



COMPOUNDING

Performance

Innovation

Reliability

History of Ethylene Propylene Rubber

Prysmian pioneered the development of Ethylene Propylene (EP) based insulation compounds in the late 1950's through the work of Nobel Prize winner Professor Giulio Natta. His research on the synthesis of the ethylene propylene copolymer was accomplished while working as a consultant for Prysmian (formerly known as Pirelli Cables & Systems). These EP compounds became commonly referred to as Ethylene Propylene Rubber (EPR).



This early work by Prysmian led to the 1963 development of the world's first EPR insulated cable to operate at 45kV as well as the first EPR insulated submarine cable in 1967. Higher voltage cable developments were achieved in 1969 and 1972 at the 69kV then 138kV voltage classes, respectively. As of today, Prysmian worldwide has produced in excess of 1.5 billion feet of EPR insulated power cable.

Early vintage cables were manufactured using a dual pass extrusion process. In the 1970's, the first advancement in extrusion technology was the addition of another head to allow for a single pass extrusion, commonly referred to as a 1+1+1 or triple tandem process. The 1980's brought about a significant change to the single pass extrusion technology; the 1+2 or dual tandem extrusion process. The most recent development in the single pass extrusion technology was the true triple process. The true triple extrusion process applies all three layers within one extrusion head; eliminating the possibility of outside contaminants.

Raw Materials

EPR insulations are complex materials in the sense they incorporate multiple ingredients in their makeup. Only a few manufacturers of EPR, compound their own material. It is important to recognize that each compounding manufacturer has a unique formulation for their EPR insulation. The total number of different raw materials will vary depending on manufacturer. Therefore, the only way to compare EPR insulations is by performance, not by ingredients.

In order to facilitate an automated handling process, Prysmian incorporated a small percentage of polyethylene into the original EPR formulation. This component was initially included to allow the EPR material to be pelletized. After extensive testing, it



was found that Prysmian's EPR also had superior mechanical and electrical performance when compared to other EPR formulations. As of today, other manufacturers now commonly incorporate polyethylene into their EPR formulation; further proof that it is the *performance* of a cable that is important not the composition of the EPR.

It is worth noting that raw material suppliers are held to the same high standards that cable manufacturers are held to by their customers. Proprietary specifications have been developed by Prysmian's R&D and Quality Assurance departments that require the raw materials to meet stringent requirements.

Material Handling Systems

Prysmian currently mixes/compounds EPR in several plants worldwide. By directly controlling the compounding process, Prysmian is able to maintain a competitive advantage with respect to product performance and quality control. Additional details, afforded to Prysmian, through in house mixing are described below.

- Control over the material handling equipment.
- Proprietary machinery, including pelletizers, which are optimized for our EPR compound.
- Control over equipment enhancement, so that state-of-the-art equipment is continuously evaluated and utilized.
- A high degree of quality control during the compounding process.
- In-plant quality control over the final product.

Prysmian accomplishes the compounding process for North America through a state of the art plant dedicated to the mixing of EPR compound. This plant has dedicated, stainless steel, handling systems which use filtered air (≤ 3 microns) to convey the appropriate materials from Class 10,000 clean rooms (equivalent to hospital operating rooms). Automated mixing processes, which assure complete blending and dispersion of ingredients, produce a compound that is filtered through two proprietary, very fine mesh screens.

From this compound, pelletizing is completed in air, not under water, so that there is no possibility of ionic contamination from a poorly operating de-ionizing water system. A closed, filtered system is then used to handle the pelletized compound. Rheological testing of the EPR compound is performed to confirm curing characteristics; while, additional testing is also routinely conducted to confirm physical and electrical properties.

EPR Performance

Since each manufacturer of EPR has their own proprietary mixture, how can the insulations be compared? The answer is industry standard qualification test reports such as an Accelerated Water Treeing Test (AWTT).

Industry standards, such as ICEA, dictate the specific details for AWTT setup requirements. This controlled test provides an apples-to-apples comparison of an insulation's performance. The

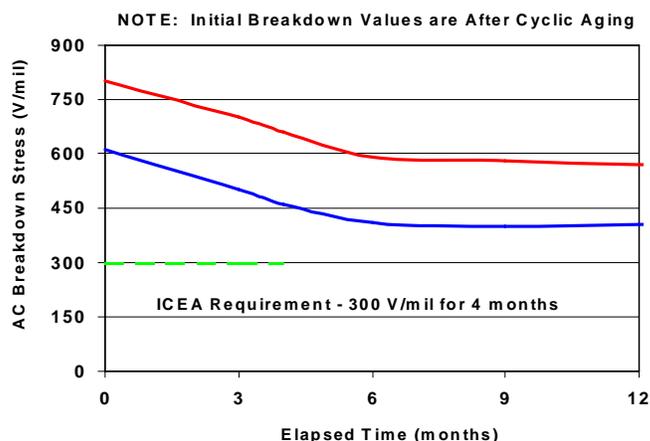


chart above shows the performance differential between Prysmian's EPR (red) and another leading manufacturer's EPR (blue).

EPR Losses

Energy losses within power cables can be divided into three categories: conductor losses, dielectric (insulation) losses, and shield losses. When comparing equivalent cable designs, the only controllable loss is the dielectric loss. The cable dielectric losses should be one factor to consider as part of the final decision making process, just as transformer losses are commonly evaluated.

The dielectric loss is based on the insulation's Specific Inductive Capacitance (SIC) and Dissipation Factor (DF). Since these values do vary between manufacturers, it is important to remember that the smaller the number the better. Prysmian's typical values for SIC and DF are 2.6 and 0.2%, respectively, for unaged cable at 80 volts/mil and 15.6°C. These values prove that Prysmian's EPR insulation offers the lowest losses in the industry.

The KEY is choosing the right insulation for the right reasons:

- Proven History - In House Mixing •
- Dielectric Performance - Losses •

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