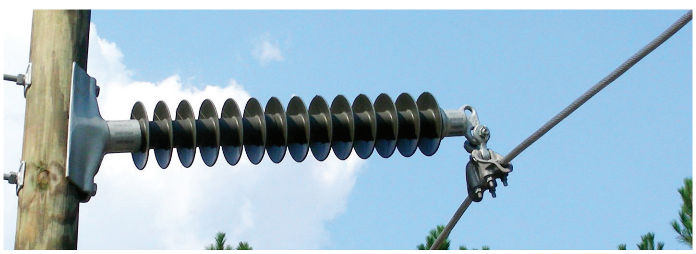
Additives also define a polymer's properties. These materials make up 10% of the overall compound but help manufacturers achieve consistency and reliability in the final product. Additives support the manufacturing processes by protecting the chemical bond between fillers and elastomer during vulcanization.

The combination of these is unique to the manufacturer and is integral to tailor the polymer to the electrical and mechanical stresses in the field. The additives in *ESP* polymer are coagents, peroxide as a curing agent, antioxidants, UV stabilizers, processing aids, coloring agents, coupling agents, plasticizers, and other special purpose materials.

The compounding of the base polymer, fillers, and additives results in a dependable polymer that can endure environmental factors which might deteriorate other polymers.

## CHARACTERISTICS AND TESTING PERFORMANCE OF ESP POLYMER

Base materials, additives, and fillers determine the final compound's ability to withstand the degrading influences a polymer insulator experiences in the field. There is a misbelief that hydrophobicity, the ability to shed water and thus contaminants, is the most important characteristic of a polymer insulator. This is an important feature of polymer insulators over porcelain because it can break up the potential leakage current path. However, it is not the only characteristic a polymer needs to possess to be a dependable housing material. There are distinctive qualities that a polymer material needs to adequately protect the fiberglass core from the environment.



The combination of characteristics listed below contribute greatly to the long-term performance of the polymer products in service. Ohio Brass developed a series of polymer testing methods, referenced later, that correlate lab performance to long term reliability in the field.[7]

**Characteristics of an Ideal Polymer:**

- Resistance to tracking and erosion
- Ultraviolet (UV) resistance
- High mechanical strength
- Short and long-term hydrophobicity
- Low flammability

The next step after defining the characteristics required of an ideal polymer housing material was to develop an appropriate test protocol. Compounds intended for high voltage insulation should be tested for the ability to resist tracking, erosion, corona, and ultra-violet (UV) radiation exposure to ensure long term reliability. The section below provides a high-level overview of the key test procedures defined to achieve the previously mentioned characteristics. Detailed information is found in "Polymer Compounds used in High Voltage Insulators"[1]. The testing regime, outlined in Table 1, allows various materials to be evaluated and leads to results that can define the optimum material selection for electrical insulation applications.[7]

| TEST | MINIMUM PASSING CRITERIA |
|---|---|
| **Tracking and Erosion** | 15,000 cycles |
| **Ultraviolet (QUV)** | 8,000 hours |
| **Corona Cutting** | 1,000 hours |

**[ Table 1 ]** Lab Performance Requirements of Hubbell Polymer Compounds [7]

## RESISTANCE TO TRACKING AND EROSION

The Hubbell tracking test was initially developed to evaluate glaze compounds for porcelain insulators. It was adapted to evaluate the tracking and erosion resistance of polymeric insulating materials and their ability to withstand electrical discharge on the surface. This test is used as a screening method to ensure any polymer material performs as well as porcelain that has decades of proven reliable service in the field.

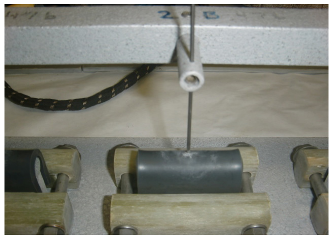
Tracking evaluation is performed on a rectangular section of the molded material. Electrodes are clamped on opposing sides with a defined gap between them. The sample is energized and repeatedly sprayed with a conducting solution. The surface current between the electrodes heats and dries the sample until the flow of current ceases. These spray cycles continue until the material shows signs of carbonization or erosion on the surface. The failure mode of this test is the result of this aggressive tracking/erosion and characterizes the polymer's ability to withstand harsh service conditions in the field.

An important characteristic of a polymer compound is its ability to resist tracking and erosion especially under contaminated conditions. With sufficiently high contamination levels, the polymer housing can begin to track and form an electrically conductive path along the surface. The presence of this new conductive path defeats the intended purpose of the insulator and can lead to a line-to-ground short across the insulator. These high leakage currents combined with associated dry band arcing can severely damage the polymer surface in the form of erosion. Dry band arcing generates ozone, high temperatures and UV radiation exposure on the polymer surface. *ESP* polymer does not track. The EPDM base, when exposed to high temperatures, will revert to a gaseous state, leaving no conductive residue. This key property serves to prolong the service life of the polymer regardless of the level of hydrophobicity.[7]

## RESISTANCE TO ULTRAVIOLET AND CORONA

This characteristic is verified by two tests – QUV and Corona Cutting. The QUV test subjects a sample to cycles of high UV light, heat, and humidity. The corona cutting test mechanically stresses a sample with concentrated corona from a "needle" electrode.

Polymer material in the field is exposed to UV from either sunlight, corona, or dry band arcing which can cause changes to the surface of the polymer. In the case of *ESP* polymer, a light chalking develops during this process as a reaction to exposure to UV. This chalking then serves to protect the underlying substrate from severe UV damage. Ultraviolet QUV testing challenges a polymer's ability to resist the absorption of this UV radiation in combination with high humidity which can affect the dielectric and weathering properties of a compound.



ESP plaque after corona cutting test

Insulator sample before testing in the QUV chamber

Chalking on polymer housing after QUV testing

The presence of corona ages polymers by generating UV and ozone. Passing these tests demonstrates that proper chemical compounding has taken place during the manufacturing process. *ESP* polymer effectively withstands the damaging effects of this type of exposure in the field. [7]

## HIGH MECHANICAL STRENGTH

To further qualify the polymer compound for electrical application, abrasion and tear testing is done to ensure the polymer has high mechanical strength. Damage to housings in insulators could compromise the effective seal and protection of the fiberglass rod and lead to moisture ingress and ultimately an electrical failure. This type of damage can result from improper handling during transportation or installation. Additionally, there are some instances of utilities around the world that have reported damage to polymer insulation from birds or other wildlife. Hubbell's *ESP* material is significantly stronger mechanically than other polymer housing materials in this regard and has shown effective resistance to this type of physical and mechanical destruction.

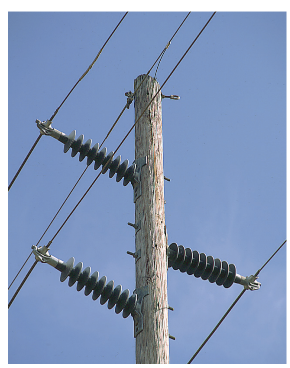
## SHORT- AND LONG-TERM HYDROPHOBICITY

Hydrophobicity is the ability to bead water on the surface of a polymer which can help to reduce electrical activity on the surface. This property is mostly valuable to polymers like silicone rubbers which depend on this low surface tension to withstand the damaging effects of tracking and erosion. Data and field history show prolonged exposure to UV and contamination can substantially degrade polymer surfaces, significantly or completely reducing the hydrophobic properties. Temporary loss in surface tension can leave some polymer materials vulnerable to tracking before their hydrophobic properties are regained. An ideal polymer needs to have a permanently hydrophobic surface or have a high level of resistance to leakage currents to withstand these currents when hydrophobicity is lacking. Hubbell's *ESP* combination of EPDM and silicone rubber displays characteristics of hydrophobicity, but unlike exclusively silicone rubber-based materials, does not rely on this characteristic alone to ensure long term reliability.

Water beading on ESP test plaque after spray test

## CONCLUSION

When Hubbell began exploring polymer materials for high voltage applications in 1964, the design goal was to meet or exceed the capability of existing porcelain designs that had been in use for nearly half a century. High voltage insulators must compete against the harsh environmental, electrical, and mechanical stresses they experience. Hubbell developed a series of tests and criteria to evaluate the performance of possible polymer compounds. Hubbell's experts formulate *ESP* polymer with a unique blend of silicone with EPDM. The enhanced silicone polymer combines properties from EPDM and silicone with additives like ATH to achieve a high level of resistance to tracking and erosion, as well as a high level of mechanical strength and resistance to moisture permeability.



Despite the use of effective base compounds such as EPDM or silicone rubber, the industry has unfortunately experienced the manufacturing of inferior polymer insulators introduced to the field. Therefore, after decades of field experience with the many types of polymer insulators, the industry now understands that the base polymer is not the only determinant of long service life. As for Hubbell, countless hours in the lab, over 40 years of field experience and tens of millions of products installed around the world have proven that the combination of base materials, compounding, processing, and design are needed to made the high-quality high voltage insulators that our customers expect.

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