INTERNATIONAL MEETING
NUCLEAR POWER IN EASTERN EUROPE : SAFETY, EUROPEAN INTEGRATION, FREE ELECTRICITY MARKET

NEW DEVELOPMENTS IN DRY SPENT FUEL STORAGE

C. BONNET Ph. CHEVALIER

SGN Société Générale pour les Techniques Nouvelles
1, Rue des Hérons
MONTIGNY-LE-BRETONNEUX
78182 SAINT QUENTIN EN YVELINES CEDEX
FRANCE

NEW DEVELOPMENTS IN DRY SPENT FUEL STORAGE

ABSTRACT

As shown in various new examples, HABOG facility (Netherlands), CERNAVODA (Candu – Romania), KOZLODUY (VVER – Bulgaria), CHERNOBYL (RMBK – Ukraine), MAYAK (Spent Fuel from submarine and Icebreakers – Russia), recent studies allow to confirm the flexibility and performances of the CASCAD system proposed by SGN, both in safety and operability, for the dry storage of main kinds of spent fuel.

The main features are :

- A multiple containment barrier system : as required by international regulation, 2 independent barriers are provided (tight canister and storage pit)
- Passive cooling, while the Fuel Assemblies are stored in an inert atmosphere and under conditions of temperature preventing from degradation of rod cladding
- Sub-criticality controlled by adequate arrangements in any conditions
- Safe facility meeting ICPR 60 Requirements as well as all applicable regulations (including severe weather conditions and earthquake)
- Safe handling operations
- Retrievability of the spent fuel either during storage period or at the end of planned storage period (100 years)
- Future Decommissioning of the facility facilitated through design optimisation
- Construction and operating cost-effectiveness.

1. Introduction

Whatever the policy adopted for the back end of the fuel cycle, spent fuel from reactors waiting for a final solution or waste generated by reprocessing must be stored temporarily.

Based upon French CEA's technology, SGN has developed for many years the Cascad concept, already well known for interim storage of :

- HLW,
- HWR spent fuel
- and certain spent fuels from the CEA's Research reactors and French Navy Submarines.

This system has been adapted to other kind of fuels, including those currently used in Former Soviet Union and Eastern Europe countries : VVER, RBMK, spent fuel from Russian submarines and icebreakers and CANDU.

This paper briefly presents the existing facilities based on the CASCAD concept as well as some proposals recently made to illustrate its performances and flexibility.

2. SGN dry storage Reference Facilities

2.1. Cascad Facility

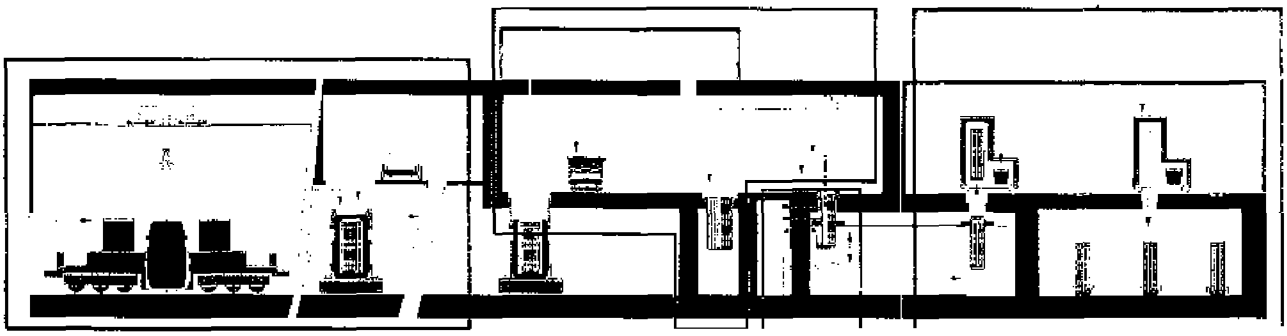
Cascad, located on the Cadarache site (France), has been operated since 1990, for a storage period of 50 years.

Fuel stored in this facility originates from the CEA (French Atomic Energy Commission) research reactors and, in particular, from the Brennilis EL 4 Heavy Water Reactor as well as spent fuel from the French Navy.

The main safety functions are :

- Containment by a multiple barrier system comprising leaktight canisters (1st barrier) and leaktight wells (2nd barrier), in addition to rod cladding,
- Subcriticality ensured in any conditions by pit arrangement,
- Cooling of fuel to preserve cladding integrity. Cooling is achieved by natural convection as an inherently safe system.

The cooling air which enters the bottom of the wells is heated along the wells and discharged to the atmosphere through a stack.



Cascad schematic

2.2. Other facilities : EVSE, R7, T7, AVM, TOR

On the La Hague site, the vitrification of fission products generated by reprocessing and associated glass canister storage take place in the R7 facility for the UP 2 plant and in the T7 facility for the UP3 plant. These facilities were respectively put into operation in 1989 and 1992.

In each facility, the following functions are performed :

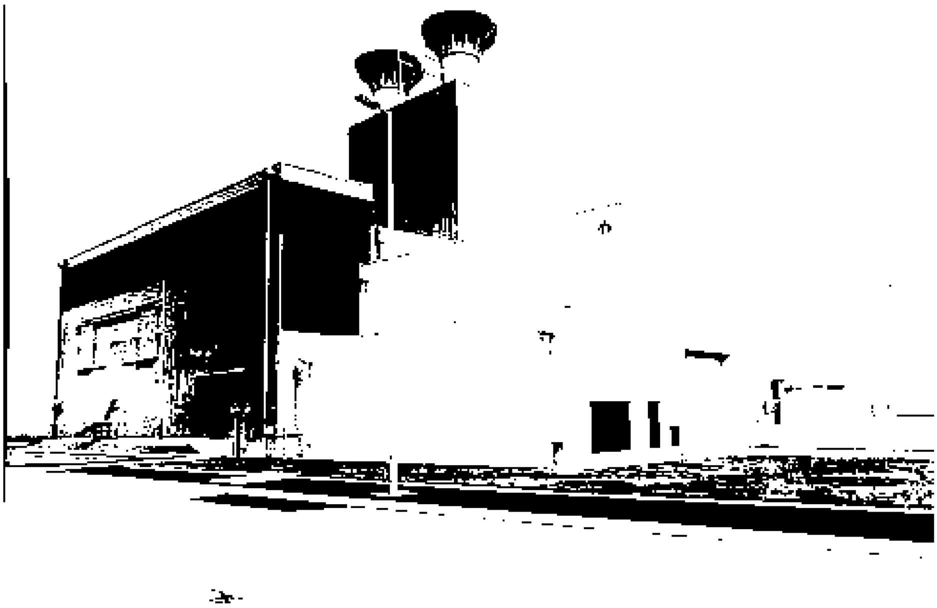
- remote transfer of empty canister to the pouring cell,
- canister docking, canister filling and lid placement,
- canister transfer into the cooling cell,
- after cooling, canister transfer to the welding cell for lid sealing,
- canister contamination checking by a smear test,
- canister transfer to the storage by a handling cask,
- canister cooling by forced convection.

The main safety criteria specific to the storage areas of 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 glass storage for T7) was built and commissioned in 1995.

In the EVSE facility, the released heat is removed by natural convection. A liner around each well forms a double jacket and the cooling air circulates in the annular space thus formed. The leaktight well in which canisters are inserted provides the 2nd containment barrier.



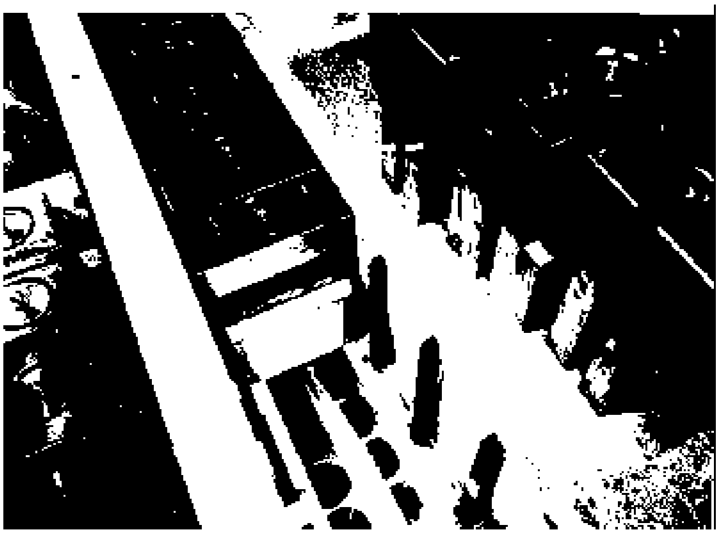
EVSE

The storage capacities are as follows :

- For R7 and T7
  900 canisters can be stored per vault. each vault includes 100 pits of 9 canisters (dia. = 430 mm, h = 1,338 mm). There are 9 vaults for both facilities.
- For EVSE
  2,160 canisters (180 pits containing 12 canisters) can be stored in 2 vaults.

AVM
Like R7 and T7, AVM is a vitrification facility with an interim storage for canisters, located at Marcoule. It has been commissioned in 1978.

TOR
Facility, also in Marcoule, was commissioned in 1986 for the reprocessing of FBR fuel from Phenix. The fuel elements is unloaded under dry conditions and transferred to storage pits, cooled by forced ventilation.



TOR Facility

3. SGN Dry Storage Concept

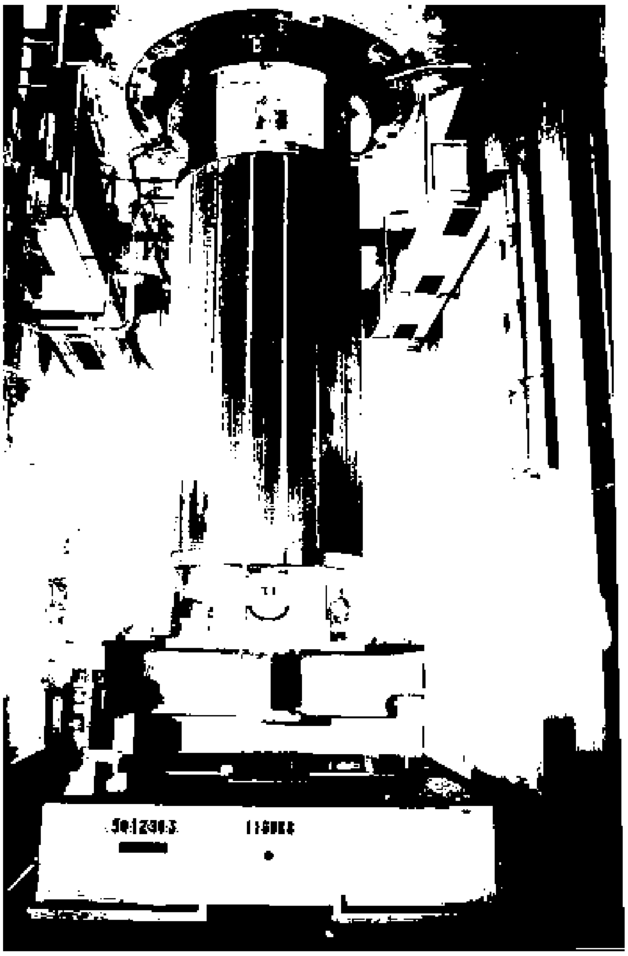
3.1. General overview

Through the experience SGN 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 of the centralised type (various types of fuels e. g. VVER 440 and VVER 1000). They include the unloading unit and the interim storage modules.

The unloading unit

This unit offers maximum flexibility, accommodating all types of casks (without any adjustment to reactor loading procedures) and fuel element. The design of this unit is based on T0 spent fuel dry unloading facility of the COGEMA La Hague Plant. Since 1986, T0 has unloaded more than 13,000 MTU of PWR and BWR.

In the handling cell, spent fuel is inserted in canisters dimensioned and adapted to the fuel to be stored, irrespective of their dimensions or nuclear properties -residual- power, enrichment, etc …). After the interim storage period has elapsed, this unit also serves to remove the fuel canisters to their final destination. This operation requires no complementary installation.



Dry cask unloading on TO

The interim storage modules

These modules are built and added as the need arises. The fuel canisters are transferred from the unloading unit to the modules by means of a shielded transfer equipment or a crane.

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

Containment is ensured by a double barrier :

- The first barrier is formed by the canister, in which the fuel elements are accommodated. The canister is inerted, tightly sealed and checked for integrity.

- The second barrier is made by the leaktight well into which the canisters are introduced.

This double containment makes it unnecessary to check the status of the cladding in conditions representative of interim storage facilities. This step is a prerequisite when the cladding is considered to be the first containment barrier. It also helps to manage damaged fuels in the same way as sound fuels.

A concept simplified and improved

The unique experience gained by SGN on interim storage facilities enables it to offer multipurpose facilities capable of accommodating several kinds of fuel stored in a single structure.

Thanks to this experience, SGN, also brought simplification in the design and therefore made easier the access of the local industry for the supply of the components.

3.2. The Habog facility

Final waste resulting from reprocessing of Deutsch fuel from Borssele and Dodewaard as well as HEU reactor fuel (Petten and Delft) and research center waste (from Petten) will be stored for 100 years in Habog : a facility built by SGN and based on the Cascad concept.

SGN has been selected by Covra in 1993 and the studies took place in 1994 (conceptual) 1995 (basic design) and 1996 (detailed design).

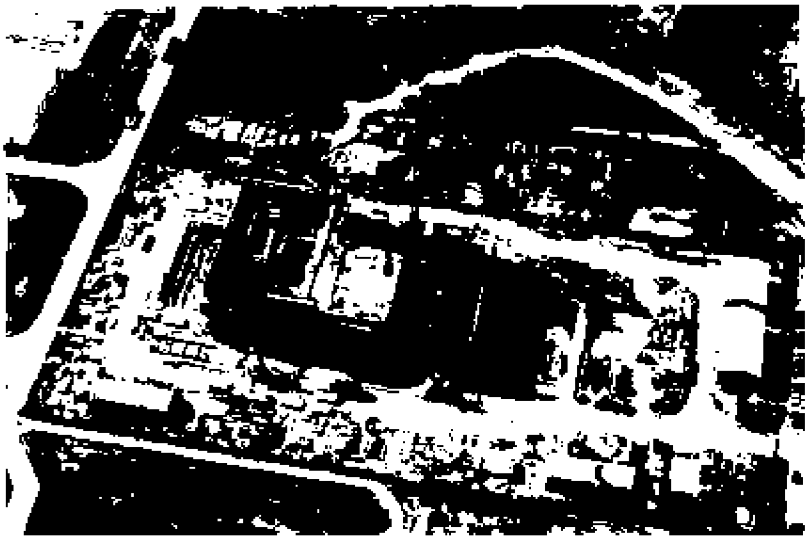
Implementation started then in 1997 and construction, started in 1999 for the civil works, will be completed by mid 2002 while commissioning is expected in 2003.

The design complies with the American standard ANSI-ANS 57-9 rules and specific events like flooding, earthquake, aircraft crash (F16-A Falcon Fighter), pressure wave resulting from external explosion and whirlwinds (velocity 125 m/s) have been considered.

Whether they are heat producing or not waste packages will be sorted and stored in appropriate structures.

Heat producing waste (vitrified canisters and fuel) will be piled in pits, and cooled by natural convection.

Storage pits can be replaced if necessary.
For the quality of foundation, the soil has been excavated and replaced by high grade sand (no piles necessary).



Habog building status of construction in September 2000

3.3. Examples of recent proposals

3.3.1. Cascad dry storage adapted for Candu (Cernavoda – Romania)

3.3.1.1. Fuel characteristics

In comparison with EL 4 - Brennilis, the main characteristics are as follows

	Candu	EL 4 (Brennilis – HWR)
Fuel geometry	cylindrical	cylindrical
Fuel bundle length	495 mm	502 mm
Diameter of fuel bundle	102 mm	92,5 mm
Fuel mass (kg of UO_2)	20,8 kg	10,6 kg
Fuel burn-up	7,800 MWd / tU (average)	20,000 (max.)
Fuel enrichment (% weight of U235)	0,72	1,42
Cladding material	Zr	Zr - Cu

EL 4 and Candu fuels are very similar vis a vis storage criteria.

3.3.1.2. Adaptation of Cascad concept

As can be seen here above, Candu and HWR fuels are very similar in terms of size and radiological features.

Therefore, SGN easily adapted the design to the Romanian customer needs, on the principle of modular storage facilities.

In particular, cask docking has been redesigned with air tight link. Basket and canister sizes have been defined according to the dimensions of Candu fuel. As the fuel elements are retrieved from a reactor pool, fuel dryness is systematically checked before canister inerting with Helium (risk of radiolysis if over pressure of H2 during storage phase).

Calculation of heat removal thanks to the natural ventilation system leads to optimise the pits heights and arrangement, as well as the stack parameters.

3.3.2. Cascad dry storage adapted for RBMK (Chernobyl – Ukraine - and Kursk, Smolensk - Russian Federation)

SGN has conceived a project for interim storage during 100 years of RBMK Spent Fuel Assemblies (FA) and Absorber Rods (AR).

The main characteristics are the following :

- Space saving design,
- Flexibility regarding types of casks / fuel / waste,
- FA canistered in vertical pits and AR stored in the same modular buildings (in dedicated canisters),
- TK 8 reception and preparation have been managed to be similar as Chernobyl NPP ones (dry conditions),
- Damaged FA can be stored without additional equipment or constraints,
- An effective drying of FA is performed and checked,
- Inerting, closing, control of canisters,
- Separate cooling system for each storage vault T° < 300°C (fuel cladding),
- The two containments barriers are monitored by gas sampling and tightness tests,
- Pits in stainless steel (100 years life time),

- Reliable criticality control based on a safe spacing of FA and pits. Bases : pessimistic geometry, maximum fuel enrichment no burn up credit and moderation conditions selected optimal by modelling water presence : subcriticality is ensured in any circumstances including all the accidents design events,

- Margin in operation thanks to efficient fuel decay heat removal (flexibility in thermal power of fuel received),

- Cooling efficiency assessed with conservative hypotheses :
  . pessimistic temperatures, wind,
  . all convective, conductive and radiative heat transfers have been considered.

3.3.3. Spent fuel from submarine & Icebreakers (Mayak - Russia)

In order to cope with the spent fuel arising from submarines of Murmansk / Kola Region Fleet, a dry store proposed by SGN has been selected.

Fuel characteristics : the reference case consists in a cylindrical zirconium alloy sleeve containing 54 fuel rods, in a cylindrical stainless steel tube 3 m long.

5 FA per canister - Leaking fuels assembly deemed to be acceptable

Safety principles :

- Dose rates in compliance with international regulations
- Subcriticality ensured by appropriate geometric spacing for all normal and accidental conditions
- Water ingress has been considered - No credit is taken for burn up in calculations.

Containment :

As fuel cladding and canister cannot be considered as reliable barriers, vaults and building have been conceived and designed to be the two containment barriers.

Description of the facility :

- Reception zone: Wagon reception area
  Loading / unloading casks (TK 18) area
  Preparation room (with transfer cask for canisters)
  Auxiliary rooms (electrical rooms, control room, utilities, …)

- Storage zone: Modular concrete vaults (according to the needed capacity)
  Two ventilation rooms
  One handling hall (with the transfer machine)

Specific cooling system :

Due to extreme weather conditions, inlet air is conditioned in order to have a temperature in the range of + 5°C - + 20°C, with forced ventilation.

The calculation design allows not to exceed 200°C at the fuel cladding.

3.4. Cascad dry storage adapted for VVER fuel (Kozloduy – Bulgaria)

In order to satisfy the needs of Kozloduy (Bulgaria), SGN proposes a tailored version of Cascad, able to cope with the two kinds of fuel in used at KNPP : VVER 440 (units 1 to 4) and VVER 1000 (units 5 and 6).

The main characteristics are the following :

- Storage facility disconnected from existing facilities with two distinct areas : reception / canistering of fuel assemblies and storage itself.
- Reception facility is adapted to TK 6 (VVER 440) and TK 13 (VVER 1000) casks and is independent from the site storage pools.
- Fuel is unloaded and transferred into stainless steel canisters, tightly welded and maintained free of external contamination.
- Storage facility structure is based on concrete vaults, providing appropriate shielding (radiation exposure) and protection of the fuel from external phenomena.
- Safe retrieval (irradiation / contamination).
- The storage modules design has been optimised according to the data of spent fuel (thermal power, criticality).
- A unique canister diameter can be used both for VVER 440 and VVER 1000.
- The canisters are enclosed in tight metallic pits, which are built in a dry vault cooled by natural convection. Cooling system is designed to keep cladding temperature under 350°C whatever the weather conditions.
- Exhaust air is continuously monitored.

4. Conclusion

In short, whatever the fuel is HWR, PWR, VVER, RBMK, Candu or Submarine reactor, the facility proposed by SGN is a solution that is :

- **Tried and proven**

  The design of the equipment and structure relies on industrial installations that have been operated for years to the full satisfaction of clients.

- **Flexible**

  All types of cask and fuel element can be accommodated as described here above.

- **Safe**

  Safety is a paramount design criterion. Two independent barriers guarantee the good containment.

- **Simple and cost effective**

  Local participation can be very high in the supply of components.

5. References

C. Bonnet “Multi purpose Dry Storage Facilities” ENC 98, Nice, France, October 25-28, 1998.

C. Bonnet, V. Lassère “SGN Experience in Dry Storage of Spent Fuel and Nuclear Waste” ASME 1995, Berlin, September 3-9, 1995.

C. Bonnet, P. Roux “SGN Experience in Dry Vault Storage for Spent Fuel and High-level Waste” IAEA Vienna, Austria, October 10-14, 1994

The Cascad spent fuel dry storage facility, C. Bonnet and M. Giorgio (SGN), ASME Int. Conf. Praha, September 1993.

Cascad dry storage concept for spent fuel, B. Singer (SGN) IAEA Technical Committee on Away from Reactor Storage concepts and Their Implications, Wien, 15-18 March 1993.

Experience acquired in Cadarache in the Cascad dry storage facility for spent fuel, R. Portal (EDF) H. Henry (CEA and C. Bonnet (SGN), IAEA Advisory Group Meeting on Design Technology and Operational Experience of Spent Fuel Storage Facilities, Wien, 25-28 February 1992.

R. Fanton, L. Baillif “Experience Acquired at the La Hague Reprocessing Plant in Receiving and Storage of LWR Fuels” IAEA Vienna, Austria, October 8-12, 1990

The Cascad spent fuel dry storage facility, ENC’90 Lyon, 23-27 September 1990.