

# DEVELOPMENT PATH OF THE A26 REPLACEMENT POLYMERIC INSULATOR FOR THE WCML PROJECT

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## Abstract:

Early 1999, TE Connectivity's (TE) Raychem team began to work with a railway maintenance company on the development of a polymeric replacement for the A26 porcelain insulator and electrification of the new WCML project, (West Coast Main Line). The interest in polymeric insulators was initiated from the market trend towards the employment of polymeric insulators used by the railway industry worldwide. The reason for this trend is because of the superior mechanical and electrical properties of the polymeric insulator.

Throughout this paper, the main advantages of the polymeric insulator will be addressed, as well as its mechanical and electrical advantages over porcelain, i.e. elimination of chipping, improved shock/impact resistance, high tear strength of sheds, and superior flashover performance. The specific advantages of employing Raychem proprietary EVA housing material (with more than 20 years worldwide experience) will be addressed. The low moisture vapor transmission rate of the EVA reduces the possibility of internal tracking and acid notching failures in the most aggressive environments. The superior mechanical performance will be illustrated through the comprehensive elastic limit testing of the core material and in the work carried out on the end fitting design, with a view to minimizing deflection and internal crimp joint stresses and maximizing strength.

The paper will also describe the development path that the A26, (designed and optimized specifically for GTRM) has taken from conception to final product. Details of the relevant standards, material selection and qualification, Finite Element Analysis of the assembly, and resulting design and type testing carried through its development phase will be discussed. Finally, Raychem from TE Connectivity's experience in the high speed and high pollution railway industries in Japan, Taiwan, Scandinavia, France and the UK will be addressed.

## Summary

In 1999, Raychem began the development work on a polymeric replacement for the A26 / A27 porcelain insulators. There is an increasing acceptance of polymeric insulators worldwide, as a successor to ceramic and porcelain insulators, based on technical merits and cost saving in terms of lifetime costs, particularly in areas where vandalism is an issue and in areas with high pollution driven maintenance costs. In general, polymeric insulators are tough assemblies when compared with their relatively brittle porcelain counterparts. An over load on a porcelain post insulator

can result in catastrophic failure and a line drop. However, a polymeric insulator with a resin bonded glass fiber (RBGF) is less likely to physically break in two pieces and result in a line drop. Another practical advantage of EVA is in the resistance to handling damage between shipment from the insulator storage depot and the installation in the field.

The project objectives were to improve the installation and maintenance costs, mechanical reliability, impact/vandal resistance and electrical performance. Other parallel benefits were translated in the form of reduced weight from 33 kg to less than 16 kg, ease of installation and excellent tear resistance of the EVA. The qualification process through which the A26 has passed includes mechanical, electrical and aging performance; the core focus of this paper is on the insulator's mechanical design and requirements and the relevant sections of national and international standards.



Figure 1. 33Kg vs 16Kg. A26 Porcelain vs. Polymeric. (Source: TE Connectivity)

### General Background and Electrical Properties of Raychem Materials

Raychem, now TE Connectivity, developed materials for use on MV cable terminations in the late 1960's. This was a massive development effort examining in detail the complex deterioration mechanisms of polymeric materials used as outdoor high voltage insulation and the correct methods of testing to ensure at least 25 years of service. This work was recognized when the Raychem product line received the 'Queens Award' for industry best practice. Now more than 35 years later, both the EVA high voltage materials and the methods of testing them are well proven in practice, with tens of millions of successful installations worldwide.

Although the materials were developed for the utility industry, opportunities in the railway industry evolved using the same technology. For example, British Rail had tracking problems on their underbridge arm 25kV insulators (which originally had a butyl rubber coating) and breakage problems caused by vandals on some of their porcelain insulators, located near pedestrian bridges.

Raychem, now TE Connectivity's, first major contract supplied in the UK was the Tyne and Wear metro insulators in 1975. Ten thousand tension insulators were supplied from 1975 to 1977. These were glass fiber core tension insulators with crimped end fittings. In 1999, one of these was returned for an aging appraisal. The tensile strength still exceeded the original spec figure (ten tons) and depth of deterioration in the polymer surface was less than 50 microns. During the qualification process for these insulators, EVA successfully passed the specific British Rail interfacial and iron oxide

pollution testing programs.

In the 1990's we have developed the mold in place, MIP. This process involves molding directly onto the RBGF core, as opposed to heat shrinking a 200S housing onto the RBGF. This process creates an impenetrable, consistent and reliable interfacial seal between the ID of the housing and the RBGF core. This is now standard manufacturing process for all RBGF core insulators including the new proposed A26 insulator.

**Manufacturing and Development Work in Shannon**

In the mid 1990's significant investment was directed towards developing a state of the art insulator-manufacturing site. Today, molding, end fitting machining, crimping, sealing and mechanical are tested in a specialized manufacturing unit. Many significant developments have been made in the past five years including the development of a 100 percent fail-safe crack detection system, employed on the crimping machines, which ensure no damage is induced in the insulator assembly at the crimping stage. All new products are designed using a validated FEA program, to ensure optimum end fitting and overall assembly designs. All Energy Division sites and component suppliers are ISO accredited.

In relation to components used in insulators, internal Raychem product line standards demanded material properties above and beyond the international standards, and to this day these material attributes have been maintained through successful partnerships with our raw material suppliers. For example, in relation to the IEC water diffusion test, (IEC 61109, section 6.5.2, draft), Raychem product line internal specification < 0.2mA, five times more stringent than the IEC standard. Also, we have a proven interfacial seal between the EVA housing and the RBGF core, which pass both IEC and the more aggressive BR bonding trials. As a result of these high standards, we have had no rod failures in the last 15 years while using the formulation of RBGF core, developed specifically for Raychem to meet the test criteria.

Insulator product management, the insulator design and development group and our state of the art manufacturing cell are all located in one location, insuring and co-coordinating rapid response on technical inquiries relating to new and existing products. The group specializes in development of custom insulators for railway specific applications.

**Practical Issues Pertaining to the Comparison between EVA, Silicone and Porcelain Housings**

EVA is a Raychem, now TE Connectivity, proprietary semi-crystalline cross-linked polyolefin, which fundamentally has better properties than simple elastomers like EPDM or silicone. Damage to the housing material resulting from rough handling, dropping on ballast chippings is greatly reduced, one cannot chip an EVA housing. EVA has inherent advantages over some silicone materials in that the tensile strength of EVA is 2.5 times that of a typical silicone material used in insulator manufacture and the tear strength of EVA is more than three times that of silicone housings, see Table 1 below.

	<b>Tensile strength MPa</b>	<b>Tear Strength N/mm</b>
<b>EVA</b>	17.5	58
<b>Silicone</b>	4.5	17.5

Table 1. Mechanical properties of silicone and porcelain (Source: TE Connectivity)

An issue of practical importance is the weight of the A26 insulator. At less than 16kg, it is less than half the weight of the current porcelain A26 insulator at 33kg. In addition to weight advantages, customized designs can result in physically smaller insulators and can help in projects where clearance between adjacent insulators is limited when using more traditional porcelain insulators.

Overall, this will reduce the need for heavy-duty mechanical hoists to elevate these insulators to the top of the support structure. The 'replacement A26' insulator is designed to directly substitute the current porcelain insulator; using the same attachment bolt position on the base plates making replacement possible during routine line maintenance

programs. Raychem product line's high quality molding technology ensures that insulators are manufactured with low flash protrusions, which could influence buildup of contamination and localized electrical activity. High quality galvanizing supplied to meet the requirements of many international standards, BS 727, ASTM A 153 and AS 1650. Consistent thickness and adherence of zinc coating is achieved using high-grade zinc during the galvanizing process. These standards ensure a minimum thickness of galvanizing of 83µm, a smooth consistent finish and 100% adhesion.

### The Polymeric Insulator

The polymeric insulator, also referred to as non-ceramic insulator (NCI), perform two main functions. It mechanically supports the electrical line and droppers and it also electrically insulates the line from the gantry or catenary structure. There are four main components of the polymeric insulator: the load bearing RBGF core, the metal end fittings, the housing material and a proprietary seal at the interface between the metal fitting and the housing material and RBGF core. The housing is molded onto the RBGF core directly, providing a zero tracking interfacial seal. The end fittings are swaged or crimped onto the end of the RBGF rod after molding, followed by the application of the sealing material.

The design of polymeric insulators is governed by a number of national and international committees. The most prominent standards include IEC 61109, IEC 61952 (draft), AS 4435 (97) & LWIWG-02 (96). The design of this insulator is being tested to the Railtrack line specification and the tender drawings, (ref 7) and encompasses all the points examined in the above standards.

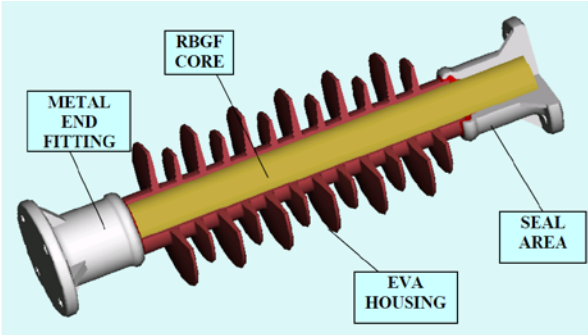


Figure 2. A26 Composite Insulator, main components. (Source: TE Connectivity)

### Mechanical Design

One insulator is being designed to perform both the A26 replacement and the WCML functions; therefore we have designed this insulator to the larger MDCL, (Maximum design cantilever load), 2.712kNm loading requirement. The first basic decision at the design stage of any insulator is to determine the core diameter suitable to sustain these loads and employ a suitable factor of safety. The core must be able to support the MDCL, (maximum design cantilever load) without creating any permanent damage in the insulator and minimizing the deflection in the overall assembly. We know from previous work that the elastic limit of our post insulator core is >500MPa, (verified below), assuming that the end fitting design and crimping are optimized to minimize damage to the rod during cantilever loading. The mechanical requirements for the A26 insulators are listed below, (Table 2):

Requirement	A26 direct replacement insulator	WCML insulator	Notes
<b>Tension</b>	133kN (54kN)	13kN (2.6kN)	
<b>Cantilever</b>	2.712kNm	1.7kNm	
<b>Operating Voltage</b>	25kV	25kV	Operating range 16.5 – 27.5 kV
<b>Nominal supply frequency</b>	50Hz	50Hz	
<b>Minimum creepage</b>	1070mm	1200mm	
<b>Wet power withstand voltage</b>	95 kVp	95 kVp	Vertical and horizontal
<b>Dry lightning Impulse withstand Voltage</b>	200 kVp	250 kVp	

Table 2. Mechanical and electrical requirements summary. Notes: Symmetrical sheds shall not be provided. Mold line should not exceed 0.2mm proud of the surface of the housing. (Source: TE Connectivity)

Employing a structural factor of safety of 2.5, we determine the maximum working stress to be 200MPa maximum, (the exact stress under 2.712MPa loading is 172MPa). Using equation 1.1, (ref 11), we can review the stresses in various diameter cores for different loading conditions up to 7 kNm. Note at this point that these results are based on the flexural modulus of the core material alone and ignore the stiffening effect of the end fitting and the additional restraint placed on the core by the crimping action. For example, the predicted deflections will always be greater than actual deflections, assuming that there is no damage to the core material during crimping or poor end fitting design.

$$y_{\max} = \frac{F * L^3}{3 * E * I} \quad \text{Equation 1.1}$$

$$Moment\_of\_inertia = I = \frac{\pi * D^4}{64} = 0.049d^4 \quad \text{Equation 1.2}$$

Using the above formula, we can predict the deflection in various core diameters stressed to 200MPa and using:

E = Ef = 34e3 N/mm = flexural modulus of the RBGF core

I = Section modulus as per Eq 1.2

L = moment arm (m)

Ymax = maximum deflection

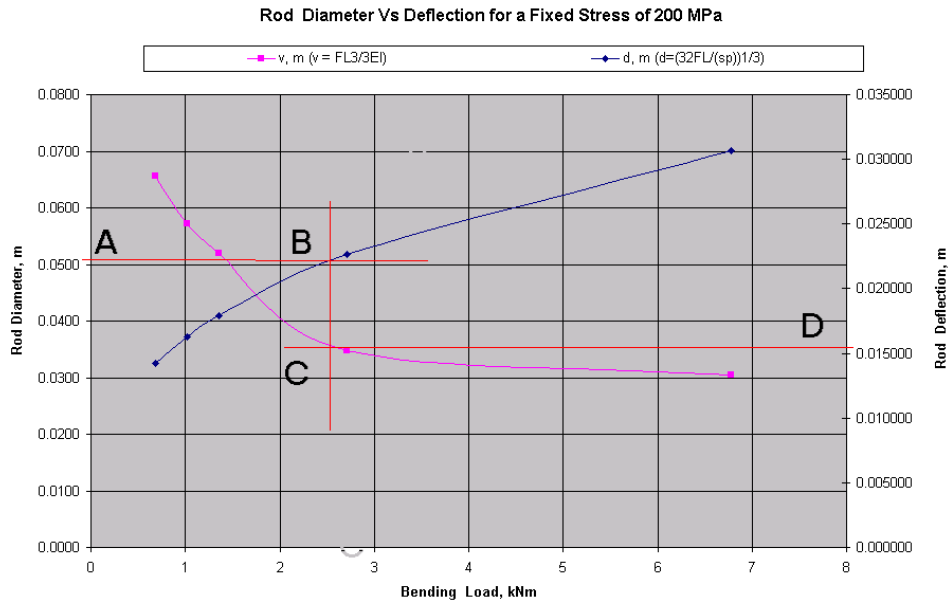


Figure 3. Rod deflection for varying rod diameters vs deflection. (Source: TE Connectivity)

Figure 3 illustrates the relationship between rod diameter and resultant deflection over a range of loading for the A26 insulator length, when stressed to 200MPa. It shows that the larger the diameter of the core, the less deflection will be observed when loaded to 200MPa. Based on the design cantilever load of 2.712kNm, indicated on the graph by line through B and C, the design diameter is derived to be 51mm approximately, (point A) with a corresponding deflection of approximately 15mm, (Point D). From experience we know that after the addition of end fittings and the crimping process, the assembly will be stiffened and this max deflection will be reduced.

### End Fitting Design and Crimping Conditions

The base end fitting is one of the most critical components in the insulator assembly, in respect of controlling the insulator assembly stiffness and limiting damage in the RBGF core at extreme loads. FEA analysis is used to predict deflections for different end fitting designs under different loading and crimping conditions. The objective of the analysis is to maximize the strength of the crimped joint, while attempting to minimize detrimental stresses in the core component. The output from the model is an end fitting design, optimized crimping die design and crimping parameters.

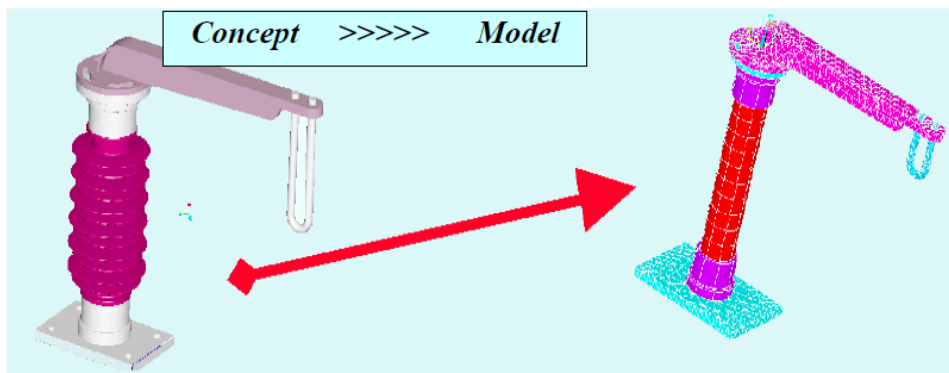


Figure 4. Concept to modelled mesh using ANSYS FEA (Source: TE Connectivity)

Since the development of insulators in Shannon we have developed a FEA model using ANSYS to simulate the crimping and the cantilever deflections in polymeric insulators. This model was developed and validated on several occasions for various core diameters, see Figure 9 below in relation to 51mm design, for predicted results vs. actual and empirical estimations.

### Determination of the Elastic Limit of the Assembled Insulator, as per AS 4435

Once a prediction for the core diameter requirements is made based on general static bending load equations, we need to consider the load/time damage relationship. The criteria for this test are defined in the Railtrack insulator specification, (ref 7). This test determines the stress that the insulator can infinitely withstand when subjected to a cantilever load. This stress level is known as the elastic limit stress.

Nine insulators were chosen from production for these trials. Each specimen is tested to different cantilever loads, such that the loading stress values vary between 100-700 MPa, in increments of 100 MPa. This load was held constant, through the 96 hours and deflection measurements were recorded after the following increments; 2,5,10, 30, 100, 1,000 and 5,760 minutes.

The relationship between force applied and the stress in the core being indicated by equation 1.3:

$F = \frac{\sigma * Z}{L}$	<b>Equation 1.3</b>
$Section\_modulus = Z = \frac{\pi * D^3}{32} = 0.098 * D^3$	<b>Equation 1.4</b>

The results of the deflection recordings will fit a family of straight lines of the general form

$\Delta f = A \log(t)$	<b>Equation 1.5</b>
<p>Therefore, Co-efficient A = <math>\frac{Log(t)}{\Delta f}</math></p>	<b>Equation 1.6</b>
<p>Where  <math>\Delta f</math> = Deflection variation in mm, i.e. = Ft – F0</p>	

And

Ft = deflection at time t

F0 = initial deflection at time 0 under a specific load

t = time in minutes

A = deflection variation co-efficient with respect to time

The elastic limit is determined by plotting the deflection/time variation co-efficient (A) versus applied stress. The resulting curve for the A26 insulator is illustrated in Figure 5 below. The graph displays two linear sections representing the elastic and plastic behavior of the material. The elastic limit is the stress value where the two zones intersect. From our graph, it is obvious that it lies between 500-600Mpa for this particular product.



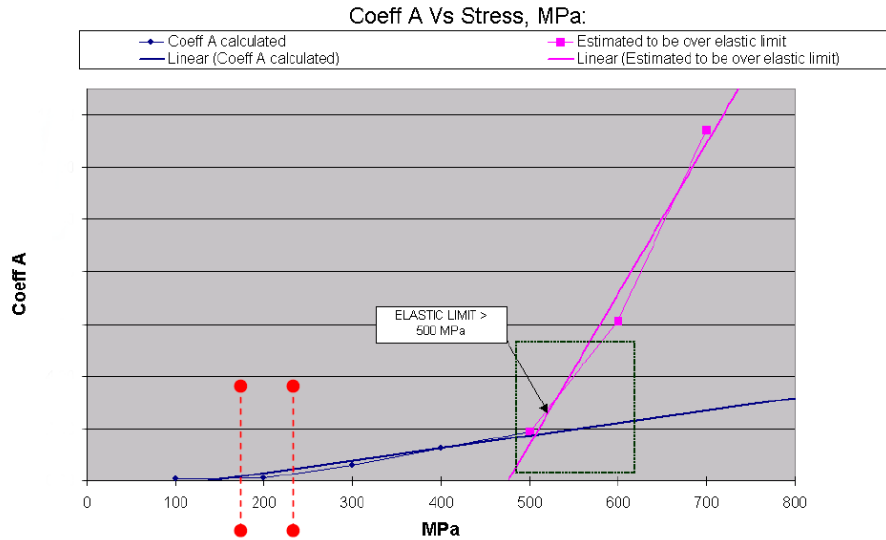


Figure 5. Deflection vs Stress for 51mm core design. (Source: TE Connectivity)

The series of the 96 hour tests are used to predict the elastic limit or the stress level at which the onset of damage occurs. In the case of the A26 design for this particular end fitting design, the critical stress level was determined to be in the range 500-600MPa for the assembly. FEA predictions up to and including this stress value can be considered and are proven in Figure 9 to be accurate. The difference between 200MPa operating stress and the 500MPa onset of damage creates a minimum FOS of 2.5.

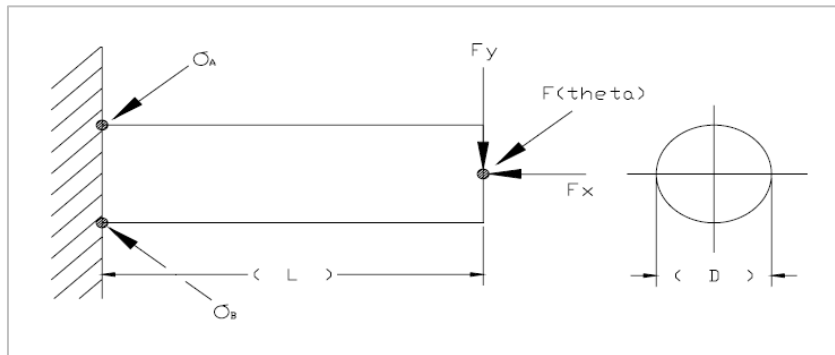


Figure 6. Cantilever loading and maximum stress regions. (Source: TE Connectivity)

### Assembly of First off Samples

Once the components are ready for crimping, the FEA model must be validated, and physical crimping and mechanical testing begins. The crimp dies design, crimp pressure and position is determined; an insulator is assembled and sealed. From Figure 6 below, note A is the point at which the theoretical maximum tensile stress occurs in the rod and the maximum compressive stress occurs at point B. From experience we know that the most likely point of initial damage will be at point B.

Having set crimping conditions, samples are assembled. The end fittings are prepared and crimped onto the RBGF core, and then the seal is installed. In order to verify that the assembly meets the required specifications, a 96 hour test is performed on the insulator under a cantilever load of 1.1 times the MDCL of the insulator, (Maximum design cantilever load) according to IEC 61952, (latest draft, ref 3), section 6.3. The load applied at room temperature, 20°C, is perpendicular to the axis of the assembly.

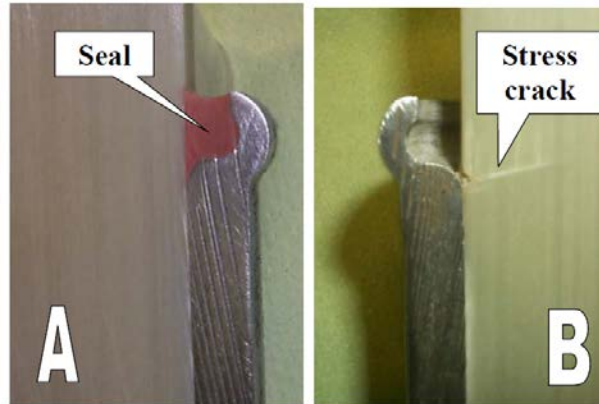


Figure 7. Examples of pass and failure inspections on the core material. (Source: TE Connectivity)

On completion of the loading cycle, the insulator is taken to the lab where a dye penetration test is performed on the seal area on the pivot end fitting. On passing this test, each insulator is cut through the core at 90° to the axis, approximately 50mm from the base end fitting. Then the base end fitting is cut longitudinally into halves in the plane of the previously applied cantilever load.

In Figure 7, both A and B focus on the area in the core where failure is anticipated. A illustrates a pass test and B illustrates a failure. Sample B clearly illustrates a crack in the fibers at an angle of approximately 79° to the fiber axis. This crack is initiated under cantilever loading and should not occur. It is a clear indication that an insulator has been overloaded. The sectioned end fitting should now be subjected to another dye penetration test on the prepared section to expose any delamination of the fibers. If the sample passes this test, it passes IEC 61952, section 6.3.

## Tension Testing

The tensile requirement or STL, (specified tensile load), for the A26 is 133kN. To confirm these insulator samples were tested in tension according to IEC 1109, 5.2.2.1. The tensile load applied to these insulators is increased rapidly but smoothly from zero to approximately 75 percent of the expected mechanical failing load, and then increased in a time between 30-90 seconds until breakage of the core or core pull out of the end fitting. Up to the time of writing of this paper, we have not been able to break this insulator in tension. Five samples were tested to 160kN, but no elongation was observed in the assembly.

In section IEC 61952, section 6.3.2, three more insulators are tested in tension. The test involves loading the insulator assemble to 75 percent of the STL smoothly but quickly and then loading to 100 percent of the STL in 30-90 sections. If the STL is reached in less than 90 seconds, then the load shall be held for the remainder of the 90 seconds. The test is regarded as successful if the core does not pull out of the end fitting and there is no breakage to the end fitting. All samples tested passed this test.

## Testing the Interfaces and Connections of the Metal Fittings as per IEC 61109, Section 5.1

According to IEC 61109, section 5.1, three assembled insulators are taken from production and are visually inspected for defects and dimensions checked against product drawings. The insulators are now tested according to section 5.1.2, dry power frequency voltage test. The dry power frequency flashover voltage is determined by averaging five flash over voltages on each specimen and this FOV, (Flash Over Voltage), is corrected for atmospheric conditions according to IEC 60-1. Section 5.1.3.1 outlines a sudden release load test. With the insulator at room temperature, the test specimen is subjected to five sudden load releases from a tensile load amounting to 30 percent of the SML, 39.9kN in the case of the A26. No damage was reported to the insulators after this test.

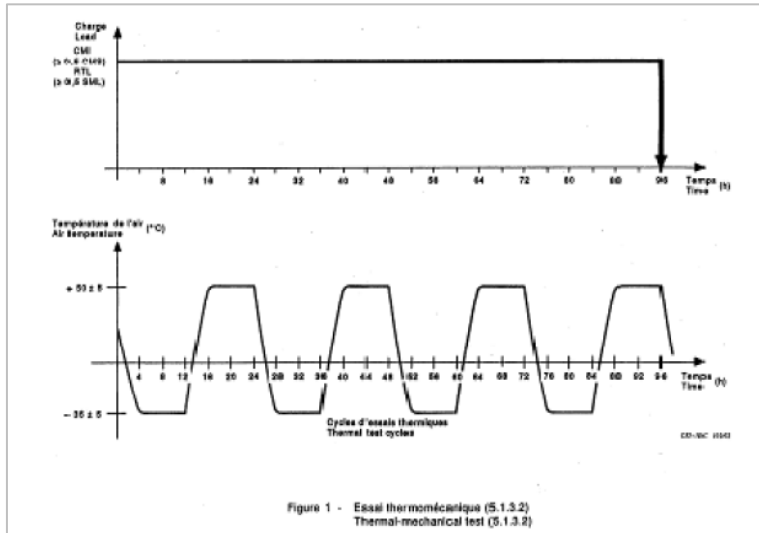


Figure 8. Thermo mechanical test profile. (Source: TE Connectivity)

The specimens are then submitted to the thermal variations under a continuous mechanical load as described in the Figure 8. The three insulators were subjected to four 24-hour thermal cycles with a simultaneously applied tensile load of 66.5kN (minimum required load is 50 percent of the SML of 133kN). Each 24-hour cycle started with a cooling period of -35°C, followed by one heating period of +50°C. Before commencing the test, the insulators were loaded at ambient temperature at 6700N (minimum required load is 5 percent of the SML of 133kN) for one minute, during which the distance between two reference points is measured. At the end of the tests, the distance between the two reference points was measured again. The reference lengths before and after the test were all within 0.2mm, therefore no significant measurable difference was recorded.

After this test the specimens are again visually inspected, and at this point no damage was reported on the A26 parts. To complete section 5.1, the insulators are immersed in boiling de-ionized water for 42 hours with 0,1 percent by weight of NaCl. At the end of boiling, the insulators are to remain submerged in the water and are cooled to approximately 50°C and maintained at this temperature until the start of the verification tests. The verification tests in section 5.1.4.2. and 5.1.4.3 are the Steep-Front Impulse Voltage test and the Dry Power frequency voltage test. At the time of writing of this paper, both tests passed requirements of their respective sections in IEC 1109.

### Practical Trials

In order to compare the robustness of the Raychem insulator and its ability to resist damage through either vandalism and/or rough handling, we completed two simple trials to compare the existing A26 porcelain insulator and our new polymeric alternative.

**Drop test:** This test is not conducted to any known standard; it was carried out in the following manner. It involves dropping the insulators from a height of 20 feet onto a flat concrete base. The insulators were dropped from a horizontal position. In both cases the galvanizing was damaged at the point of impact with the ground. In the case of the porcelain insulator, the insulator was broken in two main pieces and chipped in many locations, rendered unusable. In the case of the polymeric insulator, on visual inspection the insulator remained intact with only superficial scratching on the surface of the insulation. In order to verify that no structural damage was induced in the fall, IEC 61952 section 6.3.1, 'Test for the verification of the maximum design cantilever load' was repeated. The Raychem A26 insulator passed this re-test.



Figure 8a. Damage as a result of drop test. (Source: TE Connectivity)

**Gunshot test:** This test is not carried out to any known standard; it was carried out in the following manner. One porcelain and one polymeric insulator were mounted at an angle of 30° to the horizontal on a wooden base, one after the other. The 30° approximating the angle representing the line of fire from ground level on the trackside. Each insulator is shot from 25 feet, using a single round of a number five cartridge from a shotgun.

The results are clear; a direct hit to the main body result in a catastrophic failure of the porcelain insulator and in the field would result in a line drop. In the case of a polymeric insulator, damage is sustained to the sheds and core of the insulator and the strength of the insulator is weakened, but it will still maintain the line load in the short term. This will allow maintenance crews time to replace the damaged insulator and avoid a dangerous line drop.

	<b>Existing porcelain A26 insulator</b>	<b>Raychem A26 replacement insulator</b>
<b>Weight (kg)</b>	33	16
<b>Drop from 8 ft</b>	Galvanizing dented. Insulator fractured and chipped	Galvanizing dented, insulation intact, scratched but not torn.
<b>Shot gun damage</b>	Insulator broken in two pcs line dropped	Insulator damaged by pellets, though still structurally sound for short term
<b>Impact resistance ?</b>	N	Y

Table 3. Physical comparison of the A26 insulators. (Source: TE Connectivity)

### Raychem, now TE Connectivity's, Experience in Railway Application around the World

Over the past 25 years, TE Connectivity has served the railway industry in the UK, mainland Europe, Scandinavia, Japan, Taiwan and South America. In the last 3 years more than 500,000 EVA insulators and 200S products have been sold to customers around the world. EVA has had particular success in areas of very high pollution. Applications have included trackside, rolling stock and catenary, where terminations, joints, surge arresters and insulators have been used. TE Connectivity has a strong focus on international standards and internal standards with respect to the mechanical and electrical specifications.

One of the early large-scale opportunities was in the UK, where, 10,000 tension insulators were supplied to a Tyne & Wear Metro project in the 70's. Samples from this project were returned to TE Connectivity, Swindon for evaluation. From inspection, 50 microns surface damage was measured after more than 20 years or environmental exposure, and

the samples had maintained their tensile load requirements over the same period. More recently, TE Connectivity has supplied rolling stock insulators and cable terminations for the TGV in France and Bombardier in Canada. Custom profiled 200S housings have been supplied to the Shinkansen for a pantograph application, through our partners in Japan.

Also, in Japan a recent product review carried out by our customer (ref 18) has shown that EVA has had particular success in an area where insulators are exposed to extreme amounts of pollution. Pollution levels from a tunnel in this area were measured. The tunnel is located within 700m of the shoreline and substantial salt deposition is an issue combined with fumes from diesel locomotives. The pollution level recorded was; ESDD = 0.1mg/cm<sup>2</sup> & NSDD = 0.5 mg/cm<sup>2</sup>. Over the period of the study it was shown that EVA insulators on trial needed the least amount of maintenance in terms of regular washing, and had a lesser occurrence of external flashovers combined with minimal erosion. More specific details on Raychem materials are available from the author on request.

Other applications where 200S products are used in conjunction with porcelain material (ref 16) have proven to be successful in reducing vandal damage and increasing the reliability of the system by increasing flashover properties of the insulator. This has proven to be particularly popular design in Taiwan where pollution is a driving factor.

## Summary and Conclusions

- (1) Theoretical calculations overestimate deflection estimates, because they do not take into account the stiffening effect of the end fitting design or the crimping method.
- (2) Crimping die design, crimping process conditions and crimping methodology all contribute to the final mechanical properties of the assembled insulator.

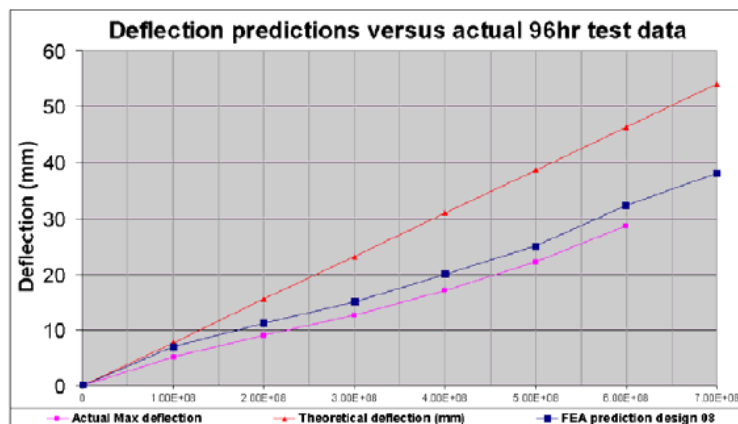


Figure 9. Deflection predictions versus actual 96 hour testing data. (Source: TE Connectivity)

- (3) A refined FEA can accurately predict insulator deflections up to the elastic limit of the assembly, in this case 500MPa.
- (4) Raychem mildly conductive seal material, acts as an electrical grader in critical seal area of the insulator ensuring that dry band arcing is reduced.
- (5) EVA out performs silicone on tear strength, nitric acid resistance and vapor transmission rate.
- (6) This new A26 insulator design will meet the requirements of both the A26 porcelain replacement project and the new insulator requirements for the WCML in respect of both mechanical and electrical specifications.
- (7) EVA polymeric insulators eliminate the attrition rate traditionally associated with porcelain insulators through damp storage, chipping and breakages.

## **RAYCHEM EVA POLYMERIC INSULATING MATERIAL IBLIOGRAPHY**

(8) Raychem EVA has more than 20 years field experience in many product applications ranging from cable accessories, insulators and surge arrestors. EVA is the world's leading outdoor polymeric insulating material, with more in service than any other formulation.

(9) EVA has passed BR iron oxide and interfacial.

### **BIBLIOGRAPHY:**

IEC: International Electro-technical Commission

STL: Specified tensile load

NCI: Non-ceramic insulator, those not containing any porcelain member

MDCL: Maximum design cantilever load

200S: Heat shrink multi-shedded molded profile

EVA: Raychem proprietary high voltage outdoor insulation material

ID: Internal diameter

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