Canadian Nuclear Society

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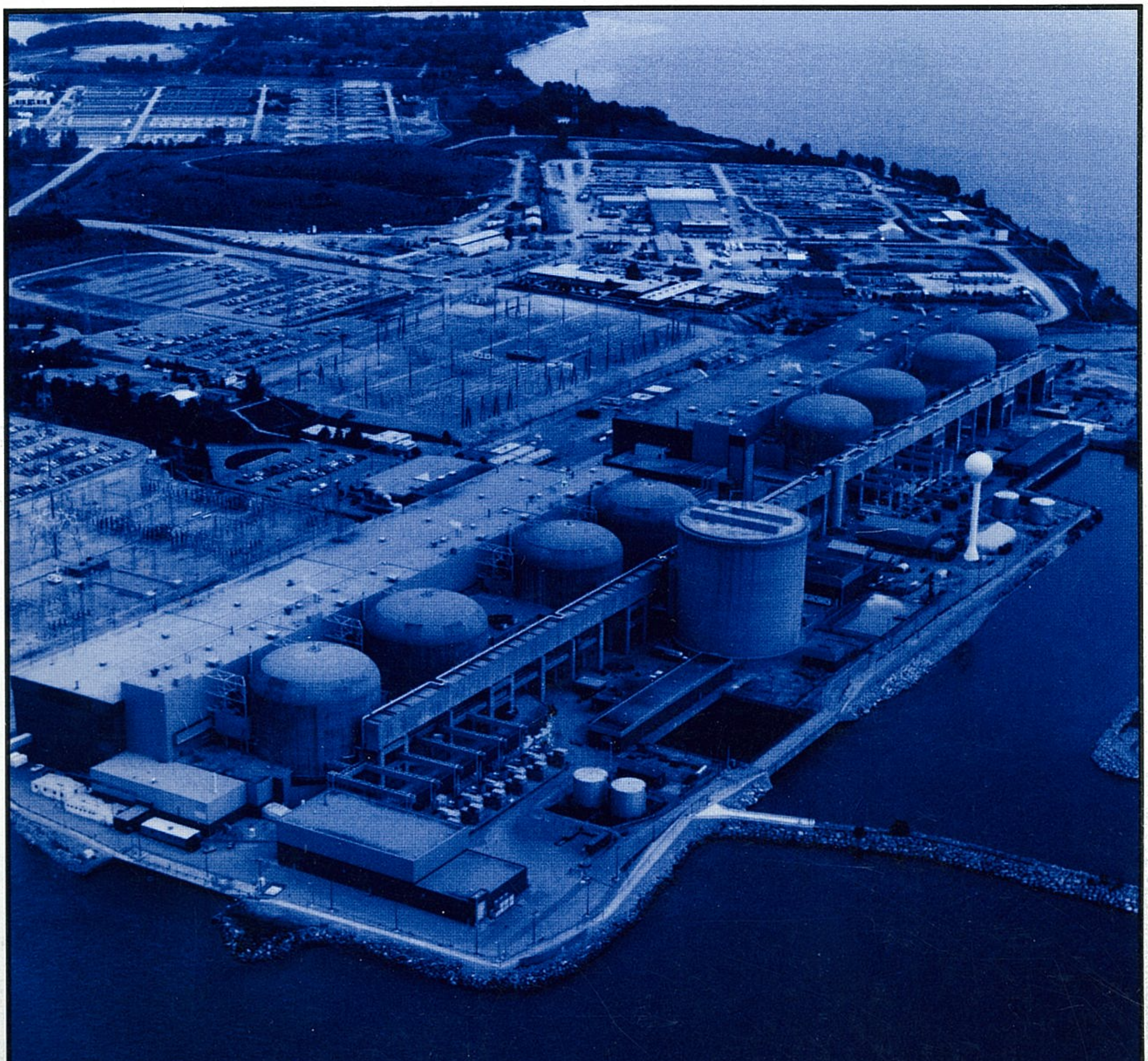

- Containment Conference
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A Message from the President

The CNS relies upon volunteer effort to enable it to make the contribution it does to the technical development of the Canadian Nuclear Industry. This is particularly noticeable in the effort required to organize the CNS-sponsored conferences and courses. It is enjoyable work and very satisfying when the event turns out well, which is invariably the case, but we recognize the efforts are frequently made on top of heavy work loads that in these times, are becoming the norm of organizational life. 1994 was a particularly successful year for the Society in terms of successful conferences and courses, and in this note I would like to recognize publicly the following people who were able to give effectively the effort which made it so:

CANDU Chemistry Course David Barber, John Van Berlo

CNA/CNS Student Conference Paul Berkeris, Nick Dinardis, Christopher Deir, Tinku Dhoum and Ana Buto

Annual CNA/CNS Conference Ian Hastings, Hong Huynh

2nd CNS International Steam Generator Conference Jim Nickerson, Derek Lister, Victor Murphy, Bill Schneider, Paul Spekkens, Glen Wolgemuth, Basma Shalaby, Isabel Franklin and Bob Roy

Simulation Symposium Peter Laughton, Rhonda Cheadle, Norm Spinks and Aslam Lone

3rd CNS International Conference on Containment Design and Operation Duane Pendergast, Sajid Quraishi, Ramesh Arora, Henry Wong, Raju Rajagopalan, Sharon Harrison, Jerry Dick and Ann McConnell

CANDU Reactor Safety Course Lou Fernandes, Dan Meneley, Paul Thompson, Chris Bailey, Fred Boyd, Jim Walaugh, Dave Wright, John Waddington, Mike Dymarski, Cedric Jobe, David Mosey, Ben Rouben, and Tim Andreef

Backing up these efforts were the anchor persons, Sylvie Caron and Tatiana Wigley from the CNS office.

We hope the Society, in its plans to hold at least two major conferences and two courses each year, can continue to enjoy such assistance from its members.

Ed Price

New CNA President

The Board of Directors of the Canadian Nuclear Association has announced the appointment of Dr. Jack Richman as Interim President of the Association. He succeeds the Hon. John Reid, who has resigned to pursue his Ottawa consulting business on a full-time basis. The CNA has negotiated a contract with him to provide consulting services to the CNA.

Dr. Richman is a professional manager with more than twenty years experience in increasingly responsible positions in Corporate and Program Management, International Business Development and Marketing, Project Engineering, Consulting and Research. For the past five years he has been Vice-President of Spectrum Engineering Corporation, Peterborough, Ontario. Between 1966 and 1990 he worked for Bristol Aerospace (Winnipeg), Dilworth Secord Meagher and Associates (Toronto), Bechtel (Montreal), Ontario Hydro (Toronto) and Friction Division Products (Trenton, New Jersey).

Dr. Richman graduated from the University of Wales in 1963 with a B.Sc. (Honours) in Mathematical Physics, and from the University of Manitoba with an M.Sc. in Mechanical Engineering in 1968 and a Ph.D. in Mechanical Engineering in 1972. He is a member of the Association of Professional Engineers of Ontario, the Ordre des ingénieurs du Québec and the Canadian Association of Physicists.

Dr. Richman has received a special award from the Nuclear Engineering Department of the Massachusetts Institute of Technology in recognition of his outstanding contributions towards public understanding of nuclear power.

CNS/ANS Agreement of Cooperation

Officials of the Canadian Nuclear Society and the American Nuclear Society signed an extension of their Agreement of Cooperation in Washington, November 16, 1994, during the ANS Winter meeting.

An amendment to the Agreement makes it possible for members of each society to attend meetings and conference of the other society at the lower members' rate. Pre-registration will be required to enable verification of membership qualifications.

The original Agreement was signed in 1989. The current one extends for five years.

The first annual plenary meeting, as called for under the agreement, took place in Toronto on January 25, 1995, during a visit of ANS vice-president/president-elect John Graham to AECL and Ontario Hydro.

CNS President Ed Price signs the renewed Agreement of Cooperation between the Canadian Nuclear Society and the American Nuclear Society in Washington, November 16, 1994. Surrounding him are (l. to r.): Jerry Cuttler, CNS vice-president; Jim Toscas, ANS executive director; Paul Fehrenbach, CNS past president and co-chair of the International Committee; John Graham, ANS vice-president/president-elect; Alan Waltar, ANS president.

The December 10 incident at Pickering

Ed. Note: *The following account is based on a talk by CNS vice-president Jerry Cuttler at CRL, January 16 and other material he provided, and on information from associate editor Ric Fluke.*

On Saturday evening, December 10, 1994, a failure of an instrumented pressure relief valve led to a serious loss of coolant at unit 2 of the Pickering Nuclear Generating Station. Although a large amount of heavy water coolant was discharged into the reactor building, the safety systems operated as designed and there was no release of radioactive material.

Event

The incident began with the failure of a rubber diaphragm in pressure relief valve CV2 (at 17:27:34 hr) allowing the discharge of primary heat transport system (PHTS) heavy water to the bleed condenser. 18 seconds later, high liquid level in the bleed condenser initiated a reactor setback at 0.5% full power per second. Simultaneously the boiler pressure control began to unload the turbine.

Pressure in the PHTS fell, resulting in a reactor trip on low PHTS pressure at 68 seconds. By 96 seconds reactor power was below 2% of full power. At about 2 minutes the PHTS pressure dropped to 4.2 MPa, approaching the saturation pressure. For the next about 4 minutes the heat flow reversed with the boiler supplying heat to the PHTS. Boiling occurred in some channels. The turbine was manually tripped at about 6 minutes to restore PHTS pressure. Both 100% PHTS feed pumps were operating to attempt to keep system full and restore system pressure. (Pickering 'A' uses a "feed and bleed" system rather than a pressurizer.) The PHTS pressure started to rise quickly at about 380 seconds into the event, going from 4.2 MPa to 9.5 MPa in 32 seconds.

At about 6½ minutes (396 sec.) relief valves RV5 and RV108 on the bleed condenser opened discharging heavy water to the boiler room sump. RV5 began chattering open and closed. This resulted in severe pipe vibrations which caused cracking of an elbow on the 3" line to RV5, pipe hanger failures and damage to the valve. The vibration carried back in the piping to the four PHTS liquid relief valves. Some copper instrument air lines broke. The loss of instrument air caused the remaining three valves to stay open after the pressure declined, releasing more coolant to the bleed condenser.

Water poured onto the boiler room floor from the cracked elbow. At just over 9 minutes the combined signals of low PHTS pressure and high boiler room pressure (resulting from the spilled hot coolant) initiated high pressure emergency coolant injection and boiler crash cooldown.

At about an hour and a half operators entered the boiler room to inspect the situation. With approval, they manually shut the four PHTS relief valves. About two hours later operators entered the boiler room again. Emergency coolant injection was terminated and shutdown cooling pumps started. At 23:10 hr, with the unit stabilized and in a safe shutdown condition, the ECI logic was reset and blocked.

There was no release of radioactive material. Nevertheless the emergency response plan was put into action. (See separate personal account by Ric Fluke.)

As a consequence of the event Unit 2 was shutdown. Units 1 and 3 were already both down for maintenance. It was decided to shutdown Unit 4 and that all four Pickering 'A' units would remain down until the incident was fully analyzed. Since the design of the bleed condenser relief system of Pickering units 5 - 8 is different it was judged that they (Pickering 'B') could safely continue operating.

At the time of the incident the Atomic Energy Control Board was considering the renewal of the Operating Licence for Pickering NGS. The AECB Board deferred its decision at its December 14 meeting but issued the renewal a week later. However, the Board stated that the four Pickering 'A' units would remain shut down until specific approval was granted for their start-up. The president of the AECB and senior staff will be holding a public meeting in Pickering town on February 1.

Causes

From Ontario Hydro's analysis of the event it appears that the initiating cause was the failure of the diaphragm on PHTS relief valve CV2 due to embrittlement. Both the rubber and the reinforcing nylon fabric of the diaphragm are known to deteriorate at elevated temperatures and the valve environment is reportedly between 40 and 55°C. Examination after the event revealed two through cracks, one 399 mm long parallel to the nylon weave and the other 45 mm perpendicular.

A subsequent problem was bleed condenser relief valve RV5. Originally there was just one relief valve on the bleed condenser, RV108. After an overpressure event in 1972 an additional valve, RV5, was added. RV5 had originally been designed to be close to the 6-inch inlet line to the bleed condenser but was separated from it by 8.5 m (28 ft) of 3-inch piping because of concern about radiation exposure during installation and subsequent maintenance. Analysis after the December 10 incident showed that this piping had a much larger pressure drop piping had a much larger pressure drop than recommended by the valve manufacturer, causing the valve chatter which led to the pipe vibrations.

RV108 was connected close to the bleed condenser and was dynamically stable. However, a long 3-inch pipe had been added to its discharge, choking the flow and reducing the capacity of the valve to below 20 % of its rated value.

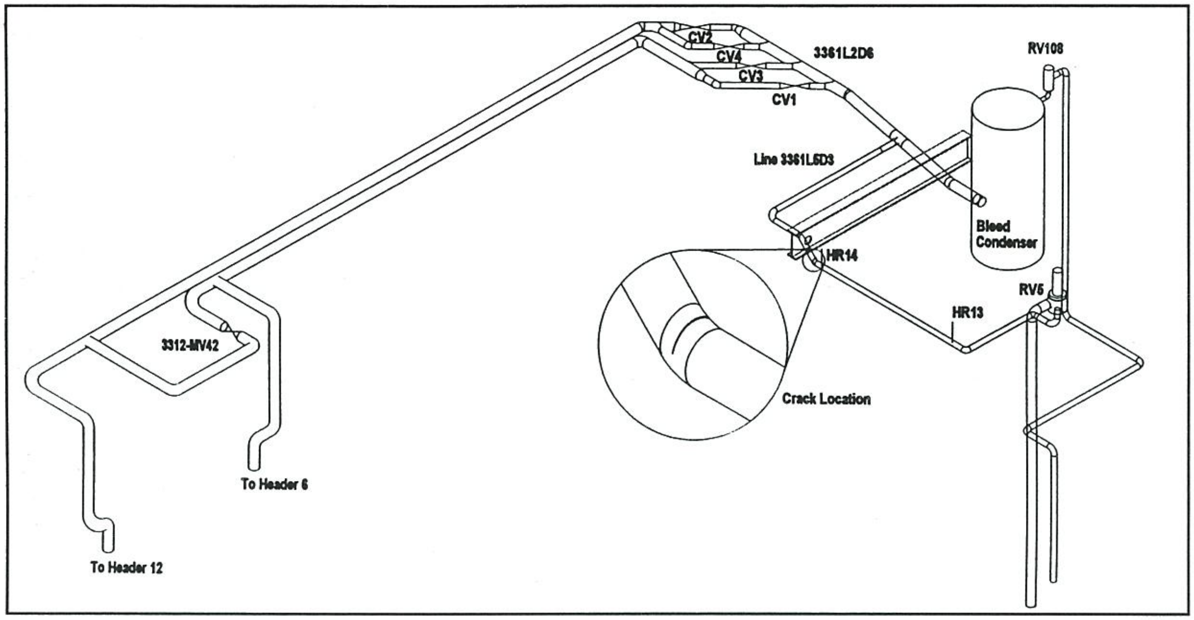
Analysis indicated the procedures (which were followed) for dealing with inadvertent opening of the PHTS relief valves need to be modified.

Corrective Actions

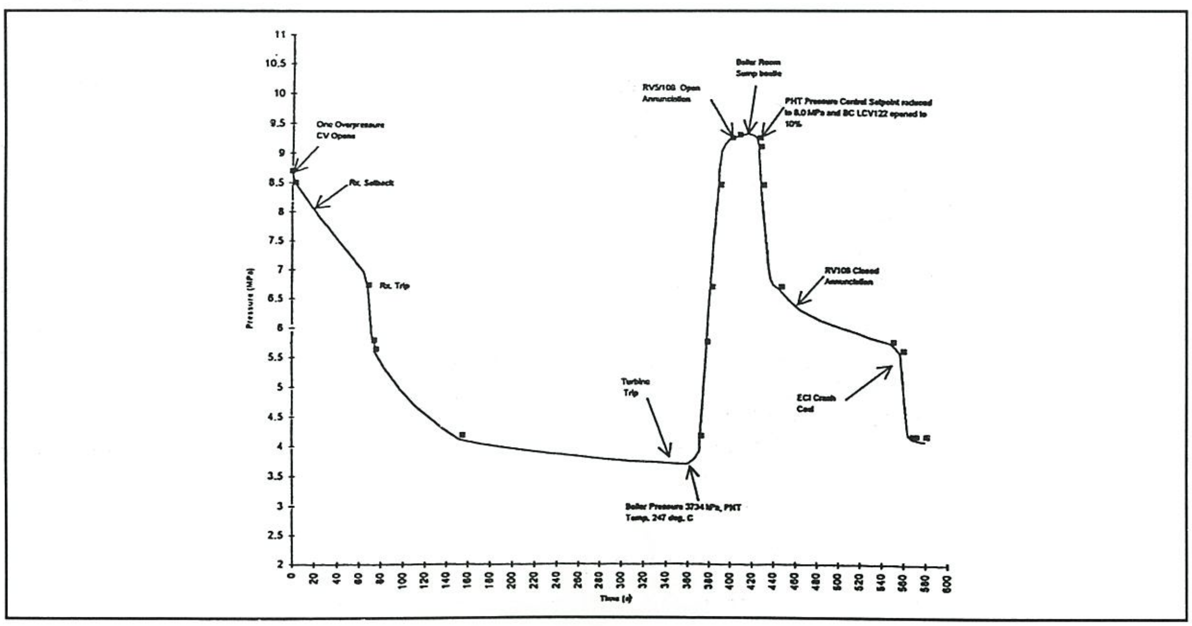
Among corrective actions decided at the time of writing, RV5 is being relocated to an existing nozzle on the bleed condenser. The 3-inch outlet line from RV108 is being replaced by a 6-inch one. The diaphragms of the PHTS relief valves are being replaced. The copper air lines and the instrument rack are being replaced by stainless steel flexible hose, SS tubing and a stronger rack. Procedures are being reviewed for potential improvement.

At the time of writing Unit 2 has been cleaned up and upgrading of the estimated 150 tonnes of water spilled was still underway. Investigations of the causes and consequences have been completed. Determination of the corrective actions is continuing. Ontario Hydro staff are meeting with AECB staff and hope to start up unit 4 in late January.

Existing Configuration – Pickering A Unit 2



Unit 2 pressure trend – from alarms



Incident at Pickering – a personal view

by Ric Fluke

Ed. Note: *The following has been extracted (and slightly edited) from a longer report by Ric on the Pickering incident, much of which has been melded with the information from Jerry Cuttler to prepare the separate article on the event.*

The December 10, 1994 incident at Pickering NGS Unit 2 was the worst incident at any of Ontario Hydro Nuclear's reactors, because it was serious enough to cause automatic actuation of the emergency coolant injection system, and because about 150 Mg of water was spilled into the containment building.

The Nuclear Emergency Plan was activated, and since I am a member of the emergency response team, it ruined my Saturday night. (I was very annoyed because I left a Christmas party, had to drive through wet snow, thought it might be another drill and I was thinking "it damn well better be an emergency"; what a relief it was when I heard it was real!)

As part of emergency planning, regular drills take place. There is a call-out procedure, which we all have. Important people are on this call out list, as well as me. The list has the names of back-up people, and back-ups for the back-ups. Sometimes, responses to the calls are unexpected.

First to be called is the "Emergency Recovery Manager", with a list of seven members to call from. First on that list is Don Anderson, General Manager of Ontario Hydro Nuclear. Recall that the incident was on a Saturday night. Don could not be reached because he was logged into the Hydro e-mail network – i.e. he was "at work"! Next is Ron Lewis, Director of Nuclear Safety. He was at the Bruce, answered the call, and proceeded to drive the 250 km to Toronto. It's a three hour drive in good weather, but recall there was wet snow. The third back-up was called as well, and responded. Within an hour, Don was reached and responded immediately. In fact, the entire emergency operations centre was fully functional within an hour. Communication systems worked well and the proper notifications, including the AECB, were made. (There was a little problem contacting Maurice Strong – it seems his phone number is "no longer in service", but the back-up strategy worked. His chauffeur transferred the message.)

It was quickly determined that there was no radiation hazard, and no off-site response was needed. The leak was isolated, and the reactor was placed in a stable and safe configuration. The emergency operations centre had completed its role. We wrote our report and put on our coats to go home. Just then, Ron Lewis arrived from the Bruce. We told him, "thanks for coming, but it's all over!" Now if Don was doing something sensible on a Saturday night, like relaxing instead of working, his line would have been clear and poor Ron could have enjoyed his weekend. Oh well, it's all heavy water under the bridge now!

Event Sequence

- **Heat Transport System Relief Valve opens**
- **Automatic Reactor power reduction (Setback)** **(18 sec)**
- **Automatic Reactor shutdown (Shutdown System Trip)**
- **Turbine runback from grid load to unit load**
- **Heat Transport pressure decreasing**
- **Operators apply "*relief valve open*" procedure**
- **Turbine manually tripped** **(5 min)**
- **Heat Transport pressure recovers high**
- **Containment pressure increase detected**
- **Emergency Coolant Injection (ECI) automatically initiated**
- **Radiation Emergency procedure started (Level 1 category)** **(~8 min)**
- **On-site & off-site radiation surveys completed (nothing detected)**
- **Entry into Unit 2 containment building finds cracked line downstream of Heat Transport relief valves**
- **Leak stopped by closing relief valves** **(~4 hrs)**
- **Reactor placed on shutdown cooling**
- **Injection by ECI manually stopped**
- **Event terminated**
- **Reactor placed in guaranteed shutdown state**

Nuclear industry perspectives
change and challenge

by REID MORDEN
AECL

***Ed. Note:** The following article is extracted from a talk given by Mr. Reid Morden, President and CEO of Atomic Energy of Canada Limited to the Annual General Meeting of the Organization of CANDU Industries held in Mississauga, Ontario in November 1994.*

Reid Morden

Introduction

In the foreign service, we used to point proudly to CANDU as an example of Canadian technical achievement par excellence and to the climate of cooperation between the public and private sectors which made the achievement possible. As I have looked closely, during the past two months, into the inner workings of Canada's nuclear enterprise I have affirmed that these earlier sentiments were not based on boosterism or chauvinism or hollow self-assurance. I am very impressed with the vitality of the different parts of the industry and especially the dedication, resilience and enthusiasm in the AECL workforce at a time of uncertainty and of unprecedented change.

It's against that backdrop of change that I am framing my remarks this morning. I will share with you my impressions of nuclear power in a global context, of the initiatives that we are taking to ensure that we have a major share of the market, of the challenges and opportunities that are facing us, of the major issues and imperatives that confront us, and of how we can make headway through a formidable and forceful team approach. My vision is a simple one: we are in this business for the long haul and we are in it to succeed.

In the nuclear power industry in the 1980s good news was rare. Reactor sales were in the doldrums. Chernobyl cast a long and sinister shadow over nuclear energy. And an unrelenting recession put an end to the traditional growth in electricity demand. In the early '90s we began to break the long drought with the sale of Wolsong 2, and later Wolsong 3 and 4. Without these the survival of the Canadian nuclear industry as we know it would have been in dire peril, politically, psychologically and economically.

Internationally, nuclear energy remains a central topic on many high-level agendas where worldwide issues touching upon economic development, energy supply, environment, safety, health and quality of life are being debated.

Let me turn to our marketing initiatives and the direction we're heading to ensure our place in the sun. I don't think I need spell out the No. 1 AECL priority. It's the sale of CANDU. And our prospects are good.

AECL-OCI

Probably the most solid way to reinforce this confident forecast is to touch on our activities country-by-country. But before I delve into details, let me reflect briefly on just what the AECL-OCI collaboration has achieved so far.

Together we have designed, engineered, supplied components and managed the building and servicing of CANDU units on four continents – frequently in highly challenging work environments. Today Canada is the world's third largest exporter of Western nuclear power systems, behind only Westinghouse and General Electric in the U.S., each of whom had a long head start on us, and ahead of such European giants as Framatome and Siemens-KWU.

We are a national and international success because it is a Canadian achievement built on cooperation. This public-private teamwork has put CANDU among the world's leading reactors in safety, economy, and production.

Our Canadian cooperative approach goes back more than 40 years. Indeed, this year is the 40th anniversary of the formation of the partnership of AECL, Ontario Hydro and Canadian General Electric to build Canada's first nuclear power plant, NPD, the Nuclear Power Demonstration plant at Rolphton. Over the years CANDU component manufacturers, designers, engineers and scientists have successfully transferred expertise and technology to CANDU customers on four continents. Much of the confidence our customers have in the Canadian team – and that confidence is crucial – has been instilled by the diligence of your members.

This unique partnership approach has catapulted us into an entity to be reckoned with in the international nuclear community. Our market is now global – wherever Canadian policy allows nuclear technology business. This puts us in a formidable league – Westinghouse, General Electric, ABB-Combustion Engineering, Siemens-KWU, and probably some Japanese industrial giants. The point is that international trade is becoming more open and only successful global players will survive.

We must shoot for a world market share larger than the six per cent we have now. We are aiming for more, perhaps as much as a quarter share. So we need to build on the strengths of this unique Canadian partnership approach.

In partnership with the private sector, AECL is determined to be a world-leading supplier of full-scope nuclear power capability, focussing on both new plant and services to existing plant.

Now let's go into some of the marketing activity in specific countries.

Canada

You are as familiar as I am with the picture at home where the short-term holds little promise. Given the lingering effects of the economic recession and the resultant electricity surplus position of most utilities, selling CANDU in North America is a poor bet in 1994.

The trend towards greater energy efficiency will likely continue to be motivated by economic, environmental and technological forces. However, the economy has become more electricity intensive, with the largest contributor to demand growth being the substitution of electricity for other fuels. Although new technology promotes energy efficiency, in many cases it also contributes to growth in electricity intensity. The longer-term market begins to brighten when you consider that older existing installed capacity will need replacing, regardless of the electricity demand growth in Canada and the United States.

New Brunswick is a good example. The province has a few aging power plants which suggests a need for 600 or 700 replacement megawatts in 10 years or so. For similar reasons, Saskatchewan also remains a clear prospect in the medium-term. In Ontario decisions will be required when the Pickering A station reaches the 40-year mark around 2011. It is up to us to ensure that the province doesn't turn to dirty coal, oil or gas to replace Pickering.

USA

In the **United States**, a major change is occurring with the deregulation policies of the Energy Policy Act. Changes in the Act have broadened transmission access. This could mean "territorial wars." Surveys of US utilities are showing that competition tops the list of concerns among utility executives who are jittery about impending price wars, downward pressure on prices, smaller earnings, and loss of traditional customers. This could reverberate back into Canada, with pressure for projects offering lower capital cost and shorter construction schedules. These are key requirements for us to meet.

Asia

Korea

The last three CANDU units into **South Korea** are proving a potent lever in a region where average GDP growth rates have been running around six to seven per cent or more. The impressive economic growth in South Korea and its successful experience with nuclear power has attracted the attention of other countries in the region which see possible development of their own nuclear power programs.

South Korea is one of our most important customers. The country's load hit a peak of 26,000MW this past summer, leaving KEPCO only three per cent spare capacity. It spurred a major review of the country's long-range energy plan which had included new nuclear capacity of approximately 12,000 megawatts over the coming 10-year period.

But some factors have changed in Korea. Availability of land has emerged as a real problem for the Koreans and they want the most electricity possible from existing sites, including Wolsong. The preferred method of accomplishing this is more megawatts per area, meaning larger-sized CANDU is the only answer for Wolsong.

Aside from South Korea, the most exciting prospect for us in Asia/Pacific is China.

China

China is, of course, one of the largest markets in the world. In terms of electricity alone, most Chinese provinces are equivalent to countries. The highest growth areas lie along the southern and eastern coast. The country's energy plan includes from 15,000 to 18,000 megawatts of installed nuclear capacity before the end of this decade.

Chinese interest in CANDU has been stirring since the 1980s but things warmed considerably last year when China showed a renewed interest, with several senior delegations visiting Canada for exploratory talks. All this has culminated in the recent visit of our own prime minister to China and the signing of the bilateral Nuclear Cooperation Agreement with the Chinese government. Also signed were memoranda of understanding and agreements between AECL and our Chinese counterpart CNNC which enables us to start immediate negotiations for two CANDU units. These negotiations will not be easy. But if they are successful, a wide window of opportunity for future orders will have opened.

Other Asian Countries

Electricity demand growth in **Thailand** and the **Philippines** is also impressive, forecast to be an additional 9,000MW by 2002 in Thailand and an additional 4,000MW in the Philippines by the end of this decade. The Thai energy plan calls for 6,000MW of nuclear capacity to be installed from 2005 to 2010. AECL has been active in Thailand since 1992 building support for a nuclear program infrastructure. In the Philippines, where a Westinghouse PWR unit sits mothballed, interest is emerging in proceeding with new nuclear installation apart from the issue of the mothballed plant. AECL continues activity in this market, currently working with a Philippines government Nuclear Public Information Team.

Indonesia also is looking to embark on a nuclear power program following research which showed (A) that nuclear power is economically and technically feasible in Java and (B) that the recommended unit size is about 600MW. Although the competition here is particularly daunting our own position is bolstered by the 600MW preference. AECL has formed a joint marketing team with Canadian private sector companies which have had successful business experience in Indonesia. These include Babcock & Wilcox Canada, General Electric Canada and Canatom which, as you know, represents Agra/Monenco and SNC/Lavalin.

Meanwhile in **Turkey**, with the death of the president and the taking of office of a new prime minister all behind us, and with the resolution of some of Turkey's economic difficulties, we are looking to getting on with a CANDU project there. Turkey is vigorously pursuing a revived interest in the nuclear project. Our CANDU 6 is already known to Turkey, having been the basis for a 1985 contract which didn't materialize. It is also a size more easily financed and more suited to the Turkish grid and offers the economic benefits of replication based on the Wolsong units.

AECL has assembled an international consortium which provides access to world-wide financing resources. Competition again is fairly fierce, but with the good progress we have made on an international financing package and the excellent performance of CANDU 6, we have an excellent chance of seeing CANDU as Turkey's first nuclear plant.

Europe

Among countries in Western Europe uncommitted to nuclear power are the **Netherlands** amd **Italy**. As you know we maintain a presence in the Netherlands and we have been working with Italy in Romania, which should give us an advantage when Italy moves toward the technology.

On the subject of **Romania**, it has been a tough haul and the most immediate challenge, aside from getting Cernavoda Unit 1 started, is organizing the financing for Unit 2. Although there is an appearance that our industry is based on technology, success really depends on financing and marketing. Finding financing for Cernavoda 2 is an excellent example of this.

Other Countries

We are also active in **Egypt** where we have been working with Bechtel since the early 1980s. We are currently involved in a two-year study on technology transfer of CANDU 6 which we are doing for the Egyptian nuclear authorities.

In **Russia**, Canada and AECL were among the first to offer assistance in improving the safety of the RBMK Reactors. Now that the financial way has been cleared, we are active in that area also.

Not to forget **Argentina**, which is still interested in CANDU. The recent developments on the Nuclear Cooperation Agreement with Argentina clear the way for us to explore further the Argentine interest in our product. On the other hand, there are moves in Argentina to privatize the nuclear industry, and while these discussions are underway any new commitments for nuclear plants are likely to be held in abeyance.

Plutonium Burning

Another area of potential opportunity is the use of CANDU to burn plutonium from the curtailed weapons programs of the US and the former USSR. AECL, with the help of Ontario Hydro, has done a preliminary study on the technical and economic viability of burning plutonium in CANDU for the US Department of Energy. The study, along with others, is now being evaluated and we expect that the DOE will announce its options and plans quite soon.

We often hear of a global hiatus in nuclear power plant construction, but it isn't the case. Today, there are more than 50 nuclear power plants under construction in 18 countries. The technology is alive and CANDU prospects are significant. The recent sale of three CANDUs to Korea has generated more than $1 billion in Canadian content, providing some 25,000 person-years of work over six years. A total of 239 Wolsong contracts have been awarded to about 100 suppliers across Canada with values ranging from $4,000 to $40 million.

I have been trying to depict the broad nuclear scene. I'm sure you would also wish me to say something more specific about AECL and the future that I envisage for it. Before looking into the crystal ball, let me take a glance into the past. 1995 will be the 50th anniversary of Canada's first nuclear chain reaction in the little ZEEP reactor at Chalk River. It has been a half-century of solid and noteworthy achievement.

Now we even have a Nobel Prize to add to Canada's nuclear hall of fame. But we can't rest on past laurels when facing a future fraught with challenge at best and apprehension at worst.

Challenges

One of the challenges is to rebuild and refurbish an aging infrastructure. We have only one research reactor – NRU – left in operation. It's 37 years old and, while it has performed yeoman service, its life is finite. We are now pursuing the need for a modern irradiation research facility to replace NRU and this will entail substantial investment. Such a facility will be pivotal to the future success of CANDU, just as NRX and NRU were the building blocks of CANDU up till now.

Another issue for AECL, and for the industry at large, is the ultimate disposition of nuclear fuel wastes. Last month AECL submitted to the federal Environmental and Assessment Review Process panel its Environmental Impact Statement for the concept we have developed for permanent disposal of used fuel. The EIS and the concept are now open to public comment and the Panel is expected to report and make recommendations to government in 1996. The outcome will be critical to the future of the nuclear industry.

The waste issue is going to be in the public eye for years to come, but I believe we are on the track to resolving it. At the same time, we have to contend with an opposition which would like the government to procrastinate on nuclear waste disposal in order to create a logjam that would cripple the nuclear power industry.

A further issue is the role of AECL as a national nuclear laboratory with a spectrum of disciplines ranging from basic to underlying to applied science. AECL is not unique in its research challenges. Science-based innovation in Canada is a topic that requires a national perspective and a high degree of cooperation by industries and governments alike. This is the subject of earnest and intensive discussion during the federal government's present Science and Technology Review.

I have recently been visiting the various AECL sites. One of the messages that I conveyed is of change as an inevitable fact of life. Any organization that doesn't embrace change as part of its modus operandi is doomed to a dismal future, or to no future. If we think Canada's nuclear establishment is immune from change, we are deluding ourselves. Change is not an action, but rather a reaction toevolving circumstances and an adjustment to the needs of the customer at any given time. This requires flexibility and versatility, and only the businesses that have these characteristics will survive.

I will not be content with mere survival for AECL. I intend it to flourish as a company that captivates its customers with products and services that are compelling and competitive. We cannot afford complacency. An industry is placed in double jeopardy when it encounters not only arduous competition, but also a persistent and well organized opposition. In our industry unpredictability has been the rule, not stability.

Since all major nuclear vendors are targeting the international arena competition will be ruthless. To win we need the backing of all parts of the Canadian nuclear industry and the Canadian government. The Prime Minister called the unprecedented trade mission he took to China "Team Canada." Not a bad name at all. But whatever you want to call it, we need it. And I suggest that we couldn't do better than follow, and build on, the example of the OCI-AECL co-operation which has brought us to where we are now.

A WORKSHOP ON

Management and Operations of Nuclear Power Stations Using Computer Systems

will be held at the University of New Brunswick, Fredericton, **June 12-13, 1995**.

For information contact: Jill Feero
New Brunswick Corporation
Tel. (506) 458-3177
Fax (506) 458-4249

Two-Phase Flow and Heat Transfer Course

A five-day workshop on the fundamentals of two-phase flow and heat transfer and their application to CANDU will by held at McMaster University, Hamilton, May 8-12, 1995. It is sponsored by McMaster University and the CNS.

Cost is $900 for CNS members, $1,100 for others (plus GST)

For information contact: Betty Petro, McMaster University, tel. 905-525-9140, FAX 905-526-7104, E-mail betty@mcmaster.ca.

A Future for Bruce 'A'

by Keith Weaver

At the final luncheon of the Third International Conference on Containment Design and Operation, October 21, 1994, Ken Talbot, Director of Bruce A, NGS, gave a significant talk on the current state and future prospects for his station. Significant, because he spoke frankly, engagingly and optimistically about overcoming the long-standing problems at Bruce A, about technical and economic challenges in the near future, about change, about uncertainty, about tough economic realities and about why we should approach all these things positively.

He began by discussing the current situation at Bruce A. Placed in commercial service between 1977 and 1979, the station supplied about 18% of the total electrical energy delivered to Ontario Hydro customers during the period 1980 to 1991; it has generated some 300 TWh of electricity to date; it has a lifetime capacity of 70.3%; and it supplies steam off-site to both the heavy water plant and to the Bruce agriculture and industrial complex. However, incapability has been increasing since about the mid-1980s, a serious maintenance backlog was allowed to accumulate (a legacy of past management philosophy) and chemistry control was poor.

To regain control of the situation, a business improvement model was put in place. It soon showed results. The corrective maintenance backlog (total number of outstanding equipment deficiencies in the plant) was brought down to 1688 (which compares with a North American average of 1600-1800), station chemistry control improved dramatically in just two years, operating manual revisions now average 2.8 days (compared with a North American average of 70 days), and the station's peer evaluation rating improved from 4 to 3 (1 = excellent; 5 = poor). A refurbishment programme was developed. It was ambitious, with a price tag of $2.8 billion over 15 years, the major items being pressure tube replacement, boiler replacement or rehabilitation, and general station rehabilitation.

Unfortunately, this capital programme was not to be realised. At the very time these plans were being formulated, the recession stalled all growth in demand in Ontario. At the same time Hydro rates for electricity were showing dramatic increases. This unsustainable situation resulted in the sweeping changes that Ontario Hydro underwent in 1993.

Not only were electricity rates frozen; a commitment was made to reduce the debt equity ratio from 87% to 60% within the decade, and a program was undertaken to place Ontario Hydro in the forefront in sustainable energy development.

The business structure of the corporation was completely reorganised, staff was reduced by 6600, capital commitments were reduced by $28 billion and 3000 MW of excess capacity was mothballed. A large part of the refurbishment programme formulated for Bruce A in 1992 was swept away. Ontario Hydro Nuclear took a capital write-off of $460 million and plans were made to lay up Bruce A unit 2 in 1995.

Ken put this mixture of good and not so good news in context: "*This is the real world folks; we might as well get used to it*". Getting used to it means looking at the facts and not moaning about the gloom. He noted that although competition from gas and coal burning and other nuclear stations is strong, Bruce A is still in the game and has years of work yet to do. Operation of units 1, 3 and 4 until the years 2000, 2008 and 2006 respectively is foreseen and possibly longer because retubing and other refurbishment remains an option. The station has to be run as a business, however. It may need to find its own sources of capital and it can't look for much protection when the economic winds blow again.

The potential for effects on the local community is clear and Ken noted these: positions lost when unit 2 is laid up; positions lost as the capital program runs down between now and 1998; and positions at risk because of the precarious economic situation of the heavy water plant.

For this listener, the main message of Ken's talk was that if the future holds threat it also holds promise. The Bruce Energy Centre already has a track record, and this can be expanded. There is considerable excitement about a synfuel project now under study; on a level economic and environmental playing field it could be a winner. Bruce A is a candidate for burning weapons plutonium (50 to 100 tonnes of it). Preliminary reviews should be completed this year, and although there will be significant competition from U.S. utilities and other options (such as burial), Bruce A is a technically and politically favourable site.

A new marketing group has been set up within Bruce A, anticipating the time, not too far distant, when power may be sold to cities or communities on contract, and spot price sales and electricity futures may form part of the reality of the nuclear business. A 25-year contract has been signed for steam, sewage handling and water supply with the Bruce Energy Centre. Steam usage at this Centre is expected to treble by 1998. There are very ambitious plans for industrial expansion in the agribusiness. Private capital may be enticed into the nuclear power industry, putting a different face on things.

For those of us in the industry who spend our time looking for problems in order to solve them before they can occur, it is easy to develop a negative outlook. The siege or bunker mentality is perhaps an occupational disease. Ken Talbot's talk delivered a stiff antidote: problems, even when they are numerous and difficult, can be overcome.

The message was clear to me: the future may be uncertain, but with imagination and effort it is possible to turn that uncertainty into opportunities. There is room for optimism. We have a talented team. We have a marketable product. There is room to move in the future. We can do it.

Winter Seminar

The annual **Nuclear Energy Winter Seminar** sponsored by the CNA and the CNS will be held in Ottawa, February 6-7, 1995.

Contact Tatiana Wigley at the CNA/CNS office in Toronto, tel. (416) 977-6152 or 977-7620 ext. 16.

Commentary

Nuclear Emergency Planning in Ontario

by Ric Fluke

The controversial and popular topic of nuclear emergency planning was Professor K.G. (Ken) McNeill's subject at the opening session, November 16, 1994, of the 1994/95 series of public presentations organised by the Toronto Branch of the CNS and co-sponsored by the University of Toronto Centre for Nuclear Engineering.

Dr. McNeill is the Technical Advisor to the Solicitor-General on Nuclear Emergency Planning. He helped set the dose limits and the planning zone boundaries which form the basis of the Ontario Nuclear Emergency Plan. This plan was developed in 1983, a few years after the accident at Three Mile Island. However, since the accident at Chernobyl in 1986, Dr. McNeill has criticized the plan because it does not assume the complete failure of the reactor containment system.

In making his point, Dr. McNeill used a number of analogies. For example, buildings are designed with fire preventive features, and yet they do catch fire. There are laws against murder and theft and police forces are hired to maintain law and order; yet, crimes are committed. His contention is that operator error, unforeseen events, violation of rules, criminal activity or acts of terrorism could result in a severe reactor accident with containment failure. Planning for such scenarios costs money, since the planning zone would need to be more extensive than the current basis. Dr. McNeill suggested that the low probability of such events is why funding for emergency planning is much less than it is for police forces.

The planning zone is the distance within which a projected radiation dose could be high enough to warrant a protective action. Protective actions include sheltering, evacuation and thyroid "blocking". (Thyroid blocking prevents a high radiation dose by saturating the thyroid gland with stable iodine, administered as a pill containing about 130 mg of potassium iodide. This "blocks" the absorption of radioactive iodine.)

Dr. McNeill explained the basis for the current dose limits which define the "Protective Action Levels". Depending on location, there are variations in natural background radiation. Therefore, the location at which people live will affect their lifetime dose. He said that a person living by Lake Simcoe will receive a higher radiation dose than one living by Lake Ontario. When variations in household radon gas is considered, the difference in lifetime dose is 50 mSv. He suggested that people are not bothered by a dose of 50 mSv because they do not worry about the difference in background radiation levels when they buy a house or lake-side property. He concluded that people would accept a dose of 10 mSv (one rem) as something of no significance. Therefore, no planning is necessary beyond a distance where the dose would be less than 10 mSv.

In setting these distances, Dr. McNeill referred to the [AECB] reactor siting guide dose limit of 250 mSv at 1 km for a "dual failure" (such as a pipe break with failure of the emergency core cooling system). Given the very low frequency of serious accidents, he concluded that a dose of 250 mSv at 1 km would be a reasonable judgement, and cited some "well known power of 1.5" relationship to suggest that this dose would reduce to 10 mSv at 10 km. No planning beyond 10 km would be necessary, since as he previously concluded, people would not be bothered by a 10 mSv dose.

This planning basis preceded the 1986 Chernobyl accident which released a lot of radioactive material. Dr. McNeill contends that an act of gross human error or terrorism could breach the CANDU containment and cause a large release similar to Chernobyl. He cited the Hare Commission recommendation that the emergency plan be based on the "Maximum Credible Release" (MCR). The Provincial Working Group #8 was set up to define a MCR. The group consulted experts from AECL and learned that water reactors "contain" 99% of the radioactivity in the water; so even if containment were breached, only about 1% of the iodine would be released. Taking this as the MCR, the working group concluded that the dose could still exceed 500 mSv at 10 km.

Although Dr. McNeill noted that the probability of such a serious accident, involving failure of emergency cooling AND complete failure of containment, is too small to quantify, he reiterated his concern about terrorist activity, war or criminal acts of sabotage. He also noted that there would be no lead time with containment failure and advocated the predistribution of thyroid pills (potassium iodide) and early warning sirens to signal people to take them. This has not been done, because as Dr. McNeill suggested, the Provincial Government has based its planning decisions on the very low probability of such a severe accident.

Commentary

The basis for setting the Protective Action Levels (PAL) appears to be an arbitrary radiation dose for which it is judged that people would not be bothered by it. Variations in lifetime dose due to differences in radon levels, 50 mSv for example, have not caused a mass exodus from Winnipeg to Hamilton (maybe not a good example?). And if people are not bothered by 50 mSv, then they surely would not be bothered by 10 mSv. This assumes that people are generally aware of radiation exposure and its significance, but such an assumption is unlikely to be valid.

The perception of public opinion should not be the basis for emergency planning. Furthermore, the public at large does not know what their background radiation is and real estate agents do not know the radiation levels in the homes they sell. There is no basis to assume that people would take radon levels into consideration when buying a home, over other factors such as convenience, location, appearance and price.

The basis for a PAL should be to protect an individual from a quantifiable harm. In the U.S. and Germany, the PALs are set to prevent casualties. Their values are 10 times higher than in Ontario. If people really are not bothered by a dose of 10 or 50 mSv, why would they want to be disrupted by evacuation and miss Wheel of Fortune? A dose of 1000 mSv could cause death due to radiation sickness, but there is no evidence that a dose of 250 mSv would cause any harm at all (although the linear dose-effect hypothesis would suggest a 0.3% chance of a cancer death within 20 years). Perhaps 250 mSv is a more reasonable limit, since it is based on real protection rather than perception of people being bothered. If that were accepted, then the planning zone need not be more than 1 km, or say 3 km for an extra margin.

Should the complete failure of containment be considered as the planning basis as Dr. McNeill contends? The frequency of such a serious accident, according to Dr. McNeill, is one in a million years. If containment failure were considered, the frequency would be much smaller, but in a biblical perspective, what does such a low frequency mean? There is no human experience with such low frequencies. How long ago was "The Great Flood" that destroyed the world except for those chosen ones in the Ark? Taking the lower range of scholarly estimates would suggest such floods occur with a maximum frequency of one per three thousand years. People are not bothered by fear of another great flood, judging from the number of arks seen in neighbours' driveways. Therefore, people should not be bothered by the frequency of a serious accident.

Dr. McNeill has not made a convincing case to consider containment failure and thereby increase the planning zone for nuclear emergency planning. By his own argument, if the dose limits are based on what people would not be bothered by, then the frequency of a serious accident used in the planning could also be based on what people would not be bothered by. People are not bothered by great floods, ice ages, or mass extinctions due to meteors crashing to earth. Why would they be bothered by something occurring once in a million years? By accepting the argument that the planning basis should be to protect people from quantifiable harm, there is no need for a planning zone beyond 3 km.

Sustainable Energy Development and Nuclear Energy

Ed. Note: *Following is a summary (by the speaker) of a luncheon talk given by Ken Nash, Director, Nuclear Waste and Environmental Services, Ontario Hydro, at the 3rd International Containment Conference in Toronto, October 19, 1994.*

Ontario Hydro has made a commitment to Sustainable Energy Development. Its mission is to help Ontario become the most energy efficient and competitive economy in the world, and a leading example of sustainable development. Sustainable development involves harnessing market forces so that they can work together for both the environment and the economy. It means integrating environment and economics in decision making. The challenge is to position nuclear technology into this vision. Aiming for long term profitability of current operations and leveraging success into a wider expanding market are sound business objectives.

Ontario Hydro's Sustainable Energy Development report had 98 recommendations and six guiding principles — Efficiency, Stewardship, Intergenerational Equity, Precaution, Partnership, and Innovation. Each part of Ontario Hydro will apply the six principles. Sustainable Energy Development principles line up with quality improvement principles.

Quality improvement includes sustainable performance, i.e. low environmental impact, efficient use of resources, economic advantages and social advantage. The nuclear industry scores well for the first three but social advantage is also our achilles heel. We are not readily accepted by society. There is a gap between what the industry believes and what society believes.

Ontario Hydro's overall objective on Sustainable Environment is to be in long term harmony with the environment and community. Ontario Hydro Nuclear's business plan objectives include: to have the lowest environmental damage costs of any form of generation, continue to reduce consumption of non-renewable resources, have a financially sound business capable of competing in an open North American market, increase our social advantage to the community, and to manage its business to have a significant increase in public support by 1997.

Looking at Ontario Hydro's existing nuclear business there are a number of positives:

- Full cost accounting shows environmental damage costs are low and compare well with almost any other form of generation
- CANDU's fuel resource efficiency is better than its nuclear competitors
- Production costs are amongst the best in the world.

Ontario Hydro intends to improve in all these areas. Perhaps the biggest need for improvement is the degree to which the nuclear industry is accepted by society.

50th Anniversary of Fission in Canada

The CNS is sponsoring a technical symposium on **Nuclear Science and Technology in Canada — Past and Future** at Chalk River, September 5-6, 1995 to commemorate the start-up of ZEEP on September 4, 1945.

For information contact Aslam Lone, CRL, Tel. (613) 584-3311, ext. 4007.

3rd International Conference on Containment Design and Operation

An Overview

by Duane Pendergast

The **Third International Conference on Containment Design and Operation,** sponsored by the Canadian Nuclear Society was held in Toronto, October 19-21, 1994. The event was co-sponsored by the CANDU Owners Group, the Chinese Nuclear Society, the Atomic Energy Society of Japan, the Euopean Nuclear Society, the American Nuclear Society, and the International Aomic Energy Agency. Drs. D. Pendergast and S. Quraishi (Canada) were conference and technical chairpersons.

Attendance from 17 countries totalled 240 with 120 from outside Canada. Countries represented by 20 or more included the U.S.A., Japan and France. Sizable contingents from Germany, Italy and Korea were present. Representatives from Sweden, the United Kingdom, India, Finland, Taiwan, Spain, Belgium, the Netherlands, Switzerland, China, the OECD, and the IAEA completed the roster.

D. Torgerson (Canada) opened the conference with a brief talk on containment evolution. Ken Nash and Ken Talbot (both from Ontario Hydro) gave luncheon talks relating to sustainable energy development and the future of the Bruce 'A' station.

The plenary session provided international perspective on containment history, current fission product containment research status, and trends in the development of future containment through papers by Prof Birkhofer (Germany), A. Tattegrain (France), and R. Ritzman (United States). These papers are published in this edition of the *CNS Bulletin* along with a summary of contributed conference papers and discussion ensuing during sessions.

The contributed papers and abstracts of oral presentations are published as **Conference Proceedings (ISBN 0-919784-39-0)** provided to participants at the conference. The Proceedings contain 83 full papers and 22 short abstracts of oral presentations. Many useful and timely technical papers are included. A small number of papers published were not represented by authors, apparently reflecting some difficulty with last minute travel plans. Additional copies of the Proceedings are available from the CNS at a cost of $90.

Eight organizations from Canada, the United States, and France exhibited products such as computer codes, containment penetration equipment, and leakage testing methods and services.

A social evening consisting of dinner and theatre (Miss Saigon) hosted by J. Dick attracted 38 participants. On the Saturday following the conference 35 participants took a technical tour of Ontario Hydro's Darlington nuclear station. A special video presentation on the inaccessible containment system was provided by Muhammad Naeem of Ontario Hydro.

In conclusion, the conference made a valuable statement of the containment art. The Proceedings combined with the plenary session papers and the conference overview published herein provide a useful record of the event and the work of the contributors.

A Summary

Following are summaries, prepared by the conference chairman, Duane Pendergast, and the various session chairpersons.

Session Overviews

Plenary Session

Co-Chairpersons: Dr. Jacques Royen (OECD / Nuclear Energy Agency, Paris) and
Dr. Ajit Muzumdar (AECL-Research, Canada) / Institute for Advanced Engineering, Seoul, Korea)

In opening the plenary session, Dr. Ajit Muzumdar remarked that the choice of the three papers in the session was consistent with the theme of the conference "Containment — Past, Present, and Future". He introduced Dr. Jacques Royen as the session co-chairman. The audience were asked to submit written questions for each of the plenary speakers to the attention of the session chairman for the discussion period following the presentations.

The first of the three papers in the plenary session was presented by Professor A. Birkhofer of GRS (Germany). The paper titled **"Containment Historical Overview"** was an excellent account of the evolution of the containment design function, beginning with the early days of nuclear power development in the U.S.A. This initially led to the imposition of a very restrictive site criterion, requiring a large exclusion zone around an (assumed) uncontained gross release of radioactivity. Pressure to build water-cooled reactors with a much smaller exclusion zone near populated areas resulted in the development of a strong containment building around the reactor, designed to withstand the loads from a "maximum credible accident" as defined within the design basis. This involved the instantaneous release of the coolant inventory plus some additional energy release.

As the PWR and BWR reactors became larger, the design of large, dry containments became expensive, and pressure suppression and mitigation systems were designed using suppression pools and ice condensers. By contrast, the multi-unit CANDU reactor designs applied negative pressure concepts, whereas the gas-cooled reactors generally utilized a "confinement structure" due to the lower stored energy in the coolant. The Europeans made particular efforts to protect containment against external impacts as well.

Within the design basis accidents analyzed, containment began to be viewed as a system, and not just as a simple vessel. Containment isolation and bypass, and the effect on redundancy and reliability of safety equipment from fires, flooding, etc., were examined. The possible challenge to the containment function during an accident from shut-down plant states was also recognized.

Although beyond-design basis accidents leading to the formation of a molten core began to be considered, initially starting with WASH-740 in 1957 (i.e., well before TMI-2), it became clear from early risk studies in the U.S.A. and Western Europe that small breaks and "transients without scram" were more important contributors to overall risk than the large break accidents which had received so much attention. This was confirmed by TMI-2 in 1979, and by Chernobyl in 1986 (although Prof. Birkhofer does not refer to the latter in his paper).

The TMI-2 accident initiated severe accident research activities in various countries, in areas such as hydrogen distribution and burn, DCH, MCCI, steam explosions or MFCI, and so on. The results of this research has led to the implementation of certain accident management strategies in some countries. Prof. Birkhofer makes the point that there are uncertainties associated with the prediction of severe accident consequences in some areas, so that accident management cannot be based upon conventional design procedures, safety margins, etc. Rather, expert opinion must be relied upon, and individual scenarios and plant conditions must be considered.

For future generation reactors, Prof. Birkhofer refers to the need for public acceptability, design improvements for accident prevention, and accident mitigation systems in containment designed explicitly for severe accidents. The different approaches and designs being adopted include various passive designs, lower power reactors, and reactors such as the German-French EPR, in which severe accident scenarios and phenomena are either "designed out" or "controlled" by engineered provisions.

In concluding, Prof. Birkhofer states that improved containment design should play a key role in ensuring that the balance between prevention and mitigation is maintained, in order to "convincingly exclude events with significant off-site radiological consequences in the long-term and at a world-wide level".

The second paper of the plenary session, titled **"The Phebus FP Programme,"** was presented by Mr. Alain Tattegrain (ISPN-DRS), Project Manager of the Phebus Program carried out in Cadarache, France. The program was introduced as the largest international program for severe accident in-pile tests, contributing for the first time to the measurement of fission product behaviour, from the release from fuel to the transport into a simulated containment vessel. This was indeed a unique opportunity to hear about the results from the first test FPT-0 performed in November-December, 1993, after five years of planning and preparation. Participating countries in the ISPN/EDF-run program include the European countries represented by the European Commission, U.S.A. (through the NRC), Japan (through NUPEC and JAERI), Canada (through COG), and Korea (through KAERI).

The main objectives of the Phebus Program were (a) the global validation of computer codes used to evaluate the quantity and nature of fission products present in a containment, following a severe accident with core meltdown, and (b) the study of core degradation mechanisms in different conditions of cooling. Its practical significance to containment safety studies is to validate certain mitigative actions such as spraying and soda injection in the sump, to define the source term for containment leakage scenarios, and to obtain a better knowledge of the composition and behaviour of the corium in the reactor vessel. In addition, testing of some special mitigation devices such as filters and hydrogen recombiners is envisaged.

Mr. Tattegrain presented the test matrix for the five tests in Phebus. The next test FPT-1, planned for summer 1995, is a repeat of FPT-0 using irradiated fuel.

The main characteristics of the FPT-0 test includes a one metre long fuel cluster of 20 PWR fresh fuel rods, pre-irradiated for nine days in the Phebus core; simulation of the physical conditions resulting from a large break downstream of the steam generator at a pressure of 2 bars; oxidizing conditions in the bundle; and acidic pH in the containment vessel sump to maximize the quantity of molecular iodine. The objective was to obtain 20% molten fuel during the degradation phase, with special attention paid to the measurement of the retention of aerosols in the piping system.

Mr. Tattegrain described the locations of various instrumentations used in the test such as the ultrasonic thermometers, gamma spectrometers, the aerosol filters and impactors, and sampling capsules for gases and fluids. He also mentioned other sensors for the measurement of pressure, temperature, relative humidity, hydrogen and oxygen content, sump water pH, and so on, together with the various supporting experiments performed in partner countries. He showed numerous figures of various important test variables such as cluster temperature, hydrogen release, and iodine activity versus time, among others. He also showed some impressive radiographic and tomographic pictures of the degraded fuel cluster showing the missing fuel section in the middle of the cluster.

The general conclusions from test FPT-0 were that the facility and the instrumentation performed very satisfactorily, but certain phenomena were poorly predicted and require substantial effort during the interpretation phase. These included significant eutectic materials interactions in the fuel cluster; large emission of non-fission product aerosols such as silver; low primary circuit, but high containment vessel wall deposition; very early presence of gaseous iodine, and as yet unexplained chemical forms of iodine in the containment vessel.

Other conclusions specific to the fuel bundle were that fuel higher temperatutres were reached than anticipated (up to 2500 Celsius); sheath oxidation was higher than predicted; fuel degradation was faster and more extended than foreseen; between 60-75% of the iodine was released; and hydrogen release was as predicted. A meeting is to be held November 17-18, 1994, at Cadarache to discuss the detailed test results.

After the morning coffee break, the co-chairman Dr. Jacques Royen introduced the last speaker in the plenary session. The paper, titled **"Current Trends in the Design of Future Containment Systems,"** was presented by Dr. Robert Ritzman (RLR Consulting Services, EPRI retired). This was an excellent summary based on a report prepared for the SAC Task Group of the OECD/CSNI Principle Working Group 4. The ground rules for the paper were that it was based on non-proprietary data supplied by sources in member countries only; the emphasis was on full containment systems; and the focus was on concepts for accommodating severe accident challenges. The scope of the discussion was on water-cooled reactors. There was no attempt to provide any cost information as the emphasis was on presenting the status of design activities only.

Dr. Ritzman's paper discussed design concepts for dealing with nine technical issues, namely, accident frequency reduction, DCH, EFCI, hydrogen combustion, overpressure, long-term heat removal, debris cooling and basemat attack, fission product control, and loss of isolation. He cited examples of relevant design concepts with reference to twelve advanced or new plants, in countries such as Canada (CANDU-3), France and Germany (EPR), Italy (LIRA and ICS), Japan (MS600, SPWR, and HSBWR), Sweden (BWR 90), and the USA (ABWR, System 80+, AP600, SBWR). In addition, he included the KfK (Germany) design of a very strong primary containment capable of withstanding a static internal pressure up to 2 MPa. The techniques for meeting the various containment challenges were summarized in a very useful matrix form in a table at the end of the paper.

Dr. Muzumdar thanked all three speakers, and opened the session for questions submitted in writing by the audience.

Several questions were addressed to Professor Birkhofer. The first one was put by Dr. G. Kuczera (KfK, Germany) who, referring to the last viewgraph shown by Prof. Birkhofer, asked for a brief illustration of design measures which had been adopted for the EPR containment to "design out" and control hydrogen combustion problems and in-vessel/ex-vessel steam explosion phenomena. Prof. Birkhofer replied that common safety objectives had been put forward by the safety authorities in France and Germany and endorsed by the two Governments. Most of these objectives could be met at this stage. Regarding hydrogen combustion, it could be controlled either by appropriate design of the containment and by installing passive recombiners close to the sources of hydrogen, or by containment inertization; detailed solutions had not yet been fully decided. In-vessel steam explosions threatening the integrity of the reactor pressure vessel had been shown in the German Risk Study to have very low probabilities of occurrence. The best way to handle ex-vessel steam explosions was to keep molten core debris separate from pools of water.

Dr. R. Krieg (KfK, Germany) asked what measures could be taken to overcome containment bypass in the case of a severe accident, how these measures could be validated under realistic conditions, and what was the influence of human errors. Prof. Birkhofer said that what he had in mind in his presentation was the problem of containment bypass as an initiator of accidents. The objective — not reached at the moment — was to design the systems penetrating the containment walls for higher pressures. Another possibility was to improve permanent leak tightness control. Designing for higher pressures would reduce the need for human intervention and therefore the risk of human error.

Mr. D. Bhattacharyya (Nuclear Power Corporation, India), making reference to Prof. Birkhofer's remark that future containments could be designed taking into account severe accident sequences, asked about current thinking on deciding the basis for this, was it deterministic, as prevailing now, or probabilistic? Prof. Birkhofer said that the philosophy was not to extend the design basis to include severe accidents. However, in several countries (including his own), political authorities were requesting consideration of severe accidents in any future nuclear power plant. This would require the development of detailed guidelines regarding design provisions to cope with severe accidents. To do this, best estimate analyses would need to be performed, and mitigative measures would need to be prescribed in detail. The approach would be largely deterministic, but it would exclude highly improbable phenomena as well as phenomena rendered almost impossible (e.g., through appropriate accident management measures). Prof. Birkhofer stressed that this approach was not a disguised way to hide current limitations in computer code development behind the mask of a new design philosophy: authorities had to make decisions now, without waiting for ultimate progress in the code area, even if there was a risk of making the wrong decisions. This was the only realistic approach.

Mr. J. Woodcock (Westinghouse Electric, U.S.A.) had a question related to designing out some sequences compared to providing mitigation. Emphasizing that the objective of public acceptance might lead to preferring to design out a sequence and that this approach might be more costly than mitigative features, he asked about the status of discussions of trade-off of cost versus acceptance in the design of future containments. Had the basis for a strategy been decided in Germany or elsewhere? How far did one need to go in demonstrating that a particular scenario had been designed out compared to low probability of occurrence? Prof. Birkhofer replied that design objectives for future plants had been laid down in Germany. The nuclear industry now had to think how these objectives could be met, either through design or other means, and to evaluate the cost of the solutions they would propose. But there would be no way to escape from the fact that the conditional probability of containment failure was still too high, it had to be reduced.

Mr. J. Low (Ontario Hydro, Canada) asked Prof. Birkhofer to comment on the effect, if any of the application of leak-before-break arguments in Germany to containment issues such as peak pressure, pipe whip/jet impingement on containment components and structures, personnel access to containment with the reactor at power, environmental qualification of components in containment. Prof. Birkhofer said that the new LBB criteria allowed to remove a number of structures installed in the 1970's hindering inspection in the containment. The possibility of personnel access to containment during operation was considered very important in Germany; this requirement would be maintained in the future.

Dr. R.P. Taleyarkhan (ORNL, U.S.A.) asked how low a frequency of core melt would be an acceptable cut-off and, given a core melt, what was the targeted frequency for containment failure. He also wanted to know how uncertainties were factored into the answers to these questions. Prof. Birkhofer said that it would be hard to demonstrate conclusively that the probability of an event was below 10^{-7}, because of the possibility of common-cause failures, the great difficulty to quantify the probability of human actions, etc. The lowest acceptable frequency for situations that could lead to core melt should therefore be in the range 10^{-5}-10^{-6}. Prof. Birkhofer stressed that one should be very careful in quoting any bottomline numbers, because of the large uncertainties involved (including subjective ones) and because of the inherent limitations on achieving very low frequencies.

Referring to Dr. Birkhofers's presentation and the mention that containment failure probability was between 1 and 10^{-3}, Dr. A.K. Ghosh (B.A.R.C., India) asked the speaker to elaborate the basis of this observation. Prof. Birkhofer said that these numbers were only illustrative as they were based on a particular accident sequence. The German Risk Study had led to the conclusion that the probability of reactor vessel melt-through in a severe accident was basically 1 and that in the long term the capability of the containment system to withstand the consequences of long-term pressure increase was limited. Filtered containment venting had been introduced to reduce the probability of late containment failure.

The first question asked from Mr. A. Tattegrain was about the characteristics of the unexplained iodine species observed in the first Phebus-FP test. Cautioning that the analysis of measurements made by several types of instrumentation, on a large number of samples, was still underway, and that it would be necessary to check the coherence of the measurements made by all the devices, Mr. Tattegrain said that, at the moment, one could only say that cesium and iodine had not been observed at the same locations. Cesium iodide did not appear to be a major component. Silver iodide was perhaps present although this had not been foreseen in pre-test calculations. Molecular iodine had been observed. Both vapour species and aerosol species were present in the test. Complete results would not be available before a few months.

Dr. G. Lowenhielm (Vattenfall AB, Sweden) enquired about the behaviour of cesium in the first test. Mr. Tattegrain said that cesium behaviour had been surprising. The same deposits had been found at 700 and 1500°C. Cesium iodide was not observed. As mentioned above, complete analyses of the results would not be available before several months. Mr. Tattegrain cautioned that fresh fuel contained less cesium than irradiated fuel; cesium behaviour might be different in future tests.

Mr. Tattegrain was asked to explain how the test facility was cleaned up, and what was done with the radioactive waste. The answer was that the facility did not need to be cleaned completely because experimental loops were replaced for each test; for the rest, usual decontamination products were used. Complete decontamination of the containment tank was underway. There was no need for any unusual procedure. The Cadarache site was well equipped to store mixtures of fuel and Zircaloy.

Dr. A.P. Muzumdar (AECL, Canada) asked how confident one could be in making predictions for the second Phebus-FP test. Mr. Tattegrain replied that improvements were needed to the ICARE code to predict fuel degradation behaviour. These improvements were being made but would not be completed in time for FPT-1. However, the first test had led to the conclusion that it would be possible to perform the second test safety. Instrumentation of the fuel bundle had been enhanced. Maypack filters would be used to separate various forms of iodine at an early stage of the experiment. Mr. Tattegrain concluded that the degree of confidence in the capacity to run the second test was high.

Turning to Dr. Ritzman, Dr. J. Nathwani (CANDU Owner's Group, Canada) enquired whether any cost data were available on the different containment concepts and designs he had mentioned, and whether there were any comparative evaluations (including cost) which showed how much risk reduction would be obtained from the various containment concepts. Dr. Ritzman said he was not aware of any serious cost evaluations, even less aware of any comparative evaluations. He stressed, however, that many of the designs he had briefly described were still conceptual, and therefore he doubted that any credible cost estimate was feasible at this stage.

Recalling that protection for future plants would be achieved through better isolation, Mr. F. Robledo (CSN, Spain) wondered how this would be done. He mentioned three possibilities: improving materials of valves and piping, increasing the number of containment isolation valves per penetration, eliminating the use of check valves as containment isolation valves. Dr. Ritzman said that the information available to him did not allow to give an accurate reply to this question. One approach was to avoid having penetrations in different directions, another was to regroup them in a second building providing protection against any leakages that might occur.

Mr. P. Vanini (ENEL, Italy) commented that in fulfilling the objective assigned to the next generation of reactor containments it would be necessary to keep in mind the additional goal of cost reduction. He added that in-vessel debris coolability would also be an important target. On the second point, Dr. Ritzman said that the question of in-vessel core debris cooling through lower cavity flooding (IDCCF) was being investigated actively. Preliminary results seemed promising.

The speakers — or the members of the regulatory agencies present at the Conference — were invited to comment on closure criteria to a severe accident issue. When was a problem considered "solved"? How much money or effort was justified seeking further improvements for extremely low probability events?

Dr. Ritzman said this was a very difficult issue which — as far as the US was concerned — would need to be examined and probably decided during the public hearing process leading to certification of the ABWR and ABB/CE System 80+ designs. The complete text of the plenary papers is included in this issue of the CNS *Bulletin*.

Contributed Papers

Session 1, Performance and Regulatory Requirements for Containment, Co-chairpersons: A. Boothroyd (IAEA — Vienna) and J. Blyth/G. Khosla (Canada)

There were five papers in this session: three dealt with general requirements and in-service inspection and testing, and two with equipment/material qualifications.

The first paper described the regulatory approach to containment in the U.K. This approach is based on the safety assessment principles which set the safety goals and objectives that should be met, and therefore, this approach is less prescriptive in nature. The role of the regulatory authority is to review the design submissions, inspect and assess the construction and commissioning of the containment, and oversee the in-service inspection. The paper described how the regulatory staff satisfied itself that these safety assessment principles had been met for the Sizewell B plant. In addition, it was able to persuade the licensee to obtain data on the ultimate structural failure and validate seismic loading model by tests on scaled models of the containment.

The second paper described the regulatory improvement program at USNRC for the operating reactors. It involves rule making regarding modifying the requirements for containment testing on the basis of the risk associated with the failure due to a lack of testing as well as on the basis of past performance. It was observed that the risk (population dose and individual latent cancer risk) from leakage was dominated by containment bypass and early containment failure, and therefore, upon testing a greater percentage of allowable leakage may be acceptable. Similarly, the testing frequency for the integrated leak tests and for the good performing local penetrations may be reduced without significantly increasing the risk. Because of the low contribution to risk due to the failure of containment isolation, the potential risk benefit from on-line monitoring was considered to be limited.

During the discussion it was pointed out that the early fatalities may not be a good indicator of the risk for acceptable leakage from the containment. Also an increase in the test interval must be done with a caution as with age the rate of failure may increase. Currently, NRC were intending only to amend the test interval but not the leakage rate.

The third paper described the environmental qualification program being instituted by Ontario Hydro. In particular, for the containment systems at the Bruce NGSs it describes the development of safety requirement matrix which identifies for all design basis accidents (including a process failure and a failure of a special safety system) safety related components, their safety functions and the mission time as well as the required environmental qualifications. It was emphasized that due consideration should be given to the fact that the containment boundary in the post accident phase may be different from that under normal operating conditions. Also EQ program must not overlook that some components may have multiple safety functions associated with different subsystems/systems.

In the fourth paper, a review of the regulatory basis for containment in-service inspection in the U.S.A. together with a description of the inspection requirements of ASME XI was presented. This included the development of the ASME rules and a summary of the types of containment ageing and degradation mechanisms found in nuclear power plant containments. During the past year NRC had made available for public comment proposed rule changes to include the ASME XI methodology. Unfortunately numerous objections to the proposals were raised by industry who have asked for a further review of the proposals. The author proposed several options which were available to progress the issue and assure the long term structural and pressure retaining integrity of steel and concrete containment. From the discussion it was apparent there was a need to adopt an inspection strategy but the scope and criteria needed further development and review. This, however, did not obviate the need to adopt a strategy in the interim.

A presentation on the development and use of non-metallic liners in CANDU containments was made by AECL in the final paper. This included a review of current performance requirements and the extent of qualification and testing which has been carried out on these materials. The paper encouraged lively debate on the method of application, the results of the qualification tests which had been carried out and the effects of ageing on the material performance. The use of this material will obviously be subject of discussion in the future until the performance of the materials are more widely known and understood.

Session 2, Radionuclide Behaviour in Containment — Experiments and Analysis, Co-Chairpersons: B. Kuczera (Germany) and R. Fluke (Canada)

Preamble

The release of radionuclides following a reactor accident has consequences to the public and the environment, for two important reasons: exposure to radionuclides poses a health and safety risk to people; and, land contamination can lead to ecological damage and economic loss. The extent of risk or loss depends on the magnitude of release, and is insignificant if the reactor containment system retains the radionuclides or limits their release to a very small amount.

Radioactive iodine, particularly I-131, poses the largest risk because it is abundant in a reactor core, it has biological significance due to thyroid function, and it can become highly volatile under certain chemical conditions. Iodine is a halide, like chlorine, and has multiple oxidation states meaning that many potential compounds can be formed. A bottle of chlorine laundry bleach, for example, has a warning on its label not to mix with acid, because that would "volatilise" the chlorine releasing deadly chlorine vapour. DO NOT TRY THIS AT HOME! [legal stuff]. The influence of pH on halide chemistry is well known, where low pH tends to be oxidising.

Dr. Dave Torgerson (Vice President, AECL Research), speaking in the plenary session, showed a chart which maps the many iodine species according to pH and oxidation potential (how oxidising or reducing the conditions are). He used this chart to explain why iodine was volatile (I2) at Windscale and Chernobyl ("Oxidising" accidents) compared to non-volatile (CsI) at TMI-2 (a "Reducing" accident). Dave's chart remains relevant and is incorporated in many computer models. However, the chemistry is further complicated by radiation and a Pig's Breakfast of radiolysis products, other impurities and a variety of containment surface materials such as steel and paint. Recent experiments performed in a radiation environment with painted surfaces have led to surprising results.

It is not surprising, therefore, that six of the seven papers in this session described experiments on and modelling of iodine behaviour. Dr. Sims discussed pH effects. Drs. Ball, Evans and Hellmann described work on surface effects. Drs. Wren and Fermandjian described modelling of iodine behaviour. The seventh paper, presented by Dr. Kuczera, was not specific to iodine behaviour; instead, it described the design features of a future PWR containment system which limits radionuclide release to within new German requirements.

The Seven Papers

Dr. Howard Sims (AEA Technology — United Kingdom) presented the paper "Some Effects of pH on Iodine Volatility in Containment", coauthored by C.B. Ashmore (AEA Technology) and J.R. Gwyther (Nuclear Electric). Dr. Sims described work which examined and quantified the effect of pH, dose rate, and concentration on the rate of radiolytic oxidation of CsI solutions. It is important to examine pH effects because there are several mechanisms that drive the pH down, including radiolytic processes and absorption of atmospheric CO_2.

Dr. Sims' results show a strong pH dependence on radiolytic oxidation of CsI, with lower rates of oxidation at higher pH. Oxidation rates were nearly proportional to dose rate, but concentration had only a small effect. He concludes that the higher the pH the better, but suggested that an optimal pH that could be reasonably achieved is in the range pH 7-8. Dr. Sims noted that a suitable buffer is trisodium phosphate, which is used in the Sizewell PWR reactor containment for accident management.

Dr. Joanne Ball (AECL Research — Canada) presented the paper "Iodine Volatility in Containment: The Role of Organic Surfaces" coauthored by J.C. Wren, R. Portman and G.S. Sanipelli, all from AECL Research. Dr. Ball noted that the inside surfaces of most containment buildings are painted with organic coatings. These paints can release organic substances into the sump water during a reactor accident. Radiolysis of these substances forms organic acids which can reduce the pH of the sump water, thereby volatilising iodine. According to Dr. Ball, a common solvent used in paint application is methyl ethyl ketone. She explained that radiolysis of ketone leads to acid formation with distinct radiolysis products. However, she also noted that experiments show variations in the rate of acid production and so radiolysis of ketone may not be the rate determining step. Furthermore, the release of ketone is independent of dose rate or pre-irradiation and she speculates that its release is likely dependent on physical parameters such as paint thickness, surface area and temperature.

Dr. Ball concludes that the prediction of pH effect due to organic surfaces remains complex because the release rate of organic substances from paints is variable. When asked if painted surfaces could be top-coated with an agent to inhibit release of ketone, she replied that control of pH would be a more effective strategy and that a better selection criterion for any paint or repaint would be its capacity to absorb iodine.

Professor G.J. Evans (University of Toronto — Canada) presented the paper "The Sorption of Iodine Onto Containment Paints" coauthored by P.A. Berkeris. He described experiments on iodine adsorption and desorption using two paints: inorganic zinc primer and vinyl, both commonly used in reactor containment buildings. Temperature and relative humidity were the two variables studied.

Dr. Evans showed that with inorganic zinc primer, the deposition decreased with increasing temperature and increased with increasing relative humidity. The rate of desorption was also measured which increased with rising temperature. I2 was determined to be the desorbing species.

With vinyl paint, deposition velocities were much slower compared with the zinc paint, but Dr. Evans' data on the effect of temperature was inconclusive. Furthermore, he showed that relative humidity had no discernable effect. He noted, however, that desorption increased with temperature.

Based on his data, Dr. Evans concludes that iodine adsorption onto inorganic zinc primer is limited by mass transfer, whereas adsorption onto vinyl paint is limited by a chemical surface reaction.

Dr. Sieghard Hellmann (Siemens KWU — Germany) presented the paper "Iodine/Steel Reactions Under Severe Accident Conditions in LWRs" coauthored by F. Funke, G-U. Greger, A. Bleier and W. Morell. Dr. Hellmann reported that molecular iodine can react with steel surfaces in containment forming metal iodides, thereby converting a volatile species to a non-volatile one. This conclusion is based on two types of experiments carried out at Siemens AG Power Generation Group (KWU). In the one type, steel coupons were submerged in an I_2 solution at 50°C, 90°C and 140°C. The reaction rate of conversion of I_2 to I- was measured. He noted that there was no retention of I2 or I- on the submerged coupons. In the other type, steel tubes were exposed to a flow of steam, air and I_2 under either non-condensing or condensing conditions, at 120°C and at 160°C. For the "dry" condition, he noted that I_2 deposited and was retained on the steel surface. Under condensing conditions, he explained that the results were qualitatively similar to the submerged coupon tests in that I_2 was converted to I- which subsequently washed off with the condensate.

Dr. Hellmann explained that the rate constants measured for each test are suitable for use in iodine behaviour codes such as IMPAIR. Although rate constants for "dry" deposition of I_2 on steel has been reported previously, he noted that this work expands the database to include German steel alloys in "as received" condition, and provides previously unreported rates for I_2/I- conversion under wet conditions.

Dr. Jungsook-Clare Wren (AECL Research — Canada) presented the paper "Modelling of Iodine Behaviour in Containment" coauthored by J.M. Ball, S.P. Mezyk, W.C.H. Kupferschmidt and C.A. Chuaqui. She began with an overview of the Canadian programme leading to development of the LIRIC iodine model and data-base. An important component of the Canadian programme is the Radioiodine Tests Facility (RTF), which she described, and compared LIRIC model predictions to the RTF data. Dr. Wren noted that LIRIC is still under development, primarily in four areas: (a) water radiolysis reactions; (b) radiolysis of organic materials; (c) surface interactions; and, (d) metal ions.

Dr. Jean Fermandjian (IPSN, Ispra — Italy) presented the paper "PHEBUS FPT-0 Exploratory Containment Iodine Chemistry Calculations" coauthored by S. Dickenson (AEA Technology — U.K.), J.B. Edward (Ontario Hydro Nuclear — Cananda), F.J. Ewig (GRS — Germany), F. Funke (Siemens KWU — Germany), C. Hueber (CEA/IPSN — France), J.J. Rodriguez-Maroto (CIEMAT — Spain) and H.E. Sims (AEA Technology — U.K.). Dr. Fermandjian began with a brief description of the Phebus-FP programme and the first test, FPT-0. [A detailed description of Phebus and test FPT-0 was presented by Dr. Alain Tattegrain, IPSN, during the Plenary session of the conference.]

Dr. Fermandjian then outlined two objectives of the code exercise: (a) to perform pretest benchmark calculations to understand differences between codes; and, (b) to perform realistic calculations to predict the outcome of the experiment and to assess instrumentation requirements including detectability. Of the four codes used, two were mechanistic primarily (INSPECT from U.K. and LIRIC from Canada) and the other two were empirical primarily (IODE from France and IMPAIR from Germany and Switzerland).

The benchmark calculations showed that the two mechanistic codes were in good agreement predicting gas phase molecular iodine, although Dr. Fermandjian pointed out that all codes predicted less than 0.01% of the iodine inventory in the gas phase. He also pointed out that the realistic calculations confirmed the adequacy of the instruments to detect gaseous iodine. He noted that the differences between the codes in the realistic calculations was due to a few key reactions, the treatment of mass transfer and assumptions about surface deposition.

Dr. Bernhard Kuczera (KfK — Germany) presented the paper "Source Term Aspects Associated With Future PWR Containment Systems" coauthored by G. Keßler, J. Ehrhardt and W. Scholtyssek. Dr. Kuczera began by explaining new German criteria for future reactor designs. For example, the dose levels for which off-site intervention applies have been reduced. He then described a new "Double Containment" concept in which the annulus is vented through an emergency standby filter. The design parameters are defined such that the levels for off-site intervention would not be exceeded following a severe accident. Dr. Kuczera described calculations using the MAEROS aerosol model and the CONTAIN containment code system, to evaluate source terms for a severe (meltdown) accident scenario. He tested parameter variations such as leak rate and filter efficiency. He concluded that a containment leakage of 1.5%/d would be acceptable assuming an aerosol filter efficiency of 99.9% and an iodine filter efficiency of 99%. Under more realistic conditions, assuming a 12 hour delay in the onset of venting, lower filter efficiencies are shown to be adequate.

It is interesting to note the dose limits at which off-site intervention would be required. As in Ontario, Germany prescribes action levels for sheltering, evacuation or issuance of potassium iodide (thyroid pills). However, the action levels in Ontario are ten times more restrictive than the new lower levels in Germany. It is also not difficult, with some imagination and use of topological permutations, to "unfold" the German double containment into a concept that is similar to an Ontario CANDU containment with a vacuum building. It too can be vented through an emergency stand-by filter. The difference, of course, is that the Canadian vacuum building design provides a negative pressure "hold-up" lasting days to weeks before the onset of venting through filters.

Session 3, Severe Accident Design and Analysis, Co-chairpersons: J. Royen (France) and M. Garceau (Canada)

The first paper summarized the major points of discussion and interest covered during an OECD Specialist Meeting on Selected Containment Severe Accident Management Strategies organised in June 1994. Three main areas had been discussed: general aspects of accident management strategies, hydrogen management techniques and other containment accident management strategies, surveillance and protection of the containment function. A number of conclusions had been drawn regarding hydrogen combustion, direct containment heating, late overpressurization of the containment, containment leaktightness, coolability of core melt debris, and steam explosions.

The second paper reported on conceptual studies of an advanced containment equipped with mitigation design features (focusing on thermal-hydraulic behaviour). The results indicated that containment overpressure could be reduced by careful selection of parameters such as drywall and pressure suppression pool values and vent area. The benefit of a suppression pool was highlighted and its applicability was judged feasible.

The third paper examined possible catastrophic failure of a PWR containment as a consequence of heavy missiles generated in the containment. The potential sources of missiles were discussed. Rocket-like movement of fragments of the upper head of the pressure vessel as a result of steam explosion was considered possible; it could lead to gross containment failure. Missiles generated in hydrogen combustion were not expected to pose a similar threat to the containment.

The next paper presented the results of finite element analyses performed to evaluate the effects of contact and friction between a steel containment vessel and an outer contact structure when the containment vessel was subjected to large internal pressures. The results showed that the material properties of an outer contact structure and the amount of friction between the two structures could have a significant effect on their behaviour. For example, friction had a dramatic effect on vertical displacement of the structure.

The last paper presented in this session reported on an analysis performed with the computer code GASFLOW of the effects of an ex-vessel steam explosion accident and the transport of steam and hydrogen throughout a typical light-water reactor confinement building. The calculations showed that hydrogen diffused and mixed in the confinement atmosphere but tended to be transported in the upper region of the containment, which indicated the possibility that a detonation could occur.

Two more papers accepted by the Technical Program Committee were not presented during the Session.

Session 4, Operations, Maintenance, Leakage and Ageing of Containment Systems, Co-chairpersons: A. Boothroyd (IAEA — Vienna) and G. Comeau (Canada)

The focus of the session on Operations, Maintenance, Leakage and Ageing of Containment Systems was on the concrete containment structure, although there were other areas discussed. Two papers, one by Claude Seni of AECL and one by Don Naus of ORNL, described data bases related to ageing management of concrete structures which were currently being developed to provide meaningful information with which to monitor containment structure degradation. There is much work to establish the data and to ensure the relevance and practicability of application of the methodologies introduced. The task is significant and focus must be appropriate to the need. Two Ontario Hydro papers detailed a current problem, namely significant air leakage through the dome of Pickering A Unit 1, and the solutions and programs used to implement them. Back-to-back papers by Gary Zakaib and Jim Sato described the efforts of a team of OH Design and Operations staff to characterize and quantify the leakage (complete with air bags), and to determine, test and apply an external liner as a solution to the Pickering A Unit 1 dome leakage. A look at R & D work related to new non-organic liner materials was presented by Claude Seni. Results showed some promise regarding strength; however, leak tightness remains a problem. A description of the extensive test program used to environmentally qualify expansion joint seals used in Pickering NGS's pressure relief test was provided by Glenn Pringle. An overview of the CANDU 600 story for Containment Leakage Prevention was provided by Tarek Aziz of AECL.

The theme and issues of this session were evident from the papers presented and questions asked by the audience; namely, what is the current R & D effort related to containment structures, and how do we effectively and practically carry out ageing monitoring, mitigation or prevention for these structures? The challenges in this area of expertise are there — development of practicable, relevant and reliable data bases of containment components and structures, relevant focusing of R & D efforts to address safety questions, and development and implementation of appropriate monitoring and maintenance techniques for Containment Systems.

Session 5, Thermal Hydraulic Behaviour of Containment Systems, Co-chairpersons: H. Karwat (Germany) and M. Cormier (Canada)

Unfortunately, out of the four papers scheduled for presentation, only two were actually presented. The first paper by D.W. Sweet and G.J. Roberts described the analysis of conditions inside a large, dry PWR containment during a TMLB accident. The analysis results showed that the pressure rise inside containment was sensitive to whether or not the accident debris was in direct contact with water. The hydrogen produced from the accident was not expected to burn, due to the inerting of the steam.

The second paper by N. Mohan, S.S. Bajaj and P. Saha discussed pressure suppression pool hydrodynamic studies for horizontal vent exit in the Indian PHWR containment. The presentation gave calculation results of vent clearing times and pool swell elevation during a LOCA.

The other two papers planned for this session appear in the proceedings.

Session 6, Hydrogen Mixing and Mitigation, Co-Chairpersons: J. Rohde (Germany) and K. Tennankore (Canada)

In this session five papers were presented, three on mixing and distribution and two on mitigation.

The first paper on mixing dealt with helium tracer experiments aimed at understanding the effect of fans on the distribution of hydrogen in the Fueling Machine Vault of a reactor and concluded that (a) fans lead to repeatable trends of good mixing and (b) if fans are inoperative, direction of release is a significant factor and downward release leads to good mixing. The second paper presented early results of an attempt to predict these experiments using a 3-D finite difference model.

The third paper presented calculations on tritium distribution/leak pertaining to the analysis of a postulated accident in a Tritium Facility. The finite-volume 3-D code, GASFLOW, used in these calculations predicted that only a small percentage of tritium inventory would leak out.

The remaining two papers dealt with hydrogen mitigation in reactor containments through the use of catalytic recombiners. The first paper presented results on a wide range of performance tests of catalytic beds in a medium-scale facility in two modes of operation, in a forced stream and in a stagnant atmosphere. Test results lead to the conclusion that these catalyst beds are effective and resistant to poisoning, fouling and radiation.

The second paper dealt with performance tests of catalytic recombiners in small and large volumes in stagnant atmospheres. Again, results lead to the conclusion that these recombiners are effective and adaptable even when large amounts of aerosol are present (such as in severe accident conditions).

Thus, catalytic recombiners have the potential to be effective hydrogen mitigation devices. A good feel for the expected hydrogen distribution through relevant calculations would help determine the number and deployment locations (in the containment) to fully exploit their mitigation potential during accidents.

Session 7, Design Methods and Concepts, Co-chairpersons: R. L. Ritzman (United States) and G. Zakaib (Canada)

The first paper of the session described a German concept for a lined reinforced containment *without* prestressing. Mechanical resistance is provided by the concrete and leak tightness by a composite non-metallic liner. Loading conditions include a design pressure of 5.2 bar and an ultimate capacity of 15 bar (to cater to severe accidents). A partial prestressing option was also explained. The coating elongated up to 9 mm before disbonding from the concrete.

The second paper gave the state-of-the-art and direction of the Indian PHWR containment design. The design incorporates a double containment structure with a pressure suppression pool. Target leakage rate is 0.1%/h at design pressure. The annular space is subatmopheric and the double concept is extended to all penetrations. The internal volume is divided in two, with V1, the dry well, enclosing all high enthalpy fluid. There is a secondary containment ventilation and clean up system. Each penetration has three isolation points. In-service tests are done every two years at 1/3 design pressure. Instead of vacuum breakers, blow-out panels protect against pressure imbalance because of condensation in V1. Free volume is up to 70,000 cu. m. The extra wall adds about 60% to the cost of the structures. It is not intended to withstand full pressure.

The third paper described "EPR" which is the design for the future French-German PWR based on new (common) European codes. Severe accidents (core melt, H2 deflagration/ and extended hazards) are explicitly considered. The double wall concept enables collecting unavoidable leakage and filtration. The inner wall is pre-stressed, outer is reinforced concrete. The outer wall protects against external hazards. LOCA load is 5 bar, 7.5 for severe accidents cases. A composite liner can be added if leak tightness at ultimate pressure is needed.

The fourth paper explained development of a coupled containment and ultimate heat sink response model. It calculates containment pressure and temperature as well as heat sink performance. The code, COPATTA, is PC based and uses simplicit finite difference method. Containment response and thermal stresses in cooling water systems are typical results. It can be used for sensitivity studies and cost and schedule reduction.

The last paper dealt with numerical structural analysis techniques to addresses complex problems in prestressed concrete containment vessels under high pressures. Graphical illustrations of crack prorogation were shown. The work is being done in preparation of a test to failure of a 1/4 scale model in 1998.

In summary double wall (or higher strength) containments and composite non-metallic liners appeared to dominate the design concepts.

Session 8, Separate Effect Verification and Global Validation of Containment Thermal Hydraulic and Radionuclide Behaviour Codes, Co-chairpersons: SD.R. Kinnersly (United Kingdom) and V.S. Krishnan (Canada)

Seven papers were scheduled to be presented in this session entitled "Separate Effects Verification and Global Validation of Containment Thermalhydraulic and Radionuclide Behaviour Codes." All the papers were presented. The session was well-attended and the audience participated in the discussion which followed each presentation. The following provides a summary.

Paper 1 described results of E11.1, E11.3 and E11.5 tests conducted in the HDR facility to study hydrogen mixing. For the bottom-break E11.3, the containment atmosphere was well mixed above the break and stratified below it. In E11.5, sump water temperature stratification was observed. Simulations of E11.1 and E11.2 performed with GOTHIC, RALOC and WAVCO were then described. In general hydrogn distribution in the dome region was not well predicted.

Paper 2 presented a simple model for describing buoyancy-driven flows developed for the FUMO containment analysis code. The methodology, suited for lumped-parameter codes, uses analogy with electrical networks to determine convection flows in the containment compartments. The model was then applied to the HDR E11.2, FIPLOC-F2 and NUPEC M-7-1 tests. These tests were respectively selected for looking at atmospheres dominated by natural circulation, well-mixed and stratified flow conditions.

Paper 3 described separate effects modelling verfication of the GOTHIC containment analysis computer code. The two separate effects considered were condensation heat transfer on a vertical flat plate, and evaporative heat transfer from a hot pool to a dry superheated atmosphere.

Paper 4 presented modelling results using WGOTHIC for the NUPEC M-4-3 hydrogen mixing and distribution test. It was shown that a subdivided model of the compartments did a much better job of calculating the temperature and helium concentration within the dead-ended volumes than the original lumpled parameter model. Thus is it important to resolve flow field details within a volume for scenarios with natural circulation flows.

Paper 5 compared WGOTHIC predictions with the HDR E11.2 test results. Again subdivision detail was shown to be important. Fine mesh size is essential for characterizing flow distribution within non-homogeneous environments.

Paper 6 presented containment thermalhydraulics analysis of the Phebus FPT0 with the JERICHO and TRIO-VF codes. The results were shown to be sensitive to condensation flow rate correlations. The Chilton-Colburn-Collier correlation was assessed to be better than the Uchida correlation for the test simulated.

Paper 7 described the verification of the computer code CAPS used for the study of pool swell dynamics of Indian PHWR. The results were shown to demonstrate the conservatism of the code.

Overall, it appears that some more work is needed before bringing the task of modelling hydrogen distribution in containment atmospheres to a closure.

Session 9, Structural Analysis and Response Tests, Co-chairpersons: R. Judge (United Kingdom) and C. Seni (Canada)

The session had programmed 6 papers and was scheduled to start on Thursday Oct.20 at 1.30 pm. Co-chairmen were R. Judge (U.K.) and C. Seni (Canada). The session start was postponed to 2:30 pm since the authors/presenters of the first 2 papers were detained.

The 1st paper, "Instrumentation and Assessment of Structural Behaviour of NAPP-1 Containment During Pressure Test", by B.K. Goyal et al. (India), was subsequently moved to the Poster Session to be presented after 5.00 pm by Mr. Dipak Bhattacharyya.

The 2nd paper, "Nonlinear Transient Dynamic Analysis of Indian PHWR Reinforced Concrete Containments Under Aircraft Impact Loading", by C.M. Madasamy et al. (India), was cancelled.

The session was attended by 25-30 people. It started with an introduction by C.Seni who stressed the importance of tests, like those to be presented in this session, when the design has attained such a level of complexity due to the use of computers and sophisticated software, that a verification by physical models has become a necessity in order to understand and validate the design results.

The 3rd paper "Plan on Test to Failure of a Steel, a Prestressed Concrete and a Reinforced Concrete Containment Vessel Model" was presented by Y. Kobayashi (Japan).

The choice of the model concrete thickness and its correlation with the real containment was questioned by one attendant. R. Judge inquired if the experience of previous tests was taken into account, e.g.the Sizwell test. (The answer was affirmative.)

The 4th paper "Plan for the Seismic Proving Test of Concrete Containment Vessels", was presented by S. Nakamura (Japan). A question was raised re the mode of failure which could demonstrate either the S1 earthquake+design pressure or S2 earthquake alone but not both. (The answer was that the design calculations will help to obtain information for both)

The 5th paper "A Study of the Nonlinear Behaviour of Reinforced Concrete Members Subjected to External Loads and High Temperature" was presented by A. Mutoh (Japan). The paper was read by the presenter, a fact which diminished the impact of this interesting topic. It also appeared that some of the test parameters (e.g. temperature) were not selected with practical applications in mind, since the presenter could not explain the rationale for their selection.

The 6th paper "Seismic Isolation of Containment" was presented by J. Biswas (Canada). It was a state of the art presentation which stirred much interest in the audience, especially from those from Japan. The presentation could have included even more aspects re construction and schedule aspects. It is unfortunate that the paper was not included in the proceedings.

In closing the session, R. Judge highlighted the point that verifications through tests is a major contribution to the credibility of our design and this session has achieved to demonstrate this.

Session 10, Containment Passive Systems — Design and Operation, Co-chairpersons: J. Woodcock (United States) and N. Spinks (Canada)

Papers were presented on passive PWRs and CANDU.

The first presentation, by the international co-chairman, J. Woodcock, differed from the written submission and consisted of an overview of the AP600 design and program status. It generated considerable discussion. Then followed in turn two papers relevant to the external air cooling of the AP600, one paper that had to do with both external and internal heat transport, and finally two papers that focussed on the internal heat transport problem.

The second paper described a first-principles approach to the external scaling problem. The derived scaling parameters look to be consistent with practise but this needs to be confirmed.

The third paper showed that, on average, wind-induced pressure differences assist convective flows. Transient wind effects can be negative but may not be important when considered together with the overall containment cooling system time constants.

The fourth paper reported the results of code comparisons to large-scale integrated tests of the AP600 passive containment cooling system. With close attention being paid to fine details of the modelling, accurate comparisons are being obtained. The code is now frozen for application to AP600.

The fifth paper from MIT Nuclear Engineering, contained a wealth of information on a variety of options to improve passive containment cooling and on the use of GOTHIC for the analysis. It is well worth reading.

Finally an AECL study, using both the Phoenics and Gothic multidimensional codes, concludes that Gothic is more suited to containment modelling work. However some discrepancies between Phoenics and Gothic results need to be resolved.

Two general conclusions can be reached: (1) the tests and test analyses relevant to AP600 passive containment cooling are understood to a high level of accuracy and (2) Gothic is proving to be a very flexible tool for the analysis of multi-dimensional fluid flow within reactor containments.

Session 11, Aerosol Behaviour in Containment, Co-chairpersons: N. Yamano (Japan) and S. R. Mulpuru (Canada)

This was truly an international session. There were papers from Canada, Japan, France, Italy and Switzerland. A total of six papers were presented. Three dealt with experimental work and the other three dealt with computer modelling.

A variety of topics, all related to behaviour of aerosols/fission products in containment were addressed by the papers. The topics included (1) measurements of water droplet sizes and velocities within flashing jets discharging into containment during a loss of coolant accident, (2) re-entrainment of fission products from a flashing pool in containment, (3) hygroscopic growth of aerosols in humid atmospheres, (4) thermalhydraulic modelling of LACE experiments using a combined thermalhydraulic-aerosol calculations, (5) pool-scrubbing of fission products and (6) analysis of removal of fission products by thermophoresis.

The session was well attended and the audience showed interest in the topics through several questions at the end of each presentation.

Advancement of knowledge in the area of aerosol/fission product behaviour in containment is essential for accurate analysis and prediction of releases of activity in outside atmosphere. This session contributed to this end.

Session 12, Containment Reliability, Integrity, and Risk Assessement, Co-chairpersons: G. M. Frescura (OECD/NEA) and J. C. Luxat (Canada)

The session covered a wide range of topics of relevance to containment integrity; including structural degradation associated with ageing, test programs to establish the capabilities of containment system components, the use of field measurements to evaluate structural integrity, and risk assessment of core damage accidents in Boiling Water Reactors (BWR's).

A paper presented by R. Judge, of AEA Technology (U.K.), described the systematic classification scheme for structural components and their ageing degradation mechanisms that is being developed to assist in quantifying the likelihood and significance of potential degradation mechanisms. The conceptual framework he presented was proposed as forming a logical basis for prioritizing inspection and maintenance schedules.

A group of papers dealt with testing of containment system components that are critical to containment integrity under accident conditions. D. Lambert, of Sandia National Laboratories (U.S.A.), presented early results from an experimental program to establish the behaviour of containment piping penetration bellows subjected to severe accident conditions. These results showed that uncorroded bellows can withstand very large deformations at elevated temperature and pressure without leakage. Subsequent tests will address corroded bellows. Programs to test and analyze the integrity of containment airlocks — both personnel and equipment — were presented by P. Vanini, of ENEL (Italy) and E. Penno, of CISE (Italy). The first paper described the ATHERMIP test program, to be initiated in the fall of 1995, which will be a full-scale test on a personnel airlock. The second paper described a new equipment hatch seal device, referred to as the DEFENDER device, which from detailed analysis appears to offer a larger margin to seal failure under severe accident conditions.

D. Lee, of KEPCO (Korea), presented an approach to structural integrity evaluation of the Wolsung-1 CANDU-6 containment employing data from embedded strain gauges. The viability of the proposed approach was demonstrated from strain gauge data which was obtained during pre-operational proof pressure testing at Wolsung.

An analysis study of containment response to core damage accidents in a BWR reactor with a Mark-II containment was presented by N. Watanabe, of JAERI (Japan). He showed that the core damage sequences could be categorized into a small number of groups, each consisting of sequences with similar containment response characteristics. This categorization could be of use in evaluating accident management strategies and defining accident mitigation actions.

Session 13, Hydrogen Deflagration and Detonation, Co-chairpersons: J. Rohde (Germany) and K. Tennankore (Canada)

In this session, five papers were presented, three on experiments and two on modelling. The papers on experiments dealt with the effects of stratification, obstacles and geometry on combustion behaviour. The effect of stratification on combustion pressure in a 1.5 m-diameter, 6-on-high cylindrical vessel, depended significantly on the igniter location (top or bottom) and average concentration (flammable or below downward propagation limit). Top ignition increased combustion pressures at low concentrations while bottom ignition decreases pressures at high concentrations. Also, stratification significantly reduced combustion time.

As for the effects of pipes as obstacles in the above vessel, flames in hydrogen/air/steam accelerated, as expected. Acceleration increased (in some cases to sonic velocities) with an increase in blockage or a decrease in obstacle spacing in the direction of propagation. A steam concentration of 20% by volume was required to reduce flame acceleration significantly.

Large scale (500 m^3 volume) experiments in a three-room connected geometry in the HDR reactor confirmed the previously observed flame acceleration in the smaller-scale test in the Battelle Model Containment that resulted from jet ignition. In addition, these tests provided further large-scale data on the effect of igniter location relative to the vent and the effect of venting.

The fourth paper presented a model for maximum flame speed that can result in a mixture from obstacle-induced flame acceleration. The model is able to qualitatively predict both the stable and the unstable regimes of accelerated flames by including the quenching effect of turbulence, in addition to its acceleration effect resulting from flame folding/wrinkling and enhanced mass/heat transport.

The fifth paper, on the basis of two postulated detonation scenarios in the ANS reactor containment, calculated transient pressures using a 2-D shock-wave code and determined that loadings do not compromise containment integrity.

All of the papers contributed to added understanding of combustion behaviour. In time, such continued increase in understanding would enable more realistic modelling of combustion behaviour in reactor containment to confirm integrity/safety during accidents.

Poster Session, Chairperson: V. Langman (Canada)

The poster session opened to a substantial enthusiastic crowd. Many animated discussions were noted and discussions of the posters continued through the duration of the conference. The reader is referred to the Proceedings for the 16 full papers and 8 abstracts which provide the basis for the poster sessions.

3rd International Containment Conference

Containment Historical Overview

A. Birkhofer[1]

1 Early Concepts

The large amount of radiotoxic substances enclosed in a nuclear reactor requires very comprehensive safety precautions. The essential basic concept is the twin strategy:

- to do everything in order to prevent mishaps capable of jeopardizing the integrity of the enclosure of the radioactive material,
- to provide, independent of those efforts, means in order to effectively mitigate the consequences of such mishaps if they should occur nevertheless.

Since the early days of nuclear energy, containments have played a key role in that strategy as a last fission product barrier providing an ultimate means for effective mitigation of accident consequences. The essential developments of the concept took place in the USA.

"The Technology of Nuclear Reactor Safety," written by Thompson and Beckerley and David Okrent's book on "Nuclear Reactor Safety" provide a good idea about these early developments of the containment philosophy:

> "The emphasis in the first nuclear reactor was primarily to prevent an accident, not to ameliorate the consequences. The next reactors built were located in unpopulated areas, in recognition of the dangers of radioactive contamination if a serious accident occurred. In 1950 the first AEC Reactor Safeguards Committee produced a very restrictive rule of thumb site criterion. The occurrence of a gross release of radioactivity from an uncontained reactor was assumed, and the site criterion required a large exclusion radius to meet its requirements. However, pressures built up very rapidly for the use of sites with smaller exclusion radii. Within a year or two a new concept was developed to allow for relaxation of the criteria. This was to place a strong containment building around the reactor to hold in the radioactive fission products released in an accident. A relatively modest-power prototype, the Submarine Intermediate Reactor, was proposed and approved for construction within a large steel sphere at a site near West Milton, New York. From that time on, containment for protection of the general public has played an important role in reactor safety. Consequently, a containment building was also provided around the first 'civilian' nuclear power plant, the Shippingport Atomic Power Station (PWR), which was approved in 1954."

An essential objective was to assure appropriate independence of the containment barrier from potential failures occurring in the reactor system. The most important phenomena considered were:

- nuclear excursion,
- chemical reactions, in particular metal-water reaction in the core,
- decay heat,
- and the stored energy in the reactor coolant fluid.

For the fairly small light water reactors considered in the early 50s, the energetic consideration of these phenomena indicated that the stored energy of the reactor coolant fluid constituted a much larger source of energy than the other phenomena. Thus, it was assumed that a rapid release of reactor coolant constituted the principal load for the containment system. The concept of a maximum credible accident was developed on that basis and the first containments were designed to withstand the instantaneous release of the total coolant inventory with additional energy release from decay heat, metal-water-reaction and some stored heat up to a few seconds.

The need to protect the containment from missiles was seen but it was also recognized that it would be very difficult to design a containment withstanding all possible loads from reactivity accidents. The SL-1 accident gave strong indications in that regard. Therefore, technical provisions were introduced in order to prevent reactivity excursions by appropriate physical reactor design. For light water reactors the possibility of substantial energy release by nuclear excursions were ruled out by core design providing negative reactivity feedback and stable behaviour together with an appropriate design of control rods, rod drive mechanisms, and specific protection against rod ejection (BWR).

Due to a considerable conservatism, these design principles resulted in solid containment structures. At first, dry containments were used for both boiling and pressurized water reactors. But soon it was seen that the relatively large water inventory of boiling water reactors of higher power level would require very large and expensive dry containments. These considerations led to pressure suppression concepts, the first of them realized within the mark-1 design.

For liquid metal cooled fast reactors, the positive void reactivity coefficient could not be overcome and the possibility of a fast nuclear excursion therefore not completely be ruled out. Therefore the energy release during a potential reactivity accident was taken into account in the design of the vessel and already the very early plants of this type were equipped with a particularly strong containment function. This concept remained the essential basis for the design of liquid metal cooled fast reactor containments.

For gas cooled reactors, the energy stored in the coolant fluid was rather small, nuclear excursions not credible and therefore a

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solid containment structure generally not believed necessary. Thus, with a few exceptions, gas cooled reactors were generally not equipped with a containment. Some designs use a "confinement structure" as an ultimate fission product barrier.

On the whole, the maximum credible accident approach to the early containments provided ample protection against a broad spectrum of accidents up to very serious events. Due to the relatively small power levels of the first nuclear power plants the design of their containments could be based on rather global considerations focusing on the complete release of the energy stored in the coolant fluid. An essential step towards achieving decoupling between the reactor system and the containment function was done by design provisions effectively preventing super prompt critical reactivity accidents.

2 Evolution of LWR-Containment Concepts

2.1 Specialization of Containment Concepts

During the second half of the sixties and the early seventies the containment design was specialized according to the search by different designers for more effective and economic solutions. For BWR's these developments led to several specific designs of pressure suppression systems. Among the new PWR concepts were:

- ice condenser containments, equipped with baskets containing borated ice as an additional pressure limiting system, in order to reduce the volume resp. the design pressure compared to dry containments,
- subatmospheric pressure containments aimed at reducing the maximum design basis accident pressure (similar developments were applied to CANDU reactors).

Nevertheless, for PWR's large dry containments, providing sufficient space to let the whole coolant inventory of the primary system and a part of the coolant of the secondary system expand without exceeding the design pressure, remained the most widespread design. Such containments are used in many countries including the France, Germany, Japan, Sweden and the U.S.A.

The comparatively high population density and a relatively large traffic of military aircraft in Germany and some other European countries resulted in particular efforts to protect the containment against external impacts such as gas cloud explosion, airplane crash and floods. The location of the fuel storage pool within the containment, also applied in Canadian designs, made part of that approach.

2.2 Research Regarding the Design Basis

Another essential aspect of that period was the research on phenomena relevant for containment design after a large loss of coolant accident:

- At first, computer codes were developed to calculate the time dependence of the pressure in a homogeneously mixed containment atmosphere after a double ended break of a large coolant pipe which was considered the "maximum credible accident". These codes did take into account the blowdown of the coolant, the release of stored energy of the primary circuit, secondary heat, cooling systems, condensation at cold structures of the containment internals and other time dependent energy sources and sinks. An important objective of these efforts was to provide better assessments of containment loads (stresses, temperatures) during accidents.
- Somewhat later, improved computer techniques allowed for a better understanding of differential pressures between the various compartments of a containment. It was a particular concern about containment internals to protect safety equipment against breaking walls, doors, concrete lids and other internally generated missiles. In some countries, these analyses resulted in considerable changes of containment internals such as the introduction of additional specially shaped opening in compartment walls.
- Other important containment research issues were fission product transport, hydrogen generation and mixing, and the resistance of equipment and structures to internal and external hazards.

Numerous containment experiments were conducted in order to investigate these phenomena and to assess the theoretical models.

An important issue was the strengthening of the protection of the containment under accident conditions. Highly energetic missiles generated by gross failure of the primary circuit or the vessel constitute an essential threat in that regard. It received increased attention when the question of urban siting of larger nuclear plants was on the agenda in the late 60s and early 70s. For the German BASF project for instance the possibility of underground siting and of specific provisions to cope with vessel failures was discussed intensively. It was concluded that it would not be reasonable to focus efforts on the mitigation of such accidents because the required provisions would not be sufficiently effective or could render more difficult the quality assurance of vessel and piping by inservice inspections and non-destructive testing. These discussions considerably accelerated the development of improved materials, fabrication processes and quality assurance technologies in view of applying a leak-before-break concept in order to exclude catastrophic failures of reactor vessels and large piping.

For BWRs the effectiveness and reliability of the pressure suppression systems were of particular concern. An essential aspect was the pressure suppression via a large number of parallel pipes connecting the dry well with a condensation pool. For some pressure suppression concepts, operating experience revealed essential weak points. In Germany, an accident at the Würgassen plant damaged heavily the wet well construction indicating the need for better understanding of long term chugging effects and for more robust design solutions. This resulted in a considerable number of experiments and theoretical investigations on BWR pressure suppression phenomena (Table 1) and in important improvements for the pressure relief systems (*e.g.* multiple hole "quenchers") and containment design of BWR's.

2.3 Containment as a System

These experiences and activities clearly demonstrated that the containment can only fulfill its role of a last independent barrier if it is considered a system and not merely a simple vessel. It was seen that there is a need for a more complete consideration of the spectrum of possible accidents and their possible course

Table 1: Relevant BWR Pressure Suppression Experiments

Year	Facility	Country	Measurement, Purpose
1960's	Humboldt Bay Bodega Bay	USA	Drywell, Wetwell pressure transients
1972/73	Marviken Full scale containment tests	Sweden	Drywell, Wetwell pressure transients
1972, 75	GKN 1, KKB	Germany	Vent Pipe Loads, Full Scale
1975, 77	Karlstein Large Tank and concrete cells	Germany	Multivent pipe tests
1978	Lawrence Livermore Lab. 1/5 scale Mark I torus, 90° sector	USA	Vent clearing, pool swell
1976/77	GKN 2S	Germany	Vent pipe and pool wall loads, condensation, transient and static tests, condensation oscillations, chugging
1976	GE Mark I, II, II Fullscale Segments	USA	Pool swell
1978/80	Studsvik	Sweden	Pool swell in different geometries
1981/82	JAERI Fullscale Segments	Japan	Vent clearing, pool swell, condensation oscillations, chugging
1984	GKSS	Germany	Vent clearing, pool swell and fall back condensation oscillations, chugging
1983/86	Sandia Nat. Labs., N.M.	USA	Large scale, Mk I, II, III overpressure tests, failure mode/timing, and design margins

than that of the early maximum credible accident concept. In that regard, it had also to be taken into account that some accident initiators turned out to be more likely than initially believed.

Bypass sequences are of particular importance for the effectiveness of the containment function because they bear a considerable potential for large radiological consequences. It is required to prevent the respective initiators or, at least, to isolate bypass lines very reliably. Two aspects were of particular importance in that regard:

- The reliable isolation of lines bypassing the containment had to be considered not only for the main piping such as main steam and feedwater lines (in BWR's) but also for a larger number of intermediate and even smaller pipes.
- The operating experience indicated that the probability of steam generator tube leaks was higher than originally anticipated. As a consequence prevention of tube rupture was considerably strengthened by a number of measures ranging from better nondestructive testing up to the replacement of complete steam generators. Independent of those efforts, a number of countries also improved the procedures to cope with such events. In Germany for instance, the handling of tube rupture events was completely automated in the short term in order to reliably avoid radioactive releases via the secondary side.

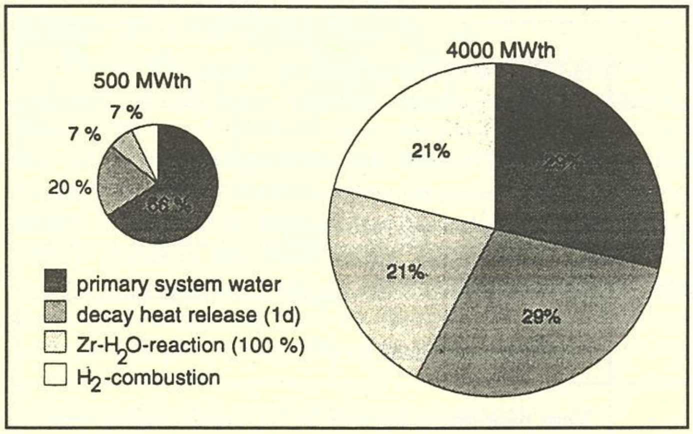
With increasing redundancy and reliability of safety equipment, hazards such as fires, floods and external impacts received more attention within the safety considerations. More recently it was recognized that shut down plant states may be a particular challenge to the containment function. The reason is that safety precautions may be not as well specified as for power operation and that the containment may be open during significant periods of revision.

2.4 Beyond Design Considerations

The completion of the accident spectrum considerably strengthened the prevention of severe accidents and the independence of the containment function. Nevertheless, there remains the possibility of beyond design events jeopardizing the integrity of the containment.

With the increasing power level of nuclear reactors the relative importance of loads from phenomena such as decay heat and metal-water reaction increases (Fig. 1) and challenges the integrity of the containment. It is increasingly difficult to cool a molten core, to keep it in the reactor vessel and to stop its progression through the basemat. Beginning in 1957, when the Brookhaven National Laboratory published its report WASH-740, the related aspects received more and more attention. WASH-740 indicated that a breach in the containment in the event of a severe core melt accident could have very far

Figure 1: Sources of Energy Relevant for PWR Containment Loads



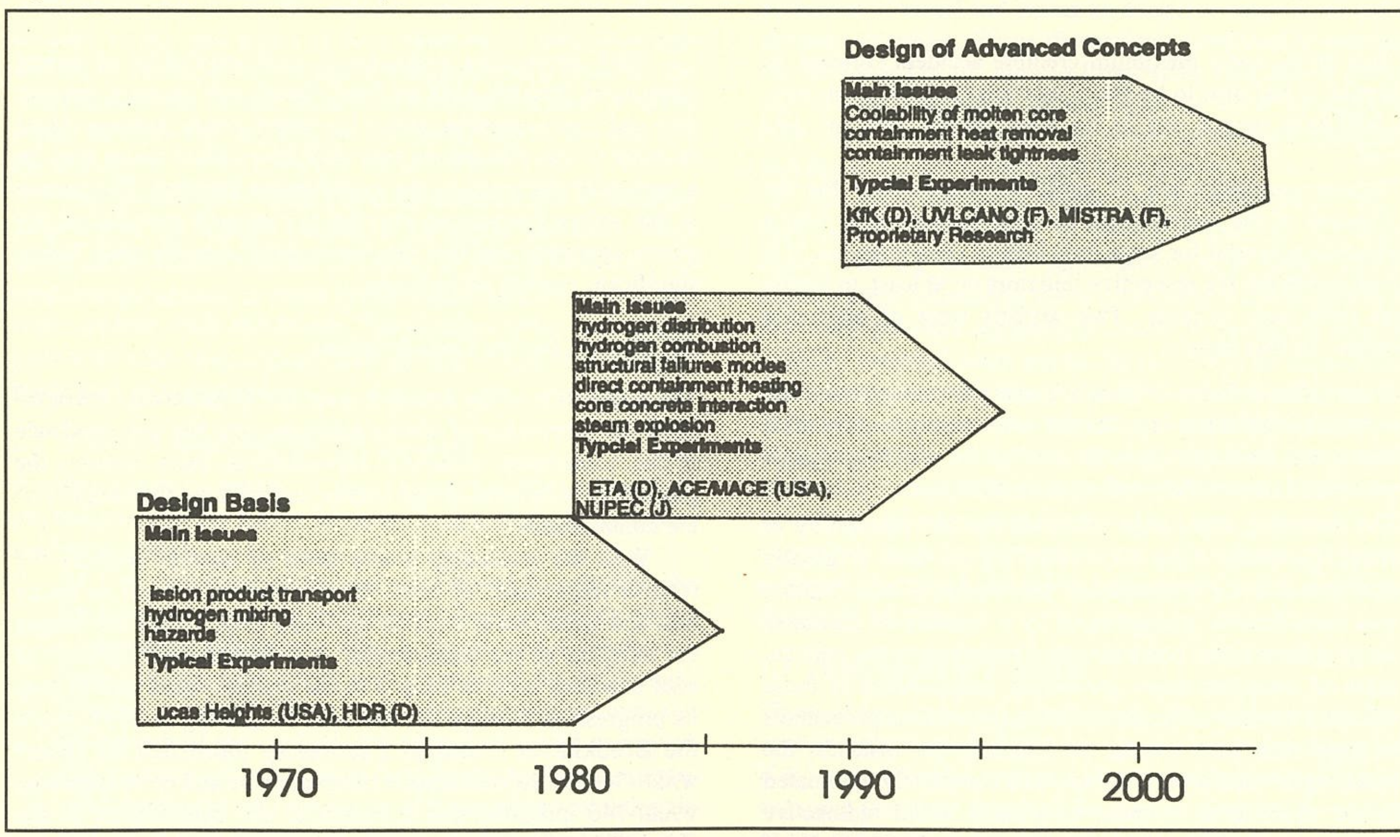
reaching consequences. In the mid 60s, when the Brookhaven National Laboratory published its report when a reevaluation of WASH-740 took place, the question of the independence of the containment with regard to the loads from a core melt accident received increased attention. It was seen that effects such as basemat penetration (China syndrome), hydrogen combustion, and steam explosion could not be ruled out. These findings emphasized the need for reliable and effective emergency core cooling and essentially stimulated the research on its efficiency. Furthermore, already more than one decade before the TMI accident, the need for intensified research on severe accident phenomena was recognized.

However, it was not felt reasonable to take into account all kinds of possible effects independent of their probability. Thus, the question of a more systematic evaluation of the risk was on the agenda.and first risk analyses were performed in the USA and in Western Europe in order to provide a more balanced picture in view of the questions "where do we stand?" and "how safe is safe enough?". Quantitative answers turned out to be difficult to understand but the investigations provided good insights into the strengths and weaknesses of plant design and operation. They indicated that small breaks and "transients without loss of coolant" would be more important contributors to the risk of pressurized water reactors than the large break loss of coolant accidents which received so much attention before.

The accident at TMI-2, Harrisburg, in 1979, confirmed these findings and the need to consider a broad spectrum of credible accidents as design basis. It proved the value of the containment concept but, on the other hand, indicated that the knowledge about severe accident and core melt phenomenology was unsatisfactory. As a consequence, research activities were initiated in various countries which included the investigations on fundamental severe accident phenomena in the containment such as hydrogen distribution, hydrogen combustion, containment structure failure modes due to overpressurization, direct containment heating, core concrete interaction, steam explosion, and fission product release and transport (Fig. 2).

These investigations demonstrated that even in the event of an accident with loss of safety systems much can still be done in order to prevent core damage or at least to effectively confine its consequences to the plant. As a consequence, many countries have implemented accident management strategies including

Figure 2: Evolution of PWR Experimental Containment Research



including mitigative measures to protect the containment from potential loads due to severe core damage. Examples are:

- primary bleed and feed to avoid heavy loads from core melt under high pressure,
- inertisation of most BWR containments and deliberate ignition in some reactor types to reduce the potential for highly energetic hydrogen combustion.

Another aspect is filtered containment venting to prevent containment failure due to long term pressure build-up in the event of a severe accident. Taking into account the serious effects of larger unfiltered leakages, filtered venting is considered by many countries to be still in accordance with the original containment philosophy of an ultimate fission product barrier. Meanwhile, it has been implemented in a considerable number of LWR plants.

Nevertheless it must be recognized that, due to the difficulties in performing realistic experiments, our knowledge of severe accident phenomena is still limited. That is reflected by the large uncertainties of analytical investigations on the probabilities and consequences of severe accidents which still essentially rely on expert opinion. As a consequence, accident management cannot be based on conventional design procedures such as conservative assumption, safety margins and the consistent calculation of design basis events. Instead, the consideration of scenarios and of overall plant conditions plays an essential role in the approach.

On the whole it is seen that strengthening the independence of the containment as a last barrier from the history of accidents was ever an important objective of the development of reactor technology. Further progress in this regard is an essential aspect of the development of new design concepts. Future research will focus more specifically on such developments. Basic objectives are the coolability of molten core, decay heat removal within the containment, and the leak tightness of the containment under severe accident conditions.

3 Future Reactors

Basically there are two different ways to improve the safety technology of nuclear reactors:

- One way is to strengthen the prevention of accidents, *i.e.* to try to further reduce the probability of events jeopardizing the integrity of the fission product barriers. Actually there is a wide international consent that core damage frequencies below 10^{-5}/ry should be strived for.
- The second way is to strengthen the function of the containment as a highly independent last barrier capable to effectively contain the fission products released after an eventual severe core damage. Current objectives aim at a containment function assuring that the probability of an accident with severe consequences is about one order of magnitude below the probability of core damage.

If nuclear energy shall have a real perspective in the next century there must be very strong evidence, perceivable by the public, that another large scale accident with severe off-site consequences is practically excluded at the long term and at a global scale. In view of the significant uncertainties of risk assessments a mere reliance on probabilistic objectives is not satisfactory. Taking into account that nearly 500 nuclear plants are expected to operate at the end of this decade a qualitative step in nuclear safety seems required.

The IAEA conference "The Safety of Nuclear Power: Strategy for the Future" has summarized this reasoning and derived essential requirements for new reactor concepts:

- "One of the necessary prerequisites for the revival of the nuclear power programme is the regaining of public acceptance, and future reactor designs must be perceived as safe by the public. Of special importance to public acceptability are the techniques used to limit off-site consequences..."
- "Next generation nuclear power plant designs will have incorporated design improvements for accident prevention."
- "The next generation of nuclear power plant designs will improve accident mitigation systems. They will consider severe accident scenarios explicitly and systematically in design. The containment system will then play a key role for the next generation of reactors."

There are different national approaches to meet these objectives. Almost all include elements such as improving the man-machine interface, increasing the thermal inertia, decreasing complexity, extending the use of passive elements, and considering preventive accident management in the plant design.

Another approach consists in reducing the power level in order to increase the safety margins and to enable the reliance on passive mechanisms for emergency core cooling and decay heat removal. Examples are the AP-600 in the USA, the CANDU-3, several mid-size BWR concepts, and the Russian WWER-407. The lower power level of these reactors also reduces the loads from potential core melt accidents and thus strengthens the independence of the containment function.

A different approach has been chosen within the French-German development of a new large pressurized water reactor (EPR). This project follows a twin strategy:

- evolution of current French and German nuclear steam supply systems in view of a larger independence of the different levels of defense-in-depth and an "optimized" balance of different safety measures,
- innovations in containment design in order to practically exclude large off-site damage even in the event of a severe core damage accident.

It is intended to create a technical basis which assures that there is no longer a need for an evacuation and no longer a possibility of a long term and large scale land contamination. Hereto, characteristic severe accident scenarios and phenomena have to be considered in the EPR design which have been recognized relevant by safety research and general considerations. They are to be "designed out" or "controlled" by sufficiently reliable design provisions (Table 2).

4 Conclusions

Summarizing the roughly four decades of containment development it is seen that the strategies to provide an "ultimate bulwark" to contain accident consequences did ever, implicitly or explicitly, include both the exclusion of extreme phenomena and a containment design withstanding the remaining loads. This twin strategy has developed from relatively simple concepts

Table 2: Scenarios and Phenomena to be considered in EPR Containment Design

core meltdown under high system pressure	designed out
low-pressure core meltdown	controlled
hydrogen burn processes	designed out/ controlled
containment bypass sequences	designed out
steam explosion (in vessel/ex vessel)	designed out/ controlled
residual heat of a molten core	controlled
core/concrete interaction	designed out
direct containment heating	designed out

to a more complex system-oriented approach considering a broad spectrum of possible threats to the containment function.

With the growing power level of power reactors the early "maximum credible accident concept" had to be enlarged and increased attention to be given to severe accident phenomena. It was recognized that the independence of the containment function from corresponding loads is limited. Nevertheless, the knowledge of such phenomena acquired by research permitted to strengthen that independence by the development of accident management.

Today, the perspective of a world wide long term use of nuclear energy puts increased requirements on the further development of nuclear safety. Defense in depth including a clear priority for accident prevention and a good balance of all safety precautions will remain the essential basis. Improved containment design should play a key role in assuring the balance between prevention and mitigation in order to exclude practically events with significant off-site radiological consequences in the long term and at a world wide level.

The Phebus FP Programme
Contribution to Reactor Containment Safety Research

by A. Tattegrain[1], B. Clement[1], C.Gonnier[1],
P. Fasoli-Stella[2], P. Von der Hardt[3], C. Lecomte[4]

1 Introduction

During a severe reactor accident the probable quantity of radioactive releases ("source term") into the environment depends on the fission product behaviour in, and on their possible leakage from, the reactor containment.

The main purpose of the Phebus FP programme is therefore to obtain a global validation of the tools used to calculate the quantity and nature of fission products (FP) present in the containment, following a severe accident with core meltdown.

This validation should firstly permit action on the quantity, and possibly the nature of the released FPs, through suitable procedures (for example, spraying, injecting soda into the containment sump), then to optimise the devices intended to avoid or minimise the consequential effects of possible containment break at the time of pressure buildup (spraying, filtering), as well as to define the source to be used for containment leakage studies (cable penetrations, etc.), and finally to provide the authorities in charge of managing the accident with the best assessment of possible releases in case of containment break or leakage.

These management decisions depend a.o. on the amount and nature of fission products reaching, and available to leave, the containment, *i.e.* on phenomena like:

- the formation of volatile species, mainly iodine,
- Cs aerosol release,
- release of low volatile species such as Ba, Sr, etc.

This programme includes the tests conducted in the facilities of the experimental reactor Phebus, as well as a number of analytical tests, closely associated to the above-defined objectives. Examples of these tests are given in the following sections.

Finally, it should be mentioned that the study of core degradation mechanism, which is the second objective of the Phebus tests, should develop a better knowledge of the composition of the corium which may pierce through the reactor vessel, and then the concrete floor (base mat) of the reactor.

1 IPSN/CAD
2 CCE/ISPRA
3 CCE/CAD
4 IPSN/FAR

2 Programme objective and test matrix[1], [2]

2.1 Objectives

The Phebus FP tests cover the various phases of a serious accident, namely core degradation, core fission product transport to the containment and their behaviour in it. In addition to the sequencing of events, this programme aims at higher fuel temperatures and a more sophisticated instrumentation than any of the previous in-pile tests, it will therefore permit better description of the ruling phenomena which govern the accident development in each phase of the accident.

Fuel degradation

The Phebus tests, as confirmed by the recent FPT0 test, can lead to melting or significant liquefaction of the fuel, which cannot be obtained in out-of-pile experiments. Now, fission product and aerosol release only depends on the state of the fuel (unaltered rods, debris, molten pool); in these differentiated geometries and experimental conditions, the Phebus tests will permit the released products to be quantified, as well as those retained in the various parts of the corium.

Understanding the degradation mechanisms is also important to determine at which time and under what form the corium will fall to the bottom of the vessel. Information elements have already been provided by the PBF[1], ACRR, NRU and CORA tests. However, the principles of formation of the melted ceramic bath observed in the TMI experiment remain a major concern. Phebus will enable us to better comprehend the passage from cluster geometry to debris bed, then to molten pool geometry, in the case of strongly irradiated fuels. The FTP0 test is already providing significant information on phenomena that had not been predicted at precalculation level. This will be discussed at length later.

Aerosol and vapour transport and deposits

Aerosol physics are relatively well known and formed the subject of a number of out-of-pile experiments such as LACE, DEMONA, MARVIKEN, etc..

However, due to the importance of retention in the tubing or the steam generator components in case of containment by-pass, special attention was paid to the retention of aerosols in the system, during Phebus tests.

The major expected contribution of the Phebus test is an improved knowledge of the aerosol source, both as regards granulometry and nature (soluble, insoluble).

Fission product chemistry

The study of FP chemistry has often been regarded as a secondary objective in the tests so far (PBF, DEMONA, LACE, MACE, MARVIKEN, etc.). Now, it is an essential objective in the Phebus project to improve the knowledge of physico-chemical forms of FPs, by paying special attention e.g. to the formation of molecular iodine.

The presence in the tank (simulating the containment) of a realistic FP source, as well as a sump filled with a water-FP mixture (with high activity level), of both dry and wet painted surfaces, permits optimum conditions to be obtained in order to enable the study of various species of gaseous iodine.

2.2 Test matrix

The planned experimental programme involves six tests, five of which will be implemented with irradiated fuel. The first FPT0 test was conducted with fresh fuel; this test is used to check the quality of the installation and measurements, the validity of the test preparation calculations as well as the proper control of test and the post-test operations.

Test conduct was based upon reactor accident calculations, in which the (relative) accident probability was the highest, by deducing, in these calculations, the important physical phenomena which govern the accident progress, in order to duplicate them in the best possible conditions in Phebus.

The first two tests with irradiated fuel (FPT1 and 2) are aimed at phenomena associated to an accident such as a large break on a primary circuit tube, resulting in a high pressure drop.

The third test is intended to study the phenomena associated to an accident scenario in which the test fuel degradation conditions are such that they permit the study of low volatile fission product emissions (such as strontium and barium).

The last two tests are currently being discussed and investigations into the effects of boric acid, pressure and air ingress are being discussed with the programme partners.

Tables 1 and 2 summarise the main characteristics of these different types of tests.

Table 1: Phebus FP Test Matrix

N°	Main objective	Fuel bundle	Prim. circuit	Cont. Vessel
FPT 0	Mechanical degradation and FP release from fresh fuel Oxidizing environment	Maximum volatile FP/aerosol release 20 % fuel degradation Mild cooling down	FP retention in the primary circuit Chemistry of deposits	Aerosol behaviour Iodine Radiochemistry of Iodine Iodine partition
FPT 1	As FPT-0 for preirradiated fuel	As FPT-0	As FPT-0 Coupons for therm. resusp.	As FPT-0
FPT 2	As FPT-1 Reducing environment (steam starvat.)	Maximum volatile FP/aerosol release. Fuel candling and relocat.	As FPT-0	As FPT-0 Recirculation spray
FPT 3	Rubble bed	Fuel degradation from rubble bed to molten pool Rel. and speciation of less volatile FPs and transuranics	Deposition and retention of less volatile FPs and transuranics	Deposit. and retention of less volatile FPS Chemistry
FPT 4	Open test			
FPT 5	Air cooling	Fuel degrad. under highly oxidizing conditions FP release and speciation	FP retention Chemistry of deposits	As FPT-2 Single droplet spray

Table 2: Objectives of the Open Test FPT-4

N°	Main objective	Fuel bundle	Prim. circuit	Cont. Vessel
F P T A 4	Some of previous tests	To be defined	To be defined	To be defined
F P T B 4	Advanced Reactors and BWR phenom.	Fuel degradation with typical Ad. Reactors & BWR materials	FP retention Chemistry of deposits	Containment radiochem. DF and chemical transf. in water pool
F P T D 4	High pressure conditions	FP release and speciation under high pressure condit.	FP retention Chemistry of deposits	Radiochemistry of iodine

3 Reminder of the main characteristics of the installation[2,3]

The experiment is based upon three major components (fig. 1):

- *A fuel cluster* (fig. 2) which simulates the reactor core. It includes 20 rods of UO_2, 1 m long, as well as a silver-indium-cadmium rod, simulating a control rod element. This cluster is contained within an experimental fixture equipped with important instrumentation, in order to follow up the various test parameters such as temperature, steam flow, pressure, neutron flux. This device is installed at the centre of the Phebus core (fig.3), which permits neutron supply, therefore power rise.
- *The experimental system* (fig. 4) which simulates the components of a pressurised water reactor in which fission products circulate during a severe accident. Its configuration is variable according to the tests. The instrumentation permits the identification and characterisation of the fission products in circulation, and those being deposited. It includes gamma spectrometers (to determine the nuclides present in the system), filters (to measure the quantity of aerosols present in the fluid at the time of sampling), impactors (to analyze the granulometric distribution of aerosols). The system temperature is controlled according to the experimental needs: for example, for the FPT0 test, 700 °C from the test assembly to the component which simulates the steam generator (SG), then 150 °C for the SG and the system downstream.
- *The 10 m3 tank* (fig. 5) which simulates the reactor building containment. Contrarily to the previous two systems which will be replaced at each experiment, this tank will be used for all tests (decontamination will be carried out on completion of each test). Its volume is defined according to the ratio between the cluster fuel quantity and that of the reactor; it represents 1/5,000 of the reactor containment volume. As the surface/volume ratio is clearly different from that of a reactor, the walls of the tank are rendered as neutral as possible for the studied phenomena (electro-polished surfaces, in slight overheating with respect to the gas temperature). The interaction between the containment atmosphere and the building walls is simulated by means of a structure so-called the "condenser", located at tank centre. By condensing the steam which penetrates into the tank, this device permits its humidity rate to be checked. Moreover, note that the tank is equipped, at its lower section, with a sump to simulate the exchanges between the water present in the reactor building and its atmosphere. A temperature control system is used to check the temperatures of the tank walls, the sump and the condenser separately.

The REPF 502 includes a number of sensors so as to analyze the physico-chemical behaviour of fission products: gamma spectrometers for analyzing the atmosphere in the tank, the condenser and the sump, filters and impactors in order to determine the weight (and activity level) as well as the granulometry of the aerosols present in the atmosphere, sampling capsules (for gases and fluids), selective filters, in order to differentiate between the chemical forms of iodine present in the atmosphere (molecular iodine I2 and "organic" iodine such as CH3). Other sensors (pressure, temperature, relative humidity, hydrogen and oxygen content, sump water pH, ..., measurements) are mounted in the tank.

4. Test Sequence and First Results

4.1 General comments

The FPT0 test was intended to evidence severe degradation of the fuel, up to 20 % melted fuel in oxidising conditions.

It simulated the physical conditions in effect in the case of a large break behind the SG, leading to a test at about 2 bar pressure and requiring the installation of a SG restraint pipe upstream of this breach.

The pH value of the water in the sump was chosen acid in order to maximise molecular iodine production.

The test itself was preceded by an irradiation period of 9 days at 180 W/cm average, in order to create short-lived FP's and, consequently, a sufficient activity level in the sump water.

The irradiation/test phases took place between November 21, 1993 and December 7, 1993 as summarised in Table 3.

The test analysis is underway and should last 2 years as shown in table 4.

Table 3: The Phebus FPT0

THE PHEBUS FPT0 IS DIVIDED IN 5 PHASES

1) The "irradiation phase"
- began on November 21,1993
- lasted 9 days

2) The "bundle degradation and fission products release phase"
- performed on December 2
- lasted about 5 hours

3) The "aerosols phase"
- began on December 2, at 15h30
- lasted about 19h

(the aim of this phase is to study the aerosols settling in the containment vessel)

4) The "washing phase"
- performed on December 3, at 16h45
- lasted about 15 mn
- preceded by a preparatory phase (December 3, from 10h30 to 16h45)

(the aim of this phase is to collect the aerosols settled at the bottom of the containment vessel and to send them in the sump)

5) The "chemistry phase"
- began on December 3
- lasted 4 days

(the aim of the chemistry phase is the study of the evolution of the gaseous iodine concentration in the containment vessel)

Table 4: Post Test Operations

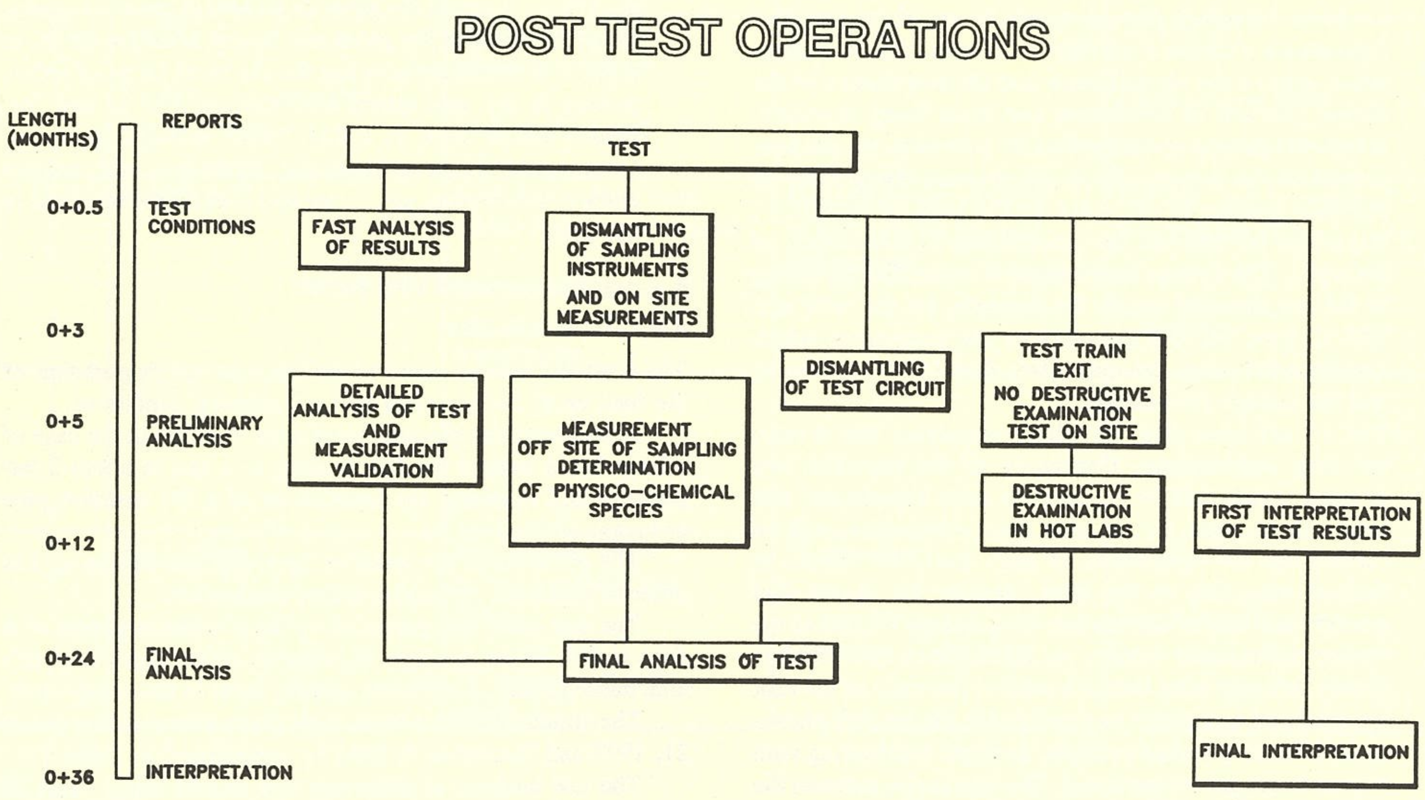


Figure 1: Different Components of the Phebus facility

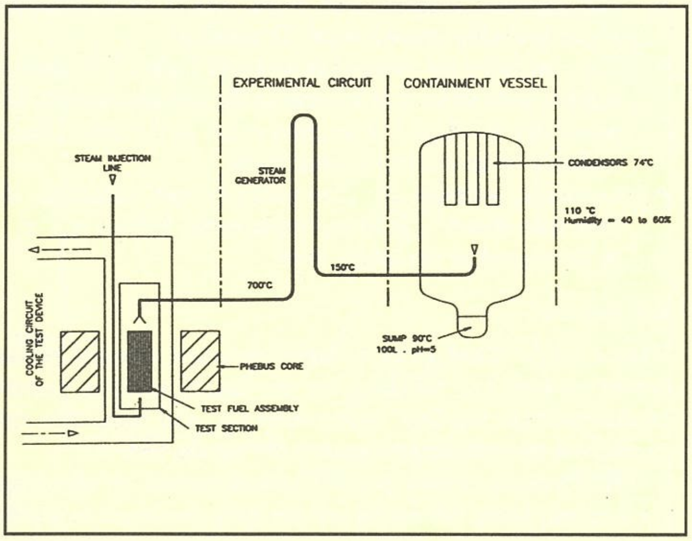


Figure 2: Section of the Test Train

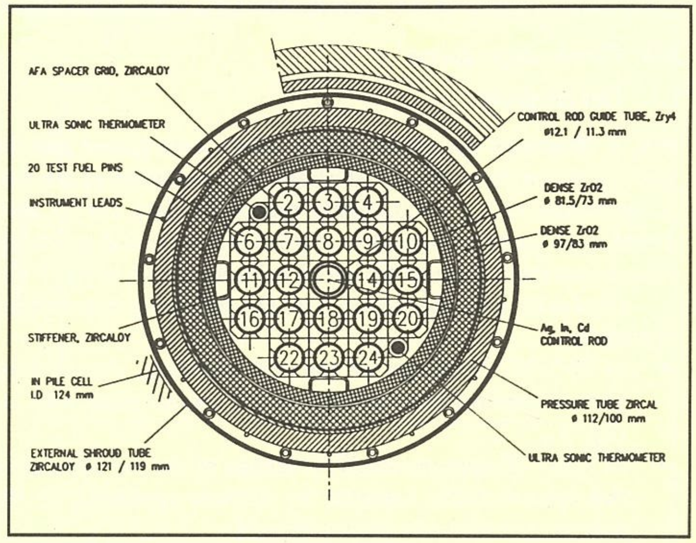


Figure 3: Driver Core

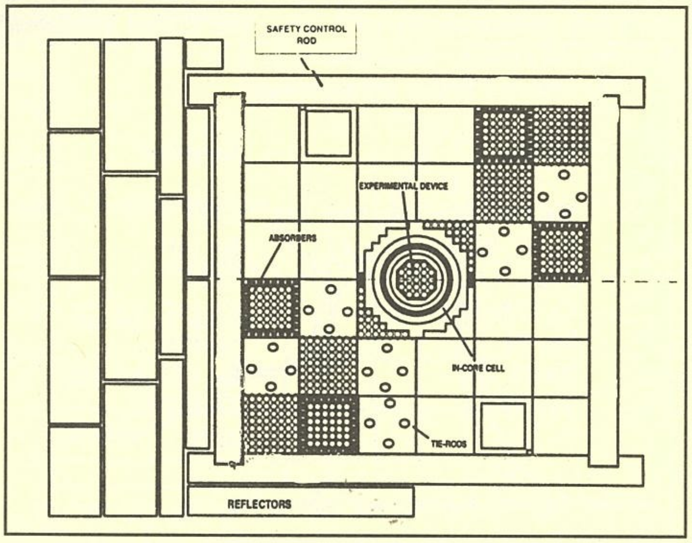


Figure 4: Primary Circuit and Instrumentation

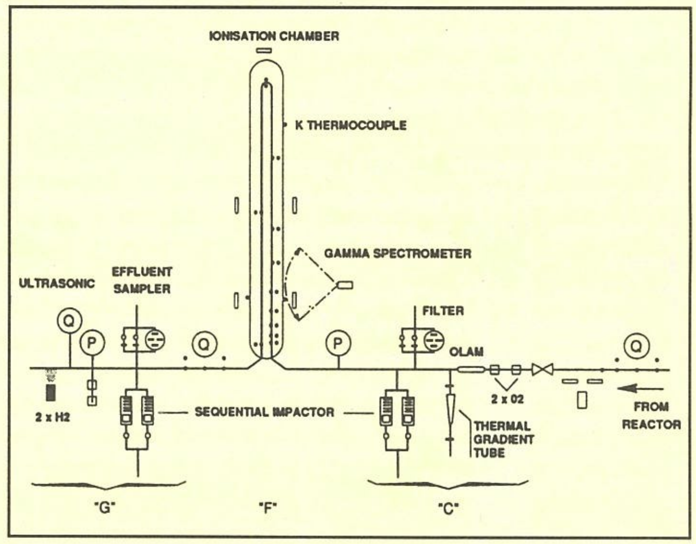


Figure 5: Containment and Instrumentation

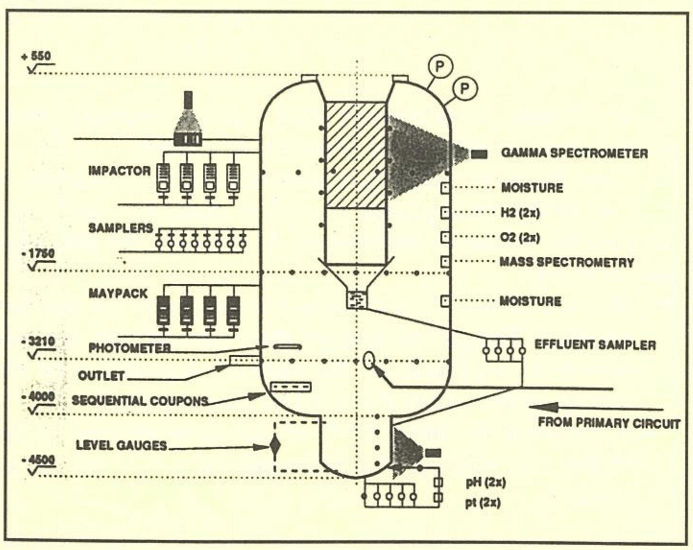
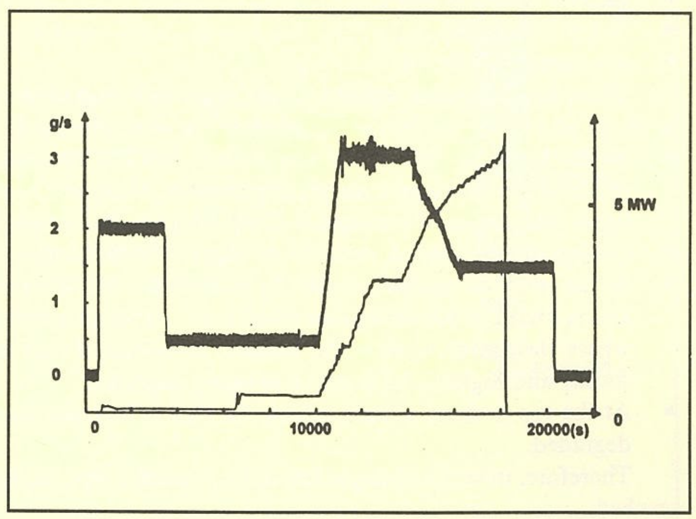


Figure 6: FPT0 Test: Evolution of core power and inlet steam flow rate in the bundle



As the irradiation phase was carried out without any particular problem, we will directly detail the degradation phase.

4.2 Cluster degradation

Test progress

Fig. 6 illustrates the values of the driver core power and the cooling steam flow. Fig. 7 illustrates the evolution in the fuel temperatures at hot point, firstly measured, then extrapolated based upon the measurements recorded in the thermal jacketing. This evolution is close to the asked value as shown in fig. 7 bis.

Gradually with the power rise, the following events were recorded:

- at 750 °C, breakage of the rod cladding, detected by gamma spectrometers and the on-line aerosol monitor OLAM (fig. 8),
- at 1,200 °C approximately, breakage of the rod simulating the control rods, detected by indium appearing in the gamma spectrometer measurements,
- beyond 1,200 °C, increase in the rod heating kinetics, up to 10 °C/s, due to the Zr-water reaction.

The maximum temperature recorded during this period was 2,500 °C, then stabilising at 2,000 °C for lack of metal (oxidising, or zircalloy melting).

A significant hydrogen release (fig. 9) was also recorded during this period.

Cladding melting probably led to a partial dissolution of the fuel (formation of a liquid compound U-Zr-O). This assumption is concerned by the high release rate of fission products in this period.

- Cluster power increase was then continued until fuel compaction was detected. The phenomenon was detected through temperature measurements, as stipulated in the test sheet (fig. 10). An important increase in aerosol and FP's release was confirmed by the OLAM and the gammaspectrometer, as well as by reactivity movements in the driver core (fig. 11 and 12).

Fuel state

Various non destructive tests were conducted so far on the test device, namely:

- gamma scanning (fig.13),
- X-ray examination (fig.14),
- tomographies (fig.14).

These examinations confirmed the high fuel degradation level. In particular, the following phenomena were observed:

- At the lower section of the test device, fuel rod remains, which practically kept their initial geometry. Materials from upper part degradation were built up between these rods.
- On top of this zone, a melted fuel ingot, re-solidified.
- In the medium section, most of the fuel has disappeared and is found in the above-described zone. At the periphery where the temperature is the coldest, re-solidified fuel is found, and higher, rod remains severely degraded.
- At the top section, a zone where the fuel is less and less degraded.

Therefore, in terms of degradation, the objective was amply reached.

General comments:

- The Zr-water reaction was more violent than expected, which probably caused metal Zr melting.
- The possibility for material movements before UO_2 melting had not been taken into account in the precalculations. The possibility for (U,Zr) O reaction exists in the codes, but is probably at an underestimated level.
- Currently, with the available codes (ICARE, MELCOR), the final state observed is hardly explainable. Efforts remain to be developed at modelling level.

4.3 Release

Fission products and gamma-emitter structure material release measurements are obtained by means of various gamma measurements: "on-line" measurements, and measurements carried out on samplings triggered during the test.

Non-gamma-emitter product measurements on samplings are currently being conducted and the early results are available.

Fig. 15 illustrates the various measurements which enabled the quantity of iodine which reached the "atmosphere" tank to be determined (direct gamma measurement, sampling by impactors, measurements on filters). The correct consistency between the various measurements is to be noted.

The detected fission products are:

On line	Sampling
Xe 135, 137, 138, 139, 140	I 131
Kr 87, 88, 89, 90	Ba 140
I 131, 132, 133, 134, 135	Sr 89
Cs 138, 139, 140	Cs 137 Cs 134
Mo 99	Sb 125
Rb 88, 89	Ru 103 Ru 106
Te 132	Te 129 m
	Zr 95

The detected activation products are:

	Ag 110 m
In 116 m	In 114 m
	Zr 95
	Sn 113

In addition, measurements other than gammametry, made on samplings, evidenced the presence of uranium.

Quantification analysis is currently being conducted. It requires an important amount of work to check for consistency between the various measurements. At this date, the following can be stated:

- between 60 and 75 % of the iodine present in the fuel was released. This value is more than forecast, but the difference is explained by the state of degradation of the cluster, which is also more severe than expected.
- Approximately 10 to 15% of the silver present in the cluster was released, which is amply more than forecast (a decade).

Figure 7: FPT0: Temperature Evolution in the bundle

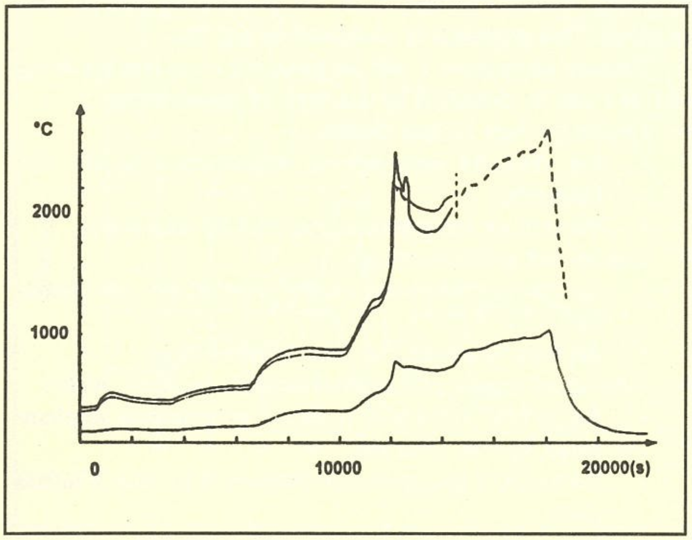


Figure 9: Hydrogen release in the containment vessel

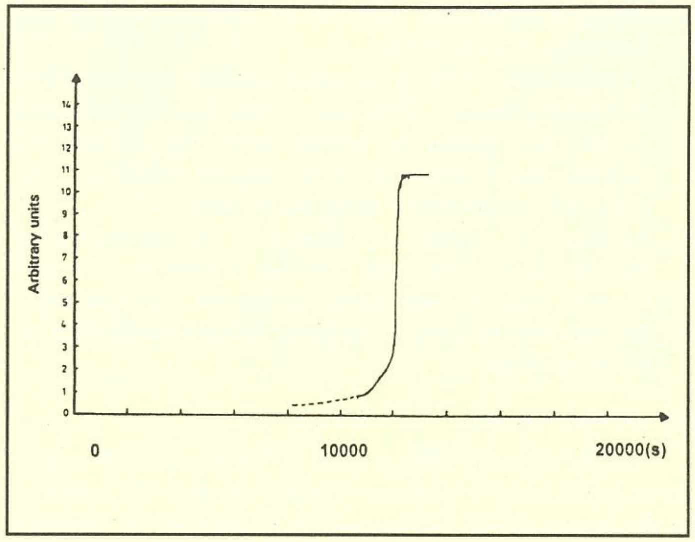


Figure 7bis: Comparison between predicted and realized temperature evolution

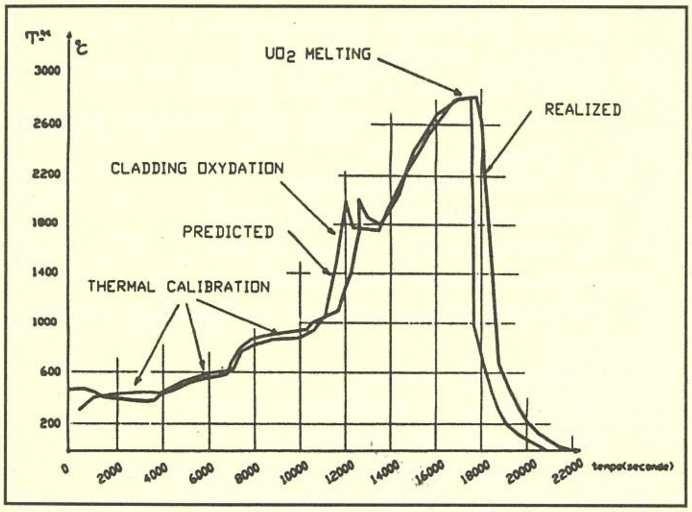


Figure 8: FPTO: OLAM signals

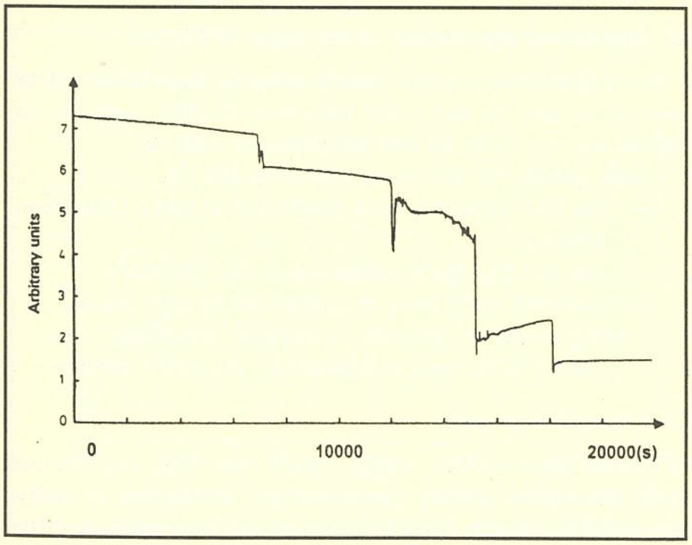
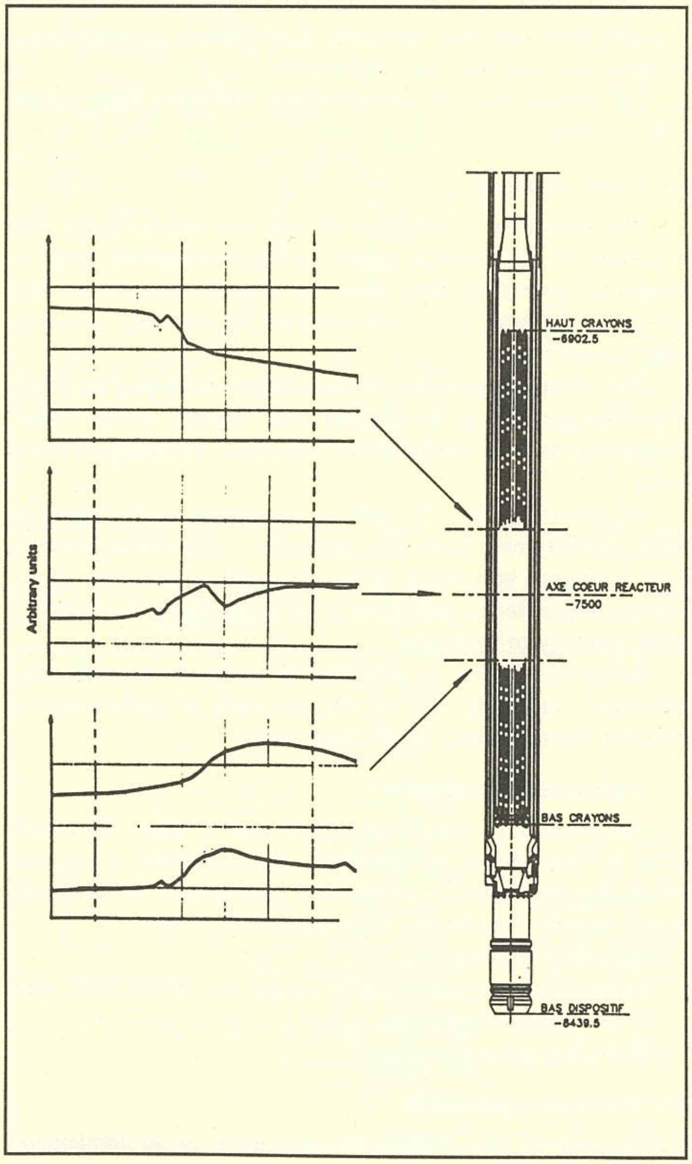


Figure 10: Detection of fuel movement by shroud temperature



- **Thermal insulation studies:**
  These studies were conducted both in France by the SICN company and in Japan by the Kyocera company, under the guidance of NUPEC.
- **Thermal property measurements in the thermal insulation:**
  These studies were conducted by ONERA and CEA in France, TUI (European Union), AECL (Canada), JAERI (Japan) and by BCL (USA).
- **Studies on filtering media, in order to separate the various forms of iodine.**
  These studies were conducted by IPSN at Cadarache, France, with experts from KFK (Germany), the AEA (UK) and AECL (Canada).
- **Studies on the containment thermohydraulics.**
  These studies were conducted by IPSN at Cadarache, France, on the PITEAS loop as well as on the Phebus containment itself.
- **Studies on the injection of boric acid.**
  These studies are currently being performed by IPSN at Cadarache, France.

Various other studies are also worth mentioning, such as studies on temperature measurements either by means of thermocouples (such as the work carried out by IPSN and the CEA, France), or by means of ultrasonic thermometers (research work by the TUI (European Union), as well as measurements with various instruments used on the facilities (impactors, filters, sampling devices, etc.) and those whose use is now envisioned (aerosol monitors, mass spectrometers, devices measuring the chemical species of iodine in water, etc.).

6 Aspects not covered by the Phebus FP Programme and Associated Tests

Three major aspects of high significance for the containment are not being studied in the scope of Phebus and the associated tests:

- hydrogen explosion,
- "direct heating",
- corium-concrete interaction and/or the study of a "sacrificial bed".

For safety reasons and in order to keep clear experimental conditions, the study of the consequences of an Hydrogen explosion has been eliminated from the PHEBUS test matrix, this has been achieved by decreasing the percentage of oxygen (until 5 %) in the REPF 502.

On the other hand, the study of the efficiency of an "hydrogen recombiner" in severe accident conditions might be envisaged by introduction of a sample inside the atmosphere tank during a PHEBUS test.

The study of the Corium-concrete interaction, of the corium spread out, of the behaviour of a sacrificial bed, are out of the scope of the PHEBUS tests. It is possible, however, to introduce into the containment tank certain gases issued from the corium-concrete interaction to study their impact on the fission product behaviour.

7 The Partners in the Phebus Programme

IPSN together with EDF and the European Commission have shared partnership in this programme since July 1988.

The European countries are represented by the European Commission at the Programme Management Committee. They participate in the working group activities.

Non-European countries are also involved in the programme:

- USA, through NRC,
- Japan, through NUPEC and JAERI,
- Canada, through COG,
- Korea, through KAERI.

The fig. 21 schematizes the organization of the programme.

8 Conclusion

Phebus FP is presently the largest international programme for severe accident in-pile tests. It also contributes, for the first time in the history of source term research,to the knowledge of fission product behaviour in the reactor containment.

After 5 years of calculation, design, manufacture and assembly, the first test was successfully operated in November-December, 1993. The facility and its instrumentation operated very satisfactorily. Certain phenomena observed, however, were poorly predicted by the pre-calculations and require substantial efforts during the current interpretation phase. Among those phenomena were :

- significant materials interactions in the in-pile test section,
- large emission of non-fission product aerosols,
- low primary circuit, but high containment vessel wall deposition,
- very early presence of gaseous iodine, and yet unexplained chemical forms of iodine in the containment vessel.

Ongoing analyses and interpretation of FPT0 and of the future, very similar, FPT1 tests will answer those questions.

References :

1 A.G. MARKOVINA, A. ARNAUD - Phebus FP, Objectives, Representativity, Test Matrix - Seminar of the Phebus FP Project, Cadarache, France, 5-7 June 1991.

2 P. VON DER HARDT and A. TATTEGRAIN - The Phebus Fission Product Project - J. Nucl. Mater. 188(1992) 115-130.

3 P. VON DER HARDT, A.V. JONES, C. LECOMTE, A. TATTEGRAIN - Nuclear Safety Research - The Phebus FP Severe Accident Experimental Programme, to be Published in Nuclear Safety (1994).

Figure 17: FPT0: Temperature distribution along the steam generator

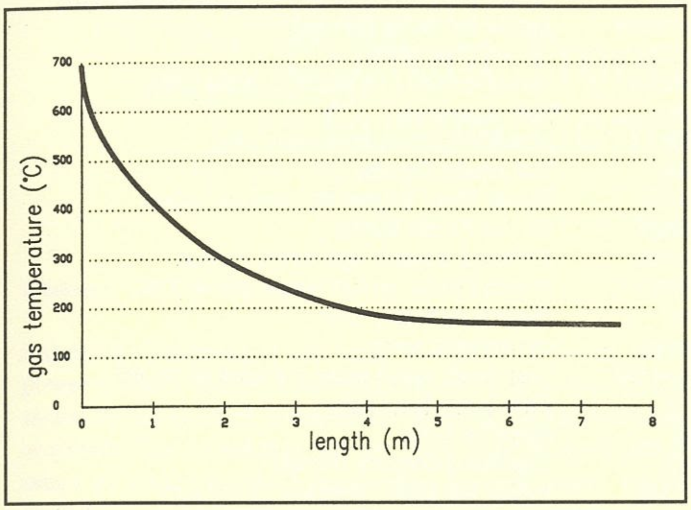


Figure 18: FPT0: Relative distribution of sequential coupon activity

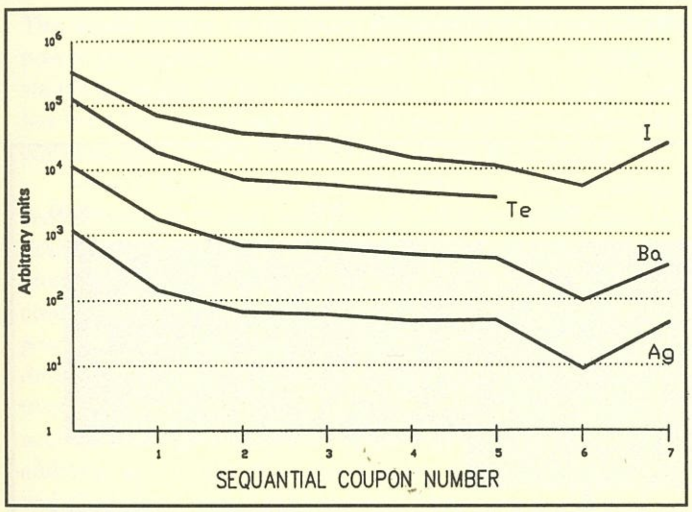


Figure 19: FPT0: Total iodine concentration in the containment gas phase

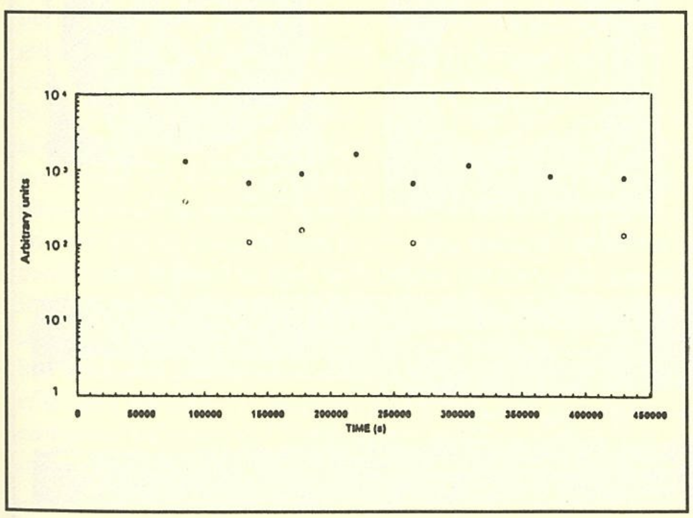


Figure 20: Software planning strategy

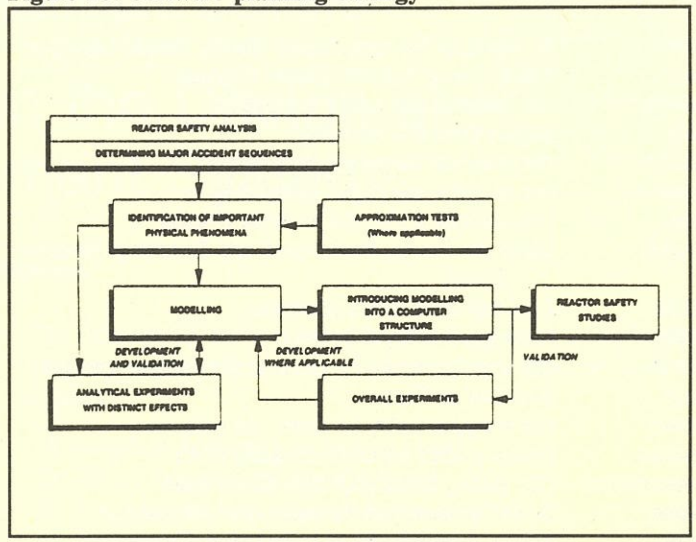
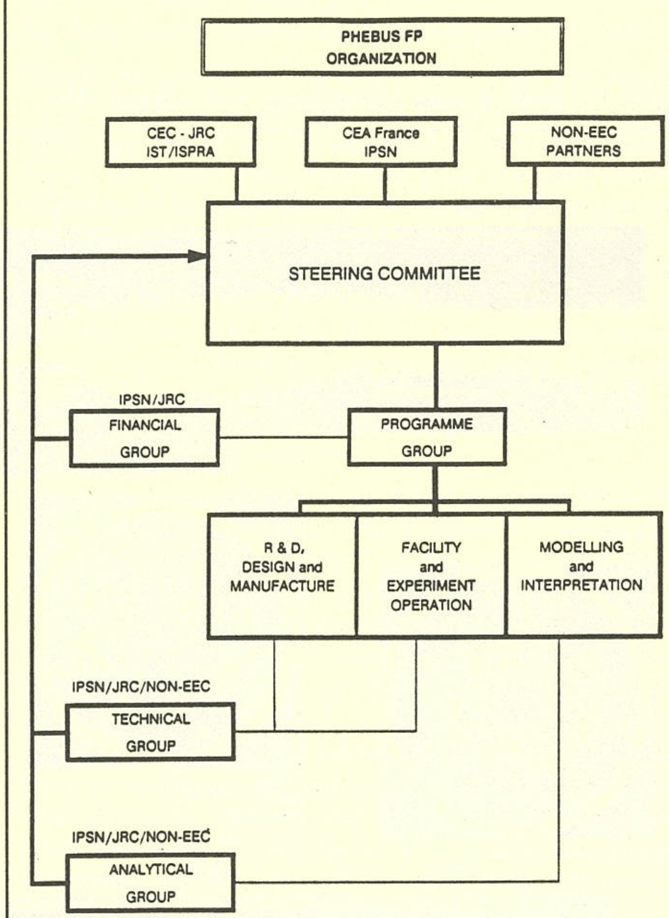


Figure 21: PHEBUS FP: Organization

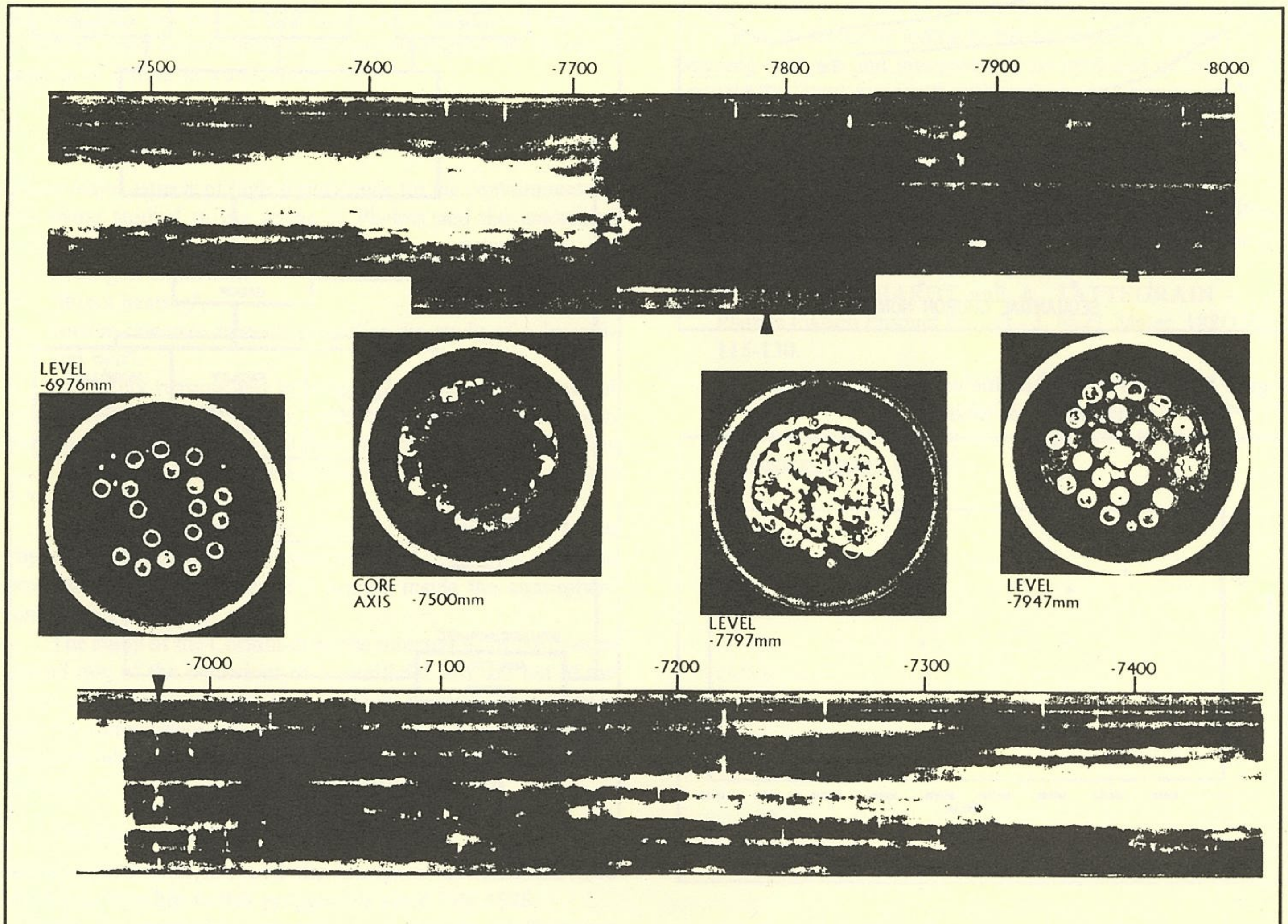


Glossary:		
	CEA	Commissariat à l'Energie Atomique
	CEC	Commission of the European Communities
	EEC	European Economic Community
	IPSN	Institut de Protection et de Sûreté Nucléaire
	IST	Institute for Safety Technology
	JRC	Joint Research Centre

Abbreviation Glossary

ACRR	Annular Core Research Reactor (Sandia National Laboratory)
AEA	Atomic Energy Authority (United Kingdom)
ASPERSION	CEA analytical test project designation
BCL	Battelle Columbus laboratory
BILLEAU	CEA analytical test project designations
CAIMAN	CEA analytical test project designations
CEA	Commissariat à l'Énergie Atomique (France)
CIEMAT	Center for Energy, Environment, and Technology Research (Spain)
CORA	Core melt down facility (Germany)
DEMONA	Aerosol test facility (Germany)
DEVAP	CEA analytical facility for fission product surface reactions
EDF	Électricité de France
EMAIC	CEA analytical facility for control rod behaviour
FALCON	Fission product experimental facility (U.K.)
FARO/KROTOS	UO_2 melting facility (European Commission)
ICARE	Severe accident core behaviour code (France)
IODE	Severe accident iodine behaviour code (France)
IPSN	Institut de Protection et de Sûreté Nucléaire (France)
JAERI	Japanese Atomic Energy Research Institute
KAERI	Korean Atomic Energy Research Institute
KFK	Kernforschungszentrum Karlsruhe
LACE	Aerosol and fission product experimental facilities (USA)
MACE	Aerosol and fission product experimental facilities (USA)
MARVIKEN	Aerosol test facility (Sweden)
MEGEVE	CEA analytical facility
MELCOR	Severe accident core behaviour facility (USA)
MP	Melt progression
NRC	Nuclear Regulatory Commission (USA)
NRU	Test reactor (Canada)
NUPEC	Nuclear Power Engineering Company (Japan)
OLAM	On Line Aerosol Monitor
ONERA	Aerospace research organisation (France)
OSTLEY	Projected fission product release test rig (U.K.)
PBF	Power Burst Facility (USA)
PITEAS	CEA analytical facility
REPF 502	Containment vessel model in Phebus FP (10 m^3)
RTF	Radio-Iodine Test Facility
SG	Steam Generator
SICN	Engineering Company (France)
STORM	Aerosol test facility (European Commission)
TMI	Three Mile Island
TRANSAT	CEA analytical facilities
TUBA	CEA analytical facilities
TUI	Transuranium Institute (European Commission)
VERCORS	CEA analytical facility

Figure 14: FPT0: Bundle radiography and tomographies



Current Trends in the Design of Future Containment Systems

by R.L. Ritzman[1]

Abstract

Improved containments are being designed for future nuclear power reactors which incorporate concepts and features that are aimed at maintaining containment integrity throughout severe accidents. The techniques that are being used to cope with the range of severe accident phenomena and challenges are discussed including examples from a variety of ongoing design efforts as described in the open technical literature.

Introduction

The world is now in its fourth decade of commercial nuclear power production. Nuclear power has become an important source of electricity in many countries. The water cooled reactor has been the main plant type in the past and this is expected to continue into at least the early part of the next century.

Most of the currently operating power reactors in the world are enclosed in strong containment buildings which have been designed to specific industry standards and which meet applicable regulatory requirements. These basically assure that the containment will perform its intended function in a variety of postulated accident situations. There are usually referred to as design basis accidents. In many cases the containments are over-designed such that they provide considerable protection in accidents which would be beyond the design basis level. In addition, as a result of lessons learned from Three Mile Island and Chernobyl, some containments have been back-fitted with equipment to mitigate the effects of some severe accident phenomena.

The reactors and containment buildings of the future are being designed now by various private and national organizations. Simplicity and safety are prominent objectives in all of these design efforts. In most cases criteria and concepts are being incorporated early in the design phase that will directly address the variety of challenges to containment integrity that are posed by low probability events and severe accident phenomena. The remainder of this paper will focus on providing an overview of the collection of concepts/features that are being considered or used to deal with severe accident challenges in future containment designs. The scope of the discussion will be limited to water-cooled reactors and to design work from what has been referred to as the "western world". In addition the emphasis will be on concepts concerned with the design of complete (integrated) containment systems rather than on individual studies not part of an overall design effort.

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The subject of severe accident challenges to containment integrity may be divided into nine areas or technical issues as follows:

1) Accident frequency reduction (AFR)
2) Direct containment heating (DCH)
3) Energetic fuel-coolant interactions (EFCI)
4) Hydrogen combustion events (HYD)
5) Overpressure protection (OP)
6) Heat Removal (HR)
7) Debris cooling & basement attack (DC/BA)
8) Fission product control (FPC)
9) Containment isolation loss/bypass prevention (CI/CB)

Design concepts for dealing with each of these nine issues in future containments are discussed in the following sections. Where appropriate, specific examples of their application are given. Altogether, documentation from the open literature regarding the design progress of twelve advanced or new water cooled power plant systems were consulted to obtain the information for the following discussions. These represented programs under way in Canada (CANDU-3), France and Germany (EPR), Italy (LIRA & ICS), Japan (MS600, SPWR & HSBWR), Sweden (BWR 90), and the USA (ABWR, System 80+, AP600 and SBWR).

Accident Frequency Reduction

While not a containment feature per se this issue has a direct effect on containment safety/integrity because it influences the frequency as well as the level of potential containment challenges. Virtually all advanced plant designs are addressing this issue by making improvements to their NSSS. Examples include ABWR (1) and BWR90 (2) (coolant recirculation pumps located inside the reactor pressure vessel (RPV) and use of fine motion control rod drives); System 80+ (3) (enlarged pressurizer volume, upgraded steam generator features, enlarged secondary feedwater inventory, and state-of-the-art instrumentation and as steam generators, pressure tubes and fuelling machines); SBWR (5) & HSBWR-600 (6) (elimination of all recirculation pumping and piping); MS600 (7) (use of horizontal steam generators and no "below the core" reactor vessel penetrations); SPWR (8) (location of all primary coolant system components within a single pressure vessel, and elimination of control rods); EPR (9) (improved quality of RPV components and use of enlarged primary and secondary coolant system volumes).

For the advanced designs which rely on active emergency core cooling systems, various improvements are being added to enhance reliability as well as capacity if these safety systems should be needed. Examples of enhancement include additional separate trains to increase redundancy and larger accumulators and/or other water supplies to increase capacities.

More than half of the advance designs are incorporating passive emergency core cooling methods for use in LOCA situations. The degree of reliance on passive systems range from the simple use of gas pressurized tanks (accumulators) in the System 80+ plant and other PWR designs to total utilization of passive methods involving natural circulation flow and gravity-driven flow systems in both the AP600 (10) and SBWR (5) plants. Since low reactor coolant system (RCS) pressure is required for effective operation of gravity driven core reflood, each plant is equipped with an automatic depressurization system (ADS). In the AP600 design the core reflood water is supplied by a large in-containment refuelling water storage tank (IWRST) which is located above the elevation of the RPV nozzles. In the SBWR the short-term gravity driven cooling system (GDCS) flow is supplied from three separate pools while the pressure suppression pool is used to provide the long term flow. Both of these designs also have passive systems to provide high pressure decay heat removal and coolant inventory control for transient events. Each uses multiple independent heat exchanger loops with natural circulation flow which allow for at least three days of decay heat removal before replenishment of the heat sink (pool water) becomes necessary. Other plant designs which feature gravity-driven core reflood systems include MS600, SPWR, and HSBWR-600.

Direct Containment Heating

The phenomenon of direct containment heating is considered to be the result of a severe core damage accident in a reactor vessel at high pressure which has proceeded to the point of rupture of the lower head. The discharge of fluids (including molten core debris) from the vessel would tend to disperse in and rapidly heat the containment atmosphere. The resulting pressure rise could be a threat to containment integrity. All of the advanced plant designs examined for this discussion have been equipped with ADS features which should effectively reduce chances of DCH events to negligible levels. In most cases low water level in the RPV triggers the ADS, and in a number of the plants (as indicated in the previous section) reactor depressurization is a necessary step for the proper operation of either an engineered low pressure or a passive core cooling system.

Some designs include additional containment features which would help to limit the challenge that could be posed by a DCH event. In the ICS (11) the main containment is connected via a vent and pressure suppression pool to a very large sub-atmospheric secondary containment building. This would provide relief capacity for DCH generated pressure loads. Also, researchers at KfK in Germany (12) are working on the design of a very strong primary containment which could withstand an internal static pressure of 2MPa and a dynamic impulse up to 0.2 MPa-s. This robust structure should withstand most if not all potential DCH generated loads. In addition they have indicated the feasibility of reinforcing vessel support structures and of adding more structure above the vessel to avoid possible upward travel of the RPV.

Energetic Fuel Coolant Interactions

Energetic fuel-coolant interactions have been the subject of research for several decades. Most analysts assign low probabilities to interactions that would be large enough to challenge containment integrity. In fact the risk of containment failure from a large-scale in-vessel (FCI) (steam explosion) is usually considered to be negligible. Even so some design work is being directed at providing added protection against such events. In the LIRA (13) design provisions are made to flood any core debris in the reactor cavity from the bottom rather than from the top to reduce the chance of experiencing the EFCI. At KfK special shields around the reactor cavity region have been suggested to protect against missiles that might result from EFCI events. Actually the internal layout and construction of most advanced reactor containments seem to already provide such features. In such cases the reactor cavities are surrounded by robust reinforced concrete structures which are normally located in the lower and central part of the containment building. This and other intervening structures inside containments should provide adequate protection against missiles that might be generated by FCI events that could accompany core debris quenching in scenarios where lower head breach of the RPV would occur. The present designs which appear to have this issue resolved include ABWR, BWR-90, System 80+, CANDU-3, AP600, SBWR, EPR and ICS.

Hydrogen Combustion Events

In severe core damage accidents the reaction between steam and overheated/molten Zircalloy and steel can generate large amounts of hydrogen in a relatively short time. The accumulation of this hydrogen in the containment volume may be a significant threat to containment integrity if conditions should develop that would lead to its rapid combustion (i.e., deflagration or perhaps detonation). Consequently the designs of future containments include a variety of features or equipment to mitigate the hazard posed by excessive hydrogen buildup.

Some of the containments being designed, usually those having smaller free volumes, utilize inerted atmospheres to keep compositions outside the measured combustion limits for hydrogen and oxygen. The ABWR, BWR 90, and SBWR are all equipped with nitrogen inerting systems to maintain primary containment oxygen concentrations below about 4 percent during normal operation. At least two of these also have companion systems to limit the buildup of radiolytic oxygen during severe accidents. The ABWR design will use dual recombiners for this purpose while the SBWR design will use a system of low-power igniter assemblies that are distributed around the containment to achieve controlled burning of near-flammable mixtures. The ICS concept with a large primary containment free volume plans to automatically discharge carbon dioxide accumulators after the beginning of an accident to inert the atmosphere of its primary containment. Excessive pressurization that could result from this action would be avoided since the primary containment is connected by a controlled vent to a very large building maintained at sub-atmospheric pressure.

Essentially all of the other large containment designs are being fitted with active igniter systems to achieve early and controlled burning of the hydrogen in severe accidents. For example the System 80+ design two separate systems of distributed igniters which are designed to prevent the average hydrogen concentration in containment from reaching 10 volume percent in case of the equivalent of 100% reaction of the active fuel cladding with steam. The igniters also have diverse power supplies including batteries connected through DC to AC inverters. The AP600 design will use a similar approach and the layout of internal structures is done with the purpose of taking advantage of natural circulation forces to help mix the atmosphere between compartments and thus avoid local accumulations. For the same reason the active igniters are strategically positioned throughout the containment compartme-nts and large volume regions.

In some of the advanced designs further protection against large hydrogen burning events is being provided by installing what are known as passive hydrogen control devices. These utilize the principle of catalytic recombination and they need no electric power to operate. Researchers have been improving the materials and design of such devices for the past decade and they are being included as primary and/or secondary systems in the EPR and LIRA designs.

There is one remaining approach for dealing with the hydrogen combustion threat that should be noted. The researchers at KfK are simply designing a very robust containment structure that would be strong enough to withstand any realistic load that could result from combustion of hydrogen, including detonation events. This rather brute force approach is considered to be both technically and economically feasible by these workers.

Overpressure Protection

Besides the rapid containment boundary loadings that can accompany transient events such as DCH or large scale hydrogen burns, containment pressure buildup can occur due to more gradual processes. These basically consist of non-condensable gas generation from various chemical reactions (i.e., water, concrete, or organic materials decomposition) or steam generation due to water evaporation/flashing. Elevated temperatures are usually required to produce significant yields of gases or vapours and so this containment issue is closely related to the issue of heat removal which will be discussed in the next section. However, overpressure protection addresses the consequences of gas/vapour production rather than the basic causes.

Virtually all of the new/advanced water reactor plant designs are equipped with containments having design pressures of at least several atmospheres as a first defense against pressure buildup. Many of these also have large free volumes (50,000 cubic meters or more and large heat capacities (massive structures) which help to limit the rate of pressure buildup. Examples of this include the System 80+, CANDU-3, AP600, MS-600, and EPR plant designs. Other designs have smaller free volumes (roughly 10,000 cubic meters) but are equipped with pressure suppression systems which are effective in limiting steam pressurization as well as providing a large passive heat sink. Examples of this include the ABWR, BWR 90, SBWR, SPWR, and HSBWR-600 plant designs. Some advanced plant designs, such as LIRA and ICS designs, incorporate both of these concepts to extend capacity and redundancy.

In addition to the above approaches some future containments will be equipped with controlled venting systems to relieve pressure in the event that containment pressure should reach a prescribed action level. This is of particular value in dealing with the buildup of non-condensable gases in containment. After appropriate pressure relief has occurred the vent can be closed to re-establish containment isolation.

Provisions are made to attenuate the radioactivity content of the vented gases either by locating the vent downstream of a pressure suppression pool (such as in the ABWR, SBWR, and LIRA designs) or by providing an engineered scrubber/filter system in the venting pathway (used in the Swedish BWR 90 design).

Heat Removal

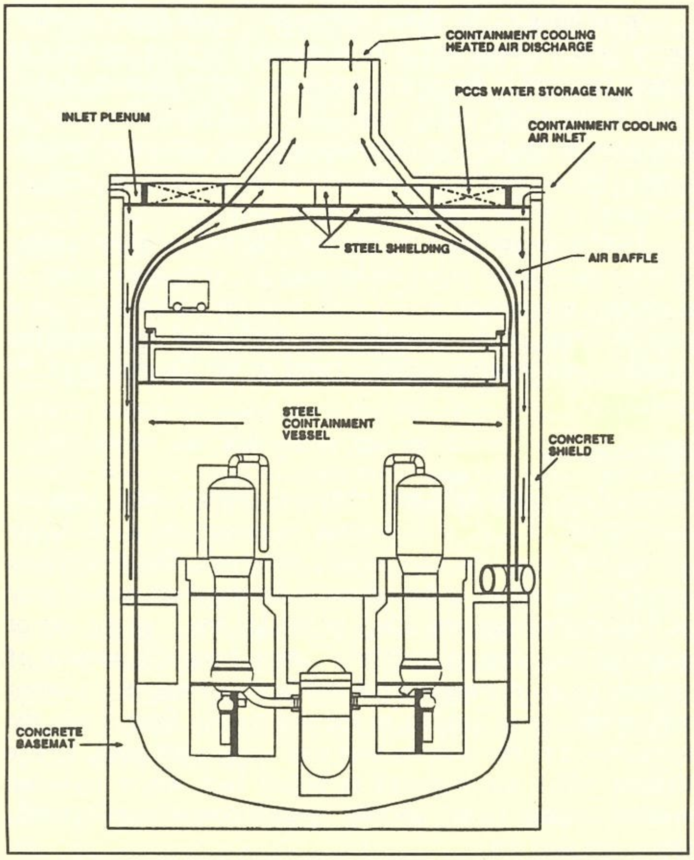
Removal of decay heat and chemical reaction heat from the containment is a crucial element in preserving its integrity during the progress of a severe accident. The traditional approach for achieving heat removal for the short-term (hours) as well as the long-term (days or weeks) has been the use of active (power driven) systems. These generally consist of multiple trains of pumps, pipes and heat exchangers combined with sprays or air coolers to transfer energy from inside the containment to the ultimate heat sink outside the plant. Future designs which are expected to utilize such active rejection systems include ABWR, BWR90, System 80+, CANDU-3, LIRA, SPWR, EPR and ICS.

Some future designs are expected to depend partially or entirely on passive methods for containment heat removal. One example of the latter is the AP600 design in which the steel containment vessel and the reinforced concrete shield building are integral parts of the passive containment cooling system (PCCS) as shown in Figure 1. Other parts of the system are the PCCS water storage tank, the air baffle (located between the steel containment and the concrete wall of the shield building), air inlets (located at the top of the shield building wall), an air diffuser/exhaust (located in the centre of the conical-shaped roof), and a water distribution system (mounted on the outside surface of the steel containment vessel.

In the event of an accident the PCCS drains water from the water storage tank through the distribution system. The water runs down the outside of the steel containment vessel and is carried out of the shield building by a drainoff system, thus removing heat that was picked up during contact with the steel containment vessel. The combination of air inlet, air baffle, and air exhaust also provide a pathway for natural circulation of cooling air through the annulus between the containment vessel and shield building for further extraction of heat form the inside. The PCCS operation is automatically initiated upon receipt of a high containment pressure signal. It is capable of removing sufficient thermal energy following an accident that pressurizes containment such that the containment pressure remains below the design value (0.42MPa absolute) with no operator action required for three days. Designers also claim that containment pressure would not exceed its ultimate limit during a core melt scenario with only air cooling via the PCCS.

Another example where only passive means of containment heat removal during accidents is used is the SBWR design as

Figure 1: Passive Containment Cooling System (PCCS)



depicted in Figure 2. This is a pressure suppression type of containment in which heat removal is accomplished with the aid of one or more of three independent passive containment cooler (PCC) loops. These loops are extensions of the primary containment and they have no vales or other moving parts. The system operates by natural circulation which is initiated by the difference in pressure between the drywall and the suppression chamber. Each PCC loop contains a heat exchanger that condenses steam on the tube side and which transfers heat to water in a large pool which is vented to the outside atmosphere. The condensed steam is drained to a gravity driven cooling system (GDCS) pool inside the containment and non-condensable gases are vented through a vent-line to a submerged outlet in the pressure suppression pool. Each of the three PCC condensers is designed for 10MWt capacity. Together with the pressure suppression system the three PCC condensers will limit primary containment pressure to less than its design value (0.48MPa absolute) for at least three days after a loss-of-coolant accident without makeup to the condenser water pool.

A third example of complete reliance on a passive method containment heat removal can be found in the HSBWR-600 design (see Figure 3). This design also uses a large pressure suppression pool for heat absorption within the primary containment but a unique approach for transferring heat to the outside ultimate heat sink. The primary containment vessel (PCV) is a steel cylinder and dome structure that is surrounded by a large reinforced concrete reactor building. The annulus between the steel PCV and the reactor building concrete wall is filled with water making an outer pool. Long-term heat removal from the PCV will be achieved by natural circulation in the suppression pool and heat conduction through the steel PCV wall to the outer pool which undergoes gradual evaporation loss. The process uses no powered components and can continue for three days without adding water to the outer pool. Means are provided for supplying additional water if required at that time.

Other advanced plant designs which are considering using passive means of containment heat removal include the MS600, EPR, and SPWR designs. Details of such plans will probably appear in future publications and/or meetings.

Debris Cooling/Basemat Attack

In severe accidents which progress to the point where the lower head of the reactor pressure vessel is breached, molten core debris will discharge into the reactor cavity. Control of debris temperatures and interaction in this region are important to preventing excessive decomposition and erosion of the concrete basemat, because these can generate appreciable amounts of non-condensable and flammable gases, promote additional release of fission products from the melt, and possibly result in basemat penetration. Most of the advanced containment designs are using the concept of debris spreading and water quenching to address this issue. Basically the idea is to provide a relatively large open space below the reactor vessel that will allow the debris to flow and spread unhindered over the reactor cavity floor. The very soon after the debris enters the cavity region provisions would be in place to flood the region with water to quench the debris and keep it cool as long as necessary to terminate the accident. Passive means, such as fusible plugs that are connected to a large in-containment water reservoir like an IRWST or suppression pool, could be used to initiate the flooding process. The advanced plant designs which have adopted this

Figure 2: SBWR Design

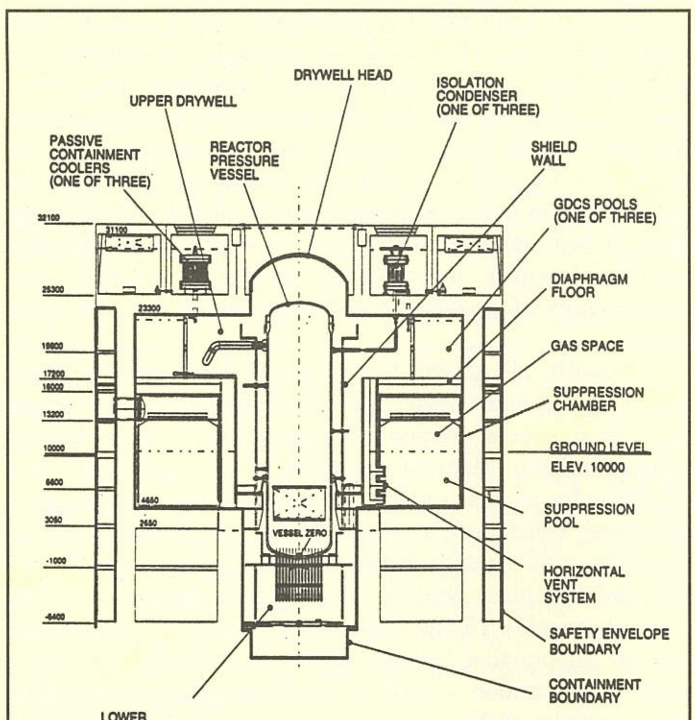
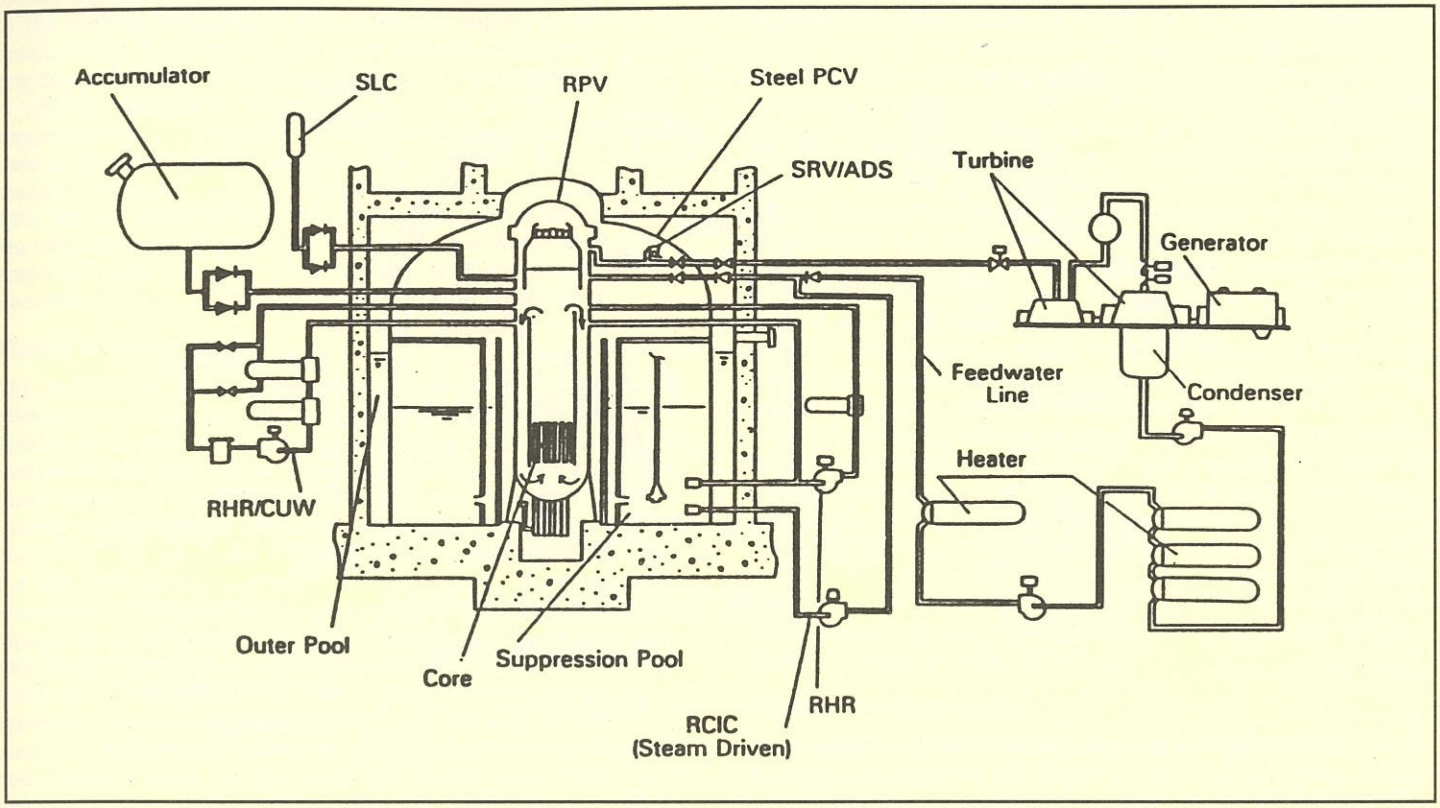


Figure 3: HSBWR-600 Design



approach include ABWR, BWR90, System 80+, CANDU-3, AP600, SBWR and EPR. Research is still in progress in various laboratories around the world to provide confirmatory data on the efficacy of the debris quenching/cooling process. Its success would essentially end further progression of the melt with only a limited amount of basemat attack having taken place.

Some design work has been done on other engineered approaches for dealing with this issue. For example researchers at KfK have designed a molten core retention and cooling device that would be coupled with a passively cooled containment structure. Schematic drawings of these designs are shown in Figures 4 and 5. The core catcher device includes a heavily latticed concrete structure at the entry to the reactor cavity that is designed to absorb the kinetic energy of the downward moving lower head from the RPV, thus preventing early damage to the core retention/cooling assembly located in the bottom of the reactor cavity. The molten core debris is cooled by water evaporation. For this purpose a water/vapour circulation system is induced by design to operate completely inside the containment. In essence the heat from the melt is transferred to the steel shell of a composite containment and then dissipated by natural air convection through the chimney formed between the steel shell and the outer concrete wall of the structure. The reactor cavity walls are protected by high temperature insulation and the core retention/cooling device contains a sacrificial material to permit some downward erosion before melt solidification and steady-state conditions are established.

A simpler core catcher concept has been proposed for use in the LIRA containment design. The reactor cavity is enlarged to provide a floor area of about 250 square meters (see Figure 6) and it is fitted with a slab of granite made up of adjacent

Figure 4: Molten Core Retention and Cooling Device

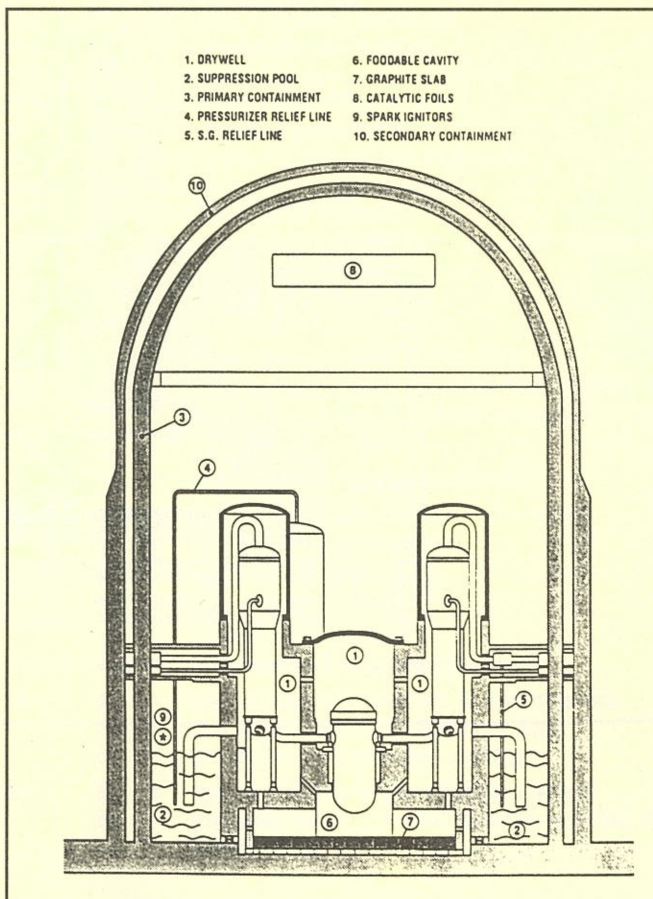


Figure 5: Conceptual Design of a Composite Containment (PWR)

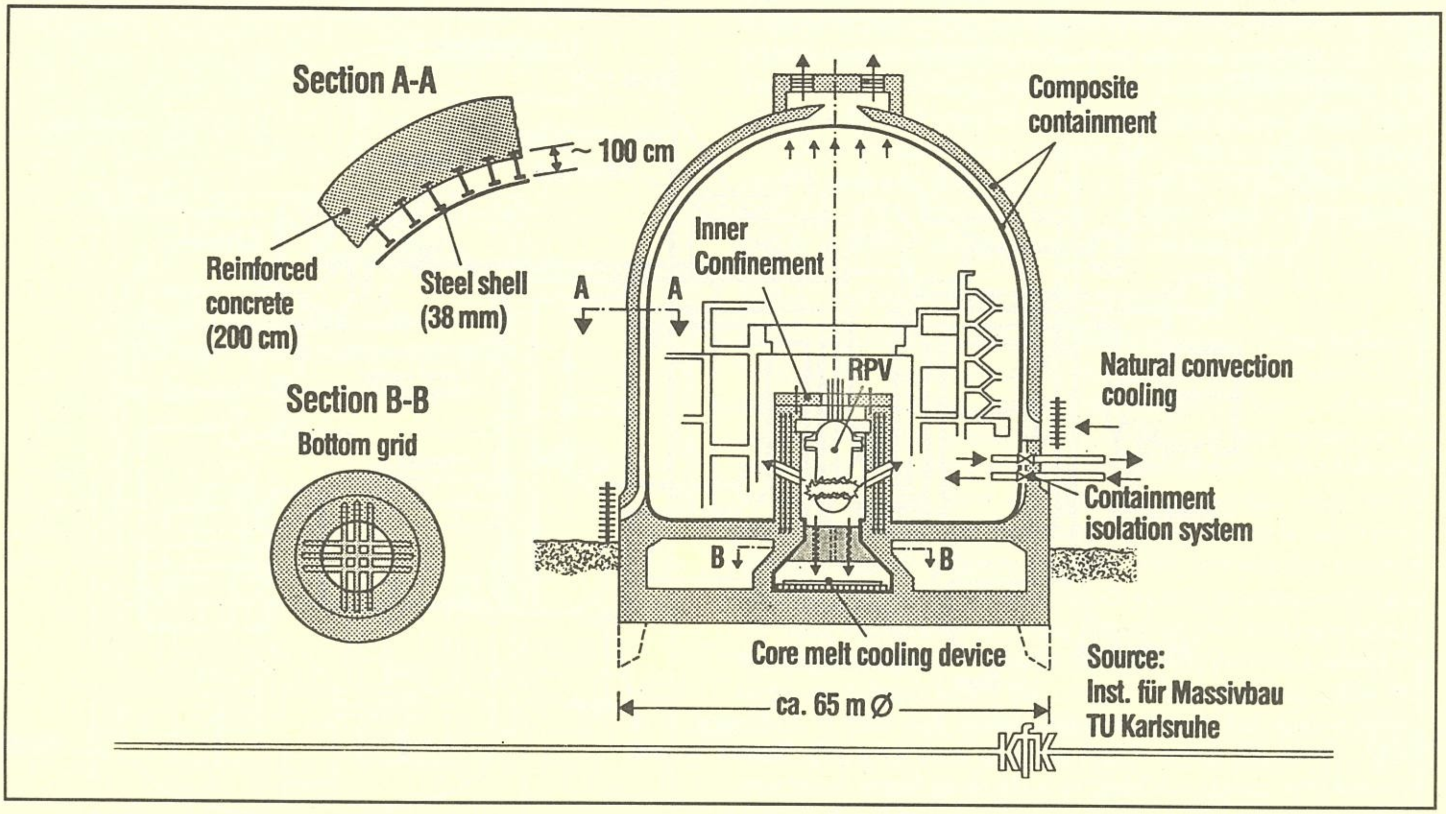
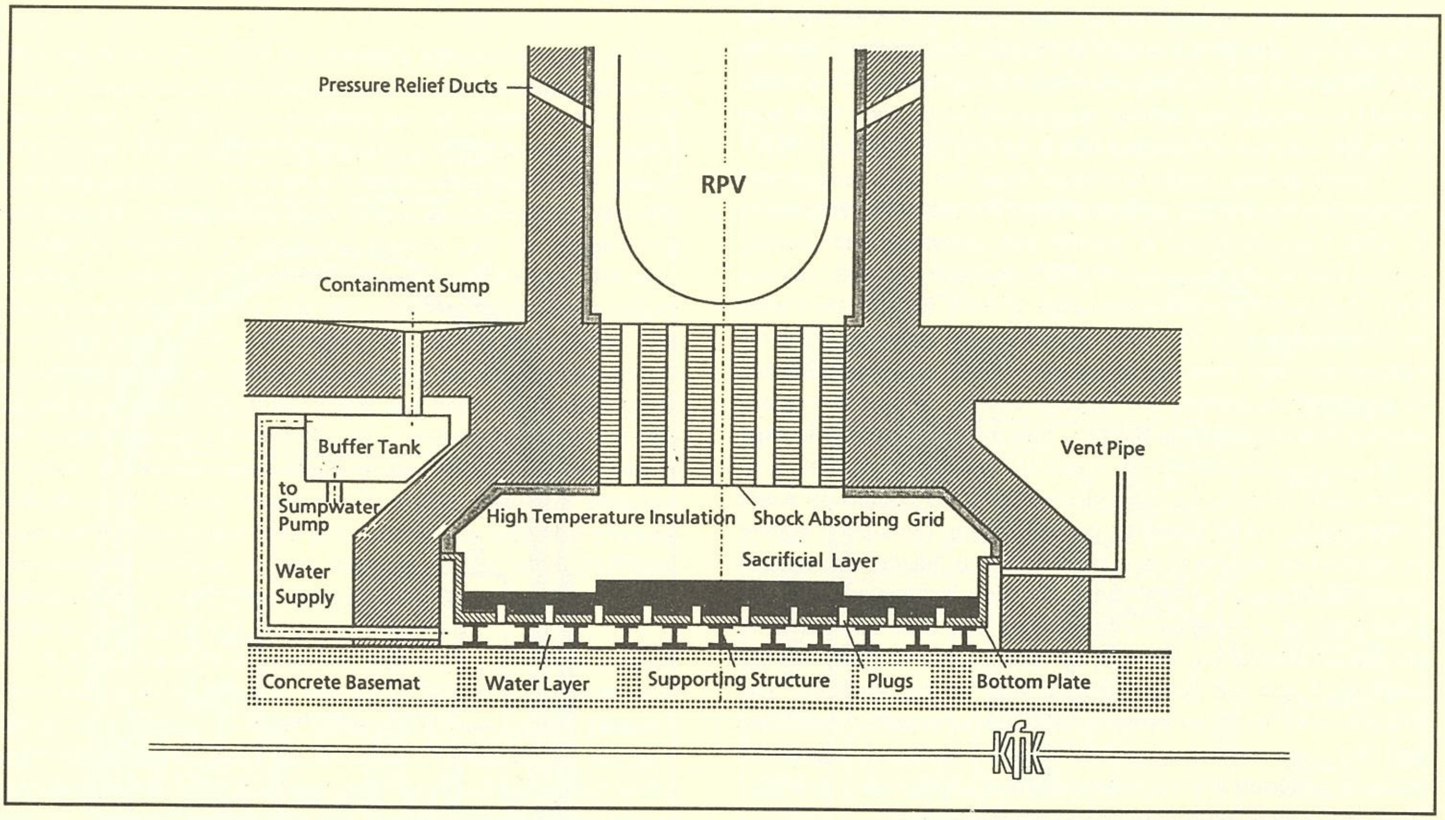


Figure 6: Core Retention Device of a Modified PWR-Concept



blocks that are one meter in height. This is to promote spreading of the molten debris into a thin layer and cooling it quickly by means of the heat capacity and good thermal conductivity of the graphite slab. After the initial solidification takes place the cavity is quickly flooded by connecting it to the lower part of the suppression pool through the actuation of either active (valves) or passive isolation devices (fusible plugs or fusible links). In this manner molten fuel-coolant interactions should be avoided along with thermal attack of the concrete basemat. As an alternative to the large flat slab of graphite, a design using a stack of staggered graphite beams has been proposed for situations where a more standard cavity (e.g. 50 square meters) should be preferred.

Fission Product Control

The radiological hazards represented by the large fission product releases which can accompany severe accidents are such that immobilization and control of these materials in an expeditious manner within containment is an important objective of any future plant design. A combination of passive and active methods are usually relied upon to meet this objective. All containments of course will benefit from the effects of natural deposition processes for the removal of airborne species from the containment atmosphere. This includes plateout on vertical surfaces (walls, equipment housings, etc.), deposition/reaction with suspended aerosols, coagglomeration of aerosol particles and settling on horizontal surfaces (floor, open pools, etc.). Containments which utilize pressure suppression pools also will have the passive process of pool scrubbing to remove and immobilize fission product vapours and aerosols from the gas mixtures which enter these large reservoirs. This applies to the following future designs; ABWR, BWR90, SBWR, LIRA, SPWR, HSBWR-600 and ICS.

A number of the future plant/containment designs also will employ active fission product control systems. For example the BWR90, System 80+ and ICS designs are equipped with independent containment spray systems. Besides being effective in heat removal from the containment atmosphere, the sprays will also be efficient in washing out airborne radioactive matter. The AP600 design includes a sump pH control system that is capable of maintaining post-accident pH conditions in the recirculation sump water after containment floodup to protect against the re-evolution of fission product iodine. Other plants are equipped with various types of filtration devices to treat containment leakage or controlled venting flows. The ABWR for example is equipped with a standby gas treatment system (SGTS) to minimize exfiltration of contaminated air from its secondary containment building. It is a safety grade active system containing both HEPA and activated charcoal filters. The plant utilizes suppression pool scrubbing to attenuate radioactivity in any controlling venting flows that might become necessary. The BWR90 design on the other hand is equipped with a separate engineered passive system for treating controlled venting flows. It is a steel pressure vessel version of FILTRA-MVSS which uses an array of venturi scrubbers and is located in the reactor building, outside primary containment. The LIRA design has also proposed use of filtration equipment in its controlled venting system. Other plant designs which consist of a steel containment surrounded by a concrete shield building usually plan to install filtration devices to process the atmosphere in the annular region between the two structures. Examples of this approach are the System 80+, EPR and MS600 designs.

Containment Isolation Loss/Bypass Prevention

In order to enhance the probability of maintaining containment integrity during a severe accident the design phase must endeavour to minimize the chances of either a loss of containment isolation or a containment bypass event occurring in such circumstances. Successful resolution of this issue depends not so much on understanding the interactions of physical and chemical phenomena with the structure, but on thorough application of the principles of good engineering practice during all phases of the design process. In general most of the advanced containment designs utilize few containment penetrations than in the past, the penetrations are often clustered in specially designed and protected areas, and improved isolation technology (logic, equipment, etc.) is being used. These concepts and features are evident in the designs for the ABWR, BWR90, System 80+, CANDU-3, AP600, SBWR, LIRA, and EPR plants. In those designs that are equipped with controlled venting systems, provisions are included to manually reclose the vents and re-isolate the containment boundary. In plants that have a secondary structure around the primary containment, the structure is usually equipped with a filtered ventilation system sufficient to maintain a slightly negative internal pressure which would be capable of attenuating primary containment penetration leakage. Known examples of this include the ABWR, BWR90, SBWR, System 80+, and EPR.

The LIRA design offers a rather effective approach to deal with the low probability but potentially high consequence issue of containment bypass. The combination of a large containment volume plus a large internal pressure suppression pool would permit; (1) location of the residual heat removal (RHR) system inside containment, and (2) piping of the system generator pressure relief discharge to the suppression pool. With the RHR system inside containment the number of necessary containment penetrations would also be reduced.

Summary and Conclusions

The general concepts and strategies being used to cope with severe accidents challenges in the design of new and advanced reactor containments are summarized in tabular format in Table 1. The definitions of the several symbols and alphabet characters appearing in the table are as follows:

Severe Accident Challenges/Phenomena

AFR	=	accident frequency reduction
DCH	=	direct containment heating
EFCI	=	energetic fuel-coolant interactions
HYD	=	hydrogen combustion events
OP	=	overpressure protection
HR	=	heat rejection (short and long term)
DC/BA	=	debris cooling/basemat attack
FPC	=	fission product control
CI/CB	=	containment isolation loss/containment or suppression pool bypass events

Strategies/Techniques Used for Protection

AFR	a)	=	improvements made to the NSSS
	b)	=	improvements made in active ECC systems
	c)	=	presence of passive cooling method(s)
DCH	a)	=	installed ADS
	b)	=	other protective means (see text)
EFCI	a)	=	presence of robust internal structures
	b)	=	addition of special shields
HYD	a)	=	installed inerting system
	b)	=	active igniters used
	c)	=	passive igniters used
	d)	=	other protective means (see text)
OP	a)	=	use of large free volume & heat capacity
	b)	=	use of pressure suppression system
	c)	=	provision for controlled venting
HR	a)	=	use of multiple active cooling systems
	b)	=	presence of engineered passive cooling system(s)

DC/BA	a)	=	promote debris spreading and water quenching
	b)	=	installed core catcher device with cooling
FPC	a)	=	pool scrubbing action
	b)	=	natural deposition processes
	c)	=	installed active spray system
	d)	=	filtration of primary containment leakage and/or vent flows
CI/CB	a)	=	reduce number of penetrations/improve isolation systems
	b)	=	enclose interfacing systems in containment

It must be emphasized that the entries in the table and the earlier discussions apply to designs and/or concepts as described in recent documentation in the open literature; no proprietary information has been examined nor used. Since some of the plants and design features are not final at this time changes are to be expected as the design process moves towards completion. The reader will have to consult future literature sources for updates on these new developments.

It should be apparent from the above discussions that significant efforts are being directed towards the design of future containment systems which will be capable of withstanding the various challenges presented by severe accident phenomena. Also, the full spectrum of these potential challenges seem to be receiving serious consideration using diverse methods to accomplish that goal. Where needed the design effort is being supported by specific research work to measure critical parameters and coefficients or to conduct proof of principle and/or confirmatory operational tests. Passive methods using natural driving forces rather than supplied power to accomplish a particular task (such as heat transfer, fluid flow, chemistry control, etc.) are producing novel and self-sufficient solutions to several of the containment challenge issues. It will be interesting to observe the implementation of some of these concepts as the next generation of nuclear power plant deployment begins to expand.

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Table 1: Summary of Techniques for Meeting Containment Challenges from Severe Accident Phenomena

Severe Accident Phenomena/Containment Challenge

Plant Design	**AFR**	**DCH**	**EFCI**	**HYD**	**OP**	**HR**	**DC/BA**	**FPC**	**CI/CB**
ABWR	a,b	a	a	a	b,c	a	a	a,b,d	a
BWR90	a,b	a	a	a	b,c	a	a	a,b,c,d	a
Sys-80+	a,b,c	a	a	b	a	a	a	b,c,d	a
CANDU-3	a,b,c	–	a	b	a	a	a	b	a
AP600	a,b,c	a	a	b	a	b	a	b	a
SBWR	a,b,c	a	a	a,b	b,c	b	a	a,b	a
MS600	a,b,c	a	–	–	a	b	–	b	-
LIRA	*	a	b	b,c	a,b,c	a	b	a,b,d	a,b
SPWR	a,b,c	–	–	–	b	a	–	a,b	-
HSBWR	a,b,c	a	–	–	b	a,b	–	a,b	-
EPR	a,b	a	a	b,c	a	a,b	a	b,d	a
ICS	a,b	b	a	a	a,b,c	a	b	a,b,c,d	-
KfK	*	b	a,b	d	a	a,b	b	b	-

* These are mainly containment design efforts but it should be assumed that in commercial service each would be equipped with the best available reactor power system.

EIS for Waste Concept Submitted

by Mary Greber and Karen Strobel[1]

Atomic Energy of Canada Limited has submitted the Environmental Impact Statement (EIS) on the Concept for Disposal of Canada's Nuclear Fuel Waste, for review under the federal Environmental Assessment and Review Process. The Environmental Assessment Panel, appointed by the federal Minister of the Environment to review the safety and acceptability of the disposal concept and a broad range of nuclear waste management issues, released the EIS to the public on October 26, 1994.

AECL's overall conclusion in the EIS is that implementation of this concept represents a means by which Canada can safely dispose of its nuclear fuel waste.

The submission of the EIS is a major accomplishment for the Nuclear Fuel Waste Management Program at AECL Research. It represents the culmination of 15 years of R & D directed at establishing a method for the safe, permanent disposal of nuclear fuel waste. Whiteshell Laboratories, near Pinawa, Manitoba, has been AECL's headquarters for this Program. AECL is confident that the disposal concept is an ethically responsible, technically sound, and socially acceptable way to provide long-term protection for humans and the natural environment.

In 1978, the governments of Canada and Ontario established the Canadian Nuclear Fuel Waste Management Program "to assure the safe and permanent disposal" of nuclear fuel waste. Disposal is a permanent method of waste management in which there is no intention of retrieval and which, ideally, uses techniques and designs that do not rely for their success on long-term institutional controls beyond a reasonable period of time. Responsibility for research and development on "disposal in a deep underground repository in intrusive igneous rock" was assigned to AECL. Responsibility for studies on interim storage and transportation of used fuel was assigned to Ontario Hydro. Ontario Hydro has also provided technical assistance to AECL in research and development on disposal. The Canadian Nuclear Fuel Waste Management Program is funded jointly by AECL and Ontario Hydro under the auspices of the CANDU Owners Group.

In 1988, then Minister of Energy, Mines and Resources Marcel Masse referred the concept for an environmental review. At the time he said, "This will be one of the most important environmental assessments ever undertaken in this country and will provide an essential foundation for future decisions on energy policy."

[1] Communications Team, Nuclear Fuel Waste Management Program, AECL Research, Whiteshell Laboratories

The EIS, a 500-page document, provides the information requested in the guidelines developed by the public after extensive public consultation and input and presents AECL's case for the acceptability of the concept. It discusses:

— the need for disposal.
— the characteristics of nuclear fuel waste,
— the current management of used fuel,
— the requirements and objectives for disposal,
— the concept and role of each of the components of the disposal system,
— how the concept could be implemented,
— the results of the preclosure and post-closure case study environmental assessments,
— the alternatives to disposal, and
— AECL's conclusions and recommendations.

A separate 47-page summary has also been published. Nine primary references — addressing major technical and social aspects of disposal — complete the EIS documents submitted to the Panel. Public and university libraries across the five review provinces (New Brunswick, Quebec, Ontario, Manitoba and Saskatchewan) have received complete sets of the documentation.

Although AECL has reached a major milestone with the completion of the EIS, a significant challenge remains in preparing for participation as the proponent in the rest of the environmental review process. The Panel has allocated nine months for the review of the EIS. In addition to the work of the Environmental Assessment Panel, a parallel review of the nuclear fuel waste disposal concept is being undertaken by an independent, fourteen-member Scientific Review Group, which was an independent, fourteen-member Scientific Review Group, which was appointed by the Panel. This Group was appointed in 1990 with representatives from various Canadian and American universities to assess the concept from a scientific and engineering perspective.

Along with the reviews being conducted by the Scientific Review Group and government departments, members of the public are invited to review the EIS and provide comments to the Panel on its completeness. Between November 1994 and March 1995, the Federal Environmental Assessment Review Office is hosting a series of Open Houses to encourage the public's participation in the environmental review process.

After the nine-month review period is over and the Panel has considered all comments received, it will determine whether AECL has addressed all the requirements in the EIS guidelines. It may request additional information from AECL. Once the Panel decides that it has sufficient information to proceed, it will hold public hearings.

The EIS, Summary and primary references may be obtained by contacting AECL Research, Whiteshell Laboratories, St.73, Pinawa, Manitoba R0E 1L0, phone 1-800-665-0436, FAX 1-204-753-2455.

The remainder of the Open Houses, scheduled during February and March 1995 are as follows:

Feb 6	Sault Ste Marie	Sault College of Applied Arts and Technology, Science and Natural Resources Building, 9 a.m. — 4 p.m. Presentation: 2 p.m.
Feb 7	Elliot Lake	W.H. Collin Centre, 12 noon — 7 p.m., Presentation: 2 p.m.
Feb 8	Sudbury	Science North, 2-9 p.m.
Feb 9,10	Timmins	Timmins Square Merchants, Feb 9, 5-9 p.m.; Feb 10, 10 a.m. — 1:30 p.m.
Feb 20	Montreal	Station du métro McGill, 10 a.m. — 6 p.m.
Feb 21	Montreal	La Place, Complexe Desjardins, 10 a.m. — 6 p.m.
Feb 22	Ville de Bécancour	Centre Culturel Larochelle, 2-9 p.m. Presentations: 2 p.m., 7 p.m.
Feb 23	Sainte Foy	Pavilion Maurice-Pollack Université Laval, 2-9 p.m., Presentations: 2 p.m., 7 p.m.
Feb 24	Sainte Foy	Centre commercial Place Laurier, 10 a.m. — 5 p.m.
March 6	Kincardine	Kincardine District Secondary School, 12 noon — 5 p.m., 7-9 p.m. Presentation: 7 p.m.
March 7,8	Oshawa	Location to be confirmed.
March 9,10	Toronto	Metro Toronto Reference Library, March 9, 2-9 p.m. Presentation: 7 p.m.; March 10, 9 a.m. — 4 p.m. Presentation: 2 p.m.
March 22	Kingston	Policies Studies Building, Queens University, 12 noon — 8 p.m. Presentations: 2 p.m., 6 p.m.
March 23	Ottawa	Rideau Centre, 10:30 a.m. — 3:30 p.m.
March 23	Ottawa	University Centre, Ottawa University, 5 p.m. — 9 p.m.
March 24	Nepean	Bayshore Shopping Centre, 10 a.m. — 10 p.m.

Pickering Operating Licence Renewed

On December 22, the Atomic Energy Control Board issued a two year renewal of the Operating Licence for Pickering NGS, to Dec. 31, 1996.

Although the licence was renewed the AECB has ruled that specific approval will be required to restart each of the four Pickering "A" units which were shut down after the December 10, 1994 incident in which failure of a heat transport pressure relief valve led to a minor loss-of-coolant-accident.

The Board decided that the re-licensing need not be referred for review under the federal Environmental Assessment and Review Process (EARP), as had been demanded by the group Durham Nuclear Awareness. Media reports emphasized the decision not to have an environmental assessment.

In an unusual move the Board issued a nine-page document setting out its reasons for the decisions. It noted that "the Board is satisfied that the performance of Pickering Nuclear Generating Station is such that a granting of a licence to operate ... for a further two years is appropriate". It pointed out that the licence contains many conditions which the AECB staff will be monitoring closely.

Much of the document dealt with the Board's communication with the public. It stated that "the Board recognizes the possibility that much of the public comment was generated by some lack of understanding of the issues" [therefore] "the Board plans to hold at least one public meeting in each community in 'the shadow of a major facility' during each licensing period". In addition it stated that "the Board will look at other methods of improving communication with the public". Such public information activity "will be intended to improve public understanding of nuclear safety issues **not** (our emphasis) to promote the use of nuclear energy".

The two year licence renewal is significant. Some recent Ontario Hydro licence renewals had been limited to six months, a signal that the AECB was not pleased with Ontario Hydro's performance on safety related issues. Since the organizational restructuring Ontario Hydro Nuclear has placed a high priority on the improvement of performance and safety. The two year licence renewal at Pickering, as well as at Bruce A, indicate that these efforts are worthwhile.

New Tritium Objective for Drinking Water

On December 22, Ontario's Environment and Energy Minister, Bud Wildman, announced a new interim drinking water objective for tritium of 7,000 Bq/l. It had been 40,000 Bq/l. This interim limit is consistent with international standards as recommended by the World Health Organization.

The Ontario objective is "interim" until the Canadian Drinking Water Guidelines for radionuclides are revised through a federal-provincial process.

The minister asked the federal government to tighten discharge limits of radioactive emissions from nuclear facilities "in keeping with recommended international standards. Actual tritium levels in Ontario drinking water are below 100 Bq/L on an annual average basis.

Earlier in 1994 the ministry's Advisory Committee on Environmental Standards (ACES) had recommended an interim objective of 100 Bq/l and an ultimate objective of 20 Bq/l.

Many individuals (including John Waddington of the AECB) and organizations (including the CNS and the Royal Society of Canada as well as Ontario Hydro) made submissions to the Minister criticising the ACES recommendation as being scientifically unfounded.

Nuclear Data Network

by Aslam Lone

The following is drawn from the Nuclear Data Newsletter *published by the International Atomic Energy Agency, issue 20, November 1994.*

An international network of recognized experts has been organized by the International Atomic Energy Agency to provide recommended databases of nuclear reaction cross sections, structure and decay data for use in basic and applied research. The information includes:

- Cross section data on nuclear reactions
- Nuclear level schemes, excitation energies, half-life, decay modes
- Level spin-parity values and justifications for those values
- Magnetic dipole and electric quadrupole moments
- Disintegration energies, radiations and their transition probabilities
- Nuclear band structure.

The information is available worldwide via electronic networks.

The international **Nuclear Structure and Decay Data (NSDD)** network was established in 1974 under the auspices of the IAEA. It is a group of 17 laboratories and universities in 10 countries. The Network scientists evaluate nuclear structure and decay data for all nuclear masses A = 1 - 266 on a continual basis. These evaluations are published in the journals *Nuclear Physics A,* for A = 3 - 44, and *Nuclear Data Sheets (NDS)* for A > 44.

The data files from these evaluations form the **Evaluated Nuclear Structure Data File (ENSDF)** which is maintained by the **National Nuclear Data Center (NNDC)** at the Brookhaven National Laboratory, U.S.A. The bibliographic information on publications in low and intermediate energy nuclear physics which forms the Nuclear Structure References file (NSR) is also maintained by the NNDC and the information on new references is published in the *Nuclear Data Sheets.* ENSDF, NSR and related data files have been made available since 1986 for online access via electronic networks.

Nuclear Data and Programs for Online Access

NSR — Nuclear Structure References file

Bibliographic information on low and intermediate energy nuclear physics, covering the period from 1910 to the present.

ENSDF — Evaluated Nuclear Structure Data File

Evaluated experimental data on nuclear level properties, radiations, radioactive decay, and reaction data for all known nuclides.

NUDAT — Nuclear Data

Evaluated numeric data containing adopted levels and gammas, ground and metastable state properties, nuclear half-lives, decay radiations, thermal neutron cross-section data, and resonance integrals.

MIRD — Medical Internal Radiation Dose

The MIRD program accesses the evaluated experimental radioactive decay data in the ENSDF database and produces tables of radiations and decay schemes in the format of the Medical Internal Radiation Committee's publications.

PHYSCO — Physics Codes

Codes to calculate physics quantities, *e.g.*, internal conversion coefficients, logR values, etc.

CINDA — Computer Index of Neutron Data

Index to the literature and computer files on neutron reaction data.

CSISRS/EXFOR — Cross Section Information Storage and Retrieval System

Experimental data on nuclear reactions induced by neutrons, photons, and charged particles.

ENDF — Evaluated Nuclear Data File

Evaluated nuclear reaction and decay data from the data libraries ENDF/B6\ (U.S.A.), JEF-2 (OECD/NEA), JENDL-3 (Japan), BROND-2 (Russia), CENDL-2 (China).

Online access

From Canada online access to the databases is available from the NNDC, Brookhaven National Laboratory, U.S.A. Information on how to access the database is given below.

A. Sample login

> SET HOST BNLND2 (see below for addresses) OR.
TELNET BNLND2.DNE.BNL.GOV (130.199.112.132)
BROOKHAVEN NATIONAL LABORATRY.
NNDC COMPUTER COMPLEX Open VMS AXP Vl . S
User Name: NNDC
Welcome to OpenVMS AXP (TM) OPERATING SYSTEM, VERSION V1.5 on node BNLND2
Enter NNDC assigned authorization code (or GUEST)
_ _ _ _ (see Authorization)
Enter your last name (or DEFAULT or ?)
LOGOUT (to terminate a retrieval session)

Networks and Telephone Access:

DECNET (ESNET only):
Command: SET HOST
Address: BNLND2 (44436 or 43.404)
TCP/IP (ESNET or INTERNET):
Command: TELNET
Address: BNLND2.DNE.BNL.GOV (130.199.112.132)

Telephone:

Number:	(516) 282-5390
Protocol:	ASCII only. Full duplex.
Speed:	1200, 2400, or 9600 bps
Word:	8-bit, parity off, 1 stop bit, or 7-bit, parity even, 1 stop bit.

After getting the online signal, type a carriage return, wait and then type a second carriage return. The VAX login prompt should then appear on your terminal.

World Wide Web:

http://necsOl .dne.bnl.gov/html/dathome.html

Telnet connection to BNLND2 node as well as National Nuclear Data Center information are available.

B. Authorization

Persons without an authorization code may access the online service by using the code **GUEST**. This authorization code restricts the amount of computer processor time to 30 seconds. Most of the databases as well as some of the utility features, namely the HELP files, the sample cases, and the newsletter can be used in this limited time. On logout from this session, a user may sign up directly for full access service by answering the computer prompts.

C. Retrieval System

A user-friendly system provides ample help to the user who specifies the retrieval criteria in response to step-by-step prompts by the system. It also provides interactive assistance through HELP files. More detailed documentation on the system may be obtained by contacting the NNDC. The output can be displayed on the user's terminal or written as a file to the online disk area for later transfer to the user's computer.

Some modules prepare files containing graphic displays in Tektronix or PostScript formats for output at a user's local facility.

D. Mail

You may contact the NNDC by mail:

ONLINE DATA SERVICE
National Nuclear Data Center
Brookhaven National Laboratory
Upton, NY 11973, USA.

Tel:	(516) 282-2901	BITNET: @BNL"
Fax:	(516) 282-2806	INTERNET: @BNL.GOV"

New Environmental Act Proclaimed

The new **Canadian Environmental Assessment Act** is expected to be proclaimed by the end of January 1995.

The new Act will create a new organization, the **Canadian Environmental Assessment Agency**, which will be, in essence, a re-structuring of the Federal Environmental Assessment Review Office (FEARO). The transition began the beginning of January.

The CEAA expands the authority of the Minister of the Environment and the extent of applicability. Projects coming under federal regulation will now be required to go through an assessment under the Act, as well as those funded by the federal government or on federal land. It will therefore apply to all "nuclear" projects licensed by the Atomic Energy Control Board.

The CCEA was passed over a year ago but proclamation was delayed until most of the regulations under the Act had been prepared.

Nobel laureate feted

The red carpet was rolled out at the Chalk River Laboratories for a visit, November 21, by Dr. Bertram Brockhouse, co-winner of the 1994 Nobel prize in physics.

It was actually a home-coming for Dr. Brockhouse since he conducted his prize winning work on neutron spectrometry when he worked at Chalk River from 1950 to 1962.

Following a morning tour of the laboratory, including NRU where he had installed his triple-axis spectrometer Dr. Brockhouse participated in a "symposium" in the CRL library auditorium. His recollections of his early work was followed by perspectives of three of his colleagues, Gerald Dolling, Bill Buyers, and Eric Svensson.

That evening over 150 present and former friends and co-workers gathered for a "Friends of Brockhouse Dinner". Gerald Dolling gave the main after dinner talk in which he noted that Dr. Brockhouse had won many other awards over the years for his pioneering work in neutron spectrometry. Noted was the role of Dr. Don Hurst, a former director at chalk River and later president of the AECB, as Brockhouse's mentor. Following the talk a number of presentations were made to Dr. Brockhouse and his wife.

Dr. Brockhouse is now professor emeritus at McMaster University where he went after leaving Chalk river in 1962.

Dr. Bertram Brockhouse and his wife open one of the many gifts presented to them at a special dinner in honour of the Nobel laureate held in Chalk River, November 21, 1994.

EPAC Program

The program of the CNS Education and Public Affairs Commitee continues to expand. Chairman Aslam Lone has provided an update in point form.

1. Educational Resource Kits

Ba137 isogenerator and cloud chamber kits were loaned to Mackenzie High School in Deep River for grade 12 laboratory experiments. About 3 kg of uranium ore has been obtained and more is requested from COGEMA for cloud chamber and radiation attenuation kits.

2. Teacher's Workshops

A teachers workshop on ionizing radiation is planned for March at Whiteshell Laboratories. Another workshop will be held at the Chalk River Laboratories on **February 8, 1995**, for a graduating class of science journalists. Two more will be held on **April 27, 1995**, during the Science for Educators Annual Seminar.

In response to a request from science teachers, a two day training program in four fields, physics, chemistry, biology and computer communications, is planned. The teachers' expenses will be paid by their school boards while resource costs will be shared by AECL and the CNS EPAC.

3. INTERNET Data Base

Establishment of AECL's WWW server, including a CNS subset, has been tentatively approved and detailed planning is in progress. The CNS page will include information on CNS activities as well as Fact Data Sheets from CNA. Teacher training will include hands-on experience in the use of this server.

4. List of Nuclear Energy Experts

Some input has been received and is being assessed for follow-up action.

5. 50th Anniversary of Fission in Canada

On **September 4, 1945** the Zero Energy Experimental Pile (ZEEP) achieved the first fission chain reaction in Canada. EPAC is organizing a technical symposium on **September 5 and 6, 1995**, at CRL on **Nuclear Science and Technology in Canada — Past and Future.** Other activities, a banquet, etc., are planned in collaboration with unions and CIC, CRPA, APEO and CAP.

6. Calendar of Key Events in Nuclear Science and Technology in Canada

One activity for the 50th anniversary celebrations is preparation of a chronological calendar listing and elaborating on the key events in the development of nuclear technology in Canada.

20th Annual CNS/CNA Student Conference

The twentieth annual Canadian Nuclear Society and Canadian Nuclear Association (CNS/CNA) Student conference will be hosted by the University of Manitoba in Winnipeg from March 9-11. Students involved in nuclear science or engineering disciplines are invited to participate.

The conference is an opportunity to share knowledge and explore new ideas by offering students from across the country a forum in which they can present their research before a group of their peers, professors and industry professionals. Topics will cover contemporary issues confronting the nuclear industry. Awards and recognition will be given to participants based on both technical and communicative skills.

Tentative Program

Thursday, March 9 1995 (Optional)

0800	Bus leaves for Whiteshell Laboratories (AECL Research)
1000-1200	Tour laboratories
1200-1245	Lunch in cafeteria
1330-1500	Tour Underground Research Laboratory (Nuclear Waste Management)
1500	Depart for Winnipeg

Friday, March 10 1995

0900	Tour of facilities at the University of Manitoba
1200	Registration at the U of M
1230	Opening of the Conference
1300-1430	First Session
1430-1500	Coffee
1500-1630	Second Session
1800	Dinner and Reception, with Dr. Agnes Bishop, President of the AECB, giving a talk.

Saturday, March 11 1995

1000-1130	Third Session
1130-1300	Lunch
1300-1430	Fourth Session
1430-1515	Coffee Break
1515-1600	Award Presentation and Conference Closing

Cost: Conference Registration is free. There MAY be some assistance in covering travel and accommodation costs, depending upon funds available.

Interested students or supervisors should contact:

20th Annual CNS/CNA Student Conference
Paul Driver, Publications Chair
AECL Research
Whiteshell Laboratories, Station 39
Pinawa, Manitoba R0E 1L0
Phone (204) 753-2311, ext. 2990
E-Mail: Conf95@wu14.wl.aecl.ca

Call for 1995 Nominations

Fellows of the Canadian Nuclear Society

CNS members who have been designated "Fellows of the Canadian Nuclear Society" belong to a membership category established by the Society in 1992 to denote outstanding merit. The criteria for admission to this membership category include "major and sustained contributions to the sciences and/or professions that relate to the advancement of nuclear technology in Canada." Demonstrated maturity of judgement and breadth of experience, as well as outstanding technical capability, service to the Society, and current CNS membership of at least five years standing, are also requirements for admission.

The newly admitted Fellows are presented with special membership certificates on a suitable occasion at the time of the CNS Annual General Meeting. In the tradition of honorary membership categories of learned societies, CNS Fellows are entitled to add the letters "F.C.N.S." to letters denoting degrees and professional certifications following their names. The maximum number of CNS Fellows at any one time is limited to not more than five per cent of the total membership.

All **CNS Branches** and **Technical Divisions** are encouraged to forward confidential nomination statements, signed by three members, to the Chairperson of the CNS Honours and Awards Committee before April 15, 1995. Alternatively, any three CNS members, not necessarily of the same Branch or Division, may together forward a nomination. The nomination statement should include a focused rationale for the nomination, supported by information on the candidate's:

(i) formal education or equivalent,
(ii) work history, professional achievements, publications and patents,
(iii) experience, demonstrated maturity of judgement and contribution to Nuclear Science and Technology, and
(iv) past services to the CNS.

The Honours and Awards Committee will consider the above criteria with weights of 20%, 20%, 25% and 35%, respectively.

Please forward nominations prior to April 15, 1995 to:

The Secretary
CNS Honours and Awards Committee
144 Front Street West, Suite 725
Toronto, Ontario M5J 2L7

The following CNS members are Fellows of the Canadian Nuclear Society:

George R. Howey	1992
John S. Hewitt	1992
Phillip Ross-Ross	1992
John S. Foster	1993
Terrance E. Rummery	1993
Kenneth H. Talbot	1993
Alan Wyatt	1993
Fred Boyd	1994
Stan Hatcher	1994
Daniel Rozon	1994

CNS Innovative Achievement Award

The Innovative Achievement Award was established by the CNS in 1991. Recipients of the award are specially recognized for *"significant innovative achievement or implementation of new concepts in the nuclear field in Canada."*

The award trophy, on which all recipients' names are inscribed, is in the form of an original sculpture showing three figures supporting the Society's logo. Each recipient retains a miniature replica of one figure from the sculpture, as well as a commemorative certificate presented at the Annual Conference of the CNS.

Members of the Society are strongly encouraged to nominate individuals who have made key contributions to a specific innovation. Such contributions should have been to the conceptual, design, development or implementation phase of the innovation, or to a combination of these phases.

Nominations letters should be signed by three persons and accompanied by:

(i) a short biography,
(ii) a description of the particular innovative achievement for which the award would be made, and
(iii) a well focused rationale supporting the nomination.

Please send your nominations in confidence, before April 15, 1995, to: The Secretary
CNS Honours and Awards Committee
144 Front Street West, Suite 725
Toronto, Ontario M5J 2L7

Previous recipients of the CNS Innovative Achievement Award:

William G. Morison	1991
Wing F. Tao	1991
Andrew J. Stirling	1992
Dé C. Groeneveld	1993
Tom Holden	1994

CNS Team Achievement Award

The Team Achievement Award was established by the CNS in 1994. Recipients of the award are specially recognized for *"outstanding team achievements in the introduction or implementation of new concepts or the attainment of difficult goals in the nuclear field in Canada."*

The award is in the form of one or more engraved plaques or certificates presented to the members of the team presented at the Annual Conference of the CNS.

Members of the Society are strongly encouraged to nominate teams of generally not more than five persons who have made key contributions to the introduction or implementation of new concepts or the attainment of difficult goals in the nuclear field in Canada. Such contributions should have been to the conceptual, design, development or implementation phase leading to the achievement, or to a combination of these phases.

Nomination letters should be signed by three persons and accompanied by:

(i) a short biography of each team members,
(ii) a description of the particular achievement for which an award would be made, and
(iii) a well focused rationale supporting the nomination.

Please send your nominations in confidence, before April 15, 1995 to: The Secretary
CNS Honours and Awards Committee
144 Front Street West, Suite 725
Toronto, Ontario M5J 2L7

Branch News

Bruce

Eric Williams, of Bruce 'A' NGS, has taken on the chair of the CNS Bruce Branch. He attended the CNS Officers' Seminar last fall and recently has met with CNS Vice-president Jerry Cuttler and Bruce 'A' Director Ken Talbot (a former president of the CNS) to plan programs and strategy. More news next issue.

Chalk River

The active Chalk River Branch has already had three meetings, in November, December and January with speakers David Thomas, AECL Executive Vice-president Finance and Administration; Dr. Jack Cornett of CRL; and Dan Meneley, Vice-president and chief engineer at AECL CANDU. Jerry Cuttler gave a special talk January 16 on the Pickering unit 2 incident of December 10, 1994.

On January 26, Ben Rouben of AECL CANDU is scheduled to speak on "Fast transient analysis" (jointly with CRL weekly colloquium). Further speakers lined up are:

March 21	Bal Kakaria, Vice-president marketing, AECL CANDU
April 26	Dr. Brian Miki on biotechnology in forestry (jointly with Algonquin College, Pembroke)
May 1	Don Anderson, GM of Ontario Hydro Nuclear on Ontario Hydro's nuclear program
May 24	AGM with Ken Petrunik, Vice-president, projects, AECL CANDU, providing an update on Cernavoda
June 20	Reid Morden, President and CEO, AECL.

The Branch is taking the lead in organizing a 50th anniversary celebration of the first criticality of ZEEP, including a seminar to be held September 5 and 6 at Chalk River Laboratories.

The annual Science for Educators seminar will be held April 27 to 29.

Darlington

The newly constituted branch at Darlington has a full program, largely due to a new member of the executive, Vic Luukonen.

On November 22, Dr. Conrad Nagle, chief of nuclear medicine at William Beaumont Hospital in Troy, Michigan, drew a large audience for his talk on "Recent Developments in Nuclear Medicine" and January 13, Don Lawson, president of AECL CANDU, presented "CANDU in the World Energy Scene".

Upcoming talks are:

- Jan. 13 Dr. Jack Cornett, "Tritium and Carbon 14 releases at CANDU stations"
- Jan. 24 John Graham, vice-president ANS, "Nuclear program in the U.S.A."
- Feb. 22 Robert Nixon, chairman AECL, "Nuclear Energy and Public Policy - One Man's Opinion"
- Mar. ?? Paul Thompson, Point Lepreau NGS, "PHT detritiation"
- Apr. 26 Bruce Lang, "Disposal of Nuclear Waste"

Other talks and activities are being planned.

Golden Horseshoe

A number of seminars are planned including waste management, plutonium burning, nuclear medicine; but the detailed schedule was not available at time of printing.

Manitoba

In November David Iftody, MP for Provencher, spoke on "Importance of nuclear energy to Canada."

Planned are:

- Jan. 25 Ralph Hart, AECL CANDU, "Options for CANDU 9". (Ralph will also participate in a panel discussion on "Celebration of life and learning" at U of M Jan 26.)
- Feb. 7 Dr. Merv Billinghurst, Health Sciences Centre, Winnipeg, on "Radiopharmaceuticals in nuclear medicine"
- Mar. 8 Jim Johnson, former GM MHWMC will speak on "Manitoba hazardous waste management facility - go or no go ?"
- Mar. ?? Claudio Chuaqui, AECL Research on attachment to Cadarche, France, on "The Phebus Program at Cadarche"

The Branch is very much involved with the CNS/CNA Annual Student Conference which will be held in Winnipeg, March 9 to 11. Dr. Agnes Bishop, president of the AECB, will be the guest speaker at the conference dinner.

Chuck Vandergraaf, past president of the Branch is on the organizing committee for the International Conference on Deep Geological Disposal of Radioactive Waste to be held in Winnipeg, September 16 to 19, 1996 and the Branch will be assisting.

New Brunswick

In November Ian Lee of the AECB gave a talk on "Recent developments at AECB" and on December 6 Kamal Verma, of Point Lepreau, spoke on "Steam generator chemical cleaning".

Proposed for the new year are talks by Malcolm Callister on "CANDU perspective on environmental qualification", and Roger MacKenzie, on "A tour of Maritime Nuclear".

A Malcolm Lightfoot memorial scholarship will be created at Saint John High School.

The branch AGM will be held in April.

Ottawa

In November the Branch co-sponsored a workshop by R. Dunders of CRL on "Managing low-level radioactive waste".

On February 9 Ken Kozier, AECL Research, will speak on "Space Nuclear Reactors". This meeting is co-sponsored by the local chapter of the Canadian Aero-Space Institute. In early March Dr. Griebenow Merle, from Idaho Falls, will talk about "Boron neutron capture therapy".

The annual banquet will be held in late April.

The Branch is assisting with the Ottawa Regional Science Fair and is organizing a trip for high school students to Nordion and Theratronics.

Quebec

Plans are underway for talks on RBMK, waste management and effects of radiation on health but details were not available at time of printing.

A visit is planned to the IREQ tokamak facility at Verennes.

Saskatchewan

An up-to-date report on the Branch activities was not available. Members of the Branch are very involved with planning for the Annual CNA/CNS Conference which will be held in Saskatoon, June 4 to 7.

Branch members are working on submissions for the environmental review of Cigar Lake and the nuclear fuel waste disposal concept.

Sheridan Park

Dr. Conrad Nagle gave a repeat of his talk to the Darlington Branch on November 20. In December, AECL CANDU president Don Lawson spoke on "A review of CANDU in 1994 and challenges for the future".

On January 24, John Graham, vice-president ANS, will give a repeat of his talk on "The Nuclear Program in the U.S.A".

Prizes were awarded to students who wrote the best essays on trips earlier in the year to Pickering NGS and a prize is being given at the Peel Regional Science Fair.

Toronto

Prof. Ken McNeill spoke in November on "Nuclear emergency planning in Ontario" (see report by Ric Fluke).

On January 31, Stephen Yu, AECL CANDU, is scheduled to talk on "CANDU 9 in Korea" at Ontario Hydro instead of U of T. In February Dr. Ron Mitchell, CRL, will be speaking on "Health effects of low-level radiation".

ANNUAL CONFERENCE

The 16th Annual Conference
of the **Canadian Nuclear Society**
will be held in conjunction with
the 35th Annual Conference
of the **Canadian Nuclear Association**
in **Saskatoon, Saskatchewan**
June 4 to 7, 1995

For information on the CNS programme contact
Dr. Al Wight in Saskatoon
Tel. (306) 665-4841 Fax (306) 975-6159
or the CNA/CNS office, Toronto, (416) 977-7620

Women in nuclear meet

The first formal gathering of the Canadian chapter of Women in Nuclear (WIN) took the form of a luncheon meeting in Ottawa on December 2, 1994 with about 50, mostly women scientists and engineers, attending. The half dozen men in attendance appeared to be somewhat ill at ease with this unusual balance.

Dr. Agnes Bishop, recently appointed president of the Atomic Energy Control Board, the guest of honour, spoke on "WIN and Pediatrics — Lots in Common." Dr. Bishop, a pediatric oncologist, talked about the difficulty of achieving informed consent, referring to her experience in dealing with parents of a child with cancer. Suggesting an analogy with communication with the public on nuclear issues Dr. Bishop noted that "inform" is not the same as "educate." Education often has the undesirable connotation of persuasion, she commented.

WIN is an association open to women nuclear professionals and communication specialists. The primary aim of the organization is to support women and inform members of the public about nuclear energy and radiation. Established in 1992 WIN now has chapters or representatives in 18 countries.

The Canadian chapter is sponsored by the Canadian Nuclear Society. CNS council member Fran Lipsett, of CRL, has been the main organizer.

CNS Safety Course

Fifty-five people attended the CNS sponsored Reactor Safety Course held in Oshawa last November.They came from AECL Research, AECL CANDU, Ontario Hydro, Hydro Quebec, AECB, and the Royal Military College.

The lecturers, all of whom had volunteered their time, came from AECL CANDU, Ontario Hydro, Hydro Quebec and a consulting firm. In the two-day course they presented the history and development of the Canadian approach to reactor safety, nuclear physics related to safety, operational aspects, and, the major topic on the second day, the problem of ageing.

In the words of Morgen Brown, a research engineer at the Whiteshell Laboratories, as published in AECL Research's INTER-COMM newsletter, "The CNS Reactor Safety Course was well worth attending and enhanced this writer's appreciation of the complexity of safely operating and managing a CANDU reactor."

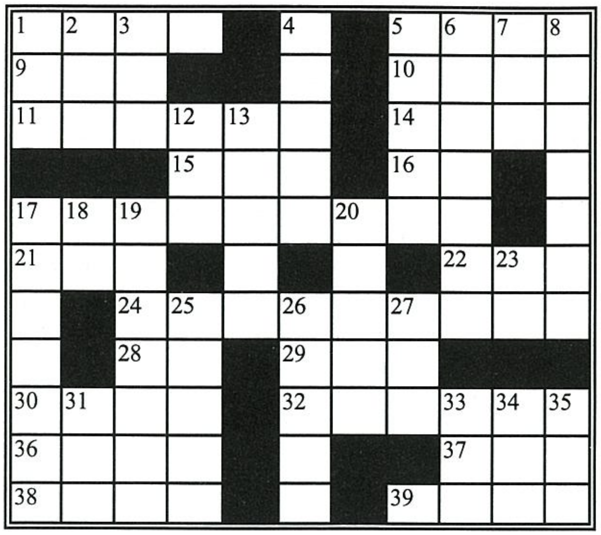
Given the response, the CNS council is looking forward to repeating the course next in late 1995 or early 1996.

STUDENT CONFERENCE

The 20th CNS/CNA Annual Student Conference will be held at the University of Manitoba in Winnipeg, March 9-11, 1995. Students involved in nuclear science or engineering are invited to participate. Some sponsorship is available.

Contact Paul Driver, AECL Research, Whiteshell Laboratories, Pinawa, Manitoba R0E 1L0; Tel. (204) 753-2311, ext. 2990; or your local CNS branch; or the CNA/CNS office in Toronto, tel. (416) 977-7620

The Cross Section: No. 1 (Easier)



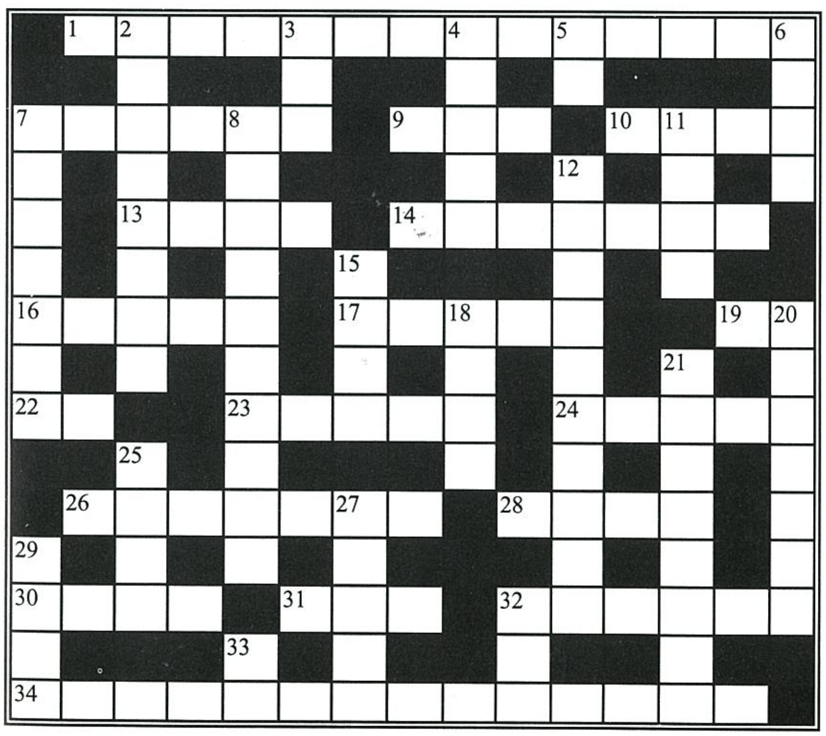
Across

1 Part of a valve (4)
5 Labourer unpopular with the union (4)
9 Mathematical term (abbr) (3)
10 Power unit (abbr) (4)
11 Lubricant (6)
14 Utterance to conclude mission statement (4)
15 Type of experimental power generation (abbr) (3)
16 Element in pressure tube alloy (2)
17 Italian tenor beloved of many nuclear engineers (9)
21 Pride or high self regard (3)
22 Chalk River reactor (abbr) (3)
24 Engineering colleague in Hydro-Quebec (9)
28 FORTRAN loop (2)
29 Japanese computer equipment manufacturer (3)
30 To improve text (4)
32 They spin discs (6)
36 Known for ice cream and mathematical sections (4)
37 Air coolers in reactor vault (abbr) (3)
38 Applied to equipment during maintenance (4)
39 Attribute of fundamental particles (4)

Down

1 Pressure tubes are subject to this (3)
2 What engineers try not to do (3)
3 As this increases, reactors decline (3)
4 A statement of belief (5)
5 An incline (5)
6 Spreadsheet operation (7)
7 To do a good job (3)
8 Francophone greeting (7)
12 American medical society (3)
13 What 24 across does, gallically, when faced with the inevitable (5)
17 The best engineers can be (7)
18 Metal used in control rods and photography (2)
19 Formation of steam bubbles in the core (7)
20 Essential material for photocopiers (5)
23 Element 44 (2)
25 The product of lectures (5)
26 FORTRAN statement (5)
27 U.K. plastics manufacturer (3)
31 Dead on arrival, like some engineering jobs (abbr) (3)
33 Subscript indicating gas phase (3)
34 Provides core cooling during accidents (abbr) (3)
35 Computer manufacturer (3)

The Cross Section: No. 1 (Harder)



Across

1 Radiant German brakes (14)
7 French stone, but Marie liked him (6)
9 Single projectile for a type of air rifle is also reactor vendor (3)
10 Belt of scotch flowing like this is bad for piping (4)
13 Fusion machine at Princeton (abbr) (4)
14 Architectural element plus home for bees equals old document repository (7)
16 Slogan for conference is signature tune (5)
17 Inventor of manometric speedometer (5)
19 Implicated in Napoleon's demise, like (2)
22 Registered nurse in mines (2)
23 Italian physicist of squash court fame (5)
24 Reduces dimensions by a whisker (5)
26 Rhonda's confused by fundamental particles (7)
28 First reactor at Harwell (4)
30 Rend decoded describes hacker (4)
31 Component of stainless steels (3)
32 RHS is zero (3,3)
34 Jay not a solution for this German's expression (6,8)

Down

2 German discovered unknown ray ((8)
3 Standard hydrogen electrode Must Be Obeyed (3)
4 Strengthening member set in concrete (5)
5 Lifts balloons but Must Obey (2)
6 A gig, replayed, becomes prefix (4)
7 Hint or clue is also dog and lecturing aid (7)
8 New Zealander fires at gold toil at McGill (10)
11 Enjoy yourself but not by touching this wire (4)
12 Bleached mollusc research in Manitoba (10)
15 Company famous for space arms (4)
18 Voyage or stumble that breaks the chain (4)
20 Cathedral in Vienna is constant in radiance (7)
21 Lone pine is home to EPRI (4,4)
25 Even in Quebec; two in Ontario (4)
27 Darlington made too much of this (5)
29 Buns can otherwise mean rejection (4)
32 Programming language makes public prosecutor (3)
33 Element gives command to exist (2)

The solution for the Crossword puzzles will be published in the next issue. If you wish to receive a FAX copy earlier please contact the editor.

Calendar

1995

Feb. 6-7 — **CNA/CNS Winter Seminar**
Ottawa, Ontario
contact: Sylvie Caron
CNA/CNS office
Toronto, Ontario
Tel.: 416-977-6152 xt18
Fax: 416-979-8356

March 9-11 — **CNA/CNS Student Conference**
Winnipeg, Manitoba
contact: Sylvie Caron
CNA/CNS office
Toronto, Ontario
Tel.: 416-977-6152 xt18
Fax: 416-979-8356

April 4 — **KAIF-CNS Meeting**

April 6-7 — **KAIF Annual Meeting**
Seoul, Korea
contact: Ian Wilson
CNA/CNS office
Toronto, Ontario
Tel.: 416-977-6152
Fax: 416-979-8356

April 10-12 — **Japan Atomic Industry Forum**
Tokyo, Japan
contact: Sylvie Caron
CNA/CNS office
Toronto, Ontario
Tel.: 416-977-6152 xt18
Fax: 416-979-8356

April 24-28 — **Safety Culture in Nuclear Installations**
Vienna, Austria
contact: Ms. A. Carnino
c/o IAEA - NENS
Vienna, Austria
Fax: 43-1-334-564

May 7-12 — **International Conference on Isotopes**
Beijing, China
contact: Prof. Lin Qiongfang
Chinese Nuclear Society
P.O. Box 275-12
Beijing, China, 102413
Fax: 86-1-935-7195

May 8-12 — **Two-phase Flow and Heat Transfer Course**
Hamilton, Ontario
contact: Betty Petro
McMaster University
Hamilton, Ont.
Tel.: 905-525-9140 Ext. 24881
Fax: 905-526-7104

May 16-18 — **Annual Meeting on Nuclear Technology**
Nuremburg, Germany
contact: Dr. K.G. Bauer
INFORUM GMBH
Bonn, Germany
Tel.: 49-02-28-507-0
Fax: 49-02-28-5072-19

May 23-26 — **CRPA Annual Conference**
Halifax, Nova Scotia
contact: G. Mawko
Victoria General Hospital
Halifax, NS
Fax: 902-426-2018

May 23-26 — **Mass Transfer in Severe Reactor Accidents**
Cesme, Turkey
contact: Dr. J.T. Rogers
Carleton University
Ottawa, Ontario
Tel.: 613-788-5692
Fax: 613-788-5715

May 28-June 3 — **5th Topical Meeting on Tritium Technology in Fission, Fusion and Isotopic Applications**
Ispra, Italy
contact: Dr. H. Dworshak
Joint Research Centre,
Ispra, Italy
Fax: 39-332-789-108

May 29-31 — **Topical Meeting: Managing Plant Life**
Nice, France
contact: Dr. Serge Charbonneau
Paris, France
Fax: 33-1-47.96-01-02

June 4-7 — **CNA/CNS Annual Conference**
Saskatoon, Saskatchewan
contact: Sylvie Caron
CNA/CNS office
Toronto, Ontario
Tel.: 416-977-6152 xt18
Fax: 416-979-8356

June 12-13 — **Workshop on Management and Operation of Nuclear Power Stations Using Computer Systems**
Fredericton, New Brunswick
contact: Jill Feero
NB Power
Fredericton, NB
Tel.: 506-458-3177
Fax: 506-458-4249

June 25-29	**ANS Annual Meeting** Philadelphia, PA contact: ANS office Chicago, IL Tel.: 708-579-8258	**October 29 - November 2**	**ANS Winter Meeting** San Francisco, CA contact: ANS office, Chicago, IL Tel.: 708-579-8258
July 3-5	**20th Meeting of Latin American Section of ANS** Rio de Janeiro, Brazil contact: J. Spitalnik, Nuclen, Rio de Janeiro, Brazil Tel.: 21-552-0945 Fax: 21-552-2993	**November 20-21**	**3rd Conference on CANDU Maintenance** Toronto, ON contact: Mr. Tim Andreef Ontario Hydro Tel.: 416-592-3217 Fax: 416-592-7111
September ??	**CNA/CNS Fusion Seminar** Toronto, ON contact: Shayne Smith Wardrop Engineering, Tel.: 905-673-3788 Fax: 905-673-8007		
September 10-15	**NURETH-7 — International Meeting on Nuclear Reactor Thermalhydraulics** Saratoga, NY contact: Dr. Michael Z. Podowski Rensselaer University, Troy, NY Tel.: 518-276-6403 Fax: 518-276-4832		
September 17-23	**International Topical Conference on the Safety of Operating Reactors** Seattle, WA contact: Dr. D.J. Senor ANS, Richland, WA Tel.: 509-376-5610		
September 25-29	**GLOBAL '95, on the Back End of the Nuclear Fuel Cycle** Versailles, France contact: Dr. J. Y. Barre CEA, Saclay Gif-Sur-Yvette, France Fax: (33.1). 69.08.90.93		
October 1-4	**Fourth International Conference on CANDU Fuel** Pembroke, ON contact: Mark Floyd Chalk River Laboratories Tel.: 613-584-3311 ext. 3899		

1996

February ??	**Plutonium Disposition with CANDU** Ottawa, ON contact: John Luxat Ontario Hydro Toronto, ON Tel.: 416-592-4067
March 25-29	**Nuclear Industry Exhibition** Beijing, China contact: Xu Honggui Chinese Nuclear Society Beijing, China Fax: 86-1-852-7188
April ??	**Conference on CANDU Fuel Handling** location TBA contact: Ron Mansfield Mississauga, ON Tel.: 905-823-2624
September 16-19	**Deep Geologic Disposal of Radioactive Waste** Winnipeg, Manitoba contact: M.M. Ohta AECL Research, WL Pinawa, Manitoba Tel.: 204-345-8625 ext. 201 Fax: 204-345-8868

AECB appointments

The Minister of Natural Resources, Anne McLellan, announced January 20 the appointment of **Dr. Yves Giroux** to the Atomic Energy Control Board.

Dr. Giroux is a civil engineer with a doctorate in Structural Engineering and is currently Assistant to the Rector of Laval University in Québec. He has been a member of the AECB's Advisory Committee on Nuclear Safety since 1988.

Last summer the AECB gained another new member with the appointment of **Dr. Arthur Carty** as president of the National Research Council. Under the Atomic Energy Control Act the president of NRC is "ex officio" a member of the AECB board.

With these appointments the five member board of the AECB is at full complement.

The Darker Side

by George Bauer[1]

Since this is being penned in January, I will invoke the deity of the month to help me determine what I should say. You will remember that Janus had two faces and looked backward and forward at the same time. I plan to do something like this in the present column: look back at significant events (significant by my reckoning) and forward as required. In preparation, I have flipped through a few reviews of the past year. It makes for a good yuk, but it's not very accurate. First, a review of 1994's two biggest news items.

By far, the most significant event of 1994 was the decision by Ontario Hydro to ban the supply of coffee in meetings. This simple act demonstrated the power that a customer focussed organisation can wield. Within weeks of Hydro's decision, the international coffee markets had collapsed in chaos. Coffee prices shot higher than the men's change room in the Energym. Nets were seen stretched across Bay and King streets in Toronto. This was to limit the civic problem caused by scores of futures traders taking the easy way out. A few wisps of misinformation on the topic surfaced in the Canadian press, but the collective brain death of our tabloid gumshoes is well known. For example, they dutifully reported, like dumb beasts trudging back from the well, that a frost in Brazil (!!) had wiped out the coffee crop. (Did you, perchance, hear about the pineapple plantation in Moosonee?)

Best to start over again. Here's the scoop.

The whole thing hinged on a reactor sale. (Ever noticed how the most interesting news in the world these days is somehow related to reactor sales?) Anyroad, the Brazilians wanted to buy a power reactor. In the running to supply it were Canada and an unidentified European vendor. We were tipped to win it, but the lads across the pond weren't having that. So, evidently on the verge of panic, they financed a group called the Pugwash Tigers to stage a coup in Prince Edward Island. It was the best they could think of at short notice, but alas, poor dears, it didn't work for them. (Bet you didn't hear about all this in the papers. It was reported in only one, *The Ajax Composter*.)

It was this coup that got the Russians involved. They aren't interested in Prince Edward Island itself, but you will remember that the largest McDonald's in the world is in Moscow, and it was established by McDonald's Canada, and where do you think they get their chips...? Right. PEI. The Russkies were loaded for bear and the spuds were apiling up something awful in Charlottetown. It was a hitherto unknown expert in beta functions at Whiteshell who provided the answer.

For a few hours there was some mighty fax traffic between Moscow, Ottawa, Toronto, Brasilia and Pugwash. To placate members of the roughly 14,000 coffee clubs in Hydro, a story about rainforests and the healthful qualities of fruit juices was thrown together. When Hydro made its announcement about the coffee ban, the trap was sprung. The Brazilians were delighted. Due to the jump in coffee prices, revenue was now pouring in. Hell, they could afford two reactors. At the height of the euphoria, and rolling in loot, some of them even talked of financing a Brazilian AECB, but fortunately cooler heads prevailed. The Europeans were frozen out and they slunk off to contemplate undersize bananas and other things European. The Pugwash Tigers hadn't counted on the Russian connection and quickly back-pedalled. Reports persisted that five Russian missile subs, stuffed to the gunwales with spuds, *(question: does a submarine have gunwales?)* raced back to Archangel, but nobody would confirm them.

The second most discussed news of 1994 was Ontario Hydro's 37th reorganisation. To mark its completion, the insides of the elevators were painted black. (There was a sale of black paint at Canadian Tire about this time, but the two events were unrelated.) However, the reorg was not a complete success, and management is continuing its strenuous efforts, spurred on by strident complaints from human rights groups, to rescue the eight women who remain trapped somewhere within the elevator mechanisms.

There were also minor events during the year, of course. Some of the more noteworthy of them were:

- After a long debate, the Ontario government decided that legislating a negative tritium concentration for drinking water could have certain drawbacks.
- The ecological parkette next door to Pollution Probe was tastefully converted to a bus access route. To commemorate this event, the Madison Pub next door produced a new beer, ***Memories of Goldenrod***.
- The radiochemical laboratory at the University of Toronto was awarded a water conservation prize for achieving the greatest recorded MTBF (mean time between flushes).
- A nuclear watchdog organisation has discovered that levels of tritium have reached "five parts of our environment". Studies continue to determine whose parts are involved.
- A unit at Pickering holds a new record. This unit has now discharged more waste electricity into the environment than any other nuclear unit in the world. Staff are taking the news well.
- In 1994, Ontario Hydro's cumulative consumption of doughnuts surpassed McDonald's production of hamburgers. (McDonald's has demanded a recount.)
- As predicted, Conrad Black failed in a bid to gain control of the *CNS Bulletin*. It was to have been rechristened *Nukes of the World*.
- Prince Edward Island announced in October that it has developed nuclear weapons.
- And finally, in December, the Atomic Energy Control Board withdrew its earlier ruling that caesium is not a metal. At the same news conference, a Board spokesman scotched rumours that the AECB considers the pumpkin to be an endangered species.

So, what does 1995 hold? Jeanne Dixon won't help you. Watch this column.

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[1] George Bauer is the pen-name of one of the CNS' most literate members. We will accept guesses for the real name but offer no prizes.

Call for Papers

3rd CNS International Conference on CANDU Maintenance
to be held in Toronto, November 19-21, 1995
Papers on all aspects of the maintenance of CANDU nuclear power plants are invited.
A summary of 500 words or less should be sent to

Tim Andreeff
Ontario Hydro
700 University Ave. H17
Toronto, Ontario M5G 1X6

FAX 416-592-5430

For general information contact Mark Brown, Bruce NGS 'B',
Tel. 519-361-5021 FAX 519-361-4998

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