HIGH INTEGRITY CONTAINERS: A DEMONSTRATED DISPOSAL ALTERNATIVE TO SOLIDIFICATION OF RADIOACTIVE WASTES[a]

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ABSTRACT

The EPICOR and Waste Research and Disposition Program at the Idaho National Engineering Laboratory developed, tested, and is using a High Integrity Container (HIC) for commercial disposal of EPICOR-II prefilter liners from the cleanup of Unit 2 of the Three Mile Island Nuclear Power Station. The HIC permits disposal of EPICOR-II liners as Class "C" low-level radioactive wastes without prior solidification of resins therein. Design rationale for and testing of the HIC are discussed, and costs of using the container for disposal of EPICOR-II liners are compared with costs of solidification. It is concluded that the HIC is a cost competitive alternative to solidification for disposal of unusual types and quantities of low-level radioactive wastes.

INTRODUCTION

The March 1979 accident that damaged Unit 2 of the Three Mile Island (TMI) Nuclear Power Station resulted in accumulations of large quantities of unusual nuclear wastes. One waste-form resulted from processing approximately 560,000 gallons of contaminated water from the basement of the Auxiliary and Fuel Handling Building.[1] With approval from the Nuclear Regulation Commission (NRC), the contaminated water was filtered through a demineralization system (EPICOR-II) to remove the fission products. During the filtering process (October 1979 to August 1980), 50 EPICOR-II prefilter liners were loaded with high concentrations of fission products and trace amounts of other radioisotopes. After use, each liner was placed in storage at TMI for approximately two years. In 1982, 17 liners were retrieved, examined, loaded in transportation casks, and sent to the Idaho National Engineering Laboratory (INEL) for interim storage and research. The remaining 33 liners were retrieved and sent to INEL during 1983.

In a parallel effort, EG&G Idaho, Inc., with the subcontract assistance of Nuclear Packaging, Inc., developed a High Integrity Container (HIC) for use as an overpack in the planned disposal of EPICOR-II liners at a commercial waste disposal facility for low-level wastes. The HIC is an alternative to solidification of dewatered resins as discussed by NRC in 10 CFR, Part 61, and is a viable means for safely disposing of highly loaded resins as Class "C" wastes. This paper briefly describes the HIC, explains results of testing the HIC, summarizes progress in effecting the demonstration disposal of one HIC/EPICOR-II liner, and presents comparative cost data for use of the HIC versus solidification/immobilization of highly loaded dewatered resins.

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DESCRIPTION OF EPICOR-II PREFILTER LINER

Each EPICOR-II liner is a cylinder (4-ft dia by 4.5-ft tall), fabricated from 0.25-inch welded steel (Fig. 1). The top surface is recessed 6 inches below the edge of the side wall. In the top, threaded ports function as inlet and outlet for filtered liquids, attachment of instrumentation, and ventilation. The inlet and outlet ports are connected individually to header systems inside the liner. The inlet header system spread contaminated water over the top of the ion exchange media, while the outlet header system collected and demineralized water from the ion exchange medium. Also in the top is a large access port covered by a cap made from the end of a standard 55-gallon steel drum. The large port was used when the liner was fitted with header systems and equipped with ion exchange media. The bottom of the liner is constructed of a steel plate larger in diameter than the cylinder and attached to the side wall via external and internal circumferential welds (study Fig. 1). The ion exchange medium in 11 EPICOR-II liners is organic resin; that in the remaining 39 liners is organic resin with an ensconcing layer of inorganic zeolite. Each liner is painted with epoxy paint inside and out to protect it against corrosion.

In processing water from the Auxiliary and Fuel Handling Building, each liner was loaded with less than 2,200 Ci, comprised mostly of strontium-90, cesium-134 and -137, and their daughter products; small amounts of other radioactive fission products; and trace amounts of transuranic elements.[2,3] The radiation field outside of some liners exceeded 1000 R/h on contact. In those liners with organic resins only, the radioactivity generally declined from the top to the bottom of the resin bed. In those containing both resin and zeolite, the radioactivity appeared concentrated in the layer of zeolite.

DESCRIPTION OF THE HIGH INTEGRITY CONTAINER

The HIC is a cylinder resembling that diagrammed in Fig. 2. Its dimensions are 5.2 ft in diameter by 7 ft tall, and it is constructed of several inches of high-strength, reinforced concrete.

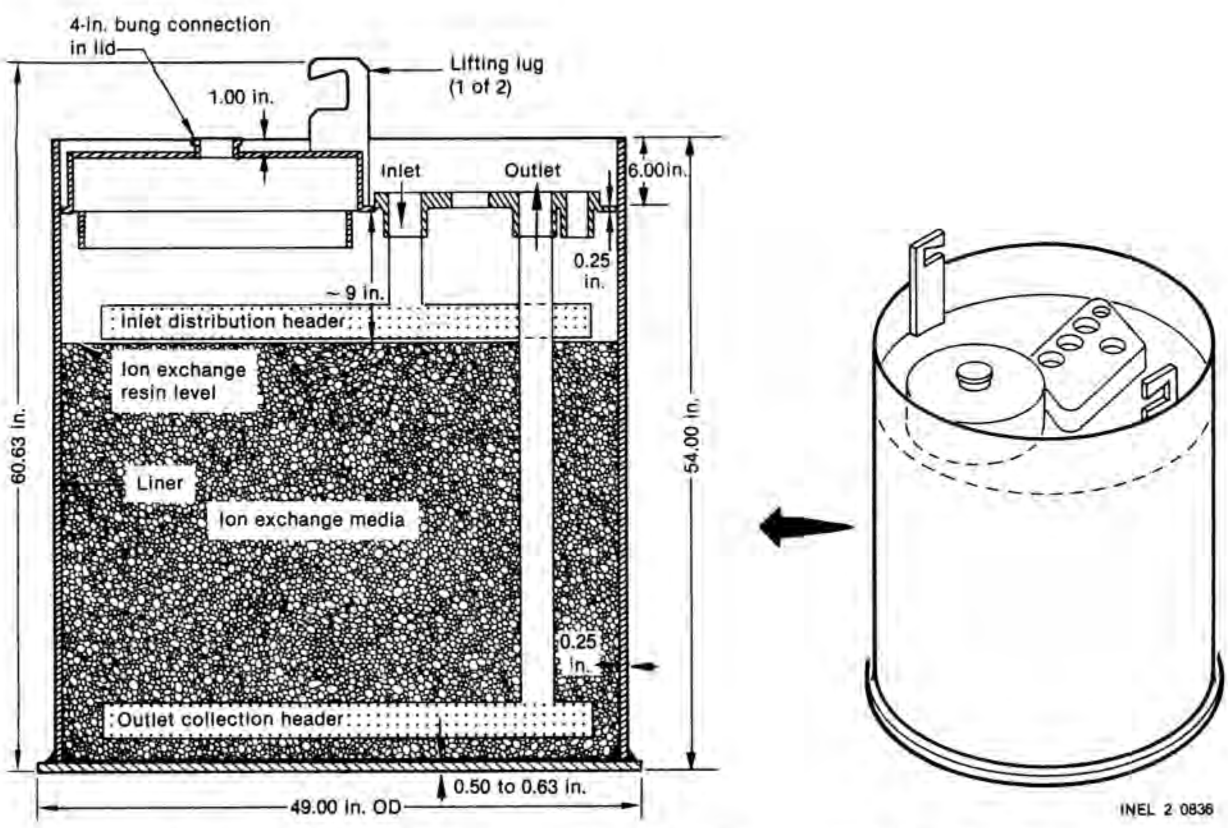

Fig. 1. Schematic diagram (full section and isometric) of an EPICOR-II liner.

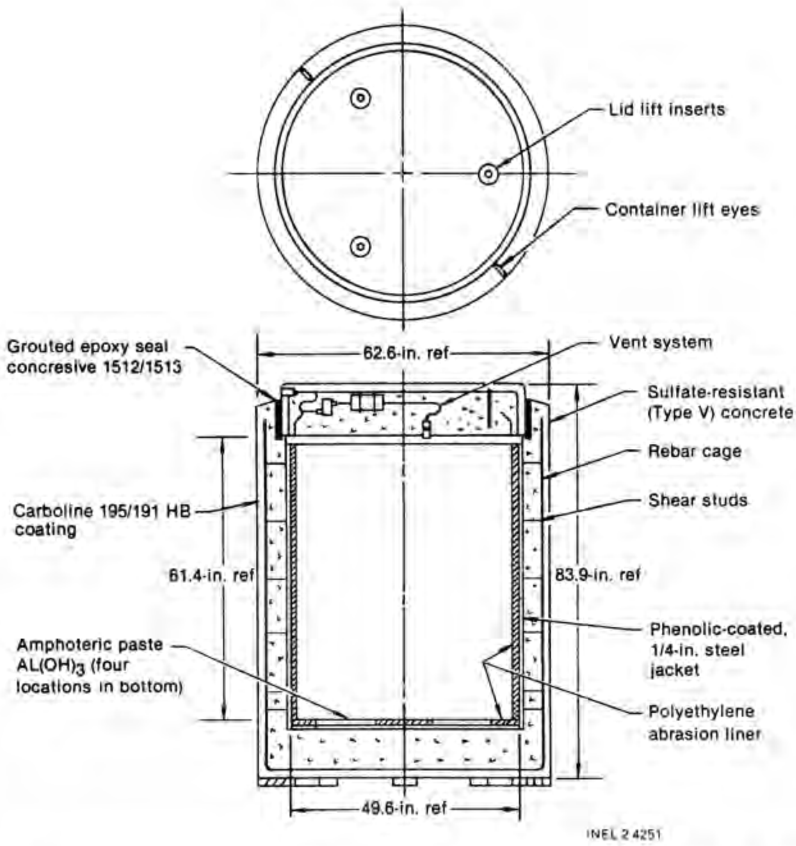

Fig. 2. Schematic diagram (top view and full section) of a High Integrity Container.

(6-in. body; 11-in. ends), with a 0.25-inch internal steel jacket (Fig. 3). As an added precaution, a high-density polyethylene sleeve is installed permanently in the HIC before loading. The plastic sleeve acts as a buffer between the EPICOR-II liner and steel jacket of the HIC, thereby preserving the integrity of the phenolic corrosion barrier of the jacket. The lid of the HIC has a built in vent system (Fig. 4) for passive removal of excess gases in the container; it is attached to the body by two separate epoxy materials, both of which form permanent seals (Fig. 5). Corrosion resistance of the container is provided by redundant barriers, supplemented by aluminum hydroxide to reduce the chemical activity of corrosives. Each corrosion barrier provides adequate containment for the 300-year life of the container. Collectively, the barriers exceed 1200 years of potential durability for the HIC. Lifting, loading, and handling features of the container are designed for quick disconnect to facilitate remote maneuvering, thereby minimizing personnel exposures to radiation during disposal operations.

Loading/Transporting

A funnel-shaped interface collar centers the EPICOR-II liner during placement in the HIC, provides for ease of insertion, and protects the epoxy seal bead around the top of the container. The epoxy seal bead is placed manually around the rim of the container; the EPICOR-II liner is inserted; then the lid is lowered into place. An epoxy grout is poured into the annular space between the lid and body of the container. The final grouting operation is facilitated by the self-leveling characteristic of the epoxy grout (e.g., use of spherical granules

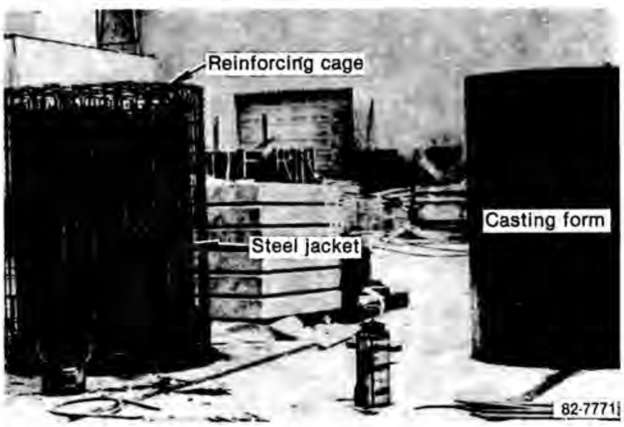

Fig. 3. Steel jacket with reinforcing cage of the High Integrity Container before casting the concrete body.

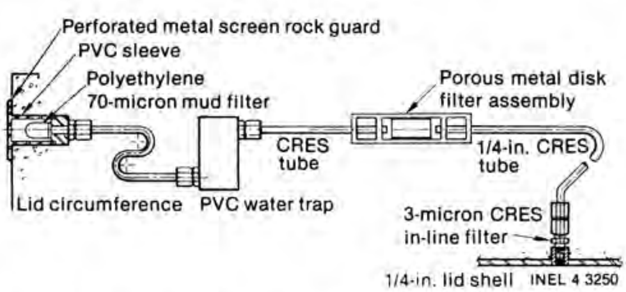

Fig. 4. Schematic diagram of the vent assembly in the lid of the High Integrity Container.

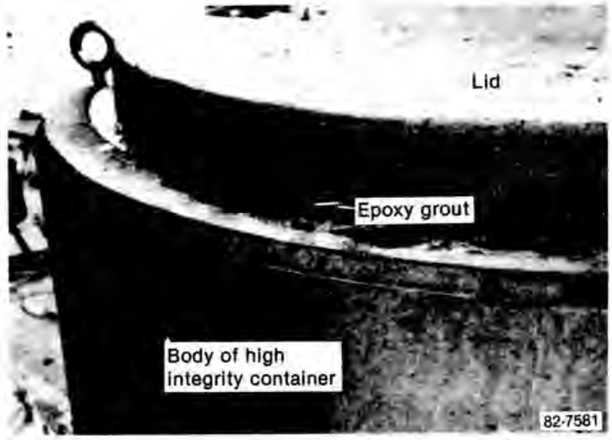

Fig. 5. Epoxy seal binding lid to the body of the High Integrity Container.

of sand). Both epoxies cure to permanent, high-strength bonds in 48 hours; they will endure for the requisite 300-year life of the container. Even though the loading/grouting/curing operations are being done remotely in shielded facilities at INEL, the container is designed for performance of those operations in-field behind temporary shielding.

Regulations of the U.S. Department of Transportation (49 CFR, Part 173) require that significant quantities of radioactive material be sealed inside a Type "B" shipping cask for transport over public roads, and that the shipment not pose any explosive risk. A new issue of the CNS-14-190 cask of Chem Nuclear System, Inc. was fabricated specifically for use in transporting HICs loaded with EPICOR-II liners to a commercial disposal facility, because (a) it was the only existing cask big enough to temporarily house and transport the HIC/EPICOR-II liner system, and (b) it possessed a valid Certificate of Compliance from NRC.

Disposal

The most important nonthermal conditions will occur after disposal of the HIC containing the EPICOR-II liner. Externally applied pressures of 150 psi at depths to 90 ft will induce compressive stresses on outer surfaces of the container. Internally, gases generated primarily by radiolysis of interstitial water in the resin bed will escape through the vent system in the HIC lid at an estimated maximum rate of 0.052 mole/day, or 0.049 liter hour. That flow rate will maintain internal pressure of the HIC well below design maxima.[4] Once an HIC is disposed, internal and external chemical environments will have little or no effect upon the container during its 300-year life.

Design Rationale

In designing the HIC, positive resolution of some fundamental concerns was paramount. The first concern was potential failure of the container in less than 300 years, by simultaneous internal and external corrosion, while in a disposed configuration. The second was passive exhaustion of potential gases from the HIC produced during internal radioactive decomposition and/or chemical activity. The third was potential failure of the container in ways other than by methodical and sequential breaching of components. The fourth concern was the potential radiation hazard to both operators and public during loading, transporting, and disposing the container. The fifth concern was exceeding as-low-as-reasonably-achievable (ALARA) goals, which influence all handling and transporting operations. The last concern was burdening the disposer with unnecessary costs associated with fabricating, loading, transporting, and disposing of containers. In designing the container, no credit was taken for the steel shell or body of the EPICOR-II liner in calculating container durability and longevity. Instead, all assumptions were based upon instantaneous disappearance of the EPICOR-II liner once sealed in the HIC (Reference 4).

In the HIC, the phenolic-coated steel jacket was selected as part of the internal corrosion barrier, after comparing its advantages and disadvantages with jackets constructed of various stainless steels or polyethylene. An amphoteric material, another part of the internal corrosion barrier, was placed in the bottom of the polyethylene sleeve lying between the EPICOR-II liner and HIC to neutralize potential corrosives which might seep into that space. Coatings of epoxy on the outer surfaces of the steel jacket and inner concrete surfaces of the container body were selected in constructing the corrosion barrier of the container system. The special filters of the vent system in the container lid were selected in favor of other types, because of their mechanical simplicity and prolonged operability in high radiation fields. Redundant epoxy seals were chosen for binding the lid to the container body in lieu of mechanical devices, because of their better sealing qualities in a high radiation field and their ease of operation during in-field handling. The resultant product is a durable container with a calculated life expectancy of 1200 years minimum.

Test Results

The HIC (both the prototypes and delivered products) was subjected to a series of tests which focused on evaluating structural and mechanical integrities of the container, as specified in the design and as requested by the State of Washington. The following paragraphs summarize tests and results obtained therefrom.

Lift tests on all hardware used in the HIC were conducted at 150% of working loads in accordance with written load-test procedures. All tests of reusable hardware involved lifting known and measured loads. No distress or damage was observed; all hardware performed as designed.

In the initial drop tests, an HIC was dropped twice (on opposite corners) onto an unyielding surface. The first test was from three feet and the second from nine feet. The three-foot test has been documented and demonstrates that the container meets Type "A" packaging requirements as specified in 10 CFR, Part 71 and 49 CFR, Part 173.

For the drop tests, the container was attached by a quick-release latch and supported by a mobile crane. A lifting bar was fixed horizontally to the lid before attachment of lifting shackles. That forced the container to list 42 degrees and caused the container to topple over following corner impact, striking the lid closure region in a "slap-down" impact. Analyses demonstrated that slap-down impact in conjunction with corner impact was the most severe orientation for the package. That angle also induced secondary prying forces in concrete adjacent to lifting fixtures (Fig. 6 illustrates the drop-test setup just before and at the instant of impact). The container, including the seals, was not breached in either the three or nine-foot tests.

Fig. 6. Drop test of the High Integrity Container showing drop-test setup (A) and instant of impact (B).

In response to a request from the State of Washington related to use of the container in burial operations, one HIC (filled with sand to simulate weight of an EPICOR-II liner) was drop-tested successfully from a height of 25 feet (see Fig. 7). The container was dropped onto INEL soil (a "yielding" surface) similar to soils found at the U.S. Ecology, Inc. commercial disposal facility near Hanford (WA). The package survived the test with full retention of contents and almost undetectable

Fig. 7. The High Integrity Container after being dropped from 25 feet onto a yielding surface at INEL.

damage, although a small chip of coating and concrete was knocked loose when the rigging cable struck the bottom edge of the container.

A penetration rod drop-test was conducted by dropping a rod of proper size, shape, and weight (as defined in 49 CFR, Part 173) from a height of 40 inches onto an HIC. Results showed no damage to the container. The impact produced a whitened impact zone on the concrete surface, measuring about 0.5 inch in diameter.

DISPOSAL DEMONSTRATION

The Disposal Demonstration focuses on disposing of one HIC/EPICOR-II liner at the commercial low-level waste disposal facility near Hanford. The liner selected for the demonstration (PF-18) was retrieved from interim storage, placed in an HIC (Fig. 8), sealed in situ with epoxy grout (Fig. 9), and the system cured and loaded in the CNS-14-190 transportation cask (Fig. 10). The radiation field outside the HIC before loading in the cask measured approximately 35 R/h. As soon as the Use Agreement between the State of Washington and General Public Utilities Nuclear Corporation (owner/operator of the Three Mile Island Power Station) is finalized, the HIC/EPICOR-II package will be transported from INEL to the U.S. Ecology disposal facility for final disposition. U.S. Ecology, under contract to EG&G Idaho, has been negotiating with the State of Washington for the Use Agreement. The State of Washington has received final concurrence on responses to comments solicited by the State from NRC on intended use of the HIC.

COMPARATIVE COST SUMMARIES

The authors evaluated costs of disposal operations using the HIC and EPICOR-II resins. Those costs are compared with costs of a disposal operation involving prior solidification of resins from a similar EPICOR filter system in an operating facility. The baseline assumptions in both cases are identified below. The estimates were developed with the cooperation of U.S. Ecology, Inc., Westinghouse Hittman, Inc., and Nuclear Packaging, Inc. The costs and assumed conditions for waste handling are based on reasonable assessments of what can be expected, but remain to be verified in practice.

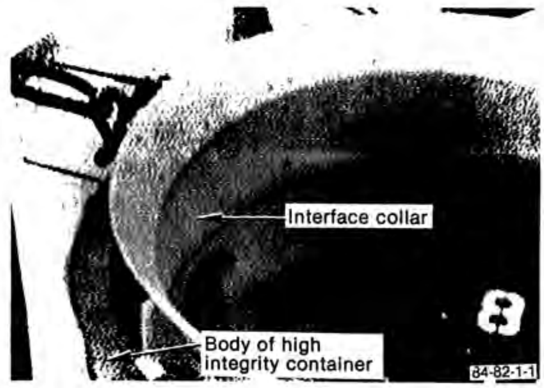

Fig. 8. EPICOR-II liner PF-18 placed in High Integrity Container as part of Disposal Demonstration at INEL.

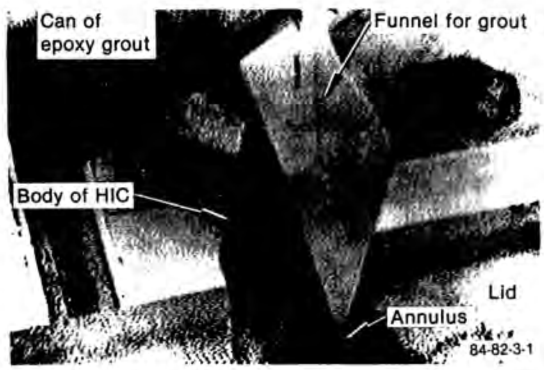

Fig. 9. Pouring epoxy grout into annulus between lid and body of the High Integrity Container during the Disposal Demonstration.

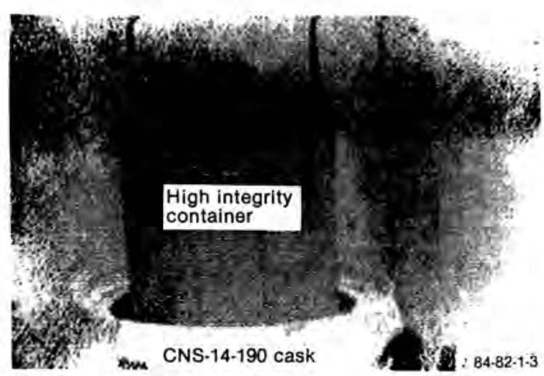

Fig. 10. High Integrity Container (with PF-18) being loaded into the transportation cask as part of the Disposal Demonstration.

Baseline Assumptions

HIC Option

- o 50 EPICOR-II liners with loadings of up to 2200 Ci/liner
- o All HIC preparation activities performed by a user employing low cost shielding arrangements (i.e., concrete shield vessels, pits, transfer bells) for semi-hands-on operations
- o Simplified dewatering procedure such as drain valve in liner
- o No liner or cask purging required
- o Preparation schedule for HIC loading, curing, and shipping based on two HICs per week
- o Transportation and cask rental costs for HIC option are about equal to those in the solidification option
- o 1750 ft^3 of resinous material not exceeding 1000 R/h at surface of each liner
- o HIC attenuates gamma radiation by factor of 10 or more depending on energy.

Solidification Option

- o 50 EPICOR-II liners with loadings to 2200 Ci/liner
- o Resins sluiced into vendor cans
- o 1750 ft^3 of resin materials results in 2200 ft^3 of material after solidification
- o Disposal of empty liners not estimated
- o Preparation schedule for solidification at a rate of one liner per day
- o No restriction on availability of shipping cask
- o No attenuation of radiation with solidification (each package reads 1000 R/h at surface)
- o Transportation and cask rental costs are about equal to those in the HIC option.

Costs

HIC Option

Purchase HICs, 50 HICs @ $8000/HIC	$400,000
Burial at U.S. Ecology, 50 HICs @ $8000/HIC	400,000
Shielding Equipment (one-time charge)	250,000
Expendable equipment for 50 liners@ $500/liner	25,000
Operations requiring 4 men @ 3 days/week	140,000
Estimated total for HIC disposal	$1,215,000

Solidification Option[b]

Hittman solidification charges	$268,000
Plenary setup charge at $25,000	
Canisters for solidified resins ($4200 each) at $210,000	
Equipment usage ($3200/month) at $8000	
Per liner solidification charge ($500 each) at $25,000	
Penalty for 1000 R/h packages	660,000
Penalty for excess curies/package	400,000
Disposal costs $14.50/$ft^3$	31,900
Disposal costs for empty liners	not determined
Estimated total for solidification option	$1,359,900

The reader is advised that the HIC loading operations in the DOE program are being performed in remote handling facilities at higher costs than indicated in the tabulated estimates. Moreover, extra operational steps are required (i.e., secondary dewatering and purging of liners) in keeping with requirements imposed by the duration of the TMI-2 cleanup and other considerations. The availability of shipping casks to accommodate the HIC would need resolution in future operations.

CONCLUSION

In conclusion, the EPICOR-II Research and Disposition Program at INEL provided the nuclear industry with a High Integrity Container for disposal of high specific activity radioactive wastes (like EPICOR-II materials) which heretofore have not been acceptable at commercial disposal facilities without first being immobilized in some matrix. When prepared and loaded in-field, the HIC appears viable and cost competitive with solidification of high activity resins and other filter media. Use of the HIC also provides the user with the option of loading filter systems more heavily and/or changing filter systems less frequently.

The High Integrity Container is presently being qualified for use with resins contained in EPICOR-II liners; adaptation of this container to other materials would require additional effort on the part of the user. The demonstration of the HIC at the commercial disposal facility near Hanford probably will be completed by mid-March 1984. That demonstration will be followed by a regular shipping campaign for the remainder of the EPICOR-II liners.

SELECTED REFERENCES

1. Reno, H. W. and Dodge, R. L. 1983. EPICOR-II Research and Disposition Program: FY-1982 Annual Report. U.S. Dep. Ener, EGG-2250.
2. ________________. 1982, The EPICOR-II Research and Disposition Program at the INEL. EG&G Idaho, Inc., EGG-M-19482 (Preprint).

b. Estimates provided by Westinghouse Hittman, Inc. in telephone conversations with H. W. Reno on 31 January and 1 February 1984. Disposal costs and penalties are those used at Barnwell, SC.