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SPENT FUEL STORAGE PRACTICES AND PERSPECTIVES FOR WWER FUEL IN EASTERN EUROPE

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1. INTRODUCTION

Operation of nuclear power plants generates spent nuclear fuel for which suitable management arrangements must be made. The amount of spent fuel to be stored continues to increase. Management of this spent fuel has always been one of the most important tasks in the nuclear fuel cycle and it is still one of the most vital problems common to all countries with nuclear reactors.

Before discussing the specific spent WWER fuel storage issues, it will be useful to review the general issues and options in spent fuel management and storage.

Storage of spent nuclear fuel is an essential element of the back-end of the nuclear fuel cycle. It is necessary whether the fuel is destined for reprocessing or permanent disposal. In all cases, the spent fuel begins its journey with wet storage in a cooling pool, connected to the reactor. Once the fuel is sufficiently cooled it may be removed from the pool and transported to a reprocessing facility, a disposal facility, or elsewhere for further storage, as appropriate. Prior to reprocessing or disposal, spent fuel is generally stored at the facility site as it awaits treatment.

Storage of spent fuel in reactor spent fuel pools for cooling, and at reprocessing or disposal sites awaiting treatment, are inherent to the nuclear fuel cycle.

All of the storage situations in which the spent fuel is removed from the reactor cooling pool, are referred to as away from reactor (AFR) storage options. The removal of spent fuel from the fuel cycle by reprocessing or disposal reduces or limits the accumulated inventory of spent fuel. At present, only a portion of the spent fuel generated is reprocessed. Although disposal is being pursued by some countries, none of them has developed a working disposal facility.

Where reprocessing is not used, and disposal is not yet available, the spent fuel, that is generated by reactors at nuclear power plants (NPP), remains in the fuel cycle, and inventories of spent fuel increase. In some cases the growing inventories have reached and threatened to exceed reactor pool capacities. To remedy this situation, utilities have first sought a solution through more efficient pool storage. Another choice, often used after the benefits of more efficient pool use have been exhausted, is the use of AFR storage. This option is becoming common throughout the world. These dedicated AFR facilities are found at reactor-sites, AFR(RS), and away from reactor-sites, or off-site, AFR(OS). The AFR(OS) option may use a facility dedicated to a single reactor, or a centralized facility that serves the storage needs of several reactors.

Upon examining the various strategy options being used or developed by countries throughout the world for spent fuel storage, a degree of commonality is observed. The variations in strategies are usually seen as adjustments to a shared theme, introduced to satisfy a country's specific needs. The observed commonality suggests that co-operative efforts may afford opportunities for mutual benefit by the countries involved.

Recognising the international nature of spent fuel storage and its importance to the management of spent fuel from power reactors, the International Atomic Energy Agency (IAEA) has taken an active role in addressing this issue. The IAEA established a Regular Advisory Group on Spent Fuel Management in 1982. One of the activities of the Advisory Group is the collection, analysis, and exchange of information on spent fuel management. Storage of spent fuel is one aspect of spent fuel management that the Advisory Group has focused on. The Advisory Group regularly conducts formal meetings to perform the stated activities.

In addition to the regular meetings and meeting reports of the Advisory Group, special topics are addressed. When the Advisory Group observed the emergence of multi-purpose cask systems for use in spent fuel management during their meetings in 1993 and 1995, they recommended a study of the topic. The study of multi-purpose systems, which may be used for two or more purposes, including storage, transport, and disposal, was completed in 1999. Other spent fuel management topics assessed by the IAEA include burnup credit and remote handling technologies.

To support the dissemination of information, the IAEA conducts symposia on spent fuel management. The symposium format allows presentation of technical papers on formally established national policies, industrial practices and trends within a country, and specific technical activities being pursued. The IAEA's most recent International Symposium on Storage of Spent Fuel from Power Reactors was held in Vienna, Austria in November 1998.

2. SPENT FUEL ARISINGS, AMOUNTS OF SPENT FUEL BEING STORED

In 1997, the annual generation of spent fuel from all types of power reactors throughout the world was about 10,500 metric tons of heavy metal (t HM). The accumulated spent fuel was about 200,000 t HM at the end of 1997, and the world's accumulation of spent fuel projected by 2010 is 340,000 t HM. The projected growth in the world's accumulation of spent fuel through the year 2010, suggests a constant annual generation of about 10,750 t HM. If the same trend continues through 2015, the world's generation of spent fuel will be 395,000 t HM.

An important factor to consider from the data on world-wide nuclear capacities is, that spent fuel generation will continue at a relatively constant level in the foreseeable future. The current and projected quantities of fuel being discharged from power plants world-wide and quantities projected to be reprocessed together with fuel awaiting a decision are illustrated in the following Table 1.

Table 1. Quantities of Spent Fuel world-wide, t HM

	1995	2000	2005	2010
Spent fuel generated	175,000	225,000	280,000	340,000
Spent fuel to be reprocessed	60,000	75,000	90,000	120,000
Spent fuel in storage expecting decision	115,000	150,000	190,000	210,000

Since the first large scale final repositories for disposal of spent fuel are not expected to be in operation before the year 2010, interim storage will be the primary option for the next 20 years.

Table 2. shows the amounts of spent fuel in storage, broken down by regions. At the beginning of 1998 this amounted to 129,300 t HM. Of this about 124,000 t HM was in wet storage and the rest in dry storage. The figures also include the pool capacities of reprocessing facilities. These data indicate that presently most of the fuel resides under water and considerable positive experience exists internationally with this kind of wet storage for periods of up to 40 years.

TABLE 2. Spent fuel amounts in storage (kt HM)[1]

Region	AR	AFR		Total
		Wet	Dry	
Asia and Africa	11.6	0.2	0.7	12.5
East Europe	7.8	9.9	0.3	18
North & South America	59.8	1.5	3.3	64.6
West Europe	13.9	19.3	1.0	34.2
World total	93.1	30.9	5.3	129.3

Table 3. shows the break-down of world-wide storage capacities by regions. At the beginning of 1998, the capacity of the existing storage facilities in operation was 231,000 t HM, and the capacity of those under construction amounted to 11,500 t HM.

TABLE 3. Spent fuel storage capacities (kt HM)[1]

Region	In operation				Under construction		
	AR	AFR wet	AFR dry	Total	Wet	Dry	Total
Asia and Africa	20.0	1.9	0.7	22.6	0.7	0.8	1.5
East Europe	14.3	19.6	0.8	34.7	0.8[2]	1.6	2.4
North & South America	94.9	1.8	10.0	106.7	-	6.8	6.8
West Europe	26.1	31.7	9.2	67.0	-	0.8	0.8
World total	155.3	55.0	20.7	231.0	1.5	10.0	11.5

3. SPENT FUEL STORAGE FACILITIES FOR NUCLEAR POWER PLANTS

Following discharge from a reactor, spent fuel is radiologically and thermally hot. In order to cool the spent fuel, it is held in a pool where it can safely dissipate its internally generated heat as many of the radioactive fission products go through rapid, exponential decay. The cooling pools are directly attached to the reactor, allowing transfer from reactor to pool in a water environment.

In the case of reprocessing, spent fuel may be held in the pool for as little as three months before transporting to a reprocessing plant where it may be stored while it awaits processing. Wet storage is generally used at reprocessing plants. In the case of the open or once through

[1] Taken from the IAEA publications.
[2] By reracking existing AFR storage capacity

fuel cycle, spent fuel generally remains in the cooling pool for extended periods of time. In the USA, pools were constructed at early generation reactors for short cooling periods and later reprocessing. When reprocessing was abandoned in the USA, later generation reactors were built with larger pool capacities. To solve the problems associated with limited pool storage at older reactors, various methods were used to improve pool storage efficiencies. These pool enhancements have included the use of neutron absorbing plates in fuel pool racks and credit for reduced reactivity, which is known as burnup credit. In addition to more efficient pool storage, many utility companies began to use dry storage technologies for older spent fuel.

Some countries have decided on a reprocessing fuel cycle (e.g., France, Russia, UK), and others (e.g., Sweden, USA) have decided on a once through fuel cycle, ending with deep geological disposal of spent fuel. Many countries remain undecided on disposition of spent fuel. The countries who are undecided are either weighing the options of recycling versus a closed fuel cycle, or awaiting further technological developments. Those who are undecided on spent fuel disposition must usually look to long term storage options for spent fuel management.

For countries needing long term storage there are a number of alternatives that may be used. Storage may be wet or dry, at-reactor, or AFR. In the case of AFR, the away from reactor facility may be at the reactor site, AFR(RS), or it may be off site AFR(OS). The off site facility may be dedicated to a single reactor's spent fuel, or to storage of spent fuel generated by several reactors. In the latter case, the facility is referred to as a Centralised Interim Storage Facility (CISF).

The nuclear industry has had considerable experience with wet storage of spent fuel. A large part of this experience stems from the fact that each reactor has a spent fuel pool. These pools are needed because newly discharged spent fuel generates a lot of heat. Learning about cooling pools is inherent in operating a power reactor. The experience gained from using these pools, since the first power reactors began operation in the late 1950s, assures their safe operation. Furthermore, Sweden's experience with their Clab facility, demonstrates the feasibility of a centralised wet storage facility.

Compared to wet storage, dry storage is a relatively new technology. For example, in the USA, the Nuclear Regulatory Commission (NRC) is preparing to begin renewal of the first 20-year storage licenses it issued. In August 1984, the NRC issued a decision on waste confidence. The decision, in part, addressed safe storage of spent fuel at reactors, even after a reactor's operating license expired. At the time of the waste confidence decision, dry storage technologies were being developed, and were therefore, a factor in that decision. One of the NRC's conclusions regarding waste confidence was that spent fuel could be stored safely for at least 30 years after a plant's operating license expired. The NRC reviews their waste confidence decision periodically. The NRC's waste confidence decision, approval of dry storage by national regulatory authorities throughout the world, and the approximately 20-years of experience with dry storage attests to its safety.

A developing technology for dry storage that was mentioned earlier is the multi-purpose canister (MPC) system. MPC designs are being developed in two varieties. One MPC concept uses a canister to hold spent fuel that fits into overpacks for transport and storage. The other, extends the canisters' use to disposal by using the transport-storage canister with a disposal overpack. In the USA, the transport-storage system is called a dual-purpose system, while

MPC refers to a transport-storage-disposal system. Studies have been done in the USA by the Department of Energy (DOE) on the use of a conceptual MPC design for its Federal Waste Management System.

DOE's study suggests that several benefits may accrue from using an MPC based system for management of a large inventory of spent fuel. For the large US inventory studied by DOE possible benefits include reduced fuel handling, reduced exposures and risks to workers and the general public, and cost savings. The study did not consider benefits of using MPC technologies for systems with small, spent fuel inventories.

Nearly all countries operating nuclear power plants have increased their existing AR capacity by re-racking using neutron absorbing materials between the assemblies, or through rod consolidation or simply by better distribution of fuel in the storage pools. Such modifications have resulted in about a twofold increase in storage capacity. Further capacity increases may invoke the so-called burnup credit in calculations of the criticality of irradiated fuels. In many cases, modifications were insufficient and separate AFR storage facilities had to be constructed. Although the majority of storage facilities are of the wet type (e.g. in France, Russia, Sweden, UK), many countries with large quantities of spent fuel have chosen or are choosing AFR dry storage (e.g. Canada, Czech Republic, Germany, Hungary, Lithuania and the USA). This type of storage has many benefits including the possibility of passive cooling, minimal or no maintenance and a non-corrosive environment.

Changes in the politics and trading relationships of the eastern European countries are affecting their spent fuel management policies. Russia now requires payment for services in hard currency at a "world price" level. Some legal problems also exist with the transport of Russian-origin fuel and its subsequent reprocessing in Russia. Such factors have lead to changes in the spent fuel management policy of these countries. Construction of a interim storage facility can be a temporary solution, with the options of reprocessing or direct disposal kept open. Details will be described below.

4. OVERVIEW OF STORAGE TYPES

A variety of spent nuclear fuel storage facilities have been designed and built in the countries operating nuclear power plants.

Having exhausted the AR storage capacity expansion opportunities, the practice adopted by many utilities has been to have some form of interim facility constructed, either in the form of "wet" or "dry" storage. These facilities are usually constructed as AFR(RS) storage facilities. This has often been a perfectly viable option but often the long-term spent fuel management option was not considered.

Water pools have certainly been built for use as AFR(RS) storage facilities with the necessary arrangements to transfer fuel across the site in the countries operating WWER reactors (Bulgaria, Germany (East), Russia, Slovakia). The largest AFR(OS) pools, however, are at reprocessing plants at La Hague and at Sellafield. These can store 5,000 to 12,000 t HM. The alternative types of storage being used or planned are dry, passive systems. These may be large, massive structures as in the case of a natural convection vault, or may be smaller, incrementally added individual units as in the examples of the metal casks, and the vertical or horizontal concrete casks (silos).

4.1. Water pool storage

Using water-filled pools for shielding and cooling of irradiated fuels and materials has been an established practice since the early days of nuclear power. This practice continues today throughout the world including a number of away-from-reactor storage facilities. A world survey of wet storage experience was published by the IAEA in 1982. It was updated and revised to include dry storage in 1988. A programme studying the behaviour of reactor fuel during extended storage in water pools (BEFAST) was reported in 1987, 1992 and in 1997. The conclusion from these studies is that water pool storage is a safe, well-understood, method for short and long-term storage of light water reactor fuels. The technology is simple to operate, the pool provides ready access to the fuel, thus assuring easy identification.

Pools are the most common option for storage of fuel immediately upon discharge from reactors, since they offer excellent heat transfer, which is essential in the early phase of fuel cooling. The exception to this are gas cooled reactors which initially cool the fuel in gas before sending to wet storage. In order for fuel assemblies to be suitable for dry storage, a minimum cooling time is required, which is related to burnup irradiation history, cooling time, pin pre-pressurization, and fission gas release from the cladding. The cooling ensures that fuel pin temperatures are acceptable, and that there is no risk of creep failure of the fuel assembly cladding when in a lower pressure dry storage atmosphere. Pool lining can be easily damaged during routine operation (dropping of tools, fuel assembly, etc) which might lead to loss of water in them. Water being the medium, which provides cooling and shielding, it is very important to avoid its loss or to ensure a reliable emergency supply.

Water pool storage, however, requires active systems to support their satisfactory performance. It is necessary to provide circulation for the water through filters and ion exchange beds to maintain the cleanliness and non-corrosive properties essential to successful long-term storage. In most cases, an active heat removal system is necessary. Water pool operation requires continuing attention preserving the water purity, and in maintenance and operation of circulation and cleanup systems. All active systems require electric power and there is a worker dose commitment.

When in the past, for various reasons, the capacity of these pools had to be increased, the nuclear plant operators have often first implemented various in-pool measures e.g. compact storage racks, before adding extensions to existing AR storage. This was usually more economic and may have been the only immediate solution. Some direct extensions have been possible to AR pools at a limited number of reactors. CANDU reactors and some LWRs on the other hand have very large AR pools, which can store nearly all lifetime arisings.

4.2. Metal storage casks

Metal casks have been used for the transport and storage of irradiated fuels and materials since the beginning of the nuclear industry. They are being utilised in a number of countries to store spent fuel when the arisings of fuel are in excess of the AR pool capacities. Metal casks are being used in Belgium, Czech Republic, Germany, India, Japan, Switzerland, and in the USA for storage. Some operational data are described in Appendix 1.

The metal casks are dry, passive devices, requiring no active systems to ensure proper cooling of the contained spent fuel, and only limited surveillance by site personnel. The equipment and practices for loading and handling these types of devices are well-established throughout the nuclear industry.

Because of the modular design of the casks, the system requires much smaller initial capital investment compared to storage pools. A principal disadvantage of the metal casks is their cost for large quantities, which is significantly higher per unit of spent fuel stored than for the other passive systems. It is often found that cask storage facilities are more economic for utilities with smaller spent fuel quantities and where they do not want a high initial capital investment. New lower cost casks and ones with greater capacity are being developed to meet the need. There may be cases, where cask storage is adopted as a short term measure but, if this is not part of a carefully devised long term option, then short term measures should be discouraged because overall costs may be higher and double handling of spent fuel and more waste generation may result.

4.3. Vertical and horizontal concrete silos

There are several concrete cask (sometimes called silo) concepts in service or being tested in several countries. Most of the silo designs are vertical, but one is horizontal (NUHOM). The vertical Canadian silo design comprises essentially a concrete cylindrical shield surrounding a central cavity, which contains the stored fuel assemblies. Cooling is by conduction through the walls and by natural convection from the outer concrete surfaces. It is generally most suitable for fuel with very low heat release due to concrete temperature limitations and has been and continues to be demonstrated in Canada for storing spent fuel assemblies from the CANDU reactors which have been cooled for many years in reactor pools.

The other concrete container concepts (vertical and horizontal) employ cooling channels within the shield structures and rely on natural convection of air through those internal channels for heat removal. These can generally accommodate fuel with higher heat release. Both systems seal the fuel in high integrity canisters.

Other important differences between the vertical and the horizontal convection-cooled units are in the handling systems needed to load, seal, install, and remove the canisters from the concrete shields.

Multi-purpose containers

Multi-purpose containers, as the name implies, satisfy more than one purpose in the area of spent fuel management. The spent fuel management functions considered are storage, transport, and disposal. In terms of spent fuel management, two design categories for multi-purpose containers are being considered:

1. designs used for storage and transport; and
2. designs used for storage, transport, and disposal.

In many countries, the first category, storage and transport, is referred to as dual-purpose, while the term multi-purpose is reserved for the second category.

Both categories are found as cask-based or canister-based systems. For the cask-based systems one integral unit serves all purposes for which the system is designed. For canister-based systems, a sealed canister contains the spent fuel, and is a common component or subsystem to the storage, transport, and disposal system, as applicable to the design (category of the multi-purpose system). Typically, canister-based systems will use overpacks to house the canister for the purposes of storage, transport, and disposal.

Typically the fuel is loaded into the cask at the power plants' loading pool or at any other facility discharging spent fuel, and the cask is directly placed in the dry storage. In this way there is no need to re-open the cask and the fuel requires fewer handling operations. Some capital savings can be achieved, because no support facilities for opening and unloading the casks are required. It is important to demonstrate that these multi-purpose storage casks are capable of remaining in good condition throughout the interim storage period and will still be able to comply with the prevailing requirements for transport, in the future. The principle of achieving and maintaining the licence for a multi-purpose cask is however very desirable.

There are a number of multi-purpose systems in use and under development at this time. Some of these are being used only in their country of origin, while others are being used in several countries. Since the list of such systems keeps growing, it will not be inclusive of every existing system. The following systems are known and licensed: TN24, VECTRA (MP-187), NAC, GNS (Castor, Pollux), BNFL Fuel Solutions, a.k.a. Sierra Nuclear (VSC), Westinghouse (MC-10), and Holtec (HI-STAR, HI-STORM).

4.4. Natural convection vaults

The vault is an above ground reinforced concrete building, containing arrays of storage cavities suitable for containment of one or more fuel units. Radiation shielding and protection is provided by the concrete structure. Heat removal is normally accomplished by circulation of air or gas over the exterior of fuel units or storage cavities, and subsequent exhausting of this air or gas directly to the outside atmosphere or cooling the air or gas via a secondary cooling system.

The natural convection vault is a dry passive system for long term storage of spent fuel, which has been cooled for some period of time. The fuel usually is stored in metal tubes in a shielded vault through which air passes, using the heat emitted from the stored fuel as the driving force to maintain an air thermosyphon. It is a self-regulating system in that as more heat is given up to the cooling air which rises up through the discharge stack, more air is drawn into the vault by the thermosyphon, assuring adequate cooling without the need for any active mechanical systems or personnel attention.

The cost per unit of fuel stored is relatively large for a small capacity vault, but decreases as the capacity of the vault is increased. For a large vault, the unit storage costs are roughly comparable with the concrete silos.

The vault concept was one of the first dry storage options considered for spent fuel studies in Canada, France, UK and the USA. A recent addition for WWER spent fuel is the MVDS (modular vault dry storage) in Hungary, which was developed by GEC-Alsthom Limited.

Selected examples of typical spent fuel storage facilities

WATER POOL STORAGE

Each nuclear power plant uses wet storage in the beginning. The safety of the underwater storage of spent fuel is demonstrated in each country. There is positive storage experience for periods exceeding 30 years for different LWR fuels.

Examples of successful AFR(OS) pool storage installations are at La Hague in France, at Sellafield in Britain, and the CLAB installation in Sweden. The capital investment in the installations has been very significant and their efficiency usually relies on large storage inventories. A good example of an AFR(RS) is the TVO-KPA storage facility.

METAL STORAGE CASKS

Metal casks are massive containers used in transport, storage and eventual disposal of spent fuel. The structural materials for metal casks may be forged steel, nodular cast iron, or a steel/lead sandwich structure. They are fitted with an internal basket or sealed metal canister, which provides structural strength as well as assures subcriticality. Metal casks usually have a double lid closure system that may be bolted or seal welded and may be monitored for leak tightness.

Metal casks are usually transferred directly from the fuel loading area to the storage site. Some metal casks are licensed for both storage and off-site transportation. Fuel is loaded vertically into the casks, which are usually stored in a vertical position.

Metal casks are used in a number of countries such as Belgium, the Czech Republic, Germany, India, Japan, Switzerland, and the United States.

Germany:

After an extended time period for design and licensing, two centralised cask storage facilities were built: one in Ahaus (close to the Dutch border) and one in Gorleben (close to the border of the former GDR). Both facilities are basically of the same design and originally had a capacity of 1,500 t HM each. Since 1996, Gorleben has extended its license to 3,800 t HM, while Ahaus has been licensed for 3,960 t HM. Both extensions are based on the use of more advanced higher capacity cask designs without increasing the size of the storage buildings.

Both the Ahaus and the Gorleben facilities have a storage building of about 200 m length, 38 m width and 20 m height. The buildings provide a well-defined controlled area for radiation and security protection measures and contribute to shielding of direct and skyshine radiation, which is essential as the sites are close to densely populated areas.

The storage buildings contain a cask reception area where the casks, after radiation and security checks, are lifted from the railway or road car. A bridge crane with a capacity of 140 t can move the casks to all handling and storage positions. The storage buildings also contain a maintenance area where the casks are prepared for storage and reshipment and where repairs can be performed. The buildings are equipped with air inlet openings in the side walls and outlets in the roof to enable natural convection heat removal.

The CASTOR casks consist of a thick-walled ductile cast iron body and a lid system. The body is cast in one piece. Four trunnions are bolted on, two at the head and two at the bottom end of the body. Cooling fins are included on the outside body except on casks with low heat load. Impact limiters are attached at the top and bottom of the cask during transportation.

The ductile cast iron wall of the cask body serves as a gamma and neutron shield. For additional neutron shielding, if necessary, concentric rows of axial borings in the wall of the cask body are filled with polyethylene rods. The cask bottom and secondary lid have a slab of the same material inserted for neutron shielding.

The cask is closed with a double barrier lid system. It consists of a primary and a secondary lid installed one on top of the other. The lids are constructed of stainless steel and bolted to the cask body. The primary lid has a typical overall thickness in the range of 250 to 300 mm. It has penetrations for flushing, venting, and vacuum drying the cask cavity as well as for leak testing the lid seals. The penetrations are sealed in an equivalent way. The secondary lid has a typical overall thickness in the range of 100 mm. It has equivalently sealed penetrations for pressurising the lid interspace, monitoring this pressure, and performing the leak-tightness measurements.

Both lids are equipped with multiple seals consisting of metal gaskets and elastomer O-rings. The metal gaskets fulfil the long-term helium leak rate requirement of a maximum leak rate of 10^{-7} mbar litre/sec. During storage, the interspace between the lids is pressurised with helium to approximately 6 bar. This overpressure is continuously monitored by a pressure gauge fitted to the secondary lid. Thus, the leak-tightness of the lid system is proven during the total storage period. (Figure 1)

The fuel basket accepts the spent fuel assemblies and ensures that criticality will not occur. The basket is of welded construction and is made of stainless steel and borated stainless steel sections. Its design is adapted to the particular spent nuclear fuel inventory.

The cask inner cavity has a nickel coating to prevent corrosion and to enable easy decontamination. The outside of the cask body is protected by a multi-layer epoxy resin coating in the fin area and nickel coating on the head and bottom parts. The cask cavity is backfilled with helium, which serves as an internal heat transfer medium as well as inhibiting corrosion.

The German AFR cask storage facilities provide for continuous monitoring of the leak-tightness of each cask during the total storage period. The CASTOR casks are pressurised with inert gas in the space between the primary and secondary lids. The interlid pressure is monitored with a pressure switch connected to an electronic monitoring system. The monitoring system provided at the Ahaus and Gorleben storage buildings will alarm if the interlid pressure drops below its specified set point.

A total of 305 CASTOR casks with HTR fuel was accepted in the Ahaus facility from 1992 until the end of 1996.

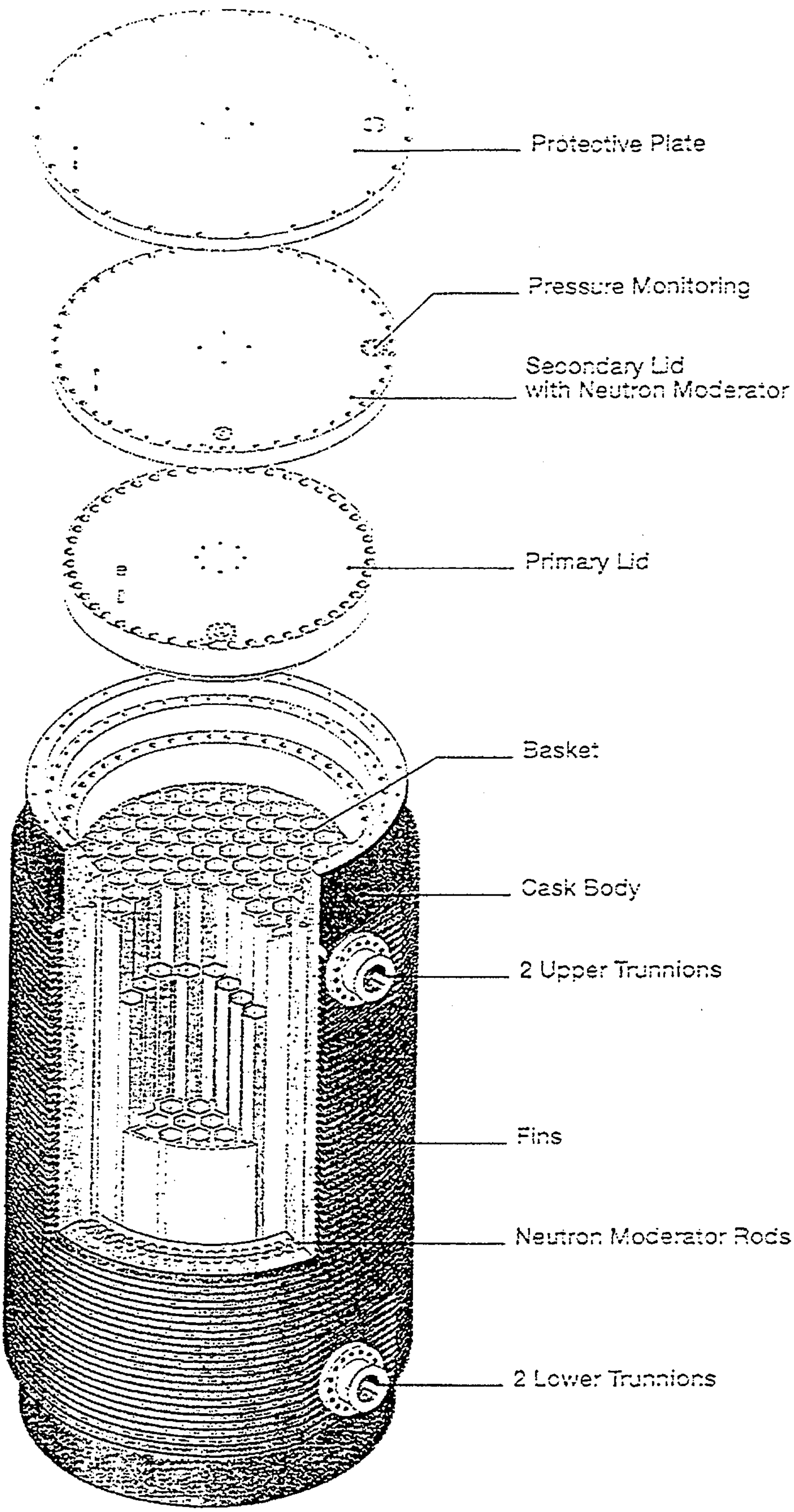


Fig. 1 CASTOR VVER 440/84
Transport and Storage Cask
Storage Configuration

GNB

In October 1993, Northern States Power Company (NSP) received a license from the NRC for an dry spent fuel storage facility using TN-40 metal storage casks at the *Prairie Island* site. NSP loaded its first TN-40 cask in 1995. The facility is licensed to store 48 TN-40 dual-purpose casks totalling 1 920 spent fuel assemblies and is located within the boundaries of the Prairie Island site.

VERTICAL AND HORIZONTAL CONCRETE CASKS

Concrete cask systems are monolithic or modular concrete reinforced structures. The concrete provides shielding while containment is provided by either an integral inner metal vessel (liner), which can be sealed after fuel loading, or by a separate sealed metal canister. Spent fuel may be stored in vertical or horizontal orientation.

Spent fuel may also be loaded directly into a concrete cask in the fuel loading station and the concrete cask would be transferred directly to the storage site. Some sealed metal canisters may be licensed for transportation as part of an off-site transportation package.

Alternatively, concrete cask systems may use a metal liner in the cask cavity to contain spent fuel and a single lid closure system. Heat transfer may take place solely by conduction through the concrete structure.

Concrete casks that rely on conductive heat transfer have more thermal limitations than those using natural convection air passages.

Canada:

In Canada, after successful investigations at Whiteshell, the first concrete silo type storage facility (AFR(RS)) at a commercial reactor site was located at the Gentilly-1 (G-1) decommissioned reactor. The concrete canisters (silos) are located indoors in an existing redundant building. For the Douglas Point and the NPD (Nuclear Power Demonstration) reactors, when these reactors were shut down, a cost comparison study showed that concrete canister (silo) storage would be less expensive than continued water pool storage and subsequently all the fuel was transferred into canisters. The canisters are located in the open at Douglas Point Nuclear Generating Station at a site adjacent to the decommissioned turbine building. The NPD fuel was moved to AECL's Chalk River Laboratories (CRL). The fuel baskets and canisters are of identical design.

Ontario Hydro are using a silo called a Concrete Integrated Canister (CIC) or Dry Storage Container as a demonstration for the storage of 6 and 10 year cooled fuel from the Pickering Plant. The demonstration CIC's are cylindrical, reinforced-steel, high density concrete containers with inner steel liners. The fuel bundles are loaded into modules, which in turn are loaded into the CIC under water. The CIC has a steel lined concrete lid, which is bolted on. An elastomer gasket is used to provide a seal between the lid and the container.

The CIC has a storage capacity of 7.7 t HM. Ontario Hydro has upgraded the CIC, and this version is referred to as a Dry Storage Container (DSC). It has the same storage capacity as the CIC, but is rectangular in configuration. It also has an outer steel casing, heavily reinforced concrete, and an inner steel liner. The steel lined lid is seal welded to the outer container liner.

AECL's concrete canister is built on-site using regular reinforced concrete and is fitted with a steel inner liner. Spent fuel is transferred in increments within sealed baskets using a shielded transfer cask and loaded vertically. Once loading operations are complete, a closure shield plug is placed and welded to the inner liner to provide additional containment.

USA:

In the US an early design for an internally ventilated vertical concrete silo was initially demonstrated at the Hanford site during the 1970s. A later generation commercial design ventilated storage canister (VSC) was tested at the Idaho National Engineering Laboratory and the design is approved by the USNRC.

Examples of *vertical concrete casks* include BNFL Fuel Solution's (formerly Sierra Nuclear's) VSC cask; and Ontario Hydro's Pickering concrete Dry Storage Container which is also designed for off site transport.

The NUHOMS storage system (NUHOMS - Nutech Horizontal Module System) is an example of a *horizontal concrete system*. Fuel is loaded vertically into metal canisters, which are stored in a horizontal orientation inside concrete storage modules. The sealed metal canister is contained in an on-site transfer cask for loading spent fuel from the fuel loading station and for transfer to the horizontal concrete storage module. The metal canisters are fitted with a double lid closure system, which following welding is tested for leak tightness. Some sealed metal canisters may be licensed for transportation as part of a transportation package. The system is not monitored for leak tightness.

This concept has been licensed by the USNRC and was in service in 1994 as AFR(RS) storage facilities at four reactor sites in the USA, with additional installations planned for the near future. At the *H. B. Robinson* site of Carolina Power and Light, the first NUHOM-07P stainless steel canister, containing seven PWR assemblies has been loaded into the horizontal module. The facility is licensed for eight modules, which have been loaded with a total of 56 spent fuel assemblies.

Larger capacity canisters capable of holding 24 PWR or 52 BWR assemblies have also been designed and developed.

The NUHOMS family of concrete modular (silo) storage systems are designed to horizontally store PWR and BWR spent fuel assemblies. Its main components include a stainless steel dry shielded canister (DSC) with an internal fuel basket, a concrete horizontal storage module (HSM) that protects the DSC and provides radiological shielding, a transfer cask used to transport the DSC to the HSM and to provide shielding during transfer, and a hydraulic ram system (HRS) used to insert the DSC into the HSM. These components will be generally described in the following section, with specific dimensions provided in Table V.

The Horizontal Storage Module (HSM) is constructed of reinforced concrete, structural steel, and stainless steel. The HSM may be constructed as a single unit or as an array of modules. The HSM provides neutron and gamma shielding for the DSC. A steel support rail structure anchored inside the HSM by the interior walls supports the DSC and extends to the access opening. Stoppers on the rails prevent horizontal movement of the DSC during a seismic event. A vertical sliding plate, consisting of thick steel and a neutron absorbing material, covers the entrance to the HSM and is tack welded closed when the DSC is in place. Cooling of spent fuel stored in the NUHOMS system is provided by a combination of radiation, conduction, and convection. Air enters shielded passages at the front of the HSM, passes around the DSC, and exits through the flow channels in the roof of the HSM.

TABLE V. DESIGN PARAMETERS FOR NUHOMS STORAGE SYSTEMS

Criteria or Parameter	NUHOMS-07P	NUHOM-24P	Standardised NUHOMS	
			NUHOMS-24P	NUHOMS-52B
Initial Enrichment (235U)	3.5	4	4.0	4.0
Fuel Burnup (MW d/t HM)	35000	40000	40,000	35,000
Fuel Assemblies Per DSC	7 PWR	24 PWR	24 PWR	52 BWR
DSC Length (m)	4.6	4.7	4.7	4.7
DSC Diameter (m)	0.9	1.7	1.7	1.7
DSC Shell Thickness (cm)	1.3	1.6	1.6	1.6
HSM Length (m)	5.9	6.1	6.1	6.1
HSM Height (m)	3.7	4.6	4.6	4.6
HSM Width (m)	1.7	2.7	2.7	2.7
Transfer Cask Length (m)	4.60	4.75	4.75	4.75
Transfer Cask Diameter (m)	.95	1.7	1.7	1.7

The DSC is designed to provide primary containment for spent fuel assemblies. The DSC is a stainless steel cylinder, 4.6 - 4.7 m in length, 0.9 - 1.7 m in diameter, and 13-16 mm thick. Stainless steel end plates and steel end plugs filled with lead are welded to the top and bottom of the DSC with double seal welds. The canister contains a basket assembly made of 7, 24, or 52 guide sleeves consisting of stainless steel. The NUHOMS-07P fuel basket is made of stainless steel clad borated aluminium, which serves as a neutron poison with the stainless steel as the structural material. The NUHOMS-52B basket has additional neutron-absorbing plates. The fuel basket guide sleeves are supported by circular stainless steel spacer disks.

The transfer cask is used to transfer the DSC from the spent fuel storage pool to the HSM. It consists of three concentric cylinders with shielding material in between, connected by top and bottom steel end plates with a solid neutron shield. The bottom end plate has a removable hydraulic ram system access port plug. The transfer cask wall consists of an inner stainless steel liner, lead shield, carbon steel structural shell, solid BISCO-N3 neutron shield, and outer carbon steel shell. It is lifted by trunnions located on its sides, and mates via the transfer trailer with the access opening of the HSM for horizontal transfer of the DSC.

The Hydraulic Ram System (HRS) provides the motive force for transferring the DSC between the HSM and the transfer cask. The HRS consists of a single-stage hydraulic cylinder with grapple assembly and is powered by a hydraulic power unit. The hydraulic cylinder is supported by a support frame and is designed to apply pushing and pulling forces of during canister transfer.

The DSC is placed in the transfer cask and is lowered into the spent fuel storage pool. After fuel is loaded into the DSC, the DSC shield plug is placed on the DSC and the transfer cask is raised out of the storage pool. The DSC and transfer cask are then decontaminated and drained. The DSC is vacuum dried, pressurised with helium, and sealed. The transfer cask lid is bolted to the cask, and the transfer cask is lowered horizontally onto a transfer trailer. The transfer cask is transferred to the storage facility and the cask is mated to the HSM. The HRS arm is inserted through the rear access port and pushes the DSC into the HSM. The transfer cask is then removed and the access steel cover plate is tack welded to seal the HSM.

The only required maintenance is the periodic inspection of the air inlet and outlet screens to ensure that they have not been blocked by debris.

The first fuel loading into the NUHOMS-24P ISFSI AFR(RS) was completed in 1990, at Duke Power Company's *Oconee* plant. At the end of 1997, the Oconee ISFSI had 816 assemblies stored in 34 NUHOMS-24P modules. The site is licensed for up to 88 modules, each of which contain 24 PWR assemblies - or a maximum of 2,112 spent fuel assemblies.

In November 1992, Baltimore Gas & Electric Company received a site-specific license for the *Calvert Cliffs* dry storage facility, which uses the NUHOMS-24P storage system. At the end of 1997, the Calvert Cliffs facility had 14 NUHOMS-24P modules loaded with 336 spent fuel assemblies. The facility is licensed to store a total of 2,880 fuel assemblies in 120 storage modules, or approximately 1,112 t HM.

During 1995, Centerior Energy loaded the first spent fuel from its Davis Besse plant into the NUHOMS-24P standardised storage system under a general license. The Davis Besse storage facility has been designed to store up to 32 concrete modules for a total capacity of 768 spent fuel assemblies. At the end of 1997, a total of 72 assemblies had been loaded into 3 NUHOMS-24P storage modules.

Consumers Power Company's *Palisades* dry storage facility was the first to store spent fuel in a certified cask under a general license in accordance with U.S. Code of Federal Regulations. In May 1993, Consumers Power loaded its first VSC-24 concrete storage cask. Presently a total of 11 VSC-24 storage casks are loaded with 264 spent fuel assemblies. In the meantime BNFL bought the company Sierra Nuclear manufacturing the VSCs, and the new company, BNFL Fuel Solutions received the permit to load further casks during the summer 1999,

The VSC-24 system was issued a Certificate of Compliance in 1993, following completion of a Safety Evaluation Report by the U.S. NRC and completion of a rulemaking process to add the VSC-24 system to the list of casks approved by the U.S. NRC for use under a general license.

The VSC-24 system is a vertical concrete cask system composed of a multi-assembly sealed basket (MSB) and a ventilated concrete cask (VCC). The welded MSB provides confinement and criticality control for the storage and transfer of spent nuclear fuel. The VCC provides radiation shielding while allowing cooling of the MSB and fuel by natural convection during storage.

The MSB consists of a steel cylindrical shell with a shield plug and steel cover plates welded at each end. The shell length is fuel specific and varies from 4.1 to 4.6 m, the diameter is 1.6 m, and the shell thickness is 25 mm. An internal fuel basket is designed to hold 24 PWR spent fuel assemblies. The steel basket is a welded structure consisting of 24 square storage locations. Support in the horizontal direction is provided by curved supports located at each end and the centre of the basket assembly. The basket is coated with a CarboZinc 11 coating for corrosion protection. The MSB is installed vertically in the VCC.

The VCC is a reinforced concrete cask. The VCC has air inlets near the bottom of the concrete cask and air outlets near the top of the concrete cask: The internal cavity of the VCC as well as the air inlets and outlets are steel-lined. After the MSB is inserted in the VCC, a shield ring is placed over the MSB/VCC gap and the cask weather cover is installed.

A transfer cask is used to shield, support and protect the MSB during fuel loading and transfer to the VCC. It is a shielded lifting devise with inner and outer structural steel cylinders which house lead and solid RX-277 neutron shield cylinders.

Auxiliary equipment includes a vacuum drying system, trailer, and cask skid used during cask loading and transfer operations.

The VSC-24 system is designed to store only intact, unconsolidated PWR fuel assemblies meeting the specifications of the cask Certificate of Compliance.

Sierra Nuclear Corporation has designed a modified version of the VSC-24 referred to as the Transtor system and has applied for licensing for storage and for transport of spent fuel.

The TranStor System includes a sealed basket containing fuel assembly sleeves, a shipping cask with impact limiters, an on-site concrete storage cask, and an on-site transfer cask. The sealed basket is used in combination with the transfer cask and the storage cask components for onsite storage of spent nuclear fuel. Offsite shipping of spent fuel is performed using the sealed basket and the shipping cask components.

The PWR fuel assembly basket has 24 cells to accommodate one of the following: 24 PWR assemblies, 20 PWR assemblies and 4 special cans of failed or partial fuel or fuel debris, or any intermediate combination of PWR assemblies and special cans. The BWR fuel assembly basket has 61 cells to accommodate the following: 61 BWR assemblies with or without channels, 52 assemblies and 8 special cans of failed or partial fuel, or any intermediate combination of fuel assemblies and special cans.

The TranStor basket is a cylindrical steel canister designed for storage and shipping of irradiated spent fuel. Its components include a storage sleeve assembly, shell assembly, shield lid, and structural lid. The shell and lids provide containment and confinement boundaries, shielding, and lifting capability for the basket. The sleeve assembly provides support to the basket contents and is designed to accommodate intact fuel, failed fuel, fuel debris, damaged fuel, non-fuel bearing components, fuel assembly hardware, and greater-than-Class C (GTCC) low-level radioactive waste. The TranStor baskets vary in length from 114 inches to 180 inches, depending on the length of the fuel assemblies. An axial spacer, of an appropriate length is inserted between the basket and the shipping cask closure lid to maintain the basket's position during shipping.

The shell assembly consists of a cylindrical shell with a bottom plate and the shield lid support ring. The sleeve assembly is placed inside the shell and consists of square tubes which include neutron poison sheets to maintain a subcritical configuration for fresh, unirradiated fuel in unborated water. The shield lid assembly is a thick steel disk that is positioned on the shield lid support ring above the sleeve assembly after the fuel has been loaded into the basket, while the basket is in the spent fuel pool. The shield lid is welded to the basket while in the decontamination pit. Two penetrations through this shield lid are provided for draining, vacuum drying, and backfilling the basket with helium.

The structural lid is a steel disk that is positioned on top of the shield lid and welded to the basket shell after the shield lid is welded in place. The structural lid has a penetration for access to the vent and drain connections in the shield lid. The structural lid is seal welded once the helium backfield process has been completed.

The concrete cask used in the TranStor System is very similar in materials, size and construction to the concrete cask that is part of the VSC-24 storage system. (Fig. 2)

Wisconsin Electric Power Company loaded its first VSC-24 concrete cask at *Point Beach* Units 1 and 2 in December 1995 under a general license. The facility is designed to accommodate up to 48 VSC-24 casks.

On May 28, 1996, after loading a VSC-24 ventilated storage cask with spent fuel, an unanticipated hydrogen gas ignition occurred inside the cask during welding of the shield lid. The gas ignition displaced the shield lid upward approximately 3 inches and at a slight angle. The shield lid is approximately 9 inches thick, 5 feet in diameter, and weighs slightly less than 6 400 pounds.

There was no damage to the spent fuel in the cask resulting from the gas ignition. The NRC concluded that there were no measurable releases of radioactivity from the cask, no unanticipated exposures to the staff, and no off-site radiological consequences as a result of the event.

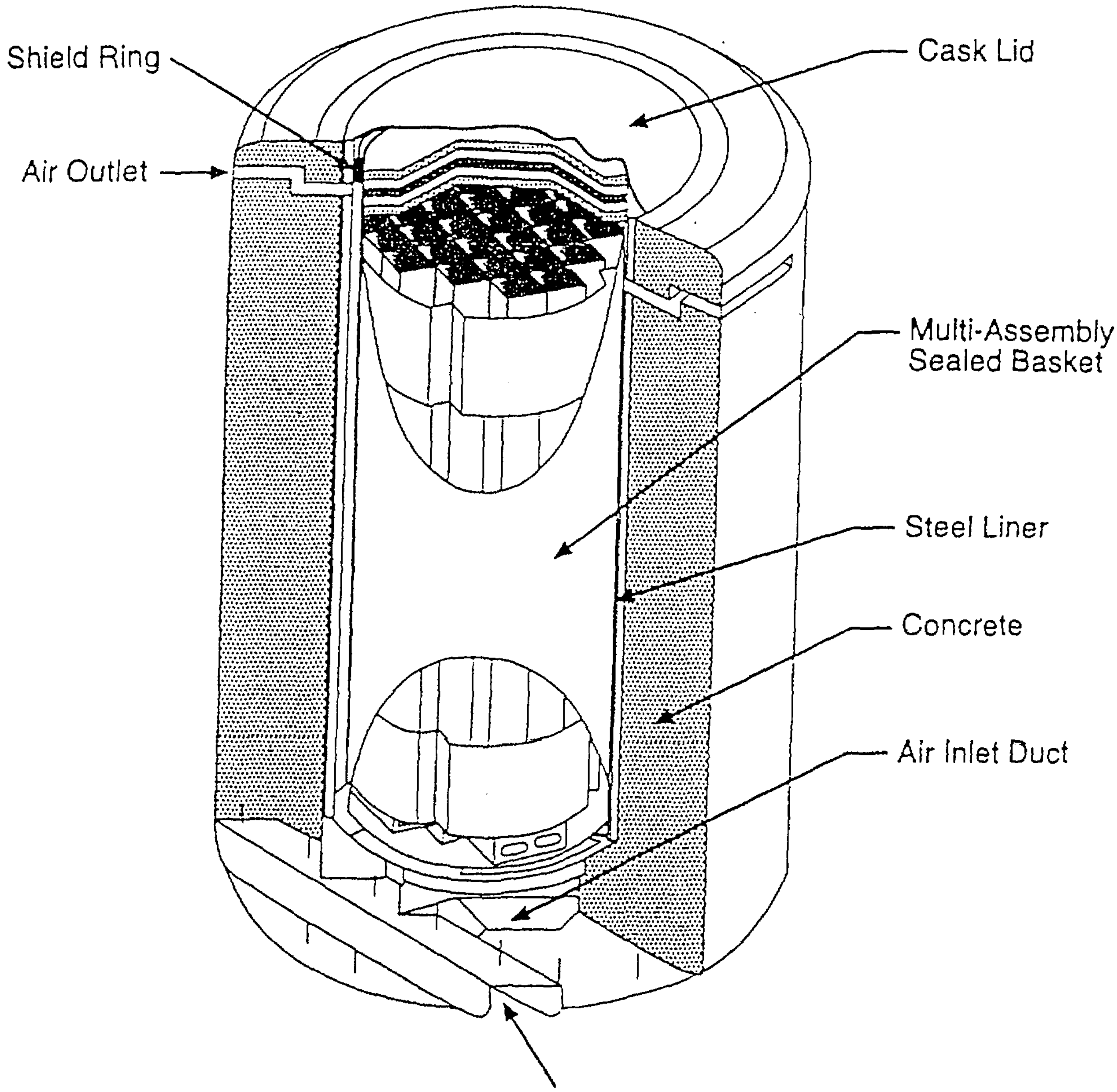


Fig.2. The Sierra TranStorTM System

Wisconsin Electric Power concluded that the source of the hydrogen was an electrochemical reaction between zinc in the Zinc coating used on the storage canister when in contact with the borated water in the spent fuel pool. The zinc coating was used to prevent corrosion of the multi-assembly sealed basket.

As a result of this incident, the NRC concluded that there were potential generic implications that could extend to other storage systems. NRC recommended that consideration be given to reviewing the adequacy of the chemical compatibility evaluations conducted during design reviews for all cask systems. NRC also recommended that consideration also be given to the suitability of Carbo Zinc 11 coating and similar coatings used in nuclear applications where there is the potential exposure to boric acid. It took more than 2 years for the utilities and Vendors to fulfil all NRC requirements stemming from this incident.

Palisades would regain full-core reload capability this summer when Consumers Energy loads five VSC-24 casks. This would be the end of a long saga for Palisades concerning problems associated with welds in the casks. In late April 1999, NRC formally lifted a confirmatory action letter in place since 1997 that kept Consumers from loading more VSC-24 casks until the problems were cleared up. The green light on the casks came just in time for Consumers. Unfortunately, some small explosions took place again during welding of the lid on the 14^{th} VSC-24 cask recently (June 1999). The cask at issue was the first since cask loading resumed at the plant earlier this month. The event may again halt all fuel loadings into similar casks in the US.

The *Dresden* Station consists of three reactors. Dresden Unit 1 was permanently shutdown in 1978. In 1993, Commonwealth Edison decided to remove the fuel from the Dresden Unit 1 spent fuel pool for two reasons: (1) there was a risk of leakage of cooling water with increasing pool age; and (2) concerns regarding the corrosion of spent fuel pool rack support bolts. Following an evaluation of alternatives for emptying the Dresden 1 storage pool, Commonwealth Edison selected dry storage as the preferred approach. The Company plans to use Holtec International's HI-STAR (Holtec International Storage, Transportation, and Repository) cask system at Dresden Unit 1. The Dresden-1 dry storage facility will include 11 HISTAR casks, with capacity of 68 BWR assemblies per cask.

Holtec international will provide *WNP-2* with 22 spent fuel storage casks under a contract the company announced June 1999. The Washington Public Power Supply System bought 22 HI-STORM 100 systems.

NATURAL CONVECTION VAULTS

Vaults consist of above- or below-ground reinforced concrete buildings containing arrays of storage cavities suitable for containment of one or more fuel units. Shielding is provided by the exterior structure. Heat removal is normally accomplished by forced or natural convection of air or gas over the exterior of the fuel-containing units or storage cavities, and subsequently exhausting this air directly to the outside atmosphere or dissipating the heat via a secondary heat removal system.

Typical features of vaults are their modularity, which facilitates incremental capacity extension, separated shielding and containment functions, capability for containment monitoring, and a vertical fuel loading methodology.

Spent fuel is received (either dry or wet) at a vault facility using transfer or transportation casks. Spent fuel is removed from the transfer or transportation casks, prepared for storage if needed, and placed in a metal storage tube (single fuel element) or a storage cylinder (single or multi-element canister) which is housed within a concrete storage cavity in the vault structure. The storage tubes or storage cylinders are sealed and may be backfilled with an inert gas to improve heat transfer from the fuel and prevent oxidation of spent fuel while in storage. They are usually fitted with connections to a continuous or periodic monitoring system.

In vaults using metal storage tubes the transfer of uncontainerised fuel assemblies is carried out, following drying if required, one by one directly into their storage location. Typical components of this type of storage facility are the vault modules, the fuel handling machine operating in the charge hall, the cask receiving area and the auxiliary facilities (areas for plant control, maintenance, services, offices etc.). Examples are the MVDS facility at Paks in Hungary and the Magnox Dry Storage Facility at the Wylfa reactor in the U.K.

Vaults using storage cylinders receive the fuel already sealed in containers (the MACSTOR system CANSTOR application at Gentilly 2 NPP in Canada, the CASCAD facility in France, or Fort St. Vrain MVDS in the U.S.). These types of vault facilities use a transfer cask handled by crane. The container transfer into the storage cylinder is either performed remotely (CASCAD) or with operator assistance (Fort St. Vrain and Gentilly 2).

France:

In France, the AFR(OS) CASCAD dry storage at Cadarache was completed in 1990 to store the fuel from the Brennilis EL4 plant of the French Commissariat á l'Energie Atomique (CEA) and the fuel from other experimental and prototype reactors. The facility is a natural convection fully passive air circulation system. The fuel is sealed in containers which are located in 319 storage tubes. The capacity of the storage facility is about 180 tones in a building 35 meters long, 25 meters wide and 16 meters high.

USA:

In the USA the first commercial dry vault facility (MVDS) went into service in 1993 for Public Service of Colorado (PSC) for the storage of spent High Temperature Gas Cooled Reactor (HTGR) fuel at Fort St. Vrain plant.

A total of 1,464 HTGR spent fuel assemblies (15.4 t HM) are stored in the MVDS. The twenty-year license authorises storage in the ISFSI of up to 1,482 spent fuel elements, 37 reflector control rod elements, and 6 neutron source elements. Fort St. Vrain spent fuel elements are graphite elements in hexagonal arrays with a 36.0 cm maximum cross section and 79.3 cm in length. The fuel characteristics for the ISFSI design included 600 day cooled, highly enriched uranium/thorium carbide fuel, maximum heat output of 150 watts per assembly and an average heat output of 85 watts per assembly.

The MVDS consists of a six concrete vault modules, two standby and one neutron source storage wells, and a transfer cask reception bay. Each vault module consists of a matrix of 45 storage positions. Each storage position holds 6 fuel elements or 12 reflector elements in a fuel storage container (FSC). The loaded FSC is brought to the MVDS in a transfer cask (TC) from the reactor building and is received in the transfer cask reception bay (TCRB). The TC is lifted from the TC trailer by the MVDS crane, and positioned vertically in the cask load/unload port. The FSC is then removed by the container handling machine (CHM) and moved by crane over the charge face structure of the storage vault. When the CHM reaches its position, the crane lowers the CHM to the CFS in the vault module.

While the above mentioned designs have been developed to store either AGR or HTGR fuel, the vault concept was always considered to be equally applicable to the dry storage of spent LWR or other types of fuel. The US licensee of GEC-Alsthom, Foster Wheeler Engineering Systems Ltd, submitted to the US NRC a Topical Safety Analysis Report (TSAR). Formal approval of the MVDS for the storage of irradiated fuel assemblies from LWRs was obtained in March 1988.

DESCRIPTION OF THE STORAGE TECHNOLOGIES APPLIED FOR WWER FUEL

Armenia

Only one reactor is in operation presently. Due to the unavailability of nuclear fuel reprocessing or a permanent geologic repository in Armenia, the pool of the operating facility is full, and the full core reserve has been used. The pool of the shut down reactor (Unit 1) is also full.

An interim storage facility using the NUHOMS system supplied by FRAMATOME has been chosen for the Medzamor site. As the number of assemblies to be stored in one module is 56, the model type is designated NUHOMS®-56V.

To enable the storage of 612 assemblies, construction of 11 Horizontal Storage Modules (HSM) has been decided. The 11 HSM are grouped together to form 2 arrays of respectively 5 and 6 HSM. The two arrays are arranged back to back.

The criticality analysis performed for the NUHOMS-56V DSC fuel does not account for fuel burnup but takes credit for soluble boron and demonstrates that fixed borated neutron absorbing material is not required in the basket assembly for criticality control. This solution and some other issues have encountered a number of licensing problems. It is expected that these issues will be resolved and fuel can be loaded in the first modules before the scheduled refuelling, i.e. before autumn 1999.

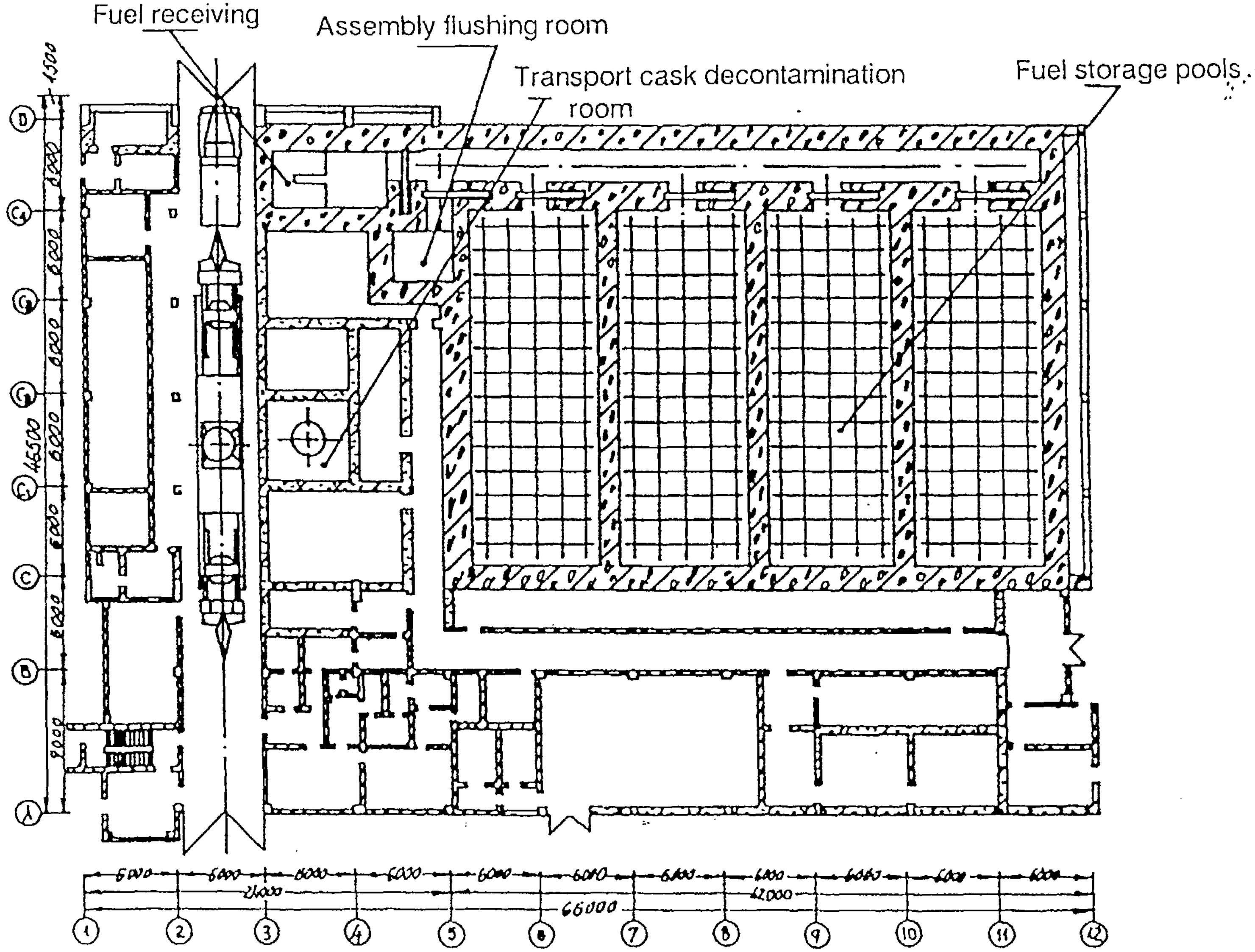
Bulgaria

Bulgaria has an AFR(RS) wet storage facility on the site of the NPP Kosloduy. The capacity of the AFR facility is 600 t HM. It is in the process of renovation to meet current seismic standards. Bulgaria considered developing a dry storage facility, but postponed that decision after deciding to rebuild the wet facility.

Proposed in 1974 as an alternative to spent fuel transportation to the USSR, construction of Kozloduy AFR(RS) facility did not began until 1982. The first fuel receipts to this facility were made on the 28th February 1990.

The facility was the first of a proposed common design for an AFR at the Soviet built reactors to store WWER fuel and it comprises of fuel receipt, unloading and storage areas. The current design is slightly different from the other facilities in that respect that this was meant for the long-term storage of 168 baskets (4,920 assemblies, ~600 t HM) of spent fuel from the sites four WWER-440 and two WWER-1000 reactors; to be loaded over a period of ten years.

After cooling for 3-years in the AR storage pools, the assemblies are transported to the AFR(RS) by an on-site transport container and a specialised trailer unit. Yearly receipts are at the rate of 25 transport baskets comprised of 4 baskets or 120 fuel assemblies per WWER-440 reactor and 9 baskets or 108 fuel assemblies from the two WWER-1000 units. (Fig. 3.)



BULGARIA

Fig. 3

KOZLODUY NPP

The storage area is made up of three operational water bays and a contingency bay to allow for preventive maintenance/provision against major in-bay failure. To afford this storage bays can be isolated from the one another by hydraulic seals/gates, and leak monitoring equipment is provided at the pool lining inter space. All pools are doubled lined with carbon and stainless steel.

Spent fuel from the WWER-440 reactors is stored in transport baskets (containing 30 fuel assemblies (FA) with intact fuel cladding or 18 bottled fuel assemblies where the cladding is leaking). WWER-1000 spent fuel is stored in transport baskets. The capacity of the baskets is: 12 intact fuel assembly, or 6 bottles of failed fuel.

Czech Republic

The pool storage capacity at Dukovany Power Station was expanded almost twofold by re-racking relative to the original design.

A dry cask storage facility is in operation at the site of the NPP. The dry storage facility is now half full. An extension of this facility by another 600 t HM is under discussion. The interim storage will have a design life of up to 50 years.

The Dukovany site can be accessed by road and rail. Facility licensing took place from February 1992 through March 1994. The construction began in June 1994 and was completed in October 1995. The first CASTOR 440/84 cask was loaded at Dukovany in November 1995.

The facility is designed to store up to 60 CASTOR 440/84 casks. The capacity of each cask is 84 assemblies or approximately 10 t HM. Spent fuel characteristics for the CASTOR 440/84 include: storage of WWER 440 spent fuel; 35,000 MW d/t HM burnup; 3.5 % ^{235}U enrichment; a minimum fuel age of 5 years prior to storage; no damaged assemblies may be stored; maximum cladding temperature of 350 °C.

The storage building has a cask receiving area, which is separated from the storage area by a concrete shielding wall. This wall is approximately 40 cm thick and 6 m high except for a centre 4.5 m high section over which the cask is lifted when being moved from the receiving area to storage area. The floor of the storage building is a reinforced concrete plate. The building has one hall with columns and a light steel roof. The columns support an overhead rail for the 130 ton crane. The external walls of the storage building were constructed with light concrete and brick wall panels. The removal of the decay-heat is achieved by natural convection through openings in the side walls and the roof of the storage building.

The handling and maintenance of the casks is performed in the receiving area. All casks are moved within the storage building using a crane that covers the receiving and storage areas. The storage building is ventilated by natural convection through openings in the walls and ceiling.

Loading the CASTOR 440 is similar to loading a transport cask. The differences result from requirements for drying of the cask cavity in accordance with long-term storage specifications; and the use metallic seals for the two lids. After loading of the cask, it is shipped by a special wagon to the storage facility, where the cask is attached to the lifting yoke of the storage building crane. Storage preparation includes filling the interlid space between primary and secondary lids with inert helium gas, installation of the inner lid pressure monitor and seal testing with a helium leak detector. The cask is then transported to its storage position in the storage building, the pressure monitoring system of cask is electrically connected, and the protection plate is fixed on the cask.

Finland

Because of the special construction of the reactor containment at Loviisa, the AR pools are somewhat smaller, and the first phase of an AFR wet store was constructed in 1980, even though spent fuel was shipped back to the Soviet Union (Russia) in the past, until 1996. A second phase was constructed in 1984. The two phases of the storage were built alongside one another at the site.

Phase 1 of the Loviisa AFR(RS) was brought into operation in 1980 increasing the storage capacity of the unit 1 NPP to take account of a need for increased fuel cooling from 3 to 5 years prior to transport/reprocessing in the Soviet Union. The AFR was later extended 1984 (phase 2) to provide additional storage capacity for unit 2 of the NPP.

The two phases of the AFR were built alongside one another three meters below ground. The services for each phase are provided by the associated unit of the NPP.

Phase 1 comprises two parallel storage bays, a loading bay, a decontamination well for casks, a dry burial ground for control rods, and a lid deck under which the cask transport vehicles are located. The storage bays are connected to the loading bay by gates and each bay has a capacity for up to eight fuel baskets. A fuel basket can accommodate 30 fuel assemblies with a hexagonal spacing of 225mm. Thus the total storage capacity is 480 assemblies (57.6 t U).

Phase 2 comprises three storage bays in a row, a loading bay, a decontamination well for the cask and lid deck under which the cask transporter vehicle is located. The storage regime in phase 2 differs from phase 1 in that each bay accommodates four fuel racks of 130 assembly capacity (total 187.2 t U).

The storage bays in both phases are connected with gates and covered by lids when there are no fuel handling operations.

Germany

A wet storage facility, similar to the Bulgarian store is in operation at the Greifswald site. A dry cask storage facility using CASTOR casks, which will substitute the wet facility, is commissioned.

Hungary

The pool storage capacity at Paks Power Station was expanded almost twofold by re-racking, during 1984 – 1987, after the first units were commissioned.

In order to ensure the continuous operation of the Paks NPP, an interim spent fuel storage system has been chosen and licensed, and the construction of the storage building has commenced. During the years 1991 and 1992 following an evaluation of the different spent fuel storage systems, the GEC ALSTHOM ESL Modular Vault Dry Store (MVDS) System has been selected. (Fig. 4.)

The licensing process took place during the years 1993 and 1994. The Construction License has already been issued for construction of the first three phases (11 vault modules – 4,950 assemblies). The operation of Phase 1 is (3 vaults) has started in late 1997.

The vault module is a reinforced concrete structure, which is covered by a structural steel building to form a charge hall. The buoyancy driven air cooling flow inlet and outlet ducts are an integral part of the vault modules.

The transfer cask reception building is a separate facility adjacent to the vault module. It houses the equipment necessary to handle and position the transfer cask prior to fuel assembly removal/drying operations. The transfer cask reception building also houses service and plant rooms, ventilation systems and provides health physics facilities for operating staff and monitoring equipment.

The MVDS provides for the vertical dry storage of irradiated fuel assemblies in a concrete vault module. The principal components are a concrete and structural steel vault module housing an array of steel fuel storage tubes each with a removable steel shield plug. Each Fuel Storage Tube houses a single fuel assembly. Nitrogen is used in the tubes to provide an inert atmosphere.

A fuel handling machine moves the fuel assembly from a water-filled transfer cask (C-30) to the Fuel Storage Tube via a drying tube. The Fuel Handling Machine operates in an enclosed volume above the Fuel Storage Tubes referred to as the charge hall.

Russia

Russia has operating wet storage facilities for RBMK fuel at Kursk, Leningrad and Smolensk. Other wet storage facilities for WWER fuel are operating at the Novo-Voronezh NPP, the Mayak reprocessing plant in Chelyabinsk, and at the RT-2 reprocessing plant to be built in Krasnoyarsk. This second reprocessing plant for WWER-1000 fuel was planned, but the Project was postponed later, and may be even cancelled. The RBMK storage facilities have mostly increased already their storage capacity by modifying the construction of fuel hangers, and moving them nearer to each other.

AFR at Novo-Voronezh NPP

The AFR (RS) WWER-1000 facility is located at the Novo-Voronezh NPP site. The design capacity is 400 t HM. Fuel assemblies are stored in racks at a space of 400 mm in a triangular arrangement under the shielding water.

The storage bays are located in a row on either side of the cask reception room. The decontamination area accommodates a facility for cask decontamination and painting. The cask reception room has a stepwise configuration with two locations. In the upper location the cask lid is removed and in the lower location the cask is unloaded. The storage bays communicate with each other through openings with sluice gates. The storage bays are rectangular ferro-concrete structures with dimensions of 6 200 × 4 400 × 16 400 mm with double lining and leakage collection from behind the liner.

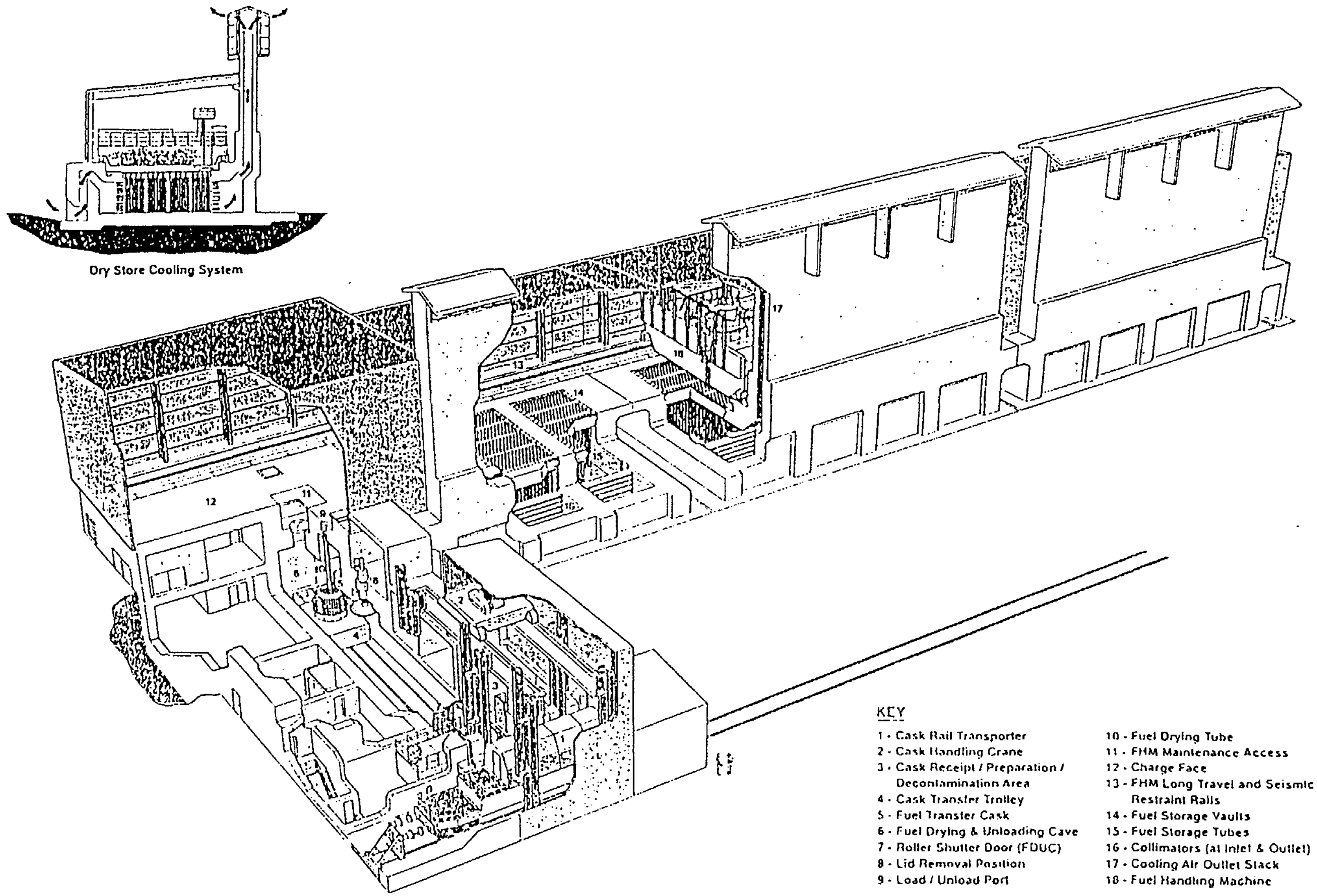


FIG. 4. Paks modular vault dry store.

Fuel arrives by rail to the AFR facility in TK-10 transport casks (capacity: 2.6 t HM or 6 WWER-1000 fuel assemblies) or in the CASTOR cask, which is the property of the NPP (capacity 5.2 t HM or 12 WWER-1000 fuel assemblies). Transport operations with casks are performed by a 160/32 t crane in the main hall. Cask loading/unloading operations are performed by a special fuel handling machine. The facility is in operation for loading/unloading operations 24 hours per day for 20 days per year.

The facility is equipped with cladding leak testing and gamma scanning for burn-up determination.

The AFR (OS) storage facility at Mayak

The interim AFR(OS) wet storage facility is located at the site of the Mayak Reprocessing Plant in Chelyabinsk. This facility reprocesses WWER-440 and research reactor (submarine) fuel.

The facility comprises a reception, storage, and process engineering areas. Fuel is stored in baskets.

Krasnoyarsk AFR (OS) storage facility

The storage facility is located at the RT-2 reprocessing plant site in Krasnoyarsk. The facility was designed to hold up to 6000 t(U) of spent WWER-1000 nuclear fuel in baskets in readiness for fuel reprocessing in the RT-2 reprocessing plant; yet to be commissioned.

The facility comprises a reception, storage, and process engineering areas. Transport cask receipt is not more than two casks per day and can be either TK-10's or TK-13's of 6 or 12 assembly capacity.

The storage pool consists of 15 bays, with one reserve bay. The bays are connected with one another and with the unloading pool via a transport corridor. Baskets with fuel assemblies are placed on the pool floor. The pool is a rectangular shaped structure measuring 11300 × 3450 × 8400 mm and lined with stainless steel. It is separated from the transport hall by a metal deck with slots, which are closed with flap covers. The slot openings afford a fixed pitch for rows of baskets since the basket is carried on a rod by a 16-t crane along the open slot in the deck. The fixed pitch is 1600 x 1600 x 1600 mm and, with a basket diameter of 1460 mm, prevents the possible collision of baskets. The pool can accommodate between 69 to 84 baskets, however, capacity can be increased if the central transport channel is also filled up.

An agreement has been signed with SGN to build two dry vault stores of the CASCAD design. The agreement allows for the construction of a 5,000 t HM capacity store at Smolensk Nuclear Power Station and another of 8,000 t HM capacity at Kursk Power Plant.

An alternative being reported is the transport of RBMK fuel also to the RT-2 site for temporary pool storage.

Licensing of a ferro-concrete dual-purpose cask has been reported, but no specific information about its use is available.

Slovak Republic

Slovakia has a wet storage facility, similar to those mentioned at Bulgaria and Germany, at Bohunice. The facility is undergoing renovation and was reported in a separate presentation. As a part of the renovation, the capacity of the facility will be increased (from 600 to 1,400 t HM) by using new baskets.

The facility consists of three working bays and one reserve bay all interconnected by a water channel. The structure including all the service areas occupies a space of about 45 m × 66 m. The pools are located at ground level and there is a substantial sized reception bay for transport containers. An overhead crane of 125/20 t capacity lifts the casks into an unloading well and the fuel is removed by a 15 t bridge crane into an assembly washing area before transferring to the storage bays.

Details about this facility and its reconstruction are given in a separate paper.

Ukraine

Ukraine currently has one AFR wet storage facility for their RBMK fuel in Chernobyl. The design and storage technology of this facility is the standard for AFRs used for storing spent fuel from RMBK -1000 reactors and thus is not subject of this paper.

A VSC storage facility is under construction at Zaporozhe, but licensing is delayed as a result of concerns that are still being resolved. There are plans to build additional dry storage capacity at Chernobyl and all other Ukrainian NPPs.

DESCRIPTION OF OTHER RELEVANT STORAGE TECHNOLOGIES

GNB POLLUX CASK

The POLLUX cask has been designed for final disposal of spent nuclear fuel in drifts and consists of a disposal container placed in a shielding overpack.

The POLLUX cask concept has been developed for direct disposal of spent fuel in salt formations and takes into account the postulated conditions of the repository. The POLLUX consists of a thick walled inner steel cask and a second outer container designed for shielding requirements during transport, interim storage and final disposal.

The CONSTOR steel-concrete cask

The CONSTOR steel-concrete cask initially was developed for transport and storage of spent RBMK fuel, but further development was made to adjust the parameters to accommodate other fuel types too.

The CONSTOR RBMK cask consists of an outer and an inner shell made of steel. The space between the two liners is filled with heavy concrete for gamma and neutron shielding. Inside the concrete, steel reinforcement is arranged to improve the strength and heat removal properties. The cask bottom has the same sandwich design as the wall. At the lid end, the shells are welded to a ring made of forged steel. The trunnions for lifting and handling are attached to this ring.

The lid system is designed as a multi-barrier system. The bolted primary lid fulfils strength and shielding functions. For temporary shielding this lid is made leak-tight by means of an elastomer seal. The sealing plate and the secondary lid are welded to the forged steel ring after loading and servicing of the cask. These two welded lids, together with the inner and outer shell (including their bottom plates), represent the double barrier system.

The RBMK spent fuel bundles are positioned in a basket inside the cask. The capacity of the standardised basket is 102 bundles (half length). The total mass of the CONSTOR RBMK cask including impact limiters, loaded with the 102 bundle basket is approx. 96 500 kg. The average enrichment is 2 %, the average burnup is 20 GW d/t, the minimum cooling time 5 years, resulting in 7.65 kW heat load for a cask.

HOLTEC INTERNATIONAL, INC., HI-STAR/HI-STORM 100 SYSTEM

The HOLTEC International (HOLTEC) HI-STAR 100 System (HOLTEC International Storage, Transport and Repository Cask System) consists of metal canisters (referred to as Multi-Purpose Canisters or MPCs) designed to store spent fuel assemblies in a dry, inert environment and a metal overpack for storage and transport. The canisters are referred to as Multi-Purpose Canisters because of the potential use of the canister with an appropriate overpack for spent fuel disposal. However, use for disposal can not be confirmed until completion of the final repository design. The HI-STAR 100 System includes three different MPC designs with different internal fuel baskets for storage of either PWR or BWR spent fuel assemblies.

Holtec has also designed a concrete and steel vertical storage overpack, the HOLTEC HI-STORM 100 Storage Overpack, that could be used for on-site spent fuel storage instead of the metal storage and transport overpack. The main structural components are provided by carbon steel and shielding is provided by concrete. The storage overpack has convective cooling ducts to allow for passive cooling of the HOLTEC HI-STAR 100 MPC. The overpack is enclosed by cylindrical steel shells, a thick steel baseplate, and a bolted-on lid. Four removable lifting lugs are attached to the top of the storage overpack for lifting the storage overpack body. The storage overpack may also be lifted from the bottom using a lifting rig.

HI-STAR 100 MPC

Each of the HI-STAR 100 MPC designs includes a fuel basket, a solid 19 mm thick bottom plate, an outer 13 mm thick canister shell, and two closure lids. The outer diameter of the HI-STAR 100 MPC is 1.7 m with a height of 4.7 m. The capacity of the three HI-STAR 100 MPCs depends on the basket configuration. There are two PWR basket designs, one which uses flux traps and one which has a higher capacity and assumes credit for burnup or an initial fuel enrichment limited to 1.9 % ^{235}U. It should be noted that burnup credit has not yet been approved for storage and transportation systems in the U.S.

The HI-STAR 100 MPC baskets consist of composite boxes that are seam-welded with a Boral neutron absorber panel attached to its external surfaces within a sheathing panel that is edge-welded. The composite boxes are assembled to form the honeycomb cell structure of the basket. The composite boxes are welded to the bottom plate. Composite boxes are attached to one another using connector bars. Additional braces or full-length spacers are welded to the inner surface of the canister shell. The outer shell assembly is then lowered over the fuel basket and welded to the bottom plate along the outside edge.

The HI-STAR 100 MPC includes two closure lids. The inner lid is edge-welded to the MPC outer shell and contains vent and drain ports, which are used for draining, vacuum drying, and backfilling with an inert gas following loading. Adjustable spacers are used on the inside surface of the inner lid to position fuel assemblies axially in the storage basket cells. The outer closure lid is also welded to the HI-STAR 100 MPC shell.

The HI-STAR 100 overpack that can be used for both storage and transportation (Type B) is a heavy-walled cylindrical vessel, approximately 200 inches in height with a maximum outside diameter of 96 inches. A steel shell, which is welded to a thick bottom plate, forms the main containment boundary along with a top bolted closure plate. The bolted lid configuration provides protection for the closure bolts and gaskets in the event the cask were to experience a severe impact. Metallic O-rings are used to seal the main flange and the closure plate. The top closure plate has a neutron shield attached to its underside.

Additional layers of carbon steel plate placed around the inner shell form a protective barrier and provide additional gamma shielding. Steel radial connectors are vertically welded to the outside surface of the outer shell, providing additional heat conduction to the overpack outer shell surface. The outer shell of the storage cask provides neutron shielding.

The cask uses layered pressure vessels. The layer construction also provides added strength from improved ductility and elimination of potential through-wall cracks due to material flaws or impacts.

Six removable trunnions are attached to the main flange and baseplate for lifting and rotating the cask body. Four lifting trunnions are located 90° apart in the sides of the top main flange. Two rotating trunnions are 180° apart on the sides of the bottom baseplate.

NAC INTERNATIONAL, INC., NAC S/T CASKS

NAC International, Inc. has developed four variations of the NAC S/T cask: NAC S/T, NAC-C28, NAC-I28, and NAC-STC. (See Table VI.)

TABLE VI. SPENT FUEL TO BE STORED IN NAC CASKS

	NAC-C28	NAC-I28	NAC-STC	
Number of Assemblies	56 (consolidated)	28	26	26
Initial Enrichment, (%)	3.5	3.5	4.2 (W 17x17 OFA) 4.1	4.2 (W 17x17 OFA) 4.1
Burnup (MW d/t)	35 000	35 000	40 000	45 000
Decay Time (years)	10	10	6.5	10
Decay heat per Assembly (kW)	.357	.357	.85	.85
Decay Heat per Cask (kW)	20	20	22.1	22.1

The NAC S/T is a metal dry storage cask designed to vertically store 26 PWR fuel assemblies. It weighs less than 113 t when fully loaded with spent fuel, contained water and the lifting yoke.

The NAC-I28 is designed to vertically store 28 intact PWR fuel assemblies and the NAC-C28 to store consolidated fuel rods from 56 PWR fuel assemblies in 28 canisters. The NAC-STC storage and transport cask is designed to store 26 intact PWR assemblies. The NAC-S/T casks weigh less than 113 t when fully spent fuel, contained water, and the lifting yoke.

The NAC-C28/ST and the NAC-I28/ST casks were developed by the Nuclear Assurance Corporation and are approved for storage of consolidated and intact spent fuel assemblies, respectively. The NAC S/T cask is a multi-wall cylinder with a 39 mm thick inner shell and a 68 mm thick outer shell both made of stainless steel, separated by 81 mm of lead. The inner and outer shells are connected at each end by an austenitic stainless steel ring and plate. The overall dimensions of the cask are 4.6 m long and 2.4 m in diameter.

NAC also plans to license a variation of the NAC-STC which would house a sealed metal canister for containing spent fuel in the place of the integral basket in the NAC-STC, referred to as the NAC MPC.

The cask body for the four cask designs is similar. The range of dimensions is included in this description. The cask body consists of a cylindrical, multi-walled construction of stainless steel components. It has an approximately 38 - 40 mm thick inner shell and a 67 mm thick outer shell of stainless steel separated by 80 - 94 mm of lead.

For the NAC-C28, I28, and S/T, the inner and outer shell are connected to each other on both ends by austenitic stainless steel rings and plates. The upper end of the cask is sealed by a stainless steel bolted closure lid. The closure lid uses a double barrier seal system with two metallic O-ring seals. A neutron shield cap encased in stainless steel is placed on top of the cask and may be welded to the cask body.

For the NAC-STC, the inner and outer shells are connected to each other on both ends by welded stainless steel forgings. The upper end of the cask is sealed by a stainless steel inner lid which is approximately 230 mm thick, with a 50 mm thick neutron shielding material in the centre and a 25 mm thick stainless steel cover plate. The upper end is further sealed by a 133 mm thick outer lid bolted to the top forging.

Gamma shielding is provided by the lead wall, and neutron shielding by a layer of a solid borated synthetic polymer which surrounds the outer shell along the cavity region, and is enclosed by a stainless steel shell with end plates that are welded to the outer shell.

For the NAC-C28, I28, and S/T, the bottom of the cask is sealed by a 152 mm thick stainless steel plate with a 25 mm outer closure plate, separated by 46 mm of lead gamma shielding. Twenty-four copper/stainless fins are located within the radial neutron shield to enhance heat conduction.

For the NAC-STC, the bottom of the cask is sealed by two stainless steel forgings and a stainless steel plate. Twenty-four copper/stainless steel fins are located within the radial neutron shield to enhance heat conduction.

Six trunnions can be attached to the cask for lifting and rotating the cask.

The cask has four containment penetrations: one cask cavity drain, one cask cavity vent, one inter-seal test port, and one inter-seal pressure transducer port. Each of these penetrations is in the single lid and utilises a double barrier seal containment.

The fuel basket is a right circular cylinder configuration with 26-28 aluminium fuel tubes that are separated and supported by an aluminium and stainless steel grid of spacers and tie bars, with borated neutron poison material for criticality control in the bask assembly.

NAC Universal MPC System (UMS)

NAC International, Inc. has designed a canister-based system for the storage and transport of spent nuclear fuel. NAC submitted a Safety Analysis Report for storage to the NRC in September 1997. The SAR for the Universal Transportation System was submitted earlier in April 1997. The canisters are referred to as Multi-Purpose Canisters (MPCs) because of the potential use of the canister with an appropriate overpack for spent fuel disposal. However, use for disposal can not be confirmed until completion of the final repository design.

The Universal Storage System (USS) is a spent fuel dry storage system that uses a stainless steel Transportable Storage Canister with a welded closure and a Vertical Concrete Cask to store intact spent fuel assemblies. The system also includes a transfer cask. The Transportable Storage Canister is designed and fabricated to meet the requirements for transport in the Universal Transport Cask.

The UMS storage system is designed to store 24 PWR fuel assemblies or 56 BWR fuel assemblies. PWR fuel requirements are a maximum initial enrichment of 4.2 % ^{235}U, a maximum burnup of 40,000 MW d/t HM and a minimum decay time of 5 years after reactor discharge. BWR fuel requirements are a maximum initial enrichment of 3.75 % ^{235}U, a maximum burnup of 40,000 MW d/t HM and a minimum decay time of 5 years after reactor discharge.

The loaded canister is moved to and from the concrete cask using the transfer cask. The transfer cask provides radiation shielding while the canister is being closed and sealed and while the canister is being transferred. The canister is placed in the concrete cask by positioning the transfer cask with the loaded canister on top of the concrete cask and lowering the canister into the concrete cask.

The Transportable Storage Canister consists of a stainless steel canister that contains the fuel basket structure and payload. The canister is defined as the confinement for the spent fuel during storage and is provided with a double-welded closure system. The canister consists of a cylindrical 16 mm thick stainless steel shell with a 44 mm thick stainless steel bottom plate and a stainless steel lid support ring. The basket assembly is placed inside the canister and provides the structural support and the primary heat transfer path for the fuel assemblies while maintaining a subcritical configuration for the spent fuel.

The shield lid assembly is a 178 mm thick stainless steel disk that is positioned on the shield lid support ring above the basket assembly. The shield lid is welded to the canister while the canister inside the transfer cask is in the work area after removal from the spent fuel pool. Two penetrations through the shield lid are provided for draining, vacuum drying, and backfilling the canister with helium. Following removal of water from the system, the system is vacuum dried and backfilled with helium and it is pressure tested and leak-tested to ensure the required leak-tightness has been achieved.

The structural lid is a 76 mm stainless steel disk positioned on top of the shield lid and welded to the shell after the shield lid is welded in place and the canister is drained, dried, and backfilled with helium.

The Vertical Concrete Cask provides structural support, shielding, protection from environmental conditions, and natural convection cooling of the canister during storage. The concrete wall and steel liner provide the neutron and gamma radiation shielding for the storage cask. Inner and outer reinforcing steel rebar assemblies are contained within the concrete. The concrete cask has an annular air passage to allow the natural circulation of air around the canister to remove the decay heat from the spent fuel stored in the Transportable Storage Canister. The top of the concrete cask is closed by a shield plug and lid which incorporates a carbon steel plate as gamma radiation shielding and NS-4-FR as neutron radiation shielding. A carbon steel lid that provides additional gamma radiation shielding is installed above the shield lid.

The transfer cask is used for the vertical transfer of the canister between work stations and the concrete cask, or transport cask. The transfer cask incorporates a multi-wall design which limits the contact radiation dose to less than 3 mSv/hour. The transfer cask design also incorporates a top retaining ring, which is bolted in place, that prevents a loaded canister from being inadvertently removed through the top of the transfer cask. The transfer cask has retractable bottom shield doors to facilitate the transfer of the canister from the transfer cask into the concrete storage cask or transportation cask.

VECTRA NUHOMS-MP/187

The horizontal storage module to be used with the NUHOMS-MP187 dry storage canister (DSC) is identical to the Standardised NUHOMS-24P HSM design described previously and will not be described again.

The DSC design under review for the NUHOMS-MP187 system is based on the Standardised NUHOMS-24P DSC design described previously, except that the MP187 DSC design includes borated neutron absorber panels in order to license the NUHOMS-MP187 for offsite transport.

There are three DSC types as part of the NUHOMS-MP187 system. The designs include: a DSC for fuel and control components; a DSC for fuel only; and a DSC for failed fuel. The DSC for fuel with control components contains up to 24 fuel assemblies with control components and has a 4.4 m internal cavity length. The DSC design for fuel only contains up to 24 fuel assemblies and the DSC for failed fuel contains up to 13 failed fuel assemblies. Both have an internal cavity length of 4.2 m.

WESTINGHOUSE, MC-10

The MC-10 cask consists of a thick-walled forged steel cylinder and weighs approximately 103 t. The cask has a cylindrical cask cavity which holds the fuel basket. The overall length is 4.8 m and the overall diameter is 2.7 m including fins. The cask body is made of low alloy steel with forged steel walls and bottom that provide radiation (gamma) shielding and structural integrity. A low alloy steel shield cover, approximately 24 cm thick, with a metallic O-ring seal, provides the initial seal and shielding following fuel loading. A carbon steel cover, with a metallic O-ring seal, provides the primary containment seal. A seal lid provides a secondary containment seal. The fourth cover, containing a BISCO NS-3 neutron-absorbing material, is welded over the first two seals to provide seal redundancy. The inside surface of the cask is thermally sprayed with aluminium to provide corrosion protection. Twenty-four carbon steel heat transfer fins are welded axially along the outside of the cask wall. Carbon steel plates are welded between the fins to provide an outer protective skin approximately 6 mm in thickness situated 80 mm from the cask wall. Neutron shielding is provided by a layer of BISCO NS-3 cured in the cavity between the cask wall and outer protective skin. Four trunnions are connected to the cask body for lifting and rotating the cask.

The basket assembly consists of 24 storage locations utilising a honeycomb-type basket structure. Each of the 24 removable cell storage locations consists of an enclosure, neutron poison material, and wrappers. The upper ends of the enclosure walls are flared to facilitate fuel loading. Neutron absorbing material is attached to the enclosure walls and held in place with a stainless steel wrapper welded to the panel.

The MC 10 is licensed to store PWR spent fuel, cooled for ten years, with a maximum initial enrichment of 3.7 % ^{235}U and a maximum burnup of 35,000 MW d/t HM. Maximum heat generation per assembly is 0.5625 kW per assembly.