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improve automotive charging cable performance

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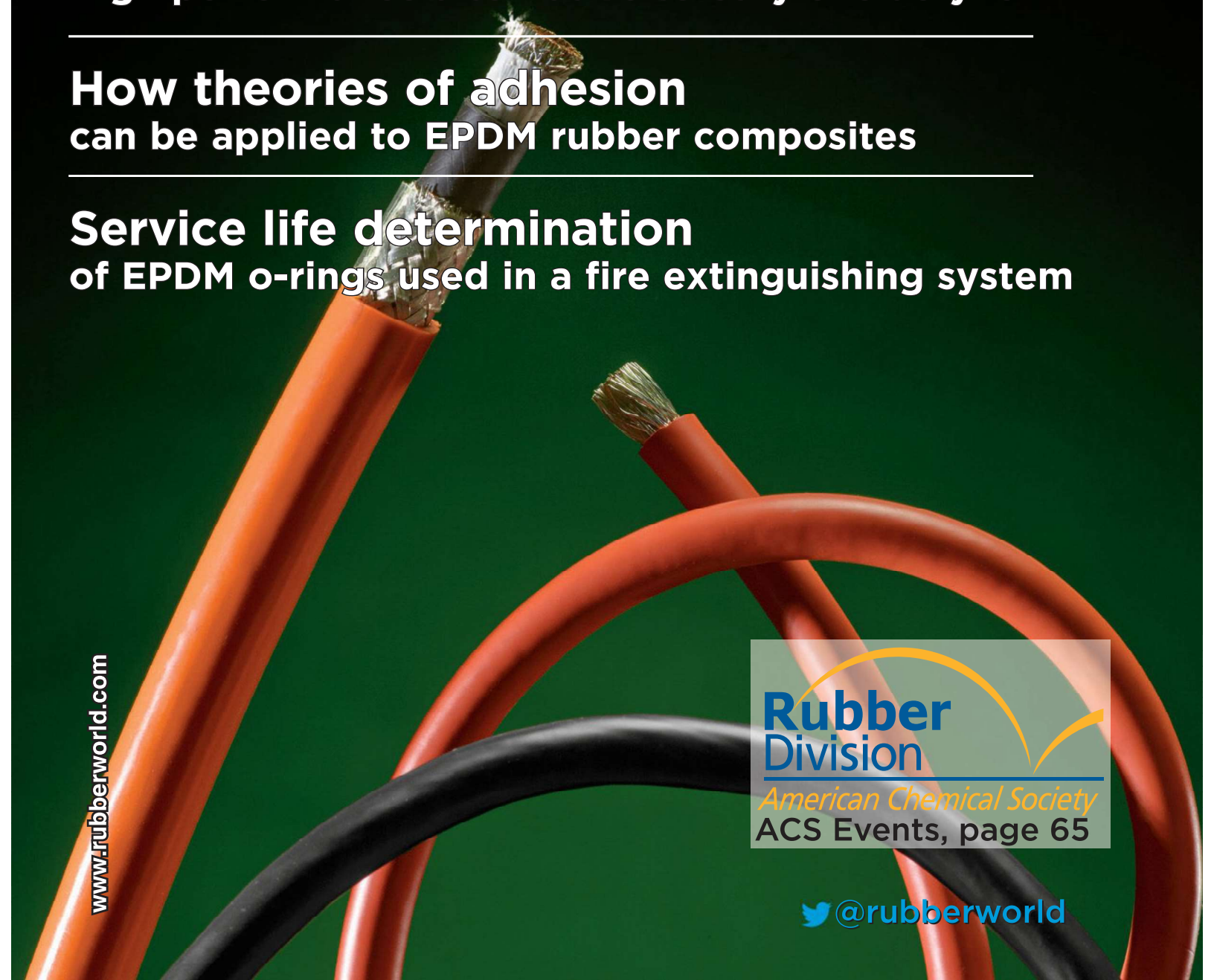

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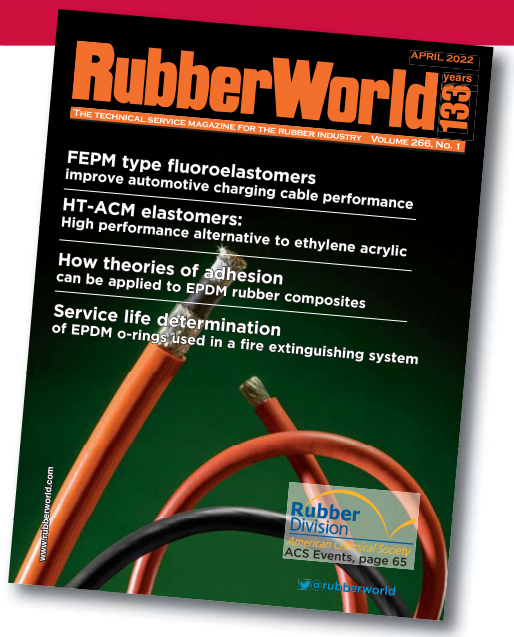

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Departments

by David J. Lavanga and Keisuke Yagi,
AGC Chemicals Americas

FEPM type fluoroelastomers improve performance of high voltage automotive charging cables

Demand for plug-in electric vehicles (PEVs), including all-electric vehicles and hybrid electric vehicles, is growing around the world due to their energy saving, emissions and environmental benefits. As production increases, automotive manufacturers are seeking advanced insulation materials to ensure high voltage charging cables perform safely and reliably at high temperatures. In addition, PEV cables need to be lightweight to offset the load of the power systems, such as batteries and

Figure 1 - volume resistivity versus temperature comparison

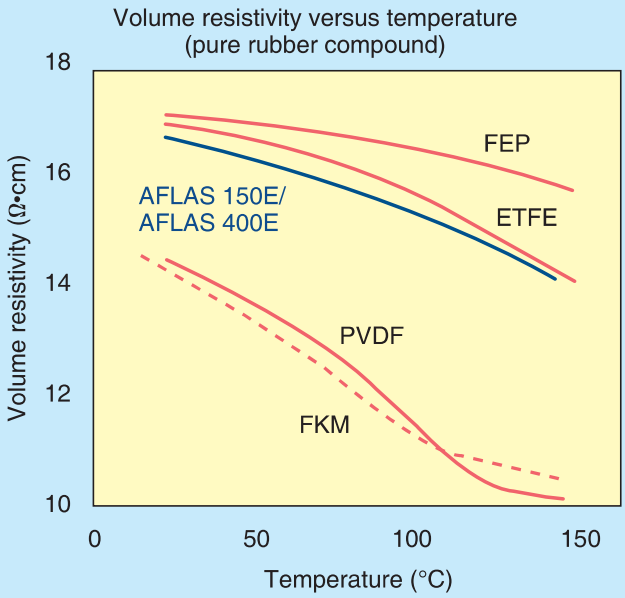


Figure 2 - dielectric breakdown versus temperature comparison

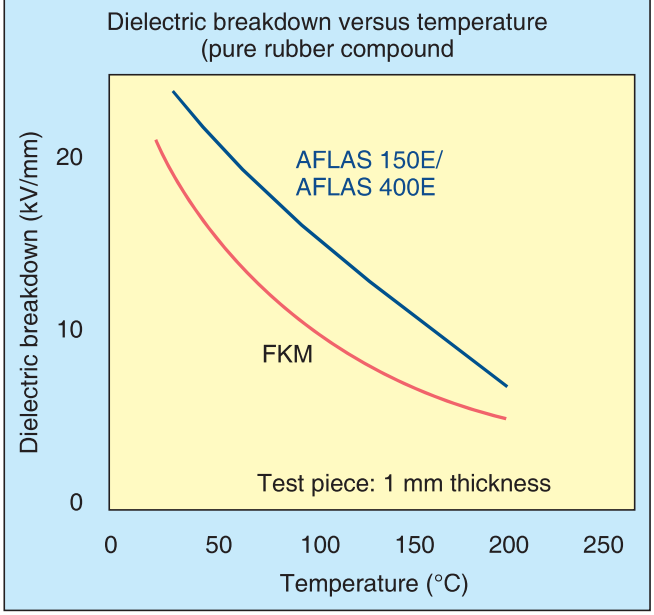


Table 1 - FEPM type fluoroelastomers outperform FKM, silicone rubber and XL-PE in cable constructions

	AFLAS FEPM	*Other fluoroelastomers FKM*	*Silicone rubber Q as compound*	*Crosslinked polyethylene XL-PE as compound*
Specific gravity	1.55	1.8	1.2	1.3
Dielectric breakdown (kV/mm)	23	20	25	35
Volume resistivity (Ω•cm)	10^{16}	10^{13}	10^{16}	10^{16}
Dielectric constant (1 kHz)	2.8	17	3-4	2-3
Flexibility	Excellent	Excellent	Excellent	Applicable
Flame resistance	Excellent	Excellent	Good	Applicable (with fillers)
Heat resistance (maximum operating temperature)	200°C	200°C	180°C	150°C
Oil resistance	Excellent	Excellent	Not recommended	Good
Hot water and steam resistance	Excellent	Applicable	Applicable	Good

Excellent | Good | Applicable | Not recommended

Figure 3 - FEPM type fluoroelastomer insulation reduces cable weight

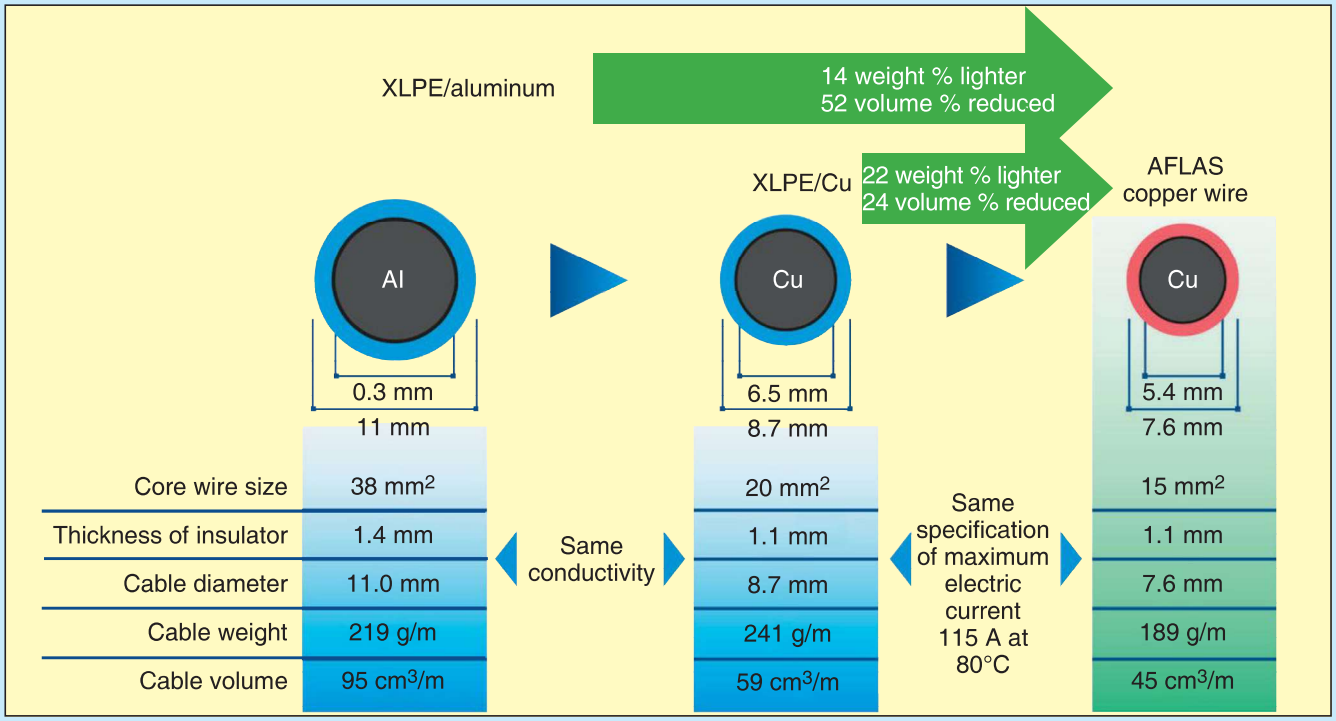
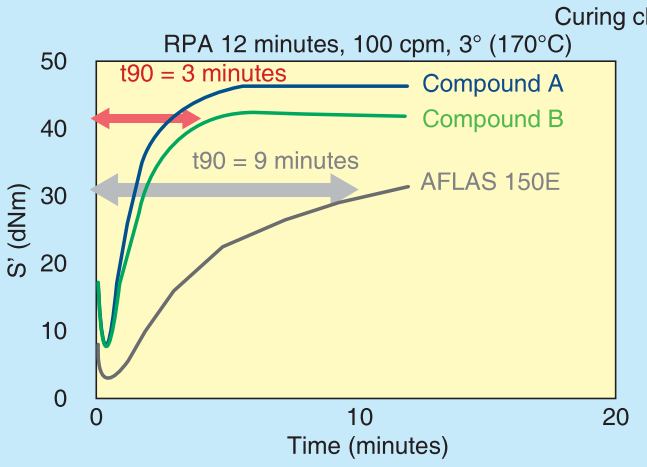
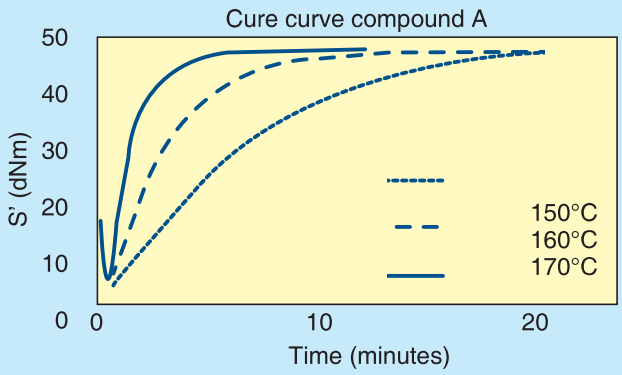
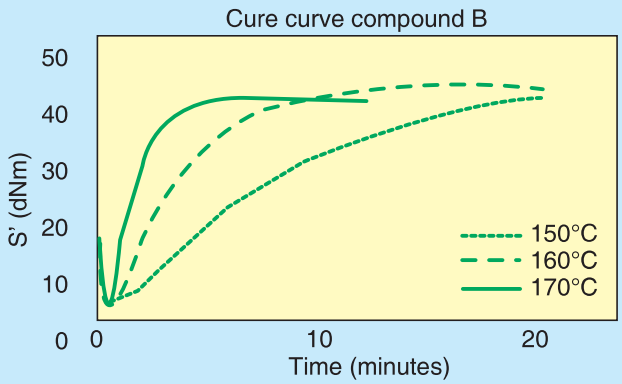


Figure 4 - new FEPM type fluoroelastomer demonstrates improved cure speed







Curing time T90 (minutes)

	AFLAS 400E		
	Compound A	*Compound B*	*AFLAS 150E*
150°C	14.9	17.7	25.4
160°C	6.7	7.5	-
170°C	3.2	3.3	8.7

Fast crosslinking speed
2-3 times faster than AFLAS 150E

electric motors, and to improve efficiency of the vehicle's all-electric range.

Nearly 50 years ago, AGC developed unique fully saturated fluoroelastomers composed of alternating units of tetrafluoroethylene (TFE) and propylene, branded as AFLAS. They are classified as FEPM type elastomers due to their saturation. FEPM type fluoroelastomers exhibit outstanding chemical and heat resistance, with a continuous service temperature of 200°C (392°F).

Therefore, they are often used for parts and components in chemical plants, food processing facilities, vehicles, wires, cables, and oil and gas downhole applications.

FEPM type fluoroelastomers for PEV cable insulation

AFLAS 150E and new AFLAS 400E FEPM type fluoroelastomers are designed to insulate high voltage power cables in PEVs. These insulation materials work with aluminum and copper wire cores to produce cable systems that outperform traditional systems insulated with silicone rubber or crosslinked polyethylene (XLPE).

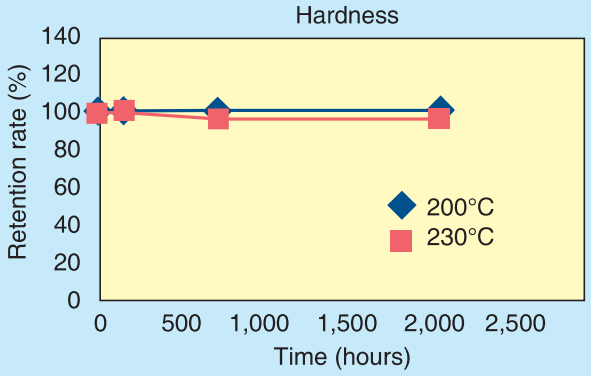
Because less material is required to achieve desired insulating properties, PEV cable systems made with these FEPM type fluoroelastomers are thinner, lighter weight and more flexible than those made with XLPE. In addition, these materials display excellent electrical resistivity and perform reliably at tempera-

Figure 5 - new FEPM type fluoroelastomer demonstrates high heat stability

Resistance to heat

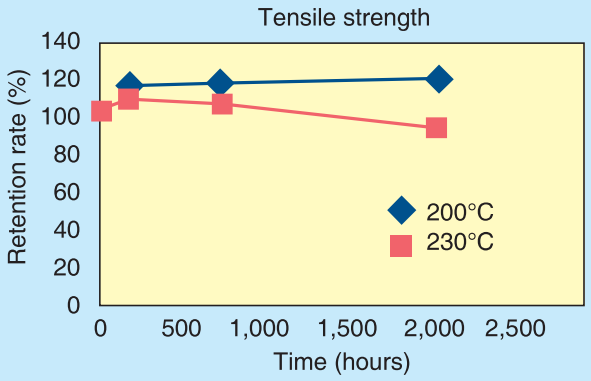
(1) Hardness change (points)

Temperature	*168 hours*	*720 hours*	*2,000 hours*
200°C	1	1	0
230°C	0	-2	-2



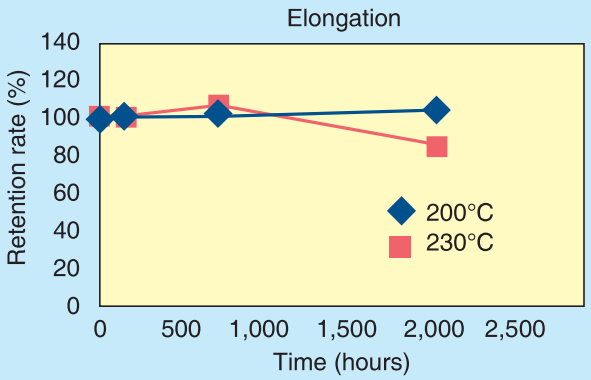
(2) Tensile strength change (%)

Temperature	*168 hours*	*720 hours*	*2,000 hours*
200°C	14	15	17
230°C	4	3	-9



(3) Elongation change (%)

Temperature	*168 hours*	*720 hours*	*2,000 hours*
200°C	0	0	4
230°C	0	6	-16



Maintaining outstanding heat resistance

Table 2 - FEPM type fluoroelastomers exhibit high electrical resistivity

	AFLAS 150E 400E	AFLAS 200	FKM	EPDM	Silicone
Volume resistivity (Ω•cm)	10^{16}	10^{15}	10^{13}	10^{16}	10^{16}
Dielectric constant (1 kHz)	3	6	17	2	4
Dielectric strength (kV/mm)	23	16	20	40	25

tures up to 200°C and 230°C, respectively. They are non-flammable and resist vibration, acids, bases, solvents, ozone and steam.

AFLAS 150E and AFLAS 400E exceed the requirements of PEV high voltage cable applications with proven adoption, as seen in figures 1 and 2.

AFLAS 400E has a faster cure speed than conventional FKMs and other FEPM type fluoroelastomer grades, and it enables a thicker coating, which is required for high voltage cables. Additional benefits include easier extrusion, white base resin color and no specific peroxide requirement for curing (table 1).

Comparing weight reduction in cable constructions under similar conductivity and maximum electric current, copper wire insulated with FEPM type fluoroelastomer is 14% lighter and 52% smaller by volume than an XLPE/aluminum construction. It is also 22% lighter and 24% smaller by volume than an XLPE/copper construction (figure 3).

The new FEPM type fluoroelastomer incorporates a novel cure site monomer, making it ideal for PEV cable constructions. It cures rapidly and exhibits crosslinking speed two to three times faster than its predecessor. As figure 4 demonstrates, AFLAS 400E has a faster cure speed compared to AFLAS 150E.

In addition, research demonstrated that the new FEPM type fluoroelastomer showed little hardness change at 200°C and 230°C over a period of 168 hours to 2,000 hours. Tensile strength remained stable under the same conditions, especially at the higher heat. Elongation showed no change after 168 hours at each temperature (figure 5).

Both FEPM type fluoroelastomers exhibited excellent electrical volume resistivity, dielectric constant and dielectric strength compared to FKM, EPDM and silicone, which make them ideal for PEV high voltage cable insulation (table 2).

In addition, this new FEPM type fluoroelastomer is colorable because of its white base resin color, which is important in automotive cable constructions to prevent contamination (e.g., carbon, etc.), to provide a clear surface image, and for identification purposes to differentiate by color based on the production line (figure 6).

Figure 6 - colorability of new FEPM type fluoroelastomer

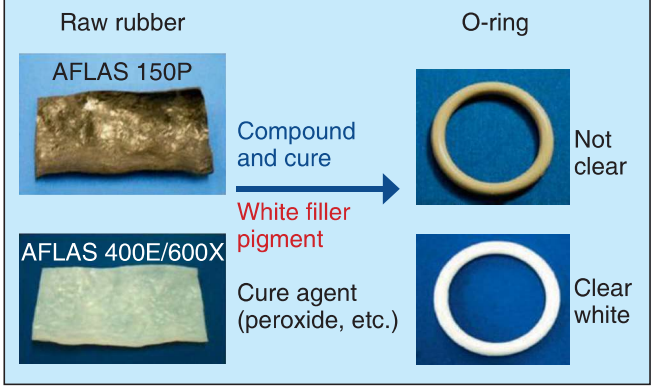
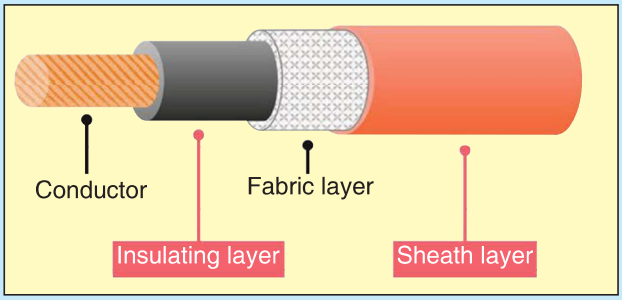


Figure 7 - wire and cable construction with FEPM type fluoroelastomer insulator and sheath layers



As illustrated in figure 7, the new FEPM type fluoroelastomer enables multilayer structures for wire and cable applications by coextrusion.

Conclusion

Lightweight cable constructions with sustained performance qualities are necessary as the demand for plug-in electric vehicles grows. FEPM-type fluoroelastomers are durable, flexible, high temperature electrical insulation rubber materials that enable thinner wire insulation at equal or improved performance levels compared to more traditional materials.