140-B Rail/Barge Spent Fuel Cask Development

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INTRODUCTION:

Development of the 90,700 Kg (100 ton) 140-B Rail/Barge Cask for OCRWM requires satisfying at least the following simultaneous and sometimes conflicting requirements.

- The payload of PWR and BWR fuel assemblies and/or consolidated fuel rods should be as large as possible to minimize life cycle costs and total radiation exposures for the entire transportation system. This may mean that the cask cost alone may not be the minimum.
- Exceed neither the 90,700 Kg crane hook capacity or the 119,300 Kg (263,000 pound) railcar gross weight limits.
- Provide a thermal path to dissipate heat outward from fuel assemblies but also not conduct enough heat inward during the hypothetical accident fire to exceed fuel pin peak cladding or seal temperatures in either case.
- Interface satisfactorily with a large number of utility and repository facilities and equipment with rapid turnaround times while keeping radiation exposures of personnel and the public as low as reasonably achievable (ALARA).
- Assure subcriticality with a large number and variety of fuel assembly designs in fuel pool loading, shipment or accident conditions. Fuels may be enriched up to 4-1/2%.
- Be licensed by NRC to 10 CFR 71, requiring survival of hypothetical accident drops, puncture tests, and fires without loss of containment or damage to fuel.
- Withstand submergence requirements of IAEA Safety Series 6.

The preliminary design of the 140-B Rail/Barge Cask is about 60% complete and incorporates several innovative features which extend current cask design techniques.

Discussion of the major items affecting the design and cask features are presented in the following sections.

MAJOR ITEMS AFFECTING DESIGN

The general philosophy of Nuclear Packaging, Inc. (NuPac) in the design of the 140-B Cask is to use a balanced combination of optimizing state-of-the-art design to minimize licensing uncertainties while adding innovations which extend payload and increase operational efficiencies, e.g., minimizing turnaround times. The major items which have affected the development of the preliminary design of the 140-B cask have been:

- Heat transfer considerations
- Criticality evaluations
- Maximizing payload, which involves a multitude of items
- Containment seal and impact limiter design

Heat Transfer Considerations

Satisfactory heat transfer in opposing directions and widely different temperatures must be achieved in the cask. The normal situation requires transferring the heat from the fuel assemblies to dissipate it outside the cask without exceeding either the fuel cladding temperature limit of 380°C (716°F) or allowable seal temperature in the 121-149°C (250-300°F) range. The fact that the impact limiter of polyurethane foam acts as an insulator must also be taken into consideration.

To conduct the fuel heat outward in the basket, copper was chosen as the main heat transfer medium because of its high thermal conductivity and good corrosion compatibility with stainless steel. The copper is totally enclosed in stainless steel to prevent any direct communication with water in the fuel storage pool. In the cask body, the heat is transferred through the neutron absorber (which has poor thermal conductivity) by radial copper fins to a copper shell and subsequently to the cask body outside cover. By using this design, both fuel cladding and the O-ring seals are maintained about 28°C (50°F) below limits.

In hypothetical accident conditions the cask exterior is subjected to at least 800°C (1,475°F) for at least 30 minutes. The heat must be prevented from raising temperatures high enough to damage the seals or exceed the fuel cladding limit. This is accomplished by providing an air gap between the cask outer shell and the next shell of heat conducting copper. Calculations show this will be satisfactory and will be confirmed by testing.

Criticality Evaluations

The worst case criticality condition results from accidental flooding of the cask. Criticality evaluations show that both a water gap for moderation and a poison are required to meet subcriticality limits of $K_{eff} < 0.95$. Two design choices were made to achieve this with minimum space and weight. First, the poison material of ^{10}B is combined in the heat conducting copper. Second, the amount of ^{10}B is increased to 5 vol. % (1.58 wt. %) from the previously planned 3 vol. % which reduces the basket outside diameter by 1".

Maximizing Payload

Two weight limitations are the main items which restrict payload - the 90,700 Kg crane hook capacity and the 119,300 Kg railcar gross weight capacity. The weight constituents of these two loads vary with the crane load being the more limiting since it consists only of the cask/basket/payload assembly, lifting fixture, and water enclosed when lifted from the fuel storage pool. The railcar load consists of the same cask/basket/payload assembly, plus impact limiters, tie-down structure between the cask and railcar, and the railcar itself.

The cask/basket/payload assembly design takes into consideration the heat transfer and criticality evaluations discussed in the previous sections. In addition, high strength 17-4 PH stainless steel and minimal basket diameter to reduce the amount of heavy shielding on the outer parts of the cask are used to maximize payload at 21 PWR and 48 BWR assemblies.

Use of high strength materials in the lift fixture, together with the items noted on the cask/basket/payload assembly allow the crane weight limit to be met. Railcar weight limits are met by use of high strength materials on the tie-down structure and impact limiter skin and employing a specially designed railcar.

Containment Seals and Impact Limiter Design

Design questions on the O-ring containment seals and the impact limiter foam arose from the need to use both at higher temperatures than encountered in past applications. Potential elastomeric materials for O-rings were evaluated for possible use in the temperature range of -40°C (-40°F) to 149°C (300°F). Seven potential materials were selected and tested at various temperatures for satisfactory sealing (determined by a helium leak test), compression set, and resiliency. For the impact limiter foam, stress/strain data for up to 149°C (300°F) was obtained. Acceptable materials and design data were found.

CASK DESCRIPTION

Overall Cask System

The 140-B Spent Fuel Shipping Cask assembled for transportation is shown in Figure 1. Impact limiters of stainless steel clad polyurethane foam are bolted to each end of the cask body. The railcar is specially designed for this application both to assure all requirements are met and also to permit weight to be less than a standard railcar. The cask lays horizontally in a cradle/tie-down assembly with vertical restraints over the top. The tie-down assembly/vertical restraint is an innovative design which not only permits release of the cask from the railcar in case of accident conditions as required by the Association of American Railroads (AAR), but also keeps the impact limiters intact.

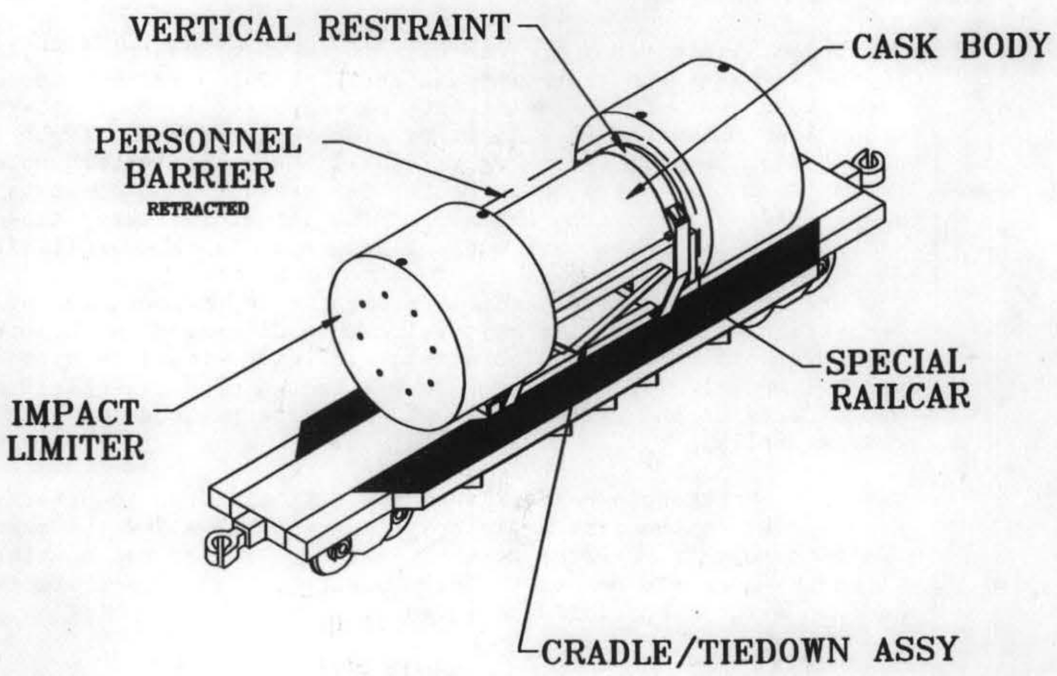

Figure 1. Spent Fuel Shipping Cask

Cask System Components

The major cask system components are shown in Figure 2. Separate fuel baskets handle either 21 PWR or 48 BWR intact fuel assemblies. Since fuel from different reactors vary in size, auxiliary spacers and guides properly position and hold the different assemblies during transportation.

The closure is bolted to the cask body and uses two elastomeric O-rings on the bore for containment seals. The closure also contains the penetrations for gas sampling, fill/drain, seal testing, cooldown and inerting. A penetration at the bottom of the cask provides for draining and/or flushing, should it be required.

Basic dimensions of system components are:

o	Cask body without impact limiters	84 in. OD x 203.5 in. long
o	Cask body with impact limiters	128 in. OD x 283.5 in. long
o	Basket cavity	57 in. ID x 180.5 in. long

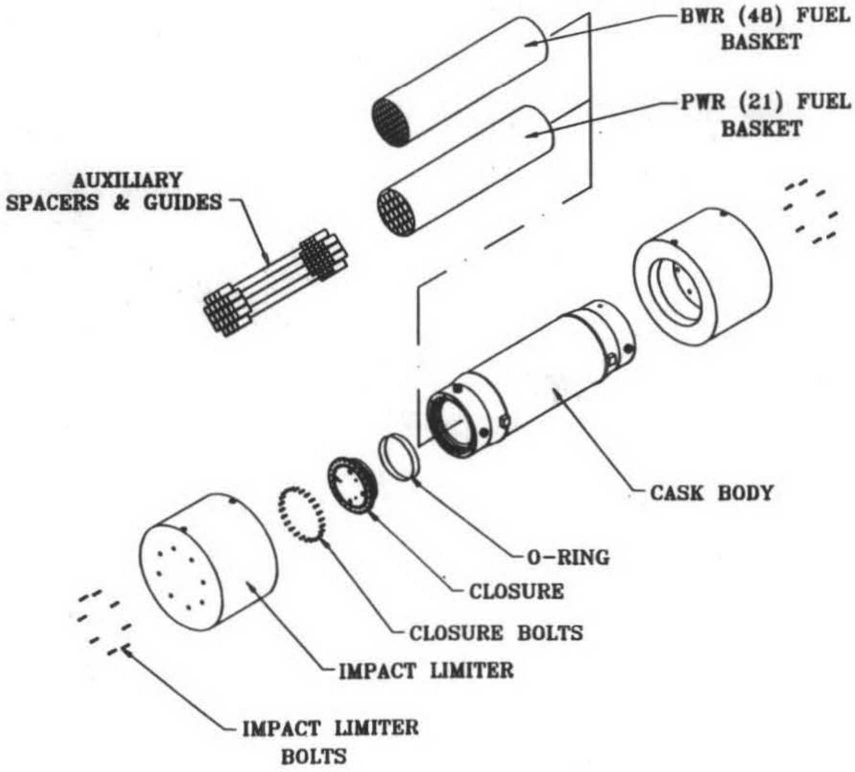

Figure 2. System Components

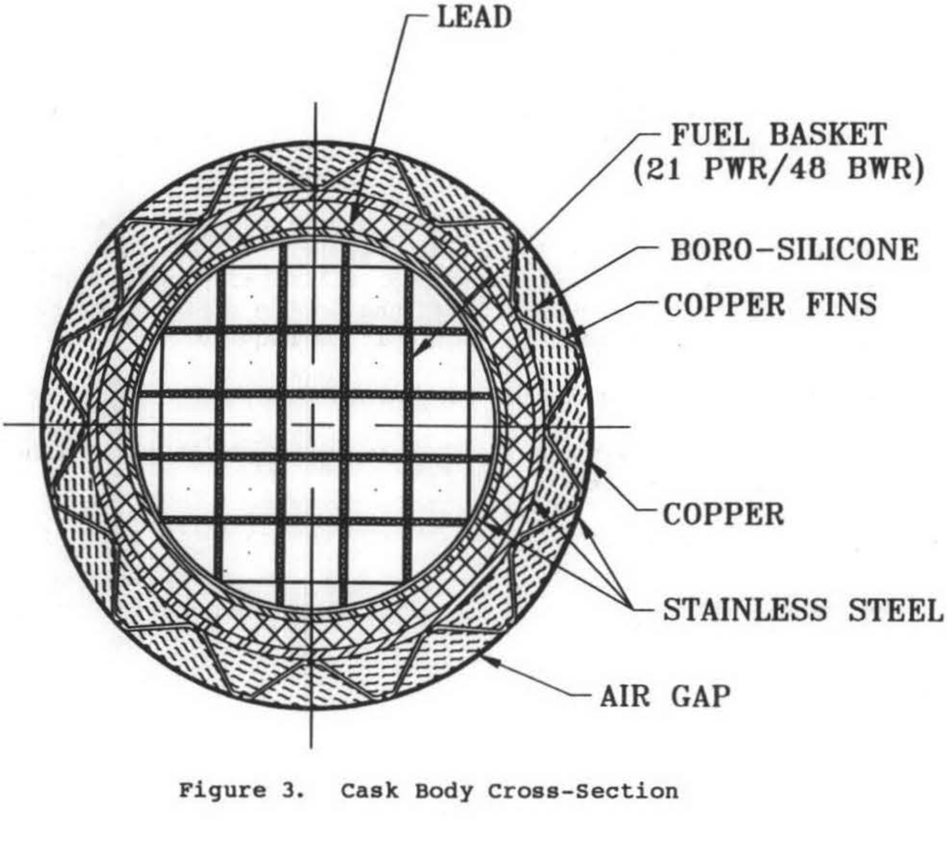

Figure 3. Cask Body Cross-Section

Cask Body

A cross-section of the cask body is shown in Figure 3. The body provides the shielding required for the basket and payload by using a combination of lead and stainless steel for gamma shielding and borated silicone for neutron shielding. The borated silicone was chosen rather than more conventional borated polyethylene because of the higher temperatures in that region. Heat from fuel is transferred via the copper fins through the neutron shielding to a copper shell under the stainless steel skin. The air gap restricts heat flow from the cask exterior. The inner stainless steel shell closest to the basket provides the primary containment. The outer shell contains the lead gamma shielding in case of fire.

Basket

For normal conditions the basket must maintain geometry to assure subcriticality and to protect the fuel from being damaged during handling. For hypothetical accident conditions of dropping or submergence in water, the basket must also assure that:

- Subcriticality is maintained
- Fuel is prevented from being damaged by drops or punctures
- Fuel heat is transferred adequately to prevent allowable fuel temperatures from being exceeded

The basket uses several innovative design features to meet these requirements as shown in Figure 4.

- The water channel provides sufficient moderation to assure that the ^{10}B poison maintains subcriticality
- The ^{10}B poison is dispersed in the copper heat transfer plate to minimize space
- High strength stainless steels, e.g., 17-4 PH, are used to minimize thickness and associated weight.
- A "tongue and groove" type joint is used at water panel joints to facilitate construction and inspection. An all-welded assembly has also been considered but appeared to be more difficult and costly to fabricate so it is considered as a back-up design.

Cask Handling and Auxiliary Fixtures

Various handling features and auxiliary fixtures for the 140-B cask are illustrated in Figure 5. To unload the cask, the vertical restraints and impact limiters are removed using fixtures or slings similar to those illustrated. The impact limiters may not be removed from the railcar nor require a handling fixture if railcar weight and design allow a retractor-replacement mechanism to be built into the railcar.

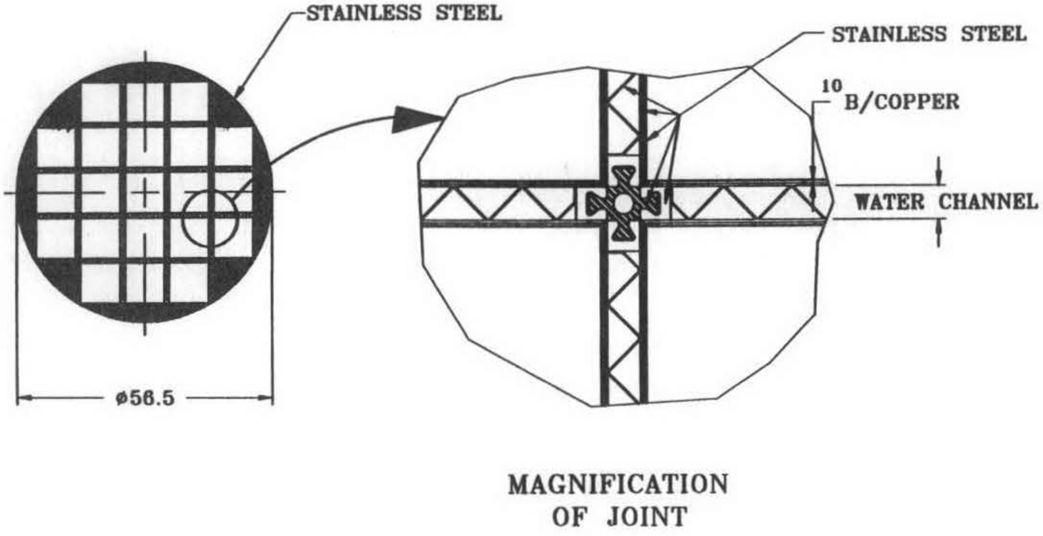

Figure 4. Basket

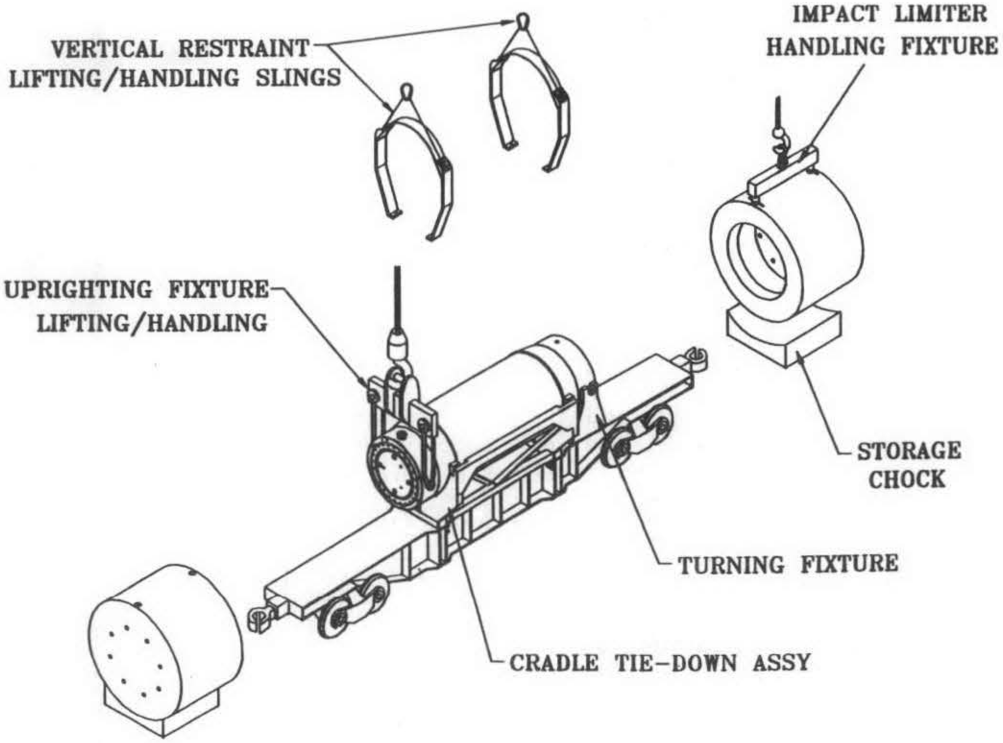

Figure 5. Cask Handling & Auxiliary Fixtures

Uprighting is done by installing the turning fixture and using the uprighting fixture to remove the cask from the railcar. A separate lift fixture, if desired, could be used to move the cask into and from the fuel storage pool.

To facilitate handling and minimize exposure of operations personnel:

- o Bolt heads are conical and/or spring-loaded or captive where necessary to permit remote or semi-remote handling, if desired
- o Closure incorporates alignment marks, is stepped with tapers, and has a large vent opening to facilitate installation
- o Penetrations are quick-disconnect types and operable by a single operator

Transfer between the railcar and reactor or barge can also be done using a skid on the cradle tie-down/cask assembly if desired.

CERTIFICATION

It is expected that the 140-B cask using the design features described can receive the needed Certificate of Compliance based on:

- o Selection of materials to meet needed requirements
  - Structural: ASME or qualified by testing
  - Thermal: High conductivity and good properties at predicted temperatures
  - Containment: Sealing retained at temperature extremes
  - Shielding: Safety maintained for all conditions
  - Criticality: Subcritical for all conditions
- o Proper design methods to meet certification requirements
  - Analysis and testing to verify proper structural, thermal and containment performance
  - Analysis to verify proper criticality and submergence performance
  - Analysis plus checking tests to verify proper shielding performance
  - Base designs on previously certified casks where practical
- o Testing to verify adequacy and acceptability
  - Component tests on seals, foam and neutron absorber
  - Scale model tests on impact limiters and the cask system

Through these methods it is expected that the innovative features of the 140-B Cask will be found acceptable not only in accordance with 10 CFR 71 but also should meet IAEA Safety Series 6 requirements.

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