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EXECUTIVE-STYLE BRIEFINGS
ON
SELECTED REPOSITORY DESIGN ISSUES

By

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REA

INTRODUCTION

This document is a collection of executive-style briefings on selected repository design issues. Most of the briefings discuss differences between the U.S. repository design bases presented in "U.S. Working Draft on Repository Physical Descriptions in a Salt Formation" (Reference 1), prepared in support of INFCE discussions of May 1978 and the FRG-Netherlands design bases, presented in "Design Study of a Radioactive Waste Repository to be Mined in a Medium-Size Salt Dome" by Hamstra and Velzeboer, Netherlands Energy Research Foundation, January 1978 (Reference 2). Advantages and disadvantages of the two sets of design bases are discussed, and the impacts of adopting either of these bases on the other's programs and positions are identified.

The topics covered in this report are as follows:

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DOMAL VS. BEDDED SITING

The U.S. repository description (Reference 1) submitted at the May 1978 INFCE meeting in Vienna is for a bedded salt site. The FRG-Netherlands design bases described in Reference 2 is for a salt dome site. This difference in siting raises two basic design issues: the lateral extent available for development and the thickness of the host formation available for development. These differences in physical shape impact a number of design parameters.

The restricted lateral extent of most salt domes leads to:

- Restricted amounts of heat-generating waste that can be buried at the site.
- Multi-level designs that allow lower heat loads at each level while maintaining similar thermal loads per plan view as for a single-level repository. This results in lower peak temperatures in the host formation.
- A higher percentage of space at each repository level being associated with shafts, support facilities, etc., rather than waste burial.

On the other hand, the thickness of salt domes allows the multi-level designs with their associated advantages, but at higher costs.

In general, the thickness of a bedded salt site may restrict the repository to designs in which no developed area overlies another developed area. However, the amount of heat-generating waste that can be buried per earth surface area is similar to that which can be buried per surface area for a dome site, since far-field thermomechanical effects determine the heat load. Because these far-field effects dominate, the plan view thermal loading* is the important thermal loading design parameter. (See the mini-position paper on surface uplift.)

*Plan view thermal loading may be defined as the kW of heat generation per hectare of earth surface overlying the waste burial area.

Bedded salt sites are apparently fairly common, with sufficient lateral extent to allow large repositories (1000 hectares or more). Therefore, it appears that in general more waste can be handled at a bedded salt site than at a domal salt site, which could lead to more efficient, or more economical, utilization of shafts and surface facilities at a bedded salt site if the amount of nuclear waste dictates a large site. —

In addition to the differences in physical shape of domal and bedded sites, the internal physical structures of the two types of sites tend to be distinctive, and the type and volume of impurities in the halite may differ.

Regardless of whether the halite is now a bedded or domal structure, most halite was originally deposited in restricted basins at a seawater concentration of approximately one-tenth its original volume. Commonly, halite is associated with beds of gypsum, anhydrite, and related evaporites which coprecipitate over a wide range of seawater concentrations. Continued concentration of seawater results in the complex precipitation of evaporites such as polyhalite, carnallite, and sylvite. In the sedimentary record, halite and other evaporites are almost always found interbedded with red shale, sandstone, and carbonate rocks.

The sedimentary character of halite in salt domes is shown by bedding. As the salt in the original flat-lying beds begins to flow into the domal structures, the halite is recrystallized, and the beds are intricately folded. Solution-mined cavities at the top of salt domes generally show very tight folds (isoclinal) with steep to vertical fold axes. In places, the folds may be interrupted by large masses of nearly structureless salt hundreds of feet across.

In the United States the salt in salt domes is almost pure halite. According to Kupfer (Reference 3), the anhydrite content in Gulf Coast salt domes is less than three percent. In addition, there are traces of dolomite, limestone, barite, pyrite, quartz, iron minerals, celestite, and sulfur. In contrast, salt in German salt domes is commonly interbedded with argillaceous and potash-rich beds and may contain larger amounts of polyhalite, carnallite, and sylvite. The differences in the core-rock composition of American as opposed to German salt domes reflect, in large part, the original purity of the source beds.

In summary, there is no clear answer to the question of whether the INFCE design should be for a bedded or domal salt site; however, the decision greatly impacts the repository's underground layout. Since the U.S. designs that have been prepared for INFCE are for a bedded site, it would be easier to prepare a bedded site repository description for the new INFCE effort.

REFERENCES

1. U.S. Working Draft on Repository Physical Descriptions in a Salt Formation, INFCE/WG7/10, May 1978.
2. Design Study of a Radioactive Waste Repository to be Mined in a Medium Size Salt Dome, Hamstra and Velzeboer, Stickting Energieconderzoek Centrum Nederland, January 1978.
3. Structure of Salt in Gulf Coast Domes: Symposium on Salt, by D. H. Kupfer, Northern Ohio Geol. Soc., Inc., Cleveland, Ohio, pp. 104-123.

SHAFTS - NUMBER AND UTILIZATION

Shafts provide a link between the repository surface facilities and the subterranean storage areas. These shafts serve a multitude of functions and, depending upon the complexity of the repository design, can either be segregated for particular uses or constructed as a multipurpose passageway. The two repository designs under review provide contrasting views on the employment of such shafts. The FRG-Netherlands design calls for construction of two multipurpose shafts centered within the repository area (Reference 2, Figure 24). Although little information is included in this report concerning the shafts and their usage, it is assumed that all repository requirements could be provided by these structures. The United States design is one of complete separation of shaft responsibilities. In the U.S. design (Reference 1), five distinct shaft structures would be sunk into the disposal horizons. These have responsibilities as follows: one for transfer of canistered waste, one for transfer of low-level waste, one each for supply and exhaust air, and one for men and materials access.

Advantages of the United States approach include:

- Safety and reliability of operation
- Redundancy of services provided through existence of other shafts
- Efficient, high-capacity mining and placement
- Segregated mining and placement operations
- Greater control of working environment through better ventilation control
- Segregated handling of waste area ventilation air and mining area ventilation air.

Disadvantages of United States approach:

- Increased cost and construction compared to less complex system
- Increased long-term geologic containment risks associated with multiple shaft penetrations.

Advantages of FRG-Netherlands approach:

- Decreased cost and construction compared to United States approach
- Fewer penetrations into geologic media.

Disadvantages of FRG-Netherlands approach:

- Complex shaft design and operational procedures to handle multi-purpose concept, yet provide personnel safety and operational reliability
- Segregation of waste handling from other operations within shafts not clearly defined.

The advantages associated with this more complex and costly shaft network are in the ease of operation, reliability, and safety for working personnel. However, the concept of multiple shaft sinking is not totally in concert with the concept of maintaining the greatest degree of geologic containment. In actual practice, the overriding concern may reside in the economy of scale. For a high-capacity installation, the large volumes of waste to be handled, in addition to the associated increased mining activities, may warrant the use of a multi-shaft complex in order to maintain smooth operation. In a low-capacity facility, a smaller number of shafts (although not less than two for safety reasons) may be found appropriate, providing that waste operations and personnel could be sufficiently separated and the safety and reliability of operation assured.

In a two-shaft network, each shaft must be of sufficient size and hoist capacity to provide for transporting the heavy machinery and large amounts of excavated material required during mining activities, provide the advantages of personnel and waste package transport without undue risk or exposure, yet keep up with the demand of incoming waste receipts. Combining any two of these requirements, in addition to providing for either supply or return air capacity within any one shaft,

will require a rather sophisticated design. In the event of a major shaft malfunction, such a combination could completely paralyze the repository storage capability.

REFERENCES

1. U.S. Working Draft on Repository Physical Descriptions in a Salt Formation, INFCE/WG7/10, May 1978.
2. Design Study of a Radioactive Waste Repository to be Mined in a Medium Size Salt Dome, Hamstra and Velzeboer, Stickting Energieonderzoek Centrum Nederland, January 1978.

MULTI-LEVEL REPOSITORY

In contrast to the single disposal horizon repository design presented by the U.S., the FRG-Netherlands repository makes use of a multi-level storage concept. This concept differs from the U.S. design in that instead of segregating the storage of waste within a relatively narrow disposal horizon, the wastes are stored in overlapping horizontal areas within a thick geologic formation. As can be expected, these concepts are best suited for different types of salt formations. Bedded salt is appropriate for the single horizon concept in which large horizontal areas are available, and domed salt for the multi-layered design in which the horizontal extent of the deposit may be limiting. However, the multi-level design is applicable to thick horizons of bedded salt or to sites with multiple salt beds and can provide certain advantages in its use.

Advantages of multi-level designs:

- Reduction of horizontal extent of repository area is reduced.
- More efficient excavated material handling and placement procedures due to decreased travel distances within each storage level
- Increased bulk volume for removal of decay heat by dividing the heat generation waste burial onto several levels, resulting in cooler peak temperatures in the immediate vicinity of the repository
- Segregation of waste types according to burial depth.

Disadvantages of multi-level designs:

- Requires thick geologic medium to assure long-term containment
- Requires a higher percentage of space at each repository level being associated with shafts, support facilities, etc., rather than waste burial

- Complicates mine layout of corridors, ventilation system and shaft support system and hence increases repository costs.

Advantages of single-horizon design:

- Simplifies layout and operation of the mine.

Disadvantages of single-horizon design:

- Requires large horizontal area for storage of waste
- Does not lend itself to efficient handling of excavated material and waste due to long haulage distances from shafts.

For a discussion of the horizontal areal savings to be made by adopting a multi-level approach over a single horizon concept, see the section within this report on "Acreage Requirements for Reprocessing Wastes and Spent Fuel for Various Burial Schemes."

SUBTERRANEAN ACREAGE REQUIREMENTS

Acreage requirements for a nuclear waste repository are based on the assumed amount of waste to be stored, the types of waste to be stored, the thermal loading criteria of the rock formation, geologic properties of the rock, and the burial scheme used.

The types of waste to be isolated in the repository will dictate the storage methods that could be used (i.e., high activity waste should be buried, while low activity waste could be stacked). The thermal loading criteria of the rock (kW/ha) will be used to determine the amount of heat-generating waste that can be stored in a unit area of the repository. Geologic properties lead to the minimum spacing of drilled holes that will not affect rock integrity. Burial schemes involve the arrangement of wastes in the repository (e.g., segregated areas vs. integrated placement) and include the method of disposal, such as stacking or burying.

The burial schemes considered by the U.S. (in Reference 1) and the FRG-Netherlands (in Reference 2) are, respectively, a fully segregated approach (different types of waste in different repository areas) and a bulk disposal approach for all non-high-level waste with segregation of HLW. For each scheme, acreage requirements have been derived using the above-stated criteria. In comparing the acreage for the two approaches, the waste from 1000 GWe nuclear power production was considered with a reactor fuel economy of 1 part MOX (mixed oxide) fuel to 2 parts UO_2 fuel (resulting in 16 kW/m³ of HLW).

United States Approach

The U.S. considered a fully segregated burial scheme. Each type of waste (high, medium, low) has a separate area of the repository devoted to it. A description of the reprocessing waste burial scheme is:

- All canistered waste (HLW, MLW, cladding) is buried in holes drilled in the floor of specifically designated rooms.

- LLW drums are stacked on pallets and stored on the floor of LLW rooms.
- Single-level storage - an areal view of this repository would show no overlapping of waste areas.

The acreage requirements for this burial scheme based on 1000 GWe reactor economy and 2.9 kW/canister of HLW (16 kW/m³) are:

- HLW area - 127 hectares
- MLW/Cladding area - 163 hectares
- LLW area - 6 hectares
- Central core area (shafts, offices, etc.) - 112 hectares
- Total for this scheme - 408 hectares.

For the burial of waste from the spent fuel cycle, the U.S. considered a similar burial scheme:

- PWR and BWR canisters buried in the floor of rooms in specifically designated areas of the repository
- LLW drums are stacked on pallets in the LLW rooms
- Single-level storage - no overlapping of storage areas.

The acreage requirements for this burial scheme based on a 1000 GWe reactor economy and one PWR or 3 BWR's per canister are:

- PWR area - 91 hectares
- BWR area - 41 hectares
- LLW area - 9 hectares
- Central Core area (shafts, offices, etc.) - 49 hectares
- Total for this scheme - 190 hectares.

FRG-Netherlands Approach

The FRG and the Netherlands considered a bulk disposal method for all non-high-level wastes. Also considered was a multi-level arrangement having an equal area per level. Their burial scheme (Configuration 1) for reprocessing waste and waste from hospitals and laboratories involves:

- Canisters of HLW buried in the floor of storage rooms in the lower two levels of the three level design
- All non-high-level wastes (MLW, LLW) are disposed of in bulk. These wastes are dumped into large bunkers or cavities excavated in the floor of rooms on the first level of the repository.

The acreage requirements for this burial scheme based on 1000 GWe reactor economy and 16 kW/m^3 for HLW (originally 12 kW/m^3 in Reference 2) are:

- HLW area - 111 hectares per level or 222 hectares total
- Bulk disposal area - 75 hectares (110 bunkers assuming a 60% volume packing factor)
- Central core area - 12 hectares per level
- Total subterranean area - 333 hectares
- Total projected surface area - 123 hectares.

The FRG-Netherlands report did not consider the spent fuel reactor strategy.

Alternative Approach

An alternative burial scheme that can be used for comparison of acreage requirements involves an integrated method of storage. "Integrated" refers to the placement of different waste types in the same repository rooms. For example, this burial scheme for reprocessing waste could be as follows:

- HLW and cladding canisters are buried in the floors of rooms. These two wastes are buried in the same room while maintaining the same HLW thermal loading, so that no additional acreage is taken up by the cladding waste.
- Drums of MLW and LLW are stacked on pallets on the floor of previously filled HLW and cladding rooms.

The maximum acreage utilized by this scheme would be only that taken up by the HLW canisters in addition to that required for shafts, service areas, etc. Assuming the INFCE arising data, the acreage requirements for waste based on a 1000 GWe reactor economy would be 127 hectares. If the central core area were specifically designed for this integrated approach, the acreage requirement might be reduced to something on the order of 50 hectares. Consequently, the total acreage for this repository concept might be as low as 175 hectares.

For the spent fuel strategy, an integrated approach would not save as much acreage because about 95% of the waste area is taken up by heat-generating waste (PWR, BWR) whose loading density is limited by thermal constraints.

For a reprocessing strategy with a 1000 GWe economy, the bulk disposal, multi-level concept (FRG-Netherlands) requires about a third of the acreage that would be utilized by the fully segregated approach (U.S.). With the integrated approach and INFCE arisings, the acreage requirement might be only about 1.4 times that of the FRG-Netherlands approach. However, much of this difference is due to the difference in central core area of the repository (shafts, offices, etc.).

REFERENCES

1. U.S. Working Draft on Repository Physical Descriptions in a Salt Formation, INFCE/WG7/10, May 1978.
2. Design Study of a Radioactive Waste Repository to be Mined in a Medium-Size Salt Dome, Hamstra and Velzeboer, Stickting Energieconderzoek Centrum Nederland, January 1978.

MULTIPLE CANISTERS PER HOLE; MULTIPLE ASSEMBLIES PER CANISTER

The present United States design basis (Reference 1) for the INFCE repository description places 1 PWR assembly or 3 BWR assemblies in a canister in the case of reactor strategy 1 (spent fuel disposal) or about 0.18 m³ of HLW per canister for reactor strategy 2. On the other hand, there is no FRG-Netherlands description for reactor strategy 1 and a smaller canister of HLW that contains 0.05 m³ of waste. The present United States design basis places only one canister per hole and allows the holes to be drilled at a minimum pitch of 1.8 m. The FRG-Netherlands basis considers three approaches that are presented in the Hamstra and Velzeboer report (Reference 2): 1) a 9 m hole in which 3 HLW canisters are stacked and covered by a 3 m shield (Reference 2, Figure 30 and p. 11); 2) a hole approximately 55 m deep in which 25 canisters are stacked; these are spaced at a 34.5 m pitch (Reference 2, Figures 25 and 29); and 3) a very-deep-hole concept (600 m deep at about a 75 m pitch; see Reference 2, Section 9). This last concept, the very deep hole, is not within the present state-of-the-art for dry-hole construction. All further discussion of this concept is in another mini-position paper, and the concept will not be further discussed here.

The question investigated in this position paper is what types of impacts are associated with emplacing multiple canisters in a hole and, for spent fuel, multiple assemblies per canister. The impacts cover a broad spectrum of issues, including:

- Formation thickness requirements
- Emplacement hole drilling technique
- Pitch between emplacement holes
- Emplacement-hole vertical accuracy
- Mechanical handling considerations
- Operational safety considerations
- Thermal considerations
- Criticality considerations.

There would be little, if any, difference in formation thickness requirements between the United States approach, which requires about a 6 m hole, and the Netherlands concept of a 10 m hole; however, the deeper holes may cause some impact. The United States repository description notes that a minimum host formation thickness of about 60 m seems adequate (Reference 1, p. 2-2). This certainly would not be the case for a 55 m emplacement hole, but might accommodate a 10 m hole. Obviously, the concern over host formation thickness applies to bedded sites rather than to domal sites. For domal sites, the major consideration becomes an increased probability of intersecting a "large" impurity pocket with the increased hole depth.

The present United States descriptions have a room height that is sufficient to allow a single-section auger or drill stem construction of the emplacement holes. If deeper holes, even 10 m holes, were accepted, a multiple-section auger or drill stem would be used. This latter technique may be slightly more costly per hole-foot; however, since fewer hole-feet would be required (There is only one shielding plug per three HLW canisters.), the total cost might be less. Further, it might be possible to reduce room height if multiple-section drilling were employed.

The emplacement of multiple canisters per hole increases the pitch between the emplacement holes if the same areal thermal loading is maintained. This increased pitch would allow the holes to be drilled with less vertical accuracy while maintaining a minimum separation between holes. This could result in more rapid drilling at less cost per hole-foot.

The mechanical handling associated with the emplacement of more than one canister per hole would be more complex than the United States design of a single canister per hole. Operational safety considerations need to be factored into the mechanical handling design. These include minimizing the probability of dropping one canister on top of another in such a fashion that a canister might rupture. Using a typical stainless steel canister design, the probability of rupture even if a canister were dropped the full extent of a 10 m hole would probably be very small; however, for a 55 m hole, the probability of rupture from a drop would

would not be inconsequential. Also, operational procedures for canister emplacement would have to consider radiation shine from a hole which is accepting additional canisters. It is likely that the mechanical handling associated with multiple canisters per hole can be designed for safe operation in the case of 10 m holes, but would be more difficult for holes as deep as 55 m.

The multiple HLW canisters per hole in the FRG-Netherlands designs, coupled with the thermal loadings per canister and the associated areal thermal loadings in their design basis, should not cause any of the United States design thermal criteria to be exceeded. It appears that, in general, the loading of multiple canisters per hole at acceptable average areal thermal loadings for single canisters per hole would not cause any of the thermal or thermomechanical criteria to be exceeded; however, to be certain of such factors as maximum allowable waste temperatures, more detailed calculations should be performed. Although the FRG-Netherlands design does not consider the emplacement of spent fuel, it appears that a similar conclusion can be drawn with respect to the thermal impacts of multiple canisters of spent fuel per hole. That is, United States thermal and thermomechanical criteria would probably not be exceeded as long as acceptable areal thermal loads are maintained. The possible exception to this may be the maximum allowable cladding temperature.

The other consideration associated with multiple spent fuel canisters per hole or with multiple fuel assemblies per canister is associated with criticality considerations. A conservative criticality calculation would assume that the fuel in the canisters was fresh. It has been shown that in a fully moderated state, two closely-packed fresh PWR assemblies or three fresh BWR assemblies can approach criticality (Reference 3). However, canisters can be designed to assure that, as long as they remain intact, criticality is not reached. The placement of multiple canisters per hole with multiple assemblies per canister should be analyzed in more detail to determine if a reasonable scenario can be envisioned in which a critical configuration is attained.

In summary, at this time, nothing is known that would rule out the possibility of the United States' accepting a repository design in which

emplacement holes of about 10 m depth containing a few (e.g., three) HLW canisters. Longer emplacement holes (on the order of 55 m or more) raise concern over increased probability of operational accidents and the possible consequences of such accidents. The emplacement of two or three spent fuel assemblies per hole could be acceptable, but thermal and criticality considerations should be analyzed further.

REFERENCES

1. U.S. Working Draft on Repository Physical Descriptions in a Salt Formation, INFCE/WG7/10, May 1978.
2. Design Study of a Radioactive Waste Repository to be Mined in a Medium Size Salt Dome, Hamstra and Velzeboer, Stickting Energieconderzoek Centrum Nederland, January 1978.
3. Criticality Analysis for the McGuire Fuel Pool, Simmons, Albert, and Gritzner, Science Applications, Inc., SAI-75-688-LJ, 26 November 1975.

OPTIONAL LONG-HOLE CONCEPT

The FRG-Netherlands design study discusses the option of disposing of high-level waste canisters in deep, dry, vertical bore-holes. These bore-holes are proposed to begin at the lower repository level (600 m) and continue to depths ranging from 100 m to 600 m (total of 700 m to 1200 m below the surface).

While this concept would reduce the mining effort involved in corridor (roadway) excavation, there are a number of problems inherent in this approach. First, the technology does not exist today to drill dry bore-holes to that depth while maintaining a given diameter. According to the Netherlands report, the deepest possible bore-hole in rock salt using proven techniques is currently no deeper than 55 m. Furthermore, with a very deep bore-hole (600 m) designed for about 300 HLW canisters, each hole would handle about 90 days of waste arrivals, according to the FRG-Netherlands arisings (an average of 1250 canister per year). Two approaches might be employed in this case: emplacement of waste as it arrives, which requires the hole to remain accessible for some 90 days, or interim storage of waste onsite until a sufficient quantity arrives to fill a hole. In either case, there are increased safety hazards and a higher potential for radioactive release to the occupational and public environments. In addition, the long-hole concept requires a thicker host formation and raises some serious questions about the reliability and safety of waste emplacement equipment and procedures. (See mini-position paper on multiple canisters per hole.)

BULK DISPOSAL

A fundamental difference between the United States repository design (Reference 1) and the FRG-Netherlands repository design (Reference 2) is the disposal method for non-high-level wastes. The FRG-Netherlands approach is to dispose of all low- and medium-level solidified radioactive waste (No mention was made of cladding waste as a separate category.) in cylindrical bunkers (cavities) excavated in the floors of the top level of the repository. The waste (presumably in a container) would be dumped down a chute into the bunker for permanent disposal. The United States approach is a more orderly method, whereby medium-level waste and cladding waste are packaged in canisters and lowered into holes in the repository floor. Disposal holes are arranged in rows, with only one canister occupying each hole. After canister emplacement, the hole is sealed. Low-level waste (LLW) is packaged in drums and stored on pallets arranged in rows in separate LLW storage rooms.

As described in the FRG-Netherlands report, the disposal bunkers are roughly 8 m in diameter and 50 m in height, located just below the floor of the upper repository level (500 m depth). Assuming a 60% volume packing factor caused by random ordering of the containers, the bunker could hold approximately 1300 m³ of waste. This volume corresponds to about 30 days of waste receipt, based on the FRG-Netherlands arisings. The bunker is filled by means of a chute through which waste is dumped. The chute is covered by a one-way flap (specified as rubber) to prevent radioactive material from escaping. Other openings into the bunker include a lid, which is sealed, and a ventilation borehole. Presumably, to maintain a negative pressure at the flap and prevent the leakage of airborne radioactive particulates, air must be drawn out through the ventilation port. This air is filtered immediately upon leaving the bunker in case the air is contaminated with radioactive particulates.

Safety concern arises over the bulk disposal method proposed by FRG-Netherlands. As it appears, the contained waste is dropped into the bunker and allowed to freefall onto the pile of previously dropped containers. Even if one assumes that the waste form is extremely stable

(i.e., solidified in concrete), such a drop could still cause damage to the package and pulverize some waste, which consequently may become airborne in the cavity. A release of this type can be compared with accidents to cemented wastes as discussed in Reference 3. The maximum airborne release resulting from an impact and rupture of the container could be on the order of 85 Ci. During normal ventilation, filtration of greater than 99.97% of the particulate matter will be accomplished, but in an abnormal situation (i.e., ventilation failure eliminating the negative pressure), this contamination may escape the flap and enter areas occupied by personnel. In essence, by allowing this type of release to occur regularly, the probability of significant releases to the environment is greatly increased.

The United States approach of orderly disposal of non-high-level wastes, coupled with the more sophisticated U.S. ventilation system design, eliminates the safety concern over the environmental release of radioactive particulates. While the United States approach is more costly than the bulking method, the safety margin for storage of this waste type is maximized. If the U.S. were to accept the FRG-Netherlands bulk disposal method as a design basis, U.S. NRC licensing requirements for construction and operation may not be met because of the potential for radioactive release. The impact on the FRG-Netherlands repository program of accepting the U.S. approach to the storage of non-high-level waste would entail a redirection of their upper-level repository design layout to include rooms for individual waste packages and could lead to a consideration of storing other wastes, along with the HLW, in the lower levels.

REFERENCES

1. U.S. Working Draft on Repository Physical Descriptions in a Salt Formation, INFCE/WG7/10, May 1978.
2. Design Study of a Radioactive Waste Repository to be Mined in a Medium Size Salt Dome, Hamstra and Velzeboer, Stickting Energieconderzoek Centrum Nederland, January 1978.
3. Office of Waste Isolation/Union Carbide Corporation, Nuclear Division, Technical Support for GEIS: Radioactive Waste Isolation in Geologic Formations, Volume 23, Environmental Effluents, prepared by Science Applications, Inc., Oak Ridge, TN, April 1978.

SEPARATION OF WASTE AND MATERIAL HANDLING

Four operations occur simultaneously in the subterranean portion of a waste repository: mining, drilling of emplacement holes, waste emplacement, and backfilling of storage rooms and access corridors. Each storage area undergoes these operations in the sequence listed above, at a rate compatible with the receipt of the waste at the surface facility. The repository designs presented by the FRG-Netherlands and United States (Reference 1) and the FRG-Netherlands (Reference 2) delegations differ in the type of mine layout used to accomplish these repository operations. The United States concept of complete isolation of mining, placement, and ventilation activities involves a more complex repository design and, hence, greater cost and mining effort. Also, this separation concept requires additional shaft construction (for separate ventilation, waste handling, and men and materials transfer), which may be less desirable in the light of minimizing formation penetrations for long-term geologic containment. The United States design seems more suited to a high capacity repository facility where construction activities must occur at a rapid pace in order to keep up with incoming waste shipments. The FRG-Netherlands design involves limited segregation of the four repository activities. For a low capacity facility, this design might prove favorable because, for example, mining could be temporarily halted during waste placement operations, which would lessen the safety hazards associated with combined usage of the corridors.

Advantages of the United States approach include:

- Separation concept provides greater personnel safety from radiation exposure and mining accidents.
- Separation increases control over ventilation streams.
- Mining operations are kept totally segregated from placement activities.
- Individual shaft network promotes ease of operation and increased efficiency.

Disadvantages of United States approach:

- Construction costs and complexity of system is greater than for the non-segregated system.
- Additional shaft construction is not desirable in the light of the long-term geologic containment requirement.

Advantages of FRG-Netherlands approach:

- Simplified concept decreases significantly the magnitude of the construction activities.
- Cost of multi-purpose corridor concept is probably lower.
- Shaft penetrations into the geologic medium are minimized.

Disadvantages of FRG-Netherlands approach:

- Interaction between mining activities and placement operations can occur, hence logistics and safety problems are magnified.
- Multi-purpose shaft designs would restrict the flexibility and ease of operation associated with segregated systems.

The FRG-Netherlands multi-level repository design (Reference 2, Section 6.0) involves the development of one main corridor on each disposal level (Reference 2, Figure 26). This corridor serves three main purposes: as a travelway for mining equipment, personnel, and excavated material; as a travelway for waste placement vehicles; and as a supply airway for branch corridors and working areas. In addition, travelways on the intermediate level would be provided for the handling of excavated salt from bulk storage areas and to serve as the return air passage for the upper and lower levels of the mine. The main corridor provides access to waste storage roadways and excavated material handling areas, as well as to the two main shafts (Reference 2, Figure 33). Operations within the mine would involve excavation of branch corridors and storage units, with subsequent salt disposal down the tippler/chute to bunkers at the bottom of the proposed mine area. After construction of storage areas has begun, waste emplacement would occur in the rooms open to transporter access. As the storage corri-

dors are filled with waste, backfill procedures would begin in which previously excavated salt and possibly some reactor decommissioning rubble is placed into the corridors, and the entryways are sealed. The sequencing of this mine development within the FRG-Netherlands repository calls for preceding the disposal operations by the mining of at least one branch road in order to separate the two activities. However, in spite of this separation, transportation of the waste would occur in the same haulageways, perhaps simultaneously with mining equipment transport and excavated material handling.

The United States design (Reference 1, Section 4.4.1) calls for four development entries or corridors. These corridors run the entire length of the single layer repository and are utilized as follows: one for waste placement, one for mining exhaust air, and two for men and excavation materials (Reference 1, Figure 4-2). The men and materials corridors accommodate the mined salt conveyor and serve as a travelway for mining equipment, trucks, and personnel. Supply air flows through all corridors except the mining air exhaust corridor. The waste placement corridor provides transporter access to previously mined storage areas. This system of individual corridors ensures that the mining and waste placement operations are separate. Crossovers are minimized by judicious sequencing of operations, and separation is also maintained by use of above-ceiling conveyors. In addition to this separation concept at the mine level, separation is also assured by the use of a segregated shaft network as described in the "Shafts - Number and Utilization" section of this report.

Both repository designs involve the use of an excavated material handling area below the storage horizons. However, the United States design has provisions for a separate men and materials shaft to accommodate the large volume of excavated material, as well as personnel and mining equipment.

The major difference between the FRG-Netherlands design and the United States layout is in the concept of complete separation of mining, and waste placement activities. Major safety concerns may arise over the FRG-Netherlands design where haulageways serve these dual purposes. Utilizing separate corridors virtually eliminates the possibility

of exposure of mining personnel to potential contamination from waste handling and decreases the risk of vehicular accidents involving waste transporters and mining equipment.

REFERENCES

1. U.S. Working Draft on Repository Physical Descriptions in a Salt Formation, INFCE/WG7/10, May 1978.
2. Design Study of a Radioactive Waste Repository to be Mined in a Medium Size Salt Dome, Hamstra and Velzeboer, Stickting Energieconderzoek Centrum Nederland, January 1978.

CONCERN OVER FLOODING

A basic difference exists in the repository design bases presented by the U.S.A. (Reference 1) and the design bases presented as a possible FRG-Netherlands approach (Reference 2). The U.S. approach emphasizes a careful site selection process that leads to the identification of an acceptable site with low groundwater hydraulic gradient and to the maintenance of a sufficiently low thermal loading to assure that the host formation and any adjacent impermeable layers remain intact, thus minimizing potential water sources and isolating the waste from such groundwater sources. On the other hand, the FRG-Netherlands design bases employ several engineering design features and construction techniques that appear to show a concern for flooding. These include "watertight dams" sealing roadways in which waste is being or has been emplaced, watertight seals above each HLW disposal hole, watertight shaft linings, watertight seals for all levels of decommissioned shafts (especially in the salt overburden transition zone), a watertight seal at the surface penetration of each shaft, and delaying the drilling of HLW disposal holes until just before waste emplacement.

Advantages of the U.S. approach include:

- Such sites exist in the U.S.
- The best way to assure no water intrusion is that water be unavailable.
- A less complicated design is required.
- The potential issue of a repository flood as the worst potential radionuclide release mechanism is minimized, if not eliminated.

Disadvantages of U.S. approach:

- Potential sites are limited to fewer locations.
- Untested shaft and borehole sealing technology is necessary, but not as heavily as FRG-Netherlands design concept depends on these.

Advantages of FRG-Netherlands approach:

- Potential site location is less restrictive.
- More control over a possible flooding of the repository during operational phase is provided.

Disadvantages of FRG-Netherlands approach:

- A more complicated engineering design is required.
- Man-made barriers to assure no flooding of areas containing wastes, and these barriers may not be effective for long enough to assure no nuclide migration from the site
- Licensing a repository design in which man-made barriers were to minimize flooding effects over thousands of years would be difficult, if not impossible.

The major impact of accepting the FRG-Netherlands design philosophy lies in complicating the INFCE repository design and possibly opening the questions of 1) whether the U.S. design should include such features and 2) whether the U.S. should consider flooding a credible accident and analyze its consequences.

The major impact on the FRG-Netherlands repository program of accepting the U.S. design philosophy would stem from an interpretation that man-made barriers are insufficient to assure no flooding and consequently to assure containment. If their acceptance of the U.S. design philosophy were so interpreted, then their site-selection program could be drastically affected.

One argument for accepting the U.S. design philosophy for INFCE purposes stems from the minutes of the May 10 meeting of Subgroup A of W.G.7, which indicates that two repository concepts are to be investigated: a "wet" concept and a "dry" concept. The "wet" concept is to be in granite, while the "dry" concept is to be in salt. A counter to this argument could be that, although the repository host formation in the case of salt is "dry," the overlying regions are not necessarily "dry." Consequently, flooding could occur through water inflow through the shafts or other bore-holes. This counter argument once again

raises the question of the ability to construct watertight seals around shaft openings, shaft sealing, and borehole sealing.

REFERENCES

1. U.S. Working Draft on Repository Physical Descriptions in a Salt Formation, INFCE/WG7/10, May 1978.
2. Design Study of a Radioactive Waste Repository to be Mined in a Medium Size Salt Dome, Hamstra and Velzeboer, Stickting Energieconderzoek Centrum Nederland, January 1978.

THERMAL LOADING CONSIDERATIONS

The heat generated within the repository due to the emplacement of spent fuel or HLW determines temperature increases within the repository and the surrounding geologic media. These temperature increases strongly influence the design for the repository. The important thermal loadings include:

- Canister loading (kW/canister at emplacement)
- Emplacement hole loading (kW/hole at emplacement)
- Local areal loading (kW/hectare associated with a given emplacement hole)
- Plan view thermal loading (average kW/hectare of earth's surface overlying the waste burial area)

Values for these loadings differ between the U.S. design bases described in Reference 1 and the FRG-Netherlands design bases described in Reference 2. Reference 1 describes U.S. designs for spent fuel disposal and reprocessed waste disposal, whereas Reference 2 describes various FRG-Netherlands designs for reprocessed waste disposal. Thermal loadings for the heat-generating waste areas are presented in the following table:

	<u>U.S.-Spent Fuel</u>	<u>U.S.-HLW</u>	<u>FRG-HLW</u>
Canister Loading (kW/canister)	0.55	2.9	0.6
Emplacement Hole Loading (kW/hole)	0.55	2.9	1.8
Local Areal Loading (kW/hectare)	320	370	180
Plan View Thermal Loading (kW/hectare)	210	290	315

The U.S. data in this table have been adjusted for the appropriate waste composition (a 2:1 U-fuel-to-MOX mixture); however, the values are still reflective of the repository design presented in Reference 1. The FRG-Netherlands values have not been adjusted to this mixture, although there is evidence that the waste discussed in Reference 2 is

from only U-fuel. If these values were so adjusted, then the canister loading would be about 0.8 kW, and the emplacement hole loading would be about 2.4 kW. The spacings between holes could be adjusted to maintain the Reference 2 design values for the local areal loading and the plan view thermal loading.

The advantages of the US-HLW design thermal loadings include:

- All U.S. thermal criteria (See the thermal criteria discussion paper.) are met by the design.
- More HLW is placed in each canister, which leads to the handling of fewer canisters.
- Higher density of HLW burial locally yields more waste buried per given amount of rock excavated.
- The plan view thermal loading is well below the thermal criteria of 370 kW/hectare and assures formation stability and acceptable surface uplift.
- The design appears to meet the FRG-Netherlands thermal criteria of 100°C maximum bulk salt temperature.

Disadvantages of the US-HLW design thermal loadings include:

- If room and pillar stability were not considerations, it would be feasible to place more waste per room (higher local areal loading), yet maintain a plan view thermal loading less than 370 kW/hectare.
- If the FRG-Netherlands maximum salt temperature of 150°C were adopted, the design would have to be modified. For example, if the 370 kW/hectare were maintained, the canister loading would have to be reduced to about 1.4 kW. Conversely, if the 2.9 kW per canister were maintained, the local thermal loading would have to be reduced to about 250 kW/hectare. Note that the maximum salt temperature of the present U.S. design is about 190°C.
- Perhaps a repository layout with more efficient space utilization could result in more HLW per hectare of repository area for such waste.

Advantages of the FRG-Netherlands design thermal loadings include:

- Lower temperatures prevail in the repository than for the U.S. design.
- All U.S. thermal criteria are very easily met, and the more stringent FRG-Netherlands thermal criteria appear to be met.
- Formation stability and acceptable surface uplift should prevail.

Disadvantages of the FRG-Netherlands design thermal loadings include:

- Less waste per can, resulting in more canisters to be handled
- Lower local areal loadings, resulting in less waste burial per given amount of rock excavated
- If U.S. thermal criteria were adopted, a much higher density of waste emplacement would be possible.

No comparison of spent fuel design is possible because the FRG-Netherlands report does not consider this reactor strategy. The spent fuel design presented in Reference 1 meets all appropriate U.S. thermal criteria, with the possible exception of the maximum spent fuel pin temperature of 200°C. A detailed analysis of the three-BWR canister configuration needs to be done to determine if this criteria can be met. Preliminary analyses of a single-BWR canister configuration indicates a borderline situation with respect to meeting the 200°C criteria.

REFERENCES

1. U.S. Working Draft on Repository Physical Descriptions in a Salt Formation, INFCE/WG7/10, May 1978.
2. Design Study of a Radioactive Waste Repository to be Mined in a Medium Size Salt Dome, Hamstra and Velzeboer, Stickting Energieconderzoek Centrum Nederland, January 1978.
3. The Effects of Variations of Selected Repository Design Parameters for Salt and Granite Host Rocks, Y/OWI/SUB-78/22340/3, Office of Waste Isolation, May 1978

THERMAL CRITERIA

Temperature and thermomechanical criteria limit the thermal loadings in the repository and therefore have a direct bearing on the repository design. The temperature and thermomechanical criteria assumed for the U.S. design bases for the repository in salt, as described in Reference 1, include the following:

U. S. Thermal Criteria

- Waste temperature in HLW repository <500°C
- Fuel pin temperatures in spent fuel repository <200°C
- Salt temperatures <250°C
- Surface uplift <0.2% of repository depth, 2 m per km
- Temperature rise at surface <0.5°F

The temperature criteria assumed for the FRG-Netherlands design bases, as described in Reference 2, include the following:

FRG-Netherlands Thermal Criteria

- Salt Temperatures <150°C
- Disposal area global temperatures, average temperatures in disposal area* <100°C
- Temperatures in mine gallery levels during required period of accessibility, neglecting mine ventilation <60°C
- Formation temperatures outside repository <60°C

*Strictly speaking, the term "global" refers to temperatures calculated in a global or far-field model, which takes no account of details of the waste distribution in the HLW disposal area. These temperatures most closely correspond to the volume-averaged temperatures predicted for this region.

The U.S. criteria attempt to take into account possible deleterious impacts on the waste matrix or spent fuel assembly integrity, upon the salt formation since the properties of domed and bedded salt above 250°C are not well-known, and upon possible adverse effects on the formation and at the surface due to unacceptable temperature increases. Shortcomings in the U.S. criteria include the fact that temperature limits to guarantee operational safety are not specified. Furthermore, appreciable amounts of impurities in the salt such as carnallite and anhydrite may be strongly affected at temperatures below 250°C, thus affecting the structural integrity of the repository.

On the other hand, the FRG-Netherlands criteria take into account these impurities, as well as the temperatures in areas of the mine where operations take place. The main drawbacks to this set of thermal criteria include the fact that the maximum salt temperature is probably too conservative, unnecessarily restricting local thermal loadings. In addition, no consideration is given to thermal impacts upon waste integrity; however, the designs in Reference 2 probably meet the U.S. thermal criteria associated with HLW. The far-field thermal limitation is specified in terms of temperatures rather than temperature increases and is specified in the vague terminology of a "maximum bulk temperature." Also, there is no clear presentation of the justification for the temperature limits in the FRG-Netherlands report.

For the present U.S. design bases, all of the FRG-Netherlands thermal criteria would have virtually no impact, with the exception of the limitation on maximum salt temperature. It would be difficult to satisfy the 150°C limit without major reductions to both local areal and individual canister loading design values.

All of the U.S. thermal criteria appear to be satisfied within the FRG-Netherlands design bases.

REFERENCES

1. U.S. Working Draft on Repository Physical Descriptions in a Salt Formation, INFCE/WG7/10, May 1978.
2. Design Study of a Radioactive Waste Repository to be Mined in a Medium Size Salt Dome, Hamstra and Velzeboer, Stickting Energieconderzoek Centrum Nederland, January 1978.

CRITIQUE OF THERMAL ANALYSIS FOR THE FRG-NETHERLANDS DESIGN BASES

A substantial portion of the repository design is based on thermal analysis to predict anticipated temperatures in given repository design bases. For the U.S. design bases, the thermal analysis involves a variety of models in order to understand the expected temperatures in different regimes (Reference 1), taking into account only the level of detail necessary to provide accurate calculations for the region of interest. The thermal analysis performed for the FRG-Netherlands design bases in Reference 2 employs a far-field, or "global," calculational model. In this model details of the repository design are ignored, and the heat sources are distributed homogeneously throughout a disc-shaped volume with dimensions roughly corresponding to the geometry of the HLW emplacement region of the repository. The model is simple and avoids difficulties associated with specification of boundary conditions, the complexity of modeling of fine details, and numerical stability and convergence. At the same time, this method leaves open for discussion the question of interpretation of temperatures predicted in the zone in the vicinity of the repository.

A second approximation made in the FRG-Netherlands analysis is the choice of thermal properties independent of temperature. Salt is known to have thermal conductivity which can depend on temperature. The assumption of a temperature-independent value for the thermal conductivity may strongly influence temperature predictions. A third approximation made is that the heat generation rate of the sources is strictly exponential, with a half-life of 30 years for 200 years, after which it takes a constant value.

The consequences of these three assumptions have been studied in a series of calculations using the HEATING-5 finite-differences heat conduction code. The repository models calculated were those referred to as Burial Configuration I and II by Hamstra and Velzeboer (Reference 2), a multi-layer repository, and a single-layer, long bore-hole repository, respectively. For the present calculation, the dimensions of the repository were chosen to reproduce these models. Simultaneous,

instantaneous loading was assumed for the heat sources. Boundary conditions were all chosen to be adiabatic but had little effect on the problem. The initial temperatures were chosen to have the values of the ambient temperature distribution given by Hamstra and Velzeboer. However, in contrast to the FRG-Netherlands analysis both the salt conductivity and HLW heat generation rate were chosen to have values assumed for the U.S. design bases (Reference 1). The salt conductivity is temperature-dependent and the heat generation rate falls off somewhat differently than a simple exponential in the time span of interest.

Figure 1 illustrates the results of the calculations. Except at the edge of the heat-generating region, the calculated temperatures for Burial Configuration I differ by 5% or less from the curves of Hamstra and Velzeboer. The values calculated at the edge of the repository differ from the Netherlands results by up to 30%, but this discrepancy could be due to a different numerical treatment of the nodal volumes in the two calculations. In the case of Burial Configuration II, the calculated results generally agree to within 10% of the Hamstra and Velzeboer results. Again, the results at the edge of the heat-generating region differed more strongly, by up to 25% in this case. In both configurations, agreement at points far removed from the heat-generating region is excellent. This agreement suggests that the constant thermal properties and exponential decay rate are adequate for this problem when the parameters are carefully chosen.

In order to evaluate the use of the global, or far-field, model to interpret temperatures within the repository, calculations were performed using a unit-cell model of the Burial Configuration I. The unit cell in this case has a radius of 6 m and contains a single bore-hole in each burial level. Each bore-hole contains 1.8 kW at emplacement. In the vertical direction the dimensions are the same as in Burial Configuration I. Adiabatic boundary conditions at the vertical wall produce the effect of an infinite array of sets of canisters with an average plan view loading of 316 kW/hectare. Surprisingly, the results for the unit cell agree very well with the global model. The results are also shown

in Figure 1. At the waste centerline in each model the temperatures differ by less than 2%, even at the depths corresponding to the level of the heat sources. These results suggest that the temperatures in the global model provide accurate reproductions of values predicted for this problem by both global and near-field models.

REFERENCES

1. U.S. Working Draft on Repository Physical Descriptions in a Salt Formation, INFCE/WG7/10, May 1978.
2. Design Study of a Radioactive Waste Repository to be Mined in a Medium Size Salt Dome, Hamstra and Velzeboer, Stickting Energieconderzoek Centrum Nederland, January 1978.

- Curves from J. Hamstra and P. Th. Velzeboer, ECN-78-023, 1978
- x Calculated from global model with temperature-dependent conductivity and U.S. design bases waste
- o Calculated from unit cell model

BURIAL CONFIGURATION I

BURIAL CONFIGURATION II

FIGURE 1

Comparisons of thermal calculations for FRG-Netherlands design bases repository

CRITIQUE OF SURFACE UPLIFT CALCULATIONS

The degree of surface uplift or subsidence due to thermal stresses is a measure of the disturbance to the rock mass overlying the repository. The amount of disruption that can be tolerated depends upon a specific site, and it is difficult to set a meaningful limit to the vertical surface movement. The studies of surface uplift to date for both the U.S. design bases (Reference 1) and the FRG-Netherlands design bases (Reference 2) have used linear elastic expansion models to estimate these effects. These estimates are conservative, since no provision is made for salt creep, progressive failure of near-surface rock, movements along pre-existing fractures, or stress relaxation modes. In studies for the U.S. design, thermal loads were restricted by a maximum surface uplift of 1 to 1.5 m, since values of this magnitude were not to be assumed detrimental to the rock layers over the repository. In the FRG-Netherlands design bases, the crude linear expansion model gives maximum surface displacements of 0.66 m for Burial Configuration I and 0.44 m for Burial Configuration II.

The linear thermal expansion model utilizes the expression:

$$\Delta z = \int_{z_1}^{z_2} \gamma \Delta T(z') dz'$$

where ΔT is the calculated temperature increase at the level, z' and α is a constant characterizing the expansion. For linear expansion unconstrained in the horizontal direction, $\gamma = \alpha$, the coefficient of linear thermal expansion. For expansion constrained in the horizontal direction

$$\gamma = \alpha \left(\frac{1+\nu}{1-\nu} \right)$$

where ν is Poisson's ratio. A recalculation of the surface uplifts for the two FRG-Netherlands configurations, using a value of $\alpha = 4 \times 10^{-5}/^{\circ}\text{C}$ as per the U.S. design bases and summing the contributions from the repository level at 600 m up to the surface, produces excellent agreement with the FRG-Netherlands results, 0.78 m and 0.47 m respectively.

A more conservative estimate based on the constraint in the horizontal direction, assuming $\nu = 0.35$, gives surface uplifts of 1.55 m and 0.94 m for Configurations I and II respectively.

On the other hand, if the thermal expansion below the repository is also assumed to contribute to the surface uplift, the total vertical displacement is calculated to be nearly the same for the two configurations, 1.59 m for Configuration I and 1.54 m for Configuration II, for expansion not constrained in the horizontal direction (3.19 m and 3.08 m respectively for constrained expansion). As has been discussed, these estimates are probably conservative and probably represent acceptable surface uplift and overburden disturbance. In addition, it can be seen that the long bore-hole concept (Configuration II) provides no advantage over the shorter bore-hole concept (Configuration I) with regard to these surface uplift considerations.

REFERENCES

1. U.S. Working Draft on Repository Physical Descriptions in a Salt Formation, INFCE/WG7/10, May 1978.
2. Design Study of a Radioactive Waste Repository to be Mined in a Medium Size Salt Dome, Hamstra and Velzeboer, Stickting Energieonderzoek Centrum Nederland, January 1978.

VENTILATION SYSTEM

Requirements for ventilation include satisfying human air supply needs and controlling the chemical and physical quality of the repository environment by providing for the removal of contaminants such as engine exhaust gases, dust, and radioactive contaminants released from contaminated surfaces and leaking canisters. The ventilation designs presented by the United States (Reference 1) and the FRG-Netherlands (Reference 2) to accomplish these requirements differ basically in the complexity of the systems.

The U.S. design is based upon:

- Segregating ventilation air for the waste handling and excavation activity areas
- Controlling of normal radioactive releases to the environment through appropriate filtration
- Controlling accidental releases through a system of zone isolation and filtration
- Assuring that air passing through an occupied area has never passed through a waste burial area.

The FRG-Netherlands design is based upon:

- Simple single ventilation system for all underground areas
- A minimum of filtration - only mentioned as being between the bunker exhaust and return air passageway
- Assurance that air passing through an occupied area has not passed through a waste burial area, with the possible exception of return air corridors on the intermediate level.

The decision as to which system is the more acceptable for INFCE designs depends primarily, then, on the importance given to total segregation of mining and placement air, assurance of personnel safety, and the desired cost and complexity.

Advantages of United States approach include:

- Better control over quality of the working atmosphere
- Total segregation of potentially contaminated air from mining exhaust air
- Segregation, which does not require the HEPA filtration system to handle extremely large volume flows
- Separate shaft concept, which provides for greater reliability and ease of operation.

Disadvantages of United States approach include:

- Cost associated with construction of individual supply and exhaust air shafts
- Increased long-term geologic containment risk associated with sinking of shafts
- Complexity of subterranean distribution system, including separate placement exhaust ducts.

Advantages of FRG-Netherlands approach:

- Simplified system, hence less costly to construct
- Smaller number of shafts sunk into geologic medium.

Disadvantages of FRG-Netherlands approach:

- Design as stated does not completely assure segregation of return air from personnel areas.
- Contaminated air resulting from contact with waste transport would be passing down same corridors as men and materials.
- Lack of segregation between potentially contaminated air from uncontaminated mining air requires filtration of entire ventilation flow prior to atmospheric release.

The FRG-Netherlands repository ventilation system description (Reference 2, Sections 6.0 and 8.0) is general in nature and leaves a number of questions unanswered. Their design calls for delivery of supply air from one shaft at approximately 10,000 m³ per minute to the main corridors at each storage level. From these corridors, air will

flow through the branch roads either to bulk disposal cavities (Reference 2, Figure 27) or to connecting roadways at the end of each high-level waste storage room (Reference 2, Figure 31). Return air will be removed via the intermediate level roadway, from above for bulk disposal ventilation (including individual filtration of each storage bunker) and from below for HLW disposal. In a multi-level HLW storage concept, several intermediate-level roadways would be mined to provide return air passage from subsequent lower HLW storage horizons. The return air will be exhausted through the remaining main shaft. Neither the amount of filtration or the type of air cleaning systems used in this repository design were identified, although it is assumed that the effluent will be treated prior to release to the environment to reduce dust and possible radioactive contaminant emissions.

In general, all subterranean work will be conducted "upstream" of waste placement operations. Air flow past the bulk storage and HLW areas is routed to the exhaust corridors, such that all potentially contaminated air would be swept ahead of working personnel. However, any airborne contamination arising from the transport of waste down the main corridors could expose mining personnel to an undue hazard because of the dual service nature of these roadways. Filled storage areas will be backfilled and sealed off from all ventilation (Reference 2, Figure 32). However, it is unclear from the report whether the return air stream from the bulk and HLW storage to intermediate-level corridors is controlled within this mine horizon such that personnel and equipment will not be present within the main corridor during this use (Reference 2, Section 6, p. 17).

The U.S. conceptual ventilation design provides for supply air entering the mine through a separate air shaft and dividing into three main corridors (two men and materials and one placement corridor). The air is then distributed to the working areas of the mine using stoppings, doors, and crossings in main airways and line brattices, along with auxiliary fans at working faces. The layout of the subterranean ventilation system (Reference 1, Figures 14 and 15) provides for the separation of the mining operations exhaust airflow from the potentially contaminated exhaust air of the canister placement operations.

This separation is accomplished by using one of the main corridors for return of air from the mining, drilling and backfill operations, while collecting the placement operations exhaust air in a separate system of perimeter ventilation drifts. This complete separation is accomplished with the use of "crossover" ducts (a common mining practice). The two exhaust air flows are brought to the surface in separate compartments of a divided exhaust shaft. At the surface, filtering (HEPA for placement exhaust or simple filter for other exhaust) would occur prior to atmospheric release. The total estimated ventilation requirement depends on repository capacity and reactor strategy used, but should vary between 10,000 and 41,000 m³/min (Reference 1, Table 4-8).

REFERENCES

1. U.S. Working Draft on Repository Physical Descriptions in a Salt Formation, INFCE/WG7/10, May 1978.
2. Design Study of a Radioactive Waste Repository to be Mined in a Medium Size Salt Dome, Hamstra and Velzeboer, Stickting Energieconderzoek Centrum Nederland, January 1978.

REPOSITORY DESIGN AGREEMENTS

As presented in the previous sections on repository design issues, several differences are evident between the U.S. and FRG-Netherlands storage concepts. However, some agreements do exist. The basic concept of deep geologic containment of waste requires that all designs contain a similar basis in terms of mining procedures and storage requirements. These include use of conventional techniques for shaft sinking and corridor and room excavation, observing underground mining safety precautions, and guaranteeing isolation of stored waste from the working environment. In addition to these basic agreements, specific points were found at which the two designs were nearly identical; these are highlighted as follows:

Quality requirements:

- Careful repository site selection including extensive geologic and hydrologic investigations
- Design waste disposal operations to minimize radiation exposure to personnel and limit radioactive releases to the environment
- Maintenance of a containment shield of undisturbed geologic media surrounding the subterranean disposal area
- Provision for careful sealing of the repository and its shafts after decommissioning to help assure long-term geologic containment.

Waste characteristics:

- High-level waste (HLW) will be stored in a solidified glass matrix at a density of about 90 liters/metric ton of heavy metal reprocessed.
- Age of HLW upon burial at the repository is 10 years after reactor discharge.
- Average waste arisings for medium-level waste were approximately 25 m³ per GWe per year of installed capacity.

Thermal considerations:

- Thermal criteria are established for local and far-field effects.
- Calculations are performed to quantify far-field (global) temperature profiles.
- Calculations are performed to determine thermal effects on surface uplift.
- Areal thermal loadings (kW/hectare) are similar for both designs.

Subterranean operations:

- Mine, drill, placement, backfill sequence is the same, with some separation between timing of operations.
- Heat-generating waste will be stored in canisters within drilled holes in storage room floor.
- Excavated material will be handled on separate levels from waste storage.
- Ventilation designs provide for minimal exposure of personnel to potentially contaminated airstreams.
- Philosophy concerning the use of explosives for excavation is that they be used only when absolutely essential.