**Current Issue Review** **83-14E**

# NUCLEAR POWER SYSTEMS: THEIR SAFETY

**Lynne C. Myers**
**Science and Technology Division**

***Revised 2 November 1999***

Library of Parliament
Bibliothèque du Parlement

**Parliamentary Research Branch**

N.B. Any substantive changes in this publication which have been made since the preceding issue are indicated in **bold print**.

# TABLE OF CONTENTS

PAGE

CANADA

LIBRARY OF PARLIAMENT
BIBLIOTHÈQUE DU PARLEMENT

# NUCLEAR POWER SYSTEMS: THEIR SAFETY*

## ISSUE DEFINITION

Human beings utilize energy in many forms and from a variety of sources. A number of countries have chosen nuclear-electric generation as a component of their energy systems. By mid-1996, there were 447 power reactors operating in 31 countries, accounting for more than 15% of the world's production of electricity. In 1996, 18 countries derived at least 25% of their electricity from nuclear units, with Lithuania leading at just over 76%, followed closely by France at 75%. In the same year, Canada produced about 19% of its electricity from nuclear units. Five new reactors were added to the grid between June 1995 and June 1996 - two in Japan, and one each in Ukraine, South Korea and the United States. Two other reactors, which had been shut down for some time, were reconnected in the last year. Brown's Ferry 3 in the United States had been closed since 1985 and Armenia 2 had been out of service since 1988. One reactor in Germany and one in Canada (Bruce 2) were closed. In the same year, 39 power reactors were under construction in 15 countries.

No human endeavour carries the guarantee of perfect safety and the question of whether or not nuclear-electric generation represents an "acceptable" risk to society has long been vigorously debated. Until the events of late April 1986 in the then Soviet Union, nuclear safety had indeed been an issue for discussion, for some concern, but not for alarm. The accident at the Chernobyl reactor irrevocably changed all that. This disaster brought the matter of nuclear safety into the public mind in a dramatic fashion. Subsequent opening of the ex-Soviet nuclear power program to outside scrutiny has done little to calm people's concerns about the safety of nuclear power in that part of the world.

Nuclear reactors in all parts of the world are "aging" more quickly than expected, raising still more safety concerns. In Canada, the recent release of a damaging review of the

---

* The original version of this Current Issue Review was published in October 1983; the paper has been regularly updated since that time.

management of Ontario Hydro's nuclear facilities has prompted new anxiety over safety issues. This paper discusses the issue of safety in complex energy systems and provides brief accounts of some of the most serious reactor accidents that have occurred to date, as well as more recent events touching on the safety issue.

## BACKGROUND AND ANALYSIS

### A. Safety in Complex Energy Systems

Assessing how complex systems fail is a complicated matter and reactor accidents and serious incidents over the years have demonstrated that this assessment is less certain than once supposed. Not only may complex systems incorporate errors in design, contributing to safety problems, but they may also suffer from defects in construction, quality assurance, maintenance and operation. This is why nuclear power stations are designed and operated following a "defence-in-depth" philosophy that incorporates such features as redundant safety systems.

The reactor accident of March 1979 at the Three Mile Island generating station in Pennsylvania illustrates how mechanical problems can be compounded by operator error, emphasizing the importance of human reliability as well as equipment reliability in ensuring safety. Indeed, the Report of the President's Commission on the Accident at Three Mile Island (the "Kemeny Report") had more to say about the people involved in reactor safety -- the equipment manufacturers, the utility managers, the plant operators and the staff of the U.S. Nuclear Regulatory Commission (NRC) -- than it did about improving the technology.

Accidents may also occur because the supposedly independent and redundant systems fail simultaneously due to a common initiating event. For example, identical valves in independent units have failed simultaneously in response to a common set of conditions because they were not designed or installed properly. Improper maintenance may also cause a common failure, perhaps because each of the independent units has been improperly calibrated or serviced. A totally unexpected failure may also occur because the sheer complexity of the system has prevented all potential accidents from being identified.

The Salem-1 reactor in New Jersey provides an example of an unanticipated failure. When a routine anomaly or "transient" occurs during reactor operation, a safety system is supposed to shut down automatically or "scram" the reactor by stopping the nuclear chain reaction. A failure of the safety system to operate in this way -- termed an Anticipated Transient Without Scram

(ATWS) -- was supposed to have such a low probability that the risk it represented was negligible. The U.S. nuclear industry argued that ATWS regulations and protective measures were unwarranted on the grounds that the basic safety systems were virtually fail-safe; in 1980 an expert on reactor safety could write: "No reactor has ever failed to 'scram' in an emergency." Yet twice within four days, in February of 1983, just such an event occurred at Salem-1. Operators manually scrammed the reactor in both cases, preventing damage to it, but the incidents demonstrated that a breakdown in electronic safety systems was not as implausible as the industry had maintained.

The subsequent investigation of the Salem-1 incident by the U.S. NRC determined that a critical component, designed to drop the reactor shut-off rods automatically, had failed in both circuits of a doubly redundant system. This component, which should have received twice-yearly maintenance, had not been maintained at all during its years of service in the station and "dirt accumulation on exposed linkages" was described by the NRC as one of the causes of failure.

The Chernobyl accident, the worst-ever accident involving a commercial nuclear power reactor, resulted from an incredible series of "human" errors. It is interesting to note, however, that an article in a Kiev newspaper, a month before the accident, had criticized acute shortcomings in materials, shoddy workmanship and low morale at the plant. All are factors influencing the safe operation of the station.

This accident sparked an unprecedented interest in the question of nuclear safety and as a direct result the International Atomic Energy Agency (IAEA) developed two new international conventions. Canada has signed both of them; the first deals with early notification to other countries about nuclear accidents and the second involves an undertaking to help other countries that have suffered such an accident. The IAEA has also received proposals involving international regulation of nuclear power.

In the United States, in the early to mid 1980s a growing number of serious operating mishaps at nuclear power installations led that country's Nuclear Regulatory Commission to make the chilling prediction that, given the level of safety being achieved by the operating nuclear power plants in the U.S., one could reasonably expect to see a core meltdown accident within the next 20 years. Such an accident could result in off-site releases of radiation as large as, or larger than, the releases estimated to have occurred as a result of the Chernobyl accident.

This prediction, coupled with the Three Mile Island mishap, prompted the United States Nuclear Regulatory Commission to implement a Severe Accident Policy in 1985. As part of that program, all existing plants were systematically examined for severe accident vulnerability and mitigative measures were suggested where necessary. As reactors in the U.S. have aged, it has become increasingly difficult for many of them to meet the higher standards. It is often financially unfeasible for the companies involved to make the necessary repairs and so a growing number of reactors are being taken out of service.

Canada also carried out a major internal review of its nuclear power plant safety in the early 1990s. In addition, the Operational Safety Review Team (OSART) of the International Atomic Energy Agency was invited to review operating practices at the Pickering Nuclear Generating Station. Results of both studies indicated that the CANDU reactor was being operated safely in Canada, although minor changes to operating procedures and emergency plans were suggested. Despite this reassurance, however, a leak of 150,000 litres of radioactive water occurred at the Pickering station in late 1994. In reviewing the accident, the Atomic Energy Control Board reported that, in addition to a fundamental design flaw in the pressure relief valves, human error had contributed to the severity of the spill. The AECB itself came under criticism because engineers at Pickering could not reach Board staff during the crisis.

More recently, in August 1997, Ontario Hydro released the results of an internally initiated Independent, Integrated Performance Assessment (IIPA). A decline in the "safety culture" at Ontario Hydro's nuclear generating stations was one of the report's main criticisms. This assessment highlighted the importance of maintaining all equipment and systems in a nuclear power plant and of operating the plant according to prescribed procedures in order to ensure the effective functioning of safety features incorporated in the original design. The essential role of the "human element" in maintaining safety in such a complex energy system was stressed repeatedly. In fact, the report was highly critical of the management of Ontario Hydro Nuclear (OHN) and its possible effect on safety. The report stated that:

> Unless fundamental problems, most notably a lack of authoritative and accountable managerial leadership, are addressed and corrected, there is limited potential for success at OHN. Moreover, many problems are so deeply entrenched within all aspects of OHN (organizational structures, practices, policies and systems) that individual managers are unable or unwilling to take corrective action....OHN staff at every level is reluctant to ask difficult questions of themselves or others. Failure to establish a questioning attitude is a primary cause of a reduction in the "defense-in-depth" concept.

The report went on to say that the deficiencies identified by the assessment team required urgent action, since they "represent departures from the 'defense-in-depth' concept that forms the erosion of the margin of safety afforded the public and employees." Though it is small comfort, the review team felt that, despite the serious decline in safety margins, "the remaining safety margins are sufficient to protect station workers, the general public and the environment at each OHN site." In response to the IIPA, Ontario Hydro announced the "laying up" of seven of its 19 reactors (four at Pickering A, and three at Bruce A) and the permanent closure of the Bruce heavy water plant. Action over the next three years was promised to remedy the deficiencies identified at Pickering and Bruce B and Darlington.

In France, a report in the early 1990s by the chief inspector for nuclear safety noted that, given the state of reactors operating in that country, the chances of such an accident's happening in the next 20 years amounted to "several percent." The potential for human error, which was responsible for the Chernobyl disaster, was cited as the main reason for such an alarming threat. The report went on to cite several previously unreported "near-accidents" at French reactor sites which could have led to large releases of radioactivity had they not been intercepted in time.

### B. Inherent Safety vs. Engineered Safety

The safety of most commercial nuclear reactors in operation today depends on engineered systems. In the event of an accident, some engineered systems must detect danger and then respond to it in order to shut down the reactor. It is also possible, and perhaps in light of the Chernobyl accident essential, to design reactors that are "inherently" safe. The shutdown of such reactors during an accident would rely solely on the laws of physics and not on engineered systems and operator intervention. In the words of one writer, "The idea behind inherent safety is to replace Murphy's law (if anything can go wrong, it will) with the laws of physics." Several countries have been developing inherently safe reactors and they will serve as illustrations of the concept.

Sweden has developed a pressurized water reactor it calls PIUS, in which the core cooling system and all heat exchangers are immersed in a solution of boron. Boron is a neutron absorber and quickly damps down the heat-generating chain reaction. During normal operation, the pressure generated by the coolant pump keeps the borated water out of the reactor. If the coolant pumping system fails, the difference in density between the hot water and cold water would immediately cause the reactor to be flooded with borated water, shutting down the chain reaction.

No human, mechanical or electrical intervention would be required to achieve shutdown. Sweden is moving away from using nuclear power and so no commercial PIUS reactors have been built.

Germany has a high-temperature, gas-cooled reactor (called the THTR 300) which has round fuel elements the size of tennis balls. These fuel elements are circulated: one drops out of the core every eight seconds and another is put in on top. Because of the size and surface-to-volume ratio of the fuel elements, it is impossible for the core temperature to exceed 1600$^{o}$C. The designers claim that this reactor could lose all of its coolant (helium gas) without getting hot enough to release fission products.

A number of reactors being worked on in the United States also incorporate self-shutdown mechanisms that require no mechanical, electrical or human intervention. Since the accident at Chernobyl, such reactors are much more attractive than they once might have been. In the U.S., in fact, observers believe that the introduction of such reactors is the only way in which that country will again accept nuclear power as a viable energy supply option. The economics of power generation in the U.S. have brought new construction of nuclear plants to a standstill in that country. No new plants, of either the old or new design, are currently on order.

### C. The Chernobyl Accident

On 26 April 1986, the town of Chernobyl, located 60 miles north of the Ukrainian capital of Kiev, became the site of the most serious accident ever known to have taken place in a nuclear power reactor. A series of human errors, combined with what some western experts believe to be serious design flaws, resulted in a catastrophic explosion and fire involving the core of the reactor itself. The immediate results of the explosion and fire were the death of two people on the site and a very large release of radioactivity. The unprecedented release of dangerous fission products from the reactor core necessitated the evacuation of tens of thousands of people, and contaminated an area of approximately 300 square kilometres of rich farmland. The radiation spread across international boundaries, contaminating food and causing much concern over long term health and environmental effects.

On 25 August 1986, the Soviet Union presented a detailed report on the causes of the Chernobyl disaster at a special meeting of the International Atomic Energy Agency (IAEA) in Vienna. Ironically, the most serious nuclear reactor accident of all time had occurred in the course of a safety test. Apparently workers were trying to determine how long the turbine generators would continue to turn due to inertia in the event of an unplanned reactor shutdown. To carry out this experiment, the workers committed no less than six serious errors - including shutting off all the reactor's automatic safety systems so that they would not interfere with the experiment.

The chain of events started on 25 April, when the power level in the reactor was reduced. Because automatic control systems were in place to prevent the reactor's operation at such low levels, the workers shut them off. This removed one of the safety systems designed to prevent the reactor from going out of control. Power levels then dropped too low for the test; in trying to bring the reactor back up to the required level, technicians committed the second fatal error. Control rods are used to regulate and, as the name implies, control the chain reaction in the reactor. In the light-water-cooled, graphite-moderated (RBMK in Russian terminology) design there must be a minimum of 30 control rods inserted in the reactor at all times. Technicians at Chernobyl removed all but six to eight of the rods. To compound the problem, a second safety system, which would have automatically shut down the reactor when the turbines stopped, was also disconnected for the test.

The actual test started at 1:23 a.m. on 26 April when power to the turbine was stopped. Just before this was done, the flow of water to cool the reactor was reduced and safety devices that would shut down the reactor in the event of abnormal steam pressure or water levels were disengaged. This latest manoeuvre caused the reactor to start overheating dangerously, but, because the emergency cooling system had been shut down 12 hours before, there was no relief from the heat build-up. Within seconds, a tremendous power surge caused two explosions which blew the roof off the reactor building and ignited over 30 fires around the plant. The damaged reactor core and the surrounding graphite moderator started burning at temperatures up to 1600$^{o}$C. The fire burned for 12 days, releasing massive amounts of radiation into the atmosphere.

Exactly how much radioactivity was released is not yet known, but there have been numerous estimates. One U.S. estimate holds that at least 40 million curies of radioactivity were released; this compares well with the Soviet estimate of 50 million curies noted in their report to the IAEA. This represents about 3.5% of the radioactivity of the core. (By comparison the Three Mile Island accident in the United States released only 15 curies of Iodine-131.) While it is hard to compare this release with that of Hiroshima or Nagasaki, because the fission products involved are different, one radiation physics expert says that, roughly speaking, the Chernobyl accident released an equivalent of 30 to 40 times the radiation of those atomic bombs.

Much of the radiation fell on the plant site and surrounding towns and farms, but some was carried into several neighbouring countries, including Sweden, Poland, Romania, Switzerland, West Germany and Yugoslavia. In these countries, radiation levels temporarily increased to several times normal levels. In the town of Chernobyl, 12 miles from the site of the accident, a maximum radiation of 15 millirems/hour was reported. Normal background radiation in most parts of the world is about 0.01 millirems/hour.

In economic terms, the accident has been a disaster for the former Soviet Union and the newly independent states of Ukraine and Belarus, which have inherited the problem. In addition to the cost of resettling 135,000 people, they face the loss of the $1.9 billion plant itself, a cleanup bill in the hundreds of millions of dollars and the loss of much needed nuclear generating capacity. This potential loss of electrical production was so serious, in fact, that in October 1986 Units 1 and 2 at Chernobyl were restarted. Unit 3, which shares a control room and generating equipment with the unit destroyed in the accident, was restarted in the early part of 1988. As noted previously, the international community has recently (December 1995) moved to provide financial assistance to Ukraine so that, by the year 2000, all four units at Chernobyl can be closed.

On top of these costs comes the cost of improving safety standards for all RBMK reactors in the former Soviet Union. Measures being instituted include an increased number of absorbers, higher enrichment of fuel, control rod modifications and improvements in the protection against human error in the early stages of an accident (i.e., more automation).

The affected countries of the former Soviet Union also face the loss of much valuable farmland and the associated loss of agricultural production. For example, Belarus has lost 20% of its farmland as a result of the disaster. One American study done soon after the accident put its total cost to the economy of the former Soviet Union at $3.7 to $6 billion (U.S.). The Soviets themselves admitted to direct losses of some $3.6 billion (U.S.) at that time. More recently, however, other authorities have estimated that some $200 billion rubbles ($380 billion Cdn.) would be required over the next 10 years to cope with the consequences of the Chernobyl disaster. Whatever the final figure turns out to be, it will represent an enormous drain on the economy of the whole region.

The immediate health effects of the Chernobyl accident were not difficult to assess. At the time 31 people were reported to have died as a result of the explosion and subsequent release of radioactivity. About 300 or so other people were treated for acute radiation sickness but were later released from hospital. A newspaper article from November 1989, however, noted that the death toll from the accident had already reached 250 people.

As for the long-term health effects of Chernobyl, the picture becomes much more clouded and there is debate over how many people will be affected. The most widely reported estimates vary from 2,000 to 6,500. That is to say that experts expect anywhere from 2,000 to 6,500 extra cancer deaths over the next 50 to 70 years as a result of Chernobyl. Other experts have expressed the fear that this number could be much higher -- as high as 50,000 to 250,000 -- due to the possible contamination of the food chain by caesium 137 and caesium 134. Caesium lodges in tissue and in muscle and delivers a large dose of radiation to those who absorb it. The absorption of radioactive iodine, especially in children, is also of grave concern.

Five years after the accident, the incidence of thyroid cancer in children in the areas that received the highest levels of contamination had already begun to rise dramatically. Doctors in the region admitted that, of the children being monitored, 14% suffered very heavy doses of radiation; however, fully 40-45% are now showing enlarged thyroids, a symptom which is a known precursor to thyroid cancer. By 1996, 10 years after the disaster, these fears were being realized. A report indicated that the rate of thyroid cancers in the most contaminated areas shot up from one per million before 1986 to 200 per million in 1994.

Authorities note, with considerable pessimism, that thyroid cancer and leukemia are usually just the first types of cancer to show up. The experiences of Japanese survivors of nuclear bombs had led experts to expect that cases of leukemia would be the first to increase. So far, however, there has been no noticeable increase in the number of leukemia cases near the Chernobyl site. This is probably due to differences in the nature of the radiation and the susceptibility of the exposed population.

In addition to cancer deaths, the damage that radiation can do to the human immune system is expected to result in an increase in all types of infectious diseases during the coming years. Fetal exposure to high levels of radiation exposure has also been linked to higher than normal occurrences of mental retardation, and emotional and behavioural disorders.

The social and political fallout from the Chernobyl accident threatens to be as long-lived as the radioactivity it released. Late in 1990, a further 73,000 people were moved out of areas of the Ukraine, Belarus and Russia that were considered to have unacceptably high levels of radiation. There are reportedly plans to relocate still another 300,000 people eventually. These figures are in addition to the 100,000 people who were moved out of the area in 1986.

## D. Recent Issues of Concern

### 1. Accident at Japanese Fuel Processing Facility – 30 September 1999

**On 30 September 1999, an accident at the Tokaimura Uranium Processing Plant, 150 km from Tokyo, sent local radiation levels skyrocketing, critically injured two workers and exposed at least 46 others to serious radioactive contamination. The plant, operated by a private company known as JCO, makes enriched uranium reactor fuel rods for Japanese power reactors. One step in this process involves mixing an oxide of uranium, $U_30_8$, with nitric acid. This mixture is then added to a solution of ammonium salt in a sedimentation tank to form the precipitate called ammonium diurinate, which is, in turn, processed into uranium dioxide fuel.**

**According to early reports, workers at the plant had mixed the uranium and nitric acid and were dumping the solution into the sedimentation tank using specially designed buckets. This is contrary to government-established rules, which call for the mixing to be done slowly, using a pipeline connection. By breaking the rules, however, the company could speed up the process to take just 30 minutes rather than three hours. Clearly, this commercial concern played a role in the accident.**

**An excess amount of uranium (16 kilograms vs. the acceptable 2.4 kilograms) was apparently added, resulting in the formation of a critical mass of fissile material. The end result was a runaway nuclear chain reaction. The fact that the plant uses a water-based process added to the problem; water acts as a moderator, slowing down neutrons released in the reaction, so they can split more atoms and thus sustain the chain reaction. Apart from Japan, Kazakstan is the only country that still uses this method, all other countries with such processing facilities having switched to a dry process for safety reasons. The uncontrolled reaction at Tokaimura was eventually brought to a halt when the water was drained out of the tanks.**

**If regulations are followed properly, the chain reaction described above cannot be caused at a processing facility so the company was not required to have an emergency plan in place to handle it. This accounts for officials' relatively slow reaction to the accident. The event has caused great public concern in Japan, a country that relies on nuclear power for over one third of its electricity.**

**Even more upsetting to the public was the revelation that JCO, which is a wholly owned subsidiary of Sumitomo Metal Mining Company, has admitted that it has been deviating from government-approved procedures for years by having its own (illegal) manual which cut out some important safety steps and, as noted above, speeded up other parts of the process. There is growing concern in Japan that companies in the nuclear industry have become complacent, or even arrogant, about their ability to handle radioactive materials. Some critics have noted that the necessary "safety culture" is missing. The fact that safety regulations for nuclear fuel processing plants are much less stringent than those for nuclear power plants is also being openly criticized in light of the accident at JCO.**

**While the chain reaction has ended, officials continue to monitor radiation levels in areas close to the accident site. Early reports indicate that workers inside the plant were exposed to radiation up to 4,000 times the level considered safe, while readings outside the plant site recorded levels about five times that of natural background radiation. It will be some time before the full extent of the contamination is known. The Japanese government is still considering laying criminal charges against the company involved.**

2. Aging Problems in East European Reactors

Recent political changes in eastern Europe have led to a greater awareness of the state of the nuclear reactors in that part of the world. This new awareness has brought a great deal of concern. Most of the reactors in eastern Europe are a Soviet design and are in urgent need of repair and/or upgrading. Following the reunification of Germany, five such reactors in East Germany were shut down because they did not meet West German safety standards. In other countries, such as Czechoslovakia and Bulgaria, the need for the power from the "dangerously antiquated" nuclear reactors is such that shutting them down is not an option. The international community has stepped in to help with upgrading the safety features, both operational and mechanical, of those Soviet-designed reactors deemed to be safe enough to be worth upgrading. The G-7 has set up a multilateral fund which started at $74m (US) in January 1993 and is hoped will ultimately total some $700m (US), the amount believed needed to accomplish the necessary work. The fund will be administered by the European Bank for Reconstruction and Development.

In addition, the European Community has two programs in place to help identify and address safety issues in Soviet-designed reactors. These programs, known as TACIS and PHARE, are set up in such a way that they complement rather than duplicate the G-7 program.

Despite international efforts to date, concern remains high as underpaid nuclear experts continue to emigrate from the former Soviet Union in great numbers, leaving this area with a critical shortage of suitably trained manpower. In late 1995 a report by Russia's official inspection body indicated that nuclear safety in that country was plummeting. More than 38,000 safety violations were recorded at civilian and military establishments in the two preceding years. The report cited the continued operation of dangerous reactors and poor radiation protection as two of the leading causes of this state of affairs. The lack of adequate, highly trained personnel was also cited as a factor.

The announcement in mid-1995 that Armenia, facing a desperate need for electricity, would be re-starting its aging nuclear power plant has caused great concern, particularly in Europe. This plant was closed as a precaution as a result of damage it suffered in the devastating earthquake in the region in 1988. The area is very prone to such quakes and neighbouring countries fear a breach of containment, since the plant is not designed or built to withstand them.

3. Ongoing Safety Concerns at Ontario Nuclear Power Stations – 1994 - Present

In December 1994, a pipe connecting a pressure valve to an overflow tank cracked as a result of excessive vibrations. The crack allowed heavy water to leak out of the reactor and into a sump tank, which then overflowed, spilling 140,000 to 150,000 litres of radioactive water into the reactor building. None of the water was released to the environment but, as a result of the accident, all four of the units in Pickering A were shut down. In its investigation of the accident, the Atomic Energy Control Board (AECB) discovered a basic design flaw in the pressure release valves. The three units not affected by the accident were allowed to return to service, but it took one year and $12 million for Ontario Hydro to re-design and re-install the new system in unit 2, which remained closed until December 1995. The same new system was also put into the other three units.

In September 1995, the AECB threatened to close Pickering station again. This time the threat came as a result of what the Board called "a significant number of serious events," including the above-noted incident and others in which workers had botched maintenance jobs (for example, adjusting the backup safety systems on the wrong reactors and leaving two reactors without a backup for several hours). The AECB was sharply critical of the plant operators and put them on notice that they must improve the safety mentality of the workers or face a shutdown. The Board noted that the problems appeared to be the attitude and motivation of the workers rather than deficient equipment. Some workers are blaming staff and budget cuts for the more relaxed approach to safety practices at the plant.

In December 1996, continuing concerns over safety issues at the Pickering station led the AECB to take the unusual step of renewing the plant's licence for a period of only six months, rather than the usual two years. In June 1997, the licence was renewed for a further nine months; the AECB was still not satisfied with the progress being made to address safety-related issues.

Claims that the station was operating safely were further undermined when 1997 Ontario Hydro "in-house" peer reviews became public as a result of a newspaper challenge under the *Freedom of Information Act*. These reviews are conducted every two to three years by senior safety and engineering personnel of Ontario Hydro's nuclear division; they are very frank and do not pull any punches. Some of the problems cited in the reviews included operators sleeping on the job, playing computer games, and engaging in other behaviour that could have led to significant accidents. The worsening safety practices at Ontario Hydro's nuclear plants were noted, as were the negative impact of personnel cuts and the fact that some practices identified as unacceptable as early as 1988 had not yet been changed.

The Ontario Minister of Environment and Energy has been quoted as saying that the nuclear plants would be closed down if the long-standing safety problems and operational difficulties were not corrected.

In response to the mounting pressures from the AECB and other sources, including the peer reviews, Ontario Hydro has engaged the services of seven foreign management experts to manage its nuclear program over the next few years. As part of the Nuclear Recovery Plan, one of the first actions of this group was to carry out an Independent, Integrated Performance Assessment (IIPA), the results of which were made public in August 1997. These were highly critical of the management of Ontario Hydro Nuclear and raised serious concern that a continuation of existing procedures and practices could soon result in reactors that were unsafe to operate. According to the outline of the 15-volume IIPA report, which was reviewed by the AECB, the IIPA and the AECB share many of the same concerns. As noted previously in this report, Ontario Hydro responded by announcing the "temporary" shutdown of Pickering A and Bruce A units and an extensive plan to remedy the management, safety culture, and procedural and equipment shortcomings identified at the Pickering B, Bruce B and Darlington stations. The New Integrated Improvement Plan has now been approved by Ontario Hydro Management and is being implemented. The AECB is closely monitoring these efforts, with future licence renewals being dependent on significant progress. In its most recent annual review of the utility's nuclear power stations, covering 1997, the AECB concluded that, while the reactors were operating safely, the rate of non-compliance with regulations remained unacceptably high. The Darlington station was cited for breaking regulations eight times, the Bruce B station 13 times and the Pickering A and B stations 15 times. The infractions ranged from mixing a piece of radioactive metal with other metal and sending it for recycling at a steel plant, to allowing workers, contrary to regulations, to eat, drink and/or smoke in areas of the plant where there was a possibility of ingestion of contaminated particles.

In addition, 13 separate fires were reported at Pickering in the year, a rate that the AECB found unacceptable. Also of concern was the high failure rate of persons being tested for positions as nuclear operators. At Pickering A only 65% of those taking the test passed, while at Pickering B the rate was just 56%. AECB concluded that the reason for the high failure rate was poor training; apparently the training manuals used at the stations had not been revised for ten years even though the stations had undergone some major overhauls during that period.

4. Ongoing Safety Concerns at Point Lepreau, New Brunswick, Nuclear Power Station

In its 1997 annual review of the Point Lepreau reactor, the AECB noted that, while releases to the public and to the environment remained low and the exposure of workers to radiation was well below legal limits, the operational safety of the plant continued to deteriorate. In fact, this aspect of plant operation had been under special watch since 1996, with the utility being required to report every six months to the AECB on progress in improving the safety culture at the site. A maintenance backlog, worker fatigue and a general deterioration of the condition of the plant were all cited as problematic.

The AECB was so unhappy with the utility's early efforts to address these problems that in August 1998 it demanded an ordered schedule of action to be prepared, and warned that failure to demonstrate progress could jeopardize renewal of the plant's licence in October 1998. At the beginning of October, AECB announced that the operating licence was being renewed for two years, but with the stipulation that progress in the plant's performance improvement plan must be reported.

## PARLIAMENTARY ACTION

On 21 March 1996, the federal government introduced Bill C-23, An Act to establish the Canadian Nuclear Safety Commission and to make consequential amendments to other Acts. The bill received Royal Assent on 20 March 1997 and is now expected to come into force by the end of 1998. Regulations have been drafted and are proceeding through the public comment phase. This Act will, for the first time, separate the legislative authority for research and development of nuclear power from the regulation of nuclear safety. The name of the Atomic Energy Control Board (AECB) will be changed to the Canadian Nuclear Safety Commission (CNSC). This will allow for a clearer distinction between Atomic Energy of Canada Limited (AECL) and its regulator (AECB).

The new Act gives the CNSC the specific legislative authority that the AECB currently exercises under a very general clause in the existing *Atomic Energy Control Act.* The Act also allows the provinces to enforce certain aspects of the operation of nuclear plants which fall within their jurisdiction. At present, these activities are technically the responsibility of the federal government, because the Act is all-inclusive and covers every activity at a nuclear facility, even health regulations in the cafeteria.

## CHRONOLOGY

1 August 1983 - An abrupt pressure tube failure occurred at Pickering-2. This was the first major failure in the primary cooling system of a CANDU reactor. The unit was shut down for re-tubing.

14 November 1983 - Pickering-1 was shut down for examination of its pressure tubes for hydrogen build-up.

7 March 1984 - Ontario Hydro announced that Pickering Unit 1 would also undergo a complete re-tubing.

26 April 1986 - An explosion and fire occurred in Unit 4 at the Chernobyl generating station in the USSR, destroying the reactor and releasing massive amounts of radiation from its core.

25 August 1986 - The International Atomic Energy Agency received and began to review an official Soviet report on the causes and effects of the Chernobyl accident. Gross human negligence was cited as the cause.

September 1986 - Canada signed two international conventions concerning nuclear safety. The first convention provides for early notification and information about nuclear accidents and the second commits signatories to help other nations that suffer a nuclear accident.

November 1986 - Construction of the concrete sarcophagus to entomb the destroyed Unit 4 at Chernobyl was completed. Today, there is concern about the integrity of the sarcophagus and its replacement is seen as a priority.

February 1991 - Unit 2 at the Chernobyl nuclear power station was damaged by fire. It was not returned to service and was scheduled for permanent closure in 1996.

December 1994 - A pressure valve failure at Pickering caused a spill of up to 150,000 litres of radioactive water into the containment structure.

May 1996 - Ukrainian officials and representatives of the G-7 nations reached an agreement on the financing and timing for closure of the Chernobyl facility. Unit 2 was set to close permanently in 1996, Unit 1 in 1997, and Unit 3 (adjacent to the sarcophagus on the destroyed Unit 4) in 1999.

March 1997 - The *Nuclear Safety Control Act* received Royal Assent, finally separating the nuclear regulator (formerly the AECB, now the Canadian Nuclear Safety Commission or CNSC) from the industry it regulates.

August 1997 - The results of an Independent Integrated Performance Assessment of Ontario Hydro Nuclear were released. Serious deficiencies in many aspects of nuclear plant operations were cited. Ontario announced the closure of all units at Pickering A and Bruce A, and extensive changes to remaining nuclear generating stations.

SELECTED REFERENCES

Cruickshank, Andrew. "Putting Policy into Practice in the United States." *Nuclear Engineering International*, March 1987, p. 24-28.

Donnelly, W. *et al.* "The Chernobyl Accident: Causes, Initial Effects and Congressional Response." Major Issue System, *Issue Brief #1B86077*, Congressional Research Service, Washington, D.C., 16 September 1986.

"Nuclear Power: Status and Outlook." International Atomic Energy Agency, Paris, July 1996.

"Still a Political Target: World Survey of Nuclear Power." *Nuclear Engineering International*, June 1996, p. 31-37.

Ontario Hydro. "Report to Management: IIPA (Independent Integrated Performance Assessment) / SSFI (Safety Systems Functional Inspections) Evaluation Findings and Recommendations." 13 August 1997.

USSR State Committee on the Utilization of Atomic Energy. *The Accident at The Chernobyl Nuclear Power Plant and Its Consequences*. Compiled for IAEA Experts' Meeting, 25-29 August 1986, Vienna, Parts I and II.