CA8004719

INFO 0002

"NUCLEAR ENERGY - SOME REGULATORY ASPECTS"

A LECTURE TO
NUCLEAR ENGINEERING STUDENTS

BY

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KINGSTON, ONTARIO

21 MARCH, 1980

1. RISK

> "In central London, the underground is paralyzed, bridges and tunnels are closed. Hospitals struggle valiantly to maintain services, their task made all the more difficult by power blackouts, loss of telephone service, contamination of the water supply and the difficulty of mobilizing rescue teams. ....Total damages....more than $6 billion."

Although the scenario may sound like the British version of "The China Syndrome", it is actually an excerpt from a Time magazine article on the disaster that a "worst case" Thames flood could produce. Flood control measures currently in progress are estimated to cost about $800 million, and additional measures being planned will bring the total to $1.5 billion. This is a very large sum of money, but obviously not excessive in comparison to the human misery and tragedy which might otherwise result.

To ensure an awareness of the risk to which they are being exposed and of the emergency procedures which should be followed in the event of a serious flood, Londoners are being asked to place instruction booklets in a prominent place in their homes and in their place of work. One poster reads: "If you live, work or travel through the Flood Risk Area, you should learn the Thames Flood Drill now. Cut it out and keep it handy. We hope you'll never need it. There's a 1 in 50 chance you will."

Most persons have very little understanding of risk and prefer to avoid any substantive discussion of the concept - an avoidance mechanism not unlike the sweet lemon rationalization process to which many persons fall prey simply because they are unwilling to learn the facts let alone face them.

The term "risk" is used and often misused to convey a great variety of meanings. I prefer to use the term in the sense that risk is a function of the probability of a harmful event and the consequences of that event. It has often been said that the function involved is the simple multiplication of the two parameters. Perhaps it is in some instances,

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but not in all, since the significance of the "unit risk" can often be easily distorted. For example, consider an industrial plant which processes a chemically toxic material which is known to be carcinogenic (e.g. vinyl chloride monomer, a relatively simple synthetic organic chemical which is polymerized industrially to produce the polyvinyl chloride used in the fabrication of a wide variety of plastic products). Assume that the plant is located near a city of 100,000 and that an analysis of certain postulated accidents shows that the probability of a serious accident is 10^{-4} accidents per year. Assume also that the consequences of such an accident are estimated to involve 1000 cases of angiosarcoma of the liver and subsequent death of the victims. Simply multiplying these two numbers gives you 0.1 deaths per year of plant operation. Consider the different impact of the following statements:

1. "the risk involved in operating the plant is approximately 0.1 deaths per year of plant operation";
2. "the risk involved in operating the plant is approximately a one-in-ten thousand chance of one thousand deaths per year of plant operation".

Remember that the average risk per Canadian of dying as a result of an automobile accident in 1980 is about one in four thousand, five hundred.

My purpose in mentioning this example is two-fold; firstly, to alert you to the need for careful examination of any statement of risk, and secondly, to indicate that there is no risk-free human activity. Lead, for example, has been recognized as an occupational, environmental and consumer hazard since ancient times, yet in 1970, total Canadian lead emissions were of the order of 17,000 metric tons. A 1977 report by the Science Council of Canada entitled "Policies and Poisons - The Containment of Long-term Hazards to Human Health in the Environment and in the Workplace" states, inter alia:

> "We are only now reacting to the insidious chronic effects of hazardous substances and have yet to learn how to anticipate them."

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Chronic low-level exposure to hazardous materials is a major concern, but it is the headline-grabbing accident that attracts and holds peoples' attention - at least sometimes.

Less than two years ago, more than 300 persons died within minutes after a tank truck carrying propylene burst into flames near San Carlos de la Rapita in Spain, and careened off the highway into a campground in which 700 people were holidaying. World-wide attention was certainly attracted by media reports of this terrible tragedy in July, 1978, but who (except the immediate friends and relatives of the victims) remembers it now. On the other hand, how many people remember the accident at the Three Mile Island nuclear power station - an accident in which no immediate minor, let alone any serious personal injury occurred to a member of the public, and as a result of which it has been estimated that there might be an increase of 1 in the approximately 500,000 cancers expected to develop from all sources over the lifetime of the population in the surrounding area.

There are several lessons to be learned from these two accidents:

1. the world quickly forgets serious tragedies if there is not continued reinforcement of memories by the media or other means;

2. the nuclear industry is seen as being uniquely hazardous;

3. modern societies have still not come to grip with the totality of the risk posed to the public by everyday industrial and commercial activities. (The November 10, 1979, train derailment incident at Mississauga is still quite fresh in the minds of the Canadian public, but there appears to be very little public or media pressure to examine the entire question of the transportation of dangerous goods by road, rail, water and air.); and

4. notwithstanding the fact that the public health and environmental effects of the Three Mile Island accident were

> essentially zero, a serious reactor accident did occur. Thus, there is absolutely no justification for complacency or for a relaxation of the stringent measures taken to ensure a high standard of nuclear safety. What is required, however, is an enlightened approach to limiting all risk in a manner which will ensure the implementation of measures which are commensurate with the risk involved. This, of course, is easier said than done.

In January, 1980, the Atomic Energy Control Board authorized a Company in Calgary to begin operation of a 70 tonne per year uranium extraction plant. There had been very vocal opposition to the plant because of the perceived risk that it would pose to the environment and to the nearby populace. One point that very few persons were willing to consider is the fact that the plant is actually a co-product operation located adjacent to a fertiziler plant. The uranium will be extracted from the phosphate feed to the fertilizer plant, thus reducing the amount of uranium that would otherwise appear in the food chain. A second by-product of the fertilizer plant is gypsum which is used in the manufacture of plasterboard for home and other construction. The removal of the uranium at the front-end of the flowsheet will therefore result in substantially lower concentrations of uranium in the plasterboard.

Mere mention of the word "nuclear" is all that is required to prompt an expression of concern by someone regardless of the situation involved. As a consequence, the demands placed upon a nuclear regulatory agency invariably include sorting out the valid from the invalid. All too often this difficult but necessary function leads to allegations about "protecting" the industry. As the now evident awareness of nuclear risks prompts a more determined attempt by the public to become knowledgeable about the subject, nuclear regulatory agencies around the world will be increasingly able to re-direct their efforts to regulating the industry instead of having to defend themselves repeatedly in the "guilty-before-proven-innocent" trials conducted by some elements of the media.

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Recently a Canadian affiliate of the Ralph Nader organization in the United States prompted extensive media coverage of the transportation of radioactive material, and in particular, the shipment of irradiated fuel to the United States. The coverage occurred during the federal election campaign and in several instances featured interviews with various candidates. One candidate (who was unsuccessful on February 18) found it necessary to describe Canadian monitoring of such shipments as "very, very lax" and to declare assurances by AECB officials as "obviously hollow". Fortunately, the thirty or so elected and appointed municipal officials who made the effort to travel to Ottawa to meet with AECB, Transport Canada and EMO (Ontario) to examine the facts of the matter, and to speak directly to the persons involved, entered the discussions with open minds and have found it unnecessary to question the adequacy of the regulatory process any further.

2. NUCLEAR SAFETY PRINCIPLES AND CRITERIA - SOME BASIC EXAMPLES

Almost 35 years ago (i.e. September 5, 1945) the ZEEP nuclear reactor at Chalk River, Ontario, first achieved criticality. During the intervening years, a great many nuclear-related scientific and technological advances were made, such as in the use of radionuclides for the diagnostic and therapeutic treatment of the ill. Unfortunately, many of these advances have been forgotten, overshadowed or overlooked in the constant clamor during recent years over nuclear "issues".

A little more than 7 years after ZEEP started up for the first time, an accident occurred in the NRX reactor which was to have a profound effect on the gradually evolving Canadian nuclear safety philosophy. The principal lesson learned was that regardless of the technology involved human error and system failure may occur. As a consequence, a safety philosophy based on what came to be known as "the defence-in-depth" concept was developed. Simply stated, the defence-in-depth concept means that several independent measures must be taken to minimize the probability and consequences of human error and system failure. In practice, the application of this concept involves:

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1. the selection of competent personnel and their subsequent training, qualification and requalification;

2. the design, manufacture, construction, commissioning and maintenance of systems and structures in accordance with nationally and internationally accepted engineering codes and standards;

3. the physical and functional separation and independence of process systems and special safety systems;

4. the frequent testing of special safety systems to confirm their availability;

5. the use of redundancy in monitoring, control and initiation systems (e.g. the triplication of circuits from the sensing element through to the control or safety device);

6. the incorporation of multiple barriers to prevent the release of fission products; and

7. the strict enforcement of compliance measures to ensure conformance with safety criteria.

A quick review of each of the seven examples of the application of the defence-in-depth concept will reveal that there is a common element - and that of course is the human element. Whether it is the designer performing a complex stress analysis, or the construction electrician installing control cabling, or the reactor operator visualizing what is happening in the many and varied process systems as he is starting up a large nuclear-electric generating station, the individual and collective competence of the persons involved is clearly the single most important factor in ensuring the safe and successful operation of a nuclear station. Although most if not all persons would quickly agree with this simple fact, it is amazing how often it is overlooked. The loss of 271 lives in the crash of a DC-10 at Chicago, on May 25, 1979, as a result of what appeared to be a completely insignificant procedural change (i.e. the

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removal of the rearmost of 3 bolts first, rather than the specified reverse order) could have easily been avoided if any of a number of the persons involved had taken the time to consider the effect of the change of even to "check it out" with more knowledgeable persons.

Frederick the Great liked to say that the older one becomes, the more one is persuaded that chance accounts for three-quarters of what happens in the universe. Perhaps so, when it comes to natural phenomena, but the over-stressing of structural bolts in an airframe or the inadvertent closure of isolating valves on a standby water system in a nuclear power station are not chance events.

Last May and again in August, Admiral H. G. Rickover, the Director of the U.S. Naval Nuclear Propulsion Program (also known as the father of the "nuclear navy") repeatedly stressed the overwhelming importance of the human operator in commenting on what he perceived to be the differences between naval reactors and commercial nuclear plants in light of the March 28, 1979, accident at unit #2 of the Three Mile Island Nuclear Power Station. The text of Admiral Rickover's remarks included statements like:

> "everyone involved must understand and appreciate the technical aspects of nuclear power and have a deep sense of responsibility and a dedication to excellence....."
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> ".....(the success of the program depends upon) managers who know what they are doing technically and who are running the job - not just reporting on it and passing on the recommendations of subordinates....."
>
> ".....reliance must ultimately be placed on the operator.."

Perhaps I need not dwell on this point any further. It is clear that regardless of the activity, the individual and collective competence of the persons involved constitute the single most important factor in determining the outcome of the activity.

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3. THE CANADIAN NUCLEAR SAFETY PHILOSOPHY

The Canadian approach to nuclear safety has been to establish a set of fundamental principles and basic criteria such as those arising from the application of the defence-in-depth concept. Primary responsibility is then placed upon the proponent to develop the competence required to show that the proposed plant will not pose unacceptable occupational or public health and safety risks. This competence must extend across all of the major phases of design, construction, commissioning and operation.

This approach differs to a considerable degree from the approach of other nuclear regulatory agencies around the world. In many instances, the practice is to stipulate a vast number of detailed requirements, thus forcing the proponent to think in terms of meeting regulatory specifications rather than in terms of a safe, efficient and reliable plant. Primary responsibility for ensuring compliance falls upon the policeman rather than the citizen. The citizen becomes preoccupied with obeying the detailed requirements of the law rather than being a good citizen.

Until only a few years ago, the AECB was a very small and largely unheard of organization. Its limited numbers of technical staff amounted to about 1 or 2 persons for each major nuclear facility - a ridiculously low number when you consider the current expectations of regulatory performance. The staff were almost totally preoccupied with getting the job done. Only a small fraction of their time was spent on explaining the "how", "what", "where", "when", and "why" to others, although anyone who really wanted to understand the process and the requirements could do so with very little effort. Thus, in the mid-1970's, the disclosure that lung cancer incidence among uranium miners was unacceptably high, and that private and public premises in various locations across Canada had been contaminated with radioactive materials, immediately called into question the validity of the Canadian nuclear safety philosophy and the credibility of the Board. It did not matter that prior to 1975, by

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federal-provincial agreement at the ministerial level, the AECB had not been operative in the field of uranium licensing (the Board's first uranium mine licensing section was established in October, 1975). Nor did it matter that the radium luminous dial painting operations which resulted in the contamination of buildings in Montreal, Toronto and Edmonton had been conducted during and immediately after World War II, and had remained undetected until February, 1975.

Particularly difficult to explain was the lack of documentation of the safety requirements to be complied with. As a consequence, the next few years were spent defending the Canadian philosophy while struggling to extend the regulatory process to include the entire nuclear fuel cycle and at the same time pulling together a federal-provincial task force to institute an investigation and remedial action program in such well-known communities as Port Hope, Bancroft and Elliot Lake, Ontario, and Uranium City, Saskatchewan.

Then on January 24, 1978, the Russian satellite COSMOS-954, with a small nuclear reactor aboard, crashed into the Northwest Territories. The additional resources by this time being allocated to the Board by the Government were quickly absorbed by virtue of its participation in the demanding task of locating and recovering satellite debris scattered over an area roughly twice the size of Switzerland.

These developments provided little time to prepare a comprehensive statement of the Canadian nuclear safety philosophy and the associated principles, criteria and requirements. Meanwhile, in the United States a massive regulatory standards-writing program had been underway for several years involving expenditures far in excess of the total resources allocated to the Atomic Energy Control Board for all purposes. However, a small advisory group had been set up in September, 1977, by the then President of the Board, Dr. A. T. Prince, to review the licensing process for nuclear power stations and to summarize, in understandable language, the general principles and criteria that had evolved over the previous two decades. This group was the Inter-organizational Working Group, or

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IOWG, which caused such a stir when the Board refused to issue copies of preliminary documents prepared by the Group on the basis that its final report would be made available for public comment prior to any action being taken on the Group's findings. Copies of the Report were made publicly available in November, 1978. Except for a very small number of obviously interested and dedicated individuals who commented on the Report quite constructively, and an equally small number who recommended total rejection, the response to the Board's request for public comment was disappointing.

Developments in the nuclear field proceed ad seriatim, but from time to time the pace quickens. At 0358 hours on March 28, 1979, a sequence of events began at the Three Mile Island nuclear power station near Harrisburg, Pennsylvannia, which set the pace for 1979. Interestingly enough, now that the reports of the Presidential Commission (the "Kemeny" Commission), of the Special Inquiry Group established by the U. S. Nuclear Regulatory Commission, and reports by literally dozens of other groups ranging from U. S. Senate sub-committees to foreign regulatory agencies, the underlying strength of the Canadian approach is becoming very apparent. This vindication of Canadian practice will become even more evident when the licensing guides which the AECB staff have been preparing are issued for public comment beginning next month.

Eventually there will be a set of licensing guides extending over the entire nuclear fuel cycle. The first guides to be issued will set out requirements which apply to CANDU nuclear power stations. The titles of four of these guides will indicate their purpose:

1. Requirements for Shutdown Systems for CANDU Nuclear power Plants;

2. Requirements for Emergency Core Cooling Systems for CANDU Nuclear Power Plants;

3. Requirements for Containment Systems for CANDU Nuclear Power Plants; and

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4. Safety Analysis Requirements for CANDU Nuclear Power Plants.

These guides will enable any interested person to obtain an understanding of the Canadian nuclear safety philosophy and to develop a solid appreciation for the stringent requirements which are imposed upon the design, testing and operation of both process systems and safety systems.

As time and resources permit, the set of guides will be expanded to embrace the entire nuclear fuel cycle. However, under no circumstance will this program of documenting regulatory criteria, principles and basic requirements be carried to the point of imposing a "design by regulation" approach. The primary responsibility for safe design and operation must rest with the licensee, and every effort must be made to guard against destroying his initiative and ingenuity.

4. THE CONTINUING INQUIRY

Beginning with the Ontario Royal Commission on the Health and Safety of Workers in Mines, which was established on September 10, 1974, there has been a continuing series of inquiries into nuclear energy issues. The most recent inquiry, the British Columbia Royal Commission of Inquiry into the Health and Environmental Protection aspects of Uranium Mining, proved to be very short-lived because of a decision by Premier Bennett to terminate it abruptly and to declare a seven-year moratorium on uranium exploration and mining in the province. In view of the clamour for public hearings on virtually any new technological development, and the vociferous demands for greater public participation in decision-making, the public response to Mr. Bennett's action will undoubtedly be instructive in assessing not only the need for further inquiries but also their expected value.

For anyone wishing to gain a broad insight into the occupational health and safety and the environmental aspects of uranium mining, the

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reports of the Ontario Royal Commission and of Saskatchewan's Cluff Lake Board of Inquiry provide an excellent source of information.

Similarly, the interim reports of the Ontario Royal Commission on Electric Power Planning, and of the Ontario Select Committee on Ontario Hydro Affairs, offer two, quite distinctively different, but equally valuable sources of information on the safety of nuclear power plants. Final reports are expected to be issued by late Spring.

Perhaps of greater value to a person wishing to comprehend the nuclear safety issues which have attracted so much attention during the past year or so are the transcripts of the hearings conducted by the Ontario Select Committee. Although much has been made of the partisan nature of the Committee's deliberations and of the confrontations (some real, most either imaginary or exaggerated by some of the journalists who observed the hearings), the sheer frustrations faced by the Committee in questioning witnesses who ranged in attitude from "difficult" to "nearly impossible" have largely escaped notice. However, this is not what makes the transcripts so valuable. It is the progressively more sophisticated questioning that occurred as the hearings continued, and the cross-referencing of information from various sources, which permit the reader to grasp the salient facts about the major issues. Unfortunately, as in the case of transcripts of any discussion, debate or hearing, there is a considerable amount of chaff amongst the grain. However, if the interest in understanding the issues is genuine, the hours spent in reading the Select Committee's transcripts are a small price to pay.

Views on the value of the many inquiries which have been held during the past six years vary widely. It is evident that the royal commission approach permits the appointment of persons possessing particular expertise both insofar as the members of the commission are concerned and of its advisory staff. A legislative or parliamentary inquiry on the other hand involves persons who are more intimately aware of the thought patterns and concerns of the public whom they represent.

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There can be no question as to the tremendous strides that have been made in terms of collecting and collating directly relevant, and largely independently verified, information on subjects which have become of high profile interest to the public. While the inquiries held so far have been critical of certain aspects of the development of the nuclear fuel cycle, and to criticize is after all one aspect of the inquiry process, it is not unreasonable to state that the result of these inquiries has been to give cautious, if qualified, approval to nuclear power development.

Despite this conclusion, it is not clear to what extent past and on-going inquiries have worked to reassure the public or to allay the deep-seated and often emotional fears that nuclear issues are so capable of eliciting. The problem is largely one of education, where a large part of the public is unwilling to make the effort required and yet remains susceptible to over-simplified and often biased (both pro and anti!) reports they do hear and read. If this problem is not resolved, then the likelihood of a continuing call for further inquiries will remain, with the public finally deciding that, if there are yet-unaswered questions, society will be better off without the source of the questions.

In this environment, the AECB must continue to operate to the best of its abilities. The AECB is established as a regulatory agency with a certain degree of independence from day-to-day governmental involvement, and is responsible for ensuring, on the government's behalf and in the public interest, that the operation of nuclear facilities and the use of prescribed substances are acceptable from the standpoint of health, safety and security. It is not a function of the AECB to promote nuclear power - the decision of whether to develop any part of the nuclear fuel cycle or to use radioisotopes is for others to make. However, as long as any such activity is either underway or contemplated, the AECB is responsible for deciding whether the activity as proposed will meet criteria for acceptable health, safety and security. Once this decision is made, the AECB must be able to and does defend it.

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Beyond that fundamental responsibility, and in the same sense that "justice must not only be done but must also be seen to be done", the AECB has a further responsibility to ensure that interested members of the public and groups can readily make themselves aware of how the AECB goes about its regulatory business. In concert with a general trend towards more open government, the AECB is becoming increasingly aware of and is responding to this latter responsibility. It is hoped that the AECB will, over the next few years, be able to take some major initiatives in this area.