TMI-2: UNIQUE WASTE MANAGEMENT TECHNOLOGY

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ABSTRACT

The 1979 accident at TMI-2 severely damaged the reactor core and contaminated more than a million gallons of water. Subsequent activities created another million gallons of water. The damaged reactor core represented a new waste form and cleanup of the contaminated water and system components created other new waste forms requiring creative approaches to waste management. This paper focuses on technologies that were developed specific to fuel waste management, core debris shipping, processing accident generated water, and disposal of the resultant waste forms.

CORE DEBRIS SHIPPING

Fuel and structural core materials from the damaged Three Mile Island Unit 2 commercial reactor at Middletown, Pennsylvania, are loaded in specially designed fuel canisters and shipped by rail to the Department of Energy's Idaho National Engineering Laboratory (INEL) near idaho Falls, Idaho. Shipment is accomplished using shipping casks specially designed to withstand severe accident conditions and certified by the Nuclear Regulatory Commission. Loaded casks are carried by Conrail from Middletown to East St. Louis, Illinois, where the shipments will be transferred to Union Pacific for shipment to the INEL. Approximately 35-40 shipments will take place during the next 2½ years. At the INEL, the fuel and core materials will be studied and analyzed as part of the DOE's TMI-2 Accident Evaluation Program to provide a complete understanding of the TMI-2 accident sequence and a better understanding of nuclear fuel behavior during severe reactor accidents. The fuel and core materials will be placed in interim storage at the INEL until a national repository or other alternatives become available for ultimate disposal.

Rail shipment was selected as the means for transporting the TMI-2 fuel and core materials because it is safe, economical and will greatly reduce the number of shipments as compared to truck transport. Shipping by rail can accomplish the task with 35-40 shipments, whereas shipping by truck would require approximately 250 shipments. The routes proposed by the railroads utilize the highest quality tracks available. Conrail and Union Pacific were selected as the carriers because of their extensive experience in transporting radioactive materials. Both of these railroads consistently earn railroad industry recognition for safety of operations and maintenance of track.

In February of 1986, the governor's designee in the states of Pennsylvania, Ohio, Indiana, Illinois, Missouri, Kansas, Nebraska, Colorado, Wyoming and Idaho were notified of the shipping plan. Officials of DOE and EG&G Idaho, Inc., a prime DOE operating contractor at the INEL, will remain in contact with state officials to answer questions they might have about the shipping campaign.

Special Cask Design

Two specially designed NuPac 125B rail casks were designed and fabricated by Nuclear Packaging Inc. for the shipments. The casks are 280 inches long by 120 inches in diameter and will weigh about 90 tons when fully loaded. Each cask provides two separate vessels for containment. The stainless steel inner vessel includes a hub and spoke arrangement to support tubes which hold loaded fuel canisters. The outer vessel has a composite wall--three thick layers of metal. The inner shell of the outer vessel is a cylinder of one-inch thick stainless steel. The outer vessel shell is made of two-inch stainless steel. A four-inch void between the two shells is filled with lead for radiation shielding. Attached to each end of the outer vessel are large energy absorbers called overpacks. The overpacks are made of stainless steel and filled with foam that crushes upon impact, absorbing impact energy and protecting the cask body.

Another safety feature of the NuPac 125B is the thermal shield to protect the cask in the event of a fire. The thermal shield consists of wire wrapped around the outer shell, covered by a thin sheet of stainless steel welded over the wire. The resulting air gap between the thin sheet and the outer shell provides heat shielding, since air is such a poor conductor of heat energy.

The structural integrity of the NuPac 125B cask was demonstrated in tests conducted at Sandia National Laboratory. A series of five drop tests, to simulate severe hypothetical accident conditions, were conducted at the Sandia Transportation Technology Center. A 1/4-scale model of the NuPac 125B was constructed for the tests. Three 30-foot drop tests were conducted to simulate an accident where a cask would impact upon an unyielding surface, and two 40-inch drop tests onto a puncture rod were conducted to simulate a puncture accident. Analysis of the 1/4-scale model following the tests showed that the cask remained leaktight without significant structural damage. The tests demonstrated conclusively the safety of the NuPac 125B even in accidents involving severe impacts.

Canister for Material

Each cask will hold seven canisters containing fuel and core materials. The canisters, specially designed for the TMI-2 materials, are made of stainless steel and measure 150 inches long by 14 inches in diameter. The integrity of the fuel canisters was demonstrated in a series of full-scale 30-foot drop tests conducted at Oak Ridge National Laboratory. Analysis showed that the canisters experienced no serious damage to the exterior shell or internal structure.

The fuel canisters and the NuPac 125B shipping cask make up a shipping package that provides three separate levels of protection for the radioactive cargo. The extensive cask and canister testing program has demonstrated that the shipping packages will remain leak-tight even in the event of a sequence of severe accident conditions.

Thorough Inspection

Each shipment will be thoroughly inspected before leaving Three Mile Island. The Department of Energy, the Nuclear Regulatory Commission, and the Department of Transportation ensure that cask, cargo, and railcar meet all necessary federal requirements for safe shipment. A thorough inspection of the railcar, including cask tiedown, is conducted to show that the railcar meets safety requirements of the American Association of Railroads. In addition, radiation surveys are performed prior to transport. Prior to the start of shipments, track that the shipment will cross was thoroughly inspected by the Federal Railroad Administration.

PROCESSING CONTAMINATED WATER

Water cleanup was accomplished at TMI-2 using two systems, EPICOR II and the Submerged Demineralizer System (SDS).

The EPICOR II system, a three-stage ion-exchange cleanup system, was used to decontaminate water in the Auxiliary Fuel Handling Building. The first stage, called prefilters, captured most of the contaminants and resulted in the generation of 50 highly loaded liners. The second and third stages, called demineralizers, further "polished" the water and resulted in the generation of 22 demineralizer liners. These 22 had loadings that allowed their burial at a commercial burial site. However, the 50 highly loaded prefilters required special handling.

At TMI-2, a solid waste staging facility was constructed for temporary storage of the prefilters. Because the prefilters generated radiolytic gases, a Prototype Gas Sampler was developed to sample, purge, and inert the liners. The gas sampler was part of a support facility that included a block house (for personnel protection), a remote control room, and a nitrogen supply. The prefilters were shipped to INEL in existing shipping containers, where they were temporarily stored in newly built silos inside the hot cells. High Integrity Containers (HICs) were designed and fabricated, primarily of structural steel and concrete, with a design life of at least 300 years. New specially designed shipping containers were used to transport the HICs to a commercial burial site where they were buried as Class C waste.

Early processing of contaminated water using the EPICOR II reactor demineralizer system showed that many hundreds of EPICOR liners would be necessary to decontaminate the total volume of water. To reduce the waste volume being generated, a much more selective Submerged Demineralizer System (SDS) was developed. Some unique aspects of the SDS include:

- An optimum mixture of inorganic zeolites was chosen to remove ions of cesium and strontium (the major contaminants) from a borated water solution.
- The resulting 19 highly loaded SDS liners represented a new waste form requiring special handling, shipping and storage.
- Radiolytically generated gases were managed with a new vacuum outgassing system and with the addition of catalysts to recombine hydrogen and oxygen within the liners.
- Three liners were used in a successful demonstration of zeolite vitrification, while the remaining 16 are retrievably buried at Hanford in concrete overpacks. One SDS vessel is in long-term monitoring as part of the Monitored Retrievable Burial Demonstration Program.

CONCLUSIONS

The development of waste management technologies is an on-going process at TMI-2. A number of significant advances were made including:

- Development of High Integrity Containers suitable for stabilizing and disposal of Class B and C waste
- Application of technology to package special high activity waste forms and control radiolytically generated gases
- Calculational methods developed to predict the build-up of radiolytically generated gases in radwaste
- Selective removal of isotopes from contaminated water using inorganic zeolites
- Successful program to vitrify zeolites and perform retrievable monitored storage on high activity waste
- Development of special equipment to remotely manage spent fuel waste, high activity waste and abnormal waste forms

Following is a listing of those waste forms and technology areas developed or addressed during the TMI-2 program. For further information contact: U.S. Department of Energy, P.O. Box 88, Middletown, Pennsylvania 17057.

Fuel Debris

- Damaged spent fuel assemblies and reactor components defueling tools,
- remote defueling techniques,
- fuel debris canister drop test program,
- catalyst recombiner test program,
- cask provides double containment,
- cask vessel "leaktight" seals per ANSI N14.5,
- quarter scale cask drop test program,
- benchmarking of structural analysis with drop test results,
- dry cask loading equipment development,
- internal shield plugs,
- cask loading collar,
- shielded transfer cask,
- seismic restraint system,
- cask hydraulic lift assembly,
- routing analyses for transport safety and risk,
- INEL response team,
- time and motion studies on rail transport.

EPICOR Wastes

- Organic resins,
- contaminated water processing,
- waste volume reduction techniques,
- resin capacity optimization,
- remote handling techniques,
- shielded transfer bell,
- dry storage at TMI,
- radiation effects on resins,
- degradation benchmarking,
- liner integrity and longevity studies,
- remote combustible gas sampling,
- remote gas control equipment,
- high integrity container (HIC) development,
- waste form stability for 300 years,
- hydrophobic gas venting,
- commercial disposal,
- resin solidification studies,
- leach rate and soil transport studies,
- calculations to predict gas generation in containers,
- compliance with NRC IE Notice 84-72,
- utility training program for gas generation calculations.

Submerged Demineralizer System Wastes

- Inorganic zeolites,
- highly contaminated water processing,
- waste volume reduction,
- radionuclide loading optimization techniques,
- remote handling techniques,
- vented underwater storage,
- radiation insensitivity of zeolites,
- combustible gas generation measurements,
- remote gas control equipment,
- catalyst materials for gas recombination,
- catalyst tests for normal and accident transport conditions,
- vacuum system for remote dewatering,
- monitored retrievable disposal demonstration,
- remote handling techniques,
- long-term temperature and pressure measurements,
- zeolite vitrification demonstration program,
- in-canister melting process,
- leach testing of vitrified waste,
- waste management strategies,
- selective Cs and Sr processing systems,
- inorganic zeolite selective isotope removal,
- better utilization of 10CFR61 limits.

Make-up and Purification System Demineralizer Resins

- Accident contaminated organic resins,
- highly loaded with fission products and TRU,
- robotic characterization techniques,
- video surveys for vessel/piping physical damage,
- contamination swipes,
- visual assistance for radiation detector placement,
- radiation measurements for fission products and fuel,
- compton recoil gamma spectroscopy (SiLi detector),
- Solid State Track Recorders (SSTRs)
- Gamma-neutron detector (Be-fission chamber),
- ion chamber detector,
- thermoluminescent detectors,
- resin damage scoping tests-temperature and irradiation,
- remote gas, liquid, and solid sampling,
- sample analysis and material characterization,
- elution process flowsheet simulation,
- remote vessel decontamination,
- elution equipment development and testing,
- use of existing plant system for future resin removal,
- DOE acceptance of resins as an abnormal waste,
- TRU removal process development program.