Canadian Nuclear Society Société Nucléaire Canadienne

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Special Report: Findings of the Ontario Nuclear Safety Review

On April 18, 1988, the report of the Ontario Nuclear Safety Review ("The Safety of Ontario's Nuclear Power Reactors: A Scientific and Technical Review") was made public. This followed the submission of the Review's findings to the Minister of Energy on March 21.

In a letter dated December 18, 1986, from the then Minister of Energy, Vince Kerrio, to the newly appointed Commissioner, Prof. Kenneth Hare, the Ontario Nuclear Safety Review was established, in line with recommendation 3 of the Select Committee on Energy in its report of July 1986. That recommendation proposed that:

The Minister of Energy should appoint an independent panel of internationally recognized experts to review, on a priority basis, the safety of the design, operating procedures and emergency plans associated with Ontario Hydro's CANDU nuclear generating plants. This panel should prepare a report to the Minister which should also be made available to Members of the Legislature."

From the beginning, the ONSR was intended to be a thorough scientific and technical review of Ontario's nuclear programme, confined to "the scientific and engineering dimensions of nuclear safety". Specifically excluded were areas such as uranium mining, spent fuel disposal, decommissioning, and tritium sales.

"Opinions are soundly based and adequately supported."

The question of adequate direction and review of the ONSR's findings was faced early by establishing a panel of three distinguished reviewers under the auspices of the Royal Society of Canada and an eight-member Advisory Panel. The Review Panel members were Dr. Henry Duckworth, President Emeritus of the University of Manitoba and Chairman of the Atomic Energy Control Board's Advisory Committee on Nuclear Safety; Dr. I.J.O. Korchinski, former Vice-President, Manufacturing, of Shell Canada; and Sir Frank Layfield, Inspector of the Sizewell B Inquiry in the U.K.

The Royal Society set out a clear mandate for its panel of Reviewers:

"The Society Reviewers will study the Commission Report, in particular, seeking to assure themselves that within the mandate:

(i) The investigation has been performed competently and thoroughly.

(ii) Recommendations made and opinions expressed by the Commissioner are soundly based and are adequately supported.

Reviewers' criticisms will, as far as possible, be resolved in discussion with the Commissioner and, as appropriate, with the Advisory Panel.

(i) If criticisms are satisfactorily resolved the Reviewers will report accordingly.

(ii) If some significant matters remain unresolved the Reviewers will record their dissenting opinion."

"The Ontario Hydro reactors are being operated safely and at high standards of technical performance."

On March 12, 1988, the Chairman of the Review Panel, Henry Duckworth, reported to the Royal Society that:

1.(i) The investigation has been performed with competence and thoroughness.

(ii) The recommendations made and opinions expressed by the Commissioner are soundly based and adequately supported.

Our criticisms of the draft Report have been thoroughly discussed with the Commissioner and have been satisfactorily resolved in every respect."

He went on to add:

"In our opinion, high scholarly standards have been achieved. By this we mean that all the relevant information has been assembled and reviewed, with critical disinterest. The Report will, we consider, serve as an authoritative document for those interested in nuclear power in Ontario.

"The Report is an outstanding piece of work done under pressure of time and polarized opinion. We have formed the opinion that it more than adequately meets the requirements set out by the Minister."

Although the report of the ONSR fills several large volumes, in essence it is straightforward, consisting of one major conclusion, two major recommendations, and a number of additional more specific recommendations.

The major conclusion concerns overall safety:

"The Ontario Hydro reactors are being operated safely and at high standards of technical performance. No significant adverse impact has been detected in either the workforce or the public. The risk of accidents serious enough to affect the public adversely can never be zero, but is very remote."

In support of his conclusion, Hare cites a number of pieces of evidence.

- Cancer mortality is low and there is general good health among the exposed work-force after two to three decades of record. Average radiation doses for this group are at least several hundred times greater than those of members of the general public.
- There has been no known radiation-related

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The Verdict Returned

Professor Hare and his staff deserve the somewhat awed admiration of all – particularly those in the nuclear power business. As is evident from our review elsewhere in this issue, working under stringent time constraints Hare has produced an unambiguous, pellucid report which has been prepared in the best tradition of scholarly investigation.

The Ontario Nuclear Safety Review has raised a number of interesting and significant issues. One rather disappointing feature of the whole review process – and one to which Professor Hare draws attention in his Summary Report – is the extraordinarily low level of news media interest throughout the period of the Review. If the issue of nuclear reactor safety is of major importance to every citizen (and we believe it is), then the citizens of Ontario have been ill-served by their journalists. With the exception of the presentation of the OSART findings and the submission of the Report itself, news media coverage of ONSR has been if not zero, at least of that order of magnitude. It would be comforting to feel that science editors throughout the province are at this moment carefully reading at least the Summary Report. But we are not sanguine.

For the nuclear power industry in general, and Ontario Hydro in particular, the principal finding of the report – that Ontario Hydro reactors are being operated safely and at high standards of technical performance – should give cause for justifiable satisfaction. Such satisfaction, however, must be qualified by Hare's two principal Recommendations relating to pressure tube performance and human performance.

Questions about pressure tube performance in CANDU reactors are not new. While public safety may not be significantly (if at all) compromised by pressure tube failure, economic performance and public confidence certainly are. And worker safety may be. In view of this, Hare rightly questions the adequacy of resources hitherto devoted to resolution of these important problems and urges allocation of "maximum and effective priority" to the issue.

Human performance at the individual and institutional level is also identified as an area requiring early and ongoing attention by Ontario Hydro. Review of previous reactor accidents and other high-consequence events seems to suggest that this area is a significant, perhaps dominant, influence.

Professor Hare's Report is a major item of scholarship in the field of CANDU reactor safety. His findings and recommendations should stimulate a prompt response from the Ontario Energy Ministry and, we trust, an early committment from Ontario Hydro.

Taking a Dive

Raising the subject of money is such a bore. Especially when it is a trivial sum like eight billion dollars. This is the amount, it will be recalled, that our Federal Government is proposing to spend on a fleet of nuclear powered submarines.

For the moment, one can leave aside the question of whether this is a wise purchase, assuming that the Navy knows what it needs, that it has made its requirements clear and that there are advantages to having these submarines. In short, let's suppose that the people doing the shopping on our behalf know what they are up to.

By way of contrast, some politicians have demonstrated, in the aftermath of the seizure of *The Maritimer* by France in the waters off St. Pierre, that they could not be trusted with buying a pound of carrots, let alone sophisticated ships. In the past few weeks there have been calls for the Federal Government to eliminate France from the running in the submarine bidding because of that country's actions in the "fish war" with Canada. Buying submarines is seen as just another political game, like setting freight rates, appointing ambassadors, or doling out make work grants.

A nuclear powered submarine is a **very** sophisticated precision tool designed to do a specific job. That job is **not** to serve as a cheap gambling chip in some seamy game of political one-upmanship.

Submarines of any sort, as far as we can determine, were not designed as means of settling disputes over fishing, just as the F-18 does not have as its design basis the alleviation of unemployment or the promotion of regional expansion and provincial pride. Perhaps the submarine of French design is the best machine for the Navy's task. If so, eliminating it in a childish tantrum in order to put pressure on the owner of eight specks of dust in the Gulf of St. Lawrence is scarcely the height of wisdom. Such an action would be a clear statement that it doesn't matter whether an inferior boat is purchased, and that any resulting effect on the Navy's ability to do its job, or on the safety of those seamen charged with doing it, are both secondary considerations. In other words, it doesn't really matter to some politicians how well this important job is done, or even whether it is done properly, nor does it matter how effectively the trifling sum of eight billion dollars is spent. All that matters is the game of politics.

Is it too much to hope that an appeal to the rudiments of common sense would help? Do our politicians really think so little of defence, of the importance of quality and safety in the choice of military hardware, and of the safety of the country's sailors and airmen?

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Guest Editorial

Fusion and Nuclear Technology

The Third Topical Meeting on Tritium Technology in Fission, Fusion and Isotopic Applications held May 1-6, 1988 in Toronto was a key milestone for Canada's fusion nuclear technology program. Sponsored by the CNS with co-sponsorship from the nuclear societies of the U.S.A., Europe and Japan, the meeting was held in Toronto to mark the fifth anniversary of Canada's Fusion Fuels Technology Program (CFFTP).

Started in 1982, CFFTP was organized as a partnership between the federal government, Ontario and Ontario Hydro, to introduce Canada's capabilities in tritium and remote handling technology to the global fusion effort. Starting with a modest $1 million R&D budget in 1982, the Program made good impact from the beginning due to the strong foundation and at times exclusive capabilities in these technologies, established in over two decades of CANDU and Aerospace development.

Today, world wide fusion research is at a turning point as experiments in the period 1990-1992, fuelled with tritium in the USA and Europe will demonstrate energy breakeven and an experiment in Japan fuelled with deuterium will demonstrate breakeven equivalent conditions. In preparing for their final tritium campaigns these major projects abroad have begun to call more frequently on Canada for nuclear research, engineering and hardware. Consequently, based on the expectation of continued financial support from Ontario, the overall budget for 1988/89 is expected to be $16 million. Of this 50% would come from fusion projects abroad purchasing engineering and research services and hardware, 13% will be contributed as matching funding by industry, universities, AECL and Ontario Hydro as participating subcontractors, and the remaining 37% shared by AECL, Ontario and Ontario Hydro as funding partners.

These financial data speak for a successful program, for international recognition and for opportunities for the nuclear industry. But perhaps more importantly they speak of the political reality for the Canadian R&D environment. Simply stated, in order to find support for R&D on a topic such as fusion where the delivery of an energy system is a very long term proposition, mechanisms must be found for short term benefits. In this case the short term benefits include the advancement of our technology, its transfer to industry and direct or spinoff business opportunities.

As we look forward to the next decade we see fusion R&D emerging from an operation in physics to a nuclear operation. A major impetus to this evolution has come from the recent agreement by the USA, Europe, Japan and the USSR to cooperate in a 2½ year $140 million program starting on May 2, 1988, to produce the conceptual design and validating R&D for the next step ignition device known as the International Thermonuclear Experimental Reactor (ITER). The purpose of ITER will be to demonstrate a continuously burning plasma, and the necessary fusion nuclear technologies including the tritium system, breeding and maintenance technologies to prepare for the construction of the first fusion energy demonstration plant.

Arrangements have been made for the participation of other countries with specific fusions capability. Discussions are in the final stages for Canada's participation and it is the intention to undertake specific engineering and research tasks at a level of 10% of the contribution of the major partners.

Following the conceptual design phase of ITER, major decisions will be needed on whether to continue on to detailed design and construction, the nature of continued international cooperation and the location for siting the experiment. Canada has a continued stake in this development. The project is estimated to cost $5 billion to build over 10 years. Canada has a technological capacity to provide up to $700 million in research, engineering, hardware and tritium fuel, regardless of where ITER would be sited. Substantial incentive exists for Canada to consider supporting a Canadian Siting. In part this comes from a further capability to contribute an additional $1 billion in material and services as well as closer proximity and access to this centre of advanced technology.

As the Third Topical Meeting in Tritium Technology closes this 6th day of May 1988, by virtue of its carefully managed investment in fusion research, the availability of tritium as a fusion fuel, and the strong similarity in the tritium and maintenance aspects between CANDU and fusion, Canada finds itself well positioned to contribute strongly in this field of global research and to recover an appropriate share of benefits.

D.P. Dautovich

ONSR Report

(continued from page 1)

fatality due to an accident at reactors operated by either Ontario Hydro or AECL.

- Although there have been several accidents at Ontario Hydro stations, none has resulted in significant releases of radioactive materials to the environment; the emergency coolant injection systems and the final containment barriers have never been needed.
- Calculation suggests that even in the case of an accident involving loss of coolant plus failure to shut down at the weakest reactors – Pickering A – containment would remain almost intact and escape of radioactive substances would be very low.
- The technical and radiological training of reactor staff is excellent.

However, Dr. Hare notes that future safe performance requires changes in four main areas. "The reactors have not behaved perfectly, and there have been several serious malfunctions. Their components are ageing. Some aspects of the operational system are open to criticism. The provincial emergency measures system requires action. There are problems in the regulatory area."

The Commissioner's major recommendations relate to pressure tube issues and the human element.

On the subject of pressure tubes, Dr. Hare makes three points.

"The most serious technical safety-related issue in Ontario Hydro's reactors is the poor performance of pressure tubes . . . These tubes are part of the high pressure heat transport system. Any failure presents a threat of a small loss of coolant accident . . . Two such failures have already occurred."

. . . .

"The causes of these failures have been discovered. Some rehabilitation measures have been taken (as in units 1 and 2 at Pickering A). Much more needs to be done."

. . . .

"The main threat is heavy damage to the reactor, and hence large repair and power replacement costs. There appears to be little danger that radioactive materials will escape into the environment. The public is unlikely to be affected. But there is a threat to operating and maintenance crews."

"maximum priority to the pressure tube problem"

Because of these problems and questions, one of the two major recommendations relates to pressure tube integrity and is stated as follows:

"That maximum and effective priority be given to finding a solution to the pressure tube problem, and to improved in-reactor monitoring. Investment in fuel channel research by Ontario Hydro should be increased, and greater emphasis given to the fundamental metallurgical problems, tapping expert knowledge available in other industries."

This recommendation is followed by a warning about quick fixes or short-cuts.

"Research on this problem cannot be short-term. In the search for better alloys, for example, prolonged in-reactor testing, over a period of years, will be necessary. So will the laboratory facilities of Ontario Hydro and AECL."

The second major recommendation relates to the human element. By way of preamble, Dr. Hare notes:

"A general conclusion is that **human performance of individuals and institutions is the key to future safety** (emphasis in original). There must be a sound safety culture in Ontario Hydro and it must be directed from the top down."

The report notes that "Ontario Hydro has an outstanding reputation among international technical and professional groups, which regard it as one of the world's leading utilities. It deserves this reputation in the technical subjects covered in this report. Especially strong are its design, construction and safety analysis groups."

However, the Commissioner considers that there are several matters in this area in which action by the province and Ontario Hydro would improve future safety prospects and probably economic performance. His second major recommendation, therefore, is directed at the human element and how this is dealt with at the corporate level by Ontario Hydro. The recommendation states:

"That Ontario Hydro:

(i) Ensure that, at an early date, its operational organisation be thoroughly re-examined, in close co-operation with independent consultants who have international management experience;

(ii) Commission a study of factors affecting human performance throughout the utility, for the purpose of achieving optimum efficiency and the maintenance of high standards of safe operation:

(iii) Examine and revise its arrangements for establishing and maintaining an overall quality assurance programme for each of its plants . . . "

The report puts forward a number of additional "less general conclusions and recommendations, each important in its own right". These broadly cover a number of areas which are summarized below.

(A) Risk of Accidents

The Commissioner concludes that the risk of accidents is remote.

"A severe accident in an Ontario reactor, with release of damaging amounts of radioactive substances, is very unlikely, but cannot be ruled out. Emergency measures planning requires that estimates be made of the range of credible accidents." The report notes that all Ontario Hydro reactors are designed specifically to contain all but the most severe accidents and that they are licensed on that basis. It also cautions against direct comparisons with the accident at Chernobyl, commenting that if a severe accident were to occur here "it would be quite unlike that at Chernobyl". Drawing on a range of information, including the studies of a LOCA at Pickering with failure to shut down, performed independently by Ontario Hydro and Argonne National Laboratory, Hare concludes that in the remote chance of an accident, there would be minimum hazard to the public. "There would, however, be severe damage to the reactors, with consequent costs and radiological penalties to clean-up and repair crews. It is desirable that this conclusion be tested for other forms of severe accidents and other reactors" (i.e. other than Pickering).

The Commissioner's recommendation in this area is that Ontario Hydro extend the analysis of severe accidents to include loss of regulation plus failure to shut down and that these analyses be broadened to cover representative Darlington and Bruce reactors.

(B) Emergency Measures

The two players in emergency measures are Ontario Hydro and the provincial government, and the report notes that Ontario Hydro's portion of the effort appears to be "well conceived and financed". The Ministry of the Solicitor General "published an excellent Nuclear Emergency Plan" in 1986 but to date little more than the plan exists, despite a decision to make funding available. On the provincial government side, "the professional staff involved still numbers only two" and "a sense of urgency is lacking. If a severe accident occurs, it will find the utility prepared and the province unready – unless prompt action is taken."

"ICRP remains the best available body for the determination of radiological dose limits"

The Commissioner recommends bluntly "that the Province of Ontario at once appropriate the funds necessary to set in place the preparedness aspects of the Provincial Nuclear Preparedness Plan."

(C) Health Matters

The Commissioner sees the threat of Ontario's nuclear stations to public and occupational health in straightforward terms:

"There is no evidence that the normal operation of Ontario Hydro's reactors has caused, or will in future cause, harmful effects in either the work-force (which is by far the most exposed group) or the general public. But vigilance is required."

The AECB occupational exposure limit of 50 mSv a year is being met with an adequate margin: "In 1985-86, work-force whole-body exposure averaged 3.9 mSv". It is also noted that "the number of exposed workers per unit of energy produced is among the world's lowest."

This exposure limit, and other AECB regulations, are based on recommendations of the ICRP, which in the Commissioner's view, "remains the best available body for the determination of radiological dose limits. AECB should continue to base its regulations on ICRP guidelines . . . Provincial practice should follow suit."

Reference is made in the report to "many ill-formed allegations" in the area of radiological protection. The Commissioner makes a point of focussing on one of the main sources of these allegations: Dr. Rosalie Bertell and the International Institute of Concern for Public Health (IICPH). The submission by the IICPH, which was paid as an intervenor, is described as "a composite document touching on several related questions, most of which are outside the Review's terms of reference". Of its author, the Commissioner notes that "Dr. Bertell is well-known for her crusading work to improve – as she sees it – standards of radiological protection world-wide."

Dr. Bertell's apparent intent is to cast doubt on the competence of international bodies involved in setting radiological standards, and to discredit the validity of their pronouncements. The brief's main thrust, as summarized by Hare, is that "the available evidence on dose-response relationships resulting from radiation exposure is being misinterpreted by the scientists who dominate the regulating and standard-setting bodies, most notably the ICRP".

The Commissioner's comments on this view are unambiguous.

"I cannot agree with the submission's recommendation "that Canada no longer rely on ICRP, UNSCEAR or BEIR as the scientific support for radiation protection standards".

On the contrary, it is essential that Canada be guided by the findings of these bodies. They are accepted by the world scientific community as the best clearing-houses for the empirical data that are available, as the authoritative bodies to judge the meaning of the evidence and (in the case of ICRP) to suggest standards for safe exposure. Canada, Ontario and Ontario Hydro need not be bound, in a legal sense, by what these bodies find, but they would be ill-advised to abandon them as the best sources of advice and intellectual authority."

(D) Regulation

Even though regulatory arrangements were outside the ONSR's mandate, the volume of comment reaching it through the submissions was so large and "the importance of regulation to safety is so great" that the Commissioner felt it appropriate to formulate some comments at least.

"There is no evidence that the AECB lacks the proper means of enforcing its regulations. The licence and the threat of unfavourable publicity if the utility does not comply with licence conditions are adequate tools of enforcement."

"The regulatory methods and powers of the AECB are sound and should not be fundamentally changed. They follow European practice, by putting the onus for safety on the shoulders of the operating utility . . . It would be inappropriate to move to the US model of tight prescription, with court action as the final sanction."

"no evidence that the AECB lacks the proper means of enforcing its regulations" and no evidence of an incestuous relationship between the industry and its regulator"

The relationship between the regulator and the regulated is also appropriate, in the Commissioner's view.

"The scientists and engineers engaged in the nuclear industry are professionals, guided by their professional ethics. The ONSR has discovered no evidence of an incestuous relationship between the industry and its regulator. . . The present situation is a healthy one and should be preserved in the future."

A specific recommendation in this area states:

"That AECB retain its present powers, sanctions, and functions, but ensure that its decisions (and reasons for them) are promptly published and enforced. Its staff complement should be increased to permit a broader programme, particularly in the radiological, socio-economic and environmental areas."

Two warning notes are also sounded, one for the Government of Ontario, and one for the AECB.

"The Government of Ontario should not invade the regulatory territory now legally occupied by AECB. The legislative and legal claims of the Government of Canada to regulate Ontario Hydro's nuclear programmes are not in question."

"AECB's work, and that of its outstanding Advisory Committees on Nuclear Safety and Environmental Protection, is almost unknown in Canada. AECB needs a higher profile and should also seek closer contact with concerned opinion in the scientific community. The advisory committees need the resources to enlarge, accelerate, and more widely disseminate their work."

(E) Role of Government

With the involvement of provincial and federal bodies and at least two levels of government, the part played by governments in nuclear safety is significant. The ONSR conducted its inquiry into the safety of Ontario's reactors "without regard to the niceties of jurisdiction. It has made clear the fact that the provincial utility is subject to close federal regulation, and that this is a source of strength – in that it separates the regulating body from Ontario Hydro in a clear-cut way. Nevertheless, the Government of Ontario retains an important responsibility for the entire question of safety."

Other areas of provincial government interest and responsibility are noted throughout the report. The provincial responsibility in the area of emergency preparedness drew comment as did the desirability of Ontario maintaining a hands-off attitude to regulation. The Commissioner recommends the formation of a provincial Advisory Council on Health and Safety, similar to that for the nuclear fuel waste management programme, which would draw on the industrial and academic communities. He also recommends in general that governments should scrutinize in more than a nominal way the documents produced by the regulatory process, for example, the annual reports of the AECB. The Select Committee on Energy is suggested as the appropriate forum for this activity. The Ontario Government is also encouraged to make use of the Environmental Assessment Review Process where this would be beneficial, particularly in the socio-economic and environmental domains.

"Hydro's safety analyses are . . . about as difficult as reading the scriptures in their original Greek or Hebrew."

(F) R&D

The Commissioner comments on the reduction in AECL's research budgets, noting that these reductions, due to federal cut-backs, "have affected the programmes and availability of AECL's laboratory and engineering divisions, both of which are essential to safety-related research and development. The Ontario Government should ensure that these cut-backs do not adversely affect safety and efficiency within its wholly owned utility."

However, there is a warning on where the onus ultimately resides:

"The research necessary to maintain efficiency and safety must be primarily the responsibility of Ontario Hydro."

A healthy level of research is needed in general, since "CANDU is still a young technology and needs support from competent research and development laboratories". But "research is particularly necessary in the safety area" and recent cut-backs in research funding "handicap the efforts to ensure public safety".

More specifically, the research effort devoted to the pressure tube problem seems inadequate, in the Commissioner's view. "Present annual expenditures of $42 million . . . ($19 million from Ontario Hydro) appear small in relation to the problem and to Ontario Hydro's revenues of $2.5 billion from nuclear power sales alone. CANDU Owners' Group analysis of research needs is excellent. In part, the fulfillment of those needs is limited by the lack of skilled specialists capable of originating and conducting original work."

Summary

The report of the Ontario Nuclear Safety

Review is a clearly thought out and well written document. Its conclusions and recommendations appear to be sensible and unambiguous.

The report is also the product of a disciplined and methodical approach to a problem which is surrounded on all sides by technical difficulties and obscurities, as well as by many emotional issues. The restricted mandate and insistence upon peer review are two very strong points.

"The Safety of Ontario's Nuclear Power Reactors" deserves careful study and a positive and considered response by all parties.

Keith Weaver

Jatin Nathwani

FYI

Basic Safety Principles for Nuclear Power Plants

(IAEA Newsbriefs)

A set of interrelated objectives and principles for further promoting the safety of nuclear power plants has been issued in a report by the IAEA's International Nuclear Safety Advisory Group (INSAG). INSAG is an advisory body to the IAEA Director General composed of senior experts in nuclear safety.

"The understanding and application of these safety principles should improve safety and benefit everyone, especially those in countries that use or intend to use nuclear power as an energy source," the report says. Chiefly addressed to nuclear plant designers, regulators, and operators, the principles are intended to consolidate the key concepts of nuclear safety in a structured, systematic form that anticipates the direction of future practice. They do not constitute a set of regulatory requirements, but are intended to provide an understanding of the underlying philosophy and logic behind essential nuclear safety requirements. The 12 fundamental and 50 specific principles, which support three overriding objectives, relate to nuclear plant siting, design, manufacturing and construction, commissioning, operation, accident management, and emergency preparedness. Overall, the document is built around the safety concept of defense-in-depth and includes discussion of the use of numerical safety targets and probabilistic safety assessment. It strongly emphasizes achievement of a "safety culture", which is defined as "the personal dedication and accountability of all individuals engaged in any activity which has a bearing on the safety of nuclear power plants". It further recognizes the crucial role of control room staff, promotes the use of plant simulators for training, and stresses the importance of feedback from operational experience.

Symposium Emphasizes Severe Accident Prevention

(IAEA Newsbriefs)

Practical steps that can be taken to reduce the radiological consequences of severe accidents that could affect nuclear power plants were among principal topics at a major international symposium in Sorrento, Italy, from 21-25 March. The symposium was co-sponsored by the IAEA and the Nuclear Energy Agency of the Organization for Economic Co-operation and Development (NEA/OECD); it was hosted by the Italian National Commission for Nuclear and Alternative Energy Sources (ENEA).

Relatively few severe accidents – defined as those with severe core damage have occurred at nuclear plants. Yet those that have happened provide important technical lessons that can be globally shared to improve accident prevention and management, papers presented at the symposium emphasized. National policies and practices were reviewed by experts from many countries. Considerable work has been done to prevent, better identify, and more effectively manage potential severe accidents. Other sessions were devoted to severe accident analysis and related research. In sessions covering accident management, it was stressed that monitoring of the plant status, preparation of special operating instructions, and proper training of personnel contribute significantly to the safety of nuclear plants.

"The results of the analysis of severe accidents and the insights gained from the work done do not invalidate existing designs of nuclear power plants," noted Prof. Leonard Konstantinov, IAEA Deputy Director for Nuclear Power and Safety, in his opening remarks. "Rather, the information confirms that the defense-in-depth concept is technically sound." He noted that many practical lessons to limit radiological consequences have been learned from analysis of past nuclear plant accidents, notably those at TMI and at Chernobyl in the USSR in 1986.

Mortality among weapon-test participants

(Nuclear Energy)

Health effects on service and civilian personnel who took part in British nuclear weapon tests in Australia and the Pacific between 1967 and 1982 have been investigated in a 5 year study by staff of the Imperial Cancer Research Fund (ICRF) and the National Radiological Protection Board (NRPB) with considerable assistance from the Ministry of Defence. The reports of the investigation show no detectable effect on total cancer mortality from participation in the tests.

. . . No significant trend of incidence with radiation dose was found for any type of cancer, including leukaemia.

After detailed discussion of the possible bias from omission of some participants in the tests, incomplete follow-up of the study population, the low mortality rates and the statistical chance of obtaining occasional high or low SMRs from the large number of analyses carried out, the report concludes that participation in the nuclear weapons test programme has not had a detectable effect on life expectancy or the total risk of developing cancer, apart from a possible but not proven effect on the risks of developing multiple myeloma and leukaemia.

Future prospects of fusion and fission

(Nuclear Energy)

A recent US publication *Summary of the Report of the Senior Committee on Environmental safety and economic aspects of magnetic energy fusion* is the result of an in depth assessment organized by the Magnetic Fusion Energy Division of the Lawrence Livermore National Laboratory. The Committee looked at fusion energy in the year 2015 and beyond and compared its prospects with other energy sources. It concluded that such fusion systems showed environmental and safety advantages and that the economics were comparable to fission systems.

Eight fusion systems, two fusion-fission hybrids and four fission systems were examined. Magnetically confined fusion has frequently been promoted as an inexhaustible source of energy, which would not only be affordable but be safer and cleaner than fission systems. However, scientific feasibility has not yet been demonstrated, and the required future investment is huge, because small demonstration systems, frequently built for fission systems, are not possible with magnetic fusion systems.

Impact of Chernobyl in OECD Countries

(Nuclear Energy)

A new report by the Organization for Economic Co-operation and Development (OECD) Nuclear Energy Agency (NEA) reviews the radiological impact of the Chernobyl accident in OECD countries. The average individual doses in the first year after the accident, based on data supplied by each country, have been documented.

The NEA concludes that individuals are not likely to have been subjected to a radiation dose significantly greater than that received from one year of exposure to the natural background. Consequently, the lifetime average risk of radiation induced harm has not been changed to any noticeable extent by the accident. The number of potential health effects will not constitute a detectable addition to the national incidence of similar effects within the population.

TECHNICAL SUPPLEMENT

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PROCESS SIMULATION WITH MICROCOMPUTERS: A GENERALIZED SIMULATION CODE FOR APPLICATION TO FISSION AND FUSION SYSTEMS

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Abstract - *Simulation of a process system requires rigorous mathematical models of the process units and the inter-unit flows to produce reliable and detailed mass and energy balances. A generalized simulation program called FLOSHEET has been developed which incorporates models of many process units commonly used in nuclear fission and fusion systems and a simple means for linking them together. The program has been successfully used for operations and commissioning support for Ontario Hydro's Darlington Tritium Removal Facility and heavy water upgraders, and in design studies for fusion fuel systems and other isotope separation systems. The simulator is available to other users through Ontario Hydro and the Canadian Fusion Fuels Technology Project (CFFTP).*

1.0 INTRODUCTION

Computer modelling or simulation of process systems is an established and cost-effective tool which allows process engineers to design and rate unit operations, processes, and entire process plants. The need for computer based simulators arises from the complexity of most practical process systems. Most large scale chemical process systems are far to complex to accurately model by hand calculations alone. Hand calculations are tedious, prone to error, and possible for only simple problems. Furthermore, in design problems there are usually several degrees of freedom to choose the appropriate design point for a system. Simulators provide a consistent basis for performing detailed comparisons of different designs.

Before process simulation came into wide use in the chemical process industry, many projects were built with minimal calculation of process alternatives. In order to minimize the risk associated with calculation uncertainties, it was common for designers to use very large design margins, resulting in over-conservative and thus more costly designs. From past designs one can also observe a strong correlation between a process system's design and the process calculation tools available to the designer. Process plant designs were frequently constrained by the ability of the designer to evaluate process options.

The benefits that accrue from the availability of good process simulation tools may be summarized as follows:

- capital savings through improved designs;
- decreased process engineering time spent on routine calculations;
- consistent and accurate data and techniques used throughout;
- improved and quicker communication between design and operations staff;
- improved troubleshooting and diagnostic capability;
- faster commissioning and increased plant efficiency due to a better understanding of the limitations and flexibility of the process variables in the plant;
- elimination of the need for users to be experts in complex mathematical and process engineering techniques such as convergence algorithms, programming techniques, etc.;
- availability of a *user friendly* program interface, which promotes faster learning by new users, greater use by existing users, and continuity through staff turnover;
- standardization of calculation techniques between users, allowing process designers to concentrate on process design principles and tradeoffs and eliminating differences based on calculation techniques.

A generalized simulation program called FLOSHEET has been developed by Ontario Hydro, which incorporates models of many process units used in fission and fusion systems and provides a simple means for linking them together. This paper describes FLOSHEET and its application to the Darlington Tritium Removal Facility (DTRF) and to fusion reactor fuel systems. The program is also applicable to many other types of systems, with minor extensions, and is available to other users through Ontario Hydro and the Canadian Fusion Fuels Technology Project (CFFTP).

The FLOSHEET program allows the user to interactively specify a complete process system consisting of interconnected process units (such as cryogenic distillation columns, catalytic equilibrators, etc.) and then calculates the performance of each process unit to produce mass and heat balances. For processes containing recycle streams, FLOSHEET iterates the recycle loops and forces recycle stream convergence.

In the past, all process simulation systems required a mainframe computer to run effectively. FLOSHEET is designed to run on IBM PC, XT, AT, PS/2 or compatible computers equipped with a math coprocessor and a hard disk. The use of microcomputers allows FLOSHEET to have an easy to use *windows type* user interface, to be highly portable, inexpensive to run, and to provide faster turnaround of simulation results.

Using FLOSHEET involves no computer programming, and requires only minimal input/output skills. The program is designed to allow the user to concentrate on solving his simulation problem rather than on the mechanics of running the program. Extensive error checking and meaningful error messages keep the user on track and notify the user of missing or erroneous data. Of course, the user should be fully competent in the theory and operation of the process units in the system being simulated in order to properly understand the simulation results. The use of FLOSHEET does not guarantee that the systems being simulated are practical or appropriate for any

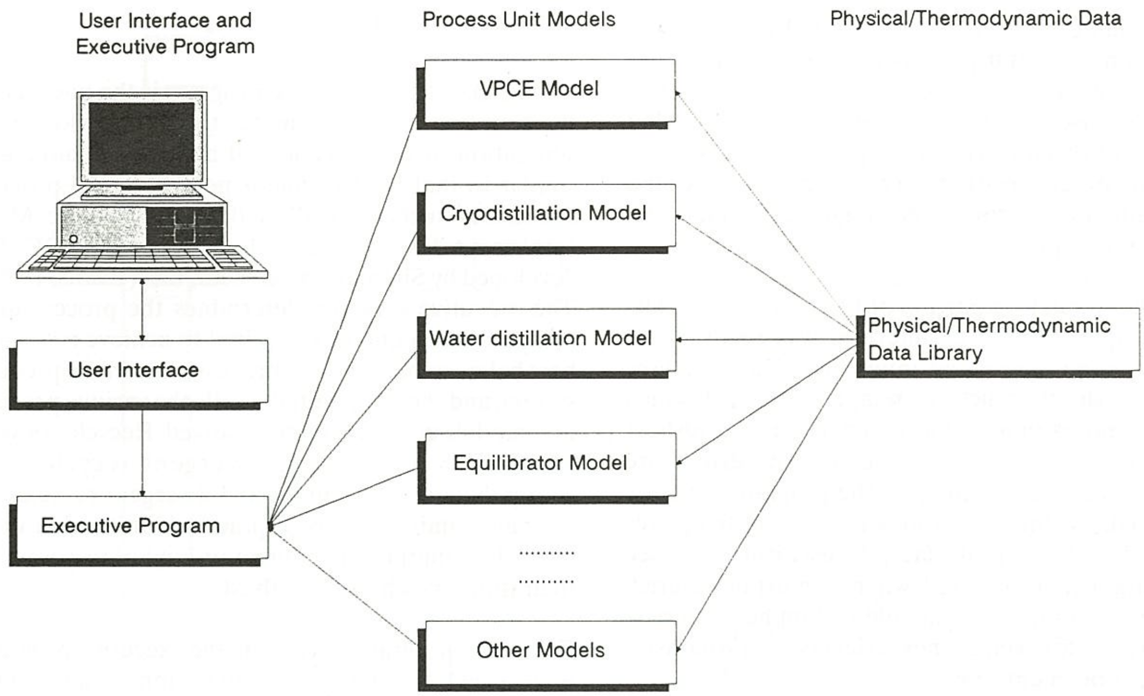


Figure 1. Schematic of FLOSHEET program structure.

given application. The final responsibility for the correctness of a design produced using the FLOSHEET simulator still rests with the user.

2.0 FLOSHEET PROGRAM STRUCTURE

The FLOSHEET simulator is comprised of the following components:

- user interface;
- executive program;
- unit operations models including:
  - Vapour Phase Catalytic Exchange (VPCE) model;
  - Cryogenic Distillation (CD) model for hydrogen isotopes;
  - Water Distillation (DW) model for hydrogen isotopes;
  - Catalytic Equilibrator model for species H_2 to T_2;
  - Stream Mixer model;
  - Stream Splitter model;
- physical/thermodynamic data library.

A schematic representation of how these components are tied together is shown in Figure 1.

To simulate a process using FLOSHEET, the user defines the flowsheet topology and those process variables for each stream and process unit which specify the system. The simulator then determines the appropriate unit computation sequence and calculates the performance of the different process units to produce mass and heat balances. For processes containing recycle streams, FLOSHEET automatically iterates the recycle loops and forces recycle stream convergence.

3.0 USER INTERFACE

To simulate a complex chemical process flowsheet, a great deal of information must be input to completely specify the simulation problem. For example, one needs to specify all the input, output, tie and recycle streams (source, destination, temperature, pressure, phase, etc.), the unit types (distillation column, reactor, etc.), and the unit specifications (for a distillation column: number of theoretical stages, reflux ratio, feeds and drawoffs, etc.).

The user interface of FLOSHEET was developed in two stages. In the first stage, when most of the programming effort was concentrated on flowsheet simulation logic and process unit models, the input was via a text file that was arranged in a specific format. This user interface was easy to program but unforgiving of data format or sequencing errors. Missing or out of sequence data were difficult to detect and it was difficult to provide meaningful error messages for diagnostic purposes.

After the simulation portion of FLOSHEET was largely complete, the user interface was rewritten to make it menu-driven and interactive. Data are now input into clearly structured templates through which the user moves in a similar manner to a spreadsheet program. In this way, data sequencing errors are eliminated and the running of the program is greatly simplified. Within the various menus and templates provided by the user interface, the user can always see what data must be entered, where it must be entered, and what options are available to him/her. There is rarely a need for even an inexperienced user to consult program documentation.

In situations where many simulations need to be performed (such as in parametric studies), FLOSHEET may be run in *batch mode* to simulate and store the results for a list of process flowsheets. This mode of operation requires no user interaction and is useful for multiple overnight runs.

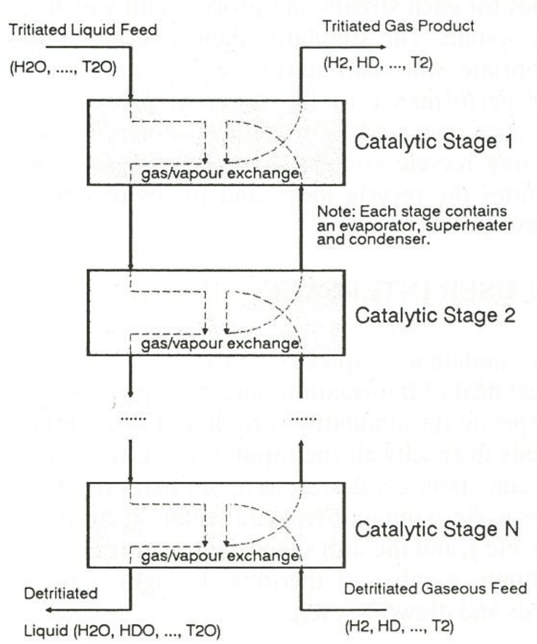


Figure 2. VPCE Process Model.

4.0 EXECUTIVE PROGRAM

The FLOSHEET executive program is the nucleus of the simulator and coordinates the overall flowsheet simulation. It has a sequential modular architecture similar to that used by major petrochemical process simulators such as ASPEN developed at the Massachussetts Institute of Technology and PROCESS developed by Simulation Sciences, Inc. (Evans, 1980). The executive program determines the process unit computation sequences required to achieve mass and heat balances between the process units in the process system, and then sequentially calls the various process unit models until the system is solved. Recycle convergence is accelerated. Convergent recycles are extrapolated to their limit, and divergent recycles to their anti-limit. There is no practical limit (other than execution time) to the number or kind of recycle configurations which can be solved.

For future program expansion, the executive program is designed to allow easy integration of additional process unit models and physical and thermodynamic data.

5.0 PROCESS UNIT MODELS

5.1 VPCE Model

The VPCE model used by FLOSHEET is illustrated in Figure 2. The main features of the model are:

- simulation of any number of linked VPCE stages;
- incorporation of equilibrium relations for all species present (H_2, HD, HT, D_2, DT, T_2, H_2O, HDO, HTO, D_2O, DTO, T_2O);
- ability to vary reaction temperature and gas and liquid flows.

5.2 Cryogenic Distillation Model

The cryogenic distillation model is one of the most complex unit operations in FLOSHEET and is illustrated in Figure 3. The main features of the cryogenic distillation model are:

- material and energy balances for each stage;
- incorporation of liquid and vapour non-idealities;
- simulation of heat input/removal on any stage;

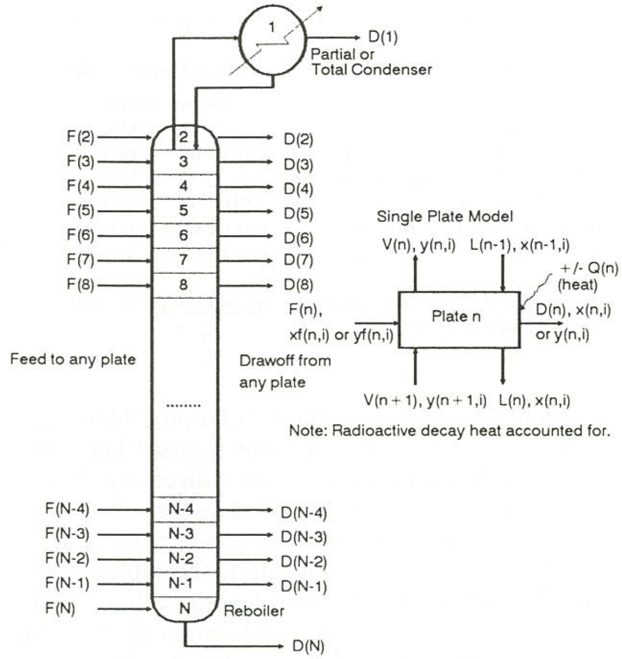


Figure 3. Cryogenic Distillation Column Model.

- incorporation of radioactive decay heat of tritium.

The FLOSHEET cryogenic distillation model has been compared to the CRYDIS-N code developed by Kinoshita (1984a). Initial comparison of the two codes showed that they produced similar but not identical results. Since the differences were greater than what could be accounted for by numerical roundoff error, the reason for the differences was investigated. The numerical methods used to solve the distillation column equations in the two codes are different, but since the model equations are the same, the results should agree. After a brief review of the calculations it was found that the vapour pressure correlations used by the two codes were slighty different. The CRYDIS-N code used vapour pressure correlations from Misra and Maroni (1977) which are based on the work of Mittlehauser and Thodos (1964), while FLOSHEET used correlations based on the work of Souers (1979). Using the same correlations, the two codes produced identical results.

5.3 Water Distillation Model

The FLOSHEET water distillation model is one of the most comprehensive available and is used extensively within Ontario Hydro to simulate heavy water upgraders and finishing units. The main features of the model are:

- water distillation cascades can be specified in great detail (i.e., packing height, column diameter, feed valve positions, packing correlations, boilup rate, multiple feeds and drawoffs, intermediate reboilers and condensers, condenser pressures, HETP and pressure drop correlations, packing liquid holdup, sump holdup, etc.);
- the model can be used to simulate multiple linked water distillation columns of different diameters and different packing types;
- the model can be used to optimize feed position, feed rate, or both feed position and feed rate;
- as adapted for use by FLOSHEET, the distillation of all six aqueous species (H_2O, HDO, HTO, D_2O, DTO, T_2O) and the equilibration reactions between these species in the liquid phase are rigorously accounted for.
- The packing correlations used by the model are based on the measured packing performance of packed columns in operation at Ontario Hydro's heavy water upgrading and production plants.

5.4 Catalytic Equilibrator

The catalytic equilibrator model simulates the equilibration of the six gaseous species H_2, HD, HT, D_2, DT and T_2 via the reactions:

$$H_2 + D_2 = 2HD$$

$$H_2 + T_2 = 2HT$$

$$D_2 + T_2 = 2DT$$

The equilibration reaction temperature is an input variable and may be specified by the user.

5.5 Mixers and Splitters

Mixer and splitter models are provided for mixing and splitting flows within a process system.

6.0 PHYSICAL AND THERMODYNAMIC PROPERTY LIBRARY

A physical and thermodynamic property library has been compiled to provide needed data to the process unit models. This library is in the form of a standard

ASCII text file which may be added to or updated using a text editor.

7.0 SIMULATION RESULTS

FLOSHEET has been used to simulate many different tritium processing systems, from Ontario Hydro's DTRF to fusion fuel systems such as the TSTA cascade (Bartlit et. al., 1979), Kinoshita's cascade (Kinoshita, 1984b) and NET type Aqueous Lithium Salt Blanket (ALSB) tritium recovery systems from light and heavy water (Kalyanam and Sood, 1988). A few of the results and general observations about these process simulations are presented below.

7.1 Simulation Characteristics of Tritium Systems

In general, tritium processing systems are concerned with removing trace quantities of tritium (T) from systems containing mostly the H and D hydrogen isotopes. The relative concentrations of H, D and T may change by ten or more orders of magnitude from one part of a process system to another. These system characteristics necessitate that the convergence criteria for the mass balances within each process unit model and between process units be satisfied to a very high degree. Loose convergence criteria may give satisfactory results for the mass balances of bulk species but may give rise to gross errors in the mass balances of trace species, i.e. typically those containing tritium. For example, the distillation column shown in Figure 4 presents a fairly severe convergence problem. The solution of the distillation column equations by a simple tridiagonal matrix algorithm fails to converge after 20 iterations and is diverging. If these unconverged results are accepted as the solution, the tritiated species results contain gross errors as shown in Table 1. The converged results in this table were obtained by FLOSHEET's Broyden algorithm which is similar to that described by Kinoshita (1984a), but with the improvement that the system Jacobian matrix is computed analytically instead of by finite differences. Similar gross errors may result in recycle stream compositions *between* process units if recycle convergence is not forced to a high degree. This difficulty has been reported for distillation columns with recycle streams by Kinoshita (1982), but we have found this to be true for tritium systems in general. Special algorithms are required to ensure recycle stream convergence. For distillation columns with a recycle stream, Kinoshita (1984b) has successfully used a Newton-Raphson convergence method based on tritium input/output atom balance. FLOSHEET uses more general algorithms which address the general recycle problem by performing an eigenanalysis of the system iteration matrix. Once the eigenvalues associated with the slow convergence of the iteration process are identified, an extrapolation is made to the sequence limit for convergent sequences or *anti-limit* for divergent sequences. This method of recycle convergence acceleration has proven very successful for all the systems we have studied to date.

Column Specification

No. Stages: 80

Reflux Ratio: 150.0

Top Gas Flow: 2.90 gmole/h

Bottom Liquid Flow: 97.10 gmole/h

Feed Rate: 100.00 gmole/h (Feed stage = 55)

Liquid Feed Composition (mole fraction):

H2: 2.76611E-4

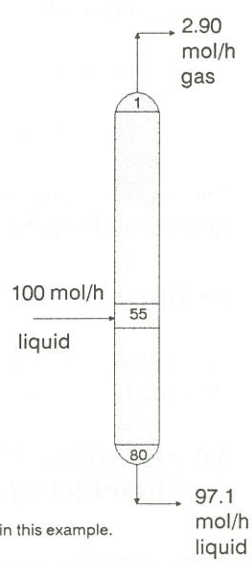
HD: 2.93111E-2

HT: 1.35105E-4

D2: 9.60437E-1

DT: 9.81338E-3

T2: 2.65010E-5



Note: Nonidealities and heat balance are ignored in this example.

Figure 4. Difficult CD column for simulation.

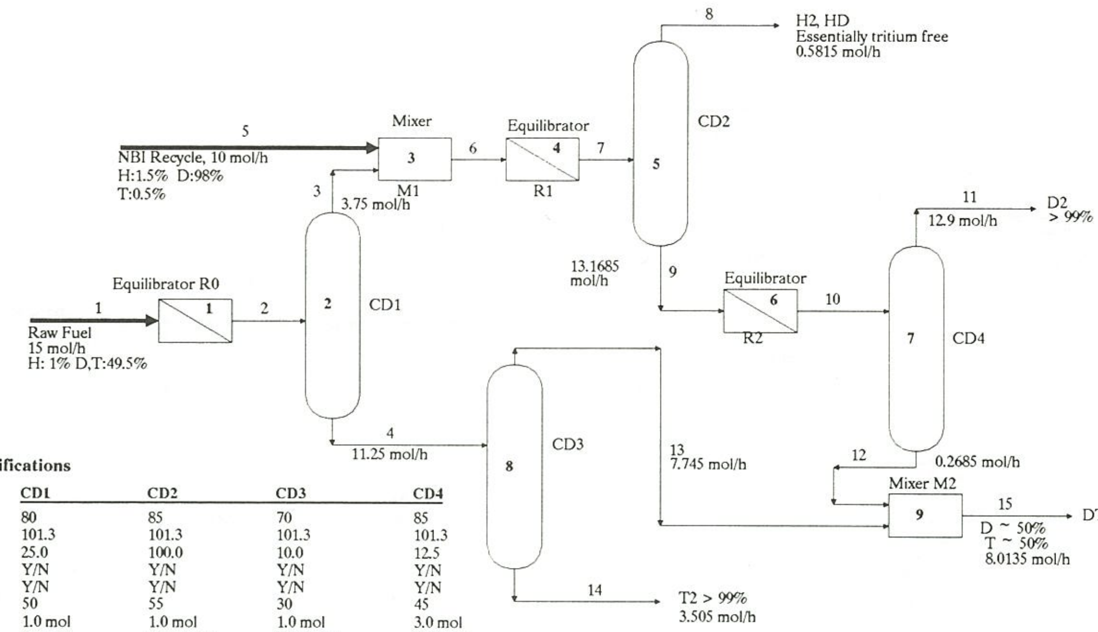
Table 1. Errors in unconverged CD simulation.

	Overhead Composition		Bottom Composition	
	Converged	**Unconverged**	**Converged**	**Unconverged**
H_2	9.538E-03	9.539E-03	4.918E-12	2.816E-12
HD	9.905E-01	9.906E-01	6.053E-04	3.497E-05
HT	1.500E-08	1.209E-06	1.391E-04	1.392E-04
D_2	3.476E-11	2.837E-09	9.891E-01	9.897E-01
DT	4.944E-19	4.763E-17	1.011E-02	1.011E-02
T_2	2.389E-27	2.832E-25	2.729E-05	2.731E-05

Note the gross errors in unconverged compositions for HT and D_2 overhead and HD bottoms.

7.2 TSTA Cascade

As an example of the application of the FLOSHEET code, the TSTA cascade which is shown in Figure 5 has been simulated. The results of the simulation are given in Tables 2 and 3. Table 2 contains simulation results for the case where liquid/vapour nonidealities are ignored and no heat balance is performed. Table 3 contains results for the case where nonidealities and heat balance are fully accounted for.



CD Column Specifications

	CD1	CD2	CD3	CD4
NTP	80	85	70	85
P (kPa)	101.3	101.3	101.3	101.3
Reflux Ratio	25.0	100.0	10.0	12.5
Nonideality	Y/N	Y/N	Y/N	Y/N
Heat Balance	Y/N	Y/N	Y/N	Y/N
Feed Plate	50	55	30	45
Cond. Holdup	1.0 mol	1.0 mol	1.0 mol	3.0 mol
Plate Holdup	0.1 mol	0.057 mol	0.098 mol	0.19 mol
Reb. Holdup	0.75 mol	1.3 mol	0.75 mol	1.0 mol
Column cooling	0.117W/plate (plates 51-79)		0.174W/plate (plates 31-69)	

Figure 5. TSTA cascade process flow diagram.

Table 2. TSTA Simulation Results (ideal, no heat balance)

	Flow (mol/h)	STREAM COMPOSITIONS (mole fraction)					
		H_2	HD	HT	D_2	DT	T_2
1	15.00	1.0000E-02			4.9500E-01		4.9500E-01
2	15.00	1.3494E-04	1.0436E-02	9.2944E-03	2.4757E-01	4.8443E-01	2.4814E-01
3	3.75	5.3975E-04	4.1743E-02	3.7175E-02	9.2024E-01	3.0378E-04	2.3989E-09
4	11.25	8.1305E-17	2.0166E-09	8.2432E-07	2.3346E-02	6.4580E-01	3.3085E-01
5	10.00	1.5000E-02			9.8000E-01		5.0000E-03
6	13.75	1.1056E-02	1.1384E-02	1.0139E-02	9.6370E-01	8.2848E-05	3.6364E-03
7	13.75	5.7930E-04	4.2130E-02	3.4659E-04	9.3988E-01	1.6987E-02	8.0371E-05
8	0.5815	1.3698E-02	9.8630E-01	7.4775E-08	1.0749E-10	3.0992E-18	2.8469E-26
9	13.1685	2.8851E-12	4.3739E-04	3.6189E-04	9.8138E-01	1.7737E-02	8.3920E-05
10	13.1685	1.9625E-07	7.9224E-04	6.6478E-06	9.8103E-01	1.8086E-02	8.7282E-05
11	12.90	2.0034E-07	8.0873E-04	6.7862E-06	9.9917E-01	1.6095E-05	3.2530E-12
12	0.2685	5.3325E-24	8.5237E-13	3.7972E-11	1.0949E-01	8.8623E-01	4.2807E-03
13	7.745	1.1810E-16	2.9292E-09	1.1974E-06	3.3912E-02	9.3543E-01	3.0659E-02
14	3.505	1.7452E-36	4.5460E-22	4.1216E-16	5.4637E-08	5.8076E-03	9.9419E-01
15	8.0135	1.1414E-16	2.8310E-09	1.1573E-06	3.6444E-02	9.3378E-01	2.9775E-02

Table 3. TSTA Simulation Results (nonideality, heat balance)

	Flow (mol/h)	STREAM COMPOSITIONS (mole fraction)					
		H_2	HD	HT	D_2	DT	T_2
1	15.00	1.0000E-02			4.9500E-01		4.9500E-01
2	15.00	1.3494E-04	1.0436E-02	9.2944E-03	2.4757E-01	4.8443E-01	2.4814E-01
3	3.75	5.3975E-04	4.1743E-02	3.7174E-02	9.1864E-01	1.8986E-03	2.2645E-08
4	11.25	1.6374E-17	2.4547E-09	1.2163E-06	2.3878E-02	6.4527E-01	3.3085E-01
5	10.00	1.5000E-02			9.8000E-01		5.0000E-03
6	13.75	1.1056E-02	1.1384E-02	1.0138E-02	9.6327E-01	5.1779E-04	3.6364E-03
7	13.75	5.7932E-04	4.2122E-02	3.5520E-04	9.3945E-01	1.7405E-02	8.4412E-05
8	0.5815	1.3698E-02	9.8630E-01	1.0393E-06	1.2650E-08	4.7863E-15	3.5440E-22
9	13.1685	2.6028E-12	4.2809E-04	3.7084E-04	9.8094E-01	1.8173E-02	8.8140E-05
10	13.1685	1.9609E-07	7.9173E-04	6.8100E-06	9.8058E-01	1.8530E-02	9.1670E-05
11	12.90	2.0017E-07	8.0821E-04	6.9518E-06	9.9912E-01	6.2258E-05	1.1479E-11
12	0.2685	6.7213E-25	8.3558E-13	4.3879E-11	8.9676E-02	9.0583E-01	4.4959E-03
13	7.745	2.3784E-17	3.5656E-09	1.7667E-06	3.4683E-02	9.2674E-01	3.8577E-02
14	3.505	5.7067E-38	1.3952E-21	2.5458E-15	4.6515E-07	2.3302E-02	9.7670E-01
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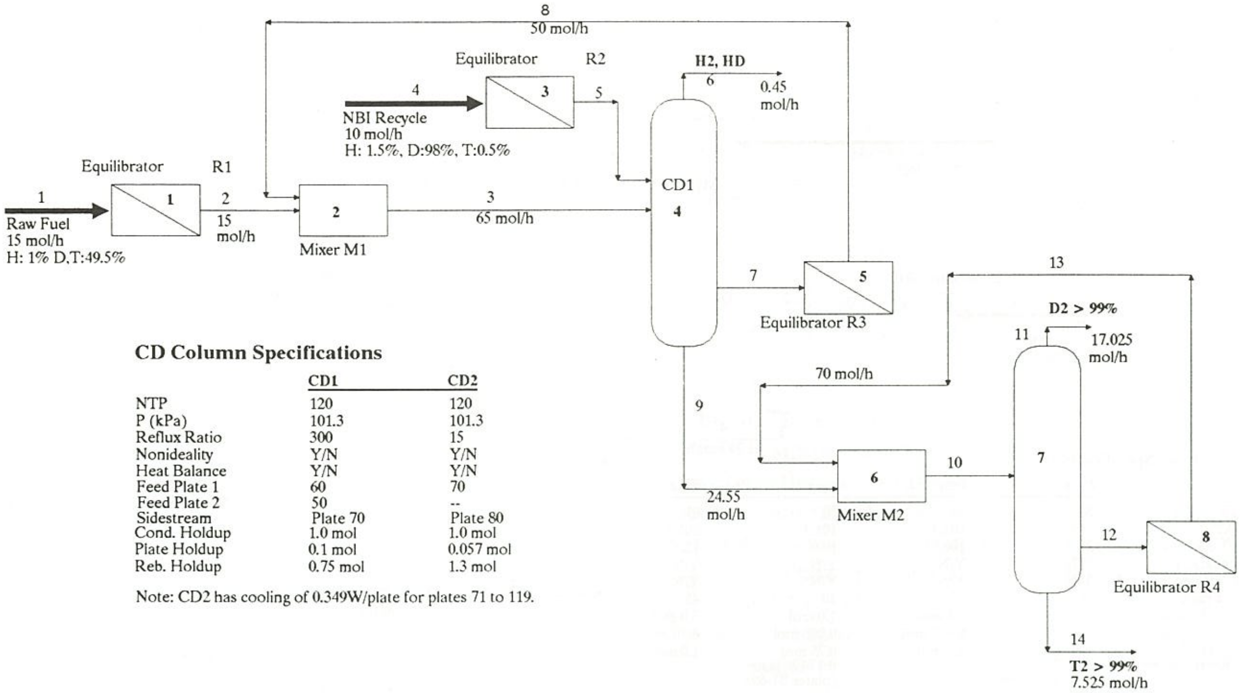

CD Column Specifications

	CD1	CD2
NTP	120	120
P (kPa)	101.3	101.3
Reflux Ratio	300	15
Nonideality	Y/N	Y/N
Heat Balance	Y/N	Y/N
Feed Plate 1	60	70
Feed Plate 2	50	--
Sidestream	Plate 70	Plate 80
Cond. Holdup	1.0 mol	1.0 mol
Plate Holdup	0.1 mol	0.057 mol
Reb. Holdup	0.75 mol	1.3 mol

Note: CD2 has cooling of 0.349W/plate for plates 71 to 119.

Figure 6. Alternative to TSTA cascade proposed by Kinoshita.

Table 4. Kinoshita Cascade Results (ideal, no heat balance)

	Flow (mol/h)	STREAM COMPOSITIONS (mole fraction) H_2	HD	HT	D_2	DT	T_2
1	15.00	1.0000E-02			4.9500E-01		4.9500E-01
2	15.00	1.3494E-04	1.0436E-02	9.2944E-03	2.4757E-01	4.8443E-01	2.4814E-01
3	65.00	2.3641E-03	6.4952E-02	1.1369E-02	5.7147E-01	2.7845E-01	7.1399E-02
4	10.00	1.5000E-02			9.8000E-01		5.0000E-03
5	10.00	2.7446E-04	2.9315E-02	1.3630E-04	9.6044E-01	9.8112E-03	2.6237E-05
6	0.45	3.2870E-01	6.7130E-01	9.0224E-08	1.5627E-11	1.3587E-18	1.4139E-25
7	50.00	1.6989E-04	8.4259E-02	1.4765E-02	6.8399E-01	1.8300E-01	3.3818E-02
8	50.00	3.0328E-03	8.1307E-02	1.1991E-02	6.6864E-01	2.1665E-01	1.8377E-02
9	24.55	5.2361E-20	3.5860E-08	8.4856E-05	5.1121E-01	3.6853E-01	1.2018E-01
10	94.55	3.6149E-12	1.5725E-06	2.3285E-05	3.4010E-01	4.6058E-01	1.9930E-01
11	17.025	2.0068E-11	8.5376E-06	1.1388E-04	9.9966E-01	2.2147E-04	4.0292E-11
12	70.00	1.8923E-15	4.7566E-08	3.7551E-06	2.1624E-01	6.2055E-01	1.6320E-01
13	70.00	4.8827E-12	2.1115E-06	1.6912E-06	2.8008E-01	4.9287E-01	2.2705E-01
14	7.525	3.2702E-34	7.6565E-20	1.1806E-14	2.3953E-06	1.4046E-02	9.8595E-01

Table 5. Kinoshita Cascade Results (nonideal, heat balance)

	Flow (mol/h)	STREAM COMPOSITIONS (mole fraction) H_2	HD	HT	D_2	DT	T_2
1	15.00	1.0000E-02			4.9500E-01		4.9500E-01
2	15.00	1.3494E-04	1.0436E-02	9.2944E-03	2.4757E-01	4.8443E-01	2.4814E-01
3	65.00	2.3152E-03	6.2510E-02	1.2928E-02	5.4225E-01	3.0301E-01	7.6994E-02
4	10.00	1.5000E-02			9.8000E-01		5.0000E-03
5	10.00	2.7446E-04	2.9315E-02	1.3630E-04	9.6044E-01	9.8112E-03	2.6237E-05
6	0.45	2.9832E-01	7.0168E-01	5.2415E-07	5.6609E-10	7.5611E-16	9.7344E-22
7	50.00	3.7980E-04	8.0810E-02	1.6518E-02	6.4622E-01	2.1476E-01	4.1313E-02
8	50.00	2.9693E-03	7.8132E-02	1.4018E-02	6.3065E-01	2.4858E-01	2.5650E-02
9	24.55	1.3032E-19	4.1624E-07	6.4149E-04	5.1076E-01	3.6887E-01	1.1972E-01
10	94.55	3.1587E-10	1.4919E-05	1.7809E-04	3.4564E-01	4.6003E-01	1.9413E-01
11	17.025	1.7537E-09	8.0500E-05	8.4512E-04	9.9161E-01	7.4595E-03	2.9929E-09
12	70.00	1.2482E-13	5.7239E-07	3.5003E-05	2.2569E-01	6.1611E-01	1.5816E-01
13	70.00	4.2665E-10	2.0005E-05	1.5570E-05	2.8774E-01	4.9200E-01	2.2023E-01
14	7.525	2.2058E-33	1.3526E-18	2.5789E-13	1.0205E-05	3.2056E-02	9.6793E-01

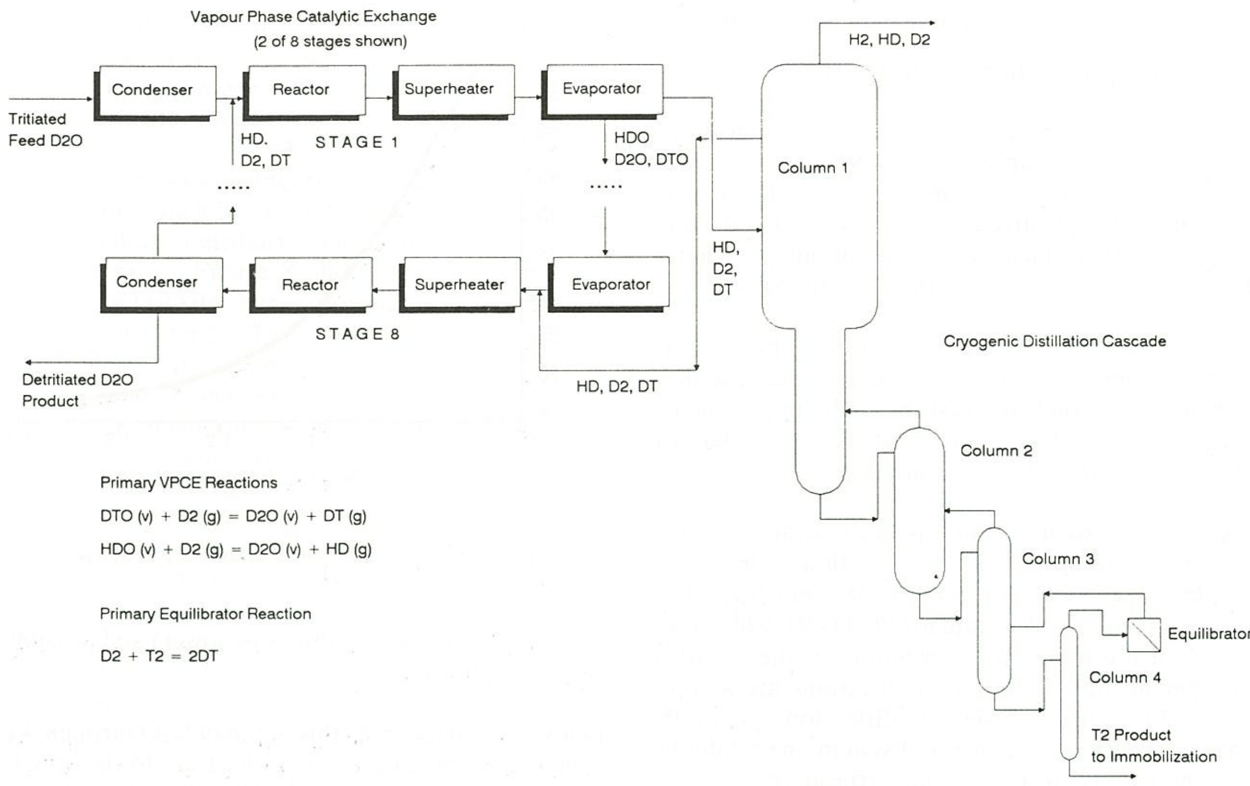

Figure 7. DTRF process flow diagram.

7.3 Kinoshita's Cascade

The cascade shown in Figure 6 has been proposed by Kinoshita (1984b) as an alternative to the TSTA cascade. The simulation results for Kinoshita's cascade are given in Table 4, for the ideal case with no heat balance and no nonidealities, and in Table 5 for the nonideal case with heat balance. The performance of this cascade is affected slightly more by nonidealities and heat balance than the TSTA cascade. However, the effects are minor and both cascades are relatively insensitive to these effects. The major differences are tritium inventory and operational considerations.

7.4 Darlington Tritium Removal Facility

FLOSHEET has been used to perform parametric studies of the major process variables for Ontario Hydro's Darlington Tritium Removal Facility (Busigin and Sood, 1987). A process flow schematic for the DTRF is shown in Figure 7. The front end of the process system consists of an eight stage Vapour Phase Catalytic Exchange (VPCE) section which extracts tritium from the heavy water into a D_2 gas stream. The tritium is then concentrated to 99.9 percent purity by Cryogenic Distillation (CD) and stored in immobilized form in containers. The main process system (VPCE+CD) was designed and supplied by Sulzer Canada, Inc., under licence to the Commisariat a L'Energie Atomique (CEA) of France.

For the DTRF, as with any complex process system, the development of an optimum operating strategy requires an understanding of the different process parameters which may be varied and how they affect plant performance. For example, one could choose to maximize system throughput at the expense of a lower detritiation factor, or one could choose to minimize operating costs and accept a lower tritium production rate.

DTRF Performance Objectives

For DTRF operation, the following major performance objectives can be identified:

- minimize operating costs;
- maximize the rate at which heavy water is detritiated;
- maximize the detritiation factor for processed heavy water;

- maximize the overall tritium production rate;
- maximize tritium product purity.

Other objectives may also be defined, but these are probably the most important ones. Not all of the above objectives are complementary. In general, if plant performance is optimized with respect to only one objective, other objectives are compromised. Therefore, an *overall best* strategy involves tradeoffs.

The relative weights which could be assigned to performance objectives are not discussed here, since they depend on external factors such as sales requirements for product quality, feed concentration, etc. Many of these factors are yet to be clearly defined.

As with any existing plant, operating strategies must take into account physical and operational constraints to plant operation. For example, it is not helpful to derive an *optimum* feedrate for the DTRF which is in excess of the processing capabilities of the installed equipment, unless design modifications are acceptable. Of course, design modifications generally involve additional expense and system unavailability, and these costs must be properly considered.

Major Process Variables

The major process variables which affect DTRF performance are:

- feedrate of D_2O to the VPCE;
- D_2 gas flowrate between the VPCE and the cryogenic distillation cascade;
- reflux ratio in the Low Tritium Column (LTC);
- tritium product drawoff rate from the cryogenic distillation cascade.

The following sections discuss the effects of adjusting these key process variables.

D_2O Feedrate to the VPCE

It is desirable for the DTRF to be able to process tritiated heavy water at as high a rate as possible. The benefits of a high throughput are high tritium production rate (important if market demand for tritium is strong) and reduced average tritium levels in reactor moderator systems (and accompanying reduced occupational exposure to tritium). The main drawbacks are a higher overall operating cost (although cost per

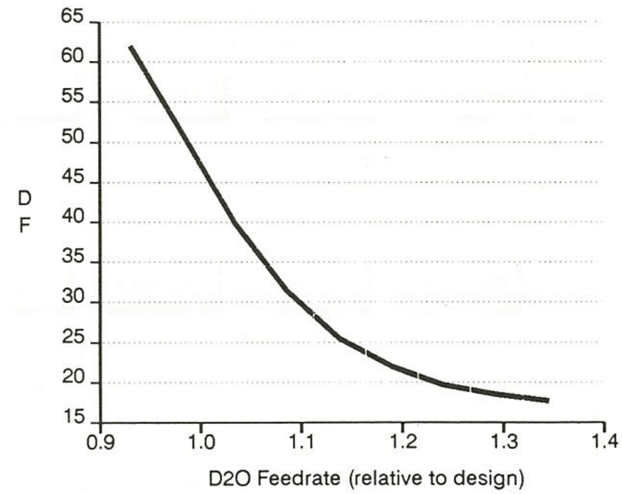

Figure 8. Detritiation Factor vs Feedrate

curie of tritium extracted may be lower) and possibly a lower detritiation factor.

One way to increase the througput of D_2O through the DTRF is to increase the D_2O feedrate to the VPCE while keeping all other variables constant. An increase in the feedrate to the DTRF can be accomplished by taking advantage of system design margins and pushing the system to the limit of its capability. Calculations using FLOSHEET show that, provided that the VPCE has sufficient reboiler and superheater capacity, the D_2O throughput can be increased by about 10 percent without the D_2O detritiation factor dropping below the design requirement of 30. The actual system may be even more capable if the designer (Sulzer Canada, Inc.) has as-

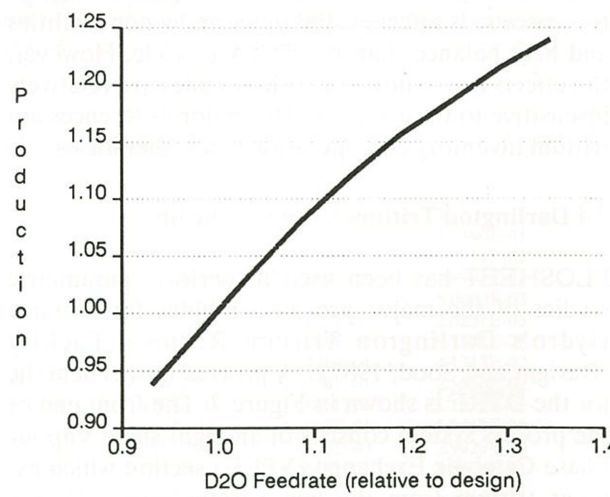

Figure 9. Relative Tritium Production vs Feedrate

sumed conservative values for key design parameters such as height of an equivalent theoretical plate (HETP) in the cryogenic distillation columns, reboiler and superheater capacity in the VPCE, etc.

For the Sulzer design, Figures 8 and 9 presents simulation results which illustrate the relationship between liquid feedrate, detritiation factor and overall tritium removal rate. Figure 8 shows that at the design feedrate of D_2O the detritiation factor is 47 (assuming 34 Ci/kg D_2O feed). This is significantly higher than the design requirement of 30 and means that the feedrate can be increased above the design value by about 10 percent (provided that the equipment has this capability) before the detritiation factor decreases to 30.

The main D_2O processing limitation in the DTRF system is the VPCE front end. A possible design change to increase the D_2O throughput is to add an electrolysis unit to work in parallel with the VPCE. In this configuration, if the total D_2 gas feedrate to the cryogenic distillation cascade is kept the same as before, the tritium extraction rate will be increased due to a higher concentration of tritium in the gas. This is because the molar fraction of tritium in D_2 gas leaving the VPCE is approximately one half of the tritium mole fraction in the liquid feed. In the case of an electrolysis unit, the molar concentration of tritium in the outlet gas stream is the same as the molar concentration in the input liquid stream. Therefore, if the VPCE were to be completely replaced by an electrolysis front end, then the tritium extraction/production rate would be doubled. If an electrolysis unit is used in parallel with the existing VPCE, then the improvement in tritium extraction/production would be proportional to the fraction of the gas coming from the electrolysis unit.

D_2 Gas Flowrate through the VPCE

The flow of D_2 gas through the VPCE affects the separation characteristics of both the VPCE and the cryogenic distillation cascade. Figure 10 shows the detritiation factor of the VPCE as a function of D_2 gas flow, with all other factors being held constant (34 Ci/kg feed case). If the gas flow is decreased, then the D_2O detritiation factor decreases although the molar tritium concentration in the D_2 feed to the cryogenic distillation cascade increases. Also, if the D_2 gas feed rate to the cryogenic distillation cascade decreases, then the reboiler duty in the LTC can be decreased proportionately (the reflux ratio is assumed to be held constant). This results in a savings of energy since the cryogenic refrigeration load is decreased. In the DTRF

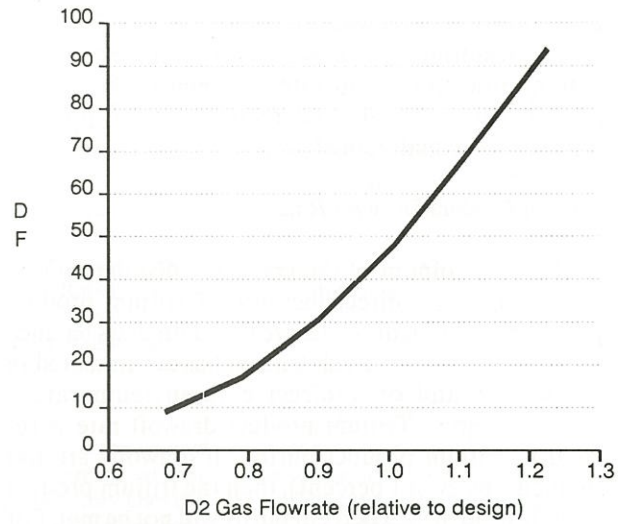

Figure 10. Detritiation factor vs D2 gas flow through VPCE

design, a decrease in the gas flowrate of 10 percent should be possible while still maintaining a detritiation factor of 30.

LTC Reflux Ratio

If the reflux ratio in the LTC is varied while all other factors are kept constant, the D_2O detritiation factor of the VPCE will be affected. Figure 11 illustrates the relationship between detritiation factor and LTC reflux ratio for the 34 Ci/kg feed case. A lower reflux ratio results in energy savings due to decreased cryogenic refrigeration load. However, the tritium

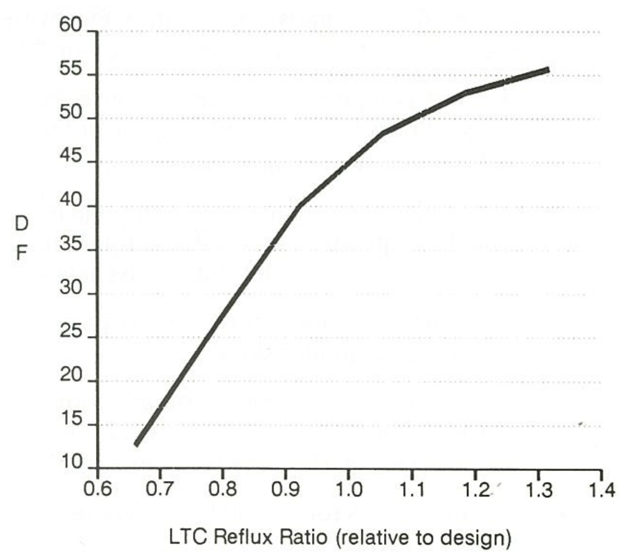

Figure 11. Detritiation Factor vs LTC Reflux Ratio

concentration in the gas flowing to the VPCE will increase, resulting in a lower detritiation factor. The tritium product drawoff rate (and hence, the tritium production) must also be reduced, if the product purity is to be maintained.

Tritium Product Drawoff Rate

In the final column of the cryogenic distillation cascade there is no direct measure of tritium product purity and tritium drawoffs are based on mass balance calculations of how much tritium has accumulated in the system and on indirect column temperature measurements. Tritium product drawoff rate is related to tritium product purity. If drawoffs are too frequent (by even 1 percent), then the tritium product specification of 99.9 percent purity will not be met. For each 1 percent excess drawoff rate, the tritium product purity decreases by about 1 percent. On the other hand, if tritium is allowed to accumulate in the system, then product purity will be very high but the degree of buildup of tritium may not be accurately known. Considerable care will need to be excercized to ensure high quality product while minimizing system tritium inventory.

8.0 SUMMARY

A powerful process simulation program called FLOSHEET has been developed for simulation of processes in fission and fusion systems. The main features of the simulator are:

- an entire process system consisting of interconnected process units of cryo distillation columns, VPCE units, equilibrators, etc. (with recycles) can be simulated in a single run
- the unit computation sequence and convergence of recycles is controlled by the program and requires no user interaction
- the simulator has rigorous and comprehensive models for process units and also forces tight convergence of local and global mass balances
- the simulator is easy to use and requires no specialized computer skills
- interactive and batch modes of operation are provided (batch mode is well suited for multiple runs when performing parametric studies)
- the simulator is robust and tolerant of user errors
- the simulator has many users within Ontario Hydro and is used extensively for DTRF and fusion fuel processing system simulations.
- the simulator is available to other users through Ontario Hydro and CFFTP.

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Letter to the Editor

Dear Sir:

I am happy to read that you are interested in the preservation of NPD for its historic value.

You may be interested to know of Ontario Hydro and AECL plans. We are removing

- all control room panels
- one channel of reactor regulating and protective system instrumentation
- the reactor regulating valves
- one fuelling machine head
- the turbine governor, steam chest and possibly rotor
- assorted pictures, models and displays
- numerous crates of documents
- turbine control panels
- reactor mockup used for practicing maintenance
- fuelling machine control computer.

All these will be stored at Darlington and Wesleyville generating stations until a proper display can be arranged. The work of removing these items has already begun and the first shipment went to Darlington April 19.

I know of no plan to erect a "laconic metal plaque", which your editorial **For the Record** in March/April *CNS Bulletin* claimed was someone's intention.

R.E. Lewis
Station Manager
NPD NGS

P R V

The Press Gang

Odd things appear in the news media. Two modest examples follow.

In a recent newscast on British television, it was reported that the CEGB had begun a large study on the effect of high voltage power lines on the health of people. In an apparently neutral post script, the newscaster added "Some of these power lines are connected to nuclear power stations."

The second example is closer to home. Even off the record, members of the fourth estate are apt to express some mystifying notions. In a presentation to the Toronto branch of the Canadian Nuclear Society, a Toronto columnist remarked that employees at a nuclear power plant were effectively working inside a bomb. In an attempt apparently to put this into perspective, he went on to note that cars carrying 15 or 20 gallons of gasoline, houses supplied with natural gas, and other everyday things are also bombs.

Before dismissing such examples as yet further cases of rampant irresponsibility and complete indifference to fact, it is worth considering some of the basic confusions surrounding the news media, especially their role and activities.

There are a great many misconceptions about the press (to take a representative medium). It is said that the press has as its job to educate the public, that its ultimate purpose should be to present the facts fairly and objectively, that it should be unbiased and have no vested interest. It's not so much that these prescriptions are wrong as that they are unrealistic.

It cannot be denied that facts are ignored and meanings distorted by the press, that positions are sometimes taken and story lines dictated before any investigation has been done. Many technical people react very indignantly to the resulting erroneous press stories. A number of things might be credited with stoking this indignation.

One is the assumption that the general public derives a good deal, or all of its information from the media, and may act on that information at face value, and that consequently the news media are morally obliged to exercise almost the same level of objectivity as the scientist. Maybe this is so, but such an assumption is still just that – an assumption.

A more important factor is the failure to take a close look at what "news" actually is, as opposed to what one thinks it ought to be. Strange as it may seem, "news" is not easy to define. Is the news a fairly objective reflection of what is happening in the world? Is it a form of entertainment? Is it a mode of instruction? Is it that commodity that sells newspapers and advertising? Is it defined simply as that which happens to appear in the newspapers? Is it just another manufactured consumer product? Is it all of these?

A third thing that seems to power the outraged, insulted, or disgusted reactions to the press, is a failure to discern the various categories of "news", "fact" and "truth" that can be involved. "Fact" and "truth" are relatively easy to distinguish, or so one might think. But in addition to the scientific "truths" and "facts" that engineers and scientists are familiar with, there is a whole spectrum of other "truths" and "facts". People acknowledge that temperatures of -40C can be uncomfortable; they might be prepared to accept that statements to this effect are "true". Exposure to ionizing radiation entails some risk; people "know" that this is "true" without necessarily having any command whatever of the "facts". If an anti-nuclear spokesman makes a statement that the nuclear station at Pickering has just exploded, then that statement becomes a reportable "fact", even when it is not true.

The view from the other side is somewhat different. A reporter is usually a generalist who is in the position of having to uncover what he thinks are the facts and then come to some kind of terms with them in order to report the story. The analogous situation (analogous at least in illustrating the approach to the problem) is of a scientist or engineer trying to decide which variables to measure in an experiment, and then how to interpret the resulting data. This latter example may be more restrictive and sophisticated but the difference is only one of degree. Needless to say, the product sometimes falls short of what would be produced under ideal conditions. Reporters may follow their own biases, or be misled. They can become very self-important and self-serving on contemplating their "mission" and throw petulant fits when others do not jump to assist them in every way in their inquiries. There are personal and professional strains: journalism has its share of loyalties, antipathies, biases, ignorance, personalities and conflicts. Scientists and engineers have also been known to exhibit these characteristics.

The type of story being reported can also make a difference. There may be important scientific aspects to a fast-breaking story in which there are minutes or hours at most to prepare the copy. In such cases, there is no time for navel-gazing and often the information which is available, no matter how impoverished, is what is used. On the other hand, science might form part of a story that is something of a backgrounder, where there is less time pressure and possibly more opportunity to get the technical facts straight. It would seem fair that different criteria of judgment should be applied to these types of story, but this is seldom the case.

The main points in all this are two. First, it makes little sense to decry the performance of the news media as measured against some assumed lofty objective that one assigns rather arbitrarily to their activities. An empirical rather than a categorical approach is needed. Second, a certain amount of confusion and fuzziness is unavoidable since there seems to be no very clear agreement on defining what it is that the press actually does, quite apart from what people think it should be doing.

It is hardly surprising, then, that so much of the discussion on the news media ends up going nowhere, and appears to be a tale which is not necessarily told by an idiot, but is certainly full of sound and fury and signifies little.

Keith Weaver

Book Reviews

Nuclear Risks: Reassessing the Principles and Practice After Chernobyl, Proceedings of conference held in London, December 1986. IBC Technical Services Limited, 1987. ISBN 1-85271-006-3.

This volume contains the transcripts of 17 papers, together with discussions, concerning the implications of the Chernobyl reactor accident for nuclear operating utilities and regulatory authorities from five countries – Britain, the USSR, the US, France and Sweden.

The topics addressed range in specificity from general observations on the broad issues raised by the accident, through emergency planning considerations and the control of serious accidents to specific details of the radiological impacts, lessons for dispersion modelling and consequence analysis. There is a concluding presentation on the media treatment of nuclear risks.

A problem with a publication of this nature is that it is essentially a verbatim record of oral presentations and as a result some of the papers seem to lack organization and focus – a case in point being USNRC Commissioner James Asselstine's discussion of American regulatory response to the Chernobyl accident where some extremely important points are sort of lost in the shuffle. Asselstine's comments about the danger of assuming that design differences between Russian and American reactors mean that there are few lessons to be learned deserve much greater emphasis, as do his observations concerning the varying degrees of protection afforded by different containment designs in the US.

The situation is even more difficult in the case of the Soviet delegates who suffer under a double disadvantage of first having to make their presentations in a foreign language, and then having their comments faithfully transcribed, to the subsequent confusion of the reader.

This having been said, there is much of value for the reader. The panel discussions (where direct transcription is fully justified) are of particular value, and anybody in the nuclear safety business will gain something from reading them. Especially worthy of note are comments by Edmondson and Asselstine on the fundamental importance of safety management (and the review of that management). These should be copied out on big sheets of paper and nailed to the boardroom walls of every nuclear facility operator.

Also worthy of special attention are:

– Brian Edmondson (UK CEGB) **"The Implications of Chernobyl for the CEGB."** This includes a lucid account of the accident and a discussion of safety principles. It not only is a valuable source for the non-specialist, but would also be of interest to any reactor safety practitioner.

– E E Kintner (GPU Nuclear) **The Lessons Learned.** This includes discussion of the TMI-2 accident and subsequent recovery operations. It is a salutary reminder that the TMI accident had some very important lessons and it is not entirely clear that everyone has learned these lessons. It also provides a useful update on the progress of the monumental recovery programme at the Middletown site.

– I Kuzmin (Kurchatov Institute of Atomic Energy). A transcript of a video tape describing the accident and the immediate recovery operations is followed by Kuzmin's description of the long term recovery and isolation operations.

– V K Krushelnitskiy (USSR State Committee on Supervision of Nuclear Power Safety), **Rules and Objectives of the USSR State Committee on Supervision of Nuclear Power Safety in Preventing Nuclear Power Plant Accidents.** An informative and fascinating summary of regulatory measures taken since Chernobyl. Of particular interest to the Canadian reader will be information about arrangements for "supervising Inspectors" to be on full-time assignment to nuclear plants. Despite the linguistic problems referred to earlier, both Soviet contributions will repay close reading.

There is something of interest in virtually all the papers and much of interest in the panel discussion and question and answer sessions. Though the stylistic and linguistic singularities inherent to such direct transcription of spoken remarks make ferreting out information a bit of a chore, it's a worthwhile chore. This set of papers makes a useful addition to the growing body of literature generated by the Chernobyl accident.

David Mosey

Competing in the New Global Economy, Report of the Premier's Council, Vol. 1, Queen's Printer for Ontario, Toronto, April, 1988.

Ontario has a problem. Its mature industries, which form the backbone of the province's industrial structure, face increasing competition and slowing growth. The high growth industries are small and uncertain and in some cases seem to have little chance of surviving. The situation appears to be getting worse, rather than better, and the Premier's Council determined to find out why and what could be done about it.

Few people have heard of the Premier's Council. It is a body of worthies representing a spectrum of interests in the province who rely on science and technology. (The ones missed out are significant, but more on that later.) The Council had several main objectives, all of them aiming in some way or other to improve Ontario's competitive edge in world markets. Among these objectives were two of particular interest: to "build a strong science and technology infrastructure" and "to improve the education, training and labour adjustment infrastructure".

The report, which is a book of 249 pages, is an interesting but odd document. Interesting because of the great amount of information squirrelled away in its tables and figures, and because of the perspectives it develops. Odd because (a) the jargon which contaminates the text makes it infuriating and strangely opaque in places, (b) it quite often relies on comparisons between greatly aggregated national or provincial statistics which can be misleading without qualification, (c) because it appears to ignore one of the most important groups of people involved in science and technology: *viz.* scientists, engineers and technologists.

The make-up of the Premier's Council is dominated by businessmen: 13 out of the 29 chairs are filled by corporate executives; there are seven government ministers (counting the Premier), four academics, three labour leaders, one attorney and one astronaut. (Yes, an astronaut!)

The people who sweat and strain to produce all this technology and its white heat don't get a look-in. There are no representatives to speak for working scientists, engineers or technologists, despite the fact that whole chapters of the report are devoted to "Meeting the Science and Technology Imperative" and "Investing in People". All through the report, science and technology, and the research that is to make them available, are discussed at length, but no one thought to ask the people skilled in these areas what their views were. Most odd.

Of the recommendations, one is directed at improving education in the province, which must also sound odd to those universities that are having to sell off their libraries for lack of funds. Although the report deals with Ontario, many of the statistics relate to Canada, e.g. the funding and effectiveness of the National Research Council, NSERC, federal government departments and other money sinks over which Ontario seems to have no control anyway.

Page 222 has possibly the most revealing figure in the report. It is a chart comparing the numbers of engineers, accountants and lawyers in Ontario and in Japan per 10,000 workers. Ontario has about one quarter the number of engineers, more than three times the number of accountants and nearly forty times the number of lawyers. A cynic could pinpoint the source of Ontario's problem without difficulty.

The report contains a three-page thumbnail sketch of the history and current structure of the Canadian nuclear industry, but in the end it really says very little about it.

An index would have been useful, but the report lacks one. The text would have benefited if the worst excesses of its MBAese had been converted into a semblance of English. From this point of view, the book is itself something of a missed opportunity, which is more than a little ironic.

Keith Weaver

Alan Turing – The Enigma of Intelligence by Andrew Hodges, Unwin Paperbacks, 1987. ISBN 0-04-510060-8.

Described as "one of the most brilliant Englishmen of the Century", Alan Turing is at once a figure of triumph, mystery and pathos. A rare mind in a rarified field, he perceived mathematics as a unified metaphor for both the physical and metaphysical worlds. While there may be numerous claimants to the title of progenitor of the modern computer, there is no doubt that scientific literature, by virtue of its adoption of the term "turing machine" with the lower-case initial letter, has recognised a pre-eminent contribution from Alan Turing.

Born in 1912, the son of an Indian Civil Service officer, Turing attended Sherbourne School (described as a "moderately distinguished Public School"), won a Mathematics Scholarship to Kings College Cambridge in 1931 and was elected Fellow in 1935. By 1936 he had already developed the idea of a machine to generate "computable numbers" and his work in this area, paralleling the efforts of Church at Princeton, led him to that university for a two year period.

Returning to England in 1938 Turing took a course at the Government Codes and Cypher School and, on the outbreak of War, moved to Bletchley Park to commence his work on unravelling Axis codes. Hodges' account of this important period in Turing's life is of particular interest although one would have appreciated a somewhat clearer explanation of the principles and functioning of the Enigma machine and the Turing "bombes". Hodges has trouble throughout the book in explaining complex technical concepts, which means that to a certain extent the reader remains distanced from the nature of Turing's achievements.

After the Second World War Turing joined the National Physical Laboratory and began work on the development of ACE, the "automatic computing engine", a device which, it was confidently expected would store up to 200,000 digits. The NPL experience was not a happy one for Turing. He was happiest in the insulated atmosphere of Kings College – or indeed Hut No 8 at Bletchley Park – where he was, in Hodges words, "protected from the harshness of the outside world". In 1948 Turing went to Manchester University and was elected a Fellow of the Royal Society in 1951. The following year he was prosecuted under Section 11 of the Criminal Law Amendment Act of 1885 ("Gross Indecency"), was convicted, placed on probation and ordered to undergo "organo-therapy" – administration of oestrogen to control libido. Turing committed suicide in 1954.

It is interesting that the received wisdom that Turing was "persecuted" by the government (presumably because of his homosexuality and general eccentricity) and "shut out" from the research mainstream, echoed by Peter Wright in *Spycatcher*, is more or less demolished by Hodges. Turing's sudden departure from NPL (in fact in breach of his agreement with them) was his decision. The University of Manchester (together with numerous friends and colleagues at Cambridge and elsewhere) exerted themselves considerably in order to devise a position for Turing in which he would be as free as possible to work on what interested him while still being able to call upon the formidable technical resources of the University. As well, Turing's conviction of the sort of offence which has typically received front page attention from Grub Street was reported only locally and does not seem to have in any way compromised his academic position.

Alan Turing was a substantial, puzzling and elusive character, and Andrew Hodges has written a substantial, puzzling and elusive book. While much has emerged from the penumbra of the Official Secrets Act under the application of the "thirty year rule" some of what has emerged remains ambiguous or incomplete – or both. So it is with Turing. Despite Hodges' best efforts the mathematical wizard, presiding genius of Bletchley Park and architect of the automatic electronic digital computer with internal program storage, remains as enigmatic as Enigma.

Part of the problem undoubtedly is the fact that, notwithstanding the application of the thirty year rule, some of the details of the activities of the Government "Codes and Cyphers School" as well as perhaps some technical details of the equipment used to create and unbutton cyphered signals, remain unclear. Another part of the problem must be that, as Hodges notes, "there is very little source material from which to reconstruct a picture of Alan Turing – few original documents, and little in the way of published commentary". But as well one cannot escape the conclusion that Hodges himself is part of the problem in view of his intellectually bifurcated approach to his subject. Hodges' approach to Turing is itself enigmatic. The less attractive features of Turing's character are candidly exposed, yet one has the feeling that what Hodges is trying to do here is praise with faint damns.

A central problem is that one is never quite clear whether Hodges is presenting the reader with an account of a brilliant mathematician who happened to be a homosexual or *vice versa*. In view of the extraordinarily sensitive work upon which Turing was engaged, the contemporary draconian legal sanctions applicable to any homosexual activity in Britain (sanctions which remained on the books until almost twenty years after the Second World War), and the (perceived or real) links between homosexuality, a major English university and treason, Hodges needs no excuse to devote attention to the problems and conflicts faced by an actively homosexual man in an actively anti-homosexual legal environment. However Hodges has little excuse for devoting so much time and space to the analysis of British society's attitude to homosexuals, going back to Oscar Wilde. Really Hodges has written two books here – one a scientific biography and the other a study of the way in which attitudes to homosexuals in England have varied with respect to time and social class.

Notwithstanding this it is still true that Hodges has assembled a well documented, readable and, at times, disturbing account of a major figure in twentieth century science.

David Mosey

CANDU Maintenance Conference Proceedings

held November 22-24, 1987, Toronto, Ontario, Canada, are now available.

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Conference Report

Tritium Technology 1988: Trends and Impressions

A report on the Third Topical Meeting on Tritium Technology in Fission, Fusion and Isotopic Applications, May 1-6, Toronto Hilton Hotel.

Tritium technology has come of age in its engineering applications. That was abundantly clear at this Conference, whose attendee list reads somewhat like an international "Who's Who" of the tritium field. Quite a number of the 168 papers dealt with solid operating experience in fully engineered systems processing considerable quantities of tritium. More than 500 delegates attended, coming from 11 countries. Twenty-three exhibitors of sophisticated products and services for tritium users received active attention, an indication of the number of large scale tritium facilities appearing in the world.

From an analysis of the presentations at the meeting, the expansion in applied tritium technology seems to be driven in large part by fusion power development needs as well as by increased activity in detritiation of reactor heavy water. This is perhaps not surprising: a 1,000 MW(e) fusion reactor of the year 2020, say, might burn around 100 kg of tritium fuel per year with a station tritium inventory of about one kg of tritium. By contrast, tritium generation in all of Ontario Hydro's CANDU reactors together, including four at Darlington, is in the region of 2 kg per year. So each future fusion plant must breed and process its own fuel, at a tiny percentage of today's processing cost.

There was a commensurate number of safety-related papers, again indicating that more and larger tritium facilities and laboratories are being built or designed, equipped for inventories of hundreds of grams of tritium.

The complex interactions of tritium with materials were much discussed, since they are most important to systems designers. For example, aging and corrosion of steels exposed to concentrated tritium is a poorly understood area. Conversion of elemental tritium to its oxide form in the environment received much attention, particularly the analyses of results from Canadian and French tritium release experiments. Conversion is important because the oxide HTO form is about 10,000 times more toxic than the elemental HT form, so environmental conversion behaviour will determine the level and distribution of off-site doses.

In the main topic groups, presentation topics at the Conference included:

Tritium Processing: Fusion reactor fuel systems; Purification and handling; Design and performance of systems and components; Experience of systems operation.

Measurement of Tritium: Process measurements, Tritium accounting, Tritium on surfaces, Discriminating HT/HTO monitors, Radio-gas chromatography.

Tritium Properties and Interaction with Materials: Fundamental studies; Fusion Breeder studies – blanket design and Tritium recovery; Materials evaluation; Tritium inventory in materials and systems; Radiolysis; Gettering and Storage devices.

Tritium Safety: HT/HTO conversion; Environmental Dispersion; Safety of tritium and fusion facilities; Licensing issues; Biological effects and dosimetry; Containment, control and maintenance of tritium systems; Waste disposal.

Comments from the delegates indicated that the meeting was well and smoothly managed, and a sound technical success. It is worth mentioning that foreign delegates demonstrated widespread recognition of Canadian tritium work. All sessions were very well attended for the whole week, indicating a high level of dedication among the delegates despite the beckoning attractions of good weather in Toronto.

This meeting, the third of its kind, was sited in Canada in part to celebrate commencement of the second five-year operating term for the Canadian Fusion Fuels Technology Project (CFFTP). The first two meetings (1980 and 1985) were held in Dayton, Ohio near the Mound Laboratories, a Mecca for many years to tritium researchers. Canada is by no means the only country outside the USA doing tritium work. Japan, for example, has invested heavily in research and laboratory facilities. France and Germany were well represented also.

Dr. Michael Rogers of Mound was the US technical co-chairman of this Toronto meeting, together with Canadian co-chairman Dr. Bill Holtslander of the National Fusion Program. Dr. Carole Burnham of CFFTP was Canadian General Chair; her US Counterpart was Dr. Harold A. Anderson of Mound. Organization and running of the conference was managed by a CNS-appointed committee. At the meeting itself, a tireless and efficient team orchestrated registration, technical tours and the spouse program. Technical tours to CRNL, Darlington and Ontario Hydro Research Division were sold out early. More than half of the papers were presented in large poster sessions. These sessions also worked well as discussion arenas for informal meetings between delegates.

The Conference was jointly sponsored by the Canadian Nuclear Society, the American Nuclear Society, the European Nuclear Society and the Nuclear Society of Japan.

Proceedings of the conference will appear as a special edition of the journal *Fusion Technology*, published by the American Nuclear Society. Order from: American Nuclear Society, Publications Division, 555 North Kensington, La Grange Park, Illinois, USA, 60525.

Robert Macphee

CNS Branch Programs

Toronto Branch

Food Irradiation: A time for rethinking

On February 1, 1988 the Toronto Branch presented guest speaker Dr. Rao, Professor of Nutritional Sciences at University of Toronto's Faculty of Medicine. He outlined the history and the nutritional effects of food irradiation, as well as discussing the current issues and the political climate surrounding food irradiation.

Food irradiation has a long history of use and study. The first United States patent was received in 1905. Although Canada and the USA led in the technology in the 50s and 60s when isotopes became more economically available, today Japan and Israel are leading the way. In 1980, the FAO/WHO/IAEA's acceptance of a 10 kGy level of food irradiation as posing no toxicological hazard, set a worldwide standard.

In spite of the significant scientific testing and application in other parts of the world, Canada has not shown acceptance of food irradiation. As application of this technology becomes more prevalent world wide, hopefully Canada will keep pace and reap the benefits of longer shelf lives and reduced levels of disease.

Robert Steadman

The Media and Nuclear Power

We have an image problem and our message does not come across clearly. This was the thrust of the message delivered by Jack Miller, Science Editor of the Toronto Star on March 28, 1988. Mr. Miller challenged the nuclear industry to make the public aware of its excellent performance and safety record. Amongst his suggestions on ways to improve the image, he indicated the following: build trust with the media, educate the reporters, establish 24-hour/day hot-line, increase exposure by encouraging more high school students and adults to visit the information centres and establish a committee to monitor news releases and stories.

Gord Sullivan

Toronto Branch News

Bill Maser, Toronto Branch Secretary, has resigned from his position on the executive. Bill has just graduated from the University of Toronto and has accepted a position at Babcock & Wilcox in Cambridge, Ont. We wish Bill every success in his career and thank him for his efforts on the Toronto Branch executive. Until the next Branch elections, Robert Steadman will be acting in the role of secretary.

John Marczak

Ottawa Branch News

Seminar Program

"The Canadian Amethyste and the French

Integrated Marine PWR"

Keith Davies of SNA Canada and Alain Tournyol du Cios of Technicatome (France) spoke to the Ottawa Branch on 24 March concerning the Canadian Amethyste nuclear attack submarine being offered to the Canadian Submarine Acquisition Program (CASAP-SSN).

The highly interesting and very well attended presentation began with a general description of the Amethyste by Mr. Davies. The Amethyste, a variant of the Rubis class, is approximately 80 metres long and has a displacement of about 2900 tonnes. Carrying a crew of 66, the boat has a top speed of 25 knots and a dive depth of 1200 ft.

The second part of the presentation, given by Mr. Tournyol du Clos, included a discussion of the history, development, technical design and supporting infrastructure of the French integrated marine PWR.

The reactor is a compact, integral-boiler type plant having a thermal power of about 50 MW. The oxide fuel has an enrichment of about ten per cent, well below the twenty per cent limit demarking weapons-grade fuel. Periodic maintenance is simplified by the presence of four large hatches located over major equipment areas.

In the question period following the presentation, issues ranging from the ice breaking capability of the boat, to the ability of the plant to withstand total loss of electrical power were discussed.

Terry Jamieson

Central Lake Ontario Branch

On Tuesday, May 10, 1987, Mr. Ron Gray of ECS Power Systems Incorporated, gave two presentations to CNS members at Pickering and Darlington NGS. His presentation was titled "Thermal Hydraulic Experimentation in Support of AMPS (Autonomous Marine Power Supply) for Submersible Vehicles". He outlined the work that is going on in the development of a nuclear reactor power source that could be retro-fitted into conventional submarines. In particular, the detailed thermo-hydraulic experiment associated with fuel elements and simulated heat flux were described as well as the future direction of the AMPS experimentation program. A highlight of each session was the following question period dealing with everything from naval architecture to reactor licensing issues.

Dan Meraw

Nuclear Science and Engineering Division

Results of the 1988 NSED Election:

The 1988 Nuclear Science and Engineering Division election has been completed. The NSED was fortunate to have very good candidates stand for election. Elected to the Division Executive are:

M.B. Carver (CRNL)
T.J. Jamieson (ECS)
J.V. Marczak (OH)
M.A. Wright (NBEPC)

On behalf of the NSED, I would like to congratulate the successful candidates, and to thank all candidates for standing for election. I hope that those who were not elected this time will be willing to run again in the future.

B. Rouben,
NSED Returning Officer

CNS Announces Short Courses in Nuclear Science and Engineering

The CNS plans to institute a series of short, comprehensive courses 1-3 days in length on topics of importance to those involved in the nuclear industry in Canada. These courses will be of interest to graduating students, practicing professionals or anyone involved in, or anticipating involvement in, the nuclear energy field. Course instructors will be highly qualified specialists working in the Canadian nuclear industry.

Each course will cover the theory and general background to the subject and will be designed to bring the non-expert up to the current state of subject development.

To help the Society in planning these courses and to provide some indication of the level of interest, members are urged to read the Notice enclosed with this issue of the *Bulletin* and complete the attached questionnaire.

N J Spinks
Chairman,
Nuclear Science and Engineering Division.

Conferences and Meetings

Nuclear Power Plant Life Extension

Sponsored by ANS, to be held in Snowbird, Utah, **July 31-August 3, 1988.** For information contact: **H. Zeile, EG&G,** (209) 526-1603.

Spectrum '88: International Topical Meeting on Nuclear and Hazardous Waste Management

Sponsored by ANS, cosponsored by U.S. DOE, Canadian Nuclear Society and others, to be held **September 11-15, 1988** in Pasco, Washington. For information contact: **Eva Rosinger, Whiteshell Nuclear Research Establishment, Pinawa, Manitoba, R0E 1L0,** (204) 753-2311.

Short Course in Reactor Safety

Sponsored by CNS/NSE, to be held in Toronto, Ontario, **September 19-20, 1988.** For information contact: **W. Midvidy, Ontario Hydro,** (416) 592-5543.

International Conference on Thermal Reactor Safety

Sponsored by ENS/ANS/CNS, to be held **October 2-7, 1988** in Avignon, France. For information contact: **H. Tamm, AECL/WNRE,** (204) 753-2311.

Tritium Safe Handling Course

Sponsored by CFFTP, to be held in Toronto and Chalk River, **April 25-29, 1988** and **October 3-7, 1988.** For information contact: **R. Matsugu,** (416) 823-0102.

12th International Conference on Plasma Physics and Controlled Nuclear Fusion Research

Sponsored by the IAEA, to be held **October 12-19, 1988** in Nice, France.

World Materials Congress

Sponsored by ASM, to be held **October 24-30, 1988** in Chicago, Illinois. For information contact: **A.R. Putnam,** (216) 338-5151.

ANS International Meeting.
Sponsored by ANS/ENS, to be held **October 30 to November 4, 1988,** in Washington, D.C. For information contact: P.D. Stevens-Guille, Ontario Hydro, (416) 592-6024.

International Symposium on Safety Standards and Practices for NPP

Sponsored by the IAEA, to be held **November 7-10, 1988** in Munich, FRG. Contact: **IAEA.**

Conference on Nuclear Power Plant Operation and Thermal Hydraulics

Sponsored by the KNS/CNS, to be held **November 14-17, 1988** in Seoul, South Korea. Contact: **K.H. Talbot, Ontario Hydro,** (416) 592-8216.

Conference on Use of Elastomers and Polymers in the Nuclear Industry,

sponsored by CNS/D&M, to be held **February 20-21, 1989** in Toronto, Ontario. For information contact: **Mr. E.G. Price, AECL/CANDU Operations,** (416) 823-9040

International Conference on Availability Improvements in Nuclear Power Plants

Sponsored by the Spanish Nuclear Society/CNS/IAEA/ENS, to be held **April 10-14, 1989** in Madrid, Spain. For information contact: **K. Talbot, Ontario Hydro,** (416) 823-9040.

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The Unfashionable Side

The Snow Job

"It's just as Chesterton said", he countered defiantly. The speaker was about 28, had longish blond hair and seemed very sure of himself. Against him was squared off a chunky fifty year old, who had that evil despotic look affected by managers of nuclear power stations.

You will recall, I am sure, that some time ago there was a general tightening up of tritium exposures to plant personnel in Canadian nuclear stations. A lot of hoopla was bandied about at the time: safety of workers, cost of heavy water, new high tech dessicants, TRF; it was dished out in generous forkloads. In fact, it had nothing to do with all this. The real driving force lay elsewhere and the scene I have just related was the beginning of the whole affair.

I had to stop and listen in discreetly. Just the sound of Chesterton's words brought a hundred lines back to me immediately. Somehow they all seemed curiously relevant too. That is, they could all be related to the deflation of overweaning station managers.

"Before the Roman came to Rye or out to Severn strode,
The rolling English drunkard made the rolling English road . . . "

Old Noah he had an ostrich farm and fowls on the grandest scale,
He ate his egg with a ladle in an egg-cup big as a pail,
And the soup he took was Elephant Soup and the fish he took was Whale . . ."

Suddenly tipped out of engineering and into literature, the wicked station manager panicked and cast about for a life raft. "Well, if your Mr. Chesterton would care to put his concerns down in a Speedimemo, we'll see what he can do", he finally rumbled darkly.

It was about two weeks later that I came across the same argument again, in the same station and involving the same trainee operator. Believe it or not, I was helping one of the young station nurses change her, ah, guitar strings when this trainee chap burst into the medical centre. My nurse jumped like a hare and sounded a rather awkward note, as she would do, of course, not having all her, er, strings in place, you see.

It turned out that it was the trainee's weekly tritium monitoring and he had come early to find out what his current body levels were. The nurse consulted a chart and took slightly too long reading the numbers. Meanwhile, I retired to study an old Hank Snow song book.

"I suppose you're going to tell me that my body levels are too high and that I have to be flushed out," he said without enthusiasm. The nurse barely had time to confirm this before a despotic wind blew the station manager in. Not an unobservant man, he noticed the scowl on the trainee's face and the, um, guitar strings littered around the floor. By this time, I had become irrevocably engrossed in Hank Snow.

"Anything wrong?" asked the station manager with a Siberian snarl.

Here it comes, I thought.

"As a matter of fact," the trainee began ominously, "yes, something is wrong. I have to go for the diuretic treatment again, that's what's wrong."

"So? Don't you like beer?"

"If it really was beer", answered the trainee, "nobody would mind. But being force-fed that three-month old equine effluent they bring in here is too much."

"You know as well as I do that it's a requirement", whined the station manager. "My hands are tied", he concluded mournfully, making gestures worthy of a Lady MacBeth or a Pontius Pilate, despite the cruel manacles.

They argued further, becoming more incensed, until finally the station manager threw up his hands, which were still heavily fettered, in all probability, and turned to me. "Bauer, don't just sit there; try to talk some sense into this fellow." He had caught me at a bad moment, though, because just then I burst uncontrollably into song.

"Yew took mah little heart and threw it oan the floor". (That's what it said in the book.) Singing country music during an argument while surrounded by diagrams of The Healthy Tooth, in a room littered with, er, guitar strings belonging to a nurse who is blushing like a beacon certainly adds a new dimension to the lyrics.

It was obvious that there would be no escape. The sooner I sorted this lot out, the sooner the nurse and I could return to our Euterpean manoeuvres. But what could I do? This was very far removed from my assigned task at the station: doing the monthly alewife count.

"I . . . er . . . ah . . . maybe you should . . . erm", I explained, quite clearly, I thought.

"Bah!" said the station manager with his usual expression of compassion and understanding, and charged out.

The trainee shook his head and followed. The nurse began chirping anxiously as she watched one of her, ah, guitar strings snag on one of the trainee's boots and follow him out in turn. But I managed to settle her down, as there were more important things afoot. I only had to cast her a knowing look and say "Shall we?" The frank and open smile she returned said she was ready and willing.

She threw herself into the task with an unseemly appetite and the frenzied energy of a dervish. I could hardly keep pace and we wrestled, struggled and sweated for several hours. We were both showing the strain rather badly by the time we finished but it had been a faultless exercise and I had to smile rather smugly. It had been all in a good cause, and she agreed that nobody would notice the subtle changes to the files, that the results of our labour were visible only to us.

Less than three days later with the new SatNav system in charge of the Lagonda, I was on my way back to the same station, reading a copy of *The Wasteland*, appropriately, having just taken an urgent call from the unspeakable station manager, and then a second call from a delighted trainee. I was shown into the station manager's office and was surprised at how haggard and drawn he looked. He scuttled out into the hallway and back incessantly and belched almost continuously, with the result that it was impossible to talk to him. I excused myself delicately and went in search of the trainee.

He was all smiles. "Almost from the day you were last here, things began to change. Look at that", he said, indicating a row of some of the finest beers available. "Why would the station manager suddenly lay in a stock like this?" he asked in puzzlement.

"I guess he isn't all bad", I observed, carefully holding onto my nonplussed expression. "Perhaps station managers move in mysterious ways as well. Or maybe he just took a close look at his own urine analysis results for the past few months. Who knows what makes station managers tick?"

But there was no time to lose, since my real purpose for the visit still lay ahead. It would take my nurse many hours to master the newly discovered 'Variations by Paganini on a Theme by Hank Snow'.

George Bauer