TE CONNECTIVITY (TE)’S SOLUTIONS FOR HARSH ENVIRONMENTS
HV and EHV HTV Composite Hollow Core Insulators

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**Abstract**

This Whitepaper has been developed to highlight the unique challenges facing the power transmission industry as it seeks to transport energy over ever-increasing distances connecting sources of power with consumers. The transfer of high levels of electrical energy across large distances means that they often traverse geographical hazards exposing equipment to extremely harsh environments that threaten system reliability, increase costs and, in some cases, failure.

Some of the solutions that TE Connectivity has developed in response to these needs are introduced here. TE has a proven history of serving power transmission industries across the world and can draw on decades of design and field performance experience.

While many aspects of the power landscape are rapidly evolving, the need to find products that perform reliably in harsh conditions is a much older, and ongoing, challenge. Specifically, this paper looks at the Axicom high voltage polymeric hollow core insulator solutions for harsh environments, considering both their applications and their benefits and seeks to provide solid case that our products meet that challenge.

1. Demands on High Voltage Power Systems and their Performance in the Harsh Environments

The need to transfer large amounts of energy across large distances, in particular in China, have driven utilities, institutions, OEMs and their suppliers to push the boundaries of technology in order to meet the unique challenges these systems now face. Site severity reports provide the groundwork to support the technical and commercial decisions system reliability managers need to make to design a network that meets the necessary reliability requirements at an acceptable cost.

**Challenges:**

- The transition from HVAC to HVDC for higher efficiency transfer of energy over large distances above 800kV.
- Detrimental performance de-rating factors for DC insulators.
- Effects of pollution and temperature on the anti-flashover, anti-aging, and mechanical integrity performance of the polymeric hollow core insulator during the serviceable life of the application.
- High mechanical, electrical, chemical and environmental stresses placed on the insulator in service.
- Lack of available standards and historical field experience needed to guide reliable product designs in HVDC and UHVDC applications.
Faced with these challenges, customers in the power transmission industry have highlighted more demanding requirements for their power systems and products including:

- Exposure to extremely low temperatures: Russia down to -60 degree C; North East China to -55 degree C; high temperatures in deserts such as those in the Middle East up to +60°C.
- High Wind conditions with sand.
- High pollution conditions in cities and coastal areas.
- Wide-ranging temperature variations.
- Areas with seismic activity.

2. TE’s Axicom History and Experience in the Composite Hollow Core Market

Axicom hollow core insulators are widely used in GIS bushings, transformer bushings, polymer arrestors, station posts, live and dead tank breakers and high voltage terminations. They perform a vital function in ensuring the reliability of power systems at ever-increasing voltages.

Axicom’s Value Proposition

- More than 25 years experience in designing and manufacturing polymeric hollow core Insulators for the global market up to and exceeding 800kV.
- Technical leadership – ‘Press Fit’ flanges, mechanical, electrical, chemical and environmental properties, superior HTV silicone material and developed flange design using minimal material.
- Over 260,000 Axicom hollow core insulators installed globally using same Fiber Reinforced Plastics (FRP) tube and flange technology.
- In compliance with IEC, IEEE and GB Design and Test Standards.
- TE Axicom – high quality product family with strong reputation globally.
- State of the art manufacturing capability in China and Switzerland offering superior products that are competitive in today’s market.
- Voltage level from 66kV to 1100kV.

TE’s Axicom facility in Kunshan – Manufacturing Axicom HTV HCI and Equipment Bushings
3. Axicom HTV Hollow Core Insulators – Product and Process Technology Advantage

3.1 Materials Technology

Correct selection and processing of materials is critical for the long-term performance and reliability of polymeric hollow core insulators. Through years of research and development, TE technical experts have developed materials that meet the most stringent application requirements. Cevosil A1002 HTV Silicon has been widely used for TE's medium voltage surge arrestor products with over 300,000 sold worldwide in all regions and climatic conditions including the arctic, deserts, coastal, tropical and high altitude.

Applications and Benefits:

• High performance HTV silicone material used for insulator shed
• Proven through comprehensive testing to perform in the harshest application environments worldwide

3.2 Design Technology

The shed design of hollow core insulators (HCI) for AC application is in accordance with IEC 60815 and is well understood. However, new applications involving harsh environments are pushing design requirements to new limits, sometimes beyond the existing standards. For HVDC and UHVDC, this is a very real issue for system designers. As voltages increase beyond 800kV and in particular in high altitude and low temperatures with ice and snow present, there are few industry standards. Therefore, today’s polymeric hollow core insulators used in high voltage harsh environments must withstand considerable stresses over many years service life if they are to be suitable for such applications.

TE’s Axicom HCI tube to flange sealing system and material section meet those requirements. Conforming to the highest standard IEC 60815 part 3 for AC application, the shed profile and Cevosil A1002 HTV material performance offer durable and reliable performance under these conditions. Axicom lightweight, thin tube design also brings benefits in rapidly changing temperature environments while also providing compatibility of both SF6 and oil-filled applications. The insulator length can be extended to increase the flashover distance as well as the creepage factor necessary for high altitude conditions. The Axicom tube offers the flexibility to meet all these harsh environments.

Another key requirement is the bonding and sealing of interfaces within the insulator body design. Effective bonding that provides a high integrity seal from SF6 gas leakage is mandatory and must be maintained under all environmental conditions. Axicom insulators’ advanced bonding technology assures this through our shrink-fit approach and secondary silicone sealing of peripheral interfaces thus meeting the most stringent leakage requirement of less than 0.1 volume % per annum.

Applications:

• Advanced shed design to meet highest pollution level specification IEC60815 part 3.
• Thin tube design with 3 different winding configurations means the mechanical performance can be tailored to the customers’ application requirements.
• Oil-filled applications such as capacitors and transformers, cable terminations and instrument transformers.
• Very low leakage applications (0.1 Volume % per annum).
Benefits:

- Axicom HCI insulators meet and exceed harsh environment application requirements through thin FRP tube and reduced size flange offer lightweight and mechanically strong performance
- Ultra low leakage conforming to future industry proposed standards
- Application using oil filling such as capacitors and transformers
3.3 Process Technology

As important as the correct selection of high performance materials is, the processing of those materials is equally critical to ensure polymeric hollow core insulators perform reliably throughout their service life. Any defect or inconsistency in processing, however small, could, and often does, result in sub-standard performance or failure. It is vital when comes to the selection of high performance materials and the process of the materials is equally critical to ensure polymeric hollow core insulators perform reliably throughout the product service life. Any defect or inconsistency during the processing could, often does but however small, result in sub-standard performance or even failure.

Without destructive testing, the defects in the power transmission system are undetectable, such as premature aging, system inefficiency or an extreme situation. Advanced sensing technology and innovation combined with TE’s robust product and process development expertise identifies and alleviates potential causes of failure in the manufacturing process. This attention to detail and conformance to rigorous design improvement procedure and tools yields many benefits that are shared and valued by our customers.

Applications:

• Bespoke equipment for each process used in the manufacture of Axicom HCI insulators.

• Innovation and technology leadership invested in the very latest manufacturing equipment and processes.

Benefits:

• Consistent and reliable quality product throughout the HCI manufacturing process.

• Defect elimination through design resulting in the manufacture of high quality products for our customers.

• Consistent and predictable service performance.

• Defect elimination at source increases customer satisfaction and eliminates waste.
4 TE’s Axicom Insulator Solutions for Harsh Environment Applications

4.1 High Altitude

The necessity to route power transmission lines through high altitude regions exposes insulators to some extreme environmental conditions affecting air pressure, low temperature, high UV and ice and snow. Exposure to low temperatures and wide-ranging temperature variations, particularly those of a cyclical nature, place high mechanical stresses on polymeric HCI’s.

The sealing integrity between the interfaces is a critical area of concern and requires attention in the design process and at the performance verification testing stage. Axicom ‘shrink fit’ tube to flange technology seal provides optimal sealing integrity in these environmental conditions. High UV levels can have detrimental effects on shed ageing and can severely shorten the service life of the product if suitable, high performance materials are not selected.

Applications:

• High altitude application with exposure to high wind, heavy rain, low temperatures, high UV and low air pressure.
• Applies to all Axicom HTV HCI insulator and equipment bushings.

Benefits:

• Materials tested and proven to withstand harsh environments offering long-term stable performance and reliability.
• No maintenance necessary during service.

4.2 Low Temperatures

Exposure to low temperatures and wide-ranging temperature variations, particularly those of a cyclical nature, place high mechanical stresses on polymeric HCI’s. The sealing integrity between the interfaces is a critical area of concern and this requires attention in the design process and performance verification testing. Axicom ‘shrink fit’ tube to flange technology seal provides optimal sealing integrity in these environmental conditions. Cevosil HTV material has been performance tested to -65 degrees in accordance with BS EN 60068-2-1 Test Ab.

Applications:

• Exposed substations and remote regions at high altitude.
• Application that are subject to periodic temperature extremes such as deserts.

Benefits:

• Axicom ‘press fit’ FRP tube to flange design provides a very strong and reliable sealing with no delamination.
• Long-term service reliability through robust design, premium quality materials and controlled manufacturing processes.
4.3 High Pollution

Increasingly, high pollution and its detrimental effects is becoming a major factor, not only for new power transmission lines but also existing installations. This trend is putting more pressure on reliability managers to factor an increased level of safety into their systems including HCI’s.

De-rating, by increasing insulator length to combat flashover and its effect, results in increases in the size, weight and cost. Axicom insulators’ advanced design and light weight, coupled with high performance allow for a much smaller, more compact solution for a given application. This advantage provides system designers with the ability to save not only the cost of the insulator but also structural costs where higher support strength is not required. Here too the advantages of silicone bring many advantages over porcelain requiring no cleaning and high hydrophobicity.

Applications:

• Areas exposed to high pollution levels around cities, heavy industry and power stations.

• Suitable for use in HVDC and UHVDC applications that are susceptible to very high pollution accretion levels.

Benefits:

• Hydrophobic properties maintained even when exposed to high pollution levels over prolonged periods.

• No washing or service maintenance required.

Axicom HCI in High Pollution Environment – Hydrophobicity Still Effective – Demonstration of Axicom CHI hydrophobicity during dielectric test under heavy rain conditions
4.4 High Wind and Sand

The effects of high wind and sand can create flashover conditions if not correctly accounted for in the insulator design while excessive abrasion is also a major concern in exposed desert regions. In dry, desert conditions, sand grains deposited on the insulator surface intensify the electric field on the surface and may lead to the formation of localised discharges in the air surrounding the insulator leading to a potential flashover. Cevosil A1002 HTV material has been used in many desert regions around the world especially in the Middle East.

High wind applications, especially when combined with airborne debris, has the potential to damage the insulator outer surface and impair its performance. Recently, TE gained approval for products using Cevosil HTV Silicone for a high-speed train application where the product is exposed to wind speeds in excess of 200km/h. The product underwent testing in temperatures down to as low as -65 degrees C to qualify for this application.

Applications:

• Dry and dusty environments such as deserts.

• High altitude and exposed regions where high wind with risk of airborne contamination may be an issue.

• Open and exposed landscapes where wind and sand abrasion can cause insulator erosion.

Benefits:

• Cevolit Silicone material has been used for applications in the Middle East and other dry and dusty environments around the world.

• High speed trains in Norway and continental Europe use products with Cevosil A1002 Silicone material, proving durability and reliable mechanical and electrical performance under severe stress conditions.

5 Product Test Reports for Axicom HTV Hollow Core Insulators and Materials

To ensure the durability, reliability and service life expectations of Cevosil A1002 HTV material, we have performed extensive testing in our in-house, fully-equipped test facility in the UK. The test programme was designed to confirm that the Cevosil A1002 Silicone outdoor insulation compound is fit for purpose for outdoor insulator use across the world.

Tests Performed:

• Moving Die Rheometer (MDR)

• Room Temperature Tensiles

• Hot Tensiles (150 degrees C)

• Volume Resistivity

• Dielectric Strength

• Nickel Crescent Tear

• Shore Hardness A

• TERT (6 Hours 4.5kV constant Voltage)

• Accelerated Heat Aging

• UV Aging (10,000 Hour)

• Acid Test
Test Methodology and Results:

- These extensive mechanical, electrical, weathering and thermal aging tests were carried out in accordance with referenced standards.

- The material formulation was thermally and UV stable and met the mechanical, electrical and chemical test performance requirements expected of a premium HTV silicone for use in outdoor applications.

- Cevosil A1002 used in Axicom Polymeric HCI’s is proven to perform and withstand the harshest environmental conditions.

- The test results shown in the table below prove conclusively that Cevosil A1002 HTV material meets and exceeds the test standards.

<table>
<thead>
<tr>
<th>Property</th>
<th>Test Method</th>
<th>Conditions</th>
<th>Unit</th>
<th>Cevosil A1002</th>
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<tbody>
<tr>
<td>Specific Gravity</td>
<td>Din 53 479A</td>
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<td>g/cm³</td>
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<td>Hardness, Shore A</td>
<td>Din 53 505</td>
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<td>Tensile Strength</td>
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<td>Elongation @ Break (E@B)</td>
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<td>M100</td>
<td>ASTM D412</td>
<td>MPa</td>
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<td>Hot Tensile Strength</td>
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<td>Tear Resistance</td>
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<td>Nicked Crescent @ RT</td>
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<td>Dielectric Strength</td>
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<td>kV/mm</td>
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<td>1mm wall dry</td>
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<td>12 weeks salt immersion@90°C</td>
<td>kV/mm</td>
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<td>12 weeks salt immersion @90°C</td>
<td>ft/cm</td>
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<td>Tracking resistance</td>
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<td>kV/6 hr</td>
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<td>Heat Ageing</td>
<td>Thermal aging</td>
<td>1 week at 150°C</td>
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<td>2 week at 150°C</td>
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<td>3 week at 150°C</td>
<td>% E@B</td>
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<td></td>
<td>4 week at 150°C</td>
<td>% E@B</td>
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<td>UV Resistance UVB</td>
<td>ASTM G154</td>
<td>8hrs @ 70°C/humidity</td>
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<td></td>
<td></td>
<td>4hrs @ 50°C</td>
<td>5,000hrs</td>
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<td></td>
<td></td>
<td>10,000 hrs</td>
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<tr>
<td>Acid Test</td>
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<td></td>
<td></td>
<td>168 hrs in 1 molar Nitric Acid</td>
<td>% E@B</td>
<td>100</td>
</tr>
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</table>

6 In House High Voltage Laboratory Test Capabilities

An essential part of any class-leading high voltage manufacturers capability is a world-class high voltage test laboratory. Located in our Kunshan facility in China is our 1,700m2 fully-shielded high voltage test laboratory capable of testing HCI’s up to 1,000kV and bushings up to 550kV. The laboratory can perform up to 1,350kVAC and PD tests with a background noise of less than 1.30pC plus a 3600kVimpulse generator.
Applications:

• Testing HCI’s up to 1,000kV to meet GB and IEC standards.
• Testing Equipment Bushings up to 550kV to meet GB and IEC standards.
• Testing HVCA products using Axicom HCI insulators from 10kV to 500kV and margin study test.

Benefits:

• In-house testing provides a fast and reliable reference point for testing our Axicom HCI and equipment bushings.
• Fully equipped and accredited laboratory to meet today’s global testing standard
7 System Reliability

In any high altitude, low temperature and polluted environment, reliability is crucial. In addition to selecting the Polymeric HCI with the correct voltage rating, creepage and arching distance, size and construction, it is also vital to choose products that are proven to perform and deliver the expected full service life. Installation is another important consideration, and customers should look to partner with responsible suppliers that provide training for installers, helping to promote long-term reliable performance. There should also be ready access for engineers to suppliers support personnel who are knowledgeable, experienced and suitably qualified.

8 Summary

• High altitude, low temperatures and polluted environments are among the hardest testing grounds for Polymeric HCI’s. The quality of the product is crucial because reliable performance is essential in ensuring a long and dependable service life.

• TE Connectivity has built a reputation over many decades for the caliber of its products, as evidenced by both their proven service life, and their adherence to global certifications. With over 260,000 products installed globally, TE Axicom technology is well proven and can withstand a variety of severe environment conditions.

• Also, TE prides itself on the service and support offered to customers. Those organisations that work with TE receive all the benefits of a lasting partnership, not simply a service provider.
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