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NUCLEAR WASTE MANAGEMENT, REACTOR DECOMMISSIONING, NUCLEAR LIABILITY AND PUBLIC ATTITUDES

By

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Atomic Energy of Canada Limited
Whiteshell Nuclear Research Establishment
Pinawa, Manitoba

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ABSTRACT

This paper deals with several issues that are frequently raised by the public in any discussion of nuclear energy, and explores some aspects of public attitudes towards nuclear-related activities.

The characteristics of the three types of waste associated with the nuclear fuel cycle, i.e. mine/mill tailings, reactor wastes and nuclear fuel wastes are defined, and the methods currently being proposed for their safe handling and disposal are outlined. The activities associated with reactor decommissioning are also described, as well as the Canadian approach to nuclear liability. The costs associated with nuclear waste management, reactor decommissioning and nuclear liability are also discussed.

Finally, the issue of public attitudes towards nuclear energy is addressed. It is concluded that a simple and comprehensive information program is needed to overcome many of the misconceptions that exist about nuclear energy and to provide the public with a more balanced information base on which to make decisions.

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1. INTRODUCTION

In any discussion of nuclear energy, there are several recurring issues. These include

- the economics of nuclear power,
- reactor safety,
- nuclear proliferation,
- the effects of radiation,
- the management of nuclear wastes,
- reactor decommissioning, and
- nuclear liability.

All of these affect public attitudes towards, and hence the acceptance of, nuclear energy, and can therefore affect the pace of nuclear development.

Several of the above issues have already been discussed by other speakers at this seminar. In this paper I shall deal with nuclear waste management, reactor decommissioning and nuclear liability, and with the question of public attitudes towards nuclear energy.

The nature of nuclear wastes and reactor decommissioning activities, and the impact of these on the cost of nuclear power, will be described, and the Canadian approach to nuclear liability will be outlined. Finally, the public acceptance of nuclear energy in Canada, and specifically in Alberta, will be explored and a suggestion will be made as to how this can be improved.

2. NUCLEAR WASTE MANAGEMENT

The three types of waste products associated with the nuclear fuel cycle are

- mine/mill tailings, which arise from the mining, milling and refining of uranium ore, in preparation for its use as reactor fuel.

- reactor wastes, which are produced during the day-to-day operation of nuclear power plants; similar kinds of wastes arise from the decommissioning of nuclear plants.

- nuclear fuel wastes, which are associated with the used fuel from reactors.

These three types of nuclear waste have quite different characteristics and require different techniques for handling and disposal. I shall describe the characteristics of these three major waste forms and outline the methods currently being proposed for dealing with them.

2.1 Mine/Mill Tailings

Mine/mill tailings are the residues that arise from the mining, milling and refining of uranium ores. They contain both chemical and radioactive materials that can pollute the environment, if proper precautions are not taken.

Interestingly, chemical pollution is the greatest problem posed by these tailings. This is because the uranium ore often contains sulphur-bearing minerals which can dissolve in water to form acidic run-off. Unless properly treated, this run-off can eventually enter adjacent rivers and lakes where it can harm aquatic life and damage the surrounding ecology. This is particularly true where acid is used to extract the uranium from the ore.

Radioactive pollution from uranium tailings is often cited as a more serious problem than acid run-off, but this is not the case. The tailings do produce a radioactive gas, called radon, and while this is a health risk to the miners working underground, it quickly disperses to safe levels in the atmosphere. More important is the radioactive material dissolved in liquids seeping through the tailings piles. Radioactive radium can dissolve in the acidic run-off and concentrate in fish living in neighbouring streams and lakes, and eventually in people who eat the fish.

The tailings problem is made more difficult by the sheer volume of these wastes, arising from the fact that typical uranium ore bodies (except some in Saskatchewan) contain only about one percent, or less, uranium.

It should be noted that this problem is not unique to the uranium mining industry, since all mining operations produce large quantities of tailings that contain chemical pollutants similar to those found in uranium ores, and also considerable quantities of radioactive materials.

In the early days of uranium mining, insufficient care was taken with the tailings and considerable damage was done to nearby water systems, e.g. the Serpent River near Elliot Lake, Ontario. In recent years, however, the mining industry has cleaned up its act. Now, the tailings, in slurry form, are pumped to man-made settling ponds. Here the solids containing the radium settle out from the slurry, which is treated in additional settling ponds. Barium compounds are used to convert the small amount of soluble radium still left to insoluble compounds, which settle to the bottom of the ponds. The resulting clean water then enters the natural water system. The treatment has recently been developed to the point where the run-off is now able to meet drinking water standards set by the regulatory agencies.

The volume of the wastes associated with refinery operations is very small compared to that of the mine tailings and they pose no real problems. The radioactive portion of these wastes is returned to the mill for additional uranium extraction and the residues are added to the mine tailings. One of the non-radioactive chemical residues (ammonium nitrate) is being sold as fertilizer and it is expected that the other (calcium fluoride) will be used in the steel industry.

There is still a need for further research and development (R&D) to resolve the problems associated with the long-term control of mine/mill tailings. The R&D is currently being carried out under the aegis of the Uranium Joint Panel, which comprises representatives from the mining industry and federal and provincial government agencies. The federal government and the governments of Ontario and Saskatchewan are currently discussing an expanded R&D program in this area.

2.2 Reactor Wastes

Reactor wastes are the wastes that are produced during the day-to-day operation of nuclear reactors. A number of low- and medium-level solid and aqueous wastes are produced. The low-level wastes are so defined because they do not require shielding or cooling during handling or transportation. The medium-level wastes do require shielding and confinement during handling and transportation, but do not require cooling.

The low-level wastes consist mainly of trash and cleaning materials that result from routine reactor maintenance operations. The medium-level wastes consist mainly of ion-exchange resins and filters, used in fluid purification systems. Typical annual quantities of such wastes for a 600 MWe CANDU reactor are as follows:

- low-level aqueous	10000 m^3
- ion-exchange resins	15 m^3
- primary coolant filters	5 m^3
- low-level solids	300 m^3
- organic oils	2 m^3.

Although the low-level aqueous wastes are the major component in volume terms, the associated radioactivity is very small (less than 5 Ci per annum). Most of the radioactivity is present in the ion-exchange resins (approximately 1000 Ci per annum) and the primary coolant filters (approximately 500 Ci per annum). The low-level solids and organic oils together produce less than 10 Ci of radioactivity per annum.

The low-level reactor wastes are dominated by cobalt-60 and cesium-137, with no identified long-lived constituents. The medium-level wastes from the purification systems may have a lifetime which is controlled by long-lived carbon-14; this would mean isolation of the wastes from man for thousands of years.

The approach used to optimize the disposal of these wastes, is to classify them according to hazardous lifetime and to select disposal concepts with the appropriate containment and isolation capabilities. The bulk of the low- and medium-level wastes from CANDU reactors present a relatively short-lived hazard requiring isolation for no more than a few hundred years. The disposal concept being proposed for these wastes is burial, in suitable packaging, tens of metres deep in Quaternary deposits, such as clays. The remaining waste, which may contain components that are potentially hazardous for geological time periods, could be dealt with in the same manner as nuclear fuel waste, as described below.

The overall disposal strategy is flexible enough to allow for present waste-management practices and anticipated future needs. For example, waste categories additional to the two described above could be used to better accommodate the radiological character of the wastes. The plan also includes the continued safe storage of wastes in engineered concrete surface structures at centralized monitored facilities, such as those currently operated by AECL and Ontario Hydro. Such storage will continue until more permanent methods of disposal have been selected.

Since the volumes of low- and medium-level reactor wastes are relatively high, it is desirable to reduce these before storage and disposal. The accumulated volume of such wastes in Canada, following volume reduction, i.e. conditioned and packaged, ready for disposal, is predicted to be 85,000 m^3 by the year 2000. This could be reduced by a factor of 2 if expected advances in waste conditioning and characterization are achieved. Waste conditioning methods are being developed at the Chalk

River Nuclear Laboratories, as part of AECL's overall nuclear waste management R&D program. The following methods are being investigated:

- incineration, for the combustible, solid wastes,
- ultrafiltration/reverse osmosis, for the removal of suspended solids and dissolved waste products from liquids,
- bituminization, for the immobilization of the waste products obtained from the incineration and ultrafiltration/reverse osmosis processes.

The estimated cost for the disposal of low- and medium-level wastes in a hard-rock vault varies from $340/m^3 (1981$) for a vault capacity of 200,000 m^3 to $180/m^3 (1981$) for a vault capacity of 800,000 m^3. As will be shown below, this represents only a small fraction of the total cost of the electricity generated.

2.3 Nuclear Fuel Wastes

Nuclear fuel consists of pellets of uranium dioxide (UO_2) housed in zirconium alloy tubes which are assembled into bundles about 50 cm long, each weighing 23 kg (see Figure 1). The composition of the fresh natural uranium fuel is given in Table I below. Inside the reactor the uranium-235 component, which comprises only 0.7% of the total uranium content, undergoes fission by absorbing neutrons. The heat released when the uranium fissions, or splits, is the nuclear energy that is used to create steam and thence electricity. Each fuel bundle remains in the reactor about 1-1½ years, during which time it produces as much energy as would be obtained from burning about 400 tonnes of coal. This is enough energy to supply the electricity needs of a typical Canadian family for over 100 years.

As shown in Table I, when the bundles leave the reactor they contain about 0.8% fission products and about 0.4% heavy elements, called

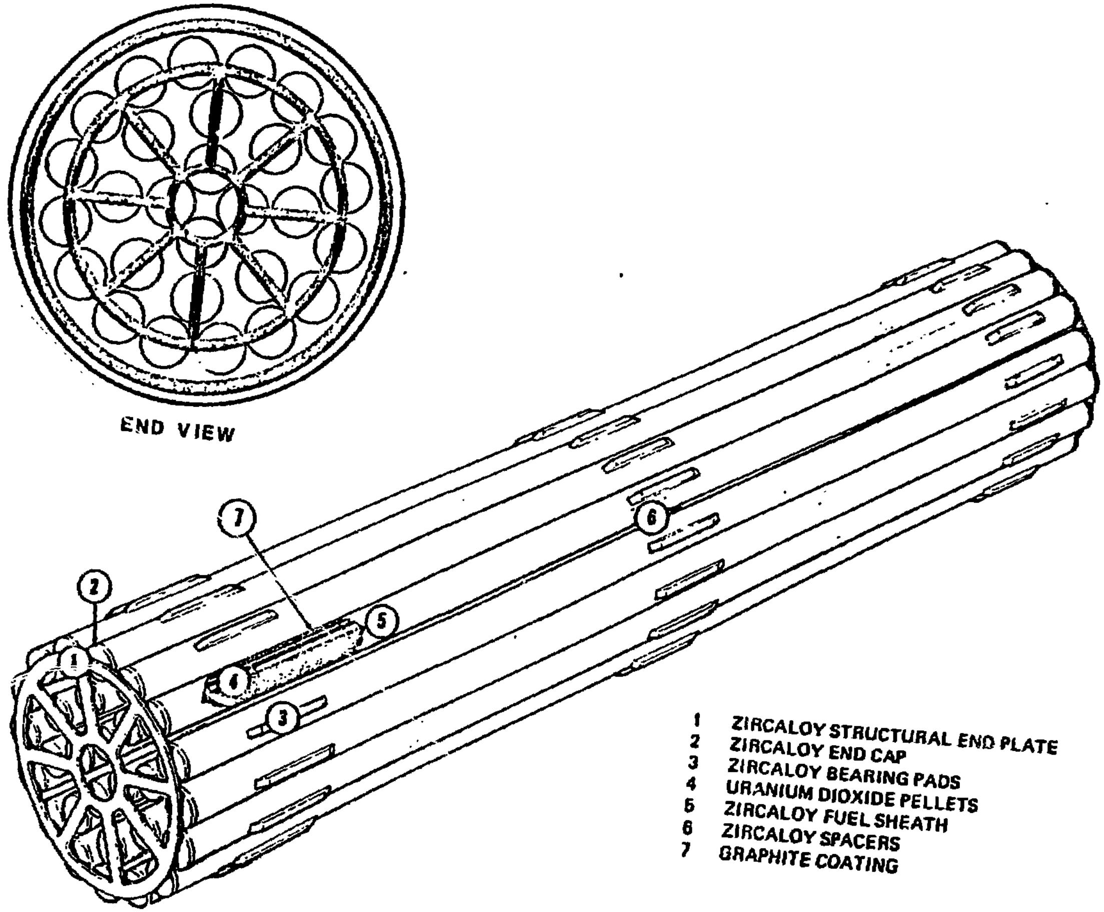

FIGURE 1: FUEL BUNDLE FOR PICKERING REACTOR, ASSEMBLED FROM SEVEN BASIC COMPONENTS.

actinides, the major component of which is plutonium, produced by neutron absorption in uranium-238. Since only about 1.2% of the original uranium is actually consumed during irradiation in the reactor, the waste volume is extremely small when one considers the amount of energy produced.

TABLE I

COMPOSITION OF FRESH AND USED REACTOR FUEL

Component	Fresh Fuel	Used Fuel
URANIUM-238	99.3%	98.6%
URANIUM-235	0.7%	0.2%
ACTINIDES (Pu)	-	0.4%
FISSION PRODUCTS	-	0.8%

The fission products are intensely radioactive, but are mostly short-lived. In fact, it is impossible for radioactive material to be both highly radioactive and long-lived. As an atom emits radiation it decays to a stable form. Thus, matter that is highly radioactive decays quickly. The actinides are much less radioactive than the fission products and decay much more slowly. Most of the radioactivity in the used fuel decays in the first few years after its removal from the reactor, as shown in Figure 2. Indeed, after a few hundred years the average radioactivity of a waste disposal vault would be comparable to some naturally occurring uranium ore bodies.

Since the used fuel bundles from the reactor are intensely radioactive, and also emit heat, they must be cooled and shielded and the radioactive material must be contained. For more than 20 years we have been storing used fuel at the reactor sites, in water-filled pools. The water

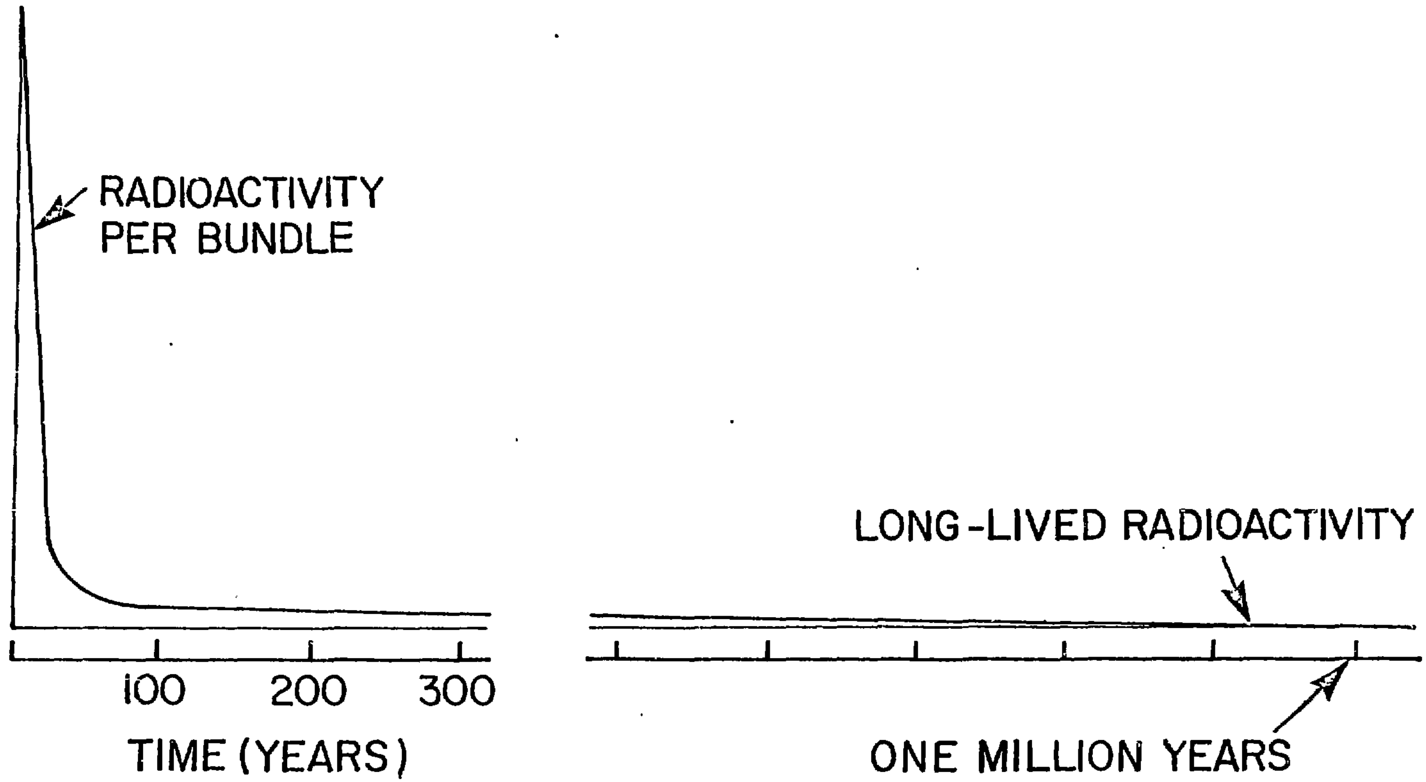

FIGURE 2 DECAY OF RADIOACTIVE FUEL WASTE PRODUCTS

provides the necessary shielding and cooling, and the zirconium alloy sheaths provide the containment. A typical storage pool at a nuclear power plant can store the fuel from 10 years of electricity production, and additional pools can be added, as needed.

As noted above, the used fuel contains a valuable energy source, plutonium. By the year 2000 the fuel stored in Canada will contain the energy equivalent of 3 billion barrels of oil, or about one-half of Canada's current reserves of conventional oil. We could extract this plutonium, put it back into new fuel bundles and generate more electricity. This fuel extraction and recycle process would result in the production of acid solutions containing fission-product wastes which would be solidified.

Anticipating this requirement, 20 years ago at Chalk River, AECL scientists mixed radioactive waste solutions with glass-making frit, melted the mixture and then cooled it. The resulting solid glass blocks were buried in sandy soil, below the water table, without any container or other protection. These blocks have been carefully monitored since then, and recently two of them were excavated and tested. The release and transport of radioactive material was found to be negligible.

No decision has yet been taken in Canada to mine the energy resource in used CANDU fuel. If and when this is done will depend upon natural uranium resources, economics and the availability of alternate energy sources. Consequently, we have two possible nuclear fuel waste forms, the spent fuel bundles themselves <u>or</u> the solidified fission-product wastes, if we decide to extract the plutonium. The fuel bundles are presently stored safely at the reactor sites, and glassified wastes in containers could, in principle, be stored in a similar way. However, this system would require monitoring and maintenance, and one of the principles we have established is that we should impose no requirement on future generations to look after our wastes after we have enjoyed the benefits that caused their production. So, we have decided to dispose permanently of either the spent fuel bundles, or the solidified wastes.

On 1978 June 5, the Federal and Ontario governments announced an agreement to co-operate in the development of technologies for the safe, permanent disposal of nuclear fuel wastes. AECL was given the responsibility for immobilization and disposal, where immobilization involves making the wastes insoluble, and developing durable containers and suitable materials to place around the containers to prevent water ingress and radionuclide movement. Ontario Hydro was given the responsibility for the development of technologies for the interim storage and transportation of used fuel. The immobilization and disposal research is directed from the Whiteshell Nuclear Research Establishment at Pinawa, Manitoba.

The program brings together a wide range of scientific and engineering expertise from all parts of Canada. AECL performs and co-ordinates research and development and contracts work out to Energy, Mines and Resources, Canada, the National Hydrology Research Institute of Environment Canada, Canadian universities and private contractors. Ontario Hydro also provides technical assistance to AECL in the immobilization and disposal program.

There is a free and open exchange of information in this field between all nations in the free world. Canada has exchange agreements with the United States, the Commission of the European Communities and Sweden, and is represented on several Technical Committees and Working Groups of the International Atomic Energy Agency and the Nuclear Energy Agency of the European Organization for Economic Co-operation and Development.

Apart from giving access to a wide store of information on nuclear waste disposal, this international co-operation has another major advantage. The various countries are studying a variety of geologic disposal concepts, including disposal in clay, salt, hard rock, shale, under the seabed, etc. This means that we can focus on the concept which appears most appropriate for Canada. If, after study, another approach turns out to be better, we will have the research results on the other options available from the other countries.

The Canadian concept for nuclear fuel waste disposal is illustrated in Figure 3. It is proposed to encase the solid waste in durable containers

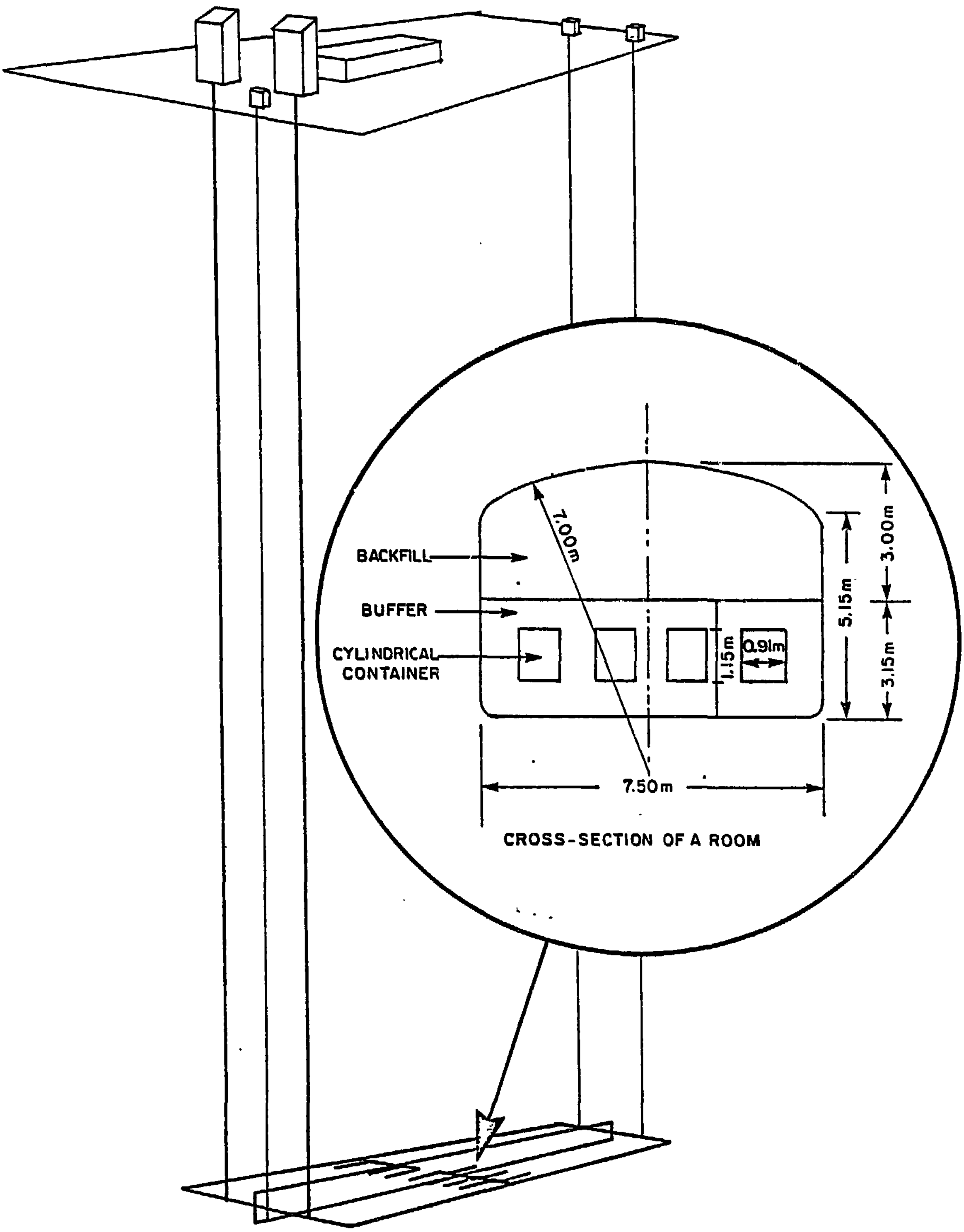

FIGURE 3 CANADIAN CONCEPT FOR NUCLEAR FUEL WASTE DISPOSAL

and emplace it about 1000 metres deep in rooms mined out of hard rock. The geologic formations of major interest are called plutons. These formations can be many tens of kilometres across and about 10 kilometres deep, and they have remained essentially unchanged since the molten rock welled up through the earth's crust, cooled and solidified billions of years ago. The Geological Survey of Canada has mapped about 1400 plutons in the Ontario portion of the Canadian Shield. It is expected that the first disposal vault will be located in Ontario since that province is, and will continue to be, the major generator of nuclear electricity.

In 1981 April, the federal government approved a 10-year generic R&D program for Nuclear Fuel Waste Management. During the 10-year period, the participating organizations will perform the research necessary to design and evaluate the proposed concept for nuclear fuel waste disposal.

The only feasible way for radioactive material to reach man's environment from the disposal vault is for groundwater to percolate to the vault, corrode the containers, dissolve the waste, and for the waste solution to seep to the surface. The objectives of the research program are to develop methods to prevent this from happening, and to obtain the data needed to evaluate to what degree the methods will succeed.

We are developing waste forms that are difficult to dissolve. The fuel itself is a ceramic, and is encased in zirconium alloy, both of which are extremely insoluble. Suitable container materials are under investigation; titanium alloys hold the promise of being very corrosion-resistant. Various buffer and backfill materials, such as clays, are being evaluated for packing around the containers. Their capabilities for retarding water movement and absorbing radionuclides are being investigated.

Then we have the massive rock formation. Hydrogeological, geochemical and geomechanical research is underway to evaluate the rock structure, water movement and the degree to which radionuclides could be transported by water. In particular, we are studying how solutions could seep through cracks in the rocks, how radionuclides could be slowed down by diffusion into pores and small cracks, and by chemical reactions with the rock materials.

Finally, if any radionuclides reach the surface before decaying away, they could be diluted in groundwater, lakes and rivers, and possibly reconcentrated in biological food chains, through plants and animals. We have been studying the movement of radionuclides in the surface environment, and the effects of radiation on plants, animals and man for 20 years, and this research is continuing in support of the nuclear fuel waste management program.

All of this research information will be used to design a suitable disposal vault and, sometime in the future, to choose a suitable vault location that will ensure that the wastes can be disposed of safely and permanently. Our major objective now is to assimilate all of the information and to distil it into an assessment of the effect of a disposal vault on people, both now and in the distant future.

We recently completed our first assessment, using the research information collected to date. The results are presented as the maximum radiation dose to the most exposed individual during the first million years after the vault is sealed, for the whole range of possible situations that we could envisage. We take a range of situations, 1729 in this case, because we can't say exactly what is going to happen, exactly how groundwater would move, and so on, but we do know within certain ranges what processes could occur. The most exposed individual was assumed to be someone living at a location where the water from the vault would reach the surface. The individual was assumed to obtain his food and drink locally.

The dose levels so obtained are shown in Figure 4, and compared with the natural background radiation dose we all receive from cosmic rays and natural radionuclides. As is evident from the figure, all of the results fall below 10% of natural background and the vast majority are very close to zero dose. These results are very encouraging, but we recognize that future research findings could cause them to change. The purpose of the research program is to reduce the uncertainties associated with the parameters used in the assessment model and thereby improve the reliability of its predictions.

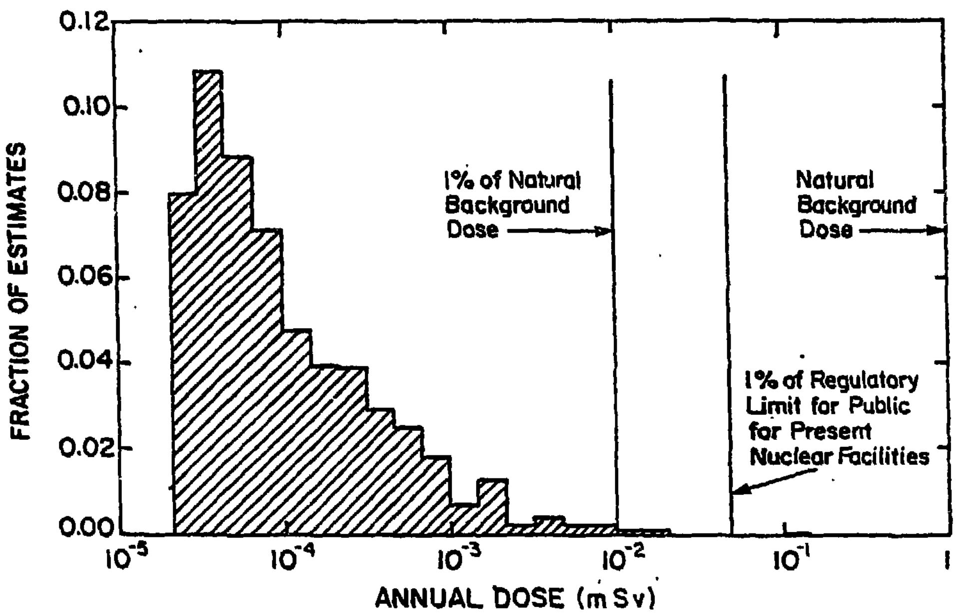

FIGURE 4: HISTOGRAM OF ANNUAL INDIVIDUAL DOSES DUE TO WASTE DISPOSAL VAULT

When the 10-year R&D program is complete the concept will be evaluated by the scientific community, the regulatory agencies and the public, so that informed decisions can be made by governments as to the suitability of the proposed concept for waste disposal. Only then will the selection of a suitable site for a disposal vault be undertaken.

There is no particular urgency to select a site for waste disposal since, as noted earlier, the present method of storing used fuel at the reactors can be continued for decades. Also, the waste volumes are not large and it has been estimated that one disposal vault could handle the waste produced by all the reactors expected to be operating in Canada for the next 50 years.

3. REACTOR DECOMMISSIONING

The term decommissioning includes all the activities associated with taking a nuclear reactor permanently out of service, placing and maintaining it in a safe mode and, if necessary, restoring the site to its natural state. There are three decommissioning options:

- Storage with Surveillance (SWS)
  Here the reactor is completely defuelled, the heavy water removed, the systems decontaminated (this is optional), and access to the buildings is controlled by physical barriers and 24-hour security.

- Restricted Site Release (RSR)
  Here the fuel and heavy water are removed, contaminated areas decontaminated, access to areas with residual radioactivity is sealed off, parts that can be dismantled are removed, and limited security (primarily by remote control) is maintained.

- Unrestricted Site Use (USU)
  Here all materials, equipment and structures are removed completely and the site is returned to its natural condition.

The technology required for decommissioning nuclear power plants is already available and 65 experimental and demonstration reactors have been decommissioned to date. No commercial-size reactors have been decommissioned yet, but the increased size should not create any new problems. As noted earlier, the wastes are similar to reactor wastes and can be treated in a similar way.

The strategy developed by Ontario Hydro for decommissioning its power plants, and on which decommissioning costs are based, involves

> "orderly shutdown of the reactors, followed by removal of the nuclear fuel and heavy water, partial decontamination of the systems, placing the facility under Storage with Surveillance for about 30 years, to

allow a reduction in overall radioactivity by a factor of 3000 or greater, followed by dismantlement of the facility and removal of all components necessary to achieve Unrestricted Site Use."

The costs of decommissioning the Pickering A and Bruce A Generating Stations has been estimated by Ontario Hydro as $162 million and $196 million, respectively, in 1980 dollars. A breakdown of the costs for the Pickering A station is given in Table II. As will be shown later, the contribution to the total cost of nuclear electricity due to the cost of reactor decommissioning is modest.

TABLE II

SUMMARY OF PICKERING GS A ESTIMATED COST OF DECOMMISSIONING IN 1980 DOLLARS ($000)

Activities	Labour	Material	Transport	Equipment	Total
*Fuel Removal	4 448	861	-	-	5 309
Heavy Water Removal	746	430	72	-	1 248
Decontamination	2 535	3 640	800	-	6 975
Security, Surveillance & Maintenance	7 200	-	-	-	7 200
Dismantling - Buildings (includes reactor building and reactor vault)	7 009	-	6 015	37 225	50 249
Dismantling - Systems (includes reactor dismantlement)	7 566	22 350	44 212	1 800	75 918
**Miscellaneous Expenditures					15 101
Total					162 000

* Includes preparation of manuals and decommissioning procedures.
** Provision for unforeseen costs.

4. NUCLEAR LIABILITY

Nuclear liability in Canada is covered by the Nuclear Liability Act (Bill C-158), which came into force on 1976 October 11. The Act primarily covers injury or damage to people and property in Canada arising from a nuclear incident in Canada, but also covers injury or damage occasioned in the United States from a nuclear incident in Canada. The Nuclear Liability Act places total responsibility for a nuclear installation on the licence holder, i.e. the operator. Subject to the Act, the operator is absolutely liable for a breach of the duties imposed by the Act, without proof of fault or negligence.

The Act sets a financial limit of $75 million on the liability of the operator of each installation. Thus Ontario Hydro, which operates the Pickering, Bruce and Douglas Point Stations, must insure each station for third-party coverage of $75 million. The insurance is provided through the Nuclear Insurance Association of Canada (NIAC), a conglomerate formed in 1958. New Brunswick Power and Hydro Quebec must insure their facilities (Point Lepreau and Gentilly-2) in the same way. However, the Atomic Energy Control Board has set a lower NIAC coverage limit for Gentilly-1, NPD, Eldorado Nuclear and Westinghouse, with the balance being indemnified by the Canadian Government.

Crown agencies, such as AECL, are exempt from purchasing third-party liability insurance. In effect, therefore, the federal government underwrites its own risks at WNRE and CRNL.

Although there is a ceiling of $75 million liability on the operator of a nuclear facility, this does not limit the financial protection of the public for personal injury and/or property loss. Rather, it guarantees the ready availability of a large sum of money for prompt compensation and restricts the amount by which the operator is liable. Should the claims of third parties exceed $75 million in the event of a nuclear accident, the federal government would appoint a commission to settle the claim, with Parliament voting the additional sums necessary. In this sense, nuclear liability in Canada is unlimited.

AECL pays liability premiums for NPD and Douglas Point which are operated for us by Ontario Hydro. Our premium is about $31,000 for NPD and $134,000 for Douglas Point. Ontario Hydro pays proportionately higher premiums for each of its nuclear stations, to provide the required $75 million third-party coverage on each.

There has never been a claim in Canada under the Nuclear Liability Act.

Nuclear liability in the United States is provided under the Price-Anderson Act of 1957. The act protects the public against loss resulting from the development of nuclear power while protecting participants in the nuclear program from the risk of unlimited liability.

Under the Act, an operator must ensure a primary financial protection to the maximum amount of liability insurance available from the private market, $140 million in 1978. This coverage is provided by an insurance pool. If the damages are greater than $140 million, the insurance pools assess each plant licensee a sum up to $5 million, leading to a secondary source of $340 million (in 1978). The combined primary and secondary sum is therefore $480 million. Indemnity agreements with the NRC provide an additional $80 million, i.e. the balance required to give the current United States limit on liability: $560 million. As in Canada, this does not limit the amount that might be paid or claimed, only the responsibility of the licensee.

5. COSTS OF WASTE MANAGEMENT AND DECOMMISSIONING

The costs associated with the management of nuclear waste products and the decommissioning of nuclear power plants have long been recognized as legitimate components of the total cost of nuclear energy, and some of these have been incorporated all along into the plant operating and maintenance costs.

For example, the costs of managing the wastes associated with the mining, milling and refining of uranium have always been included in the price of the uranium fuel used in the power reactors. Indeed, apart from governmental support for research and development activities, all costs associated with the production of uranium fuel are borne by the operators of the power plants and ultimately the electricity consumers.

Similarly, apart from R&D support, the costs of treatment and storage of reactor wastes and storing of used fuel at the reactors have always been incorporated into the operation and maintenance costs for the power plant, and passed on to the electricity user.

Recently, the utilities with nuclear generating capacity have developed cost estimates for the decommissioning of the nuclear plants and the long-term disposal of nuclear fuel wastes. Ontario Hydro has incorporated charges for decommissioning and fuel waste disposal into its 1982 rate base and the New Brunswick Power Commission has proposed similar charges in its recent proposal to the National Energy Board for the export of nuclear-based electricity. The charge rates are based on the principle that future costs should be recovered during each year that the facilities operate, assuming a plant lifetime of 40 years.

The charges derived by Ontario Hydro for the various waste management and decommissioning activities associated with the Pickering A and Bruce A stations, and included in the 1982 rate base, are summarized in Table III below. As noted above, the first two entries in the table, for interim used fuel storage and reactor waste management, have been included all along in station operating costs. The charges for fuel waste management, past service fuel (to provide for disposal of the wastes associated with previously accumulated Pickering A fuel), and decommissioning are new charges in 1982. It is interesting to note that the total costs for waste management and decommissioning are quite reasonable, about 8.4% of the bus-bar cost of nuclear electricity, or about 4.0% of the retail cost of electricity in Ontario.

TABLE III

WASTE MANAGEMENT AND DECOMMISSIONING COSTS FOR PICKERING A AND BRUCE A GENERATING STATIONS

Activity	Cost (mills/kWh)
INTERIM SPENT FUEL STORAGE	0.09
REACTOR WASTE HANDLING AND STORAGE	0.13
FUEL WASTE HANDLING AND DISPOSAL	0.80
PAST SERVICE FUEL (PICKERING)	0.20
DECOMMISSIONING	0.10
TOTAL	1.32
BUS-BAR COST OF NUCLEAR ELECTRICITY	15.6
WASTE MANAGEMENT/DECOMMISSIONING FRACTION	8.4%
RETAIL COST OF ONTARIO ELECTRICITY	33
WASTE MANAGEMENT/DECOMMISSIONING FRACTION	4.0%

6. PUBLIC ATTITUDES TOWARDS NUCLEAR POWER

Public attitudes towards, and acceptance of, large industrial projects are becoming an increasingly important factor in the smooth and expeditious development of such projects. This has become all too evident in recent years, particularly in North America and Western Europe, where hydro-electric dams, large chemical plants, industrial waste-treatment facilities and coal and nuclear power plants have been delayed by the opposition of local public interest groups. Nuclear projects have special problems in this regard, since they represent a new and highly complex technology that is unfamiliar to the general public and is all too often associated with nuclear weapons and proliferation.

Experience has shown, however, that the major factor working against nuclear and other similar projects is a lack of knowledge of the basic features of these projects coupled with the desire of the public to have a greater input into the decision-making process, particularly for projects in their own backyards.

With this background in mind, it is worthwhile to explore the public attitudes towards nuclear projects in various parts of Canada, including Alberta. Figure 5 shows the results of a Canada-wide survey to determine what the public knows about the use of nuclear power. Only 26% of those surveyed had any appreciable knowledge of nuclear power, while 56% had only heard of it vaguely, and the remaining 18% knew nothing about it. Knowledge levels in Alberta were similar to the Canadian average, being lower than Ontario, but higher than Quebec.

Those who had some knowledge of nuclear power knew about the CANDU reactor and its use for producing electricity and, in Alberta, the use of radiation for treating cancer. There was a significant lack of knowledge about waste disposal, heavy water, plant safety, regulatory controls and the possible use of nuclear energy in the tar sands.

There was considerable interest in more information on waste disposal, cancer treatment, plant safety, electricity production and the tar sands application. The levels of interest were similar in Ontario, Quebec and Alberta, except that there was less interest in Quebec in waste disposal.

Public opinion about the use of nuclear power in Canada is shown in Figure 6. These results show that about one-half of Canadians support the use of nuclear power and that, apart from minor fluctuations, there has been no significant change for several years.

Table IV shows the results of a survey on the future use of nuclear power. There is less support in Alberta than in Ontario and Quebec for an early increase in the use of nuclear power, although there is strong support for a slow increase. Outright opposition in Alberta is similar to that in Ontario, with Quebec being more strongly opposed. The major

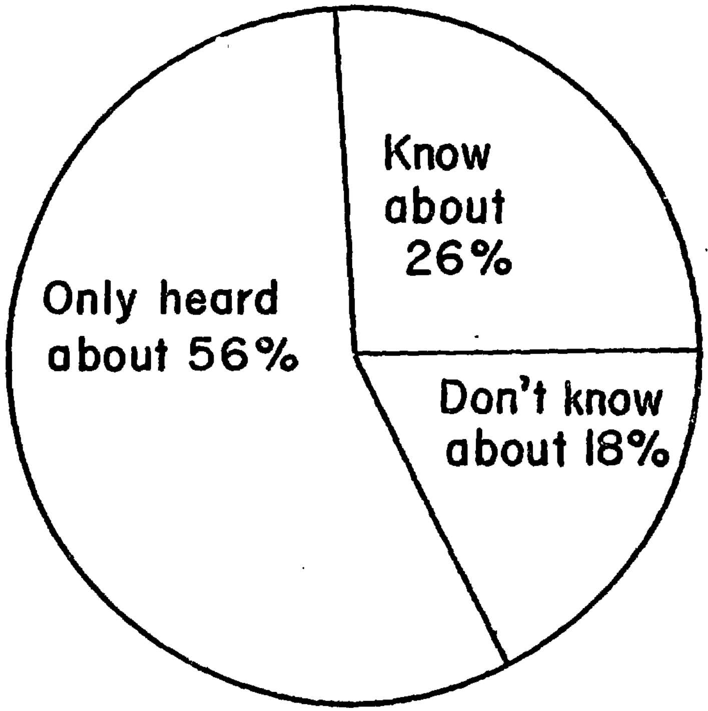

FIGURE 5: PUBLIC KNOWLEDGE ABOUT THE USE OF NUCLEAR POWER

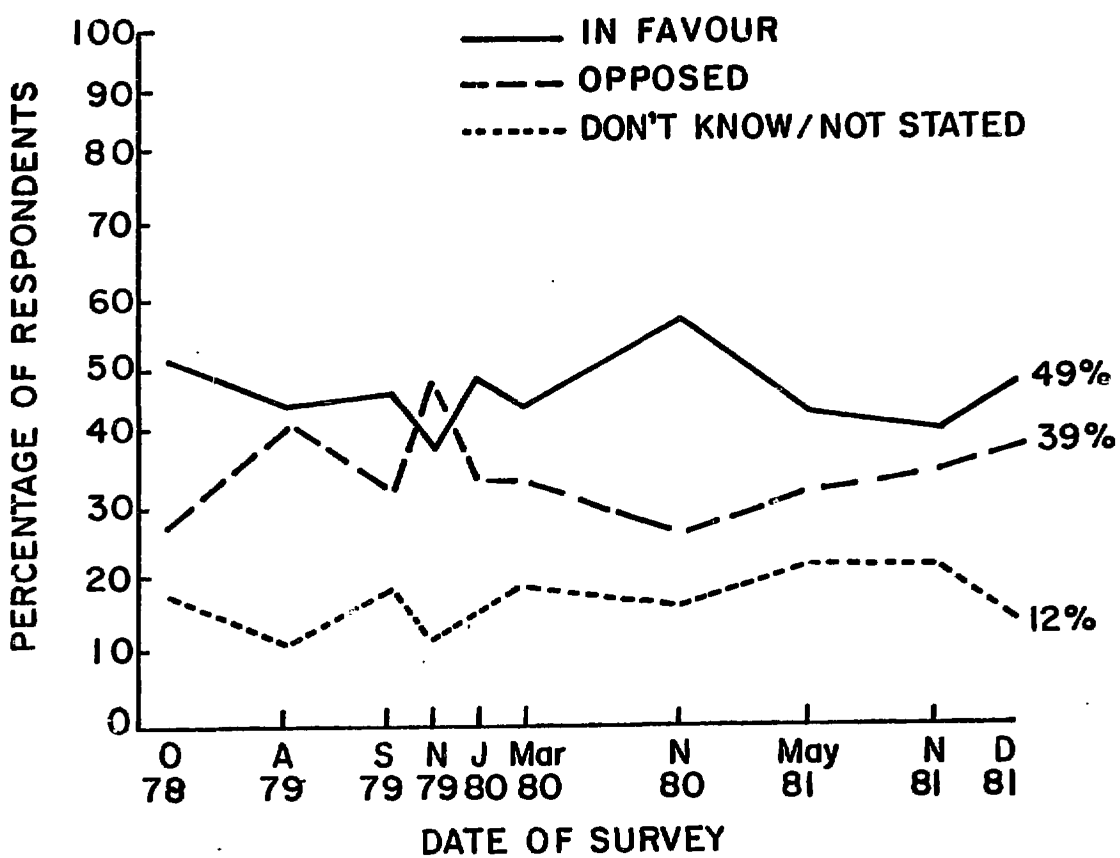

FIGURE 6: PUBLIC OPINION ON THE USE OF NUCLEAR POWER

factors influencing opinion about nuclear power were the need, economics, plant safety and radiation. Safety was the major factor in Quebec, with need and economics being of more importance in Alberta and Ontario.

TABLE IV

OPINION ABOUT THE FUTURE USE OF NUCLEAR POWER

	Ontario	Quebec	Alberta
DEFINITE INCREASE	18%	12%	8%
SLOWLY INCREASE	44%	38%	49%
NOT EXPAND	15%	10%	15%
STOP	12%	24%	13%
DK/NS*	11%	16%	15%

* DK/NS = DON'T KNOW/NOT STATED

In-depth interviews were carried out with well-informed focus groups in Alberta, to investigate in more detail the factors that influence public attitudes. About half the men and all the women interviewed had a fear of nuclear energy, which they associated with war and destruction. The only source of current information about nuclear power appears to be the press, which is preoccupied with reports of problems with United States reactors and military nuclear activities.

There is little knowledge of nuclear development in Canada, and what knowledge there is, is uncertain. For example, the perception is that less than 1% of electrical generation in Canada is nuclear. (The correct value is about 12%.) There is little understanding of the need for nuclear power for generating electricity and other peaceful, positive uses. Once these needs are explained, people become far more open to information about it. There is a widespread feeling that people in the nuclear industry cover up problems. There is a desire for unbiased, non-defensive, straightforward information, presented so the public can understand it.

Albertans say they are not involved in nuclear energy, and there is no strong motivation to become better informed since they feel they have alternative energy sources. However, there is a feeling that as responsible parents they should know more about nuclear energy so that they can discuss it with their children. Many also feel that their fear of nuclear is irrational and emotional and that becoming more knowledgeable is one way to deal logically with their fear.

These interviews strongly indicate the need for a comprehensive, unbiased, open information program aimed at the general public and therefore presented in terms they can understand.

On a more positive note, Table V shows the results of a survey on the contribution that nuclear power might make to future provincial development. These data show that the majority surveyed in all provinces believe that nuclear energy could contribute to provincial development. The support in Alberta is less than in Ontario, but stronger than in Quebec.

TABLE V

CONTRIBUTION OF NUCLEAR TO PROVINCIAL DEVELOPMENT

	Ontario	Quebec	Alberta
A GREAT DEAL	59%	28%	35%
A LITTLE	18%	26%	26%
VERY LITTLE	7%	10%	12%
NOTHING	6%	19%	12%
DK/NS	10%	17%	15%

* DK/NS = DON'T KNOW/NOT STATED

7. CONCLUSIONS

This paper has explored some of the issues that arise whenever nuclear energy is discussed. I hope the information presented shows that the nuclear industry has a good knowledge of its waste products and is putting in place the technology to deal with them so that they do not place a significant burden on the consumer, both from an economic and environmental point of view. Indeed, I would suggest that the nuclear industry is taking a more responsible approach to treating its wastes than most other industries and that the latter could do well to follow the lead of the nuclear industry.

Surveys of public attitudes in Alberta towards nuclear energy indicate that negative feelings towards nuclear energy are mainly due to a lack of knowledge of nuclear technology. The same situation probably applies to other large, complex, high-technology industrial projects. The solution would appear to be the development of a comprehensive, public information program on nuclear energy aimed at the general public. AECL would be pleased to collaborate with interested groups in Alberta in the development and implementation of such a program.