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HISTORICAL SUMMARY OF THE FUEL AND WASTE HANDLING AND DISPOSITION ACTIVITIES OF THE TMI-2 INFORMATION AND EXAMINATION PROGRAM (1980-1988)

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ABSTRACT

This report is a historical summary of the major activities conducted by the TMI-2 Information and Examination Program in managing fuel and special radioactive wastes resulting from the accident at the Unit 2 reactor of the Three Mile Island Nuclear Power Station (TMI-2). The activities often required the development and use of advanced handling, processing, and/or disposal technologies for those wastes. The TMI-2 Program was managed by EG&G Idaho, Inc. for the U.S. Department of Energy.

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INTRODUCTION

The Unit 2 pressurized water reactor at the Three Mile Island Nuclear Power Station (TMI-2) underwent an unprecedented loss-of-coolant accident on March 28, 1979, resulting in severe damage to the core.[1] Following the accident, the U.S. Department of Energy recognized that advanced technologies would be needed for handling, processing, and disposing of some radioactive wastes produced during defueling of the reactor and cleaning of the facility. Consequently, the Department committed funds for research and development in managing those wastes, as part of the TMI-2 Information and Examination Program (hereinafter called the "TMI-2 Program" or "Program").[2]

In January 1980, the Technical Integration Office was established at Three Mile Island near Harrisburg (PA) for managing the TMI-2 Program. The Office was funded by the Department of Energy and staffed primarily by employees of EG&G Idaho, Inc. on temporary assignment from the Idaho National Engineering Laboratory (INEL). Other organizational entities were formed as the Program developed and as the focus of programmatic activities shifted from TMI to INEL and other national laboratories.[3] For purposes of this report, those and other programmatic entities henceforth will be identified as part of the Program.[a]

This report is a historical summary of major activities conducted by the Program for the Department of Energy as part of the TMI-2 waste management effort. No attempt is made to document the multitude of smaller studies, tasks, and activities that were attendant to a program of such large size and long duration. Although objectives of the Program changed during the timeframe from 1980 to 1988, they still supported the mission of the Department, namely, to provide technical expertise in management of fuel and special radioactive wastes from TMI-2. While fulfilling the mission, invaluable experience and knowledge was gained in development and use of advanced handling, processing, and disposal technologies for special radioactive wastes.

a The scope of this report does not include activities of the Accident Evaluation Program, another major element of the TMI-2 Program managed by EG&G/Idaho.

PERSPECTIVE

To understand the history of the fuel and waste handling and disposition activities of the TMI-2 Program, one has to be aware of the major events and accomplishments that contributed to completion of those activities and fulfillment of programmatic goals. Major events and activities are summarized in Table 1; however, the tabulated summary is not meant to be all-inclusive.

Table 1. Major events and accomplishments in managing the TMI-2 fuel and special radioactive wastes

Date	Events and Accomplishments
Mar 79	TMI-2 accident
Oct 79	EPICOR-II filtration of accident-related water begun by GPU Nuclear[a,b]
Jan 80	TMI-2 Program and Technical Integration Office formed at TMI
Aug 80	Draft Programmatic Environmental Impact Statement on TMI-2 issued by the U.S. Nuclear Regulatory Commission[4]
1980	Procurement of CNS 1-13C-II cask for transporting Submerged Demineralizer System vessels to Hanford commenced
Aug 80	EPICOR-II filtration completed by GPU Nuclear
Mar 81	Final Programmatic Environmental Impact Statement on TMI-2 published by the Nuclear Regulatory Commission
May 81	EPICOR-II prefilter PF-16 transported to Battelle Columbus Laboratories for characterization
Jun 81	Certificate of Compliance for CNS 1-13C-II cask issued by the Nuclear Regulatory Commission
Jul 81	Submerged Demineralizer System processing of accident-related water begun by GPU Nuclear
Jul 81	Memorandum of Understanding signed by the Nuclear Regulatory Commission and Department of Energy
Mar 82	Memorandum of Understanding amended
Apr 82	Transportation of EPICOR-II prefilters from TMI-2 to INEL commenced
May 82	Transportation of Submerged Demineralizer System vessels from TMI-2 to Hanford commenced
Jul 82	"Quick look" video inspection of TMI-2 core performed
Aug 82	EPICOR-II prefilter PF-3 transported to Battelle Columbus Laboratories for characterization
1983	Procurement of CNS-14-190 cask for transporting EPICOR-II prefilters to US Ecology, Inc. commenced
Jul 83	Transportation of EPICOR-II prefilters to INEL completed
Sep/Oct83	"Grab samples" obtained from TMI-2 core
Sep 83	Sonar inspection of core cavity performed using Core Topography System
Jan 84	Certificate of Compliance for CNS-14-190 cask issued by the Nuclear Regulatory Commission

a In January 1982, General Public Utilities Nuclear Corporation (GPU Nuclear) became owner/operator of TMI. In this report, all references to GPU Nuclear imply previous owner/operators, where applicable.

b Mention of specific products and/or manufacturers in this document implies neither endorsement or preference nor disapproval by the U.S. Government, any of its agencies, or EG&G Idaho, of the use of a specific product for any purpose.

Table 1. (continued)

Date	Events and Accomplishments
Mar 84	TMI-2 Core Contract signed by the Department of Energy and GPU Nuclear
Mar 84	Certification of Compliance for the high integrity container issued by the State of Washington
Apr 84	EPICOR-II prefilter/high integrity container disposal demonstration completed
May 84	Disposal of EPICOR-II prefilters begun at US Ecology
Sep 84	Elution of cesium from Makeup and Purification System demineralizers begun by GPU Nuclear
Feb 85	Disposal of 46 EPICOR-II prefilters completed
Apr 85	19th Submerged Demineralizer System vessel transported to Hanford
Jul 85	TMI-2 Abnormal Waste Contract signed by the Department of Energy and GPU Nuclear
Oct 85	Defueling of TMI-2 reactor begun by GPU Nuclear
Dec 85	Fabrication of first NuPac 125-B Rail Cask completed by Nuclear Packaging, Inc.
Jan 86	Fabrication of second NuPac 125-B Rail Cask completed by Nuclear Packaging
Mar 86	Integrated system test of NuPac 125-B Rail Cask completed at Hanford Engineering Development Laboratory
Apr 86	Certificate of Compliance for NuPac 125-B Rail Casks issued by the Nuclear Regulatory Commission
Jun 86	Core Acceptance Criteria defined in Plan for Acceptance, Handling, Shipping, and Storage of TMI-2 Fuel Debris Canisters (Rev. 0) approved by the Department of Energy
Jul 86	Rev. 1 to Certificate of Compliance for NuPac 125-B Rail Casks approved by the Nuclear Regulatory Commission
Jul 86	Transportation of core debris from TMI-2 to INEL commenced
Mar 87	TMI-2 Abnormal Waste Contract modified
May 87	First shipment of TMI-2 abnormal waste received at INEL
Sep 87	Workshop on Spent Fuel Transportation Issues conducted at TMI
Oct 87	Fabrication of third NuPac 125-B Rail Cask completed (GPU Nuclear leased from Nuclear Packaging)
Oct 87	Second Shipment of TMI-2 abnormal waste received at INEL
Aug 88	Video entitled "The TMI Story: A Documentary" completed
1988	Certificate of Compliance for CNS 1-13C-II cask reissued

HISTORICAL SUMMARY

This section is a historical summary of activities conducted by the Program from 1980 to 1988 in managing the TMI-2 fuel and special radioactive wastes for the Department of Energy. Included are miscellaneous technical support; work conducted under the EPICOR-II and Zeolite Disposition Programs; and activities involving acceptance of the TMI-2 core; transportation, receipt, and storage of core debris; and management of abnormal wastes from TMI-2.

Technical Support

Beginning in early 1980, technical support was provided in several areas of the emerging TMI-2 waste management effort. That support was diverse and included (a) planning an archive to store research samples and components from TMI-2, (b) inventorying and disposing of those samples stored at INEL, (c) investigating development of a mobile evaporator, (d) conducting a feasibility study for constructing a fuel recovery facility at INEL, (e) performing research in removing actinides (transuranic elements) from TMI-2 abnormal wastes, (f) studying alternatives for processing the TMI-2 core debris, and (g) investigating disposal options for the core debris. Those topics are discussed below.

In 1980, the Program began plans for developing an archive to store research samples and components obtained from TMI-2 (e.g., sludge and concrete samples, electrical equipment, cables, instrumentation, etc.).[5-7] As research samples arrived at INEL, they were stored at several locations (e.g., Auxiliary Reactor Area, Test Reactor Area, and Test Area North). The objective of the archive project was to retain the samples for various lengths of time, depending on their analytical value. However, the project was delayed, then cancelled in 1983, for several reasons (e.g., changes in both priorities for cleanup activities at TMI-2 and budgetary requirements, as well as the utility of retaining samples for long-term).

In late 1984, activities commenced for inventorying and disposing of unneeded TMI-2 research samples stored at INEL, and, in 1985, investigations began for disposing of those materials at the Radioactive Waste Management Complex of INEL. By late 1987, more than half of the unneeded samples stored at INEL had been disposed. The remaining materials retained for long-term research will be disposed by the end of the Program in late 1989.

In 1981, the Program investigated developing a mobile evaporator to reduce the volume of water spilled during an accident or produced in decontaminating facilities such as TMI-2. The evaporator could (a) process liquid radioactive wastes unsuitable for cleanup via ion exchange methods, (b) serve as a backup for ion exchange processing, and/or (c) be used during emergencies. A workscope, cost, and schedule was completed, followed by conceptual design in 1982. Because of public concern about disposal of water stored at TMI-2, the evaporator concept was not pursued. GPU Nuclear, however, is continuing the effort regarding disposition of the water, with evaporation being a prime option.

In 1982, a feasibility study was conducted for constructing a facility at INEL to (a) recover fuel from TMI-2 core debris and (b) process/package the wastes for storage and/or disposal. The Program investigated designing, building, testing, and operating such a facility in Building 607 of Test Area North (TAN-607).[8] Although the fuel recovery facility and other such concepts were not implemented, the studies will contribute to eventual decisions on how to manage the TMI-2 core.

Certain TMI-2 wastes (e.g., filters and resins of the Makeup and Purification System, plant cartridge filters, organic ion exchange resins, sludges from various tanks and building sumps, filter assemblies from the Submerged Demineralizer System, and miscellaneous pieces of hardware) contained either high concentrations of radioactivity or other characteristics precluding direct commercial disposal. Categorically, those wastes were called "abnormal wastes." In 1981, the U.S. Nuclear Regulatory Commission and Department of Energy signed the Memorandum of Understanding specifying interagency procedures for removal and disposition of solid nuclear wastes from TMI-2.[9] That agreement was amended in 1982. Under terms of the Memorandum, the Department agreed to store some abnormal wastes from TMI-2 in casks at INEL, with ultimate disposition funded by GPU Nuclear. In FY-1986, EG&G Idaho funded the TMI Abnormal Waste Actinide Removal Project, under its Exploratory Research and Development Program.[10] [A small fraction of the overhead budget of EG&G Idaho is spent on development of new technology.] The purpose of the Project was to investigate methods of extracting actinides from abnormal wastes to facilitate more cost-effective, commercial disposal. At the request of EG&G Idaho, GPU Nuclear obtained samples of resin from the B demineralizer of the Makeup and Purification System. During the first half of FY-1987, efforts focused on determining conditions for extracting actinides from the samples. Results indicated that most actinides could be leached from the resins using a mixture of nitric and hydrochloric acids.

In FY-1987, the Program completed a study of disposal options for the TMI-2 core. Over 50 alternatives were identified for processing the core debris, and, from that list, eight were selected for further study.[11] In October 1987, EG&G Idaho provided Exploratory Research and Development Program funding for the TMI Core Debris Disposal Scoping Studies Project, an extension of the TMI-2 Program.[12] Scoping studies were performed to further investigate technologies for processing core debris into forms acceptable to the National High-Level Waste Repository. Tasks included (a) reviewing literature/applications for immobilizing high-level radioactive wastes in borosilicate glass; (b) investigating methods of drying core debris in canisters; (c) reviewing/selecting methods of fragmenting the debris; and (d) performing a feasibility study for melting core debris, mixing it with borosilicate glass, and preparing waste forms. Additional work is projected in preparing for ultimate disposition of the core debris in order to accomplish earliest achievable disposition.

EPICOR-II Program

Beginning in October 1979, the three-stage EPICOR-II demineralizer system was used to filter and remove radionuclides from approximately 2100 m^3 of accident-generated water in the basement of the Auxiliary and Fuel Handling Buildings of TMI-2. That process was completed in August 1980, resulting in 72 contaminated filters. In 1981, the 22 second-stage filters were disposed commercially as low-level radioactive waste. The 50 high-specific-activity prefilters from the first stage were stored at TMI awaiting disposition. Each EPICOR-II prefilter (Figure 1) comprised a cylindrical steel liner containing approximately 0.85 m^3 of ion exchange media (either organic resins, or organic resins with an ensconcing layer of inorganic zeolite). The ion exchange media in the prefilters were loaded with quantities of radioisotopes that precluded commercial disposal.

In late 1980, safety and environmental documents were prepared for transporting one EPICOR-II prefilter to a laboratory for characterization to determine the condition of its ion exchange media and steel liner.[13,14] Battelle Columbus Laboratories of Columbus (OH) was contracted to perform that work, and Prefilter-16 (PF-16) was selected for characterization. PF-16 contained both organic resins and inorganic zeolite, and was considered one of the prefilters most susceptible to deterioration.

Before transporting PF-16, several safety concerns were resolved, one of those being generation of combustible gases (hydrogen and oxygen) from radiolysis of water in the prefilter.[a] A safety analysis was performed to substantiate that venting the liner at TMI and transporting it to Battelle within 15 days of replugging would ensure compliance with regulations. Therefore, in May 1981, PF-16 was vented, replugged, loaded into the CNS 8-120 cask manufactured by Chem Nuclear Systems, Inc. and transported to Battelle. Characterization of PF-16 (plus later examination of PF-3 by the same laboratory) revealed that the prefilter had experienced minimal deterioration.[15,16] Results of the examinations provided information needed in developing methods for safely handling, transporting, processing, and disposing of the 50 EPICOR-II prefilters.

In mid-1981, a task was initiated to develop a sampling/purging device to prepare EPICOR-II prefilters for transport from TMI. Subsequently, the prototype gas sampler was designed to remotely remove/reinstall vent plugs and sample, vent, and purge the liners, thus removing potentially combustible gases.[17,18] It was delivered to TMI in early

a 49 CFR 173.21 prohibits transporting radioactive materials containing a combustible mixture of gases.

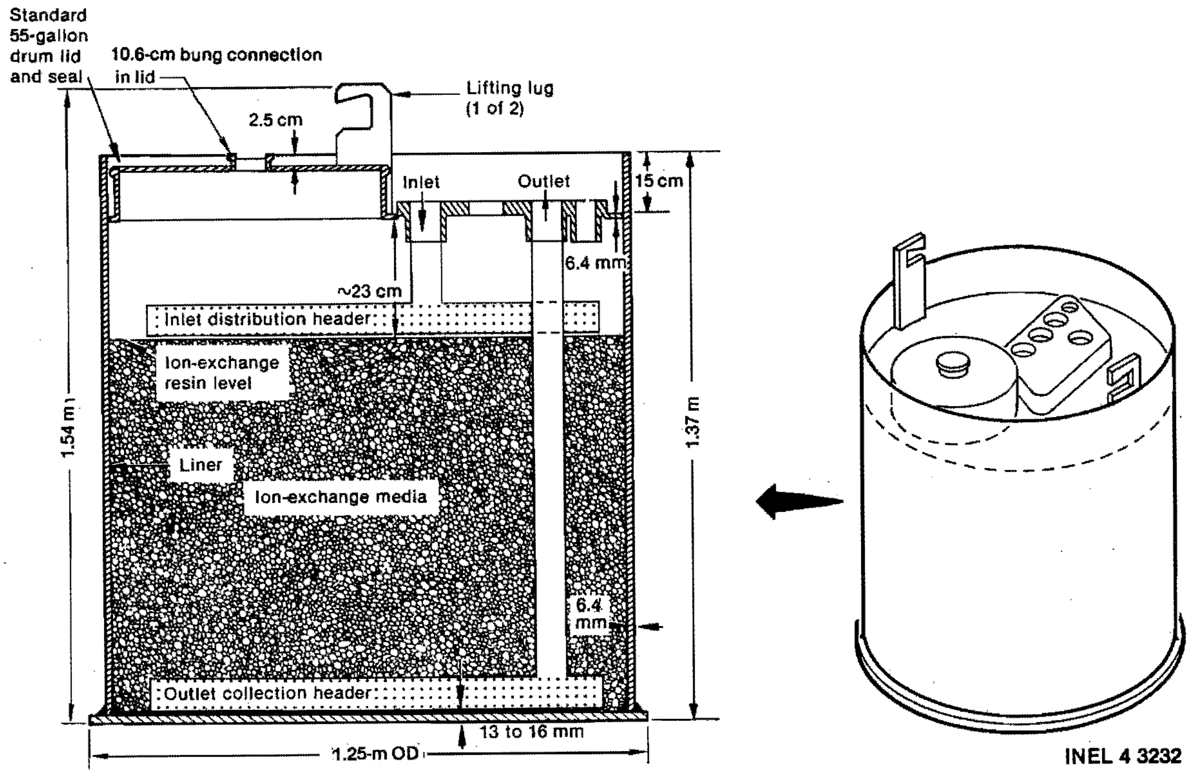

Figure 1. Schematic (full section and isometric) of an EPICOR-II prefilter.

1982, for testing/training operations. GPU Nuclear built a portable, concrete "blockhouse" to enclose the device and shield operators during opening and venting of liners. An operations trailer housed the control panel, related equipment, and operating personnel. Integrated functional testing of the prototype gas sampler, blockhouse, and operations trailer was completed in mid-1982.

In late 1981, a plan was developed for transporting, storing, examining, and disposing of the 50 EPICOR-II prefilters.[19] The plan reflected agreements outlined in the Memorandum of Understanding (Reference 9) regarding acceptance of accident-generated wastes by the Department of Energy for research. In early 1982, environmental and safety documents were prepared for transporting the prefilters to INEL.[20-23] An environmental assessment already existed (Reference 14). Radioactive materials, like the EPICOR-II prefilters, are brought to INEL for research used in answering questions important to the government and nuclear industry. Necessary safety, environmental, and operational documentation was prepared for receipt and storage of the prefilters at INEL.[24-29] Numerous structural and mechanical changes were made to and in the Hot Shop of TAN-607 (Figure 2). The changes included designing and constructing (a) two shielded storage silos (Figure 3), (b) a gas detection/venting system for each silo, (c) 24 self-venting liner support stands, (d) a liner venting tool (Figure 4) similar to the prototype gas sampler, (e) lifting device, (f) porous vent plugs for the liners, and (g) three new temporary storage casks. Additional design work included a second lifting device and liner decontamination system. Some equipment was refurbished, namely, the overhead manipulator, overhead crane, three wall-mounted manipulators, two turntables, doors of the Special Equipment Service Room, three existing storage casks, and railroad flatcars and trackage.[30]

Beginning in April 1982, each prefilter was retrieved from storage; vented and purged using the prototype gas sampler; placed in the CNS 8-120 cask; and transported individually by truck to INEL.[31] The last prefilter was received at INEL in July 1983, completing the transportation campaign 2-1/2 months ahead of schedule.[32]

Meanwhile, since 1980, the TMI-2 Program had been investigating alternative means of disposing of the EPICOR-II prefilters. After considering

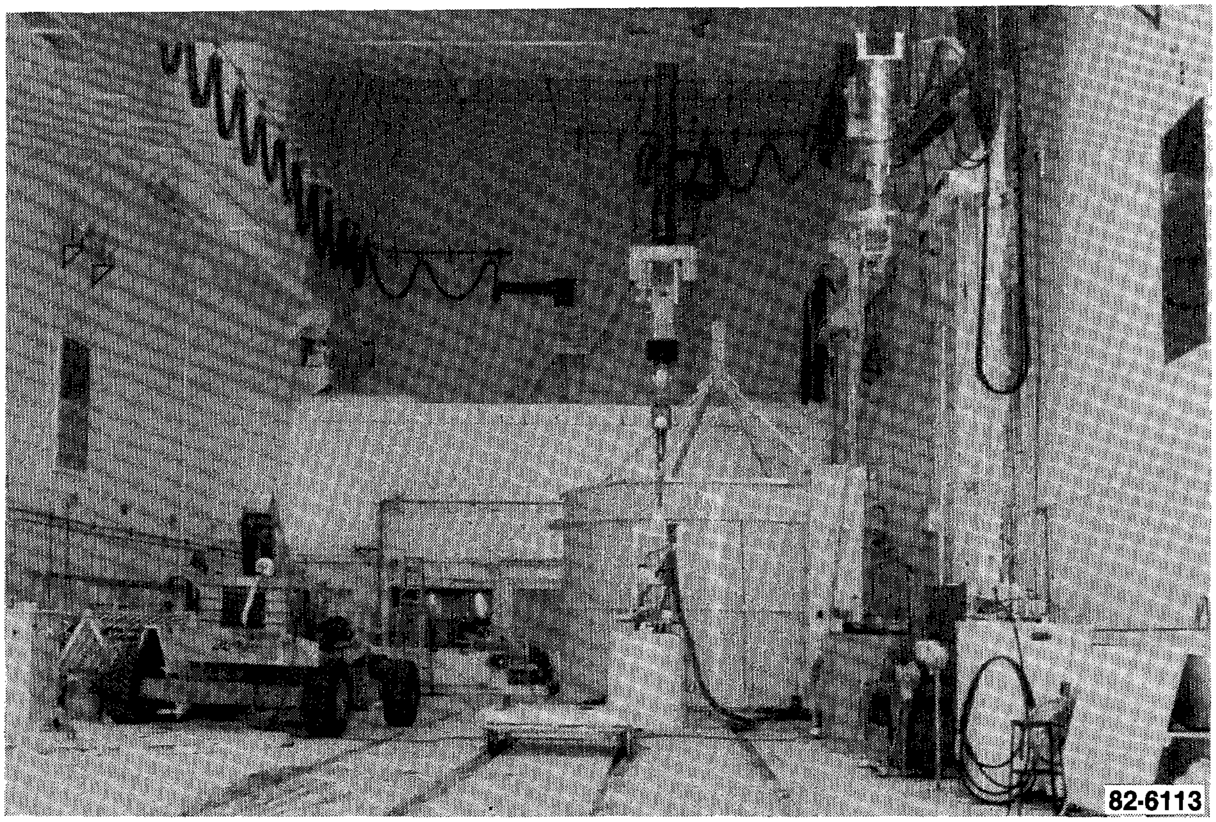

Figure 2. Photograph of the Hot Shop of TAN-607 showing some hardware used by the EPICOR-II Program.

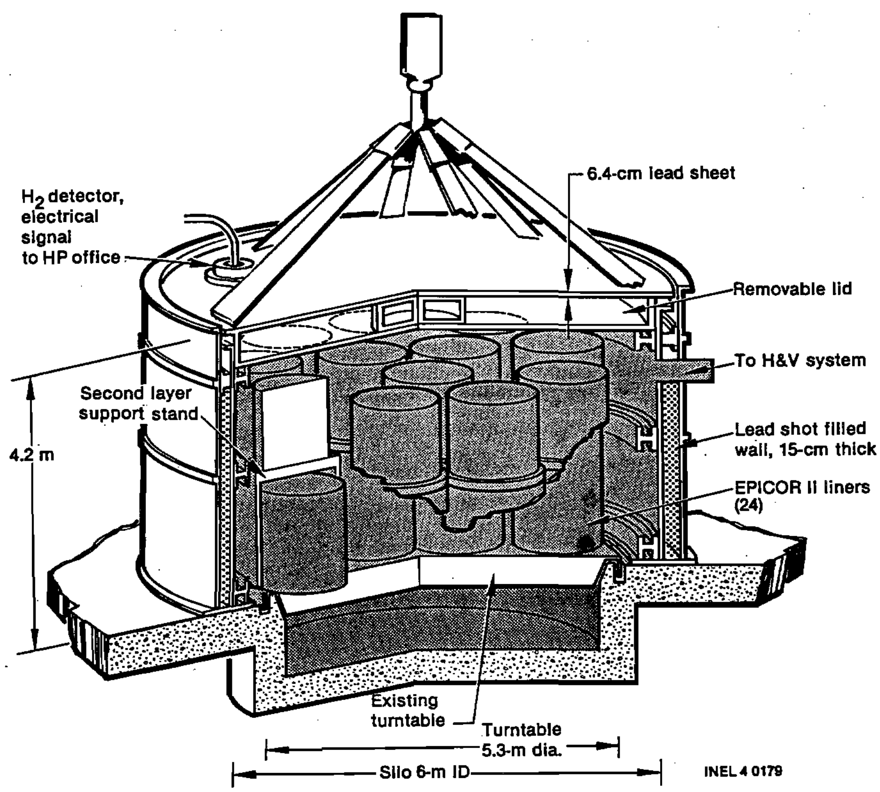

Figure 3. Schematic of a silo used for storing EPICOR-II prefilters in the Hot Shop of TAN-607.

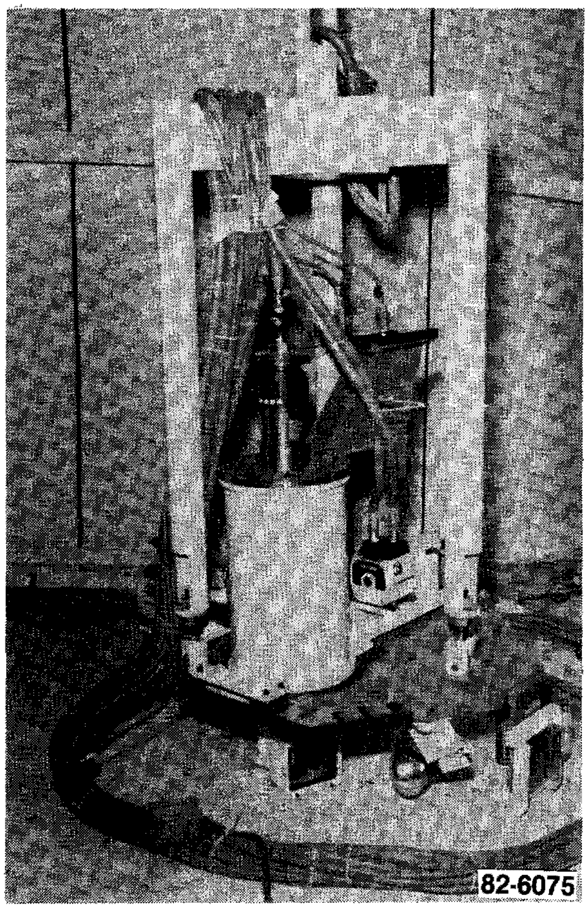

Figure 4. Photograph of the venting tool fabricated for remotely venting gases from EPICOR-II prefilters.

several options (e.g., immobilization of resins by solidification in concrete), the high integrity container was selected for possible use as an overpack in disposing of prefilters commercially as Class C waste. In early 1981, the Program drafted plans for developing the container and completed the specifications document.[33] The container was designed to retain liquid and solid wastes of a prefilter while buried at intermediate depths for 300 years (approximately 10 half-lives of the predominant isotopes).

Requests for Proposals were issued for developing a prototype, and the contract was awarded to Nuclear Packaging, Inc. of Federal Way (WA). The resulting high integrity container (Figure 5) is a steel-lined, reinforced concrete, cylindrical container, approximately 1.59 m in diameter by 2.13 m high. It meets requirements for Type A packaging specified in 49 CFR 173 and Class C waste in 10 CFR 61.

In December 1981, the Department of Energy requested that the Program demonstrate disposal of at least one EPICOR-II prefilter in a high integrity container at the commercial facility for low-level wastes operated by US Ecology, Inc. near Richland (WA). The disposal demonstration comprised five activities: (a) designing/fabricating the high integrity container, (b) testing, (c) obtaining a Certification of Compliance from the State of Washington for using the container, (d) procuring a suitable cask large enough to transport the EPICOR-II prefilter/high integrity container package, (e) obtaining a Certificate of Compliance from the Nuclear Regulatory Commission for the CNS-14-190 transportation cask,[a] and (f) performing the demonstration.[34]

During 1982, Nuclear Packaging designed and fabricated two prototype high integrity containers and conducted impact tests in the State of Washington, using the first prototype. The second prototype was delivered to INEL for additional structural testing and evaluation, prerequisite to obtaining the Certification of Compliance. It was loaded with sand and subjected to a 7.5-m, free-fall drop test onto soil similar to that found at the commercial disposal facility (Figures 6 and 7). No structural damage or loss of contents occurred. During 1983, two production high integrity containers were purchased from a second manufacturer, Bingham Mechanical and Metal Products, Inc. of Idaho Falls (ID). One was used to complete tests at INEL, the other was designated for use in the disposal demonstration.[35]

While the prototypes were being tested, meetings were held with both the Department of Social and Health Services of the State of Washington and US Ecology to discuss technical aspects of the design, licensing, and disposal of the EPICOR-II prefilter/high integrity container package. In 1983, the Program published the Design Analysis Report for the high integrity container, which subsequently was reviewed by the State of Washington, US Ecology, and the Nuclear Regulatory Commission.[36]

a Note the distinction between the "Certification of Compliance" issued by the State of Washington for using the high integrity container and the "Certificate of Compliance" issued by the Nublear Regulatory Commission to the CNS-14-190 transportation cask.

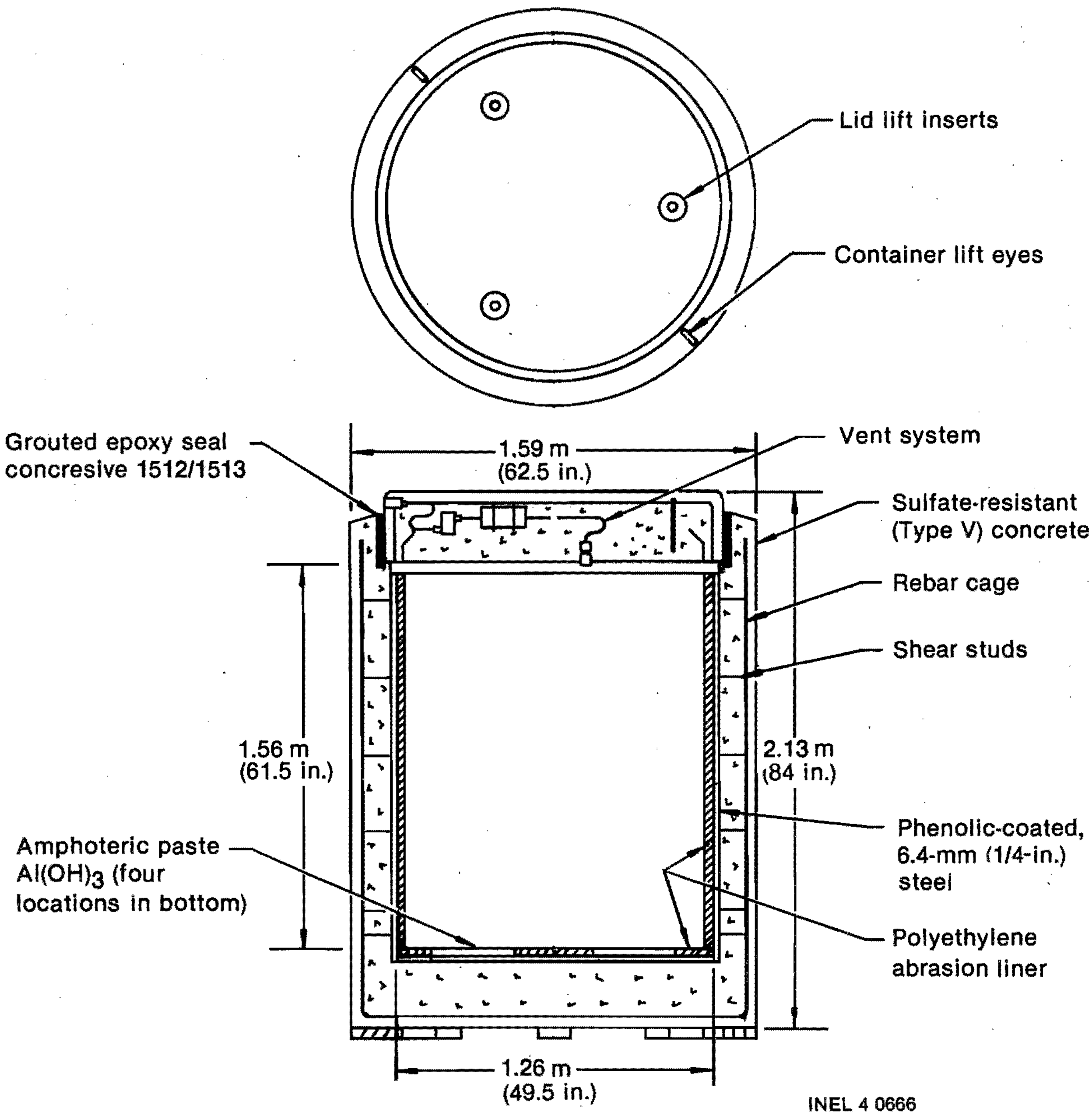

Figure 5. Schematic (top view and full section) of an empty high integrity container.

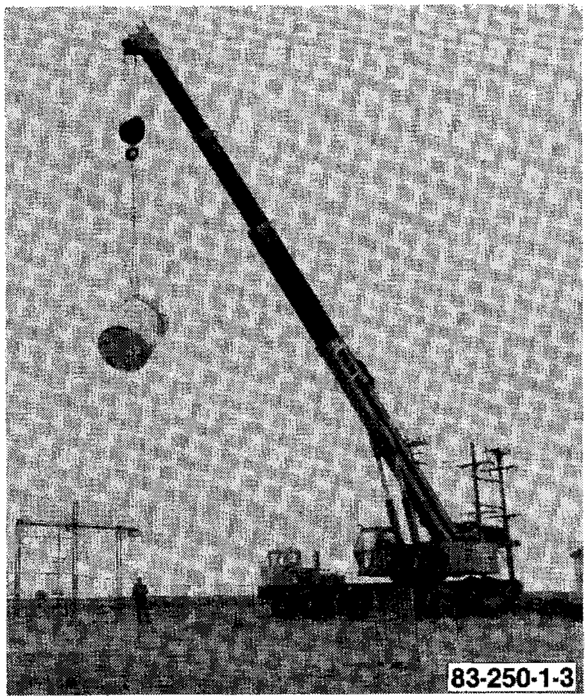

Figure 6. Photograph showing the prototype high integrity container held by a crane before being drop-tested from 7.6 m onto INEL soil.

Figure 7. Photograph showing the prototype high integrity container after being drop-tested from 7.6 m.

US Ecology was subcontracted to prepare the application for the Certification of Compliance and submit it to the State of Washington. Throughout 1983, considerable effort was expended in review cycles with the State and Nuclear Regulatory Commission in the overall effort to qualify the container for use (References 31 and 34). After review by all involved parties, the Commission recommended that the State of Washington approve the containers for use in disposal of EPICOR-II prefilters. In March 1984, the State issued the Certification of Compliance for disposing of 50 prefilters individually contained in high integrity containers at the commercial facility for low-level radioactive wastes operated by US Ecology.[37] That approval was contingent upon successful use and demonstration of the package in the disposal demonstration.

As noted previously, the Program had to obtain a transportation cask large enough to contain the EPICOR-II prefilter/high integrity container package. The only suitable choice was the CNS-14-190 truck cask; however, its Certificate of Compliance had lapsed. Therefore, Chem Nuclear Systems was contracted to fabricate a new issue of that cask (Figure 8), and, in January 1984, the Nuclear Regulatory Commission issued the new Certificate of Compliance, valid through January 1985.[38] Later, because of delays incurred in transporting prefilters from TMI-2 to INEL, an extension was obtained to the Certificate until March 1985.

To obtain data for the disposal demonstration, a full-length resin core from PF-46 was analyzed for transuranic elements. That particular prefilter was chosen because it contained the greatest quantity of transuranic elements of the 50 EPICOR-II prefilters. Results indicated that PF-46 was well within limits for commercial disposal as Class C waste [as defined in 10 CFR 61.55], when enclosed in a high integrity container.

In preparation for the disposal demonstration, PF-18 was retrieved from storage at INEL, dewatered, sealed in a high integrity container, loaded into the CNS-14-190 cask, and readied for disposal. In September 1983, the Program issued the Safety Assessment Document for transporting EPICOR-II prefilter/high integrity container units to Richland for disposal.[39] The disposal demonstration was completed successfully in April 1984, when PF-18 in its high integrity container was transported to US Ecology and disposed in a trench as Class C waste (Figures 9 and 10).[40,41] Completion of the disposal demonstration set the precedent for

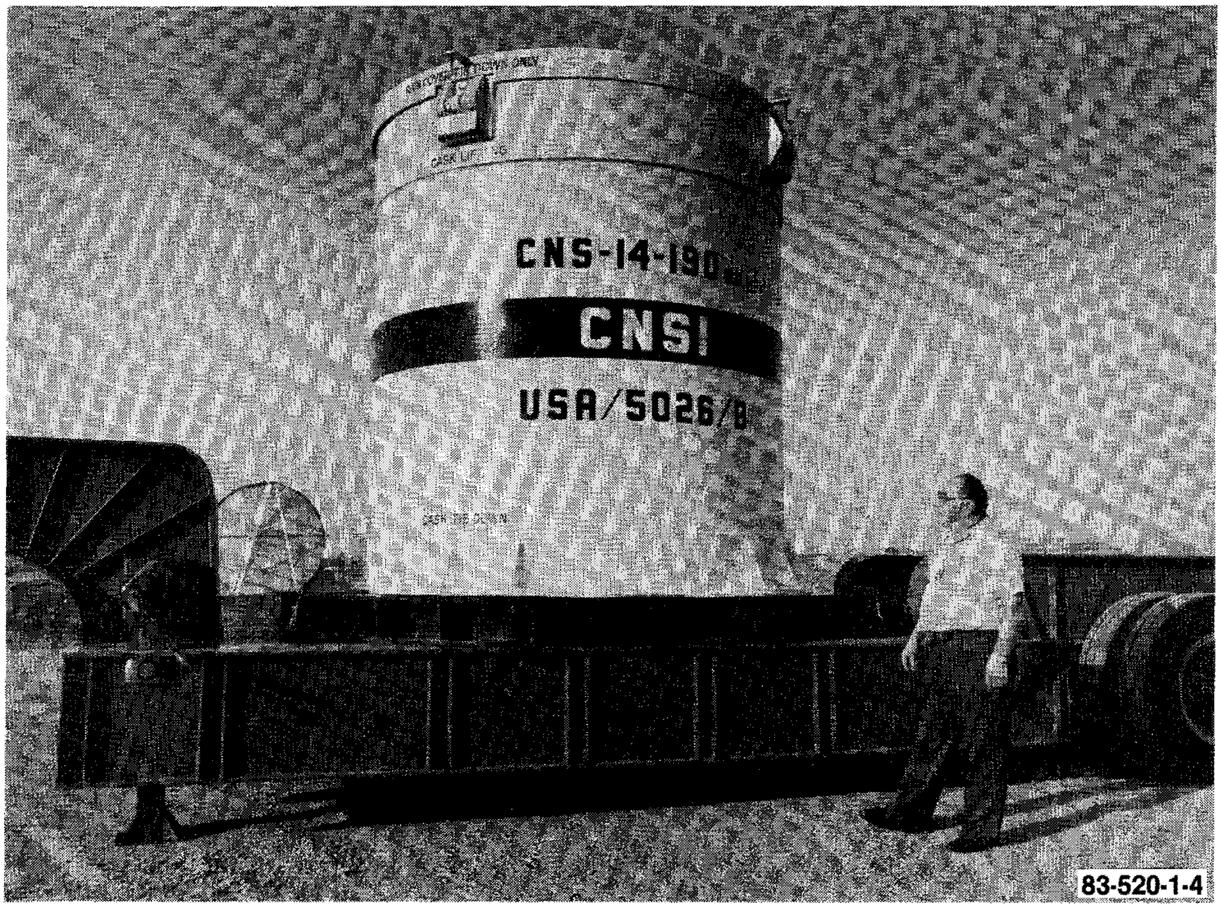

Figure 8. The CNS-14-190 cask and trailer used for transporting EPICOR-II prefilter/high integrity container units to the commercial disposal facility.

disposing of the remaining EPICOR-II prefilters stored at INEL.

During 1984, the Program designed (or redesigned) and fabricated equipment for remotely preparing the remaining EPICOR-II prefilter/high integrity container units for disposal. Besides the demonstration unit, 45 others were disposed as Class C waste at the commercial facility. Disposal operations were completed in February 1985, 3-1/2 months ahead of schedule.[42-44] Four prefilters remained at INEL for additional resin research activities, described below.

In 1982, the Program began conducting resin/liner research at INEL, using EPICOR-II prefilters.[45-47] Included were four tasks: (a) investigating degradation of organic ion exchange resins and zeolite contained in the EPICOR-II prefilters, (b) evaluating solidification as a method of immobilizing those materials, (c) determining the integrity or condition of the steel liners, and (d) field testing resin waste forms in lysimeters for as long as 20 years. Because the prefilters had been exposed to high doses (over 10^8 rads) of contained radiation for several years, information obtained from the research provided important new insights into storing and disposing of organic ion exchange resins and zeolite. Results also reinforced earlier design suppositions that the EPICOR-II prefilter/high integrity container packages could remain safely at the disposal facility for more than 300 years.

The Department of Energy funded the EPICOR-II resin/liner research at INEL through FY-1983.[48-55] Subsequently, the Nuclear Regulatory Commission assumed the responsibility for funding the remainder of the task, under the Low-Level Waste Data Base Development--EPICOR-II Resin/Liner Investigation.[56-74] Four prefilters remain in storage casks at INEL awaiting disposition at conclusion of research.

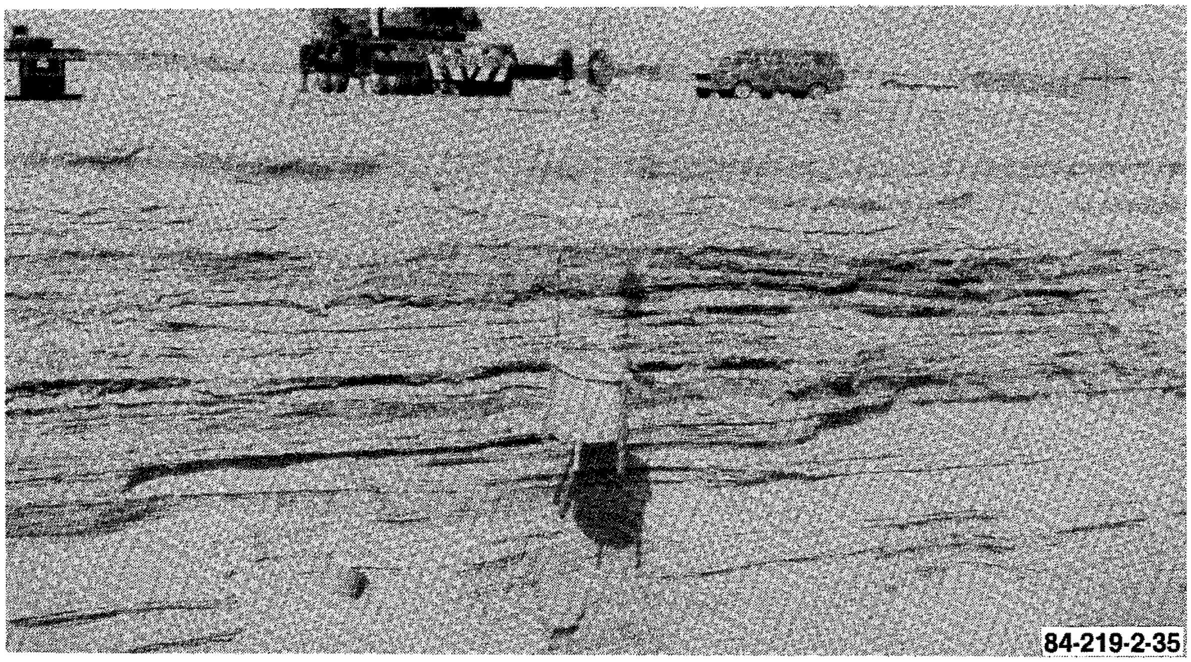

Figure 9. Photograph of the demonstration high integrity container, with cask cribbing attached, being lowered into the trench at the commercial disposal facility.

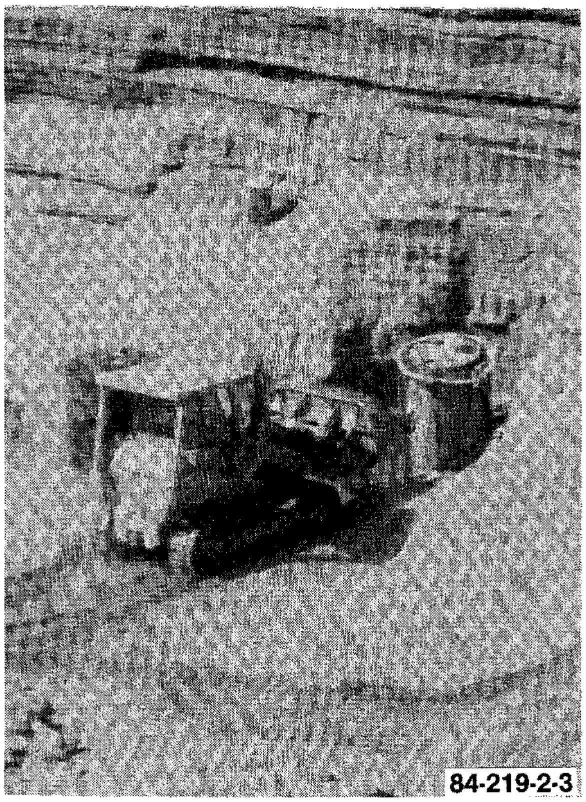

Figure 10. Photograph of the demonstration high integrity container being covered in the trench at the commercial disposal site.

Upon completion of the disposal campaign and resin sampling activities, the Hot Shop of TAN-607 was restored for other programmatic endeavors of EG&G Idaho. That work was completed in 1985.

Zeolite Disposition Program

In July 1981, GPU Nuclear began using the specially designed Submerged Demineralizer System to remove cesium and strontium from accident-related water in the basement of the Reactor Building, primary reactor coolant system, and several miscellaneous tanks.[75,76] Three years later, the system was used to remove cesium eluted from the Makeup and Purification System demineralizers. A total of 19 stainless steel vessels resulted (Figure 11), each containing inorganic zeolites loaded with as much as 112,600 Ci of radioactivity. The Department of Energy accepted those vessels from GPU Nuclear for the Zeolite Disposition Program conducted at Hanford (WA). That work included the (a) Zeolite Vitrification Demonstration at Pacific Northwest Laboratories[77,78] and (b) Monitored Retrievable Burial Demonstration at Rockwell Hanford Operations.[79]

Although EG&G Idaho was not involved directly in the Zeolite Disposition Program, it did

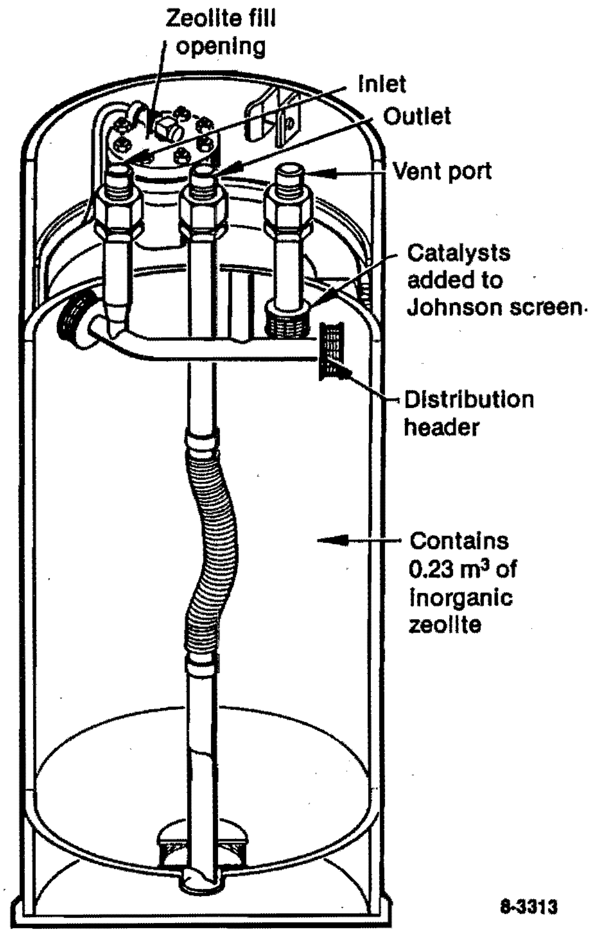

Figure 11. Schematic of a Submerged Demineralizer System Vessel.

provide technical support, primarily in procuring the CNS 1-13C-II transportation cask (Figure 12), preparing necessary safety and environmental documentation for transporting the vessels to Hanford, and conducting the transport action.[80-82] Between May 1982 and April 1985, three vessels were transported to Hanford for use in the Zeolite Vitrification Demonstration and the remaining sixteen for the Monitored Retrievable Burial Demonstration. Subsequently, the same CNS1-13C-II cask was used for transporting research samples and abnormal wastes from TMI-2 to INEL and other laboratories.

Core Acceptance Activities

It is important to note that, following the TMI-2 accident, the actual condition of the reactor core was not known, and access for better information was protracted, awaiting general cleanup of

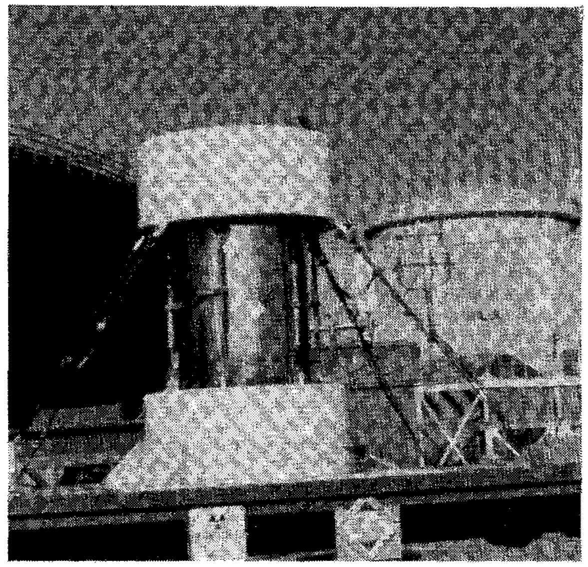

Figure 12. Photograph of the CNS 1-13C-II transportation cask on the truck transporter.

facilities. Many studies were initiated in attempting to delineate what should be done at Three Mile Island. Samples were needed to determine the elemental composition, materials, interactions, and retention of fission products in the core. Core materials would be cataloged to obtain an inventory of materials and fission products. Future access to the core would be required to obtain specific samples for physical/metallographic examination. Development of core reprocessing/waste form technologies would be needed, with the expertise/facilities for those technologies not located at TMI. Also, priorities were such that research efforts could not delay the cleanup/defueling effort.

In conjunction with the Nuclear Regulatory Commission, the Department of Energy amended the Memorandum of Understanding (Reference 9) such that the Department agreed to accept the TMI-2 core for research at one of its facilities. Contract negotiations between GPU Nuclear and the Department were based on core conditions known at that time. The basic concept involved loading core debris into canisters [yet to be designed], transporting loaded canisters to a Department facility [yet to be selected], opening the canisters, removing samples for examination, and acquiring the debris as quickly as possible so as not to compromise rapid defueling and cleanup. The fact that the actual damage to the core was much more extensive than first believed, defueling much more complex and protracted, and the sampling modified throughout the defueling effort did not alter the correctness of the original decision to remove and store the core.

In early 1980, the Program and GPU Nuclear began investigating options for packaging the core. In 1982 and 1983, "quick look" video inspections of the core were performed, "grab samples" of core debris were obtained for analysis, and the core cavity was mapped using the Core Topography System.[83-85] Information obtained from those examinations proved invaluable in formulating plans for defueling the reactor and packaging the core.

In November 1983, the TMI-2 Core Shipping Technical Working Team was formed to ensure timely, efficient, and accurate exchange of information between organizations involved in defueling, packaging, transporting, and storing the core. Included were representatives of Babcock & Wilcox Company, Bechtel National, Inc., the Department of Energy, EG&G Idaho, GPU Nuclear, Nuclear Packaging, the Nuclear Regulatory Commission, Rockwell Hanford Operations, Sandia National Laboratories, the Technical Integration Office, and various consultants.

GPU Nuclear estimated that, after the accident, the reactor vessel contained approximately 133,000 kg of core debris. In preparation for removing those materials from TMI, in March 1984, the Department of Energy and GPU Nuclear signed a contract providing transportation, storage, and disposal services for the core.[86] INEL was selected to receive and store the core, because of existing facilities and notable expertise in research on severe core damage accidents. The Department planned to accept the core debris from GPU Nuclear in canisters, transporting it to INEL for examination and storage until availability of the National High-Level Waste Repository (approximately 30 years).

An important part of the core acceptance activity included integrating interface requirements into design criteria for the canisters. In June 1984, a report was published detailing interface requirements at INEL that should be included in the criteria.[87] The requirements ensured compatibility with structures and equipment used for receiving, unloading, and storing loaded canisters at INEL. Considerations addressed included criticality, size, weight, closure, pressure, strength, design-life, vents, drains, identification, contamination, and quality and instructional manuals.[88-94]

Early during plans for defueling the reactor, GPU Nuclear and the Program determined that drying the contents of each loaded canister would be very difficult, expensive, and time-consuming, as well as unnecessary. Therefore, each canister was dewatered at TMI, and the core debris transported damp. Upon arrival at INEL, the canisters were refilled, stored underwater in the Water Pit of TAN-607, and vented continuously. However, between the time canisters were dewatered at TMI and refilled at INEL, radiolysis of residual water could generate hydrogen and oxygen. Therefore, specialized catalytic recombiners (developed by Rockwell Hanford Operations) were built into each canister, effectively controlling generation of combustible gases and resulting in a calculated safe transport window of approximately 100 days.[95] Data obtained from canisters at INEL confirmed that the design suppositions made regarding gas generation were very conservative.

In 1985, the Department of Energy requested that the Program review the Quality programs of the canister vendors, conduct first-article inspections of canisters, inspect/accept canisters delivered to GPU Nuclear after fabrication, and review documentation accompanying each canister. Those tasks were performed to ensure that each canister met Quality Assurance requirements of the Department. Additionally, the Department asked the Program to develop an extensive Overview Checklist and Canister Acceptance Plan to ensure loaded canisters were adequately characterized/prepared to meet requirements for acceptance, transport, and long-term storage.[96] The Plan was implemented throughout the duration of the core acceptance, transport, and storage activities. The total number of canisters forecast for acceptance was about 380.

Transportation, Receipt, and Storage of TMI-2 Core Debris

Beginning in 1983, the Program pursued several closely interrelated activities supporting transport of core debris from TMI-2 to INEL. Included were developing the NuPac 125-B Rail Cask, preparing for receipt and storage of the core at INEL, providing technical expertise to GPU Nuclear in defueling the reactor, conducting the transportation campaign, and disseminating information learned during those activities.

In 1983 and 1984, investigations focused on transporting the core debris to INEL for storage in the Water Pit of TAN-607. Several requirements and planning documents were published in preparation for transporting, storing, and examining the core.[97-101] Meanwhile, GPU Nuclear procured canisters for use in defueling the reactor and began defueling in October 1985.

Several factors influenced selection of a cask for transporting the core to INEL. First, the core debris contained enough plutonium that, per 10 CFR 71.73, the material had to be transported in a double-containment package. That decision was reached in consultation with the Nuclear Regulatory Commission. Second, the breached fuel rods could not be considered a level of containment. Finally, the participants in the TMI-2 Program decided that the canisters would not be designed to provide a level of containment. [The canisters needed removable lids and other loading features that made them difficult to qualify as a level of containment.] Therefore, the decision was made that the transportation cask would provide both levels of containment. Also, after considerable study, GPU Nuclear opted for dry loading of the cask instead of submerged in the fuel pool. That decision related to operational efficiencies, including the fact that much equipment dedicated to support of the cleanup effort occupied space in the pool.

One accomplishment of the Program was developing the double-containment NuPac 125-B Rail Cask. It was the first rail cask fabricated and licensed in many years, and established many precedents now being followed by other programs of the Department of Energy. The cask holds seven loaded canisters and meets all regulations for double containment of plutonium-bearing materials. It is 7.1 m long by 3.0 m in diameter (including its energy-absorbing overpacks) and is constructed as a "leaktight" inner vessel within a "leaktight" stainless steel and lead outer vessel (Figure 13).[a] The total weight of the loaded cask (with overpacks, seven loaded canisters, and transport skid) is about 93,000 kg.[102]

Beginning in 1983, the Program reviewed bids for manufacturing the cask, as well as conducted safety studies on transporting the core debris.[103,104] In 1984, Nuclear Packaging was contracted to manufacture two casks and began fabrication in mid-1985. In December 1985, the first NuPac 125-B Rail Cask, skid, and railcar were delivered to the Program (Figure 14). In January 1986, the second cask, skid, railcar, and miscellaneous handling and loading equipment were completed.

In qualifying the cask for licensing, the Program contracted with Nuclear Packaging to build a 1/4-scale model of the cask and canisters. In 1985, the model was delivered to the Transportation Technology Center of Sandia National Laboratories for a series of five drop tests [as specified in 10 CFR Part 71 (Subpart D)]. Meanwhile, Oak Ridge National Laboratory conducted a series of four drop tests with a full-scale knockout canister to provide information in answering questions raised by the Nuclear Regulatory Commission about criticality control in canisters during a worst-case hypothetical accident. Results of both sets of tests, and the corresponding analyses, were included in the Safety Analysis Report for the NuPac 125-B Rail Cask, which Nuclear Packaging submitted to the Commission as part of the licensing application for the cask.[105] In the meantime, the Department of Energy was confident enough that the cask would be licensed that it authorized construction of two casks while the Commission was reviewing the application. The Certificate of Compliance for the NuPac 125-B Rail Cask was issued by the Commission in April 1986.[106]

Meanwhile, Bechtel National, on behalf of GPU Nuclear, contracted with Nuclear Packaging to supply the facility interface and loading equipment for TMI.[107] The Program participated in that effort to the extent of reviewing and selecting systems for compatibility with the transport package. To ensure that equipment used in loading the cask performed properly, the Program arranged for the second cask and all loading equipment to be assembled and tested at Hanford Engineering

a Leakrate of less than 10^{-8} Pa-m^3/s.

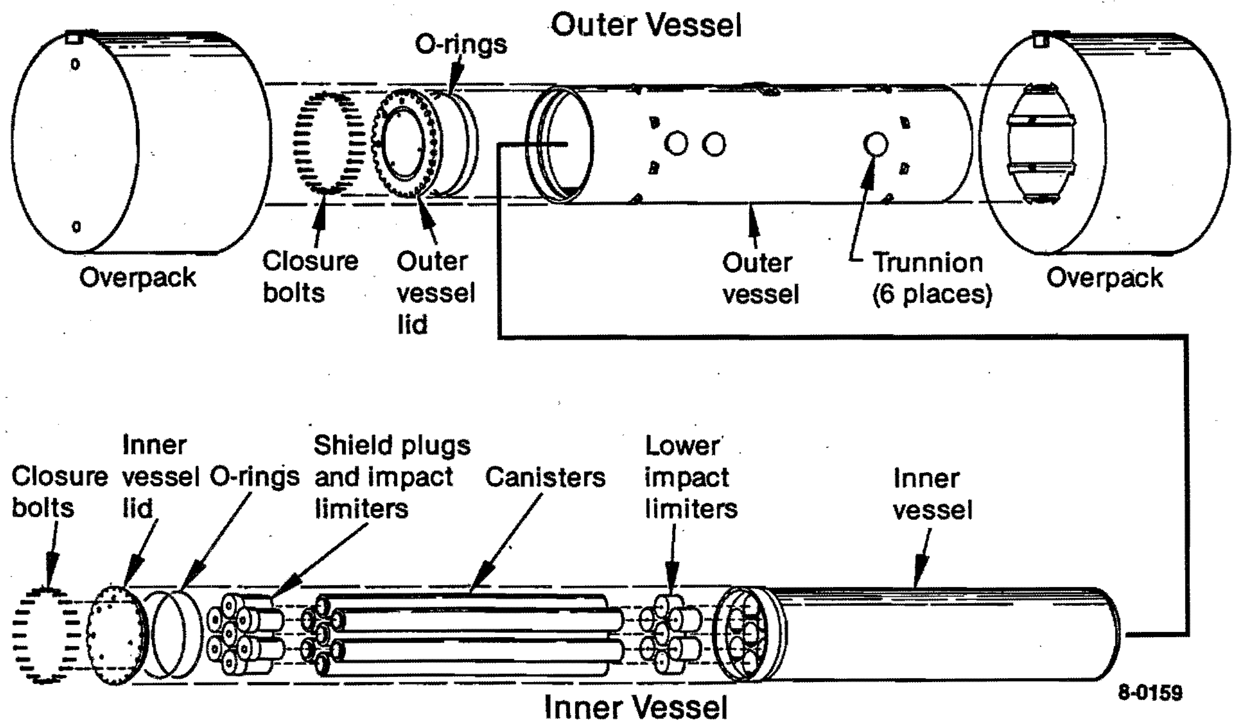

Figure 13. Schematic showing the major components of the NuPac 125-B Rail Cask.

Development Laboratory. During those operations, GPU Nuclear verified procedures and trained personnel to operate the equipment. After completion of testing, the equipment was disassembled, transported to TMI, and reassembled for use. In a parallel effort, the Program accepted the first cask and specialized hardware for use in training of personnel and verification of procedures at INEL.

Beginning in 1982, a variety of equipment in the Hot Shop of TAN-607 was refurbished and/or modified.[108] Included were reconditioning the 100 ton crane system, cleaning/refurbishing the Water Pit, cleaning/reconditioning galley windows, and rebuilding/testing remotely-controlled manipulators. Some equipment had been used by the EPICOR-II Program [described previously herein] and later was used in operations involving receipt of the TMI-2 core. During 1983 and 1984, equipment was modified for handling loaded canisters, modules were procured for use in storing canisters in the Water Pit, and most equipment for handling the cask was fabricated or procured. Included were grapples for handling canisters, a cask lifting collar and yoke, a cask unloading stand [built by another program and adapted by the TMI-2 Program for use with the NuPac 125-B Cask], sampling and venting instruments, and so forth.[109,110] Furthermore, a substantial effort was expended at Central Facilities Area of INEL to prepare equipment for receiving the rail cask, transferring the cask to a truck transporter, and transporting the cask to TAN-607. An existing gantry crane was refurbished, and a heavy-haul transporter reworked for moving casks.

In late 1984, the Program completed the Safety Analysis Report for the TAN-607 Complex and, in mid-1985, the Safety Assessment for Receipt and Storage of TMI-2 Core Debris.[111,112] In late 1985, the Operational Safety Requirements for the Hot Cells North Facilities was revised completely, and, in 1986, the documents for transporting the cask to and across INEL were released.[113-115] Environmental issues had been evaluated in preparing the Final Environmental Impact Statement for INEL, which was published in 1977.[116]

Several months before beginning the transportation campaign, a plan was developed for communicating with states along the rail route between TMI and INEL.[117-119] Representatives from each involved state were invited to TMI for a public viewing of the cask and detailed briefing on the route, safety considerations, and emergency preparedness. Initial notification was provided to the states 45 days

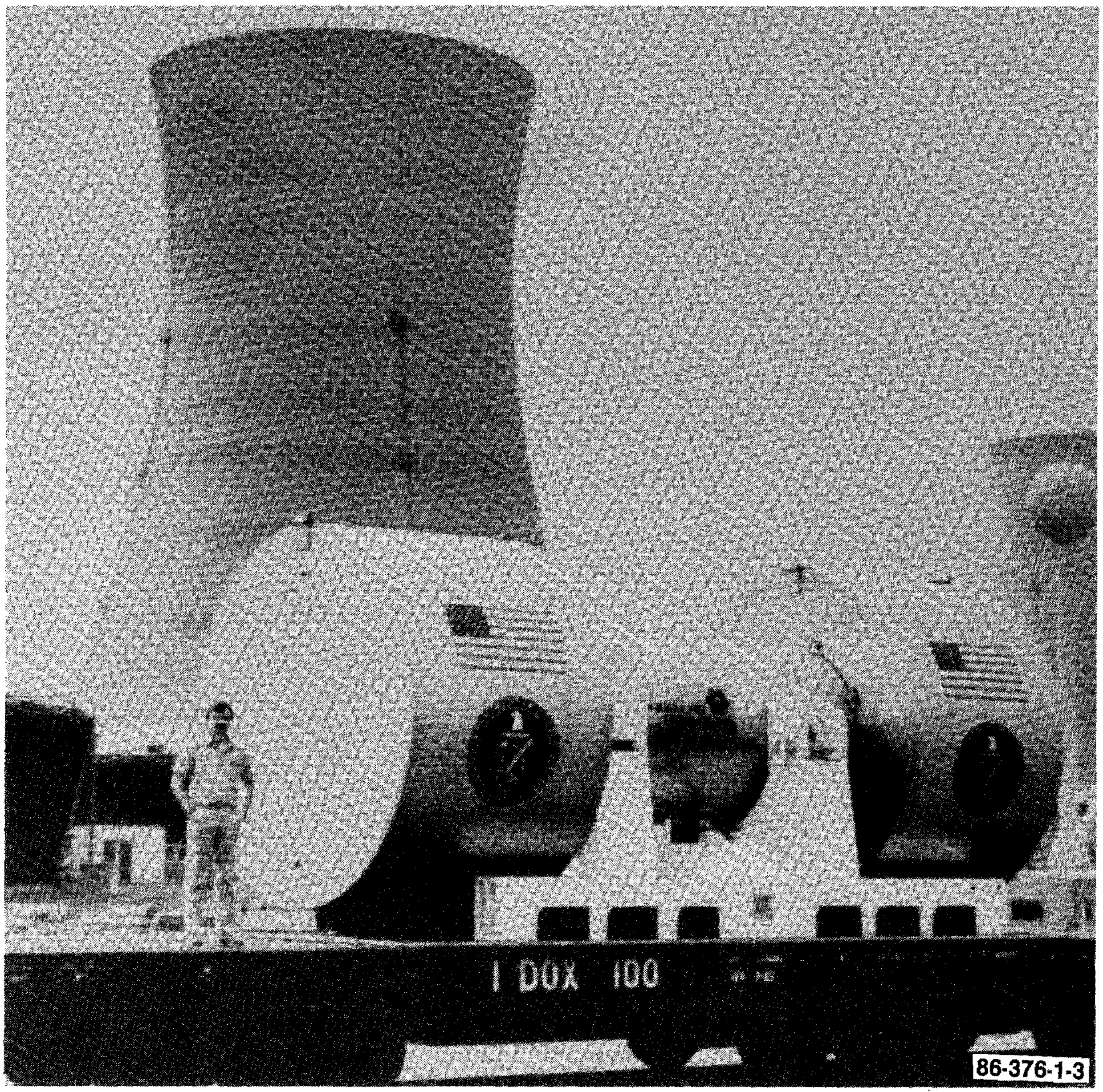

Figure 14. Photograph of the NuPac 125-B Rail Cask, transport skid, and railcar at TMI.

before the first shipment. Thereafter, the Transportation Officer of EG&G Idaho (representing the Department of Energy) notified each involved state four days in advance of each shipment.[120-123]

In early 1986, a biological growth in the water of the TMI-2 reactor vessel reduced visibility to where defueling operations were hampered severely. After considerable research by the Program and GPU Nuclear, hydrogen peroxide was used to kill the microorganisms. Another concern arose regarding the possibility of biological corrosion of the canisters. EG&G Idaho performed several studies and concluded that treating the canisters with hydrogen peroxide would effectively control the microorganisms. It also was found that refilling the canisters for storage at INEL would not result in biological growth sufficient to compromise the integrity of the containers.

The second NuPac 125-B Rail Cask was delivered to TMI in March 1986, after use in the integrated system test at Hanford Engineering Development Laboratory. Between March and June, GPU Nuclear installed and tested the loading equipment in the Truck Bay between Units 1 and 2 and completed training of personnel. In June, the cask was loaded with seven fuel canisters containing core debris. Transport of core debris from TMI to INEL commenced in July 1986. Railroad security personnel and observers from EG&G Idaho accompanied the first three shipments, collecting time and motion information important in establishing a baseline for future shipments. Upon arrival at INEL, the cask was transferred from the railcar to the truck transporter and conveyed to the Hot Shop of TAN-607. There, it was unloaded and the canisters were placed in storage in the Water Pit. After completion of unloading operations, the cask was moved to Blackfoot (ID) for public display.

It was surmised that the core debris shipments might be of concern to the public; therefore, a Public Relations Officer was assigned to the Program. Several events and organizations did precipitate public concern regarding the transport action, and the Public Relations Officer was invaluable in addressing those matters.

The Program investigated the time and cost required to complete the entire transportation campaign and considered a variety of scenarios, including (a) one cask versus two casks per train, (b) expedited versus regular train service, (c) cask pickup dates on an "as-required" basis versus Sunday-only pickup at TMI and Saturday-only pickup at INEL, and (d) using three casks instead of two. That information was used in projecting the remaining campaign and in evaluating options for completing that activity. Originally, the Program planned to use only two casks; however, in 1986, GPU Nuclear opted to lease a third cask from Nuclear Packaging to keep defueling on-schedule. The third cask was fabricated and placed in-service in November 1987. In December, all three casks were used in one rail shipment to INEL (Figure 15). As the campaign progressed, the decision was made that all shipments would include three casks, since the Department of Energy had committed to completing the transportation campaign via the cheapest and most expeditious manner possible.

Another important aspect of the TMI-2 Program was, and continues to be, disseminating information realized from its activities. Throughout its history, information has been transmitted worldwide via technical symposia and meetings, as well as publications.[124] In September 1987, a two-day workshop was conducted at TMI to discuss issues related to transportation of spent nuclear fuel.[125] It was attended by personnel and contractors of the Department of Energy involved with TMI-2 and other transport actions, and focused on *lessons learned* in transporting the TMI-2 core to INEL.

Abnormal Waste Activities

Approximately 26 m^3 of radioactive materials at TMI-2 originally were identified as potential abnormal wastes. In 1982, the Program began providing technical assistance to GPU Nuclear in planning for the removal, packaging, and transport of those wastes from TMI. Storage options were investigated, and results of the study were published in 1983 and 1984.[126,127] In June 1983, the Department of Energy requested that the Program plan to receive and store at INEL certain abnormal wastes from TMI-2 for as long as 30 years, or until disposal could be arranged at a suitable location [yet to be decided]. Acceptance criteria were defined for receiving those wastes at INEL. Permanent disposition of the wastes could involve processing the materials into acceptable waste forms, which is the subject of ongoing research at INEL.

During 1984, the Department and GPU Nuclear began negotiations toward an agreement that the Department provide, on a full cost-recovery basis, storage for abnormal wastes from TMI-2. In July 1985, a contract was signed providing for transportation, storage, disposal preparation, and disposal services for abnormal wastes from TMI-2.[128] That agreement was intended to prevent TMI from becoming a site for long-term storage of abnormal wastes.

A project plan was issued for receiving abnormal wastes at INEL, and a paved storage pad prepared.[129] Safety and environmental documents were completed for receiving and storing the wastes.[130-132] [It is worth noting that the impacts of handling and transporting EPICOR-II prefilters and Submerged Demineralizer System vessels bracketed the impacts associated with handling and transporting other solid wastes from TMI-2. Therefore, no safety or environmental documents were prepared for transporting abnormal wastes from TMI to INEL.]

In May 1987, the first shipment of TMI-2 abnormal waste was received at INEL via truck in the

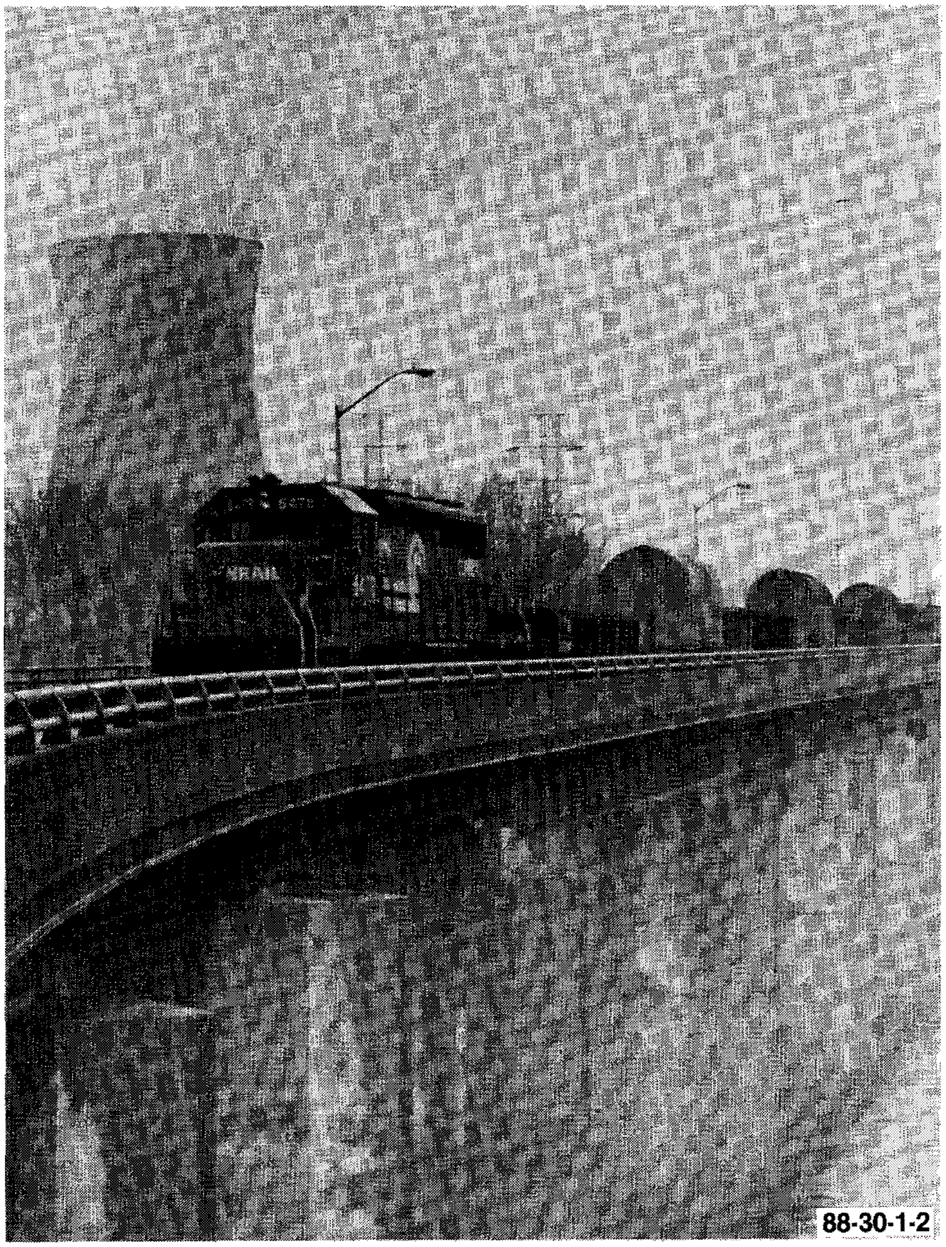

Figure 15. Photograph showing use of all three casks for one rail shipment from TMI to INEL.

CNS 1-13C-II cask. It contained the first of three Cuno filter vessels used in the Submerged Demineralizer System. The filter was placed in a storage cask on the pad near TAN-607. In late 1987, the second Cuno filter vessel was transported to INEL and placed in storage.

CONCLUSION

Whereas this document summarizes the major activities conducted by the TMI-2 Program in managing the TMI-2 fuel and special radioactive wastes for the Department of Energy, it does not include the multitude of lessons learned during those activities. The lessons learned are detailed elsewhere.[133] Although the TMI-2 accident had a negative influence on public perception of the nuclear industry and reactor safety, management of wastes generated by the accident consisted mostly of straight-forward applications of existing technology. That is, while technically challenging and sometimes innovative approaches were required to remove, package, transport, store, and, in some cases, dispose of wastes from TMI-2, solutions thereto did not depart from practices common to the industry. In conclusion, activities of the Program discussed in this report demonstrated that wastes from a nuclear accident can be managed by practical applications of existing technology.

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