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AECB STAFF REVIEW OF PICKERING NGS OPERATIONS FOR THE YEAR 1988

by

AECB STAFF

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

P.O. Box 1046
Ottawa, Canada
K1P 5S9

C.P. 1046
Ottawa, Canada
K1P 5S9

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May 1989

Canada

Report

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1. INTRODUCTION

The operation of Pickering NGS-A Units 1-4 and Pickering NGS-B Units 5-8 are monitored to ensure compliance with licensing requirements by the AECB Pickering project office staff.

This report presents AECB staff's review of major licensing issues and of the operational performance of Pickering NGS during 1988. The report is limited to those aspects that AECB staff considers to have particular safety significance. More detailed information on routine performance is contained in Ontario Hydro's 1988 Quarterly Technical Reports for Pickering NGS-A and Pickering NGS-B.

2. STATION OPERATION - PICKERING NGS-A AND -B

During 1988, the following capacity factors were achieved:

Unit 1:	88%	Unit 5:	97%
Unit 2:	13%	Unit 6:	99%
Unit 3:	84%	Unit 7:	96%
Unit 4:	70%	Unit 8:	82%

For Pickering NGS-A, the station net capacity factor for 1988 was 64% compared to the overall lifetime capacity factor of 69%.

For Pickering NGS-B, the station net capacity factor for 1988 was 93% compared to the overall lifetime capacity factor of 86%.

Unit 2 resumed operation for the first time since the August 1983, rupture of pressure tube G16. Following the replacement of all pressure tubes, and the completion of upgrade work and recommissioning, the unit achieved criticality on 27 June 1988.

A number of pressure tubes were inspected in Unit 3 during a shutdown in March and April 1988. Unit 4 was shut down in November and remained shut down at year end for upgrade work involving installation of high pressure emergency core cooling (HPECC), modifications to the containment system (new rupture panels) conversion of ten adjuster rods to shut-off rods, improvements to the annunciation system, and inspection of pressure tubes.

In March 1988, Ontario Hydro announced its intention to replace the pressure tubes in Units 3 and 4 beginning in 1989 and 1991, respectively, instead of the late 1990's as originally planned. This decision was, in part, based on finding higher than expected levels of deuterium in the pressure tubes of Units 3 and 4 inspected in 1987.

In September 1988, Ontario Hydro initiated a program for demonstrating the concept of dry storage of spent fuel above ground at Pickering NGS. Four standard fuel modules containing a total of 384 bundles of 10-year old fuel were loaded into a single Concrete Integrated Container (CIC) and shipped to the dry storage yard in November. The fuel is to be returned to the Auxiliary Irradiated Fuel Bay after two years of field monitoring and testing.

3. AECB STAFF REVIEW OF OPERATION SAFETY ASPECTS

3.1 Operation Common to Pickering NGS-A and Pickering NGS-B

3.1.1 Station Compliance with Operating Licenses

In 1988, both Pickering NGS-A and -B licences were renewed for a period of two years. The licence for Pickering NGS-A was renewed, effective 1 August 1988, and the Pickering NGS-B licence was renewed, effective 1 October 1988.

During 1988, there were seven violations of the operating licence (four of which were violations of the Operating Policies and Principles), one violation of the Security Regulations and one violation of the Transport Packaging of Radioactive Materials and Regulations. These are listed in Appendix D.

AECB staff investigation these violations has indicated that working level Ontario Hydro staff does not appear to have an adequate understanding of the conditions and requirements of the licences and regulations. Also, Ontario Hydro does not appear to have a program in place to monitor compliance with the licences and regulations. The AECB staff considers that specific actions must be taken to correct this situation and has so informed Ontario Hydro. The AECB staff will pursue this matter with Ontario Hydro in 1989.

3.1.2 Quarterly Reports

Ontario Hydro submits technical reports on a quarterly basis, which together summarize station operation for the year. During 1988, these were submitted in a timely manner. The reports have been reviewed by the AECB staff and, in general, were found to accurately reflect station operation for 1988. AECB staff comments on specific topics are given in the following sections of this report.

3.1.3 Radiation Protection

No individuals received doses exceeding the regulatory dose limits in 1988. Total whole body doses for all workers at Pickering NGS was 7.46 Sv, significantly lower than the previous year's total of 9.51 Sv. The whole body dose distribution for 1988 may be summarized as follows:

Dose (mSv) (Annual whole body dose limit = 50mSv)	Number of Individuals		
	Pickering NGS-A*	Pickering NGS-B	Total
No dose assigned	487	61	548
<5	513	255	768
5 to 10	155	79	234
10 to 15	109	13	122
15 to 20	66	3	69
20 to 25	6	0	6
25 to 30	3	0	3

*(Doses for those individuals working on both stations are reported under Pickering NGS-A.)

In April, Ontario Hydro submitted the document entitled 'Standard Program for the Assessment of Intakes for Insoluble Carbon-14 Particulates'. AECB staff review was completed, and approval to use the proposed bioassay and dose evaluation methods was granted in September. It is expected that Ontario Hydro will begin to assign lung doses to those individuals who were exposed to carbon-14 particulates in the past years.

3.1.4 Station Effluents and Environmental Monitoring

3.1.4.1 Effluent Release

No major events leading to large unplanned emissions of radioactive material occurred during 1988.

There was one occasion, during 1988, where airborne tritium releases exceeded 1% of the weekly emission limit. This was due to a spill of heavy water in the reactor auxiliary bay on 14 August (see Appendix C). Except for this, the gaseous emissions via monitored pathways for tritium, iodine-131, particulates, noble gases and carbon-14 were all less than 1% of the Derived Emission Limits (DEL) for each group.

The liquid emissions for tritium and for gross beta-gamma were similarly less than 1% of the DEL's.

At Pickering NGS-A, the reliability of both liquid and gaseous effluent monitoring has deteriorated significantly. AECB staff will be monitoring Ontario Hydro's work program to improve the situation.

At Pickering NGS-B, there has been a definite improvement in liquid effluent monitoring reliability over the previous year.

3.1.4.2 Environmental Monitoring

Environmental surveillance data in the vicinity of Pickering NGS are collected routinely by Ontario Hydro and analyzed to determine the levels of radioactive materials in the environment due to the operation of the station, and to assess the radiation dose to the public from such operation.

During 1988 tritium was detected in concentrations statistically greater than background in air, precipitation, drinking water, milk and local produce. Carbon-14 was also detected above background in food, vegetation and in milk from the surrounding area.

The resulting dose to a member of the critical group, a 6-month old infant, was assessed to be 47 uSv, which is less than 1% of the regulatory limit. The collective dose from airborne emissions was assessed to be about 1.1 person Sv; the collective dose from tritium in drinking water was about 0.39 person Sv. The doses for 1988 were slightly lower than for 1987.

AECB staff considers the results of the environmental monitoring program to be acceptable.

3.1.5 Quality Assurance Audits and Health Physics Appraisals

An audit of the Pickering NGS Operations QA Program was carried out by AECB staff in March, 1988. It covered material replacement, surveillance, temporary changes to operating instructions and temporary design changes. Compliance with selected QA procedures, although lacking in some important areas, was, in general, found to be good.

In November, 1988, AECB staff conducted an appraisal of the radiation protection program for Ontario Hydro construction large scale fuel channel replacement program activities at Pickering NGS. A number of key areas, such as construction worker training, work planning, radiation and contamination surveys, use of protective clothing and equipment, and the control of radioactive liquid effluent were covered. The appraisal team concluded that, in general, the radiation protection program for construction activities at Pickering NGS was good. However, recommendations for improvement were identified and made known to Ontario Hydro staff.

The number of actions remaining uncompleted from health physics appraisals of previous years is excessive. The problem of failure to meet target completion dates was noted in the 1987 annual review report, and the subject was discussed at the annual review meeting in 1988. The subject will be raised again at the next meeting in 1989.

3.1.6 Training

The success rates that were achieved on the AECB general and specific examinations were sufficiently high (87%) to indicate the effectiveness of the training programs in preparing authorized control room staff for their positions.

As a method for determining the precise training requirements for Shift Supervisors and Control Room Operators at Pickering, Ontario Hydro has been working towards completion of a job task analysis (JTA) for these positions. The status is as follows:

Pickering NGS-A: Updating of the JTA for authorized First Operators (FO) to reflect Pickering upgrade modifications on units 1 and 2 began in March 1988. The expected completion date is April 1989.

Pickering NGS-B: Detailed analysis of generic shift supervisor (SS) tasks associated with reactor safety and nuclear theory has been completed and learning objectives produced. Documentation of this for the delivery of two generic SS training courses is expected by June 1989.

All authorized SS and FO are required by Ontario Hydro to attend two one-week refresher training sessions annually; this consists of hands-on simulator training and classroom lectures. Ontario Hydro is currently preparing a procedure to address the methodology of formal, simulator-based testing in their development of new Continuing Training programs.

AECB staff believes that the present training programs for authorized control room personnel is generally satisfactory but there is a need for additional effort in the integration of JTA results in the training programs and in the completion of continuing training development.

3.1.7 Emergency Exercises and Drills

The annual station radiation emergency exercise was held in May, 1988. While the response of station staff was generally good, there were some problems with communications, especially radio communications with off-site survey crews. Similar problems have been observed in past exercises, and it appears that a combination of equipment upgrading and improved training will be required to resolve these problems. Ontario Hydro has completed work on upgrading the equipment except for recommissioning of the radio communication system which is scheduled to be complete by July 1, 1989. The AECB staff intends to monitor future radiation emergency exercises to evaluate the success of this up- grading in eliminating the problems observed in the past.

In addition each crew in Pickering NGS-A and Pickering NGS-B completed two shift crew radiation emergency practices and each crew in Pickering NGS-B completed two seismic emergency practices.

In order to allow staff to respond more effectively to off-site incidents involving transportation of radioactive material, Pickering NGS has acquired a specially equipped trailer and is providing special training for the transportation emergency response team.

3.1.8 Security

There were no reportable security events during 1988.

Following an inspection by AECB staff in May 1988, a number of deficiencies with security at Pickering NGS were identified and brought to Ontario Hydro's attention. These deficiencies are being addressed by Ontario Hydro staff.

During June, 1988, an access control system utilizing card access turnstiles was put in service at Pickering NGS. At the same time, changes were made to the protected area boundary at the administration building. These changes were approved by the AECB staff prior to their being implemented.

A total of 27 security drills were conducted during the year to test the response of each crew on duty. In addition, a major security exercise was carried out in June in conjunction with Durham Regional Police.

3.1.9 Station Maintenance

A large backlog in maintenance of fuel handling system components resulted in frequent unavailability of fuelling capability on the reactors. To compensate for lack of refuelling, the reactors were frequently operated with adjusters withdrawn (shim mode). Operation in shim mode was a factor in the fuel failure incident discussed in Section 4.2.4. In addition, refuelling unavailability contributed to delays in the removal of defected fuel following the incident.

The backlog is the result of several factors including the introduction of new procedures requiring equipment to be decontaminated prior to maintenance, large turnover of staff in this area, and the introduction of four rather than eight bundle shifts on some of the Pickering NGS-A reactors resulting in a significant increase in fuelling machine usage.

Given the need for the above, AECB staff agrees that the backlog was unavoidable, in the short term. However, continuation of this situation would not be considered acceptable. Ontario Hydro is currently assessing possible ways of reducing the backlog. This subject will be discussed at the upcoming annual review meeting.

3.1.10 Station Management

The AECB approved a number of organizational changes at the end of 1988 which came into effect early in 1989. These included approval of a new technical manager and some general reorganization of the technical and training staff. Proposed changes to the station quality assurance section, have not yet been approved pending further review and discussion with Ontario Hydro.

The AECB staff was pleased to see the initiative taken by Ontario Hydro in the introduction of peer evaluation audits at Pickering NGS. The first audit was carried out in October 1988, and found several good practices as well as recommending a number of improvements. Pickering station management has prepared action plans in response to the recommendations.

An area where AECB staff considers the performance of station management during 1988 to be deficient is with regard to ensuring station compliance with the operating licences and regulations. As indicated under Section 3.1.1, this matter is being actively pursued with Ontario Hydro and will be discussed at the annual review meeting.

3.1.11 AECB Staff Inspections

Field inspections have revealed deficiencies in the areas of housekeeping, conventional safety and radiation protection as follows:

- Fire extinguishers with unacceptably low pressure for extended periods of time;
- Fire doors, required to be kept closed, found blocked open on occasions;
- Compressed gas bottles not always properly secured;
- Radiological hazard warning signs frequently found to have been improperly filled out. This could be related to an excessive number of heavy water drums and drum storage areas throughout the station;
- Radiological contamination monitoring instruments at interzone boundaries often found defective. However, remedial actions were taken expeditiously upon reporting the deficiencies, to repair or replace the defective equipment.

The individual deficiencies observed may well have had only a minor impact on the safe operation of the station. However, the number of deficiencies observed is evidence of inadequate field supervision and inspection by station supervisory and management staff.

The AECB staff will monitor progress in implementation of Ontario Hydro proposed remedial actions.

3.1.12 Ontario Nuclear Safety Review (ONSR)

In response to the final report of the Ontario legislature's select committee on energy of 26 July 1986, the ONSR was established by the Government of Ontario to evaluate the safety of Ontario Hydro's nuclear power stations. Dr. Kenneth Hare was appointed as the sole commissioner. Input to the ONSR included a report by the IAEA Operational Safety Review Team (OSART) which carried out a review of the operational safety of the Pickering NGS in June 1987.

The ONSR report which was tabled in the provincial legislature in April 1988, concluded that "Ontario Hydro reactors are being operated safely and at high standards of technical performance". The report also made eighteen recommendations for improving the safety of the nuclear stations. Of these, two were identified as "major" recommendations:

The first involved the human element as it affects the overall safety. It included questions related to Ontario Hydro's operational organization, factors affecting human performance and quality assurance.

The second major recommendation raised the issue of the integrity of pressure tubes.

In addition, one recommendation applied specifically to Pickering NGS-A. It urged Ontario Hydro to press forward with the large-scale upgrading of its process and safety systems at that station.

3.2 Pickering NGS-A

3.2.1 Process Systems

During the year, a serious failure in procedure occurred in unit 1 which resulted in fuel sheath failure. This is further discussed in section 4.2.4.

3.2.2 Chemistry

Ontario Hydro Quarterly Technical reports indicate a continuing gradual improvement in overall chemical control at the Pickering NGS-A during 1988. However, the performance is still below the minimum station operating standards established by Ontario Hydro's Nuclear Generating division for process equipment performance, laboratory performance and system chemical control, particularly for the boilers and feedwater system.

The AECB staff believes that further improvements are required and possible. Ontario Hydro is continuing in its efforts to improve the quality of the chemistry control at Pickering NGS-A during 1989.

3.2.3 Performance of Special Safety Systems

Events which caused actual past unavailability of the shutdown and emergency core cooling systems occurred in 1988. These and other reportable events are discussed in Appendix C. The actual past and predicted future unavailabilities are summarized in Appendix A.

Other aspects of special safety system performance may be summarized as follows:

a) Shutdown System (SDS)

One instance of shutdown system unavailability occurred on 22 November 1988, in Unit 1 following a reactor trip and recovery. The neutron overpower protection (NOP) trip setpoints during recovery were inappropriate, being greater than the maximum allowable for the transient conditions existing at the time. This resulted in a loss of NOP protection for slow and intermediate loss of regulation accidents.

The course of events also involved reactor power being allowed to exceed the limit specified by the Operating Policies and Principles during trip recovery, followed by the occurrence of fuel failures shortly thereafter. Section 4.2.4 discusses the November 22 incident further.

b) Containment System

As part of the recommissioning of Unit 2 following retubing, Ontario Hydro carried out reactor building leakage rate measurements in April 1988. The measurements were made at 13.8 kPa(g) and 27.6 kPa(g), and at the design pressure of 41.4 kPa(g). The leakage rates were below the 1% of contained mass per hour maximum operational target in all cases. Safety analysis assumes leakage rates of 2.7% contained mass per hour.

In August, a small fire occurred inside the reactor building on the 254' elevation of Unit 4 outside the west fuelling machined (FM) service room. Damage to the concrete floor, FM valve room vapour barrier and FM shield door was repaired. A station investigation determined that poor housekeeping in combination with inadequate barricading of areas where welding was taking place were contributing factors. Appropriate corrective action was taken.

AECB staff concerns relating to predicted future unavailability of the containment system are discussed in Section 3.3.3(b).

c) Emergency Core Cooling System (ECCS)

The ECCS exceeded its target unavailability of 3×10^{-3} in each of Units 1, 2 and 4. In Units 1 and 2, unavailability was the result of air entering the ECCS piping, leading to gas locking of the high pressure emergency core cooling (HPECC) pumps. Corrective action has been implemented and is being pursued, as discussed in Section 3.3.3. In Unit 4, ECCS unavailability was due to failure of a sump level transmitter while other redundant transmitters were isolated during a unit outage for installation of HPECC.

In 1988, AECB staff requested Ontario Hydro to reclassify a design fault with the recovery subsystem of ECCS which had previously been identified during commissioning of the Unit 1 modified ECCS in December 1986. The commissioning test showed that for certain large loss-of-coolant accidents (LOCA) in the boiler room, air entrainment could occur in the boiler room sump downcomers, causing moderator pumps to gas lock and render the recovery subsystem ineffective.

The fault was corrected before the end of 1986 in Units 3 and 4, and in Units 1 and 2 during the retube outages before start-up of these units in 1987 and 1988, respectively.

The design fault was reclassified in 1988 as a Type 2 fault of the ECCS, resulting in a change in actual unavailability of the ECCS in all previous years to a value of 1.0 year per year for large LOCA's in the boiler room in all Pickering NGS-A units prior to 21 December 1986.

3.2.4 Reportable Significant Events

A list of events reported pursuant to the Pickering NGS-A operating licence is given in Appendix C.

3.2.5 Measures of Station Performance

As an indication of the quality of overall station operation, measures of the performance of Pickering NGS-A as evaluated by AECB staff are attached as Appendix A. The data contained in this appendix were taken from Ontario Hydro reports and records. Overall station operation was satisfactory except in the areas of special safety system availability, operating memos and jumper records where improvements are needed. The corresponding information for the previous year's operation (1987) has been included for comparison.

3.3 Pickering NGS-B

3.3.1 Process Systems

No serious process system failures occurred during the year.

3.3.2 Chemistry

During 1988, there was a generally improving trend in system chemistry control. In particular, progress has been made in installation of improved on-line instrumentation to contribute to better chemistry control. Nevertheless, there are some on-going problem areas such as control of heat transport hydrogen addition and excessive air in-leakage to the condensers (leading to out-of-specification boiler feedwater).

The AECB staff has concluded that Ontario Hydro is putting appropriate priority on efforts to resolve these problems but will continue to monitor progress in this area.

3.3.3 Performance of Special Safety Systems

Several events occurred in 1988 which caused actual past unavailability of special safety systems. A complete list of these and other reportable events is given in Appendix C. The AECB staff agrees that the increased surveillance program is sufficient to prevent recurrence in the meantime.

Except for SDS2, the predicted future unavailability of SDS1, containment and the ECCS, as reported by Ontario Hydro, all exceed their target of 1×10^{-3}. The reasons are as follows:

a) Shutdown Systems (SDS)

SDS1 contains a number of multiplying relays which can only be fully tested when the unit is shut down. In the past, this has meant an annual test. However, Ontario Hydro has extended the operating cycle of its units and now bases its reliability projections on a test once every two years. The results for 1988 seem to indicate that this test interval is not acceptable, especially given the problems with mercury-wetted relays (see Section 4.3.4). It is the opinion of the AECB staff that design changes should be made which will allow these relays to be fully tested while the unit is operating. The AECB staff intends to pursue this matter with Ontario Hydro.

b) Containment System

The major contributors to predicted future unavailability of the containment system are the filtered air discharge system (FADS) and the vacuum building isolation subsystem. Ontario Hydro has recently submitted details of proposed changes to the FADS and a detailed reliability assessment of the modified system. This assessment concluded that the modified FADS will be sufficiently reliable. The report is currently being reviewed by the AECB staff.

The vacuum building isolation subsystem makes an unacceptably large contribution to containment unavailability because the automatic isolation valves on the discharge of the air extraction pumps from the main volume and the upper chambers of the vacuum building are not duplicated. In response to an AECB staff comment, Ontario Hydro recently agreed to provide duplicate isolation valves on the discharge of the main volume pumps. (These motorized valves are required as part of the proposed FADS modifications. However, Ontario Hydro had not originally proposed to connect them to the automatic containment isolation logic). In the opinion of the AECB staff, a similar change will be required for the upper chamber pumps.

c) Emergency Core Cooling System (ECCS)

Significant problems were encountered with the ECCS which exceeded its target unavailability of 1×10^{-3} on all four units because of problems with partial draining of system piping and air ingress leading to gas locking of the HPECC pumps.

To prevent recurrence, Ontario Hydro has implemented increased surveillance as an interim measure while investigating possible design changes. The AECB staff agrees that the increased surveillance program is sufficient to prevent recurrence in the meantime.

The major contributor to predicted future unavailability of the ECCS comes from predicted unavailability of the atmospheric steam release valves used for boiler crash cooling. In the past, these valves have been taken out of service for prolonged periods in an attempt to correct chronic leakage problems. While this did not cause any actual unavailability, the calculation of future unavailability assumes that this practice will continue and that random failures coincident with valves out of service for maintenance could lead to future unavailability. In fact, Ontario Hydro has modified its maintenance strategy and the predicted future unavailability reported by Ontario Hydro (1.3×10^{-3}) may be unduly pessimistic. However, since the predicted future unavailability is based on a less rigorous process than the design reliability analysis, the accuracy of these predictions is uncertain. The AECB staff intends to monitor the success of the modified strategy in keeping ECCS unavailability below the 1×10^{-3} target.

3.3.4 Reportable Significant Events

A list of events reported pursuant to the Pickering NGS-B operating licence is given in Appendix C.

3.3.5 Measures of Station Performance

As an indication of the quality of overall station operation, measures of the performance of Pickering NGS-B as evaluated by AECB staff are attached as Appendix B. The data contained in this appendix were taken from Ontario Hydro reports and records. Overall station operation was satisfactory except in the areas of special safety system availability, operating memos and jumper records, and outstanding action items where improvements are needed. The corresponding information for the previous year's operation (1987) has been included for comparison.

4. SIGNIFICANT LICENSING MATTERS AND ACTIVITIES

4.1 Common to Pickering NGS-A and Pickering NGS-B

4.1.1 Steam Line Failures Outside Reactor Building

Steam and feedwater system failures in the powerhouse would result in harsh environmental conditions which could adversely affect reactor shutdown, containment and heat sink capabilities. In July 1984, Ontario Hydro was asked to investigate the consequences of such failures on Pickering NGS-A and Pickering NGS -B. In response to this request, Ontario Hydro initiated a program of study which was carried out in two phases. The phase I study focused on localized failures where the release of steam and water could affect equipment located close to the failure but would not affect equipment remote from the failure. The phase II study is a review of the consequences arising from the main steam line failures in the powerhouse. The major recommendations for Pickering NGS-A are as follows:

1. Provide structural reinforcement to ensure the integrity of the south wall of the powerhouse.

2. Install emergency steam venting system in the powerhouse.

3. House and ventilate essential class I and II electrical equipment.

4. Install an interstation electrical transfer bus to supply Pickering NGS-A 600V class II buses from Pickering NGS-B. (With this arrangement, the Pickering NGS-A class I batteries will be capable of supplying power to the 250 volt DC control circuits for a prolonged period.)

5. Provide a water supply from Pickering NGS-B to the Pickering NGS-A boilers so that the boilers may be relied upon as the long term heat sink.

6. Install piping restraints for steam piping located above the control equipment rooms to protect the control equipment rooms and the control room air conditioning penthouse enclosures from pipe whip effects resulting from failure of the steam piping.

7. Reroute the Units 1, 3 and 4 120V and 48V bus B cabling and the Unit 4 TPS (third power supply) cabling from the switchgear in the turbine auxiliary bay to the control equipment rooms so that these cablings will be immune to main steam piping failures.

8. Provide additional control room protection and ventilation so that the control room will remain habitable following a main steam piping failure above the control equipment room.

Upon review of the Pickering NGS-B design, Ontario Hydro concludes that recommendations 1, 2, 3, 6, and 8 also apply, in whole or in part, to this station.

Field installation of these design changes is progressing according to schedule. By year end, the south wall reinforcing was completed on Units 1 and 2, the cable pan for the interstation transfer bus was installed and work was started on the Pickering NGS-A emergency steam venting system.

The Pickering NGS-A design changes were initially scheduled to be installed and available for service by December 1992. AECB staff considered this initial schedule unacceptably long and asked Ontario Hydro for improvement. In response to the request, Ontario Hydro has improved the in-service schedule for the Pickering NGS-A design changes.

These modifications are now projected to be completed on Units 1, 2 and 3 by 1991, a year ahead of the previous schedule. Unit 4 is scheduled to enter into a 19-month retube outage in March 1991, and the modifications for that unit will be completed during this long outage. The in-service dates for the Pickering NGS-B powerhouse environmental modifications are less firm at this time. These modifications are currently estimated to be completed by December 1993. In the meantime, Ontario Hydro is implementing a steam line inspection program to verify the integrity of main steam lines in the interim until the modifications are completed. AECB staff has requested the inspection program be expanded to include the feedwater lines.

A number of design manuals and reliability analyses on these modifications will be submitted in 1989.

Ontario Hydro predicts that the cost of all these modifications will be about 51 million dollars.

AECB staff agrees in principle with the proposed modifications. The proposed in-service dates for Pickering NGS-A are acceptable provided the interim inspection programs are satisfactory. On the other hand, the schedule for Pickering NGS-B modifications seem overly long. AECB staff will pursue this matter with Ontario Hydro with the objective of improving the in-service dates.

4.1.2 Implications of the Accident at Chernobyl

Following the accident at Chernobyl in 1986, AECB staff conducted a study of the accident to ascertain the implication for the safety of CANDU nuclear reactors. The conclusion of the study was that the accident did not reveal any important new information which would have an effect on safety requirements for CANDU reactors. However, it did raise nine recommendations with respect to aspects of CANDU reactor safety which should be re-examined by the AECB and the reactor licensees in order to reinforce this conclusion.

Many of these apply equally to all CANDU reactors. Ontario Hydro has been requested to address the applicable recommendations and has completed most of the required reviews. AECB assessment of the submissions is not yet complete.

One of the recommendations in the AECB staff study dealt specifically with the Pickering NGS-A reactors. This matter is further discussed in Section 4.2.1.

4.1.3 Emergency Core Cooling System (ECCS) Long Term Reliability

The recovery portion of the emergency core cooling system is the credited long term heat sink following a loss of coolant accident. It is, therefore, required to operate reliably for some period of time after the accident and this long-term running reliability of the system must be assessed and demonstrated to be satisfactory. Ontario Hydro has recently completed such an assessment for Darlington and proposes to conduct a similar assessment for Pickering NGS-A. In view of its importance, the AECB staff believes that this work should be conducted without delay.

4.1.4 Filtered Air Discharge System (FADS)

The filtered air discharge system (FADS) is designed to allow filtered venting of the containment following a loss of coolant accident with fuel failures. This would maintain the pressure inside containment sub-atmospheric to minimize the risk of unfiltered release of radioactive material. However, the original design did not allow verification of filter effectiveness before initiating discharges to the environment. As a result the AECB directed Ontario Hydro to install a recirculation line which would allow air from inside containment to be passed through the FADS filters and returned to containment. Sampling and analysis of this recirculating flow would verify filter effectiveness. Progress on installation of the recirculation line was satisfactory during 1988. However, the final tie-in and commissioning of the system will not be completed until early 1989.

4.1.5 Post-LOCA Radiation Monitoring

In January 1988, Ontario Hydro presented a review of the adequacy of facilities and equipment available for radiation monitoring following a LOCA with fuel failures. This report recommended a number of modifications to ensure adequate post-LOCA radiation monitoring. The most significant recommendations were the need for modifications to the FADS stack monitoring system to allow pre-discharge verification of filter effectiveness and to allow safe handling and analysis of samples. As reported in the previous section, FADS has been modified to permit pre-discharge sample collection. However, these changes will be of little benefit until the problems of safe handling and analysis of the samples are also resolved.

In the opinion of the AECB staff, Ontario Hydro's progress towards resolving this issue has not been satisfactory. With the present arrangements, it is not certain that station staff could take the necessary samples and analyze them without creating an unacceptable risk of personal radiation exposure and spread of radioactive contamination. The AECB staff will pursue this matter with Ontario Hydro to ensure that more priority is put on its resolution.

4.1.6 Expansion of Recreational Facilities

In response to a request from Ontario Hydro, the Board agreed at a meeting in April 1988, to permit the expansion of the use of the Pickering NGS exclusion area to include new soccer fields, baseball diamonds and a running track.

The Board, however, requested that before the new facilities are placed in service, Ontario Hydro should confirm that parking along the road adjacent to the old and new facilities will be controlled to the extent necessary to not jeopardize the timely evacuation of plant personnel or of the public, should this be necessary. This request was communicated to Ontario Hydro in a letter, dated 13 May 1988. A response acceptable to AECB staff has not been received and will be required before the new facilities are put to use.

4.2 Pickering NGS-A

4.2.1 Loss of Coolant (LOCA) or Loss of Regulation (LORA) Combined with Unavailability of Shutdown System

The AECB report on the implications of the Chernobyl accident (see section 4.1.2) recommended that the safety of the Pickering NGS-A reactors be re-examined, particularly with respect to the design basis accidents involving failure of the reactor control system or loss of coolant coincident with the unavailability of the shutdown system. (Unlike other CANDU reactors in Canada the Pickering NGS-A reactors are not equipped with two fully independent shutdown systems). In response to this recommendation, Ontario Hydro has prepared and submitted a number of submissions as follows:

a) A study was undertaken to determine the minimum number of shut-off rods required to assure fuel channel integrity in the event of a large LOCA. It concludes that channel integrity is assured for a maximum of five most effective shut-off rods or ten randomly selected shut-off rods unavailable for the most severe voiding transient.

b) A study was undertaken to quantify the effectiveness of the moderator dump, when acting alone, in terminating loss of reactivity control, a loss of coolant or a loss of Class IV power transient. It concludes that moderator dump is capable of terminating all reactivity transients, with the exception of that resulting from a large break LOCA.

c) A study was undertaken to calculate the frequency of failure to shut down the reactor following various initiating events. It concludes that the total frequency of events involving failure to shut down is 6×10^{-6} per reactor year.

d) The reliability of the shutdown system was re-assessed using the latest assessment methodology. It concludes that the system meets its unavailability target of 3×10^{-3}.

e) An analysis of the consequences of failure to shut down following a large LOCA was undertaken. It concludes that despite severe damage to the reactor, the structural integrity of the containment envelope is maintained (although the containment design pressure is marginally exceeded) and that the off-site radiological consequences of this accident are not expected to be significantly different from other severe dual failure accidents analyzed.

AECB staff has reviewed and commented on some of these submissions. One of the significant findings is that the aforementioned dual failure analysis was not done with the same degree of rigor as the licensing analysis, and therefore its conclusions do not command the same level of credibility. The most significant shortcomings and uncertainties in this analysis are as follows:

a) The detailed ECCS performance is not analyzed. Massive fuel melting is predicted and it is simply assumed that the water delivered by the ECCS will cool the molten fuel and the hot fuel channels.

b) The fact that massive fuel melting is predicted raises questions regarding the possibility and consequences of steam explosion and hydrogen deflagration. These questions are not addressed in the analysis.

c) In view of the severe consequences associated with multi-channel ruptures, damage to the recovery portion of the ECCS cannot be ruled out. This raises questions regarding long term cooling.

d) It is predicted that the containment design pressure will be exceeded and that cracking of the reactor building will occur. No evidence has been presented to support the claim that the cracks will reseal themselves following the over-pressure transient.

A meeting between AECB and Ontario Hydro staff was held in December 1988 to discuss the submissions received to date. At that meeting, Ontario Hydro was informed that, in view of the uncertainties in these submissions, it was unlikely that this matter could be satisfactorily resolved solely by further analytical effort and that, consequently, Ontario Hydro should investigate various design improvements which could be made to the existing shutdown capability. Ontario Hydro agreed to examine different design options and to report progress in early 1989.

Ontario Hydro was also advised to proceed expeditiously with the remaining analysis of loss of regulation combined with unavailability of shutdown system action.

4.2.2 Rupture Panel System (RPS)

In 1986, the Board mandated modifications to the Pickering NGS containment system. These modifications would increase the time prior to containment venting and reduce the containment venting rate after a postulated LOCA in any one of the units in Pickering NGS-A or Pickering NGS-B.

To satisfy these requirements, Ontario Hydro committed itself to installing a new RPS in each of Units 1 to 4 which will isolate these units from the Pressure Relief Duct (PRD). The concept requires that the existing bulkheads between Units 1 to 4 and the PRD be modified to provide a mounting surface for a set of rupture panels, two bypass butterfly valves, and a personnel access door.

The installation of the rupture panel system was completed in Unit 2 in 1988 and in Unit 4 in 1989. Units 1 and 3 will be fitted with the same system by 1990.

4.2.3 N-16 Neutron Overpower Trip Compensation

The Pickering NGS-A overpower trip design uses the N-16 gamma field from the heat transport system to correct ion chamber flux readings to compensate for the effects of moderator boron concentration, fuelling, flux tilts and the configuration of reactivity devices.

Deficiencies in the performance and reliability of the original system led to a decision to redesign the system.

Commissioning of the re-designed system continued in Unit 3 in 1988. However, the performance of the system was still unacceptable by year end and therefore, could not be brought into active service. Meanwhile, the installation of the re-designed system was completed in all Pickering NGS-A units. AECB staff will continue to monitor the progress of this work.

4.2.4 Unit 1 Fuel Failures

On November 22, 1988, during recovery from a reactor trip, Unit 1 reactor power was increased substantially above the trip setpoint specified in the Operating Policies and Principles (OP&Ps) for the configuration of reactivity devices at the time. This operation outside of the limit specified in the OP&Ps resulted from the issuance of an incorrect operating instruction, which in turn was the result of an incomplete understanding by members of the station technical staff of reactor core operating limitation, and inadequate review of the operating instruction prior to its release to the operating staff.

Shortly after the reactor power was increased above the OP&Ps limits, the Iodine-131 level in the heat transport system was found to have reached 149 curies, indicating a number of fuel failures. Between January and May 1989, 35 fuel channels were defuelled in an effort to remove the defected fuel. At the time of writing of this report, most channels suspected of containing failed fuel have been defuelled. The residual level of Iodine-131 in the heat transport system has decreased to about 30 curies.

The cause of the fuel failure is believed to be the "power boost" (a step change in fuel power from the steady-state value existing prior to the reactor trip) which the fuel underwent when the operator increased reactor power from 65% to 87% of full power in accordance with the incorrect operating instruction. Some of the failed fuel elements have been sent to Chalk River Nuclear Laboratories to confirm the fuel failure mechanism.

AECB staff is conducting a detailed investigation of this event. This investigation addresses the following aspects:

(a) The exact cause of the fuel failures

(b) A human factor assessment of the event (which Ontario Hydro has been requested to carry out)

(c) The mechanisms in place at Ontraio Hydro to ensure compliance with licence conditions and Operating Policies and Principles

(d) the implications of continued operation with defected fuel

(e) The adequacy of the reporting procedures followed by Ontario Hydro.

4.3 Pickering NGS-B

During 1988, some progress was made in resolving outstanding licensing issues and 17 action items were closed. Nevertheless, the number of action items outstanding at the end of the year (51) was still unacceptably high.

Some of the more significant issues are summarized below.

4.3.1 Moderator as a Heat Sink

Ontario Hydro has been asked to assess the effectiveness of the moderator as a heat sink in the event that there is no forced circulation of the moderator water. The safety analysis assumed that the moderator will be an effective heat sink under these conditions but did not contain any analysis to demonstrate this. Ontario Hydro has not yet responded to this request.

In addition, discussions are continuing on resolving uncertainties in computer models used to assess the effectiveness of the moderator as a post-accident heat sink. However, this is a generic question applicable to all Ontario Hydro reactors, not just Pickering NGS-B.

4.3.2 Cobalt Adjusters

Ontario Hydro's current safety analysis states that, in the event of uncontrolled draining of the moderator water (due, for example, to a leak from the system), the release of dissolved deuterium from the moderator water and coincident heat up of the uncovered adjuster rods could lead to a deuterium burn in the cover gas, but that this would not cause significant damage. However, this analysis was judged by the AECB staff to be unacceptable because of uncertainties in the assumptions used in calculations of deuterium release and burning. Nevertheless, AECB staff authorized Ontario Hydro to continue irradiating cobalt adjusters in Unit 5 until April 30, 1989, on condition that they be replaced with steel adjusters at that time, if the issues have not been resolved in the meantime. In addition, Ontario Hydro was asked to review the safety of cobalt irradiation in the other units which, unlike Unit 5, have adjuster rod cooling circuits.

4.3.3 Failures of Mercury-Wetted Relays

Pickering NGS-B has experienced numerous failures of mercury-wetted relays. Table 2 summarizes the experience with unsafe failures of mercury-wetted relays in the four special safety systems.

Although these failures have been occurring for several years, it was believed that the systems could, nevertheless, meet their reliability targets. However, this is no longer clear, given the increasing number of failures experienced during 1987 and 1988. At the end of 1988, Ontario Hydro calculated a predicted future unavailability of 1.2×10^{-3} for SDS1. (SDS1 reliability is particularly sensitive to relay faults because it has a number of multiplying relays which cannot be fully tested with units at power.) This calculation was based on lifetime fault data. Since the failure rate in 1988 was significantly higher than the lifetime average, it is possible that future unavailabilities may be even higher, especially if the increasing trend continues. Ontario Hydro has recognized the problem and has already replaced all of the original mercury-wetted multiplying relays in the Unit 7 shut-off rod logic circuit with a different type of mercury-wetted relay believed to be less susceptible to such failures. Similar action is planned on the other units.

The AECB staff agrees that the short-term actions proposed and taken by Ontario Hydro are appropriate. However, it is not clear that these actions will be adequate in the long term. In particular, changes to allow on-power testing of all relays in the active part of the special safety systems may be necessary. The AECB staff intends to pursue this question with Ontario Hydro.

5. CONCLUSION

The assessment of the AECB staff is that overall, station performance in 1988 was satisfactory. Improvements were achieved in the control of the number of temporary design and operating changes (jumper records and operating memos). There were no personnel exposures in excess of regulatory limits, and releases to the environment remained well below 1% of the Derived Emission Limits for both Pickering NGS-A and NGS-B. Peer evaluation audits were introduced at Pickering during 1988.

The violation of operating licence conditions and requirements of regulations is considered a serious matter. However, these appear to have resulted primarily from a lack of understanding of the conditions and regulations. The objective of AECB staff efforts is to ensure Ontario Hydro has in place an adequate program for the training of staff and the monitoring of compliance with the licences and regulations to give assurance that further infractions should not occur.

While Plant operation has been generally satisfactory, the AECB staff considers that performance in a number of areas needs improvement. These are:

- the shutdown capability of the Pickering NGS-A reactors (see section 4.2.1)
- availability of special safety systems (see section 3.3.3)
- post-LOCA radiation monitoring (see section 4.1.5)
- response to AECB Health Physics Appraisals (see section 3.1.5)
- maintenance of fuel handling system components (see section 3.1.9)
- response to outstanding action items (see section 4.3)

TABLE 1

Definitions of Fault Types

Process System Faults

Type A: A fault which would, in the absence of special safety system action, cause significant fuel failures.

Type B: A fault which would not, in the absence of special safety system action, cause significant fuel failures, but which would do so if some unpredictable factors (e.g. reactor conditions) were different.

Safety System Faults

Type 0: A fault which totally incapacitates the system such that it cannot provide any protection under any conditions.

Type 1: A fault which significantly reduces system effectiveness such that it would be of little or no benefit if the worst possible process system failure occurred.

Type 2: A fault which reduces the effectiveness of the system such that it fails to meet the design intent. However, the system still operates, and would be of significant benefit if a process system failure occurred.

TABLE 2

Failures of Mercury-Wetted Relays in Pickering NGS-B Special Safety Systems

	1983	1984	1985	1986	1987	1988	Total
SDS1	1	0	0	0	0	7	8
SDS2	0	0	0	0	2	8	10
Containment	2	2	1	2	11	5	23
ECC	0	1	0	0	0	0	1
Totals	3	3	1	2	13	20	42

APPENDIX A

MEASURES OF STATION PERFORMANCE - PICKERING NGS-A, 1988

	1988	1987	AECB Staff Comments: (A = Acceptable; NI = Needs Improvement)
A. Radiation Control			
Occupational dose			
Total whole body dose (person-Sv)	6.21	7.91	A
Total extremity dose (person-Sv)	10.71	18.51	A
Total neutron dose (person-mSv)	42	35	A
No. of exposures > regulatory limits	0	0	A
No. of whole body exposures > 20 mSv	6	3	A
Releases from the Station			
No. of times the 1% DEL target was exceeded:			
Airborne tritium	1	0	A
Airborne noble gases	0	2	A
Airborne iodine-131	0	0	A
Airborne particulates	0	0	A
Airborne carbon-14	0	1	A
Waterborne tritium	0	0	A
Waterborne gross beta activity	0	0	A
Average %DEL for the year:			
Airborne tritium	0.39	0.24	A
Airborne noble gases	0.22	0.29	A
Airborne iodine-131	0.02	0.00	A
Airborne particulates	0.01	0.01	A
Airborne carbon-14	0.45	0.49	A
Waterborne tritium	0.10	0.07	A
Waterborne gross beta activity	0.07	0.07	A

MEASURES OF STATION PERFORMANCE - PICKERING NGS-A, 1988

	1988	1987	AECB Staff Comments: (A = Acceptable; NI = Needs Improvement)	
Public dose*				
Estimated dose to critical group (uSv):				
- infant	47	52	A	
- adult	41	45	A	
Estimated population dose (person Sv)	1.5	1.7	A	
B. Plant Control				
No. of reportable events	15	18	A	
No. of serious process failures	0	0	A	
No. of genuine (non spurious) reactor trips	7	2	A	
Percentage of safety system tests completed				
Shutdown system (SDS)	100%	100%	A	
ECI	100%	100%	A	
Containment	75%	100%	NI	Unit 1 RB pressure test could not be performed in the third quarter.
Special safety system unavailability ($x10^{-3}$):				
Actual past unavailability:				
SDS (Unit 1)	0.42	0	A	
SDS (Units 2,3,4)	0	0	A	
Containment (all units)	0	0.03	A	
ECI (Unit 1)	3.2	4.3	NI	
(Unit 2)	8.2	0	NI	Unit 2 in re-tube outage in 1987
(Unit 3)	0	0.3	A	
(Unit 4)	37.8	4.6	NI	
Predicted future unavailability:				
SDS (Units 1,2,4)	2.8		A	
SDS (Units 3)	1.7		A	
Containment	5.15		NI	
ECI (Units 1,2,4)	3.5		A	
(Units 3)	11.3		NI	Will be the same as Units 1,2 & 4 when HPECI is installed

* Estimated public doses include contributions from emissions from Pickering 'A' and 'B' stations.

MEASURES OF STATION PERFORMANCE - PICKERING NGS-A, 1988

	1988	1987	AECB Staff Comments: (A = Acceptable; NI = Needs Improvement)
C. Plant Maintenance and Administration			
Operating Memos:			
No. in effect at year end	104	142	NI - Efforts to reduce the number of Operating Memos and Jumper Records are in progress, but further improvements are required.
No. in effect for > 6 months	37	51	NI
Jumper Records:			
No. of operational jumpers in effect	499	802	NI
D. Licensing			
AECB Action Items:			
No. of Items outstanding at year end	42	40	NI
No. of Items opened during the year	20	26	-
No. of Items closed during the year	18	11	-
Quality Assurance Audits:			
No. of AECB audits	1	2	
No. of Directives issued	0	0	A
No. of Action Notices issued	5	10	A
Health Physics (HP) Appraisals:			
No. of AECB HP Appraisals during year	1	1	
No. of Recommendations	5	19	A

APPENDIX B

MEASURES OF STATION PERFORMANCE - PICKERING NGS-B, 1988

	1988	1987	AECB Staff Comments: (A = Acceptable; NI = Needs Improvement)
A. Radiation Control			
Occupational dose			
Total whole body dose (person-Sv)	1.25	1.60	A
Total extremity dose (person-Sv)	1.63	2.62	A
Total neutron dose (person-mSv)	26	42	A
No. of exposures > regulatory limits	0	0	A
No. of whole body exposures > 20 mSv	0	1	A
Releases from the Station			
No. of times the 1% DEL target was exceeded:			
Airborne tritium	0	0	A
Airborne noble gases	0	0	A
Airborne iodine-131	0	0	A
Airborne particulates	0	0	A
Waterborne tritium	0	0	A
Waterborne gross beta activity	0	0	A
Average %DEL for the year:			
Airborne tritium	0.07	0.09	A
Airborne noble gases	0.21	0.22	A
Airborne iodine-131	0.00	0.00	A
Airborne particulates	0.00	0.00	A
Waterborne tritium	0.17	0.27	A
Waterborne gross beta activity	0.18	0.05	A
Public dose*			
Estimated dose to critical group (uSv):			
- infant	47	52	A
- adult	41	45	A
Estimated population dose (Sv)	1.5	1.7	A

* Estimated public doses include contributions from emissions from Pickering 'A' and 'B' stations

MEASURES OF STATION PERFORMANCE - PICKERING NGS-B, 1988

		1988	1987	AECB Staff Comments: (A = Acceptable; NI = Needs Improvement)
B. Plant Control				
No. of reportable events		15	10	A
No. of serious process failures		0	0	A
No. of genuine (non spurious) reactor trips		2	5	A
Percentage of safety system tests completed		100%	100%	A
Special safety system unavailability ($x10^{-3}$):				
Actual past unavailability:				
SDS1	Unit 5	0	0	A
	Unit 6	0.86	0	A
	Unit 7	0	0	A
	Unit 8	0	0	A
SDS2	Unit 5	0	0	A
	Unit 6	0.86	0	A
	Unit 7	0	0	A
	Unit 8	0.002	0	A
Containment	Unit 5	0	0.03	A
	Unit 6	0	0.03	A
	Unit 7	0.001	0.03	A
	Unit 8	0	0.03	A
ECI	Unit 5	8.2	0	NI
	Unit 6	82.2	0.03	NI
	Unit 7	82.2	0	NI
	Unit 8	123.3	0	NI
Predicted future unavailability: ($x10^{-3}$)				
SDS1		1.20	0.06	NI
SDS2		0.45	0.27	A
Containment		4.23	4.41	NI
ECI		1.31	0.52	NI

MEASURES OF STATION PERFORMANCE - PICKERING NGS-B, 1988

	1988	1987	AECB Staff Comments: (A = Acceptable; NI = Needs Improvement)
C. Plant Maintenance and Administration			
Documentation			
Operating Memos:			
No. in effect at year end	48	115	NI - Efforts to reduce the number of Operating Memos and Jumper Records are in progress, but further improvements are required.
No. in effect for > 6 months	31	50	NI
Jumper Records:			
No. of operational jumpers in effect	373	509	NI
D. Licensing			
AECB Action Items:			
No. of Items outstanding at year end	51	63	NI
No. of Items opened during the year	5	5	
No. of Items closed during the year	17	11	
Quality Assurance Audits:			
No. of AECB audits	1	2	
No. of Directives issued	0	0	A
No. of Action Notices issued	5	10	A
Health Physics Appraisals:			
No. of AECB HP Appraisals during year	1	1	
No. of Recommendations	5	19	A

APPENDIX C

REPORTABLE EVENTS

The following reportable events occurred in 1988.

1. Events Affecting Pickering NGS-A and Pickering NGS-B

Reference	Description
B-88-126	On 14 September, during routine testing, HPECI pumps P5 and P6 failed to develop sufficient discharge pressure and flow. Subsequent investigation showed that a significant quantity of air in the system had gas locked the pumps. Since the third pump, P7, operated successfully the HPECI system was available, in spite of this common failure of two pumps.
B-88-165	On 6 December, during another routine test, all three HPECI pumps failed due to pump gas locking. The HPECI system (which supplies Units 1 and 2 of Pickering NGS-A as well as all four units of Pickering NGS-B) was unavailable for 72 hours because of this fault. Investigation of the cause of the air accumulation in the system is continuing. In the meantime, the system is being tested more frequently. This provides frequent venting of any air and prevents it accumulating to the point of causing pump gas locking.
Letter, Dewar to Tong/Power, 1989 11 87	On 7 November, Ontario Hydro reported that on-going safety analysis had identified a previously unrecognized systems response. Specifically, during events involving slow depressurization of the primary heat transport (PHT) system, there would be a gradual decrease in flow and in the temperature rise across the reactor core, due to boiling in the fuel channels. This would be (incorrectly) interpreted as a power decrease by the reactor regulating system which would respond by increasing reactor power. Thus, the previous analyses (which assumed that reactor power would remain constant up to the moment of a reactor trip) did not represent the most conservative assumption. However, the analysis which revealed the problem also showed that the effect was small and that no change in trip set points was required.

2. Events Affecting Pickering NGS-A Only

Reference	Description
A-88-21	On 8 February, Unit 4 Channels D and E shutdown system ion chamber signals were noted to be reading low, indicating 74% and 75% full power (FP) respectively. The minimum acceptable ion chamber indication at 94.8% FP with the N-16 compensation system out of service is 75.8% FP. In accordance with the Abnormal Incidents Manual, this constituted a Level 1 impairment of the shutdown system.

Channel D was rejected immediately to improve the impairment to Level 3. The low readings were attributed to boron shielding and, therefore, the readings returned to normal following boron removal from the moderator system. It was subsequently established that this was a type 4 fault (a Type 4 fault reduces the effectiveness of the system, or a single component, such that it is outside normal operating limits).

A-88-20
A-88-32

Unit 4 experienced a local loss of regulation (LOR) on 6 February when the DCC1 in-core flux detector (ICFD) for zone 2 failed low irrational. The signal then recovered to a low value which caused liquid zone 2 to drain. The assumed failure mechanism was progressive insulation sheath corrosion caused by nitric acid attack. The zone 2 signal soon recovered and indicated normal and was therefore not removed from service. It failed again in a similar way on 15 February resulting in a second local loss of regulation, and was rejected at that time. Increase in reactor power was terminated by reactor trip in each incident. It was subsequently determined that the regulating program internal filters were inadequate in detecting anomalous behaviour of the ICFD signal and as a result, the program failed to reject it.

Letter,Dewar to Pannell, 1988 03 17

On 17 March, Ontario Hydro reported that ongoing analysis of feedwater and steam supply system failures concluded that it was necessary to raise the boiler low level trip setpoint to 0.25 m from its present value of 0.1 m. The setpoint had to be revised because of possible heat-up of the boiler reference level measurement following a feedwater pipe failure inside containment. Heating up of the reference leg could cause the level to be over-estimated as a result of the density change of the liquid in the reference leg.

A-88-64

On 6 April, the Unit 3 east FM was unclamped from channel K10 during pressure tube sampling without a closure plug being installed in the end fitting. Water was observed leaking from the snout of the FM into the east FM vault. The FM was reclamped successfully onto channel K10, stopping the leak. Unit 3 was shutdown at the time. The event violated the Operating Policies and Principles and was classified as a Type B process system fault.

Letter,Dewar to Pannell, 1988 04 29

On 29 April, following the completion of the control failures update analysis, Ontario Hydro reported that the neutron overpower system required trip setpoint is 114.5% FP, as compared to 115% FP determined previously. It was also determined that the maximum margin to trip on heat transport high temperature should be 9°C, as compared to the current practice of 12°C.

A-88-172

On 30 September, during the replacement of the moderator collection pump in Unit 4, two mechanical maintainers were wetted with moderator heavy water. Subsequent bioassay results indicated they had tritium exposures of 22 and 6 MPBBs respectively. The mechanical maintainer with the higher exposure was placed on a daily bioassay sample submission

	frequency and a medically monitored dose reduction program. No quarterly or annual dose limits were exceeded.
Letter, Dewar to Tong, 1988 10 28	Based on routine heat balance test results and observation of unit output, Unit 1 reactor power exceeded 101% FP by up to 1% FP from 2 October to 14 October 1988, thus violating Reactor Operating Licence Condition A.A.5. However, no immediate action was taken due to a deficiency in the operating procedures which did not account for Unit 1 supplying steam to the heat transport D_2O upgrader. Consequently, the actual generator output appeared to be consistent with 100% FP operation.
A-88-142	On 14 August, a D_2O spill occurred at the Unit 1 254' elevation reactor auxiliary bay (Zone 3) following which tritium migrated to Zones 2 and 1, including the administration building cafeteria. The subsequent follow-up report described actions taken which contributed, in part, to the spread of airborne contamination, thereby violating the Operating Policies and Principles requirements on ventilation systems.
Letter, Dewar to Tong, 1988 12 16	On 5 December, Cobalt-60 was shipped from Pickering NGS to Nordion International Incorporated in two AECL model F-231 Type B(U) packages, Serial Numbers 7 and 22. After opening these packages, Nordion reported that each package contained approximately 470 kCi of Cobalt-60. The F-231 Type B(U) package is authorized to contain a maximum of 400 kCi of Cobalt-60 under radioactive material Type B(U) package design approval certificate CDN/2047/B(U), revision 4. The occurrence of this incident was, therefore, a violation of the Transport Packaging of Radioactive Materials Regulations. Subsequent investigation revealed that the activity of two adjuster rods discharged from Unit 4 had been incorrectly calculated due to an error in the COCAL computer program.
A-88-199	On 30 November, the Unit 4 Fuelling Machine sump level transmitters 63431-L3-LT1 and L1-LT1, associated with the east and west FM sumps respectively, were removed from service for on-going HPECI modifications. On December 13, the alternative west FM sump level transmitter 63431-L4-LT1 was found to have failed, as level indication was at zero when the actual sump level was at 0.5 m. It was, therefore, a Type 2 fault of the HPECI system and the fault duration was assessed to be 332 hours.
A-88-194	On 30 November, four employees of City-Wide Mobil Wash were on site to perform steam cleaning of the Unit 4 main transformer. One of the four employees left the site via the open vehicle gate adjacent to the guard house without advising his sponsor or security and without monitoring prior to exiting.

The breakdown in the security barrier violated the conditions stipulated in Section 7 Subsection 2 of the Physical Security Regulations.

A-88-204	On 22 November, routine chemistry sampling revealed that the Unit 1 heat transport system contained approximately 150 curies of iodine-131, indicating the presence of fuel failures. Based on investigations to-date, the sequence of events leading up to this incident resulted in the violation of Operating Policies and Principles as well as the Reactor Operating Licence conditions. Details of this incident have been reported previously to the Board via Significant Development Report No. 1989-2 and BMD 89-53.

3. Events Affecting Pickering NGS-B Only

Reference	Description
B-88-29	On 1 March, there was a breach of the Unit 7 containment lasting 29 seconds. While construction workers were exiting the Unit 7 RB via airlock number 1, the inner door failed to close properly. During attempts to close the door, the seals on the outer door of the airlock deflated causing the breach of containment. The reason for the seal deflation was not found. It is suspected that the manual seal deflation valve was inadvertently opened by the construction workers.
Letter, Dewar to Pannell, 1988 03 17	On 17 March, Ontario Hydro reported that revised safety analysis had revealed a need to increase the setpoints of the low heat transport flow trip on SDS1 from 86% to 90%. The change in setpoint was approved and has been implemented on all units.
B-88-33	On 19 March, both emergency power generators were unavailable for 75 minutes. One generator failed its routine test while the other was out of service for maintenance.
B-88-40	On 13 April, Unit 6 SDS2 was unavailable for 60 seconds because of a high level in two poison injection tanks. High tank level can cause flooding of the helium header and delay SDS2 injection. The high level was caused by a failed check valve.
B-88-46	On 9 March, an emergency power generator was removed from service for maintenance without first testing the other generator. This was a violation of the Operating Policies and Principles.

B-88-87 B-88-88 B-88-90	During a routine test on 18 July, the Unit 8 ECI system piping was found to be partially drained. Subsequent checks showed that the ECI piping of Units 6 and 7 were also partially drained. As a result, the ECI systems were unavailable for 27 days, in the case of Units 6 and 7, and for 42 days, in the case of Unit 8. This is because the ECI systems could, if they had been required to operate, have suffered water hammer damage because of the partially drained piping.
Letter, Dewar to Power, 1988 08 04	On 4 August, Ontario Hydro reported that an error in inputting data to a reactor physics computer program caused a small error in calculations of channel and bundle powers and peaking factors used in calibrating shutdown system overpower detectors of Unit 8. Subsequent investigation showed that the errors were small enough that they had no significant effect on safety margins. Nevertheless, Ontario Hydro proposed procedural changes to prevent recurrence. The AECB staff will monitor completion of these proposed changes.
B-88-89	On 24 July, Unit 8 SDS2 was unavailable for 54 seconds due to high level in two poison injection tanks. The high level was caused by a faulty check valve.
B-88-96	On 4 August, a Unit 6 adjuster rod was found to be only 51% in-core even though its position indicator showed it to be fully inserted. Subsequent analysis showed that the NOP trip coverage was not impaired by this event given the calibration values in effect at the time. However, the adequacy of the trip coverage is considered fortuitous because the instrumentation could have been incorrectly recalibrated at any time, since operating staff were unaware that the rod was partially withdrawn. As a result, the NOP trip parameter on both SDS1 and SDS2 was, conservatively, declared unavailable for 7.5 hours due to this fault.
B-88-134	On 30 September, during routine testing, the Unit 8 auxiliary condensate extraction pump failed to develop pressure when started. The pump was found to be gas-locked by air inleakage. The auxiliary boiler feed system was unavailable for 20 days because of this fault. However, alternative means of decay heat removal not dependent or class 4 power were available throughout this period. Ontario Hydro is working on a design change to all units to prevent recurrence of such failures.

APPENDIX D

Violations of Licences and Regulations

Reference	Description
Letter, Pannell to Dewar, 1988 03 17	A response to an AECB letter was requested within 30 days of the letter, pursuant to an operating licence condition. The response was not received until some time following the due date.
A-88-64 (see Appendix C)	A fuelling machine was unclamped from a channel without a closure plug having first been installed in the end fitting and the channel confirmed as being closed. This was a violation of Operating Policies and Principles.
Letter, Dewar to Tong, 1988 10 28 (see Appendix C)	Based on routine heat balance test results and observation of unit output, Unit 1 reactor power exceeded the limits specified in Reactor Operating Licence Condition A.A.5 by up to 1% of full reactor power from 2 October to 14 October, 1988.
A-88-142 (see Appendix C)	A spill of heavy water occurred in the reactor auxiliary bay with the subsequent spread of airborne tritium up to and including the administration building cafeteria. This was a violation of Operating Policies and Principles which require ventilation systems to be operated in such a manner to minimize the spread of contamination.
Letter, Dewar to Tong, 1988 12 16 (see Appendix C)	A shipment of cobalt-60 from the site contained a higher curie content of cobalt-60 than authorized for the transport package. This was a violation of the Transport Packaging of Radioactive Materials Regulations.
A-88-194 (see Appendix C)	An employee of a local firm on site to perform work, left the site via an open vehicle gate adjacent to the guardhouse without advising his sponsor or security. The breakdown in the security barrier violated the condition stipulated in Section 7 Subsection 2 of the Physical Security Regulations.
A-88-204 (see Appendix C)	On 22 November, an incident occurred on the Unit 1 reactor during which the reactor was operated at a power level higher than permitted by the Operating Policies and Principles, followed by the occurrence of a number of fuel failures. Such an event is to be reported promptly to the AECB pursuant to condition A.A.19 of the operating licence but was not reported in writing until 24 January 1989.
B-88-476 (see Appendix C)	An emergency power generator was removed from service for maintenance without first testing the other generator. This was a violation of Operating Policies and Principles.