Risks of the CANDU reactor design

Introduction

The CANDU (CANada Deuterium Uranium) reactor is a pressurized heavy water reactor of Canadian Design.

Atomic Energy of Canada Limited (AECL) developed the CANDU reactor technology starting in the 1950s. All Canadian nuclear reactors are of the CANDU type but the reactor has also been marketed abroad - until October 2011 AECL marketed and built 34 CANDU facilities worldwide: Canada (22), Argentina (1), Romania (2), South Korea (4), China (2), Pakistan (1) and India (2). In Europe Romania is the only country operating CANDU reactors (at the Cernavoda site).

The main advantage of the CANDU reactor is that it can be operated with natural uranium – so no uranium enrichment is necessary. The CANDU reactor is also recognized for its robustness. However, the Canadian experience at the nuclear power plants of Point Lepreau and Gentilly comes to prove that the CANDU reactor is far from perfect.

This text aims to draw the attention of European stakeholders and Romanian public onto specific technical problems related to CANDU reactors, but also to illustrate some corruption cases linked to the nuclear industry, particularly the Canadian one.

Advantages of the CANDU design

CANDU in Europe is recognized for its robustness, having more strong points than any other type of reactor. The passive features of the CANDU reactor design have a beneficial effect in that they delay the progression of severe accidents, thereby providing an opportunity for operator actions to stabilize the plant and mitigate the consequences. It is said that large CANDU reactors are inherently tolerant of a prolonged loss of engineered heat sinks at decay power levels. This is because two large volumes of water (the moderator and shield water) surround the reactor core and act as in situ passive heat sinks in severe accidents.

Another advantage of the CANDU reactor is that it can be operated with natural uranium, so no uranium-enrichment services have to be bought for that plant. Moreover, if uranium could be mined within the country (e.g. urnanium for the Romanian CANDU reactors is mined in the Romanian Crucea mine), the nuclear fuel cycle could become entirely indigenous. A government might choose that arrangement from the perspective of economics and/or energy security.

Risks associated with the CANDU 6 design, overview

The concept of "risk" encompasses the probability and magnitude of an adverse impact on humans and the environment. Operation of any nuclear power plant creates risks. Plants of the CANDU 6 design pose additional risks that arise from basic features of the design, especially the use of natural uranium as fuel and heavy water as moderator and coolant. Those features create additional risks in two respects.

- First, at a CANDU 6 plant it is comparatively easy to divert spent fuel in order to produce plutonium for nuclear weapons,
- Second,. a CANDU 6 reactor could experience a violent power excursion, potentially leading to containment failure and a release of radioactive material to the environment

Risk 1. The risk of diversion of spent fuel

The CANDU 6 design uses natural-uranium fuel and on-line refueling. Thus, CANDU 6 could be a preferred plant choice for a government that contemplates the possibility of deploying a nuclear arsenal.

AECL hopes to sell the CANDU 6 to a number of countries. Presumably, those countries would see advantages to the CANDU 6 that would offset risk issues such as a positive void coefficient and vulnerability to malevolent acts. It appears that the Turkish government sees such advantages. In soliciting bids for construction of new nuclear power plants in Turkey, the Turkish government has stated that it will consider the construction of CANDU-type plants only if they are fueled by natural uranium[1]. The ACR-1000 is excluded by that requirement, but the CANDU 6 is allowed.

Another reason for a government to favor a plant design that uses natural-uranium fuel.

But there is also another consideration that a government would be unlikely to discuss in public: deployment of an indigenous nuclear fuel cycle, featuring reactors that employ on-line refueling, would provide the country with a virtual capability to produce plutonium sufficient for a substantial arsenal of nuclear weapons. The country's government could draw upon that capability at some future date, depending on the government's assessment of the net benefit of establishing a nuclear arsenal.

Canadians must, therefore, consider the risk that AECL's [2] marketing of the CANDU 6 could contribute to the proliferation of nuclear weapons, albeit inadvertently. In

[1] RISKS OF OPERATING CANDU 6 NUCLEAR POWER PLANTS: Gentilly Unit 2 Refurbishment and its Global Implications, by Gordon R. Thompson, Institute for Resource and Security Studies
[2] Atomic Energy of Canada Limited, nuclear science and technology laboratory

contemplating that risk, it should be noted that growth in the number of nuclear-weapon states could increase the probability of nuclear war, in part by expanding the number of decision centers. Canada has experience in inadvertently contributing to nuclear-weapon proliferation, having supplied the CIRUS research reactor to India in the 1950s, with the condition that the reactor be used only for peaceful purposes. In fact, India produced plutonium in CIRUS for its 1974 test of a nuclear weapon, and for subsequent nuclear weapons.

Risk 2: The risk of an unplanned release of radioactive material[3]

In the context of an unplanned, radioactive release, a CANDU 6 plant has many characteristics in common with other nuclear power plants now operating worldwide. Almost all of those plants are in the "Generation II" category, and most (80 percent) are light-water reactors (LWRs) that are moderated and cooled by light water. Plants constructed during the next few decades would be in the Generation III category.

Any of the nuclear power plants now operating could experience an unplanned release of radioactive material as a result of an accident or a malevolent act. There are plant-specific aspects of the potential for such a release, but also broad similarities.

Flaws discovered in 2001 in the CANDU reactor at Point Lepreau in New Brunswick (Canada) have raised concerns about safety, inspection and management issues associated with the Canadian CANDU reactor design, in Canada and internationally.

Specifically, CANDU reactors essentially identical to the flawed Point Lepreau reactor have already been built in India, Pakistan, South Korea, Argentina, Romania, and China. The flaw consists of a potential for unanticipated sudden Loss of Coolant Accidents ("LOCAs") arising from failures in so-called Feeder Pipes through two mechanisms – one of which has been almost totally ignored by Canada's nuclear regulator, despite already having caused two Feeder Pipe failures at Point Lepreau – the first in 1997 and the second on March 8, 2001.

Energy Probe, an independent non-governmental nuclear watchdog organization in Canada, has reviewed expert evidence establishing that a long-ignored failure mechanism – known as Stress Corrosion Cracking (SCC) – has the potential to cause far more serious failures than the two that occurred at Point Lepreau, and to do so with little warning[4].

Specifically, the two Feeder Pipe cracks at Point Lepreau were both in the axial or "lengthwise" direction, and therefore produced detectable leaks before the pipes broke. But experience with natural-gas pipelines subject to SCC shows that the same

[3] RISKS OF OPERATING CANDU 6 NUCLEAR POWER PLANTS: Gentilly Unit 2 Refurbishment and its Global Implications, by Gordon R. Thompson, Institute for Resource and Security Studies
[4] http://ep.probeinternational.org/2001/06/13/emerging-safety-problem-candu-reactors/

mechanism can also produce much more serious cracks in the circumferential or "crosswise" direction, which can produce "guillotine" pipe failures with no prior detectable leaks. Such an event in any two of a CANDU reactor's 760 Feeder Pipes would produce a potentially catastrophic "Beyond Design Basis" loss of coolant accident, or LOCA.

The feeder pipes contain essential cooling water at enormous pressure – approximately 100 times the pressure of a kitchen pressure cooker – and that water would immediately "flash" into steam if the pipes broke, leaving the fuel uncooled. In the CANDU reactor, a well-known design problem means that a loss of coolant inherently causes an increase in the power level, and heat output, of the nuclear fuel, placing enormous pressure on the reactor's emergency shutdown systems. However, even after a successful shutdown, the fuel in a CANDU reactor produces approximately 140,000,000 watts of heat – heat which must be removed by circulating water, or the highly radioactive fuel will overheat and begin to release radioactive gases, or even melt.

Another study, "Exporting Disaster -The Cost of Selling CANDU Reactors", written by David Martin of Nuclear Awareness Project for the Campaign for Nuclear Phaseout, in November 1996, shows that: "The start-up of *Cernavoda-1* has been *plagued by* a number of *problems*. Perhaps most serious were the various managerial and quality assurance problems caused and aggravated by the Ceausescu regime. AECL staff had condoned the situation for many years, and claim that in 1988 they had threatened to pull out of the project. AECL's resolve was never tested however, since the 1989 revolt intervened, and the project was subsequently restructured.

After the restructuring in 1991 – adoption of the new Constitution which changed the basis for the Government and Parliament in Romania – AECL says that 25- 30% of the welds in the reactor had to be repaired.

There are a number of ***endemic design problems*** with Cernavoda-1, not the least of which is that it is a reactor with 1960s technology being started-up in 1996. Also, because of earlier grandiose plans for 5 reactors, the control room is segregated into five sections and oversized. In July 1996, it was reported that availability of spare parts for Cernavoda was a serious concern. Notably, the reactor's main process computer is a 1960s-vintage Univac data system, which has not been sold for over 15 years *(N.B: this was written in 1996!)*. Parts have been taken from the computer purchased for Cernavoda-2, as have some valves and other hardware.

In the last 10 years, a number of previously unanticipated safety problems have occurred at different power plants in Canada, all of them requiring expensive corrective action costing millions of dollars each.

For instance, when Gentilly-2[5] was built, nobody thought about the possibility that an accident could kill everybody in the control room of the nuclear reactor, possibly resulting in a catastrophic accident. In early 1990's, AECB/CNSC (Canada's nuclear regulator) discovered that a sudden break in one of the steam pipes passing over the roof of the control room could, in fact, kill everyone inside and make the control room unusable. Obviously, this improbable situation could be extremely hazardous for the population at large. At first, AECB wanted Hydro-Quebec to relocate the steam pipes, but Hydro-Quebec argued that this would be too expensive. Instead they offered to make some substantial alterations to the interior design of the building so as to minimize the effects of such a break in the steam pipes, and to carefully monitor the pipes so as to detect any weakening which might (or might not) occur before such a break would happen. Those corrective actions are still being carried out.

Another example is the LOCA event in Pickering in 1983. Every CANDU reactor has an Emergency Core Cooling System (ECCS) which is supposed to flood the core of the reactor with ordinary water in case of a large LOCA to prevent it from overheating. Sometimes, however, the ECCS is not available. The AECB allows the ECCS to be unavailable for up to eight hours in any given year, and in some cases it is unavailable for a much longer period of time. If a large LOCA were to happen at such a time, serious core damage could occur and a nuclear catastrophe could result.

The first LOCA in a Canadian nuclear generating station was at Pickering, just outside of Toronto, in 1983, when a pressure tube burst without warning in the core of the reactor. A few years earlier, nuclear experts had insisted that a pressure tube could not burst suddenly, because it would begin to leak long before it would break, giving the operators enough time to shut the reactor down and correct the situation. But the experts were wrong.

Repairs to the core of the Pickering reactor took four years and cost more than 500 million dollars. All of the pressure tubes had to be replaced, since many of them were showing signs of serious deterioration and some were developing blisters.

Conclusions

Operation of any nuclear power plant creates risks. Plants of the CANDU 6 design pose additional risks that arise from basic features of the design, especially the use of natural uranium as fuel and heavy water as moderator. Those features create additional risks in two respects. First, a CANDU 6 reactor could experience a violent power excursion, potentially leading to containment failure and a release of radioactive material to the environment. Second, spent fuel discharged from a CANDU 6 plant could be diverted and used to produce plutonium for nuclear weapons.

In the long term, nuclear and fossil-fuelled power plants are not alternatives to each other. Rather, they are both part of an environmentally unsustainable approach to

[5] http://www.ccnr.org/Gentilly_Safety.html#Gentilly

the electricity system. There are cleaner, safer, alternatives that are both technically feasible and economically sustainable. In a sustainable energy future, end-use efficiency, co-generation and renewable energy will be phased in at a pace that will ensure an orderly transition as our fossil power plants are phased out. The technological transition will be based on the phenomenal advances already taking place in energy efficiency of buildings and all types of energy-using equipment, and on the rapidly expanding wind, solar and other renewable technologies that are now globally outpacing the growth rates of all other types of power generation.

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