# Environmental Qualification for the Plant Extended life

**Leeda Samimi[1], Milad Debly[2], Dinu Milhaileanu[2] and Greg Brown[2]**
[1] Atlantic Nuclear Services Ltd, Fredericton New Brunswick, Canada
[2] Point Lepreau Generating Station, New Brunswick, Canada

## Abstract

Originally at Point Lepreau the Environmental Qualification (EQ) of safety related equipment was based on a 30 year plant life. The refurbishment of the plant, which will extend the life of the plant by another 30 years, requires the equipment to be qualified for the extended life. Also, the publication of the CSA N290.13 Guidelines in 2005 provides an enhanced template for the EQ Program at Point Lepreau. This paper discusses the methodology used to environmentally qualify equipment for the extended plant life.

## 1. Introduction

The primary goal of Environmental Qualification (EQ) is verifying that the equipment as designed and manufactured is capable of performing its safety functions when required. Thus the EQ process is concerned with establishing qualification and preserving qualification throughout the operating life of the station.

Point Lepreau Generating Station (PLGS) is in the process of extending the plant life by another 30 years through refurbishment of the plant. Thereby qualification of the EQ equipment need to be examined to see if their qualified life can be extended or they need to be replaced.

At PLGS Environmental Qualification is established for the most severe service conditions, including both normal operation and those arise from a Design Basis Accidents (DBA) conditions. This will provide assurance that degradation of the EQ equipment due to stresses such as operational service conditions will not jeopardize functionality during a DBA.

## 2.0. PLGS EQ program for the extended plant life

The first phase of the EQ work for the extended plant life involved revision of all the EQ core documentations:

- The station instruction governing the EQ program
- The procedure for developing EQ assessments
- Environmental parameters documentation for 60 years (instead of 30)
- EQ Preservation documentation

The following sections describe topics of particular interest in extending the EQ program to 60 years.

### 2.1. Environmental Parameters Documentation

During the 30 years equipment qualification program the normal environmental conditions were based on the worst ambient (temperature and radiation) conditions of the building. The advantage of this method is that a component qualified to the generic normal environmental conditions can be installed anywhere within the building without losing qualification or needing any additional assessment. The disadvantage is that this method introduces over conservatism into the normal environmental conditions for the entire building, which lead to EQ over testing.

During the 60 year extended plant life the Normal Environmental conditions, ambient temperature, pressure, humidity, and radiation level, of the specific rooms were measured or identified by analyzing the data collected from the field measurements during the 25 years of the plant operation. In most cases these measured parameters (temperature and radiation) are used to calculate aging degradation of the organic components.

### 2.2. Preparing a detailed EQ assessment for the extended life

At Point Lepreau an Environmental Qualification Assessment (EQA) is prepared to document the qualification of the equipment.

In accordance with CSA N290.13 standards Point Lepreau's qualification of the equipment is established based on the following four methods:

1. Testing: Equipment EQ testing, which included both thermal and radiation aging for normal service conditions followed by the expected harsh environments of a DBA, was used to demonstrate the proper operation and performance.

   Margin is introduced throughout the qualification in order to account for the uncertainties in demonstrating satisfactory performance, error in experimental measurements and to address the normal variations in commercial production, thereby providing greater assurance that the equipment can perform under the most adverse service conditions for which it is qualified.

2. Analysis: A detailed mathematical analysis using the Arrhenius theories are used to calculate equipment's expected life. This calculation is relatively straight forward for those equipment that are exposed to one steady normal service temperature for the entire service life. However in the case where equipment experiences multiple service temperatures, (such as the case of an electrical motor) the Arrhenius weighted average temperature $T_w$ for the entire service period is calculated. Equations (3) to (5) of the appendix A shows one method of such calculations. The value from equation (5) is used as the service temperature in the thermal design life calculation.

Qualification analysis for equipment is performed on those components of the equipment that are judged to be critical to the safety related function of the equipment.

3. Operating experience: Data from equipment of similar generic design that has successfully operated under the known service conditions are used as the basis for qualifying equipment to equal or less severe service conditions.

4. Combined qualification: A combination of the above qualification methods are used to qualify equipment.

The best method is a complete testing of the equipment. However, this may not be possible and hence a partial qualification testing coupled by an analysis can be performed to address the qualification concerns.

At PLGS an EQA considers the effects of the thermal aging, radiation aging, cycling, pressure, humidity, and submergence on the equipment. It also performs a Failure Mode and Effect Analysis (FMEA) of the organic materials of the components.

It is assumed that the harsh environment does not cause significant degradation of metallic parts of a device; however, it will cause aging of organic material, which may in turn cause the equipment to fail.

Thermal aging effects are analyzed using the Arrhenius equation and calculating a thermal design life for the equipment. This calculation is used to determine time temperature sensitivity of the organic components of an equipment.

Radiation aging effects on a device (organic components) are analyzed by considering the radiation threshold or the 25% damage level and calculating the design life due to radiation aging.

The radiation threshold is defined to be the level at which a material property changes. Since the radiation threshold is variable due to equipment accuracy, material formulation and thickness, the 25% damage level is considered to be a good general indicator of material sensitivity to radiation.

### 2.3. EQA methodology for extended life

The EQA methodology for 60 year was essentially the same as for 30 years except the template was redesigned for strict compliance with CSA N290.13 standard *"Requirements for environmental qualification of equipment for CANDU nuclear power plants."*

The method that has been adopted at PLGS is to review all the past qualification assessment (EQA) reports and to determine if the qualifications are feasible to be extended to 60 year.

If past EQA were done by analysis the Arrhenius calculations and radiation dose calculations are reviewed in an attempt to extend the qualifications to the extended plant life. If this is achievable then there is no specific action recommended. However if the qualified life is shorter than the extended plant life, the equipment qualified life can be extended using the CSAN290.13 recommendation.

If the original qualification was established through testing then the test results are reviewed. If the qualification can be extended by analysis then recommendations are to ensure all applicable Preventive Maintenances (PMS) are in place. If the review of the test indicates that analysis can not be done then recommendation will be made to retest or replace the affected equipment.

If it is determined that only certain components possess age related degradation which could prevent equipment from performing its safety function, the periodic replacement of those components with identical components provided replacement does not adversely affect the other components will take place in an attempt to extend the qualified life of the equipment to the end of the plant life.

The EQ preservation program has monitoring program such as inspection and surveillance program by mean of EQ walkdowns and the cable indenter program. Using the Maintenance plans identified in the EQ assessment the age sensitive parts of the equipment or the equipment itself are replaced before their qualified life has expired.

In many cases continuing with the regular maintenance and monitoring of the equipment will be sufficient to maintain the equipment qualified for the extended life.

## 2.4. EQ Preservation

At PLGS EQ preservation is considered one of the most important parts of the EQ program. The qualified status of the equipment will be preserved throughout the plant lifetime by following strict procedural controls which will address activities such as installation, maintenance, procurement, control of spare parts, and storage.

EQ walkdown is performed for each of the qualified equipment at least once every 5 years to confirm that, the location, manufacturer, model, and serial number together with the installation conform to the configuration as analyzed in the environmental qualification documentation.

A planned inspection program such as Preventive Maintenance Schedule (PMS) are maintained for all qualified equipment to ensure that operation and maintenance activities have not compromised the qualification status of the equipment. Any substitute part used during maintenance will have an equivalency documentation that will be approved by the EQ specialist. Appendix B shows a flow chart that depicts the PLGS EQ preservation process.

For the 60 year EQ program the EQ preservation was addressed by updating the PMS as required by the above EQA process

## 3.0. Conclusion:

The EQ program is currently underway to extend the EQ equipment to 60 years. Considerable time has been spent upfront to plan the work and develop the core documentation; now that this has been accomplished; EQA are being generated in a consistent, manner based on CSAN290.13.

## 4.0. References

1. IEEE Std 323 “IEEE standard for qualifying Class IE equipment for Nuclear Power Generating Stations”.

2. CSA N290.13 standard “Requirements for environmental qualification of equipment for CANDU nuclear power plants.”

3. IEEE Std 383 “IEEE standard for qualifying Class IE electrical cables and field splices for Nuclear Power Generating Stations”.

## Appendix A: Thermal Design Life calculation

### A1. A method for calculating the Arrhenius weighted average temperature

The following is one method of calculating the Arrhenius weighted average temperature involving multiple duty cycle and multiple normal service temperature:

Normal service temperature $T = T_N + T_O$ (1)

Where:

$T_O$ = Operating Temperature
$T_N$=Normal environment temperature

Thus for each period of interest $t_i$ (some percentage of the duty cycle) the Normal Service Temperature ($T_i$) is:

Ti(Kelvin)=($T_N$i +273)+ ($T_O$i + 273) (2)

Note: This calculation should be performed for each interval of the normal service period when the normal service temperature is widely varying (i.e. multiple normal service temperatures).

The Arrhenius weighted average temperature ($T_w$) for the entire period of time ($t_w$) is:

$$T_w = m / \ln\left( \frac{t_w}{\sum_1^n t_i \bullet e^{-m/T_i}} \right) \tag{3}$$

Where:

$m$=Slope (Found from system 1000)

$t_w$= entire period of service life

$t_i$= period of interest (some percentage of the duty cycle)

$T_i$= Normal service temperature for the time period of $t_i$

Expanding the above equation:

$$T_w = m/\ln\left\{\frac{t_w}{\left(t_1 \bullet e^{-m/T_1} + t_2 \bullet e^{-m/T_2} + \ldots + t_n \bullet e^{-m/T_n}\right)}\right\} \quad (4)$$

In terms of % duty cycle $T_w$ is equal:

$$T_w = m/\ln\left\{\frac{100}{x_1 \bullet e^{-\frac{m}{T_1}} + x_2 \bullet e^{-\frac{m}{T_2}} + \cdots + x_n \bullet e^{-\frac{m}{T_n}}}\right\} \quad (5)$$

Where:

$m$=Slope = $\frac{E_a}{k_B}$ , found on System 1000

$E_a$ = Activation Energy (Found on System 1000)

$k_B$ = Stephan Boltzmans Constant = 8.617 $E^{-5}$ eV/°K

$t_i$= Time at period i

$T_i$= Temperature at period i

$x_i$ =*P*ercentage of time interval (i) to the total normal service time

Note: This weighted average time temperature ($T_w$) can be used as the normal service temperature in the calculations of the accident degradation equivalency or in qualified/design life calculations.

**Expected Life calculations:**

To calculate the expected life the following equations can also be used without a need for the Arrhenius weighted average time temperature.

$$\text{Expected Life} = \frac{100 \bullet e^{Intercept}}{\sum_i x_i \bullet e^{-\frac{slope}{T_i}}} \quad (6)$$

Expanding the above equation:

$$\text{Expected Life} = \frac{100 \bullet e^{Intercept}}{x_1 \bullet e^{-\frac{slope}{T_1}} + x_2 \bullet e^{-\frac{slope}{T_2}} + \cdots + x_i \bullet e^{-\frac{slope}{T_i}}} \tag{7}$$

Note: In the case where there is one steady service temperature for the entire service life of an equipment the expected life can be calculated based on the following equation.

$$T = \frac{slope}{\left(\ln\left(life\right) + \text{int}\right)} \tag{8}$$

Where;

Slope $= \dfrac{E_a}{k_B}$ , found on System 1000

Int =intercept found on System 1000

$E_a$ = Activation Energy (Found on System 1000)

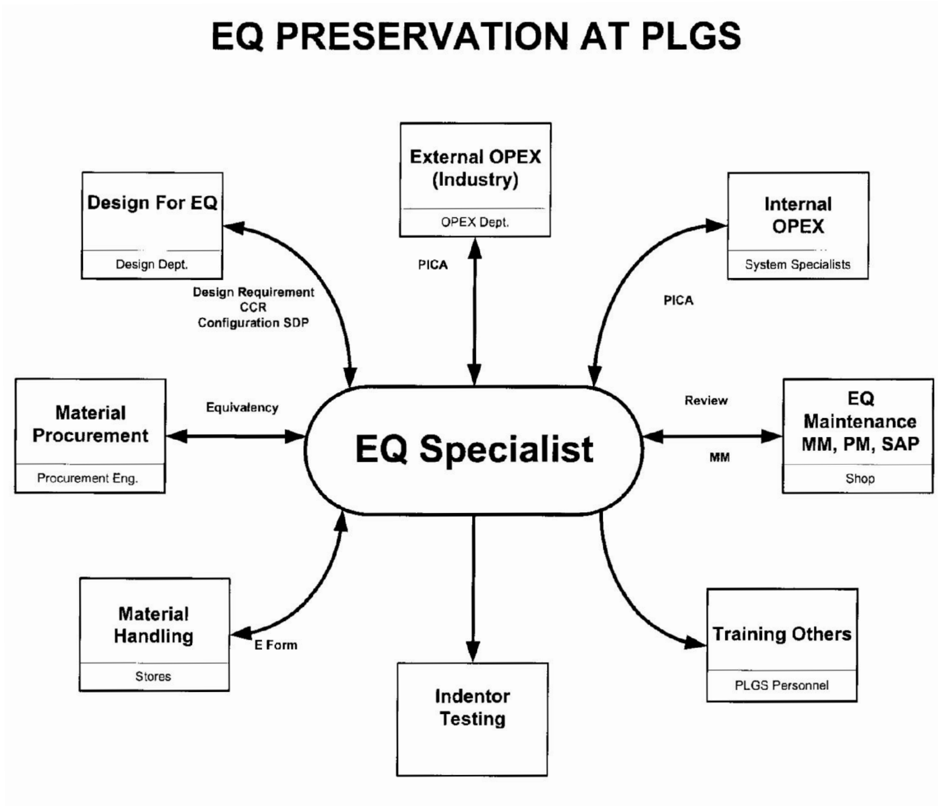
$k_B$ = Stephan Boltzmans Constant = 8.617 $E^{-5}$ eV/°K

Rearranging equation (8)

$$\text{Expected Life in hours} = \mathrm{e}^{\left[\left(\frac{\text{Slope}}{\text{(Temp (Kelvin))}} + \text{int}\right)\right]} \tag{9}$$

Using the expected life and safety factors, thermal design life can be calculated.

# Appendix B


EQ PRESERVATION AT PLGS
External OPEX (Industry)
OPEX Dept.
Design For EQ
Design Dept.
Internal OPEX
System Specialists
PICA
Design Requirement
CCR
Configuration SDP
PICA
Material Procurement
Procurement Eng.
Equivalency
EQ Specialist
Review
MM
EQ Maintenance MM, PM, SAP
Shop
Material Handling
Stores
E Form
Indentor Testing
Training Others
PLGS Personnel