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# THE DRY-CAP* SPENT FUEL STORAGE/TRANSPORT CASK

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## Abstract

THE DRY-CAP SPENT FUEL STORAGE/TRANSPORT CASK.

Increasing inventories of spent fuel and decreasing storage capacities at reactors are prompting development of alternative storage technologies. In the United States of America, the Department of Energy is engaged in the development of a geological repository and is committed to begin accepting fuel for permanent storage by 31 January 1998. Until this time, US utilities have assumed the responsibility for handling this material. The storage situation is also recognized in Japan and several utilities are now engaged in the development of alternative storage options. In recognition of these situations, Combustion Engineering, Inc. and Sumitomo Heavy Industries Ltd are engaged in a programme to develop and manufacture a cask capable of safely storing and transporting spent nuclear fuel. The cask is designed in accordance with US 10CFR71 and 10CFR72 criteria and has one of the largest capacities of spent fuel casks, with the ability to hold 24 PWR or 60 BWR spent fuel bundles and remain under the 125 t crane capacity of most power plants. The Dry-Cap spent fuel storage cask consists of a 16½ ft (5 m) long by 7½ ft (2.27 m) diameter thick-walled steel cylinder surrounded by shielding material. Dry-Cap is a relatively simple design, easily manufactured and, unlike other cask designs, requires no external fins for cooling. Dissipation of decay heat is accomplished by natural convection between the fuel and its helium environment and the cask and its surrounding environment. One of the most important features of the Dry-Cap design is that it does not require poison material for criticality control, since the basket design utilizes credit for burnup. Taking credit for the known irradiation heating of discharged fuel, and the fact that it has a low residual reactivity, can simplify and minimize the maintenance and monitoring requirements for long term storage. The Dry-Cap cask is designed to fulfil the long and short term storage needs for utilities.

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## Introduction

Increasing inventories of spent fuel at reactors are prompting development of alternative storage technologies. In the United States, the Department of Energy is engaged in the development of a geologic repository and committed to begin accepting fuel for permanent storage by January 31, 1998. Prior to this time, U.S. utilities have assumed the responsibility for handling this material. The storage situation is also recognized in Japan and several utilities are now engaged in the development of alternate storage options.

At present there are several alternatives utilities can utilize to increase on-site storage capability. These are: re-rack with maximum density racks, intra-utility transshipment of spent fuel, inter-utility transshipment of spent fuel, fuel rod consolidation and at-reactor dry storage. Presently, only the first alternative has been utilized to any great extent. The alternatives involving transshipment of spent fuel have political /institutional obstacles which often prove costly for U.S. utilities. Fuel consolidation and dry storage are under development within the U.S. and Japan.

## Dry-Cap STORAGE/TRANSPORT CASK

Combustion Engineering Inc. (C-E) and Sumitomo Heavy Industries Ltd (SHI) have agreed to develop heavy wall casks capable of safely storing and transporting spent nuclear fuel. The casks utilize advanced technology to maximize storage capacity within the weight constraints of most existing reactors. A topical report for storage of spent boiling water reactor (BWR) and pressurized water reactor (PWR) fuel was submitted to the U.S. Nuclear Regulatory Commission (NRC) in November, 1985. Approval is expected by the summer of 1986.

The Dry-Cap Storage/Transport Cask consists of a 16½ foot (5 meter) long by 7½ foot (2.27 meter) diameter thick-walled, steel cylinder surrounded by a shielding material (Fig. 1). Designed in accordance with U.S. NRC 10CFR71 and 10CFR72 criteria Dry-Cap has the capacity to store spent fuel as shown in Table I.

C-E and SHI are also designing a smaller dual purpose cask with a total weight under 100 metric tons.

The cask internals are based upon the technology of C-E's MAX-CAP spent fuel storage racks. The internal design consists of a series of thin-walled stainless steel boxes welded together to form four main structural members. The internals can easily be changed from PWR configuration to a BWR configuration (and vice versa). Removal and reconfiguration are facilitated by a (proprietary) internal structural member.

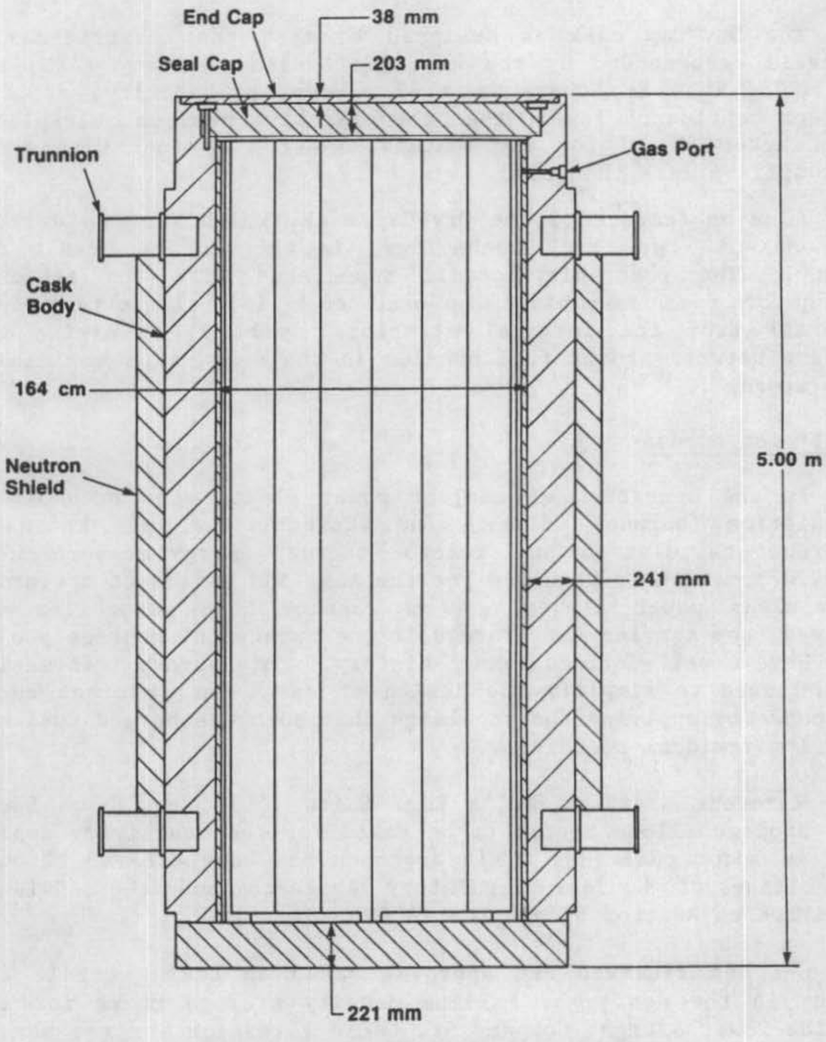


*FIG. 1. The Dry-Cap spent fuel storage cask.*

TABLE I DRY-CAP STORAGE CAPACITY

| Fuel Type | No. of Assemblies | Weight (Metric Tons) |
|---|---|---|
| PWR | | |
| Intact | 24 | 100.9 |
| Consolidated | 48 | 113.6 |
| BWR | | |
| Intact | 60 | 102.7 |
| Consolidated | 100 | 113.6 |

The Dry-Cap cask is designed to meet the sub-criticality criteria recommended by the American Nuclear Society (ANS) and the NRC. That is, there is a 95 percent probability, at a 95 percent confidence level, that the effective neutron multiplication factor ($K_{eff}$) for any postulated array of fuel within the cask will be less than 0.95.

A major feature of the Dry-Cap cask, which is also derived from MAX-CAP fuel rack technology, is the use of credit for burnup. The reactivity credit associated with the achieved burnup of fuel assemblies is used to (1) eliminate poison material from the internal structure and (2) minimize the spacing between stored fuel bundles in the cask, thus maximizing cask storage.

## Credit for Burnup

In the operation of nuclear power plants, the accumulated irradiation (burnup) of each fuel assembly is well known by neutronic calculations and reactor thermal energy measurements. Such information is required for the safe and efficient operation of nuclear power plants. As a result, when assemblies are removed from service for storage in the spent fuel storage pools, they have a well-defined burnup history. This burnup information can be used to simplify the design of spent fuel storage racks and casks by applying the knowledge that such discharged fuel has very low residual reactivity.

A recent draft of NRC's Reg. Guide 1.13, Rev. 2 on Spent Fuel Storage allows credit to be taken for the reactivity depletion in spent fuel [1]. This approach has been cleared through the office of Nuclear Regulatory Research and the Advisory Committee on Reactor Safeguards (ACRS).

C-E has received NRC approval based on taking credit for burnup in the design of maximum density storage racks for the Florida Power & Light Company St. Lucie 2 reactor and the Northeast Utilities Millstone 2 reactor. In both cases, administrative procedures can be applied to determine that a discharged fuel assembly, based upon its in-reactor history, has achieved burnup (e.g. low residual reactivity) sufficient enough to be stored in designated unpoisoned storage rack locations. (Fuel assemblies which do not meet the criteria normally have sufficient reactivity to be reused in the reactor for the production of additional energy.) This burnup history, being unchanged in the spent fuel storage rack, should be applicable when the spent fuel bundles are transferred to a dry storage cask.

## Accumulated Historical Burnup Calculations

The burnup experience of each fuel assembly is routinely calculated from the energy generated by that assembly while it resides in the core. This is done in conjunction with the safe and economic operation of the reactor. The result of these calculations can be recorded and used to provide a burnup history of each assembly.

In Combustion Engineering plants the burnup of each fuel assembly is tracked using the C-E CECORE Fixed Incore Detector Analysis System. Similar systems are also used for non-Combustion Engineering plants. The CECORE system synthesizes detailed full-core three dimensional box and pin power distributions from readings of fixed incore detectors. The detectors are 40 cm long, self-powered, rhodium neutron sensors located in approximately 25% of the assemblies. Three-dimensional power distributions are produced by the CECORE program using libraries of pre-calculated coefficients to interpolate and expand the measured signals to powers in instrumented and uninstrumented boxes. The power distribution is converted into burnup and added to any previous burnup to give total burnup for each assembly.

The overall uncertainty of the CECORE calculation is less than 6.2%. This is well within the safety band provided by taking credit for only 80% of the calculated burnup in the cask design discussed above.

## Reactivity Monitor

An alternative (or complementary) technique to pure administrative controls is to use a reactivity meter to directly measure the burnup of a discharged fuel assembly by comparison to a known standard. C-E has patented a design for a reactivity monitor which could allow credit for the burnup of irradiated fuel and is currently working with Electric Power Research Institute and Northeast Utilities in developing the reactivity meter as part of a large fully licensed Fuel Consolidation Demonstration Program [2].

The reactivity monitor is an apparatus for measuring the subcritical multiplication of individual fuel assemblies. It involves placement of a neutron flux detector in a predetermined location of a spent fuel assembly and a neutron source in another. The subcritical multiplication is measured and compared with a known 'standard '. The detector and source are attached to rods on a movable support member, as shown in Fig. 2; for PWR fuel the arrangement very closely resembles a control element assembly. The rods carrying the source and detector are maintained in a constant, fixed spatial relation so that the distance and angle between the detector and source used in the measurement of the standard fuel assembly can be accurately repeated for measuring each fuel assembly. It is believed that such a device will prove to be an accurate method for determining the reactivity remaining in a discharged fuel assembly.

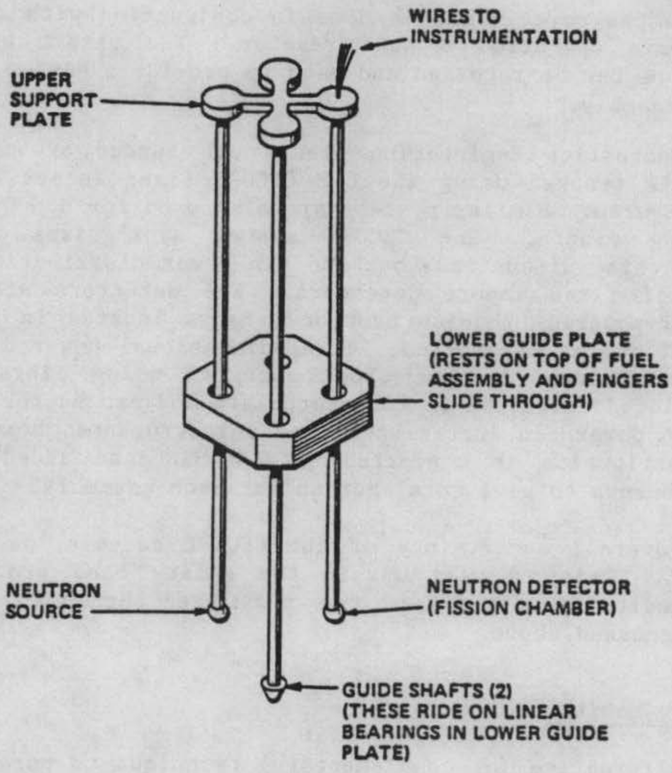


*FIG. 2. Reactivity monitor.*

## Thermal Design

Unlike several other cask designs, the Dry-Cap requires no external fins for cooling. Dissipation of spent fuel decay heat is accomplished by natural convection, radiation and conduction between the fuel, cask internals, internal helium environment and the cask to its surrounding environment. Specially designed (proprietary) features of the removable internals also enhance removal of heat from the fuel to the cask body. Benefits of these specially designed internals are apparent from Fig. 3 where the solid area is the temperature profile without the internals.

Thermal analyses were performed utilizing the ANSYS [3] finite element code. This is a versatile code capable of interactively modeling radiation, conduction and convection modes of heat transfer.

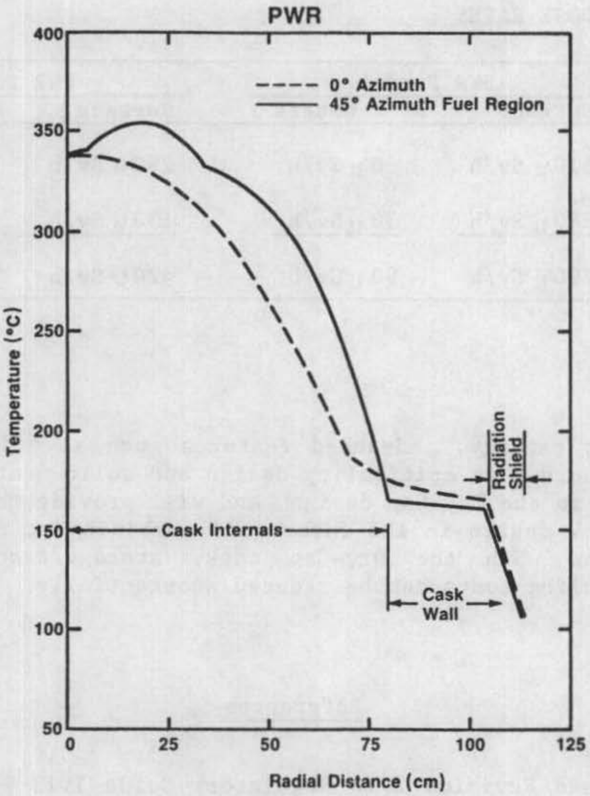


*FIG. 3. Radial cask temperature profiles.*

## Radiological Protection

The Dry-Cap cask is also designed to minimize the radiation dose rate emanating from the cask while remaining within the 110 tonne weight limitation and maintaining a simple design.

The peak combined gamma and neutron radiation dose at the worst point on the cask surface is less than 800μ Sv/h for BWR fuel and less than 500 μSv/h for PWR (see Table 2), the average combined dose is less than 500 μSv/h and 250 μSv/h for BWR and PWR's respectively.

## Summary

Both the 100 metric ton and 114 metric ton Dry-Cap dual purpose casks are designed to meet the needs of domestic and international utilities as well as the U.S. DOE well into the

TABLE 2 DOSE RATES

| | BWR Fuel | | PWR Fuel | |
|---|---|---|---|---|
| | Surface | At 2 Meters | Surface | At 2 Meters |
| Gamma | 510 μ Sv/h | 60 μ Sv/h | 290 μ Sv/h | 70 μ Sv/h |
| Neutron | 280 μ Sv/h | 30 μ Sv/h | 130 μ Sv/h | 49 μ Sv/h |
| Total | 790 μ Sv/h | 90 μ Sv/h | 420 μ Sv/h | 110 μ Sv/h |

twenty-first century. Advanced features such as utilization of credit for burnup in criticality design and solid neutron shields are present in the Dry-Cap design and will provide the bases for advanced cask design in the future and combining at reactor fuel consolidation with the Dry-Cap cask, storage/transport post reactor handling costs can be reduced substantially.

## References

1. "Proposed Revision 2 to Regulatory Guide 1.13 - Spent Fuel Storage Facility Design Basis", U.S. NRC, December, 1981.

2. R. L. Moscardini, "Fuel Consolidation Program Progress Report," Paper presented at Waste Management '85, March, 1985.

3. "ANSYS - Engineering Analysis System," Swanson Analysis System, Inc.