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LICENSING AND SAFETY OF NUCLEAR POWER PLANTS IN CANADA

by

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(Outline notes for a lecture to the IAEA Interregional Course on Nuclear Power Plant Operational Safety held at Karlsruhe, FRG, September 1981.)

ABSTRACT

This lecture will give an overview of the regulatory framework and licensing process for nuclear power plants in Canada along with an outline of the evolution of the safety philosophy followed and some comments on how this philosophy and process could be applied by a country embarking on a nuclear power program.

RÉSUMÉ

Cette conférence, prononcée lors du Cours interrégional de L'AIEA sur la sûreté d'exploitation des centrales nucléaires, à Karlsruhe (RFA), en septembre 1981, trace les grandes lignes du cadre de la réglementation des centrales nucléaires au Canada et du processus de délivrance des permis. Elle fournit également des indications sur l'évolution des principes de sûreté mis de l'avant et apporte certaines remarques sur l'expérience qu'un pays prêt à se lancer dans un programme d'énergie nucléaire pourrait tirer de ces principes et du processus de délivrance des permis.

LICENSING AND SAFETY OF NUCLEAR POWER PLANTS IN CANADA

BACKGROUND

Before reviewing the legislation and regulatory process for nuclear power in Canada it is desirable to understand the particular political organization of the country and the structure of the Canadian nuclear power industry since each of these have influenced the regulatory process.

Canada is a confederation, with ten provinces and two vast and sparsely populated territories administered by the central or federal government. The Canadian constitution is partly expressed in the British North America Act (BNA Act) of 1867 but much is unwritten, adopting concepts, usages and conventions of Great Britain.

The provinces are largely self-governing, and, in the areas assigned to them by the BNA Act, just as sovereign as the central government. These powers include local commerce, working conditions, education, direct health care, resources in general. However, the BNA gives the Parliament of Canada (i.e., the central government) legislative authority over "such works" as it declares to be "for the general advantage of Canada".

Legislation

In 1946, the Parliament of Canada passed the Atomic Energy Control Act, declaring atomic energy a matter of national interest and establishing the Atomic Energy Control Board (AECB) to administer the Act. The Act, which was subsequently amended in 1954, is a short document authorizing and defining the powers of the AECB, a body with five members one of whom is appointed President and chief executive officer. Under the provisions of the Act, the Board is empowered to make regulations governing all aspects of the development and application of atomic energy. The 1954 amendment to the Act transferred from the Board to a Minister designated by the government the responsibility for research and the exploitation of atomic energy and provided him with extensive powers for this purpose, including the power to acquire or establish companies that are wholly owned in the name of Her Majesty in right of Canada and that are supported by funds appropriated by Parliament. As a result of this transfer of responsiblity, Atomic Energy of Canada Limited (a crown company established in 1952) was made responsible directly to the designated Minister and the AECB was left clearly as the regulatory agency.

The last major revision to the Atomic Energy Control Regulations came into effect in June, 1974. These regulations prescribe the general conditions and requirements for the licensing of prescribed substances and nuclear facilities. Further amendments have been issued since that date but they do not relate to the licensing of nuclear power plants.

For nuclear facilities, the Regulations require that a licence to operate be acquired from the Board, a prerequisite of which is Board approval to construct or acquire the facility. (A proposed revision of the Regulations, issued for public comment last month, would make a construction licence also a basic requirement, with site approval a prerequisite.) The Regulations also prescribe the general requirements for applying for and obtaining a licence, records to be kept and reporting of occurrances, and set out the basic radiation exposure limits. As with most other countries the radiation protection regulations are based upon the recommendations of the International Commission on Radiological Protection.

The Act and Regulations are very broad, generalized legislation which give extensive discretionary power to the AECB, a situation very common in Canadian (and British) law. The specific regulatory requirements are applied through the licensing process as outlined below.

Other than the Atomic Energy Control Act, the only other legislation enacted by Parliament specifically in respect of atomic energy is the Nuclear Liability Act. This Act, which entered into force in October, 1976, places total responsibility for nuclear damage on the operator of a nuclear installation. It requires the operator to carry insurance in the amount of $75 million. It also provides for the establishment of a Nuclear Damage Claims Commission to deal with claims for compensation when the federal government deems that a special tribunal is necessary, e.g., if the claims are likely to exceed $75 million. The Act recognizes that Canada may enter into international arrangements in respect of nuclear liability but Canada is not at present a party to any such arrangement.

Organization of Industry

Canada entered the nuclear field during World War II when the Montreal Laboratory was established to pursue the heavy water reactor route to plutonium production. As mentioned the AEC Act was passed and AECB created in 1946. In 1952 Atomic Energy of Canada Limited (AECL) was formed as a "crown company" (meaning, simply, a government-owned company) and took over the responsibility for the operation of the Chalk River Nuclear Laboratories which had been set up in 1944/45 as an outgrowth of the wartime program of the Montreal Laboratory. AECL conducted the research and development and eventually the engineering of the CANDU design for nuclear power plants. A major sector of the company (previously Power Projects, now the Engineering Company) was created to carry out the engineering and export functions.

Ontario Hydro, the electrical utility owned by the Province of Ontario (and the largest in the country), became interested in nuclear power in the early 1950s and collaborated with AECL in the development of the CANDU design. This early association resulted in the joint building of the NPD prototype which started up in 1962. Today Ontario Hydro is its own architect-engineer for all but the nuclear reactor and also acts as its own prime contractor.

The other two utilities building nuclear power plants are also provincially owned, Hydro Quebec and New Brunswick Electric Power Commission. They both employ a private firm for much of the architect-engineer-management functions while AECL provides engineering and procurement services for the full nuclear steam supply system (NSSS). Other utilities planning nuclear programs will probably follow this course.

Canadian General Electric Company was the architect-engineer for the NPD plant. The company also designed and built the KANUPP power station in Pakistan and the WR-1 research reactor at the Whiteshell Nuclear Research Establishment at AECL. It subsequently withdrew from the full NSS business and today concentrates on the design and manufacture of fuel and fuel handling equipment.

Although there are a large number of component suppliers the basic industry is therefore concentrated in very few organizations. This has facilitated easy communication and discussion among key personnel and is one of the major reasons for the general nature of the AEC Regulations and of the safety and licensing requirements which will be covered later.

CANDU Characteristics

Canada has concentrated on heavy water moderated reactors using natural uranium as fuel. The power reactor design employs pressurized heavy water as the coolant, pressure tubes, and on-power fuelling. All nuclear power plants built or planned in Canada are of this CANDU type design except for the Gentilly 1 BLW prototype.

The combination of these features results in relatively high fuel power rating, high flux, and small excess reactivity. The reactivity constraint, coupled with small temperature reactivity coefficients, has led to extensive use of automatic (in recent plants, digital computer) control.

The pressure tube design presents some safety characteristics which are different from other designs. These include such aspects as the heat sink capacity of the surrounding moderator, flow stability questions, and the possibility of the fuel coming into contact with the pressure boundary, all of which bear on the special requirements of emergency core cooling systems, while eliminating any concern about reactor pressure vessel failure.

The safety characteristics of the CANDU have had, inevitably, a significant influence on the safety philosophy developed by the AECB although the latter has, in turn, influenced the design. Similarly the practice, to date, of completing the detailed design and analyses after construction has begun, has influenced the licensing process and has, in turn, been made possible by the flexibility of the process.

LICENSING PROCESS

Although the AEC Regulations only call for two formal steps, CONSTRUCTION APPROVAL and OPERATING LICENCE, in practice the licensing process for nuclear power plants involves a prior step of SITE ACCEPTANCE and many intermediate sub-steps. Figures 1 to 4 show schematically the various actions, submissions, reviews, etc. involved in the licensing process from the time of a letter of intent from the utility announcing the proposal to build a nuclear power plant of a particular general design at a specified proposed site, while Appendix A lists the major steps. The licensing process is described in some detail in reference (1).

The Atomic Energy Control Act does not require public hearings and, to date, the AECB has not held any for any aspect of its regulatory process, including nuclear power plants. In fact, up until recently the licensing process was essentially closed. Earlier this year the Board adopted the policy of making public applications for licences, as well as most supporting documentation, staff reports and Board decisions.

Most provinces have a requirement for public hearings on major projects under their environmental legislation. Despite some possible ambiguities concerning the application of such provincial legislation to nuclear "works" the AECB has supported such hearings. This is consistent with a long-standing AECB policy to require licensees to adhere to provincial laws of general application. It also fits with the policy to require applicants for site acceptance to make their intentions public and to hold a public meeting in the vicinity of the proposed site. For federal projects, there is a requirement, under current federal government policy, for a review, including a public hearing, by the Federal Environmental Assessment Review Office.

It has been the practice for AECB project officers (who perform both licensing and inspection functions) to be located at the plant site at least two years prior to commissioning to oversee final construction and commissioning. To date AECB officers have remained at operating stations (except for the small NPD prototype).

Site Acceptance

At the Site Acceptance stage of the licensing process the basic objectives are to establish the conceptual design of the facility and, through investigation of site characteristics, to determine whether it is feasible to design, construct and operate the facility on the proposed site and meet the safety requirements established by the AECB. The primary documentation required is a Site Evaluation Report providing a summary description of the proposed station and information on land use, present and predicted population, principal sources and movement of water, water usage, meteorological conditions, seismology and local geology. The AECB itself is primarily concerned with the inter-relationship of the site and plant, leaving evaluation of environmental impact to associated federal and provincial environmental agencies. The AECB is not directly involved in the site selection process and only judges a particular site to be either acceptable or unacceptable.

During this phase, the applicant is required to announce publicly his intentions to construct the facility and to hold public information meetings at which the public can express its views and question applicant officials.

Construction Approval

Prior to granting a Construction Approval the AECB must be assured that the design is such that the AECB safety principles, criteria and requirements will be met and that the plant will be built to appropriate quality standards. In order to do this, it is necessary that the design be sufficiently advanced to enable safety analyses of a specified set of hypothesized events to be performed and their results assessed. The primary documentation required includes a Preliminary Safety Report (which combines the essential information of the Site Evaluation Report, a description of the Reference Design, and the Preliminary Safety Analyses) a Quality Assurance plan, and preliminary plans for operation.

Construction will only be authorized once the design and safety analysis programs have progressed to the point that, in the judgement of the AECB, no further 'significant' design changes will occur. Where the design is not finalized at the time of a Construction Approval, the AECB must be assured that there will be no subsequent significant impact on the safety analyses.

Operating Licence

Prior to issuing of an Operating Licence the AECB must be assured, primarily, that the plant, as built, conforms to the design submitted and approved, and that the plans for operation are satisfactory. The requirements include submission of a Final Safety Report, completion of a previously approved commissioning program, examination and authorization of senior personnel, approval of operating policies and principles, and preparation of plans and procedures for dealing with radiation emergencies.

Typically a provisional licence is issued to permit start-up, and, subject to AECB staff approval, increases in power to the design rating. Provided all has proceeded satisfactorily a full Operating Licence is issued for a term not exceeding five years. Among the terms of an Operating Licence is the requirement that the licensee inform the AECB promptly of any occurrence or situation which could alter the safety of the plant. The AECB retains the right to impose additional conditions at any time.

During the operating life of the plant there will be continued AECB inspection, annual reviews of operation, and major reviews at times of renewal of the Operating Licence. Although the situation has not arisen yet, formal approval of the Board would be required for decommissioning.

SAFETY PHILOSOPHY

As is the case in other countries, the basic tenet of the Canadian reactor safety philosophy is one of defence-in-depth. However, there are important differences in the way this philosophy is applied.

An important characteristic of the Canadian approach is that primary responsibility for ensuring a high degree of overall safety is clearly assigned to the owner of a nuclear power station. Thus, only basic safety criteria and fundamental principles have been stipulated by the AECB with avoidance of detailed design requirements.

From the earliest days of the Canadian nuclear program the safety objective has been to ensure that the likelihood at a serious release of fission products is negligibly small. This "risk" approach has pervaded the Canadian safety philosophy throughout the years.

A serious accident to the NRX research reactor at Chalk River in 1952 was the catalyst for much of the Canadian reactor safety approach which still prevails today. The essential principles which evolved stemmed from the acknowledgement that even well designed and built systems fail and therefore there was a need for separate, independant safety systems which could be tested periodically to demonstrate their availability. In the mid-1960's these concepts were formalized by the AECB's Reactor Safety Advisory Committee* into a set of criteria commonly called the Siting Guide. Although modified over the years these criteria still constitute the basic safety requirements for nuclear power plants.

In specifying the requirements to be met by the designer and operator, a nuclear power plant is envisaged as consisting of two categories of equipment: the process systems and the safety systems. The process systems include all that equipment required for normal operation of the plant, such as the regulating system, primary heat transport system, and electrical supply system.

The safety systems, on the other hand, include the reactor shutdown systems, the emergency cooling system and the containment provisions which are designed to mitigate the consequences of failures and malfunctions of the process equipment. Those particular process equipment failures which, in the

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* The Reactor Safety Advisory Committee was disbanded in 1979. The AECB subsequently created an Advisory Committee on Radiological Protection and an Advisory Committee on Nuclear Safety.

absence of the special safety provisions, could lead to fuel failure and a release of radioactivity to the environment are referred to as "serious process failures".

It is an important safety principle in Canada that the safety systems be as independent as possible, physically and functionally, from the process equipment and from each other, and be as conceptually different as possible from each other, so that the probability of coincident failure of any two of the safety provisions or of the process equipment and one of the safety provisions, due to a common cause, is very small. If they are sufficiently independent, realistic failure rates of process systems can be accepted and demonstrable availability requirements for the safety systems can be imposed. The overall safety criteria is then defined by setting acceptable consequences in the form of reference dose limits for any "single failure" of a process system and any "dual failure", i.e. a serious process failure combined with unavailability of a safety system; see Table 1.

In 1972 this approach was modified slightly by the requirement for two separate, independent shut-down systems. This removed the necessity to analyse a runaway accident which had presented great difficulty.

Although the "single failure", "dual failure" approach adequately defined the required effectiveness of the safety systems, other situations became of increasing concern over recent years. These included:

<u>Dual Process System Failures</u>: It was recognized that some of the process systems (e.g. Class III electrical power) had a protective function. Failure of the normal Class IV power combined with failure of the Class III standby generators would eventually have serious consequences for the plant.

<u>Failure of Safety Support Systems</u>: Some systems, e.g. instrument air, service water, Class I, II and III electrical power are needed to support process systems and the long term actions of safety systems. Failure of such a system could, in the long term, cause a common-mode failure of a process system and safety system.

<u>Post-Accident Phase</u>: In some situations this phase could be many months. It is necessary, therefore, to consider random failures of process systems and the occurrence of earthquakes during this period. On the other hand more realistic meteorological conditions can be assumed for analyses than is appropriate for the short term of the initiating accident.

<u>Common-Mode Events</u>: It is necessary to design for and analyse the consequences of natural and man-made events which could damage both process and safety systems. Examples are earthquakes, missiles from turbines and aircraft, and fires.

For all of these events the safety systems must be effective to limit the short term consequences. In the longer term it must be shown that the reactor can be kept shut down, its decay heat removed, and its safety status monitored. To ensure a high reliability for these three safety functions designers have arranged the required safety-related systems into two independent and physically separated groups. Group One includes most of the process systems, Class III standby generators and electrical system, shutdown system No. 1, and emergency core cooling system. Group Two includes shutdown system No. 2, the containment system, the emergency power generators and electrical system, and the emergency water system.

The analysis of events with long-term implications for plant safety is performed by a technique known as a Safety Design Matrix. This consists of two sections known as the fault tree and the event tree. The fault tree identifies all the mechanisms which can lead to a fault such as failure of instrument air. The event tree identifies the resulting mechanisms by which radioactive material could escape to the environment and demonstrates the defences for each mechanism.

Last year, the AECB issued for comment four draft licensing guides on the three major special safety systems (shutdown systems, emergency core cooling systems, containment) and on accident analyses. These guides detail the AECB requirements more than has been done previously and involve analyses of more accident combinations. The fault-tree or event-tree approach is given greater emphasis. However most of the above principles have been retained. The first three guides, as amended this year, are referenced in the Construction Licence issued for the four-unit, 3200 MW, Darlington Nuclear Generating Station in June, 1981.

APPLICATION IN OTHER COUNTRIES

The Canadian Atomic Energy Control Act gives wide discretionary powers to the nuclear regulatory agency, the Atomic Energy Control Board. Following this broad mandate the AECB has made only general regulations for the licensing of nuclear facilities. In the case of nuclear power plants, as discussed earlier, the AECB has specified only general criteria and a few more explicit requirements.

The practice has been to build on precedents and experience. Considerable discretion is given to AECB licensing staff but with the relatively compact nature of the nuclear power industry this has not, in general, caused difficulty since there is almost continuous communication between AECB staff, designers, operators and, to a lesser degree, manufacturers. AECB staff are also in close contact with research and development groups.

The result of this situation is that the specification and documentation of detailed design and operating regulatory requirements is less extensive than in some other countries. This approach has worked well in Canada but the relative sparseness of documents can cause problems for another country wishing to follow it.

To help regulatory authorities in other countries who are interested in the Canadian system, the AECB has created an Orientation Centre. This new group will train staff from foreign regulatory agencies on the Canadian approach, supply visiting instructors or advisers, and generally enter into ongoing communication to provide information on any relevant aspect of nuclear power plant licensing. In the case of a country building a CANDU nuclear power plant using a Canadian plant as a reference, the Orientation Centre will assist that country's regulatory agency in confirming that their plant is similar to the reference plant and that any differences conform to safety criteria in Canada.

IAEA CODES AND GUIDES

Canada has been a strong supporter of the IAEA's nuclear safety standards (NUSS) program and has contributed actively to the preparation of most of the codes and guides. It is the general feeling of the nuclear community in Canada that these codes and guides provide an excellent basic reference especially for countries embarking on a nuclear power program. The Canadian safety philosophy and criteria can be applied within the context of the IAEA recommendations.

An essential element in applying the IAEA and Canadian approaches is well-trained staff in the regulatory or safety review agencies who can make mature judgements. It will never be practical to document all requirements for all cases and to attempt to do so may even be detrimental to overall safety.

Appendix A.

MAJOR LICENSING STEPS

The major steps leading up to issuance of Site Acceptance are:

- submission of a letter of intent
- public announcement by AECB
- coordination meetings between AECB and appropriate federal and provincial departments. (It has been a long-standing AECB policy to require adherance to provincial legislation and requirements of general applicability.)
- submission of site evaluation report
- public meeting or public hearing by provincial or federal governmental agencies
- AECB staff review and recommendation to Board (The AECB limits its consideration at this stage to the question of whether a plant of the general design proposed could be built and operated at the particular site to meet established AECB requirements. Socio-economic impacts are not examined.)
- Board determination
- public issuance of Site Acceptance

The major steps leading to a Construction Approval are:

- letter of application (from utility)
- public announcement by AECB
- submission of (preliminary) Safety Report
- submission of Quality Assurance program
- submission of staffing and training plans
- review and evaluation by AECB staff (including numerous meetings and correspondence with applicant)
- AECB staff report and recommendation to Board
- Board determination
- public issuance of Construction Approval

The major steps leading to an Operating Licence are:

- letter of application
- public announcement by AECB
- submission of Final Safety Report, including description of plant design as built and completion of safety analyses
- submission of Commissioning Programs
- submission of Operating Policies and Principles
- submission of policy, plans and procedures for Radiation Protection
- development of on-site Emergency Plans and completion of plans and arrangements with local public authorities for off-site contingencies.
- AECB staff approved of arrangements for safeguards and physical security
- submission of formal assurances regarding completion of construction and commissioning
- AECB examination and authorization of key operating personnel
- application to acquire heavy water and fuel
- AECB approval
- application to load heavy water and fuel
- AECB approval

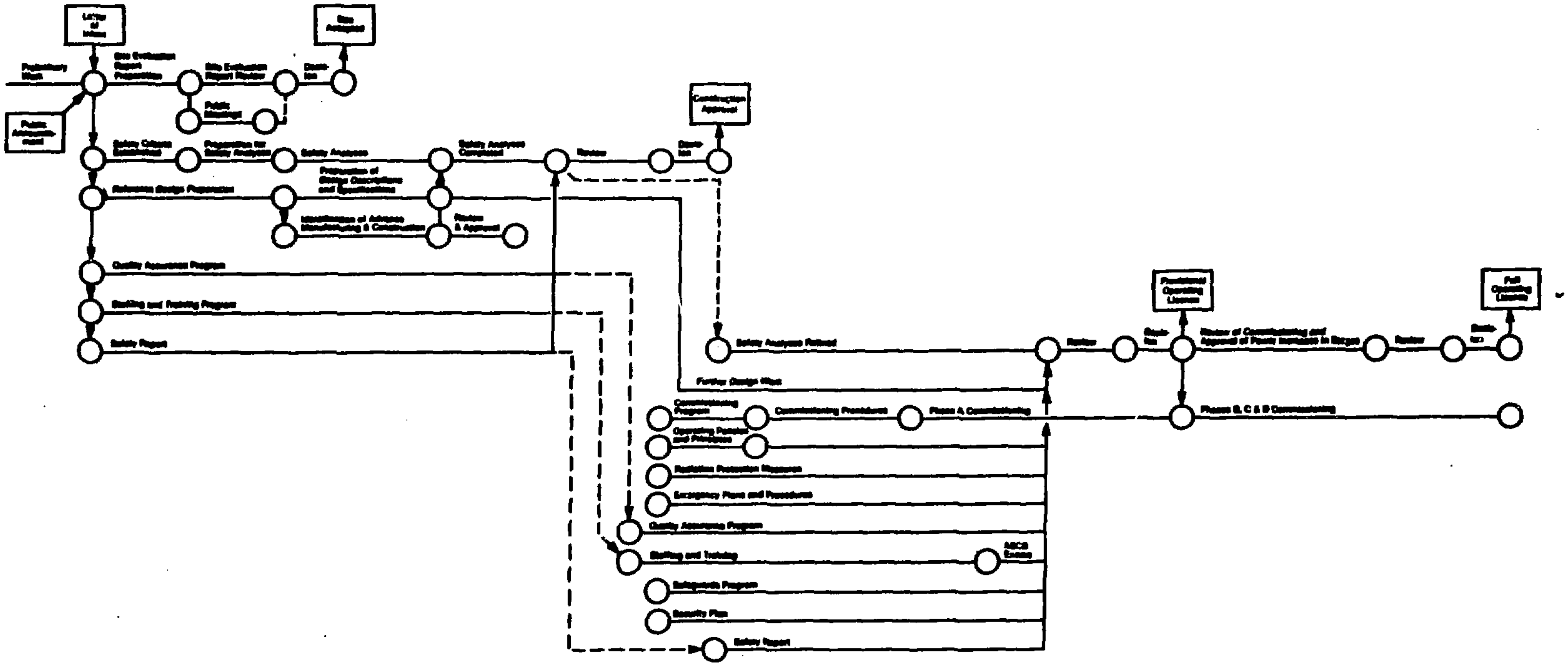
- AECB staff reviews, reports and recommendation to Board (AECB staff would have been on site for at least the latter part of construction and the complete commissioning program.)
- Board determination
- public issuance of Provisional Operating Licence (for start up and post-criticality testing)
- further AECB staff reports and recommendations
- Board determination
- public issuance of Operating Licence (for limited period, typically 1 to 5 years)

TABLE A - 1

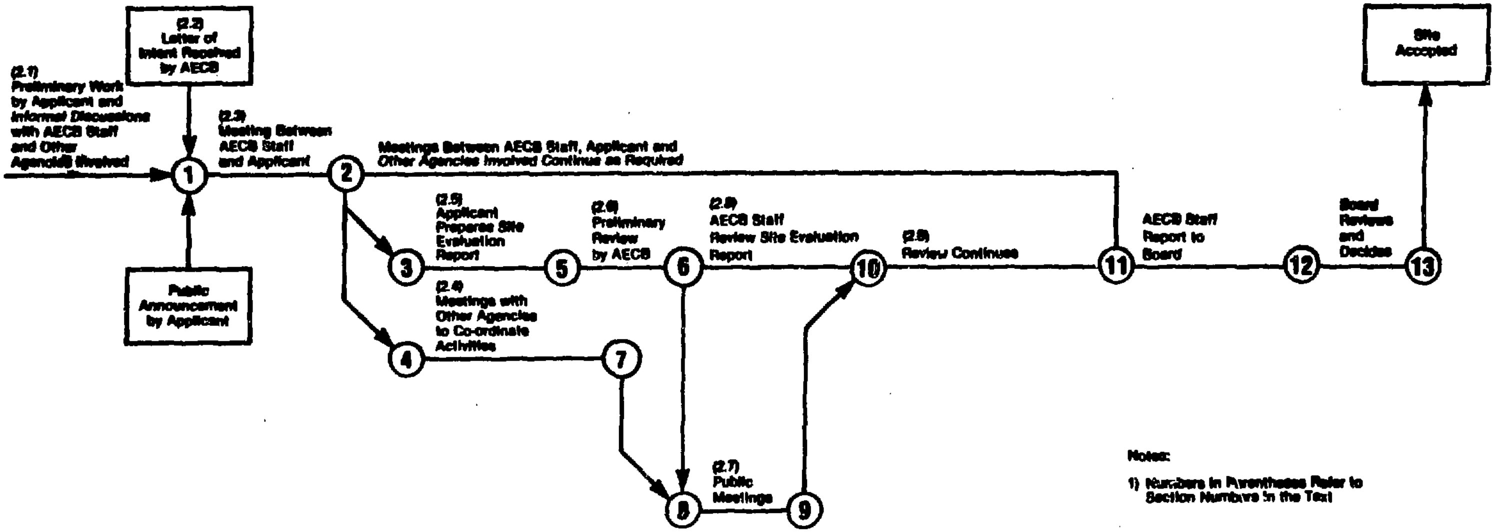
OPERATING DOSE LIMITS AND REFERENCE DOSE LIMITS FOR ACCIDENT CONDITIONS

Situation	Assumed Maximum Frequency	Maximum Individual Dose Limits	Maximum Total Population Dose Limits
Normal Operation		0.5 rem/yr whole body 3 rem/yr to* thyroid	10^4 man-rem/yr 10^4 thyroid rem/yr
Serious Process Failure (single failure)	1 per 3 years	0.5 rem whole body 3 rem to thyroid	10^4 man-rem 10^4 thyroid-rem
Process Failure plus Failure of any Safety System (dual failure)	1 per 3 x 10^3 years	25 rem whole body 250 rem thyroid	10^6 man-rem 10^6 thyroid-rem

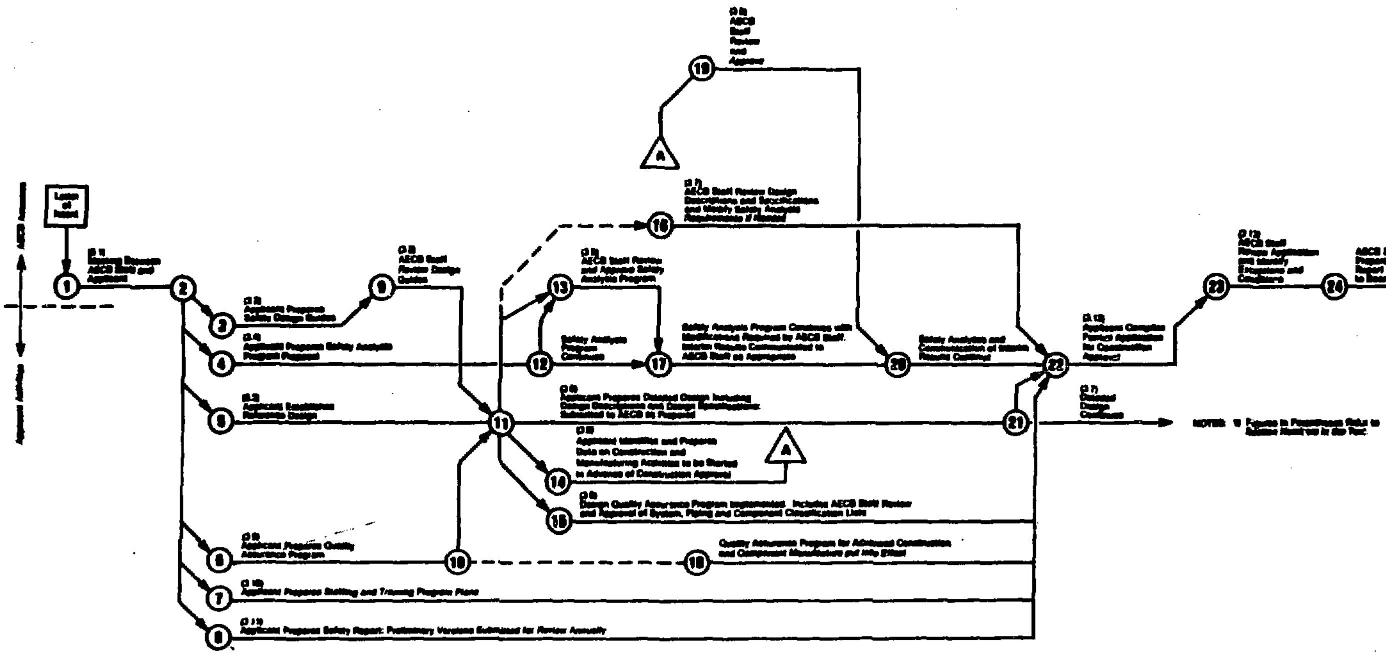
* The operating target for all nuclear power plants in Canada is 1% of these limits.



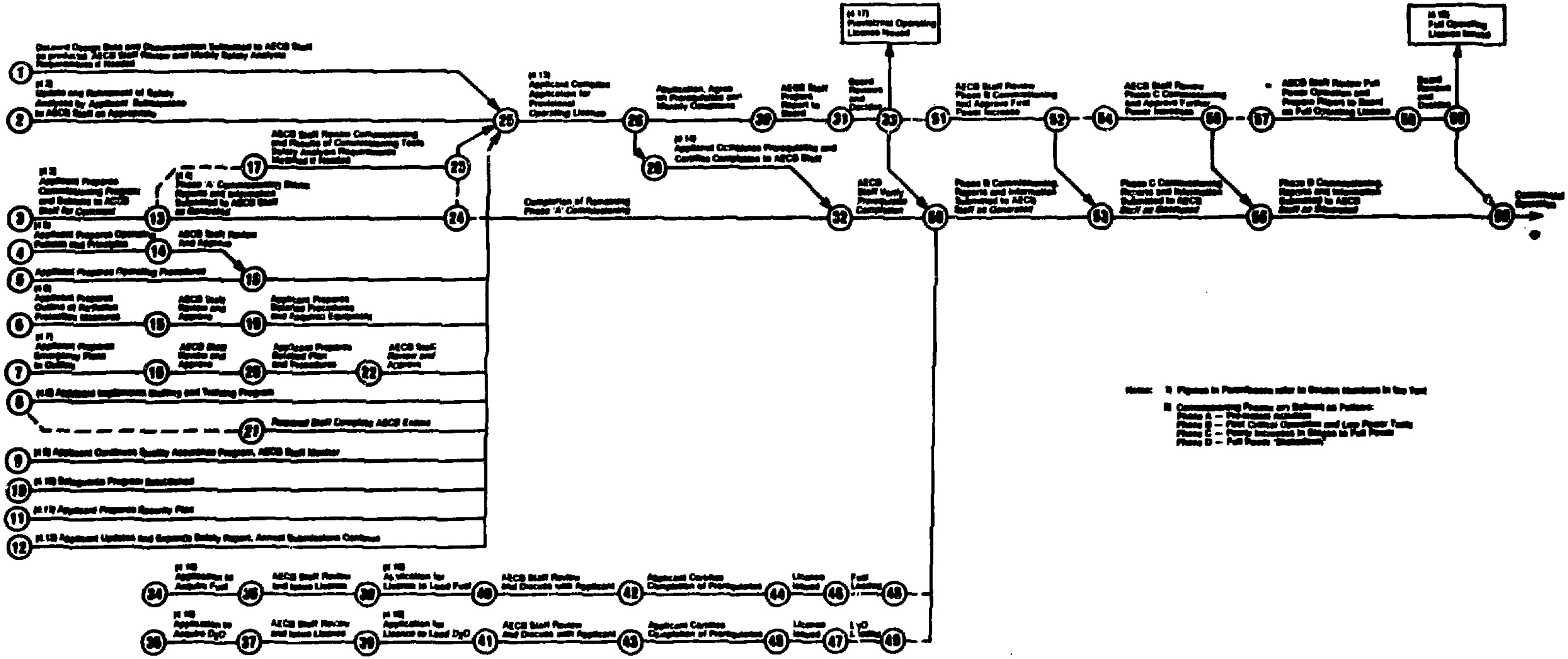
OVERALL SCHEMATIC; FIGURE B-1



SCHEMATIC OF ACTIVITIES LEADING TO SITE ACCEPTANCE; Figure B-2



SCHEMATIC OF ACTIVITIES LEADING TO CONSTRUCTION LICENCE; B-3



SCHEMATIC OF ACTIVITIES LEADING TO OPERATING LICENCE; FIGURE B-4

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