

Question & Answer Guide
Subject: Electric Utility - TransPowr® with E3X® Technology

Overview / Market Advantage

Q: What is TransPowr® with E3X® Technology?

A: TransPowr® with E3X® Technology is a groundbreaking, heat-dissipating and icephobic surface coated conductor that will transform power grid sustainability, reliability, efficiency and resilience. By lowering operating temperature, E3X® Technology reduces power losses and increases power carrying capacity, allowing greater efficiency and lower total system costs. By reducing ice formation, E3X® Technology reduces the risk of conductor breakage or tower collapse during icy conditions.

**TransPowr® is General Cable's trade name for its extensive line of bare overhead conductors for both transmission and distribution applications that are manufactured and tested in accordance with the latest applicable ASTM specifications.*

Q: What does E3X® represent?

A: high Emissivity = energy Efficiency (lower power losses) + increased Effectiveness (more ampacity)

Q: What industry challenge(s) does TransPowr® with E3X® Technology solve?

A: Industry Challenges: As of 2009, there were approximately 452,599 miles of transmission lines in the U.S. Approximately 6% of electricity is lost in transmission and distribution in the U.S. at a rate of \$25B per year.* The capacity of the nation's grid must also expand to meet growing demand, and 90,000 miles of transmission lines are expected to be built in the next decade**.

General Cable Solutions: TransPowr® with E3X® Technology addresses both challenges by reducing losses and increasing capacity. As we know, the conductor's mechanical and electrical performance has a direct impact on the structure and foundation, as well as the wire install and hardware costs. The benefit of E3X® Technology is a reduced conductor size for a given ampacity rating, or increased ampacity rating and reduced operating temperature for a given conductor size. The lower temperature results in less thermal expansion and sag of the conductor. The line designer can take advantage of this improved performance in one of two ways – a reduced conductor sag or size enables optimized structure, hardware and labor for new lines OR increasing conductor ampacity without upgrading infrastructure for reconductoring lines. Either decision leads to one conclusion – lower project costs!

* U.S. Energy Information Administration Data release date May 2014

** C Three Transmission Project Database – US Projects only

Q: How does E3X® Technology work?

A: E3X® Technology features a thin, durable coating that is factory-applied to the surface of *any* TransPowr® overhead conductor. This coating increases Emissivity and reduces absorptivity, allowing the conductor to operate at lower temperatures for improved energy Efficiency (lower power losses) and Effectiveness (more ampacity).

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Overview / Market Advantage (cont'd)

Q: What is emissivity and absorptivity, and what impact do they have on the overhead conductor?

A: The emissivity of an overhead conductor quantifies the efficiency in which it dissipates heat via thermal radiation — the higher the emissivity, the more heat dissipates. The absorptivity of a conductor quantifies the amount of solar heat absorbed from the sun — the lower the absorptivity, the less heat is absorbed.

Aluminum is ideal for overhead conductors due to its low electrical resistance, weight and cost, but its inherent low emissivity retains heat, leading to inefficiencies. The E3X[®] innovative, patent-protected Technology increases emissivity of overhead conductors for improved heat dissipation and it minimizes heat absorption, allowing the conductor to operate at lower temperatures.

Q: To what extent can E3X[®] Technology improve efficiency and effectiveness?

A: Efficiency (lower power losses): E3X[®] Technology lowers operating temperature by up to 30%*. As a result, overhead conductors of any design with this heat-dissipating coating are anticipated to reduce project costs up to 20%* and/or lower line losses up to 25%*.

Effectiveness (more ampacity): Alternatively, E3X[®] Technology increases ampacity up to 25%* for the same-size or smaller conductor, thereby increasing power carrying capacity within existing infrastructure without upgrades, lowering first project cost.

*Dependent on operating conditions.

Q: Why and how was the E3X[®] Technology developed?

A: E3X[®] Technology was built upon NASA technologies and General Cable's leadership in material sciences and technology solutions. To meet the changing needs of our customers, our highly qualified team of engineers and scientists utilized their expertise to develop an innovative Technology that provides high emissivity and low solar absorptivity characteristics, thereby allowing conductors to operate at lower temperatures.

Q: Is there a cost difference for overhead conductors with E3X[®] Technology and what is the payback period?

A: While the upfront costs of the conductor only may be higher, the overall transmission line project costs associated with designing a system with E3X[®] Technology are significantly lower than that of a conductor without. E3X[®] offers a compelling payback period for the incremental investment that is expected to be less than 2-years on average.

Application / Performance

Q: Can E3X[®] Technology be used with any bare overhead conductor?

A: Today, E3X[®] Technology is available from General Cable on any *TransPowr*[®] bare overhead conductor design (any aluminum alloy, stranding type or core). This is a unique patent-protected technology.

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Application / Performance (cont'd)

- Q:** Do E3X[®] coated conductors compromise on any key performance parameters?
- A:** No. Because only the surface of an overhead conductor is modified with the heat-dissipating E3X[®] coating, the electrical and mechanical performance remains the same as the traditional product. The only exception is that a coated conductor will operate at a lower temperature, therefore lowering sag and electrical resistance for the same current or with higher ampacity for the same operating temperature.
- Q:** How does E3X[®] Technology improve conductor performance during icing events?
- A:** As an icephobic coating, E3X[®] Technology reduces ice adhesion by over six times compared to traditional bare aluminum based on testing at the University of Quebec's Anti-Icing Materials Laboratory (AMIL). This results in less ice accumulation which lowers the risk of conductor breakage and tower collapse during icing events. Test reports are available upon request.
- Q:** Will an E3X[®] coated conductor oxidize over time like a traditional overhead conductor?
- A:** No. The coating is non-reactive and will not oxidize when exposed to air, nor will it corrode or degrade over time with environmental exposure.
- Q:** How does an overhead conductor with E3X[®] Technology compare to a traditional conductor that has aged over time in-service?
- A:** E3X[®] Technology changes previously assumed and variable values of emissivity and absorptivity. Overhead conductors with E3X[®] Technology have fixed engineered values to increase performance and reduce risk. The emissivity and absorptivity of an in-service conductor is an unknown. Assumptions are made as to these values, but emissivity and absorptivity will vary with conductor installation date, age, and location. Assuming high values can result in significant temperature risk if the actual values are lower; assuming low values can result in underutilization of the conductor.
- Q:** Can the E3X[®] Technology be applied in the field on existing transmission lines?
- A:** At this time, General Cable is only supplying E3X[®] Technology for newly manufactured conductors. The technology required to coat existing transmission lines is under development, and we will keep you informed on that progress.
- Q:** What is the maximum temperature rating of an E3X[®] coated overhead conductor?
- A:** The maximum temperature rating of a E3X[®] coated conductor is the same as a conductor without a coating, but the coating increases the conductor's ampacity rating.

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Application / Performance (cont'd)

- Q: Can an overhead conductor with E3X[®] Technology be used in areas with low ambient temperature conditions?
- A: General Cable developed E3X[®] Technology to be as durable as the conductor itself. Cold temperature testing at -40°C has demonstrated that the E3X[®] coating will not crack or become brittle when exposed to low ambient temperatures. Testing has also shown that the E3X[®] coating is not affected by the thermal expansion and contraction of the aluminum. The coating is flexible and strongly adhered to the underlying aluminum, demonstrating no flaking, damage, or removal of the coating after 500 current thermal cycles per ANSI C119.4.
- Q: Does an overhead conductor with E3X[®] Technology make a difference for ac or dc systems?
- A: An overhead conductor with E3X[®] Technology is not affected by the use of either ac or dc power. The technology provides the same benefit in both situations. Long HVDC lines with higher loadings will especially benefit from the technology.
- Q: What does a bare overhead conductor with E3X[®] Technology look like?
- A: The surface of an overhead conductor with E3X[®] coating has a factory-applied thin, durable coating that is a dull, non-reflective, matte surface similar to a non-specular surface finish. There is absolutely no change to the interior of an overhead conductor with E3X[®] coating. The underlying conductor is any one of the numerous conductor options that are available on the market today.
- Q: Are overhead conductor with E3X[®] Technology non-specular per ASTM B979?
- A: Overhead conductors with E3X[®] Technology are non-specular based on gloss measurements, but cannot be qualified per ASTM B979 due to the color specification within ASTM B979.
- Q: Are there recognized standards under which electric utilities can order *TransPowr*[®] overhead conductors with E3X[®] Technology?
- A: The universally-applicable heat-dissipating E3X[®] coating itself is not governed by any standards and can be applied to any overhead conductor design. It is the underlying conductor that is manufactured and tested in accordance with the latest applicable ASTM Standards.
- Q: Is there an ideal conductor selection for E3X[®] Technology?
- A: All conductors will benefit from the technology. Situations that have high load requirements or contingency loads will realize the best possible benefits from the thermal performance of E3X[®] because the coating has a larger impact as operating temperatures increase. Any conductor used in icy environments will benefit from the icephobic properties of E3X[®] Technology.

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Application / Performance (cont'd)

- Q: Is overhead conductor with E3X[®] Technology a “green” or sustainable conductor?
- A: The lower power losses enabled by E3X[®] Technology allow greater energy efficiency requiring less energy generation and enabling lower greenhouse gas emissions. E3X[®] Technology’s ability to increase power carrying capacity also has the potential to improve sustainability of the 90,000 miles of U.S. transmission lines expected over the next decade, including from renewable energy sources.
- Q: What is the warranty on E3X[®] Technology?
- A: Overhead conductor with E3X[®] Technology will be covered under General Cable’s standard product warranty.
- Q: Are there any existing installations of E3X[®] Technology?
- A: E3X[®] Technology has been installed across the U.S. and the world with installations in seven states and four countries. E3X[®] Technology has also been installed at the Department of Energy’s Oak Ridge National Laboratory. The first installation was in October 2013 (energized in December 2013). An installation report is available upon request. The preliminary test report from Oak Ridge National Laboratory is also available for review.

E3X[®] Technology Properties and Testing

- Q: What are the physical and mechanical properties of the E3X[®] coating?
- A: The E3X[®] heat-dissipating coating is a durable, non-toxic, icephobic and environmentally stable innovative material with high emissivity and low solar absorptivity characteristics. The factory-applied coating bonds to the underlying aluminum conductor. As a durable material, the coating is very hard and abrasion resistant to ensure durability during installation and throughout the lifetime of the conductor. A Material Safety Data Sheet is not required as the conductor is a finished article.
- Q: Has the E3X[®] Technology been thoroughly tested?
- A: The patent-protected E3X[®] Technology has been tested over several years by a General Cable-directed team of expert development partners; independent test laboratories including Kinectrics and Oak Ridge National Laboratory; and utilities with a focus on energy efficiency and reliability. The coating has been tested to the most stringent protocols above and beyond what is required for standard overhead conductor, and it has been evaluated through extensive validation in field trials.

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E3X[®] Technology Properties and Testing (cont'd)

- Q: How long will the E3X[®] heat-dissipating coating on an overhead conductor last, and what specific testing has been performed to demonstrate its durability?
- A: General Cable developed the E3X[®] coating to be as durable as the conductor itself. Performance testing shows no reduction in performance after 10,000 hours in the weather-o-meter test. Sequential mechanical testing (sheave roller, Aeolian vibration, galloping, and tension cycling) demonstrates no visible change to the coating. Additional testing to heat and humidity, salt exposure, or acid rain also shows no susceptibility.
- Q: Can the E3X[®] coating withstand thermal cycling (expansion and contraction) without damage?
- A: Testing shows that the E3X[®] coating is not affected by the thermal expansion and contraction of the aluminum. The coating is flexible and strongly adhered to the underlying aluminum, demonstrating no flaking, damage, or removal of the coating after 500 cycles per ANSI C119.4.
- Q: Is there a voltage limit for which the E3X[®] technology can be used? Does the coating affect electrical corona?
- A: There is no voltage limitation for conductors with E3X[®] Technology as voltage has no effect on the coating. Testing shows that the coating has equal or better dry corona performance compared to a traditional conductor and improves wet corona performance. Test reports are available upon request.
- Q: Will E3X[®] coating add any significant weight to the overall conductor?
- A: E3X[®] coating is a thin layer that increases conductor weight by less than 0.4% within the manufacturing tolerances of the aluminum weight.
- Q: Is E3X[®] coating conductive?
- A: E3X[®] coating is not conductive nor is it insulating. The standard practice of wire brushing overhead conductors prior to electrical termination remains in effect and is required for overhead conductor with E3X[®] Technology in order to remove the coating for electrical connection. The coating does not need to be removed for mechanical connections (such as in suspension clamps or dampers) or under armor rods. The coating also does not need to be removed when grounding the conductor with rolling grounds or grounding clamps.

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Manufacturing and Delivery

- Q: What is the manufacturing lead-time for E3X[®] Technology?
- A: Overhead conductor with E3X[®] Technology is anticipated to have the same lead-time as an uncoated bare overhead conductor.
- Q: Is the manufacturing process for E3X[®] Technology eco-friendly?
- A: The E3X[®] heat-dissipating coating is a durable, non-toxic, icephobic and environmentally stable innovative material that is applied to the surface of an overhead conductor in an eco-friendly process.
- Q: Will overhead conductor with E3X[®] Technology use the same packaging and reels that are used by standard overhead conductor?
- A: Yes. Overhead conductor with E3X[®] technology will use the same packaging and reels that are used for uncoated bare overhead conductor.

Technical – Termination, Installation, Maintenance

- Q: Does E3X[®] Technology require different connectivity, terminations, splices, and/or installation techniques?
- A: E3X[®] Technology is a highly adaptive solution that can be used without any modification to installation, termination or maintenance. The standard practice of wire brushing overhead conductors prior to electrical termination remains in effect and is required for overhead conductor with E3X[®] Technology in order to remove the coating for electrical connection. Chemical removal techniques are not effective in removing the coating and should not be used. Since the coating contrasts in color with the aluminum it provides visual confirmation that the conductor has been properly wire brushed.
- Q: What impact will the E3X[®] Technology have on sag?
- A: Since the E3[®] Technology enables operation at lower temperature, sag will decrease, leading to larger clearances and reduced risk. In addition, the technology enables the use of smaller conductors that could potentially exhibit even less sag for the same ampacity and result in reduced tower height.
- Q: Is there any special transportation or storage required for overhead conductor with E3X[®] Technology?
- A: No. overhead conductor with E3X[®] Technology uses the same transportation and storage techniques as standard overhead conductor. The coating has been engineered to withstand transportation and storage handling without any special protection.

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Technical – Termination, Installation, Maintenance (Cont'd)

- Q: Will there be a separate installation and termination guide for E3X[®] Technology?
- A: No. E3X[®] Technology will not require a separate installation and termination guide. However, we recommend reviewing General Cable's *TransPowr[®] Overhead Conductor Installation Guide* before any overhead installation. This guide, along with IEEE Standard 524, *Guide to the Installation of Overhead Transmission Line Conductors*, provides guidance for an optimized installation of overhead conductors.
- Q: Can an overhead conductor with the E3X[®] Technology coating be scrapped and/or recycled in the same way as standard overhead conductor?
- A: Yes. Overhead conductor with E3X[®] Technology can be scrapped or recycled through General Cable's Cable Recycling Program, the same as with any bare overhead conductor.
- Q: How can I learn more about E3X[®] Technology?
- A: To learn more about E3X[®] Technology visit <http://e3x.generalcable.com> or contact General Cable at info@generalcable.com, by calling (800) 237-2726 or by contacting your General Cable sales representative. General Cable's experienced cable design and application engineers are available to provide more information upon request and assist electric utilities to strategically optimize and fortify the grid by controlling losses, adding more capacity, and improving reliability.

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