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CERAMIFYING INSULATION MATERIALS FOR FIRE SAFETY CABLES

Graeme ALEXANDER, Olex (a Nexans company), (Australia), galexander@olex.com.au
Kenneth BARBER, Olex (a Nexans company), (Australia), kbarber@olex.com.au
Donavan MARNEY, CSIRO, (Australia), donavan.marney@csiro.au
Dong Churl LEE, Olex (a Nexans company), (Australia), dlee@olex.com.au

ABSTRACT

Traditional fire safe or fire performance cables rely on mechanical supports, like mica/glass tapes or metal sheaths to achieve their fire rating. A new, fully extruded design has been developed in Australia by Olex Australia, in conjunction with the Cooperative Research Centre for Polymers and CSIRO.

The new cables are insulated with a composition that progressively converts from polymer-based to ceramic when subjected to fire. Cables made with these materials have been successfully tested to international Standards (IEC 60331, BS6387 cat C,W,Z) and also the Australian AS/NZS3013, which requires 2 hours in the standard time-temperature regime used in the building industry (1,050 °C, similar to DIN4102 Pt 12), followed by 3 minutes of water-jet spray. This paper includes practical information on the testing process behind this innovative new insulation concept.

KEYWORDS

Fire safety, fire performance, circuit integrity.

INTRODUCTION

Fire in confined spaces, in particular buildings, is a hazard to life and property. There are statistics that indicate that this is a problem in all countries to a greater or lesser extent, hence the need for the many fire standards and codes which seek to regulate the design of buildings, what goes into them, and the subsequent development of the science of fire [1-5].

The presence of increasing numbers of cables in buildings has also led to concerns about the possibility of fire spreading along cables, in particular in vertical risers, and there are a number of tests that are applied to measure the tendency of this to happen (e.g. IEC60332). However, this is not the kind of cable we are addressing with our new insulation material, even though we can also comply with this kind of fire safety. The specific problem addressed by this development is providing a continuing service when there is a fire in a section of an installation. This function is generally known as providing circuit integrity [6,7]. Applicable Standards are IEC60331, DIN 4102 part 12, BS6387, etc. In Australia, the relevant test is AS/NZS3013:2005, and tests to this Standard are the main focus of this paper.

HISTORICAL SOLUTIONS

Originally, cables that satisfied the requirement of circuit integrity were of the type known as metal sheathed, mineral insulated cables (MIMS). These cables were/are difficult to install, compared to standard cables, requiring special equipment and techniques. The finished terminations are also potential sites for moisture ingress, which leads to a loss in insulation resistance and a loss in function of the circuit. The bending radius of these cables is also comparatively large and the cost of the cable and the installation is high.

Work began in the 1970's to develop cables that could still provide circuit integrity, but addressed the shortcomings of the MIMS design. The most satisfactory designs harnessed the mica-glass tapes available from the transformer industry in the form of a wrapped tape over the conductors. This solution addressed many of the shortcomings of the MIMS cable, being more flexible and resistant to moisture and lower cost of cable and installation, but new problems were introduced. The taping process was/is very slow, the tapes themselves are very expensive, there is a risk that the tapes will not be completely removed during installation and the tapes make the cable less flexible and more difficult to install than a standard cable.

Many researchers began exploring the concept of providing a material that could transform from a polymeric to a ceramic structure to overcome the remaining problems arising from use of the mica-glass tape [8,9]. An extrudable material would conceivably be much faster to apply than a tape, and could result in a lower cost solution. This paper shows some of the highlights in the development of cables of this type, focusing on the Australian market.

COMPOSITION DEVELOPMENT

Laboratory preparation of compositions for testing and prototype making is fairly straightforward, but complex and demanding. A "design of experiment" technique is used to generate possible compositions, that are then prepared and tested for key criteria, including ceramic strength and shrinkage. Standard equipment is used, and the compositions must also be suitable for normal insulation and handling requirements, as well as ceramification.

Testing for normal requirements is done before any fire testing. It has been found that due to the activity of copper metal at 1,000 °C, and also the relative coefficients of expansion and contraction of the copper metal, its oxides and the ceramic insulation, that cable prototypes are needed for evaluation of changes to the composition. Electrical resistivity at 1,000 °C is considered particularly important, and through trial and error we have found that we need a minimum of 1 megaohm at this temperature in our lab tests to make advancement to full scale testing worthwhile.

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SMALL SCALE LABORATORY TESTS

Test cables are made using 1.5 mm^2 plain copper conductors (7/0.5 mm), insulated with the test composition. The insulated conductors are then twisted into pairs, and then placed into a tube furnace. The ends are connected to a Smartek continuity tester model MI23 (Metrel), and the recording of DC resistance (500V) is begun. The furnace heating is initiated, and a plot made of resistance as a function of temperature. A resistance – temperature curve of the cables which have subsequently been tested according to AS/NZS 3013 is shown in Figure 1. An internal acceptance criterion of 1 MΩ at 1,000 °C is applied and indicated by the red cross. As can be seen from the plot, only those compositions circled meet this requirement.

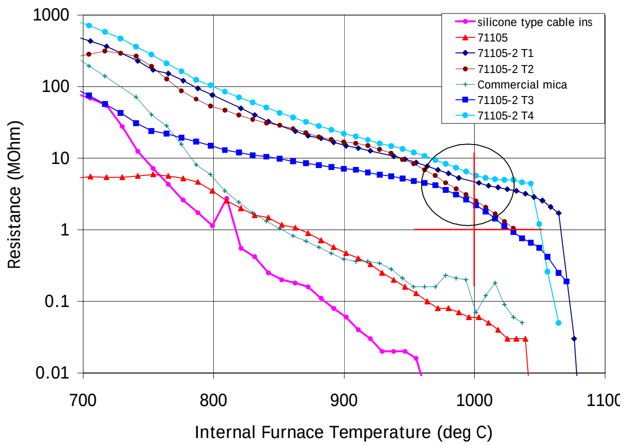

Figure 1: Tube Furnace Resistance Test Results

FULL-SCALE TEST CONDITIONS

AS/NZS3013:2005 requires 2 hours of circuit integrity under furnace conditions at temperatures of up to 1,050 °C, followed, in less than 15 minutes, by 3 minutes of water spray exposure. The time temperature curve of the furnace is shown in Figure 3. The circuits are live during the furnace and the water spray exposures. The circuits are at 240/440 V AC, with a load supplied by a 60W incandescent globe. A 4A fuse in the circuit indicates pass/fail by short circuit. A diagram of the circuit is shown in Figure 2.

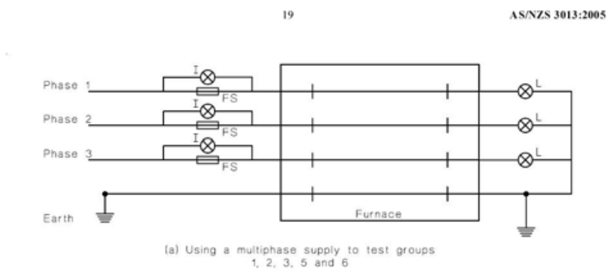

Figure 2: Circuit diagram

The Standard requires the tests to be carried out on a cable installed in a manner in which the circuits would be used in practice. As the most usual, and possibly most onerous arrangement, is installation on metal trays, this method is used for this test.

The cable specimens must also be bent through two 90 degree bends in the length of the tray as shown in Photo 1. They are held in place with stainless steel and nylon ties, although the nylon ties are not fire resistant and are destroyed in the first few minutes of the test. The tray is supported at each end outside the furnace, and also with a trapeze arrangement inside the furnace. The tray is attached to a concrete slab that becomes the top surface of the furnace – see Photo 3.

The furnace is computer controlled to the standard curve – figure 3, and any deviation is recorded both electronically and also on paper printout. The circuit monitoring lights are video taped over the period of the test, which allows both a record and a means of determining the time of failure, where appropriate.

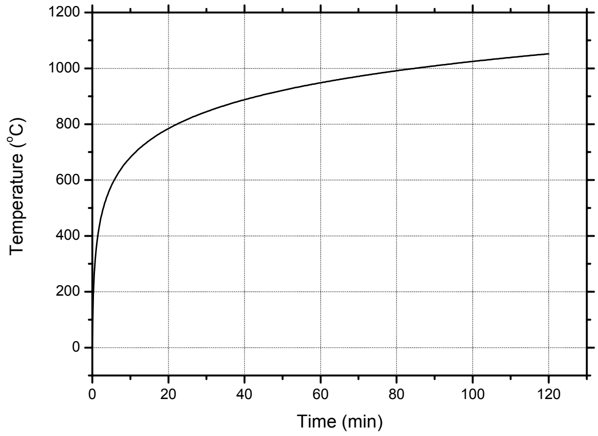

Figure 3: Standard Time-Temperature Curve for AS/NZS 3013

Photo 1: Cables on tray prior to test

SPECIFIC TEST IN FEBRUARY 2007

We have carried out more than 70 full scale tests of this type.since 2003, with the arrangement as shown in Photo 1. We have fully qualified various cable types and designs. From our experience, the most difficult types to meet this test are multicore cables, because of the reduced core to core and core to earth separation. An example of this type of test is described below.

Four cables were tested at Warrington Fire Research Australia, Dandenong South, Australia [10]. All were 1.5 mm^2 multicore designs, one being a commercially available, silicone insulated type, two being experimental ceramifying insulation, and the fourth being a mica taped cable as a reference.

This test was heavily instrumented, as shown in Photo 2 below. All circuits were monitored individually for current, and a chart of current as a function of time was recorded. Figure 4 shows typical current traces of each circuit during the test period until they fail the test. In Figure 4, one core from each cable was selected to present results of the current monitoring.

Photo 2: Image of connections on test cables

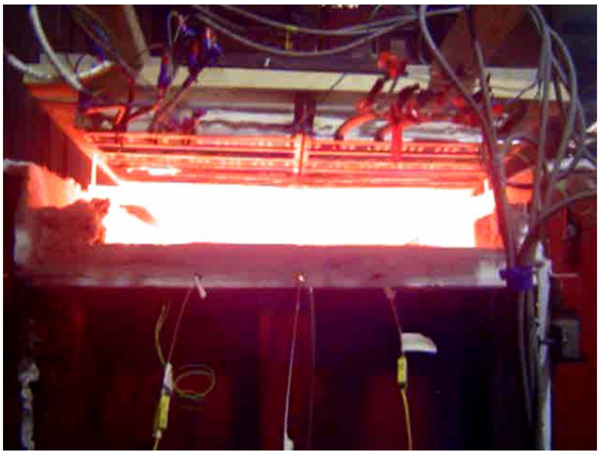

Photo 3: Slab being removed from furnace at the completion of 2 hrs exposure

TEST RESULTS AND DISCUSSION

The furnace is computer controlled to the standard curve Figure 3, and any deviation is recorded both electronically and also on paper printout. The circuit monitoring lights are video taped over the period of the test, which allows both a record and a means of determining the time of failure, where appropriate.

The additional monitoring equipment used in this test run showed that the current in the circuits remained constant at 0.25 A, unless there was a failure, at which point the current increased by *ca.* 10 mA just before the fuse tripped and the circuit failed. One possible explanation could be found in the concept of a catastrophic event, which can eventually lead to sudden failure of the test circuits. Figure 1 shows rapid drops of insulation resistance at around 1000 °C at each end of the test, which seem to be a typical behavior of the cable insulation. It is clear that our internal acceptance criterion of 1 MΩ can help to prevent such a catastrophic event. The reason for this behavior is still the subject of further investigation.

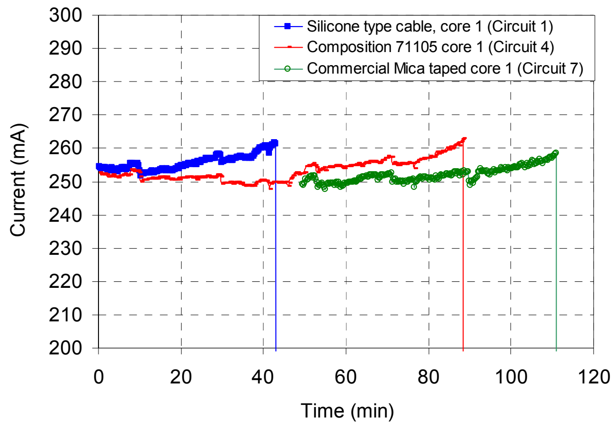

Fig 4. Current Monitoring Results

Table 1: Results for February 2007 WFR test

Circuit	Description	Furnace (min)
1	Ceramifying silicone type; core 1	48 (911 °C)
2	Ceramifying silicone type; core 2	40 (877 °C)
3	Ceramifying silicone type; core 3	40
4	Composition ref 71105 3 core; core 1	92 (1,013 °C)
5	Composition ref 71105 3 core; core 2	92
6	Composition ref 71105 3 core; core 3	120 (PASS)
7	Commercial Mica taped; core 1	112(1,038°C)
8	Commercial Mica taped; core 2	112
9	Commercial Mica taped; core 3	120 (PASS)
10	Composition ref 71105-2, 4 core; core 1	120 (PASS)
11	Composition ref 71105-2, 4 core; core 2	120 (PASS)
12	Composition ref 71105-2, 4 core; core 3	120 (PASS)

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CONCLUSIONS

It is evident from this testing that conductors insulated with a composition that transforms into a ceramic in a fire can have similar or better results than mica taped conductors. The performance of the composition can be altered to suit different fire conditions, such as are encountered in different types of fire tests. This promises to lead to more, lower cost fire safety cables and a corresponding increase in the size of the market as fire safe cables become competitive with standard cables, both in cost of materials and installation.

ACKNOWLEDGEMENTS

We would like to thank Mr Nick Rigoupolos from CSIRO Australia and Mr David Spark from Olex (a Nexans Company) for preparing the cables and assisting with both the large and small-scale tests carried out in this work.

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