WT HENLEY LTD COMPOSITE INSULATORS: REDUCING COST WHILE MAINTAINING HIGH QUALITY.

1. *WT HENLEY: An Overview*

WT Henley Ltd based at Gravesend, near London. Manufactures an extensive range of electrical equipment used throughout electrical supply distribution networks, from sub-station to the consumer. Founded in 1880 as a cable manufacturer, WT Henley soon started to produce cable accessories to sell together with cables. In 1960, the Company was taken over by AEI Cables and again in 1967 by GEC. The latest change coming in March 1997 with the acquisition by TT electronics plc. For over 100 years, the name Henley has been associated with quality, experience and reliability.

WT Henley has an excellent reputation for supplying reliable quality products for the Electricity Distribution Industry in the UK and to Electricity Utilities worldwide.

WT Henley produces a full range of accessories for underground power cables including low and medium voltage resin joints. A variety of service Cutouts for street lighting and domestic house service, a choice of insulated connector boxes, a range of composite insulators to replace 2 or 3 glass or porcelain discs up to 36KV.

WT Henley products can be found in service in many different parts of the world, including the hot desert areas of the Middle East, the snow covered areas of Northern Europe and Canada and the humid areas of the Far East.

2. INSULATORS AND OVERHEAD LINES

An insulator is a fundamental accessory for the aerial distribution of electricity. Not only does it sustain and maintain the position of the aerial cable, but it also assures the transition of Electricity and the insulation between different materials with different electric potential.
Because of their importance, insulators must meet specific mechanical requirements and they must be reliable. The failure of a **single** insulator can cause the shutdown of a distribution line, creating disruption for customers and a headache for the utility concerned.

2.1 The traditional materials for overhead insulators: glass and porcelain

Porcelain and glass have been the traditional materials used for the production of insulators. The very long service history and the proven reliability of these materials make it hard for utilities to switch to something new.

Glass/Porcelain insulators are by their very nature heavy products; this makes installation complicated, requiring the use of a specialist lifting equipment. Furthermore, Glass and Porcelain are fragile materials. Utilities have experienced breakage during transport and installation. In addition, the surface of these insulators can be chipped very easily. The performance of the glass/porcelain insulator depends on the external glaze not being damaged. A small chip will create a rough surface making it easier for airborne pollutants such as salt and other particles to stick. This creates a defect in the surface, where Volts can move easier with the consequent leakage of current.

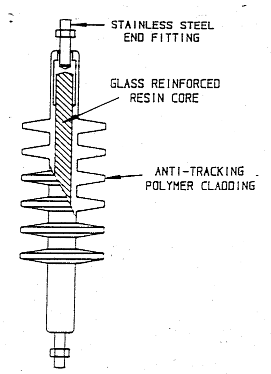
The external glaze can be also ruined by strong and constant exposure to corrosive substances like salt, sand and pollution.

2.2 The development of composite insulators

Glass and porcelain insulators are manufactured today at very low costs and they are still widely used. However, in the last 30 years, many companies have started to concentrate their efforts in the development of alternative products that could prove to be more impact resistant and lighter. The result was the development of composite insulators.

The design of a composite insulator is based on three basic parts:

1. The central rod, usually produced from GRP, provides the mechanical strength of the insulator.
2. The outer covering of the rod. On composite insulators, this is done using a synthetic material. This is necessary to protect from humidity, water and other substances.
3. The end-fittings are normally metallic.



Having a synthetic material covering a central lightweight rod instead of porcelain or glass, reduces the weight of the insulators by some 75/85%. Since the beginning, the great practical advantages of synthetic materials were obvious. However, the development had to ensure those standards of electrical and mechanical performance and reliability could be maintained.

Different materials were soon developed. The material used was and still contains a base of elastomer: Ethylene Propylene Rubber (EPR), Ethylene Propylene Diene Monomer (EPDM) or Poly-Di-Methyl Siloxane (PDMS or Silicone). Using these synthetic materials, a whole range of insulators, surge arrestors, terminations and other products were manufactured. Composite insulators had an immediate success in America. Today, composite insulators represent 8% of the market worldwide. Whilst the major area of use is in the United States, the use of these lightweight alternatives continues to grow in Europe and in other parts of the world.

3. COMPOSITE INSULATORS: WHY CHANGE?

- *LIGHTWEIGHT*

As mentioned before, a composite insulator weighs 75/85% less than a glass or porcelain insulator. This simplifies transport and installation enormously. WT Henley customers have learnt that composite insulators can cut installation time by up to 50%. Time is also saved in loading, unloading and storing the goods.

Other advantages include a reduction in the overall centre of gravity, particularly important in high installations.

- *IMPACT RESISTANCE*

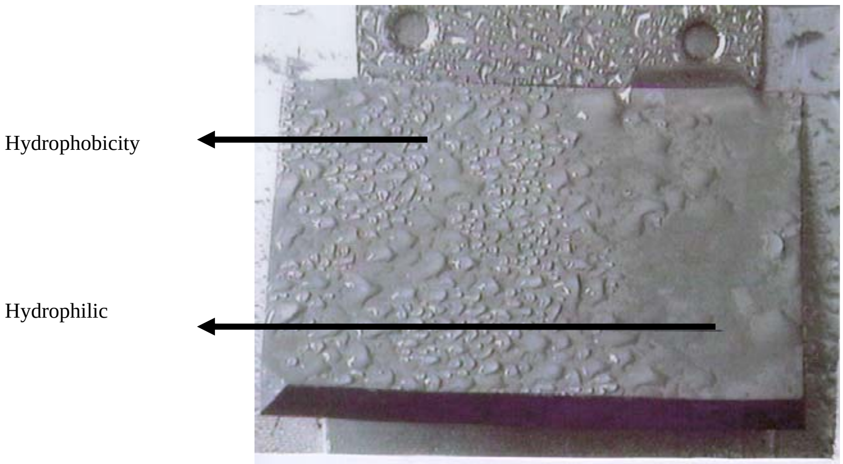
It is estimated that approximately 7 to 10% of porcelain/glass insulators break during transport, storage and installation. More break in the field when hit by balls, shotguns, stones, etc. Broken insulators have to be replaced. Composite insulators are impact resistant. They do not break during transport or in the field. For this reason, composite insulators are very often used in areas of high vandalism.

The picture below shows the after effects of two Insulators, 1-porcelain and 1-polymeric, after a blast from a shotgun. The porcelain insulator has broken whilst the polymeric equivalent has only been slightly damaged and its performance has decreased only by some 8%. It will eventually need replacement; meanwhile the line continues to function. If hit by a stone, a ball or similar object, polymeric insulators are not damaged at all. On the other hand, porcelain can be damaged very easily.

- *HYDROPHOBICITY*

It is commonly known that composite insulators are hydrophobic. This means that the synthetic material is water repellent. On the surface of a hydrophobic material, we have water droplets and natural dry spaces in between. A surface that is not hydrophobic is called hydrophilic (see picture below).

Hydrophobicity helps the insulator to maintain a better performance in polluted environments. In fact, where water wets the whole material, like on porcelain/glass insulators, there is a subsequent adhesion of contaminants and pollution that will form like a film around the insulator. On a hydrophobic material there is a low surface "stickiness". This, combined with the natural cleaning action of wind and rain, offers excellent resistance to polluted or very salty environments.



Picture taken form the magazine "Épure " Published by EDF, Direction des études et recherché, No 58, April 1998.

- *HOMOGENEITY OF THE MATERIAL*

A further advantage of composite insulators is the homogeneity of the material. Unlike ceramic or glass which depends on a comparatively thin surface glaze, material removed from the insulator surface by electrical activity or abrasion caused by salt or dust exposes only more of the same material.

We have already mentioned in paragraph 2.1 how a small scratch or chip can create serious problems of electrical movement and leakage of current on a glass/porcelain insulator. This does not happen with a composite insulator where the external and the internal material are the same.

This feature enables us to have a more compact composite insulator with shorter creepage than what is usually required for glass/porcelain. This also means that within given dimensional specifications, it is usually possible to achieve better performance capability with a composite insulator.

4. *COMPOSITE INSULATORS: OUR EPDM*

As part of continuing development, WT Henley began work on the development of a synthetic material to use for insulators at the end of the 60’s. We have been one of the companies at the forefront in composite insulator' development.

The chemical formulation of the composite material developed in the 60’s is based on Ethylene Propylene Diene Monomer (EPDM) compounded with a blend of additives to provide tracking resistance, UV stability, resistance to water pooling and temperature extremes, plus other desirable proprieties. WT Henley was aware that a composite material to be used in place of glass and/or porcelain had to meet high standards, in order to offer resistance to weathering, long-term ageing, retention of electrical and surface proprieties and anti-wetting proprieties.

Using its own **special formulated** EPDM material; WT Henley started to produce modular components for bushes and terminations. At the beginning of the 70s WT Henley manufactured insulator claddings for surge arrestors and switchgear. Moulded substrates for tension, suspension and pin insulators followed, to complete the range.

Today, WT Henley has a whole range of tension, suspension and pin insulators for overhead lines. They are a direct replacement for 2 or 3 glass discs or of the equivalent porcelain insulators up to 36KV. WT Henley insulators can replace a traditional set without the need to re-tension the line.
Our insulators are manufactured in house according to our own design. All the moulding and manufacturing processes are carried out at our own on site laboratory. This gives us the ability to develop insulators of different length, creepage, etc. if required. Also the end-fittings can be designed according to customer specifications.

5. *REDUCING THE COSTS USING COMPOSITE INSULATORS*

In cases where the initial purchase price is the overriding consideration, ceramic and glass may still be the obvious choice. Although composite insulators can be produced today at very low costs, porcelain and glass still tend to be cheaper. However, the end user should also consider the costs involved in the long run.

As stated in paragraph 3, between 7 and 10% of porcelain/glass insulators break during transport, storage and installation, a point that should be considered when evaluating overall costs. In addition, the extra time necessary to store or load the glass/ceramic insulators adds cost. Other factors include the extra care that must be taken all the times these products are being moved and the attention that must be paid in selecting the method and place for storage.
During the construction of new overhead lines, it is sometimes necessary to use a helicopter for the transport of the glass/porcelain insulators. More porcelain/glass insulators are damaged once installed on the overhead lines. All these are added expenses.

It is obvious that the easy breakable and very heavy material that characterises glass/porcelain insulators; implies a series of additional costs and difficulties in handling the products. If all the additional expenses are considered, the difference in the initial purchasing price is soon paid for.

More and more utilities have realised the cost advantages of composite insulators and are slowly moving away from the traditional material. If a certain level of scepticism has remained, this is usually the technical quality of the product. This is a topic that we will discuss further in the next paragraph.

6. *EPDM: RAW MATERIAL AT LOWER COSTS*

We had to be sure that our range of composite products could compete price-wise and the choice of using EPDM as the base elastomer was guided by the consideration that the average price of EPDM is less than that for Silicone.

Paying more for the base elastomer does not necessarily equate to a high quality in the final compound. *Our* compound is the result of years of testing with a complex mixture of fillers and additives. The whole formula influences the performance of the final product and not just the base elastomer.

Many statements on the quality of the different base rubbers have been made. The reality is that remarks like "DMC is stronger than EPDM", "Silicon rubber wets less than polyolefin" are of no relevance. Good or bad compounds can be made using any synthetic material. The base elastomer used in an insulator is not as important as the fillers and additives that are mixed with it, to make the finished compound. The additives are the products that give the material the necessary properties for its good performance.

WT Henley chose EPDM because we were confident in the knowledge that our formula is perfectly suited for overhead line applications.

7. *WT HENLEY EPDM: A COMPOUND OF HIGH QUALITY*

WT Henley's compound is based on Ethylene Propylene Diene Monomer (EPDM), mixed with 12 other selected ingredients to give a balance of proprieties. As we have stated in the previous paragraph, it is the whole formula (including additives and fillers) that makes a compound good or bad.

To prove that the base rubber used in outdoor insulators is not as important as the fillers and additives used, WT Henley carried out a comparative test. Three insulators made using three different rubbers were subjected to a salt fog test for 3000 hours (constant high voltage on the insulators while they are surrounded by salt fog). The three insulators were:

- A silicon rubber insulator manufactured by a highly respected manufacturer.
- A proprietary red heat shrink polymer covered insulator.
- A WT Henley EPDM insulator.

The result of the test was as follows:
- The silicon insulator broke down after 1000 hours.
- The red polymer terminated after 3000 hours
- The WT Henley insulator completed the test. On this insulator, two sheds were bridged out after 1500 hours to increase the stress on the rest of the insulator by about 50%.

The photograph below shows the insulators at the end of the test.

The test was to prove that it is wrong to draw conclusions on the quality of an insulator knowing only the base rubber used. There is usually a tendency to say that silicon performs better that EPDM, but WT Henley EPDM performed better than the silicon insulator selected for the above test.

The base rubber used cannot guarantee the good performance of an insulator. The whole formulation of the compound used is the secret for a successful product. In order to be able to judge and evaluate the performance of a product, it is necessary to carry out a long -term examination of the performance of the compound in the field and also to perform tests in laboratories.

7.1 *Ageing test: IEC 1109 and the recovery of Hydrophobicity*

The main argument against composite insulators is that these products do not retain their proprieties for a long time. In particular, by exposure to a wet and contaminated environment, composite insulators can lose their Hydrophobicity. For this reason, it is very important to understand how the ageing process affects the performance of an insulator and which weathering factors have the worst impact on the product.

The IEC 1109 is the most complete specification available today for composite insulators. Part of the specification is intended to create in the lab an accelerated ageing process. The insulators are exposed for 5000 hours to all sorts of possible weathering conditions: simulated solar radiation, artificial rain, dry heat, damp heat, saturated air at room temperature, salt and fog. The 5000 hours test represents between 5 and 15 years of operation in the field.

During the test, it is possible to observe the behaviour of the compound when exposed to weathering and ageing. Bad compounds can reveal severe damage, erosion and perforation. Good compounds reveal hardly any sign of ageing. After the test, it is also possible to evaluate the ability of the compound to recover its Hydrophobicity.

The photograph shown above features two of our insulators. The insulator on the left has undergone tests in accordance with IEC 1109. Whilst the one on the right is brand new. The compound on the older insulator is in perfect conditions. Rust and ageing appears only on the metallic parts (end-fittings). The two insulators have also been sprayed with water to show that the older insulator retains the same hydrophobic ability of the new one.

Many reports state that EPDM tend to lose Hydrophobicity quickly, while silicon tends to recover its Hydrophobicity better than other materials[1]. Tests on our EPDM insulators have revealed that *our* compound has an amazing ability to recover its Hydrophobicity. Once again, this proves that it is not the base rubber used, which defines the quality of the compound, but the whole formula and a good use of the additives.

The Swedish Transmission Research Institute carried out the IEC 1109 test on our insulators and this is their conclusion: "In addition to the results given in the reports, we got some interesting information about the speed of recovery of the Hydrophobicity on your insulators, after the test was stopped. It was a rather fast recovery process from HC7 back to HC2-3"; … "Good recovery proprieties could be valuable for the long-term performance in severe environments"[2].

7.2 *More tests carried out on WT Henley EPDM compound*

Apart from IEC 1109, a variety of controlled tests can be used in order to predict the long-term material behaviour. The following properties are very important for a composite insulator:

- ***Tracking and erosion resistance:*** Three tests can be used to asses a materials resistance to the formation of conducting surface paths (tracking) and bulk loss of material (erosion), caused by weathering and pollution.

  IEC 587 assesses the material's behaviour under electric stresses whilst subject to a continuous flow of liquid contaminant. A voltage classification gives a measure of merit. WT Henley EPDM insulators have passed this with the highest classification recognised: No tracking at 4.5 kV (4.5kV method 1A and kV rated 2A).

  IEC 1109 1000 Hours Salt-Fog Test examines **t**he performance of a composite insulator, when working at normal electric stress and whilst being subjected to a continuous salt fog environment, causing very high current leakage of up to 1A. A failure is defined as more than three flashovers, tracking or unacceptable erosion. Four samples of WT Henley EPDM insulators have passed this test with no flashover. The test was carried out twice consecutively on one of our four insulators. On both occasions, there was no flashover and the material presented no signs of degradation.

[1] "Ce processus de récupération de l'hydrophobicité est plus marqué pour les silicones" (The process of recovery of hydrophobicy is more evident on silicon), Published by EDF, Direction des études et recherché, No 58, April 1998.

[2] A copy of the letter is attached at the end of the report.

The MERRY-GO-ROUND (or Tracking Wheel) Test lasts 1000 hours. The composite material is fixed on a rotating vertical wheel, partly immersed in water so as to periodically wet fully the material that is subjected to electric stress, with intense electrical activity. WT Henley insulators have undergone and passed this test.

- ***Resistance to water, rain and sunlight:*** It is important to test the effects of long term exposure to the weather, particularly rain and sunshine. Two tests are particularly useful in order to do so.

With the **wetherometer Test:** The material is subjected to cycles of rain and UV exposure. Cycles tend to be of 1000 or 5000 hours and material samples are assessed by visual examination and % retention of initial properties. WT Henley EPDM has been subjected to a total of 40000 hours (> 4½ years) weathering in a Xenon arc wetherometer with very little deterioration.

Natural Sunlight Exposure: This is also called the D.S.E.T test. There is a facility in the Arizona desert (USA) that uses reflectors, which track the sun during daylight hours and focus the radiation onto the material. This gives exposure to a natural daylight spectrum but at a much-enhanced level. WT Henley EPDM showed no deterioration after a standard test (40 weeks).

- ***Resistance to specific contaminants:*** Particular areas of use may involve specific risks, which require individual assessment. Examples are acids, alkalis, oils, brake dust and cleaning solvents. WT Henley EPDM has been assessed when contaminated with a range of common materials, as well as very specific ones like Glycol Ether Antifreeze and Iron Oxide Burning.

7.3 *The service history*

We have already underlined the advantages of composite insulators and we have exposed the technical and price issues that make these insulators preferable to traditional materials.

There are still a number of utilities that have maintained a certain level of scepticism as regards composite insulators. It is always difficult to move from something known and that is technically satisfying to something less known. What makes it even more difficult, is the fact that while glass/ porcelain has been used for decades and their behaviour in the fields is very well known, composite insulators have been used for a limited time. Tests carried out in the laboratories can recreate the ageing process, but the service history still remains a very important issue.

To make things even more complicated; manufactures have been constantly changing their material composition, in order to achieve a better performance. Because of this, there are not many composite insulators whose material has actually been in the field for more than a decade. WT Henley can proudly claim *more than 25 years service history for their EPDM*.

WT Henley material was first used for outdoor terminations in 1973. Composite insulators have been manufactured sine 1975. Although different products and design have been made, *the formulation of the EPDM used has never been changed.* This gives a continuous long-term service history of about 27 years with our formulation.

Throughout its service history, there has not been a single failure attributable to a deficiency in the material

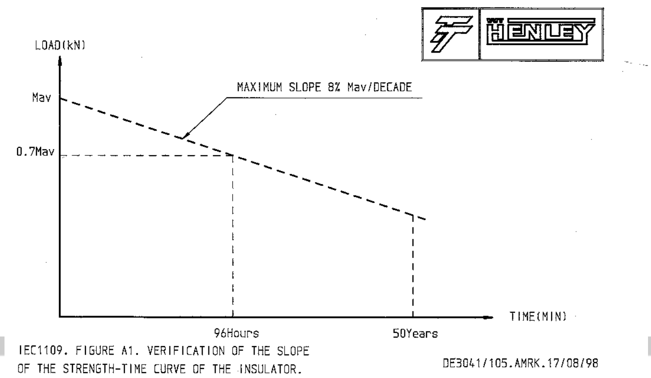
With the support of all the tests carried out on our EPDM and with 32 years of service history, WT Henley has great confidence about the high quality of the compound used to produce composite insulators. It has proven to be a very good formulation, able to deliver a high performance in the field.

7.4 *The mechanical specifications*

The long list of tests carried out on our EPDM is more than enough to prove a high quality for our composite material. However, this alone is not enough guarantee good results from an insulator.

An outdoor insulator requires adequate mechanical properties from its structural core and end fittings. The interface between the core and the cladding must be stable and void free preventing the ingress of contaminants, whilst the cladding profile must be properly designed with due regard to material bulk properties, insulation orientation and intended use.

IEC 1109 is the most complete composite insulator specification available today. It covers all aspects of manufacture, from incoming materials, through development and type testing, to production and routine testing.

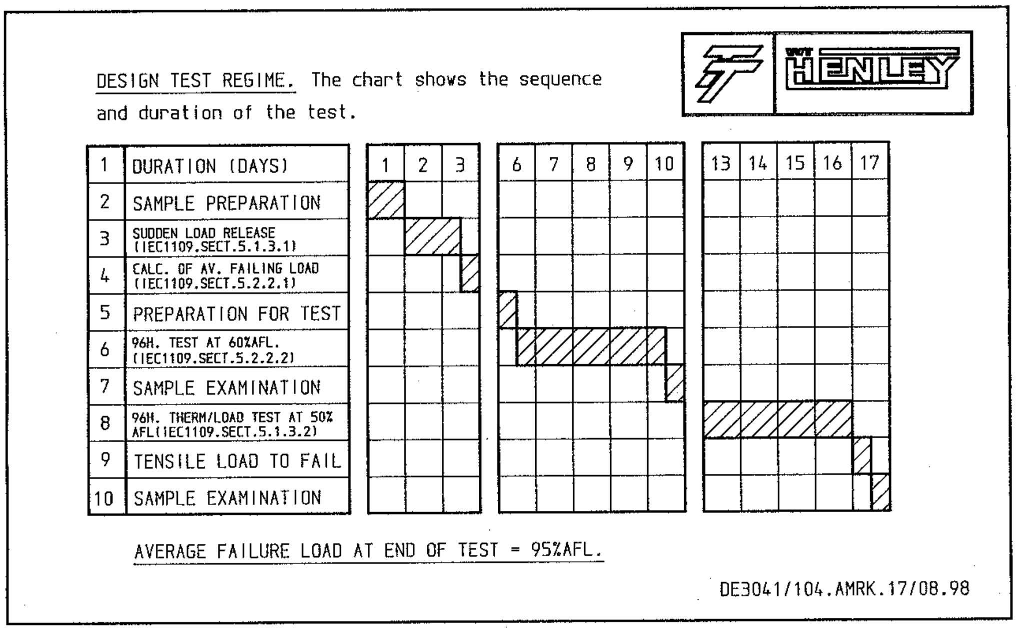


At W T Henley, we recognised the importance of the substrate/end-fitting, substrate/EPDM and EPDM/end-fitting interfaces in the overall performance of the insulator and have introduced in-house test regimes to test these interfaces further. Forty years is considered to be the average life of an insulator in the field. Unfortunately, composite insulators do not have the luxury of historical experience over this time-scale. The design tests in Section 5 of Specification IEC 1109 do address this problem, but rely on extrapolation of results obtained over a few hours, to estimate the performance over 50 years.

To further test the validity of the design, WT Henley introduced the following interface tests:

Interface Test 1: ***Substrate/End-fitting***

The sample is assembled ***without*** rubber and subjected to the test regime as shown.



Interface Test 2: ***Substrate/EPDM***

The Water Immersion test conforms to Balfour Beatty Power Construction Specification QA/P.1-A and is designed to check the quality of the bond.

The test requirements are:

Moulded substrates are plunged into a bath of tap water at 50°C. during the following 8 hours the water is allowed to cool to an ambient temperature. This completes the first cycle. On completion of the cycle, the substrates are removed from the bath and plunged into a second bath at 50°C.

This continues for 10 cycles.

At the end of the 10 cycles the substrates are removed from the bath, dried and a voltage applied equal to 26 volts/mm of creepage. The leakage current measured must not exceed 1 x 10^{-7} amps.

All production-moulded substrates are subjected to this test as a routine quality check.

Interface Test 3: ***EPDM/End-fitting***

To ensure the designed EPDM/End-fitting interface is effective, the assembled sample is tensioned to 70% of the Specified Mechanical Load. One end of a plastic bag is connected to a container of tap water containing a dye; the other end of the bag is fixed around the EPDM/End-fitting interface.

The whole assembly is then transferred to an oven set at 50 C.

At the end of 6 weeks (1000 hours), the assembly is removed from the oven, the load released and the insulator removed.

The insulator is then pulled to failure and the interface examined. No dye penetration must be evident.

Clearly, we need to ensure that the design features and assembly techniques learned during the design stage are transferred to final manufacture. In order to achieve this, a rigorous training programme is undertaken to ensure that production personnel are made aware of the 'critical' and 'non critical' points throughout the assembly

Members of the factory inspectorate undertake constant monitoring during the production stage while the design team carries out ad hoc testing to ensure compliance.

The final 100% Routine Tension Test of the complete assembly is supplemented by a 1% 'Pull to Fail' Test, to ensure that the standard of the manufacturing process has not dropped. This 1% 'Pull to Fail' test is carried out in the following manner.

The selected insulator is tensioned to the RTL (50% of SML) for 1 minute. The load is increased to 15% above the SML and held for 1 minute. The load is increased to induce failure.

The components and method of failure are examined before production can continue.

8. *CONCLUSIONS*

Rubber materials present major advantages over traditional glass and porcelain. Composite insulators today account for 8% of the total market and their use is steadily growing. Utilities worldwide are showing more and more interest in this type of product.

However, many utilities do not feel ready to switch completely to composite insulators yet. Their scepticism is due mainly to the short service history. A wide-variety of tests with accelerated ageing can now be used to study the performance of an insulator

Insulators of synthetic material have been developed during the last 30 years and WT Henley has been at the forefront in developing its own formula of EPDM. This has given us the possibility to gain a great deal of experience compared with some other manufacturers.

WT Henley EPDM has been subjected to a very wide range of tests and has always passed them, performing very well. In addition, tests to check the mechanical construction of the composite insulator have been carried out and some of them are part of our routine quality check during manufacturing. Most important of all, is the fact that we can refer to about 27 years of service history.

WT Henley has proved to people that tend to prefer silicon rubber, that the base rubber used in a compound is not relevant. The chemical combination of additives and filler is what makes a compound good or bad. WT Henley's "exclusive" formulation of EPDM has performed better than many other compounds including silicon based ones. The material has also revealed an ability to recover its Hydrophobicity revealing a very high quality of performance, not usually expected from EPDM compounds.

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TO COMPANY: Henley

FROM: Dan Wikström

ATTENTION: Mr. P. R. Gilbert

DEPT: Marketing

DEPT:

NO. OF PAGES (incl this): 2

DATE: February 7, 1995

MESSAGE:

07 FEB 1995

Dear Mr. Gilbert,

Thank you for your kind and interesting letter of January 30.

Regarding *Polymer Hydrophobicity* I have discussed your letter with our research project leader for ageing test methods, Dr. Igor Gutman, and we are pleased to give you the following comments.

We have the same opinion as you that hydrophobicity and erosion resistance can be two separate properties of the material. Thus, as you also indicate, two different modes of high performance could be valid. If a certain material can keep its hydrophobicity on a high level we will never have a high leakage current on its surface (mode 1). From the other side if we have this current on a high tracking and erosion resistant surface only limited, or insignificant, damage on the insulator will occur (mode 2).

You have a combination of two materials, which work in series: silicon rubber sealings with mode 1 and EPDM compound on the whole insulator surface with mode 2. Possible insulator performance in this case could be as follows. In the beginning of the test there is a fast reduction of the initial hydrophobicity of the EPDM, which leads to an increased electrical stress on the sealings with its relatively higher resistance at that stage. The discharge activity across the sealing might causes erosion damages. The discharge activity will also deteriorate the hydrophobicity of the sealing. Eventually, the hydrophobicity on the whole surface including sealings decreases and rather stable level of currents in the salt fog phase up to 200-250 mA were measured. This is a rather high level of current comparing for example with our experience in the same test with other test objects. However, the IEC 1109 cycle test is an accelerated ageing test and cannot be directly related to the real insulator performance in service. In addition to the results given in the reports, we got some interesting information about the speed of recovery of the hydrophobicity on your insulators after the test was stopped. It was a rather fast recovery process from HC 7 back to HC 2-3. If you are interested we would be pleased to forward these recovery measurements to you. Good recovery properties could be valuable for the long term performance in severe environments.

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We hope that you feel our information and conclusions given in the more extensive report, T94-205, could be useful in your product development. Our intention is not only to be a test laboratory, but also a collaboration partner who will apply the knowledge obtained within the different ongoing research projects. It is a pleasure for us to discuss the test result with our clients. For technical discussions you can also contact Igor Gutman, or our Research Manager, Ralf Hartings, directly.

Finally, we would of course be pleased to offer you further tests according to IEC 1109 annex C also on any new type of insulator you might have. We are planning to run the chamber more or less continuously in the future and after the presently planned test series (estimated completion in November this year), test positions could be available for you to the same conditions as for the previous test. We would be pleased to send you a formal offer and reserve the necessary test positions for you.

Yours sincerely,

Dan Wikström