Environmental Qualification Program For New Designs

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Abstract

Qualification of nuclear power plant equipment and components important to safety (ITS) is an integral part of the design process. The qualification methodology differs based on the severity of service conditions (operational and ambient), to which the ITS equipment is exposed. In Canada, the licensing requirements for environmental qualification for new designs are governed by the Canadian Standard Association (CSA) standard, N290.13-2005 titled "Environmental Qualification of Equipment for CANDU Nuclear Power Plants" [1] and the pre-consultation draft, "Requirements for Design of Nuclear Power Plants"(DRD), issued for trial use by the Canadian Nuclear Safety Commission (CNSC) in March 2005.

This paper will describe AECL's current Environmental Qualification program developed to comply with the above licensing requirements as applied to new designs. The focus will be given to qualification of ITS systems structures and components (SSC) to harsh conditions occurring due to the Design Basis Accidents (DBA).

1. Introduction

The Environmental Qualification (EQ) Program presented in this paper was designed and implemented by Atomic Energy of Canada Ltd. (AECL) for the Advanced CANDU Reactor (ACR) project. It addresses and optimizes EQ requirements during the design, procurement and equipment installation phases of the ITS systems. The ACR EQ Program ends at the commissioning phase. It ensures that the commissioned plant is EQ qualified and also defines requirements necessary to maintain the EQ qualified status during operation.

The program implements the licensing requirements for environmental qualification specified in the "Requirements for Design of Nuclear Power Plants" issued by CNSC for consultation and application for new designs and regulatory requirements of the CSA standard on Environmental Qualification of Equipment for CANDU Nuclear Power Plants, CSA N290.13-2005 [1], and the IEEE Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations, IEEE Std 323 [2]. The program also covers environmental qualification of mechanical equipment. The applicability of these licensing requirements to refurbishment projects is subject to CNSC recommendation(s).

The purpose of the EQ Program is to demonstrate in a technically sound and auditable form that the required ITS equipment and components will perform their important to safety functions in postulated accident event conditions, taking into consideration their pre-accident normal service. The program consists of a set of planned, coordinated, and verified activities that identify and document the following:

- the equipment to be qualified,
- its required safety function(s),
- normal and accident conditions, and mission time over which the identified equipment is required to function,

- environmental qualification requirements and equipment performance criteria,
- assurance that the equipment qualification is complete, and
- specific requirements on how qualified equipment should be maintained for the life of the plant.

Equipment and components meeting the requirements of the EQ Program are considered environmentally qualified. Environmental qualification for a new design shall be part of the design process when equipment requiring EQ is identified and specified, and the procurement process when the identified equipment is qualified for those conditions resulting from design basis events, which cause harsh environment.

2. Reference Codes and Standards

The controlling standards and principal regulatory criteria related to the design, construction, and operation of nuclear power plants, hence to the ACR, are facilitated by the Canadian Standard Association hierarchy of standards and shall be followed. They are an integral part of environmental qualification process and listed in Table 1.

STANDARD	TITLE
CNSC Design Requirements Document (Draft)	Pre-Consultation Draft "Requirements for Design of Nuclear Power Plants", CNSC, March 2005
CAN/CSA-N286.0-92 (Reinforced 1998)	Overall Quality Assurance Program Requirements for Nuclear Power Plants
CSA-N286.1-00	Procurement Quality Assurance for Nuclear Power Plants
CSA-N286.2-00	Design Quality Assurance for Nuclear Power Plants
CSA-N286.3-99	Construction Quality Assurance for Nuclear Power Plants
CAN/CSA-N286.4-M86 (Reinforced 2000)	Commissioning Quality Assurance for Nuclear Power Plants

Table 1 Reference Standards and Regulations.

The standards and regulations directly applicable to the methodologies used in the environmental qualification of equipment are listed in Table 2.

STANDARD	TITLE
CSA N290.13-05	Environmental Qualification of Equipment for CANDU Nuclear Power Plants
IEEE Standard 323 2003	Qualification of Class 1E Equipment for Nuclear Power Generating Stations
IEEE Standard 334 1974	Type Testing of Continuous Duty Class 1E Motors for Nuclear Power Generating Stations

IEEE Standard 344 1987	Recommended Practice for Seismic Qualification for Class 1E Equipment for Nuclear Power Generating Stations
IEEE Standard 382 1996	Qualification of Actuators for Power-Operated Valve Assemblies with Safety-Related Functions for Nuclear Power Plants
IEEE Standard 383 1974	Type Testing of Class 1E Electric Cables, Field Splices and Connections for Nuclear Power Generating Stations
ASME QME-1-2002	Qualification of Active Mechanical Equipment Used in Nuclear Power Plants
IEC-60780 1998	Qualification of Electrical Equipment of the Safety Systems for Nuclear Power Plants

Table 2 EQ Related Reference Standards and Regulations.

The CSA standard on Environmental Qualification of Equipment for CANDU Nuclear Power Plants, CSA N290.13-05, has been endorsed by the CNSC in their response to the AECL comments on the "Requirements for Design of Nuclear Power Plants" document and constitutes the main source of EQ requirements for ACR power reactors.

The standards identified in Table 2, except for CSA N290.13-05, were written primarily for Light Water Reactors (Boiling Water and Pressurized Water) and, therefore, consideration must be given before application of these standards to the ACR power reactors. They address directly qualification of Class 1E equipment, but the qualification methodology, which they recommend has also been extended by the nuclear industry to cover mechanical equipment.

3. Basic Concepts and Definitions Used in Environmental Qualification

Aging A general process in which physical, chemical, or electrical properties of a component or equipment gradually change with time under normal service conditions including Anticipated Operational Occurrences (AOO), which may result in degradation of significant performance characteristics; also, the process of simulating these changes [3][4].

Degradation Immediate or gradual deterioration of equipment/component functionality characteristics that could impair its ability to function within acceptable criteria (see Figure 1) [3].

Design Basis Accident A postulated event (specified by the safety analysis of the station) used in design to establish the acceptable performance requirements of the systems, equipment and components [1][3].

Design Life The time during which satisfactory performance can be expected for the specific set of service conditions, based upon component selection and application (see Figure 1) [1][2][3].

Environmental Conditions Ambient physical states surrounding a SSC [3].

Environmental Qualification Generation, documentation, and maintenance of evidence to assure that equipment important to safety located in a harsh environment caused by the design basis accidents will perform its safety function on demand during its installed life – a more limited term than equipment qualification [1][3].

Equipment Qualification Generation and maintenance of evidence to assure that the equipment will operate on demand to meet the system performance requirements [2][3].

Expected Life The time predicted, for normal service conditions, for which a material would remain useful, for a specific set of service conditions (see Figure 1).

Harsh Environment An environment experienced as the result of the postulated service conditions during and after the design basis accident of the station. Harsh environment bounding conditions are the result of a loss of cooling accident (LOCA) or/and a main steam line break (MSLB) [2][3].

Installed Life The interval from installation to removal during which the equipment or component may be subject to design service conditions and system demands [3].

Mild Environment An environment expected as a result of normal service conditions and extreme AOO conditions [3].

Mission Time The period of time for which the component is required to perform its safety function under harsh environment measured from the start of the Design Basis Accident (see Figure 1) [1].

Operational Conditions Influences on a SSC resulting from the performance of design functions (operation of a system or component and loading of a structure) [3].

Qualified Life The period of time, prior to the start of a design basis accident, for which equipment was demonstrated to meet the design requirements for the specified normal service conditions. At the end of the qualified life, the equipment shall still be capable of performing the safety function required during the mission time (see Figure 1) [1][2][3].

Safety Function Safety functions include action or operation required for shutdown of the reactor, removal of decay heat, prevention/containment of radioactivity releases, or the monitoring of the reactor and its systems after a design basis accident [3].

Service Conditions Environmental, loading, power and signal conditions expected as a result of normal operating requirements, expected extremes in operating requirements, and postulated conditions appropriate for the design basis accidents of the station [1][2].

Figure 1 presents the relationship between these concepts and their application to the component/material degradation/functionality as a function of time.

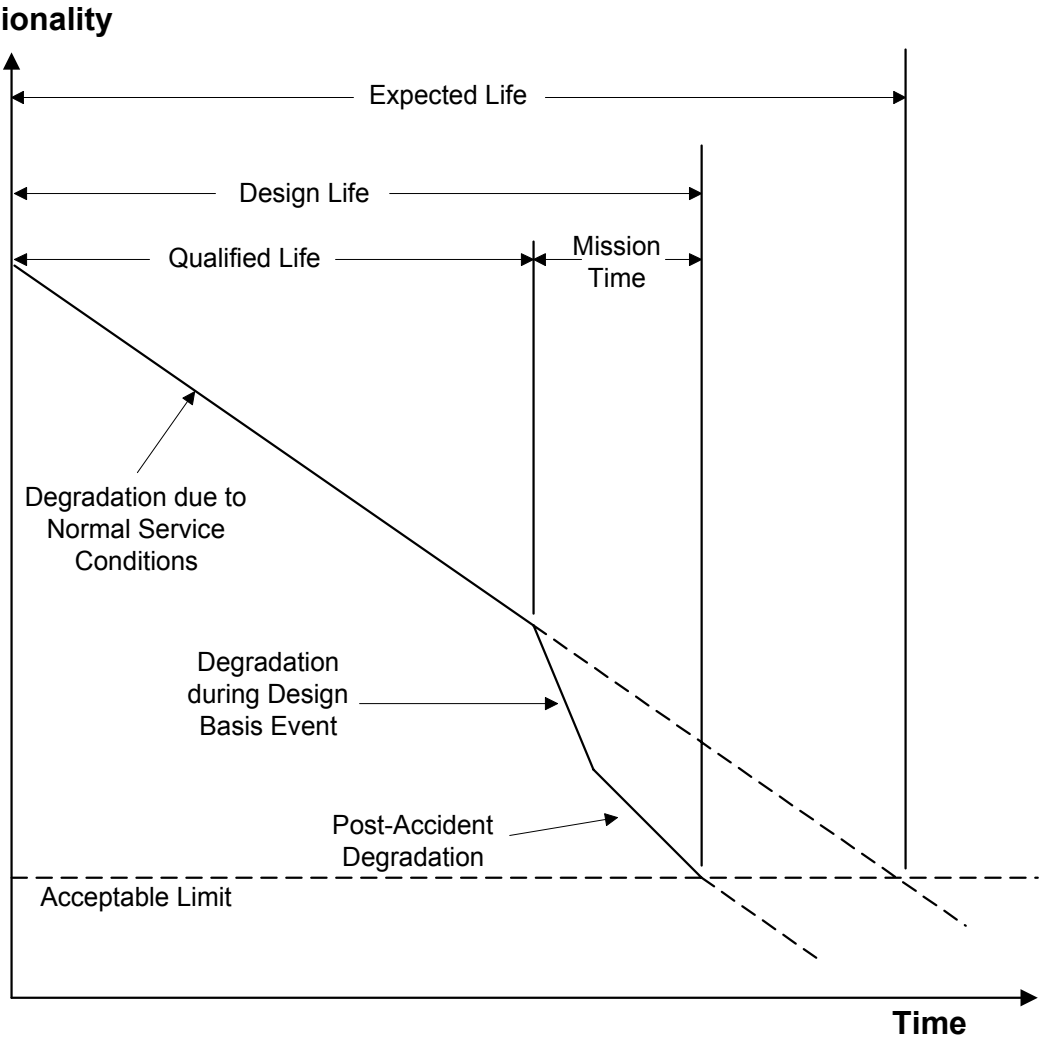

Figure 1 Diagram Illustrating Component/Material Degradation Due to Aging.

4. Environmental Qualification Program

A comprehensive Environmental Qualification Program refers to a process that begins at the concept design stage and continues throughout the operating life of the plant. The program ensures that equipment credited to perform functions important to safety will function as required for the life of the station in all service environments, namely normal operation (NO), anticipated operational occurrences, and postulated design basis accidents. First, the systems and their safety functions are identified and normal, anticipated operational occurrences and accident environmental conditions are predicted. Next, the equipment performing or supporting safety functions is identified along with its safety function(s) and location. Equipment located in a harsh environment is recognized as requiring formal EQ and its EQ requirements are specified. Then the environmentally qualified equipment is procured and installed according to specific EQ instructions. Finally, by means of ongoing maintenance and replacement of parts, the qualified status of the equipment is sustained during the operating life of the plant. Proper documentation is required at all stages of the program.

The execution of the EQ Program on the ACR project ends at the commissioning phase of the plant; however, the program provides the client utility with all necessary information needed to preserve the EQ'ed status of the plant.

4.1 Objectives

The EQ Program shall meet the following objectives:

- Meet licensing and safety requirements.
- Provide the necessary information and guidance to operations for the preservation of equipment qualification during its installed life.
- Ensure that the information generated by the EQ process is documented and organised in an auditable manner.
- Provide regulatory bodies with the means to readily assess and audit the EQ Program.

4.2 Responsibilities

The EQ Program is implemented by a multi-disciplinary team consisting of Safety Design Engineers, Reactor Core Engineers, Systems Designers/Design Engineers, and Procurement/Equipment Engineers and coordinated by the EQ Program Coordinator. The program concludes with the station walkdown performed after installation to confirm correct implementation of the EQ Program stages outlined below.

4.3 The EQ Program Process

The EQ Program process is shown in the flowchart in Figure 2. The following is a description of the activities required during the various stages of the qualification program and identification of the related documentation.

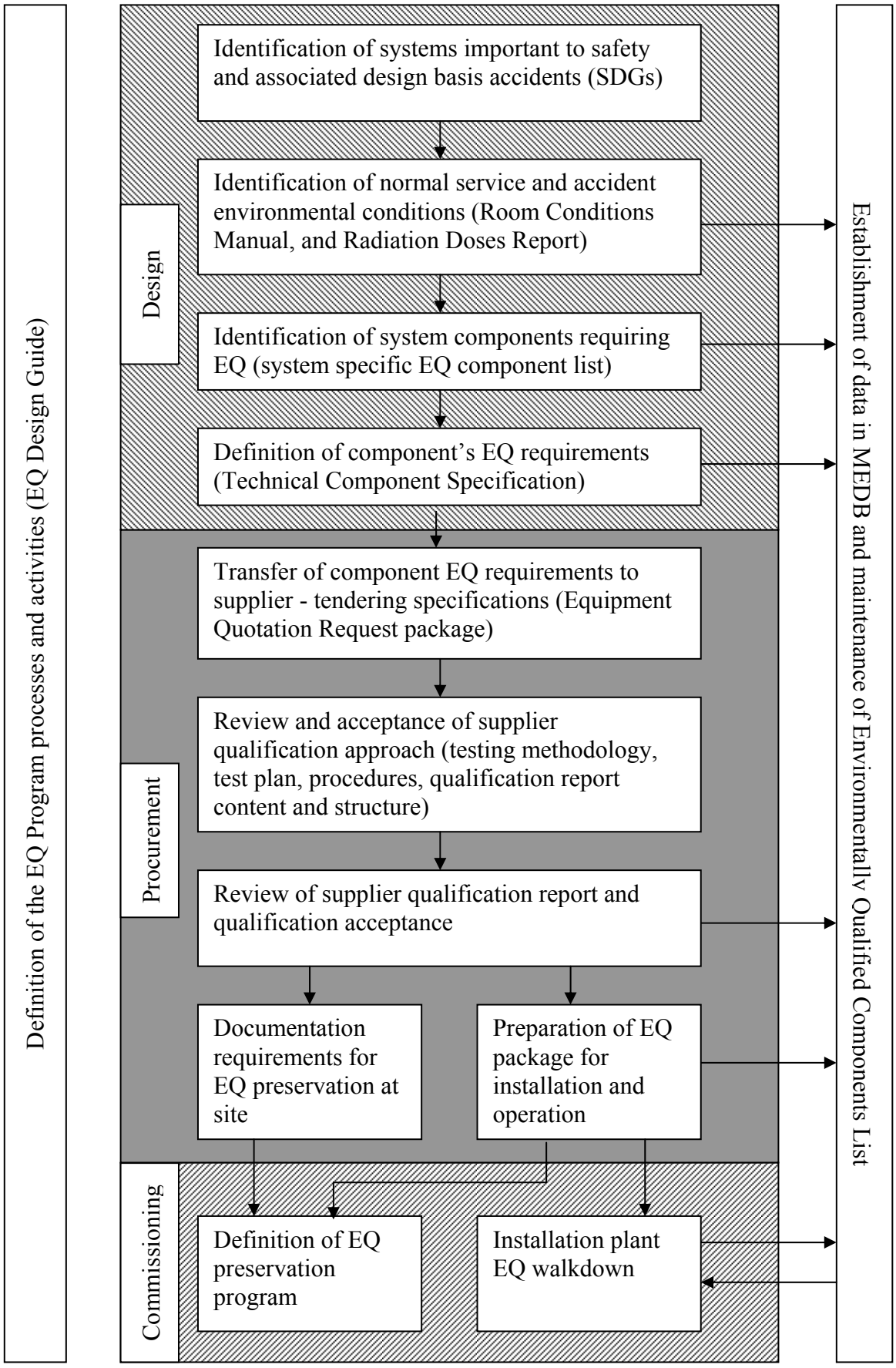

Figure 2 Environmental Qualification Program.

4.3.1 The Design Stage

As presented in Figure 2, the Environmental Qualification process begins with the identification of postulated Design Basis Accidents, and systems and major components credited to mitigate these events. This is covered by the overall plant and EQ specific Safety Design Guides (SDG). The harsh environment conditions caused by postulated DBA(s) and prediction of the associated harsh condition envelopes for the postulated accidents is a result of safety analysis and documented in the relevant safety analysis reports. The ACR reactor type specific radiation doses and dose rates are provided in a radiation dose analysis report. The ACR project will collect all room conditions by room number in the Room Conditions Reference Manual.

It may not always be necessary to environmentally qualify the entire system, but only those components whose failure due to harsh environment conditions may adversely affect the performance of the system safety function(s).

The general rule for identification of components requiring formal EQ is that a component required to perform an ITS function in harsh environment conditions caused by design basis accidents must be environmentally qualified unless it can be shown by engineering assessment other than EQ methodologies that the component:

- Performs its important to safety function prior to exposure to the harsh accident environment conditions, or
- It can either withstand the harsh environment conditions or its failure will not impair the safety function of the system (i.e. equipment has fail safe condition).

This rule also applies to systems and/or components, which do not themselves perform any important to safety function, but which interface with an ITS component in such a way that their failure due to the DBA harsh environment conditions could impair the function of the ITS component or system.

As a result of this activity, all ITS components of the systems indicated in the SDGs are identified, evaluated from the EQ requirement perspective (exposure to a harsh environment) and recorded in the ACR Master Equipment Database (MEDB) together with the corresponding EQ parameters and identifiers. This data, after it is approved and put under revision control, becomes an official design basis data repository. The traceability of the MEDB inputs and justification of the EQ requirement are documented in the system specific EQ Component Identification Package (EQCIP). Furthermore, the normal service conditions, operational and environmental ambient temperature and radiation rate are identified and documented. The minimum acceptable performance requirements for the components, and the harsh process conditions internal to the component are also identified.

The MEDB is a multidisciplinary database application used to facilitate specification and definition of all tagged engineering devices and to produce reports such as Component Specification Sheets (CSS), Component Specification Sheets–EQ (CSS-EQ), valve reports, instrument reports, system specific Environmentally Qualified Component Lists (EQCL), and finally the ACR EQCL.

The documentation related to EQ at the design stage includes the following:

a) EQ Component Identification Package, a system specific document.

   The system specific EQ Component Identification Package identifies all system components that perform or support the ITS function(s) along with the design basis accidents they are credited to mitigate and their mission times. In addition, the document identifies the ITS function(s) of a component and its operational category(s), distinguishes components located in

a harsh environment. In addition, the components are further analysed as to their operability in a harsh environment and justification is provided if they do not have to be environmentally qualified. The reason for excluding a component from further EQ (for example all metallic) has to be clearly documented.

b) Design Requirements and Design Description documents.

   The Design Requirements (DR) document for a system describes the EQ requirements at the system level. The Design Description (DD) describes how the EQ requirements have been implemented in the system design.

c) Component Specification Sheet –Environmental Qualification.

   EQ requirements are incorporated into the general technical specification by attaching the EQ specific Component Specification Sheet to the Component Specification Sheet when applicable. Both sheets are produced from the MEDB.

d) Environmentally Qualified Components List.

   As described above, the Environmentally Qualified Components List is a list of all environmentally qualified components. The list is a report obtained from the ACR MEDB.

   The MEDB is continually updated as the project progresses and the EQCL is reissued on an "as required" basis. The final version of the EQCL is issued at the end of the project.

The majority of items which are to be environmentally qualified are either electrical or mechanical devices. Structural components are typically not subject to EQ as they are made of non-degradable materials and designed taking environmental qualification into consideration. The possible degradation mechanisms resulting from the environmental conditions such as corrosion must be considered during design. Paints and coatings can be susceptible to the harsh conditions of a DBA and therefore, if they are part of or affect an ITS system, shall be environmentally qualified.

Environmentally qualified components are identified at the design stage and the information related to the components available at time of design is collected. Further information required for each of the components is compiled during the procurement stage. Furthermore, the key information related to maintenance of EQ of components may be incorporated into the MEDB to provide the plant operations with the information required to preserve the EQ status of the plant.

4.3.2 Procurement Stage

The specifications related to how the qualification requirements are to be met by the supplier are prepared during the procurement stage. The preferred qualification method and the minimum interval between maintenance activities are specified. If testing is required, then the test sequence is specified. Information related to the interfaces with the component, and the mounting/orientation of the component for the test are included in the specification.

All of this information is transmitted to the component supplier in addition to the EQ related technical specification. The component supplier prepares a qualification report outline, which describes the qualification method chosen and the justification for the selection. The equipment engineer reviews and accepts the report outline or provides comments. Upon the acceptance of the outline, if testing is to be done, the supplier prepares a test plan and/or procedure. The test plan and/or procedure shall be reviewed and accepted by the equipment engineer prior to the start of the testing.

The qualification, either by testing or analysis, is documented in a qualification report prepared by the supplier. The report is then reviewed for acceptability and when the qualification process and equipment meet specified requirements, the qualification report is accepted by the equipment engineer.

The documentation related to the environmental qualification of the components at the procurement stage includes the following:

a) Information for Tendering Document.

   The information developed in the procurement stage related to the qualification instructions to the suppliers is added to the EQ component Specification Sheet or the Technical Specification. The Component Specification Sheet –EQ form shall be used for all items.

b) Component Qualification Report.

   Component testing or qualification by analysis is documented by the equipment supplier and/or test laboratory and is submitted to the equipment engineer for review and acceptance. The content and the format of the qualification report are defined in the EQ technical specification. The qualification report demonstrates that the acceptance criteria specified in the component Technical Specification have been met.

c) Environmentally Qualified Components List.

   EQ information that was not available during the design stage is entered to the MEDB and approved through the EQ Component Specification Sheet review and comment process during the procurement stage.

In any case, the EQ related supplier documents shall be properly identified to be easily included into the separate EQ file for future plant operation. This requirement shall be specified in the tendering documents.

4.3.3 Shipping and Site Storage Stage

In the interval between procurement and installation, the EQ status of the component shall be maintained. This interval will include packaging, shipping, receiving and handling of the component prior to installation. The EQ of the equipment and components shall specify appropriate measures to ensure the qualification is maintained. The packaging provided should take into account the sensitivity of the equipment, method of shipping and site storage conditions. Site receiving procedures shall include a detailed inspection resulting in the equipment being declared acceptable, non-conforming, or conditionally released. The storage of EQ equipment should address proper storage environmental conditions, periodic equipment checks/care, if required, and maintenance of records. Handling will identify any unique requirements for hoisting, rigging and transporting of the equipment on the site.

4.3.4 Installation, Commissioning and Operation Stage

The EQ requirements for the systems important to safety and their components defined in the design stage and implemented in the procurement stage are confirmed by the plant walkdown performed after installation. The walkdown should also confirm that the temperature and radiation fields in normal operation are as assumed in design. At this point the final revision of the EQCL shall be produced and forwarded to the plant operations.

The Environmentally Qualified Components List is provided to the plant operations. The list indicates the qualified life of each component so that the EQ maintenance schedule and parts

replacement schedule may be established. The equipment operating and maintenance manuals also provide the information regarding the replacement of components. The plant operations should establish a spare parts inventory program to ensure that qualified parts are available for replacement purposes when needed. It should be ensured that the qualified lubricants are replaced by the once of same or better qualification status.

The plant is responsible for the EQ preservation program. Although it is beyond the scope of the ACR EQ Program to provide this program to the client, AECL is capable to offer the EQ preservation program, if requested. As a minimum the EQ documentation has to be prepared in such a way that it is ready to become a basis of the EQ preservation program at site.

5. Conclusions

The presented Environmental Qualification Program was designed and implemented by AECL for the Advanced CANDU Reactor project. It addresses and optimizes EQ requirements during the design, procurement and equipment installation phases of the ITS systems. The program is based on the "Requirements for Design of Nuclear Power Plant" issued for trial use by CNSC for new nuclear power plant designs. The EQ Program also implements regulatory requirements of the CSA standard "Environmental Qualification of Equipment for CANDU Nuclear Power Plants", CSA N290.13-2005 [1] endorsed by CNSC. The ACR EQ Program ends at the commissioning phase. It ensures that the commissioned plant is EQ qualified and defines requirements necessary to maintain the EQ qualified status during operation. The plant is responsible for the EQ preservation program. Although it is beyond the scope of the ACR EQ Program to provide this program to the client, AECL is capable to offer the EQ preservation program, if requested.

6. References

[1] CSA N290.13-2005 "Environmental Qualification of Equipment for CANDU Nuclear Power Plants", 2005
[2] IEEE 323-2003 "Qualifying Class 1E Equipment for Nuclear Power Generating Stations", 2003
[3] EPRI Report TR-100516 "Nuclear Power Plant Equipment Qualification Reference Manual", 1992
[4] ASME QME-1-2002 "Qualification of Active Mechanical Equipment Used in Nuclear Power Plants", 2002