# SHIPMENT OF GAS GENERATING SPENT FUEL ON THE U.S. DEPARTMENT OF ENERGY HANFORD SITE

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## SUMMARY

Approximately 2,100 metric tons of unprocessed, irradiated nuclear fuel elements are stored in the two K Basins at the U.S. Department of Energy (DOE) Hanford Site near Richland, Washington. The basin water contains significant quantities of dissolved nuclear isotopes and radioactive fuel corrosion particles. The condition of the spent fuel elements varies from intact to severely damaged, where the cladding is badly split or has peeled, with substantial fuel missing. The K Basins are located within a few hundred meters of the Columbia River and have leaked twice in the past. One of the highest priorities of the DOE is to remove the spent fuel from the K Basins, stabilize it, and move it to a Canister Storage Building (CSB), built well away from the Columbia River, for long-term storage prior to final disposition at a repository.

## ONSITE TRANSPORTATION PROGRAM

Transportation of the K Basin spent fuel will occur entirely within the confines of the 1450 $km^2$ Hanford Site, which does not have routine public access. Consequently, the transport is onsite, and does not fall under the Federal Hazardous Materials Regulations (DOT 1997). DOE Order 460.1 (DOE 1995) enables DOE facilities to develop onsite transportation programs that provide equivalent safety to the Federal Hazardous Materials Regulations (DOT 1997). The basis for the Hanford Site onsite transportation program is detailed in HNF-PRO-154 (FDH 1998).

The Hanford Site onsite transportation program was developed to meet the "equivalent safety" requirement, be consistent with analogous commercial operations, interface appropriately with facility safety analysis requirements, and utilize a risk-based management approach to ensure effort is applied consistent with the risk. The program focus is on the establishment of defendable safety bases. Authorization to use an onsite transportation system is granted by the approval of the applicable Safety Analysis Report for Packaging (Onsite).

The K Basin spent fuel transportation activity is similar, in some respects, to the onsite movement of commercial spent fuel from a reactor pool to a dry storage facility. The methodologies used to evaluate those types of movements were incorporated into the onsite program as applicable. In the case of the K Basin spent fuel, the nature of the fuel (e.g., gas generating) played a significant role in the safety analysis.

## TRANSPORTATION SYSTEM SAFETY BASIS

The transportation system was designed to meet DOE onsite transportation requirements. The transportation system consists of a Multicanister Overpack (MCO), the MCO Cask, and a dedicated trailer system. The MCO is vented to the interior of the cask during the transfer from the K Basins to the Cold Vacuum Drying (CVD) Facility, so the cask provides the containment boundary during that transfer. The criteria for the MCO cask design were spelled out in a packaging design criteria document (Edwards 1997a), which complies with the requirements of the onsite transportation program. For conservatism and to account for design uncertainties, that packaging design criteria took essentially no credit for the presence of the MCO inside the cask. The design criteria for the MCO Cask were the following:

- Cask must remain leaktight in accordance with ANSI N14.5 during all normal onsite conditions of transport.
- Cask must prevent a leak that exceeds the onsite transportation release criteria after a 6.4-m free drop onto a reinforced concrete surface while the MCO is filled with water.
- Cask must prevent a leak that exceeds the onsite transportation release criteria after a 9.1-m free drop onto a reinforced concrete surface after the MCO has been cold vacuum dried.
- Cask must maintain full containment after a six-minute 800°C fully engulfing fire. Active cooling can be provided following the fire.

The cask was evaluated in an onsite Safety Analysis Report for Packaging (Edwards 1997b), which showed the cask satisfies all criteria for an onsite shipment.

## SPENT NUCLEAR FUEL PROCESS STEPS

The spent nuclear fuel in the Hanford K Basins consists of fuel elements, which have been stored underwater for at least ten years. The cladding on some fuel elements is so badly damaged that the uranium metal is exposed to the basin water. Corrosion products, including uranium metal and hydride, are adherent to the fuel elements themselves and have formed a sludge at the bottom of the fuel element canisters. Some of the fuel elements have been so badly damaged that they have broken down into chunks that are called scrap. Scrap is defined as pieces of fuel which have at least one dimension larger than 0.64 cm. Figure 1 shows an example of severely damaged fuel.

Figure 1 – Severely Damaged Fuel

Fuel elements are stored underwater in double-barreled canisters in the K Basins, with seven fuel elements stored within each canister. The fuel elements will be retrieved from the canisters and cleaned to remove as much of the adherent sludge and corrosion products as possible. The cleaned fuel elements will then be loaded into fuel baskets. The fuel scrap will be loaded into specially design scrap baskets. The fuel and scrap baskets are loaded into the MCO underwater in the K Basins. Depending on fuel type, five or six baskets will be loaded into each MCO, including up to two scrap baskets. The MCO is located in the transportation cask in the K Basin during loading of the baskets. The cask itself will sit inside an immersion pail to prevent its exterior from being contaminated by the basin water.

Once the fuel baskets have been loaded into the MCO, a 26.7-cm thick shield plug will be placed onto the MCO and the immersion pail will be raised from the basin. The MCO will be sealed, the cask lid will be installed, and the cask will be placed onto the specially designed transportation trailer. The cask transportation system will then be moved to CVD Facility. A photograph of the cask transportation system is provided as Figure 2. At the CVD facility, the cask lid will be removed, process connections will be made to the MCO, the MCO will be drained of water, and the MCO will be vacuum conditioned to remove all freestanding water. Once cold vacuum drying is complete, the MCO will be sealed, the cask lid will be replaced, and the cask transportation system will be moved to the CSB. At the CSB, the MCO will be removed from the cask and placed into long-term storage in a storage tube. An empty MCO will be loaded into the cask, and the cask will be returned to the K Basin to repeat the process. An overview of the entire process is provided in Figure 3.

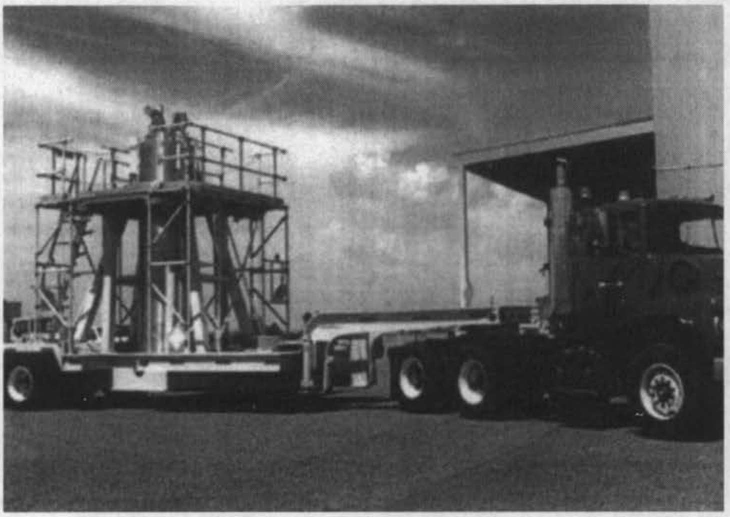

Figure 2 – Cask Transportation System

The Multicanister Overpack (MCO) provides multiple safety functions. The MCO is the long-term storage container for the fuel at the CSB and is the process vessel during conditioning at the CVD Facility. The cask provides containment and shielding for the fuel in the MCO during onsite transportation. The MCO is transported full of water and fuel from the basins to the CVD Facility, located no more than 400 meters from the K Basins. At the CVD Facility, while the MCO is within the MCO Cask, the water is drained from the MCO, the MCO is evacuated, and the fuel is heated to 50°C for conditioning. The package will then be transported 13 kilometers to the CSB, where the MCO is removed from the MCO Cask and long-term storage of the MCO occurs.

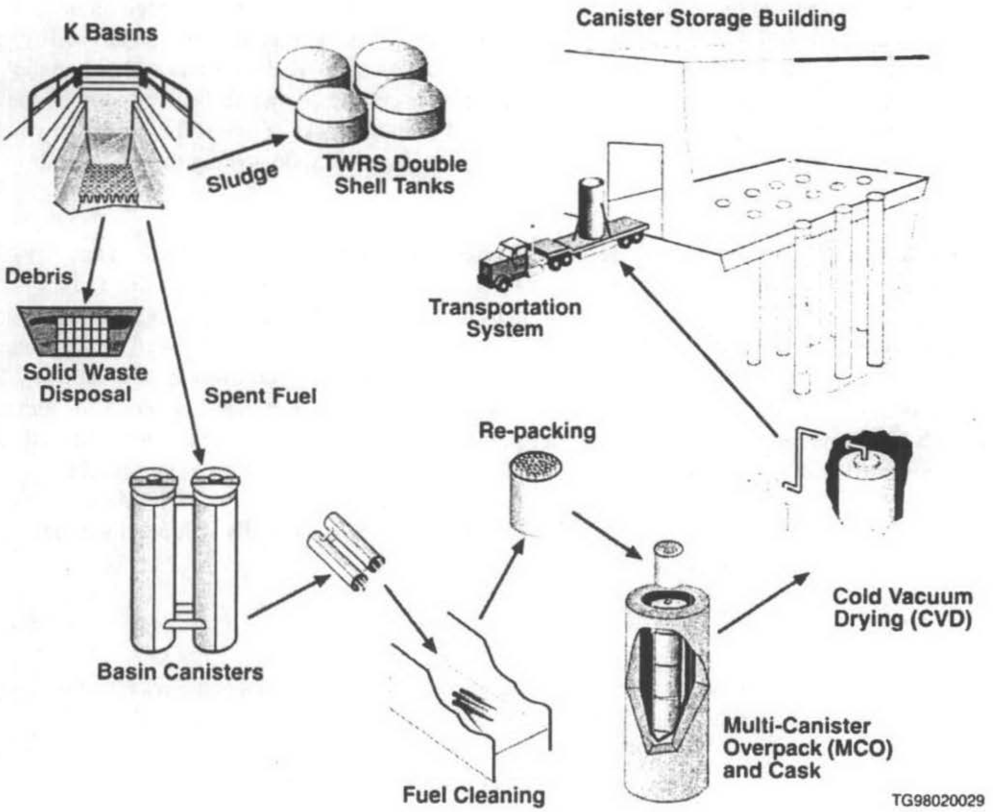


Figure 3 – Spent Nuclear Fuel Process Overview

## GAS GENERATION

A major issue with transportation of this fuel is hydrogen gas generation from the reaction of exposed uranium metal with water in contact with the spent fuel. If oxygen is present in the package, any hydrogen generated can quickly form a flammable or explosive mixture within the vapor space of the package. During the transfer from the K Basins to the CVD Facility, the fuel is covered with water, so some uranium metal is in direct contact with water. Since there is limited vapor space above the water during that transfer, rapid gas generation might lead to overpressurization of the cask. Another safety concern is the potential for a runaway chemical reaction from the reaction of the fuel with water in the MCO, since the uranium-water corrosion reaction is highly exothermic and that reaction rate increases with temperature.

Removing all oxygen from the vapor space within the package and replacing it with an inert gas solved one gas generation issue. This action prevents a flammable gas mixture from forming within the package. The CVD Facility design includes features to handle the inert gas/hydrogen pressurized packages. As an additional safety control measure to prevent overpressurization or runaway chemical reactions within the package, the shipping window for the transfer from the K Basin to the CVD Facility is tightly controlled. Based on the safety analysis, 24 hours are allotted for the transfer from the K Basins to the CVD Facility. That shipping window begins when the cask lid is sealed at the K Basins and ends when the cask arrives at the CVD Facility and process piping is connected one of the vent ports on the cask and the hydrogen/inert gas mixture is purged from the cask. If that shipping window is exceeded, emergency procedures have been developed and include venting the package to relieve pressure.

The CVD process will remove freestanding water from the MCO, which alleviates any potential runaway chemical reaction. The water remaining within the MCO will be in the form of hydrates of corrosion products such as uranium trioxide hydrate ($UO_3 \bullet 2H_2O$). The other source of hydrogen will be from hydroxides in the corrosion products such as aluminum hydroxide [$Al(OH)_3$]. Radiolysis is expected to create free hydrogen from those chemical compounds. Since radiolysis is a slow process, it was easily shown that there is no concern with MCO overpressurization during transport from the CVD Facility to the CSB. The MCO is designed with a pressure rating of 2760 kPa, which will be adequate to withstand the pressure produced by radiolytic gas generation throughout its 40 year design lifetime. Backfilling the MCO with inert gas prior to sealing at the CVD Facility will preclude the formation of a flammable gas mixture.

## REFERENCES

American National Standard for Radioactive Materials - Leakage Tests on Packages for Shipment, ANSI Standard N14.5, New York, 1987, ANSI.

Edwards, W. S., Packaging Design Criteria for the MCO Cask, HNF-SD-TP-PDC-030, Rev. 4, Richland, Washington, 1997a, WMNW.

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