# AECL REVIEW OF CANDU 6 DESIGN IN LIGHT OF THE ONTARIO HYDRO NUCLEAR IIPA TECHNICAL FINDINGS

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## ABSTRACT

In the spring of 1997, Ontario Hydro (OH) conducted an Independent, Integrated Performance Assessment (IIPA) to address long-standing management, process and equipment issues within the Ontario Hydro Nuclear (OHN) organization and its multi-unit CANDU stations. This review included six Safety System Functional Inspections (SSFIs) on:

- Bruce A Emergency Coolant Injection System
- Bruce B Service Water Systems
- Darlington Compressed Air Systems
- Pickering Electrical Distribution Systems
- Fire Protection (Programmatic)
- In-Service Environmental Qualification Program (Programmatic)

Overall, the OHN inspections found that “the design of the CANDU plant is robust and plant hardware (including equipment and materials), for the most part, is adequately reliable.” However, the SSFIs also identified a number of deficiencies in the areas of management, control of design/engineering, operations, training, maintenance, testing and quality assurance. Atomic Energy of Canada Limited (AECL) has undertaken an in-depth review of all design-related issues to assess their applicability and impact on the current CANDU 6 design.

The AECL review has determined that equipment/design and programmatic deficiencies identified at the OHN plants have been addressed in the current CANDU 6 design through an effective design feedback process and the application of modern codes and standards that were not in place during the design of the early OHN stations.

Many of the design-related SSFI findings can be attributed to inadequate configuration management and the impact of unauthorized design modifications. Problems in these areas can arise at any nuclear station and prevention requires adherence to quality engineering procedures and documentation processes.

## 1. INTRODUCTION

In the spring of 1997, Ontario Hydro carried out an Independent Integrated Performance Assessment (IIPA) in order to address the long-standing management, process, and equipment issues within the Ontario Hydro Nuclear (OHN) organization and its nuclear generating stations. This review was mandated to obtain a rigorous assessment of OHN and to provide the basis for a plan to recover operations to a high performance level.

The IIPA assessment identified only problems which need to be resolved for achieving excellence. All OHN plants meet public safety standards. Furthermore the IIPA explicitly recognized that "the design of the CANDU plant is robust and plant hardware (including equipment and materials), for the most part, is adequately reliable" and the IIPA found that there is substantial conservatism in the design and operation of process and Special Safety Systems.

As part of the IIPA, OHN carried out six Safety System Functional Inspections (SSFIs) on the following:

1. Bruce A Emergency Coolant Injection System,
2. Bruce B Service Water Systems,
3. Darlington Compressed Air Systems (Instrument and Service Air),
4. Pickering Electrical Distribution Systems,
5. Fire Protection (all plants), and
6. In-Service Environmental Qualification Program (all plants).

An SSFI is a detailed technical review of a system's design, primarily to confirm that it will fulfill its safety functions, and secondarily to assure that inadequacies do not exist that may cause challenges to safety systems. Review of the design's implementation, and maintenance is conducted by investigating change control, operations, maintenance, training and other areas to determine that comprehensive safety assurance is achieved.

The SSFIs found deficiencies in all functional areas, including management, control of design/engineering modifications, operation, maintenance and testing, and quality assurance. There were several common findings for all except the Environmental Qualification SSFI (which was programmatic in nature):

1. Design basis documentation is not accurately maintained.
2. There is a fundamental lack of appreciation for the impact of unauthorized changes on safe plant operations.
3. Station activities are not effectively managed to ensure that plant operation and configuration conform to design basis and remain within the bounds of analyzed conditions.

After nuclear plants are declared in-service, OHN (the owner) retains full control and responsibility for maintaining the design basis documentation, design changes and configuration control, consistent with the design basis of the OHN plants. This is in accordance with the Canadian Standard CSA N286.5 which delineates design authority and configuration control as part of the owner's operating authority. OHN performed most of the in-service design changes, documentation control, inspection services, maintenance services and operations activities at its plants using in-house capabilities. AECL and other contractors were requested to assist only as specified by OHN.

Since design-related issues identified by the SSFIs could have relevance or applicability to other CANDU, AECL has undertaken a comprehensive review of all of the design-related findings of the SSFIs, with a particular focus on the findings which relate to AECL's areas of responsibility as the designer and supplier of CANDU 6 reactors. The following sections summarize the results of AECL's review.

## 2. BRUCE A ECI SYSTEM SSFI

The Bruce A Emergency Cooling Injection (ECI) system SSFI identified the following significant issues:

1. The lack of understanding, support analysis, and appropriate testing regarding the issue of valve timing for the $H_2O$ injection and the gas tank valves, and the effect of this timing on the $H_2O/D_2O$

air gap are serious concerns. The potential consequences (severe waterhammer) make this an important issue to resolve in a timely manner.

2. Many deficiencies exist in the station's calibration program (methodology, procedures, and documentation) with adverse consequences on required testing, system maintenance and operations.
3. Design control and documentation for the ECI system lack sufficient formality and rigor, eroding confidence in the reliability of the ECI system.

Despite these issues, the SSFI concluded that the ECI system would likely perform its safety function as designed.

With the exception of the waterhammer issue, the major findings of the SSFI relate to problems which have developed as a result of lack of clear roles and responsibilities, lack of an aggressive approach to identifying and resolving system deficiencies, lack of accountability, complacency and inadequate training. All of these are station operations, and management issues.

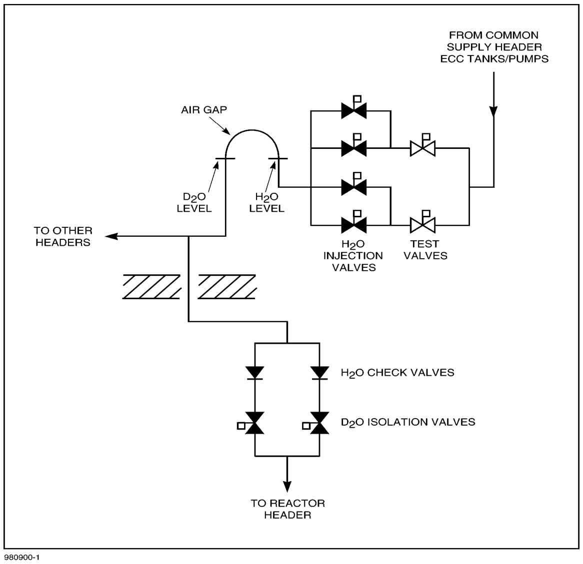
## 2.1 Waterhammer Mitigation

The SSFI found that there was a potentially significant safety issue with the design of the Bruce A ECI system. The design includes two injection valves in series with an air gap separating the high pressure $H_2O$ water supply (used for emergency injection) and the $D_2O$ in the heat transport system (the gap minimizes downgrading of the $D_2O$ by leakage of $H_2O$). To minimize the potential waterhammer loads during injection, a small $H_2O$ injection bypass valve is designed to fill the air gap at a low rate before the main $H_2O$ injection valve is opened. The sequence and timing of valve actuation are important in minimizing waterhammer loads in this design. The SSFI found a lack of supporting analysis and appropriate testing regarding valve timing during the high pressure $H_2O$ injection to ensure prevention of unacceptable waterhammer loads.

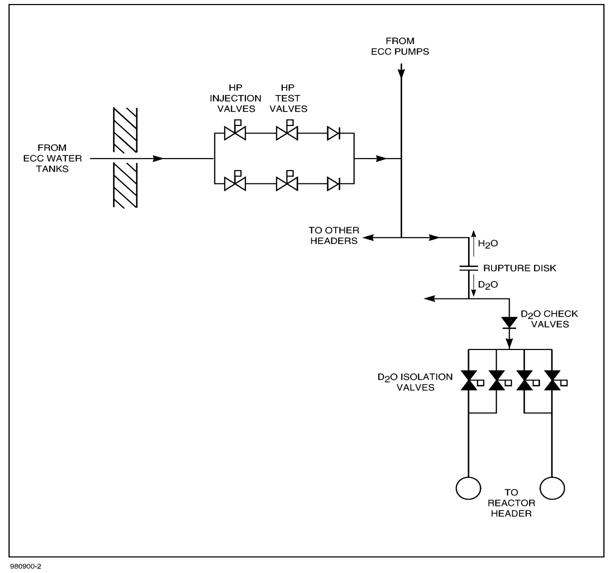
The design of the comparable CANDU 6 Emergency Core Cooling (ECC) system (Figure 1) has no deliberate air-filled lines; separation between $H_2O$ and $D_2O$ is accomplished with a rupture disc. Hence, $H_2O$ injection bypass valves are not required nor included in the CANDU 6 design. This eliminates any concerns with failures of these valves or their timing.

In the CANDU 6 ECC system, the gas isolation valves, the high pressure $H_2O$ injection valves and the $D_2O$ isolation valves are designed to open simultaneously on the LOCA signal for ECC injection. The ECC system is tested routinely and the testing procedure ensures that the system is completely filled with water.

Waterhammer analyses for the CANDU 6 ECC system are performed for both the designed operational requirements (heat transport system makeup during a LOCA) and for the operating sequences used in scheduled ECC system testing, including commissioning tests.




Bruce A ECI System




CANDU 6 ECC System

**Figure 1** Schematic Flow Diagrams of the Bruce A ECI system and CANDU 6 ECC system, showing the different designs for separation of $D_2O$ and $H_2O$.

## *2.2 Safety Support Systems*

The Bruce A SSFI also found that “the safety significance of some support systems, such as recovery area drainage and ventilation, has not been appropriately recognized” for the ECI system. The need to address the safety significance of support systems has been recognized in the current CANDU 6 design and the top-level Safety Design Guide lists all Safety Related systems and their high-level role in the operation of the nuclear power plant. Based on the classification of a system within this document, the guide specifies general design requirements. Testing requirements to ensure reliability are established by the Probabilistic Safety Assessment for the plant. In the CANDU 6 design the ECC system “support systems” are classified as Safety Support systems and are included in the Safety Design Guide. As a consequence, the CANDU 6 design fully addresses the safety significance of the ECC support systems and the design provides for their assured operation as required.

## *2.3 Cable Separation*

The Bruce A ECI SSFI has identified deficiencies in cable separation that have arisen as a result of in-service configuration changes that have been made at Bruce A to resolve other safety related issues. These deficiencies are not found in the CANDU 6. The physical layout and detailed cable routings are different between the Bruce A and CANDU 6 plants. In addition, the tools used for the current CANDU 6 wiring design are much stricter, and have more stringent requirements built in to prevent channelization violations, than the tools used to design Bruce A. The CANDU 6 design guides provide clear requirements for cable routing and separation and clear requirements for an equipment, cable, and cable routes numbering system. The CANDU 6 Grouping and Separation Safety Design Guide also mandates physical separation requirements.

## 3. BRUCE B SERVICE WATER SYSTEMS SSFI

The systems examined in this SSFI were the Common Service Water, Low Pressure Service Water, Closed Loop Demineralized Service Water, High Pressure Service Water and the Emergency Water systems. The findings of the SSFI can be grouped together under five technical issues:

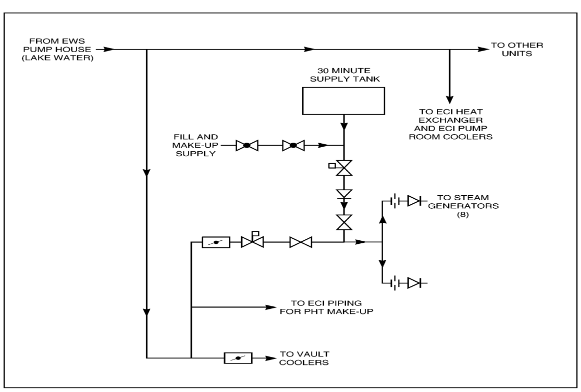
1. Lack of reasonable assurance that the Emergency Water System (EWS) will function as intended following either a seismic or main steam line break design basis accident.
2. Lack of a set point calculation methodology for the service water systems.
3. Inadequate seismic and environmental qualification programs.
4. The design, analysis, modification and substitution processes lack rigor.
5. Inadequate configuration control and documentation.

The first three are design-related while the latter two are station operations and management issues.

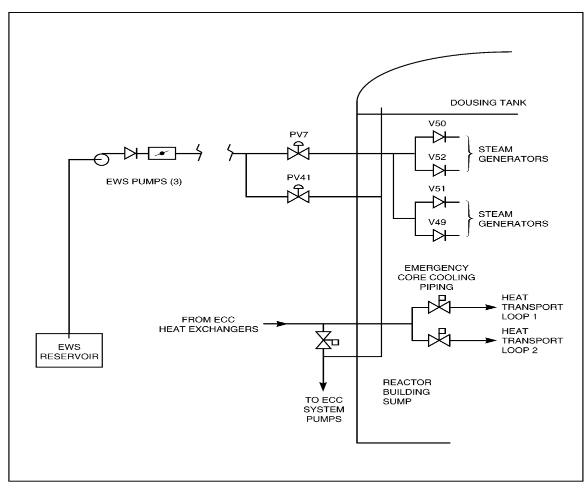
### *3.1 Emergency Water System*

The most important findings of the SSFI relate to a lack of assurance that the EWS system at Bruce B would function as intended following either a seismic or main steamline break design basis accident. The fundamental problems are associated with design configuration and documentation, as-built conditions, maintenance, and the conduct and documentation of testing. The issue is not the basic design of the system.

There are key differences in the EWS design for Bruce B and for CANDU 6. The Bruce B EWS includes a relatively small storage tank at a high elevation to provide water before pumps can start to supply water from a lake. The CANDU 6 EWS draws water initially from the much larger dousing tank located in the Reactor Building (RB) dome (Figure 2). This gives the CANDU 6 EWS much more time for manual start-up of pumps to supply water from an EWS storage pond. The CANDU 6 EWS design also uses more reliable pressure transmitters. Inadequate design analysis support was found for in-service modifications to the EWS piping at Bruce B. The CANDU 6 design is supported by complete design analyses and is fully qualified for seismic loads and thermal stresses.




Bruce B EWS




CANDU 6 EWS

**Figure 2** Schematic Flow Diagrams of the Bruce B and CANDU 6 EWS showing the different sources of water.

### 3.2 Inadequate Calibration Program

The SSFI found that a set point calculation methodology for the service water systems was not implemented, with the result that some set points could not be justified. The calibration program for instruments and indicators associated with the service water systems did not adequately support proper calibration, set point determinations, calibration frequencies, Safety System Test performance, and operability of system components.

All of the service water systems for the CANDU 6 design include operating and alarm set points which reflect the design requirements and specifications of the components and systems, as documented in the CANDU 6 engineering documents. Uncertainties in the tank level set points on the Bruce B EWS are not a concern for the CANDU 6 EWS because it is supplied by the much larger dousing tank.

There is a broader issue of the treatment of instrument loop uncertainties in general. In the CANDU 6 design, instrument loop uncertainties are systematically analyzed and documented for Special Safety System actuation parameters, and for additional safety parameters which are invoked in the Abnormal Operating Manuals. In accordance with Atomic Energy Control Board (AECB) requirements, Minimum Allowable Performance Standards (MAPS) are specified for the Special Safety System. These are achieved by allowing margin between the design values (the setpoint) and safety analysis values (the safety limit) to give conservative (pessimistic) evaluation of the safety system performance.

However, for the other process systems, including the service water systems, the treatment of loop uncertainty analysis was based on engineering judgment. Favourable operating experience in the operating CANDU 6 plants attests to the robustness of the design. Nevertheless, in light of the Bruce B SSFI findings, AECL has identified the need to review the treatment of instrument loop uncertainties for the Group 2 Safety Support Systems, including the EWS System.

### 3.3 Seismic Qualification

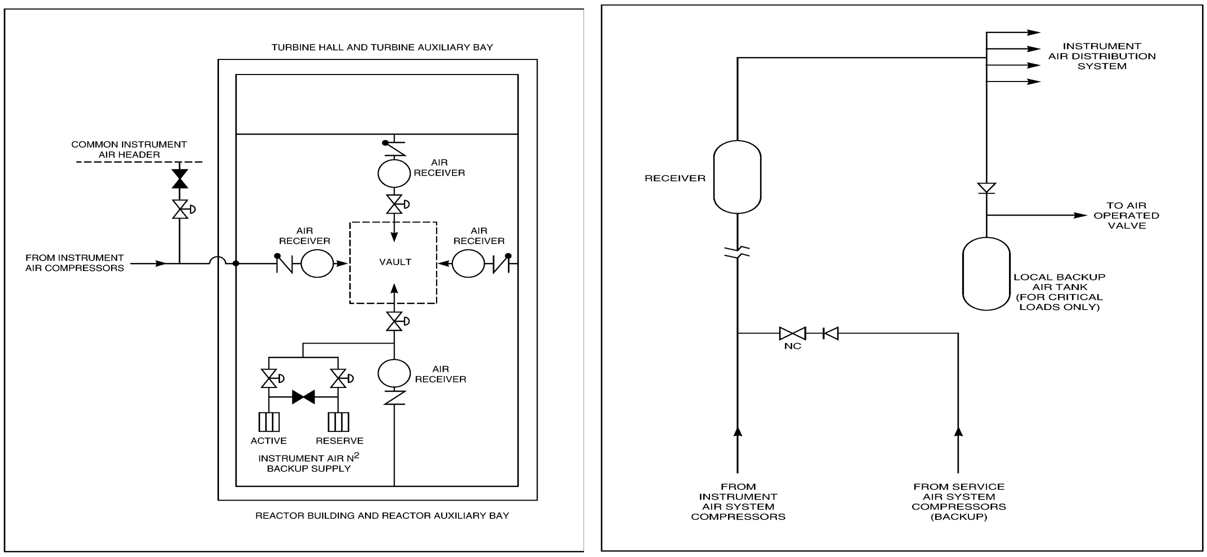
The SSFI found that the seismic and environmental qualification of the Bruce B water systems was not adequate. The CANDU 6 EWS is seismically qualified to Design Basis Earthquake (DBE) Category B, in accordance with the Safety Design Guide on Seismic Qualification, to supply water to the secondary side of the steam generators and to the heat transport system for makeup following a DBE. The seismic qualification is documented and supported by appropriate analysis and tests. Environmental qualification issues are discussed in Section 7.

## 4. DARLINGTON COMPRESSED AIR SYSTEMS SSFI

This SSFI examined both the Instrument Air (IA) and Service Air systems and found that the original design of these systems was robust, but that there were several inadequacies in interfacing support systems which decreased assurance in the overall system's ability to meet design requirements. There were three major issues:

1. There is no documented and verifiable assurance that the backup $N_2$ supply to the Instrument Air (IA) system can perform its intended function.
2. Testing and maintenance were found to be inadequate; valves were installed without appropriate tests, valves and gauges were found without adequate calibrations, and maintenance call-ups were missing.
3. Modifications have been made to the plant after in-service that are not documented to be properly analyzed and assessed; configuration control is lacking.

Only the first of these issues is related to the original design. Unlike Darlington, the CANDU 6 IA system does not include a backup $N_2$ system. Instead, critical loads (including dousing valves, liquid injection valves, main steam safety valves, and airlocks) have their own local, seismically-qualified air tanks to ensure IA supply (Figure 3). Important control valves in the steam and feedwater systems, including liquid relief valves are provided with local nitrogen bottles. Furthermore, the current CANDU 6 IA system design includes a Post-Loss-of-Coolant-Accident (LOCA) Instrument Air system to supply IA to equipment in the Reactor Building after the normal IA is turned off a few hours following a LOCA.




Darlington Instrument Air System

CANDU 6 Instrument Air System

**Figure 3** Schematic Flow Diagrams of the Darlington and CANDU 6 Instrument Air Systems showing the different strategies for backup air supply.

## 5. PICKERING ELECTRICAL DISTRIBUTION SYSTEM SSFI

The scope of this SSFI included portions of the Electrical Distribution system (both AC and DC), emergency protection circuits and devices, mechanical support systems, and associated instrumentation and focused on the Class I, II, III, and IV systems, with emphasis on those system aspects that could affect either the safety of the plant or reliability of the Electrical Distribution system. The Site Electrical System, standby generators, 600 V Interstation Transfer Bus, and emergency coolant injection (ECI) system buses were reviewed in detail.

The inspection found that “the original design of the Pickering Nuclear Generating Station (NGS) Electrical Distribution system was robust and included substantial design margins”. However, the inspection also found that “poor design and configuration control practices have, over the years, undermined the system’s design basis to the point that it does not meet design requirements in some cases. In other instances, design margins have been reduced to unreasonable levels. Ineffective maintenance further reduces confidence in the system’s reliability and readiness. Certain design engineering and maintenance activities were found to be well below standards and in need of additional management attention”.

The key findings of the SSFI were grouped into four areas:

1. Engineering Design: The design basis for the electrical systems has not been adequately maintained. The original electrical analyses have not been updated in many cases and the system

capability is indeterminate with respect to key electrical performance attributes, including short circuit, electrical coordination, power flow, voltage drop and transient stability.

2. Design Basis and Configuration Management: A failure to maintain the design basis and ineffective configuration management is a problem for the electrical systems as well as for other plant systems. Calculations, evaluations, and analyses that support design basis assumptions and requirements have not been maintained.
3. Maintenance and Testing: The maintenance and testing area produced the greatest number of inspection findings and was evaluated as unacceptable. Maintenance procedures were found to be inadequate.
4. Operations: The most significant concern in this area was a weakness in the Abnormal Incident Manual which was overly complex and unclear.

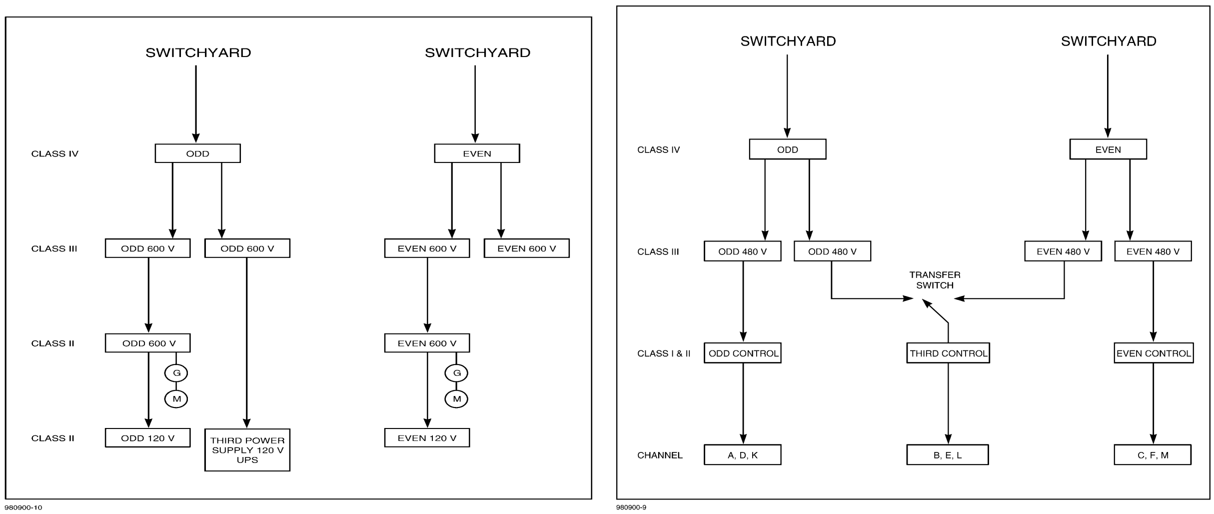
All of these issues relate to the manner in which the electrical systems have been modified and maintained. They do not reflect any basic flaws in the overall design, or effectiveness of the systems as they were originally designed. They are also specific to the operation and maintenance of the Pickering NGS and are not directly applicable to the CANDU 6 design.

## *5.1 Electrical System Design*

Pickering A is OHN's oldest CANDU station and it was designed before modern, rigorous Institute of Electrical and Electronic Engineers (IEEE) standards were in place. As a result, some of the Pickering A electrical system does not meet current standards. In addition, the SSFI found numerous instances where modifications to the original electrical distribution system had created situations which had not been analyzed to reveal and correct faults. Fundamental to these problems was a lack of a well documented and verified electrical analysis and coordination study for the Class 1 and Class II power systems.

The design of the electrical systems for CANDU 6 is considerably improved over the Pickering A design. Batteries have been properly sized to IEEE standards with appropriate margins for temperature, aging and loads. The CANDU 6 Class II power system has identical triplicated buses instead of a special 'Third Power Supply', as included in the Pickering A design (Figure 4). The CANDU 6 design has improved fault handling and does not use motor-generating sets (which has caused problems at Pickering) for uninterruptible power supply. The electrical systems have improved protection, rated to meet load requirements.

The designs of all four classes of electrical power (Class I, II, III, and IV) for current CANDU 6 plants are verified by electrical analyses. AECL has taken steps to ensure that Class I and Class II coordination studies are carried out as an element of the commissioning of the CANDU 6 plants.




Pickering Electrical System CANDU 6 Electrical System

**Figure 4** Simplified Line Diagrams of the Pickering A and CANDU 6 Electrical Distribution Systems showing the different strategies for Class II power supply (special Third Power Supply vs. triplicate busses).

## 6. FIRE PROTECTION

The Fire Protections SSFI focused on three areas:

- the OHN fire protection organization from a functional alignment, redundancy, overlap and accountability perspective,
- applicable fire protection regulations at OHN's plants, including an evaluation of the current state of compliance, and
- the state of the fire protection program.

The SSFI found that "the original design was robust with respect to fire protection. However, improvements are needed in the areas of program definition, fire suppression, fire detection, emergency response, analysis, and operations". The SSFI further found that "the inherent robustness of the Ontario Hydro Nuclear CANDU nuclear plant designs provides the basic defence-in-depth protection of the units against the effects of fire. This protection is derived from the separation of the required systems from the effects of fire resulting from the layout of the physical plant and from the design criteria applied to the cable routings for the important plant safety systems."

Many of the detailed deficiencies identified in the Fire Protection inspection relate to the Pickering A and Bruce A stations. These stations were designed and built when fire protection requirements were themselves evolving. Prior to the IIPA, Ontario Hydro had already recognized that fire protection deficiencies existed, but had not yet completed all initiatives geared to meet the modern standard (CAN/CSA-N293) established in 1987.

In assessing fire protection, the SSFI recognized that the OHN multi-unit stations have unique physical building layouts such that there are a minimum of classical fire areas comprised of a physical volume surrounded by rated fire barriers such as floors, walls, and ceilings, with barrier penetrations sealed to the rating of the barrier.  The OHN stations are characterized by expansive openness, with the design intent of facilitating access for manual fire-fighting, which is the prevailing method of fire suppression, containment and control.  A second feature, unique to the Bruce A and Pickering A stations, is the absence of a secondary control area in addition to the main control room.  All other CANDU units have a secondary control area which provides operators with the capability to perform essential safety functions in case of a need to evacuate the main control room in the event of a fire.

The reliance on manual fire-fighting, while it is an recognized as an acceptable approach in principle, led to a number of findings of deficiencies including:

- inadequate training of fire fighters,
- inadequate resources (under some circumstances operators are double tasked to fire fighting),
- difficulty in gaining access to fires with proper equipment in some locations,
- insufficient correct equipment in correct locations, and
- insufficient planning for consequences of inability to fight fires manually.

## *6.1 CANDU 6 Fire Protection Design*

Fire protection for the current CANDU 6 design complies with the Canadian standard, CAN/CSA-N293 which was issued in 1987.  In addition, input from Fire Protection authorities has led to the implementation of further improvements in the CANDU 6 fire protection systems.

The CANDU 6 Safety Design Guide on fire protection and CSA standard place emphasis on fire prevention, fire detection and suppression, and mitigation of the effects of fires in the design.  They also outline ways to limit the use of combustible materials in areas containing safety related equipment, control of combustible materials (including gases), and storage requirements.  Limits on the flame spread characteristics and acid gas evolution of cables are also addressed.  Requirements for fire detection systems and fire extinguishing systems are identified.  Requirements to mitigate the effects of fires include the routing of safety-related cables, and grouping and separation of systems and equipment to ensure that one set of equipment can always perform the required safety functions during a fire, and provision of barriers at critical locations.

The CANDU 6 design for fire protection is reviewed in a comprehensive Fire Hazard Assessment (FHA) for the plant, which identifies the location of combustible materials and key safety related equipment and provides an overall review of the fire hazards in the plant.  This information is provided to the owner and is intended to be used as input to the Fire Protection Program for the operating plant.  CAN/CSA-N293 also includes operating requirements for the control of combustibles, training, inspections, organization of the fire brigade, etc.

The following summarizes the improvements already incorporated in the current CANDU 6 fire protection design which address the major SSFI findings:

- Older CANDU 6 plant designs make substantial use of the “fire influence approach” which relies on open areas and manual fire suppression to mitigate fire propagation.  The current CANDU 6 design makes greater use of fire areas and fire barriers, with major barriers established between the Group 1 and Group 2 outside the Reactor Building, between the Reactor Building and the Service Building, and between the turbine/generator area and the Control Room.
- Fire suppression systems are provided with at least manual fire hose coverage for virtually all areas, and automatic fixed suppression systems provided for most areas outside of the Reactor Building and Control Rooms.

- Fire detection systems and fixed suppression systems are provided in the cable spreading rooms.
- Sprinkler heads are installed in accordance with National Fire Protection Association (NFPA) recommendations.

# 7. IN-SERVICE ENVIRONMENTAL QUALIFICATION

This SSFI assessed the status of the In-Service Environmental Qualification Project which was in place for the Bruce A and B, and Pickering A and B stations and evaluated Darlington's 'mature' Environmental Qualification (EQ) program. The inspection was intended to evaluate the value and quality of the project to date and its effectiveness and found that the approach and methodology being used to develop the project bases (the Environmental Qualification List and environmental conditions) appeared to be sound and consistent with OHN's commitments to the Canadian regulator. However, the inspection found deficiencies in the project including: inconsistencies in the distinction between harsh and mild environments for different equipment and inappropriate use of probabilistic risk assessment (PRA) and best estimate methods to reduce the scope and/or post-accident conditions. It recommended that the PRA should only be used to prioritize and focus EQ activities.

The inspection also found a number of deficiencies in the EQ documentation. In particular, it found that formal design calculations did not appear to exist at OHN. Instead, the data required for EQ analyses is pieced together from various reports, studies and informal communications. As a result, there is inadequate access to the required assumptions, boundary conditions or limitations required to interpret and use data correctly.

## *7.1 Comparison of OHN and CANDU 6 Environmental Qualification*

The OHN stations were all designed and constructed to the EQ standards established at that time. With the exception of Darlington, the methodology for assessing EQ conditions and determining which systems, support systems and equipment needed qualification, and the level of qualification required, was less demanding than the modern standards. As a result, the older OHN stations face the difficult task of backfitting the EQ requirements for their equipment based on modern standards, and then meeting those requirements.

OHN has a program to identify the design basis accidents that can lead to harsh environments and to use these to develop Safety Requirements Matrices. OHN establishes a Harsh Environment Components List (HECL) and then an Environmental Qualification List (EQL) which is a subset of the HECL. All components on the EQL are assessed for their ability to perform the required safety function using an Environmental Qualification Assessment (EQA). All components on the EQL must satisfy EQ requirements or be upgraded or replaced. This establishes the environmental qualification which then must be maintained.

This process is hard to carry out for an operating station because of difficulties in performing assessments consistently and establishing the ability of as-built equipment to meet the EQ requirements. The inspection found inappropriate efforts to justify the EQ status of equipment through analysis and engineering judgment of the existing plant configuration, rather than through more rigorous equipment testing and/or replacement. Such problems do not exist for a new reactor where EQ deficiencies can be identified and remedied during the design and procurement phases.

For the current CANDU 6 design, a comprehensive EQ program is an integral part of the design and procurement processes as documented in a high-level Safety Design Guide. Environmental qualification begins at the design concept stage and continues throughout the operating life of the station. Design principles are established to identify the number of safety related components which needed to be qualified and to simplify the process of establishing and maintaining qualification. Areas of the plant subject to harsh conditions are contained through the use of barriers or relocation of high energy lines, which may be a source of harsh environmental conditions. Where practical, safety-related components are located outside of areas subject to harsh conditions. The number of different conditions used for environmental qualification of components is minimized. Safety-related components are located outside of areas subject to flooding.

To qualify equipment, the environmental conditions are predicted for postulated design basis events, and the safety functions of each safety system and its associated components are identified. The design ensures that safety related systems, structures and components that are required to perform safety functions during an accident can withstand the environmental conditions which could occur as a consequence of the accident. Next, suitably qualified equipment is specified and procured. This equipment is installed according to specific instructions. Finally, by means of on-going maintenance and replacement of parts, the qualification of the equipment is maintained during the operating life of the plant.

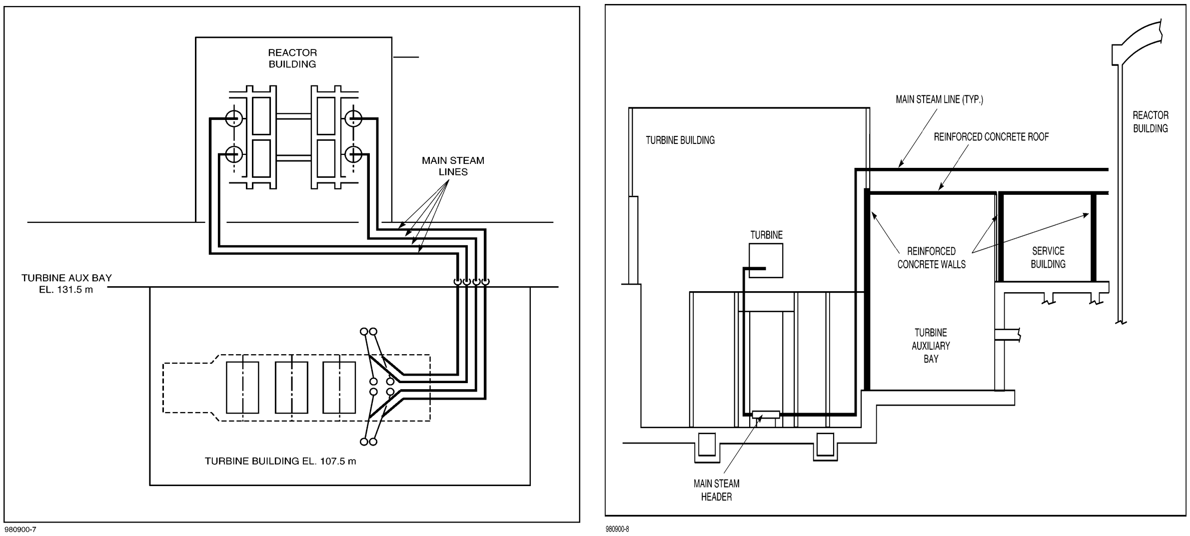
Proper documentation and traceability are required at all stages of the EQ process. AECL is responsible for supplying complete and consistent EQ information when the plant is transferred to the owner. The owner is then responsible for continuing maintenance and record keeping to preserve the qualified status of the plant.

### *7.2 Plant Layout Considerations*

The layouts of the multi-unit OHN stations are very different from the layout of the single-unit CANDU 6 design. As a consequence, safety related equipment for the CANDU 6 design is located in different areas and subject to different environmental conditions in the event of postulated design basis accidents. This means that many specific EQ issues at OHN stations are not applicable to the CANDU 6 design.

All OHN stations have containment structures which are connected to a central vacuum building that provides pressure relief and steam suppression in the event of a LOCA. As well, the layouts of the Pickering A and B stations differ from the layout of the Bruce and Darlington stations. The containment structures of the latter stations are interconnected by a fuelling machine duct which runs under the length of the station and the containment volume only includes the reactor core, the heat transfer system (HTS) piping and the fuelling machine vaults. The HTS pump motors, the upper portion of the steam generators and the reactivity mechanism deck of the reactors at Bruce and Darlington are located outside of the containment volume. At all OHN stations, the turbine generators for all units are located in a single hall. As a result of these design layouts, certain types of accidents, and particularly main steam line breaks outside of containment, can create harsh environmental conditions for equipment throughout the multi-unit station.

The CANDU 6 layout has a standard single-unit containment design. The Reactor Building houses the reactor, fuel handling systems, heat transport system (including the steam generators) and the moderator system together with their associated auxiliary and special safety systems. A Service Building, attached to the Reactor Building, houses nuclear systems which need not be located in the RB, service areas, heavy water support systems, spent fuel storage bays and low pressure ECC. The main steam and feedwater lines are located outside of the Service Building and there is a wall in the Turbine Building to separate the Turbine Hall and the Turbine Auxiliary Bay. This wall provides protection for the Turbine Auxiliary Bay and the Service Building against a main steam line break (MSLB) in the Turbine Hall (Figure 5).




Darlington Main Steam Lines — CANDU 6 Main Steam Lines

**Figure 5** Schematic Diagrams of the layouts of the Darlington and CANDU 6 Main Steam Lines. The CANDU 6 steam lines are routed outside of the Service Building while the Darlington steam lines run through the Reactor Building to the Turbine Hall.

### *7.3 Cables*

The environmental qualification of cables is an issue for the OHN EQ Program. The design of the older OHN stations included extensive use of polyvinylchloride (PVC) insulated and jacketed cables. The nuclear industry has recognized that PVC cables may not meet the requirements for station life performance and design basis accidents. This has been addressed in the current CANDU 6 design and the use of PVC-insulated cables for control and instrumentation cables is prohibited.

## 8. SUMMARY

AECL's review of the design-related findings in the recent OHN SSFIs concluded that the current CANDU 6 design addresses the issues raised in the SSFIs through the implementation of an effective design feedback process and adherence to modern codes and standards. There is no need for modifications to the current CANDU 6 design arising from this review.

The SSFIs have highlighted the importance of complete, accurate engineering design information. As a results of its review, AECL has identified a few instances where the CANDU 6 design documentation may be deficient and has taken steps to review these areas and make necessary improvements.

The problems observed at the OHN stations developed as a result of poor engineering practices which could arise at any nuclear plant. The findings provide valuable lessons to all nuclear plant owners in the areas of:

- configuration management,
- review and documentation of design changes, and
- installation and acceptance testing.

All nuclear plant owners are advised to review their own situation to ensure that appropriate controls are in place to avoid the problems which arose at