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FUEL REMOVAL, TRANSPORT, AND STORAGE[1]

Harley W. Reno
Idaho National Engineering Laboratory
EG&G Idaho, Inc.
Idaho Falls, ID 83415

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ABSTRACT

The March 1979 accident at Unit 2 of the Three Mile Island Nuclear Power Station (TMI-2) which damaged the core of the reactor resulted in numerous scientific and technical challenges. Some of those challenges involve removing the core debris from the reactor, packaging it into canisters, loading canisters into a rail cask, and transporting the debris to the Idaho National Engineering Laboratory (INEL) for storage, examination, and preparation for final disposal. This paper highlights how some challenges were resolved, including lessons learned and benefits derived therefrom. Key to some success at TMI was designing, testing, fabricating, and licensing two rail casks, which each provide double containment of the damaged fuel.

INTRODUCTION

Since March 1979, TMI-2 has presented the engineering and scientific communities with numerous challenges, some of which have been resolved, others of which are being resolved, and still others of which have yet to be resolved. Some challenges that have been resolved include storage and disposal of highly contaminated liquids,(1,2) disposal of dewatered but heavily loaded filter systems,(3,4) development of equipment for accessing the damaged core,(5) and remote examination and sampling of that core.(6) Challenges presently being resolved include removing and packaging the core debris,(7) transporting the debris from TMI to INEL,(8) and receipt and storage of that material at INEL.(9) Challenges yet to be resolved include cleanup of primary cooling system and peripheral in-containment areas, storage and ultimate disposition of abnormal wastes, and repackaging or processing of stored core debris for eventual disposal at a federal repository.

This paper highlights some of the technical challenges addressed in preparing core debris for transportation from TMI to INEL and receipt and storage of that material at INEL. Challenges discussed include developing, testing, and licensing a new design rail cask; loading operations and interfacing of equipment and facilities at TMI; transportation strategy; and receipt and storage operations at INEL. It is interesting that resolution of technical issues, other than those associated with development and licensing of the NuPac 125-B Rail Cask, depended more on overcoming institutional concerns and conservative interpretation of regulations than applying expertise or developing new technology.

PROJECT COMPONENTS AND CASK

The operational sequence of getting core debris canisters from TMI into safe storage at INEL can be divided into three phases: loading at TMI, transportation between TMI and INEL, and receipt/storage at INEL. Each phase necessitated resolving many technical issues before beginning operations. Key to the success of the entire project was designing, developing, fabricating, and licensing the NuPac 125-B Rail Cask (manufactured by Nuclear Packaging, Inc.), which is described briefly herein and detailed in a companion paper.

The NuPac 125-B Rail Cask (Fig. 1) was developed after GPU Nuclear Corporation (operator of TMI) decided to load core debris dry at TMI and was based on federal requirements to doubly contain plutonium during transport.(10) The cask is a stainless steel vessel within a stainless steel and lead composite vessel, each of which is closed with a leak-tight lid (Fig. 2). Each of the seven tubes of the inner vessel accommodates a single canister. Spaces between the tubes and structural components of the inner vessel are filled with special neutron absorbing material to control the possibility of a criticality. There are impact limiters (or energy absorbers) at the ends of each tube to cushion canisters in case of sudden de-accelerations, and large energy absorbing overpacks which ensconce each end of the cask to protect the contents in case of a transportation accident. The

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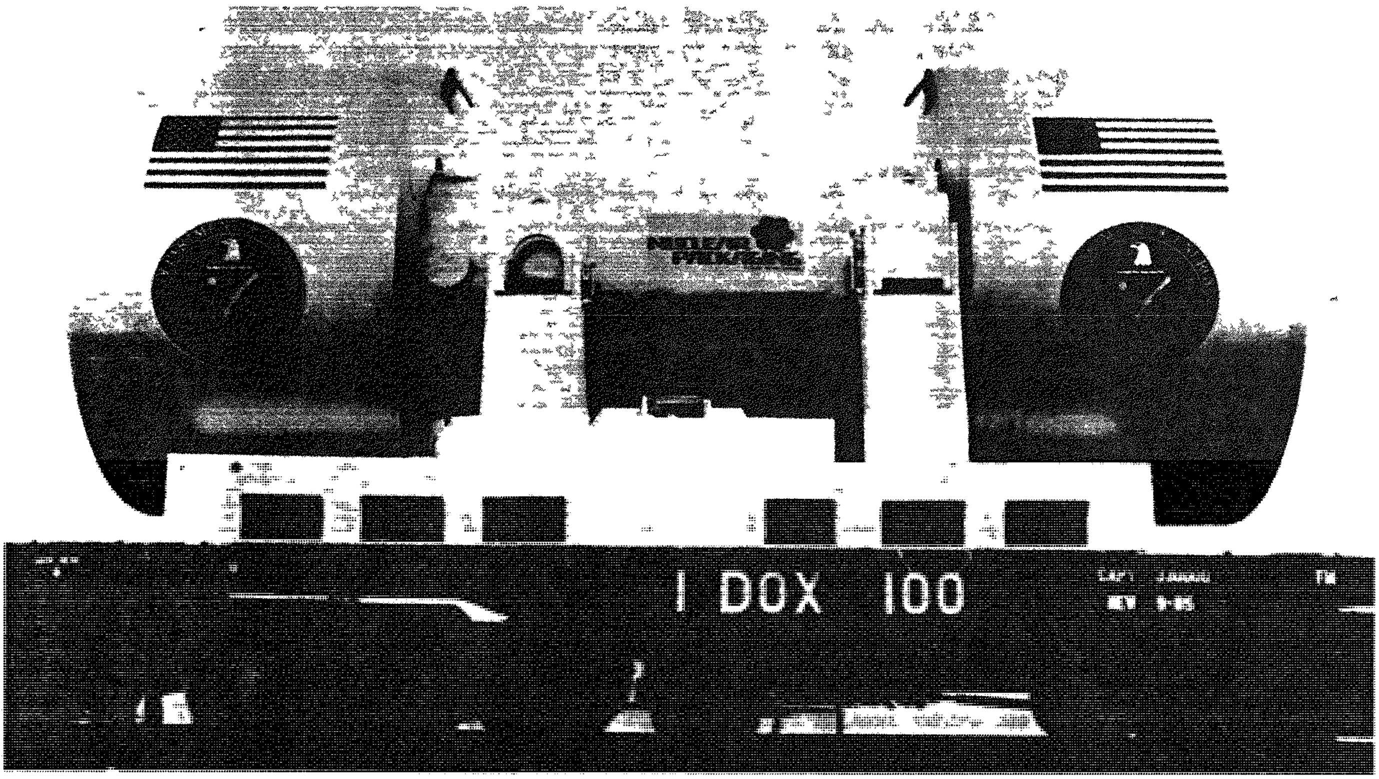

FIG. 1 PHOTOGRAPH OF THE NUPAC 125-B RAIL CASK ON ITS RAILCAR.

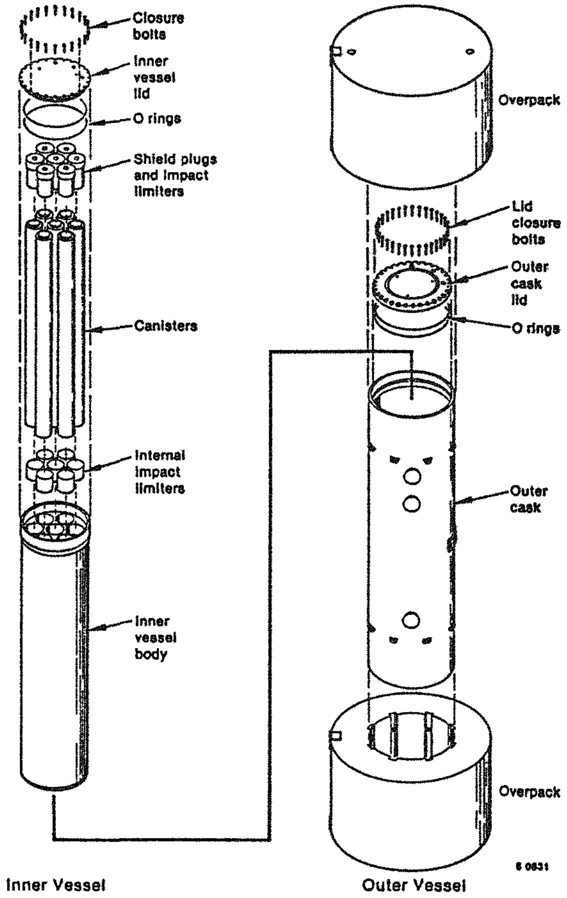

FIG. 2 SCHEMATIC OF THE NUPAC 125-B RAIL CASK.

cask, including overpacks, is 280 inches long by 120 inches in diameter. The total loaded weight of the cask (with overpacks, seven canisters, and transport skid) is about 200,000 lb.

Loading at TMI

Early in the project, GPU Nuclear opted for dry loading of canisters into the cask, because that would better suit its needs, require less modification of existing equipment and facilities, and be faster and more economical. That precipitated the decision to develop the NuPac 125-B Rail Cask. After deciding to build the cask, the last technical hurdle at TMI was to interface the cask with facilities. However, two stipulations included in the restart license for Unit 1 issued by the U.S. Nuclear Regulatory Commission (NRC) limited activities and use of space in the Truck Bay for operations related to Unit 2. Specifically, those stipulations were that (a) the cask and loading operations in the Truck Bay not infringe on space dedicated to operation of Unit 1 and (b) operations and equipment must not damage underlying support structures and electrical cabling for Unit 1. To meet those stipulations and also weight, space, and seismic constraints of the Truck Bay necessitated designing/constructing several pieces of equipment that simultaneously would permit passage of the rail cask and railcar, be removable in part, facilitate lifting the rail cask/transport skid assembly from the railcar, and satisfy safe-shutdown seismic criteria. Obviously, strength, versatility, simplicity, and portability were foremost in the minds of designers and engineers.

To describe loading operations, a schematic of the canister handling sequence within the TMI-2 Reactor Building is shown in Fig. 3. After a canister is loaded with core debris, it is sealed closed, withdrawn from the reactor vessel, and squeegeed as it is raised into the shielded transfer device. That device conveys the canister to the refueling canal, where it is transferred to the upender and shuttled through the fuel transfer tube from the Reactor Building to the "A" Pool of the Fuel Handling Building. There, the canister is placed in the storage rack. At the appropriate time, it is retrieved, dewatered using forced argon gas, and readied for retrieval by the fuel transfer cask.

Meanwhile, in preparation for loading, the overpacks are removed from the rail cask and the railcar with cask is pushed into the Truck Bay under both the tower and cask unloading station. The cask and transport skid are lifted from the railcar, the railcar is withdrawn from the Truck Bay, and the rail cask/transport skid assembly is lowered onto the floor. Next, the cask is rotated to vertical, a platform is bolted to the tower, the cask is opened, and the shielded loading collar is installed (Fig. 4). Then, the mini-hot cell withdraws a shield plug from a predetermined tube in the cask (Fig. 5). The fuel transfer cask retrieves a dewatered and weighed canister from the "A" Pool, transfers it into the cask (Fig. 6), and the shield plug is replaced. The transfer/loading process is repeated six more times until the cask contains seven canisters. After loading is complete, each lid of the rail cask is replaced and leak-tested (to 10^{-3} atm·cc/s; leak-tight defined as 10^{-7} atm·cc/s), ensuring that the cask is assembled correctly. The cask is returned to horizontal and lifted, using the cask unloading station. The railcar is retrieved from outside and the cask reattached thereto. The overpacks are placed on the rail cask, and the package is

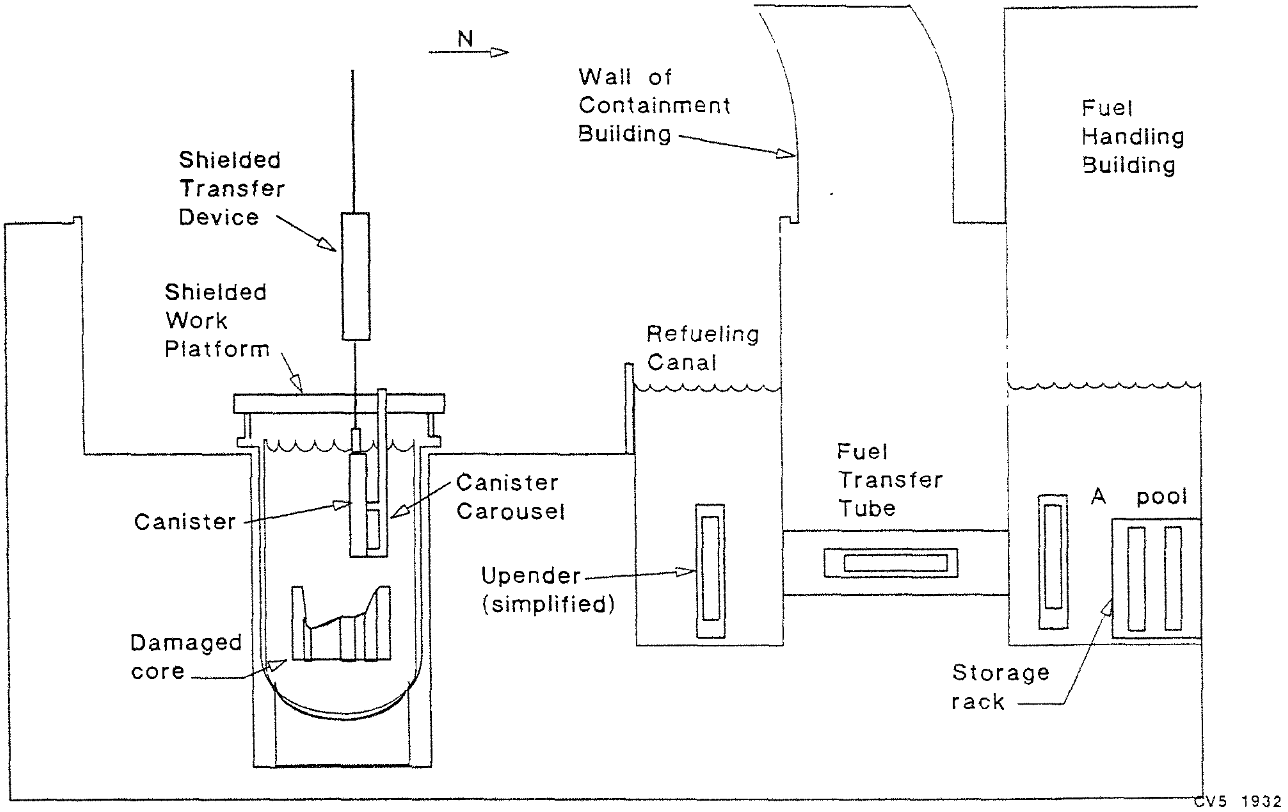

FIG. 3 SCHEMATIC SHOWING A LOADED CANISTER BEING TRANSFERRED FROM THE REACTOR VESSEL, THROUGH THE FUEL TRANSFER TUBE, TO THE STORAGE RACK IN THE "A" POOL OF THE FUEL HANDLING BUILDING

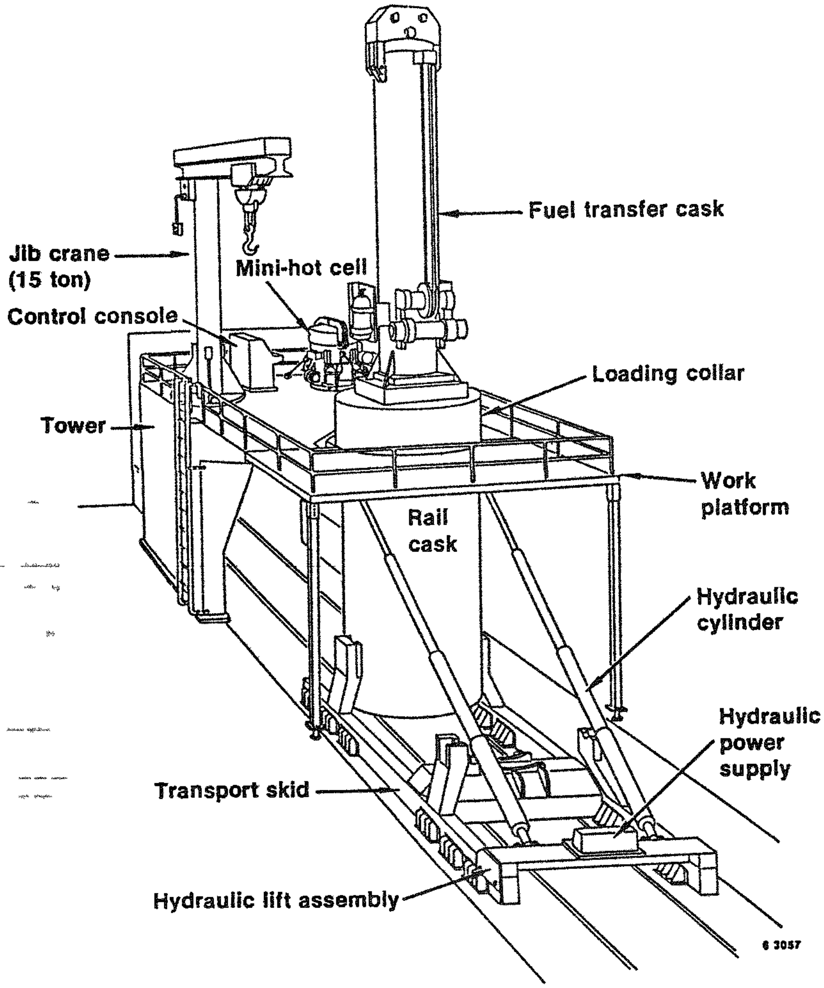

FIG. 4 SCHEMATIC OF THE NUPAC 125-B RAIL CASK BEING LOADED WITH A CORE DEBRIS CANISTER AT TMI-2, USING THE SHIELDED FUEL TRANSFER CASK.

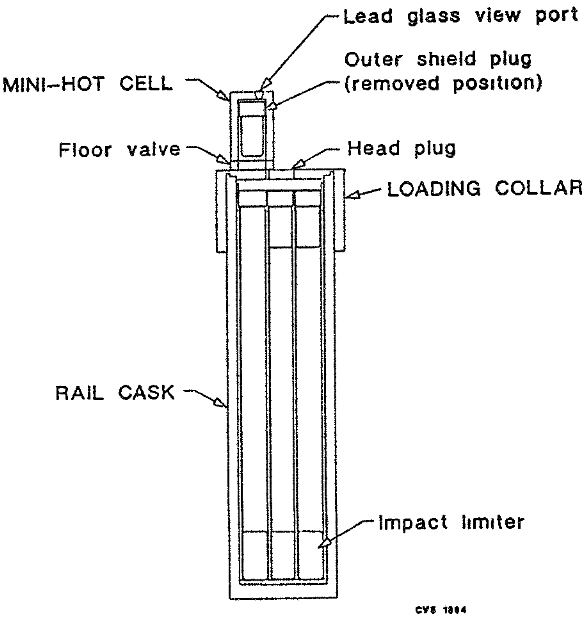

FIG. 5 SCHEMATIC OF WITHDRAWING A SHIELD PLUG FROM THE EMPTY RAIL CASK BEFORE LOADING A CANISTER.

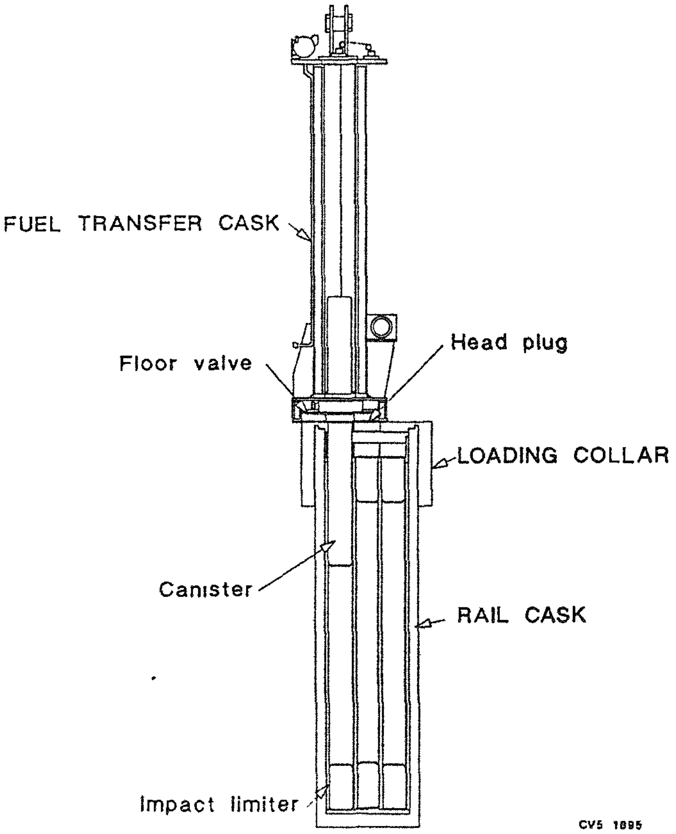

FIG. 6 SCHEMATIC SHOWING A CANISTER BEING LOADED INTO THE RAIL CASK USING THE FUEL TRANSFER CASK.

surveyed and certified for release to EG&G Idaho at the front gate of TMI.

Transportation

Transportation aspects of the project involved two separate but interrelated components. The first was designing and building a new cask--one that provided double containment of plutonium. The task of licensing that cask by NRC was shortened by building and testing models and full-sized components of the transportation package. The second was evaluating transportation strategies and optimizing numbers of casks and cyclic transcontinental trips needed to move all core debris from TMI to INEL.

Heretofore, licensing a new design cask generally took several years after preliminary design, as well as additional time for fabrication after licensing. However, the NuPac 125-B Rail Cask was designed, built, and licensed in less than 24 months (Certificate of Compliance issued by NRC on 11 April 1986). Such an accomplishment was made possible by (a) the combined efforts and professional dedication of several commercial entities, a government contractor, several national laboratories, and two federal agencies; (b) completion of drop tests of the cask and canisters in a minimum time period; and (c) the willingness of the subcontractor (Nuclear Packaging, Inc.) to dedicate its resources to designing, testing, and building the rail cask within the limits of an abbreviated schedule.

Drop testing involved building 1/4-scale models of the rail cask and canisters and subjecting them to a series of five tests at the Transportation Technology Center of Sandia National Laboratories (Fig. 7); then subjecting full-scale core debris canisters to a series of four tests by the Chemical Technology Division of Oak Ridge National Laboratory (Fig. 8). All tests satisfied concerns voiced by NRC regarding structural behavior of the cask and canisters during postulated accident scenarios.

After the decision was made to build the NuPac 125-B Rail Cask, the next activity was to evaluate different transportation strategies; that is, evaluate regular train service or exclusive-use trains and numbers of casks. Into that evaluation was factored the number of casks per shipment, dynamics of canister inventory at TMI, safety considerations, duration of the transport campaign, and costs and schedules at TMI and INEL. The strategy selected involved using two casks, regular train service, one cask per train, and approximately 20 round trips between TMI and INEL per cask.

Receipt/Storage

After the rail cask is received at Central Facilities Area (CFA) of INEL, the overpacks are removed and stored. The Gantry crane (mounted on rails and used years ago for manipulating gun barrels from large surface vessels) is used to transfer the cask from the railcar to the truck transporter (Fig. 9). After transfer to the transporter, the cask is hauled slowly to the Hot Shop of TAN-607 at INEL.

In the Hot Shop, after the cask has been rotated to vertical, tested for internal airborne contamination, and opened, all operations involving manipulation of canisters are conducted remotely.

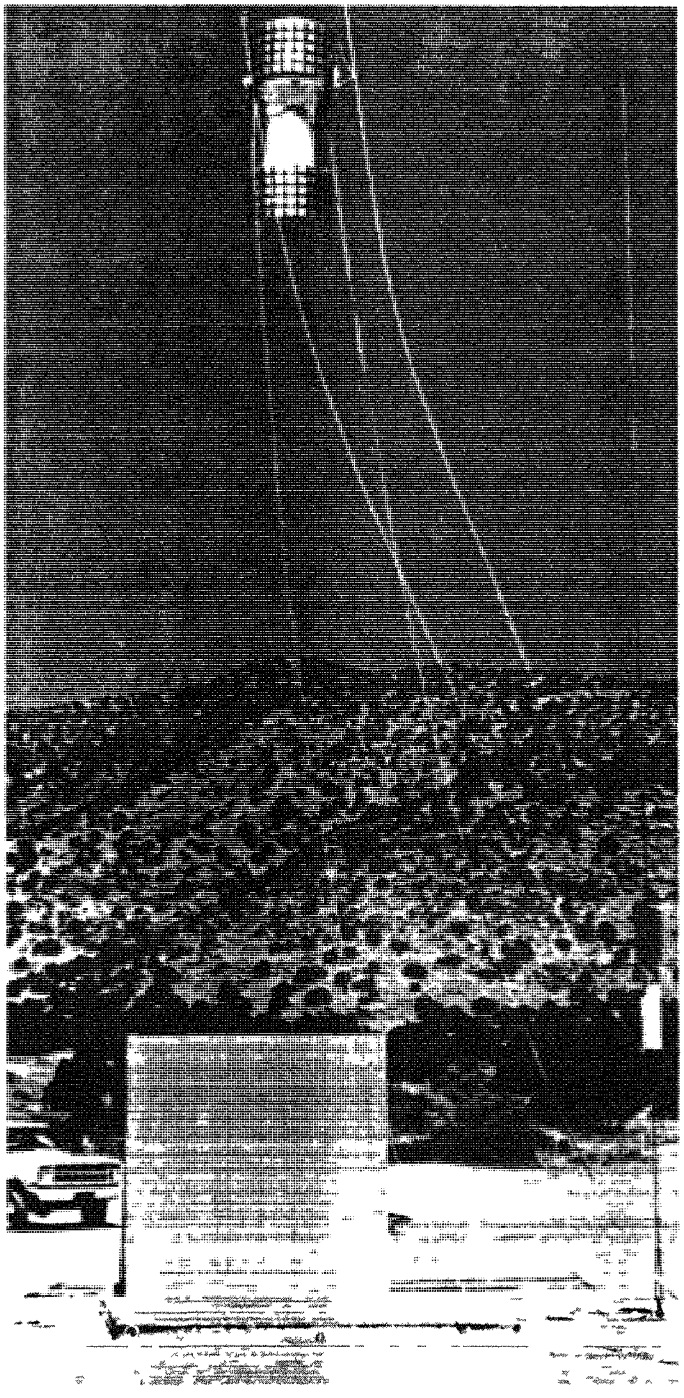

FIG. 7 PHOTOGRAPH OF THE 1/4-SCALE MODEL OF THE NUPAC 125-B RAIL CASK DURING A 30-FT, END-ON DROP TEST AT SANDIA NATIONAL LABORATORIES.

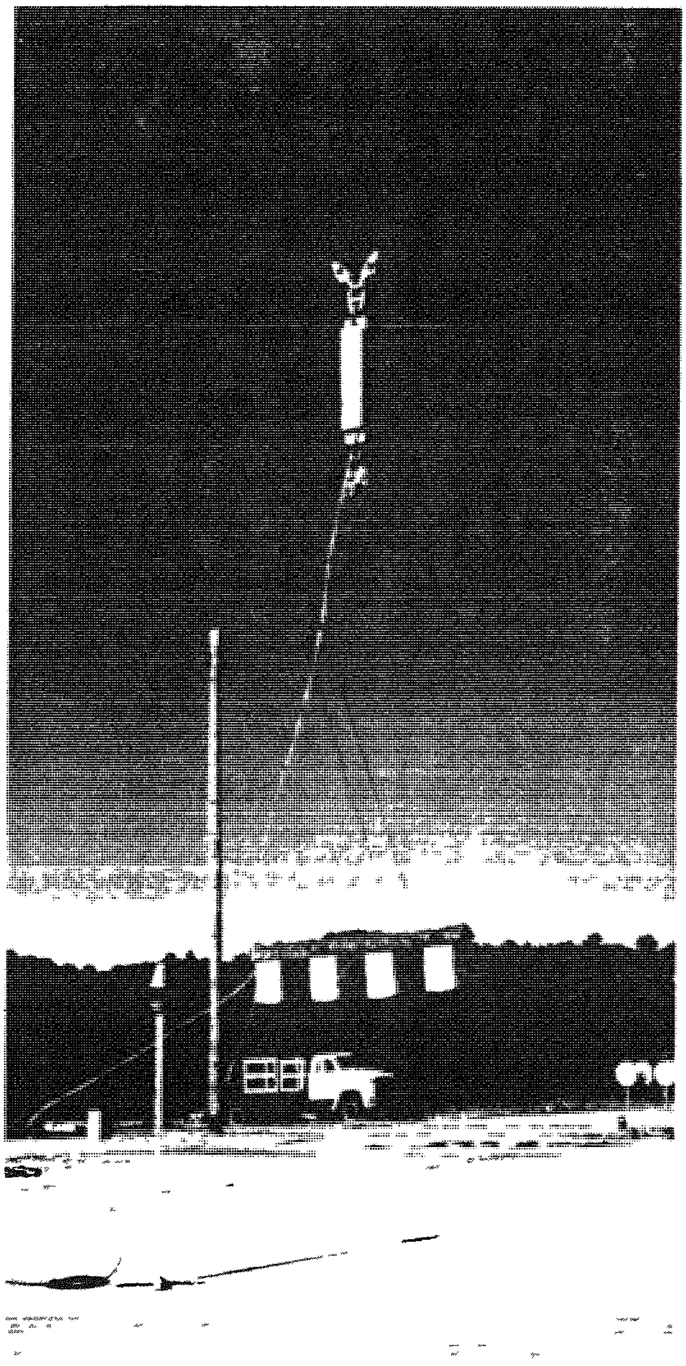

FIG. 8 PHOTOGRAPH OF THE HORIZONTAL CANISTER DROP TEST AT OAK RIDGE NATIONAL LABORATORY.

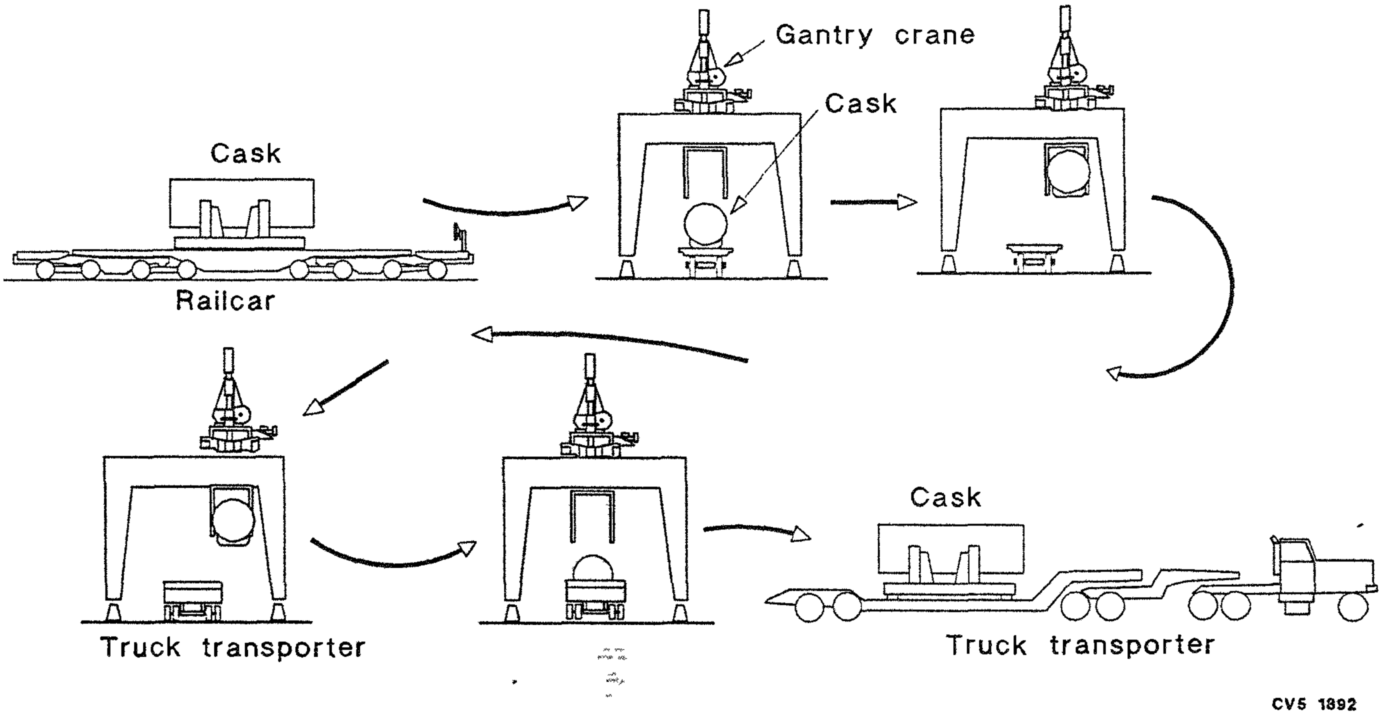

FIG. 9 SEQUENTIAL DIAGRAM OF TRANSFERRING THE NUPAC 125-B RAIL CASK (WITHOUT OVERPACKS) FROM THE RAILCAR TO THE TRUCK TRANSPORTER AT INEL, USING THE GANTRY CRANE AT CENTRAL FACILITIES AREA.

Each canister is withdrawn from the cask, conveyed to the Vestibule of the Water Pit, and lowered into a storage module situated atop the underwater pool cart (Fig. 10). Each module (Fig. 11) holds a maximum of six canisters. When a module is full, each canister is vented and filled with demineralized water. Then, the module is conveyed to the Water Pit, where modules simply are placed together in rows, forming a continuum termed the storage rack (Fig. 12). Computer analysis of a module has shown it to be seismically stable and criticality safe in all accident orientations. Once each module is in place, a vent line is connected to each canister.

Storage of TMI core debris at INEL is planned for as long as 30 years. That means all storage equipment, including the canisters, must endure the environment of the Water Pit for 30 years minimum, and stored canisters must be criticality safe under routine situations during that period. About the only maintenance anticipated on hardware will be replacement of seals in the connectors and fittings in the heads of canisters.

LESSONS LEARNED

Many important lessons were learned while resolving challenges at TMI and INEL; moreover, others are being learned daily as defueling of the TMI-2 reactor progresses. Some lessons have widespread value and utility for the industry at large and regulatory agencies. For example, early in the TMI-2 program, it was realized that interfacing equipment with facilities at TMI would be complicated; therefore, intensive and continuous planning, combined with close cooperation between competing organizations at TMI, eventually produced hardware, software, and facility modifications which smoothly meshed together. Whereas technical accomplishments at TMI probably are not directly applicable elsewhere because no two nuclear power stations are exactly alike, they do demonstrate that early recognition of complexities followed by detailed planning can resolve perplexing questions. Moreover, resolving complexities like those at TMI is dependent in large on establishing and maintaining close interfaces with federal and state agencies (particularly regulatory organizations), the utility and its myriad of subcontractors, and outside interests.

In dealing with the regulator, it was prudent to respond in ways which did not challenge regulations. Wherever possible, the TMI-2 Program involved the regulator in interpretation of guidelines and demonstrated how conservative assumptions met regulatory requirements. And when it was realized that a testing program for certain hardware would shorten review processes, developing such a program and quickly seeing it through to completion in support of the license application was effective management. The TMI-2 Program, following advice of the regulator, made only one application in licensing the NuPac 125-B Rail Cask. That single submittal avoided the pitfall of altering courses of action which sometimes accompanies multiple submittals.

Other lessons learned included (a) whenever possible, assumptions were validated [time and dollars spent examining the core of Unit 2, for example, paid off many times, not only in determining how best to remove the damaged fuel, but how to handle, transport, and store it]; (b) technical assessment and evaluations by independent groups proved useful, both in reviewing and gaining consensus and support from participants, technical and political communities, and review/regulatory organizations; (c) most issues related to TMI-2 were more institutionally complex than technically complex; and (d) comment and advice

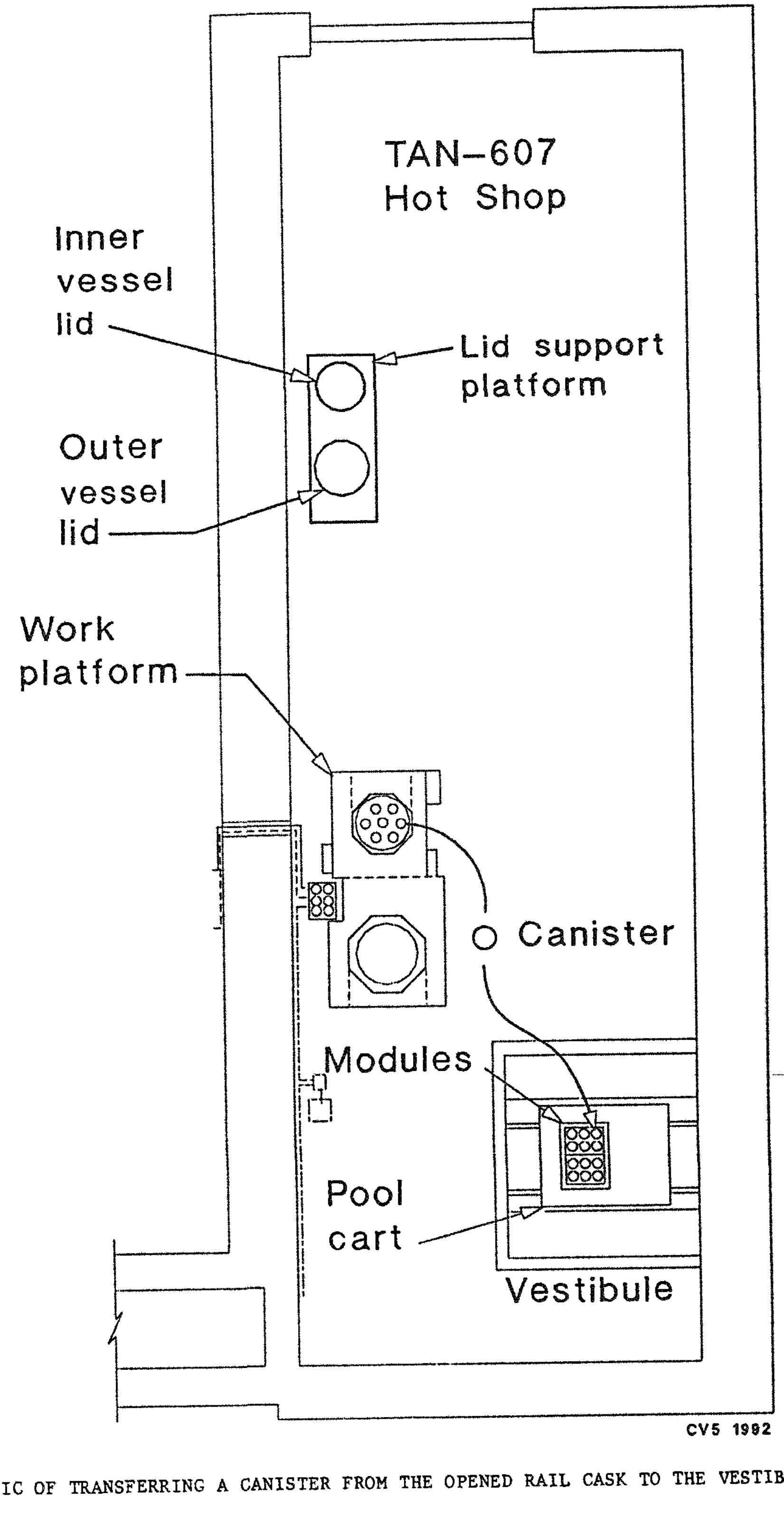

FIG. 10 SCHEMATIC OF TRANSFERRING A CANISTER FROM THE OPENED RAIL CASK TO THE VESTIBULE IN TAN-607 OF INEL.

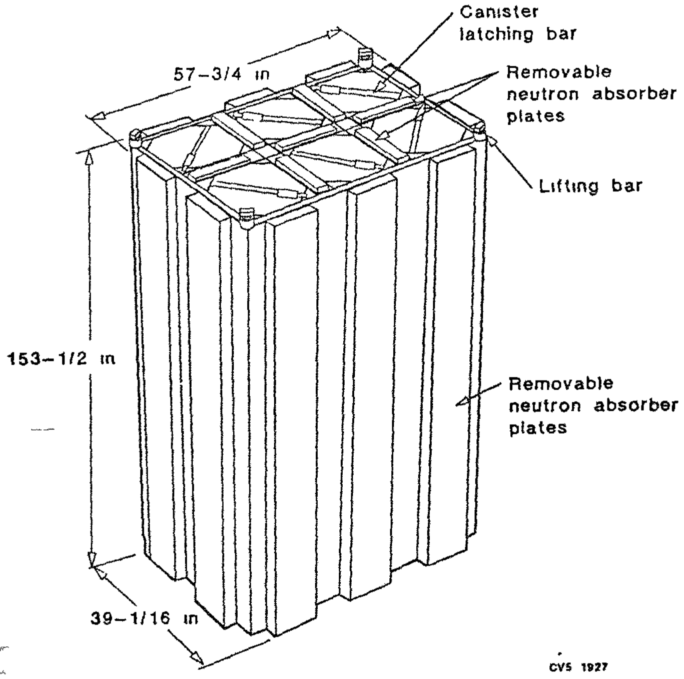

FIG. 11 SCHEMATIC OF A STORAGE MODULE, SHOWING THE SPACES FOR SIX TMI CORE DEBRIS CANISTERS AND THE REMOVABLE NEUTRON ABSORBERS.

was received from elected officials from all levels of government [each comment and piece of advice was responded to promptly and responsibly by appropriate members of the Program].

BENEFITS

Many benefits have been and are being derived from TMI. Feasibility and economic evaluations will have been made of dry loading of nuclear fuel in the transport cycle from reactor to storage facility and/or terminal repository. New types of hardware (canisters, fuel transfer cask, and related equipment) are available for manipulating containers filled with damaged fuel. The nuclear industry and government now have a rail cask which provides double containment of damaged fuel; and acquisition of the NuPac 125-B Rail Cask shows that cask procurement and licensing periods can be shortened. Incidentally, acquisition of that cask is the road map through the maze of institutional issues--not technical ones. The significance is not in designing/building a new cask, but in addressing institutional issues, such as management of radioactive wastes, legal and regulatory systems, acceptance by the public, and dry loading of nuclear fuel, to name a few. And finally, the scientific community will have a resource (core debris, samples, core bores) available at INEL for future examination and research. Because of those benefits, TMI can be recognized as an experiment whose usefulness lies in benchmarking safety codes predicting reactor behavior during transients, and which indirectly will reduce the risks of a reoccurrence.

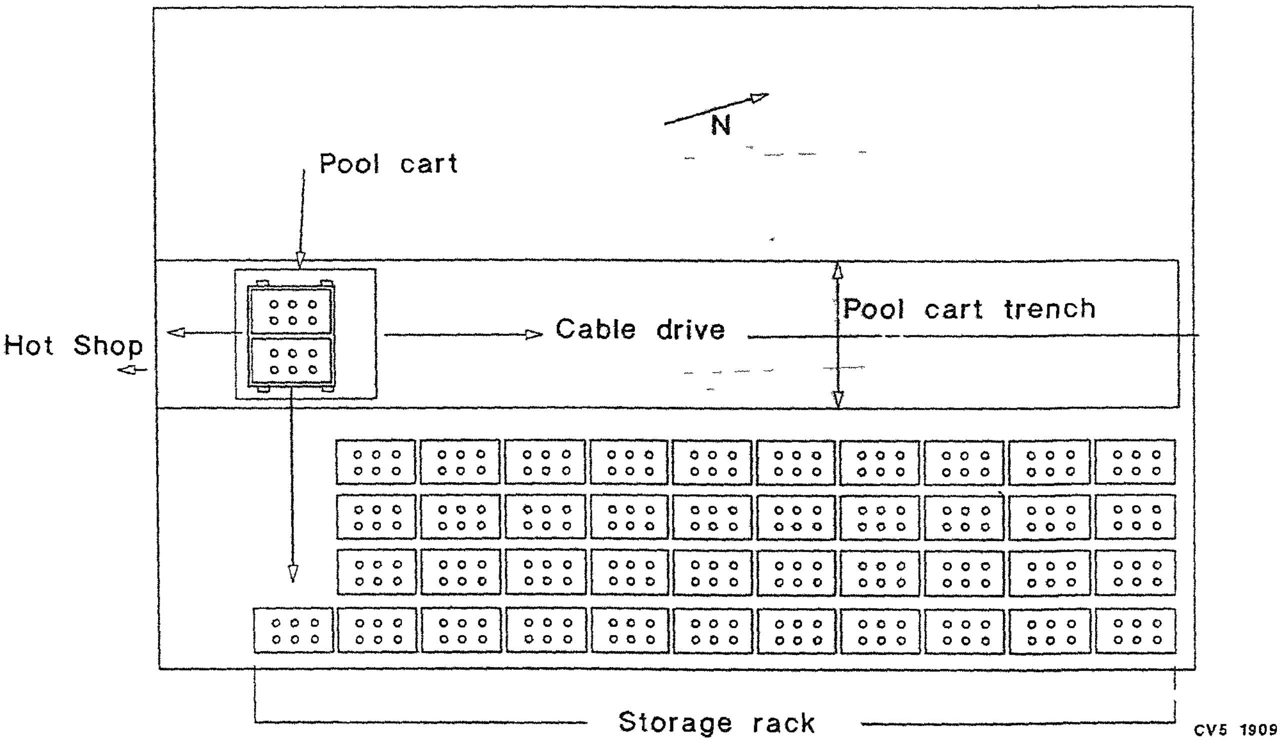

FIG. 12 SCHEMATIC OF TRANSFERRING MODULES WITH CANISTERS FROM THE VESTIBULE TO THE WATER PIT OF TAN-607.

CONCLUSIONS

In conclusion, technical challenges discussed in this paper were met within the present regulatory framework and guidelines because the federal entities, government contractors, and myriad of private industries involved had the resolve to openly discuss issues confronting all participants. Open dialogue was initiated early in the project, when it was realized that interfacing equipment with facilities at TMI would be complicated. Dialogue has continued throughout the project and will continue until all core debris is loaded safely into canisters, transported to Idaho, and stored at INEL.

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