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# Interfaces between transport and geological disposal systems for high level radioactive waste and spent nuclear fuel

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INTERFACES BETWEEN TRANSPORT AND GEOLOGICAL DISPOSAL SYSTEMS FOR HIGH LEVEL RADIOACTIVE WASTE AND SPENT NUCLEAR FUEL

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# FOREWORD

This document identifies and discusses the interfaces and the interface requirements between high level waste, the waste transport system used for carriage of the waste to the disposal facility, and the high level waste disposal facility. The development of this document was prompted in part by the initiatives in various Member States to select, characterize and design the facilities for potential high level waste geological repositories. These initiatives have progressed to the point where an international document would be useful in calling attention to the need for establishing, in a systematic way, interfaces and interface requirements between the transport systems to be used and the waste disposal packages and geological repository.

The discussion of the interfaces is based on two key IAEA documents, namely:

- Regulations for the Safe Transport of Radioactive Material, 1985 Edition (As Amended 1990), Safety Series No. 6 (1990), and

- Safety Principles and Technical Criteria for the Underground Disposal of High Level Radioactive Wastes, Safety Series No. 99 (1989).

The contributors have also compiled a set of definitions consistent with these two documents that can serve as input to the update of the IAEA's Radioactive Waste Management Glossary.

While the contributors developed a consensus view in the document, it was recognized that different technical and regulatory approaches may be required in various Member States.

CONTENTS

# 1. INTRODUCTION

## 1.1. BACKGROUND

In 1985, the International Atomic Energy Agency (IAEA) initiated development of Safety Principles and Technical Criteria for the Underground Disposal of High Level Radioactive Wastes, Safety Series No. 99 [1] with the "aim of providing IAEA Member States with basic guidance on protection of humans and the environment from the hazards associated with deep geological disposal of high level radioactive wastes." Safety Series No. 99 [1] which was published in 1989, dealt with the design, characterization, safety assessment, quality assurance, construction, operation and closure of a repository. The document did not address the transport of wastes to the disposal facility, nor did it address, in other than very general terms, the receipt of the waste or the interfaces between the transport system and the disposal facility.

In order to remedy these omissions the IAEA undertook the development of the present report in 1991. This document recognizes that a significant body of information exists concerning the safe transport of radioactive material. The key information among this is the Regulations for the Safe Transport of Radioactive Material, 1985 Edition (As Amended 1990), Safety Series No. 6 [2], and its supporting documents [3, 4]. These documents also deal in a general way with the interfaces between the waste transport package and the originating and receiving facilities.

Examples of other internationally-developed information pertaining to the transport of these materials are listed in Refs [2–4]. In addition, a large number of international documents on underground disposal-related, safety and technical issues are listed in the Bibliography of Safety Series No. 99 [1].

## 1.2. OBJECTIVE

It is noted that radioactive wastes arise from the nuclear generation of electricity and from other activities in which radioactive materials are used. Since ionizing radiation is recognized as a potential hazard to human health, there is a common concern in all countries that radionuclides from radioactive wastes must not enter the environment in concentrations or quantities that would cause unacceptable health hazards. This is especially true for high level waste which contains high concentrations of certain radionuclides that will remain radioactive for much longer than human lifetimes. Thus, a significant emphasis is being placed internationally on the safe management of these wastes.

The identification of the interfaces between the waste disposal system and the transport system, and the understanding of their functioning are important since the interfaces have to provide a flawless course for the waste (packages) throughout the whole implementation of the back-end of the waste management system. A flawless course means that the waste is handled over between the various steps and facilities in a safe, technically sound, economically justified and documented manner.

Of particular significance in this matter is that, according to the waste management system and strategy adopted, the transport of the waste package may:

- occur at points in time different from their generation or disposal;
- convey the ownership of the waste from one body to another;
- transfer responsibilities from one or more bodies or authorities to one or more other bodies or authorities, taking into account that the responsibilities for the transport itself may belong to still other bodies or authorities.

The main objective of the current document is to identify and discuss the interfaces and the interface requirements between the high level waste, the waste transport system used for carriage of the waste to the disposal facility, and the high level waste disposal facility, the transfer system used for carriage of the waste within the disposal facility.

## 1.3. SCOPE

Technical interfaces are identified and discussed, in relation to the following:

(a) high level waste;
(b) the transport systems delivering these wastes to the disposal facility;
(c) alternative designs of the waste transport packages and the waste disposal packages; and
(d) the design, construction and operation of the disposal facility.

Because the text was developed with particular regard to disposal of high level wastes in deep geological repositories, the interfaces and associated requirements considered are not necessarily suitable for disposal of other types of wastes, or for disposal of high level wastes by other means such as sub-seabed emplacement.

High level waste includes not only spent nuclear fuel (if classified as waste by a Member State) arising from the generation of electrical power and the highly radioactive wastes resulting from the chemical reprocessing of these fuels, but may also include any other wastes of a similar radioactive nature such as those that arise from the dismantling of irradiated fuel assemblies, from non fuel-bearing assembly hardware resulting from the operation of nuclear reactors, and from similar materials resulting from the operation of research reactors, or from the generation of radioisotopes if classified as high level waste by a Member State.

The disposal facilities taken into account include on-site transfer systems, waste disposal package preparation, emplacement equipment, the host geological formation and, generically, facility backfilling and closure.

This document is concerned with the operation and handling of the transport system inside the disposal facility boundary and the manner in which the design of the transport system interfaces with the disposal facility. The document is concerned with the operational phase of the repository. It is not concerned with the operation of the transport system outside the facility boundary or with the characteristics or design of the confinement barrier system; it does not address the repository post closure period nor specific details concerning retrievability requirements, either during the period of waste emplacement or during a subsequent testing or observation period prior to final sealing of the repository. The document does not address the impact of physical protection regulations and measures on the interfaces between the different elements of the waste management system.

## 1.4. STRUCTURE

Section 2 provides a set of definitions and explanations of terms used in the report. Section 3 defines all the systems and interfaces that are addressed in the report, and describes alternatives in system design strategies. Section 4 compiles all the technical requirements for the systems and interfaces defined in Section 2. Section 5 provides a tabular summary of all the key identified technical interface requirements and alternative strategies for two examples. Finally, in Appendices A–E the status of high level waste management in five Member States is summarized with emphasis on the interface issues.

# 2. DEFINITIONS AND EXPLANATIONS OF TERMS USED

The following definitions and explanations are included to ensure the correct interpretation of terms used in this document. If a term has been defined elsewhere and the definition or explanation has been taken over, a reference to the source is given. These definitions bridge Refs [1] and [2]; they are compatible with, and can serve as input to future updates of, IAEA glossaries such as Refs [7] and [8].

**backfill**
The material used to refill the excavated portions of a repository or of a borehole after waste has been emplaced [7].

**barrier (natural or engineered)**
A feature which delays or prevents radionuclide migration from the waste and/or repository into its surroundings. Natural barriers are, in the case of deep geological repositories, represented by the host rock and the surrounding geological formation. An engineered barrier is a feature made by or altered by humans. It may be a part of the waste package and/or part of the repository [1].

**buffer**
Any substance placed around a waste container in a repository to serve as an additional barrier to stabilize the surrounding environment, and to reduce the rate of radionuclide migration from the waste into the repository.

**canister**
A primary sealed container for nuclear fuel or other radioactive material, which isolates and contains the material, and which may rely on other barriers for shielding during transport and storage or for containment after emplacement in the repository.

**closure**
Refers to the status of or an action directed at a facility at the end of its operating life. In the case of disposal, the repository is placed into permanent closure, usually after completion of waste emplacement, by sealing of a geological repository and the passages leading to it, and termination and completion of activities in any associated structures.

**disposal**
The emplacement of waste in an approved, specified location without the intention of retrieval.

**disposal, deep geological**
Disposal of radioactive waste, usually with engineered barriers, at a depth of several hundred meters in a geologically stable formation.

**dose**
A term denoting the quantity of radiation energy absorbed by a medium [5].

**fission product**
A nuclide produced either by fission or by the radioactive decay of radionuclides formed by fission [4].

**fuel (nuclear)**
Fissile and fertile material used as a source of energy when placed in a critical arrangement in a nuclear reactor [8].

**fuel assembly (or fuel bundle)**
An array of fuel rods held in place by end fittings or plates and separated by spacers or grids.

**fuel rod**
A basic component of nuclear fuel fabricated for service in a reactor, comprising fissile and/or fertile material sealed in a metal tube [3].

**fuel, spent (or fuel, spent nuclear or fuel, irradiated)**
Nuclear fuel rods or fuel assemblies removed from a reactor following irradiation, which are not intended for further reactor service.

**high level radioactive waste (HLW)**
(1) The highly radioactive materials, containing mainly fission products, as well as some actinides, which are separated during chemical reprocessing of spent fuel;
(2) Spent fuel, if classified as waste by a Member State; and
(3) Any other wastes which are classified as high level by a Member State.

**hot cell**
A heavily shielded compartment in which highly radioactive material can be handled, generally by remote methods.

**operational period**
The period during which a nuclear facility is being used for its intended purpose until it is shut down and decommissioned [4].

**post-closure period**
The period of time following the final sealing of the repository.

**pre-closure period**
The period of time covering the construction and operation of a repository up to and including its final sealing.

**quality assurance**
Planned and systematic actions necessary to provide adequate confidence that an item, facility or person will perform satisfactorily in service [1].

**repository, geological**
The deep geological underground portion of a waste disposal facility where the waste is emplaced. Usually, the repository will be located in a stable geological formation such as clay, salt, granite or welded tuff, to provide long term isolation from the biosphere.

**retrievability**
The capability to remove and regain physical control of emplaced waste.

**safeguards**
Measures including inspections and instrumental observations, employed for the exclusive purpose of verifying in a timely fashion that significant quantities of nuclear material are not diverted from peaceful nuclear activities to the manufacture of nuclear weapons or of other nuclear explosive devices or for purposes unknown (based on information from Ref. [9]).

**transfer**
Intentional movement of radioactive waste within the boundary of a nuclear facility after completion of unloading operations.

**transport**
Intentional movement of radioactive waste from one nuclear facility to another. It includes loading operations at the consignor's facility and unloading operations at the consignee's facility.

**waste disposal facility, geological**
The surface and subsurface systems, including the surface facilities and equipment (the receipt system, the waste preparation system, etc.); trenches, tunnels, shafts (e.g., the transfer system) and the waste emplacement locations in geological media; and the backfill, barrier and sealing materials used for disposal of waste.

**waste disposal package (WDP)**
The waste and any packaging as prepared for disposal.

**waste disposal system, geological**
The surface and subsurface systems, including the surface facilities and equipment; trenches, tunnels, shafts and the waste emplacement locations in geological media; the waste packages; and the backfill, barrier and sealing materials used for disposal of waste.

**waste management**
All administrative and operational activities that are involved in the handling, treatment, conditioning, packaging, transport, storage and disposal of waste.

**waste management system**
All facilities, equipment, personnel and procedures that are assembled in a systematic manner to provide for the safe and efficient handling, treatment, conditioning, packaging, transport, storage and disposal of waste.

**waste transport package (transport package)**
The waste and any packaging as prepared for transport.

# 3. SYSTEMS AND INTERFACES

This section defines the systems and interfaces imposed by the receipt of high level waste (HLW) at a geological disposal facility. The systems considered, and the major physical interfaces are depicted in Fig. 1 and are as follows:

## 3.1. PRIMARY SYSTEMS

Several systems are to be defined; two are the bounding systems for this document: the transport system and the local barrier system. Three systems contribute to the interface between transport and geological disposal: preparation, transfer and emplacement systems. The waste disposal package (WDP) is an identified system although it may be part of the other systems in some design strategies; if it is not, it has the potential of interfacing with all the other systems. In addition, depending upon the design strategy, different systems may be integrated, and their interface(s) may not be identifiable.

### 3.1.1. Waste transport system

The waste transport system includes the waste transport package, the vehicle and ancillary equipment used to transport the HLW from its originating and/or storage location to the disposal facility, as well as the appropriate area and equipment required to unload the package from the vehicle.

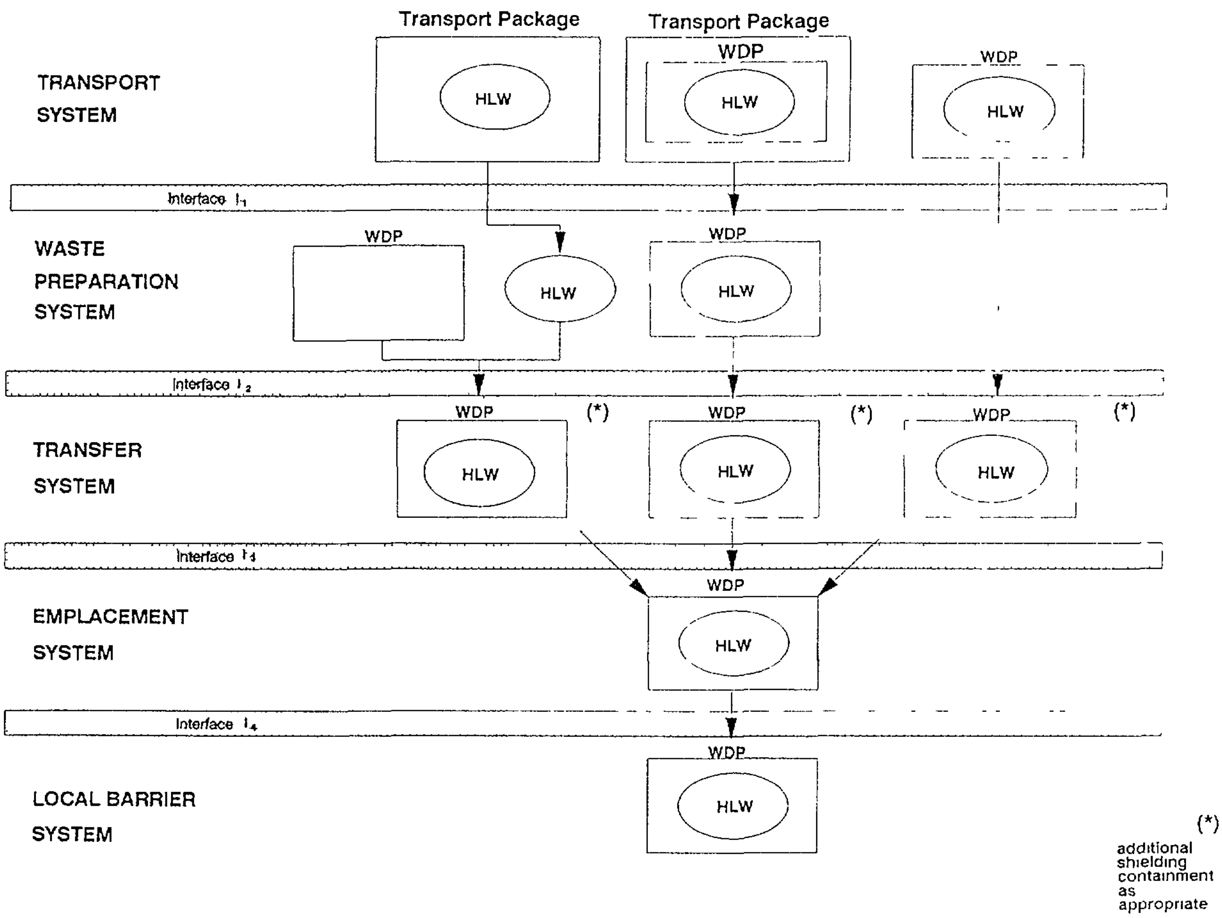


*FIG. 1. Systems and interfaces for different strategies.*

### 3.1.2. Waste preparation system

The waste preparation system includes the areas and equipment where the hlw is unloaded from the waste transport package and, as needed, prepared and packaged for disposal. This would normally be a hot cell equipped with remote handling equipment. Depending upon the strategy adopted (see Section 3.3), the waste preparation area may not be required, and the transport system would then directly interface with the transfer system.

### 3.1.3. Waste transfer system

The waste transfer system includes the areas and equipment required for transfer of the HLW in its waste disposal package from the preparation area to the underground emplacement area. It requires vehicles and ancillary equipment within the surface facilities as well as in the underground drifts. In addition, it may include hoisting devices in a shaft or a ramp between the surface level and the repository level.

### 3.1.4. Waste emplacement system

The waste emplacement system includes the WDP handling equipment, other ancillary equipment, and areas in the geological repository required for emplacing the WDP.

### 3.1.5. Local barrier system

The term 'local barrier system' (LBS) is used to designate the actual location at which the WDP is emplaced. It includes the local host geological formation and the engineered barriers used in emplacing the WDP. The detailed configuration depends on the type of host geological formation and on several parameters related to the repository performance requirements. These vary widely between reference designs for each Member State and the possible alternatives are not discussed in detail in this report.

### 3.1.6. Waste disposal package

The waste disposal package includes the HLW and any packaging as prepared for disposal. Depending upon the strategy adopted (see Section 3.3), the WDP may also be the waste transport package.

## 3.2. PRIMARY INTERFACES

There are four primary interfaces involved in the receipt, handling, preparation, transfer and emplacement of waste in a disposal facility. These are illustrated in Fig. 1 and described in Sections 3.2.1–3.2.4. The technical requirements associated with all of these interfaces are discussed in Section 4.2.

### 3.2.1. Waste transport system/waste preparation system interface ($I_1$)

The interface between the waste transport system and the waste preparation system is designated as $I_1$ in Fig. 1. This involves physically and administratively interfacing the off-site transport system with the site receiving area. This includes accepting the transport system on to the site, and physically interfacing the transport system, including the waste package, with the waste preparation system.

### 3.2.2. Waste preparation system/waste transfer system interface ($I_2$)

The interface between the waste preparation system and the waste transfer system is designated as $I_2$. **It involves the direct physical interfacing between the waste transfer system and the emplacement system during the operations of transferring the WDP from one system to the other**. This involves either physically or administratively verifying waste characteristics to demonstrate compliance with the disposal facility's waste acceptance criteria for each consignment of HLW. It includes interfacing the waste prepared for disposal with the waste transfer system for movement within the disposal facility.

### 3.2.3. Waste transfer system/waste emplacement system interface ($I_3$)

The interface between the waste transfer system and the waste emplacement system is designated as $I_3$. It involves the direct physical interfacing between the waste transfer system and the emplacement system during the operations of transferring the WDP from one system to the other. This involves physically interfacing and handling of the disposal-prepared waste within the disposal facility, moving it from the waste preparation system to the emplacement location and interfacing with the emplacement system.

### 3.2.4. Waste emplacement system/local barrier system interface ($I_4$)

The interface between the waste emplacement system and the local barrier system is designated as $I_4$. This involves compatibility between the handling and other ancillary equipment of the emplacement system and the host geological formation and buffer. It includes interfacing the WDP with the engineered barriers, as well as interfacing the engineered barriers with the host geological formation. These are not addressed in this document.

### 3.2.5. Interfaces with the waste disposal package

The waste disposal package potentially interfaces with more than one of the other systems depending upon the specific design strategy selected. The possible interfaces with the other five systems are indicated in Fig. 2, a simplified version of Fig. 1. This interface is denoted here as dashed arrows to differentiate it from the other interfaces, $I_1$, through $I_4$, as it is the only interface with the potential of involving more than two systems. The impact of strategy selection on the interfaces with the WDP are elaborated in Section 3.3. The interface between the WDP and local barrier system is not addressed in this document since it is mainly concerned with long term safety.

## 3.3. ALTERNATIVE STRATEGIES

Several different waste management strategies can be used to accomplish the required functions leading to disposal by emplacement of the HLW in the underground repository. These strategies hinge on several choices that can be made along the design process for the HLW management systems.

Some designs use HLW packaging designed with a single specific function in mind, for example transport or interim storage. Other designs consider packaging the waste at origin into containers compatible with the disposal function. Other HLW management strategies may derive from choices unrelated to container design, such as repository location, geological characteristics, or from regulatory imposed parameters such as retrievability requirements.

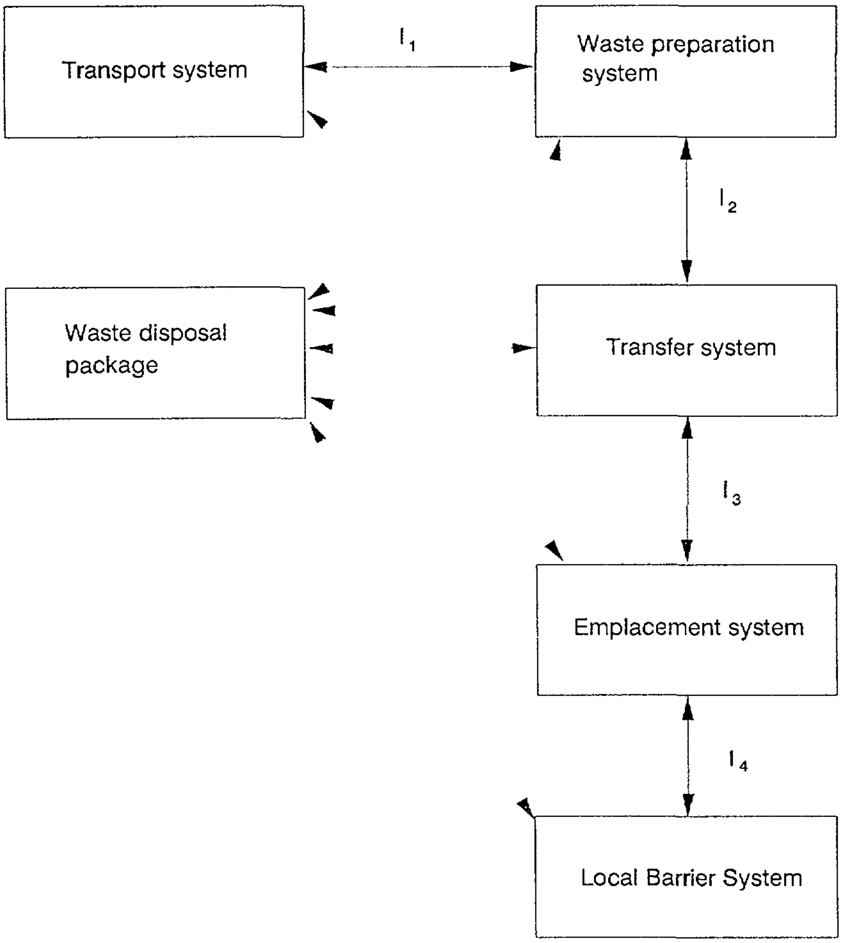


*FIG. 2. Major systems and key interfaces.*

In the section that follows, two major examples of strategies affecting the transport system/repository interface based on the choice of waste packages will be discussed. These different alternative strategies can be visualized/represented by variations of Fig. 2. Two examples are addressed in Figs 3 and 4.

It is apparent from a review of disposal system conceptual designs (either existing or under development) that in the case of spent fuel, one of the most striking variables from the technical point of view is the packaging strategy. Some typical strategies to consider are:

(1) dedicated packages for each function (transport, storage, disposal);
(2) spent fuel encapsulated at origin, with overpacks (additional packaging) added as required for transport, storage or disposal; and
(3) spent fuel placed at origin, in a multipurpose package which constitutes the final WDP.

Wastes arising from spent fuel reprocessing are usually incorporated into a matrix and encapsulated at the reprocessing plant. Depending on the disposal configuration, this reprocessing waste package may satisfy the disposal requirements and therefore constitute the WDP, or require additional overpacking before emplacement in the repository. In the second case, the disposal overpack could constitute a multipurpose package if it meets transport requirements.

The interfaces for the above strategies 1 and 3 are schematically illustrated in Figs 3 and 4 respectively. They are discussed in Sections 3.3.1 and 3.3.2.

### 3.3.1. Single purpose packages

Many designs for HLW management systems, particularly for spent fuel, use packaging that is designed to meet the requirements of the transport function or those of fuel interim storage but not those of disposal. In such cases, the waste preparation system performs the operation of removing the fuel from the transport package and packaging it for disposal. This normally includes testing the WDP and interfacing with both the waste transport package and the repository waste transfer system.

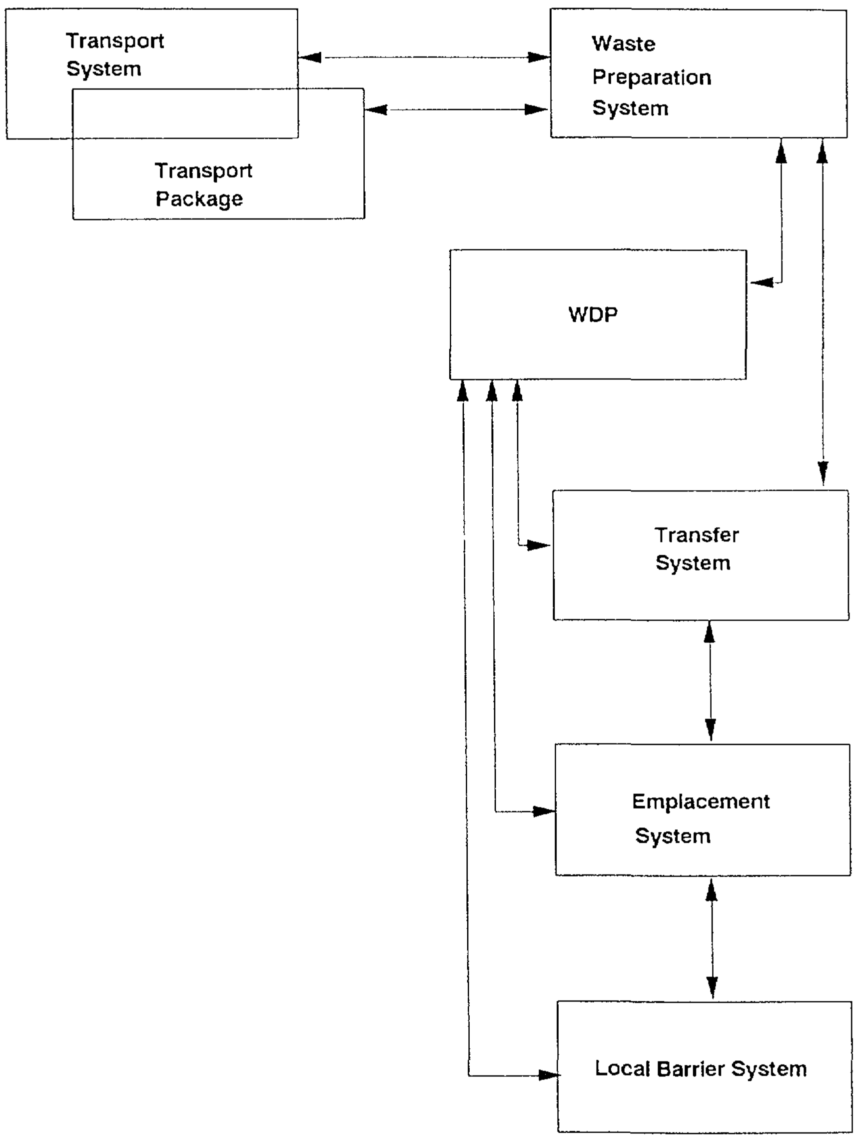


*FIG. 3. Interfaces for single purpose (transport only) waste transport package.*

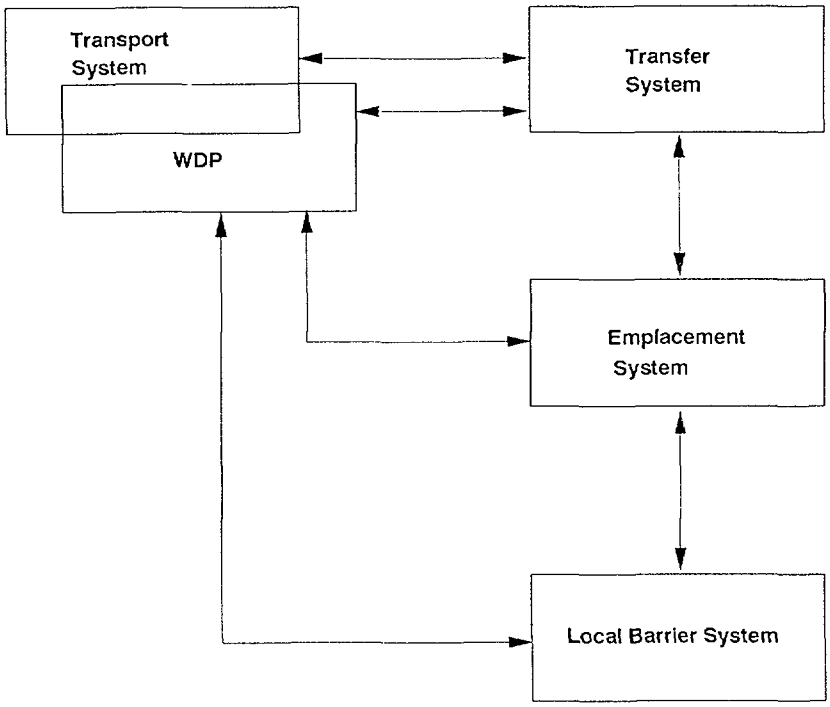


*FIG. 4. Interfaces for multipurpose (transport, storage and disposal) waste package.*

### 3.3.2. Multipurpose packages

The use of multipurpose packages, designed to meet the requirements of more than one function, for example interim storage, transport, and disposal, are the basis for spent fuel management strategies being considered by some Member States. In this case, the key interfaces previously identified in Fig. 2 change, depending on the specific functions of the package.

To illustrate one such example: Figure 4 shows the system interfaces where the HLW is placed at origin in a package that constitutes the waste disposal package and that meets also the transport requirements. In this case, there is no waste preparation at the surface facilities, and the transport system interfaces directly with the geological repository transfer system. All the facility systems interface with the WDP.

## 4. INTERFACE REQUIREMENTS

### 4.1. GENERAL INTERFACE REQUIREMENTS

The general requirements for ensuring adequate definition of the technical and administrative interfaces between the different subsystems include those arising from consideration of basic radiation protection principles, safety and environmental protection, quality and compliance assurance, safeguards; and non-technical issues related to costs, wastes ownership and institutional factors.

### 4.1.1. Radiation protection

Radiation protection is here concerned with the protection of humans and the environment from the effects of ionizing radiation resulting from the receipt at the disposal facility boundary, handling, and emplacement of the HLW in the geological repository. The Basic Safety Standards for Radiation Protection [5] incorporate the system of dose limitation recommended by the ICRP [10]. This system of dose limitation contains three components which are justification of practice, optimization of protection, and individual dose limits.

Justification provides that no practice resulting in human exposure to radiation should be authorized unless its introduction produces a positive net benefit, taking into account also the resulting radiation detriment. Relative to the requirement for justification, "radioactive waste disposal is considered one part of a practice which has to be justified as a whole, rather than a separate practice to be justified in itself" [11].

Optimization provides that all exposures should be kept as low as reasonably achievable (ALARA), while taking economic and social factors into account [5, 11]. It should be applied to all levels in developing systems and procedures for radioactive waste management including:

(i) comparison of design alternatives for a specific facility;
(ii) comparison of different disposal options for particular waste streams;
(iii) comparison of different overall management systems for particular waste streams; and
(iv) comparison of complete waste management systems including conditioning, storage, transport, and disposal alternatives for a given source or practice.

Optimization at each of these levels may need to be addressed in different ways.

Practical application of the optimization procedure often requires consideration of subsets, looking at specific areas. When doing so, one must be aware that performing optimization for each subset independently does not necessarily lead to the optimization of protection for the larger set of activities. Several techniques, such as cost-benefit analyses or multiattribute techniques may be used to perform optimization analyses (see e.g., Refs [12–14]).

There is an inherent limitation in the application of the radiation protection principles, derived from the fact that it is not possible with currently available methods and data to obtain an accurate evaluation of the radiological impacts over the time periods involved in the implementation of the various HLW management options.

It must be kept in mind that the radiological protection aspects are only one factor to be taken into account in the decision-making process. Other factors, of an economical or social nature may carry, in this case greater weight. For example, the merit of disposal versus extended storage of HLW should be assessed considering the burden imposed on future generations by the need to continue monitoring and institutional controls over the nuclear waste.

Individual dose limits require that the doses to individuals from all practices (except for medical and natural radiation exposures), either as members of the public or as a result of their occupation, should not exceed the appropriate dose limits [11]. It must be recognized that many present-day practices give rise to doses that will be received in the future. This should be taken into account to ensure that present or future practices would not be liable to result in a combined undue exposure of any individual. Therefore, the doses to the public due to radioactive waste disposal during operation and following closure of the repository, will be limited, in most cases, by source related dose upper bounds or constraints [15] imposed by national authorities.

#### 4.1.2. Safety and environmental protection

Various regulations and standards exist in the fields of nuclear and conventional safety and environmental protection. The different subsystems of the entire waste management system have to comply with these regulations or subsets of regulations. Although a considerable amount of experience exists, the way in which compliance is achieved may depend on the system or phase of operation. For example, criticality safety in the transport system may be achieved using methods different from those used for the various operational phases of the disposal facility.

Occupational health and safety concerns associated with the design and operation of the disposal facility (including the transport system, WDP, waste preparation system, transfer system and emplacement system) must be considered in a similar manner as for any other type of nuclear facility. The likelihood of injury and death, and potential for human error should be minimized.

In summary, the design and operation of the disposal facility, including the receipt, handling and shipment off-site of the transport system, must be carefully evaluated to identify interfaces and to avoid incompatibilities pertaining to accident prevention, assessment of accident consequences, and emergency response planning and preparedness, protection of the environment and consideration of other hazardous materials. Applicable regulations must be evaluated when facilities are sited and designed, and when related activities to these facilities are defined. The interfaces between the different subsystems must be defined so that compatibility between the subsystems can be ensured.

#### 4.1.3. Quality assurance

It must be recognized that of the various quality standards that exist aimed at ensuring the safety of the public and workers and to protect the environment, no single one is likely to embody all the necessary elements of an all-embracing quality assurance programme covering the full spectrum of an integrated waste management system. Such a programme will need to be formed from elements of the individual operations making up the total system. It is inevitable that some elements may be duplicated and that elsewhere there may be apparent omissions. Ensuring compatibility at the interfacing stage is an important objective.

The establishment of a quality assurance programme for the transport of high level waste to a disposal facility is required by para. 209 of Safety Series No. 6 [2]. This applies to the design, manufacture, testing, documentation, use, maintenance and inspection of all waste transport packages; the preparation for transport of the packages; and the transport and in-transit storage operations involving these packages. Development of this type of programme is essentially the responsibility of the consignor. The responsibility for ensuring compliance lies with the regulator, i.e. the competent authority, as specified in para. 210 of Safety Series No. 6 [2]. Safety Series No. 37 [3] provides both a detailed discussion of acceptable quality assurance programmes and the graded approach that may be used, and assists in understanding how the requirements are to be satisfied. Further guidance may be found in Safety Series No. 113 [16], Quality Assurance for the Transport of Radioactive Material.

The consignor's quality assurance programme must be interfaced with those of the carrier and the consignee (the organization receiving the transport package), each of whom has different responsibilities. When a nuclear power plant acts as a consignor, shipping spent nuclear fuel, the quality assurance programme specified in Safety Series No. 50-C-QA [17] will apply to the plant operations, and this programme must interface compatibly with those for the transport operations.

The disposal facility may also serve as either the consignee (receiving loaded transport packages) or the consignor (returning unloaded transport packages). In either event, the requirements of para. 209 of Safety Series No. 6 [2] and those of Safety Series No. 99 [1] must be compatible and the quality assurance programmes must interface.

Criterion No. 10 of Safety Series No. 99 is very general in nature, requiring "a quality assurance programme for components of the disposal system and for all activities from site confirmation through construction and operation to closure of the disposal facility shall be established to ensure compliance with relevant standards and criteria" [1]. The operation of the disposal facility, controlled by the quality assurance programme for the facility [1], will include the handling of loaded transport packages, the unloading of these packages and preparation for return of the unloaded transport casks, and possibly even their maintenance. These quality assured activities will need to be fully compatible with the quality assurance programme for the transport package developed to meet the requirements of Safety Series No. 6 [2].

When developing a comprehensive waste management system, the importance of ensuring compatibility between the various quality assurance requirements cannot be over-emphasized. For example, the programme given for transport in Safety Series No. 37 [3] contains two topics (control, use and care of packages; and staff qualifications and training) which are not listed separately as elements in the nuclear power plant programme in Safety Series No. 50-C-QA [17]. These should be integrated into programmes for those serving as consignors and consignees.

### 4.1.4. Safeguards

Generally, the transport and disposal system will need to be operated using procedures and equipment which will satisfy safeguards requirements. The application of safeguards with the transport system will be a continuation of the current safeguards practices, and the safeguards employed at a disposal facility will generally be similar to those employed earlier in the fuel cycle, and should give the same level of assurance of non-diversion as elsewhere in the fuel cycle. International instruments, including the statute of the IAEA, and other basic safeguards documents are summarized in Ref. [9] and have been considered for application to geological disposal facilities by various experts[1].

[1] For example, safeguards for disposal of spent fuel in geological repositories were considered by a group of consultants to the IAEA in August 1991.

Implementing safeguards provisions ensure that significant quantities of nuclear material are not diverted from peaceful nuclear activities to the manufacture of nuclear weapons or of other nuclear explosive devices or for purposes unknown. It is noted in Ref. [6] that terms such as "significant quantities" are amenable to quantification and should be approached objectively. In the context of safeguards, the spent nuclear fuel and high level wastes which do not meet safeguards termination criteria transported to and handled by a disposal facility will be subject to safeguards measures.

The effective application of safeguards to high level waste and spent nuclear fuel in transport to, conditioning for, and emplacement in a disposal facility, requires an unbroken continuity of knowledge of the nuclear material content of the high level waste, based on operator data and verified by the IAEA. To accomplish this, the item accountancy approach appears appropriate.

Crucial to the safeguards approach will be the identification and evaluation of items coming into and transferred from the process area. Hence, an integrated safeguards verification system could be used to confirm process flows by surveillance of all potential diversion paths from the process area. In addition, nondestructive assay measurements for verification of the nuclear material content of the spent fuel may be required if continuity of knowledge is not maintained. Continuity of knowledge of nuclear material will depend on a containment/surveillance system and maintenance of the integrity of items being counted. The safeguards measures should involve a combination of design verification and monitoring of all movements into or out of the process area, supplemented if necessary by monitoring nuclear material within the process area to confirm that the nuclear material in the items going into and out of the process area are accounted for without loss of continuity of knowledge.

When the wastes subject to safeguards measures are located within a sealed container such as a sealed transport package or waste package, safeguards inspection requirements might be satisfied by actions which verify containment and seal integrity. As noted in Ref. [9], the "continuing integrity of the containment itself is usually assured by seals or surveillance measures". All movements of such verified containers to or within a disposal facility may require surveillance for safeguards purposes. When the waste is not located within a sealed container, safeguards may be accomplished with inspector observation and/or surveillance equipment which would require monitoring of all movements of the material. In either case, the safeguard inspection requirements might also be satisfied by actions which verify the seal integrity of a filled disposal hole or of the entire filled disposal tunnel.

Ensuring that safeguards requirements are satisfied may, in some of the operations at the disposal facility, also ensure that some safety requirements are satisfied since both may rely on transport package or waste package integrity. The breaching of a containment barrier might result in both a safeguards and a safety violation.

### 4.1.5. Costs

The total life-cycle cost of the entire waste management system should be considered when design alternatives are being evaluated. The evaluation should probably include not only the disposal facility, but also the waste package and the transport system used for carrying the HLW to the disposal facility. In addition, it may need to include the costs associated with the loading of transport packages, satisfying safeguards requirements and related waste preparation activities at the originating sites.

Total system life-cycle costs are needed to aid in the financial planning of, and annual budgeting for, the system operation. Thus the financial interface of the disposal facility and the remaining elements of the overall system must be clearly defined and maintained to ensure control and to properly reflect programmatic policies, plans, strategies and changes and to facilitate trade-off studies in the development phase. For example, the selection of one transport package concept over another (e.g. transport-only package as compared with multipurpose package as discussed in Section 3.3) can have significant impacts on elemental costs, and should really be assessed based on estimates of total system costs. Ultimately, the total system life-cycle cost analyses, coupled with all of the technical analyses and institutional factor considerations, will provide the basis for deciding on system structure, estimating the needed full life funding, and ensuring the timely availability of funds.

#### 4.1.6. High level waste ownership

The ownership of the HLW may change from one entity to another as these materials move from the reactor or waste generating sites, through the transport system to the disposal facility. This ownership can affect the administrative requirements which must be satisfied by the various organizations involved.

Decisions must be made relative to where, when and if in the process, ownership of the materials changes from the originating entities to the disposal facility. This exchange — depending upon organizational, political, and financial arrangements in a specific Member State or group of Member States — could occur at the point when the materials are retrieved from their storage location at the originating site, at the point where the materials are transported across the originating facility's site boundary and enters public domain transport, at the point of receival at the disposal facility, or after a period of time following disposal emplacement.

#### 4.1.7. Institutional factors

Non-technical, institutionally-related factors can very often prove to be critical to the successful implementation of the transport system and the design, construction, operation and closure of the repository. These issues, which may be real or perceived, must be considered in ensuring that the design and operating requirements, and the appropriate interfaces, are adequately defined.

Institutional factors which may need to be addressed include:

- economic impact on the local population and governments and economic incentives provided by the facility and effects on employment;
- social impacts, including effects on public facilities (schools, hospitals, etc.), private facilities (housing), and public confidence;
- environmental impacts;
- public perceptions of risk and safety, and perceived liabilities; and
- political impacts where local governments take different positions from larger-area governments and where both of which have control over the funding, locating, licensing and/or operating of the facility.

### 4.2. TECHNICAL INTERFACE REQUIREMENTS

This section contains requirements and issues for the interfaces defined in Section 3.2.

### 4.2.1. Waste transport system/waste preparation system interface ($I_1$)

The various requirements and issues for the waste transport system/waste preparation system interface are as follows.

#### *4.2.1.1. Waste transport and receipt*

The first step in the receipt and acceptance of a transport package should be the review and verification of the shipment documents (including marking and labelling of the package), the quality assurance and safeguards records for the waste transport package, and consignor supplied information relating to the waste acceptance criteria for the facility.

The consignor is required by regulation (para. 447 of Ref. [2]) to provide information in the transport documents which may address part of the waste acceptance criteria. Other information, separate from that in the transport documents may be required by the operator of the waste disposal system. The waste acceptance criteria may require that the HLW be characterized in terms of the following parameters:

(a) type,
(b) origin,
(c) physical and chemical form (including such characteristics as solubility, volatility, toxicity, and susceptibility to corrosion and leaching),
(d) material properties,
(e) mass,
(f) radionuclide inventory,
(g) packaging,
(h) decay heat,
(i) radiation level, and
(j) surface contamination levels.

After arrival, the transport package should be physically checked for:

(a) radiation levels,
(b) surface contamination levels,
(c) containment integrity,
(d) physical condition, and
(e) mass.

Following completion of physical and administrative checks, the waste transport package will be removed from the vehicle. This operation may include removal of package protective components, such as impact limiters or thermal shields. The receiving area should include provisions to either temporarily store the transport package or to implement any remedial actions that may be required. The receiving area should also have adequate package handling tools, proper hoisting capacity and proper floor loading capability.

After unloading, the transport vehicle and packaging will be decontaminated as needed, and prepared for return. The transport system is required by the Transport Regulations [2] to be checked for contamination and physical condition before leaving the site.

The receiving area will have to accommodate the possible transport modes that will be used and the different requirements dictated by the use of either multipurpose or transport-only packages.

*4.2.1.2. Waste disposal package*

The requirements for the waste disposal package must address three primary issues:

- *Waste form.* High level waste to be disposed of at a geological disposal site should comply with criterion No. 3 of Ref. [1][2]. Thus, HLW from reprocessing will be incorporated into a solid matrix (glass, ceramic, glass/metal). Spent fuel could arrive either as intact or dismantled fuel assemblies. Spent fuel could, however, be embedded into a matrix which could improve heat transfer and shielding, physical protection and waste retention properties.

- *Primary containment canister.* The canister performs a key function in the handling chain. It will be, together with its content, the basic form of any disposal package. The canister can be designed to fulfill the following functions: containment, handling, long term containment, shielding, and mechanical protection. If the waste does not arrive at the disposal site packed into an appropriate canister, as may be the case with irradiated fuel, encapsulation must be carried out in a special facility on site. This facility will be a hot cell with the necessary equipment to extract the fuel from the transport package, transfer it into a canister, perform the embedding operation if required, and load it into a transfer system after control for conformity to specifications.

- *Additional packaging.* A disposal overpack might be a necessary component of the waste disposal package. The overpack may provide containment, radiation shielding, chemical/corrosion barriers, and standardized emplacement operations. An engineered buffer may be used between the canister and the overpack to improve heat transfer and the retention properties of the complete waste disposal package.

*4.2.1.3. Waste preparation system*

Within the waste preparation area, the main activities may include removal of the waste from the transport package, encapsulation of the waste, verification of containment integrity of the packaged waste and material accounting for safeguards purposes.

These activities may require the following facilities:

(a) hot cells, including remote handling equipment;
(b) WDP sealing equipment;
(c) radiation and contamination monitoring equipment;
(d) inspection and test equipment; and
(e) cranes, lifting devices and transporters.

### 4.2.2. Waste preparation system/waste transfer system interface ($I_2$)

Two cases of the preparation/transfer interface $I_2$ are possible, depending on the transport system configuration:

---

[2] Criterion No. 3 of Ref. [1]: "The waste form. High level radioactive wastes to be emplaced in a repository shall be in a solid form with chemical and physical properties favouring the retention of radionuclides and appropriate to the disposal system".

(1) Multipurpose package, which would be transferred for emplacement directly with no waste preparation required and therefore $I_1$ and $I_2$ become a single interface.
(2) Transport-only package, in which case the WDP might require appropriate preparation before loading into the transfer system. If the WDP does not provide sufficient shielding, the transfer system should be shielded.

For the handling of the WDP, the handling and assembly features of package designs should be standardized to facilitate remote and/or automated handling procedures. As above, hoists, package lifting devices, and possibly on-site transfer vehicles of suitable capacity will be required.

### 4.2.3. Waste transfer system/waste emplacement system interface ($I_3$)

Once transferred to the designated location, the WDP package is emplaced in the repository. The handling equipment included in both transfer and emplacement systems should be standardized and compatible to facilitate remote/automatic handling procedures. Hoists and package lifting devices of suitable capacity will be required.

### 4.2.4. Waste emplacement system/local barrier system interface ($I_4$)

The requirements and issues for this interface are as follows:

#### *4.2.4.1. Emplacement*

The major requirements for the local barrier system come are related to long term safety considerations. Normally, the WDP and the repository configuration are designed to maintain the migration of radionuclides below acceptable limits during both operational and post-closure periods. During the operational period, remote/direct monitoring may be provided to verify the performance of the waste containment barriers.

Monitoring of ambient air for the radioactive contents during the emplacement operations should be instituted as part of the routine measures for operational safety during the pre-closure period.

Specific requirements can apply for emplacement interfacing purposes. Technical means must be adapted to the characteristics of the host rock such as:

- elastic modulus
- strength
- creep properties
- initial stresses
- initial temperature.

#### *4.2.4.2. Waste retrievability*

Retrievability of the HLW may be considered for two reasons: e.g., if it became necessary to remove the radioactive waste for safety reasons, or if it became necessary or desirable to reuse some of the materials in the waste. HLW disposal programmes may allow some provisions to retrieve the waste during the operational phase. These retrievability provisions may form part of the HLW disposal programme philosophy.

#### 4.2.4.3. *Facility closure*

The routine operations of the disposal facility will normally include backfilling and sealing of emplacement areas which have been filled. Institutional controls such as radiological monitoring and surveillance should be maintained throughout the operational (pre-closure) period and may be extended into the post-closure period depending upon the requirements of individual Member States.

## 5. INTERFACE REQUIREMENTS SUMMARY

Based upon discussion of the systems and interfaces presented in Sections 3 and 4, this section provides a summary of the requirements imposed on the systems and interfaces by the receipt in a transport package of HLW at a geological waste disposal facility, and an initial analysis of their interactions and derived requirements. This initial analysis is presented in Table I, which summarizes the primary activities in the technical considerations, as necessary, for each interface and its requirements.

Table I is developed using the logical sequence of events which might be expected to occur at the geological waste disposal facility, beginning with the arrival of a waste shipment at the facility and ending with the emplacement of wastes at the emplacement site and backfilling of the underground spaces. Also, it is developed assuming a single-use transport package, where the HLW is unloaded from the transport package and the WDP is prepared in the Waste Preparation System prior to transfer to the repository area. The table lists, in order:

(a) a primary activity,
(b) the elements and subsystems involved in that activity,
(c) the functional interfaces important to that activity, and
(d) the applicable interface requirements.

Wherever the primary interfaces $I_1$, $I_2$, $I_3$ and $I_4$ are involved, they have been identified in the third column. The remaining interfaces involve either:

(1) interfaces within a system,
(2) where the WDP interfaces with one of the systems,
(3) where the WDP interfaces with equipment associated with one of the systems,
(4) where the HLW interfaces with one of the systems, or
(5) administrative interfaces.

Table II is for the case of a multipurpose package (transport, storage and disposal) where the waste transport package is also the WDP. It is presented with the same features as Table I. Where the transport package is also the WDP, fewer activities at the waste disposal system are required.

TABLE I. INTERFACE REQUIREMENTS FOR SINGLE-PURPOSE (TRANSPORT ONLY) WASTE TRANSPORT PACKAGE

| Primary activity | Elements and subsystems involved | Functional interfaces | Interface requirements |
|---|---|---|---|
| Receiving of waste shipment | Administrative controls, waste acceptance criteria<br><br>Inspections, physical checks and waste acceptance criteria | Carrier/Consignee<br><br>Transport system/receiving area | Verification of transport documents according to Transport Regulations, and of waste characteristics, ownership and safeguards documents<br><br>Verification of transport system integrity, transport package containment and safeguards seals integrity, radiation levels, and surface contamination levels |
| | | | |
| Unloading of transport vehicle | Transport system, transport package handling system | Transport system/receiving area | Adequate transport package handling tools, hoisting capacity, operating space and floor loadings |
| | | | |
| Transfer of transport package to surge storage, as required | Transport package, Transport package handling system | Transport system/Receiving area | Adequate handling and transfer equipment, operating space |
| | | | |
| Transfer of transport package to hot cell entrance port | Transport package, transport package handling system | Transport package/waste preparation system ($I_1$) | Adequate handling and transfer equipment, operating space |

TABLE I. (cont.)

| Primary activity | Elements and subsystems involved | Functional interfaces | Interface requirements |
|---|---|---|---|
| Removal of waste from transport package | Hot cell, handling equipment, HLW | Transport package/hot cell ($I_1$) | Hot cell remote handling system with capability to unload the waste from the transport package |
| Return of unloaded transport packaging and vehicle | Transport package handling system, administrative controls | Transport system/receiving area | Space and capability to monitor and to handle components of transport system<br><br>Preparation and verification of transport documents, according to Transport Regulations |
| Preparation of WDP | WDP, hot cell, HLW handling equipment, HLW | Waste preparation system/HLW | Hot cell(s), canisters and overpacks, closure system, remote handling equipment<br><br>Adequate WDP handling equipment |
| WDP inspection | WDP, hot cell, inspection and handling equipment | WDP/inspection equipment | Hot cell remote/automatic inspection equipment |

TABLE I. (cont.)

| Primary activity | Elements and subsystems involved | Functional interfaces | Interface requirements |
|---|---|---|---|
| WDP repair and decontamination as needed | WDP, hot cell, handling system, remedial action equipment | WDP/hot cell equipment | Hot cell remote/automatic repair and decontamination equipment |
| | | | |
| WDP verification | Administrative control | Operator/inspector | Disposal facility records<br><br>Safeguards documents |
| | | | |
| Transfer WDP out of hot cell | Hot cell, WDP handling equipment | Hot cell/transfer system ($I_2$)<br><br>WDP/hot cell equipment<br><br>WDP/transfer system | Appropriate WDP handling equipment<br><br>Radiation shielding |
| | | | |
| WDP transfer to underground repository | Transfer system, handling equipment<br><br>Administrative control inspections | WDP/transfer system | Adequate handling equipment and radiation shielding<br><br>Administrative control documentation |

TABLE I. (cont.)

| Primary activity | Elements and subsystems involved | Functional interfaces | Interface requirements |
|---|---|---|---|
| WDP transfer to emplacement system | WDP transfer system, and emplacement system | Transfer system/emplacement system ($I_3$)<br><br>WDP/transfer system<br><br>WDP/emplacement system | Adequate handling equipment and radiation shielding |
| | | | |
| WDP emplacement | Emplacement system<br><br>Local barrier system<br><br>Administrative controls | WDP/emplacement system<br><br>Emplacement system/ local barrier system ($I_4$)<br><br>WDP/local barrier system | Emplacement equipment, materials available<br><br>Safeguards documents, repository records |
| | | | |
| Backfilling of underground spaces with WDP in place | Backfilling equipment<br>Administrative controls | WDP/local barrier system | Backfilling equipment and material |
| | | | |
| Closure of Repository | | | |

TABLE II. INTERFACE REQUIREMENTS FOR MULTIPURPOSE (TRANSPORT, STORAGE AND DISPOSAL) WASTE PACKAGE

| Primary activity | Elements and subsystems involved | Functional interfaces | Interface requirements |
|---|---|---|---|
| Receiving of waste shipment | Administrative controls, waste acceptance criteria<br><br>Inspections, physical checks and waste acceptance criteria | Carrier/consignee<br><br>Transport system/receiving area | Verification of transport documents, according to Transport Regulations, and of waste characteristics, ownership and safeguards documents<br><br>Verification of transport system integrity, transport/waste package containment and safeguards seal integrity, radiation levels, and surface contamination levels |
| | | | |
| Unloading of transport vehicle | Transport system, Transport package handling system | Transport system/Receiving area | Adequate transport/waste package handling tools, hoisting capacity, operating space and floor loadings |
| | | | |
| Transfer of transport waste package to surge storage/remedial area, as required | Transport package, Transport package handling system | Transport system/Receiving area | Adequate handling and transfer equipment, operating space |
| | | | |
| Transfer of WDP to waste preparation system | WDP, WDP handling system | WDP/Waste preparation system ($I_1$) | Adequate handling and transfer equipment, operating space |

TABLE II. (cont.)

| Primary activity | Elements and subsystems involved | Functional interfaces | Interface requirements |
|---|---|---|---|
| Return of unloaded transport vehicle | Transport/waste package handling system, administrative controls | Transport system/receiving area | Space and capability to decontaminate vehicle<br><br>Preparation and verification of transport documents according to Transport Regulations |
| | | | |
| WDP inspection | WDP, inspection area, inspection and handling equipment | WDP/inspection equipment | Appropriate inspection equipment |
| | | | |
| WDP repair and decontamination as needed | WDP, handling system, remedial action equipment | WDP/remedial action equipment | Appropriate repair and decontamination equipment |
| | | | |
| WDP verification | Administrative control | Operator/inspector | Disposal facility records and safeguards documents |

TABLE II. (cont.)

| Primary activity | Elements and subsystems involved | Functional interfaces | Interface requirements |
|---|---|---|---|
| WDP transfer to emplacement system | WDP, transfer system, and emplacement system | Transfer system/emplacement system ($I_3$)<br><br>WDP/transfer system<br><br>WDP/emplacement system | Adequate handling equipment and radiation shielding |
| | | | |
| WDP emplacement | Emplacement system<br><br>Local barrier system<br><br>Administrative controls | WDP/emplacement system<br><br>Emplacement system/ Local barrier system ($I_4$)<br><br>WDP/local barrier system | Emplacement equipment, materials available<br><br>Safeguards documents, repository records |
| | | | |
| Backfilling of underground spaces with WDP in place | Backfilling equipment<br>Administrative controls | WDP/Local barrier system | Backfilling equipment and material |
| | | | |
| Closure of repository | | | |

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## APPENDICES

It was proposed, in the final consultants meeting, to append to this TECDOC further supplementary information which can help readers to situate the interface issue within the waste management programmes of some countries.

The appendices hereafter represent a compilation of contributions submitted by some of the participants attending the meetings for preparing this document. The contributions provide the status mostly of strategy, management system, transport system and disposal system for high level radioactive waste in some Member States. Readers interested in more detail about the interface issue may refer to other information available from technical papers of Member States with operational waste management programmes.



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## Appendix A

## THE MANAGEMENT OF CANADIAN USED NUCLEAR FUEL

### Canada's Nuclear Energy System

Canada's nuclear energy system includes twenty two commercial power reactors which are owned and operated by provincially owned utilities in Ontario, Quebec and New Brunswick. All three provinces operate CANDU reactors, which are fuelled with natural uranium and moderated and cooled with heavy water. These CANDU reactors, designed by Atomic Energy of Canada Limited (AECL) and built by the respective provincial utilities, produce 16,700 MW of power equivalent to about 16% of Canada's electricity.

Twenty of these reactors are owned and operated by Ontario Hydro at three multi-reactor sites, Bruce, Pickering and Darlington. They produce approximately 50% of Ontario's electricity supply. New Brunswick Power and Hydro Quebec currently operate one reactor each at Point Lepreau and Gentilly respectively.

### The Canadian Nuclear Fuel Waste Management Program (CNFWMP)

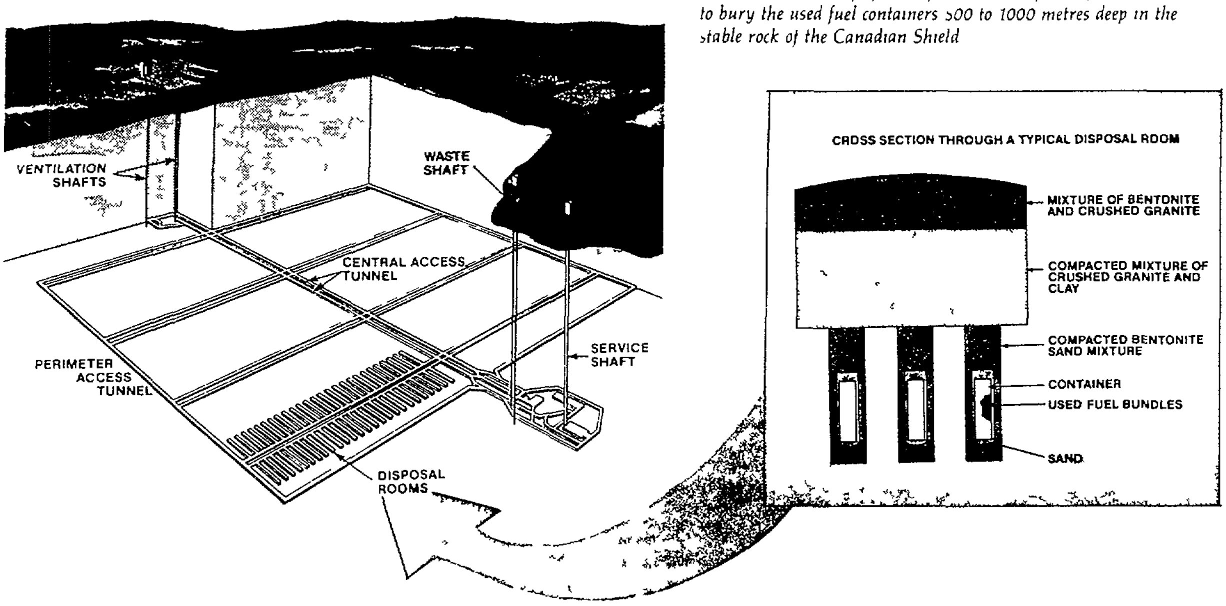
In 1978, following provincial studies into various options for the management of nuclear wastes, the Ontario Royal Commision on Electric Power Planning recommended that permanent disposal of nuclear fuel in a deep geologic repository be pursued. Subsequently, in the same year, the CNFWMP was initiated by an agreement between the governments of Ontario and the Canadian Federal Government.

The objectives of the program are to develop and demonstrate a technology for the disposal of nuclear fuel, based on the following principles: **safety**, the management of radioactive waste so that the hazards are negligible, and: **responsibility,** the management of radioactive waste to minimize the need for involvement of future generations. Under the agreement, AECL was assigned responsibility for research and development ina deep underground repository in intrusive igneous rock, and Ontario Hydro for studies in interim storage and transportation of used fuel.

AECL's research has focused on isolating the nuclear waste from the biosphere by using a series of engineered and natural barriers. A **disposal concept** was developed by AECL which consists in sealing the nuclear fuel waste in corrosion resistant containers and emplacing the containers in a repository deep in plutonic rock in the Canadian Shield. The development work has concentrated in studies on rock formations at the Underground Research Laboratory (URL) located at the Lac du Bonnet batholith, near Winnipeg in eastern Manitoba.

As part of its responsibilities in the CNFWMP, Ontario Hydro has developed, tested and licensed a transport cask for large-scale movement of used fuel to a future disposal facility. Also, following CNFWMP directives, Ontario Hydro provides expertise and advice to AECL in a number of research areas, including used fuel container development, buffer and backfill research, and environmental and safety assessment of the preclosure phase of disposal.

*The Canadian concept for the permanent disposal of used fuel is to bury the used fuel containers 500 to 1000 metres deep in the stable rock of the Canadian Shield*




## The Disposal Concept

The disposal vault will resemble a deep mine, consisting of an underground network of tunnels and disposal rooms covering an area of about 2 kilometers by 2 kilometers, at a depth between 500 to 1000 metres. The containers will be placed in boreholes, drilled on the floor of the disposal rooms. A diagram of the Used Fuel Disposal Facility is shown in the attached figure. Based on installed nuclear capacity, the reference facility is designed to accomodate all of Canada's used nuclear fuel to beyound the year 2035.

The radionuclide inventory in used the fuel would remain immobilized in the ceramic fuel pellets encased in a zircaloy sheath (fuel pencils), and be further isolated from the environment by various engineered and natural barriers. These include: the disposal container, the buffer, the backfill and the host rock (granite).

## Status of the Concept Assessment

The aproval process for the Canadian nuclear fuel waste repository calls for independant examination and acceptance of the design concept prior to selection of a site. In 1981, in response to public concerns about siting issues, a joint decision of the Canadian and Ontario governments deferred site selection activities until after the concept assessment was completed under the Federal Environmental Assessment Review Process.

The CNFWMP is currently concluding 14 years of research and concept development on the underground disposal of nuclear fuel. The results will be submitted in the form of an Environmental Impact Statement (EIS) to an eight-member Federal Environmental Assessment Review Panel appointed in 1988 and assisted by an independant Scientific Review Group.

In 1990, the Assessment Review Panel held public scoping meetings in 14 Canadian cities to determine the scope of issues that needed to be addressed in the EIS of the disposal concept. In 1992, the Panel issued a set of guidelines for preparation of the EIS. AECL expects to submit the EIS for review by the Panel in the first quarter of 1994. If the EIS is found to comply with the guidelines, full public hearings will be called in 1995 as the final stage of the concept assessment.

## Appendix B

## DEVELOPMENT OF SPENT FUEL MANAGEMENT IN FINLAND

The waste producer is responsible for the safe management of radioactive wastes in Finland. One of the two Finnish nuclear power companies, Imatran Voima Oy, has an agreement with the Russian fuel supplier to return the spent fuel from its nuclear power plant to Russia. The other power company Teollisuuden Voima Oy (TVO) plans to have a final repository of spent fuel into the Finnish bedrock. Both strategies are in accordance with the guidelines originally set by the Finnish Government in 1983.

Based on nuclear legislation and the above mentioned Government policy decision, TVO has carried out a site investigation programme so that 101 feasible candidates for investigation sites were selected in 1985. Preliminary site investigations were carried out at five sites and in 1992 three sites were selected for further characterization. The final selection of the host site will take place in 2000, allowing the start of construction of the repository in the 2010s and operation by 2020.

Parallel to the site investigation programme, an R & D programme has been run with the aim of developing the technology for encapsulation and disposal. The spent fuel from TVO's nuclear power plant will be stored in water pools for 20 – 40 years. Fuel assemblies will then be transported in transport casks to an encapsulation facility co–located with the final repository. For the operation of the encapsulation station and the final repository, office buildings and various auxiliary facilities are located in the area of the encapsulation station (Figure 1), which is 500 m x 740 m. The repository will be situated in rock underneath the encapsulation station, several hundred metres below the surface (Figure 2). The repository and the area of the encapsulation station are connected by three shafts.

TVO's technical plan for encapsulation of spent nuclear fuel is based on a cold process technique. Fuel bundles are encapsulated in copper–steel canisters (ACP canisters). Solid granulates, e.g., lead shots or quartz sand, are used as filling material for the canisters. The structure consists of a steel canister as a load–bearing element, with an outer corrosion shield of copper. The total number of canisters is 1 200, corresponding to 1 840 tonnes of uranium.

The repository will be constructed at a depth of several hundred meters (e.g., 500 m) in crystalline bedrock. The waste canisters are deposited in vertical holes in the floors of the horizontal disposal tunnels. The distance between the holes is 6 m and between the tunnels 25 m. The repository area is 440 m x 860 m, of which the disposal tunnels take 250 m x 860 m.

The buffer material in the vertical disposal holes is highly compacted bentonite. The disposal tunnels are filled during the operations phase with a mixture of sand and bentonite directly after the canisters have been emplaced in the holes. Finally, the central tunnels and shafts are filled with the same material.

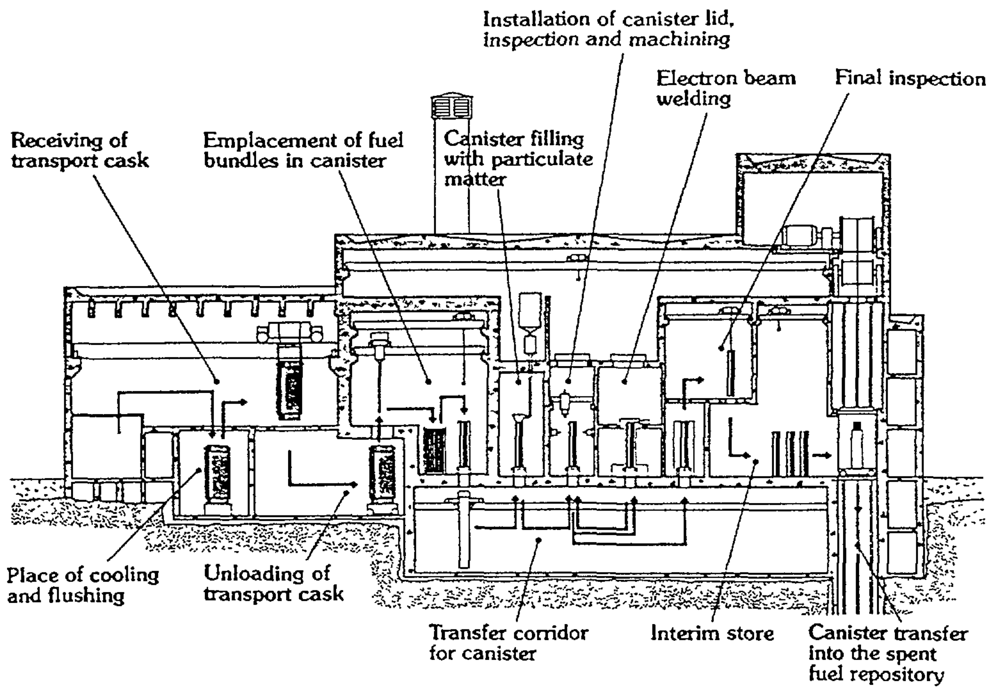



Figure 1. Encapsulation station

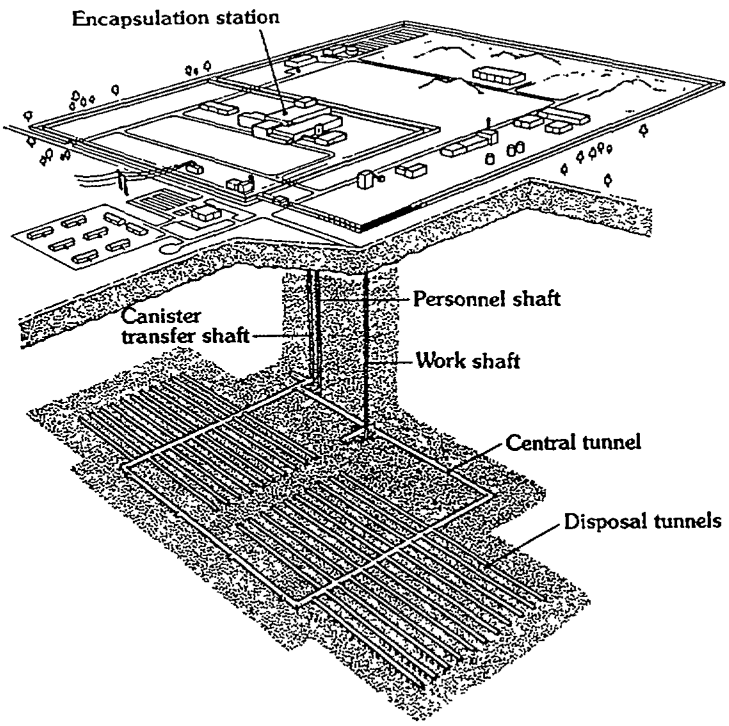



Figure 2. Encapsulation and final disposal facilities for.spent fuel.

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## Appendix C

## THE RESEARCH RELATED TO HIGH LEVEL AND ALPHA BEARING WASTE DISPOSAL IN FRANCE

ANDRA, the National Agency for Radioactive Waste Management, is responsible in France for the design, construction, operation and closure of waste disposal facilities.

ANDRA is in charge of all types of waste. Concerning long lived waste, it arises essentially from spent fuel taken from the reactor and reprocessed; fission products and vitrified actinides, cladding and structure elements from the dismantling of fuel assemblies, chemical solvents and contaminated equipment used for processing. This waste is subdivided into two categories, defined by the amount of heat they emit, i.e., low (category B) or high (category C).

The volume of long-lived waste already generated in France is low and the waste itself is stored temporarily at the production centers. Main producers provide an important effort to reduce the volume of this waste which will certainly apply to future waste.

The Act voted by the French Parliament in December 1991 provides for three research directions to propose a solution for long-lived waste in the long term.

The first research direction is related to the partitioning of the long-lived radionuclides contained in the waste and, eventually, of transmuting them into short-lived radionuclides.

The second option is to improve waste conditioning techniques and to store the waste temporarily while awaiting a definitive solution.

The third option consists of the research work conducted on the feasibility of disposal in deep geological formations, with respect to "retrievability or unretrievability". The concept behind this third option is to assign sheltering of the waste from human activities and from erosion to a geological formation, which can contribute to the containment of radionuclides in the long term. Most research in this area will be carried out in two underground laboratories to be built in crystalline rocks (granite) or sedimentary rocks (clay, salt).

The three options will be assessed by the year 2006 by a national review board. No decision relating to the implementation of any such deep disposal system will be taken prior to this assessment. Moreover, any such decision would have to be legislated by Parliament.

The establishment and creation of underground laboratories will take place within the framework provided under the 1991 Act. Consultation is the fundamental fuel at all levels. In this context, the Government has appointed a mediator to publicize and prepare discussions with the elected representatives and populations of regions in which the possibility of establishing laboratories exists, and in which some communities may be volunteer candidates.

Indeed, although these laboratories are exclusively research tools and no waste may be introduced into them, the prospect of such an installation may give rise to concerns locally, which should be heard.

The first works undertaken will be made from the surface. This will involve confirming general hypotheses about the geological features of the sites. The works will comprise drilling, and geophysical and seismic surveys. The initial condition of the site will also be established during this phase.

Each laboratory when decided will comprise surface support facilities, mining infrastructures for access to depth, and underground installations where the research and experiments will take place.

Generally speaking, the following common objectives will be assigned to in situ studies of geological formations:

- to disturb as little as possible rocks and fluids;
- to determine their behavior through more general experiments allowing for natural phenomena and changes caused by the construction of a repository;
- to survey the environment, particularly its spatial variability, in order to evaluate its capacity in terms of amount of waste and the possible location of works;
- to determine methods of excavating, covering and sealing the cavities created;
- to assess the efficiency and reliability of waste transfer and emplacement.

Prior to an experimental phase within the underground laboratories, to assess the constructibility and the safety of the disposal concept, preliminary studies include an inquiry for candidate disposal concepts, a comparison and selection of some concepts, then the design of the major components of the selected concepts.

Thus any deep disposal concept is drawn up to ensure the protection of man and the environment, by containing, limiting and delaying in the long term the return of radionuclides into the biosphere. The utilized philosophy relies on a multi-barrier system. The first barrier is the waste form and canister. The second barrier consists of the underground disposal works, in particular the materials placed between the waste and the wall of the underground excavations. These works are referred to as the "engineered barrier". Finally the geological barrier provides long term containment.

The French basic safety rule III.2.f provides recommendations for the different barriers as for their role in removing the heat from the waste, in reducing the intensity of mechanical stresses and in offering favourable physical and chemical properties as regards corrosion of the containers and migrations of radionuclides.

With respect to these requirements for the long term safety, a function analysis is being performed n order to optimize specified performances of each barrier of the disposal system. These include for example: the containment and retardation properties as well as minimum lifetime and reliability of the technical barriers and the seals placed in the access tunnels and shafts, the distance to be kept between disposal facilities and potential water pathflows, the temperature limits within the disposal area, etc.

While the prime objective of any disposal concept is the long term containment of the waste, the safety of the operators and the protection of the environment during construction and waste emplacement are just as important as with any other industrial installation.

To minimize external irradiation by the gamma radiation emitted by the waste packages, provisions can be made to conduct all the handling operations underground using a mobile shielded cell which accompanies the waste package throughout its transfer. Moreover the packages can be disposed of inside closed cells, permanently isolated form the drifts accessible to the operators.

To avoid dispersion of radioactive particles in the underground drifts, only externally non-contaminated packages are to be lowered to the bottom.

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## Appendix D

## INFORMATION ON THE HIGH LEVEL WASTE MANAGEMENT SYSTEM IN ITALY

At the present there is no specific law concerning the final disposal of High Level Waste and spent nuclear fuel in Italy, other than the law issued at the beginning of nuclear industry (1)

Main authorities involved in the repository program are: the Ministry of Industry and other Ministries that are responsible for approval of licence applications for the management of wastes; the ENEA Direction for Safety and Protection (ENEA-DISP) that is responsible, together with Technical Commission for Safety and Radiation Protection, for technical report to the Ministry of Industry on the proceeding licence applications.

In the past,several studies, also in agreement with the European Community, were carried out in Italy to identify the suitable site for the final disposal of high level waste, which is quite easy for the special national geological characteristics.

The studies on geological sites were stopped after the result of referendum taken place in Italy in 1987, about the use of nuclear energy for generating electricity, that decided for a moratoria.

Of paramount importance is the Technical Guide n° 26 (2) issued by the ENEA-DISP. Lately some considerations and proposals on the waste management system has been developed and collected into an updated document (3) issued by the Technical Commission for Safety and Radiation Protection.

Other alternatives are being considered for spent nuclear fuel management and high level waste taking into account the result of the referendum. The policy of ENEA-DISP (Italian Control Authority) is in favour of an interim dry storage both for spent fuel and high level waste for about 50 years to be realized in the nuclear power plant sites, waiting for the Interim National Storage site (4).

At the moment there are no specific details on the interfaces between transport and geological disposal system although there is a good experience in the transport of spent nuclear fuel.

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## Appendix E

# THE DEVELOPMENT OF A HIGH LEVEL WASTE MANAGEMENT SYSTEM IN THE UNITED STATES OF AMERICA

The United States of America (U.S.) has had a high level waste (HLW) management system under development since the early 1960s. This system is being developed for the permanent disposal of both spent nuclear fuel and vitrified high level waste.

Various geologic media and locations have been considered, starting with the study of salt formations throughout the United States. In 1983, the U.S. Congress passed the Nuclear Waste Policy Act (1) and this was amended in 1987 (2). This led to nine sites being initially considered, which were narrowed to three, each having different geologic characteristics, and finally having one site, the Yucca Mountain site in Nevada being designated for detailed characterization studies.

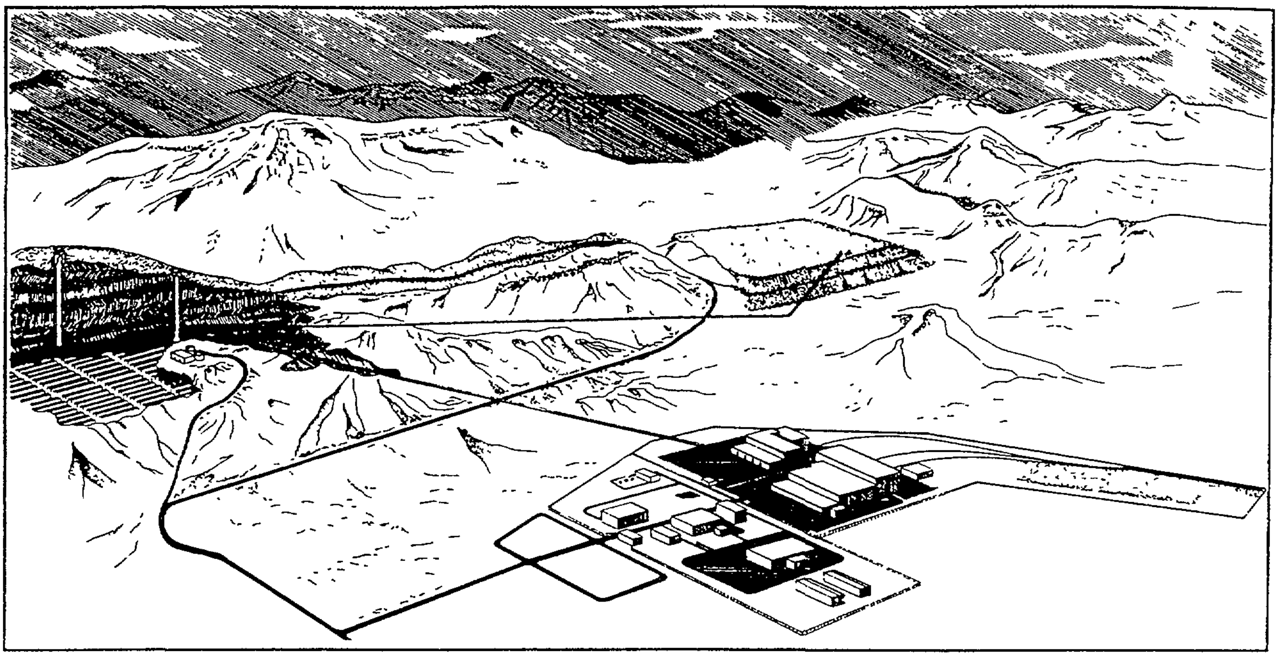
The Yucca Mountain site is currently being evaluated for suitability. The U.S. repository program involves three federal organizations: the U.S. Department of Energy (DOE) which is responsible for characterization of the site, the U.S. Nuclear Regulatory Commission (NRC) which is responsible for regulations and rejections/approvals of license applications, and the U.S. Environmental Protection Agency (EPA) which is responsible for the general environmental protection standards of a high level waste repository (3).

The Yucca Mountain site, if deemed acceptable, will provide an underground geologic repository in an unsaturated media of welded TUFF. The repository envisioned for this candidate site (4) will resemble a large mining complex consisting of approximately 5700 acres (23 $km^2$) including a controlled area 3 miles (4.8 km) wide, surrounding the perimeter. Utilities, roads, and a railroad line will extend to the site. It will combine two types of industrial facilities -- a facility at the surface for waste handling and a facility constructed about 1,000 ft (305 m) below the surface for permanent disposal of containerized waste.

If the site is determined to be suitable, and if it is approved for construction, the probable location of the surface facilities is on the east side of Yucca Mountain (see figure). Waste handling buildings, fire and medical stations, administrative offices, repair shops, water and sewage treatment plants, warehouses, a machine shop, an electrical shop, and a security office will all be included in the surface facilities. These facilities will cover from 150 to 400 acres (0.6 to 1.6 $km^2$).

Gently sloping ramps connecting the underground and surface facilities will allow shielded transport vehicles to carry the waste packages to the subsurface disposal area.

The subsurface facilities will cover an area of about 1,400 acres (5.6 $km^2$); and will include main access tunnels, called drifts, leading to the areas where the waste will be emplaced. The disposal areas will consist of smaller drifts with boreholes in the drift wall or floor to accept the waste disposal packages. Service areas near the shafts and ramps will also be built underground. The disposal system will rely on both geologic and manmade barriers to isolate the waste. The studies to determine the suitability of Yucca Mountain continue, and no decision has been made concerning its suitability (3, 5).



*Surface facilities at the repository will be located about one mile east of the underground facilities.*

Various alternatives are being considered for the transport system. These include single purpose transport packages (4) where the spent nuclear fuel or the high level waste canister is placed into the transport packaging, to a multiple purpose canister (MPC) containing one or more spent fuel assemblies or multiple high level waste canisters which would then be placed in separate overpacks for storage, transport and disposal. In the latter case, once loaded, the MPC would not be reopened after being sealed, and both the canister and applicable overpack would be required to satisfy NRC regulations for reactor loading, storage, transport and disposal (6).

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