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January 2, 1987

MEMORANDUM FOR: Charles E. MacDonald, Chief
Transportation Safety Certification Branch
Office of Nuclear Materials Safety and Safeguards

FROM: William D. Travers, Director
TMI Cleanup Project Directorate
PWR-B, Office of Nuclear Reactor Regulation

SUBJECT: SAFETY EVALUATION RELATED TO TMI-2 CORE SHIPMENTS

Attached is the staff's safety evaluation in support of reducing defueling canister void volumes for shipment of TMI-2 core debris in the NUPAC 125-B shipping cask. Our evaluation concluded that there are sufficient conservatisms in the shipping safety analysis to assure public health and safety and no adverse environmental impact from both normal and hypothetical accident conditions during transport of TMI-2 fuel debris if the canister void volume requirement is reduced from 50 to 25 percent. The operational constraints specified in the licensee's Canister Handling and Preparation for Shipment (CHAPS) program are modified to allow reduced canister void volumes as described in the licensee's submittals of November 10 and December 30, 1986. These submittals are attached for your information.

I believe that the attached safety evaluation addresses the safety issues which have been discussed by members of our respective staffs during consideration of this subject. I appreciate both your comprehensive technical input on this issue and your quick turnaround. I would appreciate any comments you may have on the attached SER as soon as possible.

ORIGINAL SIGNED BY
William D. Travers

William D. Travers, Director
TMI Cleanup Project Directorate
PWR-B, Office of Nuclear Reactor Regulation

Attachments: As stated

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NRC STAFF SAFETY EVALUATION IN SUPPORT OF

REDUCED CANISTER VOID VOLUMES

In the original staff evaluation of the licensee's Canister Handling and Preparation for Shipment SER, it was assumed that all defueling canisters would be sufficiently dewatered to achieve a free void volume equal to or greater than 50 percent of the empty canisters' void volume. One of the purposes for stipulating a 50 percent free void volume was to insure that a sufficient quantity of recombiner catalyst would be exposed to the canister gas space to provide for effective recombination of the highest expected quantities of radiolytic hydrogen and oxygen.

The catalyst beds installed in the defueling canisters were developed after an extensive series of laboratory tests conducted by Rockwell Hanford Operations in Richland, Washington. A total of 103 tests were conducted during catalyst bed development. The test program and apparatus are described in GEND 051. The testing program demonstrated that 100 grams of catalyst was sufficient to provide for recombination of the theoretical maximum gas generation rate of 0.11 liters per hour of hydrogen plus oxygen in stoichiometric proportions. Tests of the final design of the catalyst beds showed that 100 grams of catalyst was effective and performed at a level that showed a minimum factor of safety of 23. This factor of safety was derived from the observed recombination rates, which equalled the gas feed rates, and the ratio of the equilibrium oxygen concentration to the 5 percent flammability limit. Subsequent tests were performed to determine the effects of various contaminants on catalyst performance. In addition, a series of tests was performed to determine the cumulative effect of all potential catalyst contaminants. These tests showed a minimum factor of safety of 6. This factor would be reduced to 1.5 if the quantity of exposed catalyst was reduced from 100 grams to 25 grams as would occur if the canister void volume was reduced to 25 percent. This safety factor is still considered to be conservative because of the following:

1. The degraded catalyst performance due to contamination was based on all contaminants being present. This included potential contamination during canister fabrication and inspection as well as contamination from all possible sources simultaneously during canister use and subsequent storage. Additionally the contaminants were present on the test catalysts in concentrations much higher than realistically possible in actual field use. It is very unlikely that any catalyst bed could be contaminated to the same degree as the test beds.

2. The test program used a total gas production rate of 0.3 liters per hour and demonstrated acceptable catalyst performance at this gas production rate which is about three times greater than the theoretical maximum. No attempt was made originally to determine the actual maximum recombination ability of the catalyst. It is expected that the catalyst would in fact provide for recombination of much higher quantities of gas with a slightly higher, though acceptable, equilibrium concentration of gases

remaining. This was in fact demonstrated during later tests where gas production rates were varied above and below the theoretical rates.

3. The factors of safety from the RHO testing stated above assume that each canister has the minimum of 100 grams of installed catalyst exposed to the gas space. The fabrication drawings specified minimum quantities of catalyst, yet also required that the catalyst beds be completely filled. A review of fabrication documents shows that most catalyst beds have more than the minimum specified quantity of catalyst, thus a larger amount of catalyst could possible be exposed.

4. The maximum radiolytic gas generation rate was based on conservative estimates of the amount of fuel and retained fission products in a canister, the quantity of water present, hydrogen generation "G" values, and peak to average decay heat energy ratios in the fuel debris.

Based on the above, the staff concludes that the exposure of 25 grams of catalyst to the gas space in a defueling canister will provide for sufficient hydrogen and oxygen recombination to preclude the formation of a flammable gas mixture in the canister.

In addition to insuring that a sufficient quantity of catalyst is exposed, it is necessary to insure that the catalyst remains functional. Submergence of the catalyst in water will render it inoperable. Wetting of the catalyst will retard its recombination rate, but laboratory tests have shown repeatedly that the recombination rate recovers as the heat of reaction causes drying of the catalyst. Of concern is the potential for sufficient free water being available for the motion induced during transport to cause enough splashing to keep the exposed catalyst continuously wetted.

The design of the defueling canisters is such that when the canister is dewatered while vertical, a maximum volume of about 1.6 gallons of free water will remain in the lower head. Any water remaining in the fuel debris is interstitial water similar to that typically remaining in dewatered ion exchange resins. This may also be thought of as similar to the water present in a handful of wet beach sand. It is not readily drained by gravity, and thus not capable of wetting the catalysts due to "sloshing" back and forth during transport. The small volume of water remaining in the lower head will readily flow into the porous fuel debris when the canister is placed horizontally as it is during transport. To date, eight canisters that have been shipped to the storage facility have been opened. One of these canisters was carefully opened to quantitatively determine the amount of free water remaining. During a 15 hour draining process, only 0.85 gallons of free water was removed. Six other canisters were observed during opening and qualitatively determined to have "about one gallon" of free water that drained out. The eighth canister that was measured qualitatively contained about two gallons of free water. However, this canister was not typical of the lower void volume canisters in that its dewatered void was about 85 percent and it did not contain substantial amounts of compacted debris nor was it dewatered as many times as the other canisters.

In reviewing the residual water remaining in the dewatered canisters from the previous shipments the staff concludes that excess water of more than two gallons is unlikely. In addition, the probability of this residual water affecting the performance of the catalyst from the agitation and splashing is not considered credible because the catalyst beds are located at each end of canisters. The likelihood of this water being not dispersed in the solid debris and thus being able to continuously wet the catalyst is not credible.

The staff has therefore concluded that preparation of canisters in such a manner that the amount of free water remaining is minimized and that enough free void space exists in the canister to insure that at least 25 grams of catalyst is exposed will provide adequate assurance that gas concentrations will be maintained within required limits.

The above evaluation shows that if hydrogen and oxygen are produced radiolytically in stoichiometric proportions, the catalytic recombiners will prevent the buildup of a flammable gas mixture in the canister and will also prevent any appreciable increase in canister pressure. Of concern though is the potential for removal of the radiolytic oxygen by other chemical reactions with the canister contents. This oxygen scavenging would result in the buildup of free hydrogen gas in the canisters and the consequent increase in canister internal pressure. An additional reason for the stipulation of 50 percent free void in the canisters was to provide for sufficient volume to accommodate the hydrogen gas generated without exceeding the Maximum Normal Operating Pressure (MNOP) of the cask. The determination of MNOP assumed maximum theoretical hydrogen generation of 0.076 liters per hour in each of seven canisters loaded into the shipping cask. This analysis is discussed in details in the NUPAC 125-B shipping cask Safety Analysis Report.

If oxygen scavenging occurs, the performance of the catalytic recombiners is of no consequence since they can perform no useful function in the absence of oxygen. If oxygen scavengers, such as carbon, organics, or unoxidized metals are present in the canister contents, it is likely that scavenging will occur preferentially over catalytic recombination. This is because monatomic or free radical oxygen will form when a water molecule is radiolytically dissociated. This relatively reactive free radical is likely to react with an oxygen scavenger, if present, much more quickly than it can combine with another free radical to form diatomic oxygen gas and diffuse to the recombiner catalyst. Thus, it is unlikely to observe a combination of catalytic recombination of gases and chemical scavenging of oxygen taking place simultaneously. To date, 35 canisters have been prepared for shipping. Preparations included analysis of gas samples from the canisters after a monitoring period of several days. All samples showed either a lack of oxygen and excess of hydrogen, or the presence of both in very small concentrations. The first would indicate uninhibited buildup of hydrogen and complete scavenging of oxygen, whereas the the second would indicate gas recombination due to the function of the catalyst. In all cases where oxygen scavenging was apparent, the hydrogen appearance rate was found to be less than 10 percent of the theoretical maximum used in previous analysis. In addition, an experiment is in progress in the licensee's spent fuel pool in which a typical loaded fuel canister has been dewatered, purged with inert gas, and allowed to sit with no operable catalytic recombiners. After 30 days, gas samples taken from that canister indicate that oxygen scavenging is taking place and that the hydrogen generation rate is less than .005 liters per hour. This is less than 10 percent of the theoretical maximum generation rate. All data collected to date indicate that in most cases oxygen scavenging occurs and in all cases, the radiolytic gas generation rate is much smaller than projected. Thus, a reduction in the canister void volume to 25 percent will still provide sufficient free space for the accumulation of the radiolytically produced hydrogen without exceeding the MNOP specified in the shipping cask Certificate of Compliance (C of C).

These conditions will be verified in the field prior to shipping a filled canister. After dewatering and inert gas purging, a canister will remain in the spent fuel pool to allow radiolytic gases, if present, to accumulate. A gas sample will be taken from the canister and analyzed using a gas chromatograph. All hydrogen detected will conservatively be assumed to be due to non-stoichiometric generation. A gas appearance rate will be calculated and used to project future pressures and gas concentrations within the canister.

The cask Certificate of Compliance requires assurance that a flammable gas mixture does not develop in the canisters for a period of "twice the expected shipping time." This has been conservatively set by the licensee at 54 days. If the gas appearance rates are measured and found to be low enough to preclude reaching flammable concentrations in 54 days, then it can be shown that continued gas generation at that rate for a period of one year will not produce pressure in excess of MNOP.

The staff has concluded based on the above evaluation and on review of the calculations in the licensee's submittal that there are considerable margins of safety in the licensee's proposed fuel shipping program. Required canister void volumes can be safely reduced to the volume needed to assure exposure of 25 grams of recombiner catalyst in any canister orientation. This is equal to a void of 25 percent for the fuel canisters. Because of geometric difference in the types of canisters, a slightly larger void volume will be required in the filter and knockout canisters. This will provide adequate volume to assure catalyst operability and sufficient volume to accommodate the accumulated radiolytic gases without achieving excessive canister pressures. Verification of void volumes and gas appearance rates will be done in accordance with operating procedures subject to onsite NRC staff review and approval.