



**PHYSICAL PROPERTY
AND TOXICOLOGICAL IMPROVEMENTS
IN PREMISE CABLE INSULATIONS**



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PHYSICAL PROPERTY AND TOXICOLOGICAL IMPROVEMENTS IN PREMISE CABLE INSULATIONS

J.S. Borke, Equistar Chemicals, LP

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ABSTRACT

Specifications for premise cable are constantly changing to compensate for faster networks and broader bandwidths, as well as the demand for more environmentally friendly cable materials. To address these issues, a new halogenated, non-diphenyl oxide flame retarded polypropylene compound has been formulated for use in premise wire applications. The new compound shows improved electrical, physical and toxicological properties.

BACKGROUND

In the local area network (LAN) market there is a continual demand for premise cables that have faster data transfer rates and broader bandwidths. These demands have forced manufacturers to optimize current premise cable constructions as well as to develop new constructions for the future.

In the past, PVC had been the standard insulation material for premise cables. In recent years, increasingly stringent flame, smoke and signal transmission speed requirements have opened the market for flame retardant polyolefin and fluoropolymer materials (FEP). With the high cost of FEP and the advances in jacketing materials and flame retardant systems, polyolefins have become commonplace in the premise cable industry. Advances in electrical, toxicological and flame properties of polyolefin based systems are the key to their continued use in the premise cable market.

The quality foci for all premise cables start with the insulated copper conductor. Insulation type and dimensional stability of the insulated copper conductor dictate electrical, toxicological and flame properties of the final premise cable¹. Electrical properties such as attenuation, impedance and capacitance are directly influenced by insulation dimensions, eccentricity of the conductor to the insulation, twisted pair configurations and other construction based variables².

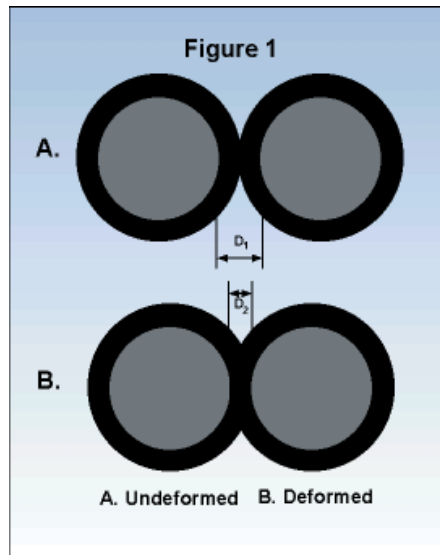
Flame and toxicological properties depend upon what types of raw materials and flame retardants are used to construct the premise cable. One of the most common flame retardant systems used in polyolefins is based on the efficient and inexpensive brominated compound, decabromodiphenyl oxide (DBDPO). However, debates have been occurring for years as to whether diphenyl oxide (DPO) based flame retardants produce trace quantities of toxic dioxins and furans when burned. Initial studies³ in 1986 showed that incomplete combustion of DBDPO at 510°C-630°C produced dibenzofurans (PBDFs) and dibenzo-p-dioxins (PBDDs) with total yields of 10 percent. Further studies by several companies and laboratories confirmed the production of PBDFs and PBDDs at burning conditions between 400°C and 800°C but at much lower quantities⁴.

In response to these studies, the European Economic Community proposed a directive to ban the use of brominated DPOs. Though the directive was never implemented, several European companies require signed documentation that no components of a cable contain brominated DPOs.

OBJECTIVES

Many polyolefin premise wire insulations are based on high density polyethylene (HDPE) because of its excellent dielectric, toughness and mechanical properties. After insulating the conductor, processes such as twinning (process of twisting two conductors together) and jacketing would routinely damage or deform the insulation causing inferior electrical properties in the final cable.

As manufacturers developed Category 5 cables that required 100 MHz signal ratings, twisting of the conductor pairs became tighter and even HDPE lacked the toughness to withstand the deformation or cut-in that occurs during the twinning process (Figure 1). Greater insulation wall thickness helped compensate for the insulation deformation but at a higher cost.



Another approach would be to use a tougher material that could reduce wall thickness, and in turn, cost. One method to address the above would be to replace HDPE with polypropylene (PP) insulation compounds. This replacement would improve electrical and physical properties of the premise wire. These improvements would result from PP's inherently superior thermal resistance, dielectric constant and toughness when compared to HDPE.

In the following report, formulations based on HDPE and PP were evaluated for electrical and mechanical improvements. Also addressed is the replacement of the commonly used DBDPO flame retardant system with a new halogenated system that does not form dioxins or furans but maintains equivalent flame retardancy and physical properties.

EXPERIMENTAL TEST METHODS

All insulation compounds were extruded using a 2-1/2" 20:1 Davis Standard extruder equipped with a Maddock screw to apply a 10 mil wall onto 22 AWG solid copper conductor.

CRUSH RESISTANCE (UL1581)

Crush resistance is a test method used to correlate the ability of insulation to resist deformation under an applied load. The crush test uses an Instron Universal Testing Machine to apply an increasing load at a constant rate. The test is complete when the insulation

DIELECTRIC TESTING (ASTM D 150)

Dielectric properties were acquired using a HP4342A Q-Meter. In accordance with ASTM D 1928 two 50 mil compression molded plaques of each insulation compound were used for Q-Meter testing.

LIMITING OXYGEN INDEX (LOI) (ASTM D 2863)

This test method describes a procedure for measuring the minimum concentration of oxygen that will support flaming combustion. In accordance with ASTM D1928, 125 mil compression molded plaques were used.

TENSILE PROPERTIES (ASTM D 638)

Tensile properties were measured using insulated wire with the conductor removed.

RESULTS AND DISCUSSION

ELECTRICAL AND MECHANICAL ENHANCEMENTS

Figure 2 compares the dielectric constant of PP and HDPE based insulation compounds used for CMR (riser specification) rated constructions. Compared to HDPE, PP has a lower dielectric constant even after formulation.

The dielectric constant is important whenever capacitance effects can deteriorate electric properties of the final cable⁵.

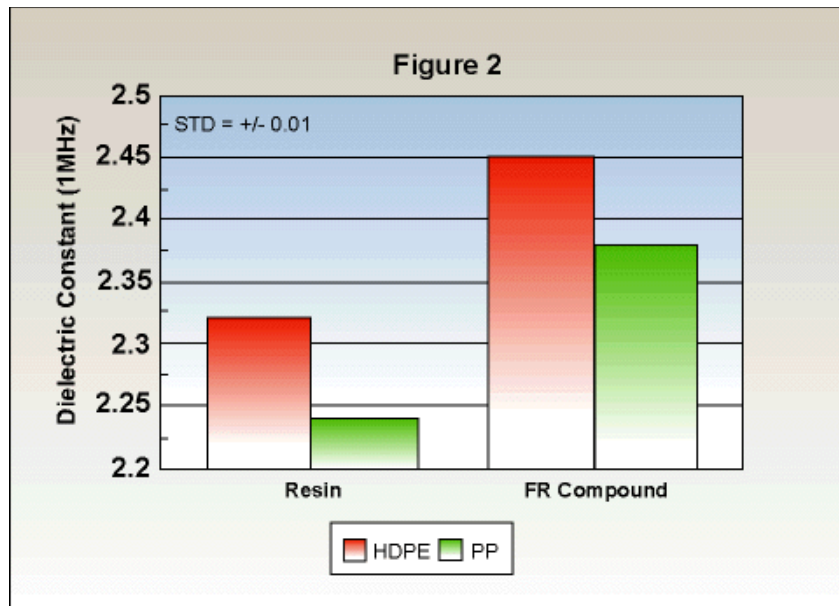
The capacitance of a parallel plate capacitor (Figure 3A) is given as:

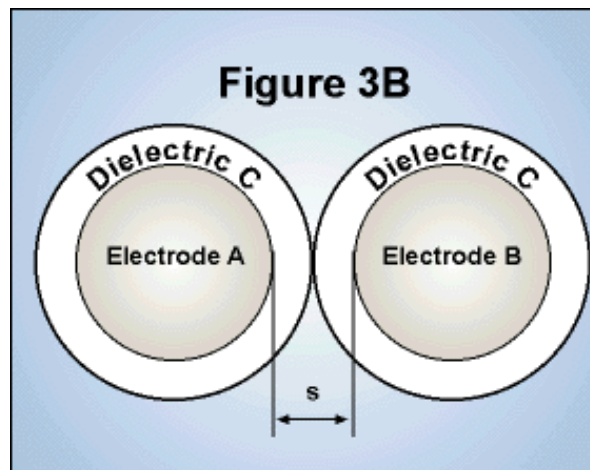
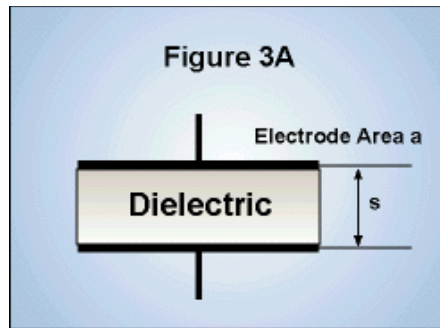
$$C = \frac{Da}{4 \pi s}$$

Where C is capacitance, D is the dielectric constant, a is the electrode area, and s is the distance between electrodes.

In Figure 3B the electrodes have been replaced by a twisted pair, with the insulation as the dielectric. In this configuration there are two possible ways to reduce the capacitance effects.

1. Reducing the dielectric constant D of the insulation and
2. Increasing the distance between conductors s by increasing insulation thickness.



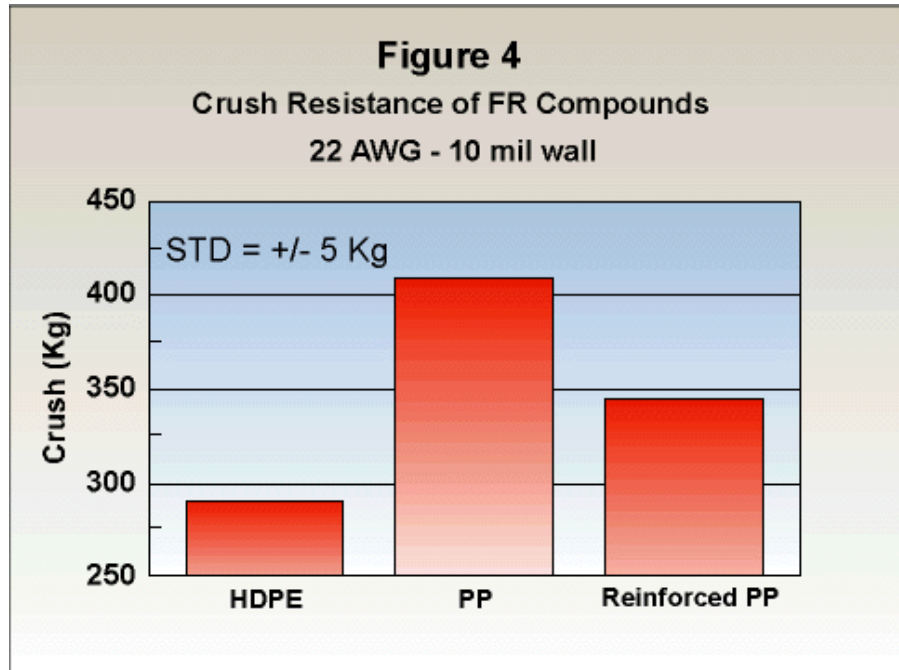


The most desired resolution is to reduce the dielectric constant of the insulation compound which allows manufacturers to reduce the wall thickness of the insulation as well as saving raw material costs.

As previously stated, when using insulation materials that deform during the twinning process the capacitance is adversely effected. Figure 4 shows crush resistance data of three insulation compounds used for CMR rated constructions. Due to PP's inherently better hardness and higher yield strength, the PP based compounds outperformed the HDPE based compounds in crush resistance by 40%.

FLAME RETARDANCY ISSUE

The reinforced PP compound in Figure 4 addresses a flame retardancy issue inherent to polypropylene. Unlike polyethylene, polypropylene has an abundance of tertiary hydrogens on the polymer chain. When burned, these tertiary hydrogens induce an unzipping reaction that breaks the polymer chain into smaller chains more rapidly than polyethylene. During combustion, the polymer chains decrease in size, causing the polymer viscosity to decrease to a point where dripping readily occurs.



Dripping can have both positive and negative effects during large-scale flame tests. The positive effect of dripping is that dripping material takes with it the heat required to maintain combustion, causing the flame to extinguish. The negative effect of dripping occurs in flame tests that include a smoke specification. In the case where dripping material accumulates in the bottom of the testing apparatus, smoldering develops resulting in high smoke density levels.

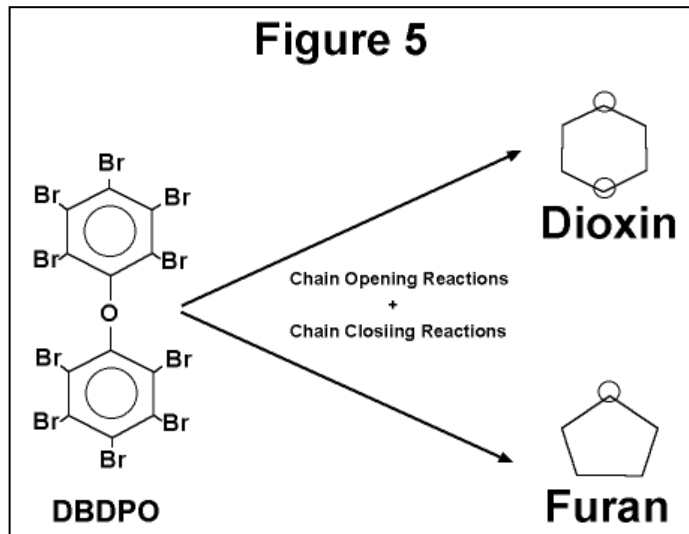
To prevent dripping, manufacturers sometimes use specific jacketing materials that help encapsulate the insulation materials during the burn test. These jacketing materials help keep the insulations from being exposed to the flame. The reinforced PP compound addresses the dripping issue by the addition of a reinforcing filler that prevents dripping during the burning process.

Once this reinforcing filler has been added, an improvement of 20% in crush resistance over polyethylene is still seen in the PP formulations. These improvements in crush resistance will help manufacturers reduce wall thickness of the insulation that had been previously increased to compensate for insulation deformation and inferior capacitance values.

TOXICOLOGICAL ENHANCEMENTS

PHYSICAL PROPERTY	COMPOUND 1 DBDPO BASED	COMPOUND 2 NDFP FLAMERETARDANT
Limiting Oxygen Index % LOI (ASTM D 2863)	25%	25%
Tensile Strength (ASTM D 638)	22.7 MPa	22.7 MPa
% Elongation (ASTM D 638)	650%	650%
Crush Resistance (UL 1581)	410 Kg	410 Kg
Dielectric Constant (ASTM D 150)	2.39	2.39
Dissipation Factor (ASTM D 150)	0.0005	0.0005

Table I shows the physical properties of insulation compounds when a non-dioxin and furan forming (NDFF) flame retardant is used as a replacement for DBDPO. Compound 1 uses DBDPO as the brominated flame retardant. Compound 2 uses a brominated NDFF based flame retardant. Without the DPO type molecule, the ring opening and closing reactions that form brominated dioxins and furans cannot occur (Figure 5). As seen in Table I, using the NDFF flame retardant as a direct substitution to DBDPO does not degrade the flame, mechanical, and electrical properties.



CONCLUSIONS

By replacing the traditionally used HDPE based insulation compounds with polypropylene, the superior dielectric and mechanical properties inherent to polypropylene are retained even after flame retardant incorporation. Dielectric constant and crush resistance enhancements found in polypropylene allow manufacturers to reduce costs by reducing insulation thicknesses.

The replacement of DBDPO with another non-DPO base flame retardant showed no properties deficiencies. Other observed benefits included enhanced processability and bloom reduction. This compound will allow manufacturers to sell premise cables into applications where the manufacturer restricts the use of DPO based compounds.

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Lyondell Chemical Company
1221 McKinney Street, Suite 1600
P.O. Box 2483
Houston, TX 77252-2583

Cincinnati Technology Center
11530 Northlake Drive
Cincinnati, OH 45249
(513) 530-4000

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