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SGN MULTIPURPOSE DRY STORAGE TECHNOLOGY APPLIED TO THE ITALIAN SITUATION

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Abstract

SGN has gained considerable experience in the design and construction of interim storage facilities for spent fuel and various nuclear waste, and can therefore propose single product and multipurpose facilities capable of accommodating all types of waste in a single structure. The pooling of certain functions (transport cask reception, radiation protection) and the choice of optimized technologies to answer the specific needs of clients (transfer of nuclear packages by shielded handling cask or nuclearized crane), the use of the same type of storage pit to cool the heat releasing packages (vitrified nuclear waste, fuel elements) makes it possible to propose industrially proven and cost-effective solutions.

Studies carried out for the Dutch company COVRA (HABOG facility currently under implementation phase) provide an example of a multipurpose dry storage facility designed to store spent fuel, vitrified reprocessing waste, cemented hulls and end-pieces, cemented technological waste and bituminized waste from fuel reprocessing, i e. high level waste and intermediate level wastes.

The study conducted by SGN and GENESI (an Italian consortium formed by Ansaldo's Nuclear Division and Fiat Avio), on behalf of the Italian utility ENEL, offers another example of the multipurpose dry storage facility designed to store in a centralised site all the remaining irradiated fuel elements plus the vitrified waste.

This paper presents SGN's experience through a short description of reference storage facilities for various types of products (HLW and spent fuel). It continues with the typical application to the Italian situation to show how these proven technologies are combined to obtain multipurpose facilities tailored to the client's specific requirements.

1. SGN EXPERIENCE IN DRY STORAGE

1.1. Introduction

Whatever the policy adopted for the back end of the fuel cycle, spent fuel from reactors or waste from their reprocessing must be stored temporarily. A number of technologies have been developed and applied by SGN to meet these needs. They concern:

- Interim storage of waste generated by reprocessing, the alternative selected by France and other countries for civilian fuels. This includes:

  ⇒ medium level waste (MLW): hulls and end-pieces immobilized in concrete and bituminized waste are stored respectively in the EDS and STE3 facilities at La Hague. Both types of waste are stacked in ventilated concrete bunkers. These facilities respectively put into operation in 1990 (EDS) and 1989 (STE3) are covered in [1].

  ⇒ high level waste (HLW): fission products and transuranics are embedded in a glass matrix. The glass packages are stored in vertical pits, and cooled with air by forced convection (AVM, R7, T7 facilities at Marcoule and La Hague), or natural convection (EVSE facility at La Hague).

- Long-term storage provided for some spent fuels from the CEA's research reactors at the CASCAD facility pending a final decision. The fuels are stored dry in vertical pits cooled by natural convection.

1.2. HLW facilities: R7, T7 and EVSE facilities

The fission products separated by reprocessing operations are vitrified, poured in stainless steel canisters and stored on site in a dry storage building. At the La Hague site, the vitrification and associated glass canister storage take place in the R7 facility for the UP2 reprocessing plant and in the T7 facility for the UP3 reprocessing plant. These facilities were respectively put into operation in 1989 (R7) and 1992 (T7). The R7 and T7 facilities are almost identical. Each facility has three vitrification lines. In each facility, the following functions are performed:

- remote transfer of empty canister to the pouring cell;
- canister docking;
- canister filling and lid placement;
- canister transfer into the cooling cell;
- after cooling, canister transfer to the welding cell for lid sealing;
- canister contamination checking by a smear test;
- canister transfer to the storage building using a shielded handling cask. The storage building consists of several concrete vaults in which glass canisters are stacked within vertical and evenly spaced dry storage pits;
- canister cooling within the store by forced convection.

The main safety criteria specific to the R7 and T7 facilities are:

- containment obtained by the glass matrix and the glass canister (1st barrier) and HEPA filters on ventilation exhaust (2nd barrier);
- residual heat removal (average of 2,500 W/glass canister) to maintain glass matrix temperature less than or equal to 510°C.

To increase the storage capacity, the EVSE facility (extension of T7 facility) has been built and was put into operation in 1995. In the EVSE facility (Fig. 1), the released heat is removed by natural convection: a liner around each storage pit forms a double jacket and the cooling air circulates in the annular space thus formed. The leak-tight pit in which canisters are inserted provides the 2nd containment barrier. The main characteristics of R7, T7 and EVSE facilities are given in Table I.

TABLE I. MAIN CHARACTERISTICS OF R7, T7 AND EVSE

	Number of storage vaults	Storage capacity per vault	Number of pits per vault	Canister external dimensions
R7	5	900 canisters	100 pits of 9 canisters	D = 430 mm H = 1338 mm
T7	4	900 canisters	100 pits of 9 canisters	D = 430 mm H = 1338 mm
EVSE	2	2160 canisters	180 pits of 12 canisters	D = 430 mm H = 1338 mm

1.3. Spent fuel storage facilities

Typical SGN spent fuel dry storage facilities fulfil two main functions: unloading and canistering of fuel and dry storage.

As regards unloading, SGN has designed and constructed notably the T0 facility [2] for dry unloading of LWR spent fuel transport casks to be stored underwater in the La Hague pools, for decay heat prior to reprocessing. The T0 facility (Fig. 2), put into operation in 1986, has unloaded about 8,000 tU.

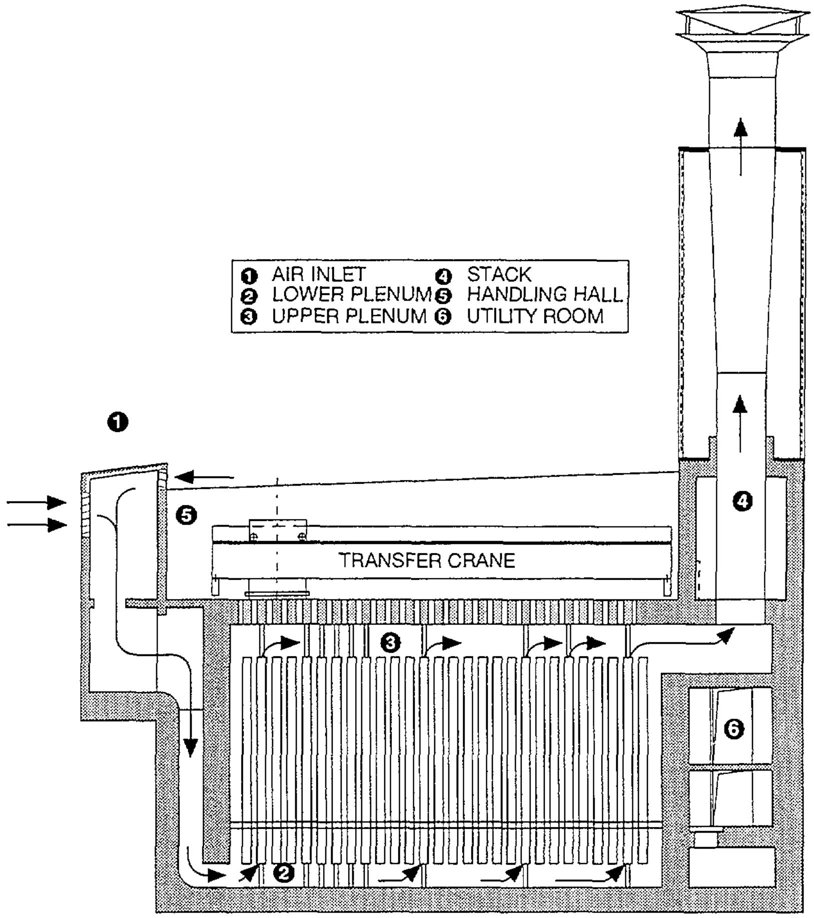

FIG. 1. Glass canister storage in EVSE facility

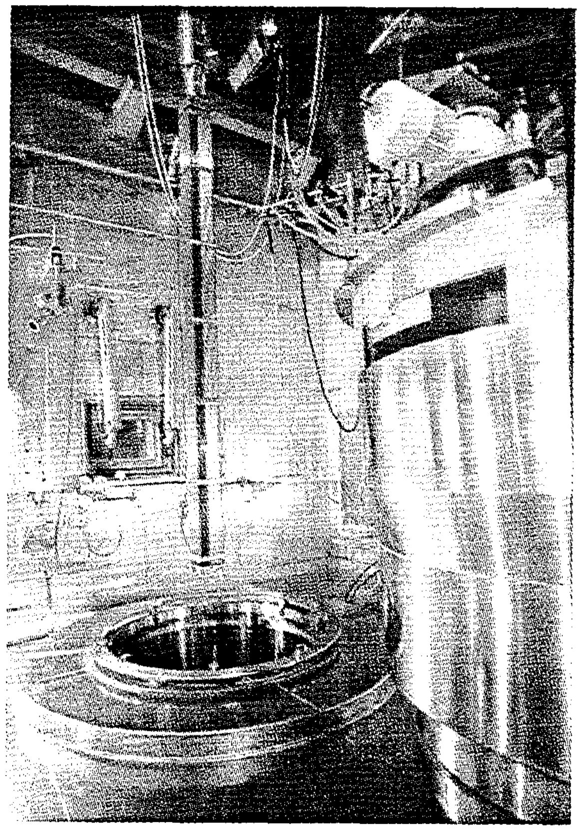

FIG. 2. T0 Facility - Fuel handling

Dry storage of fuel is also performed in the APM and Cascad facilities. APM (Atelier Pilote de Marcoule) is a pilot scale reprocessing plant for fast breeder reactor fuel, particularly spent fuel from the Phenix reactor. In the head-end unit of APM, called the TOR facility, leaktight canisters containing the fuel are received, unloaded and dry stored before mechanical and chemical treatment.

CASCAD (CASemate CADarache), located on the Cadarache site, is intended for the dry storage of exotic fuel which cannot be economically reprocessed because of its special properties. This facility, which has been operated since 1990, is planned for a storage period of 50 years after which the fuel will be rehandled according to final decision. Fuel to be stored comes from the CEA (French Atomic Energy Commission) research reactors, particularly from the Brennilis EL4 heavy water reactor. The operations implemented in the CASCAD facility are shown in Fig. 3.

The main safety functions are:

- containment by a multiple barrier system formed by leaktight canisters (1st barrier), leaktight pits (2nd barrier) and rod cladding;
- subcriticality ensured by pit arrangement;
- cooling of fuel to preserve cladding integrity.

Cooling of fuel by natural convection is a passive and thus inherently safe system (Fig.4). The cooling air enters the bottom of the pits, is heated along the pits and discharged to the atmosphere through a stack. The main characteristics of the storage vault are summarized in Table II.

TABLE II. MAIN CHARACTERISTICS OF STORAGE VAULT

	Number of storage vaults	**Storage capacity per vault**	**Number of pit per vault**	**EL4 canister external dimensions**
CASCAD	1	Equivalent to 180 tU	319	D = 104 mm H = 1,100 mm

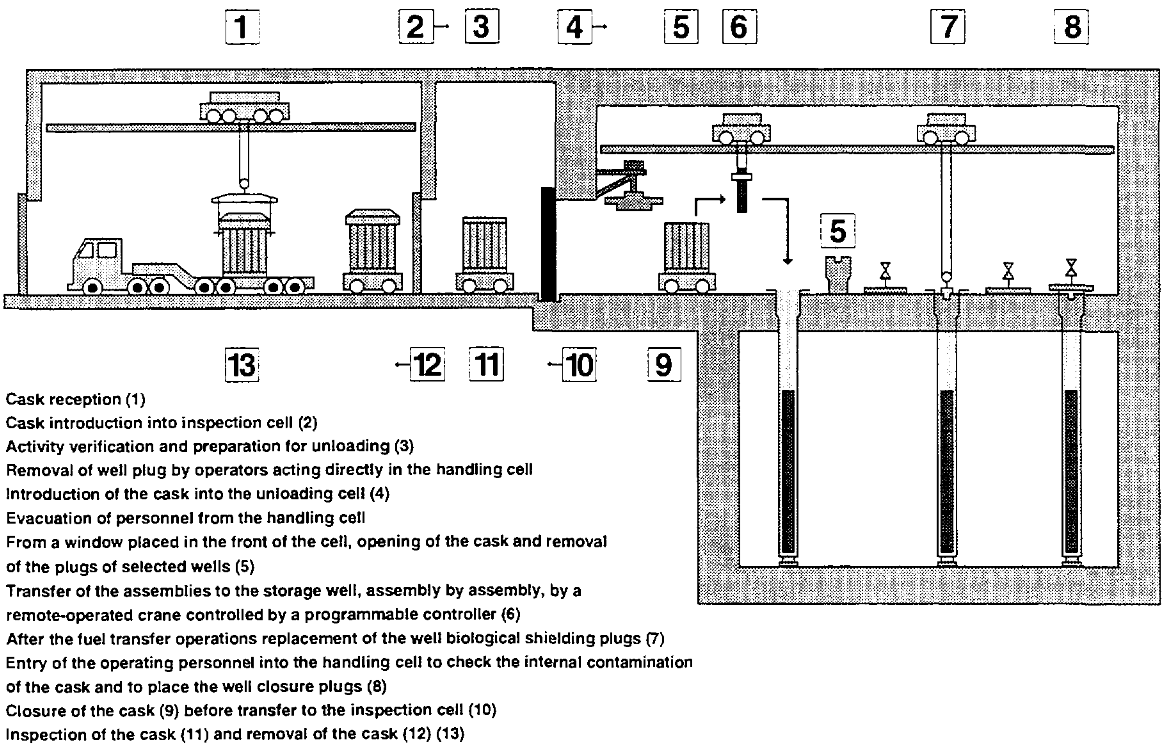

FIG. 3. Sequence of operations of CASCAD facility

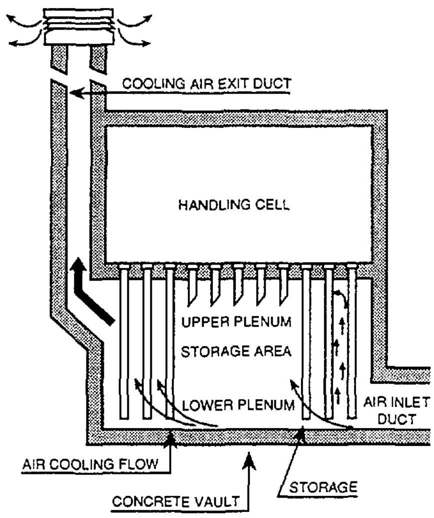

FIG. 4. Principle of passive air cooling system by natural convection

The T0 and TOR facilities put into operation in 1986 are not described in this paper because they are covered in references [2] and [3].

1.4. SGN multipurpose dry storage concept

Through the experience SGN has gained in interim storage facilities, for spent fuel, HLW and MLW, the company can offer its clients solutions ideally tailored to their needs. The facilities proposed may be dedicated to a given type of product (fuel element or waste), or may be of a centralized type (various types of waste). They include:

- The unloading unit: this unit offers maximum flexibility, accommodating all types of cask (without any adjustment to reactor loading procedures) and waste and fuel elements. In the handling cell, spent fuel is inserted in canisters dimensioned and adapted to the fuel characteristics to be stored, including nuclear properties (residual power, enrichment, etc.). After the interim storage period has elapsed, this unit also serves to remove the waste packages and fuel canisters to their final destination. This operation requires no complementary installation (Fig. 5).
- The interim storage modules: these modules (vaults and/or bunkers) are built and added as the need arises. The waste packages and fuel canisters are transferred from the unloading unit to the modules by means of shielded transfer equipment (R7 type) or a crane (CASCAD type).

The fuel canisters and waste packages are stored in a concrete structure which protects both the personnel and the public against radiation, but also the fuel and waste against external phenomena, such as earthquake, explosion, etc.

Containment is guaranteed by a double barrier:

- For fuel, the first barrier is formed by the canister, which contains the fuel elements. The canister is inerted, tightly sealed, and checked for integrity. The second barrier is ensured by the storage pit.
- For HLW and MLW, the first barrier is constituted by the matrix of the embedded waste and the associated canister or drum which also offers mechanical protection. For HLW stored in vaults, the second barrier is made by the tight pit into which the canisters are placed. For MLW stacked in bunkers, the second containment barrier is formed by the walls and the building ventilation.

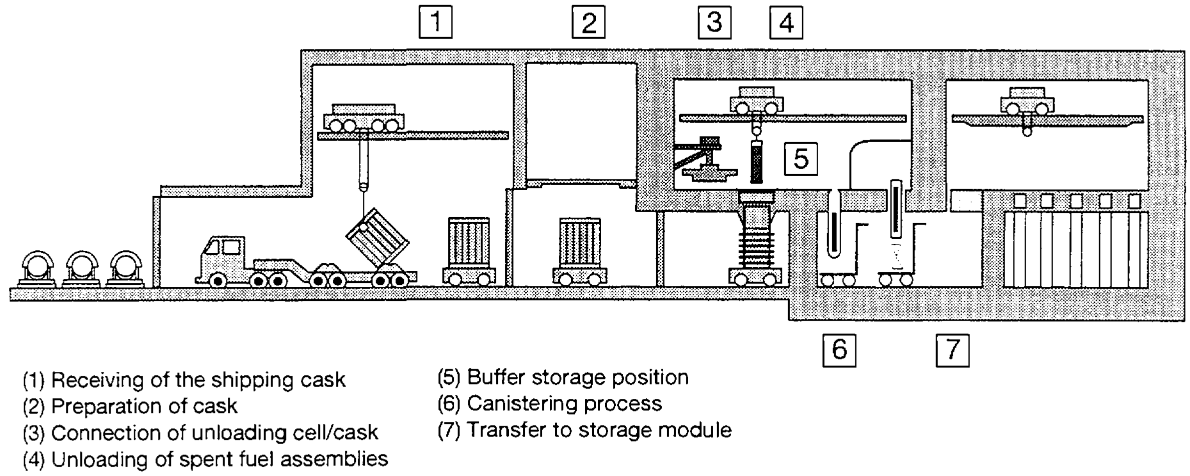

FIG. 5. Handling operations performed in the CASCAD facility adapted to LWR and VVER fuel

Studies carried out for the Dutch company COVRA (Centrale Organisatie Voor Radioactief Afval) provide an example of a multipurpose dry storage facility designed to store:

- spent fuel;
- vitrified reprocessing waste;
- cemented hulls and end-pieces, cemented technological waste and bituminized waste from fuel reprocessing;
- miscellaneous waste from research reactors and nuclear facilities.

The first two types of waste will be stored in three vaults, in vertical pits cooled by natural convection, using the technology implemented for the EVSE facility. The last two types, packaged in cemented containers or stainless steel drums, will be stored in three bunkers similar to those in the EDS facility. Currently, the project is in the implementation phase, tender specifications for equipment are being prepared and the construction permit is expected by the end of 1998.

2. APPLICATION TO THE ITALIAN SITUATION

2.1. Italian context

The Italian nuclear programme was abruptly halted in 1987 by a moratorium. The three operating nuclear power stations, one BWR, one PWR and one Magnox GCR, were all shut down. In addition, another small BWR nuclear plant was already in the decommissioning phase. All Magnox and part of PWR and BWR spent fuel elements were sent abroad for reprocessing before 1995.

At the end of 1995, an investigation was started regarding an Away From Reactor (AFR) Storage Facility to store all the remaining irradiated fuel elements plus the vitrified waste which should return from reprocessing. Furthermore, the possibility of storing the part of Superphenix's fast breeder reactor (FBR) spent fuel (one third of the core) charged to ENEL was also contemplated.

Besides the typical storage requirements (subcriticality, heat removal, radioactive material containment and radiation), the facility was also to comply with the following main requirements:

- dry type, passive cooling;
- proven, licensed technology;
- years design life;
- single centralised site;

- self sustaining, in order to allow maintenance in case of problems and shipment to final storage at the end of the interim period, also after decommissioning of all nuclear power plants in Italy;
- capability to store different types of fuel elements (BWR, PWR, old BWR in bottles, high power FBR) and Vitrified high level waste;
- capability to withstand severe accidents (in particular, earthquake and air crash);
- capability of monitoring containment.

Another important constraint was related to existing equipment and physical restrictions in the three current Italian storage sites (Caorso and Trino NPPs and Saluggia storage pool), limiting loads and dimensions of components which could be handled without significant modifications.

The GENESI consortium (Ansaldo Nuclear division and Fiat Avio) was first in charge to select the most suitable storage concept based on the above mentioned concept. As a result of this study, the SGN dry vaults storage was chosen.

2.2. Description of the designed dry storage facility

The interim dry storage facility is composed of one concrete building with a roughly parallelepiped shape of approximately 63 m length, 37 m width and 20 m height. A light structure metal building annex to receive the trucks carrying the casks completes the facility. Two stacks, partially made of concrete with upper part metal chimneys, are provided on the roof for cooling air discharge to the atmosphere; a third stack is also planned for building ventilation. The building has four main levels and can be basically divided in three parts:

1. the waste processing system area;
2. the storage area;
3. the services and control area.

The interim dry storage facility is designed for the following purposes:

- reception and unloading of different types of spent fuel and vitrified high level waste (vitrified HLW) transport casks from road trucks or rail wagon;
- unloading of spent fuel elements from transport casks, checking of fuel conditions and conditioning inside welded canisters filled with helium;
- unloading of vitrified HLW packages from transport casks and related contamination checking;
- storage of both fuel canisters and vitrified HLW packages in vertical pits cooled by natural air convection;
- retrieval of all stored waste for final disposal.

To perform the above tasks the facility has been functionally divided into five units, each one in charge of a part of the process.

2.2.1. Cask reception, preparation and shipping

Different types of transport casks are to be received in the interim dry storage facility. They arrive in horizontal position on special trailers and are tilted and placed in vertical position onto a transfer trolley after removal of shock absorbers.

The preparation for both spent fuel and glass canister transport casks consists of:

1. cask external contamination checking;
2. cask internal atmosphere checking by internal pressure measurement;
3. check for contamination of the internal cavity (glass canister only);
4. check of fuel integrity by krypton detection in internal cavity (spent fuel only);
5. cask lid unbolting by an unscrewing machine supported by an overhead crane;
6. transfer of the cask to its unloading position.

For transport cask return shipping, the same operations have to be performed in the reverse order. Moreover, a leak test on lid gaskets and a contamination check of the external surface are performed.

2.2.2. Spent fuel handling in the unloading cell

For spent fuel transport cask unloading, the cask is placed in and anchored to the unloading cell by means of a specially designed docking station, which is provided with inflatable seals to ensure a leak-tight connection and prevent contamination of the upper part of the cask lid and the lower surface of the unloading cell plug. The cask lid is then removed by the in-cell crane and the fuel elements are extracted from the cask and placed into the buffer storage in the unloading cell; depending on the type of fuel, some checking may also be performed. The cask lid is then re-positioned on the empty cask, which can be undocked and transferred to the preparation area for reshipment. A docking station, similar to the one for the transport cask, is provided for the canister, which is docked in the same way. The fuel elements can then be transferred by the buffer storage to the canister, which is closed after filling by repositioning the lid.

2.2.3. Spent fuel encapsulation in storage canisters

Following the operations performed above, the canister is undocked and brought by a transfer trolley to a position where the remote welding of the lid can be performed. After the welding, a helium leak test is performed on the weld, and the canister is vacuumed and inerted by filling with helium gas. A cover cap is then welded on top of the quick coupling connection used for gas filling, and the canister is moved by the trolley to a position under the penetration for access to the storage hall.

2.2.4. Transfer of fuel canisters and vitrified HLW packages to the storage wells

Once positioned by the transfer trolley under the storage hall penetration, fuel canisters are rehandled to their storage pit by means of a remote controlledbridge crane.

The crane performs the following operations:

1. storage well lid and shield plug removal;
2. canister recovery from the transfer trolley and transfer to its storage pit;
3. canister positioning;
4. storage pit closing by shield plug and lid repositioning.

After the repositioning of the plug, operators can enter the storage hall for lid bolting.

The same procedure is followed for vitrified VHLW packages, with the difference that the canister is extracted directly by transport cask positioned in a specific location under the storage hall and the packages are stacked on four levels inside the pits.

2.2.5. Cooling of the storage vaults

The air cooling system is based on the natural convection concept. Fresh air is supplied through air inlets into the bottom plenum, circulates around pits and is exhausted through the stack. The products are stored according to the decay heat to be evacuated:

- for the highest heat producing products (fast breeder reactor fuel and vitrified fission products), one specific vault equipped with double jacket vertical pits cooled by natural convection and using the technology implemented in the EVSE facility is provided;
- for the lowest heat producing product (BWR spent fuel), a separate vault equipped with single vertical pits cooled by natural convection using the technology implemented in the CASCAD facility is provided.

3. ADVANTAGES OF THE PROPOSED TECHNOLOGY

The main highlights and strengths of the proposed technology are:

- Flexibility:
  - the dry storage technology can accommodate any type of fuel and any type of cask can be handled;
  - special waste can be stored in the facility, including vitrified high-level waste (HLW) and other heat releasing waste;
  - the modular design of the storage concept allows storage capacity to be increased as needed;
  - canisters are completely retrievable in the storage concept.

- Safety:
  - double containment barrier;
  - double containment barrier monitoring;
  - passive air cooling;
  - proven technologies.

- A simple, cost-effective solution. Dry storage provides several benefits:
  - low capital and operating costs;
  - no effluents;
  - fewer operating personnel;
  - storing multiple products in a single facility also offers significant cost savings, since only one receiving unit and one set of utilities (electric power, ventilation, etc.) serve multiple modules.

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