INFO-0677

REPORT

AECB Staff Annual Assessment of the Pickering A and B Nuclear Generating Stations for the Year 1996

Atomic Energy Control Board
Ottawa, Canada

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

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

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

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

SUMMARY

This report is the Atomic Energy Control Board (AECB) staff assessment of safety at the Pickering Nuclear Generating Stations A and B (PNGS-A and PNGS-B) for 1996. Our on-site Project Officers and Ottawa-based specialists monitored the station throughout the year.

PNGS-A and PNGS-B operated safely during 1996. Although the risk to the workers and the public is low, major safety-related changes are necessary at the stations and the sustainability of those changes needs to be demonstrated. In December 1996, the AECB wanted to reflect the need for improvements. To do this, it gave only short-term (six-month) licence renewals to PNGS-A and PNGS-B.

In 1996, compliance with the AECB Cost Recovery Fees Regulations was satisfactory. However, compliance with the Transport Packaging of Radioactive Materials Regulations requires improvement. The performance of the special safety systems was good. Releases of radioactive materials from the stations were low and well below the legal limits for public safety.

There was no serious process failure in 1996. Improvement is needed by Ontario Hydro in meeting the time limits for reporting reportable events. Ontario Hydro's follow-up to events and causal factor analyses continue to need improvement.

We believe that improvements to operational safety and reactor maintenance at both PNGS-A and PNGS-B are required. In 1996, as in 1995, the number of times Ontario Hydro failed to comply with the conditions of the stations' operating licences and the Atomic Energy Control Regulations was unsatisfactory.

No worker received a radiation exposure greater than the legal limit. As reported in 1994 and 1995, Ontario Hydro needs to improve on the contamination control aspects of its radiation protection program.

In our Annual Assessment Report for the year 1995, we reported the persistent breakdown of one or more of the multiple layers of defence with respect to safe operation. This led us to conclude that Ontario Hydro needed to pay more attention to nuclear safety, supervision, and management issues. Also, we reported that the non-compliances with operating licences, if not corrected, could result in unsafe operation. This adverse trend in operational safety continued into the first quarter of 1996. In response to our request in 1995, and recognizing the need for improvement, Ontario Hydro developed a Quality of Work program. In 1996, to address the adverse trend in operational safety, Ontario Hydro adjusted several of the program initiatives. Also, Ontario Hydro adopted a strategy for maintaining the safety and reliability of the running units while improving their condition by reducing outstanding maintenance work.

Ontario Hydro management needs to devote more attention to resolving issues related to inadequate human performance. In 1996 as in 1995, there were still many events related to such performance. We have observed some encouraging signs of improvement through Ontario Hydro's plan for recovery, and in station management changes. There also appears to be commitment to safety expressed at the highest level of the utility, and "buy in" by the staff at PNGS-A and PNGS-B.

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INTRODUCTION

PNGS-A and PNGS-B are located on the north shore of Lake Ontario, about 32 kilometres east of downtown Toronto. Each station contains four reactor units. PNGS-A consists of units 1 to 4 while PNGS-B consists of units 5 to 8. Each unit can generate about 540 megawatts of electricity. All eight units are located within a single enclosure. Ontario Hydro has assigned one Director with authority over both stations, but each station has its own organization. We issue a separate operating licence for each station.

This report is the *Atomic Energy Control Board* (AECB) staff assessment of the PNGS-A and PNGS-B safety performance in 1996. It also contains other aspects that we consider to have significant impact on nuclear safety. We based our conclusions on our observations, *audits*, inspections and review of information that Ontario Hydro submits to us as required by the stations' operating licences.

Throughout this report we include tables and charts with more detailed information to compare yearly station performance on selected topics. Although we use similar terms to describe the safety performance of 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 *italicized* glossary terms the first time they appear in the body of the report.

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

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OPERATIONAL SAFETY

COMPLIANCE WITH REGULATIONS MADE UNDER THE ATOMIC ENERGY CONTROL ACT

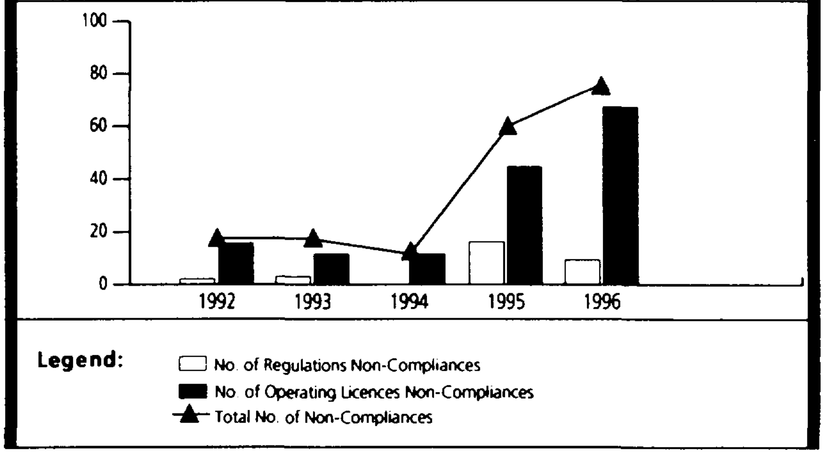
We require Ontario Hydro to operate PNGS-A and PNGS-B according to the legal requirements governing the nuclear industry in Canada. These requirements come from the *Atomic Energy Control Act* and regulations made under the Act. The regulations directly applying to PNGS-A and PNGS-B are the *Atomic Energy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

Figure 1 shows that there were 12 events where Ontario Hydro did not comply with the conditions of the Atomic Energy Control Regulations, as compared to 17 in 1995. For seven of these 12 events, Ontario Hydro did not post radiation warning signs in locations where ionizing radiation exceeded the regulatory limit of 0.025 *millisievert*. The decrease in the number of events observed in 1996 is an improvement over the previous year. The number of such non-compliances, however, is still too high. Station management must continue to take action to further reduce the number.

Four of these 12 events were related to the Physical Security Regulations. The Physical Security Regulations define the security measures that Ontario Hydro must maintain at the stations. Our annual security assessment verified that the measures Ontario Hydro has in place at PNGS-A and PNGS-B meet our Physical Security Regulations. The four events resulting in non-compliance with our regulations were minor in nature and Ontario Hydro quickly dealt with them in an acceptable manner.

The remaining event involved non-compliance with the Transport Packaging of Radioactive Materials Regulations. Contrary to the requirements of these regulations, a shipment of radioactive material was accepted by a department of Ontario Hydro which was not authorized to do so.

Figure 1: NUMBER OF NON-COMPLIANCES WITH REGULATIONS AND OPERATING LICENCES (number of non-compliances vs year)



In 1996, compliance with the AECB Cost Recovery Fees Regulations was satisfactory.

COMPLIANCE WITH THE OPERATING LICENCES

The operating licences we issue to Ontario Hydro for PNGS-A and PNGS-B contain conditions that it must observe. ***Operating Policies and Principles*** and the Ontario Hydro ***Radiation Protection Regulations*** referred to in the licences also govern the operation of the stations.

In 1996, there were 67 events (not including non-compliance with the Atomic Energy Control Regulations) where Ontario Hydro did not comply with the licence conditions. We reviewed each of these events and concluded that none of them had caused any safety hazard to workers or the public. As in 1995, some events showed that the non-compliances resulted in the breakdown of one or more of the multiple layers of defence. As also stated in 1995, these, if not corrected, could result in unsafe operation. The persistent breakdown of these defences, and the fact that the number of events initiated by workers increased from 38 in 1995 to 50 in 1996, led us to conclude that there was a continuing lack of attention to nuclear safety, supervision and management issues.

Figure 1 shows the number of non-compliance events for the last five years. The figure shows a substantial increase in non-compliances in 1996 over 1995. Failure to observe the Operating Policies and Principles accounted for nine of these events.

There were a small number of non-compliance events involving equipment or component design deficiencies. In all cases the impact on safety was small. Ontario Hydro took actions to correct the design deficiencies.

Many of these non-compliance events occurred when workers did not follow mandatory radiation protection practices or procedures. Two of these events did lead to unplanned radiation ***dose*** to the workers involved although not in excess of administrative or legal limits. Many of these events included the discovery of radioactive ***contamination*** in areas where it is not allowed, and finding evidence of eating in the radiation area.

There were 50 non-compliance events related to human performance. These were caused by workers not following established procedures. Most of the events resulted in the breakdown of one or more of the multiple layers of defence.

We describe below the more noteworthy events:

MAJOR HIGH PRESSURE SERVICE WATER LEAK IN REACTOR BUILDING INTERRUPTS PRIMARY AND BACK-UP FUEL HEAT SINK

While the reactor was critical at low power, a major leak of high pressure service water occurred when mechanics removed the bonnet flange from a non-return valve they thought was already isolated. It turned out that the isolating valve was open instead of closed due to an earlier installation error that left the valve 90° out of position. The bonnet had blown off resulting in a large cooling water leak inside the ***reactor building***. Because of need to stop the leak, the high pressure service water cooling to the shutdown cooling ***heat exchangers*** was reduced and briefly interrupted.

The sprayed water resulted in wetting of a large number of safety-related devices. Many ground fault indications resulted and several junction boxes were found to contain small quantities of water. However, no safety-related devices failed to function as required.

We agreed that the reactor safety consequence was insignificant. However, this event demonstrated inadequate licensee maintenance, planning and work protection practices. Ontario Hydro allowed the reactor to remain critical throughout the event and we believe that this was not conservative operation.

ION CHAMBER UNAVAILABILITY DURING APPROACH TO CRITICALITY

On February 20, 1996, during the approach to criticality on unit 2, three reactor regulating system *ion chambers*' signals were simultaneously isolated for about 20 minutes. During this period the *reactor regulating system* was unable to respond to power changes. Fortunately, the *special safety systems* were effective at that time and would have shut down the reactor in case of a power transient.

Ontario Hydro has completed a *root cause analysis* of this event and has taken action to avoid reoccurrence.

HIGH PRESSURE SERVICE WATER SYSTEM ISOLATED FROM SHUTDOWN COOLING SYSTEM HEAT EXCHANGER

Unit 2 was critical at low power. Its primary and backup *heat sinks* utilized *shutdown cooling system* configurations. Since the unit had been shut down for a long time, little heat was being generated by the reactor and, as such, the primary heat transport piping temperature was getting too cold. Ontario Hydro staff filed *jumpers* to close the high pressure service water system isolators to all shutdown cooling system heat exchangers to reduce the cooling flow caused by passing control valves. The action was based on previous practice, but with the reactor in *guaranteed shutdown state*. Operators reopened the isolating valves about six weeks later when we questioned the presence of the jumpers.

Contrary to Ontario Hydro's position, we considered this event to be reportable. We believed that the event was a degradation of both primary and back-up reactor heat sinks. During this event, the primary heat sink was not in service due to it having been valved out. Thus, the requirements of the Operating Policies and Principles were contravened.

Throughout the period when the high pressure service water system manual isolators were isolated, fuel cooling was demonstrated to be adequate. However, since the unit was not in the guaranteed shutdown state, Ontario Hydro agreed that the action taken to isolate (or throttle) the service water cooling flow via manual isolators was unacceptable because of inadequate consideration for unrequested reactor power increases.

UNIT 8 AIRLOCK 1 SERVICE DOOR LEFT OPEN

In April, while doing maintenance on the inner door of *airlock* 1 in unit 8, station staff left the outer door open. A particular step in this maintenance resulted in the inner door losing its seal and this meant that containment was breached. The staff quickly recognized the problem and the containment boundary was reestablished within two minutes.

The containment boundary is one of the barriers that protects the public from very unlikely events which could lead to a release of radioactivity. Since the boundary was quickly reestablished, public risk was very small. We, however, view this event as serious because it is an example of poor job briefing, failure to follow procedures, poor communications, and a lack of understanding of the job to be done. Ontario Hydro has put into place programs to deal with these issues and we are actively monitoring the progress.

EMERGENCY CORE COOLING SYSTEM VALVE FAILURE AND STATION SHUTDOWN

On April 15, 1996, Ontario Hydro tested two valves in the discharge line from the *emergency core cooling system* storage tank. One of the valves failed the test, and closure of that valve could not be confirmed.

On April 20, 1996, after extensive testing and investigation still could not confirm the position of the valve, Ontario Hydro began shutting down the five running units. The other three units had been shut down previously for maintenance. By the following day, all units were shut down. Inspection of the defective valve determined its failure to be caused by a bent position-indicating rod, preventing the valve from fully opening or fully reseating. We reviewed and approved a design change to correct the problem. On April 29, 1996, having completed the modifications and having tested both valves successfully, Ontario Hydro returned the valves to service.

TRITIUM RELEASE TO LAKE ONTARIO

On April 15, 1996, Ontario Hydro accidentally released a higher than normal amount of tritiated *heavy water* to Lake Ontario from unit 4. The tritiated water came from a leaking shutdown cooling system heat exchanger. Ontario Hydro estimated that 1400 curies of *tritium* had escaped before the leak could be stopped. The release amounted to about 0.07 percent of the monthly *derived emission limit* for waterborne tritium emissions for Pickering NGS-A, well below the operating target of one percent.

DRUG AND ALCOHOL EVENTS

On five separate occasions, Ontario Hydro reported finding empty bottles or cans of beer, and one empty bottle of alcohol within the radiation area. On two occasions, Ontario Hydro reported finding drug paraphernalia within the radiation areas. On one occasion, a small amount of marijuana was found. None of these events are likely to have affected reactor safety directly. However, the attitudes and behaviour which these events represent suggest a lack of respect for radiation protection and for fitness for duty on the part of the individuals involved. Management and employee representatives issued a joint communiqué to remind all Ontario Hydro staff of the expectations regarding fitness for duty, and the consequences of ignoring them.

EVENTS REPORTED TO THE AECB

In 1996, Ontario Hydro reported 177 events to us for both stations, 53 more than in 1995. PNGS-A made 112 reports and PNGS-B made 65 reports. In many cases, Ontario Hydro did not meet the time limits for reporting *reportable events*.

Errors related to human performance accounted for 81 of these reportable events, and the remaining were mainly due to component failures. As in 1994 and 1995, the many errors related to human performance were due to situations where Ontario Hydro's staff failed to follow approved procedures. Procedural compliance is important to the safe operation of a nuclear generating station.

Figures 2 and 3 show a comparison of the number of reportable events for the last five years. There has been a significant increase in the number of events related to human performance. We believe that the number of these occurrences continues to be unduly large and we expect Ontario Hydro to take actions to reduce the number. In addition, we believe that the nature of some of these events shows that workers continue to have inadequate nuclear safety awareness.

Figure 2: PNGS-A REPORTABLE EVENTS, INCLUDING THOSE COMMON TO BOTH PNGS-A AND PNGS-B (number of events vs year)

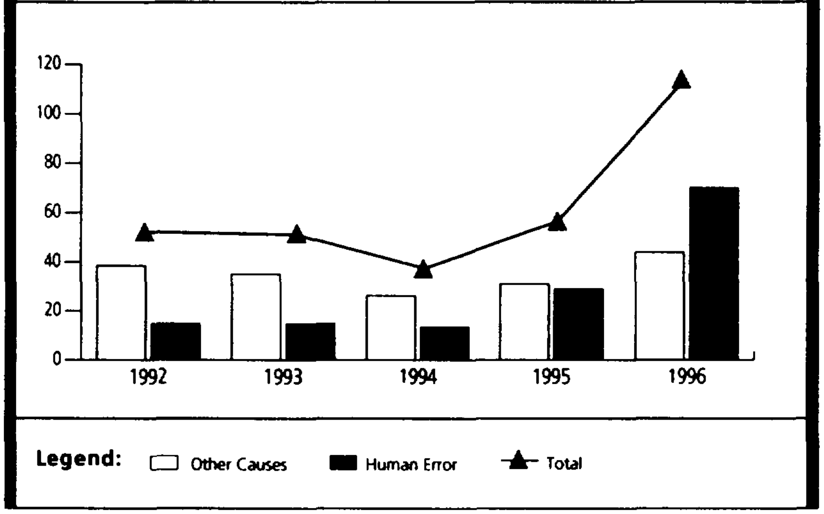
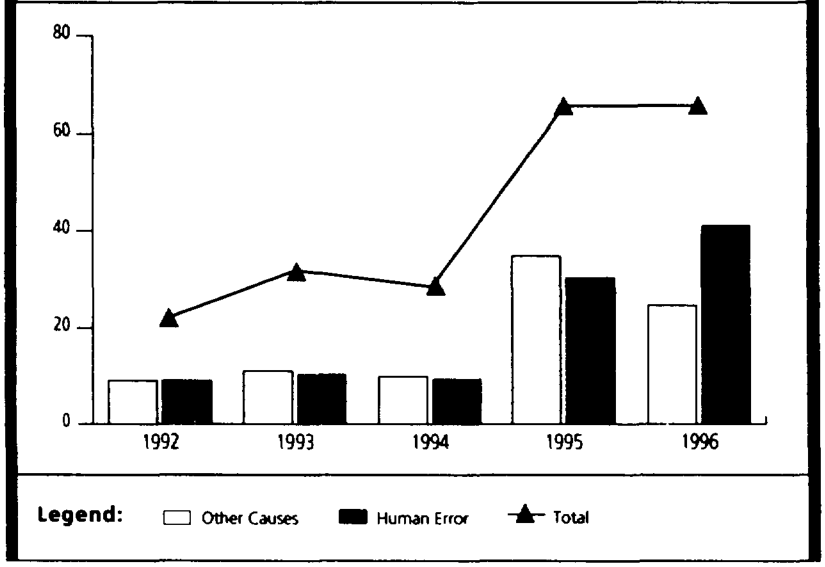


Figure 3: PNGS-B REPORTABLE EVENTS (number of events vs year)



RADIOACTIVE EFFLUENT COMPLIANCE MONITORING

In 1996, Ontario Hydro reported 23 events involving the failure of compliance monitoring of a gaseous effluent pathway. Only one event involved the failure of liquid effluent pathway monitoring. In 1995, Ontario Hydro reported a total of 26 such failures. Whereas the *availability* of liquid effluent pathway monitoring is acceptable, this is not the case for gaseous effluent pathway monitoring. Improvement will be required.

Figure 4: REACTOR TRIPS (number of trips vs year)

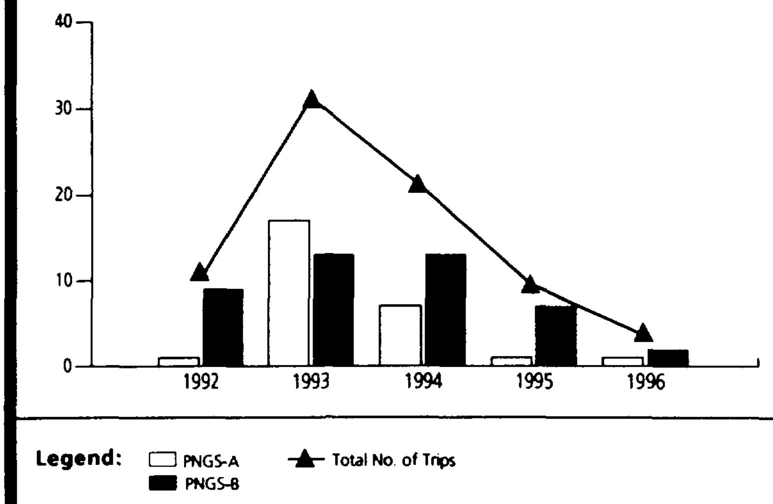


Table 1: NUMBER OF REPORTS OF FIRES FOR DIFFERENT EVENT TYPES

	1995	1996
Flames, sparks smoldering	6	11
Overheating equipment (e.g. bearings)	3	8
Alarm failure	2	12
Other (e.g. dust from grinding sets off smoke detector)	2	3

Ontario Hydro was able to estimate the quantity of radioactive material released during each period of ***unavailability*** of pathway monitoring. The impact on public safety is very small and can be verified from the data collected by Ontario Hydro's environmental monitoring program.

REACTOR TRIPS

Reactor *trips* occur in response to the detection of abnormal conditions. This is to ensure that a reactor remains within a safe operating envelope.

The number of trips from the reactor critical state in 1996 was less than in 1995. There was a total of three reactor trips from this state reported for PNGS-A and PNGS-B in 1996, four fewer than in 1995. One trip occurred at high power and the other two at low power. One trip was caused by operator error while the other two trips were due to equipment failures and abnormal unit conditions. Figure 4 shows the number of reactor trips and the trends for PNGS-A and PNGS-B since 1990.

FIRES

In 1996, Ontario Hydro staff issued 34 fire reports compared to 13 in 1995. A breakdown of the nature of the events reported is given in Table 1.

Two of these events occurred in the reactor ***main control rooms***. On April 2, 1996, smoldering cigarette butts were dumped into a garbage can that contained paper located in a designated smoking area in the PNGS-A control room. On December 29, 1996, a coffee maker was plugged into a faulty receptacle in a designated coffee area in the PNGS-B control room. Although the fires in these two events were minor and did not pose a threat to reactor safety, any fire in a control room has the potential for serious consequences.

We find this increase in fire-related events unacceptable and will ask Ontario Hydro to identify the root cause and eliminate them.

SECURITY

There were eight reportable security events in 1996. These consisted of the four reported in the previous section on Physical Security Regulations and four others. All events were minor in nature and Ontario Hydro has dealt with them.

WORKER RADIATION SAFETY

In 1996, no worker received a radiation dose above the regulatory limit of 50 millisieverts. Table 2 summarizes the ***whole body dose*** distribution at PNGS-A and PNGS-B in 1996.

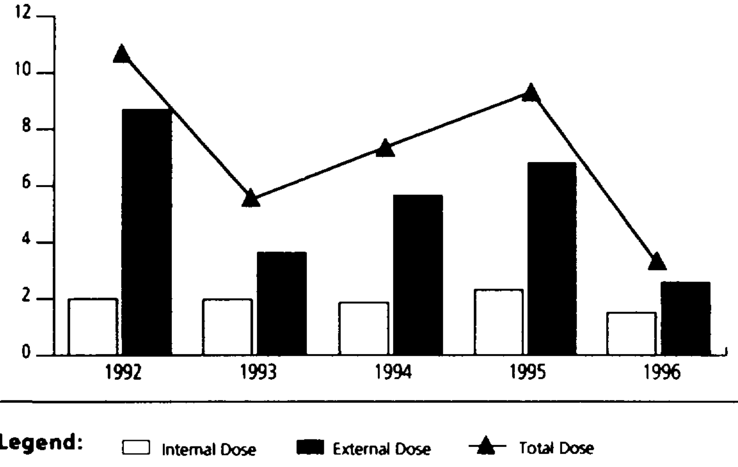
Figure 5 shows the total of whole body doses for all workers and the history over the last five years.

Table 2: SUMMARY OF WHOLE BODY DOSE DISTRIBUTION FOR EQUIVALENT CALENDAR YEAR PERIOD ENDING IN 1996

	NUMBER OF INDIVIDUALS		
DOSE (mSv)	**PNGS-A***	**PNGS-B**	**TOTAL**
No dose	1266	155	1421
< 5	1216	311	1527
> 5 to 10	164	20	184
> 10 to 15	17	0	17
> 15 to 20	8	0	8

* Includes doses for those working on both stations.

Figure 5: TOTAL WHOLE BODY DOSE FOR WORKERS (sieverts vs year)



PUBLIC RADIATION SAFETY

Ontario Hydro's control of radioactive effluent releases from the stations was satisfactory during the year. The operation of PNGS-A and PNGS-B did not result in undue radiological risk to the public or the environment.

We assess radioactive effluent releases from the stations in terms of the derived emission limits. PNGS-A and PNGS-B each operate to a target of one percent of these limits. Ontario Hydro reports the liquid releases to us monthly; the airborne releases are reported weekly. Each of the radionuclide groups has its own derived emission limit.

Table 3: MEASURES OF PNGS-A PERFORMANCE: RELEASES FROM THE STATION, ANNUAL AVERAGE IN PERCENT DEL

RADIONUCLIDE GROUP	1992	1993	1994	1995	1996
Airborne tritium	0.22	0.16	0.14	0.17	0.11
Airborne *noble gas*	0.32	0.45	0.40	0.37	0.35
Airborne *iodine*-131	<0.01	0.01	<0 .01	<0.01	<0.01
Airborne *particulates*	<0.01	<0.01	< 0.01	<0.01	<0.01
Airborne *carbon*-14	0.08	0.02	0.01	0.05	<0.01
Waterborne tritium	0.49	0.06	0.06	0.05	0.05
Waterborne *gross beta/gamma* activity	0.14	0.35	0.38	0.18	0.14

Table 4: MEASURES OF PNGS-A AND PNGS-B PERFORMANCE: RELEASES FROM THE STATIONS

NUMBER OF TIMES WEEKLY PERCENT DERIVED EMISSION LIMIT TARGET EXCEEDED	1992	1993	1994	1995	1996
Airborne tritium	0	0	0	0	0
Airborne noble gas	0	0	0	0	0
Airborne iodine-131	0	0	0	0	0
Airborne particulates	0	0	0	0	0
Airborne carbon-14	0	0	0	1*	0
NUMBER OF TIMES MONTHLY PERCENT DERIVED EMISSION LIMIT TARGET EXCEEDED	**1992**	**1993**	**1994**	**1995**	**1996**
Waterborne tritium	1*	0	0	0	0
Waterborne gross beta/gamma activity	2*	0	0	0	0

* PNGS-A only. Releases from PNGS-B were 0.

Tables 3 to 5 show a breakdown of station releases over the past five years. These tables also show the number of times the releases exceeded weekly and monthly targets. In 1996, the annual average gaseous and liquid emissions did not exceed one percent of the derived emission limits. The amount of radioactive material released from the stations was comparable to the levels released during previous years.

Ontario Hydro regularly measures the concentration of radioactive material in the environment around PNGS-A and PNGS-B. It uses this information to assess the radiation dose that people living near the stations receive from routine operation of the stations. We considered the radiological impact of the operation of PNGS-A and PNGS-B on the surrounding population to be insignificant for 1996.

During 1996, as in past years, Ontario Hydro detected very low levels above background of tritium in air, rain and snow, drinking water, milk and in local produce. It also detected very small amounts of above background *carbon*-14 in fruits, vegetables and milk from the nearby area. Table 6 summarizes the measurements for 1996 and compares them with the previous years' values.

By analyzing environmental samples, Ontario Hydro calculates the maximum annual radiation dose to members of the public at places where it expects the exposure from releases to be highest, usually at the station boundary. We call this the *critical group* dose. From PNGS-A and PNGS-B, an adult in this critical group would have received a dose of 0.0109 millisievert (mSv) during 1996. For a six-month-old child in this group, Ontario Hydro calculated the dose to be 0.0102 mSv. We judged these doses to be insignificant when compared to our legal limit of 5 mSv per year and the 2 mSv per year that people normally receive from sources other than the nuclear station.

Table 7 shows the estimated critical group doses.

Table 5: MEASURES OF PNGS-B PERFORMANCE: RELEASES FROM THE STATION, ANNUAL AVERAGE IN PERCENT DEL

RADIONUCLIDE GROUP	1992	1993	1994	1995	1996
Airborne tritium	0.07	0.07	0.07	0.05	0.06
Airborne noble gas	0.20	0.25	0.26	0.25	0.24
Airborne iodine-131	<0.01	<0.01	<0.01	<0.01	<0.01
Airborne particulates	<0.01	<0.01	<0.01	<0.01	<0.01
Waterborne tritium	0.01	<0.01	0.01	0.02	<0.01
Waterborne gross beta/gamma activity	0.01	0.05	<0.01	0.05	<0.01

Table 6: MEASURES OF PICKERING NGS-A AND NGS-B PERFORMANCE: PUBLIC AND ENVIRONMENT DOSES

ENVIRONMENTAL MEASUREMENTS	1992	1993	1994	1995	1996
Average boundary dose rate external (Gy/hour)	4.27×10^{-8}	4.27×10^{-8}	3.93×10^{-8}	4.21×10^{-8}	4.24×10^{-8}
Average boundary tritium in air (Bq/m^3)	12	8	6.4	6.5	4.9
Average boundary tritium concentration in precipitation (Bq/L)	1080	620	650	725	460
Average boundary gross beta in precipitation and dry deposition (average over all measurement sites) (Bq/m^2/month)	27.9	24.7	21	20.9	23
Average tritium in milk (Bq/L)	39	26	36	35	29
Average C-14 in milk (Bq/kg carbon)	429	422	445	408	350
Average I-131 in milk (Bq/L)	<0.15	< 0.13	< 0.14	0.19	< 0.21
Average tritium in drinking water at the Ajax water supply plant (Bq/L)	27	16	15	18	20
Average gross beta/gamma in drinking water at the Ajax water supply plant (Bq/L)	0.11	0.12	0.12	0.10	0.11

Table 7: MEASURES OF PICKERING NGS-A AND NGS-B PERFORMANCE: CRITICAL GROUP DOSE

ESTIMATED DOSE TO CRITICAL GROUP (mSv)	1992	1993	1994	1995	1996
Infant	0.0224	0.0152	0.0137	0.0113	0.0102
Adult	0.0231	0.0157	0.0141	0.0118	0.0109

SAFETY SYSTEM PERFORMANCE

With the exception of the emergency core cooling system (ECCS) on unit 4, all the special safety systems for PNGS-A and PNGS-B performed within their target. The effectiveness of the ECCS on unit 4 was reduced for 84.3 hours due to failure of a valve to open.

Each unit in PNGS-A has three special safety systems:

- *shutdown system* (SDS);
- emergency core cooling system (ECCS); and
- *containment* system.

We require the emergency core cooling system and the containment system to be fully available 99.7 percent of the time. To meet this requirement, these systems can only be unavailable for 26.4 hours a year. The shutdown system is required to be fully available 99.9 percent of the time. To meet this requirement, the system can only be unavailable for 8.8 hours a year.

Ontario Hydro measures both how well special safety systems have performed in the past and predicts how they are expected to perform in the future. This is done on the basis of actual operating experience and on tests performed on the systems and components. The results are expressed as actual past unavailability and *predicted future unavailability*. Small actual past unavailability and predicted future unavailability numbers that are less than our requirements shows good performance of the system.

Predictions of future unavailability are important because they give insights into the reliability with which the systems can be expected to perform in the future.

Each unit in PNGS-B has four special safety systems:

- *shutdown system one* (SDS1);
- *shutdown system two* (SDS2);
- emergency core cooling system; and
- containment system.

We require each system to be fully available 99.9 percent of the time. To meet this requirement, a special safety system can only be unavailable for 8.8 hours a year.

Tables 8 and 9 show the actual past unavailability and predicted future unavailability of the PNGS-A and PNGS-B special safety systems. The predicted future unavailability for all systems is within our requirements.

[Tables 8 and 9]

SHUTDOWN SYSTEM ENHANCEMENT

As ordered by the AECB, Ontario Hydro continues to upgrade the shutdown capability and reliability for the PNGS-A reactors. The PNGS-A operating licence requires all four reactors to have the enhancement system installed and available by the end of 1997. If this target is not met, any reactor that does not have the change completed must be shut down.

Design work for the lead unit (unit 4) was essentially completed in 1996. Installation of the shutdown system enhancement (SDSE) is in progress within the constraints of available resources. Major work on the lead unit included installation of the new instrument panel in the main control room, reactor building penetrations and platforms. Installation of electrical work and the instrument room are nearing completion. The new instrument panel has been installed in the *simulator.*

Ontario Hydro staff has completed most of the preliminary safety analyses to demonstrate that the *trip coverages* for SDSE for most postulated events are at least equally effective as those provided by the existing shutdown system for the same *trip parameters*. These preliminary analyses include: large and small *loss of coolant accidents*, loss of *moderator*, loss of pressure control, feedwater and steam line failures, and loss of *class* IV *power*. We have completed the review of these preliminary analyses and found that they are adequate. We have, however, identified a number of necessary improvements which must be incorporated into the final analyses.

Table 8: PNGS-A SPECIAL SAFETY SYSTEM UNAVAILABILITY

SPECIAL SAFETY SYSTEM		ACTUAL PAST UNAVAILABILITY (hours/year)	PREDICTED FUTURE UNAVAILABILITY (hours/year)	SYSTEM TARGET UNAVAILABILITY (hours/year)
SDS	units 1-4	0	5.0	< 8.8
ECCS	unit 1	0	24.0	< 26.4
	unit 2	0	24.0	< 26.4
	unit 3	0	24.0	< 26.4
	unit 4	84.3	24.0	< 26.4
Containment	units 1-4	0	13.2	< 26.4

Table 9: PNGS-B SPECIAL SAFETY SYSTEM UNAVAILABILITY

SPECIAL SAFETY SYSTEM		ACTUAL PAST UNAVAILABILITY (hours/year)	PREDICTED FUTURE UNAVAILABILITY (hours/year)	SYSTEM TARGET UNAVAILABILITY (hours/year)
SDS1	units 5-8	0	3.6	< 8.8
SDS2	unit 5	0	5.2	< 8.8
SDS2	units 6-8	0	6.7	< 8.8
ECCS	units 5-8	0	8.3	< 8.8
Containment	units 5-8	0.03	8.3	< 8.8

IN-CORE REGIONAL OVERPOWER DETECTORS

In 1996, the 34 vertical in-core regional overpower detectors for the unit 6 SDS1 *regional overpower trip* protection parameter were replaced and successfully commissioned. Similarly, the 23 horizontal in-core regional overpower detectors for the unit 6 SDS2 trip parameter were replaced and successfully commissioned.

OPERATIONS AND MAINTENANCE

PREVENTIVE MAINTENANCE AND CALL-UPS

A good *preventive maintenance* program is essential to the safe operation of the station. Proper preventive maintenance on plant equipment will minimize or eliminate equipment breakdown. Ontario Hydro has taken steps toward better management of maintenance. Ontario Hydro staff tracks station performance by recording the ratio of preventive maintenance completed to the total maintenance completed during the same period.

The goal of Ontario Hydro is to attain a 70 percent ratio by the year 2000. In 1996, the operating preventive maintenance ratio at PNGS-A and PNGS-B was still at the same level of 22 percent attained in 1995. Ontario Hydro still requires much improvement in this area.

MAINTENANCE PROGRAM

The maintenance program is documented in station reference plans. Recently Ontario Hydro issued documents to improve the activities related to maintenance. These documents contain the details necessary to meet the performance objectives and criteria established by Ontario Hydro for the maintenance of nuclear power plants. The issuance of these documents is a positive step to achieve a better performance for plant maintenance.

JUMPERS

The total number of *jumpers* at the stations went up by approximately 25 percent in 1996. An increase in the number of jumpers for PNGS-B was significant compared to a slight decrease in number for PNGS-A. At the end of 1996, there were still three units on *outage*. Ontario Hydro staff uses jumpers to record temporary changes. Therefore, we expect to see an increase in the number of jumpers when units are shut down, as jumpers are used to record and authorize temporary conditions which are required during maintenance. These jumpers should be removed after the outage and before the unit returns to power. For safety reasons, it is important to keep the number of outstanding jumpers low.

Figure 6 shows the total number of jumpers that is active for more than six months in 1990 to 1996. The figure shows that the number increased to 1043 in 1996 from 827 in 1995. Table 10 gives the 1996 distribution of jumpers associated with special safety systems, *safety support systems* and *safety-related systems*, and other systems for both PNGS-A and PNGS-B.

PROCESS SYSTEMS

There were no *serious process failures* in either PNGS-A or PNGS-B during 1996.

CHEMISTRY

The PNGS-A station Chemistry Performance Index averaged 93.6 percent in 1996 as compared to 93 percent in 1995. This is above the Ontario Hydro standard of 90 percent. PNGS-A has been successful in exceeding its self-imposed yearly targets since 1990. Maintaining good chemistry control is important for worker and public safety, and for station reliability.

Chemistry control at PNGS-B also maintained its level through 1996. PNGS-B achieved an average total Chemistry Performance Index of 95 percent in 1996, as in 1995. This is better than the station target of 93 percent.

STEAM GENERATOR MAINTENANCE

During the month of December, water lancing was done in the PNGS-B unit 8 *steam generators*. Steam generator inspections and evaluation of the water lancing effectiveness will be done in early 1997.

PNGS-A AND PNGS-B COMMON SYSTEMS - MAINTENANCE OF THE EMERGENCY CORE COOLING SYSTEM

The repair of a defective testable emergency core cooling system (ECCS) valve in April 1996 required isolation of the ECCS storage tank, and the shutdown of all units operating at the time. In light of this event, we asked Ontario Hydro to review the design and operation of ECCS to identify potential improvements to the reliability and maintainability of the system. We also asked Ontario Hydro to affirm the adequacy of the system to meet the requirements for independence and separation between ECCS and the containment system.

Ontario Hydro informed us in December 1996 that some improvements could be made to ECCS, but the results of this review had not revealed deficiencies in the current design which would impact on safe operation of the stations. We are expecting a final report from Ontario Hydro in 1997 on its findings and its proposals for improving the system.

COMPLIANCE INSPECTIONS

In March-April 1996, we conducted an intensive inspection of all plant areas. We presented our general findings to Ontario Hydro staff and these prompted them to make improvements in housekeeping, material condition, worker attitudes, procedural compliance, configuration management and safety practices.

Some of the results of other routine inspections that we carried out prompted the licensee to take specific corrective actions, for example:

- rehabilitation of the auxiliary *irradiated fuel bay* ventilation system which we found in unsatisfactory condition;
- a comprehensive program to deal with zebra mussels that now infest Lake Ontario and the stations' service water intake;
- better procedures and practices in taking the reactor to criticality and in checking valves which are guaranteed to be in certain positions.

Figure 6: JUMPERS
(number of jumpers vs year)

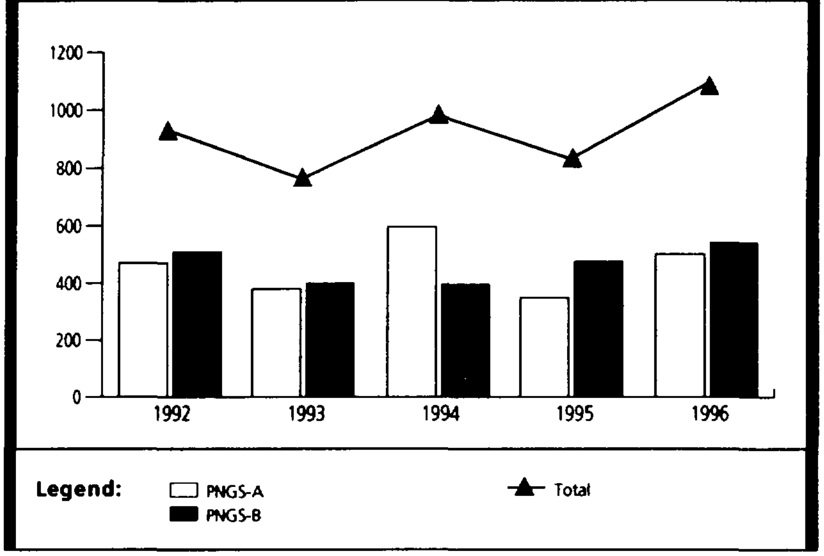


Table 10: JUMPERS ACTIVE FOR MORE THAN SIX MONTHS BY END OF 1996

SYSTEM	PNGS-A	PNGS-B
Special safety systems	22	18
Safety support and safety-related process systems	140	33
Other systems	326	504

ENHANCED ASSESSMENTS

We carried out an enhanced assessment of the radiation protection program at PNGS-A and PNGS-B between July 8 and August 30, 1996. The scope of the assessment included organization and administration, worker dose and exposure control, radiation instrumentation, radioactive contamination control, radioactive waste handling and shipping of radioactive materials.

We found aspects of the radiation protection program which were adequate or for which plans for improvement were already in place. Aspects requiring improvement included:

- controlling the spread of radioactive contamination, in particular, the control of *rubber areas*;

- ensuring that the Radiation Field Services unit has the resources to carry out its assigned responsibilities on a continuous, on-going basis;
- ensuring that radiation survey instruments are calibrated routinely, and are used according to approved station protocols and procedures.

We wrote Ontario Hydro about our findings, bringing to its attention remedial actions which we believed were necessary to improve radiation protection performance at PNGS-A and PNGS-B.

We intend to reassess the radiation protection program early in 1997 to determine the extent of improvement during the intervening period.

During the last quarter of 1996, we began enhanced assessments in seven other areas in addition to radiation rotection:

- system surveillance testing and monitoring;
- reportable event report follow up;
- nuclear safety;
- training;
- self-assessment;
- procedural compliance; and
- maintenance.

The purpose of these assessments is to determine underlying deficiencies in the stations' managed programs and processes, and to assess if the stations have adequate improvement plans in effect to remedy these. Our assessments will be completed in the first quarter of 1997, and will be used as input to our recommendation on relicensing.

STATION MANAGEMENT

Over the past few years there has been an adverse trend in operational safety at PNGS-A and PNGS-B. On December 10, 1994, a small loss of coolant accident occurred on unit 2. This identified deficiencies in both design and operations. Our 1994 Assessment Report noted many events related to human performance. In 1995 there was a substantial increase in the number of events where there was a breakdown of one or more of the multiple layers of defence.

On August 11, 1995, we requested Ontario Hydro to make rapid improvement to correct this trend. In response to our letter and recognizing the need for improvement, Ontario Hydro management developed a Quality of Work program. The initiatives in the program were established to allow Ontario Hydro to demonstrate an acceptable level of improvement in operational safety.

Early in 1996, several events occurred having operational safety significance. These raised questions whether the corrective actions taken by Ontario Hydro to correct the adverse trends seen in operational safety in 1995 were effective. We sent a letter to Ontario Hydro on April 16, 1996, questioning the effectiveness of the initiatives taken.

On April 10, 1996, and May 6, 1996, we sent letters to Ontario Hydro reporting deficiencies we found in the areas of ***housekeeping***, material condition, worker conduct, configuration management, procedural compliance, tagging, and radiation and conventional safety.

On April 21, 1996, all eight PNGS-A and PNGS-B units were shut down to repair and modify emergency core cooling system valves. Before restart of the units, Ontario Hydro initiated a restart strategy. The strategy focused on maintaining the safety and reliability of the operating units while continuing to improve unit condition by reducing maintenance and procedure backlogs, improving housekeeping and material condition and improving quality of operations and maintenance with better pre-job briefing procedural compliance, operator rounds and surveillance. Ontario Hydro's priorities were on the safe operation of the units and additional units were restarted only when it was satisfied and when resources could be committed. This restart strategy was acceptable to us. Shortly after this a new Director and a new Operations Manager were appointed. Funding and resource support from the Ontario Hydro corporate level was increased. In addition, a technical advisory panel on nuclear safety, reporting directly to the Ontario Hydro Board of Directors reviewed PNGS-A and PNGS-B operational safety. Its findings were much similar to ours. We are encouraged with these recent changes made both to the PNGS-A and PNGS-B organization and in operational safety.

In 1996, Ontario Hydro embarked on a corporate-wide recovery plan for improving the safety and reliability of nuclear generation within Ontario Hydro. At PNGS-A and PNGS-B changes occurred in station management and programs. Ontario Hydro management adopted a strategy for maintaining the safety and reliability of running units while improving their condition by continually reducing outstanding maintenance work.

Ontario Hydro also adjusted the Quality of Work program which was introduced in 1995 to address the need for improvement.

Ontario Hydro is continuing to make progress on the short-term improvements to operational safety, such as housekeeping, procedural compliance and rigour in work assignment. Many areas of the station have been painted and areas have been made tidier. Some refurbishing of equipment is in progress such as pump and valve refurbishing, new insulation installed and leaks repaired.

Improvements to procedural compliance and rigour in work are more difficult to assess as training has not yet been given to all work groups. There is still a larger number of reportable events than we would like occurring because of not following procedures.

The longer term improvements which deal with enhancement to the managed processes, such as surveillance monitoring, configuration management issues and training are still in the process of being developed or are in the early stages of implementation. These improvements are required for continued and sustained improvement. We will assess progress on these managed processes over the first few months in 1997.

Recently, we noted that two new departments, Outage Maintenance and Operations Integration, are being established. This should

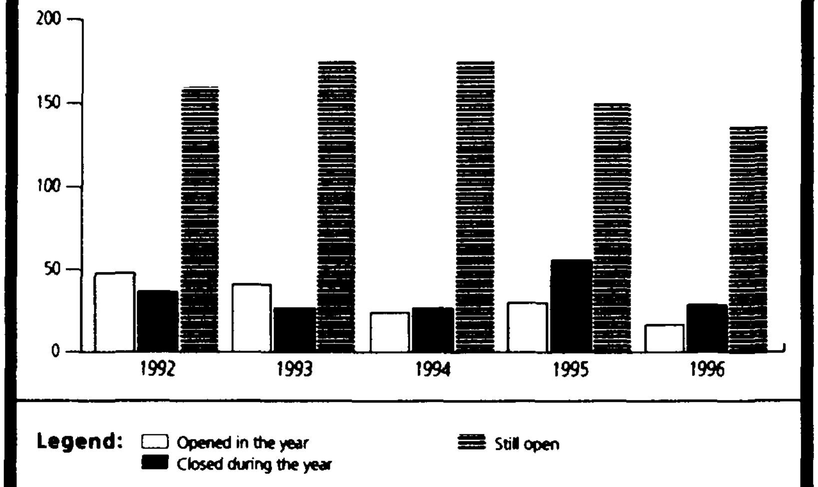


Figure 7: NUMBER OF FORMAL REQUESTS FOR ACTION OPENED, CLOSED AND STILL OPEN (number of requests vs year)

improve the resource coordination, planning, scheduling, work control and execution for outage maintenance and plant operation.

FORMAL REQUESTS FOR ACTION AND COMMITMENT

During the reporting period, we raised 16 formal requests for action. Of the 166 requests outstanding, Ontario Hydro completed work on 26. Thus, at the end of 1996, there were 140 open formal requests for action, which is 10 fewer than in 1995. Due to the variation in complexity of each request, we do not measure station performance on the number completed. However, it is important to keep the number of outstanding formal requests for action low to ensure that as few as possible safety-related issues remain unresolved.

Figure 7 shows the number of formal requests for action opened, closed and outstanding for the years 1993 to 1996. To resolve the backlog of AECB formal requests for action, in 1995, Ontario Hydro Nuclear Safety Department began a program to reduce the number of outstanding issues. The program has worked well and is still in effect.

TRAINING

During 1996, three training program evaluations were conducted at PNGS-A and PNGS-B. The evaluation of continuing training for ***authorized staff*** found that substantial training and re-qualification testing is taking place at the simulator. The re-qualification testing method used for the ***shift supervisors*** was judged by us to be not adequate and we advised them accordingly. The contingency strike training activities that were conducted in early 1996 were found to be satisfactory. The revised radiation protection training program comprised some good improvements but some uncertainties with the skills and refresher training need to be addressed.

EMERGENCY PREPAREDNESS

RADIATION EMERGENCY PREPAREDNESS DRILLS AT PNGS-A AND PNGS-B

Ontario Hydro performed fewer radiation emergency drills in 1996 compared to 1995. Ontario Hydro attributed this to vacancies created by the transfer and promotion of staff responsible for radiation emergency drills. We believe that the current staffing of the emergency preparedness unit is inadequate to handle the number of drills and exercises required by the newly proposed Ontario Hydro emergency drill and exercise policy. Events in 1996 indicate a need to revise current emergency procedures and to train personnel on these revisions. No deficiencies were observed when we evaluated a station drill in 1996.

STATION FIRE EMERGENCY EXERCISES

The station showed a commitment to station fire emergency training as all crews did two formally evaluated fire drills in 1996. Ontario Hydro requires only that each crew do one formally evaluated fire drill per year.

SECURITY EXERCISES

The security force at PNGS-A and PNGS-B did not schedule a major security exercise during 1996. It did, however, conduct a number of security drills as a method to validate the contingency plans and to test its capability to effectively deal with emergency situations.

SAFETY ANALYSIS

As stated in the operating licences, Ontario Hydro must review and update the *safety reports* according to a schedule we approve. This is to show that the stations continue to meet our safety requirements. In 1996 Ontario Hydro submitted several safety analyses, and proposals for change. We assessed these safety analyses and proposed changes. Given below is a summary of the results and status of our assessment.

BLEED CONDENSER RELIEF VALVES

The malfunction of *bleed condenser* relief valves following an overpressure transient in the *primary heat transport system* may result in a loss of coolant accident. In 1996, Ontario Hydro submitted the results of the bleed condenser relief valve test program for PNGS-B. The testing showed that one of the present valves could be unstable, either fluttering or chattering. A possible cause was the test facility itself, which has a long inlet line to the valve, as our calculations indicated that the reactor layout would be more stable than the test rig. Ontario Hydro is planning to replace the existing valves with ones which have been shown by testing to be stable and more consistent in operation. Prior to installation of these valves, we will review and approve the valve capacity certification testing and piping system design. Until the valves are replaced, operation with the existing valves carries some risk. But, we judged the risk to be very small for the following reasons:

- Operation of the bleed condenser relief valves is a remote event.
- Overpressure protection is not compromised.
- Valve chattering may not occur on the reactor with existing piping.
- Tests assure that, even after chattering, valve leakage will be small.
- Small loss of coolant analysis has addressed the worst consequence of valve leakage.

BOILER DIVIDER PLATES

In 1994, Ontario Hydro notified us of a deficiency in the safety analysis for PNGS-A and PNGS-B. The analysis assumed that the *divider plates* in the steam generators would stay intact following piping ruptures in the primary heat transport system. The divider plates separate the inlet and outlet chambers in each steam generator. They must normally resist a pressure of only a few atmospheres between inlet and outlet. But, Ontario Hydro discovered that large pipe breaks might produce pressure surges that could exceed the divider plates' strength. As a result, the consequence of a large primary heat transport pipe failure may be greater than that documented in the safety report.

Since then, Ontario Hydro has discussed with us how to predict the outcome of pipe failures. In 1996, Ontario Hydro submitted its analysis of the divider plates at PNGS-A and PNGS-B. This analysis confirmed that some large pipe breaks would cause divider plate failures. Such failures, however, do not affect the consequences of large pipe breaks as presented in the safety report. Divider plate failures do affect the analysis of smaller breaks where the steam generators are assumed to act as heat sinks. Ontario Hydro claims the divider plates will survive such breaks. We expect Ontario Hydro to submit more analysis to support its case.

SEISMIC MARGIN ASSESSMENT

Since 1994, Ontario Hydro has committed to conducting a seismic margin assessment for PNGS-A. The assessment is to identify the improvements to plant systems for ensuring that the risk due to seismic events is acceptable. In October 1996, Ontario Hydro issued an interim report. The work remaining is to evaluate the adequacy of the selected systems and components which are needed to perform safety-related functions after an earthquake. Ontario Hydro has committed to complete this assessment by May 1997. We will monitor the progress.

QUALITY ASSURANCE

Over May 21-23, 1996, we did a follow up to our 1995 *quality assurance* audit on the first batch of 42 *dry storage* containers. We advised Ontario Hydro that its change control, document control, verification and surveillance practices require review.

In August 1996, we and the Ministry of Consumer and Commercial Relations staff conducted a joint audit at both PNGS-A and PNGS-B to evaluate the effectiveness of the design process.

The audit revealed deficiencies in the design quality assurance program. The design authority responsibilities had not been identified. Neither had the design process been properly described.

SAFEGUARDS

Ontario Hydro at PNGS-A and PNGS-B provided excellent cooperation and support to the AECB and the *International Atomic Energy Agency* (IAEA). Reports and notifications of activities involving *safeguards* were provided in a timely manner, as required by the licences.

Canada is a signatory of the *Treaty on the Non-Proliferation of Nuclear Weapons*. Pursuant to the Treaty, Canada has entered into a safeguards agreement with the IAEA. This agreement gives 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.

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

During 1996, the IAEA successfully verified all transfers of irradiated fuel to the dry storage facility.

CONCLUSIONS

The Pickering Nuclear Generating Stations (PNGS-A and PNGS-B) operated safety during 1996. Although the risk to the workers and the public was low, we believe that improvements to operational safety and reactor maintenance of both PNGS-A and PNGS-B are required.

In 1996, Ontario Hydro maintained good performance in the following areas:

- compliance with the Physical Security Regulations and maintenance of a high level of security reliability;
- compliance with the AECB Cost Recovery Fees Regulations;
- availability of the special safety systems;
- no serious process failures;
- chemistry control; and
- International Atomic Energy Agency safeguards support.

Areas where improvements are needed include:

- station and radiation emergency drills;
- compliance with the Atomic Energy Control Regulations;
- compliance with the conditions of the operating licences;
- compliance with the Transportation Packaging of Radioactive Materials Regulations;
- reducing the errors related to human performance and procedural compliance;
- nuclear safety, supervision and management issues;
- radiation contamination awareness;
- compliance with the time limits for reporting events;
- airborne radioactive effluent compliance monitoring;
- preventive maintenance and call-up performance;
- reducing the number of jumpers;
- completing outstanding causal factors analyses and follow-up actions;
- training of field operators;
- material state of equipment; and
- reducing the number of fire-related events.

Many of these areas where improvements are needed were also reported in our 1995 Annual Assessment. We expect Ontario Hydro to continue to implement the improvement plans identified in the Quality of Work program and to make significant progress in all these areas in 1997. In 1996, we noted some improvement, but progress is slow and much remains to be done.

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GLOSSARY

AECB Cost Recovery Fees Regulations	Regulations made pursuant to the *Atomic Energy Control Act* by the *Atomic Energy Control Board* which set out the fees for licences and approvals issued for nuclear facilities and activities.
airlock	The means of access to and from the ***reactor building***. There are two doors on each airlock, an inner door and an outer door. Automatic controls ensure that only one door is open at a time so that ***containment*** is always sealed.
annulus gas system	A continuously circulating system of carbon dioxide gas in the spaces between the ***pressure tubes*** and ***calandria tubes***. It thermally insulates the tubes from each other and permits early detection of tube leaks.
Atomic Energy Control Act	The federal act that established the *Atomic Energy Control Board* and allows it to regulate the nuclear industry in Canada.
Atomic Energy Control Board (AECB)	The federal nuclear regulatory agency established in 1946 by the *Atomic Energy Control Act*. The AECB controls the development, application and use of nuclear energy in Canada and participates for Canada in international measures of control. The AECB reports to Parliament through the Minister of Natural Resources.
Atomic Energy Control Regulations	Regulations made pursuant to the *Atomic Energy Control Act* by the *Atomic Energy Control Board*.
audit	Verification and evaluation of a document, process or work related to station operation.
authorized staff	Licensee staff who the *Atomic Energy Control Board* has licensed or approved for specific positions at the station.
availability	The percentage of time a piece of equipment is able to perform its designated function.

bleed condenser	Equipment that reduces pressure and temperature of *heavy water* before passing it through the *ion exchange system* to storage.
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.
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.
carbon-14	A radioactive isotope of carbon produced in some reactor systems.
class IV power supply	The electrical power supplied to auxiliaries and equipment that can tolerate long interruptions without endangering personnel or station equipment.
condenser	Equipment that condenses the steam leaving the *turbines* into water for return to the *steam generators*.
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 room operator	A person responsible for operating the reactor controls. A control room operator needs authorization from the *Atomic Energy Control Board* before acting in this position.
core	The heart of a reactor containing the fuel, the *heavy water* coolant and the heavy water *moderator*. It also includes various sensing and control devices.

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*.
derived emission limit (DEL)	A calculated amount of radioactivity that, if released from the station, would result in a radiation dose of five *millisieverts* to a member of the public in the worst possible case. Five millisieverts is the maximum annual radiation dose allowed for members of the public by the *Atomic Energy Control Regulations*. The calculation is done by examining the effect of the radioactivity on a theoretical person who lives full time at the station boundary, eats only food harvested locally, and drinks only water from the station's discharges. This theoretical individual is known as the "critical individual".
divider plates	Plates are situated in the bottom portion of the *steam generators* to keep the *primary heat transport system* heavy water inlet and outlet areas separate.
dose	Generally, the quantity of radiation energy absorbed by a body.
dry storage	A method of storage for irradiated fuel. Concrete containers are used to store the *fuel bundles* and to prevent the spread of radioactive material. Prior to dry storage, the fuel bundles cool in the *irradiated fuel bay*. The licensee can only use containers to store fuel when air cooling can safely remove any remaining *decay heat*.
emergency core cooling system	An automatic system that injects cold water into the reactor's *fuel channels* if there is a problem with the normal coolant system. It also provides long-term cooling for the fuel by recovering water from the *reactor building* floor.
emergency service 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.
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.
guaranteed shutdown state	A method for ensuring that the reactor is shut down. It includes adding *poison* to the moderator or draining the *moderator* from the reactor.
heat exchanger	Equipment that transfers heat between systems.

heat sink	Any system used to dissipate the heat produced in the fuel. At all times a main heat sink must be in service, normally the ***steam generators***, and an alternative or backup heat sink must be available. Failure to dissipate the heat produced in the fuel by means of an adequate heat sink can increase the temperature of the fuel and thereby damage it.
heavy water (D_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.
housekeeping	The act of keeping a station neat and tidy, with equipment and components stored properly.
interlock	A connection between pieces of equipment that ensures that they cannot be operated unsafely.
International Atomic Energy Agency (IAEA)	A United Nations agency. It provides a system of ***safeguards*** to make sure that states do not divert nuclear materials to non-peaceful activities. It also provides an international forum for nuclear safety.
iodine 131	A radioactive isotope of iodine produced in the fuel when the reactor is operating.
ion chamber	An instrument that detects and measures ionizing radiation. It does so by measuring the electrical current that flows when radiation ionizes gas in a chamber, making the gas a conductor of the electricity.
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.
neutron flux	A measure of the fission power in the reactor.
noble gases	Gases produced in the reactor fuel when the reactor is operating. They are radioactive and decay to produce *particulates*, some of which are also radioactive.
nuclear generating station	A facility comprised of a single or multi (usually four) reactor units. Each unit converts the fission energy released in the reactor to electrical energy.
Operating Policies and Principles (OP&P)	A licensee document, approved by the *Atomic Energy Control Board*, that outlines the safe operating limits for the station. It also defines which staff have the authority to make decisions on safety matters.
outage (forced, planned)	The time during which a reactor is not delivering power to the *grid*. Outages may be forced, by equipment malfunction, for example, or planned to carry out routine maintenance.
particulate	Any radioactive material that is in solid particle (e.g. dust) form.
Physical Security Regulations	Regulations issued pursuant to the *Atomic Energy Control Act* by the *Atomic Energy Control Board* which set out the required security standards at nuclear facilities.

poison	A substance which absorbs neutrons and hence removes them from the fission chain reaction.
predicted future unavailability	A measure of how well a *special safety system* can be expected to perform in the future. A mathematical model of the system and statistics of faults affecting the system are used to derive a theoretical prediction of the expected frequency of system failure.
pressure boundary	Pressure-retaining equipment or components of a system that contain a pressurized material such as *heavy water* coolant or steam.
pressure tubes	Tubes that pass through the *calandria* and contain 12 or 13 *fuel bundles*. Pressurized *heavy water* flows through the tubes, cooling the fuel. They form part of the *pressure boundary* for the *primary heat transport system*.
preventive maintenance	Also known as call-up. A routine maintenance item or performance check completed at regular intervals.
primary heat transport system	A closed cooling circuit that carries heat produced in the *fuel bundles* to the *steam generators*. It does this by circulating *heavy water* at high pressure through the *fuel channels* and the steam generator tubes.
process failure	Failure of a *process system*.
process system	Any of the reactor's systems which are used in the process of turning nuclear fission energy into electricity. This distinguishes them from safety systems which are incorporated only to protect the reactor.
quality assurance	A formal program of standards, procedures and checks controlling the quality of work on the station.
Radiation Protection Regulations	Regulations the licensee issues that state the radiation protection standards to be met at a station. These regulations require approval by the *Atomic Energy Control Board*.
reactor building	A reinforced-concrete building which serves as a support and an enclosure for the reactor and some of its associated equipment.

reactor regulating system	A system that controls reactor power. It monitors *neutron flux* shape and important operating parameters so that power may be reduced if any parameter is outside specific limits.
regional overpower trip	Also known as neutron overpower trip. A system that will shut the reactor down if it detects high neutron power anywhere in the reactor.
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.
rubber area	A specially prepared area of the floor in the station where it is foreseen that there will be loose radioactive *contamination*. Its purpose is to contain the contamination and not let it spread. Persons entering put on rubber overshoes before stepping into the area, and remove them when leaving.
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 service water system* and the *standby generators*.
safety-related systems	A system required for the successful operation of safety systems. Such systems include the various classes of electrical power, plus instrument air and service water supplies.

safety report	A licensee document that describes the design of the station. It also describes the safety analysis completed to show that the risk of operating the station is acceptably low.
serious process failure	A failure in the station's components or systems, which is sufficiently serious that one or more of the *special safety systems* must operate to prevent reactor damage.
setpoint	The value of a parameter at which a safety system operates, as required by the reactor operating conditions.
shift supervisor	The technical expert who manages a shift, ensuring that the station meets all safety requirements. A shift supervisor requires approval of the *Atomic Energy Control Board* before acting in the position.
shutdown cooling system	A collection of equipment that cools the *fuel bundles* to remove *decay heat* after a normal reactor shutdown.
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.
trip coverage	The measure of how well the *trips* protect the reactor against specific potential accidents.
trip parameter	A property (e.g. temperature, pressure) of a system that is continuously measured and compared with a limiting value (trip *setpoint*). If it reaches the trip setpoint, it activates a *shutdown system*.

tritium	A radioactive isotope of hydrogen that is produced in the reactor's *heavy water* during operation.
turbines	Equipment comprising several bladed wheels that rotate when steam from the *steam generators* flows through them. The kinetic energy of the steam converts into mechanical energy that turns the rotor of an electrical *generator*, producing electricity.
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.
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.