INFO-0673

REPORT

AECB Staff Annual Assessment of the Bruce A 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 staff assessment of safety performance at Bruce Nuclear Generating Station A (Bruce A) for 1996. Our on-site Project Officers and Ottawa-based specialists monitored station operation throughout the year.

We consider that Ontario Hydro operated Bruce A safely in 1996, maintaining the risk to workers and the public at an acceptably low level. Radiation doses to the workers and releases to the environment were well below regulatory limits.

Special safety system performance at Bruce A was adequate. Availability targets were all met.

Ontario Hydro began implementation of its plans to reorder the fuel bundles in the reactor fuel channels and change the direction of fuelling in order to overcome a postulated accident scenario that could result in an unacceptable power increase. The program was well planned and managed to minimize the risk associated with the transition.

Improvement is needed to reduce the number of operating licence non-compliances.

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INTRODUCTION

Bruce Nuclear Generating Station A (Bruce A) is located on the shores of Lake Huron, between the towns of Kincardine and Port Elgin. It houses four 850 megawatt *Canadian Deuterium-Uranium* (CANDU) reactors with a design life of 40 years.

This report is the *Atomic Energy Control Board* (AECB) staff assessment of the safety performance at Bruce A during 1996. AECB staff at the Bruce site office and the head office in Ottawa compiled the report. We base our review on our own observations and on information submitted to us by Ontario Hydro as required by Bruce A's operating licence.

At our head office in Ottawa, the public can consult documents relevant to the licensing process for 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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The nuclear industry uses many technical terms in its day-to-day operations. 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.

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OPERATIONAL SAFETY

COMPLIANCE WITH REGULATIONS MADE UNDER THE ATOMIC ENERGY CONTROL ACT

Ontario Hydro's compliance with the *Atomic Energy Control Regulations* was acceptable during 1996. There were three cases of non-compliance, none of which had any impact on the public or the environment. The first two non-compliances involved movement of contaminated material from the station. In the first case, a small amount (estimated to be less than a gram) of some contaminated scrap metal was sent out from the station to an adjacent warehouse for disposal as inactive material. In the second case, nine contaminated shield plugs were shipped from Bruce A to the same warehouse for storage. Investigations of these events found areas where improvements could be made for the control of contaminated material. We are satisfied that Ontario Hydro's follow-up actions were adequate.

The third non-compliance involved the discovery of an unposted radiation hazard. A sink drain in a mechanical maintenance shop was found to have a contact dose rate greater than 0.025 *millisievert* per hour. The hazard was then posted and a report was filed to replace the active pipe.

Ontario Hydro's compliance with the *Physical Security Regulations* was acceptable during 1996. An active security awareness program is now maintained and Ontario Hydro management has demonstrated a greater involvement and support for facility security. We view this as a positive step. Facility security personnel conduct regular security drills which test its capability to respond to emergency situations. Our yearly review of security identified some areas where improvements could still be made. We are satisfied that these are being addressed.

Ontario Hydro did not report any non-compliances with the *Transport Packaging of Radioactive Materials Regulations* at Bruce A in 1996.

Ontario Hydro remains in good standing with respect to the AECB *Cost Recovery Fees Regulations*.

COMPLIANCE WITH THE OPERATING LICENCE

The number of Ontario Hydro non-compliances with the Bruce A operating licence was unacceptably high during 1996. However, our assessment of the individual non-compliances was that none of them represented a significant increase in risk to the public and, in each case, the Ontario Hydro corrective action was appropriate.

Atomic Energy Control Regulations state that the operation of the station must be in accordance with the reactor operating licence. The reactor operating licences that we issue define the conditions that the licensee must meet. One condition requires the licensee to operate according to a set of *Operating Policies and Principles*, and to comply with a set of *Radiation Protection Regulations*. Failure to comply with a licence condition is a licence non-compliance.

Ontario Hydro reported 44 non-compliances with the licence at Bruce A in 1996. Last year there were 27 reported non-compliances. We have assessed every one of these non-compliances and looked into the reasons for the significant increase in the number of events reported compared with the previous year. Our conclusions are:

- For each of the events, the reduction in safety margin was small, or the time of increased incremental risk was short; therefore, none of the events represented a significant risk to the public.
- The increase in the number of reported non-compliances is unlikely to represent a real increase in the actual number of non-compliances over last year. Improved management practices and increased vigilance and safety awareness of station staff will have resulted in fewer non-compliances going undetected and unreported.

Notwithstanding the above, we are concerned about the large number of reported non-compliances and have told Ontario Hydro that we expect it to take appropriate action to improve performance in this area in 1997.

EVENTS REPORTED TO THE AECB

Ontario Hydro at Bruce A complied fully with the reporting requirements of the AECB regulatory document, R-99, "Reporting Requirements for Operating Nuclear Power Facilities". This required providing oral reports within 24 hours of knowledge of a *reportable event* and written reports within 15 days.

There were 71 events reported by Ontario Hydro at Bruce A during 1996. Table 1 provides a breakdown of events by R-99 category. Some reportable events fit in more than one category, thus the number of events shown in the table add up to more than 71.

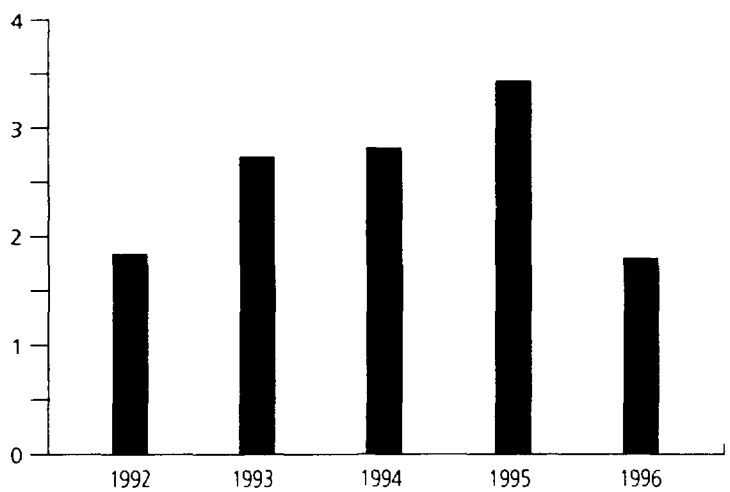
As can be seen from the figures in the table and as discussed in the previous section, it is evident that Ontario Hydro

Table 1: REPORTABLE EVENTS BY R-99 CATEGORY

TYPE	NO.
Operating licence condition non-compliances	44
Degradation of special safety system or safety-related system	15
Automatic or intentional reactor trip	4
Discovery of safety problem arising from operating experience	4
Pressure boundary degradation	3
Hydrogen or deuterium concentration in cover gas greater than 4%	3
A failure to monitor or control a release path of radioactive material	3
A discovery of a safety problem that arises from research findings or improved analysis	3
Failure to perform a required test	1
A declaration of an alert or emergency within or beyond a unit of the facility	1
Possible serious process failure[1]	1

[1] Whether or not this event was a serious process failure is still under investigation. The event is outlined in the section on Operations and Maintenance.

Figure 1: AVERAGE WORKER DOSE (dose in millisieverts vs year)



must improve its management of compliance with the operating licence at Bruce A, in particular, compliance with the Operating Policies and Principles.

In its Fourth Quarter Technical Report, Ontario Hydro states that of all the events reported last year, six were judged to have resulted in an actual risk increase to the public. We agree wit:. this assessment and consider the increased public risk from those six events to have been small.

As noted in Table 1, one event, while not impacting on public safety, may eventually be classified as a *serious process failure*. A brief description of this event is given in the Operations and Management section of this report under "Power Levels".

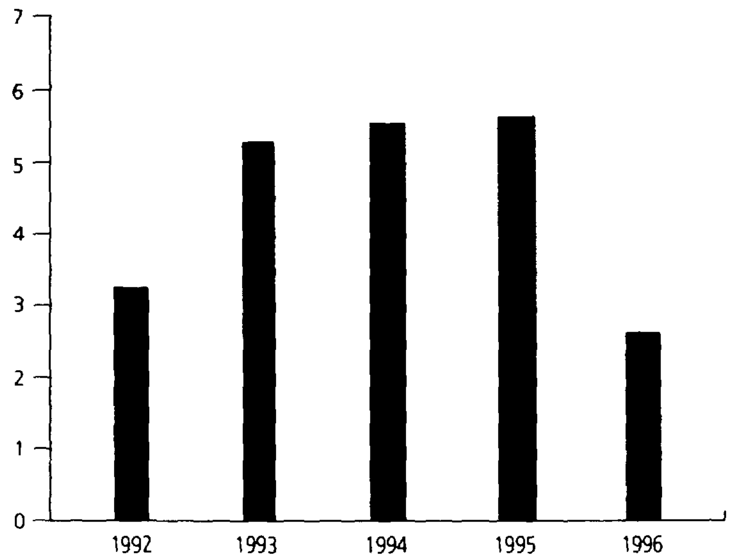
WORKER RADIATION SAFETY

No worker at Bruce A received a dose in excess of the regulatory limit of 50 millisieverts (mSv) per year in 1996.

As Figure 1 shows, the average worker dose in 1996 was 1.81 millisieverts (mSv), down from

Table 2: RADIATION DOSE DISTRIBUTION FOR 1996					
DOSE RANGE (mSv)	0-5	5-10	10-15	15-20	ALL OTHERS
Number of workers	1289	143	5	2	0

Figure 2: COLLECTIVE DOSE
(dose in sieverts vs year)



3.54 mSv in 1995. Figure 2 shows that the total dose received by all station staff combined is 2.66 *sieverts* (Sv), down from 5.64 Sv in 1995. Table 2 shows the distribution of dose among station personnel. These lower doses are due to a reduction in the amount of work that had to be done in relatively high radiation fields and to the Bruce A dose management system. Better radiation practices, such as better hazard posting in the field and improvements in radiation protection training have also contributed to keep doses *as low as reasonably achievable* (ALARA). We were also pleased to see that Bruce A management increased its field survey activities and tightened its acceptance criteria of radiation protection practices at the station.

PUBLIC RADIATION SAFETY

No member of the public received a dose in excess of the regulatory limit of 5 mSv per year. In 1996, Ontario Hydro used updated environmental information to estimate the highest dose a member of the public could have received from Bruce A. The estimated dose is 0.0028 mSv. This is approximately one two-thousandth of the regulatory limit.

Figures 3 and 4 show the airborne and liquid releases from Bruce A during the last five years. The releases of radionuclides from Bruce A to the environment were below the operational annual target of one percent of the regulatory limit. Also, Bruce A releases did not exceed any weekly target during 1996.

Besides monitoring radioactive releases from the station, Ontario Hydro carries out a Bruce Nuclear Power Development (BNPD) environmental program. This program measures levels of radioactivity in the environment surrounding BNPD and accounts for contributions from Bruce A and other licensed facilities at the

Figure 3: AIRBORNE RELEASES
(Percentage of *derived emission limit* vs year)

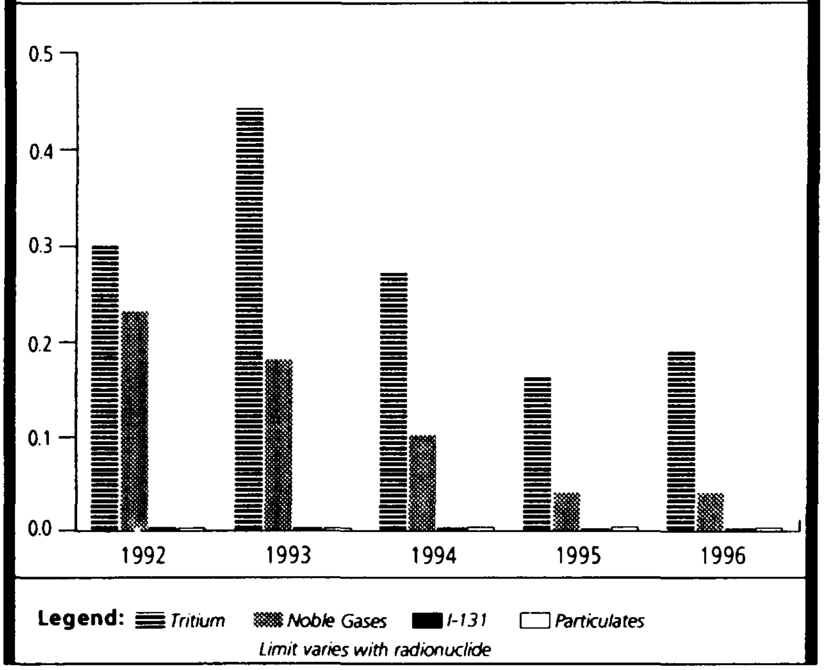
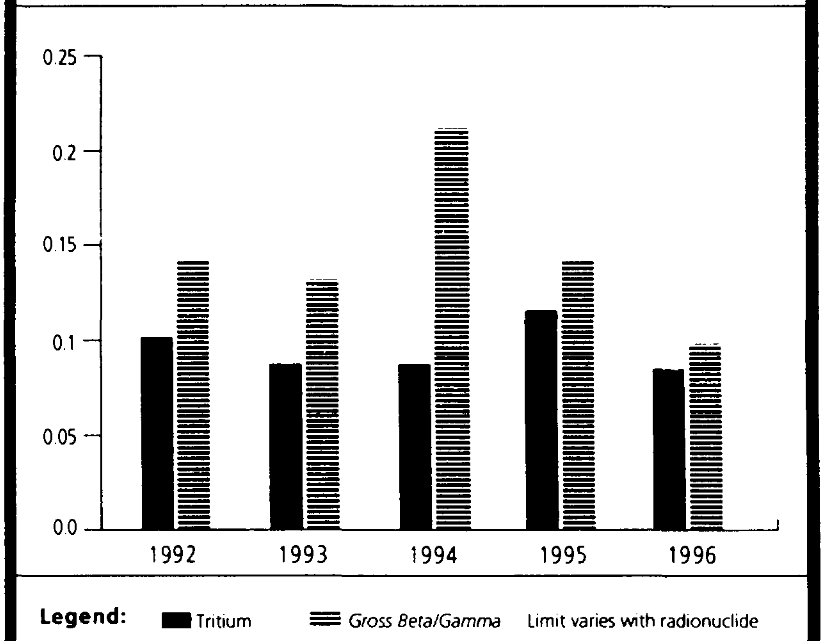


Figure 4: LIQUID RELEASES
(Percentage of derived emission limit vs year)



BNPD site. The doses to members of the public, estimated from the environmental program, remain lower than the doses estimated from the station releases.

In 1996, we conducted an appraisal of this environmental monitoring program. We found that the operations of the environmental monitoring laboratories are in accord with standards we approved. We also found that 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

Special safety system performance was acceptable during 1996. Table 3 summarizes the 1996 special safety system performance. The target availability of the special safety systems is 99.9 percent. To meet this, a special safety system must not be unavailable for more than 8.76 hours per year. As Table 3 shows, all the special safety systems met this target in 1996.

The 5.6 hours of reduced availability of the containment system was a cumulation of ten short duration events. Most of these involved problems with the seals around *airlock* doors.

In an effort to improve containment availability, Ontario Hydro at Bruce A gave its operators some extra training during 1996. We consider this to be a positive initiative and we believe it contributed to the improvement over the previous year. Operator action can be credited in many cases for minimizing the duration of the unavailability of the system. On the other hand, since some of the seal problems mentioned above were compounded by operator inattention (e.g. allowing an air hose to become lodged under a seal), further improvement can still be made.

The 0.75 hour unavailability of *shutdown system one* on unit 1 occurred due to a human error. During an attempt to re-seat a seal on a *primary heat transport system* pump, some required low reactor power *trips* were not first established.

Table 3 also shows the *predicted future unavailability* of each special safety system. Ontario Hydro calculates these using models that include the past six years of operational data and the current design of the system. We consider the figures calculated for the predicted future unavailabilities acceptable.

All predicted future unavailabilities have improved over the past year. This has been, in part, due to the good actual past unavailability. In the case of *containment* (which is now only marginally above target), the improvement is due largely to the partial completion of an airlock upgrade program. We would expect that the predicted future unavailability of the containment system will be within target for 1997 as the airlock upgrade program nears completion. In the case of the *emergency core cooling system*, we expect that when Ontario Hydro completes a new analysis of the system, it will be shown that its predicted future unavailability is within target.

Table 3: SPECIAL SAFETY SYSTEM UNAVAILABILITY

SYSTEM	PREDICTED FUTURE UNAVAILABILITY (h/yr)	1996 UNAVAILABILITY (h/yr) (Target: 8.76 h/yr)				
		UNIT 0	UNIT 1	UNIT 2	UNIT 3	UNIT 4
Shutdown system one	0.66	n/a	0.75	0	0	0
Shutdown system two	2.23	n/a	0	0	0	0
Emergency core cooling	12.1	0	0	0	0	0
Negative pressure containment	8.8	5.6	5.6	5.6	5.6	5.6

OPERATIONS AND MAINTENANCE

POWER LEVELS

We are satisfied that Ontario Hydro operated Bruce A reactors throughout the year at power levels and in a manner consistent with current safety analysis limits. Bruce A achieved a 1996 net capacity factor of 58 percent, up from 53 percent in 1995. The 1996 value is for three operating units since unit 2 is now out of service. The main reason for the low capacity factor continues to be the power limit of 75 percent due to the power pulse issue discussed in previous reports.

There were four completed reactor trips during 1996. The trips were of no public safety concern but one was the result of a possible serious process failure. It happened because an instrument air supply line was left isolated by operator error. This caused some control valves to open from the normally closed state. Pressure in the primary heat transport system (PHTS) decreased via these opened valves until the PHTS low pressure trip *setpoint* was reached. Ontario Hydro's analysis of this event concluded that the event was not a serious process failure. However, we are not convinced of this, and discussion is ongoing. Ontario Hydro has taken actions to minimize the likelihood of a similar operator error. Further action may be taken pending the outcome of our on-going discussions.

Last year, we reported that there were chronic leaks of the hydrogen used to cool the electrical *generators*. The repairs in unit 1 done at the end of 1995 were successful. The repairs in unit 3 done during the 1996 long *outage* were also successful. During a planned outage in 1997, Ontario Hydro will attempt to repair unit 4. This unit had, in 1996, an average hydrogen leak of around 150 cubic metres per day during operation. This is less than the maximum leak rate reported last year for other units and does not represent a safety hazard. Operational measures to prevent and control hydrogen fires and explosions (see last year's report) continue to be in effect.

During 1996, no problems with the operation of the preheaters were reported. Last year we reported that the *divider plate* of the preheaters of units 3 and 4 were damaged and subsequently repaired. Unit 1 had no damage. Ontario Hydro completed the investigation of the possible cause and could not reach a conclusive explanation. Ontario Hydro has improved its primary heat transport system venting procedure during refill after maintenance in case the damage was caused by an air pocket.

STEAM GENERATORS

During 1996, Ontario Hydro managed *steam generator* performance satisfactorily. The one *steam generator tube* leak that appeared in 1995 in unit 1 was identified as a fatigue failure in steam generator number six, and was plugged and removed for examination. When the unit restarted in January 1996, a new low level leak was identified in steam generator number three, and has continued at the same level of approximately 0.5 kg/hr.

Ontario Hydro chemically and physically cleaned the unit 3 steam generator internals on the secondary side. The tubes were also inspected. Only one tube had flaw indications exceeding the 40 percent acceptance criterion. This was a 58 percent through-wall fret and the tube was plugged. Ten tubes were removed for laboratory tests. Four tubes were damaged during the installation of anti-vibration devices and were plugged. This completed the program to install anti-vibration devices in the steam generators of all operating units.

Currently, we are assessing the unit 3 detailed steam generator inspection report and continuing to monitor steam generator performance.

PRESSURE TUBES

Ontario Hydro has a satisfactory program to manage the aging *pressure tubes* in Bruce A reactors.

Ontario Hydro must carefully monitor pressure tubes for hydrogen uptake, *calandria tube* contact, mechanical damage and longitudinal growth. We are satisfied that the pressure tube inspection program adequately addresses these phenomena.

The main pressure tube activities during 1996 took place on unit 3 as part of the planned outage. These activities included *garter spring* repositioning, inspecting for flaws and taking scrape samples for hydrogen concentration analysis.

As pressure tubes age, the hydrogen concentration in the tube material increases. This can cause *hydride* blisters to form. These blisters are unacceptable in an operating reactor and Ontario Hydro must remove the pressure tube from service before blisters form. Blister formation will occur earlier in spots where the pressure tube contacts the calandria tube. During 1996, Ontario Hydro continued its campaign to remove pressure tubes from calandria tube contact by repositioning garter springs that separate the two tubes. By the end of the 1996 maintenance outage, enough garter springs had been repositioned that the potential for hydride blister formation has been eliminated in this unit for the remainder of its predicted operating life.

Five pressure tubes in unit 3 were inspected for flaws. Sixteen flaws were found consisting of debris and *bearing pad* frets. None of the flaws found were unusual. Ontario Hydro calculated the probability of the failure of pressure tubes due to these types of flaws and concluded that it was very low. We accepted this conclusion.

Scrape samples were taken from six pressure tubes to measure hydrogen concentration. The results indicated that the concentration is increasing within predicted rates.

UNIT 2

Ontario Hydro continues to maintain unit 2 in a safe, shutdown state which we have approved.

CHEMISTRY

Overall plant chemistry control at Bruce A was acceptable in 1996. Ontario Hydro established tighter controls, achieving an annual performance of 92.4 percent. This is an improvement from last year's 91.2 percent and of its own target of 92 percent.

ENVIRONMENTAL QUALIFICATION

We are satisfied with the progress made by Ontario Hydro at Bruce A on ***environmental qualification***.

During 1996, we approved structural modifications at Bruce A to increase the release of steam from the powerhouse to the atmosphere in case of a steam line break. By releasing more steam, the harsh environmental conditions, such as heat and humidity, around essential equipment are diminished. These modifications to the powerhouse are progressing well. In addition, Ontario Hydro continues advancing in other activities included in its environmental qualification program.

PERIODIC AND IN-SERVICE INSPECTION

Ontario Hydro completed all equipment inspections scheduled for 1996 in the documented periodic and in-service inspection programs.

Ontario Hydro has two main programs for physical inspections of Bruce A plant. The periodic inspection program is a requirement of, and must comply with, Canadian Standards Association Nuclear Series standards. This program is supplemented with an in-service inspection program designed by Ontario Hydro and which we carefully review.

In 1996, Ontario Hydro concentrated most of its inspection activities on unit 3. All unit 3 areas inspected either met the acceptability criteria or were returned to acceptable conditions.

The findings of steam generator and pressure tubes inspections conducted in 1996 were discussed previously in this section.

CONTROL ROOM COMPUTERS UPGRADE

Ontario Hydro is upgrading the safety systems monitoring and the unit control computers on units 3 and 4. We have been reviewing the design and documentation of this change. Thus far, we have approved installation of the monitoring computer upgrade.

WORK PROGRAM MANAGEMENT

We are satisfied with the way Ontario Hydro managed risk during the 1996 portion of the future work program.

The Bruce A licence was renewed in 1996. In considering our recommendation for licence renewal, we required Ontario Hydro to provide us with details of its program for assessing and managing the risks associated with carrying out the transition to fuelling with the flow and raising power on all operating units (1, 3, and 4). At the time, this was referred to as the future work program. Fuelling with the flow is Ontario Hydro's solution to the power pulse problem at Bruce A described in previous reports. During this transition period of over two years, Ontario Hydro is to conduct a number of non-routine activities. These include installation of fuel string support ***shield plugs***, ***fuel bundle*** re-ordering, and fuelling some channels against the flow and others with the flow. These activities are to be performed in all three operating reactors. In addition to this, unit 1 will be operated with a limited number of empty ***fuel channels*** in order to extend the life of the pressure tubes.

In addition to closely reviewing and formally accepting the programs proposed by Bruce A staff to manage risk during the transition period of the fuelling with the flow program, we continuously monitored the progress at the station. We also hired a human factors consultant to assess the human factor aspects of the program. The consultant identified a number of areas where improvement was needed to avoid difficulties in the operational phase. These were communicated to Ontario Hydro.

At the end of 1996, Ontario Hydro had completed the installation of fuel string supporting shield plugs in the inner zone of the operating reactors, and had almost completed the re-ordering of the fuel bundles in the fuel channels of the inner zone of unit 3. During 1996, Ontario Hydro complied with its commitment to perform such activities in different units at different times in order to minimize the risk. It also maintained a multiple barrier system to recognize, correct, and prevent errors. Isolated errors were identified, particularly during tests, trials, and emerging situations. When this happened, Bruce A staff stopped the on-going operation and re-assessed the situation before resuming the activity.

AECB COMPLIANCE INSPECTIONS

We continued with our compliance inspection program at Bruce A which covers all aspects of station operation. In 1996, we completed the following inspections or ***audits***:

- an assessment of unit 3 startup after an outage;
- an appraisal of security;
- an appraisal of radiation protection;
- an audit of the design process;
- a shutdown system one system inspection;
- four main control room rounds;
- various field rounds;
- a 48 volt DC system inspection in units 0, 3 and 4; and
- a 250 volt DC system inspection in all units.

We also worked on the development of several other assessments and system inspections.

Ontario Hydro addressed any findings we identified in our inspections satisfactorily. Where appropriate, specific findings are discussed elsewhere in this report.

MAINTENANCE

Ontario Hydro achieved acceptable standards of maintenance at Bruce A during 1996. However, maintenance is not improving as rapidly as in previous years.

We are pleased to see that the implementation of a reliability-centred maintenance program at Bruce A continues to progress. This program involves analysing systems to identify critical components and tailoring the preventive maintenance tasks to prevent the failure of these critical components.

Call-ups are scheduled preventive maintenance activities. The number of overdue call-ups is an indication of preventive maintenance performance. Bruce A staff continue to reduce the number of overdue call-ups at year end. More importantly, the number of overdue call-ups related to reactor safety have also continued to decrease.

The operating corrective maintenance backlog is an indication of Bruce A's capability to keep up with required corrective maintenance. At the end of 1996, this number stood at 1358 outstanding deficiencies. This is a small decrease from the 1416 outstanding deficiencies at the end of 1994 and a much smaller decrease than in previous years.

For the third year in succession, the number of *jumpers* increased during the year. Although we have not performed an analysis to determine the safety significance of the number of jumpers, configuration management becomes more difficult with more jumpers. Increased attention is required by Ontario Hydro to reduce the number of jumpers at Bruce A.

In 1996, we performed an assessment of the activities associated with the start up of unit 3 following a prolonged planned maintenance outage. During this assessment, we found that all safety-related maintenance originally scheduled for the outage was completed. All outstanding corrective maintenance and call-ups requiring an outage were completed.

In 1995, Ontario Hydro issued guidelines to all of its nuclear generating station organizations for them to develop station-specific management of aging programs. We met with Ontario Hydro at Bruce A during the year to discuss the progress made. While progress is under way, we believe that, in consideration of the age of the station, more priority should have been placed on this work and more progress should have been made. We will be paying more attention to this area in 1997. At the present time, except for pressure tubes and steam generator tubes, we are not satisfied that Ontario Hydro has an effective program in place at Bruce A for managing aging of safety significant systems, structures and components.

STATION MANAGEMENT

In our opinion, Bruce A's management team is competent and continues to demonstrate a strong commitment to public safety as a first priority for station operation. This opinion is based on our observations while attending meetings with managers and other licensee staff, our review of reported events, our compliance inspection activities in the plant and our review of station work plans. We have observed a pattern of conservative decision-making, and thoroughness in assessment of safety-related issues.

The future work program for Bruce A shows a steady increase in the number and complexity of work programs needed to ensure safe operation of the station as reactor components continue to age.

We will continue to monitor management decision-making closely as Ontario Hydro deals with the challenging task of managing the future work program.

We continue to attend the Bruce A Nuclear Integrity Review Committee meetings. The goal of this committee is to provide the station director with assurance that Bruce A is complying with Ontario Hydro's nuclear safety policy. The meetings provide a good opportunity for us to observe management in action. While the focus is always on operational safety, the topics under discussion cover a broad spectrum; for example, an upcoming unit outage, a pattern analysis of significant events, an audit report, actions to address peer evaluation findings. We have found these meetings to be well run and the committee members dedicated to resolving identified problems and achieving improvements in safety performance. Attending these meetings allows us to maintain an awareness of the safety issues important to station management and its plans for dealing with them.

During 1996, Ontario Hydro established a new committee at Bruce A, the Nuclear Safety Surveillance Committee. This committee deals with newly emerging safety issues and can be convened at short notice. Issues remain active until the committee is satisfied that appropriate action is effectively under way to resolve them. We believe this committee provides an important contribution to the management of public risk.

About every three weeks, we hold meetings with station management to discuss on-going and emerging safety issues. At these meetings we raise items of concern to us arising from our on-going assessment of plant operation and the managers apprise us of new developments. We continue to find management responsive to our requests for information and action.

The station director introduced an on-going process of "management self-assessments" to Bruce A early in the year. This process is designed to allow station management to identify weaknesses in the managed processes and to take corrective action when required.

All managers in the operations section continually conduct *housekeeping* tours in the plant. We have accompanied the managers on some of these tours. From our observations, the managers conduct these tours in a diligent and thorough manner paying attention to detail. We believe the tours have contributed to improvements in housekeeping standards and in the communication of management expectations to field staff.

The station director has set a target for performance improvement for Bruce A and a comprehensive improvement plan has been developed to meet this target. By the end of 1996, a team had been established, responsibilities assigned and execution of the plan was well under way. We believe this program will raise performance standards at the station. We have already seen improvements in some areas such as housekeeping, equipment upkeep, radiation protection practices, and work planning.

Although the nuclear safety department still has difficulty meeting the demands for safety analyses to support reactor operation, management has not allowed this to compromise safety. Where necessary, it has imposed constraints on unit operation or held up the start of a work program.

TRAINING

We found that some aspects of training at Bruce A require improvement. Bruce A was requested to take the necessary corrective actions.

Our examinations continue as part of the regulatory process for authorization of ***shift supervisors*** and ***control room operators***. During 1996, we administered one station-specific and one simulator-based examination at Bruce A. All of the candidates passed these examinations. In 1996, we also approved one person as a Bruce A shift supervisor and one person as a Bruce A control room operator.

During 1996, we evaluated the continuing training program for ***authorized staff*** and strike contingency training activities. Strike contingency training is the training which is intended to provide individuals with the necessary knowledge and skills to maintain the shutdown units in the event of a strike by the Power Workers Union staff.

We found through our evaluation of the continuing training program for authorized staff that substantial training and re-qualification testing is taking place at the Bruce A ***simulator***. This simulator-based training and testing is conducted in accordance with Bruce A documentation. However, the other aspects of continuing training such as science fundamentals, station systems, design and procedural modifications, and operating experience feedback are not addressed adequately. Also, the re-qualification testing method used for the shift supervisors is not adequate.

The strike contingency training activities that were conducted by Bruce A in early 1996 were found to be acceptable.

Table 4: EMERGENCY EXERCISES AND DRILLS COMPLETED IN 1996

TYPE	NO.
Basic Drills:	
Toxic gas	5
Radiation emergency	5
Emergency response team practice	10
Others:	
Public announcement team practice	2
Off-site potassium iodide pill distribution	2
Monitoring and decontamination team practice	1
Off-site exposure control centre	2
Site management group assembly	3
Site management and station advisory groups notifications (including off-hours)	4
Other notifications	2

EMERGENCY PREPAREDNESS

We are satisfied with Ontario Hydro's emergency response capabilities at Bruce A. As Table 4 shows, Ontario Hydro maintained, in 1996, an effective program of exercises and drills for emergency preparedness. Each crew participated in at least one of the basic drills. We actively participated, as appropriate, in some of these drills.

Bruce A teams also responded to nine actual events in 1996. Of these, six were casualties, two were fires, and one was a hazardous chemical spill response.

SAFETY ANALYSIS

We are satisfied with the safety analysis performed by Ontario Hydro to support operation of the station and in response to questions we raised during 1996.

BRUCE A RISK ASSESSMENT

The Bruce A Risk Assessment (BARA) project continues. As discussed last year, BARA is a probabilistic risk assessment tool which should assist in maintaining the station in the safest possible configuration. Over 30 percent of the BARA was completed at the end of 1996. In addition, some BARA results are already being used to select safer configurations during maintenance of equipment, and to retrofit changes to the station. An example of a major application is the enhanced powerhouse venting project discussed below.

POWERHOUSE ENVIRONMENT ANALYSIS

Ontario Hydro is engaged in a major project to improve the qualification of essential equipment in the powerhouse at Bruce A so that it will operate in a hostile environment, such as after a large steam release (see the previous section on Environmental Qualification). To support this approach, Ontario Hydro has submitted analyses to us that determine the harsh environmental conditions, show the beneficial effects of the improved venting arrangements, and identify essential components required to survive these events. We have accepted the approach in principle, though some detailed questions remain to be resolved as the project progresses.

ANALYSIS IN SUPPORT OF RAISING POWER

As discussed in previous years' reports, Ontario Hydro has restricted the Bruce A reactors to 75 percent of full power to limit the power increase in the event of an inlet side *loss of coolant accident*. Much of Ontario Hydro's safety analysis effort for Bruce A was directed towards justifying reactor operations at higher power.

In January, Ontario Hydro submitted its large break loss of coolant accident analysis for operation after it has reversed the order of the fuel bundles in the reactor fuel channels. During the year, Ontario Hydro did additional analysis based on questions we raised during our review of this and other related submissions. We reviewed these analyses and found them acceptable. We subsequently approved the re-ordering of fuel bundles in unit 3.

Ontario Hydro also developed monitoring and testing programs to verify the results obtained from the safety analysis. We reviewed reports from this program as Ontario Hydro reversed the order of the fuel bundles in unit 3. Re-ordering had not been completed by the end of 1996 (it was started on November 26), but our assessment at year end was that the process was working smoothly with all defined limits met.

QUALITY ASSURANCE

We believe that Ontario Hydro's *quality assurance* program at Bruce A is acceptable. This is based on our review of the audit schedule and topics and the reports of the individual audits. We believe the station's method of measuring performance against its 13 quality principles has merit and we have found that the findings are sound.

In 1996, we conducted a joint-jurisdictional audit with the Ministry of Consumer and Corporate Relations of the Bruce A design modifications process. This was part of a series of audits we conducted to assess the effectiveness of the design modification process at all the operating stations. We concluded that Bruce A is not meeting all the requirements of the Canadian Standards Association standard for nuclear power plant design quality assurance. Specifically:

- Bruce A has not adequately described the design process for personnel engaged in design activities. The interim design program is not updated to reflect the current organization or design methods.
- The lack of clear instructions also affected design records. Ontario Hydro does not systematically control and maintain design records to ensure that essential information is readily available for technical evaluation of changes or purchased items.

We have requested that Bruce A take the appropriate corrective action on these items.

Our audit also identified several strengths in the Bruce A design program. Specifically, the design authority function, the organizational structure, and self-assessments are among the best observed at any station.

The Bruce A Management Assessment Department (Quality Assurance) carried out several assessments of the design function in 1996 and has expanded the scope of station audits to include design activities.

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 provides the IAEA with 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.

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

During 1996, the planning and execution of all safeguards-related work was carried out by Ontario Hydro as scheduled. This included the installation and testing of a new generation of core discharge monitor (CDM) in unit 3, developed under the Canadian Safeguards Support Program. The CDM will be used by the IAEA to monitor the irradiated fuel bundles discharged from unit 3. Plans are under way to install CDMs in units 1 and 4 during 1997 outages.

Ontario Hydro began a dialogue with us and the IAEA to ensure that satisfactory safeguards measures are applied to the transfer of irradiated fuel and to the *dry storage* facility, planned for the near future.

Ontario Hydro provided excellent cooperation and support to us and the IAEA. Reports and notification of activities involving safeguards were provided in a timely manner, as required by the licence.

CONCLUSIONS

We consider that Ontario Hydro operated Bruce A safely during 1996 and that the risk to the public and to workers remains acceptably low. We draw the following specific conclusions from our review of Bruce A's safety performance in 1996:

AREAS OF GOOD PERFORMANCE:

- Ontario Hydro's compliance with regulations made under the Atomic Energy Control Act was acceptable.
- Ontario Hydro staff has consistently met the new AECB reporting requirements.
- Worker and public radiation safety was satisfactory.
- Safety system performance was acceptable. Availability for all the special safety systems met targets.
- Programs to manage the aging of pressure tubes and steam generators are effective.
- We are satisfied with the progress made by Ontario Hydro at Bruce A on environmental qualification of equipment.
- Ontario Hydro staff was successful in efforts to demonstrate good management of the risks associated with the many tasks required to complete the fuelling-with-the-flow program.
- Ontario Hydro's management at Bruce A continues to demonstrate a strong commitment to safety as a first priority.
- The safety analysis performed in support of the operation of the station and in response to questions we raised during 1996, was satisfactory.
- Ontario Hydro continues to meet its safeguards obligations.

AREAS WHERE IMPROVEMENT IS NEEDED:

- To reduce the number of non-compliances, compliance with the licence must be better managed.
- To further improve maintenance standards, the number of jumpers must be reduced and a process to effectively manage plant aging must be established.
- The continued training program is strong on simulator training but needs improvement in class work in areas such as science fundamentals, and station systems.
- To improve the design change process, more attention must be paid to meeting all the requirements of the Canadian Standards Association standard for nuclear power plant design quality assurance.

GLOSSARY

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.

authorized staff
Licensee staff who the *Atomic Energy Control Board* has licensed or approved for specific positions at the station.

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*.

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 Canadian Deuterium-Uranium.

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.

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

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".

divider plates — Plates are situated in the bottom portion of the *steam generators* to keep the *primary heat transport system* heavy water inlet and outlet areas separate.

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.

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.

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.

garter spring

A spacer ring that fits between a ***pressure tube*** and the ***calandria tube*** to ensure that they do not come into contact.

generator

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

gross beta/gamma

A measurement of the total beta and gamma radioactivity in a sample.

heat exchanger

Equipment that transfers heat between systems.

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.

hydride

A binary compound of hydrogen, especially with metal.

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.

iodine-131

A radioactive isotope of iodine produced in the fuel when the reactor is operating.

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.

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.

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.

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.

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.

outage (forced, planned)

The time during which a reactor is not delivering power to the *grid*. Outages may be forced, by equipment malfunction, for example, or planned to carry out routine maintenance.

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

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.

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*.

pressurizer — A large steel vessel connected to the *primary heat transport system* to control pressure.

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 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.

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.
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.
setpoint	The value of a parameter at which a safety system operates, as required by the reactor operating conditions.
shield plug	A stainless steel plug that provides gamma ray shielding at the ends of the *fuel channels*.
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*.
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.

trip margins

The difference between the normal operating value of a measurement and the value at which a *special safety system* will actuate. It is important to have fairly small trip margins, so that the safety system will act promptly when station conditions change. However, station operators need some margin so that the safety system does not actuate during normal variations in station conditions.

tritium

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

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.