A MULTISCALE ANALYSIS ON K1 QUALIFIED CABLES, TAKEN ON NUCLEAR POWER PLANTS, FACE TO THERMAL AGEING, IRRADIATION AND ACCIDENTAL CONDITIONS (LOCA)

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ABSTRACT

The objective of this study is to characterise the behaviour of a series of K1 qualified cables based on EPR (Ethylene Propylene Rubber) insulation, which have been sampled from French nuclear power plants between 2013 and 2016 after several years of service. The purpose is to verify that these cables exhibit good behaviour in the face of thermal ageing (TA), irradiation (IA 500 kGy) and finally to test their resistance to a LOCA (Loss of Coolant Accident). A multi-scale examination demonstrates the good resistance of these different K1 qualified cables face to thermal ageing, irradiation and LOCA conditions. Tests performed showed that they retain their functional properties during and after the LOCA, even after more than 30 years of service in the nuclear plants completed by additional thermal ageing and irradiation.

KEYWORDS

Rubber, EPR, Thermal ageing, irradiation, LOCA, multi-scale analysis

INTRODUCTION

Polymer materials are extensively used in electric power applications. In fact, due to their mechanical properties and excellent thermal stability, polymers are mainly used as external sheaths and insulations of cables. In service, these materials are potentially submitted to constraining environmental conditions such as elevated temperature or irradiation. In these conditions, chemical degradation can take place and affect the mechanical integrity of rubber pieces, reducing their lifetime. Since the early 2000s, the EDF R&D team of polymers is interested in the study of the multi-scale analysis ageing of polymers (at the molecular, macromolecular and macroscopic levels) used in nuclear power plants, in particular in electrical cables. EPR (Ethylene Propylene rubber) is usually used as insulation for K1 qualified cables that are subjected to thermal and irradiation ageing and to accident conditions. The aim of this study is to demonstrate the good behavior of these K1 qualified cables for long term operation and especially during and after a LOCA *beyond 40 years of service*.

1. STUDIED MATERIALS

Two types of cables are studied:

- 4 cables sampled from the nuclear power plants (A, C and C units) after more than 30 years of operation (A(with three insulators: A-a, A-b, A-c), B, CBT and CMT)
- 2 stored cables from EDF library of cables used for comparison (D and E).

2. AGEING CONDITIONS

Natural ageing: for cables taken on site (about 30 years of operation) and for stored cables (about 30 years at room temperature)

Complementary ageing: applied to simulate additional 20 years of operation, all cables have been submitted to a thermal ageing (TA) of 240 h at 125°C and a total radiation dose (IA) of 500 kGy (including 250 kGy for ageing and 250 kGy for accident) at a dose rate of 1 kGy/h at 70°C.

Aged samples configurations: For practical and technical reasons, samples characterized after **LOCA** were aged as «**whole cables** (where insulators protected by some barriers: reinforcement bars or intermediate sheaths)» whereas samples characterized after **TA** and **IA** ageings were aged as «**conductors** (where the insulators are aged in the most penalising conditions: direct exposure to the stress)».

3. MATERIAL CHARACTERIZATIONS

Material characterizations are performed before and after each type of stress (thermal, irradiation and LOCA tests).

3.1. Mechanical characterization :Tensile strength test: determination of ultimate mechanical properties

The tensile strength tests are carried out according to the recommendations of standard NF EN 60811-501. Two mechanical properties are studied: the elongation and the stress at break determined on tubular specimens (for low voltage cables (LV)) and on dumbbells type H3 (for medium voltage (MV) cables and those originating from the library of cables). The measurements are carried out using an INSTRON machine. Each time, 7 test pieces per insulator are pulled, using the following characteristics:

- Useful length (by extensometer): 20 mm
- Cross piece speed: 50 mm/min
- Force cell: 500 N

The tests are carried out in an air conditioned room at 20°C ± 1°C and 50 % ±5 % relative humidity.

3.2. Physico-chemical characterizations

3.2.1. DSC analysis: determination of glass transition temperature (Tg) /melting temperature and enthalpy (T_m, ΔH_m)

The measurements are carried out using an ETZSCH DSC 204 F1 Phoenix machine. The experiments are carried out