INTERNATIONAL COMPARISON OF HIGH-LEVEL WASTE DISPOSAL CRITERIA

Neil J. Numark
International Energy Associates Limited
Fairfax, Virginia

ABSTRACT

This paper surveys the characteristics and status of development of high-level waste disposal criteria in five countries: the United States, Canada, the Federal Republic of Germany, Sweden and Switzerland. It describes the regulatory philosophies and positions of the regulatory authorities and the organizations developing repositories on five topics: qualitative safety goals, radiation protection requirements, technical performance criteria, time periods for compliance demonstration, and waste retrievability. This information can provide an improved understanding of the considerations important for regulation of waste disposal.

INTRODUCTION

Underground investigations of candidate geologic media in several countries are under way or will begin within the next decade to assess the capability to safely isolate high-level radioactive waste or spent fuel. For example:

- The U.S. has an aggressive repository development program, with shaft activities scheduled to begin in 1988 at three candidate sites for the first geologic repository. The target is to begin repository operation by 2003.
- The Federal Republic of Germany intends to begin disposal before 2000, and has conducted extensive tests at the Asse salt mine and initiated underground studies at the Gorleben salt dome.
- Canada has developed and is now deepening an underground research laboratory in crystalline rock at Whiteshell, but screening for an actual repository site has not begun.
- France is narrowing down sites for an underground site validation laboratory which it hopes to site by 1989, where tests would be conducted to confirm the site's suitability for high-level waste and transuranic waste disposal.
- Sweden intends to construct an underground research laboratory by about 1992, select a disposal site by about 1998, and begin repository operation in about 2020.
- Switzerland is now conducting field studies as well as crystalline rock investigtions at the Grimsel test site, and hopes to begin constructing an underground laboratory within 10 years to determine the site's suitability as a high-level waste repository.
- Belgium is operating an underground laboratory in clay at Mol and will expand the facility for further exploration in the early 1990s.

As these repository development activities progress, regulatory criteria which govern the siting of these facilities and which will establish the performance requirements for the disposal facilities are evolving and have emerged in several countries. Although the end result of assuring adequate protection of public health and safety is the common objective of regulatory programs in all these countries, the philosophies behind the development of the criteria differ substantially, resulting in requirements of differing specificity and stringency which could require differing efforts to demonstrate compliance.

This paper surveys the characteristics and status of development of high-level waste disposal criteria worldwide. It describes the regulatory philosophies and positions of the various agencies on:

- qualitative safety goals;
- radiation protection requirements;
- technical performance criteria;
- the time periods over which compliance must be demonstrated; and
- waste retrievability.

Regulatory efforts will be discussed for the five countries which have most thoroughly defined their policies on the protection goals for high-level waste disposal: the United States, Canada, the Federal Republic of Germany, Sweden, and Switzerland. France and other countries have addressed these issues extensively, but several items are still under discussion and therefore these countries were not included here.

It must be recognized in considering the criteria discussed in this survey that it is sometimes misleading to compare regulatory requirements among different countries head on. Differing responsibilities of the organizations developing the repositories and different relationships between these organizations and the regulatory agencies can be expected to produce very different regulatory approaches. Differences in cultures and attitudes about exerting independent regulatory control over a responsible public authority can also produce differing regulatory approaches. For example, the following discussion will show that in the United States, specific regulatory requirements having the force of law have been established for all five categories compared in this survey, whereas in Sweden, although all five issues have been thoroughly

discussed and protection of public health and safety are strongly emphasized, specific regulatory requirements have not been established in any of the five categories and may not be established in the future.

QUALITATIVE SAFETY GOALS

Each of the countries included in this survey has developed its own unique approach for defining the public health and safety objectives to be achieved by the repository system. These objectives are described for each country in this section.

Regulatory standards of the U.S. Environmental Protection Agency seek a "reasonable expectation" that certain release limits for specific radionuclides have a low probability of being exceeded, and that undisturbed performance of the disposal system will not cause certain individual dose limits to be exceeded.(1) The standards are intended to ensure that risks to future generations from disposal of the wastes will be no greater than if the uranium ore from which the waste originated had never been mined.

The Atomic Energy Control Board of Canada has established a policy that after repository closure, there must be a small probability that radiation doses to the public attributable to a repository will exceed a small fraction of natural background radiation doses.(2) Furthermore, a proposed policy statement of the AECB gives three overall qualitative objectives of radioactive waste disposal: to minimize burdens placed on future generations; to protect the environment; and to protect human health (no more than 10^{-6} serious health effects per year).(3)

Criteria recommended by the Reactor Safety Commission in the Federal Republic of Germany simply call for a guarantee to protect man and the environment from radiation emitted by wastes, as well as the closing off of the repository from the biosphere after the completion of operations.(4)

Switzerland's safety authorities have established a goal that a repository should be designed so that at any time it can be sealed within a few years, after which it should be possible to dispense with safety and surveillance measures.(5)

Sweden's safety authorities have not established specific qualitative health and safety goals for a high-level waste repository and do not intend to. However, a related objective has been presented by the Swedish Nuclear Fuel and Waste Management Company (SKB) in its recent research and development program: the waste problem shall be solved by the generation that utilizes electricity produced by nuclear power plants.(6)

RADIATION PROTECTION REQUIREMENTS

Radiation dose limits for a high-level waste repository differ somewhat from country to country. The U.S. EPA's standards allow a maximum individual whole body dose of no greater than 25 millirem (0.25 millisieverts) per year. The FRG uses a 30 millirem per year criterion from its general radiation protection regulations. Switzerland's policy is that radionuclides anticipated to enter the biosphere must not at any time lead to individual doses exceeding 10 millirem per year. Sweden's safety authorities have not issued radiation protection requirements specific to waste management; however, the government has approved SKB's plan for managing the back end of the fuel cycle, KBS-3, which estimates actual doses to be much less than the Swedish dose limit for nuclear power plants of 10 millirem per year for individual whole body dose.(7) Finally, the Canadian authorities do not believe it is appropriate to apply dose limits to a repository because they do not believe it will be possible in the long term to enforce compliance with pre-selected dose limits. AECB states that the 10^{-6} per year risk objective which it has proposed is the risk associated with a dose of 5 millirem per year.

TECHNICAL PERFORMANCE CRITERIA

Specific numerical requirements on the performance of a high-level waste repository have only been developed in the U.S. The Nuclear Regulatory Commission requires:

- substantially complete containment of waste within the waste package for the first 300 to 1,000 years after the repository is permanently closed;
- a release rate of any radionuclide from the engineered barrier system to the accessible environment no greater than one part in 100,000 per year of the inventory of that radionuclide that remained 1,000 years after the repository was closed; and
- siting of the repository such that groundwater travel time along the fastest path from the disturbed zone to the accessible environment is at least 1,000 years.(8)

Other countries may develop quantitative performance criteria on a site-specific basis once sites have been selected and studied. In the FRG, for example, numerical criteria for the Gorleben repository will be developed and established by the state licensing authority. Such criteria will be chosen by the authority from the safety analysis prepared by PTB, the Physical Technical Institute. Some parameters which may be restricted include, for the operational phase of the repository:

- annual rate of airborne release of volatile radionuclides;
- annual amounts of radioactivity per nuclide which may be emplaced in the repository, depending on waste form and packaging;
- transmission rate of volatile radionuclides through sealed emplacement rooms; and
- minimum gamma ray attenuation factors.

Criteria for the prevention of accident situations during the operating phase will also be established in the FRG, including limits on radioactivity per waste package and precautions such as installation of automatic sprinklers. For the post-operational phase, the expected criteria will limit the total amount of radioactivity which may be emplaced in the repository; it has not yet been decided whether such criteria will be nuclide-specific.

Sweden does not intend to develop specific technical criteria for the performance of a high-level waste repository. Nor have quantitative criteria been developed for Sweden's SFR repository for low- and intermediate-level waste, which is already at the licensing stage. The assurance of safe waste disposal programs is achieved through an independent monitoring mechanism, where SKB must, by law, submit a research plan to the government every three years for review and approval.

PERIOD OF COMPLIANCE DEMONSTRATION

There is substantial deviation in viewpoint among the regulatory authorities regarding the period over which it should be possible to demonstrate compliance with either individual dose risk or radionuclide release rate limits.

As stated earlier, the U.S. EPA's standards for high-level waste disposal seek a "reasonable expectation" that certain release limits for specific radionuclides have a low probability of being exceeded, and that undisturbed performance of the disposal system will not cause certain individual dose limits to be exceeded. However, the time periods over which such compliance must be demonstrated differ. A 10,000 year time period is used for the containment requirements, based on EPA's view that this is sufficiently long to encourage use of disposal sites with natural characteristics that enhance long-term isolation. In contrast, a 1,000 year time period was chosen for the individual radiation protection limits, based on EPA assessments which indicate that this is sufficiently long to ensure that good engineered barriers would need to be used at potential sites where groundwater may be present, and because demonstrating compliance beyond 1,000 years involves great uncertainties. EPA stated that at some of the sites being considered, the only way to comply with requirements on the order of 10,000 years would be to use very expensive engineered barriers which would rule out any potential releases over this time period. EPA explained that although this could provide longer-term protection for individuals, no substantial benefits would accrue to populations, whose risk is already very low due to the containment and other assurance requirements of the EPA rule.

The proposed policy statement of Canada's AECB states that the period for demonstrating compliance with the individual risk requirements using predictive mathematical models need not exceed 10,000 years. In situations where predicted risks do not peak before 10,000 years, AECB's proposed policy is that there must be a reasoned argument leading to the conclusion that beyond 10,000 years, sudden and dramatic increases in the rate of radionuclide release will not occur and individuals will not encounter acute radiological risks. Such a situation might occur where long-lived wastes are isolated in geological formations that are not strongly affected by natural surface phenomena and that are likely to remain stable over extended timescales. AECB notes that experts believe the next glaciation will commence as early as several to tens of thousands of years from now, drastically changing the human environment and justifying an upper bound on the time span for individual risk calculations.

Authorities in the FRG are still debating the issue regarding the time period for which compliance with the radiation protection standard needs to be demonstrated. PTB's opinion is that assessment of calculated doses makes sense only for about 10,000 years. Calculated values for individual doses become very uncertain for longer time periods, especially because of the high probability of a significant change in climate or other factors. Furthermore, PTB holds the view that beyond about 10,000 years, the potential risk does not need to be calculated in the form of individual doses because the risk becomes comparable to other environmental risks, such as the risk due to a comparable quantity of uranium ore. The Federal Ministry of Environment, Protection of Nature, and Reactor Safety and the licensing authority for the State of Lower Saxony have accepted the 10,000 year limit for the radiation protection criterion, but are still discussing the significance of calculated doses beyond that time limit.

Finally, no specific policy has been stated by the Swedish authorities regarding time periods for compliance demonstration. There is discussion of using periods longer than 10,000 years, particularly for predicting radionuclide release rates to the geosphere rather than the more uncertain prediction of radiation dose rates to the biosphere. Sweden's National Institute for Radiation Protection (SSI) has taken the position that 10,000 years is a reasonable time period, since ice ages occur at 10,000 to 50,000 year intervals and create changes in the environment which could render meaningless any predictions made into the more distant future. However, periods of 10,000 to 100,000 years are under discussion. There is a view in Sweden that release rates to the geosphere need to be predicted beyond 10,000 years due to the strong possibility that the repository system will prevent substantial release during the initial 10,000 years.

RETRIEVABILITY

Regulatory positions on the retrievability of spent fuel or high-level waste from a repository vary from country to country. In the U.S., EPA's 40 CFR Part 191 requires that the disposal system must be selected such that removal of most wastes is not precluded for a reasonable period of time after disposal. EPA states that this is intended to give future generations an opportunity to rectify the situation if new discoveries give compelling reasons to change the manner of disposal. EPA also states that this provision should not have any effect upon plans for mined geologic repositories; rather, it is intended to call into question any other concept that might not be so reversible, such as deep-well injection of liquid wastes. No additional procedures or design features are mandated by this requirement, and it is only required that the sealed repository can be mined and the waste recovered, even if at high cost and occupational risk.

NRC's requirement on retrievability in 10 CFR Part 60 is consistent with the EPA policy: the repository must be designed to preserve the option of waste retrieval throughout the waste emplacement period and until the completion of performance confirmation testing. To meet this requirement, the repository must be designed such that waste could be retrieved

"on a reasonable schedule starting at any time up to 50 years after waste emplacement operations are initiated." NRC states that the rationale for this policy is to preserve the ability to make a decision on the acceptability of permanent closure. The 50-year time period was determined based on estimates that the repository would operate for 25 to 30 years, and that 10 to 15 years would be needed after operation is complete for performance confirmation. NRC stated that its policy should not preclude it from allowing backfilling or closure of the repository in less than the 50 year period, but that the repository should not be designed such that retrieval would be so expensive, difficult, or have such high radiological impact that the option of retrieval would be foreclosed and corrective actions could not be taken. Maintaining the retrieval option does not require mined areas to be kept open.

Canada's Atomic Energy Control Board has adopted a policy stating that, although there will be no design requirement for post-closure retrievability of waste, any such provisions which are made must be of a nature that does not compromise the effectiveness of the repository. For the pre-closure operating period, the concept must incorporate methods for waste retrieval as a contingency measure. This resembles the U.S. policy, which does not require retrievability following repository closure. The Canadian policy appears to preserve AECB's ability to make a decision on permanent closure. In one respect the Canadian policy goes beyond the U.S. requirements, in that they require any provisions for post-closure retrievability to be of a nature that does not compromise the repository's effectiveness.

Switzerland's Regulatory Document R-21 requires that a repository be designed so that it can at any time be sealed within a few years. The Project Gewahr report of Switzerland's National Cooperative for the Storage of Radioactive Waste (NAGRA) states that the aim of final disposal is the definitive removal of the waste without the intention of retrieval.(9) Licensing authorities in the Federal Energy Office have stated that retrievability should never be considered as a last safety exit in case anything goes wrong, and that if there is not confidence in the safety of a waste disposal system, then the time is not ripe for that system and another proven method such as controlled storage should be pursued. Although retrievability may still be required for socio-political reasons, state the authorities, this decision should not be made solely by the safety authorities, and for this reason R-21 neither requires nor rules out retrievability.

Sweden has not stated a policy on retrievability of spent fuel from a waste repository. It is understood that spent fuel will be retrievable for the approximately 40 years that it will be held in intermediate wet storage in the Clab facility. Furthermore, SKB intends to keep spent fuel retrievable during approximately 40 years of repository operation, or until about 2060. This can be viewed as a policy of flexibility, allowing a substantial time period, throughout both the storage phase and the repository operation phase, during which there is still access to the spent fuel. The Swedish Government accepted these schedules when they were presented in KBS-3, but has not explicitly endorsed any position with respect to retrievability.

CONCLUSION

This comparison survey has revealed noteworthy differences in national regulatory approaches for high-level waste repositories, both in the overall goals for repository safety and radiation protection and also on specific issues such as waste retrievability and the time periods over which compliance with these goals must be demonstrated. It is useful to compare these approaches in order to understand the considerations used for regulations in each country and the specific criteria used for regulation and their differences between countries.

Continued observation of changes in these regulatory positions and of new criteria developed in countries not addressed here can contribute to improved understanding of the regulatory issues associated with assurance of the protection of public health and safety.

REFERENCES

1. U.S. Environmental Protection Agency, "Environmental Radiation Protection Standards for Management and Disposal of Spent Nuclear Fuel, High Level and Transuranic Radioactive Wastes," 40 CFR Part 191, August 15, 1985.

2. Atomic Energy Control Board of Canada, "Deep Geologic Disposal of Nuclear Fuel Waste: Background Information and Regulatory Requirements Regarding the Concept Assessment Phase," Regulatory Document R-71, January 29, 1985.

3. Atomic Energy Control Board of Canada, "Regulatory Objectives, Requirements, and Guidelines for the Disposal of Radioactive Wastes," Proposed Regulatory Policy Statement, Consultative Document C-104, April 30, 1986

4. "Safety Criteria for the Final Disposal of Radioactive Wastes in a Mine," Recommendations of the Reactor Safety Commission of the Federal Republic of Germany, December 17, 1982.

5. Swiss Federal Commission for the Safety of Nuclear Installations and Swiss Federal Energy Office, "Protection Goals for the Final Storage of Radioactive Waste," Regulatory Document R-21, October 1980.

6. Swedish Nuclear Fuel and Waste Management Company, "Handling and Final Disposal of Nuclear Waste: Programme for Research, Development and Other Measures," September 1986.

7. Swedish Nuclear Fuel and Waste Management Company, "Final Storage of Spent Nuclear Fuel - KBS-3," May 1983.

8. U.S. Nuclear Regulatory Commission, "Disposal of High-Level Radioactive Wastes in Geologic Repositories," 10 CFR Part 60, June 21, 1983.

9. Swiss National Cooperative for the Storage of Radioactive Waste, "Nuclear Waste Management in Switzerland: Feasibility Studies and Safety Analyses," Project Gewahr Report NGB 85-09, June 1985.