CNS BULLETIN SNC

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Editorial

Chernobyl

The magnitude of the shockwave generated by the Chernobyl accident has yet to be fully assessed. Response to the accident has ranged from thinly disguised gloating about supposed Russian inadequacies in nuclear design and construction to satisfied horror that the true nature of the nuclear beast has been finally demonstrated. Both reactions are inappropriate. A sober review of the available literature on the RBMK-1000 reactor design reveals a rational design which has undergone considerable development and refinement over the years. It would be surprising were this not the case. And the immediate death toll appears likely to be of the same order of magnitude as that of a very severe railway accident or the crash of a small airliner. Since these are almost certainly the first direct deaths clearly attributable to a commercial nuclear power station it's worth noting that this is not a disgraceful record for a technology with a history of about thirty years of commercial application.

This is not to minimize the serious nature of the accident. It was a tragedy—as indeed any accident involving death and injury must be. The human cost must also include the thousands of families uprooted from their homes for an as yet undetermined period. But on a global scale it was not a major catastrophe.

The impact of the accident on society's acceptance of nuclear energy continues to be an area of much concern in Britain, Western Europe, the United States and Canada. However, this concern has tended to be expressed in ways which could be described as facile and misleading. Nuclear industry and utility spokespeople have been quoted in the news media at length about reinforced concrete containment walls many feet thick, about the non-combustible nature of water (heavy or not) and about the unlicensability of the RBMK-1000 reactor in the western world.

These are all *non sequiturs,* and dangerously midleading ones at that. It is a fact that the RBMK-1000 does not live inside a containment structure of the kind favoured in, for example, the U.S. Neither does the British AGR. It is a fact that the RBMK-1000 reactor uses thin-walled pressure tubes instead of a thick-walled pressure vessel. So does the CANDU—and pressure tubes of the same material. So what? Evaluation of the RBMK-1000 cannot be based on how much it looks like (or doesn't look like) a CANDU or a PWR any more than vodka can be evaluated on the basis of its resemblance to scotch. The real issue has been best formulated by England's Central Electricity Generating Board in a statement transmitted over the INPO communications network:

> "The provision of a containment building or the use of graphite as a moderator has no intrinsic value or importance at all as an isolated fact. Neither is the choice of water or gas as a coolant an important fact. What is essential is that each reactor concept is provided consistently with what the technology demands."

Public confidence in nuclear energy will be earned and retained not by simplistic comparisons of different reactor systems but by ongoing review of the actual system in use to demonstrate that it has been provided with the appropriate design, construction and operational features to ensure it performs as a safe and economic source of energy.

At the present time it is not known to what extent the accident at Chernobyl-4, the latest and presumably the best of the RBMK-1000 reactors, was due to unrecognised design weaknesses or an unhappy one in a million chance. Whatever the cause, it is certain that, as with all other serious reactor accidents from NRX to Three Mile Island, lessons will be learned from the accident and the effect of these lessons will be applied. The commitment of the USSR to provide information on the accident, as it becomes available, so that IAEA member states may further improve the safety of nuclear power is entirely appropriate to the nature of the nuclear energy enterprise which should transcend political boundaries.

Perspective

Nuclear Research in Indonesia: AECL's Contribution

Contributed by Stephen Salaff, a freelance writer on nuclear energy who specializes in nuclear technology and commerce in the Pacific Basin region.

Atomic Energy of Canada Limited (AECL, a Crown Corporation) contracted in June 1985 to design, equip and commission a nuclear mechano-electronic installation (NMEI) being constructed by Indonesia's National Atomic Energy Agency (BATAN, Badan Tenaga Atom Nasional). This installation will conduct applied research in electronics and instrumentation, reactor technology, nuclear physics, and safety and health physics.

Contents | Page

The NMEI (formerly named the nuclear mechano-electronic laboratory) is one of seven ancilliary facilities clustered around the MPR-30 research reactor at the National Centre for Research, Science and Technology (PUSPIPTEK, Pusat Penelitian Ilmu Pengetahuan Dan Teknologi). In addition to its nuclear research complex, PUSPIPTEK houses more than a dozen other laboratories, institutions and research projects. The Centre occupies 3.5 square kilometres of land south of Serpong in West Java, 25 kilometres southwest of Jakarta.

The AECL portion of the NMEI, scheduled for completion in October 1988, is valued at approximately $37 million. Each of AECL's three main branches contributes to the NMEI, and the Corporation is also procuring NMEI equipment from private firms in Canada, the United States, Western Europe and Japan.

The key tasks of AECL's CANDU Operations, Research Company and Radiochemical Company divisions are defined in Table 1.

The nuclear mechano-electronic installation consists of three buildings. The AECL contribution is apportioned to these structures as follows:

Building A:

- A computer centre with terminals in most of the NMEI, and elsewhere on site;
- A general analytical and nuclear instrumentation laboratory for the site;
- A health and safety laboratory for site radiation monitoring and emergency control.

Building B:

- A large mechano-electrical workshop for the site.

Building C:

- A CS-30 cyclotron, a 26 MeV proton machine manufactured by Computer Technology and Imaging Inc. (CTI) of Berkeley, California to produce short-lived radioisotopes;
- A radioisotope processing facility.

This amalgamation comprises the first laboratory ever marketed by AECL. However, AECL has exported two research reactors: CIRUS to the Department of Atomic Energy, India (contract signed in 1956), and TRR to the Institute of Nuclear Energy Research, Taiwan (1969). Both CIRUS and TRR are modelled on the NRX high neutron flux heavy water moderated research reactor at AECL's Chalk River Nuclear Laboratories.

Like India, Taiwan and other recipients of Canadian help across the nuclear energy threshold, Indonesia has requested AECL to maximize its transfer of technical know-how. In response, the Crown Corporation has agreed to train 68 Indonesian experts for a total of 332 person-months over a 21-month period in the operation and maintenance of the CS-30 cyclotron and other specialized NMEI equipment, and in the research and development use of this equipment.

Table 1 *AECL responsibilities in the NMEI Project*

AECL Division	Role in AECL	Role in NMEI Project
CANDU Operations Mississauga, Ontario and Montreal, Quebec.	Develops and designs the CANDU nuclear steam plant, and in conjunction with Canadian industry and utilities constructs nuclear generating stations at home and abroad.	CANDU Operations, Montreal will execute the project management, procurement and design engineering portions of the work.
Research Company Chalk River, Ontario and Pinawa, Manitoba.	Provides the technological base for CANDU Operations and the Radiochemical Company, and for Canada's nuclear industry.	Conceptual design and much of the training.
Radiochemical Company, Kanata, Ontario.	Supplies isotopes and related equipment and services to nuclear medicine and radiation processing markets, primarily abroad.	Supply of hot-cell equipment for use with the cyclotron to be housed in the NMEI.

Training will be delivered at Research Company facilities in Canada whenever they possess the right apparatus. Instruction will also be given at the National Research Council and Energy, Mines and Resources Canada in Ottawa, and the Ontario Ministry of the Environment and Ontario Geological Survey in Toronto. Training will also occur at major equipment suppliers in Canada and at the Berkeley cyclotron plant. Schooling in the separation and handling of isotopes (including gallium-67 and thallium-201) will be given at the Radiochemical Company's 42 MeV compact new commercial isotope production cyclotron at TRIUMF, Canada's national meson facility in Vancouver. AECL has made provisions to train an additional group of senior Indonesian scientists in Canada, if co-operation can be secured from suitable research and development establishments and specialized equipment vendors.

To finance the nuclear mechano-electronic installation the Indonesian Ministry of Finance has concluded loan agreements with the Export Development Corporation (an Ottawa Crown Corporation) and with the Export-Import Bank of the United States. The EDC will finance 85 percent ($21.8 million) of the value of Canadian goods and services, while Eximbank will support 65 percent ($5.5 million) of the goods and services purchased in the US, the major item of which is the CTI cyclotron. The balance of the contract ($9.7 million) will be funded directly by the Indonesian Ministry of Finance. Repayments by the Ministry to EDC and Eximbank will begin shortly after project completion.

In parallel to its contract with BATAN, AECL has undertaken a countertrade obligation which will assist Indonesia to create foreign exchange. AECL has retained Philipp Brothers (Canada) Ltd. to source and sell Indonesian products, including bulk commodities, valued at approximately $20 million over the three-year NMEI construction period. Philipp Brothers (Canada) is the Toronto subsidiary of Philipp Brothers, Inc., a leading New York commodity and securities trader. Counterpurchasing was introduced to Canada's nuclear commerce in 1984 by the Romanian government agencies which procured Canadian equipment for the multi-unit CANDU station under construction at Cernavoda, Romania.

BATAN currently operates a pair of TRIGA Mark II research reactors, constructed with support from GA Technologies Inc. of San Diego. These are located at the Nuclear Technology Research Centre in Bandung (1000 kilowatts, or one megawatt, thermal)

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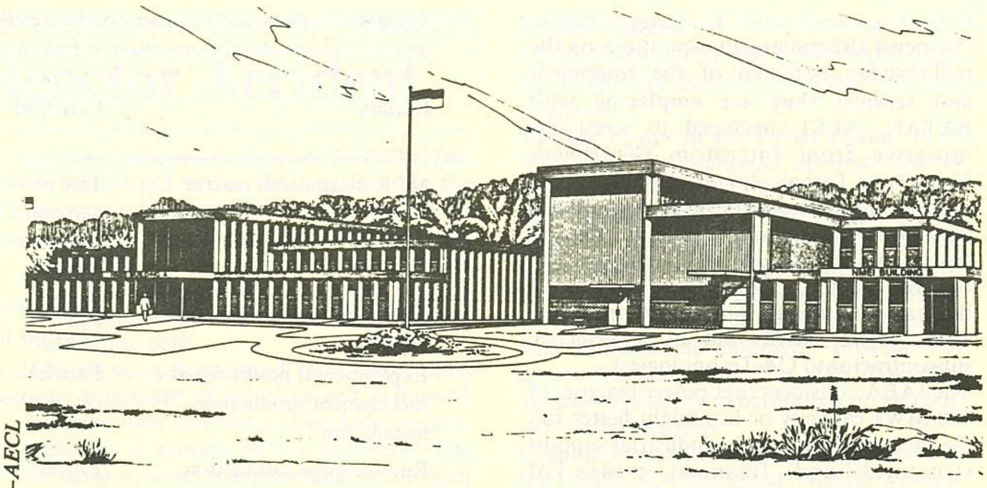
and at the Gajah Mada Nuclear Technology Research Centre in Yogyakarta (250 kilowatts). Indonesia has jumped from this modest beginning to the comprehensive and sophisticated $250 million (US) nuclear establishment at the PUSPIPTEK complex, whose focus is the 30MW(th) light water moderated and cooled multipurpose research reactor. In the short and medium term, according to Mr. Djali Ahimsa, Director General of BATAN, MPR-30 will produce isotopes, test materials, and perform neutron physics experiments.

AECL also bid in BATAN's research reactor competition, but its March 1980 offer of a 35 MW multipurpose test reactor similar in scope to Taiwan's TRR was not accepted. The winning designer was instead Interatom GmbH, a subsidiary of Kraftwerk Union of West Germany. A second West German concern, NUKEM GmbH, was chosen to design and equip a production facility which will fabricate 19.75 percent enriched uranium fuel elements for MPR-30. The broad scope and components of the two-phase PUSPIPTEK nuclear complex, and of its supplier mosaic, are indicated in Tables 2 and 3.

Superimposed on PUSPIPTEK's physical and biological science agenda is a longer range mandate: to develop a nuclear engineering and manufacturing infrastructure and the cadres to staff it. Indonesia's Minister of State for Science and Technology Dr B.J. Habibie has charged PUSPIPTEK with "training reactor operating and licensing personnel, and acquiring the know-how to plan, design, construct, operate and maintain future nuclear power plants."

Since the late 1970s, the International Atomic Energy Agency (IAEA) has advised BATAN on the costs and benefits of



-AECL

Artists representation showing nuclear mechano-electronic buildings A and B of BATAN's installaion at the PUSPIPTEK Centre, Serpong, Indonesia.

nuclear power in comparison with other energy sources. (Domestic oil is currently the main fuel for electric power generation in Indonesia, which is a member of OPEC). In 1979, BATAN engaged NIRA of Italy to assess the economic and technical feasibility of CANDU nuclear power stations and problems of their siting in Indonesia. A revision and expansion of this study is now evaluating also the pressurized light water reactor (PWR) option. A site in Central Java is under consideration.

AECL President James Donnelly expects that the deployment of Canadian science and technology at BATAN may help in CANDU power reactor sales to Indonesia's State General Electricity Company (PLN, Perusahaan Umum Listrik Negara). He affirms that AECL's share in PUSPIPTEK is "strategically significant as it will ensure a role for Canadian nuclear technology as Indonesia moves toward long term energy decisions." CANDU reactors are fueled by natural uranium and moderated and cooled by heavy water. AECL has exported CANDU 600 megawatt electric (MWe) reactors to governmental utilities in Argentina (Embalse, comercial operation 1983), South Korea (Wolsung, 1983) and Romania (the first two reactors in the station under construction at Cernavoda). Smaller CANDU reactors were supplied earlier by AECL to India and by Canadian General Electric to Pakistan.

Apart from the radioisotope installation, the PUSPIPTEK constellation could help prepare Indonesia technically for the installation of power stations of either CANDU or PWR type. Table 4 briefly specifies the functions which each facility might exercise in a nuclear infrastructure. The PWR manufacturers Framatome (a subsidiary of France's Atomic Energy Commission, CEA, and several other major

Table 2 *Phase One of nuclear contracting at PUSPIPTEK, scheduled for completion in 1987.*

Contract awarded[1]	Supplier firm
30 megawatt multipurpose research reactor	Interatom
Research reactor fuel element production facility	NUKEM
Experimental power reactor fuel element installation	Ansaldo, NIRA division
Radioisotope installation	GA Technologies
Radioactive waste management station	Technicatome

[1]Erection of the buildings for these facilities is directed by BATAN's official architect-engineer firms ARCHITEN and MID, and carried out by their local constructors.

Table 3 *Phase Two of nuclear contracting at PUSPIPTEK.*

Contract awarded	Supplier firm (date of contract)
Nuclear mechano-electronic installation	AECL (June 1985)[1]
Engineering and safety laboratory	Ansaldo, NIRA division (June 1985)
Radiometallurgy laboratory	German Consortium Nuclear Facilities (April 1985)[2]

[1]AECL lodged unsuccessul bids for the engineering and safety laboratory, and for the radiometallurgy laboratory (as a subcontractor to GA Technologies).

[2]The German Consortium Nuclear Facilities comprises Kraftanlagen AG, Interatom GmbH, ISA-Technik GmbH and NUKEM GmbH.

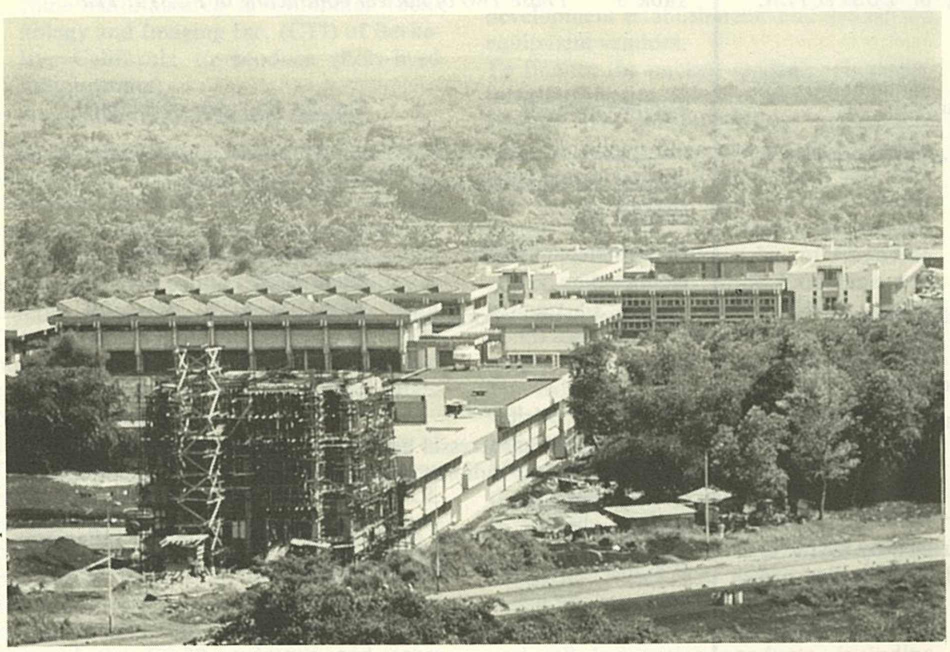
French groups) and Kraftwerk Union (Siemens) also pin export aspirations on the pull-through potential of the equipment and services they are emplacing with BATAN. AECL managed to wrest the initiative from Interatom (Kraftwerk Union) and Technicatome (CEA) to win the nuclear mechano-electronic installation appointment. However, AECL lost to Interatom the award not only for the research reactor in Phase One, but also for the radiometallurgy laboratory in Phase Two (where AECL bid as a principal subcontractor to GA Technologies).

The IAEA considers that power reactors of 600 MWe capacity or less might better suit the limited electric grids, industrial support structures and financial means of developing nations than the 900 MWe and up units which are the forte of Framatome and the three US reactor exporters. Kraftwerk Union is AECL's chief competitor in the small- and medium-size reactor niche, although Framatome and Technicatome also offer PWRs of capacities 600 and 300 MWe, respectively.

Indonesia's choice among power reactor suppliers will depend significantly on attributes such as those AECL sought to mobilize for the nuclear mechano-electronic installation transaction: substantial staff training and technology transfer, innovative financing, and flexible integration with the contributions of other nuclear vendors to Indonesia.

Table 4 *Potential functions of PUSPIPTEK facilities in preparing a power reactor and isotope production program in Indonesia.*

Facility	Function
MPR-30 research reactor	Test power reactor fuel rods and clusters; train personnel in irradiation testing; instruct operations personnel before they train on simulators and power reactors.
Research reactor fuel element facility	Manufacture reload fuel for MPR-30; fabricate test elements for irradiation experiments in MPR-30.
Experimental power reactor fuel element production installation	Fabricate CANDU reactor (and with suitable modification PWR) fuel elements.
Radioisotope installation	Process radioisotopes produced in MPR-30; prepare medical isotopes.
Radioactive waste management station	Plan disposal of low and medium level radioactive waste from reactor operations.
Nuclear mechano-electronic installation	Develop, manufacture and service reactor components and other nuclear plant equipment; provide mechanical, electrical, analytic, computer and radiation health physics support services; produce radiopharmaceuticals for medical research and treatment.
Engineering and safety lab	Develop and fabricate in-pile loops and capsules for irradiation in MPR-30 to test power reactor fuel materials and components.
Radiometallurgy lab	Conduct full post-irradiation examination of power reactor fuel elements tested in MPR-30, and later of power reactor fuel bundles.


–Kaleidoscope International

PUSPIPTEK laboratory buildings under construction.

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1. Martias Nurdin (BATAN); J.E. Matos and K.E. Freese (Argonne); "Performance and Fuel Cycle Cost Analysis of One Janus 30 Conceptual Design for Several Fuel Element Design Options," Proceedings of the International Meeting on Research and Test Reactor Core Conversions from High Enriched Uranium to Low Enriched Uranium Fuels," Argonne National Laboratory, Argonne, Illinois, 8-10 November 1982.
2. Henry Leeds, "PUSPITEK: Preparing for a Technological Future," *Kaleidoscope International* (Hong Kong), Vol. IX, No. 1, 1984, pp 294-296.
3. Panusunan Simanjuntak, "Letter From Jakarta," *AECL Ascent*, Winter 1984-1985, p 17.
4. "Project 52-BATAN", *Power Projections*, CANDU Operations, AECL, April 1986, pp 1-2.
5. S.G. Haddad (Bechtel) and S. Supadi (BATAN), "The Indonesian Multipurpose Reactor and Supporting Laboratories: Design Features and Utilization Programs," paper presented to the American Nuclear Society Annual Meeting, Reno, 18 June 1986.

Stephen Salaff

The Chernobyl Reactor Accident

The following information has been gathered from the sources listed and from the Soviet representative at the International Atomic Energy Agency.

Reactor General Description: The Chernobyl nuclear power station comprises 4 completed 1000 MWe RBMK-1000 reactors with two more units under construction. The accident unit, Chernobyl-4, is the most recently completed unit and came into service in 1984. The other three units entered service between 1977 (Unit 1) and 1982 (Unit 3). There are currently 16 RBMK-1000 units in service or under construction. An uprated version of this reactor has been developed, with an output of 1450 MW(e), and one is in service with three more under construction. Russian experience with graphite moderated channel type power reactors goes back to 1954 when Russia's first nuclear power plant was commissioned at Obninsk. The first of the RBMK-1000 units entered service in 1973 at the VI Lenin nuclear power station and since then 11 more similar units (including Chernobyl-4) have entered service. In 1980, reactors of the RBMK-1000 type accounted for over 60 percent of all the nuclear generated electricity produced in the USSR. Operating experience with these units has been described as "outstanding" and station annual capacity factors are quoted as typically being in the range of 70 to 75 percent. Annual station capacity factors have ranged from 64.1 percent for the Kursk station in 1979 to 80.9 percent in 1981 for Chernobyl (the first two units only in service).

The RBMK-1000 is a vertically oriented graphite moderated pressure tube reactor using boiling light water in a direct cycle to drive two 500 MW turbines. The fuel is uranium dioxide with enrichment levels of up to 2 percent U-235 reported. Fuel handling is on-power with a single fuelling machine serving two reactor units. Average steam quality is 14.5 percent with maximum steam quality for the highest powered channel of 27 percent. The 1693 fuel channels are served by two coolant loops each supplied with four pumps (1 on standby) and two steam drums. Coolant is supplied to the channels via inlet headers which supply "distributing group collectors" (distribution headers) which in turn supply the individual feeders supplying the fuel channels. Pressure tubes are of Zr-2.5wt%Nb with an ID of about 80 mm.

The core is made up of 250 mm x 250 mm x 600 mm high graphite bricks threaded by zirconium-niobium pressure tubes. The core dimensions are 12m diameter by 7 m high. The temperature of the graphite is in the range 600 to 700°C, a temperature considerably higher than that at which Wigner energy effects play any significant role (Wigner energy effects are of concern at graphite temperatures below 300°C). Heat is transferred from the graphite to the pressure tubes and thence to the coolant by an arrangement of graphite rings which are alternately tightly fitting on the pressure tube and tightly fitting within the hole in the graphite bricks thus providing a thermal conduction path.

The graphite is enclosed in a vessel filled with a mixture of nitrogen and helium to promote heat transfer and exclude oxygen. This gas is monitored for moisture. The moderator vessel is surrounded by nitrogen gas at a slightly higher pressure to ensure that any leakage is nitrogen into the moderator rather than nitrogen/helium out.

The core and the heat transport piping (including the steam drums) are enclosed in thick-walled cells which appear to be steel lined. A design pressure of 4 atmospheres (58 psi) is quoted for some of these enclosures, while that surrounding the core is reported as having a design pressure of 27 psi. The enclosures are vented to a "bubbler pond" or pressure suppression pool located below the reactor.

The structure which houses the fuelling machine and forms the "charging hall" for the two reactor units is not a containment structure. Although it is provided with very substantial walls to carry the vertical loads of the fuelling machine and a travelling crane the roof appears to be of a structure typical of any industrial-type building.

Absorber rods for shutdown and control are aluminum sheathed boron carbide and constructed in six articulated sections, an arrangement that will allow the rods to accommodate misalignment or distortion of their guide tubes. The rods are water cooled and are fitted with graphite followers to displace the water following rod withdrawal, thus increasing their relative reactivity worth. The rods are divided into groups to handle power level, power distribution, axial power distribution and shutdown, and the literature describes the development of local automatic (computer) control of the power distribution.

Initial emergency coolant injection is provided by high pressure accumulators followed by injection pumps drawing from a storage tank. ECI water is supplied to injection headers which supply the distribution headers. The distribution headers are fitted with check valves which preclude ECI water loss to a failed inlet header. ECI water is directed to the failed loop only.

Emergency electrical power is available from diesel generators and supplies feedwater pumps and ECI pumps. It is reported that effective thermosyphoning has been demonstrated both in test rigs and in actual operating reactors.

USSR Sources

The information on the RBMK-1000 reactor design was obtained from the following sources:

Nuclear Power in the Soviet Union, B.A. Semonov, *International Atomic Energy Agency Bulletin*, Vol.25, No.2.

An overview of the USSR nuclear power program. Includes list of main nuclear power plants in operation as of the end of 1982. Contains brief description of RBMK-1000, list of RBMK units in operation and outlines development program to uprate the design to 1500 MW. Describes nuclear regulatory structure but no reference to safety analysis.

Graphite-water steam generating reactor in the USSR, N.A.Dollezhal, *Nuclear Energy*, October 1981.

Detailed description of RBMK-1000 design including major reactor systems schematic, typical RB cross-section, fuel channel closure and fuel assembly. Identifies enrichment level originally 1.8 percent but "recent reactors" now have 2 percent. Describes control/absorber rods, cooling provisions and control system. Identifies average outlet steam quality as 14.5 percent. Notes that ECI system designed to accommodate failure of "main coolant pipe" (900 mm dia. inlet header) and that "reliable cooling of the core by natural circulation in the event of a total failure of the electricity supply has been demonstrated."

State of the art and development prospects for nuclear power stations containing RBMK reactors, E.V.Kulikov, *Atomnaya Energiya*, Vol. 56, No. 6, June 1984.

Description of reactor and fuel channels including schematic and cross-section of fuel channel showing closure, fuel assembly and support, positions of upper and lower shields and graphite stack support detail; also schematic showing relationship between ECIS and PHTS. Describes ECIS and states explicitly that ECIS is designed to accommodate main coolant piping failure. Describes gas pressurized accumulators for initial injection, then tank and pumps for "long time (term) cooling." Notes that ECI water is directed to failed loop only. Reactor physics description identifies some concern about "substantial" changes in reactivity coefficients during pre-equilibrium operation and describes measures adopted to ameliorate this situation -- a form of zone control to maintain set power using "individual effectors" to provide "automatic power control in the individual core regions" together with provision for "emergency power reduction" when there are "impermissible local power rises." Additionally identifies increasing enrichment as a measure taken to reduce steam reactivity coefficient. Some data on operating staff exposure and environmental emissions.

Fuel elements of the RBMK-1000 reactor, V.G.Aden et al, *Atomnaya Energiya*, Vol.43, No.4.

Detailed description of fuel, cladding and assembly, including illustration of assembly and cross section. Maximum power channel (3000kW) parameters tabulated, inc. outlet temperature 284°C and steam quality 27 percent (cf average steam quality 14.5 percent). Describes out- and in-reactor fuel tests.

Design measures to maintain operating efficiency in nuclear power plants with RBMK type reactors under emergency conditions, paper presented at the IAEA International Conference on Current Nuclear Power Plant Safety Issues, Stockholm, October 1980.

Detailed description of three accident scenarios and summary description of reactor and reactor control system. Describes (i) total loss of electrical power, (ii) deviations in normal feedwater supply and (iii) large piping breaks.

i. Loss of electrical power: Circulation provided by pump rundown followed by natural circulation. Standby power (diesel) available in 1-2 minutes and supplies emergency feedwater pumps and emergency reactor cooling pumps (ECI pumps). Notes that steam in downcomers will impair natural circulation but cites tests at experimental facilities and operating reactors confirming that steam blockage will not be a problem.

ii. Deviations in feedwater supply: Loss of single feedwater pump (one of four) can be accommodated by manual power reduction. For loss of two or more there is automatic power setback. Total loss of feedwater brings in reactor trip at 50 percent flow and trips main coolant pumps (after 9 second delay) to avoid drawing steam into downcomers. Emergency feedwater pumps can supply 10 percent of nominal flow within 10-20 seconds. With main PHT pumps tripped cooling provided by natural circulation -- similar to loss of power scenario.

iii. Large piping break: This scenario postulates the failure of a 900 mm ID pipe -- the largest in the system. Safety systems initiated by increased "reactor area pressure" (probably equivalent to our boiler room pressure -- high signal) and low separator (steam drum) level or reduction in pressure differential between inlet header and separator. ECI feeds to distribution headers. Initial ECI is from accumulators. As this supply depletes and main pumps begin to cavitate, supply is from tank and ECI pumps. Limiting case is guillotine failure of 900 mm ID pump suction header. PHT piping enclosed in "strong boxes" with a design pressure of 4 atm (58 psi). Arrangements for handling the discharge of steam/water include "bubbling-through type condensing devices (a pressure suppression pool), a system of bypass valves, a sprinkler system and heat exchangers."

Sequence of Events

While there has been much (and continues to be much) speculation as to the cause of the accident, there exists little substantive information. In a statement by the USSR representative to the Board of Governors of the IAEA the following information was given:

"the accident developed at the power station in the following manner. At 01:23 hours and 40 seconds on 26 April, an emergency occurred in the fourth unit of the Chernobyl nuclear power station during the scheduled shutdown of the unit while at a power level of seven percent. The reactor power suddenly increased and there began intensive evaporation of the cooling water and considerable formation of steam. The ensuing reaction between the steam and the zirconium led to the formation of hydrogen, which then exploded. The explosion caused a fire, and the reactor building together with the equipment in it, the reactor itself, and the core, were extensively damaged, causing the release of fission products beyond the site. During the accident the chain reaction ceased."

It is possible to infer from the Russian statement that some fuel *may* have been ejected from the core, since later on in the statement it is noted that "the bulk of the fuel was inside the reactor."

Whatever the actual sequence of events it is clear that at some point the vessel containing the graphite moderator must have failed allowing air to contact the hot graphite, which then began to oxidize. The strong uplift from this heat source reportedly lifted radioactive emissions to an altitude of about 3300 ft (1000 m). Two people were killed immediately — one from steam burns and one by falling debris. To date there have been 25 further fatalities (plant workers and firemen) from radiation exposure with 299 people hospitalized. It is calculated that 5 people received exposures greater than 1000 Rem and 18 received exposures of the order of 700 Rem. The Russian statement to the IAEA included the information that no inhabitants of the villages in the vicinity of the plant received exposures hazardous to their health.

The reactor building fire (not the reactor fire itself) was prevented from spreading and then extinguished by fire brigade whose members, the Russian statement noted "suffered most heavily" from radiation exposure. In order to halt the release of fission products from the reactor (and to extinguish the reactor fire) helicopters were used to drop sand, clay, lead, dolomite, limestone and boron on the reactor. A total of 4000-5000 tons of these materials was applied and by 13 May releases had ceased.

Core temperatures were brought down to 200-250 C through injection of nitrogen, which also re-established an inert atmosphere around the graphite therefore preventing further oxidation. In order to preclude contamination of groundwater, the bubbler pond below the reactor has been drained and will be filled with concrete (incorporating water cooling coils). At the same time a concrete structure is being erected around the top deck of the reactor.

In the immediate vicinity of the reactor precautions have been taken to prevent rainfall from washing surface contamination into the nearby river. One method of ground decontamination cited by the Russian IAEA representative was the use of "polymer materials" presumably sprayed onto the ground where they form a film trapping the radioactive contamination. The film is then subsequently removed with the contamination and disposed of.

Populations within a 30 km zone around the station have been evacuated and additional evacuations have been reported from "hot spots" at greater distances.

David Mosey

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septembre/octobre	le 1 septembre
novembre/décembre	le 1 novembre

TECHNICAL SUPPLEMENT

CNS Bulletin May/June 1986 Canadian Nuclear Society

ON-POWER CONTAINMENT INTEGRITY MONITORING IN CANDU MULTI-UNIT STATIONS

Paper Presented at the Second Workshop on Containment Integrity for Nuclear Power Plants, June 13-15, 1984, in Washington D.C. Reprinted in Nuclear Engineering and Design, 90, December 1985. The Error Analysis section has been abridged for conciseness.

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Abstract — *Based on a general review of current on-power test methods and experience in CANDU multi-unit containments, it is concluded that such tests make a significant contribution to plant safety. In particular, continuous monitoring at low pressure differentials merits further development and more widespread application.*

Current on-power tests include individual component testing, quarterly reduced pressure tests (typically at -15 kPa(g)), and continuous pressure trend monitoring at normal operational pressure of -3 kPa(g). A continuous monitoring concept is outlined which consists of a periodically updated mass balance. Instrument error uncertainty for this technique was estimated to be on the order of a 1 cm hole. However systematic fluctuations (often attributable to physical causes) dominate the error analysis in on-power tests. With precautions on sampling interval, a moving regression may be used to generate a leakage rate time series such that the fluctuations can be bounded or eliminated.

Experience to-date has indicated that most containment boundary impairments are detectable by component tests or continuous monitoring. On-power test methods are capable of addressing a significant portion of the containment failure mode spectrum. Station risk assessment and regulatory testing requirements are identified as means by which these methods can be credited in demonstrating containment integrity.

AUTHOR'S FOREWORD

Recent international events have emphasized the critical importance of a properly designed and maintained nuclear containment system. Even in the event of a serious incident, a containment system is capable of ensuring that off-site consequences are negligible.

Recently, R&D and regulatory attention has been focussed on high pressure testing and containment survival beyond design basis events. Increasing importance has been assigned to conditions arising from chemical reactions of coolants and reactor materials at very high temperatures. Scenarios are being postulated which can challenge the ultimate strength of containment structures. Tests such as the hydrogen deflagration experiments in the U.S. can be very costly and address low probabilty events.

Notwithstanding the merit of these investigations, experience indicates that the most likely containment failure modes are those due to containment "bypass" - which may occur as a result of operator activities, maintenance, leaks into secondary or service systems, or even as a result of procedures involved in periodic pressure testing. Inadvertant boundary leakage can arise if containment is accessed frequently, if any maintenance or modifications are being made to the plant, or if, as in a multi-unit station, the containment is placed in-service in stages or shares common services.

The following paper describes on-power test methods which can detect the most likely failure modes. These tests are performed on a *frequent* basis and eliminate the possibility of a significant containment impairment going undetected for a long period of time. The less likely failure modes, ie., those that require an aging effect which is only evident at high pressures, are appropriately tested for in less frequent positive pressure tests at conditions bounding those expected in design basis accidents.

INTRODUCTION

The provision of a physical barrier to mitigate the potential release of radionuclides represents a fundamental safety requirement at nuclear electric generating facilities. Implicitly this containment boundary must maintain a high degree of leak tightness during both normal operation and accident conditions. Leakage rate testing is the primary means of demonstrating this requirement is being met over the plant life.

The purpose of this paper is to indicate the type and quality of information that is available from on-power leakage rate tests and continuous monitoring of containment parameters.

System description

The layout of a typical CANDU multi-unit station is illustrated in fig. 1. The cornerstone of the containment concept in such a station is the Vacuum Building. This large post-tensioned concrete structure is maintained at very low pressure (about 7 kPa abs (1 psia)). In the event of a pressure excursion (ie. LOCA) in any unit, pressure activated relief valves open, enabling the Vacuum Building to rapidly draw containment pressure subatmospheric. A pressure activated water spray system in the Vacuum Building condenses any steam present, thus aiding the pressure reduction. Containment overpressures are therefore of low magnitude and short duration.

The resultant effect is lower containment design pressures and less stringent leakage rate targets than other containment systems. Table 1 provides containment design parameters for multi-unit stations operated by Ontario Hydro. The design target leakage rate for all stations is based on 1% per hour of the contained air mass at the positive design pressure.

Two "types" of containment are used. In earlier stations a unitized concept is employed, wherein a low pressure relief panel provides for atmospheric separation of the buildings. The shared containments are connected during normal operation by the fuelling machine ducts.

The reactor buildings and ducts are thick walled (typically 4 ft) conventionally reinforced concrete structures. Epoxy liners are the norm in the early stations with steel lining prevalent at the Bruce and Darlington stations.

Table 1
Containment parameters

Station	Reactors (net output)	Type	Volume	Positive design pressure
Pickering A and Pickering B	8-520 Mw(e)	unitized	51000 m^3 per reactor bldg	41 kPa(g) (6 psig)
Bruce A	4-750 Mw(e)	shared	95000 m^3 (Station)	69 kPa(g) (10 psig)
Bruce B	4-750 Mw(e)	shared	95000 m^3 (Station)	84 kPa(g) (12 psig)
Darlington	4-880 Mw(e)	shared	150000 m^3 (Station)	96 kPa(g) (14 psig)

CURRENT ON-POWER TEST METHODS

In keeping with the system-wide goal of achieving high station availability, information on containment integrity status is collected on-power. The methods employed may be grouped into the following categories.

Component testing

This includes periodic pressure testing of airlocks, containment isolation dampers and penetration seal plate interspaces. Test periods vary from one month to five years. Active components such as airlock seals and isolation valves are tested more frequently than passive components.

We can also include in this category periodic visual inspection (which may reveal incipient failures) and laboratory tests of non-metallic components.

Low pressure leakage rate tests

Typically performed four times annually, there are currently two types of tests in use. In the unilized containment concept, there is a significant amount of instrument air in-leakage for control valve operation. With containment isolation valves closed, analysis of the rate or pressurization indicates the presence of leakpaths for each building. The test is terminated in several hours, prior to approaching reactor trip setpoints. Constant power operation is maintained during the test interval.

In the shared containment concept, the Vacuum Building is used to draw all the reactor buildings and associated ducts significantly below atmospheric pressure in a controlled manner. Once at pressure,

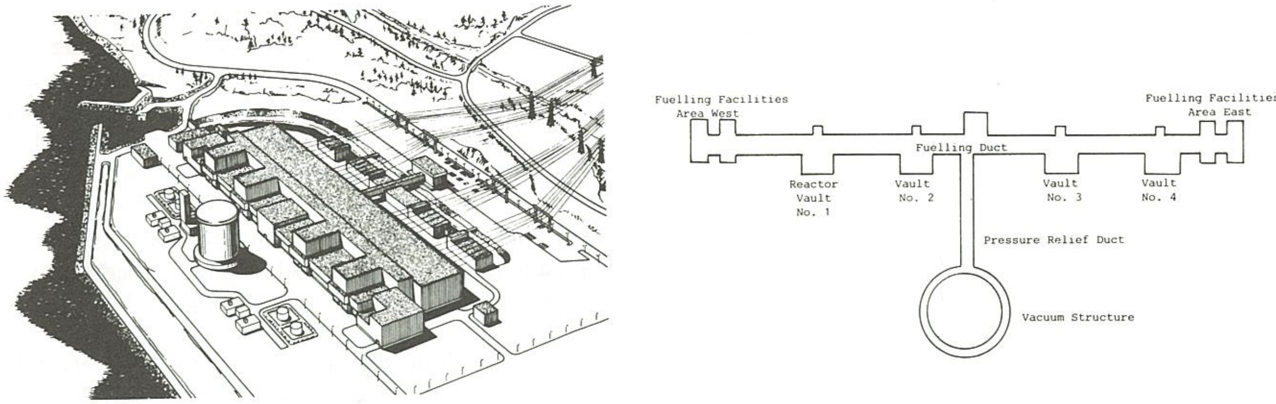

Figure 1:
Example of Multi-Unit Containment Layout (Darlington GS)

typically −15 kPa (g) (− 2 psig), leakage rate analysis is performed with measured instrument air in-leakage subtracted.

In order to interpret low pressure in-service test results a comprehensive commissioning program is undertaken. Leakage rates are measured over a complete range of pressures between the positive and negative design pressures. A good example is the results for Bruce A, illustrated in fig. 2. These results provide strong evidence for a reproducible laminar leakage assumption [1].

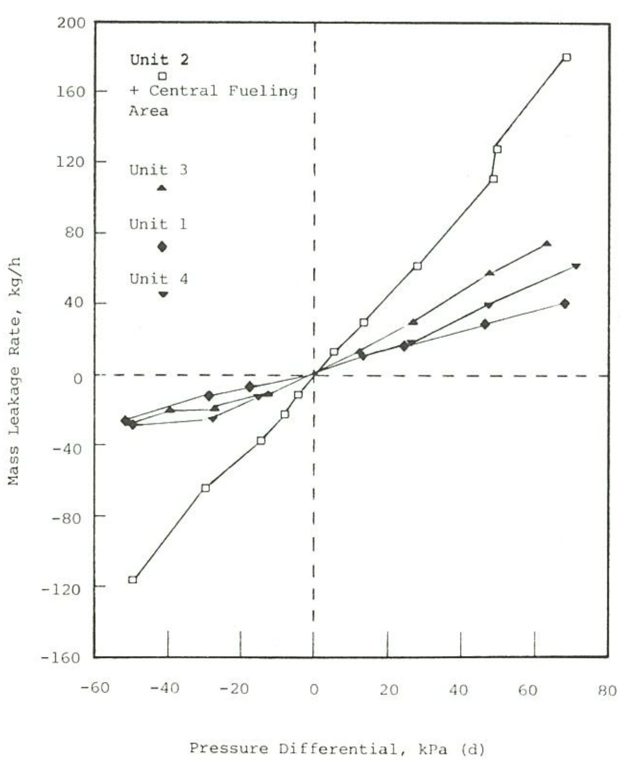

Figure 2:
Bruce 'A' Commissioning Leakage Rate Data

Continuous monitoring

The shared containments are continuously operated at about -3 kPa(g) (-0.5 psig) with continuous pressure trend monitoring. An abrupt change in containment integrity status is diagnosed by a change in computer generated pressure trend or a high containment pressure alarm (-1 kPa(g)) depending on severity. This capability along with exhaust flow metering represents a practical first approximation to the ideal continuous monitoring concept.

Leak tightness in the Vacuum Building is even more readily monitored since it continuously must operate at its design pressure differential. Not only is the pressure trend monitored between pumpdown phases, but vacuum pump running hours are also recorded. As well, atmosphere separation between the main vacuum chamber and a smaller upper chamber (required for spray system activation) is monitored. Integrity is confirmed by maintaining the two chambers about 3 kPa apart. The Vacuum Building will be excluded in future references to "continuous monitoring".

CONTINUOUS MONITORING CONCEPT

The continuous monitoring concept is illustrated in fig. 3. A purge fan connected to the heavy water Vapour Recovery System is the means by which the containment boundary is maintained subatmospheric. The Vapour Recovery System is normally used to maintain the reactor vault dew point very low (about -20°C) to conserve costly heavy water vapour and to minimize radiological hazards (i.e. tritium) for workers.

The principle underlying an absolute measurement of containment leak tightness is that of continuously updated form of the mass conservation equation, integrated over a sampling interval.

$$\text{Rate of mass outflow} - \text{Rate of mass inflow} = \frac{dM}{dt} \quad (1)$$

where,
Mass outflow = measured outflow rate
Mass inflow = measured inflows + structural leakage rate
dM / dt = rate of change of air mass in containment as determined by regression analysis of mass versus time data using leakage rate instrumentation and ideal gas laws.

The outflow is measured by a hot wire-type flowmeter in the 20 cm (8 in) exhaust duct although other methods are being investigated. Each unit has an exhaust fan, but only one is needed to maintain containment pressure subatmospheric. Inflows may be monitored by rotameters on the smaller instrument air lines but in-line integrating gas meters are preferred. Whereas some instrument air is always required for control functions, service air and breathing air sources are intermittent (required during maintenance activities).

With readily available instrument errors and quarterly in-service leakage rate results we can estimate a target uncertainty for this technique. Flowmeters of the aforementioned types have accuracies better than 5% of scale and a typical in-service leakage rate may produce a result with an error bar of ± 10 kg/h for a 4 h test. With these assumptions, and considering only random instrument errors for a 4 h mass balance at - 3 kPa(g), an uncertainty on the order of the leakage rate through a 1 cm hole is projected.

Non-random systematic errors, however, must also be taken into account. These errors can dominate and include factors such as thermal stability in an operating unit, process air in-leakage fluctuations, volume changes, etc.

ERROR ANALYSIS

Leakage rate analysis by the "Mass Plot" method is now widely accepted [1,2]. In this method the leakage rate is defined as the rate of change of contained air mass,

$$L = dM / dt, \quad \text{kg/h.} \quad (2)$$

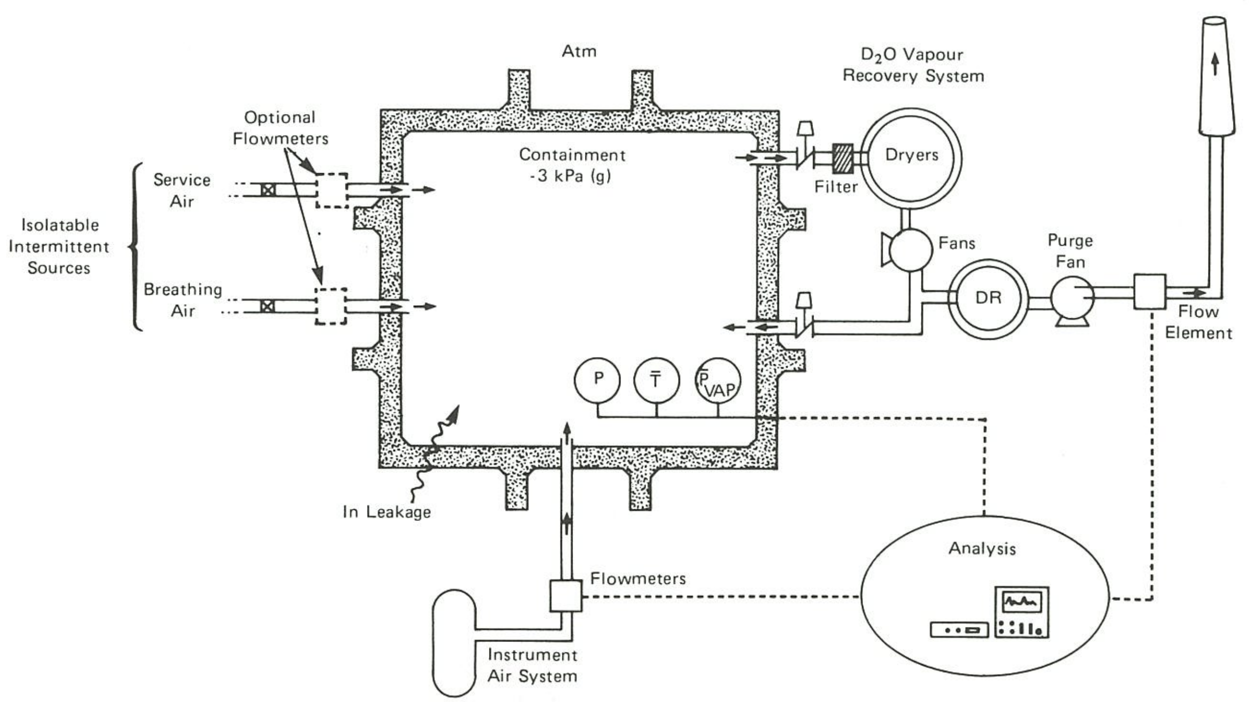

FIGURE 3
Continuous Monitoring Concept

The best estimate of slope is the result of a linear regression applied to the mass versus time data and an associated 95% confidence interval is computed.

The presence of "systematic" errors or non-random fluctuations are often the result of actual physical variations in containment conditions such as those previously mentioned and an example of this behaviour is shown in fig. 4A for a recent Pickering test.

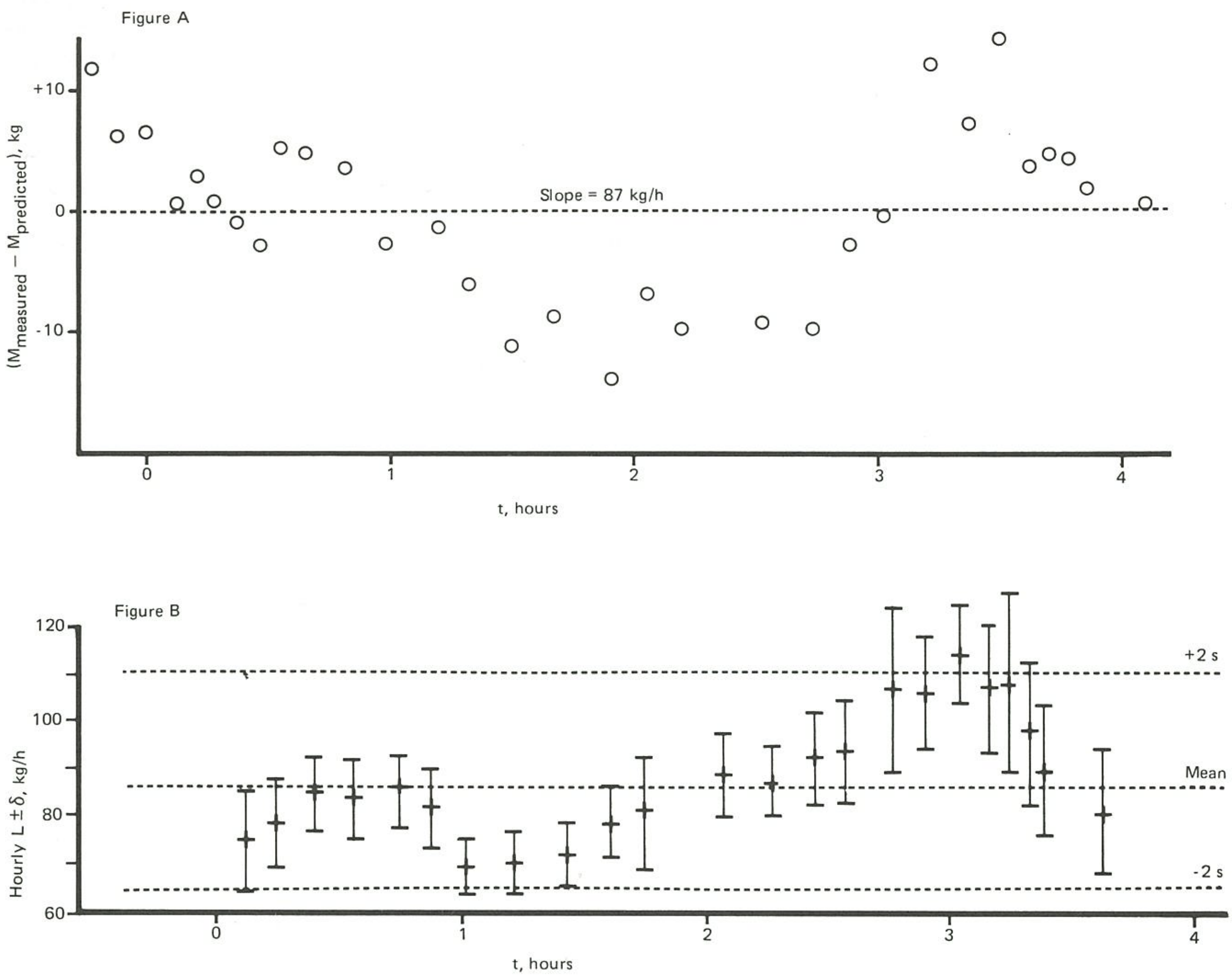

FIGURE 4
Example of Leakage Rate Test Results
with Systematic Fluctuations

(A) Residuals Plot from Linear Regression Analysis (Mass Plot)
(B) Moving Regression Leakage Rate Results Based on Hourly Sampling (Error Bands = 95% Confidence Intervals)

Test Conditions:
Pickering A, Sept. 1983
V = 51 000 m^3
Decay heat removal; all coolers and driers operational.
ΔP = 13.8 kPa (g) (+2 psig)
Quartz manometer, 13 Pt RTD's

Figure 4:
Example of Leakage Rate Test Results with Systematic Fluctuations

For many cases however, the fluctuations will not be periodic or attributable to a known cause. Fig. 4B shows how such a situation may be treated. Regression analysis is performed for subintervals of the total test time, and the regression is moved along as more data comes in, thereby tracking the fluctuations. The moving regression "averages" out the noise and minor fluctuations in the mass plot providing a reasonably accurate "view" of leakage rate with time.

The key means of treating systematic error is sufficient time or a sufficient number of repeated measurements to bound or preferably characterize the leakage rate-time spectrum. If operational transients occur that are beyond the capability of the instruments to track, the information can be disregarded until conditions stabilize.

For continuous monitoring we must trade-off the desirability of having frequently updated information on containment status against the improved accuracy of the result if we sample for longer times before updating the mass balance.

EXPERIENCE

Quarterly on-power tests in the latest stations have been able to measure the leakage rate with accuracies a small fraction of operational targets. Their main use is diagnosis of trends, but any apparent increase in longterm leakage trends to-date has been small enough that it is not considered statistically significant at a high confidence level.

Individual test results often show the presence of systematic errors as discussed above. However, with the large number of results acquired over the years, the true error for any given test result has been estimated. In addition the presence of a seasonal component has been noted with results in winter up to 20% higher than the mean value now anticipated. This is

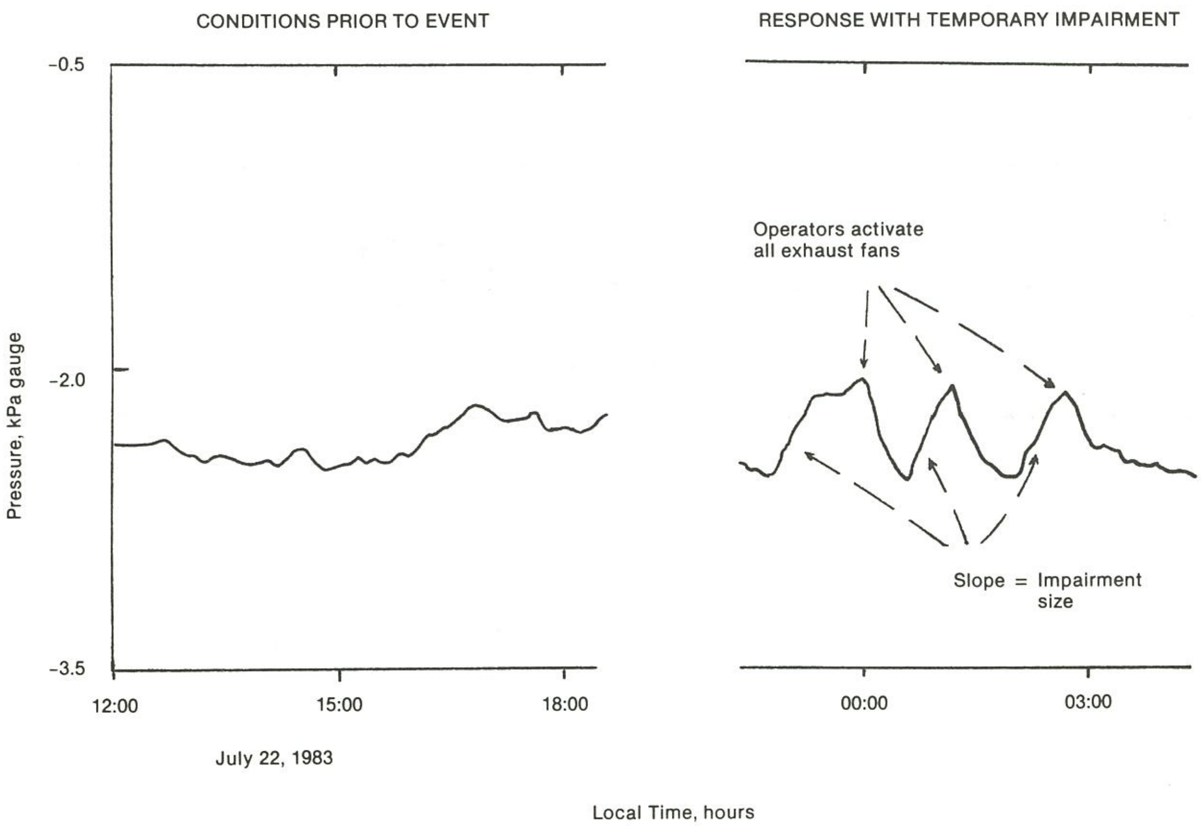

Figure 5:
Example of Continuous Pressure Trend Monitoring of Containment

particularly evident in Vacuum Building results and may be a sign of concrete shrinkage.

As mentioned previously, Vacuum Building leakage has proven to be relatively easy to monitor. This includes a recent roof seal problem at Bruce 'B' which was detected immediately by a rapid pressure rise. A brief station outage was required to implement repairs.

Experience in conducting verification tests at low pressures has shown that it is preferable to input a metered amount of air from the station compressed air system rather than to superimpose an orifice. The test can be completed quickly with a small gas meter and involves no breach of containment with units on-power.

Almost all of the few containment impairments experienced to-date have been detected by our components test , visual inspection or continuous pressure trend monitoring. Fig. 5 is a particularly interesting example of continuous monitoring during a reported event at the Bruce A station. The abnormal slope of the computer generated pressure trend was readily detectable by operators. Their efforts to maintain containment pressure is evident. Simple equations fitted to the slope of the pressure rise indicated that an 8 cm (3.3 in) impairment existed when modelled as an idealized orifice. In actual fact, a promptly called leak search revealed that a nominal 10 cm (4 in) airlock equalizing valve represented the leakpath.

In practice a high pressure alarm (at typically -1 kPa(g)) would indicate large sudden impairments.

RELATED INVESTIGATIONS

Concomitant with the process of detecting abnormal leakage during overall leakage rate tests or continuous monitoring, is the problem of prompt location of the leak site. In large complex containments this is a non-trivial problem. Containment operation at negative gauge pressures makes the task even more difficult because of the flow direction of the leakage.

To assist leak search efforts, assessment and development programs are now underway in the following areas:

(i) Ultrasonic detectors. These hand held units provide for remote leak site identification and have directional capability.

and

(ii) Tracer gases.

It is hoped that these techniques may supplement the current approach which usually consists of a pre-planned leak search starting with known leak-prone components (e.g. airlocks).

APPLICATION TO RISK ASSESSMENT

In order to gain widespread acceptance and to merit further development, continuous monitoring and other on-power tests must have a quantifiable benefit. One means is in probabilistic risk assessments if containment event trees are designed to discriminate failure modes. Failure modes may be categorized by size, as well as by time of occurrence.

In the size category we can have leakages,

(1) On the order of design target values,

(2) Corresponding to hole sizes that result in siting guide release limits being exceeded,

and

(3) Resulting from significant structural or large component failures.

Depending on the station there may be up to an order of magnitude difference in the leakages for these categories and hence in their release consequences.

By time of occurrence we have,

(A) During normal plant operation,

(B) Caused by LOCA,

(C) Long-term post-LOCA.

Continuous monitoring has the potential for making the probability of undetected Type A failure modes zero. The larger, more significant failures or those due to active components (airlock seals, isolation valves) or human misoperation are the most readily detectable, even on-power at low pressures.

Potential Type B failures, of all sizes, can only be detected by pressure testing at accident pressure levels. Integrated full pressure tests are almost always costly to undertake, hence test frequencies should be traded off against the incremental benefit as experience accumulates.

Type C failure modes are addressed by laboratory LOCA qualification tests and aging tests.

Regulatory authorities have an important role to play in encouraging or discouraging implementation or improvements to in-service test methods. Proposed regulatory guide C-7 by the Canadian Atomic Energy Control Board permits the period between full pressure leakage tests to be twice as long if successful reduced or negative pressure tests are frequently performed. Flexibility in this direction is considered appropriate since it recognizes the safety benefits of in-service tests and gives the owner incentive to develop a credible integrity monitoring program.

CONCLUSION

On-power integrity monitoring makes an important contribution to the safety of CANDU multi-unit containments. Continuous monitoring is technically feasible using instruments commonly available for periodic pressure tests. Although at present it may only detect larger failure modes occurring during routine station operation, this portion of the failure mode spectrum is considered significant enough to warrant further development. More widespread implementation or retrofitting requires that credit be given for the improved assurance of containment boundary integrity in station risk assessments and regulatory testing requirements.

REFERENCES

[1] G.D. Zakaib, Interpretation of leakage rate data for vacuum containment structures, Proc. Third Annual Canadian Nuclear Society Conf., C-31, ISSN 0227-1907, Toronto, Canada (June 9, 1982).

[2] American National Standard ANSI/ANS-56.8-1981, Containment system leakage testing requirements, American Nuclear Society, La Grange Pk, Illinois (USA).

[3] G. Box and G. Jenkins, Time Series Analysis: Forecasting and Control (Holden-Day, San Francisco, California, 1976).

FYI

New Test Facility at Chalk River (Staff)

This summer will see the commissioning of the Blowdown Test Facility at Atomic Energy of Canada's NRU reactor at Chalk River. This new test facility (originally intended for installation in the NRX reactor) will permit the in-reactor testing of severely damaged fuel at temperatures up to 2500C while safely containing, and providing online monitoring of, all fission products released from the fuel.

Westinghouse to Test Submarine Reactor System (Westinghouse)

Westinghouse Canada has received a contract to carry out a complete systems test program on the reactor for the world's first nuclear-powered commercial submarine.

The work, commissioned by Energy Conversion Systems Inc. of Ottawa, will be carried out in the Westinghouse Contract Engineering Laboratory in Hamilton. The test program involves building a full-scale replica of the ECS reactor to be used in the vessel, and conducting thermal and hydraulic tests using resistance heaters in place of actual fuel. The tests will be completed by late winter, 1987.

Named the SAGA-N, the submersible is under construction in Marseilles, France, by a Canadian-French consortium. After launching next October, the vessel will undergo sea-trials and crew-training, followed by docking at an Eastern Canadian port for installation of the ECS reactor-based power source.

In operation, the SAGA-N will be able to cruise thousands of miles from base, carry up to six divers, descend to 600 metres, remain submerged for up to 30 days, and run for about seven years on a single fuel charge.

Mathematics and Physics of Neutron Radiography

A new book by A.A.Harms of McMaster University and D.R.Wyman of the Cancer Research Foundation.

In recent years, neutron radiography has emerged as a useful and complementary technology for radiation diagnosis. It is now used routinely in industrial quality assurance and in support of selected research-development activities. While neutron radiography has certainly grown from a scientific curiosity to a subject of technical relevance, it is a sign of its continuing dynamic evolvement that little material has appeared which provides an integrated mathematical-physical analysis possessing both instructional and reference functions. This monograph provides detailed descriptions and analyses of selected neutron radiographic experiments and their mathematical characterization; it provides illustrative and quantitative procedures for applications and develops a coherent framework for further research and development.

The book is directed to scientists, engineers, university students and technologists involved in radiography, non-destructive testing, and nuclear reactor utilization.

Available for $39.50 (U.S.) from Kluwer Academic Publishers Group, Hingham, Massachusetts.

CNS News

Nuclear Journal of Canada to Appear March '87

The Canadian Nuclear Society announces incorporation of the Nuclear Journal of Canada. Containing scholarly works in all fields related to the utilization of nuclear reactions and radiation in science, engineering and medicine, it will be published quarterly commencing in March 1987.

Papers received by September 1, 1986, will be considered for publication in the first issue. All papers will be peer-reviewed prior to publication. A brochure describing editorial policies, review procedures, and other information for authors is available from the editor, care of the CNS office.

Nuclear Science and Engineering (NSE) Division Executive Election

Eight CNS members were nominated to stand for election. As a result of the election, the following five members were declared as elected to the 1986 and 1987 NSE Division Executive: Jerry Hopwood, Joe Q.Howieson, V.S.Krishnan, Norman Spinks, and Evan G. Young.

The 1986 NSED Executive is now comprised of the above, plus the three continuing Executive members, W.J.Garland, G.M.Frescura, and A.L.Wight.

The following were selected by and from the Executive to serve as Officers: A.L. Wight: Chairman, N.J.Spinks: Vice-Chairman, J.Q.Howieson: Secretary-Treasurer.

On behalf of the new Executive, I would like to thank the retiring Executive members (J.Griffiths and J.Pauksens) and the retiring Chairman (D.Rozon) for their efforts and enthusiasm on behalf of the Division.

J.Q.Howieson

12th Simulation Symposium on Reactor Dynamics and Plant Control – Conference Report

Sponsored by the Nuclear Science and Engineering Division of the Canadian Nuclear Society (CNS), and hosted by McMaster University, the 12th Annual Simulation Symposium on Reactor Dynamics and Plant Control was held in Hamilton, Ontario, April 21-22, 1986. The Symposium Chairman was Dr. Bill Garland and the Technical Program Chairman was Dr. Mandouh Shoukri, both of McMaster University. The organizing committee included a number of graduate students from McMaster University. The symposium was attended by 77 participants representing 17 different organizations.

The conference covered all aspects of nuclear reactor simulation and modelling. A total of thirty-three papers were presented. The papers were presented in seven sessions covering a wide range of topics. The two traditional areas of reactor thermal-hydraulics and reactor physics remained the two major areas of interest. However, reflecting current concerns in the nuclear industry, a session was organized on pressure tube integrity, in which five papers were presented. A special session on system simulation and information processing was also organized. With the evolving interest in microcomputers and their applications in nuclear engineering, a workshop was held on "The Emerging Role of Microcomputers in the Workplace." The workshop panelists were Bill Garland, Duane Pendergast of AECL and Mark Kwee of Ontario Hydro. The workshop attracted significant interest and wide participation. The main theme of discussion centered on setting up short and long term goals to facilitate information exchange. In general, the quality of papers and their presentation in the symposium was very high, resulting in many stimulating discussions.

The conference banquet, which was held on the evening of April 21, was fortunate to be addressed by Dr. Ralph Green, Vice-President of Reactor Development at CR-NL. He provided a wide view of the current state of R&D and its future direction in the nuclear industry as reflected by the new role and directions of CRNL.

In summary, this annual symposium was a success and fulfilled its main objective of providing a forum for stimulating discussions and exchange of views among engineers and scientists working in the Canadian nuclear industry.

M. Shoukri
W. Garland

Some Afterthought to the 12th Simulation Symposium

A suggestion I would like to make for future symposiums is to arrange an informal discussion period at the end of each session, at which authors from the session can describe their particular problems and experience on the work they discussed in the session. One such panel discussion was held in the symposium on the topic of "The Emerging Role of the Microcomputer in the Workplace," which I found to be very useful. The biggest concern was the possibility of standardizing microcomputer hardware and software in the Canadian nuclear industry. Much interest was generated as discussion on this subject was carried on well beyond the end of the panel discussion.

Between the technical discussions are, of course, many personal conversations. I was quite happy to learn that none of my old colleagues in the CANDU Operations who were affected by the 1983 reorganization was without a job, or had moved to another industry or another country. Hopefully this situation can be maintained so that the human resource in the Canadian nuclear industry can be preserved until the next boom of the industry arrives.

The preservation of Canadian nuclear technology know-how and the searching of new directions for the Canadian nuclear industry are also the main motives of the recent reorganization at the AECL Research Company, according to Dr. Ralph Green, the guest speaker at the symposium banquet. His speech certainly enlightened most of us attending the banquet.

Dr. Green also mentioned the development by AECL of a small, electricity-producing and operator-free reactor. Under the shadow of the recent nuclear accident in the Ukraine, the idea of developing such a small reactor with simple control mechanism seems to be at least politically appealing, if not adding a new dimension to the progress of nuclear technology.

Rayman Sollychin

Electricity Planning in Ontario – A Brief to the Select Committee on Energy

Following is an abridged brief submitted by the Canadian Nuclear Society to the Ontario Select Committee on Energy, March, 1986.

Introduction

This brief is submitted in response to the Committee report on Darlington Nuclear Station, released in 1985 December, and in anticipation of the study by the Committee of the supply/demand planning process of Ontario Hydro.

The importance of the subject is illustrated by the fact that, in a very real sense, Darlington is Ontario's "Hibernia". During its forty-year amortization life, the station will produce energy equivalent to almost one billion barrels of oil, putting it in the same class as a major oil field. We would note, however, that the differences between the two are as significant as the similarities. The economic viability of Darlington, unlike that of an oil field development, is not vulnerable to swings in international oil prices. Moreover, the nuclear station is not a depleting resource to be used up and abandoned. As pointed out in the CNS Brief of 1985 September, Darlington is likely to continue producing well beyond its forty-year amortization life; the CANDU nuclear plant can be upgraded and modernized as appropriate, and its fuel "diet" can be adjusted to match evolving trends in the uranium market, thus extending its useful life indefinitely.

We note that the Committee has found that the Darlington project does not pose a threat to Ontario in terms of financing, safety, or environmental quality, and that it offers a cost advantage over coal for electricity generation.

> We therefore agree with the Committee that the *key criterion is NEED,* and we are pleased that the Committee intends to investigate the supply/demand planning processes of Ontario Hydro. Our comments are offered in that context for this opportunity.

Our prime recommendation is that the Committee give careful consideration to the validity of demand projections, the benefits to Ontario of capacity expansion, and the penalties associated with electricity shortage.

The Growth of Electricity Demand

The Committee report states that the full capacity of Darlington is not likely to be needed to meet demand until the turn of the century, because growth in demand has broken from its historical patterns, forcing utilities to reduce their lead growth projections. We submit that the evidence does not suggest a break in the pattern, and that the projections are therefore questionable.

Analysis shows that:

- electricity demand has been firmly tied to GPP for several decades, through boom times and recession, through energy glut and energy shortage, and through periods of cheap oil and expensive oil. This relationship is more robust than any other economic correlation that we have seen.
- the rate of growth of electricity demand is greater than that of GPP.

It can be concluded from these observations that the reduction in total energy displayed in Exhibit 1 of the Committee report is due, at least in part, to the increased use of electricity. Such a hypothesis would be consistent with basic principles and engineering realities. The properties of electricity make it highly efficient; it allows precise control, on/off as needed, and is applied only where and as the energy is required.

Electricity Intensity

Exhibits 2, 3, and 4 of the Report introduce a key question: Should Ontario seek to reduce electricity intensity? Perhaps, as the Report states, growth of electricity intensity is a matter of policy choice, but what choices are available, how would the policies be implemented, and what would be their consequences?

The Report bases much of its case on California experience, which is not necessarily relevant to Ontario. California has a warm climate, a rich agricultural sector, high-tech electronics and aerospace industries, a dominant entertainment industry, high electricity costs and a scarcity of energy resources. Ontario in contrast, depends on mining and smelting, iron and steel, pulp and paper, general manufacturing and low-cost electricity, in a cold climate and with a relatively small domestic market. What is right for California is not necessarily right for Ontario.

One of Ontario's assets is low-cost electricity; to adopt decreasing electricity intensity as a policy goal might well be self-defeating. There is strong evidence for the conclusion that Ontario, if it is to remain prosperous, must engage in more energy-intensive activities than California or Japan.

The "high-tech" future is not likely to eliminate the so-called smokestack industries but, by converting their processes from combustion-based to electricity-based, will largely eliminate the smokestacks.

The transition to electrotechnologies, while providing a competitive edge for the industries concerned, also provides business opportunities for a whole range of suppliers in Ontario.

At some stage of development, a country might expect the level of electricity intensity to stabilize, or even begin to decline. It is possible that some regions, say California or Japan, have now reached that point, but there is little to suggest that Ontario is at the threshold of the "post-industrial" economy.

Projected Electricity Demand: The "Downside"

In this light, we turn to Exhibit 5 of the Report, which shows the most probable growth rates for various assumptions regarding electricity intensity. Only the downward range is presented; the possibility of constant or increasing intensity is not examined although, as argued above, increase is at least as likely as decrease.

Moreover, exhibit 5 is based on a GPP growth rate of 3% per annum. Thus, the demand forecast involves a double gamble; the low growth can be realized only if the economy remains slack throughout the forecast period and electricity intensity decreases. In one sense, however, this might be a self-fulfilling prophecy rather than a gamble; electricity shortage might well inhibit economic growth in Ontario.

A slack economy is undesirable, perhaps even unacceptable, to a public who are well aware of individual and social needs, of unemployment, and of the potential capabilities of a province blessed with natural resources and an educated work force.

Electricity and Jobs

On average, an individual at work uses five times as much electricity as an individual at home. This illustrates two main points:

- electricity is primarily a production tool, not a consumer commodity; Canadians use electricity mainly to produce goods and services and only incidentally to contribute to their domestic ease and comfort.
- if half of the one million unemployed Canadians had found jobs in 1984, the resulting increase in electricity demand would have been about 12,000 GWh, an increase of more than 3%.

We are not suggesting that the mere production of electricity can dramatically reduce unemployment. It is the use of electrical energy, rather than its production, that creates the bulk of jobs.

Projected Electricity Demand: The "Upside"

Looking at the "upside" of the range of possible futures, it is possible to offer policy goals at least as persuasive as those already invoked for the downside. For example, a GPP growth rate of 3-4% is required to meet reasonable expectations of employment and quality of life. Why should Ontario plan for less?

Assuming that Ontario plans to grow and to provide satisfying employment for its population, a reasonable minimum expectation would be an electricity growth rate continuing, as in the past, about 30% greater than the GPP rate. For the desired GPP rate of 3-4%, this implies an electricity growth rate of 3.9 to 5.2%.

We strongly recommend that, in examining the Ontario Hydro planning process, the Committee pay particular attention to the assumptions made with respect to economic growth and electricity intensity. In particular, the combination of 2.6% load growth and 3.0% GPP growth in the base case (Exhibit 15) is inconsistent with the evidence.

The Committee has examined the possibility of saving money by delaying completion of Darlington, in view of the possibility that it will not be required until the late 1990s. If, however, load growth is above forecast, due to higher economic growth, higher electricity intensity, or both, it is quite possible that Darlington is already too late and, moreover, that Ontario Hydro is already late in launching additional capacity beyond Darlington.

Uncertainty and Risk

We also recommend that the Committee obtain an assessment of the risks inherent in the planning process. History clearly shows that one statement can be made with confidence about a forecast: It will turn out to be wrong. The oil price shocks of the 1970s were not predicted and yet had an enormous impact on the world's economies. Similarly, the current sharp decline in oil prices and the glut of oil were not forecast; since 1980, energy planning has been based on steady or rising oil prices.

The key to planning is not accuracy, which is unachievable, but flexibility to respond to the unexpected.

Given the uncertainty of forecasts and the long lead time, 10 years or more, required to introduce new electric generating or transmission capacity, it is almost certain that planned capacity, when it enters service, will be either too large or too small, i.e., either too early or too late. Each outcome has its penalties.

In examining the risks, the Committee might ask whether the penalties are symmetrical, that is, whether the penalty for a given surplus of capacity is equal to that for a corresponding shortage. A surplus allows nuclear capacity to substitute for coal, thus reducing acid gas emissions, and allows maximum exports of electricity as well as permitting incentives to Ontario industry for upgrading its manufacturing processes. More fundamentally, surplus capacity is most likely to exist as a result of slow economic growth; the industrial activity associated with construction of the surplus capacity would at least provide some employment in a slack economy, not just in a "make-work" sense, but as a capital investment in the future.

Conversely, in a period of prosperity and growth, a mega-project such as the construction of a generating station imposes additional demands on a busy economy, thus increasing inflationary pressure. What better time than now to build the capital infrastructure for the future?

The question facing the Committee is not whether or not to expand electric generating capacity, but when. Are the risks entailed in delay offset by the benefits? We urge the Committee to explore this question in depth during its review of the Ontario Hydro planning process.

PRV

"The Charm of Nuclear Power"

PRV is exercised in this issue by Hugues Bonin, CNS Communications Chairman and Associate Editor of the Bulletin. His topic is the news media's coverage of the Chernobyl accident. As always we must remind the readers that in PRV the views expressed are solely those of the writer.

This was the title of an article published in a recent issue of *The Economist* (March 1986). In summary, this article suggested that nuclear energy was *the* choice for Western Europe and, in America, it should become a close contender with coal and oil especially if the many problems plaguing the nuclear industry there could be ironed out. It is interesting to note that the Swedish PIUS-type light water reactor was identified as the next generation of inherently safe reactors. The CANDU reactor was completely ignored.

Then came Chernobyl. It made the title of the above article sound like black humour. The accident is certainly damaging to the nuclear industry in general, mostly through its impact on public perception. Unfortunately, the lessons which should have been learned from the Three Mile Island ordeal were quickly forgotten by the mass media who went on a hysterical news rampage. We probably all remember the first articles that appeared in the mass media after Chernobyl. These "professional" journalists were simply making "news" with no information at all. I certainly do not support the childish attitude of the Russians who tried to cover up the accident. The point is that you do not write a headline claiming 2000 deaths at Chernobyl without even considering if there were indeed 2000 people available to be killed on that day in the vicinity of the reactor.

In the most recent article I have read in the *Kingston Whig Standard,* a so-called "expert" was predicting tens of thousands of deaths among the irradiated people in the Ukraine. Then, later in his article, he was honestly recognizing that these figures were highly speculative since sound information was lacking. What is the point of publishing such an article other than to get some national coverage and frighten people? Why is a reporter so ashamed to write "I do not know"?

The problem is serious. There are more and more youngsters who drop out of school simply because the future, as they see it, is so dark to them that they have lost their will to prepare for it. As an educator, this troubles me very deeply. The Chernobyl accident coverage in the mass media is one more sad ordeal as far as mass media work is concerned. The obsession with getting *the* scoop and *the* selling news item, which has become obvious in the Chernobyl coverage, proves the irresponsibility of most of the mass media. To me, reporting all news in an alarmist fashion is equivalent to intellectual terrorism.

Hugues Bonin

CNS Branch Programs

Ottawa Branch News-Chernobyl

Joe Howieson Jr. of AECL CANDU Operations presented to the Ottawa Branch on June 5 a summary of what is known about the consequences of the Chernobyl accident.

After introducing the audience to the basics of the effects of radiation on man, Mr. Howieson went on to describe the Russian nuclear power program, the reactors at Chernobyl and the likely sequence of events during the accident. Based on information provided by the USSR to the IAEA and on long range atmospheric dispersion modelling and fission product measurements made as far away as Sweden and Finland, the following sequence of events is postulated:

- Reactor had been operating at 7%power prior to the accident.
- A chemical explosion occurred.
- A graphite fire ensued.
- Between 10% and 70% of the fission product inventory was released to the environment.

Radiation doses as a function of distance from the damaged reactor have been estimated by staff from AECL and other organizations, and agree well with details released by Russian authorities through the IAEA.

The similarities alleged by Norm Rubin of Energy Probe between the reactors at Chernobyl and our own CANDU reactors were discussed, and it was shown that the CANDU design would not be vulnerable to such an accident (D_2O doesn't burn!). Finally, Mr. Howieson asserted that no significant short or long-term implications for export sales of CANDUs exist.

Local interest in the subject matter was evidenced by the numerous questions posed after the presentation, and by the capacity crowd which attended the presentation, hosted by ECS Power Systems.

Terry Jamieson

Toronto Branch Activities – The Reality of Nuclear Accidents: What Canada's CANDU Won't Do

The Toronto Branch finished off its 1985-86 season on May 27 with a special presentation by Mr. W.G.Morison, Vice-President Design and Construction Branch of Ontario Hydro, and Prof. O.J.C.Runnalls, Chairman of the Centre for Nuclear Engineering, at the University of Toronto. The topics for discussion were the Chernobyl incident and the dangers of creative journalism. About 150 people attended the meeting held at the University of Toronto.

Bill Morison opened the meeting with a discussion of the design and safety features of the RBMK-1000 units in operation at Chernobyl. Mr. Morison noted that the vertical orientation of the pressure tubes in the RBMK-1000 could pose problems under accident conditions in that the tubes can be blocked by sagging fuel following a major loss of coolant accident. The containment system at Chernobyl is not as complete as in most Western nuclear stations, Mr. Morison said, but its upper structure was designed to withstand the effects of a single pressure tube rupture.

The RBMK-1000 Units have been designed with single contingencies and hence are able to withstand most single failures. In the CANDU design, defence in depth is the basis of the safety philosophy, and the ability to withstand combined process and safety system failures is a licensing requirement. Through the use of redundancy, diversity and fail-safe components, and with the highest quality materials and training, Ontario Hydro and Atomic Energy of Canada Limited continue to have every confidence in the safety and dependability of the CANDU design.

Professor Runnalls expressed disappointment with the news media's handling of the Chernobyl and TMI accidents, as well as other nuclear incidents. False headlines and exaggerated and unsubstantiated reports intensifying public fears have not given the nuclear industry the credit it deserves for providing the world with a safe and economic form of energy. He provided comparisons of hazards of nuclear energy production and other risks we face in our every day lives. In the past there have been about 150 nuclear weapons tests that each released "100 Chernobyls' worth of radioactivity" into the atmosphere. Living within 8 km of a nuclear station for 60 years is as dangerous as smoking 1.4 cigarettes or breathing New York air for 2 days.

The truth is getting through to people, but it's a very slow process. Professor Runnalls suggested the "quiet majority" is becoming less impressed with the scare tactics of the media and anti-nuclear groups, and are taking the time and effort to look carefully at all of the information available, put risks in their proper perspective and make their own decisions. It is incumbent on everyone involved in the nuclear enterprise to further the public education process, said Prof. Runnalls, and our efforts should be focussed on ensuring that the information we do disseminate is as clear to the public as possible.

John Marczak
Eva Hampton

Conferences & Meetings

Second International Conference on Radioactive Waste Management

Sponsored by CNS, cosponsored by ANS, to be held **Sept. 7-11, 1986** in Winnipeg, Manitoba. For information contact: **T.S.Drolet, Conference Registration Chairman, CFFTP, 2700 Lakeshore Rd. W., Mississauga, Ontario, L5J 1K3.**

International Topical Meeting on Waste Management and Decontamination and Decommissioning

Sponsored by ANS, cosponsored by CNS, US DOE et al., to be held **Sept. 14-18, 1986** in Niagara Falls, NY. For information contact: **Eva Rosinger, AECL, 275 Slater St., Ottawa, ON K1A 0S4.**

Topical Meeting on Advances in Reactor Physics and Safety

Sponsored by ANS, EPRI, NRC and CNS, to be held **Sept. 17-19, 1986** in Saratoga Springs, NY. For information contact: **D.R.Harris, Department of Nuclear Engineering, Rensselaer Polytechnic Institute, Troy, NY 12180-3590.**

International Topical Meeting on the Operability of Nuclear Power Systems in Normal and Adverse Environments

Sponsored by ANS, cosponsored by CNS et al., to be held **Sept. 29-Oct. 3, 1986,** in Albuquerque, NM. For information, contact: **L.L.Bonzon, Division 6446, Sandia National Laboratories, P.O. Box 5800, Albuquerque, NM 87185.**

International Conference on CANDU Fuel

Sponsored by CNS, to be held **Oct. 6-8, 1986** in Chalk River, Ontario. For information contact: **Dr. I.J. Hastings, AECL Research Co., Chalk River, Ontario, K0J 1J0.**

CNS 2nd International Conference on Simulation Methods in Nuclear Engineering

Sponsored by CNS NSED, to be held **Oct. 14-16, 1986** in Montreal. For information contact: **D.Rozon, GAN, Ecole Polytechnique, 6600 Cote-des-Neiges, Suite 215, Montréal, Québec, H3S 2A9,** (514) 340-4201.

Water Chemistry & Materials Performance Conference

Sponsored by CNS, to be held **Oct. 21, 1986** in Toronto, Ontario. For information contact: **N.A.Graham, Westinghouse Canada Inc., Dorset St. E., Port Hope, ON L1A 3V4,** (416) 885-4537, ext. 297.

International Topical Meeting on Remote Systems and Robotics in Hostile Environments

Sponsored by ANS, cosponsored by CNS et al, to be held **March 29 - April 2, 1987** in Pasco, Washington. For information contact: **James D. Berger, Technical Program Committee Chairman, International Topical Meeting on Remote Systems and Robotics in Hostile Environments, P.O.Box 928, Richland, Washington 99352.**

International Conference on Methods and Applications of Radioanalytical Chemistry –Call for Papers

Sponsored by ANS, CNS, et al., to be held **April 5-10, 1987**, in Kona, Hawaii.

The objective of this conference is to promote an interchange of information on radioanalytical chemistry among societies from the United States and other countries, particularly those of the Pacific Basin. The Conference will be comprised of invited review papers plus contributed papers presenting original research accomplishments. The central geographical location of Hawaii should encourage participation and attendance of Pacific Rim country scientists, while also providing European scientists with easy accessibility. The isolated nature of Kona on the island of Hawaii provides an excellent atmosphere for informal discussions and working groups among the anticipated 175-200 attending scientists. The full manuscripts of the presentations will be published in the Conference proceedings.

Tentative Topics:

I. Ultralow Level Radioanalytical Methods
II. Activation Analysis and its Applications
III. Nuclear Track Techniques
IV. On-Site and In-Situ Analysis
V. Radiochemical Separation Techniques
VI. Tracer Techniques and Their Applications
VII. Radiochemical Methodology Applied to Radioactive Waste Disposal
VIII. Applications to Environmental, Biomedical, Geochemical, Material Science & Energy Related Problems

The conference will consist of a series of invited lectures by experts as well as the presentation of particularly appropriate contributed papers. Both oral and poster sessions will be scheduled and all papers presented in these sessions will be included in the conference proceedings.

Contributed papers are now solicited for the conference. Summaries of between 700-900 words, with figures or tables counting as 150 words each, should be submitted no later than **September 1, 1986.** Authors of papers which are accepted will be required to submit camera-ready manuscripts at the conference. Summaries of contributed papers should be submitted to:**Dr. Richard C. Ragaini, Lawrence Livermore National Laboratory, P.O. Box 808, Mail Stop L-128, Livermore, CA 94550, U.S.A.**

Canadian Engineering Centennial Convention

Sponsored by CNS, CSME, et al., to be held **May 19-22, 1987**, in Montréal. For information, contact: **Engineering Centennial Board Inc., Suite 410, 276 Saint-Jacques St., Montréal, Québec H2Y 1N3.**

14th International Reliability, Availability, and Maintainability Conference (1987 Inter-RAM Conference)–Call for Papers

Sponsored by the Institute of Electrical and Electronics Engineers Reliability Society; cosponsored by the Canadian Nuclear Society, the American Society for Quality Control and others, to be held **May 26-29, 1987**, in Toronto.

Conference theme: "RAM–Getting More Out of What We Have." The theme emphasizes the applications of RAM techniques in operating, maintaining, upgrading, and extending the life of existing production and delivery systems. It reflects today's operating environment, which is characterized by moderate load growth, limited resources, complex regulatory requirements, and increasing public involvement and complexity of system operations. Topics for papers include areas of reliability relating to the electric power industry, e.g., distribution, transmission, and generation. Abstract deadline: **August 15, 1986.** For more information contact: **M.S.Grover, Ontario Hydro, H14-G4, 700 University Avenue, Toronto, Ontario, Canada M5G 1X6**; phone (416) 592-7728.

27th Annual International Conference of the CNA and 8th Annual Conference of the CNS

To be held **June 14-17, 1987**, in Saint John, New Brunswick. For information contact CNS office.

Topical Meeting on Probabilistic Safety Assessment and Risk Management – Call for Papers

To be held **August 31 – September 4, 1987** at the Federal Institute of Technology (ETH), Zurich, Switzerland. The Meeting is being organized by the Swiss Nuclear Society (SNS) in collaboration with the European Nuclear Society (ENS). Other sponsors are: American Nuclear Society (ANS), Society of Risk Analysis, Canadian Nuclear Society, Atomic Energy Society of Japan, International Atomic Energy Agency (IAEA), OECD Nuclear Energy Agency (NEA) and the Commission of the European Communities. English is the meeting language.

Specialists in PRA/PSA and damage control are invited to submit contributions in the following fields:

- General PRA/PSA Methodological Research and Developments.
- Probabilistic Systems Analysis.
- Probabilistic Consequence Analysis.
- Applications of PRA/PSA in decision making, backfitting, emergency planning and accident management for conventional as well as novel reactor systems, fuel facilities, waste management, etc.
- Probabilistic safety criteria and management of safety and economic risks.

The detailed Call for Papers for PSA '87 is available from: **PSA '87, c/o ENS, P.O. Box 2613, CH-3001 Berne, Switzerland;** Telephone (++4131) 21 61 11, Telex 912 110 (atag ch), Telefax (++4131) 22 92 03.

1987 International Waste Management Conference –Call for Papers

Sponsored by the American Society of Mechanical Engineers in cooperation with the International Atomic Energy Agency and cosponsored by the American Nuclear Society, Canadian Nuclear Society, Chinese Nuclear Society, et al., to be held **November 30 - December 5, 1987**, in Kowloon, Hong Kong. Papers are solicited internationally for this conference covering the following high and low-level radioactive waste management topics:

High-Level Waste Management

International Update of High-Level Waste Management Activities (Invited)
Fuel Reprocessing/Waste Management Issues
Back-End Fuel Cycle Economics
Monitored Retrievable Storage
Fuel Storage Experience at Reactor
Spent Fuel Conditioning and Rod Consolidation
Repository Issues

Low-Level Waste Management

Low-Level Waste Disposal–An International View (Invited)
Liquid Radwaste Processing Experience
Solidified Waste Forms
Incineration–Development and Experience
Solid (DAW) Waste Processing
Recent Radwaste Processing Technology Development
Low-Level Waste Management Trends

All papers approved for the conference will be bound in a special publication and distributed at the conference.

Two copies of a 600-800 word summary are due to the Technical Program Chairman by **September 5, 1986,** as they will be reviewed at the Niagara Falls, New York, Radioactive Waste Management meeting on **September 18, 1986.**

Full papers will be due to the Technical Program Chairman by **February 18, 1987,** for review at Waste Management '87 in Tucson, Arizona, **March 1, 1987.** A few of the papers prepared for Waste Management '87 will be eligible to be given at the Hong Kong meeting.

Send high-level waste summaries to the Technical Program Chairman, High-Level Waste: **Mr. A.M. Platt, Battelle Pacific Northwest Laboratories, P.O. Box 999, Richland, Washington, 99352, U.S.A.,** Telephone (509) 375-2273.

Send low-level waste summaries to the Technical Program Chairman, Low-Level Waste, **Mr. R.J.Tosetti, Bechtel National Inc., 50 Beale Street, P.O.Box 3965, San Francisco, California 94119, U.S.A.,** Telephone (415) 768-0191.

The technical sessions will be followed by a three-day short tutorial course titled "Low-Level Radioactive Waste Management for Nuclear Power Reactors," **December 3-5, 1987.** Radwaste technical experts from at least six countries will serve as instructors. Further information may be obtained from **Mr. L.C.Oyen, Conference General Chairman, Sargent & Lundy, 55 East Monroe Street, Chicago, Illinois 60603, U.S.A.** Telephone (312) 269-6750, or **Dr. A.A. Moghissi, Course Director, Institute for Regulatory Science, P.O. Box 7166, Alexandria, Virginia 22307, U.S.A.,** Telephone (703) 765-3546.

A technical exhibit will be held concurrently with the technical sessions. If you are interested in having one of the limited number of booths (less than 25), please contact the **Exhibits Manager, Mr. S. Stockinger, Ebasco Services Inc., 2 World Trade Center, New York, New York 10048, U.S.A.** Telephone (212) 839-3298.

The Unfashionable Side

Darlington, I Presume

Ernest Worthing is on extended vacation at the Whiteshell Nuclear Research Establishment's Underground Research Laboratory. Temporarily replacing his highly replaceable contributions is George Bauer, part-time investigative reporter, and holder of the World Speed Record for elastic-powered roller-skating.

My shrieking editor had just shrieked himself hoarse. He had called for a definition of "bufonite," was informed by a minion that it is "toadstone," flew into a rage at such obtuseness, was transported to the borders of apoplexy when it wasn't in his dictionary and finally rose to white heat on being told by a new secretary that it probably appeared on the same page as "bugger," which page she had removed as a contribution to improved moral health. He railed for twenty minutes, dealing comprehensively with free trade, politicians with and without chins, mercury poisoning, imminent Appalachian volcanic activity as a threat to the stability of cotton prices and the role of wine snobs in undermining Western society, all the while throwing out clever hints on the next story he wanted. Gentle reader, if there be any of you out there, I relate this not to raise sympathy, but for your understanding: when you next read a confused news story, please remember its equally confused origin.

But the gauntlet had been thrown, the challenge of a once-in-a-lifetime story had been proffered, although a lesser practitioner would not have recognized it, hidden as it was amid the thunder and spray from my editor's rabid plosives.

"Look alive, scribe," I said to my trusty amanuensis, Themistocles. "We're on the trail of tomorrow's technology." My editor could have meant nothing less than such a scoop by his references to the far-sightedness of Canadian utilities, the untapped potential of "the little neutral one" and the gold mine in reverse near Bowmanville.

The Lagonda started first crank and we zoomed off toward our goal, situated in rolling countryside east of the Greek warrior-cleanser.

Of course, this wasn't my first visit to Darlington. At an earlier tour arranged for the press we had been shown the business end of the works, which one was encouraged to identify as "the facility" and it had been explained with the help of working models how the coolant goes down and around woa-oh-woa-oh woa-oh and it comes out here. But that was all small fish now. Mere alewives! We were trolling for marlin!

I kept up a concentrated monologue as the Lagonda purred eastward, gradually piecing together the editor's clues, my own knowledge of the industry (won in the teeth of biting competition through hard drinking and bribes) and snippets off the news wire that had been collated, their substance rendered down to pithy intelligence in the quiet secrecy of my priest-hole. It all pointed to just one man. Only one vital force could operate on this scale: it had to be Dr. Manton Wilkinson, genius extraordinaire!

Darlington had now come into view, lodged securely in its iron age fort. The Lagonda buzzed through the security gate, spun to a halt and was still wheezing and clicking as we passed confidently through the double glass doors. We crossed the access bridge and entered the station. It was shambolic inside, but this suited our purposes, and we soon found our way through the coiled wire, stacks of piping and crated equipment and emerged facing the lake. We turned east and moved toward a group of Quonset huts huddled in suspicious isolation at one corner of the site. Instinct told me our quarry was there. The entire set-up had all the earmarks of Wilkinson, and I grew more confident with each stride.

The scoop was at hand. We had surprise and preparedness on our side; the interview was already unfolding in my head and, perversely, now that success was near, the bloom was already disappearing from the fruit.

In hindsight, I shouldn't have underestimated Wilkinson so badly, but nothing could have prepared me for what was waiting inside that hut. I pushed open the door with a bold thrust and was confronted by fifteen eminent brows, the ranged excellence of the Canadian nuclear industry. I knew them all; each of them had writhed on the skewer of my questions at press conferences; all except the now smiling Wilkinson.

"Bauer," he chirped jovially. "We've been expecting you. Do come in. There is much to do and we have little time."

End of Part 1

George Bauer