INFO-0674

REPORT

AECB Staff Annual Assessment of the Bruce B Nuclear Generating Station for the Year 1996

Atomic Energy Control Board
Ottawa, Canada

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The Atomic Energy Control Board is the independent federal agency that controls all nuclear activities in Canada. Our mission is to ensure that the use of nuclear energy in Canada does not pose undue risk to health, safety, security and the environment.

A major use of nuclear energy in Canada is electricity production. We have an office at every nuclear generating station, and we monitor the stations on a day-to-day basis. Specialists in our Ottawa head office work with the on-site staff to accomplish our mission.

We assess every station's performance against legal requirements, including the conditions in the operating licence we issue. To do this, we review all aspects of a station's operation and management, and we inspect each station.

SUMMARY

This report is the Atomic Energy Control Board (AECB) staff assessment of reactor safety at the Bruce Nuclear Generating Station B for 1996. Our on-site Project Officers and Ottawa-based specialists monitored the station during the year. We concluded that Ontario Hydro operated Bruce B safely in 1996.

We accepted Ontario Hydro's safety arguments to increase reactor power from 90 to 94 percent of full power. To operate at this higher power level, Ontario Hydro must now manage the fuel channel gaps carefully so that any possible power pulse during an accident is within acceptable limits.

Although the cases of non-compliance with the licence were minor, the number increased from 19 in 1995 to 38 in 1996. We consider this unacceptable. We have raised this issue and requested improvements by Ontario Hydro as part of the Bruce B licence renewal.

Radiation doses to workers and the public were well below the legal limits and remained well within Ontario Hydro's internal targets.

However, on nine occasions, Ontario Hydro was in non-compliance with the Atomic Energy Control Regulations. This is another area where we have requested improvements as part of the Bruce B licence renewal.

We noted that in the areas of environmental qualification, improvements to maintenance backlogs, management strategies for pressure tubes and steam generator tubes and carrying out improvements to the station, the rate of progress is slow. By way of explanation, Ontario Hydro has informed us that it is unable to reach its desired staffing levels.

In last year's report, we stated that temporary changes (jumpers) needed to be reduced. In 1996, Ontario Hydro reduced the number of jumpers by 34 percent, exceeding its target reduction of 25 percent.

We concluded in our 1995 report that Ontario Hydro management needed to ensure that reactor safety is not compromised by production pressure. In 1996, we noted that management allowed adequate time for reactor shutdowns and maintenance, giving reactor safety a high priority.

The Ontario Hydro management team demonstrated conservatism in its decisions to shut down reactors when equipment problems occurred and in extending outages to complete necessary work. However, we noted that management had difficulty implementing lasting solutions to problems.

Although we believe the Bruce B plant is safe, we noted that the number of outages and the number of secondary and tertiary equipment failures during reactor unit upsets increased. Similar precursors were seen before other CANDU plants experienced a marked decrease in safety performance. We believe Ontario Hydro needs to pay special attention to prevent such a decrease in the safety performance at Bruce B.

Inspection of pressure tubes and steam generator tubes by Ontario Hydro showed continuing degradation of these components. However, we believe that Ontario Hydro continues to make progress in correcting and managing these areas.

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INTRODUCTION

Bruce Nuclear Generating Station "B" (Bruce B) is located on the shores of Lake Huron, between the towns of Kincardine and Port Elgin. It houses four 915 megawatt *Canadian Deuterium-Uranium* (CANDU) reactors with a design life of 40 years. The reactor units are numbered from 5 to 8.

This report is our assessment of the safety of the operation of Bruce B during 1996. It has been compiled by *Atomic Energy Control Board* (AECB) staff at Bruce B with input from head office staff in Ottawa. We have based our assessment both on our own observations and on information submitted to us by Ontario Hydro as required by the station's operating licence.

The nuclear industry uses many technical terms in its day-to-day activities. To help our readers, we have provided a glossary of the technical terms used in this report. We have *italicized* glossary terms the first time they appear in the body of the report.

Although we use similar terms to describe safety performance for each of the nuclear generating stations in Canada, many of them have different contexts. Readers should be aware that direct comparison between stations is difficult and often not appropriate.

At our head office in Ottawa, the public can consult all documents related to the licensing process of nuclear facilities. Our public library also contains an important collection of documents, available on request. Apart from the AECB Staff Annual Assessment Reports, we publish an AECB Annual Report, research reports, communiqués, information bulletins, notices and pamphlets. Board meeting minutes are also available. Our address is: 280 Slater Street, Ottawa, Ontario, Canada.

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OPERATIONAL SAFETY

COMPLIANCE WITH REGULATIONS MADE UNDER THE ATOMIC ENERGY CONTROL ACT

We require Ontario Hydro to operate Bruce B according to the legal requirements governing the nuclear industry in Canada. These requirements come from the *Atomic Energy Control Act* and regulations made under the Act. The regulations directly applying to Bruce B are the *Atomic Energy Control Regulations*, the *Physical Security Regulations*, the *Transport Packaging of Radioactive Materials Regulations*, and the AECB *Cost Recovery Fees Regulations*.

In 1996, Ontario Hydro's compliance with the Atomic Energy Control Regulations was unacceptable. Compliance with the remainder of our regulations was satisfactory.

Ontario Hydro reported nine non-compliances with the Atomic Energy Control Regulations in 1996. Most of these events concerned failure to post adequate radiation warning signs within the station. It is a requirement of our Regulations that signs are posted in nuclear facilities to warn workers of *radiation fields* above 0.025 *millisievert*. Ontario Hydro failed to comply with this requirement seven times during 1996. We consider such performance to be unacceptable. Ontario Hydro has taken corrective action and we expect to see a marked improvement in 1997.

None of the reported non-compliances was intentional. We reviewed these events in detail and concluded that they were not of major safety significance.

In June, we carried out a formal appraisal of Ontario Hydro's compliance with the Physical Security Regulations. We concluded that compliance was acceptable. However, some areas need to be improved. Many areas that require improvement were noted in our 1993, 1994 and 1995 appraisals. To address our findings, Ontario Hydro has begun a project to initiate changes to equipment and procedures.

Ontario Hydro did not report any non-compliances with the Transport Packaging of Radioactive Materials Regulations, and it met all conditions of the AECB Cost Recovery Fees Regulations.

COMPLIANCE WITH THE OPERATING LICENCE

The Atomic Energy Control Regulations state that operation of the station must be in accordance with the reactor operating licence. The licence that we issue includes conditions that the licensee must meet. Failure to comply with a licence condition is a licence non-compliance.

Our review of the 1996 Bruce B event reports revealed that Ontario Hydro reported 38 non-compliances with the operating licence. This is a considerable increase over previous years and is unacceptable.

Table 1: REPORTABLE EVENTS

TYPE	NUMBER
Reactor operating licence non-compliances	20
Operating Policies and Principles non-compliances	18
Pressure boundary leaks	9
Regulations non-compliances	9
Degradation of special safety system or safety-related system	6
Miscellaneous	6
Reactor trips	4
Reduction in effectiveness of power control or heat transport system control	2
Unit alerts	2
Potentially serious process failures	1
TOTAL	77

Eighteen of the reported events related to the licence condition that requires Ontario Hydro to operate Bruce B in accordance with an approved set of *Operating Policies and Principles*. Eight related to the licence condition that Ontario Hydro comply with the *Radiation Protection Regulations*, while four more related to the condition requiring that a minimum shift complement be present in the station to deal with emergencies. The remainder concerned non-compliances with other licence conditions.

We reviewed each event and concluded that none of the events resulted in a safety hazard to the public.

Steps are being taken by Ontario Hydro to reduce the number of licence non-compliances in 1997. We will monitor Ontario Hydro's programs designed to meet this objective. In addition, as part of licence renewal, we asked Ontario Hydro to show how it will comply in this area.

EVENTS REPORTED TO THE AECB

As a condition of the operating licence, Ontario Hydro must report certain types of events, known as *reportable events*. Ontario Hydro must report any event in the station that contravenes the operating licence or any of the governing regulations. Ontario Hydro must also report events that may be precursors to more serious events. It also analyses the reported events to decide what action must be taken to prevent a recurrence.

Our assessments showed acceptable performance in reporting in 1996. Bruce B reported events promptly and kept us informed of the progress of follow-up actions initiated from the events. None of the events had a major effect on public safety.

The types of events reported by Ontario Hydro are shown in Table 1. The total number of events reported was down slightly from 1995. Human errors were a factor in more than half of the reported events. They included lack of self-checking and failure to follow prescribed procedures. We believe Ontario Hydro must improve on its efforts to reduce the number of reportable events in 1997.

Ontario Hydro has reported that the number of corrective actions arising from events is increasing while the completion rate of corrective action is decreasing. We will closely monitor this situation in 1997.

During 1996, no *serious process failures* or major fires occurred.

Several events are discussed in the Operations and Maintenance section of this report.

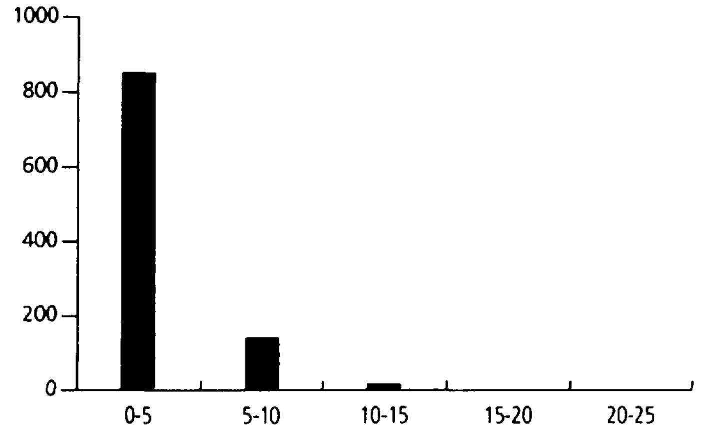
WORKER RADIATION SAFETY

The operation of Bruce B in 1996 did not result in any undue radiological risk to workers at the station.

No worker at Bruce B received a radiation dose in excess of our regulatory limit of 50 millisieverts (mSv). Most workers at Bruce B received a dose of less than 5 mSv (see Figure 1). The total radiation dose received by the workforce remained at about the same level as last year. We believe that the radiation control practices remain in accordance with the ALARA principle (*as low as reasonably achievable*).

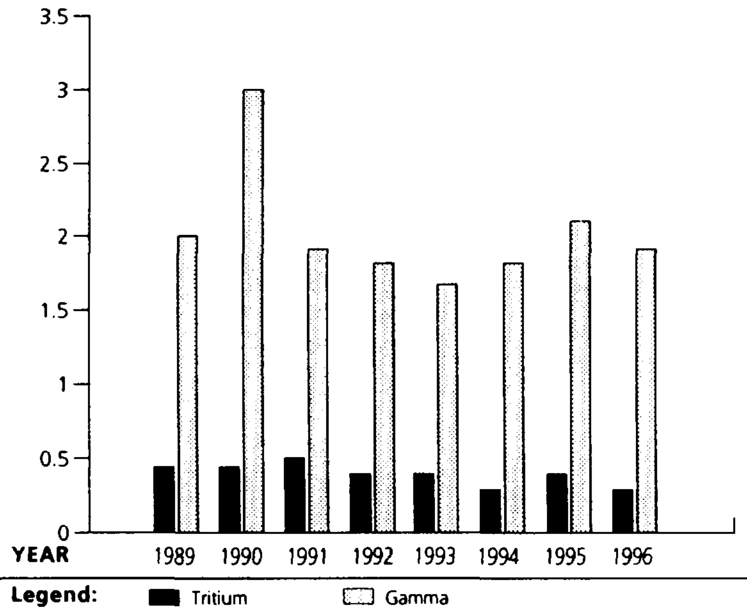
A significant contributor to dose at CANDU plants is *tritium*. By sending *moderator* water to the *tritium removal facility* at Darlington, Bruce B staff was able to reduce the moderator tritium by more than 65 percent. Removing the tritium from the moderator *heavy water* reduces worker radiation doses from this source. The total

Figure 1: BRUCE B WORKER DOSE: DISTRIBUTION BY DOSE RANGE (number of workers vs dose range (mSv))



Annual legal limit is 50 mSv.
The station target is to be less than 10 mSv per person per year.

Figure 2: BRUCE B OCCUPATIONAL DOSE TREND TO 1996 (dose in sieverts vs year)



Tritium forms a significant part of the total radiation dose.
Tritium growth is separate from gamma field growth and requires different controls; thus it is shown separately.

tritium dose to workers has been well controlled (see Figure 2). Removing the tritium also reduces releases to the environment.

Events reported by Ontario Hydro, and our own observations during compliance inspections, indicate that posting of radiation fields needs to be improved. We believe that Ontario Hydro management needs to put processes in place to improve the reliability of the routine radiation monitoring carried out by station staff.

A number of events were also reported to us concerning the careless handling of radioactive waste. Waste was not monitored, put in the right location or correctly posted. We raised this matter with Ontario Hydro management early in 1996 and requested that action be taken to correct the situation. As Bruce B continued to report similar events in the second half of 1996, it appears that management has not found an effective permanent solution to the problem.

In 1996, Ontario Hydro staff improved the way that radiation fields are monitored in the reactor building during outages. Continuous, remote read-outs now reduce the time needed to alert personnel working in the *reactor building* to rising gamma and tritium levels.

PUBLIC RADIATION SAFETY

The operation of Bruce B did not result in any undue radiological risk to the public or the environment in 1996.

The regulatory limit for radiation releases to the environment is known as the *derived emission limit* (DEL). Radioactive releases from Bruce B to the environment were well below the station's annual target of one percent of DEL (see Table 2). Releases have remained stable over the last five years. Bruce B did not exceed the one percent target anytime during 1996.

Based on data obtained from its environmental monitoring program, Ontario Hydro estimated that the dose to the most exposed members of the public, in the vicinity of Bruce A and B, was about 0.004 millisievert (mSv) in 1996. The regulatory limit is 5 mSv per year. Natural background radiation in Canada is typically 2.0 to 2.5 mSv per year. The average gamma dose rate was about 0.05 micrograys per hour and the average tritium activity

Table 2: BRUCE B ENVIRONMENTAL RELEASES

PATHWAY	YEAR				
AIRBORNE	**1992**	**1993**	**1994**	**1995**	**1996**
Tritium	0.072	0.082	0.077	0.048	0.065
Noble gases	0.0068	0.017	0.012	0.011	0.012
Radioiodines	0.0050	0.0044	0.0046	0.0091	0.0035
Particulates	0.0025	0.0035	0.0021	0.0025	0.0016
WATERBORNE	**1992**	**1993**	**1994**	**1995**	**1996**
Tritium	0.028	0.022	0.019	0.012	0.008
Total gamma	0.047	0.023	0.026	0.041	0.020

Note: All values are indicated as a percentage. The limit is 100% and the target is less than 1%.

in the air at the site boundary was about 3 *becquerels* per cubic metre, both of which are very low.

We carried out an appraisal of the environmental monitoring program at the Bruce site in 1996. All aspects of the environmental monitoring program, including organization and administration, program design, field operations, laboratory operations, and data analysis and reporting were appraised. We concluded that, overall, the operations of the environmental monitoring laboratories are in accord with Ontario Hydro's standard. However, effective management control of all aspects of the program has yet to be established. We have requested that Ontario Hydro take action on this matter.

SAFETY SYSTEM PERFORMANCE

The performance of *special safety systems* was acceptable in 1996.

We require that each special safety system be fully functional at least 99.9 percent of the time. To meet this requirement, the time that a special safety system does not fully meet its performance specification is limited to less than 8.8 hours per year. A system is labelled unavailable whenever it is anything less than 100 percent capable, though it may retain considerable effectiveness.

The actual unavailabilities for 1996 are shown in Table 3. The unavailabilities of the special safety systems were well below the limits we set.

Approximately two hours of *unavailability* were assigned to the *shutdown systems*. This was due to inadmissible operation of three *primary heat transport system* pumps, following the *trip* of one pump. Such operation is not permitted since no safety analysis exists for *neutron overpower trip* settings with three pumps in operation. During the two hours that the inadmissible operation existed, both shutdown systems were considered to be unavailable.

Ontario Hydro estimates how well each special safety system will perform in the coming year. The estimate is based on experience and tests performed on the system and components, and the result is expressed as the *predicted future unavailability* of the system. The smaller the predicted future unavailability value, the better the expected performance of the system. The predicted future unavailabilities for all special safety systems, except the *negative pressure containment system*, are below our limit of 8.8 hours (see Table 3). The predicted future unavailability for containment is expected to exceed the limit since the

Table 3: SAFETY SYSTEM PERFORMANCE

SYSTEM	PREDICTED FUTURE UNAVAILABILITY (hours/year)	1996 UNAVAILABILITY (hours/year) (target less than 8.8 hours)			
		UNIT 5	UNIT 6	UNIT 7	UNIT 8
Shutdown system one	5.6	2.1	0	1.9	0
Shutdown system two	6.5	2.1	0	1.9	0
Emergency core cooling	7.6	0	0	0	0
Containment	12.9	0.1	0	0	0.2

unavailability of the airlocks is expected to be higher in 1997.

OPERATIONS AND MAINTENANCE

We consider that Ontario Hydro made acceptable progress in improving standards of operation and maintenance. This conclusion is drawn from our review of Bruce B staff's handling of events and from our monitoring of maintenance activities.

AECB COMPLIANCE INSPECTION

We inspect all areas of the station on a routine basis. During these inspections, known as 'rounds', we found that, overall, equipment in the station appeared to be in a good state of repair. *Housekeeping* in the station was acceptable.

We also carry out detailed system inspections (see Table 4). These inspections involve a thorough review of test and maintenance records, deficiencies, temporary design changes and temporary operating procedures. In addition, we verify valve and breaker positions and the state of equipment in the field.

Table 4: AECB SYSTEM INSPECTIONS COMPLETED IN 1996
Shutdown system one
Shutdown system two
Containment
Inter-unit feedwater tie
Annulus gas system
Standby *class III power supply*

The system inspections revealed no significant safety problems. However, anomalies were identified and reported to Ontario Hydro. Ontario Hydro subsequently took corrective action.

As part of our compliance inspection program for Bruce B, evaluations, assessments, appraisals and *audits* are carried out by staff from our head office. These are discussed in the appropriate sections of this report.

Late in 1996, we set up a team of five experts who carried out an electrical distribution system assessment at Bruce B. The need for these assessments arose from our review of CANDU plant events involving the electrical distribution system. The team assessed the capability of the electrical distribution system to perform as designed. It also assessed the licensee's technical and operational support of the electrical distribution system. The team concluded that the electrical distribution system will perform as designed under normal operating and under upset conditions, provided the upset was not initiated by or did not extensively involve the electrical distribution system. However, improvements to both the *preventive maintenance* and the *environmental qualification* programs are required to ensure the electrical distribution system will function under harsh conditions. We requested Ontario Hydro to take action.

MAINTENANCE

Good maintenance is essential to the safe operation of the station. A clear link exists between effective maintenance and operational safety as it affects the *availability* and reliability of equipment. Routine maintenance was acceptable at Bruce B in 1996.

Both the preventive and corrective maintenance programs continue to have a considerable backlog of work. The number of outstanding preventive maintenance *call-ups* at the end of 1996 was about the same as last year (see Table 5). Call-ups are used to remind Bruce B staff that regularly performed preventive maintenance work is due.

Safety-related call-ups are high priority call-ups. About 60 percent of all call-ups at Bruce B fall into this category. Ontario Hydro completed 99 percent of the designated safety-related call-ups in 1996.

The number of *deficiency reports* outstanding per unit, which represents the corrective maintenance backlog, was approximately the same as last year.

Late in 1996, Ontario Hydro introduced a 13-week rolling maintenance schedule. This is a process by which all equipment is checked in the station, and worked on if necessary, once every 13 weeks. Benefits of this process should include reductions in the backlog and 100 percent completion of preventive maintenance.

Bruce B has also introduced a preventive maintenance enhancement process based on reliability-centred maintenance techniques. Reliability-centred maintenance techniques identify

Table 5: MAINTENANCE

	1992	1993	1994	1995	1996
Number of preventive maintenance call-ups not completed per unit at year end	808	725	646	343	367
Completion rate for all call-ups	74%	87%	91%	89%	88%
Completion rate for safety-related call-ups	80%	100%	98%	99%	99%
Number of deficiency reports outstanding per unit at year-end	2514	1052	851	1078	1006

components important to the reliable operation of systems and specify the frequency and nature of preventive maintenance to be applied to these components. The Bruce B staff plans to complete reliability-centred maintenance on many selected systems over the next four years.

We are pleased to note that a cornerstone of Ontario Hydro's recently announced strategy for excellence in nuclear operations is the improvement of maintenance.

During 1996, units 5 and 7 were shut down by Ontario Hydro for planned maintenance outages.

Systems are often placed in abnormal configurations during outages. The effect of this on safety-related systems, such as *heat sinks*, must be carefully considered. In 1996, Ontario Hydro improved its control of system configuration changes during maintenance outages. These controlled changes involved the use of hold points, check sheets and management approval prior to changing a defined system configuration. We consider this a positive step for ensuring reactor safety during outages.

MANUAL OPERATION OF CONTROL VALVE

In February 1996, when unit 5 was operating in a steady state at 90 percent of full power, a *liquid zone control system* control valve failed in the open position due to an actuator problem. As a result, one of the zone control units filled with water. Control of water level in two other zone control units was also affected.

The control valve is normally on automatic control. When the valve failed, operating staff placed the valve on manual control to regain control of the zone control units. An attempt to repair the valve actuator at high power was planned.

A *neutron flux tilt* then caused a reactor power setback to approximately 70 percent of full power. Operating staff manipulated the valve manually to end the flux tilt and then raised reactor power back to 90 percent of full power.

We consider that raising power with the valve on manual control was an unacceptable operating practice and accordingly advised Ontario Hydro. The Bruce B Nuclear Safety Department assessed the event and also concluded that such a practice should not be permitted. As a result, Bruce B procedures have been modified.

Due to a design weakness, malfunctioning of control valves in the liquid zone control system has been a chronic problem at Bruce B. Ontario Hydro has made a design change to correct the problem.

SHUTDOWN SYSTEM TWO SPURIOUS TRIP

Unit 7 was operating normally at 90 percent of full power when it experienced a *shutdown system two* (SDS2) trip. This was in fact a spurious trip caused by malfunctioning SDS2 equipment. We are concerned with the many operational problems that followed the trip. Equipment did not function as expected and some procedures were inadequate. Ontario Hydro classified this as a highly significant event and is acting accordingly.

FUELLING EVENT

While Bruce B staff was performing routine fuelling operations, a reactor area bridge moved down to its lower stop instead of a Central Service Area bridge. The reactor area bridge was stopped by the *fuel handling* protective computer and no equipment was damaged. The *fuelling machine* was not clamped on a *fuel channel* at the time of the event so there was no potential for damage to the reactor *pressure boundary*. The event was caused by human error. Computer memory locations were mistakenly changed in a fuel handling control computer. In response to the event, Ontario Hydro issued temporary instructions to fuel handling operators requiring independent verification of memory changes. Ontario Hydro will implement software changes to protect important memory locations from being changed in error. It will also install an interlock to prevent operation of the bridge's brakes and drive motors when a fuelling machine is clamped to a fuel channel.

PRESSURE TUBES

Based on both the analysis of frets found by Ontario Hydro during inspections and on the results of laboratory tests, we consider that pressure tube *fretting* is unlikely to cause *pressure tube* failure at Bruce B.

As pressure tubes age, they become longer. As a result, the *fuel bundle* at the end of the fuel channel where the heavy water coolant enters (the inlet end) becomes abnormally supported and gradually moves over the pressure tube rolled joint. Abnormally supported bundles vibrate in the coolant flow and the bearing pads cause fretting in the rolled joint area. The frets locally increase the stress in the rolled joint area. This increased stress can cause *delayed hydride cracking*. To date, no pressure tube cracking has occurred from fretting in Bruce B reactors.

During 1996, Ontario Hydro inspected pressure tubes in units 5 and 7. In the distribution and dimension of frets, Ontario Hydro found little difference between these results and those found in previously inspected units at Bruce B.

Ontario Hydro is attempting to control fretting by using longer than normal fuel bundles. Bundles with rounded ***bearing pads*** have also been used to a limited extent. Inspections to date have shown little difference in the size and number of frets observed in channels where long fuel bundles or rounded bearing pads are used. The longer than normal fuel bundles do, however, move the fretting from the rolled joint area to a less sensitive area of the pressure tube.

STEAM GENERATOR TUBES

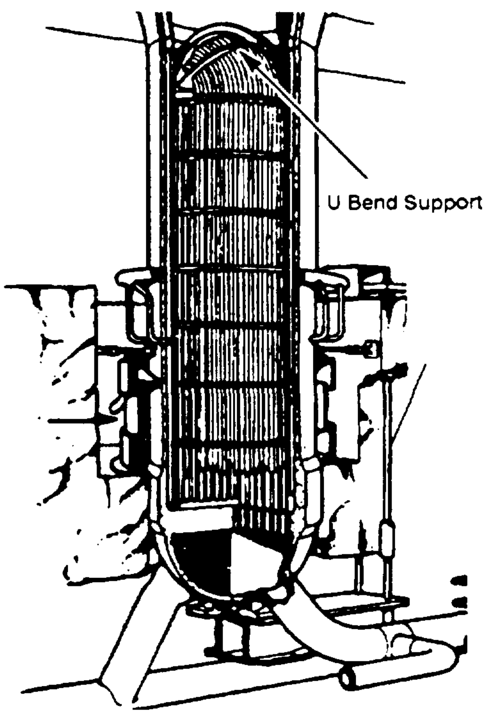
We believe that ***steam generator tubes*** at Bruce B remain fit for service. However, we are disappointed that Ontario Hydro is slow in updating its strategy for managing ***steam generator*** fretting.

The steam generators at Bruce B have operated reliably since the units started. Nevertheless, the normal turbulent flow of steam and water in the steam generators causes the tubes and the supports in the U-bend region to vibrate (see Figure 3). This has resulted in mechanical wear (or fretting) of the tubes to varying depths. At present, 5 to 10 percent of the tubes are affected.

Ontario Hydro has defined a fretting wear limit of 87 percent of the tube wall thickness, minus allowances for measurement error and growth. In practice, Ontario Hydro has plugged tubes it finds with frets deeper than 40 percent through wall. All steam generators at Bruce B have been inspected at least once for fretting.

In December 1995, a tube leak, due to fretting, occurred in a unit 7 steam generator tube. Ontario Hydro shut down the unit and plugged the leaking tube. Further inspection, carried out in January 1996, at our

Figure 3: A CUT-AWAY VIEW OF A TYPICAL BRUCE B STEAM GENERATOR



request, found a fret deeper than the wear limit.

In the fall of 1996, Ontario Hydro inspected the remaining steam generators in unit 7. The inspection found three more tubes with frets beyond the limit. Ontario Hydro asked for a 28-month interval before re-inspecting unit 7. We reduced this interval to one year.

Ontario Hydro also inspected four unit 5 steam generators in 1996. Fretting in unit 5 is milder than in unit 7. No frets reached the limit. Several years ago, Ontario Hydro fitted anti-vibration supports in two steam generators of unit 5. The 1996 inspection showed that the supports appear to have stopped the fretting. Ontario Hydro is now planning to modify other steam generators.

In 1995, we requested Ontario Hydro to prepare a strategy for managing steam generator tube degradation. Ontario Hydro submitted an assessment of the consequences of tube leakage. It concluded that 164 tubes at risk of failure would be tolerable under accident conditions. Although we consider this figure high, we are satisfied that the steam generators remain in a safe condition.

Several points in our 1995 request remain outstanding, and we have asked Ontario Hydro to accelerate its response. Ontario Hydro has committed to submit reports and plans by March 1997.

PLANT CHEMISTRY CONTROL

We believe Ontario Hydro continued to maintain good chemistry control in 1996.

Good chemistry control helps prevent premature failure of important station equipment including pressure tubes and steam generator tubes. A chemical environment that minimizes corrosion also helps keep the radiological dose to workers low.

Ontario Hydro did not report any non-compliance with chemistry-related licence limits. It also reported that it had met its own more stringent chemistry control targets 97 percent of the time in 1996. Our periodic monitoring of Ontario Hydro's chemistry data confirmed this.

TEMPORARY CHANGES

We were pleased to see a considerable reduction in the number of *jumpers* in 1996.

Ontario Hydro uses two types of forms to document and control temporary changes. The Jumper Record Form (jumper) is used to control temporary changes to equipment, and the Operating Memo is used to control temporary changes to operating procedures. For operational safety reasons, we believe that keeping the number of temporary changes as low as possible is important.

In 1995, Ontario Hydro committed to reduce the number of jumpers from about 200 to 100 per unit. Good progress has been made in achieving this goal (see Table 6). We were also pleased to note that the number of jumpers past the review date has almost halved and the average age of jumpers has started to decline. The number of jumpers on the special safety systems has also decreased.

The number of Operating Memos per unit remained acceptable to us.

ENVIRONMENTAL QUALIFICATION

In 1996, we were not satisfied with the progress made in the implementation of the environmental qualification program. We are concerned that Ontario Hydro will not complete the program on schedule.

In 1996, Bruce B staff worked on the environmental qualification of the special safety systems and cables. The ***emergency core cooling system*** is closest to being environmentally qualified. Ontario Hydro plans to complete the qualification of the special safety systems by 2002. All other ***safety-related systems*** are scheduled to be qualified by 2003.

Since 1990, when the program was initiated, we have monitored the progress of this work in terms of quality, procedures, timeliness and resources. We are satisfied that procedures used are adequate and find the quality of the work acceptable. However, we are not satisfied with the progress made. The program is behind schedule and is understaffed. Ontario Hydro is having trouble finding qualified staff to do certain environmental qualification activities.

Table 6: TEMPORARY CHANGE DOCUMENTATION

	1992	1993	1994	1995	1996
Number of jumpers	274	300	274	212	141
Number of jumpers past review date	65	61	97	50	29
Average age of jumpers (days)	526	567	630	706	687
Number of jumpers on special safety systems	*	10	13	16	10
Number of operating memos	27	33	23	29	31

* No data available.

Note: Numbers are a per-unit average and are year-end values.

Until the environmental qualification of equipment is complete, we also believe that Ontario Hydro must do more to ensure that the safety of the station is not compromised.

CONFIGURATION MANAGEMENT

Ontario Hydro recently recognized that its process for maintaining control of plant configuration (ensuring that the physical plant and the designed/documented plant are the same) was inadequate. Consequently, in 1996, Ontario Hydro initiated a project called CoMPaSS (acronym for Configuration Management and Process and Systems Support) to improve configuration management. Ontario Hydro expects this project to be fully implemented in late 1998. Since better control of configuration will bring about improvements to safety, we see this project as a positive development.

STATION MANAGEMENT

We conclude that the management of Bruce B was acceptable in 1996.

Bruce B has had several serious events in the last few years, including the unit 5 liquid relief valve event and the fuel handling trolley event, described in our 1995 annual report. Consequently, Bruce B senior management conducted a culture and leadership assessment to understand the organizational and cultural issues that could be contributing to such events. The results showed that management has to put more emphasis on people issues to improve staff motivation and morale. We believe Bruce B management is now acting to address this matter.

We are concerned that too many key management positions are filled on an acting basis. In July 1996, the Station Director retired. The Operations Manager became Acting Director and his position has since been filled by other managers on an acting basis. The Nuclear Safety Manager position has also been filled on an acting basis. We believe this situation potentially undermines the stable environment needed when making strategic decisions at this crucial point in the life of the station.

We have observed that Bruce B management has become more conservative in its approach to dealing with unit upsets and outages. If necessary, outages are extended to complete planned maintenance work on equipment that is important to safety.

We believe that the Bruce B management team must find ways to ensure that its staff follows procedures and processes established to address problems. For example, a procedure was put in place to guarantee the positions of manually operated valves that are important to safety. In spite of this, during our compliance inspections, we continue to find guaranteed valves in the wrong position. Other problem areas include configuration management, design compliance and communications to operating personnel.

Ontario Hydro has backlogs in the areas of design changes, event report corrective actions, surveillance and audit corrective actions, maintenance work, radiation protection and licensing actions. This situation appears, in part, to be due to a lack of appropriately trained staff. At present, there are no plans to increase staff at Bruce B.

In 1996, Ontario Hydro senior management established a strategy for excellence in nuclear operations. The intent of this strategy is to attain and maintain world class operational and safety standards at all its nuclear stations. The objective of this strategy is to exceed minimum safety compliance standards by improving employee accountability, management performance and maintenance and by reducing human performance errors. If this strategy is successful, it will go a long way in addressing many of our concerns.

TRAINING

We found that Bruce B's performance in training was acceptable.

We are responsible for obtaining assurance that nuclear generating stations operations personnel are competent. One method used for this purpose is the conduct of regulatory examinations for senior ***main control room*** staff. Following the completion of the ***authorization training program***, candidates must pass a series of examinations we set in order to be authorized.

In 1996, we authorized three Bruce B candidates who had passed our examinations in previous years.

Due to a lack of candidates, no AECB examinations were set at Bruce B in 1996.

We carried out four training program evaluations in 1996.

An evaluation of continuing training revealed that substantial training and testing to requalify authorized Ontario Hydro staff is taking place at the Bruce B *simulator*. However, we found that other aspects of this training such as science fundamentals, station systems, design and procedural modifications, and operating experience feedback were not addressed adequately. We also found that the simulator assessment process being used does not adequately test the competence of *shift supervisors*. Ontario Hydro was requested to take appropriate corrective action.

An evaluation of the revised Authorization Fundamentals Training Program, that was presented by Ontario Hydro for the first time in 1996, showed some improvements over the previous version. However, we found that it was overall unsatisfactory because the scope and depth of the training was not adequate in some subject areas, some training manuals contained errors and there was no evaluation process in place to note and correct the deficiencies. Ontario Hydro has prepared a plan to correct the deficiencies we have found.

In early 1996, we evaluated some activities being conducted to train staff required to work in the station in case of a labour disruption. We found these activities to be acceptable.

In 1993, we carried out an evaluation of the training program for Bruce B control technicians. A follow-up verification in 1996, revealed that most of the corrective actions, to remedy the deficiencies identified by us, had not been completed by Ontario Hydro as planned. We requested Ontario Hydro to prepare a new plan of action with firm deadlines for completion of the needed action.

EMERGENCY PREPAREDNESS

We are satisfied that Ontario Hydro maintained an adequate emergency response capability at Bruce B for emergencies such as radiological releases and major fires.

In April 1996, we formally assessed Bruce B's radiological emergency preparedness program. We found strengths in some areas such as personnel qualifications and training, state of equipment readiness, and in Ontario Hydro's self-evaluation of personnel performance. We noted a lack of an overall emergency preparedness plan, however, and have told Ontario Hydro to develop one.

Ontario Hydro carried out many drills and practices throughout the year. It reported minor problems with its personnel accounting procedures and has initiated upgrades to these procedures.

The number and types of drills are listed in Table 7.

In our 1995 annual report, we stated that Ontario Hydro needed to improve its ability to respond to nuclear security alerts. Ontario Hydro has initiated changes both to equipment and procedures. When it completes this project, we believe Ontario Hydro's response to security alerts will improve.

Ontario Hydro has revised its radiological emergency response procedures for Bruce B and has requested AECB approval.

Table 7: EMERGENCY DRILLS AND PRACTICES	
DRILL TYPE	**NUMBER COMPLETED**
Emergency response team (Fire, Rescue, First Aid)	8
Full station radiation emergency	2
Toxic gas	4
Security practices	19
Emergency response team	9
Radiation	3
Toxic gas	2

SAFETY ANALYSIS

POWER PULSE

During 1996, Ontario Hydro continued to reduce the fuel channel gaps in the reactors at Bruce B using a combination of longer than normal fuel bundles and extensions to the inlet shield plugs. This action was taken to reduce the size of the power pulse should a large *loss of coolant accident* occur (see our 1995 annual report).

By the beginning of 1996, Ontario Hydro had reduced the average gap to 2.5 inches in the inner zone of all Bruce B reactors. The minimum gap was 2.0 inches, and the reactors were operating at 90 percent of full power. Both the power level and the minimum gap had been approved by us.

During 1996, Ontario Hydro expended a large effort to produce an analysis in support of a power raise to 94 percent of full power. In September, we accepted a new minimum gap of 1.5 inches. A gap management program had previously been introduced by Ontario Hydro to ensure that the minimum fuel channel gap in any individual fuel channel is not less than the minimum value approved by us.

As Ontario Hydro developed its analysis in support of a power raise to 94 percent of full power, meetings were held to clarify our concerns and give our perspective on many complex technical issues related to raising power. The scope of the safety analysis to be carried out by Ontario Hydro in support of a power increase to 94 percent of full power was mutually agreed upon.

During a large loss of coolant accident, with reactor power at 94 percent of full power, we were concerned that the thermal expansion of the fuel bundles in some channels could be greater than the minimum gap. This condition could lead to deformation of the fuel bundles and damage to the pressure tube. Ontario Hydro agreed to carry out a series of experiments to show that damage to the pressure tube would not occur.

The analysis, subsequently submitted, has confirmed that most of the specific concerns that we raised have been taken into account. We are also satisfied with Ontario Hydro's commitment to do additional confirmatory work.

In December 1996, we gave approval in principle to a request from Ontario Hydro to raise the power of Bruce B reactors to 94 percent of full power.

RISK AND OPERATION

Ontario Hydro made acceptable progress in developing a probabilistic safety assessment for Bruce B.

The probabilistic safety assessment is a mathematical model of the station's systems and functions that is used to determine how safety and risk goals can be met. It can be used to review and improve the safety adequacy of the station design and as an aid for operations. The Bruce B risk model is known as Bruce B Risk Assessment (BBRA).

BBRA will allow Ontario Hydro and us to more accurately estimate the changes in risk associated with station operations activities. For example, it will be possible to determine what effect non-functioning equipment or maintenance outages have on risk. BBRA will also be used to estimate the effect on risk of proposed design changes. Overall, BBRA should allow Bruce B staff to manage risk more effectively. Based on insights gleaned from the BBRA, Ontario Hydro will be better able to set its priorities in respect to staffing, maintenance and training.

Most of the analysis work has been completed. The remaining work consists largely of completion of documentation, reviews of the results by Bruce B staff and preparation of the main and summary reports.

We consider BBRA to be an important tool for estimating and managing risk. We consider it an important addition to the current techniques used to make safety decisions at the station.

QUALITY ASSURANCE

Overall, we found that the Bruce B *quality assurance* program functioned acceptably in 1996. However, our annual quality assurance audit revealed that improvements must be made to this program as it applies to the control of design changes.

During our 1996 quality assurance audit, eight Ontario Hydro projects were examined in detail. Although the team did not identify any major technical deficiencies, the process for design modification was found deficient.

The Ontario Hydro reorganization in 1993 included transferring the design function from Ontario Hydro's head office to the respective stations. Since then, station management has not given its design personnel clearly documented responsibilities and practices for controlling design and design interfaces. Our auditors also found that the mandatory annual reviews of the quality assurance program by management are not being conducted. Ontario Hydro was directed to take appropriate corrective action.

The Bruce B quality assurance section carried out 35 internal surveillance assessments in 1996. Assessments are done to verify that the quality assurance program remains effective. A shortage of staff prevented the quality assurance section from completing 24 percent of its planned surveillance activities. Assessments completed were done well.

The quality assurance section has a total of six approved positions. We believe this number is barely enough to allow this section to fulfill its mandate. However, by the end of 1996, the section was operating with four people. As mentioned above, this lack of staff affected the important surveillance program. We will monitor the situation closely in 1997.

A considerable backlog of incomplete corrective actions arising from surveillance and audit activities existed at the end of 1996.

SAFEGUARDS

Ontario Hydro continues to cooperate fully with the *safeguards* program.

Canada is a signatory of the *Treaty on the Non-Proliferation of Nuclear Weapons*. Pursuant to the Treaty, Canada has entered into a safeguards agreement with the *International Atomic Energy Agency* (IAEA). This agreement gives the IAEA the right and the responsibility to verify that Canada is fulfilling its Non-Proliferation Treaty commitment not to use its peaceful nuclear program to make nuclear weapons or nuclear explosive devices.

The requirement for the application of IAEA safeguards is included in the Bruce B reactor operating licence. To comply, Ontario Hydro is required to provide timely reports on the movement and location of all nuclear materials within the station. It must also provide access and assistance to IAEA inspectors for verification purposes and for the installation and maintenance of IAEA equipment at the station.

During 1996, Ontario Hydro provided assistance to us and the IAEA in the testing of an underwater telescope for reading the serial numbers on fuel bundles stored in the *irradiated fuel bays*.

Ontario Hydro began talks with us and the IAEA to ensure that satisfactory safeguards measures are applied to the transfer of irradiated fuel to the irradiated fuel bays and to the planned dry storage facility.

Bruce B staff provided excellent cooperation and support to us and the IAEA. Reports and notification of activities involving safeguards were provided quickly, as required by the licence.

CONCLUSIONS

We conclude that Ontario Hydro continued to operate Bruce B safely in 1996 and that the risk to workers and the public remained acceptably low.

We found that Ontario Hydro's performance at Bruce B had significantly improved or was fully satisfactory in the following areas:

- worker radiation dose control;
- radiation releases to the environment;
- plant chemistry control;
- life management of pressure tubes;
- compliance with the safeguards program;
- conservative decision-making of management;
- special safety system availability;
- progress in preparing a probabilistic risk assessment; and
- progress in reducing the number of jumpers.

To continue to meet both our requirements and Ontario Hydro internal targets, we believe improvements are needed in the following areas:

- compliance with the licence and the Atomic Energy Control Regulations;
- reduction of maintenance backlogs;
- environmental qualification;
- security upgrading;
- emergency planning;
- steam generator tube life management strategy update;
- communications between management and the workers; and
- procedural adherence.

In 1996, Bruce B had a number of events where there were multiple failures of equipment after an initiating event. Other CANDU plants showed similar symptoms prior to a decrease in plant performance. We believe Ontario Hydro must take corrective action to improve the condition of the Bruce B plant before there is a similar decrease in performance.

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GLOSSARY

actuator (valve actuator)
An electrical or pneumatic device which positions a valve in response to a signal from the *main control room* or from an automatic controller.

AECB Cost Recovery Fees Regulations
Regulations made pursuant to the *Atomic Energy Control Act* by the *Atomic Energy Control Board* which set out the fees for licences and approvals issued for nuclear facilities and activities.

airlock
The means of access to and from the *reactor building*. There are two doors on each airlock, an inner door and an outer door. Automatic controls ensure that only one door is open at a time so that *containment* is always sealed.

annulus gas system
A continuously circulating system of carbon dioxide gas in the spaces between the *pressure tubes* and *calandria tubes*. It thermally insulates the tubes from each other and permits early detection of tube leaks.

as low as reasonably achievable (ALARA)
The principle, applied internationally, of keeping radiation doses "as low as reasonably achievable", social and economic factors taken into account.

Atomic Energy Control Act
The federal act that established the *Atomic Energy Control Board* and allows it to regulate the nuclear industry in Canada.

Atomic Energy Control Board (AECB)
The federal nuclear regulatory agency established in 1946 by the *Atomic Energy Control Act*. The AECB controls the development, application and use of nuclear energy in Canada and participates for Canada in international measures of control. The AECB reports to Parliament through the Minister of Natural Resources.

Atomic Energy Control Regulations
Regulations made pursuant to the *Atomic Energy Control Act* by the *Atomic Energy Control Board*.

audit
Verification and evaluation of a document, process or work related to station operation.

authorization training program
A program of training set up by a station to train candidates for positions that require authorization by the *Atomic Energy Control Board*. These positions are *control room operator* and *shift supervisor*.

availability
The percentage of time a piece of equipment is able to perform its designated function.

bearing pads
Metallic pads brazed to the outer ring of elements in a *fuel bundle*. They maintain proper clearances between the bundle and the *pressure tube*.

becquerel (Bq)
The Système International unit for the radioactivity of a source. It is equivalent to one disintegration per second.

calandria
A cylindrical stainless steel tank which holds the moderator *heavy water*. *Pressure tubes* containing the fuel and the heavy water coolant pass through the calandria.

calandria tubes
Calandria tubes surround the *pressure tubes*. The space between the tubes is filled with inert gas that thermally insulates the *moderator* from the coolant. The *annulus gas system* monitors the space for leaks.

call-up
Also known as scheduled *preventive maintenance*. A routine maintenance item or performance check completed at regular intervals.

Canadian Deuterium-Uranium (CANDU)
A Canadian-designed reactor that is moderated and cooled by *heavy water* and fuelled with natural uranium. The name comes from Canada Deuterium-Uranium.

class III power supply
Alternating current supplied to auxiliaries that can tolerate short interruptions.

containment — The building surrounding the reactor. It is designed to contain the effects of any accident involving the reactor, isolating any hazard from the public.

control room operator — A person responsible for operating the reactor controls. A control room operator needs authorization from the *Atomic Energy Control Board* before acting in this position.

core — The heart of a reactor containing the fuel, the *heavy water* coolant and the heavy water *moderator*. It also includes various sensing and control devices.

decay heat — Heat generated in the reactor by the decay of radioactive material in the *fuel bundles*.

deficiency report — Also known as a work order. All work on the station is controlled. A document produced to identify a problem in the station and to initiate repairs.

delayed hydride cracking — A condition can exist in which wearing or *fretting* of a *pressure tube* can occur faster than designers anticipated. The combination of this condition and the penetration of *deuterium* into the tube wall can, in theory, lead to a phenomenon known as delayed hydride cracking.

derived emission limit (DEL) — A calculated amount of radioactivity that, if released from the station, would result in a radiation dose of five millisieverts to a member of the public in the worst possible case. Five *millisieverts* is the maximum annual radiation dose allowed for members of the public by the *Atomic Energy Control Regulations*. The calculation is done by examining the effect of the radioactivity on a theoretical person who lives full time at the station boundary, eats only food harvested locally, and drinks only water from the station's discharges. This theoretical individual is known as the "critical individual".

deuterium — An isotope of hydrogen that has one proton and one neutron in its nucleus.

dose — Generally, the quantity of radiation energy absorbed by a body.

dry storage
A method of storage for irradiated fuel. Concrete containers are used to store the *fuel bundles* and to prevent the spread of radioactive material. Prior to dry storage, the fuel bundles cool in the *irradiated fuel bay*. The licensee can only use containers to store fuel when air cooling can safely remove any remaining *decay heat*.

emergency core cooling system
An automatic system that injects cold water into the reactor's *fuel channels* if there is a problem with the normal coolant system. It also provides long-term cooling for the fuel by recovering water from the *reactor building* floor.

end fittings
Attachments to the ends of *pressure tubes* that provide entry and exit connection for the *heavy water* coolant. They provide pressure-tight connections for the *fuelling machines*.

end plates
Plates welded to the ends of the elements in a *fuel bundle* (one at each end) to hold the bundle together to form its cylindrical shape. Besides maintaining separation between the elements at the bundle extremities, the end plates have holes in them to allow for coolant flow.

environmental qualification
Equipment essential to maintain required safety functions must operate when called upon. Some of this equipment may have to operate in the harsh environment that could surround it following accidents. Environmental qualification of that equipment means taking measures to protect it from conditions such as high temperature and humidity.

fretting
The wearing or damage caused by one material upon another due to vibration.

fuel bundle
A collection of 37 pencil-shaped elements containing natural or depleted uranium. *End plates* hold it together as a cylinder.

fuel channel

A fuel channel consists of a *pressure tube*, which contains fuel, *end fittings* connecting it to the feeders supplying *heavy water* coolant, and closure plugs that can be removed by the *fuelling machines* for refuelling. Each pressure tube is located inside a *calandria tube*, which separates it from the cold moderator heavy water. Carbon dioxide gas between the pressure tube and the calandria tube provides insulation for the hot pressure tube.

fuel handling

The system that is responsible for fuel changing and storage of new and irradiated fuel.

fuelling machine

Equipment that fuels the reactor. Two remotely controlled fuelling machines work at opposite ends of the same *fuel channel*. One machine inserts new fuel and the other removes irradiated fuel while the reactor continues to operate.

gray

The Système International unit of absorbed radiation dose, equal to one joule per kilogram. One microgray is one millionth of a gray.

generator

Equipment that converts the mechanical power delivered by the *turbine* into electricity. There is one generator for each reactor.

heat exchanger

Equipment that transfers heat between systems.

heat sink

Any system used to dissipate the heat produced in the fuel. At all times a main heat sink must be in service, normally the *steam generators*, and an alternative or backup heat sink must be available. Failure to dissipate the heat produced in the fuel by means of an adequate heat sink can increase the temperature of the fuel and thereby damage it.

heavy water (D_20))

Also known as deuterium oxide. Heavy water is a clear, colourless liquid that looks and tastes like ordinary water. It is about 10 percent heavier than ordinary, or "light", water. It occurs naturally in the environment. It consists of deuterium and oxygen (D_2O), rather than the hydrogen and oxygen of ordinary water (H_2O). A deuterium atom is a hydrogen atom with an extra neutron in its nucleus. CANDU reactors use heavy water as a *moderator* and as a coolant.

housekeeping
The act of keeping a station neat and tidy, with equipment and components stored properly.

interlock
A connection between pieces of equipment that ensures that they cannot be operated unsafely.

International Atomic Energy Agency (IAEA)
A United Nations agency. It provides a system of *safeguards* to make sure that states do not divert nuclear materials to non-peaceful activities. It also provides an international forum for nuclear safety.

inter-unit feedwater tie
A system that allows water to be transferred between the steam generator *feedwater systems* of different units at a multi-unit station. It operates if the *steam generators* lose their normal supply of feedwater.

irradiated fuel bay
A large pool of ordinary water, rather like a swimming pool, where used fuel is stored. The water cools the fuel and provides shielding from radiation.

jumper
The term used to describe a documented and authorized temporary change to equipment or systems.

liquid zone control system
The primary means for regulating reactor power level and the spatial distribution of power in the *core*. Ordinary water is introduced in varying amounts into each of 14 zone control units. The variation of neutron absorption by this ordinary water provides ocal control.

loss of coolant accident (LOCA)
A failure in the reactor's *heavy water* coolant system that causes water to be lost faster than the normal heavy water supply can replace it. The *emergency core cooling system* provides fuel cooling if this happens.

main control room
A centrally located room that contains a control panel and console for each reactor unit, the *fuel handling* control panels, the common services control panel and the unit and common electrical control panels.

millisievert (mSv)
A measurement of radiation exposure. One millisievert is one thousandth of a *sievert*.

moderator

The *heavy water* in the *calandria* that slows the neutrons released by fission to energies at which they are likely to produce additional fissions. Because the moderator surrounds the *fuel channels*, it also provides cooling and protection if a major accident were to cause a complete loss of cooling in the fuel channels.

negative pressure containment system

The containment of multi-unit stations consists of the reactor buildings themselves, the pressure relief duct, pressure relief panels and valves, and the vacuum building with its dousing system. These structures are designed to be maintained below atmospheric pressure following an accident, preventing the release of radioactive materials. Ontario Hydro refers to this complete system as a negative pressure containment system.

neutron flux

A measure of the fission power in the reactor.

neutron flux tilt

A change from the desired normal distribution of *neutron flux* across the reactor, in which the neutron flux simultaneously increases in one region and decreases in another.

neutron overpower trip

Also known as regional overpower trip. A system that will shut the reactor down if it detects high neutron power anywhere in the reactor.

noble gases

Gases produced in the reactor fuel when the reactor is operating. They are radioactive and decay to produce *particulates*, some of which are also radioactive.

particulate

Any radioactive material that is in solid particle (e.g. dust) form.

Operating Policies and Principles (OP&P)

A licensee document, approved by the *Atomic Energy Control Board*, that outlines the safe operating limits for the station. It also defines which staff have the authority to make decisions on safety matters.

Physical Security Regulations

Regulations issued pursuant to the *Atomic Energy Control Act* by the *Atomic Energy Control Board* which set out the required security standards at nuclear facilities.

poison

A substance which absorbs neutrons and hence removes them from the fission chain reaction.

predicted future unavailability
A measure of how well a *special safety system* can be expected to perform in the future. A mathematical model of the system and statistics of faults affecting the system are used to derive a theoretical prediction of the expected frequency of system failure.

pressure boundary
Pressure-retaining equipment or components of a system that contain a pressurized material such as *heavy water* coolant or steam.

pressure tubes
Tubes that pass through the *calandria* and contain 12 or 13 *fuel bundles*. Pressurized *heavy water* flows through the tubes, cooling the fuel. They form part of the *pressure boundary* for the *primary heat transport system*.

preventive maintenance
Also known as *call-up*. A routine maintenance item or performance check completed at regular intervals.

primary heat transport system
A closed cooling circuit that carries heat produced in the *fuel bundles* to the *steam generators*. It does this by circulating *heavy water* at high pressure through the *fuel channels* and the steam generator tubes.

quality assurance
A formal program of standards, procedures and checks controlling the quality of work on the station.

radiation field
An area in the station where there is a significant amount of ionizing radiation.

Radiation Protection Regulations
Regulations the licensee issues that state the radiation protection standards to be met at a station. These regulations require approval by the *Atomic Energy Control Board*.

reactor building
A reinforced-concrete building which serves as a support and an enclosure for the reactor and some of its associated equipment.

reactor regulating system
A system that controls reactor power. It monitors *neutron flux* shape and important operating parameters so that power may be reduced if any parameter is outside specific limits.

reportable event
An event which affected, or which under slightly different circumstances could have affected, public or worker safety, health, security or the environment. Such events must be reported to the *Atomic Energy Control Board* through formal communication channels.

safeguards

An international program of monitoring and inspection carried out by staff of the *International Atomic Energy Agency*. Safeguards ensure that nuclear materials in the station are not diverted for non-peaceful uses.

safety-related systems

A system required for the successful operation of safety systems. Such systems include the various classes of electrical power, plus instrument air and service water supplies.

serious process failure

A failure in the station's components or systems, which is sufficiently serious that one or more of the *special safety systems* must operate to prevent reactor damage.

setback

An action taken by the *reactor regulating system* to reduce power at a controlled rate if any one of certain station parameters is out of specific limits.

shield plug

A stainless steel plug that provides gamma ray shielding at the ends of the *fuel channels*.

shift supervisor

The technical expert who manages a shift, ensuring that the station meets all safety requirements. A shift supervisor requires approval of the *Atomic Energy Control Board* before acting in the position.

shutdown systems (SDS)

All CANDU reactors, with the exception of Pickering A Nuclear Generating Station, have two independent systems. Each can shut down the reactor. The first shutdown system uses gravity-drop solid *shutoff rods*. The second injects pressurized liquid *poison* (gadolinium nitrate) into the *moderator*.

shutdown system one (SDS1)

Shutdown system one works by dropping neutron-absorbing rods into the reactor core if its instruments detect a potentially unsafe condition. It is completely separate and independent from *shutdown system two*.

shutdown system two (SDS2)

Shutdown system two automatically shuts down the reactor by injecting a neutron-absorbing chemical into the *moderator* if its sensors detect a potentially unsafe condition. It is completely separate and independent from *shutdown system one*.

shutoff rods
Neutron-absorbing rods that can be dropped into the reactor under abnormal conditions to shut it down quickly and safely.

sievert (milli, micro)
A measurement of radiation exposure. One *millisievert* (mSv) is one thousandth of a sievert. One microsievert (μSv) is one millionth of a sievert.

simulator
The simulator represents the station's *main control room* in the same way that a flight simulator represents the cockpit of an aircraft. It is used for training and testing staff.

special safety systems
There are four independent special safety systems: *shutdown system one* or *shutdown system two* shuts down the reactor if a problem occurs, the *emergency core cooling system* provides cooling and the *containment* system contains any radioactivity.

steam generator
A *heat exchanger* that transfers heat from the *heavy water* coolant to ordinary water. The ordinary water boils, producing steam to drive the *turbine*. The *steam generator tubes* separate the reactor coolant from the rest of the power generating systems.

steam generator tubes
The inverted U-shaped tubes that contain the *heavy water* coolant, separating it from the ordinary water outside the tubes which boils to produce steam. *Steam generators* typically contain several thousand tubes.

Transport Packaging of Radioactive Materials Regulations
Regulations made pursuant to the *Atomic Energy Control Act* by the *Atomic Energy Control Board* which set out the packaging and safety marking requirements for radioactive materials for transport.

Treaty on the Non-Proliferation of Nuclear Weapons (NPT)
An international treaty that came into force in 1970, and to which Canada is a party. Its primary aim is preventing the spread of nuclear weapons.

trip
A rapid shutdown of the reactor in response to the detection of certain abnormal and potentially dangerous conditions.

tritium
A radioactive isotope of hydrogen that is produced in the reactor's *heavy water* during operation.

tritium removal facility
A facility at Darlington Nuclear Generating Station designed to remove radioactive ***tritium*** from the ***heavy water*** used in reactors. Such removal reduces the hazards to operating staff and the release of radioactive material to the atmosphere.

turbines
Equipment comprising several bladed wheels that rotate when steam from the ***steam generators*** flows through them. The kinetic energy of the steam converts into mechanical energy that turns the rotor of an electrical ***generator***, producing electricity.

unavailability
The unavailability of a system or component is the fraction of time that it is unavailable to perform its function if it would be called upon to do so.