Sealing pre-qualification for extreme operation conditions.

Zavadil, M.
ÚJV Řež, a.s.

Sealing of penetration at the reactor could be exposed to extreme operation conditions. Materials to be tested might be expensive, but still we do not know, which one is suitable. Experience is helpful, but sometimes there are new materials with unknown properties. If we want to distinguish suitable materials, we need to perform pre-qualification experiments. And if we want to be effective, we need to choose optimal solution, or, testing strategy. Initial considerations, possible set of experiments, few unexpected difficulties and several result examples will be presented to show complexity of testing. Main aim of the contribution is to share the experience, and to open discussion about possible testing strategies.

Environmental Qualification of Motor Insulation Systems

James M. Dean
AES Nuclear, Inc. (Representing Schulz Electric)

Most nuclear power plants have motors that are utilized in end use applications that require environmental qualification (EQ). This includes inside and outside containment applications including critical pumps, cooling fans and motor operated valves. This presentation will provide an overview and discuss the methodology utilized to qualify low and medium voltage motor insulation systems using the following standards:

• IEC/IEEE 60780-323 - Nuclear facilities –Electrical equipment important to safety – Qualification

• IEEE 344 - IEEE Recommended Practice for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations

• IEEE 334 - IEEE Standard for Qualifying Continuous Duty Class 1E Motors for Nuclear Power Generating Stations

• IEEE Std 382 - IEEE Standard for Qualification of Actuators for Power-Operated Valve Assemblies With Safety-Related Functions for Nuclear Power Plants

• IEEE 1776- 2008 - Recommended Practice for Thermal Evaluation of Unsealed or Sealed Insulation Systems for AC Electric Machinery Employing Form-Wound Pre-Insulated Stator Coils for Machines Rated 15 000 Volts and Below • IEEE Std 275–1992 - Recommended Practice for Thermal Evaluation of Insulation Systems for Alternating-Current Electric Machinery Employing Form-Wound Pre-Insulated Stator Coils for Machines Rated 6900 Volts and Below”

• IEEE Std 117–1972 - Standard Test Procedure for Evaluation of Systems of Insulation Materials for Random-Wound AC Electric Machinery • IEEE Std 101–1987 - Guide for the Statistical Analysis of Thermal Life Test Data

Two qualification campaigns of sealing types for nuclear application

F. Destaing, L Biringer**, E. Sauger*, J. Leray**

** Cetim : Centre Technique des Industries de la Mécanique*

*** EDF : Electricité De France*

Cetim is regularly implied in qualification of sealing systems for nuclear applications. This presentation will focus on two qualification campaigns concerning valves packings and mechanical seals.

Friction forces of valve packings are identified by EDF as an axis of improvement to avoid either changes of electric actuator or heavy and expensive modifications of valves.In this context, packing manufacturers have developed graphite and PTFE low-friction packings whose performance must be known.

In order to qualify these new products, EDF has decided to set up a project in partnership with Cetim as a testing laboratory as well as packings manufacturers.

In this project, several types of packing are tested for corrosion at ambient and high temperature. Cycling tests are performed to determine their sealing and friction performance. And cycling tests coupled with irradiation phases are carried out to qualify their resistance to radiation.

The approach adopted by EDF will be described, as well as type of tested packings, existing or developed test facilities in this project and experimental conditions.

Finally, test results carried out are presented as well as several scopes.

Development of ultimate safety pumps need the development of high performances mechanical seals.

In these applications, one of the main topics is the ability of elastomers seal to resist to high temperature ageing and high radiation level.

A specific test bench and test protocol has been developed by Cetim and Latty International in order to prove the O-ring capacities.

This presentation will describe the test performed and the results obtained.

In this study 8 different elastomeric materials were tested. Sealing properties were more particularly tested. Several phases were done: initial state of O-rings, mechanical ageing with fretting, thermal ageing at high temperature, thermal dynamic ageing, high level of irradiation with intermediary tests at lower irradiation levels, and final properties to know if the material is qualified or not.

In this study, test bench bespoke development for this test and means developed by Cetim will be highlighted.

Qualification of sub-suppliers and materials

Tomas Nälsen
Habia

The process of making sure the material we ship with each cable has the same properties as the material originally qualified through type testing.

Determining the uncertainty of activation energy of thermal degradation used for lifetime prediction

Vladimír Hnát

ÚJV Řež, a. s., Czech Republic

The presentation discusses the main sources and components that contribute to the total uncertainty in determining the activation energy used for lifetime prediction of materials subjected to thermal degradation. Either possibility of minimalization of some of these uncertainty components or even their total correction, which can be performed by proper evaluation procedure of experimental data coming from thermal ageing data, is discussed.

In the practice, the largest source of uncertainty is formed by temperature variance in the volume of the thermal chamber, the next one by time instability of temperature during different periods of thermal ageing (which is reflected also in the uncertainty of the ageing temperature). The less one is formed by the uncertainty of thermometers applied. The iterative method of thermal ageing data processing which makes possible the total correction of time instability of temperature and thus minimizes the uncertainty of thermal ageing temperature will be demonstrated.

Further, there will be discussed ways to overcome the problems arising from ageing curves that have various “non-standard” shapes and thus make more difficult to estimate the mean time to the end--point and its uncertainty. Finally, there will be shown some examples of influence of all the above discussed uncertainty components to the standard deviation of the linear regression line (Arrhenius plot) and thus to the uncertainty of lifetime prediction represented by confidence bands for the Arrhenius plot.

Selection of Strategy for Seismic Qualification of Equipment for Design Extended Conditions ("Beyond Design")

Rizzo Associates Czech
Marek Tengler

The subject of equipment seismic qualification is to verify functional capabilities in cases of postulated design earthquake events. Usually, for licenses purpose, there are stipulated minimally two levels of earthquakes. One is dedicated for earthquake events that can occur repeatedly during the facility operational lifetime and equipment shall sustain motions without any impairment and shall be ready for further operation. The second level is much stronger where the probability of the occurrence is very rare and only specific systems, its components, and structures shall withstand such motion in order to meet essential seismic safety mission. After this earthquake level, there is not count with further exploitation.

The two levels of earthquake determine a basic design robustness, all anti-seismic provisions and appropriate grade of documentations with respect to distinguished design codes, qualification standards and applicable design verification procedure.

In case of “beyond design” issues, gets on the evaluation of residual design capacity that stay above allowable limits given either design code or functional limitation defined by manufacturer. Critical aspect of seismic qualification for design extended conditions (i.e. loading parameters above postulated extreme conditions) is determination of seismic safety goals. The appropriate margin of design shall be accordingly quantified. The very useful and proven technique of the margin quantification is Seismic Margin Assessment (SMA). Application of SMA in the phase of plant equipment design is comprehensive method to assessed available reserves in the equipment design and herewith control predefined plant safety targets.

Experiences Taken from Preparation of Qualification Program for Cable Penetration Assemblies for 60+ years Target Qualification Life

Marek Tengler - Rizzo Associates Czech; Michal Klauber – Kabelovna Kabex

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Cable penetration assemblies (CPA) designed for applications in safety-related systems of nuclear power plants (facilities) shall follow general and specific design principles described by the standard IEEE Std 317-2013. CPA perform two important general safety functions. The first intended safety function is ensuring the pressure boundary of the containment and, in the case, keeps the harsh environment generated by accident conditions just inside hermetized zones. The second intended safety function is providing a conductive channel through a wall for medium voltage, low voltage, and coaxial/signal/optic cables in any service and postulated design conditions.

Although, the design of CPA is represented as passive component, it is formed into several functional groups comprise polymeric compounds, metallic and ceramic components integrated one tubular piece.

In general, the mission time of CPA is limited primarily by used polymeric materials that are mostly sensitive for thermal and radiation ageing. Equipment qualification process as is recognized in the new dual-logo standard IEC/IEEE 60780-323:2017 defined principles for determination of the qualified life. Important part of the process is performance of equipment type testing program during whose shall be simulated, in part, accelerated ageing conditions of thermal, radiation, wearing, vibrational (etc.) effects occurred during mission time (qualification life), thus, environmental conditions generated by accident conditions (severe radiation; sharp thermo-hydraulic elevation). Qualification process of CPA for long-terms mission is demanding and results are frequently wide scattered and ambiguous. Therefore Condition Monitoring (CM), as is introduced by IEC/IEEE 60780-323:2017, should always accompany qualification process.

Degradation of functional capability of the penetration assembly is bundled with degree of deterioration of material properties that can be expressed by measurable mechanical characteristics. Confirmation of qualified life and prediction of residual lifetime of sensitive components, in order planning of the equipment refurbishment, should be an essential part of long-term reliable service of safety-related system components.

Company Kabelovna Kabex (a.s.) are developing the new generation of CPA that are specifically designed for applications in nuclear facilities towards long-term service. Inseparable part of equipment qualification program is determination of CM indicators, nomogramig of predictive indexes, prescriptive guide for follow-up plant in-situ data gathering and benchamarking surveillance program encompassing natural aged witnessing samples. The complex qualification program involving ongoing qualification fully complies with nuclear quality requirements as are determined by Czech nuclear legislation.

ŠKODA JS EXPERIENCES WITH QUALIFICATION OF SELECTED COMPONENTS FOR CONTROL ROD DRIVE MECHANISMS

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This contribution describes experiences with process of selected components qualification designated for use in various types of control rod drive mechanisms (later CRDMs) and their parts, which were developed and are fabricated by company ŠKODA JS a.s.

In the beginning the review of main qualified components for CRDMs for VVER 440 and VVER 1000 type of reactors are mentioned together with description of standard qualification process that is based on our long-term cooperation with ÚJV Řež, a.s. Latest qualification program for position indicator of CRDM for LABGENE project in Brazil is described as well.

The final part of contribution deals with detailed presentation of qualification process of new stainless steel roller bearings that were designed and developed in cooperation of ŠKODA JS a.s. and company SLB, spol. s.r.o. During the products development the modern thermoplastics material KETRON PEEK 1000 was used for cages design to improve bearings performance and long life. Qualification of this solution is a first of this kind of qualified thermoplastic material for permanent operation in the CRDM in the environment of primary cooling water of reactor type VVER 440/213. Process of qualification was handled with respect to the all operation conditions of CRDM type PRO and PRO-M, which are produced by ŠKODA JS a.s.

LOCA Laboratories in Research Centre Řež

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Nuclear power plant safety systems and equipment have to stay functional during the normal operation as well as under the harsh conditions that may occur in the case of an accident. Therefore, the essential equipment for safety systems have to be tested and qualified to ensure their long-time durability. The process of testing involves subjecting the equipment to the conditions, comparable to the real accident. Our LOCA laboratories are designed to test the equipment located in the containment of nuclear power plant. The LOCA laboratories consist of the LOCA facility, the Gamma irradiation facility and the High voltage test laboratory.

The purpose of the LOCA facility is to create the same environment as in the containment of a nuclear power plant during the Loss of Coolant Accident. The laboratory is used for testing and development of new components for current and future generations of nuclear power plants

Our gamma irradiation facility is capable of irradiation of samples or components made of various materials for research and commercial activities. Due to its recent modernization, which involved the installation of an experimental box, it is possible to conduct experiments under temperatures ranging from -196 to 400 °C and pressures approaching high-vacuum. Such conditions allow to perform a large variety of experiments. The synergy of irradiation, temperature and pressure induces structural changes, which lead to material degradation. It is used for material aging before material test. The obtained knowledge is then applicable to multiple engineering fields like nuclear, aerospace and biological engineering.

The High voltage test laboratory allows us to perform testing of electrical components and cables. It is used in synergy with the LOCA facility and the Gamma irradiation facility to verify the electrical properties of tested components and specimens.

Fiber Optic Cable for NPP Harsh Environment

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The good experience with optical communication and its advantages in industrial applications have lead to the introduction of optical communication technology into more conservative areas, such as the nuclear and aerospace industries. The number of optical cables in nuclear power plants has been increasing. Fiber optic cables are commonly used at nuclear power plants in I&C systems but they are usually used in mild environments. For example, the Czech nuclear power plant in Dukovany, a PWR type with four 440 MW units, has 1330 installed optical cables. All the optic cables are situated in mild environments, i.e. without radiation. Nevertheless, currently, the number of applications in harsh environments with radiation is increasing. Application of safety-related fiber optic cables in harsh environments of nuclear power plants (NPPs) requires their qualification. The international standard for qualification IEEE 1682: Standard for Qualifying Fiber Optic Cables, Connections, and

Optical Fiber Splices for use in Safety Systems in Nuclear Power Generating Stations – has existed since 2011.

One of the most prevalent effects of radiation exposure is an increase in signal attenuation (signal loss). This is a result of fiber darkening due to radiation exposure and it plays a very important role in application of fiber optics in radiation environment. After the irradiation, the fiber optics goes through a “recovery” process during which the optical properties improve again. The extent of recovery can be affected among others by time and temperature after the radiation aging. Tested simplex and breakout cables with MM fibers increase their attenuation during irradiation. Nevertheless, during next 30 days of the recovery process after irradiation, the attenuation decreased as expected. Quite different was the situation for jelly filled loose tube SM cable. Attenuation decreased (recovered) 3 days after the irradiation. After this short period, the trend changed and attenuation increased to a value well above the attenuation just after the irradiation, see red line in Figure. Well above the acceptance criterion for NPP application. A lot of experiments were carried out to explain such unexpected behavior. Different samples were irradiated and measured the recovery process; e.g. only SM fibers with different dopants, tubes filled with jelly as well as dry loose tubes (without jelly), cables made from the tested tubes and different tubes material. The presentation will describe all the experiments and bring an explanation for this unexpected property.

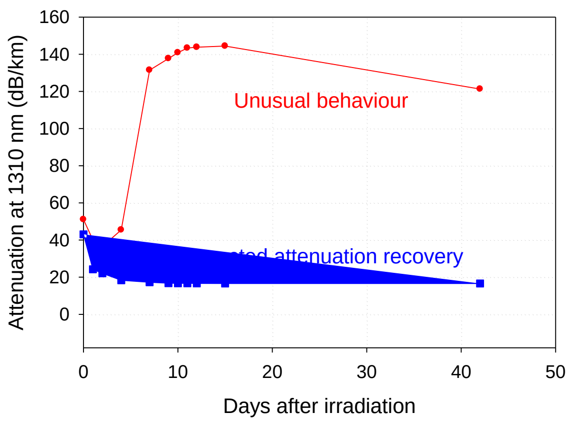

Fig.1: Attenuation recovery after fiber optic cable irradiation. Expected is attenuation decrease, i.e. improvement of optical properties. Some types of fiber optic cables exhibit unusual attenuation increase after few days of recovery time.

Cooperation helps standardization in the EQ field IEC/IEEE working together.

Sven-Olof Palm
Expert Environmental Qualification
Forsmarks Kraftgrupp AB

The Nuclear industry is quit small in an international perspective. To divide our technical competence in to many different organisations is not beneficial for the industry.

Regarding Qualification of equipment in the nuclear industry we have more than ten years of cooperation between IEC and IEEE that have been very important.

I will give some description about the history of cooperation and the result.
I will talk about for example IEC/IEEE 60780-323 (Qualification), IEC/IEEE 62582-x (Condition Monitoring Methods) and IEC/IEEE 60980-344 (Seismic).

What could you do to support this work?
What do you want to know?

Qualification of primary electrical penetration assemblies for Belgian NPPs Doel 1 and 2

Scheepers Kevin (Tractebel)/Dr. Monnaie Frederic (Engie Laborelec)

The Belgian NPP units Doel 1 and 2 were commissioned in 1975 for a lifetime of 40 years. In 2015, the government awarded a lifetime extension (Long Term Operation) for 10 years. As a result of this decision, different (electrical) safety related equipment needed an extension of its qualified life.

In a first phase, an inventory of the safety related electrical components was made. After which the lifetime extension qualification of specific equipment was performed. To facilitate the qualification processes of the various electrical components, a multidisciplinary team composed of engineers with different backgrounds from Engie Electrabel (NPP operator), Tractebel (engineering office) and Engie Laborelec (research centre) was created.

One of the big challenges was the qualification of the primary electrical penetration assemblies (EPA). A variety of different EPA types were identified (LV, MV, I&C, Triax and Twinax) for which the 1E qualification for harsh environment, according the IEEE standards (Belgian qualification level 1EA), is required. Two types (LV and triax-twinax) were exposed to a test sequence of thermal and radiation ageing, overload and short-circuit currents (only LV), seismic accident, Design Basis Accident (i.e. LOCA) and post-DBA ageing. Throughout the qualification program, gas leakage tests and electrical tests were performed to verify the good condition and required functionality the EPA samples.

Additionally, because of the limited timeframe of the LTO project, it was a necessity to start the preparation of the replacement of all EPAs before the outcome of the qualification program was known. Plan A (qualification) and plan B (replacement) were launched in parallel to meet the tight deadlines.

The qualification programs of all EPA types were succeeded successful. The EPAs are qualified to perform their safety functions until the end of 2025. No EPA replacements were required.

Equipment testing for severe accident conditions

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The operational states of a nuclear power plant can be generally categorized as normal operation and accident conditions. The latter one can be further divided into so-called design basis accidents (DBA) and design extension conditions. Design extension conditions include in the worst case conditions with core melting, called severe accidents (SA). Instrumentation and equipment important for mitigating severe accident need to be tested to ensure the functionality during the severe accident environmental parameters and the mission time, which may be in the order of weeks or even years. The traditional environmental qualification method is not suitable in all cases for testing the severe accident instrumentation and dedicated mitigation equipment. Moreover, design extensions conditions and especially severe accidents are mostly not addressed in equipment qualification standards.

Some issues concerning the SA qualification procedure are following:

- Quite clear rules and regulations. There is not wide spreading agreement how to test the equipment for SA conditions.
- Knowledge of the environmental parameters during SA that shall be simulated. In some cases, the procedure may be quite complicated and new test procedures have to be developed. This is, for example, the case of hydrogen combustion.
- The required mission time may be quite long, more than 1 year. Simulation needs to be accelerated to achieve reasonable testing time. Nevertheless, models and procedures need to be developed.
- Very high irradiation doses up to few MGy. Simulation of irradiation conditions with the definition of the role of gamma, beta and neutron irradiation. Moreover, the energies of the irradiation and the dose rates dramatically change during the SA. Therefore, the influence of the irradiation on the equipment during accident progress will change.
- Acceptance criteria could differ from the criteria for DBA.
- Qualification margin need to be defined. Standards recommend some margins for DBA. However margins for SA should be developed.

Presentation will describe issues, propose steps to solve them and show some examples of equipment testing for SA conditions; i.e. high test temperatures, high doses, hydrogen burning test.

Simulation of long term cable ageing at elevated temperature Problems, Limitations

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Simulation of thermal ageing is an important part of qualification of materials designed for the use in containment of nuclear power plants (NPP). The results from thermal endurance testing, together with the results from simulation of radiation ageing and simulation of design basis event, serve for assessing material service lifetime under NPP conditions. The simulation of long-term service thermal ageing (degradation) is usually performed by isothermal ageing at elevated temperature using Arrhenius methodology, which assumes that the short-term simulation of thermal ageing at higher temperature causes the same degradation as the service long-term ageing at lower temperature.

Therefore, temperature and time in thermal chamber must be defined at first. The maximum ageing temperature is given by the range of chemical stability of the material and shall not be exceeded during the ageing. Any phase changes (softening and glass transition) should be taken into account as well. The time of accelerated thermal ageing at selected temperature is usually calculated by using Arrhenius approach (in accordance with international standards). This approach requires – besides the temperature and time data – also the knowledge of activation energy (EA), which must be determined prior to the ageing.

Presentation will show (very) basic chemistry which is associated with the Arrhenius equation. How the formula, which is used to calculate parameters of thermal ageing, was derived from original Arrhenius equation. It will outline problems and limitations of activation energy determination.