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REPORT

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REPORT

AECB Staff Annual Assessment of the Bruce B Nuclear Generating Station for the Year 1994

Atomic Energy Control Board
Ottawa, Canada

June 1995

Atomic Energy Control Board | Commission de contrôle de l'énergie atomique

Canada

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 or 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 the station's operation and management, and we also inspect each station.

SUMMARY

AECB staff believes Ontario Hydro operated Bruce B safely in 1994.

The Bruce B reactors will remain limited to 88% full power until Ontario Hydro is able to demonstrate that it is safe to operate at higher powers (see Safety Analysis section).

Ontario Hydro's compliance with our regulations and the Operating Licence was satisfactory. We found no major violations. The station performance was similar to previous years.

Radiation doses to workers and the public were well below the legal limits and also remained below Ontario Hydro's internal targets. Worker radiation doses increased slightly but were comparable to previous years.

Inspection of pressure tubes and steam generator tubes by Ontario Hydro showed continuing tube degradation. However, we believe that Ontario Hydro made progress in correcting and managing these problems.

Ontario Hydro carried out a full-scale fire drill at Bruce B in 1994. We witnessed the drill and were pleased to observe a significant improvement in the station's fire-fighting capability.

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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 1994. 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.

At our head office in Ottawa, the public can consult all documents relative to the licensing process of nuclear facilities. Our public library also contains an important collection of documents, available on request. Apart from the AECB Annual Assessment Report, we publish research reports, communiques, information bulletins, notices and pamphlets. Board meeting minutes are also available. Our address is: 280 Slater, Ottawa, Ontario, Canada. Written requests for information should be mailed to: Atomic Energy Control Board, Office of Public Information, P.O. Box 1046, Ottawa, Ontario, Canada, K1P 5S9. We can also be reached by telephone at 613-995-5894 or 1-800-668-5284.

The nuclear industry uses many technical terms in its day-to-day operations. To help our readers, we have compiled a glossary of the technical terms used in this report. Items included in the glossary are *italicised* the first time they appear in the body of the report. The glossary begins on page 23.

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 THE ATOMIC ENERGY CONTROL REGULATIONS

We were satisfied with Ontario Hydro's compliance at Bruce B with our Regulations. There were no major non-compliances in 1994.

We require Ontario Hydro to operate Bruce B in accordance with the legal requirements governing the nuclear industry in Canada. These requirements are in the Atomic Energy Control Regulations, the Physical Security Regulations, the Transport Packaging of Radioactive Materials Regulations, and the Cost Recovery Regulations made under the *Atomic Energy Control Act.*

Ontario Hydro reported two non-compliances with the Atomic Energy Control Regulations. On two separate occasions, Ontario Hydro did not post appropriate radiation warning signs as required by the Regulations. We reviewed both events and determined they had only minor safety significance. We were also satisfied that Ontario Hydro had taken suitable corrective action.

COMPLIANCE WITH THE OPERATING LICENCE

As well as complying with the Regulations mentioned above, Ontario Hydro must also comply with the Operating Licence for the station. In general, we were satisfied with Ontario Hydro's compliance with the Bruce B Operating Licence.

Ontario Hydro reported 10 licence non-compliances. We reviewed each of these events and concluded that none had any significant effect on nuclear safety. We were also satisfied with the corrective action taken by Ontario Hydro. All the non-compliances related to one licence clause which requires Ontario Hydro to operate Bruce B in accordance with an approved set of *Operating Policies and Principles.* This is one of the most stringent clauses in the Bruce B licence.

COMPLIANCE WITH THE PHYSICAL SECURITY REGULATIONS

We were satisfied with Ontario Hydro's compliance at Bruce B with our Physical Security Regulations. AECB staff carried out a formal appraisal of Ontario Hydro's compliance with the Physical Security Regulations. In general, we found that the station is complying with the legal requirements of the Regulations. However, a number of deficiencies were found and Ontario Hydro was notified and requested to take appropriate corrective action.

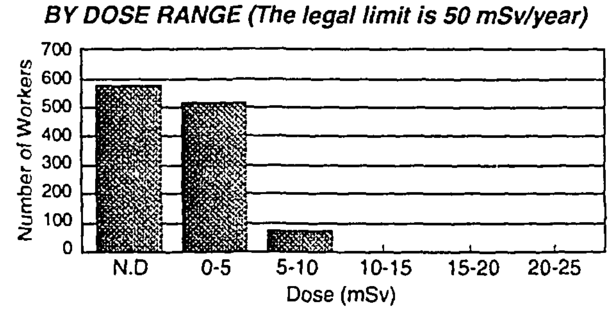
WORKER RADIATION SAFETY

Operation of Bruce B 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 milli*sieverts* (mSv). As can be seen from Figure 1, the radiation dose received by most of the workers at Bruce B was less than 5 mSv. The total radiation dose received by the workforce increased slightly (see Figure 2). This was mainly due to the significant amount of inspection work carried out by Ontario Hydro on the steam generators (see Operations and Maintenance section). In spite of the increase, Bruce B again had one of the lowest total radiation dose figures for CANDU nuclear reactors in Canada. We consider Bruce B's performance to be commendable and in accordance with the as low as reasonably achievable principle.

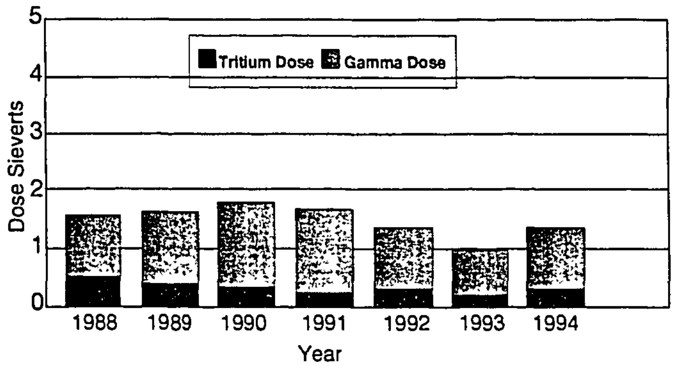
A significant contributor to dose at CANDU plants is *tritium*. By sending *moderator* heavy water to the tritium removal facility at Darlington, Bruce B was able to reduce the moderator tritium concentration by more than 60%. Removing the tritium from the moderator heavy water reduces worker radiation doses from this source. Figure 2 shows that the total tritium dose to workers has been well controlled. Removing the tritium also reduces releases to the environment.

Figure 1: ***BRUCE B WORKER DOSE DISTRIBUTION BY DOSE RANGE (The legal limit is 50 mSv/year)***



The station target is to be less then 10 mSv per person per year.
ND - No detectable dose

Figure 2: ***BRUCE B OCCUPATIONAL DOSE***



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.

We are pleased to report that we found less evidence during our field inspections of smoking within zones where *contamination* may be present. Workers who smoke in a radiation zone increase their risk of ingesting contamination.

In 1992 and 1993, we reported the results of our inspections of "rubber areas". A rubber area is a temporary area set up by Ontario Hydro to contain loose contamination and prevent its spread. In 1994, rubber area control was again found to be good, with about 90% of the rubber areas inspected meeting Ontario Hydro's own standard. We were also pleased to note that Ontario Hydro is using improved contamination monitoring equipment at rubber area exits and that new hand and foot monitors have been installed throughout the station.

AECB staff carried out an appraisal of the Bruce site dosimetry service. We concluded that, in general, the dosimetry service is adequate. We noted several areas where improvements could be made. For example, we found that not all laboratory procedures are documented. In addition, the documented laboratory quality assurance program and the training program for laboratory technicians have not been implemented. Ontario Hydro has been requested to take corrective action.

PUBLIC RADIATION SAFETY

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

Our 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 1% of the DEL (see Table 1). It can be seen that the releases have remained stable over the last five years. Ontario Hydro did not exceed the 1% target at any time during 1994.

Based on data obtained from its environmental monitoring program, Ontario Hydro estimated that the annual dose to the most exposed members of the public in the vicinity of Bruce A and Bruce B, resulting from radioactive emissions from both stations, was 0.007 mSv. The regulatory limit is 5 mSv/year. The average gamma dose rate was about 0.040 *microgray*/hour. The average tritium activity in air at the site boundary was 3.5 *becquerel*/cubic metre.

Table 1: *BRUCE B ENVIRONMENTAL RELEASES*

All Values are a Percent of the DEL

Pathway	Year				
	1990	1991	1992	1993	1994
Airborne:					
Tritium	0.16	0.082	0.072	0.082	0.077
Noble Gases	0.006	0.0058	0.0068	0.017	0.012
Radioiodines	0.0092	0.010	0.0050	0.0044	0.0046
Particulates	0.0029	0.0029	0.0025	0.0024	0.0021
Waterborne:					
Tritium	0.015	0.017	0.014	0.022	0.019
Total Gamma	0.017	0.012	0.021	0.023	0.026

PERFORMANCE OF SAFETY SYSTEMS

With the exception of *containment*, the performance of the *Special Safety Systems* was satisfactory.

We require that each Special Safety System be fully functional for 99.9% of the time. To meet this requirement, a Special Safety System can only be unavailable for 8.76 hours per year. It should be noted that a system is labelled unavailable if it is anything less than 100% capable, even though it may retain considerable effectiveness.

On two separate occasions in 1994, Ontario Hydro found that the containment system was leaking. The leaks occurred because, in the first instance, rubber door seals had been accidently damaged and in the second, a valve had malfunctioned and stuck open. Although the leaks were minor, and suitable corrective action was taken by *Ontario Hydro*, containment was nevertheless considered to be impaired. Ontario Hydro calculated that containment was unavailable for a total of 15.38 hours (see Table 2). With leaks of the magnitude experienced, the impact on the containment system's ability to perform its function in an emergency would be minor.

Containment was the only Special Safety System to exceed the unavailability limit of 8.76 hours in 1994. In 1993, three of the four special safety systems exceeded this limit.

Ontario Hydro determines how well Special Safety Systems are expected to perform in the future. This is done on the basis of experience and tests performed on the systems and components. The results are expressed as Predicted Future Unavailability (PFU). The smaller the PFU value, the better the expected performance of the system. PFUs for the Special Safety Systems are estimated to be within the target of 8.76 hours per year in 1995 (see Table 2).

Table 2: *SAFETY SYSTEM PERFORMANCE*

System	Predicted Future Unavailability (Hours/year) (Target less than 8.76 Hours)	1994 Unavailability (Target less than 8.76 Hours)			
		Unit 5	Unit 6	Unit 7	Unit 8
Shutdown System No. 1	6.46	0	0	0	0
Shutdown System No. 2	2.09	0	0.114	0.06	0
Emergency Coolant Injection System	7.52	0	0	0	0
Containment	7.52	15.38	15.38	15.38	15.38

EVENTS REPORTED TO THE AECB

We were satisfied with Ontario Hydro's compliance with this licence requirement. Bruce B reported events promptly and kept us informed of follow-up actions. Our assessments did not indicate any non-compliances with reporting requirements.

Under a licence condition, we require the licensee to report certain types of events to us. Ontario Hydro must report to us any event which contravenes its Operating Licence or any of the governing regulations. Ontario Hydro must also report to us events that may be a precursor to an event that may contravene the licence or regulations. Ontario Hydro analyses the reported events and determines what action must be taken to prevent a recurrence. Our assessments indicated acceptable performance in 1994.

The types of events reported in 1994 are listed in Table 3. Three events, "Lightning Strike", "Partial Loss of 48 Volt DC Supply" and, "Incorrect Channel Fuelled" are discussed in the Operations and Maintenance section of this report.

Human errors contributed to approximately 50% of station events. A primary cause of these errors still appears to be a lack of verification or self-checking. Ontario Hydro has taken steps to rectify the situation by improving its training programs (see Training section). Maintenance errors contributed to approximately 20% of the events reported by Ontario Hydro in 1994.

The percentage of work protection errors was similar to last year. Work protection errors contributed to approximately 10% of the 1994 reportable events.

Table 3: ***REPORTABLE EVENTS***	
Number of Regulation Non-Compliances	2
Number of Licence Non-Compliances	10
Total Number of Reportable Events	30

Table 4: *BRUCE B NET CAPACITY FACTORS (percent)*

Unit	1994	Lifetime
5	75	84
6	86	81
7	73	82
8	86	80

OPERATIONS AND MAINTENANCE

❑ General

The station continued to operate well this year. There were no serious process system failures. One reactor trip occurred during the year while the reactor was at high power. The trip was the result of a lightning strike (see below).

There were two very small fires at the station in 1994.

The net capacity factor for each unit is shown in Table 4. The net capacity factor is the ratio of the power actually delivered to the grid by the generator to the power the generator is capable of producing. This is expressed as a percentage. All reactor units were derated in 1994 (see Safety Analysis section, Power Pulse).

❑ Lightning Strike

In June, a lightning strike caused a loss of power to two of the main heat transport pumps in Unit 7. Because the reactor power was momentarily higher than the ability to take away heat, pressure built up in the *Primary Heat Transport System* causing both shutdown systems to operate. Analysis by AECB staff after the event confirmed that the station operated well within the safe limits defined in the *Safety Report.*

❑ Partial Loss of 48 Volt DC Supply

In November, while Unit 5 was shut down for maintenance, an electrical failure occurred. Problems with the air conditioning in an electrical equipment room caused a partial loss of the unit's 48 volt DC power supply. This caused a number of system upsets, including a three-minute loss of cooling water to the primary *heat sink.* Bruce B staff treated this event seriously. They thoroughly investigated this event and took suitable corrective action. We are satisfied with their actions at this time.

❑ Incorrect Channel Fuelled

In October, station staff inadvertently added fuel to the wrong *fuel channel*. The operators discovered the error just before closing the channel. The error was caused, in part, by a computer program that helps monitor fuelling operations being temporarily out of service.

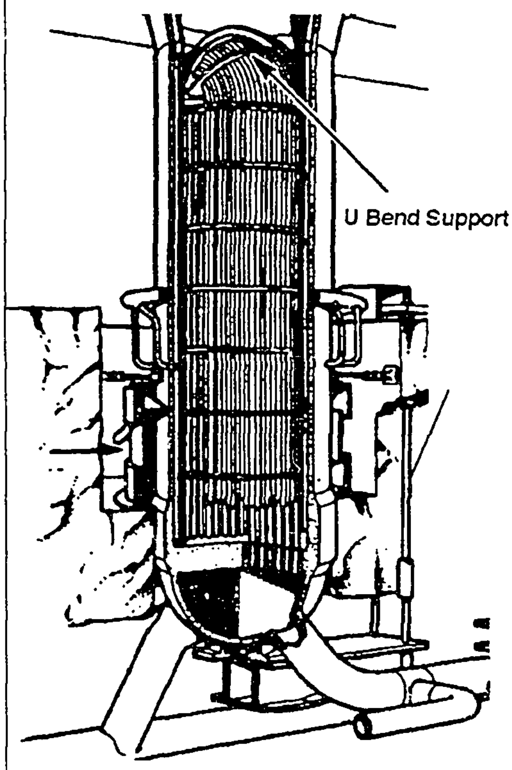
❑ Steam Generator Tubes

Although in 1994 Ontario Hydro found deeper frets in steam generator tubes than had been found before, we believe Ontario Hydro has an effective steam generator tube life management program and there is adequate assurance of their continued fitness for service.

The steam generators at Bruce B have operated reliably since the units started up. However, the design of the steam generator tube supports at Bruce B allows some motion and the normal turbulence in the steam generators causes the tubes and their supports to vibrate. This results in mechanical wear or fretting of the tubes to varying depths. From 5 to 10% of the tubes are affected and frets are found mostly in the U-bend support region of the steam generators (see Figure 3).

Ontario Hydro has defined a fretting wear limit of 87% of the tube wall thickness. We consider that, with additional allowance for measurement uncertainty and continued wear, this maintains an adequate safety margin for tube strength. In addition, we have asked Ontario Hydro for a better

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



definition of the possible effects of vibration on tube strength and leak rate in all Bruce B units. In practice, Ontario Hydro removes any tube from service that it finds with fretting wear greater than 40% through-wall. There have been no tube leaks at Bruce B due to fretting wear.

During 1994, Ontario Hydro inspected steam generators in Units 5 and 7. Most of the frets found by Ontario Hydro were less than 40% through-wall. However, in Unit 5, Ontario Hydro found that 1% of the tubes inspected had frets deeper than 40%.

The deepest fret mark found was 73%. The deepest fret previously found was 61% through-wall.

The fretting found in Unit 5 prompted Ontario Hydro to advance its steam generator inspections by one year. Ontario Hydro will now inspect all 32 steam generators at Bruce B by the spring of 1996. In addition, Ontario Hydro has supplied us with analysis of the likely results of leakage from potential tube failures caused by fretting. It intends to carry out tests in 1995 to support this analysis. We shall review the analysis and closely monitor the test results.

❑ Pressure Tubes

Based on the analysis of frets found by Ontario Hydro during inspections and the results of laboratory tests, we consider that *pressure tube* fretting is unlikely to cause pressure tube failure at Bruce B. This view could change as the pressure tubes accumulate more hydrogen and the frets age.

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 becomes abnormally supported and gradually moves over the pressure tube rolled joint. Abnormally supported bundles vibrate in the coolant flow and their bearing pads wear fine grooves or frets in the rolled joint area of the pressure tubes. Frets locally increase the stress in the rolled joint area which increases the probability of pressure tube cracking. However, for cracking to occur, the hydrogen content of the pressure tube, which increases with time, must also be above a certain threshold level. Ontario Hydro's analyses indicate that the hydrogen content of Bruce B pressure tubes is not above this threshold. In 1995, Ontario Hydro plans to measure the hydrogen content of selected pressure tubes by scrape sampling. To date, no cracking of pressure tubes has occurred as a result of pressure tube fretting at Bruce B.

During 1994, Ontario Hydro inspected pressure tubes in Units 5 and 7. These inspections again showed there is little difference among Bruce B reactors in terms of distribution and degree of fretting. Ontario Hydro calculated the probability of pressure tube failure due to the measured frets. Based on our review of these calculations, we accepted that it was safe to operate the reactors with the fret marks.

As mentioned in last year's report, Ontario Hydro has studied a number of options to eliminate rolled joint fretting. One option is the use of long fuel bundles. Long fuel bundles are 20 inches (508 mm) long, whereas normal fuel bundles are 19.5 inches (496 mm) long. By using one or more long bundles in combination with normal bundles, it is possible to push the inlet fuel bundle back into normal support and hence out of contact with the rolled joint area of the pressure tube. Ontario Hydro has performed both laboratory and power reactor tests on long bundles. Following appropriate modifications to the *Fuel Handling System*, and with our concurrence, Ontario Hydro is now loading some long bundles into the outer fuel channels of all four reactor units at Bruce B.

❑ Temporary Changes

There has been no detectable change in the control of temporary changes to equipment at Bruce B. The station made no progress in reducing the number of temporary changes or in reducing the average time that temporary changes remain in effect. We consider this performance to be unsatisfactory.

Ontario Hydro uses two types of forms to document and control temporary changes. The Jumper Record (jumper) controls temporary changes to equipment and the Operating Memo gives operators temporary operating instructions. For operational safety reasons, it is important to keep the number of changes low.

There was a slight reduction in number of jumpers in 1994 (see Table 5). The number of jumpers past their review dates, however, increased to 97 per unit. We believe that this requires improvement in 1995. The number of jumpers past their review dates should be close to zero. (T5 / PAGE)

Table 5: *TEMPORARY CHANGE DOCUMENTATION*

	1991	1992	1993	1994
Number of jumpers	281	274	300	274
Number of jumpers past review date	81	65	61	97
Average age of jumpers (days)	650	526	567	630
Number of jumpers on Special Safety Systems	–	–	10	13
Number of operating memos	38	27	33	23

Note: The numbers in the table are a per unit average. Numbers are year-end values.

❑ Plant Chemistry Control

We believe Ontario Hydro continued to maintain good chemistry control at the station.

Ontario Hydro reported that it met its chemistry control targets 97% of the time. Our periodic reviews of chemistry data confirmed this fact. Because Ontario Hydro's targets are stringent, we consider this to be very good performance.

In our monitoring of the station, we saw evidence that station staff continues to focus its efforts on maintaining good steam generator chemistry control. For example, Ontario Hydro has upgraded the instrumentation in the water treatment plant. Maintaining good steam generator chemistry control is important for safety as well as for plant reliability and productivity.

❑ AECB Compliance Inspections

We routinely inspect all areas of the station. We completed 98% of our planned inspections, known as 'rounds', during 1994. In general, we found that equipment in the station appeared to be in good working order and in the required state. Housekeeping in the station remained excellent.

In addition to rounds, we also carried out detailed inspections of the *Active Liquid Waste* and the *Annulus Gas Systems*. These inspections involve a thorough review of test and maintenance records, review of deficiency reports and jumpers, field verification of valve and/or breaker positions and a review of temporary operating procedures. We found no significant problems during 1994. However, a number of pieces of equipment were found which did not have identification tags attached. Ontario Hydro has taken corrective action.

❑ Maintenance

Good maintenance is essential to the safe operation of the station. There is a clear link between effective maintenance and safety as it affects the operation and reliability of equipment. We believe that routine maintenance at Bruce B was acceptable. However some problems, identified in our report for 1993, have only been partially resolved.

Bruce B staff again reduced the number of outstanding preventative maintenance call-ups and thus improved the call-up completion rate (see Table 6). Call-ups are used to remind station personnel that regularly scheduled preventative maintenance work is due. "Reactor safety" call-ups represent about 60% of the total number of call-ups at Bruce B. Ontario Hydro completed 98% of the designated reactor safety call-ups. In effect, 100% were completed since the remaining 2% were subsequently reclassified as non-reactor safety call-ups. Bruce B staff also reduced, once again, the number of outstanding deficiencies. At the end of the year, there was, essentially, no maintenance backlog at Bruce B.

Table 6: *MAINTENANCE*

	1991	1992	1993	1994
Number of preventative maintenance call ups not completed per unit at year end	791	808	725	646
Percent completion rate for all call ups	54%	74%	87%	91%
Percent call up rate for reactor safety call ups	82%	80%	100%	98%
Number of deficiency reports outstanding per unit at year end	2556	2514	1052	851

In last year's report we indicated that Ontario Hydro needed to improve the analysis of indicators used to measure the effectiveness of preventative maintenance activities. We noted little improvement in 1994. In addition, we noted there are no indicators to show what benefit is derived from the predictive techniques, mentioned below, or from the Reliability Centred Maintenance program. Bruce B has started a thorough review of indicators and it is hoped that ultimately the ability of the station to measure and interpret maintenance trends will be enhanced.

In last year's report, we indicated that the interface between unit management and maintenance support organizations at the station needed clarification. We noted that Bruce B staff has made some progress in defining these interfaces. However, the responsibilities of these groups are yet to be formally documented.

Reliability Centred Maintenance (RCM) is a technique used by Ontario Hydro to identify components important to the reliable operation of systems, and to specify the frequency and nature of maintenance to be applied to these components. Bruce B has given a higher profile to the RCM program. Resources have been committed and a deadline has been established for the completion of the program. This is encouraging since we feel that the RCM program is very important and serves to focus maintenance efforts in the right areas.

For some time Ontario Hydro has used various predictive techniques, such as erosion and corrosion monitoring of pressure boundaries and vibration monitoring of rotating equipment, to detect deterioration. In 1994, techniques to monitor motor-operated and air-operated valves were also introduced.

Bruce B has been recertified for a further three years by the Pressure Vessel Branch of the Ministry of Consumer and Corporate Relations to repair and test pressure relief valves.

Bruce B staff has introduced many separate initiatives which will have a long-term positive impact on maintenance. We believe that if these initiatives are effectively implemented, the quality of maintenance and hence the safety of the station will be enhanced. We consider this an important step towards developing a long-term maintenance strategy to cope with the aging of the plant.

In 1994, Bruce B staff shut down Units 5 and 7, for approximately 40 days each, to have extensive pre-planned maintenance work performed. Ontario Hydro plans to have a maintenance outage every two years for each unit at Bruce B.

❑ Environmental Qualification

We believe that the implementation of the Environmental Qualification (EQ) program progressed satisfactorily.

Should an accident occur at the station, it is possible that steam or water would be released and come into contact with safety-related equipment. Such equipment may be part of a safety system which must function to mitigate the consequences of the accident. The EQ program identifies components which must continue to function when exposed to steam and water, in some cases for prolonged periods. Steps are then taken to protect or change (environmentally qualify) the equipment to ensure that it functions as required under accident conditions.

Bruce B staff has identified the Emergency Core Injection System components to be environmentally qualified and is currently reviewing the other Special Safety Systems. All Special Safety Systems are planned to be fully environmentally qualified by 2001. All other *safety-related systems* will be completed at the end of 2003. We are monitoring the progress of this work in terms of quality, timeliness and resources.

STATION MANAGEMENT

From the viewpoint of reactor safety, we are satisfied with the management of Bruce B. Station management responded well to safety issues.

The transition to the new station organization, mentioned in last year's report, has, in general, been well handled at Bruce B. Communications problems between the newly created organizational units and also between these units and Ontario Hydro's head office specialist groups have been apparent. Ontario Hydro is well aware of these problems and has initiated corrective action.

Ontario Hydro continues to have difficulty in attracting and retaining the appropriate staffing complement at Bruce B. Last year, we reported that there was a shortage of specialist staff in the nuclear analysis and assessment area. Ontario Hydro has been attempting to correct this deficiency by retraining station staff in these areas and hiring contract staff to do the work in the interim.

There were two major maintenance outages in 1994. From a safety point of view, we believe these were managed well by Bruce B staff. We were particularly pleased to observe the care taken to maintain the integrity of the primary and secondary heat sinks as the outages proceeded.

In last year's report, we mentioned that Bruce B management had formed a Nuclear Integrity Review committee. This committee is responsible for seeing that reactor safety issues are thoroughly reviewed. We believe that this committee, which consists of station managers and other technical experts as required, did valuable work in 1994 and, as a result, the safety of the station was enhanced. We were pleased to note that the Bruce B Quality Assurance Superintendent has become a permanent member of this committee.

Safety culture can be defined as a set of beliefs, norms, attitudes and technical practices which if followed, will reduce the risk of exposure to radiation for workers and the public. In 1994, we believe that the safety culture at Bruce B improved.

Bruce B management responded appropriately to our formal requests for action in 1994.

TRAINING

We believe that Ontario Hydro's performance at Bruce B in the area of training was acceptable.

The AECB is responsible for ensuring that the senior operating personnel in the *main control rooms* of nuclear stations in Canada are competent and thus contribute to the safe operation of the station. Two positions we approve are the *Shift Supervisor* and the *Control Room Operator* positions. The required assurances are obtained, and approvals given, on the basis of the successful completion of a series of AECB examinations, set at the end of a lengthy period of training.

In 1994, 78% of Ontario Hydro candidates for the above positions passed the AECB examinations. In 1993, 96% of candidates passed. Late last year, we introduced a simulator-based examination for Shift Supervisor and Control Room Operator candidates. In 1994, 57% of candidates who took simulator-based examinations passed.

Human error contributes to about 50% of station events. Consequently, station management has implemented an improved self-checking training course. All station staff are scheduled to attend, including the managers. Workers in the station, such as maintenance workers, whose activities have a major impact on safety, are scheduled to take the course first.

As a result of the Ontario Hydro reorganization there was a lack of fully qualified people at Bruce B to carry out safety analysis. Ontario Hydro, therefore, set up a training course for staff at Bruce B who are involved in safety analysis. Once the requirements were identified, the courses were developed and given to licensee staff. AECB staff has monitored some of the courses and found that the training provided was comprehensive and effective.

EMERGENCY EXERCISES AND DRILLS

We believe Ontario Hydro maintained an adequate emergency response capability at Bruce B. We base this conclusion on our observations of drills throughout the year and on our formal appraisal of a large-scale fire drill held in November.

Ontario Hydro planned 114 emergency drills at Bruce B in 1994. It completed 107 of these and reported no major deficiencies (see Table 7).

Table 7: *STATION DRILLS*

Drills	Planned	Completed
Fire and Medical	63	63
Radiation Emergency	21	21
Toxic Gas	10	10
Security	20	13

One of the Bruce B drills simulated a large fire. To formally appraise the station's emergency response capability in this drill, we hired consultants who specialize in fire fighting assessments. The consultants, who had witnessed a previous drill in 1989, found that Ontario Hydro's fire fighting capability had improved significantly. They also concluded that the station now demonstrates adequate performance in most aspects of emergency response. The consultants made a number of recommendations to which we shall ask Ontario Hydro to respond.

In 1995, Ontario Hydro plans to simulate a large-scale security alert. We plan to formally appraise the station's response to measure its compliance with the Physical Security Regulations.

SAFETY ANALYSIS

Ontario Hydro provided a number of safety submissions and a major safety analysis update in 1994. In general, we found these to be satisfactory although, as mentioned below, a number of issues remain unresolved.

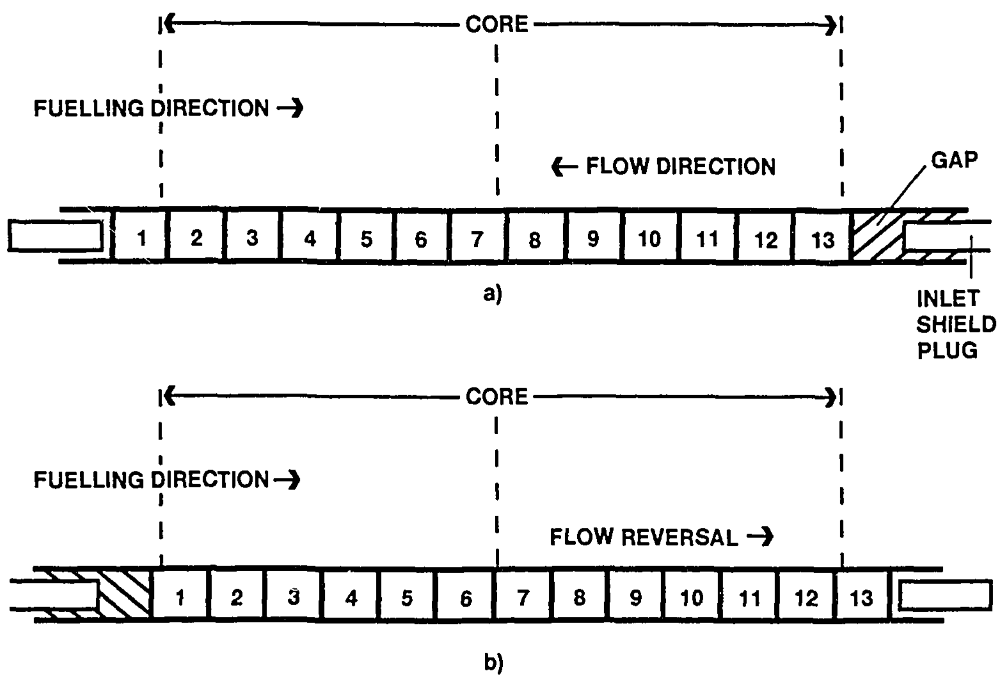
❑ Power Pulse

At the beginning of 1994, the Bruce B reactors were operating at 80% of full power. Ontario Hydro had discovered that its safety analysis had overlooked the effect of fuel relocation during the rapid power increase that would occur under certain loss of coolant accident (LOCA) conditions. This so called 'power pulse' could be of such magnitude and occur so rapidly that the shutdown systems may not be able to act quickly enough to prevent significant damage to the fuel. The only way to ensure adequate shutdown system performance was to reduce reactor power to reduce the size of the power pulse.

Each fuel channel at Bruce B contains 13 round fuel bundles. The bundles at position one contain relatively fresh fuel and are partially out of the core. As can be seen in Figure 4a, there is a gap between the 13th bundle and the inlet shield plug. This gap has been increasing as the pressure tubes age and become longer. Ontario Hydro's analysis has shown that should certain LOCA's occur, the flow through the channels would reverse. Consequently, as shown in Figure 4b, fresh fuel would be pushed into the core. This sudden injection of fresh fuel would cause a sudden, large increase in reactor power.

In early 1993, when the implications of the analysis were realised, Ontario Hydro reduced power on all the reactors at Bruce B to 60% of full power. It also reduced the setting at which the shutdown systems activate. Later in 1993, Ontario Hydro submitted analysis which permitted us to accept a power increase to 80% of full power.

Figure 4: *FUEL CHANNEL GAPS*



In last year's report, we mentioned that Ontario Hydro planned to reduce the average channel gap in stages. At the end of each stage, Ontario Hydro will seek our approval for a power increase. Ontario Hydro has modified the inlet shield plug of central fuel channels by adding flow straighteners. This had the effect of reducing the average gap and thus the size of power pulse should a LOCA occur. Ontario Hydro also modified the shutdown system setpoints. Subsequently, analysis was submitted by Ontario Hydro to support raising power. Based on this analysis and additional submissions, we granted permission to raise power to 85% of full power in April and to 88% of full power in August.

❑ Large LOCA Analysis

Ontario Hydro submitted an updated large LOCA analysis. We are still reviewing this document. So far we have not accepted its conclusions because it uses new computer programs that Ontario Hydro had not adequately tested against experimental data.

The analysis assumes that the inlet shield plugs have been modified and long fuel bundles have been added to reduce the distance the fuel can shift should certain large LOCAs occur (see Power Pulse above). However, this means that when the fuel heats up and expands during the LOCA, the fuel will contact the shield plug and increase the stress in the fuel channel. We are reviewing the acceptability of reducing the fuel channel gap so that the fuel contacts the shield plug during a LOCA.

❑ Risk and Operation of Bruce B

We believe Ontario Hydro specialists are making acceptable progress in producing a Probabilistic Safety Assessment (PSA) for Bruce B. Ontario Hydro expects to complete the PSA by 1996.

PSA is a technique for measuring the risk in operating a nuclear plant. PSA is a tool to determine how safe a plant is or if any design or operating changes need to be made to improve the level of safety.

When the PSA is complete, it will be possible for Bruce B and AECB staff to more accurately estimate the level of risk associated with operating the station. They can also determine if any design or operating procedure change can be made to reduce risk further. A PSA will also allow station staff to continue to manage risk during the operational life of the station. For example, Bruce B staff can use it to determine the affect on risk when several pieces of equipment have to be taken out of service at the same time for maintenance.

We consider a PSA to be an important tool for estimating and managing risk. AECB specialists have been closely monitoring the development of the Bruce B PSA.

QUALITY ASSURANCE

We believe that the Bruce B Operations *Quality Assurance* (QA) Program functioned satisfactorily during the year.

Ontario Hydro filled the last of the six approved positions in the Bruce B QA section. Although staffing levels in the QA section have increased in recent years, the scope of the QA program to be administered has also grown considerably. We will continue to monitor the capability of the Bruce B QA section to cope with the increased workload.

The Bruce B QA section carried out 43 surveillance assessments during 1994. Assessments are done to verify that the QA program remains effective. We were pleased to note that the QA Section continued to be proactive with respect to the monitoring of activities at the station.

Ontario Hydro issued a revised QA manual towards the end of the year. The new manual integrates the QA activities related to the procurement, design, construction, commissioning and operations into one document. Prior to Ontario Hydro's reorganization in 1993, most of these activities were administered by separate, non-station groups within Ontario Hydro. Now the responsibility for these activities lies with Bruce B staff. AECB staff is currently reviewing the revised QA manual.

We conducted an audit in October which revealed that Ontario Hydro has made satisfactory progress in correcting deficiencies found in previous AECB audits. The areas of improvement included work protection training, work protection planning prior to unit outages and the revision of flowsheets. We found, however, that some corrective actions proposed by station management had not been carried out. For example, the establishment of a set of master flowsheets at each unit desk and the introduction of a computerized equipment calibration system were lagging behind schedule. During the audit, we also examined work being carried out on pressure retaining components during the Unit 5 maintenance outage. The auditors observed one non-compliance involving a weld repair. Ontario Hydro took suitable corrective action.

SAFEGUARDS

Ontario Hydro continued 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.

The requirement for the application of IAEA safeguards is included in the Bruce B 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 the installation and maintenance of IAEA equipment at the station.

Ontario Hydro provided reports as required. The planning and execution of all safeguards-related work was carried out by Ontario Hydro as scheduled. Very good cooperation was received from Ontario Hydro staff at all levels.

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CONCLUSIONS

We believe Ontario Hydro operated Bruce B safely in 1994 and that the risk to workers and the public remained acceptably low.

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

- Radiation dose control;
- Radiation releases to the environment;
- Plant chemistry control;
- Preventative maintenance backlog;
- Managing reactor safety during unit shutdowns;
- Compliance with Safeguards Agreement and Non-Proliferation Treaty.

To continue to meet our requirements and its own targets, we believe improvements are needed in the following areas:

- The quality of safety analyses. We noted in 1994 that quality assurance of the analysis process has been improved. This is the first year of a multi-year program by Ontario Hydro;
- The coordination of its maintenance programs to better integrate the many maintenance functions and specialist areas;
- Control of temporary changes (jumpers) and in particular the timeliness of jumper reviews.

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GLOSSARY

Active Liquid Waste	The system used to collect, sample and control liquid waste which contains, or is like to contain, radioactive material.
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.
Atomic Energy Control Act	An act passed by Parliament in 1946 to provide for the control and supervision of the domestic development of atomic energy and to enable Canada to participate effectively in measures of international control of atomic energy.
Becquerel	The SI unit for the radioactivity of a source. It is equivalent to one disintegration per second.
Calandria	A cylindrical unpressurized stainless steel vessel which holds the moderator. *Pressure tubes* span the two end plates of the calandria.
Canadian Deuterium-Uranium Reactor (CANDU)	Canadian designed reactor moderated and cooled by *heavy water* and fuelled with natural uranium. "CANDU" is derived from Canada, Deuterium, Uranium.
Containment	The building surrounding the reactor. It isolates the reactor from the environment and prevents radiation, which might be released in an accident, from escaping.
Contamination	The deposition of radioactive material in any place where it is not desired, and particularly in any place where its presence may be harmful.

Control Room Operator	A Control Room Operator is responsible for operating the controls for the reactor. Only persons whom the AECB approves can occupy this position.
Derived Emission Limit	A calculated amount of radioactivity that if it were released from the station, would result in a radiation exposure of 5mSv to a member of the public in the worst possible case. Five mSv is the maximum annual radiation exposure 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 local to the station, and drinks only water from the station's discharges. This theoretical individual is known as the 'critical individual'.
Dose	Generally, the quantity of radiation energy absorbed by a body.
Emergency Coolant Injection System	Also known as the Emergency Core Cooling System, or ECC. A supply of cold water that can quickly be injected into the fuel channels of the reactor if the normal source of cooling water is lost. It also provides long term cooling for the fuel by recovering water from the reactor building floor.
End Plates	Two end plates welded to the ends of the elements of a *fuel bundle* 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.
Fuel Bundle	A collection of thirty-seven pencil shaped elements containing natural or depleted uranium that are held together by *end plates* into the form of a cylinder.
Fuel Channel	See Pressure Tube.
Fuel Handling System	The system that is responsible for fuel changing and storage of new and irradiated fuel.
Gray	The SI unit of absorbed radiation dose, one joule per kilogram. One Gray is the same as 100 rads. One nanoGray is one billionth of a Gray.

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 primary heat sink must be in service, normally the *steam generators* and an alternative or back-up 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 the fuel.
Heavy Water (D_20)	A chemical compound made up of deuterium (D), an isotope of hydrogen, and oxygen. It is chemically and physically similar to ordinary water (H_20), but is about 10% heavier. Heavy water occurs in small concentrations in nature, and it is made by separating it from natural water. It is used as a moderator and coolant in a CANDU reactor.
International Atomic Energy Agency (IAEA)	The IAEA is a United Nations agency. It provides a system of safeguards to make sure that nuclear materials from peaceful applications are not diverted to non-peaceful activities. It also provides an international forum for nuclear safety.
Loss of Coolant Accident (LOCA)	An accident in which a failure in the *primary heat transport system* causes the *heavy water* coolant to be lost faster than it can be replaced by the normal heat transport coolant supply. The *emergency coolant injection system* is installed to permit 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.
Moderator	The *heavy water* in the *calandria* that shows 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 was to cause a complete loss of cooling to the fuel channels.

Operating Policies and Principles	A licensee document, which we approve, that outlines the safe operating boundaries for a station. It also defines when staff may make decisions and when they must get approval from a higher authority.
Pressure Tubes	Also known loosely as *fuel channels*. Tubes that pass through the *calandria* and contain twelve or thirteen fuel bundles. Pressurized *heavy water* flows through the tubes, cooling the fuel.
Primary Heat Transport System	A closed cooling circuit that carries heat produced in the fuel to the *steam generators*. It does this by circulating *heavy water* at high pressure through the *fuel channels* and the steam generator tubes.
Process System	Any of the reactor's systems which are used in the process of turning nuclear fission energy into electricity. This distinguishes them from safety systems, which are incorporated only to protect the reactor.
Quality Assurance (QA)	A formal program of standards, procedures and checks that control the quality of work carried out on the station.
Safety-Related Systems	Those systems, components, structures or design features which, by virtue of failure to perform in accordance with the design intent, directly contribute to radiological risk to the public or station personnel.
Safety Report	A licensee document that describes the design of the station. It also describes the safety analysis completed to show that the risk of operating the station is acceptably low.
Shift Supervisor	The technical expert in charge of a shift, who ensures that the conditions of the Operating Licence and the *Operating Policies and Principles* are rigorously observed. The shift supervisor also ensures that all production, commissioning and maintenance work is carried out to an acceptable standard.

Shutdown System No. 1 — The primary method of quickly shutting down the reactor when certain parameters enter an unacceptable range. It involves the release of spring assisted gravity-drop neutron absorber elements known as shutoff rods.

Shutdown System No. 2 — An alternate method of shutting down the reactor by rapidly injecting a neutron poison (gadolinium nitrate) into the moderator.

Sievert — A measurement of radiation exposure. One Sievert is the same as 100 rem. One millisievert is one thousandth of a Sievert (0.001 Sv). One microsievert (1 μSv) is one millionth of a Sievert.

Special Safety Systems — There are four special safety systems: *shutdown system one, shutdown system two, emergency coolant injection* and *containment*. They are each functionally independent systems which can shut down the reactor, provide cooling and contain any radioactivity if a problem occurs with the normal process systems.

Steam Generator — A *heat exchanger* that transfers heat from the *heavy water* coolant to light water to form steam in its upper portion, which is delivered by piping to the *turbine.*

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

Turbine — Equipment comprised of 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.