CNS BULLETIN SNC

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Editorial

Orwell Plus One

It wasn't all that bad a year after all. For the Western world, at least, the more brutally dramatic features of *1984* failed to materialise, although Newspeak continued its insidious advance — most notably in a CBC radio "news documentary" on Canada's contribution to the increase in the availability of nuclear materials and technology for military purposes.

Also on the downside, in the US TMI Unit 1 remained shut down and the rehabilitation of TMI-2 proceeded with what appeared to be agonizing slowness. And in England the Sizewell Inquiry went on... and on...

But there was, at least on the domestic front, some cheering news. CANDU performance was, routinely, exceptional. Especially noteworthy was Ontario Hydro's Bruce "A" 4-unit installation, where a station average of over 90 percent was recorded. And progress so far on the retubing of the Pickering Units 1 and 2 was encouraging. Some more optimistic people were beginning to suggest that maybe retubing was going to be a little easier than had been thought originally.

An international workshop on irradiated fuel storage, held in Toronto last October, seemed to show that Canada was in a particularly enviable position in comparison with other countries, in that future irradiated fuel storage did not promise onerous costs, or require the urgent development and licensing of new storage systems.

For the CNS, as President Peter Stevens-Guille's "Mid-Year Report" in the CNS News section as this issue notes, 1984 was a productive year, especially in the area of international meetings, with 1985 holding even better prospects. Especially exciting is the fact that there seems to be growing off-shore interest in the Canadian nuclear scene, and a growing recognition that, as one visitor noted to us, "In Canada you don't just do things differently — you seem to do them right."

Technical Supplement

This issue marks another stage in the *Bulletin's* development — the introduction of a technical supplement. Our aim is to republish technical papers/articles which we feel will interest a broad range of CNS members. The process started informally in the September/October issue, with Dr. Pendergast's fascinating discussion of microcomputer applications in nuclear safety analysis, carried in the "Perspective" section. For making this mildly ambitious step possible our grateful thanks must be expressed to the authors (initially Dr. Pendergast and Dr. Field) for their permission to reprint their work. Also, and equally, we must thank Gould Graphic Services for devising an appropriate format for the Supplement and doing their usual first rate job against the usual very tight deadline. The confidence and encouragement of the CNS council has been invaluable (and, one hopes, not misplaced). And finally, all *Bulletin* readers, as well as the editor, should salute Production Editor David McArthur who saw the whole thing through with his usual conscientious efficiency, losing, in the process, little of his hair and none of his cool.

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Perspective

An Overview of China's Nuclear Power Development

Excerpts from the address by Professor Jiang Shengjie, President of the Chinese Nuclear Society and Director of the National Nuclear Safety Bureau, to the Toronto Branch of the Canadian Nuclear Society, November 19, 1984, at University of Toronto.

I am very glad that the agreement of cooperation between the Canadian Nuclear Society and the Chinese Nuclear Society has been signed. We believe, henceforth, that between Canada and China in the area of the peaceful use of nuclear energy, scientific and technological cooperation and exchange will be strengthened and the personal contact and friendship of scientists and engineers of these two countries will be developed. The cooperation agreement has many prospects. On this occasion, I would like to briefly give an overview of Chinese nuclear power development.

China began its nuclear activities in the 1950s. Thanks to the efforts made in the past thirty years, it has established a relatively complete nuclear industrial system and a nuclear research system including uranium geology, mining, conversion, enrichment, fuel-element manufacturing, reprocessing and waste management, etc.

In the field of reactor engineering, about ten reactors have been constructed in China. Through the design and construction of these reactors (production reactors, power reactors and experimental reactors) an experienced group of scientists and engineers has grown.

Isotope applications are also making headway in China. More than 10,000 scientists and technical personnel are now engaged in the research, production and application of isotopes. A number of institutes have been set up for the research of isotope products. Isotopes and radiation have successfully been applied to various sectors of the economy. In agriculture, we have so far cultivated over 160 new varieties of grain, oil-bearing crops, fibre crops, vegetables, fruit trees and mulberry trees by radiation breeding, many of which grow well in many parts of the country. In industry, the use of radiation instruments, radiography and radio-tracers as well as activation analysis and irradiation processing is on the increase. In the field of nuclear medicine, at present, more -than 700 medical units are using nuclear technology in clinical diagnosis and therapy, which in some areas, proves very successful.

Thus, in the field of nuclear energy utilization and the application of nuclear techniques, China already has a firm foundation.

In modern China, nuclear energy is one of the three main sources of energy for the generation of electricity. The Chinese goal that energy resource development match national economic growth is mainly dependant upon coal, assisted by hydro and nuclear power.

China has a vast territory and also is a developing country. The 12th National Congress of the Communist Party of China, held in 1982, set important policies for China's economic growth. In the twenty years from 1981 to 2000, the general strategic goal of the Chinese economy is to quadruple the national annual value of industrial and agricultural production, i.e. from 710 billion yuan (RMB) in 1980 to 2800 billion yuan in the year 2000. To fulfill this task, the average annual growth rate of GAIP shall be more than 7%. In order to keep pace with the economic growth the energy demand by the year 2000 has been estimated to be around 1.3 - 1.4 billion tons of coal equivalent (TCE), i.e., more than a two-fold increase, but the growth rate of electricity should be the same as that of industry, i.e., quadrupled.

It is estimated that by the year 2000, the total amount of electricity generated should be 1200 billion kWh to meet the needs of the country, in which 900 billion kWh (75%) comes from fossil fuel, 240 billion kWh (20%) from hydro power and 60 billion kWh (5%) from nuclear power. 75% of the total amount of electricity will be generated by burning coal. Though the coal consumption falls in old power plants due to technical improvements, yet 400 million tons of coal is necessary for electricity production. The energy shortage has seriously affected the growth of the national economy. Therefore, it is of prime importance for nuclear energy to supply electricity and heat in East China and northeast China where there is less coal and hydro resources.

From the long-term point of view, to maintain the environment, to solve the difficulties of the long distance transportation or transmission of coal or hydro electricity and the high power generation cost, and to conserve fossil resources as far as possible, the development of safe, clean, and economic nuclear energy and other energy resources is imperative.

The Energy Resources in China

Coal Up to 1980, verified existing coal reserves are about 600 billion tons in which carefully explored reserves are about 170 billion tons. Total prospective geological resources have been estimated at 1500-2000 billion tons.

Oil Total prospective oil resources are around 50 billion tons.

Hydropower Total hydro-electricity resources amount to an annual output of 1900 billion kWh, of which only 3% are being tapped.

Uranium and Thorium Verified uranium reserves are sufficient to meet military needs and to keep PWR nuclear power plants with a total capacity of 15,000MWe operating for 30 years. In many areas, geological surveys have yet to be made and new resources may be found. China also has abundant thorium resources which can be used in breeder reactors.

Although China has plentiful energy resources, the average value of energy resources per capita is very low and equals only one third the world's average.

China is rich in energy resources, but they are unevenly distributed. 61% of coal reserves are concentrated in North China, (Shanxi Province and Inner Mongolia), whereas the densely populated six provinces to the south of the Yangtze River and Shanghai have only 1.6% of the coal. In terms of hydropower which can be tapped, 71% concentrates in Southwest China, 11% in Northwest China, whereas in the above-mentioned energy-lacking region, there is only 5%. More than half of the oil deposits is in the Northeast part of China.

China's Nuclear Energy Policies

- We aim to build 10,000 MWe of nuclear power plants by 2000, especially in the coastal areas which are well developed in industry, and short of energy resources.
- The PWR is being regarded as the main reactor type for China's first generation of nuclear power plants by the year 2000. Units will be in the 1,000MWe range.
- Though China has the capability to design and develop nuclear power plants by its own efforts, yet we still want to import equipment and introduce technology from aboard for large-sized and advanced nuclear power plants so that much time can be saved. On the basis of foreign technology, which will be digested and mastered, China is to quicken its steps to establish and develop its own technology, make the equipment used in the plants themselves and build up the nuclear industry for civilian application.
- Nuclear fuels will be supplied on the basis of self-reliance. Production of enriched uranium must be expanded, the exploration of uranium resources strengthened and economically reasonable reserves expanded.
- To conserve natural uranium and separation work, spent fuels will be reprocessed to separate uranium and plutonium, which will be recycled.
- In China, fossil fuel is mainly used to supply heat with low efficiency. An effective way to solve energy problems in the areas short of energy resources is to use nuclear power instead of oil. Therefore, the reactor technology we have now, should be used to develop nuclear power plants to produce process heat and space heat in low temperature areas.
- Final disposal techniques for the radioactive wastes produced in nuclear power plants and the rest of the nuclear fuel cycle will be researched.

The Present State of Nuclear Power Development in China

The Qinshan 300MWe PWR Nuclear Power Station. The research and development work for Qinshan 300MWe PWR nuclear power station started in the mid-seventies. Due to the efforts in those days, a large amount of R&D has been done, such as the work concerning nuclear fuel assemblies, zirconium alloys, pressure vessel steels, control rod drive mechanisms as well as reactor physics, thermohydraulics, etc. The preliminary design of NSSS has been completed and approved. The site was approved at Qinshan, Zhejiang Province (East China). Construction began on June 1, 1983. The excavation of one million cubic meters of earth is due for completion by the end of 1984, and the concreting will begin in the new year, and commissioning in 1989.

The main purpose of constructing this 300MWe nuclear power station is to gain experience and knowledge in the whole

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CNS provides Canadians interested in nuclear energy with a forum for technical discussion. For membership information, contact the CNS office, a member of the Council, or local branch executive. Membership fee is $30.00 annually, ($5.00 to students).

La SNC procure aux Canadiens intéressés à l'énergie nucléaire un forum où ils peuvent participer à des discussions de nature technique. Pour tous renseignements concernant les inscriptions, veuillez bien entrer en contact avec le bureau de la SNC, les membres du Counseil ou les responsables locaux. La cotisation annuelle est de $30.00 ($5.00 pour les étudiants).

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range of work, from engineering design, equipment manufacturing, construction, commissioning and operation, to the training of both technical and managerial personnel, and building up an industrial infrastructure.

The Jinshan 450MWt PWR Nuclear Power Station. Nowadays, fossil fuel is mostly consumed to supply industrial and district heating (approximately 70% of total fossil fuel) instead of electricity. As the oil supply is becoming ever-increasingly tight, and as oil is needed for export, the idea of using coal and nuclear energy in place of oil to supply industrial heat is being considered. However, since the capacity of the industrial heat network is generally quite limited and transport of heat is far more difficult than electricity, plants must be relatively small-sized. Nevertheless, the thermal efficiency of nuclear power plants for sole electricity generation is only about 30%, which is much lower than that of dual purpose plants, being above 90%. Thus, in spite of the relatively higher construction cost per kW of these medium to small-sized plants, they can still yield excellent economic benefits.

The idea of using nuclear energy to provide steam for petro-chemical works, paper mills and others is being studied now. Big petrochemical complexes such as the Jinshan Petro-Chemical Complex of Shanghai need large quantities of steam for processing. In Jinshan, steam is supplied by oil-burning boilers. Being a valuable raw material for chemical industries, oil supply is becoming tight, and after the completion of the second stage of construction which is now going on, oil supply at Jinshan will be even tighter. The coal option has been proposed and studied, but transportation difficulty seems insurmountable and the dust and detrimental gases released from the burning of coal must be considered.

Therefore, the nuclear option of a 450MWt small nuclear power unit was put forward. In order to ensure the reliability of steam supply, the nuclear power plant will comprise two reactor units, each of which can provide saturated steam of 500 tons per hour and at a pressure of 16 kg/cm^2. The feasibility study and the preliminary design are underway.

The study and design of a low-temperature reactor for district heating is also underway. It is planned that a 500MWt commercial size reactor will be built in one of the big cities in northeast provinces, i.e., Shengyan, Xarbin, etc., in the late 1980s.

The Quangdong 2x900MWe PWR Nuclear Power Station. The Quangdong nuclear power station is a joint venture between Quangdong Province and the China Light and Power Company in Hong Kong. The feasibility study was approved by our government last year. The NSSS supplier is Framatome and the turbine-generator set will come from GEC. The equipment supply contract will be signed in the near future. This nuclear power station will be completed in Daya Bay (Quangdong Province) around 1990.

Early work on plans for nuclear power stations to be built on the east coast and northeast coast of China have been prepared. Each nuclear power station will be 2x900MWe PWRs. The civil work on these two nuclear power stations is expected to start before 1990.

Development of New Reactors

The development of new reactor types should be carried out on the principles of "spending less money while doing more work," with special investment and by the cooperation with foreign countries.

China has been developing the scientific research work on fast neutron breeder reactors for the full utilization of its uranium and thorium resources. We plan to construct an experimental fast reactor around the year 2000, so as to get technically ready for commercial fast reactors to be constructed in the 21st century.

The high temperature gas-cooled reactor is a multi-purpose reactor type. It can give process heat at high temperatures, which can be used for gasification and liquifaction of coal and their related procedures. Research work is underway. We hope to build an experimental high temperature gas-cooled reactor in the latter 1990s for hot extraction experiments in densely-characterised oil fields.

Further development of energy resources will have to turn to the application of controlled thermonuclear fusion. We shall have to strengthen the techniques of controlled fusion and combine our scientific research work with international cooperation. We shall strive to make the "451" Tokamak reach its design goals before 1990, to prepare for construction of a break-even fusion experimental facility.

The achievements of the above projects in the eighties would enable us to lay a solid foundation for further developing nuclear power in the nineties. This is consistent with the general development proclaimed by Hu YaoBan in connection with the economic construction of China: the economic construction during these 20 years should be divided into two steps. In the first 10 years, the main task is to lay down a good foundation, to develop technical forces and to create necessary conditions; the following 10 years will be a period characterized by economic-boom.

The National Nuclear Safety Bureau

The Chinese Government pays much attention to the safety of nuclear power plants and recently has set up the National Nuclear Safety Bureau (NNSB) in charge of all domestic nuclear safety issues.

The NNSB is a special agency to audit, review and regulate nuclear installations and to direct and coordinate safety research work in China.

The general principle on nuclear safety in China conforms to international practices. That is to protect the safety of the site personnel, the public, plant facilities and to guarantee environmental protection.

Since we are just starting China's nuclear program, we have less achievement on safety research in China to date. The exchange and cooperation with other countries in the field of nuclear safety is warmly welcomed. We appreciate the two years of fruitful cooperation between China's State Science and Technology Committee and the US NRC. We hope such cooperation will be strengthened and enlarged.

The peaceful use of nuclear energy will be strengthened by international cooperation and the cooperation between Canada and China. China began participating in the IAEA on January 1, 1984.

In summary, there are now two nuclear power stations under construction and the early work of the other two nuclear power stations has been prepared. The nuclear power steering group of the State Council had been set up and a moderate nuclear power development program is underway. The National Nuclear Safety Bureau has been set up. The prospect of nuclear power development in China is bright.

International Cooperation

We are willing to strengthen the cooperation of science and technology with foreign countries in the field of peaceful uses of nuclear energy. Agreements of cooperation have already been signed with France, the Federal Republic of Germany, Italy and Brazil.

Negotiations with the United States for an agreement of cooperation in the peaceful use of nuclear energy have met with some difficulties although the two governments initialled an agreement in April 1984, but we are sure that the existing problems will be solved through the joint efforts of the two countries.

Now the science and technology cooperation agreement between the Canadian Nuclear Society and the Chinese Nuclear Society has been signed. We believe the cooperation between these two countries will develop. Although the type of reactor to be used in our nuclear power stations (China's first generation nuclear power reactor is PWR) is different from Canada's, there are many areas of possible cooperation. Some HWR technologies and experience may be very useful to us because we have a heavy water experimental reactor, and some may be used in the PWR. These include:

- Uranium geology, mining, etc.
- The production and application of isotopes.
- The research, design and application of small reactors, such as SLOWPOKE and district heating reactors.
- Waste management.
- Personnel training.

In brief, Canada's nuclear science, uranium technology, heavy water reactor, isotopes, etc., are well advanced and have special characteristics. We can learn from Canada. We believe the prospect of cooperation is vast and shall be developed.

We believe that through the efforts of our people, in conjunction with technology transfer from abroad and assimilation of others' experience, we shall be able to realize our plan and make nuclear energy an important factor to satisfy China's energy needs and to make our contribution to the peaceful use of nuclear energy.

Jiang Shengjie

FYI

Rick Bonalumi in Hospital (Staff)

All CNS members will be distressed to hear that Rick Bonalumi suffered a serious health setback at the end of the year. He is presently in Mount Sinai Hospital in Toronto and could be sent greetings.

Dan Meneley Receives International Appointment (Staff)

Dan Meneley has been invited to serve as Canadian representative on the IAEA's International Nuclear Safety Advisory Group. This newly constituted group, consisting of experts from national regulatory authorities, research organizations and industry, has been formed not to produce standards or exercise regulatory powers, but rather to work towards commonly agreed international nuclear safety objectives.

John Hewitt Joins Submarine Firm (Staff)

John S. Hewitt has joined Energy Conversion Systems Inc. in Ottawa to head the reactor development group. Dr. Hewitt is Immediate Past President of the Canadian Nuclear Society and was Professor of Applied Nuclear Studies at the University of Toronto. ECS is developing a nuclear-powered submarine work system.

Sligl Joins EMR (Staff)

V.R. (Rudy) Sligl has been appointed to a rotational assignment as Advisor, Nuclear Power, with Energy, Mines and Resources Canada. He will advise the federal government on all aspects of nuclear power generation and will liaise between government, nuclear industry and utilities.

Maritime Nuclear Reduces Expenditures (Maritime Nuclear)

Maritime Nuclear has decided to reduce expenditures on its operations in Fredericton until conditions warrant a return to earlier activity levels.

In a news release in January, it announced that to date much pre-project work has been completed and results have confirmed the commercial and economic viability of the Point Lepreau 2 concept and provided confidence in approaching the regulatory approval process. This work has also provided project sponsors with assurance that the project could meet realistic construction schedules within existing cost estimates. However, it has become increasingly evident that markets for the power to be generated are going to take longer to develop than previously envisaged and without such firm contractual commitments, the project cannot proceed.

Both Atomic Energy of Canada Ltd. and New Brunswick Electric Power Commission will continue with diligence their efforts in support of project realization.

In February 1983, Atomic Energy of Canada Ltd. and New Brunswick Electric Power Commission signed a Memorandum of Understanding which set out an agreed approach to determine jointly the feasibility of constructing a second 600 megawatt CANDU Reactor to be known as Lepreau 2 at the existing Lepreau Nuclear Generating Site.

AECL, with the approval of the federal government, agreed to fund pre-project commitment expenditures against a planned start of construction in late 1984.

AECL Lays Off 540 (Staff)

Atomic Energy of Canada Ltd. announced in February it would be laying off 500 employees at AECL CANDU Operations in Mississauga and another 40 employees from its Montreal office. More than 240 highly qualified engineers and scientists will lose their jobs. The reductions were necessary due to the winding down of construction of CANDU nuclear power plants in Ontario and abroad, and due to the lack of new orders. The new reductions, coupled with the first layoffs of 600 in 1983, mean that the AECL workforce in its nuclear design bases of Mississauga and Montreal will be reduced by about half by the end of this year. AECL indicated "The reduced staff level will enable the company to maintain commercial and technical viability during this period of slow growth in electricity demand and to respond to improved prospects for the nuclear power industry in the longer term as the demand for electricity increases."

AECL Radiochemical Reorganized (Staff)

Management and operations of the medical products division of Atomic Energy of Canada Ltd. Radiochemical Co. have been separated from the highly successful radiochemical division. The move is part of an effort to increase efficiency in the medical products division, which laid off 240 employees last year. The division is facing increasing competition from international manufacturers of cancer treatment products.

Graphite Moderated Reactor Designed at WNRE (Staff)

Atomic Energy of Canada Ltd.'s Whiteshell Nuclear Research Establishment in Manitoba has completed a conceptual design of a new reactor in a joint project with the US Department of Energy.

The reactor would provide electricity for up to 20 years, generating about 20 kilowatts of electricity from about 65 kilograms of 20% low-enriched uranium fuel.

The reactor would be graphite moderated, heat pipe cooled, and with its intrinsic safety features, would be capable of operating for long periods of time unattended.

The reactor could be used to supply power to remote locations, and would be "disposable" after its 20 year lifetime expired.

It is conceptually different from the SLOWPOKE-3 which is also under development at Whiteshell Nuclear Research Establishment.

AECL Develops New Research Reactor Concept (Chalk Talk)

A new reactor is on the drawing board for Chalk River. The MAPLE-X (Multipurpose Applied Physics Lattice Experimental) will be developed for two purposes: first, as a dedicated isotope production facility (DIPF) and second, to demonstrate a research reactor type for sale to developing countries initiating their nuclear programs.

The MAPLE-X has key features of an uprated SLOWPOKE reactor and a "mini-NRX": It would be rated at 10 megawatts thermal (upgradable to 20 MWth), light-water moderated and cooled, with a heavy water reflector. It would use low-enriched uranium fuel, and will be built within the existing biological shield of the NRX reactor, using much of that reactor's hardware and facilities. AECL's future plans are to decommission NRX and mothball WR-1 research reactors for economic reasons, with NRU becoming the company's sole research reactor. As such, NRU would be unavailable to supply the AECL Radiochemical Company with important short-lived medical isotopes such as molybdenum-99.

The proposed schedule calls for the conceptual design to be completed by April 1985 and the detail design to start in May. NRX would be shut down in June 1987, with first critically for MAPLE-X in April 1988. A useful life of 20 years is envisaged.

CANDU LOCA Study Completed For AECB (AECB)

The Atomic Energy Control Board has released the results of the study "Thermal and Hydraulic Behaviour of CANDU Cores Under Severe Accident Conditions."

This report gives the results of a study of the thermo-hydraulic aspects of severe accident sequences in CANDU reactors. The accident sequences considered are the loss of the moderator cooling system and the loss of the moderator heat sink, each

TECHNICAL SUPPLEMENT

CNS Bulletin January/February 1985 Canadian Nuclear Society

ANALYSIS OF THE PRESSURE TUBE FAILURE AT PICKERING NGS "A" UNIT 2

Paper Presented at the 23rd Annual Conference of Metallurgists, Quebec City, Quebec, August 19-22, 1984

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Abstract — *The failure of a Zircaloy-2 pressure tube in Pickering Unit 2 in August 1983 has been found to have been caused by an accelerated pickup rate of deuterium, contact between the pressure tube and its surrounding calandria tube, and rapid growth of zirconium hydride blisters.*

The pressure tubes in all later CANDU reactors are made from a zirconium-niobium alloy. Examination of several Zircaloy-2 and zirconium niobium pressure tubes from different reactors has clearly shown that the deuterium pickup rate of the two materials is significantly different. The zirconium niobium pressure tubes have absorbed very little deuterium and they do not appear to be susceptible to the type of failure experienced at Pickering Unit 2.

INTRODUCTION

About noon on August 1, 1983, the pressure tube in fuel channel G16 of the Pickering NGS A Unit 2 reactor developed a critical through wall crack and failed by fast fracture after 342 days of continuous full power operation.

Following removal of the fuel, a TV inspection inside the fuel channel revealed an axial crack in the bottom of the pressure tube approximately 2 metres long, in which two fuel pencils were lodged.

After extracting the fuel pencils, the fuel channel was removed and shipped to the Atomic Energy of Canada Limited's Chalk River Nuclear Laboratories (CRNL) for detailed examination to determine the cause of failure.

Examination of failures normally takes a course of looking at the fracture and gradually refining the work into finer detail to determine the actual origin of the failure. In this case, several other aspects also needed to be examined. The position of the garter spring was very important, as was examination of the calandria tube which was subsequently removed. During the inspection, several other fuel channels in Pickering A, Bruce A and NPD reactors were inspected, and some removed for further assessment at CRNL. All these aspects came together to outline the cause and mechanism of failure. The following gives a very brief review of the salient features of the examination of Zircaloy 2 and zirconium niobium pressure tubes and the implication for operation of subsequent reactors which have zirconium niobium pressure tubes.

EXAMINATION OF PRESSURE TUBE P2 G16

Visual

The examination of the outside of the pressure tube began with a close inspection using a Questar Telescope through 12 feet of water in the fuel bay at CRNL. This was the first time the actual extent of the crack could clearly be seen. The crack was very long extending from just inside the rolled joint to a point about two metres along the tube (approximately the design location of the outlet garter spring). It ended at this point in a T configuration of two circumferential tears from the axial crack. Parts of the fracture surface could be seen which showed a radial crack in many areas but developing into a ductile failure towards the outboard end of the crack. Near the T of the crack several dark round marks could be seen which were unexpected. About 14 of these were seen in the zone from about 1.5 metres to 2 metres from the outlet end of the pressure tube. The marks and the crack can be seen in Figure 1 along with the inside and outside of the calandria tube which is discussed later.

When the tube was cut lengthwise to allow closer examination, the unexpected marks were seen to extend into the pressure tube wall, and at the outside surface of the tube the marks had the form of small craters. For want of a better name they were called blisters. Fourteen clearly identified blisters could be seen together with a fairly large dark patch (later shown to be a concentration of zirconium hydrides near the outside surface of the tube). Figure 2 shows a typical blister before sectioning. The brittle nature of the material in the blister can easily be surmised. The crack ran through several of the blisters, but in only one case did it pass through the middle of the blister.

The fracture surface could be divided into three clear zones: Zone I (0.0-0.6 m) having a 45 degree shear fracture with markings which indicated propagation toward the outlet end of the tube. Zone II (0.6-1.3 m) a flat radical crack surface with intermittent shear lips at the outside and inside surface end of the tube. Zone III a flat radial crack with shear lips on the inside surface of the tube (1.3-2.0 m). Markings on the fracture surface indicated that the crack started in this zone. Close examination of the fracture surface around blisters C, D and F revealed what appeared to be the initiating crack, which was about 100 mm long, and at its centre, about 90 percent through the wall prior to the failure.

Subsequent deuterium analysis and metallography of the area showed that the deuterium level close to the inside surface of the wall was very low and this prevented the growth of the crack completely through the wall, such that failure was by break before leak. Thus the crack appears to have started at blisters D and E and extended axially along the tube to a critical partial through wall crack about 100 mm long. There is still a question remaining of why the crack initiated in the first place. A considerable R and D program has been initiated to determine the behaviour of blisters in pressure tubes.

The historical sequence of a delayed hydride crack can usually be determined by variations in oxide thickness on the fracture surface. In this case, however, very little oxidation had occurred suggesting that the crack grew rapidly to the critical size, or a lack of oxygen in the annulus gas system prevented the oxidation.

Metallography

The metallography of the tube began with a section through one of the blisters. A typical cross section is shown in Figure 3. Here, the white area is seen to be zirconium hydride having a very high deuterium concentration. The dark radiating spikes are areas of high hydride concentration, with the general hydride population clearly visible outside this area. This evidence strongly suggested a deuterium/hydrogen concentrating mechanism.

The blister of Figure 3 also shows a number of cracks in the zirconium hydride. In general all the blisters examined had this type of crack and preliminary theoretical analysis of stresses around blisters in the failed pressure tube had cracks passing through the zirconium hydride area into the base metal of the tube. It is uncertain whether they existed before the tube failure or were a consequence of it. A number of other blistered tubes were examined, but only the failed tube had such cracks.

Of all the blisters examined on Pickering A NGS Units 1 and 2 pressure tubes, most were about 0.5 to 1.3 mm deep and 2 mm to 8 mm in diameter. Their shape was generally circular, but the number varied widely from tube to tube.

Deuterium Analysis

The blisters were shown to be a high concentration of hydrogen or deuterium forming solid zirconium hydride (deuteride) at the surface of the tube. Analyses were initiated to determine the level of these two hydrogen isotopes in the vicinity of the blisters, and later along the tube. This was the first Zircaloy 2 pressure tube to

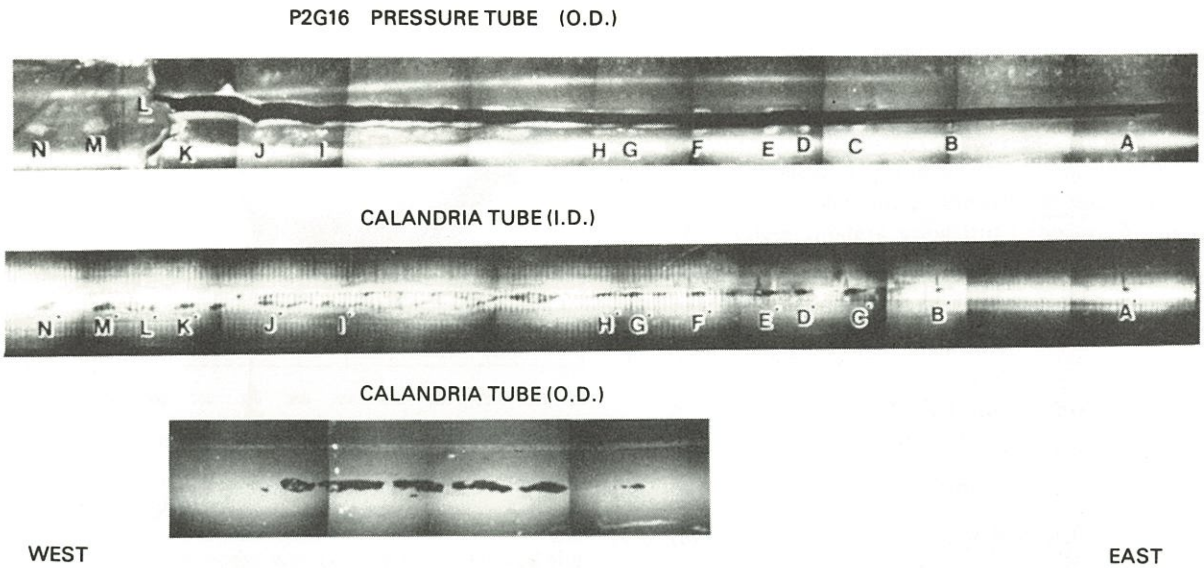

Figure 1 Blisters on East Outlet Section of P2 G16 Pressure Tube and Corresponding Contacting Section of Calandria Tube.

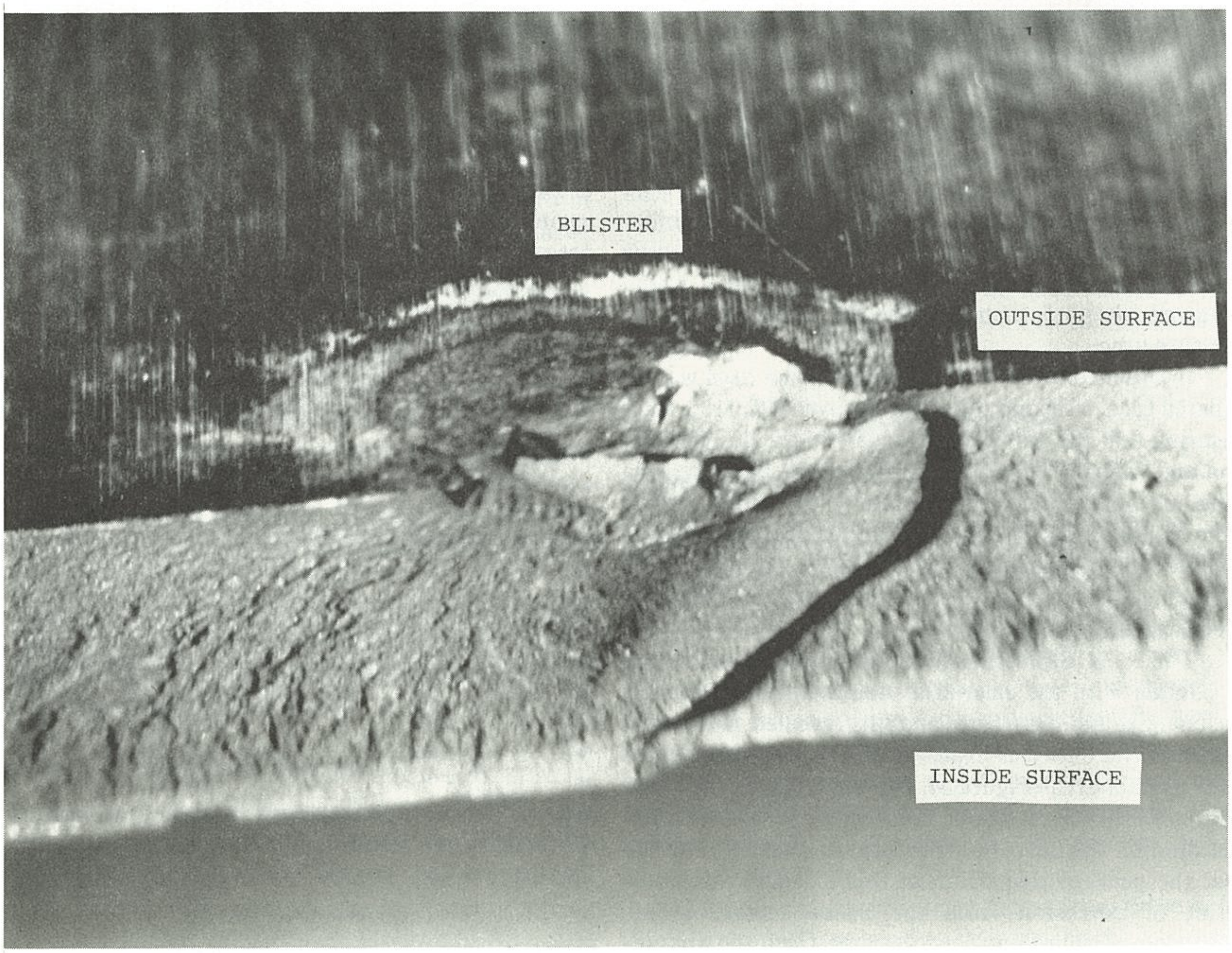

Figure 2 Typical Blister at Fracture Surface

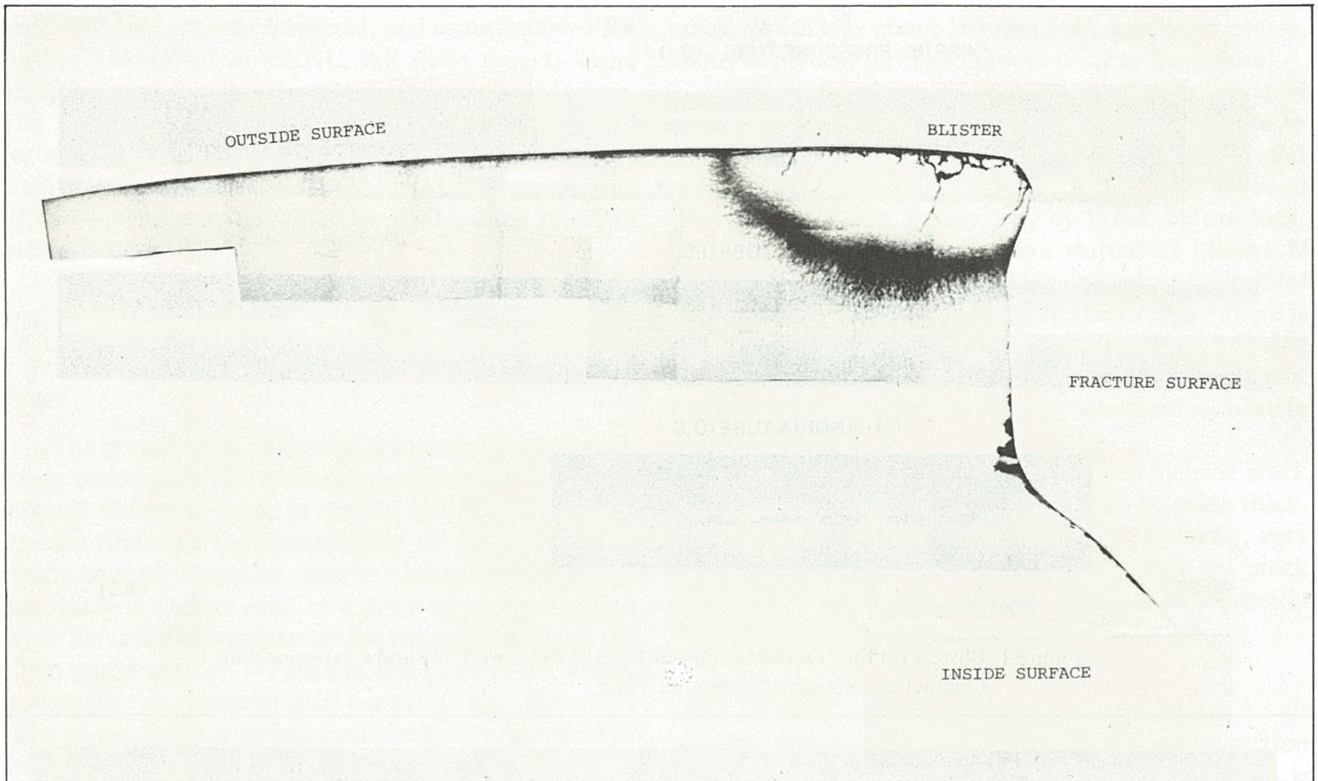

Figure 3 Cross Section Through Blister

be examined after 12 years of service in a power reactor, and the deuterium levels were much higher than had been predicted. In general, the deuterium levels had been expected to be below the terminal solid solubility throughout the bulk of the tube, but were found to be in excess of 250 ppm of deuterium at a peak which occurred about 5 metres from the inlet end of the pressure tube.

In order to determine if this deuterium level was an isolated case, a second tube was removed (P2 J15), after ensuring that the garter springs were in the design location and contact between the pressure tube and calandria tube had not occurred. Deuterium levels were found to have a similar distribution, but at a slightly lower level (Figure 4). Subsequently several more channels from Pickering A Unit 2 and Unit 1 were removed following their inspection in reactor.

The P1 K18 pressure tube was found to have been in contact with the calandria tube at the inlet half of the channel and deuterium analysis revealed two peaks, one near the outlet as expected and a lower one at the inlet contact area (Figure 5). On the basis of the oxide thickness at this area (about 15 microns) and some understanding of the corrosion process, it became apparent that the peak of deuterium at this location was not a result of corrosion from the inside surface alone. Diffusion of deuterium into the tube from the annulus gas system must also have occurred. This appeared to be plausible because the annulus gas system in Units 1 and 2 had always operated in a stagnant mode such that deuterium, diffusing through the end fittings, could build up in the annulus gas atmosphere on the outside of the pressure tube, and subsequently enter the pressure tube.

The peak in oxide thickness and deuterium level at the outlet of the pressure tubes appears to have arisen from an enhanced corrosion rate which started when the oxide reached a thickness of about 15-20 microns. In effect the local environment within this thick oxide,

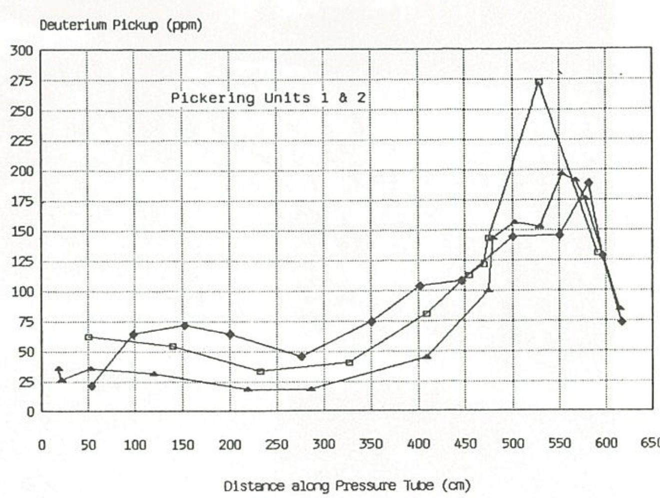

Figure 4 Deuterium Concentrations in Zircaloy 2 Pressure Tubes

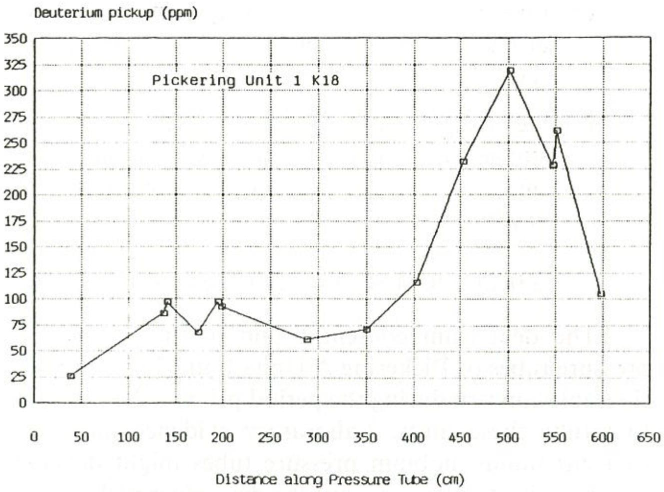

Figure 5 Deuterium Concentrations in Zircaloy 2 Pressure Tube P1 K18

where the corrosion process was occurring, assumed the worst characteristics of both reducing and oxidizing chemistries, and appeared to be independent of the bulk chemistry of the primary heat transport coolant.

CALANDRIA TUBE EXAMINATION

Visual

At this stage in the investigation, the location of the garter springs prior to the failure was unclear. Whilst it was suspected that the failed pressure tube had been in contact with the calandria tube as a result of a misplaced garter spring, there was some evidence that both garter springs were in the correct location — i.e. contact where the blisters were seen would not have been possible. Confirmation of contact or gap could only be obtained by careful inspection of the calandria tube, and it was subsequently removed and examined at CRNL.

Visual examination of the outside of the calandria tube showed a dark deposit which corresponded with the expected contact location. The deposit was later shown to be a copper oxide corrosion product from materials in the moderator system.

Examination of the inside of the tube revealed dark marks which correlated with the marks on the outside surface of the pressure tube and confirmed that the two tubes had been in contact, Figure 1.

Comparison with Pressure Tube Blisters

A careful comparison of the position and spacing of the marks on the two components and their creep and operating history gave a fairly clear historical sequence of events. This clearly shows contact occurring after 9000 Effective Full Power Hours (EFPH), and gradually extending and creating blisters F to N until 52700 EFPH, when the fuel channel was shifted relative to the calandria tube by a reactor maintenance operation associated with pressure tube elongation.

After this operation, the five most outboard blisters A-E began to form. This time appears to approximately correspond with the onset of enhanced corrosion which resulted in rapid deuterium ingress, combined with the formation of a blister due to the contact with the calandria tube. These blisters grew until the crack initiated, and the subsequent fast fracture of the tube occurred at 86700 EFPH.

Mechanical Properties

Several tests were carried out on the calandria tube with very encouraging results:

(a) there was no deuterium pickup;

(b) the contact points showed no detrimental effects on the calandria tube;

(c) the mechanical properties were as expected in an irradiated material;

(d) burst testing of three sections gave burst pressures in excess of 13 MPa (Primary Heat Transport System operating pressure is 9.5 MPa).

As with the P2 G16 pressure tube, properties of the P2 G16 calandria tube were under suspicion, having already experienced the pressure tube failure and pressure transient, and a second calandria tube was removed (P2 K13) which had also experienced contact. Prior to a burst test of the contacted section, a 0.4 mm deep gauge was accidentally made on the tube outside surface. In spite of this the burst pressure was still in excess of 13 MPa.

GARTER SPRINGS

Examination

The two garter springs from channel P2 G16 were badly damaged. Both visual and metallographic examination failed to reveal any reason to believe that the garter springs were broken prior to the pressure tube failure. Sections of the springs were extensively deformed, yet still retained reasonable ductility. Deuterium analysis of these and garter springs from other channels showed that the ends of the springs generally had higher values than the centre, levels up to 100 ppm deuterium being typical for ends and about 10 pm at the centre. These results strongly suggest that the annulus gas system contained deuterium.

All removed garter springs, apart from those in the P2 G16 channel appeared to be in reasonable condition and suggests that the damage to the P2 G16 garter springs occurred either during the incident or during removal of the pieces of pressure tube from the reactor.

Location in Fuel Channel P2 G16

It was essential to determine the location of the garter springs prior to the failure. There was conflicting evidence on the location of the garter springs from the pressure tube and the calandria tube examination at CRNL. However, the two tubes showed obvious signs demonstrating that the tubes had been in contact for a considerable period of time (approximately 78000 EFPH), which implied that the outlet garter spring could not have been in the design location.

Very careful examination of garter springs, calandria tube and pressure tube eventually found conclusive evidence that the inlet garter spring was in the correct location. No such clear evidence could be obtained for the outlet garter spring, although a dent in the bottom of the calandria tube, the obvious signs of contact and investigation using an analytical approach strongly suggest that the outlet garter spring had been about 1 metre inboard of the design location.

FAILURE MECHANISM

The failure mechanism of the P2 G16 pressure tube is now reasonably clear, but not fully understood. The events leading to the failure were as follows:

(a) the outlet garter spring moved about 1 metre inboard from its design location probably during the construction or commissioning phases;

(b) due to the increased span between supports, the pressure tube sagged into contact with the calandria tube after about 9000 EFPH;

(c) the temperature gradients in the pressure tube wall caused the hydrogen and deuterium to diffuse to the cooler contact area initiating the formation of the blisters;

(d) the enhanced corrosion and deuterium pickup accelerated the growth of the blisters, creating high local stresses in an area of high hydride content and initiated a defect;

(e) the defect grew by delayed hydride cracking to form a partial through wall crack about 100 mm long;

(f) when the crack reached a critical size, it suddenly broke through the wall, and extended to the 2 metre length.

In general, the current understanding of the failure mechanism requires at least three conditions to co-exist:

(a) high hydrogen/deuterium content in the metal;

(b) a means of concentrating the hydrogen/deuterium at a local area — such as a thermal gradient in the metal;

(c) high deuterium ingress rate such that high local stresses are produced in the concentration region, thus creating the necessary preconditions for crack initiation.

ZIRCONIUM NIOBIUM PRESSURE TUBES

The deuterium content found in the Zircaloy 2 pressure tubes of Pickering A Units 1 and 2 was of considerable concern during the period prior to the decision to retube these units. Laboratory evidence indicated that zirconium niobium pressure tubes might develop similar oxide thicknesses, but the deuterium pickup was expected to be about five times lower. However, very little data were available from in-reactor tubes. To obtain some preliminary data, the pressure tubes from Bruce A Unit 2 which had been removed in 1982 for cracks in the rolled joint area, were analyzed and found to contain about 5 ppm deuterium. These tubes however, had only been in service for about five years and plans were therefore made to remove two tubes from NPD; one original Zircaloy 2 tube (from 1962), and one of zirconium niobium installed in 1967. While the operating life and chemistry of the system is different to Pickering A, it was felt that tubes of the different alloys having seen the same operating conditions would provide a good comparison of their relative oxidation and deuterium pickup rates.

The results were very encouraging for zirconium niobium, as can be seen in Figure 6. The Zircaloy 2 tube appeared to behave in a similar manner to those in Pickering A Units 1 and 2, while the deuterium pick up was very low in the zirconium niobium tube — a maximum of 5 ppm.

The "lead" unit, using zirconium niobium pressure

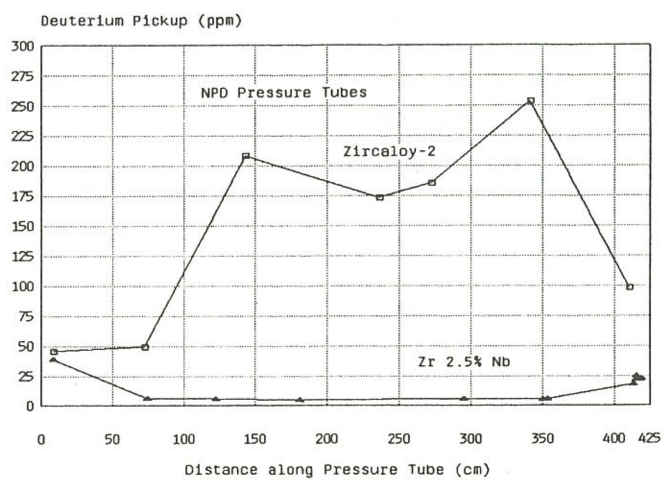

Figure 6 Deuterium Concentration in Zircaloy 2 and Zr-2-1/2% Nb Pressure Tubes

tubes in terms of operating time and fluence, was Pickering A Unit 3. Preparations were being made throughout 1983 to remove a tube from Pickering A Units 3 or 4 but the failure of P2 G16 delayed their execution. During the recent outage (May, 1984), fuel channel P3 J09 was removed and shipped to CRNL for examination.

This pressure tube had been in contact with the calandria tube for about four years, and visual examination of the tube showed evidence of this. The results confirm the data from the Bruce 2 and NPD zirconium niobium pressure tubes in that the deuterium concentration was again approximately 5 ppm along the length of the tube. Metallography of the contact area revealed no signs of hydride concentrations. A pressure tube removed from Pickering Unit 4 gave comparable results for deuterium concentration.

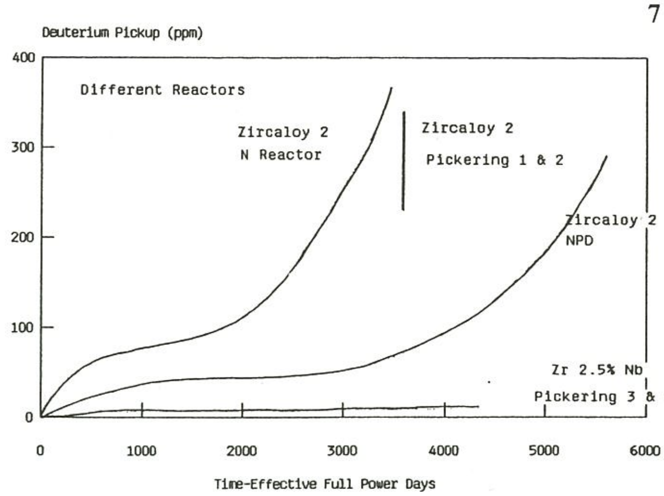

Figure 7 Deuterium Pickup Rates for Zircaloy 2 and Zr 2-1/2 Nb P/T's

CONCLUSIONS

The failure of the pressure tube in Pickering Unit 2 on August 1, 1983 has been found to have been caused by a combination of factors:

(a) a fast pickup rate of deuterium from the primary heat transport and annulus gas systems to levels significantly exceeding terminal solid solubility;

(b) contact between the pressure tube and calandria tube resulting in significant thermal gradients and deuterium migration;

(c) rapid growth of a "blister", the resulting stresses initiating a defect;

(d) growth of a delayed hydride crack from the defect, leading to ultimate failure.

Examination of several Zircaloy 2 and zirconium niobium pressure tubes has clearly shown that the deuterium pickup rate of the two materials is significantly different — that of Zircaloy 2 being very high, and that of zirconium niobium being very low (Figure 7).

While the pressure tube failure caused a major loss of electricity production from Pickering Units 1 and 2, the consequence of the failure and results of the subsequent investigation demonstrate that:

(a) sudden pressure tube failure in the CANDU system presents no public safety or worker safety concerns;

(b) the zirconium niobium pressure tubes of all CANDU reactors built since Pickering Unit 2 have absorbed very little deuterium. Even if contact between pressure tube and calandria tube occurs, they do not appear to be susceptible to the type of failure experienced by Pickering Unit 2.

ACKNOWLEDGEMENTS

The work described above is the result of a great deal of effort from people in Ontario Hydro and AECL. In particular the authors would like to thank the members of the Failure Analysis Group and the staff at CRNL who spent many long hours carefully examining the highly active components.

following a large loss-of-coolant accident accompanied by loss of emergency coolant injection.
Factors considered include expulsion and boil-off of the moderator, uncovery, overheating and disintegration of the fuel channels, quenching of channel debris, re-heating of channel debris following complete moderator expulsion, formation and possible boiling of a molten pool of core debris and the effectiveness of the cooling of the calandria wall by the shield tank water during the accident sequences. The effects of these accident sequences on the reactor containment are also considered.
Results show that there would be no gross melting of fuel during moderator expulsion from the calandria, and for a considerable time thereafter, as quenched core debris re-heats. Core melting would not begin until about 135 minutes after accident initiation in a loss of the moderator cooling system and until about 30 minutes in a loss of the moderator heat sink. Eventually, a pool of molten material would form in the bottom of the calandria, which may or may not boil, depending on property values. In all cases, the molten core would be contained within the calandria, as long as the shield tank water cooling system remains operational. Finally, in the period from 8 to 50 hours after the initiation of the accident, the molten core would re-solidify within the calandria.
There would be no consequent damage to containment resulting from these accident sequences, nor would there be a significant increase in fission product releases from containment above those that would otherwise occur in a dual failure LOCA plus LOECI.
The report was authored by J.T. Rogers of Carleton University and is available as INFO-0136 from the AECB.

USSR Allows Inspection of Nuclear Stations (Staff)

An undisclosed number of Soviet nuclear power plants will soon be subject to inspection by the International Atomic Energy Agency, after the recent concluding of a agreement between the USSR and the IAEA. As a nuclear weapon state before it joined the IAEA, inspection of Soviet nuclear stations has not been mandatory. The nuclear weapons states US, Britain and France already have inspection agreements with the IAEA.

TMI-2 Core Hotter Than Calculated

(Nuclear Engineering International)

Core temperatures reached during the 1979 accident at Three Mile Island 2 were at least 3500°F. This is the point at which non-nuclear core materials such as zirconium alloy and steel melt, according to a preliminary analysis of fuel debris.
This is also higher than calculated by several different severe core damage computer code analyses, conducted shortly after the accident, which estimated the gross average temperature in the damaged region was less than 3100°F.
Evidence of peak temperatures as high as 4800°F came from one of the seven debris particles used for the analysis. This temperature is close to the melting point of the fuel (5080°F).
The peak temperatures predicted by the earlier computer code analyses were at least 4000°F. One code, the Severe Core Damage Analysis Package, predicted peak temperatures approaching 5000°F.
The latest information comes from research carried out by scientists from EG&G Idaho, working under a Department of Energy contract at the Idaho National Engineering Laboratory.
Their analysis of debris samples can provide clues to the nature of the material below the rubble bed at the bottom of the reactor vessel and aid the design of tools to remove the material.

Waste Management Consultation Program Announced (AECL)

Atomic Energy of Canada Limited is seeking input from a broad cross-section of public and special interest groups on the issues associated with the safe permanent disposal of nuclear fuel waste.
"AECL hopes that the public consultation program will help establish the conditions that society feels are necessary for the disposal of nuclear fuel wastes to be acceptable," said Egon Frech, head of AECL's Waste Management Public Affairs.
The Federal and Ontario governments asked AECL in 1978 to develop the technology for disposing of high-level wastes from CANDU reactors. Highly insoluble waste would be sealed in corrosion-resistant containers and emplaced in a disposal vault up to a kilometre deep in a stable hard rock formation in the Canadian Shield. The objective of the program is to ensure there will be "no significant adverse effect on man or the environment from nuclear fuel waste at any time."
Work to date has shown good progress. "But we think it's also important that the waste disposal technology meet the expectations of the public. We're consulting with public and special interest groups as one way of finding out what those expectations are," said Frech.
The consultation process is open to any group wanting to participate.

CNS Conference Proceedings Published (Staff)

Proceedings of the Fifth Annual Conference of the Canadian Nuclear Society, held June 1984 in Saskatoon are now available. The full text of twenty technical papers dealing with modelling and analysis, nuclear technologies, tailings and reactor waste management are included.
The 126 page proceedings are edited by Dr. I.J. Itzkovitch, Conference Chairman, and are available for $30.00 to CNA/CNS members, $40.00 to non-members.
Also available are proceedings of two recent CNS technical conferences: Robotics and Remote Handling in the Nuclear Industry (275 pages) and International Conference on Containment Design (221 pages). These are $40.00 each to CNS members, $50.00 each to non-members.

CNS News

Midyear Report from the CNS President

I am happy to report to you on the events and happenings that your Council and the many Officers and members of the Society have brought about since June 1984, the start of our program year. In addition I'd like to give you an idea of the events we have planned for both the short and long term.
Objectives One of the first things we undertook was to formulate a set of objectives for the year. They total 19, and cover Membership, Communications, Finances, Program, Brancheasnd general items. Examples are: Target for 600 members in 1985, make a decision on a CNS journal, establish a new Branch in 1985. We are well on our way to achieving these objectives; some of the task lies with you to assist in increasing the membership of the Society. I will give you a more complete list later in the year when you can examine our 'report card' for the year.
Conferences Two two international conferences held in 1984 were a great success and a credit to the organizing committees. The Containment Design Conference attracted over 100, many from outside Canada. The Robotics in the Nuclear Industry Conference drew 150, and received good reviews in *Nuclear Engineering International* and *Nuclear News*. Together the conferences produced substantial revenue and established our Society as a credible and professional organizer of world-class events.
Outreach In November a CNS Brief was presented to the IPPANI Interfaith Hearings on Nuclear Issues in Toronto. It was well received, and we trust will provide a thoughtful input to the final report. This event was reported in the last two issues of the *Bulletin*. Also in November, the Society hosted a visit to Canada by the President and three senior members of the Chinese Nuclear Society. At a reception, an Agreement of Cooperation was signed between the two Societies. The visit is already opening doors for Canada to communicate further with China.
Branch-in-formation On your behalf I addressed a dinner meeting of the New Brunswick branch-in-formation in Frede-

ricton at the end of January. There is considerable interest in things nuclear among NB Power, Maritime Nuclear, UNB and consulting companies in the Province.

Branches Several successful events have been held by the various branches.

Outlook A decision on the future of a CNS technical journal will be made shortly. For many, a journal is the hall-mark of a professional society. For others it represents a business decision similar to that faced by many small companies. If the decision is favourable, a start will likely be made later in 1985.

Interested in Contributing to the CNS Bulletin?

To submit original articles, letters, FYI items, reviews, calls for papers, etc. contact one of the following:

- D. Mosey, Editor, *CNS Bulletin*, c/o Ontario Hydro, 700 University Ave., Toronto, Ontario, M5G 1X6.
- H. Bonin, Associate Editor, *CNS Bulletin*, c/o R.M.C., Dept. of Chem. & Chem. Eng., Kingston, Ontario, K7L 2W3.
- The *CNS Bulletin*, c/o the CNS office.
- Your local branch representative.

CNS Bulletin Issue:	Editorial Deadline:
January/February	End of January
March/April	End of March
May/June	End of May
July/August	End of July
September/October	End of September
November/December	End of November

Intéressés à contribuer au Bulletin SNC?

Pour soumettre des articles originaux, de lettres, des nouvelles, des revues, des appels aux communications, etc., veuillez bien entrer en contact avec l'une des personnes suivantes:

- D. Mosey, Rédacteur, *Bulletin SNC*, a/s Ontario Hydro, 700 University Ave., Toronto, Ontario, M5G 1X6.
- H.W. Bonin, Rédacteur Associé, *Bulletin SNC*, a/s Royal Military College, Département de Chimie et de Génie Chimique, Kingston, Ontario, K7L 2W3.
- Le *Bulletin SNC*, a/s Bureau de la SNC.
- Le représentant de votre section locale.

Numéro du *Bulletin SNC*	Date limite pour l'éditorial
janvier/février	Fin de janvier
mars/avril	Fin de mars
mai/juin	Fin de mai
juillet/août	Fin de juillet
septembre/octobre	Fin de septembre
novembre/décembre	Fin de novembre

This year is the 25th anniversary of the CNA, and the 6th of the CNS. At the Annual Conference in Ottawa this June our program will run parallel with the CNA, and will involve over 100 papers, our largest yet. I urge you to attend this event which promises to be an historic one for things nuclear in Canada.

In October, the Third International Technology Transfer Conference will be held in Madrid. The CNS Program Committee has organized three major events, and expects a total compliment of 9 or 10 Canadian papers to represent this country to the world as a supplier of nuclear technology to developing nations.

The CNA/CNS student conference will be held in March, followed by the Simulation Symposium in May. Other events are planned for the Fall and may include a Fuel Information Meeting, and a Symposium in New Brunswick.

Next year the Second International Conference on Waste Management will be held in Winnipeg, to coincide with the opening of the Underground Laboratory. In 1987 a joint Topical Meeting with the ANS Power Division is in the planning stages.

The CNS has, as you can see, a bright potential and a busy future. If you are interested in joining in these activities contact me, one of the Councillors, or any Officer. Your enthusiasm and help is needed!

Peter Stevens-Guille
CNS President

CNS Conference Preview

Plan now to attend the Sixth Annual CNS Conference in Ottawa, June 2-4. Judging by the number and quality of the papers submitted it promises to be the best CNS Conference to date.

The paper review committee selected 107 papers for presentation, with all members commenting on the high quality of the submissions. Presentation will be in five parallel sessions over two days. Thirteen topics are covered: (1) Fuel technology and behaviour, (2) Fuel channel replacement, (3) Thermal hydraulics, (4) NPP design and operation, (5) Public and regulatory matters, (6) Reactor safety, (7) Reactor physics, (8) Waste management, (9) Instrumentation, (10) Materials, (11) Fusion technologies, (12) Accelerator applications, and (13) New reactor concepts.

Along with the Canadian Nuclear Association, which will be holding its 25th Annual International Conference concurrently, this year's CNS Conference is being held in the new Westin Hotel in the heart of Ottawa. Although the two conferences are separate, a single registration ($275 for CNS members) will include entry to both conferences, two luncheons, the closing banquet, and a special nostalgic dinner Sunday evening to which many pioneers of the Canadian nuclear program will be invited.

Members of this year's Conference Committee are Peter French (Chairman), Fred Boyd, Irwin Itzkovitch, Frank MacDonnell and Gil Phillips.

A full program will be mailed to all members in a few weeks and will be included with the next issue of the *Bulletin*. But make your plans now, to be in Ottawa, June 2-4.

Fred Boyd

CNS Branch Programs

Report on the New Brunswick Branch-In-formation Meeting

This meeting of January 31 in Fredericton was arranged jointly by Neil Craik of Maritime Nuclear and Prof. Dan Meneley of UNB. The program included an illustrated lecture by Roger McKenzie, the plant manager at Point Lepreau 1, a social hour in the faculty club, a dinner and a witty speech by the President on the structure and program of the CNS.

The lecture, attracted between 50 and 60. The audience was from NB Power, UNB, Maritime Nuclear, Point Lepreau 1, and some small consulting firms in the area. All parties felt both the lecture and turn out was good. The dinner attracted 40 and continued to about 9:30 p.m.

A formal commitment was not made at the meeting to form an interim committee (perhaps it should have been). However the local people must be responsible for their own arrangements; our role is to provide assistance.

Elections are slated to occur in the summer with the possibility of a fall event centered around Point Lepreau 1 as a topic.

Peter Stevens-Guille

Roger McKenzie, Plant Manager at the Point Lepreau Nuclear Generating Station lectures at the CNS NB meeting-in-formation on January 31st at University of New Brunswick.

Interested in CNS Membership?

Membership in the Canadian Nuclear Society offers:

- Activities at local branch levels
- Activities within areas of your technical interest
- The *CNS Bulletin* bimonthly
- And more.

Contact the CNS office for a membership application form or further information.

Intéressés à devenir membres de la SNC?

La Société Nucléaire Canadienne vous offre:

- Des activités au niveau des sections locales
- Des activités dans les domaines techniques qui vous intéressent
- Le *Bulletin SNC* bimestriel
- Et bien plus.

Ecrivez ou téléphonez au bureau de la SNC pour obtenir un formulaire de demande d'admission ou de plus amples informations.

Ottawa Branch Hears About Tomography

In December 1984 the Ottawa Branch members had as guest speaker Dr. Colin Allan, Head of the Instrument Development Branch at Chalk River. Dr. Allan introduced the subject of industrial tomography and provided an overview of the CRNL program.

During his presentation Dr. Allan explained that tomography is a non-intrusive imaging technique now being developed at Chalk River to generate quantitative cross-sectional density maps of objects. A three-dimensional image of the object, be it a solid or a liquid, can be constructed from a series of such tomographs. While its principles were discovered decades ago, it is the availability of low cost computing power that is now making tomography practical for wide-spread use.

Potential industrial applications could include: (i) R&D studies of such things as multi-phase flow/mixing, casting and extrusion processes, (ii) inspection of products such as spent fuel containers, test fuel, rocket motors, complex castings and structures, concrete columns and beams, turbine blades, artillery shells, and (iii) a dimensional measurement of the internals of complex objects and vessels such as castings, moulds, and even rotating machines.

In these applications tomography can provide precise and detailed data that has not, heretofore, been possible to obtain.

To develop this technology as an industrial tool CRNL staff members are performing fundamental R&D to put them in a position to specify the limits of the technology, evaluate the efficacy of using tomography in any given application, and to specify, design and build state-of-the-art instrumentation for transmission tomography.

In addition to the R&D activities CRNL is actively interacting with industry. Probably the features of tomography of most interest to industry are the ability to distinguish features within complex geometry, to detect and locate small density changes or defects within objects, (e.g. void fraction measurements within thick-walled vessels, shrink cavities in casting, etc.), to provide quantitative data that can be used in analyses of complex processes, or fracture mechanics, and to provide objective quantitive data that can be used for (computer-based) quality assurance decisions, thereby reducing and in some cases eliminating the present subjectivity often encountered in NDT.

The CRNL program was reviewed in detail and examples were presented to illustrate the potential and the limitations of the technology.

This first meeting of the 1984/85 Ottawa Branch season was well attended and a lively discussion followed Dr. Allan's presentation.

On January 2, the Ottawa Branch broke with tradition and joined the local EIC Branch to hold a meeting at the RA Centre on the subject of radioactive waste management. An excellent synopsis of irradiated fuel waste disposal was presented by Bob Lyon of the Whiteshell Nuclear Research Establishment.

Clearly New Year's Eve hangovers were not too bad this year, since 30 people attended. Bob Lyon's talk provoked an animated discussion that continued to well after ten o'clock — convincing demonstration that Ottawa CNS members will support events of interest at any time and place.

The Ottawa Branch is also gearing up to provide assistance to Peter French, Program Chairman for the annual CNS meeting which is to be held in Ottawa in June 1985.

Frank McDonnell
Joe Howieson

Conferences & Meetings

International Meeting on Advances in Nuclear Engineering Computational Methods

Sponsored by ANS, ENS, et al., to be held **April 9-11, 1985** in Knoxville, Tennessee. For information contact: **H.L. Dodds, 12629 Red Fox Dr., Knoxville, Tennessee 37922.**

11th Simulation Symposium on Reactor Dynamics and Plant Control

Sponsored by CNS Nuclear Science and Engineering Division, to be held **April 22-23, 1985** in Kingston, Ontario. For information contact: **Hugues Bonin, Dept. of Chemistry and Chemical Engineering, Royal Military College, Kingston, ON K7L 2W3.**

Second European Community Conference on Radioactive Waste Management and Disposal

To be held **April 22-26, 1985** in Hemicycle du Centre Europeen, Luxembourg. For information contact: **D. Nicolay, Commission of the European Communities, Jean Monet Building, C4/005, L-2920, Luxembourg.**

Second National Topical Meeting on Tritium Technology in Fission, Fusion and Isotopic Applications

Sponsored by American Nuclear Society and cosponsored by Canadian Nuclear Society, to be held **April 30 - May 2, 1985** in Dayton, Ohio. For information contact: **T. Drolet, Canadian Fusion Fuels Technology Project, 2700 Lakeshore Road W., Mississauga, ON L5J 1K3.**

Tritium Safe Handling Course

Conducted by the Canadian Fusion Fuels Technology Project, to be held **May 6-10, 1985** in Toronto and Chalk River. For information contact: **Robert Macphee, CFFTP, 2700 Lakeshore Rd. W., Mississauga, ON L5J 1K3.**

The Third Review of the NPT — A Time for Reassessment: Non-Proliferation and Global Security

Sponsored by the York Research Program in Strategic Studies, to be held **May 16-17, 1985** in Toronto. For information contact: **David Dewitt, York University, Research Program in Strategic Studies, 4700 Keele St., Toronto, ON M3J 1P3.**

International Symposium on Advances in Nuclear Power Plant Availability, Maintainability and Operation

Sponsored by the International Atomic Energy Agency, to be held **May 20-24, 1985** in Munich, West Germany. For information contact: **Conference Service Section, IAEA, P.O. Box 100, A-1400 Vienna, Austria.**

CNS 6th Annual Conference

To be held **June 2-4, 1985** in Ottawa, Ontario, in parallel with the Canadian Nuclear Association's 25th Annual International Conference. For information contact: **P.M. French, c/o Atomic Energy Control Board, P.O. Box 1046, Ottawa, ON K1P 5S9.**

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Branch Activities Chairman / ***Président du Comité des activités des sections locales de la SNC***	
Ernie Card	(204) 956-0980
CNS Division Chairmen / ***Président des divisions de la SNC***	
• **Nuclear Science & Engineering /** ***Science et ingénierie nucléaires***	
Riccardo Bonalumi	(416) 978-3064
• **Design & Materials / Conception et matériaux**	
Nabila Yousef	(416) 592-5983
• **Mining, Manufacturing & Operations /** ***Exploitation minière, fabrication, exploitation des centrales***	
Joe Howieson	(613) 995-1118
• **Waste Management and Environmental Affairs /** ***Gestion des déchets radioactifs et environnement***	
Eva Rosinger	(204) 753-2311
Members-at-Large / ***Membres en général***	
Jan-G. Charuk	(514) 934-4811
Ex-Officio / ***Ex-Officio***	
CNS General Manager and CNA Liaison / ***Directeur-général de la SNC et agent de liaison de l'ANC***	
Jim Weller	(416) 977-6152

CNS Branch Chairmen / ***Responsables locaux de la SNC***

Chalk River	Ian Crocker	(613) 687-5581
Quebec	**Contact/Responsable**	(514) 934-4811 x334
Ottawa	Frank McDonnell	(613) 236-6444
Toronto	Rudi Abel	(416) 823-9040
Manitoba	Ernie Card	(204) 956-0980

CNS 1985 Annual Conference Chairman / ***Président de la conférence annuelle de la SNC (1985)***

Peter French (613) 996-2810

Uranium Mine Radiation Safety Course

Sponsored by the Atomic Energy Control Board, to be held **June 3-7, 1985** in Saskatoon, Saskatchewan. For information contact: **Canadian Institute for Radiation Safety, P.O. Box 460, Elliot Lake, ON P5A 2J9.**

ANS Annual Conference

To be held **June 9-14, 1985** in Boston, Massachusetts. For information contact: **J.W. Landis, Stone & Webster, 245 Summer, Boston, Massachusetts 02210.**

1985 International Energy Workshop

Sponsored by the International Institute for Applied Systems Analysis, to be held **June 11-13, 1985** in Laxenburg, Austria. For information contact: **Leo Schrattenholzer, IIASA, A-2361 Laxenburg, Austria.**

International Topical Meeting on Computer Applications for Nuclear Power Plant Operation and Control

Sponsored by ANS, cosponsored by CNS and ENS, to be held **September 8-12, 1985** in Pasco, Washington. For information contact: **Lino Magagna, Ontario Hydro, 700 University Ave., Toronto ON M5G 1X6.**

27th Annual Radiation Protection Course

To be held **September 30 - October 4, 1985** at Chalk River Nuclear Laboratories. For information contact: **Mrs. C.L. Nagy, Health Sciences Division, AECL, Chalk River Nuclear Laboratories, Chalk River, ON K0J 1J0.**

ENC '86: Call for Papers

Comprising ENC-4, the fourth International Conference of the European Nuclear Society (with ANS) and FORATOM IX — the 9th Foratom Congress, to be held **June 1-6, 1986** in Geneva, Switzerland. Morning sessions are joint plenary review sessions of invited speakers; afternoon sessions are parallel ENS/ANS sessions on: Technical improvements to nuclear power systems, advanced developments with industrial applications, breeder technology, fusion technology, performance and safety, nuclear fuel cycle, decommissioning and waste management. Selection of contributed papers is based on abstracts received before **May 10, 1985**, with deadline for final papers **February 28, 1986**. For further information contact: **Dr. Peter Bucher, ENC-4 Conference Secretary, European Nuclear Society, P.O. Box 2613, CH-3001 Berne, Switzerland.**

The Unfashionable Side

Telephonic Etiquette

I recently had cause to telephone a friend in the Department of Energy Studies at Aphasia University. Unfortunately, I chose a time when she was lecturing and the Departmental Secretary answered my call. Having exchanged the courtesies usually applicable to such situations and left my name and phone number, I was about to hang up when I was asked "Can I tell her what this is with reference to." My first instinct was to suggest that at that moment in time this would be impossible since I had not yet vouchsafed the subject matter, but second thoughts suggested that this was no time for pedantic by-play of this nature. In fact, what I was calling about was (a) to ask whether she'd read a recently published review by a mutual friend in the English department, and didn't she agree that it raised vituperation to an art form in its dissection of a particularly pretentious modern novel, (b) to ask if I could borrow her copy of a certain IAEA report and (c) to inform her that I was slipping out of work early to grab a few beers at the faculty club, and could she and her husband join me. This was, it is true, a not unduly complicated message. But in that form it might possibly have been interpreted at the other end as not being totally concordant with the dignity and professionalism normally associated with the activities of the department. So after a second or five of indecision and inarticulacy I merely mumbled that it was really nothing very important, and just say I called etc., etc., and hung up.

Shortly after this incident I bumped into my good friend, Dr. Dennis Molestrangler, Aphasia University's Visiting Distinguished Reader in Energy Studies, at an informal meeting of the Tay Bridge Club and he informed me that he had himself encountered this situation but was developing a WRT (With Reference To) phrasebook to cope with the problem. A few examples follow. (The WRT phrase is followed by its actual meaning in parentheses).

- There's a technical meeting at 12:00 in the lab to review the feed-and-bleed system. *(We're popping down to the bar at 12 for a few beers).*
- Could he/she attend the full-scale ECI demonstration at 17:30? *(We're all going for a big booze-up after work).*
- Has he/she reviewed that recent report by X? *(Did you see that crazy memo X sent out?).*
- Report that the unit tripped on high flow at 22:30 last night, and then poisoned out. Restart not expected till tomorrow. *(I have a rotten hangover and can't make it to the meeting today. Cover for me).*
- Will he/she be able to attend the seminar on Management Decision Making at Stratford next week? *(I've got tickets for Hamlet at Stratford next week).*
- Need to urgently discuss last week's budget meeting with him/her. *(You still owe me $50 from last week and I need it now).*
- No thanks, this is just a personal call. *(No thanks, this is just a personal call).*

Ernest Worthing