A Study of the Equality of Cable Insulations by comparing aging trend using an Oxidation Induction Time Measurement Test

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1. Introduction

There are numerous cables in the nuclear power plants, and the cables, especially inside containment, are exposed to the harsh environment. They need to be environmentally qualified; by and steam test; high temperature and high pressure with the same condition of DBA and radiation condition.

Usually, the environmental qualification test is carried out by the cable manufacturer and the test report is presented while the cable manufacturer supplies the tested cables in nuclear power plant.

If a cable manufacturer has environmentally qualified a cable for nuclear power plant more than a decade ago and the composition of the cable material is same, is it acceptable to use the old EQ report for recently manufactured cable?

Even though the manufacturer insists the composition of the tested cable and recently manufactured cable's material are same, there can some questions or opposing opinions for two cables, tested cable and recently manufactured cable's equality.

In this case, how can I determine the equality for the two cables?

It is well known method to use FT-IR to determine the similarity of cable materials. FT-IR is easy tool to compare compositions of each material. But FT-IR method is not proper to compare aging trend of these materials.

Oxidation induction time(OIT) testing is a technique that can be used to evaluate aging of organic materials and life assessment technique for cables used in nuclear power plants.

In this paper, I studied the OIT technique to compare aging trend for the tested cable and recently manufactured cable to determine the equality for the two cables.

2. Methods and Results

2.1 OIT Measurement

The OIT measurement test is a technique that can be used to evaluate the aging of organic materials. The OIT measurement test can be used as an evaluation of the cable life time technique for electric cables used in electric power plants, including the control, instrumentation, and power cables. Polymers age by means of chemical reactions with oxygen. Antioxidants are chemicals added to polymers in order to inhibit oxidative reactions. As long as the antioxidants remain in an insulating polymer, the properties of the cable insulation material do not degrade significantly. The OIT assessed is related to the amount of antioxidant remaining in a polymer, and thus to the age, or remaining life, of the polymer[1].

For the OIT measurement test, we followed the recommendations provided by the ASTM D3895 standard [2]. The sample to be tested and the reference material are heated at a constant rate in an inert gaseous environment (nitrogen). When the specified temperature (typically between 180℃ to 220℃) has been reached, the atmosphere is changed to oxygen maintained at the same flow rate. The specimen is then held at constant temperature until the oxidative reaction is displayed on the thermal curve. The time interval from when the oxygen flow is first initiated to the oxidative reaction is referred to as the induction period. The end of induction period is signaled by an abrupt increase in the specimen's evolved heat or temperature and may be observed by a differential scanning calorimeter (DSC). The OIT is determined from the data recorded during the isothermal test. Figure 1 shows how to evaluate OIT from recorded-time-base thermogram.

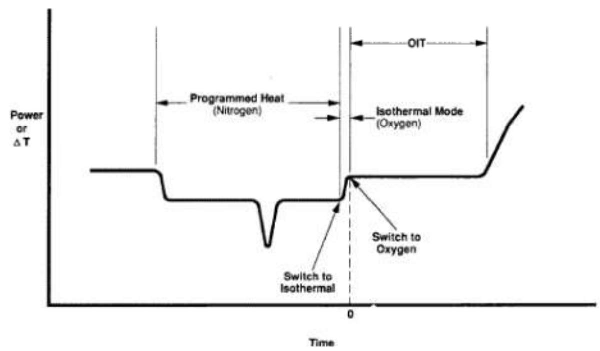

Figure 1. Evaluation of the OIT from recorded time-base thermogram

2.2 Sample Preparation

The sample material used in this paper is 'tested cable' and 'recently manufactured cable'.

As the test report is prepared for Han-Ul NPP Unit 3&4 EQ cable in 1995, the 'tested cable' is selected as Han-Ul NPP Unit 3&4 EQ cable produced in 1995 stocked in the Han-Ul NPP Unit 3&4 warehouse. The 'recently manufactured cable' is chosen as Shin-wolsong Unit 1&2 EQ cable produced in 2013 by the same manufacturer that the manufacturer insists the composition of the two cable is same.

Figure 2 shows the 'tested cable' from Han-Ul NPP Unit 3&4 and figure 3 shows the 'recently manufactured cable' from Shin-Wolsong Unit 1&2 EQ.

Figure 2. The 'tested cable' from Han-Ul NPP Unit 3&4

Figure 3. The 'recently manufactured cable' from Shin-wolsong Unit 1&2

2.3 Equality analysis method

To investigate the two cables' aging degradation trend s, the OIT tested for three steps; initial OIT test, after Normal Radiation OIT test and after Thermal Aging OIT test for the cable produce in 1995(called '95 cable) and the cable produce in 2013(called '13 cable). The normal radiation and thermal aging condition is determined as same as the test reports. Table 1 shows the equality analysis procedure.

No	Step	Remark
1	Initial OIT test	
2	Normal Radiation Aging Test	Total Integrated Dose 40MRad
3	After Normal Radiation OIT test	
4	Thermal Aging Test	Thermally aged for 144 hours at 170℃ equals to 40 years qualified life at 90℃
5	After Thermal Aging OIT test	

Table 1. The equality analysis procedure

2.4 Experimental Results

The OIT measurements were performed using a Diamond Pyris DSC by PerkinElmer. An OIT temperature of 225℃ was used to reduce the experimental time. The weight of 5mg, as recommended in ASTM D3895, was used.

2.4.1 The OIT measurement test results of the '95 cable

The OIT measurement test results of the '95 cable of initial, after Normal Radiation and after Thermal Aging are shown in table 2 and figure 4, 5 & 6.

Temperature (℃)	Initial Test OIT(min)	After Normal Rad OIT(min)	After Thermal Aging OIT(min)
225	111.141	30.115	4.728

Table 2. The OIT measurement test results of the '95 cable

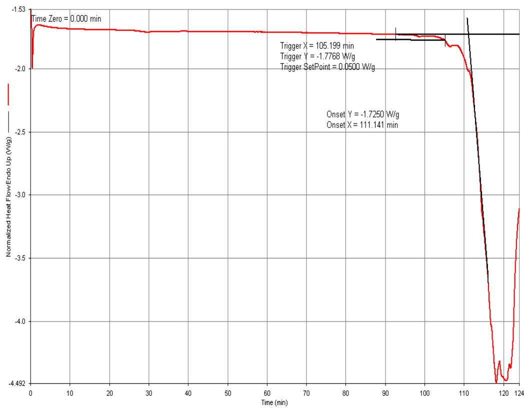

Figure 4. The initial OIT measurement test result of '95 cable

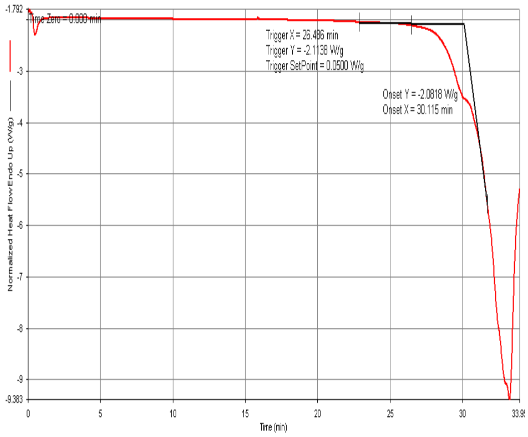

Figure 5. After Normal Radiation OIT measurement test result of '95 cable

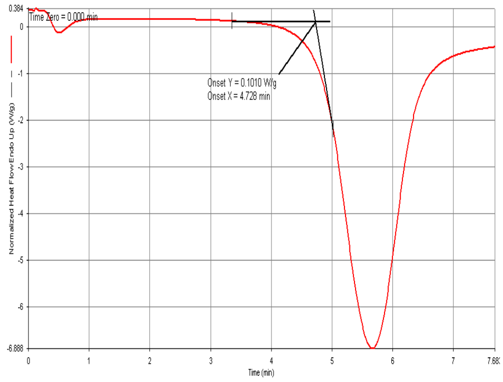

Figure 6. After Normal Radiation OIT measurement test result of '95 cable

2.4.2 The OIT measurement test results of the '13 cable

The OIT measurement test results of the '13 cable of initial, after Normal Radiation and after Thermal Aging are shown in table 3 and figure 7, 8 & 9.

Temperature (℃)	Initial Test OIT(min)	After Normal Rad OIT(min)	After Thermal Aging OIT(min)
225	114.361	26.053	4.879

Table 3. The OIT measurement test results of the '13 cable

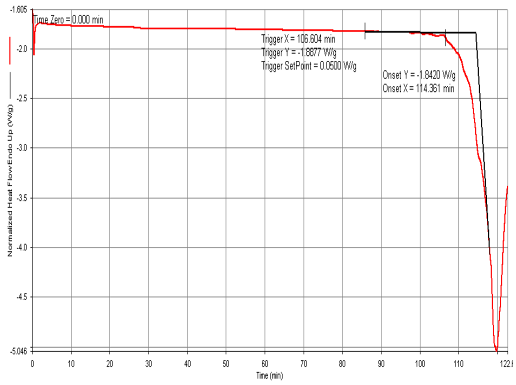

Figure 7. The initial OIT measurement test result of '13 cable

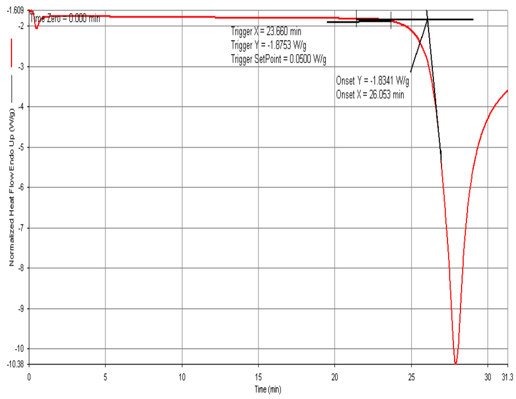

Figure 8. After Normal Radiation OIT measurement test result of '13 cable

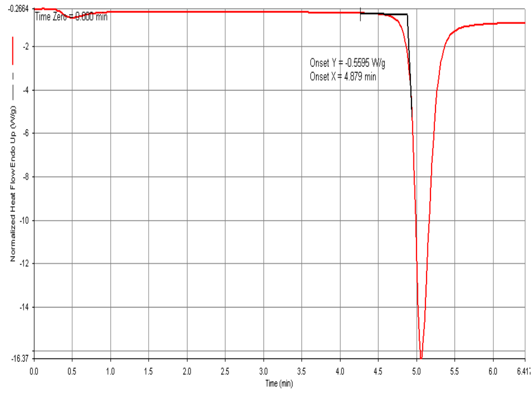

Figure 9. After Normal Radiation OIT measurement test result of '13 cable

2.4.3 The comparison of aging degradation trends

To analyze the two cables' aging degradation trends, the OIT measurement test results of the '95 cable and '13 cable of initial, after Normal Radiation and after Thermal Aging are compared. The comparison of the two cables' OIT value decrease trend is shown very similar, is described in table 4 and figure 10.

sample	Initial Test OIT(min)	After Normal Rad OIT(min)	After Thermal Aging OIT(min)
'95 cable	111.141	30.115	4.728
'13 cable	114.361	26.053	4.879

Table 4. The comparison of the two cables' OIT value

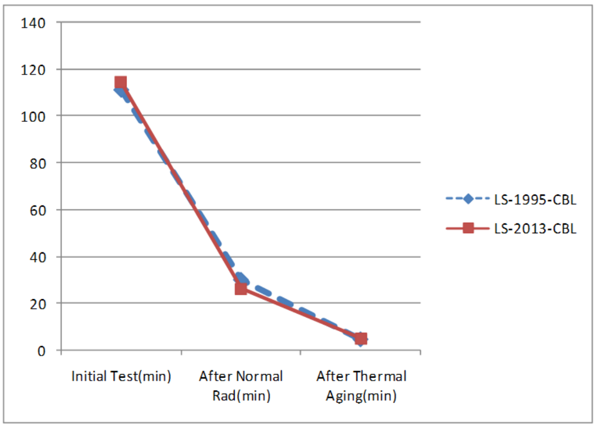

Figure 10. The comparison of the two cables' OIT value decrease trend

3. Conclusions

To study a equality analysis for cable materials, OIT measurement tests were performed for two cable insulation(produced in 1995 and produced in 2013) which were supplied from same manufacturer.

The two cables were irradiated up to 40Mrad to simulate normal 40 years and thermally aged for 144 hours at 170℃ equals to 40 years qualified life at 90℃.

The OIT measurement were made in order to compare aging trends of the ’95 cable and the ’13 cable, the test were performed for three sequential steps; initial, after Normal Radiation and after Thermal Aging.

The OIT measurement results at the temperature of 225℃ showed very similar degradation trend, it means the two cables' aging degradation characteristics are almost same.

Therefore we could conclude that there is no difference between ’95 produced cable and ’13 produced cable. Consequently, the EQ test report of ’95 cable is valid for the cable produced in 2013.

From the result of this test, it was found that OIT measurement test can be effective to compare aging trend or degradation characteristics of polymer materials.

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