REACTOR LICENSING IN CANADA

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ATOMIC ENERGY CONTROL BOARD

SUMMARY

An order of the Atomic Energy Control Board is required for any nuclear reactor in Canada except those wholly owned and operated by the Federal Government. The prerequisites for the three stages of approval involved; site approval, construction permit, operating licence, and the criteria for approval are outlined.

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1. Introduction

The construction and operation of nuclear reactors in Canada are subject to the conditions of the Atomic Energy Control Act and Regulations. The Act, promulgated in 1946, states in its preamble that its purpose is "to make provision for the control and supervision of the development, application and use of atomic energy." To administer the Act the Atomic Energy Control Board was established also in 1946. Although the early concern was mainly security, matters of health and safety soon became an important aspect of the Board's activities.

In 1956, the Board created the Reactor Safety Advisory Committee to advise on the health and safety aspects of nuclear reactors. This Committee is composed of senior engineers and scientists, mostly from federal government organizations, chosen because of their competence and not as official representatives of their employers. Representatives of the departments of health and labour of the province concerned and the local medical officer of health are invited to join in the Committee's deliberations.

A permanent staff has been set up to assist the Committee in its review. The staff, which is gradually being enlarged, also performs the necessary inspection and compliance functions.

A "Nuclear Reactors Order" was issued in 1957, specifying nuclear reactors as "prescribed equipment" within the meaning of the Regulations, thus requiring a Board order (or licence) for any "dealing" (including construction, operation, disposal) in any reactor except those owned and operated by the Federal Government.
As a matter of policy no reactor would be licensed without first being reviewed and approved by the Committee. The extent and detail of the Committee's review would depend, of course, on the complexity, novelty, size and location of the project. All meetings between applicants and the Committee are confidential and submissions to the Committee are treated accordingly.

2. Licensing Steps

Three steps have evolved in the licensing process of a nuclear reactor. These are (1) site approval, (2) construction permit, (3) operating licence.

The Site Approval is primarily a formal acknowledgement by the Board that it and its advisors see no objection to building and operating a particular reactor on the site in question. This gives the owners some assurance in proceeding to acquire the necessary land. The required "exclusion zone" i.e. land totally under the control of the owner, is usually stipulated at the time of approval of the site. The general concept of the containment provisions may also be approved at this time.

The Construction Permit authorizes the first "dealing" in a nuclear reactor, that is, its construction. Issue of the permit implies approval of the general design or design specifications. It does not mean that an Operating Licence will automatically be granted. This will depend upon subsequent approval of the safety aspects of the plant as actually built and of the arrangements for operation. Many specific details of the design may still need approval after the Construction Permit is issued.

The Operating Licence authorizes operation of the plant, within certain defined limits, including the use in the reactor of fuel and heavy water which must be obtained under separate Board Orders. The present policy is to limit the term of operating licences to a few years, and to require an annual report reviewing the operation of the plant.

3. Prerequisites

3.1 For site approval

Prior to making application for approval of a site, potential applicants are encouraged to hold exploratory discussions with the RSAC and/or the Board's staff. At the time of these early confidential discussions, when the entire project may be in a very conceptual stage, it is necessary only that the plant size, reactor type and the proposed containment method be identified.
Siting criteria, which will be outlined in Section 4, can be used for guidance on the requirements for the site and containment.

To support a formal request for approval of a site specific information pertaining to the site is required as well as the general concept of the proposed plant. The proposed site must be properly identified. Maps are essential and aerial photographs are useful. Information on land use, population and principal sources of water in the surrounding area for a radius of approximately 15 miles is required. Details of land use and locations of buildings within approximately 2 miles should be given. Only limited meteorological information is necessary unless there is suggestion of unusual conditions. The geology and seismicity of the region should be reviewed. Sufficient information on hydrology and hydrography should be given to permit a general assessment of the fate of radioactive material which might be accidentally released from the plant.

3.2 For Construction Permit

As noted above, the granting of a Construction Permit implies the approval of the general characteristic of the design. It is design specifications rather than the actual design that are required and considered at this time.

To support an application for a Construction Permit a comprehensive report, sometimes termed a "Safety Report", is required giving (1) a design description and (2) preliminary analyses of possible accidents or equipment failures.

Although many aspects of the design may not be firm the Design Description must provide a clear picture of the plant design and be sufficiently complete to enable independent accident analyses to be done. The report must make it evident that aspects of safety will be considered adequately throughout all stages of the design.

The description of each system or major component should first indicate the intended purpose of that system. The physical and functional features of the system should be outlined, showing clearly how the system will fulfill its stated requirements. Finally, the main parameters governing the design and function of the system should be given with their design limitations, together with the reasons for the limitations or the consequence of exceeding them. Codes to be followed in the detail design should be stated. The expected normal releases of radioactive material from the plant must be presented together with the proposed methods of control. Systems essential for the operation of the nuclear plant or installed especially for safety reasons require more complete descriptions.
The containment provisions (see section 4.1) must be clearly and fully described at the time of the application for a Construction Permit. This description should include a statement of the pressure and temperature of the gases or vapors for which the containment provisions are designed together with an estimate of the conditions that could arise from the rapid escape of the primary coolant on a large failure in the system. The maximum leakage rate for which the containment is designed should be given, together with a description of all auxiliary equipment or systems intended to decrease the pressure or temperature, or otherwise ameliorate the situation. The shielding afforded by the structure for gamma radiation from radioactive gases that may be released into it should be given. Penetrations and access openings into the containment structure, especially if the latter is designed for pressures considerably above atmosphere, should be described.

The Accident Analyses should present an outline of and the conclusions of the analyses of various assumed major equipment failures. The failures that should be analyzed are those that could produce conditions likely to lead to fuel failure, such as increased heat production in or reduced heat removal from the fuel. The analysis should be carried out to the point of determining how much radioactive fission products may be released to the building. The siting criteria currently being used require analysis of single failures of the essential process equipment only, as well as analysis of coincident failures of the process system and the safety systems. This is discussed further in section 4.

The granting of a Construction Permit does not necessarily imply acceptance of every argument or conclusion in the Safety Report. The Committee and Staff may, from their independent analysis, conclude that certain aspects of the design are adequately safe without accepting all the claims made in the report. For example, the report might claim that a Safety System has an unreliability of $10^{-8}$, whereas the Committee might conclude that $10^{-4}$ would be a more realistic estimate but that this would still be adequate.

Since many aspects of the design may not be decided at the time of the Construction Permit, subsequent submissions, or revisions, will be required as the design progresses. For the essential process equipment and the protective devices a complete description of the final design must be submitted prior to commencing installation of these systems.
Meetings between the applicants and the NCA are held at the time of the application and as the Committee deems necessary throughout the period of design and construction. The Committee and staff maintain an active interest in the project throughout the design, construction, commissioning and early operation.

3.3 For Operating Licence

The Operating Licence implies acceptance by the Board of the safety aspects of the plant as constructed and authorizes its operation. The licence is likely to be preceded by two sub-stages of authorization: (1) permission to load fuel, and (2) permission to start up.

Fissile material and heavy water, being "prescribed substances" in the regulations, can be acquired only under Board Orders. In addition, a separate Criticality Licence is needed to obtain enriched fuel that could constitute a criticality hazard outside the reactor.

For permission to load fuel it is necessary to show that all reactor systems affected by having fuel in the reactor have been satisfactorily tested as far as it is possible to do so without fuel.

A permission to start up requires assurance that all reactor and auxiliary systems have been constructed according to the submitted design, and satisfactorily tested as far as possible prior to start-up of the reactor. The Design Descriptions and Accident Analyses must be revised to include all interim submissions and to reflect the reactor as built. The final description must be sufficiently complete and accurate that it may be referred to in the licence as a factual description of the plant and may be used to outline limitations on changes that may be made without prior approval of the Board.

A description of the operating organization must be submitted. Senior members of the operating staff will be individually authorized. Operating procedures must have been prepared in conformance with operating policies or principles approved by the Board. A procedure for handling incidents or emergencies involving radiation is required and is subject to specific approval.

Finally the actual Operating Licence requires assurance of satisfactory completion of the commissioning program, including start-up, with demonstration that all significant systems meet the design intent. Arrangements for adequate maintenance, testing and review of operation should be completed at this stage.
The Operating Licence will include certain conditions or restrictions. Most important of these will be the broad conditions defining which modifications to the plant require prior approval of the Board. An annual report reviewing the operation of the plant, changes made, radiation exposures and prescribed materials is required.

The staff follows the operation of the plant throughout its life and the Committee periodically reviews the operation; usually after submission of the annual report.

4. **Safety Principles**

4.1 **General philosophy**

Safety should be considered at all levels of design and operation. In the design, all process systems should be examined for the possibility of failure of equipment and for the consequence of such failure on the system and on the entire plant. Where indicated, special safety systems must be included to prevent the failure of process equipment from leading to fuel failure. In addition a final barrier against the release of radioactive fission products to the environment should be provided.

In considering the probability of serious nuclear accidents, events leading to large release of radioactive fission products from the fuel to the environment, it has been found useful to think of a nuclear plant in the three divisions suggested above.

The first division is called the **essential process equipment**. It includes that equipment which is essential for the intended function of the plant. It includes the reactor core, the fuelling equipment, the heat removal equipment, control rods, and the instrumentation needed for regulation and operation. It does not include equipment and instruments which are added **only for safety**, such as the reactor shutdown system.

The second division is the **protective devices**. It includes equipment which is intended to limit the damage that can result from the failure of any part of the process equipment. In particular it is intended to prevent damage to the nuclear fuel in the reactor, which is the source of the radioactive fission products. It includes the automatic shutdown or trip system, emergency cooling system, emergency power supplies, and other standby equipment and safety devices.
The third division of the plant comprises the containment provisions. These are features which are provided to prevent the escape of radioactive matter in dangerous quantities from the building. They may include containment shells, vapor suppression systems, and involve the dampers of the ventilating system, the doorways, and their interlocks.

The protective devices are intended to reduce, and as far as practicable, to prevent, the escape of fission products from the fuel into the building enclosure if there is a failure of essential process equipment. The containment provisions are intended to reduce the amount of radioactive material escaping from the building if both process equipment and protective devices fail.

4.2 Design principles

It is considered extremely important to design the plant with the above divisions in mind. The design should ensure that these divisions, the essential process equipment, protective devices and containment provisions, are as independent as possible from one another structurally and operationally.

Protective systems should be independent of essential equipment, especially in the case of the reactor shutdown system and the regulating control system. Emergency cooling systems should be designed to prevent fuel failure for any credible loss of coolant and therefore sufficiently independent of the primary coolant system not to be incapacitated by its failure.

The containment provisions, which need not necessarily be a pressure shell, should be independent of both the process equipment and the protective systems. It is only through such independence that it is possible to achieve an adequately low probability of a major accident. The siting guides, which are discussed later, are based on the intention in design that process failures do not occur more than once every three reactor years and coincident process and safety system failures not more than once per 1000 reactor years.

Throughout the plant, the use of proven, highly reliable, components is desirable. All applicable (or otherwise applicable if not a nuclear station) codes should be met or exceeded. Design parameters should be well within demonstrated capabilities.
Provisions should be made in the design to permit testing of normal protective and containment systems at any time. The two-out-of-three triplicated shutdown system is one means of achieving this. All systems should be designed to be accessible, to the maximum extent feasible, for inspection, testing, and repair, except where this would conflict with other safety requirements. During operation, testing is required with a frequency sufficient to ensure the reliability assumed in the safety analysis.

The design must provide sufficient shielding, monitoring, ventilation, and other means of controlling radioactive contamination so that there should be little difficulty in keeping exposure of workers in the plant well within the recommendations of the ICRP.

4.3 Siting Principles

In 1964 the NRC adopted broad criteria which help specify site and containment requirements. These siting guides are not legal requirements but are the standard currently used by the Committee.

The guides state the acceptable exposure to individuals in the population and to the total population affected by the plant, and are given in two forms: (1) requirements for normal operation, and (2) design dose limits for accident conditions.

The operating requirements consider the hazards to the public from radioactive contamination, primarily of the atmosphere, that results from the normal operation of the reactor. These may arise from gaseous effluents such as argon-41, tritium and the volatile fission products. The radiation exposure of the public outside the exclusion area due to these normal operating effluents must not exceed levels consistent with the recommendations of the International Commission on Radiological Protection. For this purpose the limits have been taken to be 0.5 rem in one year of whole body exposure, and 3 rem in one year to the thyroid of an infant resulting from the inhalation of radio-iodine. An exposure of 3 rad to an infant's thyroid would result from exposure to 0.0010 curie-seconds per cubic metre (cs/m³) of Iodine-131 which is accompanied by concentrations of other iodine isotopes in proportion to their occurrence as fission products. Exposure in cs/m³ is the product of the concentration in the air and the time during which it is breathed.

Such limits ensure that the probability of injurious effects from radiation on any one member of the public is small. They may determine the size of the exclusion area. They have no bearing on, or relation to, the density of the population outside the exclusion area.
If the density of the surrounding population is high, it is necessary to consider not only the greatest dose received by any person, but also the number of persons in the whole population that receive significant exposure. Accordingly a limit is set not only to the individual dose but also to the population dose. The population dose is obtained by multiplying individual dose by the population density and integrating over exposed area outside the exclusion area. The limit for the population dose from normal operating effluents is set at 10^4 man-rem per year for whole body exposure, and at 10^4 man-rem per year to the thyroid if radio-iodine is inhaled or ingested. For a population of all age groups it is assumed that a weighted average annual population dose of 10^4 man-rem would result from an annual exposure of 10.4 man-curies per second per cubic metre (man-cs/m^3) of iodine-131 mixed with other iodine isotopes in proportion to their occurrence as fission products. The exposure in man-cs/m^3 is obtained by integrating over the land area the product of population density, concentration of iodine-131 in the air inhaled, and the time during which it is inhaled. Any exposure likely to be received, through the food chain, from deposition on the ground should be included.

The population dose due to normal effluents, including both continuous emission and any routine purging operation, is integrated over a yearly period taking into account variations in wind direction and other conditions of the weather. It is recommended that the integration extend over all areas in which the external individual dose exceeds 0.005 rem/yr or the individual thyroid dose exceeds 0.03 rem/yr.

For accident conditions there are two levels of criteria. For single failures of process equipment the calculated exposure due to the event must not exceed the annual allowable operating exposure, i.e., 0.5 rem to the whole body, 3 rem to the thyroid and 10^4 man-rem. For process equipment failures coincident with failure either of the protective system or containment the guide is: for any individual, 25 rem whole body, 250 rem to the thyroid; and for the population 10^6 man-rem whole body and 10^6 man-rem to all thyroids.

It is assumed that the individual dose of 250 rem to an infant's thyroid will result from 0.063 cs/m^2 of iodine-131 with which is mixed other iodine isotopes in proportion to their occurrence as fission products. It is assumed further that the population dose of 10^6 man-rem to all thyroids would result from an exposure to 10^4 man-cs/m^3 of iodine-131 mixed with other iodine fission products.
These dosage limits are called design dosage limits because the designer is expected to design the plant so that they will not be exceeded under certain assumed conditions. It is necessary to assume the conditions of the accident because they are unpredictable. Failures of process equipment which could lead to failure of the fuel must be considered. For the coincident failure case, the protective or containment system of most value in preventing fuel failure or fission product release must be considered to fail at the same time as the process equipment failure.

It is assumed that at the time of the accident the condition of the atmosphere is in Pasquill's Class F and that the wind is directed towards the densest population. If adequate meteorological information is available, the worst diffusion conditions which exist for at least 10 per cent of the time may be used.

5. Conclusion

This paper has outlined the procedures and prerequisites for the three steps followed by the Atomic Energy Control Board in licensing nuclear reactors. These steps are: site approval, construction permit, and the operating licence.

Of the principles adopted by the Board's Reactor Safety Advisory Committee for judging the safety of nuclear plants, the most important is the concept of the plant in three divisions. Grouped in these divisions are the essential process equipment, the protective devices and the containment provisions. These should be physically as independent as possible.

The Committee has set reference limits for the exposure of individuals and the total population as a guide to the special safety provisions necessary at a particular site. Application of these reference dose limits to the analysis of coincident failure of essential process equipment and related protective devices will specify the requirements for the containment provisions.
Acknowledgement

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References

1. Atomic Energy Control Act, Revised Statutes of Canada, Ch. 11 (1952) as amended by Ch. 47 (1953-54).

