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REPORT

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

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

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

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

SUMMARY

This report is the Atomic Energy Control Board staff assessment of safety at the Darlington Nuclear Generating Station for 1996. The report is based on our observations, and on information submitted to us by Ontario Hydro.

Ontario Hydro operated the station in a safe manner in 1996. All four special safety systems were fully available 100 percent of the time. There were more problems that affected the safety support systems in 1996 than in the previous year.

In 1996, Ontario Hydro complied with the Regulations made under the Atomic Energy Control Act, except for two instances of non-compliance: one with the Transport Packaging of Radioactive Materials Regulations, and the other one with the Physical Security Regulations. It also failed to comply with operating licence conditions on 19 occasions. We found that the individual events had a small and thus acceptable impact on safety. Although the goal should be full compliance with the operating licence conditions, we recognize the progress made by Ontario Hydro to reduce the number of non-compliances in 1996 compared to previous years.

Radiation doses received by Ontario Hydro station staff were below the regulatory limits. Radioactive emissions from the station were well below the regulatory limits. Ontario Hydro has made progress to resolve two previous issues related to radioactive doses and emissions: by establishing proper interzonal airflows between radiological zones to minimize the spread of airborne radioactive contamination, and by improving the reliability of the stack emission monitoring equipment.

All units operated at full power for most of 1996. We found Ontario Hydro's maintenance program satisfactory. We note in particular its continuing success in maintaining good chemical control in station systems.

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INTRODUCTION

Located on the north shore of Lake Ontario in the Municipality of Clarington, Ontario, the Darlington Nuclear Generating Station has four 936 MWe(gross) *Canadian Deuterium-Uranium* (CANDU) reactors. These units have a design life of 30 years.

On November 28, 1996, the *Atomic Energy Control Board* (AECB) approved the renewal of the operating licence for a period of two years. Operating Licence 13/96 authorizes operation of the Darlington Nuclear Generating Station and the *tritium removal facility* until November 30, 1998.

This report is the Atomic Energy Control Board staff assessment of safety at the Darlington Nuclear Generating Station for 1996. The report is based on our observations, and on information submitted to us by Ontario Hydro. We currently have five staff members located at the Darlington site. Other staff members are located in our head office in Ottawa.

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.

Although we use similar terms to describe safety performance for each of the nuclear generating stations in Canada, many of them have different contexts. Readers should be aware that direct comparison between stations is difficult, and often not appropriate.

At our head office in Ottawa, the public can consult documents relative to the licensing process of nuclear facilities. Our public library also contains an important collection of documents, available on request. Apart from the AECB 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 comply with 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 which apply to the Darlington Nuclear Generating Station are the *Atomic Energy Control Regulations*, the *Physical Security Regulations*, the *Transport Packaging of Radioactive Materials Regulations*, and the AECB *Cost Recovery Fees Regulations*.

In 1996, Ontario Hydro met all the requirements of these Regulations, except on two occasions. One incident resulted in a non-compliance with the Transport Packaging of Radioactive Materials Regulations, and the other one with the Physical Security Regulations.

The non-compliance with the Transport Packaging of Radioactive Materials Regulations involved a shipment off-site of three small water samples that were slightly contaminated with *tritium* and which was labelled as a non-radioactive shipment. This incident did not result in any radiological consequences to the public. Ontario Hydro has since issued a new policy for radioactive shipments which incorporates several measures to prevent improper shipments. We believe that strict adherence to this new policy should eliminate non-compliances with these Regulations in the future.

The non-compliance with the Physical Security Regulations involved a brief lapse in the monitoring of security equipment. However, this incident posed negligible threat to plant security. During our annual compliance inspection in May 1996 of the physical security measures in place at Darlington, we found a marked decrease in the number of deficiencies observed. The inspection report listed six deficiencies (four from the two previous years) for Ontario Hydro's attention. By year's end, a reply was received from Ontario Hydro that addressed all six deficiencies, and we are currently assessing this reply.

COMPLIANCE WITH THE OPERATING LICENCE

The Atomic Energy Control Regulations give the Atomic Energy Control Board the authority to issue a power reactor operating licence to Ontario Hydro. The operating licence for the Darlington Nuclear Generating Station contains conditions the licensee must observe including specific reference to the licensee's own *Operating Policies and Principles* and *Radiation Protection Regulations*. To comply with an operating licence, the licensee must demonstrate that the nuclear facility has been operated within the framework set out by the licence conditions.

Ontario Hydro reported 19 non-compliances with the operating licence conditions in 1996. Ten incidents involved non-compliances with the Operating Policies and Principles, seven others were non-compliances with the Radiation Protection Regulations and two were non-compliances with other licence conditions. Ontario Hydro believes that its policy on procedural adherence, together with the major rewrite of the station procedures to provide a reference to the Operating Policies and Principles requirements, where necessary, was instrumental in achieving fewer non-compliances in 1996 than in previous years.

The ten Operating Policies and Principles non-compliances that occurred in 1996 are very much of the same types of non-compliances as seen in previous years. Examples of such types are: undocumented or unapproved changes to safety equipment, and modifications or errors resulting in impairments of *safety support systems*. All non-compliances can be attributed to human performance errors.

We reviewed each of these events and found that none had an unacceptable impact on safety, and that Ontario Hydro had instituted appropriate corrective actions. Although the goal should be to operate the station in full compliance with the operating licence conditions, we conclude that Ontario Hydro has made progress in 1996 to reduce the number of non-compliances with respect to previous years.

In 1996, Ontario Hydro requested that the wording related to the operating licence condition that specifies the limit for reactor power be changed to remove any ambiguities to ensure its compliance. We agreed with the licensee that there was a need to revise it, and deleted the reference to maximum electrical power output. We realized that electrical power output is not an accurate reflection of reactor power as it varies with lake water temperature and other factors affecting *turbine* efficiency.

EVENTS REPORTED TO THE AECB

We found that Ontario Hydro's response and follow-up to the 51 events reported to us in 1996 was acceptable. Reporting of these events was required under an operating licence condition referencing AECB Regulatory Document R-99 "Reporting Requirements for Operating Nuclear Power Facilities". None of these events resulted in a *serious process failure*.

In our annual assessment report for 1995, we mentioned two events caused in each case by the failure of a single component, a programmable controller in the primary heat transport pressure and inventory control system, which we considered Ontario Hydro should have reported to us under the requirements of R-99. However, after a careful review of these events and discussions with Ontario Hydro staff, we have now concluded that both events were not strictly reportable under the current intent of the R-99 requirements. Therefore, after correction, the number of reportable events to the AECB in 1995 was 54.

WORKER RADIATION SAFETY

The number of Radiation Protection Regulations non-compliances in 1996 decreased compared to the previous year. None of these events in 1996 resulted in any undue radiological risk to the workers at the station. In our opinion, Ontario Hydro's worker radiation safety practices at Darlington are good and in accordance with the ***as low as reasonably achievable*** (ALARA) principle. In fact, the total ***whole body radiation dose*** (on a reactor unit basis) received by station staff at Darlington consistently ranks to be the lowest among CANDU stations.

None of the station staff received a whole body radiation dose in excess of the 50 *millisievert* (mSv) regulatory limit. The total whole body radiation dose to the station staff was 1123 mSv. (See Table 1.) Table 2 summarizes the information on whole body radiation dose to station workers

In the last quarter of 1996, Ontario Hydro put into service at Darlington a new self-serve whole body counter. Close to 300 station staff workers completed a training session and were whole body counted. The experience thus gained during this session indicated that the counter was sensitive, reliable and quite simple to use. Ontario Hydro intends to have everyone who works in *radiological zones* 2 and 3 to be trained and whole body counted on this counter, such that these workers can perform self-serve whole body counts routinely in the future.

The total internal exposure from tritium decreased from 30 percent in 1995 to 24.7 percent of the total whole body radiation dose in 1996. The lower internal dose from tritium in 1996 was achieved through better utilization of the reactor vault vapour recovery equipment, and attention to personnel protection prior to allowing the work to proceed.

Regulatory annual limits also exist for radiation exposure to individual organs (150 mSv), to the skin (300 mSv) and to the extremities (500 mSv). The maximum additional dose received by any one worker during 1996 in these three categories, respectively, was 0 mSv, 3 mSv and 29 mSv. Two workers were assigned a small whole body dose due to exposure to radioactive ***carbon-14***, where the maximum dose received was 0.18 mSv. There were no thyroid or lung counts taken in 1996.

Table 1: RADIATION DOSE TO STATION STAFF

	1996	COMMENT
Total whole body dose (mSv)	1123	Acceptable
Exposures > regulatory limit	0	Acceptable

Table 2: DISTRIBUTION OF WHOLE BODY DOSE FOR STATION WORKERS

DOSE RANGE (in mSv)	0-MRL	>MRL-5	>5-10	>10
Number of workers	982	688	44	2

MRL = Minimum Recordable Level

Lastly, a long-standing issue which we first raised in 1993 concerns the station interzonal airflows between radiological zones. We had then discovered that sometimes the airflows were in the wrong direction. Proper interzonal airflows are necessary to minimize the spread of airborne radioactive ***contamination***. Ontario Hydro has since established a multi-discipline team to work actively on ventilation problems generally, and on the interzonal airflows in particular. A number of changes have been implemented in the last two years resulting in a stable ***powerhouse*** pressure slightly lower than outside, and acceptable airflows at interzonal boundaries. Also, Ontario Hydro installed temporary pressure gauges to monitor pressure differentials during various operating conditions. These measurements will be used to conduct an air balance analysis of the various airflows. We are satisfied with the actions taken by Ontario Hydro and consider this matter to be no longer an issue.

PUBLIC RADIATION SAFETY

The operation of Darlington did not result in any undue radiological risk to the public or the environment in 1996. Ontario Hydro's control of radioactivity in effluents from the station met all our requirements during the year.

We discuss radiation releases from the station in terms of the ***derived emission limit*** (DEL). The radioactive emissions from the station during 1996 were far below the derived emission limits and below the licensee's operating target of one percent of the DEL. The radioactive ***noble gases*** were the dominant component of these emissions. Tables 3 and 4 contain more information about the airbome and liquid releases from the station in 1996.

In 1995, nearly half of the non-compliances with the Radiation Protection Regulations were ascribed to the ***stack*** emission monitoring equipment not

Table 3: AIRBORNE EMISSIONS

SPECIES	PERIOD	1996	COMMENT
Tritium (oxide)	No. weeks >1% DEL Average % DEL	0 0.096	Acceptable Acceptable
Tritium (elemental)	No. weeks >1% DEL Average % DEL	0 0.001	Acceptable Acceptable
Noble gases	No. weeks >1% DEL Average % DEL	0 0.180	Acceptable Acceptable
Iodine-131	No. weeks >1% DEL Average % DEL	0 0.004	Acceptable Acceptable
Particulates	No. weeks >1% DEL Average % DEL	0 0.001	Acceptable Acceptable

Table 4: LIQUID EMISSIONS

SPECIES	PERIOD	1996	COMMENT
Tritium	No. months >1% DEL Average % DEL	0 0.0022	Acceptable Acceptable
Gross *beta/gamma*	No. months >1% DEL Average % DEL	0 0.0154	Acceptable Acceptable
D_2O	total losses (kg)	9500	Acceptable

Table 5: PUBLIC RADIATION EXPOSURE		
ENVIRONMENTAL MEASUREMENTS	1996	CRITERIA
Average boundary gamma dose rate (nGy/h)	42.7	average anywhere in Canada: 228
Average boundary tritium in air (Bq/m^3)	0.9	range anywhere in Canada: 0.1-0.3[1]
[1]Maximum permissible concentration: 15 000 Bq/m^3		

meeting its availability requirement for continuous monitoring. In 1996, that equipment met the requirement for the monitors to be available 99 percent of the time (which allows up to 88 hours per year of ***unavailability*** for maintenance). Ontario Hydro also has a program in progress using one of the tritium removal facility annex exhaust stacks to test a new software package to monitor calibration as well as other equipment modifications to increase the reliability of its monitoring equipment. Ontario Hydro has internally targeted to implement them on all station stack monitors by 1999. We conclude that Ontario Hydro has satisfactorily resolved, through the actions being taken, the stack emission monitoring equipment problems mentioned in our previous annual assessment reports.

In 1996, Ontario Hydro reported only one event about the stack emission monitoring equipment. Ontario Hydro found, while implementing a new calibration procedure on the noble gas monitors, that previous releases for the noble gases had been underestimated due to an inappropriate calibration factor (originally supplied by the manufacturer) and used since their installation. However, a review of all noble gas emission data since the Darlington reactors started to operate indicated that it was unlikely that the one percent derived emission limits had been exceeded at any time.

Ontario Hydro's environmental monitoring program for radioactive material is similar at all nuclear sites. We compare Ontario Hydro's environmental measurements with background reference measurements established for an average person living anywhere in Canada. All environmental radiation measurements for Darlington were below or near background levels in 1996 as shown in Table 5.

SAFETY SYSTEM PERFORMANCE

SPECIAL SAFETY SYSTEMS

We require the ***special safety systems*** to be fully available 99.9 percent of the time. In order to meet this requirement, a system must be unavailable for less than nine hours per year. The four special safety systems all met this availability target in 1996. The number of hours each special safety system was unavailable in 1996 and the ***predicted future unavailability*** of each system are reported in Table 6. Since all four special safety systems were fully available 100 percent of the time, we consider this to be very good performance.

SHUTDOWN SYSTEMS

Each of the four units at Darlington uses two computerized ***shutdown systems***. In 1990, we instructed Ontario Hydro to redesign the software for both shutdown systems to better

Table 6: SPECIAL SAFETY SYSTEM UNAVAILABILITY[1] (IN HOURS)

SYSTEM	UNIT	1996	COMMENT	PREDICTED FUTURE
Shutdown system one	1	0	Acceptable	7.20
	2	0	Acceptable	
	3	0	Acceptable	
	4	0	Acceptable	
Shutdown system two	1	0	Acceptable	4.30
	2	0	Acceptable	
	3	0	Acceptable	
	4	0	Acceptable	
Containment system[2]	1	0	Acceptable	8.87
	2	0	Acceptable	
	3	0	Acceptable	
	4	0	Acceptable	
Emergency core cooling system[2]	1	0	Acceptable	8.78
	2	0	Acceptable	
	3	0	Acceptable	
	4	0	Acceptable	

[1] See glossary.
[2] Any faults on common portions of the containment system or the emergency core cooling system are included with each unit.

standards. Ontario Hydro staff, in conjunction with *Atomic Energy of Canada Limited* staff, has since written a new standard for the software engineering of safety critical software. Subsequently, they started to redesign the software. From the past six years of operational experience, together with a review of the design requirements, Ontario Hydro found that it needs some functional changes to the systems. In 1996, Ontario Hydro reported on how these changes would affect the safety of the systems and the plant. We have reviewed most of these reports, and conclude that the changes will result in shutdown systems that are as safe as, or safer than, the existing systems.

We performed a *quality assurance* audit of the Darlington shutdown system software redesign project in August 1996. The purpose of this *audit* was to check, at an early stage of the project, whether the software modification processes are satisfactory. The audit found that the project was generally well managed. Some problems were found with configuration management of documents, with independence between developers and verifiers and with the use of tools. In all problem areas, Ontario Hydro took prompt action to improve the situation. This gives us confidence that the redesigned software will be of good quality and will be completed on schedule. Ontario Hydro's most recent schedule indicates that completion of the redesigned software for the shutdown systems is targeted for mid-1998, with its implementation starting shortly thereafter. For comparison, the original schedule had targeted the redesigned software for *shutdown system one* to be complete by mid-1997 and for *shutdown system two* by the end of 1996.

We conducted a compliance inspection of shutdown system one (unit 2) in February 1996. We found that a large number of *deficiency reports* was still outstanding, 75 percent of them pre-dating 1995. Ontario Hydro indicated in response to this finding that the deficiency reports were being addressed as part of its on-going technical surveillance for the shutdown system one work program in 1996.

NEGATIVE PRESSURE CONTAINMENT SYSTEM

In the spring of 1997, Ontario Hydro will shut down all four Darlington reactor units for a major station *outage*. During this outage, inspection and leak rate testing of the *containment* structure will be performed, in accordance with standards requirements of the AECB and the Canadian Standards Association (CSA). In 1996, we reviewed Ontario Hydro's plans for this outage and confirmed that the activities proposed for the 1997 station outage will permit the verification of the structural integrity and leak tightness of the containment.

SAFETY SUPPORT SYSTEMS

There were more problems in 1996 affecting the *safety support systems* than in the previous year. In total, there were seven reportable events in 1996 compared to three events in 1995 and 13 events in 1994. Five of these events resulted in impairments of two of the safety support systems: the *steam generator emergency cooling system* (three events on different reactor units), and the *shutdown cooling system* (two events on same reactor unit). Two of these five events also resulted in non-compliances with the Operating Policies and Principles.

Ontario Hydro also reported two other events about the impairment of a *safety-related system* which, although not considered to be a safety support system, is nevertheless credited to mitigate the consequences of some postulated accidents, such as a steam main line break inside the powerhouse. Modifications were made to repair the powerhouse north wall pressure release cladding without the necessary approval being obtained (a non-compliance with the Operating Policies and Principles) and in a fashion such that it impaired its performance. The cladding has since been repaired to restore it to meet its original design intent.

We conducted in 1996 compliance inspections of the following safety support systems: *emergency service water system* (all four units and common portion), steam generator emergency cooling system (unit 2), *inter-unit feedwater tie system* (common to all four units), and shutdown cooling system (unit 1). We found for the emergency service water system a large backlog of high priority deficiency reports and active *jumpers* outstanding. Although Ontario Hydro took some actions to reduce this backlog, at year's end we still considered it to be unsatisfactory.

OPERATIONS AND MAINTENANCE

Three of the reactor units were shut down once during the year for a planned maintenance outage. Ontario Hydro carried out a number of inspections on *pressure tubes, steam generators, heat exchangers* and *feeders*, and completed the modifications to the primary heat transport *bleed condenser* relief valves of these units. Ontario Hydro also completed a program to reduce and reconfigure the *adjuster rods* in the reactor core of the same three units to achieve better neutron economy and neutron flux control. This program will be completed on the last unit in May 1997.

In unit 1, the *generator* rotor was replaced because of a ground fault which developed due to three slim copper bars that were inadvertently left in the rotor winding cooling channels during its assembly at the manufacturer's facility. Also in unit 1, all four steam generators were inspected for evidence of deterioration and were subsequently water lanced to dislodge deposits. The amount of deposits found was smaller than expected, thereby indicating that the chemistry control is good. One moderator heat exchanger was likewise inspected for signs of deterioration. Lastly, in both units 2 and 4, a number of ***emergency core cooling system*** check valves was inspected for freedom of movement. Table 7 presents a summary of station operation.

We carried out four rounds in the ***main control room*** to check on unit control panels, including one while a reactor was in the ***guaranteed shutdown state***. There were only minor findings from these rounds. We also conducted compliance inspections of the following process systems: containment atmosphere heating/cooling system (unit 1 and the east and west fuel facilities auxiliary areas), common instrument air and breathing air systems (central service area), end shield/shield tank cooling system (unit 1), condensate extraction system (unit 3), steam generator ***feedwater system*** (unit 4), and unit instrument air system (unit 1). We found from these inspections that there were many ***call-ups*** with past due dates and master flowsheets requiring updating for some of the systems. At year's end, we were satisfied with the actions taken by Ontario Hydro to correct these deficiencies.

Table 7: STATION OPERATION

INDICATOR	1996	COMMENT
Non-spurious reactor trips	3	Acceptable
Formally reported incidents	51	Acceptable
Fires	2	Acceptable
Special safety system jumpers at end of 1996	78	Acceptable

In addition, in preparation for a potential Power Workers Union strike, we devoted a substantial amount of time to the review and assessment of the operational readiness of systems required to maintain the reactors, at all times, in a safe shutdown state with adequate ***heat sink*** capabilities, and to the reliability of electric power supplies. We concluded from this review and assessment that, provided some outstanding work packages for a few identified safety systems were addressed promptly by Ontario Hydro, the required systems would be in a reasonable state of readiness to perform their expected functions.

PRESSURE TUBES

We are satisfied for now with Ontario Hydro's plans for inspection and maintenance of the Darlington pressure tubes.

However, one of the main causes of pressure tube damage is the accumulation of hydrogen and ***deuterium*** in the pressure tube material. Over time, this makes the material more brittle and therefore more prone to cracks, especially in the ***rolled joint areas*** of the pressure tubes, and at fret marks along the pressure tubes as more of them are produced or deepened due to *fretting* by the fuel bundle *bearing pads*. Therefore, we believe that repeat scrape sampling of the pressure tube material is necessary to measure hydrogen and deuterium ingress rates for better management of the pressure tubes. Ontario Hydro has not yet initiated scrape sampling on a routine basis at Darlington.

In 1996, Ontario Hydro carried out scheduled inspections of 20 pressure tubes in unit 1 and seven in unit 4. Four pressure tubes in unit 1 and two in unit 4 were found to have fret marks deeper than 0.15 millimetre caused by bearing pad fretting. After assessment, the fret marks were not considered to be a risk to the integrity of the pressure tubes, and thus the pressure tubes were allowed to return to service.

Ontario Hydro has chosen to manage the bearing pad fretting at Darlington by using a combination of long and standard length *fuel bundles* in the *fuel channels*. This does not arrest the fretting, but does move the fretting to a less sensitive area of the pressure tube. In March 1996, we approved the routine use of long bundles for refuelling operations in unit 4. We will continue to assess the effectiveness of this measure to ensure pressure tube integrity.

FEEDERS

Following reports that the *primary heat transport system* feeder pipes at the Point Lepreau Nuclear Generating Station were showing wall thinning due to corrosion, Ontario Hydro undertook to do similar measurements on unit 1 during its annual outage in 1996. Ontario Hydro found that wall thinning of the unit 1 feeder pipes had also taken place, and at rates that appear comparable to those measured at Point Lepreau. Ontario Hydro plans to do more measurements on all units in 1997. The general safety concern is that wall thinning could eventually lead to a feeder pipe failure resulting in a small *loss of coolant accident*. We have sent a generic letter to all licensees asking them to formally report how they intend to address this potential problem.

BLEED CONDENSER RELIEF VALVES

In response to the December 1994 event at the Pickering Nuclear Generating Station in which a primary heat transport bleed condenser relief valve failed open, Ontario Hydro initiated extensive design changes at Darlington, including the replacement of the current spring-operated relief valves with pilot-operated relief valves.

The replacement of the bleed condenser relief valves has been completed on three of the four reactor units in 1996. The modifications on the last unit will be done in May 1997. This is better than the original schedule proposed by Ontario Hydro whereby modifications on only two units were to be completed by the end of 1996.

Since Ontario Hydro does not yet have an approved quality assurance to cover fabrication and installation activities (see section on quality assurance), we conducted a quality assurance assessment during the installation of the new bleed condenser relief valves in unit 1 in May-June 1996. We found that most quality assurance and code requirements were generally being met although some non-conformances were discovered. These were corrected prior to the modifications being carried out on the other two units.

Lastly, we reviewed the manufacturer's reliability and maintainability study of the new relief valves. Although the study included past operating experience, failure modes and rates and measures required to ensure their reliability, we requested more data, which the manufacturer subsequently submitted, to prove that the failure rates of critical failure modes were sufficiently low to enable us to accept the claimed reliability of these relief valves for their first year of operation.

DUAL DIGITAL CONTROL COMPUTER FAILURE

In June 1996, a dual digital control computer failure was experienced on unit 3. A faulty power supply to a contact input chassis that is read by both digital control computers for ***annunciation*** alarms caused the failure. Numerous alarms were generated in a short time that could not be processed fast enough, at which point the software program failed both digital control computers as per design.

In 1995, there had been two other dual digital control computer failures. In all such events, the result of the dual failure is a safe reactor shutdown. Therefore, a dual digital control computer failure is considered by Ontario Hydro to be an economic penalty rather than a safety concern. It is our view, however, that dual digital control computer failures suggest reduced computer system reliability and thus contribute to increasing overall plant risk.

CHEMISTRY

As in previous years, Ontario Hydro continued to maintain good chemical control in the Darlington systems.

The overall chemical performance target of maintaining system chemistry within specifications 96 percent of the time was met. The performance is based on monitoring and controlling 12 chemical parameters in both primary and secondary side systems.

MAINTENANCE

The number of outstanding ***work packages*** at the end of 1996 was higher than the number at the end of 1995. This is attributed to outages on three reactor units lasting longer than originally planned, and which tend to favour completion of outage work packages to the expense of more general station work packages. Table 8 shows the outstanding work packages by category.

We pay particular attention to the number of outstanding work packages for safety systems. This year, the backlog of work for safety significant systems is about nine percent of the total number of outstanding field work packages. This is an acceptable number. Work packages that have been active

Table 8: OUTSTANDING WORK PACKAGES

	1995	1996
All systems	3259	4281
Safety significant systems	502	741
Backlog-safety significant systems	293	384

for longer than three months fall into the backlog category.

We are satisfied with the amount of ***preventive maintenance*** on equipment (call-ups) completed in 1996. The station target is to complete 90 percent of all scheduled call-ups on time. In 1996, 93.3 percent were completed on time and 99 percent were eventually completed. This means only one percent of all scheduled call-ups were either cancelled or never performed.

STATION MANAGEMENT

We consider that Ontario Hydro management has demonstrated through the years a proactive stance with respect to the safety of the plant workers and the public, and the protection of the environment. This was particularly illustrated in 1996 with regard to low volume of solid radioactive waste generated, low losses of ***heavy water*** from the station resulting in lower tritium emissions, and installation of a simple and reliable self-serve whole body counter for staff use. At year's end, Ontario Hydro was also pursuing to have its environmental management system program certified under the International Standards Organization ISO 14001 quality standard. (Certification was granted in early 1997).

However, we are concerned by the occurrence of three non-compliances with the Radiation Protection Regulations involving a few individual workers who broke the rules by consuming food in a radiological zone. Our main reasons are first of all for the safety of these workers, and secondly that these incidents may indicate the beginning of a cavalier attitude by some workers towards radiation protection. We asked Ontario Hydro management to redouble its efforts to ensure that all station staff adheres to the requirements of the Radiation Protection Regulations at all times.

LICENSING COMMITMENTS

Frequently, licensing issues are resolved when Ontario Hydro makes a commitment to do a number of things. The commitment can be to perform analyses, experiments, commissioning tests, safety-related system tests or maintenance call-ups, or to implement design or operating procedure changes.

We are satisfied with Ontario Hydro's progress on commitments made or met during the year. In 1996, Ontario Hydro had firmly proposed to complete seven of the outstanding commitments, and actually achieved the completion of six of them. At the end of 1996, there were 86 outstanding commitments with firm and target dates proposed by Ontario Hydro for completion.

TRAINING

We are satisfied overall with the adequacy of Ontario Hydro's training programs at Darlington.

In 1996, we administered four different examinations for the Darlington staff enrolled in the ***authorization training*** program for main control room personnel. A total of 25 candidates wrote the examinations and 23 achieved a pass, for a very satisfactory pass rate of 92 percent. Two candidates required additional special oral examinations. We authorized one ***shift supervisor*** and four main ***control room operators*** in 1996.

Also in 1996, we evaluated Ontario Hydro's program of continuing training for authorized shift supervisors and main control room operators. Our evaluation found that substantial training and re-qualification testing is taking place at the ***simulator***. However, we found that other aspects of this training program, such as refresher training to cover science fundamentals, station systems, design and procedural modifications, and operating experience feedback, as well as the re-qualification testing method used for the shift supervisors need to be improved. We also evaluated the contingency strike training activities that were conducted in early 1996, and these were found to be satisfactory.

EMERGENCY PREPAREDNESS

Ontario Hydro completed 18 shift crew drills in 1996 to test the capabilities of the emergency response teams. The site management group made up of senior management representatives also held two drills. The drills are shown by emergency types in Table 9. We are satisfied that Ontario Hydro maintained adequate emergency preparedness at Darlington in 1996.

Table 9: EMERGENCY RESPONSE DRILLS

Emergency response teams	No. of Drills
– reactor incident	4
– fire incident	8
– tritium removal facility incident	5
– casualty incident	5
Site management group (reactor incident)	2
TERP team (transportation incident)	4
Security guard force (intrusion incident)	1

The transportation emergency response plan (TERP) team also held four drills in 1996. The Ontario Hydro corporate TERP requires the Darlington TERP team to respond to transportation accidents within a designated area of southern Ontario.

There was one major security guard force drill in 1996 held in conjunction with the Durham region police services response team. Also, the station's security guard force conducts periodic security drills, at a frequency of about one drill a month for each shift crew, to validate security procedures and provide operational training for guards.

SAFETY ANALYSIS

We require the licensee to periodically review and update the safety report to reflect all design changes in the description of the nuclear facility, and to update the ***safety analysis*** according to an approved schedule. Ontario Hydro submitted an updated version of chapters 1 and 2 of the ***safety report*** at the end of March 1996. Ontario Hydro also proposed at the end of August 1996 a schedule to perform a number of safety analyses (chapter 3 of the safety report) over a two-year period.

The accident scenarios chosen to be analysed are: loss of primary heat transport flow, large and transient break loss of coolant accidents, loss of moderator cooling/flow, and low power operation (states not analysed in detail in the past). These analyses will be performed under the umbrella of a safety analysis quality assurance program we previously requested. Ontario Hydro has developed and issued several procedures in the context of that program which should result in better control of all aspects of the safety analysis process, including code development, configuration management and validation.

These analyses will be performed using a new approach, called the "operating parameter methodology" and developed by Ontario Hydro at Darlington, where best estimate code predictions include all uncertainties in plant state addressed to a certain confidence level. We have, however, not yet formed an official position on this methodology, nor its licensing implications.

In 1995, Ontario Hydro began a program to remove the adjuster rods that were locked in the reactor core and to reconfigure the remaining ones to achieve better neutron economy, thereby improving fuel economy and reducing costs and amount of radioactive waste produced. The safety analyses performed over the last two years in support of that program showed that the reactor can be safely operated with one third fewer adjuster rods, and with better neutron flux control.

The current methodology used at Darlington, as elsewhere at other nuclear stations, to establish the ***poison*** requirements for the guaranteed shutdown state, involves the use of static calculations, as transient models are not available. There is also limited experimental data to support the uniform mixing model which is used for poison dilution calculations. However, limiting assumptions are used in the static calculations to ensure that conservative predictions are obtained in terms of poison concentration. Ontario Hydro has committed to redo the calculations with a well documented set of conservative assumptions and to include all possible operating conditions while in a guaranteed shutdown state.

In the Darlington shutdown system software redesign project, Ontario Hydro has proposed to separate the moderator high level and moderator low level ***trip parameters*** in the trip computer software, control room displays and annunciations. The redesigned software will thus be consistent with the principle of separation of trip parameters. With regard to the safety analysis issue concerning shutdown system two ***trip*** effectiveness for loss of moderator cooling/flow events, Ontario Hydro has committed to installing design changes to improve the reliability of the moderator level measurements and to demonstrate effectiveness of the moderator high level trip parameter. These changes were installed on unit 1 in 1996. A technical scope document, analysis methodology and a schedule were submitted in 1995, and two progress reports on the effectiveness of the moderator high level trip parameter were received in 1996. We are currently reviewing both reports. We conclude that resolution of this issue has progressed in a satisfactory manner.

QUALITY ASSURANCE

We consider that Ontario Hydro has made good progress towards having an approved quality assurance program, in accordance with the Canadian Standards Association (CSA) N286 series of standards.

The reorganization of Ontario Hydro in 1993 has had a direct impact on Darlington's quality assurance program. The design function of that program, which used to be the responsibility of a department located at Ontario Hydro head office, was transferred to the site. However, our audit carried out in April 1996 to determine the effectiveness of the design modification process found that the transfer of design responsibility to the site did not include an effective transfer of the corresponding control aspects of the design function. In particular, many procedures were outdated with regard to the present organization and current practices.

Ontario Hydro has since submitted a completely revised quality assurance manual for operation of the Darlington Nuclear Generating Station, in accordance with the quality principles specified in the relevant CSA standards. This manual references some 234 procedures and Ontario Hydro undertook in 1996 a very large effort to update those procedures needed to reflect the present organization and practices. By year's end, 88 percent of those procedures had been revised. We are currently assessing the adequacy of this manual.

We also instructed Ontario Hydro that fabrication and installation activities for pressure-retaining items and components at Darlington should be carried out under a program that meets the CSA N285.0 standard and be subject to the required approvals and certification by the jurisdictional authority. This program was received from Ontario Hydro in December 1996. We are currently assessing this program with the staff of the Ministry of Consumer and Commercial Relations.

SAFEGUARDS

Canada is a signatory of the *Treaty on the Non-Proliferation of Nuclear Weapons*. Pursuant to the Treaty, Canada has entered into a *safeguards* agreement with the *International Atomic Energy Agency* (IAEA). This agreement provides the IAEA with the right and the responsibility to verify that Canada is fulfilling its Non-Proliferation Treaty commitment not to use its peaceful nuclear program to make nuclear weapons or nuclear explosive devices. A requirement for the application of IAEA safeguards is included in the Darlington operating licence.

To comply with this, the staff of the Darlington Nuclear Generating Station is required to provide timely reports on the movement and location of all nuclear materials within the station, and to provide access and assistance to IAEA inspectors for verification purposes and for the installation and maintenance of IAEA equipment at the station.

In 1996, the IAEA installed and tested the new generation of mark II bundle counters, developed under the Canadian safeguards support program. The bundle counters are used by the IAEA to monitor fuel bundles discharged into the *irradiated fuel bays*.

The staff of the Darlington Nuclear Generating Station provided good cooperation and support to our staff and that of the IAEA during these activities. Reports and notifications of activities involving safeguards were provided in a timely manner, in compliance with the operating licence.

TRITIUM REMOVAL FACILITY

We are satisfied that Ontario Hydro is operating the tritium removal facility safely and complying with licensing requirements. Removal of tritium from the heavy water used in a nuclear power station reduces the risk of radiation exposure to station staff and releases of tritium to the environment.

The Darlington Nuclear Generating Station, including the tritium removal facility, is required to operate with a radiation protection program as defined in the licensee's own Radiation Protection Regulations. As mentioned earlier, these Regulations are referred to in the Darlington operating licence. We conducted a health physics appraisal from May 13 to 17, 1996, to assess various aspects of the radiation protection program during normal operation of the tritium removal facility, and as a follow-up to the 1991 appraisal on radiation contamination control.

The scope of the appraisal included the organization and management of the radiation protection program in place at the tritium removal facility (and in the heavy water management building in which the facility is located) personnel, qualification and performance, radiation dose control practices, radiation protection instrumentation, equipment and facilities, and radioactive contamination control. The appraisal results indicated that radiation contamination control has greatly improved due to changes in the facility design (with the addition of the tritium removal facility annex), and due to the strong support of line management. We concluded that, overall, the radiation protection program in the tritium removal facility/heavy water management building adequately minimizes the contamination of personnel, areas and equipment.

However, we noted that further improvement in contamination control could be achieved by conducting periodic and formal assessments of the tritium removal facility radiation protection program and by implementing a more systematic approach to training for occasional tritium removal facility workers. A few other minor areas of concern were also noted to Darlington management.

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CONCLUSIONS

Ontario Hydro operated Darlington Nuclear Generating Station safely during 1996.

It maintained the good performance seen last year in the following areas:

- meeting all the requirements of the Atomic Energy Control Regulations and the AECB Cost Recovery Fees Regulations;
- adequate response and follow-up to the 51 reportable events;
- good worker radiation safety practices in accordance with the ALARA principle;
- satisfactory control of radioactive materials released in effluents from the station;
- very good performance of the special safety systems which were fully available 100 percent of the time;
- completion of preventive maintenance call-ups on time satisfactorily;
- maintenance backlog of work for safety significant systems kept at a reasonable level;
- maintaining good chemical control in the various station systems;
- safe operation of the tritium removal facility;
- replacement of the primary heat transport bleed condenser relief valves completed on three units in 1996;
- proactive stance demonstrated by Ontario Hydro management with respect to safety of plant workers and the public, and protection of the environment;
- adequate training programs for control room staff requiring AECB authorization;
- adequate progress on commitments made in 1996;
- adequate emergency preparedness; and
- good cooperation for safeguards activities.

We noted improvements to nuclear safety at Darlington in the following areas:

- marked decrease in number of deficiencies observed in 1996 with regard to physical security measures at Darlington;
- reduced number of noncompliances with Operating Policies and Principles, Radiation Protection Regulations, and other operating licence conditions;
- marked decrease in total internal exposure from tritium;
- proposed functional changes for the redesigned software of the trip computers that should result in shutdown systems as safe as or safer than the existing systems;
- acceptable airflows at interzonal boundaries achieved to minimize the spread of airborne radioactive contamination;
- marked improvement in reliability of the stack emission monitoring equipment in 1996;

- satisfactory progress with regard to safety analysis update in terms of proposed accident scenarios, methodology, and schedule;
- satisfactory progress on demonstration of dual parameter trip coverage (moderator high level trip) on shutdown system two for some postulated accidents;
- much improvement on the quality assurance program issue in 1996; and
- much improved radiation contamination control in the tritium removal facility due to changes in the facility design, and strong support of line management.

We would like to see the following improvements:

- elimination of non-compliances with the Transport Packaging of Radioactive Materials Regulations;
- elimination of non-compliances with the Physical Security Regulations;
- better adherence to the Radiation Protection Regulations, particularly incidents of food consumption in radiological zones should be eliminated;
- necessary efforts made to ensure that the shutdown system software redesign is completed as per target schedule;
- better reliability for the safety support systems;
- decrease in backlog of high priority deficiency reports and active jumpers for the emergency service water system;
- smaller probability of dual digital control computer failure;
- decrease in number of outstanding work packages;
- better defined requirements for refresher training to cover additional topics such as science fundamentals, and better defined process to test the continued competence of shift supervisors; and
- periodic assessments of radiation protection program and implementation of a more systematic approach to training for occasional workers in the tritium removal facility.

GLOSSARY

AECB Cost Recovery Fees Regulations — Regulations made pursuant to the *Atomic Energy Control Act* by the *Atomic Energy Control Board*.

adjuster rods — Neutron-absorbing rods, normally fully in the reactor *core*, that adjust the distribution of power in the reactor.

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

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

as low as reasonably achievable (ALARA) — The principle, applied internationally, of keeping radiation doses "as low as reasonably achievable", social and economic factors taken into account.

Atomic Energy of Canada Limited (AECL) — A crown company incorporated in 1952 to conduct research into and develop peaceful uses of nuclear energy. Its objectives include the development of nuclear power systems to meet Canadian needs.

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) — A federal departmental corporation 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.

authorization training program — A program of training set up by a station to train candidates for positions that require authorization by the *Atomic Energy Control Board*. These positions are *control room operator* and *shift supervisor.*

bearing pads — Metallic pads brazed to the outer ring of elements in a *fuel bundle*. They maintain proper clearances between the bundle and the *pressure tube*.

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.

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

Canadian Deuterium-Uranium (CANDU)) — A Canadian-designed reactor that is moderated and cooled by *heavy water* and fuelled with natural uranium. The name comes from <u>Can</u>adian <u>D</u>euterium-<u>U</u>ranium.

carbon-14 — A radioactive isotope of carbon produced in some reactor systems.

central service area — An area that serves all units of a multi-unit station. It contains laboratories, workshops, storage supplies, administrative offices, the *irradiated fuel bay* and the *main control room*.

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.

decay heat

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

deficiency report

Also known as a work order. All work on the station is controlled. A document produced to identify a problem in the station and to initiate repairs.

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".

deuterium

An isotope of hydrogen that has one proton and one neutron in its nucleus.

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.

feeder

There are 480 *fuel channels* in the reactor. The feeders are pipes that supply *heavy water* coolant to each fuel channel and return the hot coolant to the *steam generators*.

feedwater system

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

fretting

The wearing or damage caused by one material upon another due to vibration.

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 stays shut down. It includes adding *poison* into 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.

International Atomic Energy Agency (IAEA) — The IAEA is 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.

inter-unit feedwater tie — A system that allows water to be transferred between the steam generator *feedwater systems* of different units at a multi-unit station. It operates if the *steam generators* lose their normal supply of feedwater.

iodine-131 — A radioactive isotope of iodine produced in the fuel when the reactor is operating.

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.
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* 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.

powerhouse — That part of a station that contains the equipment used to convert the energy in the steam from the *steam generators* to electricity.

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 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*.

quality assurance — A formal program of standards, procedures and checks that control the quality of work carried out 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*.

radiological zones — A nuclear facility is divided into radiological zones for the purpose of controlling the spread of radioactive contamination.

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

rolled joint areas — The area of a *pressure tube* which contains the joint between the pressure tube and the *end fitting*. The joint is formed through a mechanical rolling process.

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 analysis
Analysis completed to show that the risk of operating the station is acceptably low.

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.

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*.

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.

stack
The chimney-like exhaust of a ventilation system.

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 emergency cooling system
A system that provides an interim ordinary supply to the *steam generators* following a rupture of a *steam generator tube* and/or loss of *feedwater*. It operates until the *emergency service water system* is available.

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 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 produced in the reactor's *heavy water* during operation.

tritium removal facility

A facility at Darlington designed to remove radioactive *tritium* from the *heavy water* used in reactors. Such removal reduces the hazards to operating staff and the release of radioactive material to the atmosphere.

turbines

Equipment comprising several bladed wheels that rotate when steam from the *steam generator* 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 radiation dose

The radiation exposure that affects all of the body tissue. Radiation that penetrates the body completely, or radioactive materials absorbed by the body, cause it.

work package

The document Ontario Hydro uses to track work done in a station. It outlines the steps necessary to complete a particular task and identifies the necessary work groups.