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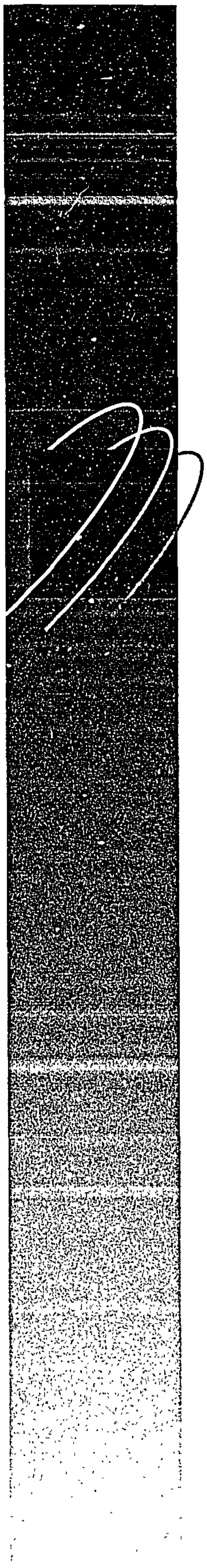

REPORT

RAPPORT

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

Canada

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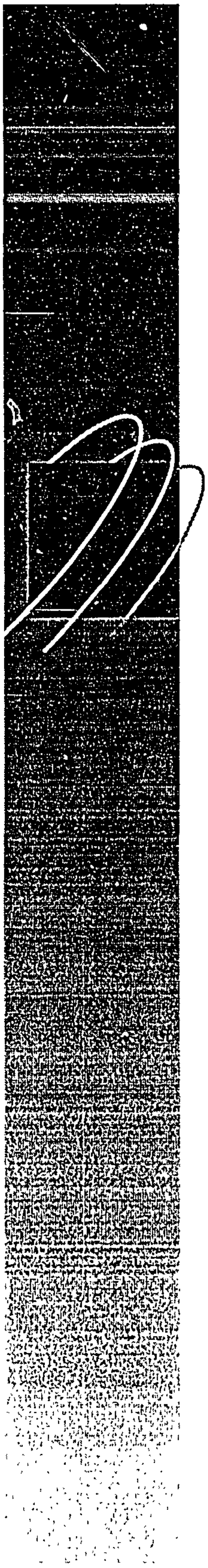


REPORT

AECB Staff Annual Assessment of the Bruce A 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 inspect each station.

SUMMARY

We believe that Ontario Hydro operated Bruce A in a safe manner during 1994, and that the risk to workers and the public has been maintained at an acceptably low level. Radiation *doses* to workers and releases to the environment were well below regulatory limits.

All *special safety systems* met availability targets. We noted improvements in operation and maintenance but some further improvements are still required. This is particularly true of the station's compliance with the Operating Licence.

We believe that the station continues to be well managed, with a high priority placed on safety. However, there is a need for increased capability in the area of safety analysis and assessment.

CONTENTS

SUMMARY

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 Reactors* (CANDU) with a design life of 40 years.

This report is AECB staff's assessment of the safety performance of Bruce A during 1994. It was compiled by AECB staff at the Bruce site office and our head office staff in Ottawa. We have based our review on our own observations and on information submitted to us by Ontario Hydro as required by the station's Operating Licence.

The nuclear industry uses many technical terms in its day-to-day 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 21.

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 Report, we publish research reports, communiques, information bulletins, notices and pamphlets. Board meeting minutes are also available. Our address is 280 Slater Street, Otttawa, 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 be reached by telephone at 613-995-5894 or 1-800-668-5284.

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.

OPERATIONAL SAFETY

COMPLIANCE WITH THE ATOMIC ENERGY CONTROL REGULATIONS

Although Ontario Hydro did not comply with the Atomic Energy Control Regulations on 14 occasions, none of these events resulted in radiological or conventional safety consequences. We require Ontario Hydro to operate Bruce A 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, and the Cost Recovery Regulations made under the *Atomic Energy Control Act.*

In our opinion, Ontario Hydro's compliance with the Atomic Energy Control Regulations was satisfactory.

There were eight events involving improperly labelled radioactive waste that was left in high traffic areas within the station. This is a significant increase over the three events that occurred last year. We believe the increase in reported events is the result of more vigilance in identifying non-compliances.

One of these events involved laundry bags that had contact radiation fields that measured 35 milli*sievert* (mSv/hr). The Atomic Energy Control Regulations require that hazards of this nature be clearly labelled and hazard warning signs be placed. There was also a non-compliance with the Atomic Energy Control Regulations for improperly disposing of radioactive material as inactive waste.

These events, and the three similar events last year, prompted Ontario Hydro to form a team to look into the problem of proper management of radioactive waste. The team recommended major changes to go into effect at the beginning of 1995, involving the transfer of sole responsibility for waste handling to a dedicated group. We expect that this change will result in a significant improvement in the waste handling practices at Bruce A and will look for evidence of this in an appraisal we are planning to conduct in 1995.

Ontario Hydro is required to take reasonable precautions to prevent radioactive material from leaving the station. One non-compliance was caused by a person leaving the station with *contamination* on his watch.

Two non-compliances occurred when two mechanical maintainers failed to properly protect themselves from contamination. As a result, they inhaled some contamination. A further two non-compliances occurred when two groups of workers walked into an area where radiography was in progress. The event report states that they had ignored both public announcements and clearly posted warning signs in doing so.

All four of these events violated the Atomic Energy Control Regulations requirement for workers to take appropriate precautions and due care, to ensure their own safety and that of their fellow workers. We consider these events to be indicative of deficiencies in Ontario Hydro's management of safe work practices by the workers.

Ontario Hydro did not report any non-compliances of the Transport Packaging of Radioactive Materials in 1994.

COMPLIANCE WITH THE OPERATING LICENCE

The Atomic Energy Control Regulations state that operation of the station must be in accordance with the Reactor Operating Licence. The reactor operating licences that we issue define conditions that must be met. One of these conditions requires the licensee to operate according to a set of *Operating Policies and Principles* (OP&P), and to comply with a set of *Radiation Protection Regulations* (RPR). Failure to comply with a licence condition is a licence non-compliance. We judged Ontario Hydro's performance in this area to be in need of improvement.

There were 25 non-compliances with the operating licence in 1994: 12 events involving non-compliance with the Radiation Protection Regulations and 13 involving the OP&P. The 'Compliance with the Atomic Energy Control Regulations' section discusses the 12 events related to the RPR. We consider that only 3 of the 13 events related to compliance with the OP&P were important to safety.

Inadequate control of work on special safety systems was the cause of these three events. In one case, improper valving in the *moderator* system resulted in flooding of the *shutdown system 2* (SDS2) poison tanks. A second impairment of SDS2 occurred when two parts of the system were worked on simultaneously, contrary to OP&P requirements.

A third event impaired the *emergency coolant injection system* (ECI). Operators failed to adequately test and return to service a part of the system following maintenance work and thus failed to notice the existence of a failed component prior to beginning work on another part. The failed component caused partial draining of the ECI system.

Ontario Hydro responded to these events by reinforcing the importance of following approved procedures and self-checks by operators. The duration of each impairment was short; the special safety systems affected still met the *unavailability* targets as indicated in the 'Performance of Special Safety Systems' section.

Four other events, in our opinion, represent notably poor performance by Ontario Hydro:

- Three of these events involved unauthorized operation and maintenance activities. One was a violation due to unauthorized personnel operating equipment in the *main control room.* Two other events were violations due to personnel carrying out maintenance activities without the authorization of the *shift supervisor.* Station management reviewed the events with the personnel involved, and stressed the importance of ensuring that all activities were properly authorized. This has not been a problem area in the past.

- The fourth event involved a failure by Ontario Hydro to comply with the Canada Fire Code. During an internal audit of the Bruce A hydrogen addition system by Ontario Hydro, there were several problems discovered with the emergency hydrogen addition station. It was located too close to station ventilation air intakes, and the system *pressure relief valves* were improperly designed. The emergency hydrogen addition station was in use, because the normal hydrogen addition station had been out of service for five years due to equipment failures. Ontario Hydro is preparing to repair the hydrogen addition station and to make design changes to the emergency station. In our opinion, this event reflects several areas of poor performance by Ontario Hydro. A delay of several years to carry out repairs and a willingness to make do with the emergency system is unacceptable. The emergency hydrogen addition station should also have met Canada Fire Code requirements.

The OP&P Manual, as it is currently written, is, in some areas, open to interpretation. This makes it sometimes difficult to follow. In last year's annual report, we commented that Bruce A management was reviewing how it complies with the OP&P. During 1994, this review was expanded to also compare how it operates the station, against the assumptions made in the safety analysis. This review should identify any gaps in the OP&P definition of safe operating limits for the plant. In the meantime Ontario Hydro has revised the OP&P to more clearly define how the station is to be operated, and further revisions are pending. In the end, Ontario Hydro should have a set of OP&P that can be followed more easily, and will explain operational safety requirements more thoroughly.

COMPLIANCE WITH THE PHYSICAL SECURITY REGULATIONS

Ontario Hydro operated Bruce A in compliance with the *Physical Security Regulations* in 1994. Our annual assessment of Bruce A security identified some areas where improvements should be made. We have requested that Ontario Hydro take action on these.

Ontario Hydro conducted security drills throughout the year to validate security procedures.

WORKER RADIATION SAFETY

We consider the radiation protection program at Bruce A to be satisfactory. No worker at Bruce A received a *dose* in excess of the regulatory limit of 50 millisieverts (mSv) per year. As illustrated in Figure 1, the average worker dose in 1994 is 2.8 mSv, approximately the same as last year. Table 1 indicates the distribution of dose that personnel in the station received.

Figure 1: ***AVERAGE WORKER DOSE***
Annual Limit - 50 mSv

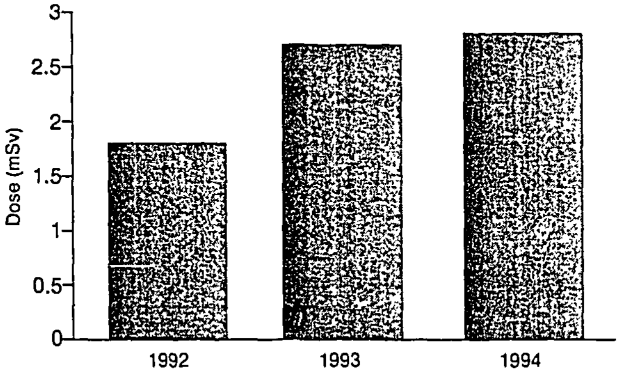


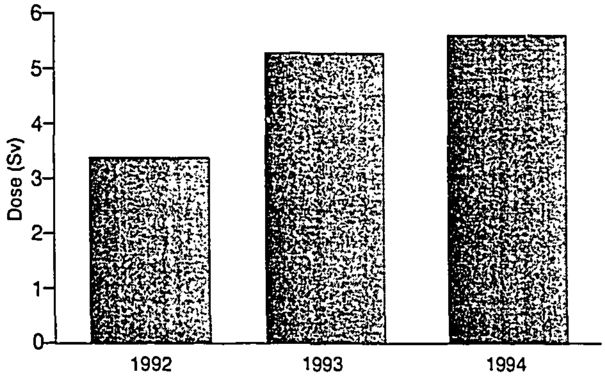
Table 1

Dose Category (mSv)	0	MRL* to 5	5 to 10	10 to 15	15 to 20	20 to 25	25 to 30	30 to 35	35 to 40	40 to 45	45 to 50	> than 50
Number of Workers	753	895	255	32	13	0	0	0	0	0	0	0

*Minimum Recordable Level.

Figure 2 shows that the 1994 *collective station dose* is 5.55 person-Sv, again approximately the same as last year. Given that more work was performed in 1994 than in 1993, we regard this collective dose as a good achievement.

Figure 2: *COLLECTIVE DOSE Four Reactors*



Ontario Hydro completed two long outages and many inspections, rehabilitation and maintenance programs in 1994. Examples are inspections and maintenance of *pressure tubes* and *boiler* tubes. Workers who perform these jobs are exposed to high radiation levels. During 1994, Ontario Hydro applied the dose management program started in 1993, on a trial basis to these jobs. The purpose of this program is to keep individual and collective doses *as low as reasonably achievable* (ALARA).

We saw a temporary resurgence of poor waste handling practices during a long outage (see the 'Compliance with the Atomic Energy Control Regulations' section). We requested improvements. In response, Ontario Hydro consolidated some administrative and procedural changes for an improved waste handling program in 1995.

We completed an appraisal of the dosimetry program at Bruce Nuclear Power Development and found the dosimetry services at Bruce A to be satisfactory.

PUBLIC RADIATION SAFETY

We are satisfied that Ontario Hydro's operation of Bruce A in 1994 maintained the radiological risk to the public and the environment at an acceptably low level.

☐ Releases to the Environment

No member of the public received a dose in excess of the regulatory limit. The maximum dose that could have been received by any member of the public from the Bruce A radioactive releases is estimated at 0.0058 mSv. This is about the same as in 1993, and approximately 900 times lower than the regulatory limit of 5 mSv per year.

The releases of radionuclides from Bruce A to the environment were below the operational annual target, which is 1% of the regulatory limit. Also, the weekly targets were not exceeded any time during the year. Figures 3 and 4 show the airborne and liquid releases from Bruce A during the last three years.

Figure 3: ***AIRBORNE RELEASES***
Limit Varies with Radionuclide

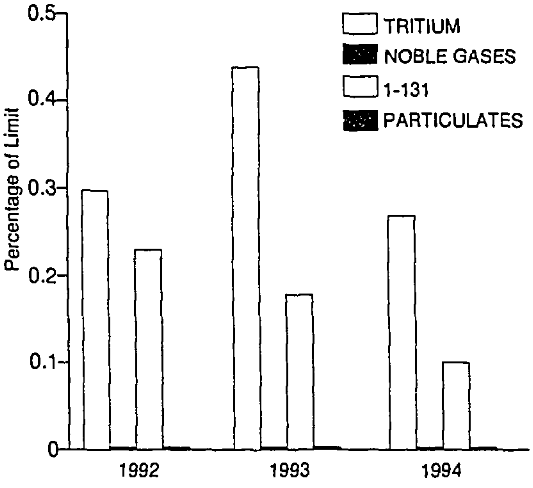
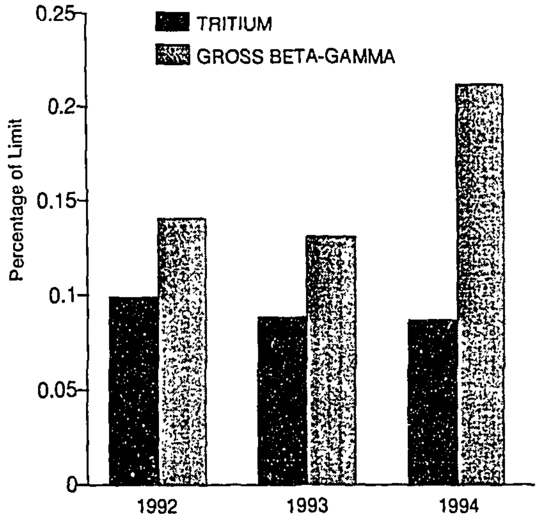


Figure 4: ***LIQUID RELEASES***
Limit Varies with Radionuclide



Ontario Hydro put into operation a new liquid effluent monitoring system, thus fulfilling an outstanding AECB requirement. The new system is an addition to the existing capabilities to sample radioactive liquid effluent from the station.

Our routine surveillance of the reported concentrations of *tritium* in the Steam Transformer Plant (STP) and in the STP liquid discharges continued in 1994. Ontario Hydro is operating within the approved concentration limits.

In addition to monitoring the radioactive releases from the station, Ontario Hydro has been running a Bruce Nuclear Power Development (BNPD) environmental monitoring program for many years. This program measures levels of radioactivity in the environment surrounding BNPD and accounts for contributions from Bruce A and other licensed facilities at the BNPD site. The doses to members of the public estimated from the environmental monitoring program have been traditionally lower than the doses estimated from the station releases.

☐ Environmental Assessment Reviews

No new environmental concerns were identified in 1994, including concerns expressed by members of the public during the licence renewal process.

We completed a screening review for the Bruce A licence renewal, in accordance with the Environmental Assessment Review Process and Guidelines Order.

PERFORMANCE OF SAFETY SYSTEMS

Special safety system performance was fully satisfactory during 1994. However, further progress is required to bring the predicted future unavailability of all the special safety systems within target.

We require that each special safety system be fully functional 99.9% of the time. To meet this, a special safety system must not be unavailable or impaired (not fully functional) for more than 8.76 hours per year. Table 2 shows a summary of special safety system unavailability during 1994 and the predicted future unavailabilities. As shown in this table the 1994 performance of all four special safety systems was within target.

Ontario Hydro predicts the future unavailabilities of the special safety systems using models that include the past six years of operational data and the current design of the system. These are also shown in Table 2. As can be seen from this table, the predicted future unavailability of the emergency coolant injection system and the *negative pressure containment* system are above target. The negative pressure containment predicted future unavailability should improve when Ontario Hydro completes some design changes to *airlocks*. Improved analytical modelling is required to bring the emergency coolant injection system predicted future unavailability within target.

EVENTS REPORTED TO THE AECB

Ontario Hydro reported 70 events to us in compliance with licence conditions. This number is not significantly changed from last year. Our comments on trends and conclusions from our review of these events follows.

Equipment failures continued to occur in events during 1994. As was seen in previous years, there were several events in which multiple equipment failures occurred. One of the more serious of these events

Table 2

System	Predicted Future Unavailability (hr/year)	1994 Unavailability (hr/yr, Target <8.76 hr/year)				
		Unit 0	Unit 1	Unit 2	Unit 3	Unit 4
Shutdown System 1	0.94	—	0	0	0	0
Shutdown System 2	5.84	—	0	0	0	0.18
Emergency Coolant Injection System	12.7	1.6	1.6	1.6	1.6	1.6
Negative Pressure Containment System	14.0	0.15	0.15	0.15	0.15	0.15

is covered in the 'Operations and Maintenance' section (see the Operation subsection). While Ontario Hydro's maintenance programs continue to address the issue of equipment degradation, we expect it to be some time before a significant reduction will be achieved in the number of events involving equipment failure.

Lack of adequate verification continues to occur, with self-checking continuing to be a key problem area. Ontario Hydro continues to reinforce self-checking during crew meetings, and is reviewing on-the-job training of staff.

In general, we are satisfied with Ontario Hydro's planned corrective actions for all of these events.

Ontario Hydro is diligent in identifying events and in making improvements in the event reporting system. However, problems with the completion of *root cause analyses* of events and of follow-up actions arising from events continues. Ontario Hydro also had difficulty issuing event reports in a timely manner during 1994. As a consequence, management is devoting more attention to event reporting and follow-up. Standards for the writing, review and follow-up of events are being written, and internal audits will be carried out in an effort to improve. We are satisfied with the planned corrective actions, and we are planning to conduct an audit of this area in late 1995.

OPERATIONS AND MAINTENANCE

We believe that Ontario Hydro continues to make satisfactory progress in improving operation and maintenance. This conclusion is drawn from our review of events, monitoring maintenance activities and reviewing the monthly maintenance report issued by the station. From the maintenance report, we examine levels and trends of preventative and corrective maintenance. Also, Bruce A continues to lead the Canadian nuclear industry in the development of a reliability-centred maintenance program. This maintenance program is designed to ensure that equipment meets reliability targets, and provides for more effective use of maintenance resources.

☐ Operation

Bruce A achieved a 1994 net capacity factor of 47%. This was higher than last year's figure of 33%. The low station *capacity factor* can be attributed to long maintenance outages and restrictions imposed on power level.

One of the reported significant events, involving a reactor trip, was particularly noteworthy since it involved multiple equipment failures.

During checks on instrument and control circuits in Unit 4, equipment supplying the circuits with electrical power failed. Two consequences immediately arose:

the *turbine* tripped and *low pressure service water* to the unit was lost. A complete and automatic transfer of Unit 4 power supplies to backup sources also failed. This was due to the original failure of electrical power to instrument and control circuits. Two of the four main reactor *heavy water* coolant pumps thus lost their electrical supply and shut off. The resulting drop in reactor coolant flow initiated a Shutdown System 1 trip. Restoring cooling water to the unit was complicated by failure of a relay, and the failure of several valves which had not been adequately maintained. Shift crews needed several hours to return cooling water supplies to normal.

Although there were no safety consequences to the event, it presented the shift crew with a difficult situation to control. Had they not handled it so well, there could have been safety consequences. The event also indicates that the preventative maintenance programs are not yet effective in preventing unexpected failures of important equipment.

☐ Maintenance

Call-ups are scheduled preventative maintenance activities. Call-up completion rate is an indication of preventative maintenance performance. At the end of 1994 the total call-up completion rate was 79%. Examining some of the more specific numbers, it is apparent the trend is in the right direction. For example, at the end of 1994 the number of overdue special safety system call-ups was 10 (call-up completion rate was 92%). This compares with 100 call-ups, 18 months earlier. In response to an audit of the fire protection systems, the total overdue operating fire protection system call-ups was brought down to zero (from 13, six months previous).

The total number of *jumpers* on special safety systems in the station as of December, 1994 was approximately 100. The number of jumpers in the station has not been decreasing at the rate targeted by the station. While we have not done an analysis to determine the significance of this number of jumpers, the general statement can be made that configuration management becomes more difficult with more jumpers. We are of the opinion that increased attention by the station management is required in the coming year to reduce the number of jumpers to their target levels.

An indication of the station's capability to keep up with required corrective maintenance is the operating corrective maintenance backlog. At the end of 1994, this number stood at 1416 outstanding deficiencies. This is an improvement from 18 months ago when it was 2241. It should be noted that deficiencies which have an obvious impact on safety are corrected promptly on the authorization of the shift supervisor.

☐ Restrictions on Reactor Power

As noted in last year's report, it was necessary to reduce power at Bruce A to 60% to limit the power increase after certain types of *loss of coolant accidents.*

In 1994, modified inlet *shield plugs* were installed in the central high power *fuel channels* of the reactors to reduce the distance the fuel can move. This distance is known as fuel channel gap. A reduction of the gap reduces the rate and magnitude of power rise after a break in the *primary heat transport system* piping. The allowable variation (during normal operation) for *neutron flux tilt*, coolant purity, and shutdown system performance were also reduced to minimize the power increase following a loss of coolant accident. This allowed us to give approval to increase the power to 75%.

Ontario Hydro is planning to install modified shield plugs in the remaining fuel channels. It also plans to use a single longer *fuel bundle* in the central fuel channels. Together, these two changes will further reduce fuel channel gap such that operation at a higher power level (80%) may be justified.

The above changes are a short-term solution to the problem of the power pulse. Ontario Hydro has developed a long-term solution. This solution involves reversing the direction in which the fuel channels are refuelled. With this change, the power pulse during a loss of coolant accident causing flow reversal would be reduced. Changes to the fuelling machine software and equipment are in progress. A trial will be carried out on Unit 4 in the spring of 1995.

❑ AECB Compliance Inspection

In early 1994, we assessed the start-up of Unit 4. It had been shut down for maintenance for most of 1993. Before the unit went critical, we reviewed the start-up plan in detail and attended every start-up planning meeting. We also looked in detail at many systems important to safety to verify that Ontario Hydro had restored them to a satisfactory state following maintenance. Once the unit went critical, we attended shift turnover meetings, observed activities in the control room and did field inspections. An AECB project officer accompanied the responsible Ontario Hydro manager during his final vault inspection. We concluded that Ontario Hydro has improved its start-up practices at Bruce A, particularly the organization and system review. We were particularly pleased to see flowsheet checks included in the start-up plan. However, we did observe some areas where Ontario Hydro can make further improvement, such as in the accuracy of the computerized work management system and shift turnover practices, and have asked them to do so.

❑ Pressure Tubes

It is our opinion that Ontario Hydro has a satisfactory program to manage the aging of pressure tubes in Bruce A.

Pressure tubes must be carefully monitored for hydrogen content and any mechanical damage. As pressure tubes age, the concentration of hydrogen in the tube material increases, which can cause hydride blisters to form. This makes the pressure tubes unsafe for continued operation and they must be removed.

An inspection of pressure tubes in Unit 3 during its 1994 outage showed a hydrogen uptake higher than expected (a rate unique to this unit). This enforced the need for repeated sampling of pressure tubes so that an accurate model of hydrogen uptake by the pressure tubes can be made. This will allow improved prediction of when pressure tubes are no longer safe for continued operation.

A pressure tube in unit 2 was left in service beyond the predicted time of first blister formation for about six months as a test. Some areas of hydride accumulations were present but no blisters were found.

Other inspections of pressure tubes in units 1, 2, and 3 showed no significant change in the degree of mechanical damage.

In CANDU reactors, pressure tubes are separated from *calandria tubes* by coiled springs formed into a ring (called garter springs). In many tubes, the garter springs have moved, allowing the pressure tubes to sag and touch the calandria tubes. This reduces the life of the pressure tube. Ontario Hydro has a program at Bruce A to move the garter springs back to their proper positions. This work was completed on Unit 3 involving 232 channels.

☐ Test of the Annulus Gas System

The *annulus gas system* provides dependable indication of a pressure tube leak. Due to the recent problems with pressure tubes, we asked Ontario Hydro to provide experimental support of their claimed capabilities to predict annulus gas system performance. Ontario Hydro performed a test of the system in Unit 4 which provided evidence that the system performance is acceptable. It also demonstrated that Ontario Hydro is able to model and predict the system's performance.

☐ Boilers

We believe that Ontario Hydro has continued to manage boiler performance satisfactorily.

Efforts were continued to improve the reliability of the Bruce A boilers. Boiler tube leaks were kept at a very low level and did not cause any unit to shut down. In 1994, Bruce A staff focused its maintenance and inspection activities on Units 2 and 3. Last year's main activities were on Units 2 and 4.

Unit 2 had a 100% tube inspection in boilers 2 and 3 (which were contaminated with lead several years ago). A sample inspection in the other six boilers was carried out. The inspection was done in October 1994, after nearly a year's operation. The inspection showed that boiler tube cracking is continuing, with several more tubes in boilers 2 and 3 showing cracks greater that 40% through wall. This amount of cracking was consistent with Ontario Hydro's and AECB's expectations. Tubes believed to be likely to leak during the next operating period were plugged. *Boiler divider plates* were reinforced in boilers 1 to 4 to cope with the redistribution of flow caused by the plugging of tubes. This has resulted in an operating life for Unit 2 to September 1995. Unit 2 will be put in a *lay-up* condition after that date. This is a condition of the station's operating licence.

Ontario Hydro completed laboratory tests on boiler tubes with simulated defects. The purpose was to demonstrate the tubes' strength and show that radioactive releases due to potential tube failures would be within regulatory limits. We have asked Ontario Hydro for a better definition of the possible effects of flow induced vibration, including *fluid elastic instability* on tube strength and leak rate in all Bruce A units.

A mechanical and chemical boiler cleaning operation, similar in scope to the one performed in Unit 4 last year, was performed on Unit 3. The operation removed more than 6,700 kg of deposits. Such deposits lower the efficiency of the boilers and contribute to boiler tube degradation. Ontario Hydro made modifications to all Unit 3 boilers, including the installation of devices to reduce boiler tube vibrations and hence the probability of tube cracking. It also inspected tubes in two boilers, and no significant indications were found. No tubes required plugging due to indications or defects.

☐ Chemistry

We believe that the overall plant chemistry control was acceptable in 1994. The Bruce A systems remained within targets 93.1% of the time, which is the same performance level achieved in 1993.

Late in the year, a new water treatment plant became operational. The plant restores the required demineralized water supply capability of the station, correcting the deficiency we mentioned in last year's report. The plant meets the new provincial environmental requirements for liquid discharges from the station to Lake Huron.

STATION MANAGEMENT

We believe that Bruce A's management team is competent and places high priority on safe operation of the station. We formed this opinion by observing management reaction to internal and external events, by the conservative decisions made, and by the active involvement of management on safety committees.

We have been favourably impressed by the continued, systematic application of good practices. Areas where weaknesses exist are identified (by the review of significant events, for example) and a "managed process" is put in place to correct the deficiency. Targets are established and the results are monitored. Good practices have been learned from participation in external audits/evaluations and have been adopted at the station. The result has been continued improvement in operation and maintenance standards.

We believe the Bruce A Nuclear Integrity Review Committee is effective in meeting its objectives. By attending committee meetings, we are aware that station management is giving appropriate attention to safety. A sub-committee (Nuclear Safety Surveillance Committee) has recently been formed to ensure that newly emerging safety issues are identified and properly dealt with.

Notwithstanding the above, significant improvement is needed in the area of nuclear safety support. The re-organization of 1993 left Bruce A with inadequate expertise in the area of nuclear safety analysis and assessment. We found this group to be slow to follow-up on some events. It is apparent that the few qualified staff who are available to work on Bruce A safety issues have difficulty keeping pace with the demands imposed on them. These problems were identified by Ontario Hydro in response to our request for investigation of this support function. We are satisfied that station management is committed to implementing corrective actions.

TRAINING

AECB examinations continue as part of the regulatory process for authorization of Shift Supervisors (SS) and *Control Room Operators* (CRO). Table 3 shows the current examination types and 1994 results for Bruce A candidates.

In 1994, we completed our assessment of the chemical technician training program at Bruce A. The training involves a combination of classroom work conducted by Ontario Hydro's Western Nuclear Training Department and practical experience conducted by Bruce A. Although the program is not yet complete, we found it to be of good quality.

We also began looking at control technician training for Bruce A. In 1994, we looked at the development and classroom work at Western Nuclear Training Department. We found that the job analysis for control technicians is not complete, and requested that Ontario Hydro complete this analysis. We cannot complete the on-the-job portion of our assessment until this is done.

Table 3

Examination	SS Candidates Writing	SS Candidates Passing	CRO Candidates Writing	CRO Candidates Passing
Radiation Protection	3	3	5	5
General	0	n/a	4	3
Station Specific	6	5	5	5
Simulator Based	3	3	5	5

EMERGENCY EXERCISES AND DRILLS

We are satisfied with Ontario Hydro's emergency response capability at Bruce A. Ontario Hydro maintained an effective program of exercises, drills and training for emergency preparedness at Bruce A in 1994. Table 4 shows the number of drills by type completed at Bruce A in 1994. Ontario Hydro completed 100% of the scheduled drills at Bruce A in 1994.

Bruce A Emergency Response Teams (ERT) also responded to 50 actual emergencies at Bruce A in 1994. Almost 75 percent of these were personnel injuries, where the ERT provided the necessary casualty care. The ERT also responded to, and successfully extinguished, 11 fires at Bruce A in 1994. None of these events threatened public safety.

In November 1994, we asked a consultant to evaluate Ontario Hydro's capability to fight a large fire at Bruce B, the other nuclear station at BNPD. Our consultant concluded that Ontario Hydro could effectively deal with a large fire at Bruce B. Since Bruce B and Bruce A emergency response capability is similar, and Ontario Hydro's Western Nuclear Training Centre trains both Bruce A and Bruce B ERT crews, we are satisfied that Ontario Hydro could effectively deal with a large fire at Bruce A.

Table 4: ***EMERGENCY EXERCISES AND DRILLS COMPLETED IN 1994***

Off-site Survey	10
Toxic Gas	4
Radiation Emergency	7
ERT Practice	97

SAFETY ANALYSIS

This section of the report discusses important safety analyses submitted by Ontario Hydro for Bruce A during 1994.

☐ Heat Sink Availability during Shutdowns

A principle of reactor operation is that two *heat sinks* are always available: a primary heat sink, and a back-up heat sink. In August of 1994, uncertainty arose regarding the adequacy of the back-up heat sink under specific circumstances.

The circumstance is as follows: when a unit is shut down for maintenance, the primary heat sink is usually *maintenance cooling*. If maintenance cooling is lost, the procedures call for refilling the primary heat transport system (if necessary), pressurizing and momentarily starting the main pumps to establish flow around the primary heat transport system. The alternate heat sink is then provided via *thermosyphoning*, with heat rejection to the boilers.

If thermosyphoning cannot be re-established then there is a means of heat transfer out of the *core* called *intermittent buoyancy induced flow* (IBIF).

It is this last method of heat removal which Ontario Hydro is presently unable to demonstrate analytically. Current IBIF methodology requires that the reactor headers be maintained full of sub-cooled water. A new review of the piping configuration at Bruce A suggested that the temperature of the water in the headers may not stay below boiling. Ontario Hydro is presently working on extending the IBIF analysis to include the piping in question. It is also working on other back-ups to maintenance cooling.

We have concluded that the chances of concurrently losing maintenance cooling, not being able to establish thermosyphoning, and IBIF not working, are low enough that the situation is acceptable while Ontario Hydro actively pursues an analytical or design solution to this problem. However, we have required that Ontario Hydro takes interim action to improve the reliability of the maintenance cooling system and reduce the risk of *secondary side system* failures.

☐ Risk and Operation of Bruce A

Ontario Hydro has adopted a technique for estimating the risk in operating a nuclear station. This is called Probabilistic Safety Assessment (PSA). PSAs are a tool to determine how safe a station is, and if design or operating changes are needed to achieve the required level of safety.

Ontario Hydro expects to complete development of a station-wide PSA for Bruce A within the next two years. We expect the new PSA to be an important tool for effective risk management and assessment.

☐ Large Loss of Coolant Accident Analysis

As described in last year's report, in June of 1993, Ontario Hydro submitted an update to the Bruce A analysis on large loss of coolant accidents (LOCA). We have not yet accepted its conclusions. We are continuing to review the calculational methods and computer programs used for this safety analysis. We have asked Ontario Hydro to provide better documentation of the computer programs and to perform more testing against experimental data.

QUALITY ASSURANCE

Ontario Hydro has revised the Bruce A *Quality Assurance* Manual to account for quality assurance through all stages of the station's life. We have not yet completed our review of this manual.

The Bruce A Quality Assurance Section now has a full complement of Quality Officers and Engineers.

Together with our colleagues at the Ontario Ministry of Consumer and Commercial Relations, we completed an audit of Bruce A design and procurement quality assurance programs. We conducted the audit in two phases. The first phase looked at control computer software and hardware design upgrades work underway at *Atomic Energy Canada Limited.* The second phase focused on projects at the Bruce A site. Our preliminary findings indicate that design quality assurance for the projects examined is less than satisfactory. When the report is issued, we intend to request that Ontario Hydro take action on our findings. We did find, however, that procurement quality assurance, conducted by Ontario Hydro head office staff, was generally satisfactory. We had not issued the final audit report at year-end.

SAFEGUARDS

During 1994, Ontario Hydro planned and executed all *safeguards* related work it was required to perform at Bruce A as scheduled and it cooperated at all levels. It did not report any safeguards incidents in 1994.

Canada has signed the Treaty for the Non-Proliferation of Nuclear Weapons. As required by the Treaty, Canada has a Safeguards Agreement with the *International Atomic Energy Agency* (IAEA). This agreement gives the IAEA the right and responsibility to verify that Canada is fulfilling its treaty commitment. Canada should not use its peaceful nuclear program to make nuclear weapons or nuclear explosive devices.

The Bruce A Operating Licence includes a condition on IAEA safeguards. Ontario Hydro must report to the AECB the movement and location of all nuclear materials and give access and assistance to IAEA inspectors, as required.

CONCLUSIONS

Overall, we believe that Ontario Hydro operated Bruce A in 1994 in a manner that satisfactorily meets AECB requirements and that the risk to the worker and public has been maintained at an acceptably low level. The following are the specific conclusions, which we have drawn from our review of the safety performance of Bruce A in 1994.

Areas of Good Performance:

- Ontario Hydro generally operated Bruce A in compliance with the Atomic Energy Control Regulations. Any non-compliances were minor in nature. Ontario Hydro was in complete compliance with the Physical Security Regulations.
- Radiation protection for the employees and public was satisfactory.
- Safety system performance was satisfactory.
- We remain satisfied that Bruce A is being well managed.
- Satisfactory progress continues to be made towards attaining standards set for operation and maintenance.
- We are satisfied with Ontario Hydro's emergency response capability.
- Procurement quality assurance is satisfactory.
- Ontario Hydro continues to fulfil its safeguards obligations.

Areas Where Improvement is Needed:

- Improvements are needed in the area of waste handling within the station.
- The number of non-compliances with the Operating Policies and Principles should be reduced.
- Improved timeliness and effectiveness are required in the follow up of events.
- Operation and maintenance practices must be improved to reduce the number of events caused or exacerbated by equipment failure.
- Increased capability is required in the area of nuclear safety analysis.
- Improvements are required in the implementation of design quality assurance.

GLOSSARY

Airlock	The means of access to and from the *reactor building*. It maintains the *negative pressure containment system* integrity during personnel and equipment transfers.
Annulus Gas System (AGS)	A continuously circulating system of carbon dioxide gas in the space between the *pressure tubes* and the *calandria tubes* for the purpose of thermally insulating the tubes from each other and to permit the early detection of leaks.
As Low As Reasonably Achievable (ALARA)	The principle of keeping radiation doses 'as low as reasonably achievable', social and economic factors being taken into account.
Atomic Energy of Canada Limited	A crown company incorporated in 1952 to conduct research into and development of peaceful uses of nuclear energy. Its objectives include the development of nuclear power systems to meet Canadian needs.
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.
Atomic Energy Control Regulations	Regulations made pursuant to the *Atomic Energy Control Act* by the AECB.
Boiler	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*.

Boiler Divider Plate	Boiler divider plates are situated in the bottom portion of the *boilers* to keep the *primary heat transport system* inlet and outlet areas separate.
Calandria	A cylindrical unpressurized stainless steel vessel which holds the *moderator. Pressure tubes* span the two end plates of the calandria.
Calandria Tubes	Zirconium tubes that pass through the *calandria*. The *pressure tubes* run through the calandria tubes. They are intended to separate the hot pressure tubes from the cold moderator water.
Canadian Deuterium-Uranium Reactor (CANDU)	Canadian designed reactor moderated and cooled by *heavy water* and fuelled with natural uranium. "CANDU" is derived from **Can**ada, *Deuterium*, **U**ranium.
Call-up	A scheduled preventive maintenance. A routine maintenance item or performance check completed at regular intervals.
Collective Station Dose	The total radiation exposure to the people working in the station. It is the sum of all of the *doses* to each of the workers in the station and contract staff who received some dose while in the station.
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 (CRO)	A CRO is responsible for operating the controls for the reactor. Only persons whom the AECB approves can occupy this position.
Core	The heart of a nuclear reactor containing the *fuel bundles, moderator (heavy water)*, as well as various detectors and control devices. Heavy water coolant passes through the *fuel channels.*
Deuterium	An isotope of hydrogen which has one proton and one neutron in its nucleus.

Dose	The quantity of radiation energy absorbed by a body.
Emergency Coolant Injection System (ECI)	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.
Fluid Elastic Instability	This is a form of flow induced vibration of *boiler* tubes that occurs only under specific conditions in the boilers. It can result in the cracking of the boiler tubes.
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*".
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 boilers, 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.
Intermittent Buoyancy Induced Flow	When conditions in the reactor *core* do not permit *thermosyphoning* to occur, heat is removed by water boiling in the *fuel channels*. The steam then intermittently bubbles up the feeder pipes to the *boilers*. Once in the boilers, the steam condenses back into water and flows back into the core. This cycle will repeat as long as there is cold water in the boilers.

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.
Jumper	A temporary change from the documented state of the configuration of a system or equipment.
Lay-up	Similar to mothballing; in this case the unit is not ready for a return to service without major work. The unit is, however, protected against further deterioration until a decision is made to either carry out repairs for a return to service or to begin decommissioning.
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.
Low Pressure Service Water (LPSW)	A system that provides cooling water to many systems in the station.
Main Control Room (MCR)	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.
Maintenance Cooling System (MCS)	The system that provides cooling to the *primary heat transport system* when it is being depressurized and drained to allow for maintenance of components.
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 was to cause a complete loss of cooling to the fuel channels.
Negative Pressure Containment (NPC)	The building surrounding the reactor. It isolates the reactor from the environment and prevents radiation, which might be released in an accident, from escaping.

Neutron Flux Tilt	An imbalance in power between one location and a symmetrically opposite location in the *core.*
Operating Corrective Maintenance	Repairs that can be made to equipment while the reactor is at power.
Physical Security Regulations	Regulations issued by the AECB that state the physical security standards at nuclear facilities.
Pressure Relief Valve	A valve that opens to reduce the pressure on a system when it exceeds a pre-established limit.
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 (PHT)	A closed cooling circuit that carries heat produced in the fuel to the *boilers.* It does this by circulating *heavy water* at high pressure through the *fuel channels* and the boiler tubes.
Quality Assurance (QA)	A formal program of standards, procedures and checks that control the quality of work carried out on the station.
Root Cause Analysis	A methodology and techniques used to evaluate human performance and equipment problems, uncover their causes and determine corrective actions to prevent recurrence.
Radiation Protection Regulations	Regulations issued by the licensee and approved by the AECB that state the radiation protection standards to be met at a station.
Reactor Building	A reinforced-concrete building which serves as a support and an enclosure for the reactor and some of its associated equipment.
Safeguards	An international program of monitoring and inspection that is carried out by staff of the *International Atomic Energy Agency.* Safeguards ensure that nuclear materials in the plant are not diverted for use in weapons.

Secondary Side Systems	The collection of non-nuclear systems related to transporting the heat produced in the reactor to the *turbine.*
Shield Plug	A plug inserted in *fuel channels* that shields personnel from the high radiation fields of the reactor *core.*
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 (SDS.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 (SDS2)	An alternate method of shutting down the reactor by rapidly injecting a neutron poison (gadolinium nitrate) into the *moderator.*
Shutoff Rods	Neutron absorbing rods that can be dropped into the reactor under abnormal conditions to shut it down quickly and safely.
Sievert (Milli, Micro)	A measurement of radiation exposure. One 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 *negative pressure 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.

Thermosyphon	A means of heat removal from the reactor core. The hot *core* heats water in the *fuel channels*, this hot water then naturally rises into the *boilers* where it cools down. The cold water in the boiler then naturally flows back down into the reactor core where it heats up and rises again. The process continues as long as the *primary heat transport system* is full and the reactor core is warmer than the boilers.
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 *boilers* flows through them. The kinetic energy of the steam is converted into mechanical energy that, in turn, is delivered to the electrical generator.
Unavailability	The unavailability of a system or component is the fraction of time that it is unavailable to perform its function if it would be called upon to do so.
Vault	A concrete enclosure around the reactor. It is inside the *negative pressure containment system.*