BLACK EPR INSULATED MEDIUM VOLTAGE CABLES

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INTRODUCTION

The predecessors of black EPR were natural rubber, oil-base rubber, synthetic styrene-butadiene rubber (SBR) and butyl rubber. All of these rubber compounds were black, due to a carbon black additive. Carbon black gave the insulation the necessary tensile strength, elongation and hardness needed for a cable insulation.

Soon after the first synthesis of EPR in 1955 by Giulio Nattta cable engineers began to study the possibilities offered by this new material in cable applications, well in advance of the industrial production of the polymer.

COMPOUNDING

The new EPR immediately appealed to the skilled cable compounders because of its attractive properties, particularly the non-polar hydrocarbon structure that allowed a "clean" type of cure by organic peroxides, resulting in a pure carbon-to carbon polymer network. This opened the door to superior dielectric characteristics.

Compounding of EPR is both science and art. Manufacturers guard their formulations very closely. Several ingredients are of fundamental importance to the quality of the insulation. But the most important is the polymer itself. Carbon black was added to give tensile strength, elongation and hardness. Used in the correct amount resistivity, dissipation factor and dielectric strength was not degraded

Although the phenomenon of carbon black reinforcement has been known for a century or more, the nature of the mechanism is not yet fully understood and is a subject of debate. It is generally accepted that the particle size, aggregate structure and surface area of the carbon black are important factors in reinforcing the EPR.

Carbon black also acts as a light-absorbing additive that inhibits chemical reactions that would lead to insulation degradation.

SERVICE EXPERIENCE

In 1964 a 45 kV black EPR insulated cable without any water barrier was installed. The circuit was direct buried. The purpose of this installation was to prove the feasibility of medium voltage EPR insulated cables, and to monitor the cable behavior in actual service conditions, in particular the response of the insulation to the water present in the ground. This cable remained in service for over 20 years without any problems. It was removed for reasons not related to service performance.

The design of this cable was:

Conductor:	*125 kcmil copper*
Conductor shield:	*semiconducting tape*
Insulation:	*470 mils, black EPR*
Insulation shield:	*semiconducting varnish, semiconducting tape and tinned copper tape*
Jacket:	*black polyethylene*

The first submarine cable connection employing a black EPR insulation compound dates back to 1967 when a 20 kV circuit was commissioned. Further installations were made up to 1971. These cables were still in service after 25 years.

Shielded trailing cable and dredge cable for the mining industry, 5 kV to 25 kV, were put in operation in 1967. These cables were exposed to severe conditions generally encountered in Canadian mines and heavy industries. The black EPR insulated cables gave excellent service and lasted for at least 10 years, when repairs became excessive.

5 kV – 25 kV directly buried distribution cables manufactured and installed at this time are still in service.

23 kV black EPR insulated cables were used for feeders for a large commercial development in 1970. The underground ducts are periodically flooded with sea water. These cables are still in service.

THE DEMISE OF BLACK EPR FOR MEDIUM VOLTAGE CABLE

5001 - 35,000 VOLTS

On May 1, l971 the standard color for EPR insulated cable above 5 kV became light beige. The advantage of a light color is that a good contrast is thereby provided between the insulation and the black extruded insulation shield now being used.

The insulation shields must be completely removed when splicing and terminating the cable. The color contrast helps the cable installer by providing visual evidence that all conducting residue has been removed.

The color change had no significant effect on physical properties and did not change the insulation's electrical performance.

AGING OF BLACK EPR

Black EPR insulated medium voltage cables were installed in nuclear plants. As nuclear plants continue to age, these cables degrade as a result of long-term operation and exposure to harsh conditions that include high radiation and extreme temperatures. Aging management and condition monitoring of electrical cables

requires research that is necessary to understand the degradation and to enable development and demonstration of cost-effective aging strategies that may prevent, detect, monitor, or mitigate the degradation. Operating predictability is required.

<u>TEST REQUIREMENTS</u>

XLPE and BLACK EPR
INSULATED CABLES 500/ - 35,000 VOLTS

TEST	***XLPE***	***BLACK EPR***
PHYSICAL PROPERTIES		
Tensile Strength-Unaged	***1800 psi minimum***	***700 psi minimum***
Elongation -Unaged	***250% minimum***	***250% minimum***
Aged in Air oven-7 days @ 121C		
Tensile Strength	***Minimum 75% retention of unaged value***	
Elongatrion	***" " " " "***	
ELECTRICAL PROPERTIES		
Insulation Resistance Constant @ 15.6C (60F)	***10,000 minimum***	***20.000 minimum***
Dielectric Constant (SIC) at room temp.	***3.5 maximum***	***4.0 maximum***
Power Factor at room temperature	***2.0% maximum***	***2.0% maximum***
MOISTURE RESISTANCE		
Dielectric Constant after 24 hrs. Immersion in water at 75C	***3.5 maximum***	***4.0 maximum***
Increase in capacitance 1 – 14 days	***3.0% maximum***	***3.5% maximum***
7 – 14 days	***1.5% "***	***1.5% "***
Stability Factor after l4 days	***1.0% "***	***1.0% "***
Alternate to stability factor 1 – 14 days	***0.5% "***	***0.5% "***
Water absorption-milligrams per sq.in	***-***	***10.0 max***
OZONE RESISTANCE-25C 0.025 to 0.030% concentration		***3.0 hours minimum (no cracks)***
DIELECTRIC STRENGTH TESTS		
A-C 5 min. withstand Test D-C 15 min. withstand Test	***Test voltages in accordance with IPCEA***	

CORONA LEVEL	*Corona Extinction Voltage Minimum*	
Rated Circuit Voltage	*Grounded Neutral*	*Ungrounded Neutral*
5001- 8000 volts	*6000 volts*	*8000 volts*
8001-15000 “	*11000 “*	*15000 “*
15001-25000 “	*19000 “*	*26000 “*
25001-28000 “	*21000 “*	*-*
28001-35000 “	*28000 “*	*-*

FORMULATION
MEDIUM VOLTAGE BLACK EPR INSULATION

EPR	*100*
Carbon Black	*10*
Treated Clay	*110*
Anti-oxidant	*1.5*
Lead Oxide	*5*
Zinc Oxide	*5*
Process Oil	*15*
Paraffin	*5*
Silane	*1*
Peroxide	*3.5*

Q. (Rick Hartlein).
How can you determine whether a cable is insulated with butyl rubber or black EPR?

A. At high temperatures butyl rubber insulation reverts, i.e., the cross links between polymer chains break down.

The procedure to differentiate between butyl rubber and black EPR is as follows:

Place the cable sample in an air oven at 200 C. After 16 yours, the butyl rubber insulation would have a retention of tensile strength approaching

zero. After only 3 hours, 50% retention of tensile strength would remain. The butyl rubber insulation becomes very soft and porous within ½ hours of oven aging at 200 C.

Black EPR's retention of tensile strength is relatively high.