SPENT FUEL DRY STORAGE EXPERIENCE AT GENTILLY 2 NGS

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1. ABSTRACT

In order to provide the needed interim storage facility for the spent fuel, Hydro-Quebec chose the dry storage CANSTOR module developed by the Atomic Energy of Canada Ltd (AECL). The decision was made based upon the technical feasibility, public and environmental protection criteria, operational flexibility, economic and space saving advantages.

Before the commissioning of the spent fuel dry storage facility, the project received all the required approvals. A joint provincial - federal public hearings was held in summer of 1994 in order to assess the project in term of its impact on the environment.

In September 1995 took place the first transfer of spent fuel from the station bay to the dry storage facility and since then 21000 bundles of spent fuel were transferred in the two CANSTOR modules built on the station site located within the protected area of the Gentilly-2 station.

To date, the expected performance of the dry storage units and equipment have been met. A third CANSTOR module is to be built in summer of 1997 on the station site.

2. INTRODUCTION

Gentilly 2 NGS is a single unit CANDU 6 PHW[1] type station located on the south shore of the St-Lawrence River, at about 15 km southeast of the city of Trois-Rivières (Québec). The Gentilly 2 station was built, commissioned and operated since in service (October, 1983) by Hydro-Québec. Hydro-Québec operates only one nuclear power station, i.e. Gentilly 2.

[1] CANDU - CANada Deuterium Uranium; PHW - Pressurized Heavy Water

Since in service until the end of 1996, the Gentilly 2 station achieved a gross cumulative production of 62.9 TWh and a gross capacity factor of 80.24%. Its nominal production of 675 MW represents about 3% of the total energy produced by Hdyro-Québec.

In order to provide the needed interim storage for the spent fuel, Hydro-Quebec chose the dry storage CANSTOR module developed by AECL. The decision was made based upon the technical feasibility, public and environmental protection criteria, operational flexibility, economic and space saving advantages.

As the CANSTOR module was the first of its kind to be built in Canada on elsewhere, it was subject to a complete review by the Atomic Energy Control Board (AECB). Before the commissioning of the spent fuel dry storage facility, the project received all the required approvals. A joint provincial - federal public hearing was held in summer of 1994 in order to assess the project in term of its impact on the environment. To obtain higher flexibility of the interim storage installations particularly at the end of the useful life of the station when smaller quantities of spent fuel might be needed to be stored, Hydro-Quebec also requested and obtained the license for AECL concrete canister method.

3. THE CANSTOR MODULE

3.1 General

The dry storage CANSTOR module concept (CANadian STORage) was developed by the AECL after the good results obtained since 1976 by the concrete canister dry storage program.

The CANSTOR module consists of a monolithic shielded concrete vault structure containing several spent fuel cylinders. Its geometry is compatible to the all the equipment developed for the canister dry storage program.

3.2 Technical Description

3.2.1 CANSTOR Module Dimensions

The CANSTOR module has a length of 21.6 m, a width of 8.1 m and a height of 7.5 m (Figure 1).

A CANSTOR module accommodates twenty vertical steel cylinders (hot spray zinc coated) containing the spent fuel storage stainless steel baskets. The cylinders are permanently installed in two rows of ten, in the module's top slab. They are enclosed by the top slab, side walls and floor in a single vault-like cavity (Figure 2).

3.2.2 Stored Fuel

The CANDU 6 fuel bundle is composed of 37 elements welded at theirs extremities at two end plates (Figure 3).

The length of a bundle is 495 mm and the diameter 102 mm; the total weight is around 24.1 kg (19.0 to 19.3 kgU).

The irradiated fuel bundles to be dry stored in a CANSTOR module must have a minimum cooling period of 6-7 years with a residual heat load of about 6.1 w per bundle. The maximum fuel temperature of dry stored fuel has to be kept below 160 °C (by design).

3.2.3 Stainless Steel Basket

The spent fuel bundles are stored in a cylindrical stainless steel basket (wall 9.5 mm thick); it is equipped with a base plate and a cover (Figure 4). The diameter of the basket is 1070 mm and the height is 560 mm. The storage capacity of the basket is 60 bundles.

3.2.4 CANSTOR Storage Capacity

The CANSTOR module can accommodate 12000 CANDU 6 fuel bundles stored in 200 sealed stainless steel baskets kept in 20 storage cylinders (10 baskets per cylinder).

3.2.5 Shielding

The CANSTOR module concrete walls are 0.96 m thick and the top slab 1.07 m thick. The concrete thickness is determined mainly by the shielding criteria rather than structural requirements.

The design dose rate on contact (at module concrete wall) is maximum 25 μSv/h and at the storage site fence maximum 2.5 μSv/h.

3.2.6 Cooling

The passive heat rejection of the spent fuel stored in a CANSTOR module is achieved mainly by a convective process inside the module Ambient air is drawn into the module's cavity through ten air inlet ports near its base. The air rises along the surfaces of the storage cylinders as it picks up the decay heat produced by the fuel and exists through twelve outlet ports near the top of the module (Figures 1 and 2). The heat rejection capability of the CANSTOR modules was demonstrated experimentally at AECL Research Whiteshell Laboratories.

Inside the first CANSTOR module built in the summer of 1995, fourteen RTDs were installed inside the module in order to obtain the temperatures of air, concrete walls and cylinders. The data obtained between October 1995 and the beginning of 1997 showed that the actual temperatures of the fuel, concrete walls and the temperature gradient through the concrete walls of the module are well below the design estimates temperatures [1]. Figure 5 shows the design estimated distribution of temperatures in a CANSTOR module.

3.2.7 Safety Features

CANSTOR modules, have two physical barriers enclosing the spent fuel: **a) the spent fuel basket** (a stainless steel seal-welded cylinder containing 60 fuel bundles); **b)** the storage cylinder (a steel container that is seal-welded to its permanent cover after it is filled with 10 spent fuel baskets).

The integrity of the two barriers is monitored by an air sampling system that monitors the captive air for possible leaks from the exterior or from the baskets (Figure 2).

3.2.8 Safeguards Features

As a signatory of the *Treaty on the Non-Proliferation of Nuclear Weapons*, Canada complies with the international regulation relating to nuclear products security safeguards laid down by the International Atomic Energy Agency (IAEA), in agreement with the AECB.

The safeguards measures designed to prevent any potential diversion of the spent fuel kept in stainless steel baskets include a dual system of seals as well as reverification tubes. A E-type seal (steel wire) system covers the shielded plugs of one row of 10 cylinders on the top of the CANSTOR module through tubes embedded in the concrete of the module structure and the shielded plugs, and another covers the second row. The two seals overlap at each extremity of the CANSTOR module for the containment/surveillance (C/S) of the wall and the construction opening. Also a Cobra-type seal (optic fibre) covers two shielded plugs of the same row. This means that there are five (5) Cobra-type seals on each side of the module. These seals on the same side of the module also overlap to cover the surface of the wall between the air inlets. Finally, a third safeguards system is integrated to the design. It consists of reverification tube embedded in the concrete walls in front of each storage cylinder to determine the radiation signature of each cylinder content using a special IAEA probe. This system is used for the purpose of comparison with subsequent signatures.

All seals are accessible from the bottom of the CANSTOR module for periodic verification by the IAEA inspectors.

The IAEA inspectors are also present when the fuel is loaded and transferred, in order to provide continuous surveillance. When the permanent cover has been placed over the CANSTOR storage cylinder filled with fuel baskets, they affix the two seals on each cylinder.

3.2.9 Fuel Storage Density and CANSTOR Performance

The storage density of a CANSTOR module is about 1.3 TU or 69 bundles per square meter of CANSTOR. For the dry storage purposes, one CANSTOR module can replace twenty two AECL type concrete canisters. The use of CANSTOR module reduces therefore the required surface area for spent fuel dry storage by more than 50% compared to the canister alternative.

The CANSTOR module have a design life of a minimum of 50 years and his equipment is compatible with the stainless steel baskets and handling equipment utilized for the AECL canister dry storage method.

3.2.10 Canstor Module Cost

The total cost of a CANSTOR module (including the 200 stainless steel storage baskets) is around 3 millions Can$ or 13$/kgU stored. Site preparation cost as well as the cost for all the equipment required are not included.

4. DRY STORAGE SITE

The dry storage site is located within the protected area of the Gentilly 2 station, inside the existing fence (Figure 6). The site area (130 m x 89.5 m) allows the construction of the CANSTOR modules units needed for the spent fuel produced during the 30 years expected life of the station. If required, a site extension is possible toward the west.

The road inside the storage site is asphalted. The site is provided with security systems, thermoluminescent dosimeters, electrical and compressed air supply as well as a gantry crane. A small building (4m x 5 m) situated north-east of the site allows the control and the access of personnel on site.

The site preparation including the erection of the first CANSTOR unit and commissioning of facilities took four moths.

5. PRÉPARATION AND TRANSFER OPERATION

The irradiated fuel bundles are loaded inside stainless steel storage baskets, under the water of the station bay. Each loaded basket is transferred to the shielded work station inside a transfer flask, and dried by heated air. Next, the basket cover is automatically seal welded to its base plate and lifting post. The basket then is loaded into a second transfer flask which is loaded on a transporter. Once the content of the transfer flask has been unloaded into the CANSTOR cylinder, a permanent cover plate is mounted and seal welded over each filled cylinder. Figure 7 and 8 show the sequence of operations at Gentilly 2 NGS.

The team in charge of the preparation and transfer of the irradiated fuel from the station bay to the dry storage site is composed of five persons: two operators (at the bay), one welder and two other operators (for transfer operation including CANSTOR loading). On average, three baskets (180 irradiated bundles) were processed from the bay to CANSTOR module in one day (12 hours operation).

6. INSPECTION AND MONITORING OF DRY STORAGE SITE

The inspection and monitoring activities related to the dry storage site are:

6.1 General

- Quarterly inspection of the storage area, CANSTOR units, concrete structures, air inlets and outlets, site fence, and surveillance equipment;
- Quarterly inspection of the electrical equipment;
- Semestrial leak test of the CANSTOR storage cylinders and fuel baskets.

6.2 Environment

- Weekly sampling of surface water;
- Monthly sampling of underground water,
- Quarterly gamma monitoring of the CANSTOR modules with portable monitors;
- On-going gamma monitoring of the storage area (thirteen thermoluminiscent dosimeters installed on site fence);

7. CONCLUSION

To date, the overall performance of the interim dry storage of irradiated fuel at Gentilly 2 NGS was good. At the end of June 1997, a total of 21000 irradiated bundles were transferred from the station bay and stored in the AECL type CANSTOR modules.

The expected performance of the dry storage units, equipment, operational flexibility environmental protection and expenses have been met.

An improvement regarding the loading operation of the stainless steel baskets with irradiated bundles is desirable.

8. REFERENCES

1. R. Moffett et H. Paquin, "Étude du comportement thermique du module CANSTOR", Rapport AECL 66-62500-220-01, 97-03.

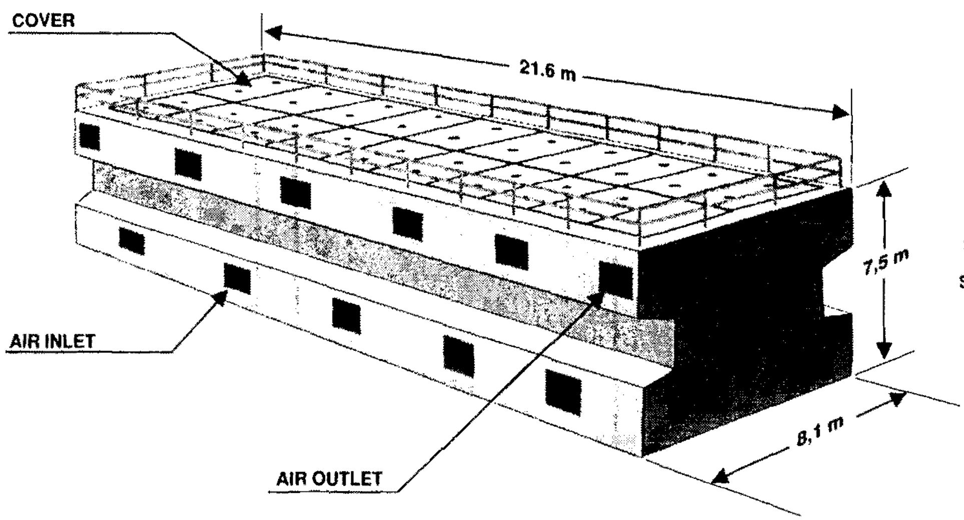

Figure 1 -CANSTOR MODULE VIEW

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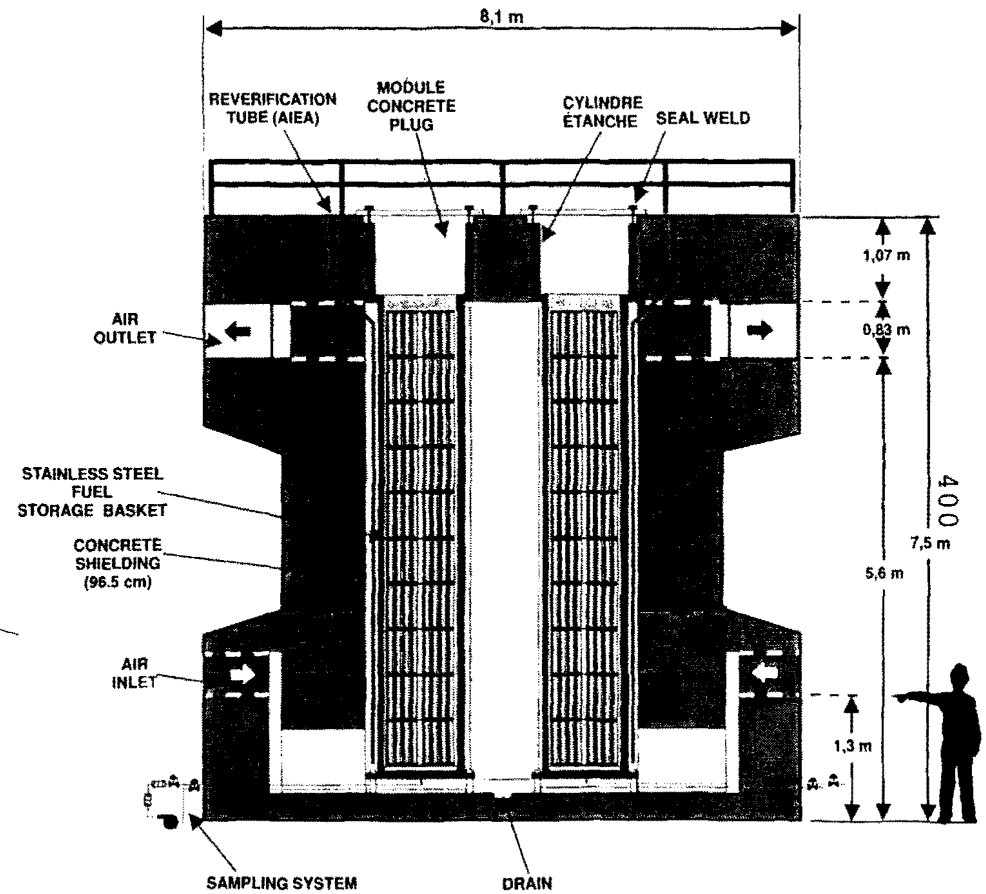

Figure 2 Section View of the CANSTOR Module

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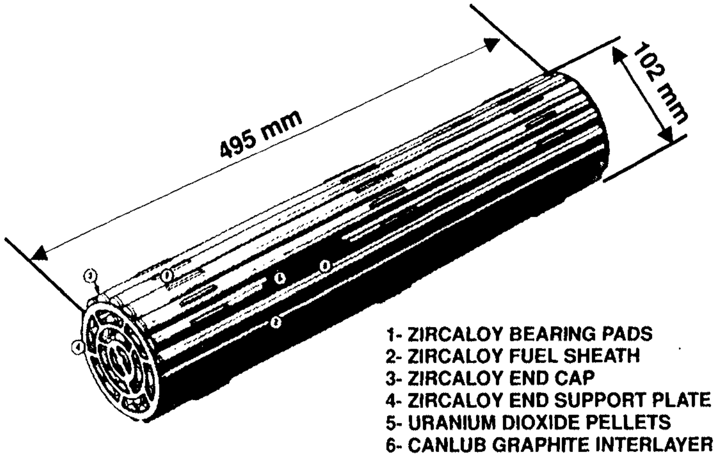

Figure 3 -37 Elements Candu Fuel Bundle

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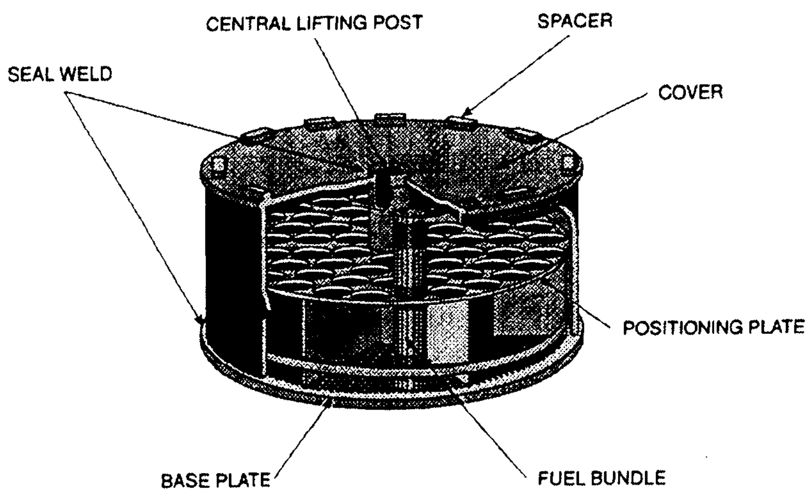

Figure 4 -STAINLESS STEEL BASKET FOR 60 IRRADIATED BUNDLES

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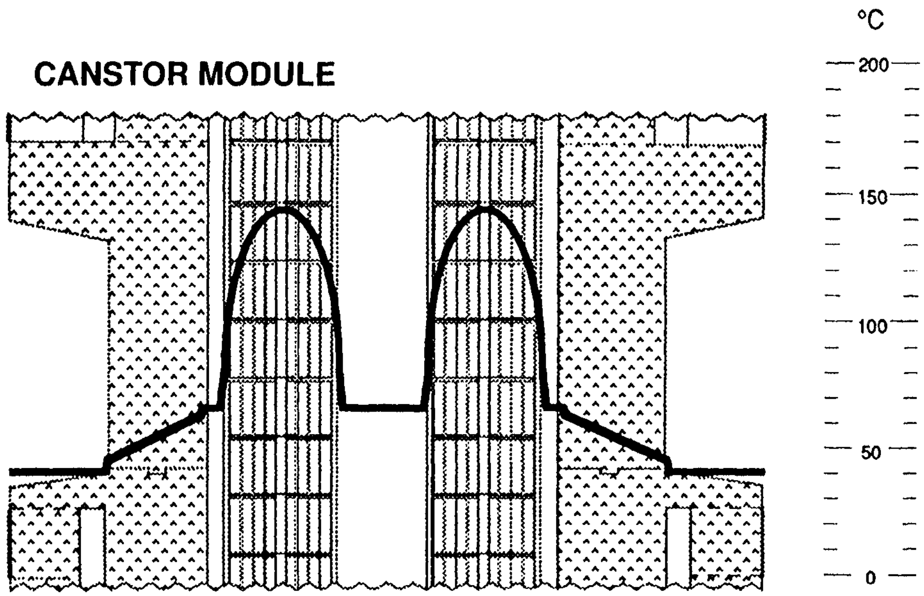

-Ambient air température	40° C
-External Canstor wall temperature	45° C
-Temp. variations across the CANSTOR wall	19° C
- Cylinder temperature	82° C
-Stainless steel basket temperature	104° C
-Maximum temperature of fuel bundle	145° C

Figure 5 - Design Estimated Distribution of Temperature In a CANSTOR module

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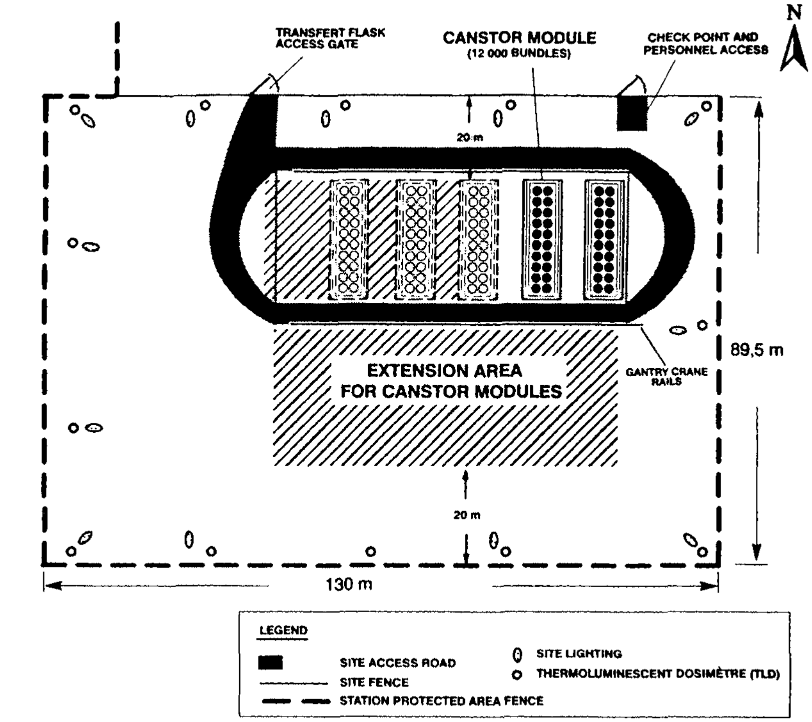

Figure 6 – Irradiated Fuel Dry Interim Storage Site

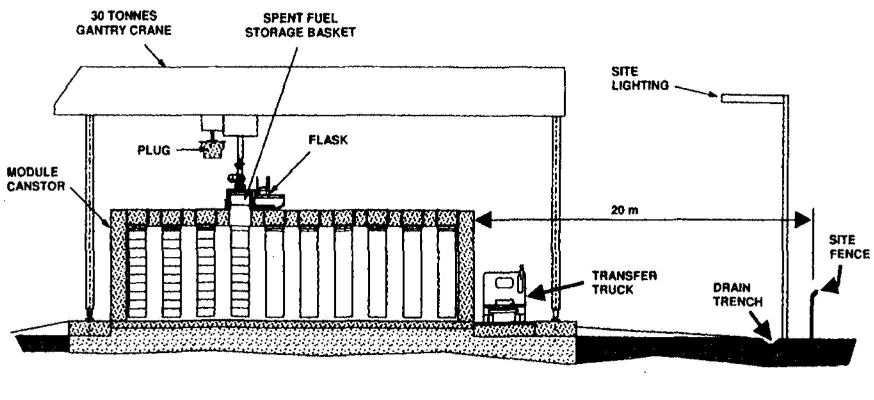

Figure 8 -Canstor Module Loading -Section View-

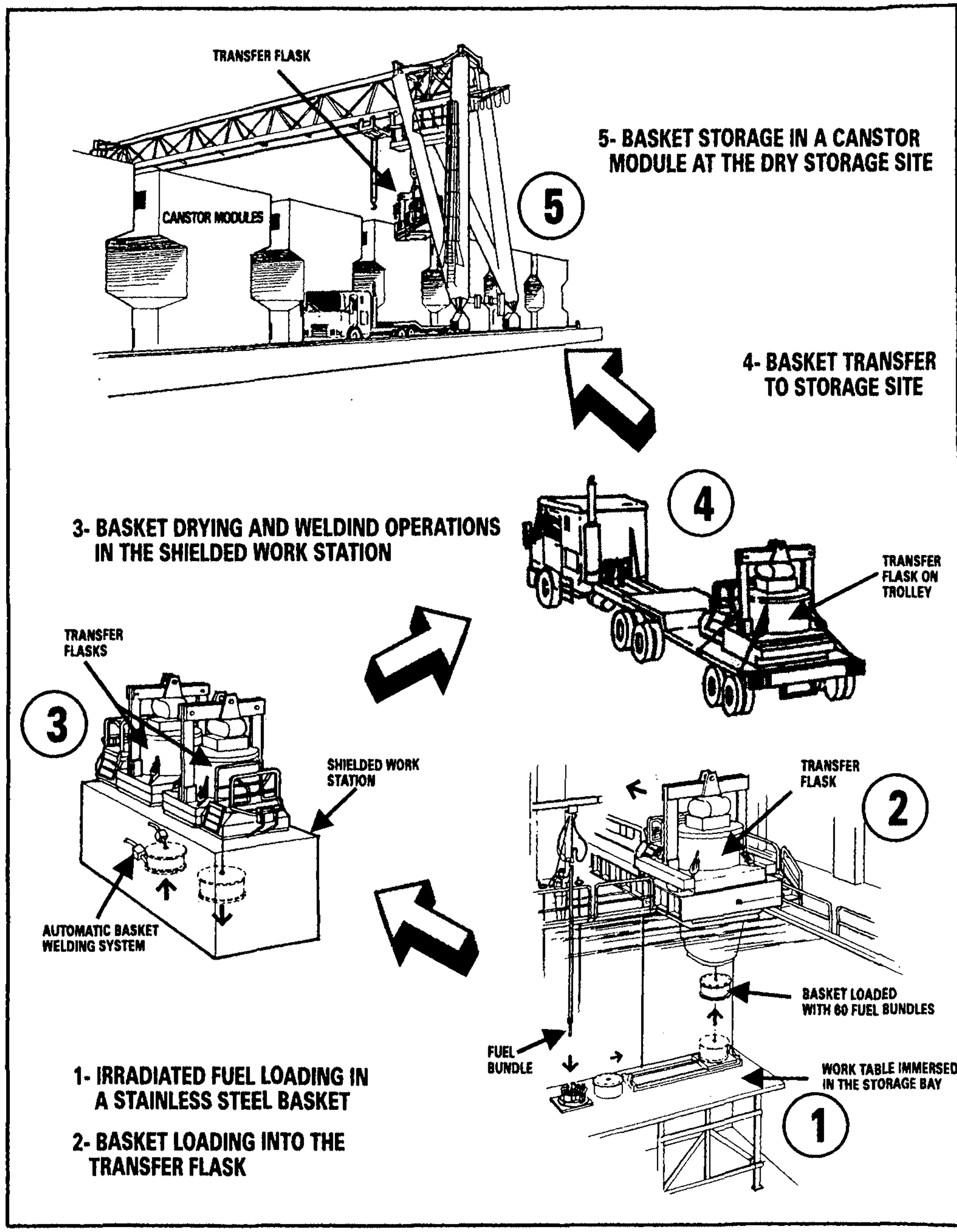

Figure 7 -Irradiated Fuel Dry Storage Sequence of Operations