An Assessment of Canister Needs for Defueling the TMI-2 Core

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Introduction

The March 1979 accident at Three Mile Island Unit 2 (TMI-2) severely damaged the reactor's fuel and resulted in approximately 130 metric tonnes of radioactive fuel debris. Based on a March 1982 memorandum of understanding between the Nuclear Regulatory Commission (NRC) and the Department of Energy (DOE), the debris is shipped to DOE's Idaho National Engineering Laboratory (INEL) for research and interim storage. The debris from the reactor core will remain at the INEL until a permanent repository becomes available.

Since the TMI-2 fuel was damaged and significant portions were reduced to rubble, special shipping containers were required to transport the core debris. Existing spent fuel transport systems lacked the required capacity, were designed to carry intact fuel assemblies, were nearly impossible to reconfigure internally, and were designed for wet loading (TMI-2 pool space is limited). Rail transport was selected over truck transport because it has the advantage of requiring fewer shipments, thus reducing the chance of an accident.

Transport Cask

The choice of rail transport led to the development of the Nuclear Packaging Incorporated (NuPac) 125-B rail cask (Nuclear Packaging, Inc. 1988). This cask was specifically designed, tested, and fabricated for the transportation of the TMI-2 fuel debris. The cask incorporates two containment boundaries (inner and outer vessels), criticality control materials, and 20 cm of stainless steel and lead shielding. Each transport cask holds seven canisters. The cask incorporates two large energy absorbers, called overpacks, attached to each end. The overpacks are made of a thin plate of stainless steel and are filled with foam. The overpacks give the cask a dumbbell shape and are designed to crush and absorb the energy of an impact, thereby protecting the cask. The casks were designed and fabricated to comply with NRC regulations. A total of three shipping casks have been used in the shipping campaign. Two casks are owned by DOE and one cask has been leased from NuPac.

Canisters For Spent Fuel Debris

The three types of non-reusable canisters (fuel, filter, and knockout) were designed to load and hold the fuel debris. Each is 35.6 cm (14 in.) in diameter, 3.8 m (150 in.) long, and is constructed of stainless steel. The canisters provide an effective containment for the long-term storage of the TMI-2 core debris, and were designed to be compatible with various defueling techniques (Babcock & Wilcox Company 1985). The three types of canisters are discussed in the following paragraphs.

Fuel Canisters - Fuel canisters have a removable upper lid. A full-length square shroud froms the internal cavity, which is 23 cm (9 inches) square, and can accommodate partial fuel assemblies or large pieces of fuel debris. Neutron absorber materials are built into the canister to ensure subcriticality. The neutron absorber materials are in the form of borated aluminum sandwiched between two sheets of stainless steel.

Filter Canisters - Filter canisters were designed to capture fine powder-like debris on pleated stainless steel filters. The filter canisters operate either as part of the Defueling Water Cleanup System (DWCS) or the Debris Vacuum System. The filter assembly module consists of a circular cluster of 17 filter elements and a neutron absorber assembly. The first batch of filter canisters were designed to remove particulates in the range from 0.5 to 800 microns. Due to early clogging of the filter elements of these canisters, a new type of filter canister was ordered. The newly-ordered filter canisters have a smaller particle size limit of between 16 to 25 microns and their operation has been most effective.

Knockout Canisters - Knockout (k/o) canisters are used in conjunction with a hydraulic vacuum system. Loading is by directing a slurry of water and loose debris into the canister, and allowing the heavier particles to settle to the bottom. The water and residual fines are then directed to a filter canister. The k/o canister is designed to separate debris ranging in size from 800 microns to whole fuel pellets. Criticality control is by five absorber rods filled with B_4C pellets.

Some of the features common to all three canister designs are:

(1) The outer shell serves as a pressure vessel protecting against leakage.

(2) All fittings are quick disconnect and are located in the upper end.

(3) The canisters are designed for wet loading and subsequent transfer to the Fuel Handling Building.

(4) Neutron absorber materials are built into each type of canister.

(5) Catalytic material is installed on each end of the canisters to recombine any hydrogen and oxygen gases that may form.

(6) Design loaded weight (dewatered) is 1270 kg (the maximum is 1333 kg).

(7) Each has capabilities for dewatering, gas inerting, and leak testing.

(8) Each maintains structural integrity for criticality control under all loading due to normal handling and cask loading operations.

As of May 1989, a total of 259 canisters have been shipped to the INEL (215 fuel, 38 filter, and 6 knockout canisters). This was accomplished with 37 cask-trips. Shipments from TMI to INEL use dedicated trains where the only freight is the damaged fuel. The dedicated trains incorporate buffer cars on either side of each railcar holding a shipping cask. Up to three casks have been shipped at one time. There were eighteen rail shipments to date, and it is estimated that an additional five rail shipments of three casks each will be required to complete the program. The two rail carriers used are Conrail and Union Pacific. The distance of the rail route is approximately 3800 km.

Discussion

Early estimates indicated that approximately 250 canisters would be required to load the damaged fuel (GPU Nuclear Corporation 1985). The canister mix estimate favored k/o canisters and included 77 fuel, 39 filter, and 134 k/o canisters. However, with ongoing data acquisition of core conditions and defueling experience, the estimate of the number and mix of canisters ordered has required several mid-course corrections. The procurement changes were made for the following reasons:

1. Due to initial lack of accurate core conditions data, the weight of vacuumable debris was grossly overestimated. It was initially estimated that 73 metric tonnes of rubble material was in fine powder-like form, and therefore vacuumable. As of May 31, 1989, with the cleanup effort 90% completed, it is now estimated that the initial weight of vacuumable material was only 18 metric tonnes. Therefore, fuel canisters were substituted for k/o canisters.

2. The debris vacuum system exhibited low production rates and its use was limited due to clogging (high differential pressure buildup of the filter canisters). Most of the loose debris was collected either by a spade bucket tool or by an airlift system which was designed on site. These tools did not require underwater visibility and attained high collection rates. Since

both the airlift system and the spade bucket tool were used in conjunction with fuel canisters, k/o canister requirements were further reduced while fuel canister requirements were further increased.

3. The loading of items such as end fittings, loose fuel rods, and partial fuel bundles into fuel canisters were often governed by usable volume considerations (rather than maximum payload). This lowered the attainable payloads of fuel canisters and increased fuel canister requirements. The average payload of the fuel canisters used to date is 483 kg/canister as compared with a design payload of 680 kg/canister.

4. The first batch of filter canisters incorporated filter elements designed to remove particulates with a smaller particle size limit of 0.5 to 2 microns. These canisters exhibited early clogging which limited the throughput. The life of some of these filter canisters was somewhat extended by the use of coagulant and body feed (diatomaceous earth). However, additional filter canisters had to be ordered to meet reactor vessel and spent fuel pool filtration requirements. The extended defueling schedule, in conjunction with continuous requirements for filtration of defueling water, also increased filter canister requirements.

Table 1 presents the overall Cleanup Program canister requirements, the number and mix of canisters used to date, the estimate of additional canisters required, and the number and mix of the canisters procured.

TABLE 1
TMI-2 DEFUELING CANISTERS
CLEANUP PROGRAM REQUIREMENTS vs. PROCUREMENTS

Type of Canister	Canisters Used as of 6/1/89	Estimate of Additional Canisters Required(a)	Overall Cleanup Requirements	Canisters Procured
Fuel	246	24 to 28	270 to 274	285
Knockout	8(b)	0	8	66
Filter	47	28	75	76
Totals	301	52 to 56	353 to 357	427

Notes:

(a) for completion of the Cleanup Program
(b) three canisters were used with the debris vacuum system and five canisters were used for sand and DE from the temporary filtration system

As of May 1989, approximately 118 metric tonnes of rubble material (90% of the total rubble inventory) have been removed from the Reactor Vessel. The majority of this rubble (116.7 metric tonnes) was loaded into fuel canisters. A total of 246 fuel canisters were used to load this mass. Approximately 12 metric tonnes of fuel debris still require removal. It is estimated that the remaining defueling campaign will require 24 to 28 additional fuel canisters. Also, up to 28 filter canisters may be required for DWCS operations. This will bring the total canister requirements to between 353 and 357 canisters, which is within the 360 canister space allocation at the INEL water pit facility.

As of May 31, 1989, there appears to be a sufficient number of procured fuel and filter canisters to meet the remaining Cleanup Program requirements (37 fuel and 28 filter canisters remain available). When a new assessment of canister needs was completed in May 1986, it was realized that k/o canister requirements were significantly below earlier projections. However, 66 k/o canisters had already been delivered to the site. As of May 1989, only 8 k/o canisters have been used and no additional use of k/o canisters is contemplated.

Summary

It is projected that the TMI-2 Cleanup Program can be completed with a total of 355 canisters (272 fuel, 75 filter, and 8 k/o canisters). This is within the 360 canister space allocation at the INEL. There is a sufficient number and mix of available canisters on-site to meet the outstanding requirements. As of May 1989, the shipment campaign has included 18 rail shipments, with a total of 259 canisters. It is estimated that an additional five rail shipments of three casks (21 canisters) each will be required to complete the program.

The achievements of the shipment campaign, the challenges that have been presented, and the reasons for its success can be outlined as follows:

1. Very few reactors have ever had to undertake a fuel shipment program paralleled to the magnitude of the TMI-2 program.

2. The cleanup project faced a task of transporting an entire damaged reactor core from TMI-2 to the INEL.

3. The shipment campaign may one day become a blueprint for future shipments of spent fuel by other utilities.

4. The transport system essentially consists of three major subsystems: the casks, the cask support systems, and the shielded dry fuel transfer system. The program successfully worked out the interactions and operation of these subsystems.

5. To date, the shipment program has compiled an impressive record of safe, on-time, and essentially trouble-free performance.

6. Aspects credited with the success of the program are 1) careful planning of all steps and interfaces deemed necessary to the campaign, 2) a GPU Nuclear committment to an exhaustive hands-on training program of a selected team of employees that covered all aspects of the canisters and cask handling operations, 3) close involvement of management in all evolutions affecting the program and the resolution of problems, and 4) the maintenance of a continuous liaison with DOE and its agent EG&G, continuous monitoring of the required documentation, and technical, mechanical, and procedural readiness for each shipment.

REFERENCES:

Babcock & Wilcox Company, TMI-2 Defueling Canisters Final Design Technical Report, Document No. 77-1153937-04, Babcock & Wilcox Company, Lynchburg, VA (1985)

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