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REPORT

AECB Staff Annual Assessment of the Point Lepreau Nuclear Generating Station for the Year 1996

Atomic Energy Control Board
Ottawa, Canada

June 1997

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

Canada

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

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

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

SUMMARY

This report is the Atomic Energy Control Board staff assessment of safety at Point Lepreau Generating Station for the calendar year 1996. Our on-site Project Officers, and Ottawa-based specialists monitored the station throughout the year.

Point Lepreau operated safely during the year. However, there are worsening trends in NB Power's safety performance which lead us to conclude that urgent action is required. We have required NB Power to report formally to our Board on progress with measures to improve safety management every six months. And we have warned NB Power that we will take further licensing action if it fails to make needed improvements.

NB Power's level of compliance with the conditions of the operating licence we issue continues to be unacceptable. An important feature of failures to comply with the licence is personnel failure to follow required rules and procedures.

Worker radiation safety was satisfactory during 1996. There were no exposures greater than legal limits. We consider total exposure to staff to be typical for this type of reactor, although unscheduled maintenance work has increased the figure. Releases of radioactive materials from the station continue to be acceptable, and are very much lower than the limits we set.

The two shutdown systems performed satisfactorily during the year. We believe the containment envelope would have been unable to meet the safety requirements for earthquake resistance for much of the year. This was because degradation of steam generator emergency water system headers could have affected steam generator tubes. Maintenance problems may have affected emergency core cooling system motorised valves during the year. NB Power has not yet completed its assessment of the effects of these problems. NB Power still needs to complete work to bring the predicted future availability of special safety systems in line with our target.

NB Power's management of the station has caused us some concern during the year. We found it necessary to intervene in a proposed start up when we considered there was insufficient assurance of safe reactor configuration. We believe that station management has focused too much attention on maximising production and minimising costs. An additional result of this has been NB Power's continued failure to meet commitments it has made to us for work responding to our requests for action.

Our evaluation of NB Power's emergency preparedness program showed that the program is well documented, and NB Power maintains emergency equipment in good condition. However, the training, drill, and exercise aspects of the program are weak. Our audit of NB Power's quality assurance program also found problems. The quality assurance program does not adequately ensure the quality of design work done for the station. In both areas, we have issued directives to NB Power requiring improved performance.

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INTRODUCTION

Point Lepreau is a single reactor nuclear generating station of the *Canadian Deuterium-Uranium* (CANDU) 600 MW design. It is located on the shore of the Bay of Fundy, near Saint John, New Brunswick.

This report is the *Atomic Energy Control Board* (AECB) staff assessment of the safety of the operation of the Point Lepreau Nuclear Generating Station. It has been compiled by AECB staff at the Point Lepreau site, and in our head office in Ottawa. We have based our review on our own observations, and on information submitted to us by New Brunswick Power (NB Power). We restrict the information we present in this report to station operation during the calendar year 1996. The station has encountered some well publicised difficulties in early 1997. These difficulties are linked to issues discussed in this report, but detailed discussion of these events will be included in our report on 1997 operation.

Throughout this report, we have included tables with more detailed information on specific topics. These tables also give a detailed breakdown of our assessment of NB Power's safety performance. 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.

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

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

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OPERATIONAL SAFETY

COMPLIANCE WITH REGULATIONS MADE UNDER THE ATOMIC ENERGY CONTROL ACT

We require NB Power to operate Point Lepreau Generating Station according to the legal requirements governing the nuclear industry in Canada. These requirements come from the *Atomic Energy Control Act* and regulations made under the Act. The regulations directly applying to Point Lepreau are the *Atomic Energy Control Regulations*, the *Physical Security Regulations*, the *Transport Packaging of Radioactive Materials Regulations* and the AECB *Cost Recovery Fees Regulations*. NB Power complied fully with all these regulations, except as noted in the following paragraphs.

There were two incidents in which NB Power failed to comply with the Atomic Energy Control Regulations requirements for signposting radiation hazards. In the first event, two narrow beams of radiation existed for several months because shielding had not been replaced in ***horizontal flux detector*** housings after work in the 1995 ***outage***. In the second event, contaminated tools stored near the main ***airlock*** caused ***radiation fields*** which should have been signposted. We discuss both these events in the 'Worker Radiation Safety' section of this report.

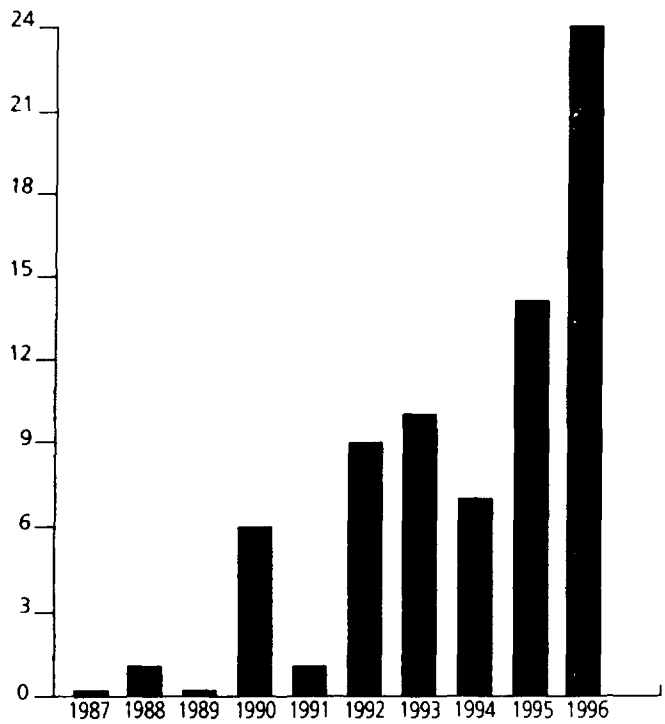
The Physical Security Regulations define the security measures which NB Power must maintain at Point Lepreau. During 1996, NB Power continued to improve its efforts to comply with these regulations. In November, we conducted assessments of security arrangements at Point Lepreau. NB Power has corrected several items from previous assessments. Overall, we found general improvement to station security. However, NB Power must improve further in some areas, particularly in observing the requirements of procedures.

COMPLIANCE WITH THE OPERATING LICENCE

The operating licence we issue to NB Power contains conditions that it must observe. NB Power's level of compliance with these conditions continues to be unacceptable. It is essential that NB Power diagnose and correct the underlying causes of these problems.

There were 30 instances in 1996 where NB Power failed to comply with these conditions. However, six of these events related to NB Power's management of its waste water facilities, which were not related to nuclear safety. These events were ***reportable*** to us because of an operating licence condition which required NB Power to comply with provincial legislation. In these cases, NB Power had failed to observe the conditions of the waste water permit issued by the New Brunswick Department of the Environment. We have now removed the condition, and the associated need for

Figure 1: COMPLIANCE PROBLEMS
(number of non-compliances vs year)



reporting from the operating licence. Figure 1 shows the history of compliance problems at Point Lepreau. The 1996 entry in Figure 1 does not include the waste water events.

We have included details of these events, and our assessment of their safety significance, in the appropriate sections of this report. Many of these failures to comply with the operating licence conditions involved the failure of personnel to follow required procedures. We noted similar problems in our 1995 report. This aspect is also discussed in more detail later in the report.

EVENTS REPORTED TO THE AECB

NB Power reported 50 events to us under the terms of the operating licence during 1996. This number includes the 30 events where NB Power failed to comply with the operating licence. Twenty events directly involved personnel error. The number of events reported is an increase from 1995, and continues an adverse trend we have observed in recent years.

NB Power's performance is not acceptable. NB Power is evaluating improvements to its event investigation process. Improvements in this process are urgently required.

In past reports, we have noted that it is not possible to distinguish between events which occur because of on-going safety management deficiencies, and events which are discovered in increasing numbers because of increasing safety awareness and safety culture. However, in the latter case, we would expect the numbers of events reported to decline after an initial increase, as safety problems are found and corrected. The increasing trend of events at Point Lepreau therefore leads to a conclusion that there are underlying safety management problems which have not been addressed.

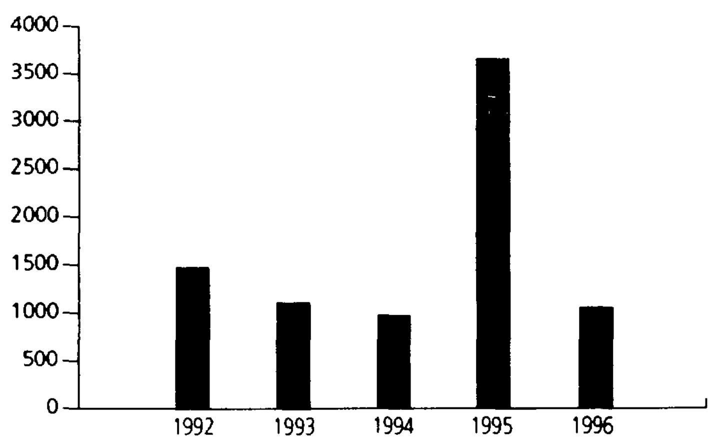
Personnel error and failure to comply with procedures are significant components of events reported by NB Power. We consider that some level of personnel error is natural and expected, and we have placed formal actions on NB Power to ensure that it includes in its work processes and procedures adequate checks to detect and correct such errors. In 1996, we also placed actions on NB Power requiring it to improve its event investigation and follow-up processes. In previous reports we expressed dissatisfaction with the process NB Power has been using. An assessment we completed in 1996 showed the approach to be largely informal, and without a documented systematic process. NB Power has told us that it recognises the weaknesses in its approach, and it is evaluating a more systematic process. This is necessary to ensure that NB Power identifies all the *root causes* of an event, and analyses and understands trends in event causes.

Table 1: SUMMARY OF EVENTS 1996

		ASSESSMENT
Number of events reported to the AECB	50	Needs improvement
Number of non-compliances with Operating Policies and Principles and licence conditions[1]	30	Unacceptable
Number of fires	1	Acceptable

[1] Included in the total number of events reported

Figure 2: COLLECTIVE STATION RADIATION DOSE (person•mSv vs year)



WORKER RADIATION SAFETY

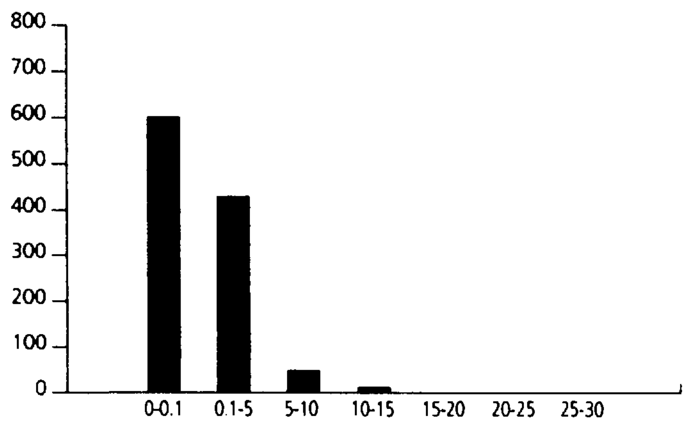
NB Power's radiation control programs were acceptable during 1996, and worker radiation doses were within required limits. However, human error resulted in some unnecessary radiation exposures.

The total worker radiation exposure during 1996 was 938 *person•millisievert*. We consider this level of exposure to be typical for this reactor type. Approximately two-thirds of this exposure was accumulated during the repairs to the steam generator *emergency water system* headers. We discuss this event in the 'Operations and Maintenance' section of our report. Although radiation work planning was effective during this exercise, we believe that the unplanned nature of this outage resulted in higher exposures than would have been experienced under more favourable conditions.

Table 2: WORKER RADIATION SAFETY

		ASSESSMENT
Total *whole body dose* (person•mSv)	938	Acceptable
Number of exposures greater than legal limit	0	Acceptable

Figure 3: RADIATION DOSE DISTRIBUTION — NB POWER STAFF (number of employees vs dose range (mSv))



We carried out an appraisal of some aspects of NB Power's radiation protection program at the end of February 1996. We examined the effectiveness of radioactive source control, radioactive waste handling, and shipping of radioactive materials. Our appraisal team found that the radiation protection program is acceptable in most of the areas investigated. However, improvements are desirable for the ventilation of certain station areas, in procedures for managing radioactive sources which are no longer required, and processes for minimising the quantity of radioactive waste.

During the year, two avoidable incidents caused significant radiation hazards. In one incident, workers failed to replace two radiation shields which had been removed from horizontal flux detector housings during the 1995 outage. During reactor operation, two narrow radiation beams caused unnecessary exposure to workers in the area. The hazard was present from reactor start up in December 1995, until NB Power discovered and corrected the problem in May 1996. Assessment of radiation exposures received from this event was very difficult because of the narrowness of the beams, and the difficulty of determining workers' positions with respect to the beams. Fortunately, the area is subject to routine surveillance by *International Atomic Energy Agency* (IAEA) *safeguards* cameras. The IAEA cooperated fully in making available images from these cameras to assist in dose evaluation. NB Power's assessment, which we have now accepted, shows that the most exposed worker received 2.1 *millisieverts* from this event, and total exposure was less than 11 person•millisieverts. These exposures are low, but we believe there was a very significant potential for radiation exposure greater than the required limits. This event was one of several where NB Power's control of work was not of an acceptable standard.

In a second event, two workers received avoidable radiation exposures from *tritium* of 1.5 millisieverts, and two other workers received exposures of 0.5 millisievert. They had used a *heavy water* drum which had a history card showing it to be empty. In fact, someone had improperly disposed of a small amount of *moderator* heavy water in the drum. Again, although the doses received were quite low, there was a potential for higher radiation exposure to occur.

There were three events where incorrect ventilation air flows occurred in the *service building*. The station's *Operating Policies and Principles* require air to flow in a way designed to minimise the possibility of *contamination* spread. In the first event, NB Power's assessment claimed that unusual weather conditions were responsible for improper airflows in the *upgrader* area. The second two events involved the fuel handling maintenance shop, where there were inadequate controls over ventilation in the area. Although NB Power staff made adjustments on the first occasion, they did not properly report the event. The problem recurred a few days later. In each case, no actual radiation hazard resulted.

In another event, NB Power found that used tools which had been stored in a laydown area outside the main airlock were causing a radiation field of up to 50 microsieverts per hour (0.05 millisieverts per hour) at the boundary of the area. In contact with the tooling, the radiation field measured up to 500 microsieverts per hour. NB Power had not posted the area as containing a radiation hazard. NB Power's *Radiation Protection Regulations* require caution signs to be posted when fields exceed 10 microsieverts per hour. The Atomic Energy Control Regulations require posting when fields exceed 25 microsieverts per hour. No significant radiation exposure occurred from this event.

PUBLIC RADIATION SAFETY

The station's control of radioactive material in effluents from the station continued to be satisfactory during the year. The amounts of radioactive materials released to the environment were very much less than the limits we set, and were similar to release levels in previous years.

In the following paragraphs we discuss radiation releases from the station in terms of the derived emission limit, or DEL. The *derived emission limit* is a calculated annual limit, that is specific to each reactor site. The DEL for Point Lepreau defines the amount of radioactive material release that could result in a radiation exposure of one millisievert to a member of the public. This is one-fifth of the current annual dose limit for the public specified in the

Table 3: AIRBORNE RELEASES

			ASSESSMENT
Tritium	No. weeks > 1% DEL	0	Acceptable
	Average % DEL	0.061	Acceptable
Noble gas	No. weeks > 1% DEL	0	Acceptable
	Average % DEL	0.007	Acceptable
Iodine 131	No. weeks > 1% DEL	0	Acceptable
	Average % DEL	0	Acceptable
Particulate	No. weeks > 1% DEL	0	Acceptable
	Average % DEL	0	Acceptable

Table 4: LIQUID RELEASES

			ASSESSMENT
Tritium	No. months > 1% DEL	0	Acceptable
	Average % DEL	0.018	Acceptable
Gross beta/gamma	No. months > 1% DEL	0	Acceptable
	Average % DEL	0.008	Acceptable

Table 5: PUBLIC EXPOSURE

		ASSESSMENT
Dose rate to ***critical group*** from plant emissions	0.001 mSv/year	Acceptable
Average tritium in air at station boundary	1.4 Bq/m^3	Acceptable

Atomic Energy Control Regulations. The station operates to a target of one percent of the DEL. NB Power reports liquid releases to us on a monthly basis, with the releases compared against a monthly limit which is one-twelfth of the annual DEL. Airborne releases are compared against a weekly limit.

Radioactive material in liquid effluents averaged 0.03 percent of the corresponding DEL during 1996. The radioactive material released in the gaseous effluents averaged 0.07 percent of the DEL. The total potential dose to the public was 0.001 millisievert. For comparison, the total radiation exposure to members of the public from naturally occurring sources in the area of the station averages about 1.5 millisieverts per year. The typical average ***background radiation*** level in Canada is 2 to 2.5 millisieverts per year.

The operating licence we issue for Point Lepreau requires that NB Power monitor all releases of radioactive material from the station. Three events in 1996 affected NB Power's ability to meet this requirement.

In February 1996, NB Power discovered unusual levels of tritium in the site drainage system. The source was leakage from a concrete tank which holds used water treatment resin. NB Power took prompt action to contain the leakage. The amount of tritium released to the environment was very small, and is included in the figures for liquid effluents which are shown in Table 4.

Also in February, NB Power discovered that a sample line in the gaseous effluent monitor was leaking. Because the monitor sample flow was affected, the effective calibration of the monitor had changed. NB Power corrected the gaseous emission data to account for this change. In the third event, the sample flow into the liquid effluent monitor stopped while tanks were being discharged. NB Power used back-up sample measurements to determine the releases.

During the year, NB Power experienced problems with steam generator tube leakage, described in the 'Operations and Maintenance' section of this report. This heavy water leakage resulted in only marginal increases in the releases of tritium from the plant. NB Power accounts for steam generator leakage in its release calculations, and the data is included in the effluent release figures noted in Tables 3 and 4.

SAFETY SYSTEM PERFORMANCE

Special safety systems performance has not been satisfactory in 1996. The two *shutdown systems* performed well during the year. However, the *containment* envelope was not available to meet its required design capability because of emergency water system header problems. We have described these problems in the 'Station Management' section of this report. Also, the *emergency core cooling system* may have been affected by difficulties NB Power experienced with motor-operated valve maintenance. *Predicted future availability* for three of the special safety systems is still higher than the standard we set. NB Power has made some improvements, but further work is necessary to ensure satisfactory performance for these systems.

Table 6: SPECIAL SAFETY SYSTEM UNAVAILABILITY*

SYSTEM	1996	PREDICTED FUTURE	ASSESSMENT
Shutdown system one	0.2 h	8.0 h	Acceptable
Shutdown system two	0 h	9.0 h	Needs improvement
Containment	6650 h	39.0 h	Unacceptable
Emergency core cooling	0** h	16.0 h	Needs improvement

*Target unavailability is less than 8.8 hours per year.
**Pending evaluation of uncertainty of loop isolation valve stem thrust settings.

We require each of the special safety systems to be fully available to perform its design functions for at least 99.9% of the time. To meet our requirements, the time for which a special safety system does not fully meet its performance specifications must be limited to 8.8 hours per year. We consider a system to be unavailable if it is anything less than 100% capable of performing its function, even though it may retain considerable effectiveness. Predictions of future *availability* are important because they give insights into the reliability with which systems can be expected to perform in the future. Predicted future availability is calculated using *reliability analysis* for the systems.

Shutdown system one was unavailable for 0.15 hour during 1996. This occurred while the reactor was shut down, when the shutdown system actuated because of electrical noise. The *trip* was not actually needed; however, the system was not available during the time taken to re-poise the *shutoff rods* and reset the system. The event had minimal safety significance.

Shutdown system two was fully available when required during the year. The system operated twice to trip the reactor. In September, the system fired during refuelling. Operators had failed to reduce power to a level where local changes in power caused by fuel movement would not cause the overpower trip to actuate. Shutdown system two tripped the reactor again in September, during start up. In this case, false low level readings from *steam generator* three caused the trip. Although the system instrumentation was incorrectly reading steam generator level during this event, the inaccuracy would always have led to the system tripping the reactor sooner than actually required.

Therefore, the level measurement problem had no direct safety significance. The follow-up to this event was complex, and we have included a detailed discussion in the 'Station Management' section of our report.

All of the containment systems operated correctly during 1996. There was no ***unavailability*** of the containment isolation system, ***dousing***, airlocks, local air coolers or the spent fuel discharge bay containment. However, the containment envelope may not have met its design requirements for much of the year. This is because the degradation of the steam generator emergency water system headers affected the seismic qualification of the ***steam generator tubes***, which form an important part of the containment structural boundary. We do not know at what time the headers degraded to a state where they could fail to meet these requirements. Therefore in Table 6, the unavailability we show in 1996 is for the portion of 1996 for which the unit operated before the discovery of the problem. NB Power has not acknowledged this deficiency in containment availability in any of its reporting, and it has declined to fully assess the risk impact of the event. We have advised NB Power that we consider that it has failed to comply with an operating licence condition which requires it to report this unavailability.

There were some notable events affecting containment equipment during the year. In February, NB Power reported to us that some components in local air coolers' controls did not meet ***environmental qualification*** requirements. This meant that the coolers would have been unreliable following an accident. In November, NB Power found foreign material in the duct associated with one pair of containment isolation valves. The valves were still working correctly, but NB Power closed off the ventilation using its manual isolation valve, in case the material affected the isolation valves' leak tightness. It appears the foreign material is the result of overflow of water from a ***poison*** mixing tank into the tank vent.

In 1995, NB Power requested relaxation of our requirement to perform a full pressure leakage test of the ***reactor building*** every three years. NB Power argued that the additional risk to workers from the test was not warranted. We consider that the data currently available from leak rate testing does not allow sufficient confidence in reactor building leak performance as it continues to age. Therefore, we have denied NB Power's request.

NB Power reported no unavailability of the emergency core cooling system in 1996. However, it has found that its maintenance programs for motor-operated valves used in the system had not ensured that valve ***actuator*** operating thrust would have met specifications. At the end of the year, NB Power had not completed a full assessment of these findings.

NB Power continues to make progress with special safety system reliability studies. NB Power's analyses are proving very valuable in finding areas where reliability performance can be improved. Current predicted future unavailabilities remain high primarily because NB Power has not yet resolved potential contributors to unreliability which it identified in 1995. NB Power will need to continue to take action to improve the predicted figures. In NB Power's component reliability reporting, we have noted several components where faults have been allowed to persist for an extended duration, because of their apparently minor significance. However, NB Power has not used its reliability models to assess the impacts of these faults when several of them exist simultaneously. We believe that NB Power needs to make full use of its reliability models to properly assess repair priority.

Calibration drift of pressure transmitters forms an important contribution to the high predicted future unavailability of shutdown system two and the emergency core cooling system. There has been a measurable improvement in the calibration performance of transmitters. NB Power has told us this may be because maintainers working on the instruments have improved calibration and handling practices. Performance can be further improved by a process of on-line calibration, which NB Power has proposed for some of the worst affected instruments.

Table 7: STATION OPERATION

		ASSESSMENT
Number of non-spurious reactor trips	33	Acceptable
Number of serious process failures	0	Acceptable
Total outstanding *call-ups* (year end)	1265	Needs improvement
... on special safety systems only	52	Needs improvement
... on standby *safety support systems*	98	Needs improvement
Total number of *jumpers* in effect (year end)	697	Needs improvement
... on special safety systems only	32	Needs improvement
... on standby safety support systems	10	Acceptable

Reliability of airlock door seals and containment isolation valves dominate the predicted future unavailability of containment. The ability of containment isolation valves to consistently seal tightly has been a problem in the past, caused by fast operating times which tended to damage the valve mechanisms. As we reported in 1995, NB Power has slowed isolation valve closing time, improving reliability. NB Power plans further isolation valve overhauls in 1997. Airlock door seals have not been subjected to a rigorous reliability-based maintenance approach. In most cases, seals are replaced only when they fail. NB Power needs to place these seals under the control of a proper management program. Future improvements in seal design and materials may also be necessary to ensure acceptable performance.

OPERATIONS AND MAINTENANCE

Operations and maintenance activities were subject to a number of problems during 1996. The reactor operated at high power for ten months of the year. The plant was shut down for two months in September and October for unscheduled repairs to the steam generators. There were no *serious process failures*. The reactor tripped three times while at power.

In January, there was a spill of approximately 10 tonnes of heavy water in the reactor building. The spill occurred from a low pressure system that operations staff was preparing to use to ready ***ion exchange*** resin for use in the ***primary heat transport system***. To speed start up, station management instructed operating staff not to proceed with this process. When returning system valving to normal, a valve was left open. As a result, full heat transport system pressure was applied to low pressure components, failing flexible hoses in the system. During the event, operators had difficulty closing the isolating valve. This was because the actuator of the motorized valve was not developing sufficient thrust to close the valve. NB Power has found that its maintenance programs were not adequately assuring the capability of the motorised valves. This problem also affected valves in the emergency core cooling system, as discussed in our section on 'Safety System Performance'. The spill of heavy water was contained within the reactor building. Resulting releases of tritium from the plant were small, and very much less than the applicable limits. However, NB Power did experience on-going problems with contamination in the reactor building for some months following the event. NB Power also experienced difficulty maintaining proper heat transport system chemistry, because the ion exchange resin systems were out of service while staff inspected and repaired the components which had been over pressurised.

In May, NB Power reported to us that it had discovered a design deficiency in the main output transformer. This deficiency is causing a long-term degradation in the internal insulation of the transformer's three units. NB Power intends to replace the transformer during 1997. In the meantime, it has set up enhanced monitoring and evaluation to ensure the transformer units remain within safe operating limits.

In September, NB Power shut down the plant to repair leaking tubes in steam generators one and two. This effort was only partially successful, because NB Power experienced difficulty in locating one of the leaks. Following problems with shutdown system two steam generator level measurements during start up from this outage, NB Power conducted inspections of steam generator secondary side internals. It found severe degradation of the steam generators' emergency water system headers. This finding is discussed in detail in the 'Station Management' section of this report. During this second part of the outage, NB Power was able to locate and plug the leaking tube which had caused problems in steam generator two.

In October, NB Power discovered that a gag had been left in one of the main steam safety valves. A gag is used to prevent the valve from operating during testing or maintenance. If it is not removed when the work is finished, the valve cannot operate in the event of an overpressure in the steam generators or main steam lines. This error was serious, and NB Power's assessment showed that personnel had not been following required procedures. The other 15 main steam safety valves were operational, and would have had sufficient capacity to protect the plant.

In September, shutdown system two tripped the reactor because operators had not reduced power as required during fuelling. Because this event resulted from miscommunication between fuel handling and reactor operators, NB Power is examining the quality of personnel communication in the ***main control room***. Another significant error occurred during reactor start up, when operators left a ***feedwater*** valve in the closed position. This reduced the supply of water to steam generator four as power was increased, reducing its level. Operators reduced power, and the ***control computers*** automatically completed power reduction, before a shutdown system trip was required.

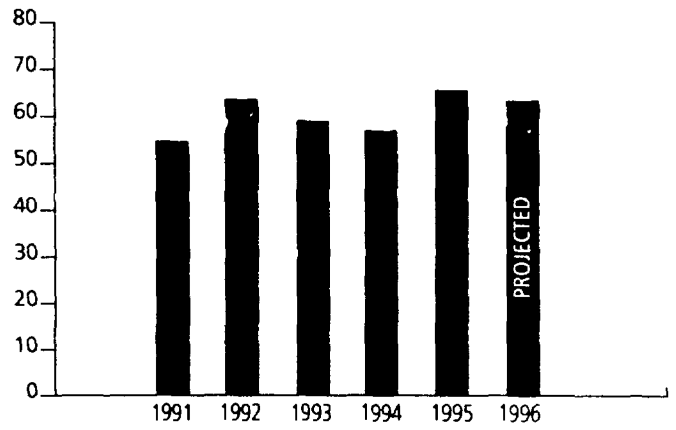
In 1995, NB Power completed measurements of ***feeder*** pipe thickness. These measurements showed that thinning of the walls of the feeders was occurring more rapidly than allowed for in the original design. In fact, the measurements showed some feeders to already be thinner than the minimum thickness which had been allowed for in the original design. However, NB Power staff did not realise the significance of the results immediately, and it was not until June 1996 that NB Power formally reported this conclusion to us. NB Power was able to complete a new analysis to show that the feeders still met all applicable requirements. This was fortunate: the failure to respond promptly could have had more serious implications under other circumstances. NB Power's results show all feeders to be fit for service for several years. During that time, NB Power will need to develop means either to arrest the thinning, or to replace affected sections of feeder before they reach the minimum allowable thickness.

Following the 1995 'wood cover' incident, NB Power instituted inspections of fuel discharged from the affected quadrant of the reactor. These inspections are intended as a check, in case debris, or remaining screws, enter a ***fuel channel***. At the end of the year, NB Power had conducted fueling operations on 85 affected fuel channels, and discharged 986 ***fuel bundles***. Of these, 858 have had inspections completed so far. Minor marks have been found on a small number of fuel bundles. If there is residual metallic debris in the system, it does not currently appear to be causing significant problems. NB Power will be inspecting three fuel channels where marks were seen on discharged fuel, to confirm that the ***pressure tube*** is in satisfactory condition.

STATION MANAGEMENT

NB Power managed the station safely during 1996. However, we observed worsening trends which led us to conclude that Point Lepreau could encounter significant safety management problems if they were not promptly checked. As part of operating licence renewal for Point Lepreau in October 1996, the Atomic Energy Control Board asked its staff to include an additional condition in the licence. This condition requires NB Power to report every six months to AECB Board meetings its progress on the implementation and evaluation of measures to promote safety at the facility.

Figure 4: OPERATING AND MAINTENANCE BUDGET*
($ million vs fiscal year)



*Does not include taxes, insurance or computer services.

In previous years, our reports have focused on a number of distinct areas which affect safety culture, safety standards, and quality of work. The primary areas of concern have been the numbers of failures to comply with operating licence conditions, on-going tight levels of resources, and the lack of a rigorous process for event analysis and follow up. In response to our concerns, NB Power developed and delivered safety culture training to station staff in 1995.

Events in late 1995 and 1996 have shown that the situation is not improving. As well as worsening performance in terms of both number and severity of reported events, we noted production pressures involved in decision-making which did not meet our expectations for conservative operation. We also observed what we considered to be inappropriate perceptions of risk in some areas of the organisation. This particular problem is made more difficult because NB Power lacks objective processes of risk assessment. We have also been aware of significant tensions between station management and its safety experts.

A key event, in September 1996, illustrates the growing disparity between NB Power's view of acceptable risk, and that of the AECB. The event involved a spurious trip of shutdown system two, caused by inaccurate steam generator level measurements on steam generator three. NB Power conducted low power tests to attempt to diagnose the problem. The tests showed that flow and levels in steam generator three were unstable at low power. Based on its measurements, NB Power concluded that the steam generator was experiencing disturbances to the flow in the steam generator's downcomer, because steam was being entrained in the water flow. This disturbed steam generator circulation, and affected level measurement. The problem could be avoided by operating with a slightly higher steam generator level. Based on this conclusion, NB Power informed us that it was ready to proceed to full power.

NB Power's conclusion represented a likely explanation for the steam generator's behaviour. However, it was not the only possible explanation, and we believed a more positive assurance of correct steam generator operation was necessary.

There were a number of reasons for our concern. In the first place, the problem had affected a special safety system trip measurement. Secondly, of the four nominally identical steam generators, steam generator three's behaviour was markedly different. If the flow instability was the result of some structural problem inside the steam generator, then many steam generator tubes could be at risk, either during normal operation, or during an accident or earthquake. This is important because the steam generator tubes form the boundary of both the primary heat transport system and the containment system. In all other areas of the plant, these two systems form two separate barriers to the release of radioactive materials. In considering this problem, we also noted that the steam generator secondary side internals had not been inspected since 1987.

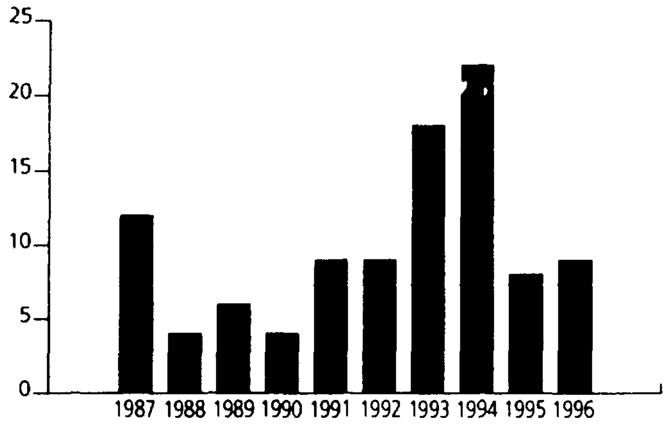
We therefore intervened in the start-up process. NB Power had also discovered higher than expected leakage in steam generator two, and shut down the unit for steam generator two leak repair and steam generator three secondary side internal inspection. NB Power's inspections confirmed that the steam generator measurement anomaly was not caused by structural problems. But it did find severe flow-assisted corrosion damage to the emergency water system header inside the steam generator. NB Power subsequently found this problem on all the steam generators. The extent of the damage was such that continued operation could have led to a header falling onto the steam generator tubes. In fact, in one steam generator, a part of the header had already fallen. NB Power replaced the headers with a more corrosion-resistant material.

This event revealed a very serious degradation of the level of *defence-in-depth* available at the station. In the first instance, a header falling on the steam generator tubes during normal operation could have caused a *loss of coolant accident* outside containment. Secondly, an earthquake which the plant is designed to withstand could have dislodged one or more headers, with similar results. Thirdly, seismic qualification of the primary heat transport system and the containment boundary was compromised. This represents a degradation of defences which should be available to mitigate a very broad spectrum of other accidents. Fourthly, this undetected corrosion, coupled with other similar discoveries, such as the feeder thinning noted in our 'Operations and Maintenance' section, suggests that NB Power's programs to manage plant ageing are not sufficiently effective or comprehensive. Finally, the damage to the headers could have led to a degradation of the emergency water system function, and consequential damage if it was used.

The role of station management in this example is significant. NB Power had deferred inspections of the steam generator secondary internals. Point Lepreau management was prepared to start up the unit without a proper assurance of safety. We believe NB Power placed an improper emphasis on production in this instance.

A further area of concern is NB Power's response to the formal

Figure 5: AECB REQUESTED ACTIONS COMPLETED
(number of actions completed vs year)



requests for action we make. In our 1995 report, we noted that NB Power's response to these requests had been slowed substantially by the demands of the long 1995 outage, and the clean up following the 'wood cover' incident. Progress was again slow in 1996, at least partly because of the unscheduled work on the steam generators. It has now become routine for NB Power to fail to honour the commitments it has made to us.

We regard progress with our requests for action as an indicator of how well a station is maintaining its safety programs. The delays we have seen result when the limited resources available are diverted from these safety programs to the needs of the production schedule. We have observed similar strategies in use at stations which have encountered significant safety management difficulties.

TRAINING

Training activities continued satisfactorily in 1996. We completed three training program evaluations at Point Lepreau during the year. We found that NB Power has introduced a well structured program for the continuing training of ***authorised staff***. This training includes testing on the plant's ***simulator***. We found some deficiencies in training programs for field operators and chemical maintainers. NB Power has proposed appropriate corrective actions in response to these findings. During our evaluations, we noted that NB Power's continuing commitment to a systematic approach to training seemed uncertain. NB Power has since assured us that it does remain committed to the application of the systematic approach.

EMERGENCY PREPAREDNESS

NB Power's capability to deal with emergencies needs improvement. In November, we conducted an appraisal of NB Power's emergency response capabilities and emergency response program. We found that NB Power has a well documented emergency response program, and maintains its emergency equipment in good condition. But we found the training, exercise and drill aspects of the program to be weak. We found also that the station had not met its commitment to conduct annual reviews of its emergency response arrangements with off-site authorities.

NB Power did successfully complete 44 shift crew drills during 1996. These drills exercised the crews' ability to deal with radiation, fire, chemical, medical and security incidents.

SAFETY ANALYSIS

NB Power's progress with safety analysis matters continued to be slow in 1996. In some cases, this has delayed safety analysis which was committed to us by NB Power. Many of the delays result from safety assessment support for outage work.

In our 1995 assessment, we reported that NB Power had replaced the steam generator *divider plates* with a stronger design. This upgrade was necessary to ensure that the divider plates would be strong enough to withstand flows if a large loss of coolant accident were to occur. We approved the installation of the new plates because they are a clear safety improvement over the old design. However, final analyses were not complete. Although NB Power committed to complete analysis by April 1996, it has significantly delayed completion of this work.

The protection of the plant against failures in the steam and *feedwater systems* is an important topic, which we have discussed in several assessment reports in the past. As part of this protection, NB Power installed 66 *pressure relief panels* in the *turbine* building. We have completed a review of the performance analysis of these panels. The assessment shows that NB Power has made considerable progress. But we will be holding further discussions to make sure that AECB requirements have been met.

NB Power is currently working on analysis of the performance of the primary heat transport system *degasser condenser* pressure relief valves. This work is in response to the small loss of coolant accident that occurred on Pickering unit 2, in December 1994. At Pickering, unstable relief valve behaviour contributed to the severity of the accident. NB Power has committed to resolve issues arising from the Pickering accident in 1997. Currently, NB Power is working towards replacing the Point Lepreau degasser condenser *pressure relief valves* with an improved design.

In 1993, NB Power submitted to us analysis of single channel stagnation failures. A stagnation failure results from a break in an inlet feeder of a specific size. The flow through the break could cause channel flow to stop, causing fuel to heat up and threaten the integrity of the affected fuel channel. Our review of this analysis is now complete, and we have found the results to be acceptable. However, we have requested NB Power to complete analysis of a wider range of possible accidents, to make sure that the performance of the plant's safety systems will be adequate.

QUALITY ASSURANCE

NB Power continued to maintain its *quality assurance* program in a generally satisfactory manner. However, we did find a significant deficiency in NB Power's quality assurance program for design work. An *audit* we completed in November showed that NB Power is not meeting the requirements of the applicable Canadian Standards Association standard.

Our audit was the last of a series conducted in 1996 at each of the operational CANDU sites. These audits assessed the effectiveness of each station's design modification processes. We had completed an initial examination of this area of quality assurance in 1995, as described in our 1995 report. In 1996 we looked at design modification processes in greater detail.

Our 1996 audit concluded that NB Power has not written, and not executed, a quality assurance program for design work done by its engineers. In particular, procedures describing how engineers should carry out design work do not exist. As a result, NB Power does not maintain acceptable control over the planning and verification of design work. We did note that the existing operations quality assurance program does cover some design activities. We also found that change control activities, such as installing and commissioning design changes, were satisfactory.

During our audit, we found that NB Power's own internal audit activities had made similar findings as long ago as 1992. NB Power's response to this quality assurance program deficiency is not satisfactory.

SAFEGUARDS

During 1996, the station continued to provide excellent support to the *International Atomic Energy Agency* (IAEA) and the AECB. NB Power provided reports and notification of activities involving safeguards in a timely manner.

Canada has signed the *Treaty on the Non-Proliferation of Nuclear Weapons*. As required by this Treaty, Canada has signed a safeguards agreement with the International Atomic Energy Agency. This agreement provides the IAEA with the right and the responsibility to verify that Canada is fulfilling its Non-Proliferation Treaty commitment not to use its peaceful nuclear program to make nuclear weapons or nuclear explosive devices.

We include a requirement for the application of IAEA safeguards in the Point Lepreau operating licence. To comply with this, the station must provide access and assistance to IAEA inspectors for verification purposes, and for the installation and maintenance of IAEA equipment. The station must also provide timely reports on the movement and location of all nuclear materials within the station.

During the year, the IAEA conducted a major overhaul of its video surveillance system. This was done to replace old cables which had become unreliable, and to improve the capabilities of the system. The IAEA successfully verified transfers of spent fuel to the *dry storage* canisters, and checked new canisters built in 1996.

CONCLUSIONS

Point Lepreau operated safely during 1996. By this we mean that the station's direct impacts in terms of actual releases to the environment, radiation exposures to workers, or the creation of actively hazardous situations were acceptable. However, the level of risk of unacceptable impacts, as evidenced by the events described in this report, is too high. This level of risk cannot be accepted for any extended duration.

NB Power has many expert and dedicated staff, who have shown that they have the capability to operate the station to very high standards. We view management approach, and a longer term management focus on minimising cost and maximising production, as important components of current problems.

In renewing the operating licence for Point Lepreau in 1996, the AECB has required NB Power to report every six months on the progress of measures it has promised to improve the safety performance of the station. The first of these reports is due in April 1997. We have also warned NB Power that we are prepared to take further licensing action if safety performance does not improve.

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GLOSSARY

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

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

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

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

annunciation
An alarm windows system in the ***main control room***. The system alerts operators to unusual conditions in the reactor or its systems. The windows light up when measurements exceed pre-set limits. They will not clear until reset by the operator.

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

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

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

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

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

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

background radiation — The radiation that exists naturally. It is present everywhere and is not a product of station operation.

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

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

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

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

collective dose — The total radiation exposure that people living around a station receive because of its operation. It is an estimate of the sum of all radiation exposures to individual members of the public and is usually expressed in units of person•millisieverts. For example, if a thousand people each received one ***millisievert*** of radiation, the collective dose would be one thousand person•millisieverts, or one person-sievert.

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

contamination
The presence of radioactive material anywhere it is not wanted, particularly in places where its presence may be harmful.

control computer
One of two digital computers that control the reactor. The computer also provides ***annunciation*** and data display for the operators. A fault in the computer that is in control causes an automatic transfer to the second computer. If both computers fail, the controls rapidly reduce reactor power until it is shut down.

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

critical group
A well-defined group of people that receives more radiation from a given source, for example, a particular waste discharge, than any other defined group.

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

defence-in-depth
An important and fundamental principle in the design and operation of a nuclear facility. Multiple barriers prevent unsafe conditions from developing, and separate people from hazards.

degasser condenser
A vessel which receives a bleed flow of ***primary heat transport system*** water to allow periodic removal of unwanted gases. It also receives the flow from the primary heat transport system liquid relief valves when they open to reduce pressure in the system.

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

divider plates

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

dose

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

dry storage

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

emergency core cooling system

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

emergency water system

A system that supplies cooling water to important reactor systems if normal service water supplies fail.

end fittings

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

end plates

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

environmental qualification

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

feeder — There are several hundred *fuel channels* in the reactor. The feeders are pipes that supply *heavy water* coolant to each channel and return the hot coolant to the *steam generators*.

feedwater system — The system that returns and processes the condensed steam and water from the *turbine* to the *steam generators*.

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

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

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

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

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

grid — The provincial electrical distribution system.

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

heat exchanger — Equipment that transfers heat between systems.

heavy water (D_2O)

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

horizontal flux detectors

Devices located inside horizontal tubes in the reactor to measure power. The reactor shuts down automatically if the detectors sense a reactor power exceeding a pre-established *setpoint*.

International Atomic Energy Agency (IAEA)

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

iodine-131

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

ion exchange system

Equipment that purifies water.

irradiated fuel bay

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

jumper

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

loss of coolant accident (LOCA)

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

main control room

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

millisievert (mSv)

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

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

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

Operating Policies and Principles (OP&P)
A licensee document, approved by the *Atomic Energy Control Board*, that outlines the safe operating limits for the station. It also defines which staff have the authority to make decisions on safety matters.

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

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

person•sievert
A unit of *collective dose*.

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

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

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

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

pressure relief panels
Panels built into the walls of a room or building that open automatically when needed to prevent a build-up of pressure.

pressure relief valve

A valve that opens to reduce the pressure on a system when it exceeds a pre-established limit.

pressure tubes

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

primary heat transport system

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

quality assurance

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

radiation field

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

Radiation Protection Regulations

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

reactor building

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

reliability analysis

A study provided by the licensee that demonstrates that a system can be relied upon to a specified degree of confidence to carry out its designed function.

reportable event

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

root cause

The fundamental or primary cause of an incident or event in the station.

root cause analysis

A methodology and technique used to evaluate human performance and equipment problems, uncover their *root cause* and determine corrective actions to prevent recurrence.

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

safety support systems
Systems and features of a station used only to perform safety functions. Examples include the *emergency water supply system* and the *standby generators*.

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

service building
The building next to the *reactor building*. It contains auxiliary systems. For example, *heavy water* management, maintenance facilities and the *main control room*.

setpoint
The value of a parameter at which a safety system operates, as required by the reactor operating conditions.

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

shutdown system one (SDS1)
Shutdown system one works by dropping neutron-absorbing rods into the reactor core if its instruments detect a potentially unsafe condition. It is completely separate and independent from *shutdown system two*.

shutdown system two (SDS2)
Shutdown system two automatically shuts down the reactor by injecting a neutron-absorbing chemical into the *moderator* if its sensors detect a potentially unsafe condition. It is completely separate and independent from *shutdown system one*.

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

sievert (milli, micro)

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

simulator

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

special safety systems

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

standby generators

Diesel or gas turbine-powered generators that can provide electrical power if the station loses its normal supply.

steam generator

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

steam generator tubes

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

Transport Packaging of Radioactive Materials Regulations

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

Treaty on the Non-Proliferation of Nuclear Weapons (NPT)

An international treaty that came into force in 1970, and to which Canada is a party. Its primary aim is preventing the spread of nuclear weapons.

trip

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

tritium

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

turbine

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

unavailability

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

upgrader

A system which removes ordinary water from a mixture of heavy water and ordinary (light) water. The system is used to recover heavy water which has become mixed with light water, for example, as a result of leakage.

whole body dose

Also known as deep dose. The radiation dose that affects all of the body tissue. Radiation that penetrates the body completely, or radioactive materials absorbed by the body, cause it.