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Method and Experience of Equipment Qualification(EQ) for Cable in NPP

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1. Introduction

Various kinds of insulated cables are used to carry electricity or electronic signals, more precisely, to provide power, control and signal to instrumentation or equipment in nuclear power plants. The performance of cable mainly depends on polymeric insulating materials, since bad insulation of the cable makes a false signal or a short circuit. Polymeric cable materials are usually made up with cross-linked polyethylene (XLPE), ethylene propylene rubber (EPR), silicone rubber (SR), and chlorosulfonated polyethylene (CSPE). The cables should be qualified to last for over 40 years in plant areas exposed to normal and accident environments.

This paper introduces not only codes, procedures, and acceptance criteria of the cable qualification test, but also the type testing experience of the EPR insulated cable during testing period.

2. Analysis of the test standards for EQ

The cable qualification test is presented in a variety of regulations, codes and guides including the Enforcement Regulation and Rules of the Nuclear Safety Law, technical requirements applying to the nuclear equipment installations. The major points are summarized in Table 1.

<Table 1> Major technical standards of EQ for Cables

Technical standards		Applications
KOREA	USA	
Nuclear Safety Law, Enforcement Regulation and Rules	10CFR50.49 [1]	Legal requirements for qualifications
Ministerial Ordinance of Technical Requirements Applying to the Nuclear Installations Article 15,40,70	Reg. Guide 1.89[2] Reg. Guide 1.211[3]	Regulatory requirements for qualifications
Regulatory Standard and Guideline for PWR		
KEPIC END 1100	IEEE 323[4]	Comprehensive test requirements for qualifications
KEPIC END 3810	IEEE 383[5]	Test requirements for Cables

The Enforcement Regulation and Rules of the Nuclear Safety Law, which is considered as the high-level basis for qualification test, describe the qualification program for safety related electric equipments. IEEE 323 prescribes the test requirements of qualification test for all the safety related electric equipments describing the purpose, object, test plan and paperwork in detail. In particular, IEEE 383 is the most detailed requirement for the qualification test of cables. Therefore, the main standards of qualification test for the cables are IEEE 323 and IEEE 383.

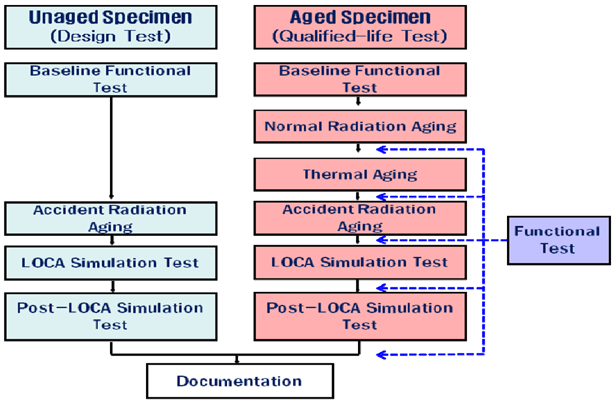
3. Test procedures and methods

3.1 Test procedures

The qualification test is divided into performance tests and aging tests of postulated conditions for normal and accident environments. According to the type of the qualification cables, the test items of the aging test are similar to each other, but those of the performance test are the same. Performance tests are conducted to determine whether the cables maintain the function and performance in line with acceptable standards during the test.

Normal environment aging tests are thermal and radioactive aging tests during design life time in service location. Accidental environment aging tests of the so-called Design Basis Event (DBE) are MSLB and LOCA simulation tests for 1 year period after design life time. The procedures of the qualification test for the cables are shown in Figure 1.

The qualification test shall include design test for new cable and qualified-life test for end-of-design life cable. The design test will demonstrate the adequacy of design to meet requirements which are related to accident aging. The qualified-life test will address aging and establish the qualified life after the accident conditions. Design test may be performed in any sequence on different test specimens. Qualified life test shall be performed on preconditioned test specimens in the sequence and may be performed on test specimens that have not been subjected to design test.



<Figure 1> Test procedures (IEEE 323, 383)

3.2 Performance Criteria

The unique function and performance parameters on cables are in accordance with the test requirements of IEEE 383. The items of qualification test are the insulation resistance test, the voltage withstand test and bend test. The qualification test may be performed in any sequence on two test specimens. The insulation resistance test should be passed over 1Mega ohm for control cables. The voltage withstand test may be based on cable insulation thickness, and it is passed for 5 minutes at a potential of 80V/mil ac or 240V/mil dc. The bend test mechanically stresses the cable's insulation for flexibility test.

The acceptance criteria satisfied with the test conditions shall be used to determine whether the test is qualified or not. After all at the end of the test, qualification should be considered to be completed if the acceptance criteria of the performance are accepted. The key items of performance tests are insulation resistance, voltage withstand and flexibility. These performance values are compared between initial values and aging values. In particular, the acceptance criteria of the performance test shall depend on the requirements of either the service condition or the manufacturer specifications.

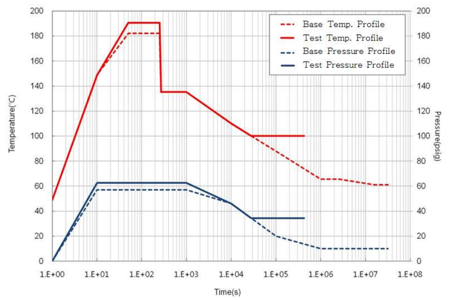
3.3 Qualification test

Qualification test shall be performed on the test specimens of both unaged and aged specimens. Each test specimen shall be subjected to an essential preaging prior to performing the DBE test.

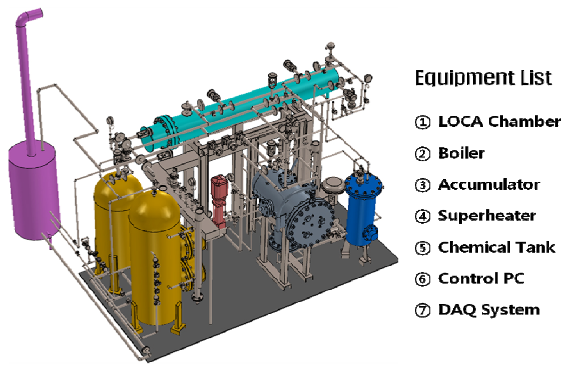
For thermal preaging, the test specimen shall be thermal age conditioned to simulate operation at design normal service temperature for the installed life. Accelerated thermal preaging time and temperature derived from arrhenius data or other methods. For radiation exposure simulation, the test specimen shall be exposed to radiation simulating the normal and accident service environment radiation for the installed life.

After preaging the following tests should be performed in the sequence given with the test set-up simulating the accident condition. This test is LOCA simulation test of the most severe DBE environmental conditions. This simulation test includes a rated load and voltage test, insulation resistance test at the same time.

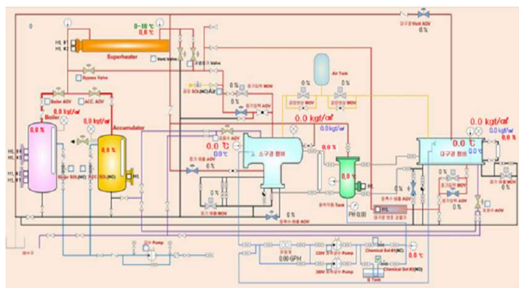
For example, Figure 2 is the typical test profile for LOCA simulation test. Figure 3 is the test facilities for LOCA simulation test. Figure 4 is the schematic diagram of test facilities.



<Figure 2> Test profile for LOCA simulation test



<Figure 3> Test facilities for LOCA simulation test



<Figure 4> Schematic diagram of test facilities

4. Experience and Lessons Learned from Test

Cable performance was demonstrated after thermal and radiation preaging by sustaining rated load throughout the accident test sequence with the cables wound on grounded mandrel. Cable post-LOCA bend voltage withstand test is performed with specimens immersed in tap water. The bend test stresses the cable's insulation such as creating a slightly strain and brittle on the insulation surface. It is likely to fail during the immersion voltage withstand test. Cable qualification test was performed with cables mounted on a 40-times diameter mandrel, and the cables were unwrapped and wrapped during the bend test.

SNL researches indicate that many cables subsequently failed in immerse voltage withstand test, but those cables performed satisfactorily during the accident simulation tests. The voltage withstand test was severe and it was noted that bend test of unaged cables didn't significantly increase the test severity [6].

Generally for control cable, the role of jacket is to provide mechanical protection to the underlying insulation during cable installation and handling, and it is not relied upon to perform an electrical function. Nevertheless, the qualification test of the bonded jacket is typically required in applications where the integrity of the cable jacket is essential to ensuring acceptable cable performance under postulated accident conditions [7].

Cable jackets have experienced more severe degradation than insulations during test programs. Although this may be due to the jacket's direct exposure to the accident conditions, it is more likely due to the jacket materials and their fire-retardant formulations. During the qualification test, these jacket materials have experienced longitudinal cracks and splits. In virtually all of these test programs, conductor insulations continued to perform their insulation functions. However, in several programs insulation failures have occurred due to interactions between CSPE jacket and EPR insulation. In these cases, conductor insulation damage is apparently caused by the brittle jacket cracking due to insulation swelling or extensive thermal and radiation degradation.

Jacket cracking of multiconductor cables may affect the performance of cables. The jacket cracks may provide moisture pathways into these devices, which bypass the connecting device-to-cable jacket environmental barrier. Pressurization can further force moisture longitudinally down the cable into these terminal devices. The testing lab has experienced test chamber steam leaks when using chamber-to-jacket seals, not individual wire seals.

5. Conclusions

In order to ensure EQ of cables, this study has analyzed the test codes and procedures of the qualification test for the cables which are used in NPP and systematized the test items, methods, and test equipments. The standards of the qualification for cables are laws, regulatory guidelines, industry standards in order, and the test codes are subdivided depending on the test items. The regulations and guidelines are the Enforcement Regulation and Rules of the Nuclear Safety Law. The industry standards are IEEE 323, and 383. After the completion of the test, the cable quality depends on whether the performance standards meet the acceptance criteria or not.

IEEE 383 requires LOCA simulation of both aged and unaged specimens. This study suggests that aged specimens are more susceptible to failure during LOCA testing. Cable jacketing materials have exposed more severe degradation than insulation during test programs, and then the jackets except for bonded jackets should be aged lower than insulation materials according to actually use normal and accident conditions.

Cable manufacturer should do appropriate nonmetallic materials selection, design and test. The nonmetallic materials are selected against thermal and radioactive weak materials. This study has used for localization of cable development, design qualification and cable qualification test method.

REFERENCES

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