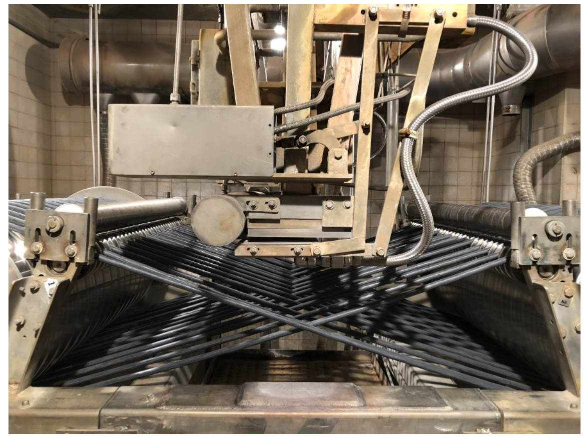
EXRAD® Irradiated XLPE vs. EPDM Rubber Automotive Battery Cables

Irradiation Cross-Linking allows cost effective modification of a wide array of polymers to significantly improve their performance, allowing them to be used in harsh vehicle environments such as temperature extremes, fluid exposure, mechanical stress and other challenging conditions.

Thoughtful polymer formulation and processing techniques can bring about additional features such as flexibility, reduced diameters, longer life, improved automated cut and stripping advantages, and other application-specific benefits. EXRAD® irradiated XLPE's and XLPO's are thermo-set materials, which means the molecules are set in place and won't melt if an excessive thermal event occurs.



Cable under an irradiation beam

EPDM Rubber is a chemically cross-linked material. It is a thermo-set with good electrical performance and flexibility characteristics, but also has fundamental deficiencies that make it undesirable in many automotive and commercial vehicle battery cable applications.

Below are some examples of how these deficiencies affect performance.

Heat Age Performance

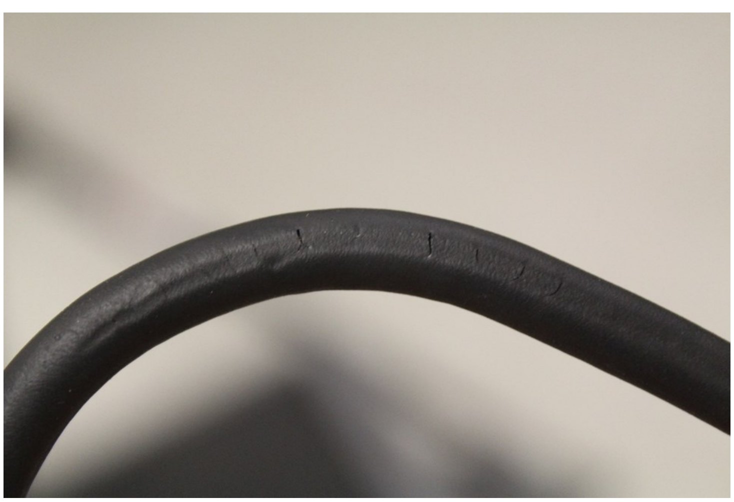
Specification	EXRAD® IRR-XLPE	EPDM RUBBER
ISO 6722-1, 150C	Passes - No Cracks	Fails - Visible Cracks

The ability of battery cables to withstand heat exposure over time is a critical design factor. If the cable insulation degrades after typical heat exposure, system failures can occur.

EXRAD® and EPDM thin-wall battery cable samples were heat-aged for 3,000hrs at 150C.

EXRAD materials are very thermally robust and passed the ISO-6722-1 requirement. EPDM materials degraded and samples cracked when bent around a mandrel per the ISO 6722-1 procedure.

In service on a vehicle, this poses a significant risk of electrical failure.



EPDM samples cracked in many places after 150C heat age

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Heat Age Performance and Tape Layers

EPDM sample with incomplete tape wrapping of the conductor

EPDM Rubber battery cables utilize a conductor tape to assist stripping. This tape barrier also reduces the chance of copper poisoning between the conductor and the EPDM rubber. Copper poisoning degrades the insulation from the inside out and can cause a heat-induced crack.

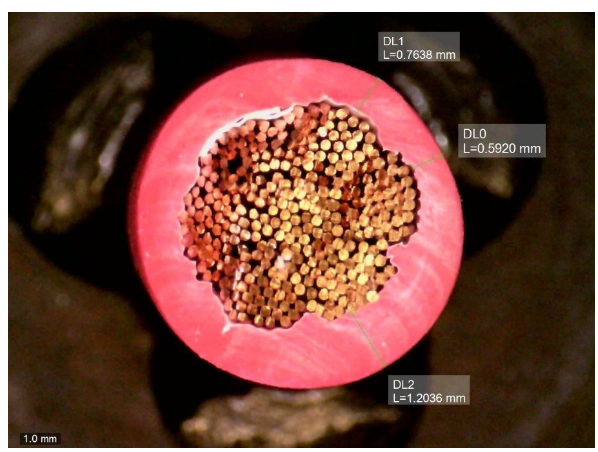
During extrusion, the tape must be applied with 100% coverage. A tape fold or other processing issue can cause incomplete coverage. Missing areas of tape subject that section of insulation to copper poisoning. Also, tape cores occasionally require replenishment with a fresh roll of tape during processing. This needs to be executed properly to avoid two potential issues:

First, there can be a gap between one roll ending and the other beginning. This may only be a few feet or yards, but the flaw is undetectable after extrusion and creates a weak point in the insulation which will be more susceptible to a heat-induced crack.

The second potential issue occurs when the changeover to a fresh tape roll results in two layers of tape instead of one. This would not affect cable performance, but during stripping the inner most tape is prone to being left on the conductor resulting in termination issues. (see "Strip-ability", next page)

Irradiated XLPE's are much less susceptible to copper poisoning, do not typically need conductor tapes, and thin-wall constructions perform well at 150C and higher temperatures.

Concentricity Control



EPDM sample with 49% concentricity. Min wall was 0.59mm thick. ISO 6722-1 requires 0.80mm min.

Concentricity is a measure of how centered the conductor is within the insulation layer. A well centered cable helps with consistent strip-ability on high-speed stripping machines. Poor concentricity causes thin sections of insulation and can also result in cut conductor strands.

If a thin spot is too thin, the cable is at risk of a heat age failure, a voltage failure or other issue. For example, the thin area would be particularly vulnerable to a heat age failure which is a crack in the insulation.

In the EPDM thin-wall samples tested, concentricity averaged 50%. Industry best practice is 80% or higher. There were multiple areas where the insulation thickness did not meet ISO 6722-1 requirements.

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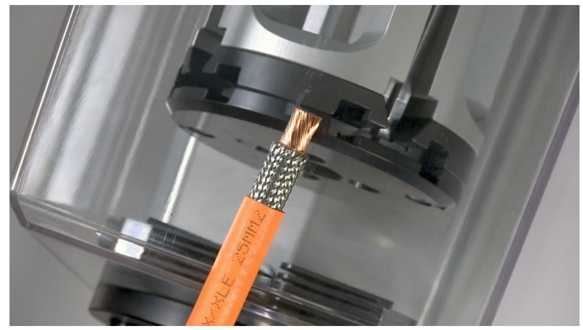
Strip-ability

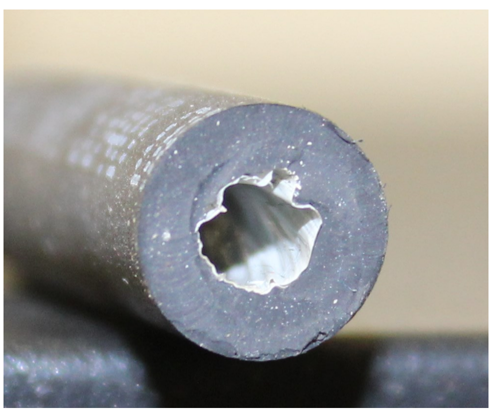
The ability to strip cables cleanly and consistently increases throughput and reduces costs. This is of great concern to the cable assembly provider, and ultimately the OEM.



Example of a clean cut and strip of shielded EXRAD battery cable
Image courtesy of Schleuniger Corp.

EPDM rubber typically utilizes an inner conductor tape to improve strip-ability. This is necessary due to the tremendous pressure exerted on the insulation during processing, which causes the EPDM material to creep deep into the interstices of the conductor or braid.

The tape separator is not always stripped cleanly and can remain on the conductor. The remaining tape must be removed. Terminating the connector over the tape causes in increased resistance at the wire/terminal interface, poor or even no electrical contact, and overheating.



Tape Layer

Some stripping processes burn off the residual tape, but occasionally there are two layers of tape due to processing changeovers. This can result in a tape layer remaining after the burn process, necessitating manual tape removal.

EPDM Rubber also has high elongation (stretch) which helps flexibility but can make the material difficult to strip cleanly leaving small sections of insulation un-stripped, sometimes referred to as pig-tails. To combat this, stripping blades must penetrate the EPDM jacket nearly completely, which can cause conductor strands to be cut away. Some customers allow a few cut strands, but others allow none. The 3-part goal of ensuring the tape strips completely, eliminating pig-tails, and also not cutting strands often slows production considerably. Poor concentricity affects this as well.

EXRAD® materials are flexible and cut and strip cleanly without the need of an inner tape over the conductor. Proper equipment and stripping techniques allow the insulation to strip cleanly and squarely leaving a consistent uniform surface for connectorization.

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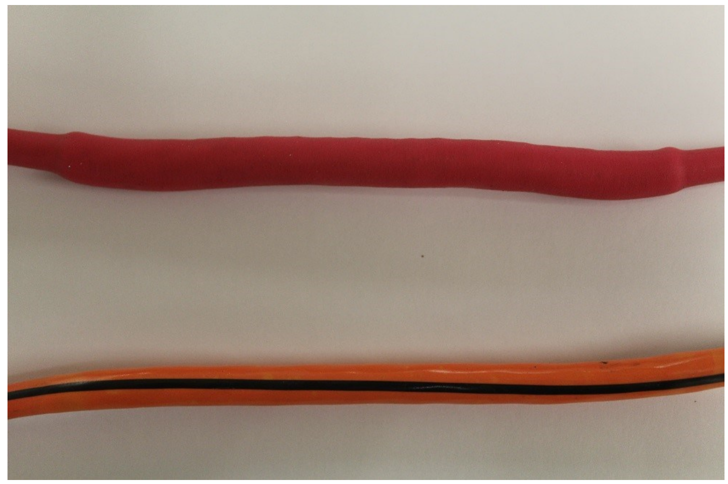
Oil Swell

Automotive fluids can have a degenerative effect on cable insulations. The insulation material can absorb / react to the fluid, which weakens the insulation and can cause a split in the insulation and an electrical short.

Specification	EPDM	EXRAD®
ISO 6722-1	17% swell = Fail	6% swell—Pass



Top: EPDM sample. Bottom: EXRAD sample

To evaluate suitability, ISO-6722-1 requires fluid testing and references two different test methods to determine fluid resistance.

Method 1 is 10 seconds of fluid exposure at 23C followed by heat aging at rated temperature. This is repeated 4 times on the same sample. Total heat aging is 1,000hrs and the failure mode is percent swell. This is a required test in ISO-6722-1

Method 2 is 20hrs of fluid exposure at 23C followed by a winding and voltage test. This was a required test in the prior ISO-6722, but is an optional test in ISO-6722-1. Not all insulation materials can pass both test methods.

EXRAD® products meet both methods of the ISO-6722-1 fluid test parameters. EPDM battery cable samples showed significant swelling after exposure to IRM 902 motor oil, and failed ISO-6722-1 for motor oil, ATF and power steering fluids. This translates to a weaker insulation, more prone to a split, cut through, and electrical failure.

From a global perspective, Irradiated XLPO's / XLPE's are accepted world-wide as 150C battery cable products, meeting both ISO and specific OEM standards. EPDM rubber materials lack global 150C approvals, only North American suppliers continue to use them, and many are moving away from both EPDM and Silicone rubber to irradiated XLPO/XLPE solutions.

Champlain Cable is a world leader in irradiation crosslinking technology, developing and perfecting methods for over 45 years. We have more irradiation capacity that any other wire and cable manufacturer in the United States. Our eight irradiation units are capable of cross-linking wires ranging from 26awg to 700MCM, ($0.14mm^2$ to $350mm^2$) and cables with diameters up to 1.5 inches (3.8 cm).

Learn more about our ingenuity at www.champcable.com