SITING - THE MEANS BY WHICH NUCLEAR FACILITIES ARE INTEGRATED INTO A CANADIAN COMMUNITY

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In Canada, the Atomic Energy Control Board considers the siting implications of a number of different kinds of nuclear facilities. Our overall objective is to ensure that nuclear facilities are sited, designed, constructed and operated so that the level of risk to the health and safety of people and any adverse impact on the environment are acceptable. This requires in part the establishment of siting criteria, which involves the balancing of safety, environmental, sociological and economic factors. The application of these criteria is performed in light of the need to integrate the plant with its surroundings in a manner acceptable to all those involved, particularly the public.

This paper discusses the implications of siting two of the major types of facilities in Canada: nuclear power plants and heavy water production plants. The former presenting radiological hazards, the latter being of concern due to the severe chemical toxicity of one of the process fluids.

The paper indicates the similarities and differences in safety standards and regulatory approach for the two types of plants, the site approval procedure, the intergovernmental relationships required for efficient regulation and the current status of public participation.
1. INTRODUCTION

In Canada, the Atomic Energy Control Board (the Board) considers the siting implications of a number of different kinds of nuclear facilities. Some of these facilities, however, such as large gamma irradiation machines, accelerators and fuel fabrication plants, present very few problems in siting because of the limited hazards associated with them. Of major concern, from the radiological safety point of view, are research and power reactors. In addition, there are other facilities, some related to the fuel cycle and others to the production of heavy water, which are also considered because of the significant public hazards posed by the chemical toxicity of the working fluids, the most important of these at this time being the heavy water production plants. To date, we have not licensed spent fuel reprocessing plants, but the experience gained in assessing radiological and chemical hazards associated with these other facilities should provide sufficient background to enable us to deal with reprocessing plants should the occasion arise.

Our overall objective is to ensure that nuclear facilities are sited, designed, constructed and operated so that the level of risk to the health and safety of people and any adverse impact on the environment are acceptable. This requires the establishment of siting criteria for these facilities, which involves the balancing of safety, environmental, sociological and economic factors. The application of these criteria is performed in light of the need to integrate the plant with its surroundings in a manner acceptable to all those involved, particularly the public.

This paper deals with the siting of two types of facilities which are currently of primary significance to the Canadian nuclear programme - nuclear power plants and heavy water production plants.

2. LEGISLATION

In any nuclear licensing process there are legislation and regulations which give a regulatory agency the legal basis on which to set requirements governing the safe design, construction and operation of nuclear facilities and to establish guidelines which outline such requirements.

The degree to which these safety requirements are documented depends on the obligations imposed by relevant legislation, the legal system, the size and complexity of the industry, the working relationship between the regulatory agency and the licensees, public
interest and, to an increasing degree, international interest, particularly on the part of international customers.

In Canada, the Atomic Energy Control Act allows, among other things, the Atomic Energy Control Board to make regulations governing the production and use of prescribed substances. Uranium used in nuclear reactors and heavy water produced in heavy water plants are two of the prescribed substances of interest. The regulations made under the Act stipulate the requirement for an operating licence for a nuclear facility*, which refers to a plant which uses, produces or processes prescribed substances, and further stipulate that no operating licence will be issued unless prior permission is obtained from the Board for construction of the facility, part of which involves approval of the site.

3. APPROACH

Although the primary objective, as stated earlier, of reducing risk to the public and workers to an acceptably low level applies to both nuclear power plants and heavy water production plants, the basic safety and siting considerations differ because of the characteristics of the processes, the nature of the hazards and the way in which safety criteria evolved for the nuclear industry compared to other similar industries. Typically, a nuclear power plant is energy producing, a heavy water plant is energy consuming; a nuclear power plant presents mainly a radiological hazard, the hazard associated with a heavy water plant is one of chemical toxicity; the nuclear industry has been strictly regulated and externally overseen since its inception, the chemical industry has been mainly self-controlled with some basic regulations evolving over the years.

Since heavy water plants are essentially chemical plants, their regulation has been a compromise between that normally applied to the chemical industry and the highly regulated nature of the nuclear industry. The difference becomes evident when comparing the siting criteria.

* The Atomic Energy Control Regulations define "nuclear facility" as follows: "nuclear facility" means a nuclear reactor, a sub-critical nuclear reactor, a particle accelerator, a plant for the separation, processing, re-processing or fabrication of fissionable substances, a plant for the production of deuterium or deuterium compounds, a facility for the disposal of prescribed substances and includes all land, buildings and equipment that are connected or associated with such reactor, accelerator, plant or facility.
The siting criteria for heavy water plants are deterministic, that is, the characteristics of an acceptable site are defined by a number of guidelines, and the suitability of proposed sites is judged by the degree of conformance of their characteristics to these guidelines. The criteria were selected on the basis of judgement to ensure that the risk to the public would be acceptably low. The siting criteria for nuclear power plants, on the other hand, are in part probabilistic and in part deterministic. The basic safety criteria for the plant are expressed in terms of probability vs. acceptable consequences (i.e. acceptable risk); however, there are some guidelines concerning the site characteristics and the design of the plant which indicate how the basic safety criteria are to be met.

The regulatory approach taken by the Board is to stipulate the basic safety criteria and to require the applicant to show how his proposed plant will meet the basic safety criteria. Figure 1 shows a simplified "hierarchy" of the safety considerations for a nuclear facility with the more general considerations at the top and with an increasing degree of detail going from top to bottom. The word "considerations" is meant to imply safety-related considerations for design, construction, commissioning and operation of the facility.

The documentation associated with licensing of a nuclear facility does not divide along such clear-cut lines as indicated by Figure 1 but, at some risk of oversimplification, may be grouped as follows:

**Level 1:** Legislation - applies to all uses of atomic energy.

**Level 2:** Basic safety and siting criteria - apply to all nuclear facilities, but may be different basic criteria for different types of nuclear facilities.

**Level 3:** Licensing documents - for a particular nuclear facility:

- Construction Licence/Operating Licence*
- Safety Report** (design description and accident analysis)

* issued by the Board
** prepared by the applicant; reviewed and approved by the Board
Levels 4 & 5 Reference documents:
Design Manuals
Construction Documents
Commissioning Manuals
Operating Manuals

The foregoing approach works well when there are only a few plants in existence and only a few organizations involved in the design, construction, commissioning and operation of those plants. Such is the case in Canada but the situation is changing because of the rapidly expanding national nuclear power program and because of international interest in the CANDU type nuclear power plant.

4. SITE APPROVAL PROCEDURE

4.1 Governmental Relationships

Although Board approval of a site is not a legal requirement before an application for a construction licence is made, it has become customary for applicants to seek approval of a site at an early stage. Indeed, when federal funding is involved, it is now federal government policy that the site must be approved.

The Board is concerned largely with health and safety aspects of nuclear facilities, although the Atomic Energy Control Act permits broad consideration of the national interest. Some aspects of siting are also

** prepared by the applicant; reviewed and approved by the Board
*** Off-site emergency procedures are prepared by provincial government authorities.
reviewed by other federal government agencies which also become involved in site approval in the event of federal funding.

Provincial governments also exercise authority in the site approval, the extent of provincial government involvement varying from province to province.

Generally speaking, environmental and other societal effects are evaluated by both levels of government and there is a developing trend to holding public meetings on such matters.

Good communication between levels of government and co-ordination of federal and provincial activities minimize duplication of effort. A single environmental impact report prepared by or on behalf of the applicant serves the purposes of both federal and provincial environmental agencies and arrangements are often made for joint evaluation with one of the agencies taking the lead.

4.2 Procedure

A site evaluation report dealing with health and safety matters is submitted to the Board by the applicant. This report is reviewed by the appropriate one of a number of safety advisory committees and the Board's staff, and recommendations are made to the Board on the suitability of the site for the nuclear plant or heavy water production plant as the case may be. Such committees are composed of independent experts and appropriate representatives from federal, provincial and local government agencies. This arrangement has been very satisfactory in providing a wide range of expertise for the committees and in facilitating inter-governmental communication and cooperation.

The applicant is then informed by the Board whether or not there are any major obstacles to eventual site approval. At this time, if he has not already done so, the applicant must announce publicly his intention to build the facility at the particular site, giving the public an opportunity to comment on the proposal. If no substantive safety issues are raised, the Board issues final site approval after allowing a suitable period of time for public comment.

4.3 Public Participation

Our limited experience with public participation in Canada
indicates that most public comment can be expected at the site approval stage. Public participation programs are a relatively recent development and are conducted by the applicant. Public meetings have been held regarding nuclear power plants and a heavy water plant in the Province of Ontario, a heavy water plant in Quebec and a nuclear power plant in New Brunswick. It is of interest to note that in some provinces, public meetings are now held regarding site approval for any type of proposed power plant. Meetings are relatively informal and their purpose is to inform the public and to give members of the public a chance to ask questions and present their views. Even so, planners must allot several months in their project schedules for the public participation program. In the case of nuclear facilities, much of this process occurs in parallel with the Board's licensing and safety review process.

Public attitudes to nuclear facilities have been generally favorable but there are signs that opposition is growing in certain parts of Canada. For example, eight environmental groups in New Brunswick and adjoining Nova Scotia have combined to oppose the proposed nuclear power plant in New Brunswick.

5. NUCLEAR POWER PLANTS

5.1 General

From the health and safety point of view, the suitability of a site for a nuclear power plant depends on the design of the plant and the way it is to be operated and maintained. The Reactor Safety Advisory Committee (RSAC), which advises the Board on the safety of nuclear power plants, has established basic safety criteria which define in a quantitative way what is regarded as "safe enough" or, put another way, "low risk to the public". These criteria were first published in 1964\(^{(1)}\) and have been applied to the Pickering Generating Station and later plants. Earlier plants were designed to similar safety criteria proposed by the designers. The "Reactor Siting Guide", as the basic safety criteria, collectively, have come to be called, has been modified since 1964 but the basic concepts remain and are tabulated in Appendix A. Supplementary safety criteria and principles are listed in Appendix B\(^{(2)}\).
5.2 Basic Safety Criteria

5.2.1 Background

A nuclear power plant is envisaged as consisting of process systems and special safety systems. The process systems are those systems required for normal operation of the plant and would be provided, though not necessarily to the same standards, even if the result of nuclear fission did not include radiation and radioactive fission products. However, nuclear fission does produce radiation and radioactive fission products which are a potential hazard to the public and the plant staff. The special safety systems are designed to mitigate the consequences of failures and malfunctions in the process systems which, in the absence of special safety system action, could lead to fuel failures and a release of radioactivity to the environment. Such failures are called "serious process failures".

The "defence-in-depth" approach inherent in the Reactor Siting Guide is developed as follows (refer to Appendix A):

(1) Process systems are designed and operated to high standards so as to minimize the frequency of serious process failures.

(2) The total frequency of all serious process failures must not exceed once per three plant-years and the consequences as mitigated by the action of the special safety systems must not exceed the values listed in the second situation referred to in Appendix A. Because of the relatively high assumed frequency of serious process failures, the risk is combined with that associated with radioactive releases from normal operation of the plant (first situation listed in Appendix A).

(3) The total frequency of serious process failures coincident with failure of any one special safety system must not exceed once in three thousand plant-years and the consequences must not exceed the values listed in the third situation of Appendix A. Such postulated failures are often described as "dual failures".
5.2.2 Application of Basic Safety Criteria

The criterion regarding the frequency of serious process failures is too general to be used in the detailed design of individual process systems but it is useful in assessing the adequacy of the safety of plants which are operating. The design of individual process systems is generally done by reference to proven design techniques which have given satisfactory results in the past; or else a reliability target for a given process system is assigned which is a small fraction of once in three years.

Consideration of process failures and dual failures leads to several requirements on the design of special safety systems:

(1) The unavailability of each special system must be less than $10^{-3}$.

(2) Special safety systems must be physically and functionally separate from process systems and from each other to the maximum extent practicable in order to minimize the possibility of cross-linked or common mode failures under normal and accident conditions.

(3) The operation of the special safety systems must be analysed for a spectrum of serious process failures and dual failures with the required effectiveness of each system being determined by the most exacting case analysed. Analysis of a broad spectrum of postulated accidents ensures that each special safety system will cope with the "worst case", which is not always an obvious case.

5.3 Limits and Targets for Radioactive Releases from Normal Operation

The Board subscribes to the internationally held view that releases of radioactive materials from normal operation of nuclear facilities should be minimized to the extent considered practicable. Experience has shown it to be practicable to limit releases from a four unit station such as the Pickering G. S. "A" to 1% or less of the Derived Release Limits, which are the licensed limits derived from the dose limits for normal operation in gaseous and in liquid effluents. Accordingly the Board has specified that new nuclear power stations be designed and operated with a target
of 1% of the Derived Release Limits (DRL's) for each effluent pathway. Should the target value be exceeded, it is envisaged that the action taken to correct the situation would be graded depending on the circumstances.

On most sites in Canada there are two or more nuclear facilities on one site (Appendix D). Since the design and operating target for radioactive releases is based on practicability, each type of facility or each group of similar facilities (e.g. a four-unit nuclear power station) can have an individual target which is a small percentage of the DRL's for the site. The licensed limits, i.e. the DRL's themselves, are applied to the site as a whole.

There may be some argument that the part of the population which lives around a certain site should not be exposed to more than a certain part of the whole risk associated with the nuclear power industry. In practice other considerations, such as a utility's desire to avoid excessively large blocks of power on one site, availability of cooling water and other practical problems would probably limit the concentration of nuclear facilities at a particular site before it could be argued that the risk to a particular part of the population is excessive.

5.4 Codes and Guides

The preparation of codes and guides for nuclear power plants at Levels 3, 4 and 5 in Figure 1 was begun largely through the initiative of the nuclear industry itself in cooperation with, and sometimes provoked by, the Board. The Canadian Nuclear Association (CNA), a body representing the Canadian nuclear industry, formed the Committee on Codes, Standards and Practices which was subsequently accredited as a Sectional Committee of the Canadian Standards Association (CSA), a nationally-accepted standards-issuing body. The Board is also preparing Licensing Guides which will cover topics not covered by industry codes and guides or will promote the use of codes and guides prepared by the industry.

It is expected that such activities will help to streamline the licensing process by consolidating accumulated experience with nuclear power plants and by avoiding repetition of effort where the safety considerations from plant to plant are similar.

5.5 Licensing and Site Considerations

The licensing steps consist of site approval, as described earlier in the paper, construction licence and operating licence and are described fully in reference 2.
At the time of issuance of a construction licence, many aspects of the design may not be firm but the general characteristics of the plant are known. This situation has led to the practice of having a standard sized exclusion zone with a radius on the landward side of 900 to 1000 metres. In other words, the applicant has some confidence that his site will be accepted by the Board (considering the preliminary nature of the plant design) if he proposes a site with that size of exclusion zone (see Appendix C) and provided the other characteristics of the site are acceptable.

Appendix A lists design basis dose limits for the most exposed individual and the surrounding population for normal operation and for accident conditions. Either the population dose or the individual dose is limiting in determining the design basis releases under normal and accident situations, depending on the density of the surrounding population. For accident conditions, the Pickering site near Toronto is "population dose limited". All other present sites in Canada are "individual dose limited". In the absence of peculiar geographical features, such as deep valleys, the concept of a standard-sized site is of some assistance in a utility's long term planning for nuclear power plants. Of course, size is only one of the many characteristics of a site that must be considered.

6. HEAVY WATER PLANTS

6.1 Background

Heavy water plants are essentially conventional chemical plants, but are under the Board's jurisdiction because they are defined as nuclear facilities in the Atomic Energy Control Act and Regulations. (see Section 3)

The process currently used is one of dual-temperature isotope exchange between ordinary water and hydrogen sulphide (H₂S), taking place in large contacting towers, some of which are approaching 300 feet high and 30 feet in diameter, containing over 100 tons of H₂S.

The potential for hazard from heavy water production plants was recognized in Canada at the time the first plant at Glace Bay, Nova Scotia was proposed, but it was not until the second plant at Point Tupper, Nova Scotia was under way and the Glace Bay plant had experienced some difficulties that the Board stepped in to take a leading role in the safety assessment and licensing of these plants.
The hazard is not radiological, but is associated with the large quantities of highly-toxic and corrosive hydrogen sulphide held up in the process under elevated temperature and pressure. Concentrations of \( \text{H}_2\text{S} \) in air in excess of approximately 500 ppm. are considered to be lethal if breathed for a very few minutes.

6.2 Basic Safety Considerations

Minimization of exposure of the plant workers and surrounding public to excessive quantities of \( \text{H}_2\text{S} \) and its combustion product, sulphur dioxide (\( \text{SO}_2 \)), is the basic safety consideration relative to the current design of heavy water plants. The occurrence of excessive releases of \( \text{H}_2\text{S} \) from the process system must therefore be minimized and provisions must be made to mitigate the consequences of such a release should it occur. This is the same basic safety philosophy which is applied to nuclear power plants.

The process itself does not have the potential for fast pressure or temperature transients, its control being relatively sluggish and its energy sources being limited to that imparted to it by the external steam source. Hence, a heavy water plant does not require the complexity nor depth of protective measures as does a nuclear power plant. This same consideration applies to the safety assessment of a heavy water plant, wherein the analyses performed are concerned with single events only, major emphasis being placed on an accidental release due to failure of the process envelope and on other events which could cause an abnormally high gas release from normal process effluent release points, e.g. by lifting of safety valves. However, the risk to the public and workers is substantial, which necessitates application of a similar approach to safety as for nuclear power plants.

The integrity of the process system is the first line of defence against inadvertent releases of \( \text{H}_2\text{S} \). Proper process and equipment design and material selection are essential, as is an effective quality control program which begins at the preliminary design stage and continues throughout the plant lifetime.

Provision is made to isolate sections of the plant quickly in order to minimize the quantity of \( \text{H}_2\text{S} \) released to atmosphere should a leak occur. Other means used to minimize the release from a leak are to reduce quickly the quantity of \( \text{H}_2\text{S} \) in the affected part of the plant by pumping the \( \text{H}_2\text{S} \) back into a storage tank or to divert the \( \text{H}_2\text{S} \) to a flare system via blowdown valves where the \( \text{H}_2\text{S} \) is burned and released mainly as \( \text{SO}_2 \) at high elevation for better atmospheric dispersion. The dispersion of
course, reduces the concentration as the gas moves downwind from the plant.

Steam strippers, aeration lagoons and chemical treatment are used to reduce the \( \text{H}_2\text{S} \) concentration in the liquid effluent from the plant.

To aid in reduction of \( \text{H}_2\text{S} \) concentration in the atmosphere in the remote event of a large gas release, some plant owners are proposing installation of a unique gas dispersion system, which consists of a ring of propane burners around the plant to provide a large thermal input into the discharging gas to cause it to rise, and thus obtain better atmospheric dispersion. This system could be triggered automatically by plant sensors or manually by the plant operator.

Personal protective equipment for plant workers, emergency plans for both workers and public and land use control for a significant distance outside the plant fence are also employed to provide protection against the possible effects of a gas release.

6.3 Codes and Guides

Heavy water plants are designed, built and inspected to a similar combination of codes and standards as other chemical plants, with special provisions being made for \( \text{H}_2\text{S} - \text{H}_2\text{O} \) service conditions where appropriate. The pressure vessels are built basically in accordance with ASME Boiler and Pressure Vessels Code Section VIII and the piping to USAS B31.3 for Petroleum and Refinery Piping as a minimum standard.

Material specifications and selection for \( \text{H}_2\text{S} - \text{H}_2\text{O} \) service have always been contentious items in heavy water plant design. In order to correlate the current information, Atomic Energy of Canada Limited (AECL), the crown company mainly responsible for research, development, design and promotion of nuclear energy in Canada, has recently compiled a document which is currently being assessed by the Board with the possibility of its being adopted as a Guide for future plants.

Guides have been, or are in the process of being, issued to the industry by the Board to cover siting, emergency plans, safety report content, content of other licensing documents, as well as an outline of the licensing procedure. These guides should aid the applicant in proceeding through the licensing procedure with a minimum of delay. The latter is further facilitated by coordination at the preliminary design
stage of the Board's licensing schedule and the applicant's project schedule.

6.4 Siting Considerations

The siting of heavy water plants in Canada has, in some cases, caused as much concern to regulatory bodies and the public as the siting of nuclear power plants. As mentioned previously, the severe toxicity of H$_2$S, its corrosiveness, and the large quantities which are held up under elevated temperature and pressure in the process and in storage at a heavy water plant cause these plants to be regarded as potentially very hazardous.

In order to provide those interested in establishing a heavy water plant with some guidance as to the Board's concerns regarding siting of these facilities, the Board issued, on 29 August, 1973, "Siting Guidelines for Heavy Water Plants Utilizing the Girdler-Sulphide Process", which have just been revised and reissued (see Appendix B).

This document reflects the safety considerations mentioned previously and outlines possible protective provisions which should be employed to reduce the risk to the surrounding population to an acceptable level.

The guidelines are concerned with the effects within the "zone of influence" of the plant, this zone extending out to the point where the risk posed by the plant is judged to be reduced to an acceptable level. The risk, of course, involves exposure to high concentrations of H$_2$S and/or SO$_2$ in the atmosphere, the concentrations being reduced by dispersion as the gas moves away from the plant.

The size of the zone of influence depends upon the provisions made to mitigate the consequences of a major gas release, and could extend out as far as five miles from the plant.

The zone of influence is divided into three areas, A, B and C. Areas A and B are restricted to controlled population only, i.e. persons under the direct supervision of the heavy water plant management or a management which has committed to cooperate with the heavy water plant management in the event of an emergency. This combined area extends out to approximately one mile from the plant. The restriction to controlled population within this area relates to the belief that most individuals would be unable to respond and protect themselves from the
consequences of a gas release with normally available means within the short time it would take for the gas to travel from the point of release out to about one mile. Beyond this distance, in area C, it is felt that individuals would be able to cope, utilizing the means at hand, provided they were aware of the hazard and were provided with ample warning. The most appropriate form of protection in any event is felt to be a stay-in procedure wherein persons enter a building or other shelter which is relatively leak tight and remain there during the period of gas passage.

It is of prime importance that the number of persons which could be subjected to additional risk be minimized. To facilitate this, a low population guideline has been set down, limiting population density in the zone of influence to that found in a typically rural area.

As mentioned before, reduction in the size of the zone of influence would be considered, depending on the effectiveness and reliability of protective measures provided to reduce the risk to the surroundings. Currently, consideration is being given to the extent of reduction warranted if a highly-reliable and effective gas dispersion system were to be supplied. This reduction could even be to the extent of eliminating area C altogether.

It is evident, from the siting considerations, that locating a heavy water plant in a particular area can have a widespread impact, possibly even more so than a nuclear power plant, particularly when considering the local sociological implications of restricted land usage and establishment of extensive emergency plans.

7. STANDARDIZATION AND EVOLUTION OF SAFETY REQUIREMENTS

For reasons of economy there is a trend toward repeating proven facility designs with relatively few changes. The trend toward standardization of designs should facilitate licensing; however, safety requirements are evolving. Experience with earlier plants is reflected in the requirements for later plants. The spectrum of postulated failures and accidents is being widened and made more detailed. Postulated events are being examined in greater depth. Increased attention is being given to events originating outside the plant, such as earthquakes and the risk posed by the possibility of aircraft crashes onto the site. The latter example is gaining increased attention because some nuclear facilities are being located closer to centres of population where one can expect a higher density of aircraft movements.
The evolution of safety requirements presents two dilemmas. One is to the applicant who, for example, faces new requirements for a repeat of a design which was earlier licensed. The second is to the regulatory agency itself which must justify the continued operation of earlier plants when (usually) more stringent requirements are applied to later plants. There is no complete answer to the two dilemmas but much, if not most, of the answer includes the following:

1) The nuclear power industry is regulated on the basis of risk posed by postulated events, most of which have never happened at any nuclear facility. (For most other industries the definition of "credible events" is "those events which have actually happened").

2) Consideration is given to the cumulative risk posed by all nuclear facilities, particularly nuclear power plants. The incrementally higher risk posed by the relatively few early plants designed to less stringent requirements than later ones may be negligible.

3) The larger size of later plants and the tendency to locate them closer to centres of population warrant the imposition of more stringent requirements in order to maintain the same low level of risk to the public.

4) When deemed necessary, new requirements can be backfitted to existing plants.

8. PUBLIC EDUCATION

In Canada, as in other countries, public opinion, or, more exactly, certain elements of public opinion are influencing the licensing of nuclear power plants. One of the comments frequently expressed is, "Tell us what we should know (about nuclear power plant safety)". One group of high school students went so far as to suggest that the teaching of nuclear technology should be mandatory in schools.

One of the problems of dealing with the public is to determine what is "the public". It is clear, however, that graphic displays, models and brochures, while necessary, are no longer sufficient means of communicating with the public. It is necessary to establish some sort of
dialogue with the public which is based on reasoned argument. Such a dialogue can be established only if the public is given an understanding of nuclear power technology. The establishment of this basic knowledge should begin in the schools, as suggested earlier, so that upcoming generations will be able to balance more easily all sides of the current arguments.

9. CONCLUSION

The ever-increasing complexity of the systems of nuclear facilities and of the process for licensing these facilities could, if not given careful consideration, cause many delays in the ordered development of the nuclear industry.

It is evident that a great amount of communication, coordination and cooperation is required among the owners of a nuclear facility, the regulatory bodies and the public in order to ensure that no unnecessary delays occur, while still ensuring that the facilities are properly sited.

The establishment of guides, the involvement of all pertinent regulatory bodies in the Board's advisory committees, the continued working-level contact between owners and regulatory bodies throughout the facility's schedule and provision of opportunities for public comment are only a few examples of the means employed in Canada to ensure that the facilities will become an accepted part of a community.
REFERENCES


### APPENDIX A

Design Basis Dose Limits For Normal Operation and Accident
Situations

<table>
<thead>
<tr>
<th>Situation</th>
<th>Assumed Maximum Frequency</th>
<th>Meteorology to be Used in Canada</th>
<th>Maximum Individual Dose Limits</th>
<th>Maximum Total Population Dose Limits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal Operation</td>
<td></td>
<td>Local long-term average weather</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Serious Process Equipment Failure</td>
<td>1 per 3 years</td>
<td>Either worst weather existing at most 10% of time or Pasquill F condition if local data incomplete</td>
<td>0.5 rem/yr 3 rem/yr to thyroid(a)</td>
<td>10(^4) man-rem/yr 10(^4) thyroid rem/yr</td>
</tr>
<tr>
<td>Process Equipment Failure Plus Failure of any Safety System</td>
<td>1 per 3x10(^3) years</td>
<td>Either worst weather existing at most 10% of time or Pasquill F condition if local data incomplete</td>
<td>25 rem whole body 250 rem thyroid(b)</td>
<td>10(^6) man-rem 10(^6) thyroid-rem/yr</td>
</tr>
</tbody>
</table>

\(a\) For other organs use 1/10 ICRP occupational values

\(b\) For other organs use 5 times ICRP annual occupational dose (tentative)
### Power Reactor Safety Criteria and Principles

1. Design and construction of all components, systems and structures essential to or associated with the reactor shall follow the best applicable code, standard or practice and be confirmed by a system of independent audit.

2. The quality and nature of the process systems essential to the reactor shall be such that the total of all serious failures shall not exceed 1 per 3 years. A serious failure is one that in the absence of protective action would lead to serious fuel failure.

3. Safety systems shall be physically and functionally separate from the process systems and from each other.

4. Each safety system shall be readily testable, as a system, and shall be tested at a frequency to demonstrate that its (time) unreliability is less than $10^{-3}$.

5. Radioactive effluents due to normal operation, including process failures other than serious failures (see 2 above), shall be such that the dose to any individual member of the public affected by the effluents, from all sources, shall not exceed 1/10 of the allowable dose to Atomic Radiation Workers and the total dose to the population shall not exceed $10^4$ man-rem/year.

6. The effectiveness of the safety systems shall be such that for any serious process failure the exposure of any individual of the population shall not exceed 500 mrem and of the population at risk, $10^4$ man-rem.

7. For any postulated combination of a (single) process failure and failure of a safety system, the predicted dose to any individual shall not exceed (i) 25 rem, whole body, (ii) 250 rem, thyroid, and to the population, $10^6$ man-rem.
APPENDIX B continued

8. In computing doses in 6 and 7 the following assumptions shall be made unless otherwise agreed to:

(i) meteorological dispersion that is equivalent to Pasquill category F as modified by Bryant\(^{(1)}\)

(ii) conversion factors as given by Beattie\(^{(2)}\)

\(^{(1)}\) Bryant, P. M. UKAEA report AHSB (RP) R42, 1964.

\(^{(2)}\) Beattie, J. R. UKAEA report AHSB(S) R64, 1963.
EXCLUSION ZONE

Definition

An Exclusion Zone is an area, specified by the Atomic Energy Control Board, immediately surrounding a nuclear facility and under the control of the licensee or the operator.

Conditions

1. There shall be no permanent habitation within the Exclusion Zone.

2. Use of the land for purposes other than the licensed activities shall require separate AECB approval.

3. Exclusion Zones shall be posted in a manner acceptable to the Board.

4. Radiation safety within the Exclusion Zone is the responsibility of the licensee, or, subject to AECB approval, his designate. Methods and measurement for ensuring radiation safety are subject to review as required by the Board.

NOTE

For all power reactors licensed to date the Exclusion Zones extend from the reactor core to a radius of 3000 feet with the exception of navigable waters and minor other exceptions.
APPENDIX D

Major Multi-Nuclear-Facility Sites in Canada

1. Bruce Nuclear Power Development Site
   1.1 Douglas Point G. S.* - operating - 200 MWe, CANDU - PHWR.
   1.2 Bruce G. S. "A" - under construction - 4 x 750 MWe, CANDU - PHWR
   1.3 Bruce G. S. "B" - construction started - 4 x 750 MWe, CANDU - PHWR
   1.4 Intermediate term waste management area.
   1.5 Bruce heavy water production plants:
       - 2 units of 400 t/a capacity each operating
       - 4 units of 400 t/a capacity each under construction
       - 2 units of 400 t/a capacity each planned

       (no release of radioactivity associated with heavy water production plants)

2. Pickering Site
   2.1 Pickering G. S. "A" - operating - 4 x 500 MWe, CANDU - PHWR
   2.2 Pickering G. S. "B" - starting construction - 4 x 500 MWe, CANDU PHWR

3. Gentilly Site (and environs)
   3.1 Gentilly - 1 NPS** - operating - 250 MWe, CANDU - BLW
   3.2 Gentilly - 2 NPS - starting construction - 600 MWe, CANDU PHW

       (more CANDU - PHW units being considered)
   3.3 Intermediate term waste management area.
   3.4 La Prade heavy water production plant - 2 units of 400 t/a capacity each, starting construction

* G. S. - generating station
** nuclear power station
APPENDIX E

Siting Guidelines For Heavy Water Plants Utilizing The
Girdler-Sulphide Process

1. INTRODUCTION

Heavy water production plants which employ the Girdler-Sulphide (G. S.) process contain large inventories of hydrogen sulphide ($H_2S$). $H_2S$ and its combustion product, sulphur dioxide ($SO_2$), are highly toxic at relatively low concentrations. Both also have an offensive odour at extremely low concentrations, and $SO_2$ can be injurious to vegetation. Radiological safety problems might be significant if these plants are used to process irradiated heavy water. However, a complete assessment of the situation, particularly with regard to tritium, would be required before such use.

It is necessary to ensure that minor releases of $H_2S$ and $SO_2$ from the plant into the surrounding environment are controlled and larger releases prevented, particularly those releases which could have a harmful effect on the workers at the plant site and the public in the vicinity of the plant. This is achieved by strict attention to safety considerations in design, commissioning and operation, but there always remains a remote possibility that a dangerous release could occur.

To mitigate the consequences of such a release, the siting of the plant and the provision of appropriate protective measures for the public and workers, including contingency plans, are of primary importance.

2. RELEASES INTO WATER

Releases into water occur mainly when the liquid effluent treatment system malfunctions. Provincial and federal regulations strictly limit the allowable concentrations of $H_2S$ in the effluent stream and also the total quantity of $H_2S$ allowed in the particular receiving waters during a specific time period. Also, the heat input to the receiving waters is closely regulated.
3. RELEASES INTO ATMOSPHERE

Releases into the atmosphere can result from gas coming out of solution during liquid effluent treatment, from the flare stack in the event of equipment blowdown or as a result of failure of the system pressure envelope.

The two former situations would likely result in only nuisance-type releases, whereas the pressure envelope failure could have serious effects on the surroundings. Released gas would disperse over the countryside, decreasing in concentration as it moved downwind from the plant. For large releases, the effects could be serious for a significant distance from the plant. For this reason, care in site selection and provision of protective measures are necessary.

4. SITING GUIDELINES

The following guidelines make use of the experience gained from the safety assessments of the existing heavy water plants:

4.1 The site should be chosen with a very low population density within the zone of influence of the heavy water plant (e.g. typically rural, about 20 to 30 persons per square mile). Population concentrations such as villages, major service and recreational facilities, particularly overnight camping facilities, schools and hospitals, should be avoided. Municipal plans for future land use should be reviewed by the appropriate governmental agencies and provision should be made to control population growth in this area during the plant lifetime.

4.2 The topography, hydrology and meteorology of the area should be such that there are no abnormal conditions which could result in a substantially increased risk in one sector as opposed to the surroundings in general, (e.g. a plant should not be located in a deep valley which would channel a gas release with little dispersion occurring and possibly cause a hazard to a populated area which would otherwise have been sufficiently distant as not to be at risk).
4.3 The possibility of the plant being subjected to external forces which could cause major damage, such as earthquakes, tornadoes, floods or aircraft crashes should be assessed for the sites being considered. Plant design should account for these external forces where appropriate.

4.4 All use of water by the plant for feedwater or for receipt of effluents must be in accordance with the applicable provincial and federal regulations. Both chemical and thermal effects must be considered.

4.5 Effluents released into the atmosphere must be controlled in accordance with applicable provincial and federal regulations.

4.6 The "Provisions for Protection of the Population" listed in Table I should be applied.

4.7 The plant should be surrounded by a Restricted Zone which is an area, specified by the Board, immediately surrounding a heavy water production facility and under the direct control of the licensee or the operator. The conditions applied to the Restricted Zone are:

4.7.1 Access to the Restricted Zone shall be limited to persons forming part of a Controlled Population.

4.7.2 There shall be no permanent habitation within the Restricted Zone.

4.7.3 Use of the land for purposes other than the licensed activities shall require the prior approval of the Board.

4.7.4 The Restricted Zone shall be posted in a manner acceptable to the Board, including traffic warning signs on all roads entering the Restricted Zone.
4.7.5 Protection from toxic substances within the Restricted Zone is the responsibility of the licensee, or, subject to the prior approval of the Board, his designate. Methods and measurement for ensuring toxicological protection are subject to review as required by the Board.
<table>
<thead>
<tr>
<th>Area</th>
<th>Uncontrolled Population</th>
<th>Controlled Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. 0 to 1/2 mile from H₂S containing part of plant</td>
<td>No uncontrolled population is acceptable in this area</td>
<td>(1) Direct Warning&lt;br&gt;(2) Training for Emergencies&lt;br&gt;(3) Respiratory Protection&lt;br&gt;(4) (i) Stay-in Procedure with controlled ventilation area or (ii) Evacuation Procedure</td>
</tr>
<tr>
<td>B. 1/2 to 1 mile</td>
<td>No uncontrolled population is acceptable in this area</td>
<td>(1) Direct Warning&lt;br&gt;(2) Training for Emergencies&lt;br&gt;(3) (i) Respiratory Protection or (ii) Stay-in Procedure with controlled ventilation area or (iii) Evacuation Procedure</td>
</tr>
<tr>
<td>C. 1 mile to x* miles from H₂S-containing part of plant.</td>
<td>(1) Warning Mechanism&lt;br&gt;(2) Written Information on Emergency Procedures&lt;br&gt;(3) Stay-in Procedure for enclosure with leak-tightness equivalent to a normal residence</td>
<td>(1) Warning Mechanism&lt;br&gt;(2) Written Information on Emergency Procedures&lt;br&gt;(3) (i) Stay-in Procedure for enclosure with leak-tightness equivalent to a normal residence or (ii) Evacuation Procedure</td>
</tr>
</tbody>
</table>

* Distance "x" could extend to 5 miles for plants of current design depending on the extent of provisions to mitigate the consequences of a gas release

(See Appendix I for Definitions)
(i) "Controlled Population" refers to persons who are under direct supervision of the heavy water plant management or are under the direct supervision of a management which has made a commitment to cooperate with the heavy water plant management in the event of an emergency.

(ii) "Controlled Ventilation Area" refers to a building which has special controls on the ventilation system and all other openings to atmosphere which would allow immediate closure to provide a relatively leak-tight enclosure in which persons could withstand the passage of a plume of gas from a major release from the heavy water plant.

(iii) "Direct Warning" means that the controlled population receives a known warning signal from a device which is actuated directly from the control room of the heavy water plant without any further decisions having to be made by any other group regarding the need for emergency action.

(iv) "Evacuation Procedure" refers to a procedure wherein people move in an orderly fashion to a safe position away from the source of hazard.

(v) "Respiratory Protection" refers to provision of some means of adequately purifying the air breathed by each individual or supplying him with fresh air from uncontaminated sources during the period of exposure to excessive H₂S in the atmosphere. Sufficient resuscitation equipment should also be available.

(vi) "Stay-in Procedure" refers to a procedure wherein people remain in, or enter into, an enclosure close at hand which is isolable from the source of hazard.

(vii) "Traffic Warning Signs" are signs erected on all roads which enter the Restricted Zone, for the purpose of indicating the action to be taken if a warning is annunciated.
"Training for Emergencies" involves instruction in emergency procedures and periodic practices. For plant operating staff and supervisory personnel of subcontractors, this should include first aid and resuscitation training.

"Uncontrolled Population" includes all persons not covered in the definition of "Controlled Population".

"Warning Mechanism" refers to a means of communicating a prompt and effective warning to the population either directly from the heavy water plant or by a responsible public authority upon receipt of information from the heavy water plant.

"Zone of Influence" is an area within which emergency procedures or other special precautions are necessary due to the presence of the heavy water production plant. The extent of the zone of influence (out to distance "x" mentioned in Table I) depends on the extent of the provisions taken to mitigate the consequences of a gas release from the plant.
Fig. 1: Simplified "Hierarchy" of Nuclear Power Plant Safety Considerations
SITING - THE MEANS BY WHICH NUCLEAR FACILITIES ARE INTEGRATED INTO A CANADIAN COMMUNITY

ERRATA

(1) Sect. 4.3, para. 1, line 10, word 9 - "change" should be "chance".

(2) Sect. 5.3, para. 1, line 8, word 2 - "current" should be "new".

(3) Section 5.3, para. 2, lines 3 and 4 - delete "each facility can have a target of 1% of the DRL's for the site." and replace with "each type of facility or each group of similar facilities (e.g. a four-unit nuclear power station) can have an individual target which is a small percentage of the DRL's for the site."

19/11/74 R. M. Duncan

J. W. Beare