Test method

Test protocol

1 Introduction

This document describes the method of testing winding wire insulated with corona resistant (CR) polyimide (PI). The CR-PI material has a thermo-adhesive layer (typically of fluorinated ethylene propylene, FEP). This type of wire is manufactured by wrapping CR-PI tape around the wire with a predetermined overlap and thermally bonding the FEP layer with a subsequent heat treatment. The amount of overlap (and resulting number of layers) depends on the specific voltage demands and is determined in separate material specifications for insulated winding wire types.

The test method is based on an earlier testing method used in the past for approval of winding wire [1]. It is performed by applying a sinusoidal high voltage with frequency 1050 Hz to wire samples that are placed in a container filled with metal balls (a 'shot-bath'). The shot bath is at ground potential and the wire samples are exposed to voltage levels predetermined for the type of wire being tested (i.e. depending on the insulation thickness). The time to electrical breakdown determines the 'lifetime' of the sample at the given test voltage. The voltage levels to be used and the minimum times to failure (or 'lifetimes') are specified in separate material specifications for each type of winding wire.

This test is to be performed as a type test to approve (or renew the approval of) the suppliers of this type of wire. This means that the test is performed to provide concurrent approval of the insulating CRPI *material* together with the *method* with which the insulation material is applied to produce insulated wire.

This test can also be conducted at frequencies of 10 kHz and 20 kHz to increase the rate of aging. The target is to simulate a 20 000 and 40 000 hours aging in corona effect.

2 Test equipment

The equipment used for testing includes a high voltage source that provides the stable high frequency voltage with associated safety measures and connected to circuit breakers and timers that can measure the elapsed time to the electrical breakdown of the samples being tested. The shot-bath sample holder must also conform to specifications that ensure repeatable measurements. Both of these items are described in more detail below.

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2.1 Voltage source

The voltage source shall provide a constant, sinusoidal voltage with a frequency of 1050 Hz. The power of the equipment shall be sufficient to deliver the necessary voltage and current for the specific type of wire being tested and the number of samples tested in parallel (minimum of 5 tested concurrently). The voltage source shall be equipped with timers and circuit breakers or fuses that can determine the time from the start of the test to the electrical failure of each sample (the so-called 'lifetime' of each sample).

2.2 Sample holder

The sample holder to be used for the tests consists of a container or tub filled with metal balls (or 'shot-bath') that can be placed in an oven for preconditioning the samples. The container shall be constructed so that continuous ventilation of the shot bath is possible during the testing process (to remove any erosion byproduct materials from the testing area).

2.2.1 Description of metal balls

The shot bath shall consist of balls with a diameter of 1.5 mm. The shot shall be made from stainless steel, (see e.g. [2]) or in special cases from lead. *Over a period of time of testing with discharging, the surface of the shot in the bath can be affected in such a way that the surface resistance of the balls increases (and consequently also reduces the voltage applied to the samples). To avoid this the balls shall be replaced or cleaned on a regular basis (note: metal balls are not to be changed during an ongoing test). With new, unused balls the resistivity can be determined using the method described in [3]. This value can then be used as a future reference to ensure that the ball resistivity has not changed in a way that can affect the test results.* This need to be proved.

The depth of the shot bath shall be sufficient to place the center of the samples under the surface with a depth of about 100 mm.

2.2.2 Relative humidity and ventilation

During the testing process the relative humidity in the test chamber shall be kept below 20%. This can be achieved by ventilating the shot bath and chamber with clean, dry air blowing from nozzles. Preconditioning the shot bath with samples shall be performed by placing it in an oven for 24 hours at a temperature of 40 - 50°C.

2.2.3 Electrical contacts

Electrical contact shall be made with the shot bath so that it is at the ground potential. This shall be implemented by making the ground connection to a large surface area of metal below the shot bath (e.g. copper foil) at the bottom of the container holding the shot. Note that the foil may need some form of perforation to allow the ventilation. The high voltage source shall be connected to the sample objects.

3 Sample objects

For comparison of test results it is important that the samples tested be of comparable size and with comparable surface areas. The samples are to be made from insulated winding wire as provided by wire suppliers for approval according to the test method.

3.1 Insulation thickness

The thickness of the insulation layers on the insulated copper wire according to the relevant material specification shall be verified by measurements on a piece of insulated wire with a length of at least 100 mm prior to sample fabrication. This is performed by measuring the total thickness on wire with insulation in five places and then repeating the thickness measurements after the insulation has been removed from the copper wire. The difference between the arithmetic mean of the five measurements before insulation removal and the arithmetic mean of the five measurements after insulation removal is the double sided insulation thickness (2s). The value obtained must be the same as in the relevant material specification (within tolerances). Note that the value obtained is two times the insulation thickness applied on the copper wire.

3.2 Sample size and preparation

The winding wire used for testing shall have a thickness of 1.5 mm or greater and a width of 6.0 mm or greater. The winding wire shall be cut into samples with lengths of about 600 mm for testing. Each sample shall have the insulation removed on one end for connection of high voltage source.

~~The samples shall be bent into a 'U' shape so that the ends can be held above the surface of the shot bath with a safe distance (to avoid flashover). The U-shape shall be formed so that at least 400 mm of the sample length is in contact with the metal balls of the shot bath (i.e. under the 'surface' of the shot bath).~~

The samples are straight and not formed in a U shape to be sure there is no problem with anamorphosis due to the thickness of the wire. There is 400 mm straight in the shot balls (show the **Figure 1**).

3.3 Sample preparation in test cell

The number of samples to be tested (as determined by the relevant wire specification) shall be prepared and placed into the shot bath of the sample chamber and connected electrically as described above.

Note: Once the samples are placed in the shot bath they shall not be moved until *all* of the samples tested concurrently have failed or testing is concluded.

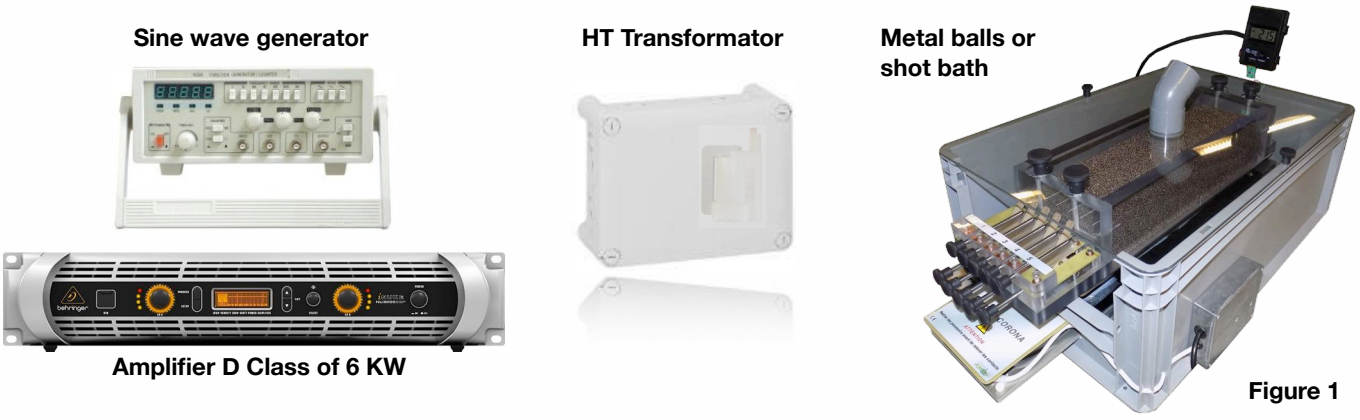


Figure 1

4 Testing process

The process for testing shall be performed as shown schematically in **Figure 1**:

4.1 Preparation for testing

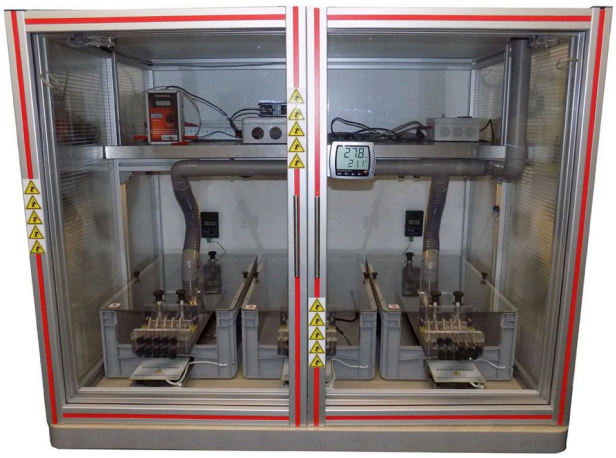
- Check the resistivity of the shot bath to determine that it is acceptable [3].
- Prepare samples and put in shot bath as described above
- Pre-condition the samples in the shot bath by heating for 24 hours at 40 – 50 °C.
- Make electrical connection to each of the samples
- Start the ventilation of the test chamber with the dry air

4.2 Testing process

Note: Once the samples are placed in the shot bath they shall not be moved or touched until *all* of the samples tested concurrently have failed or the testing process is terminated (e.g. when minimum required lifetimes are reached for samples that haven't yet failed).

The testing process shall be performed according to the following:

- Ensure that the ventilation of the testing chamber maintains the relative humidity at levels of 20% or lower.
- Increase the voltage to the level prescribed in the relevant material specification.
- The applied voltage and ventilation shall be periodically checked during the entire testing period.
- When a sample fails electrically note the corresponding failure time and disconnect the HV source from the failed sample (do not remove the sample from the shot bath!).
- Continue the testing process until all samples in the group being tested have failed (or reached the minimum required lifetime).



5 Reporting

At the conclusion of the test the results shall be reported with information about the samples tested (supplier, dimensions, insulation material supplier, …) and the results (number of tested samples, lifetimes, pass/fail, …). A documentation of the appearance of the tested samples after testing (color, locations of any failures), preferably with photographs, is also important.

6 Reference List

‘Beglimmversuche an Drahtprüflinen” (Eng: Corona testing of wire samples). Test document from ABB, 1994-11-17, Document number HTAE 660173. Note the same document is in Bombardier’s electronic document system with the same number.

“Winding wires - Test methods – Part 5 Electrical properties”, Testing standard IEC 60851-5 §4.7.1, July 2008.

Documentation of method from Birr Lab for determining resistivity of shot bath with pressure and resistance measurements.