TMI-2 WASTE MANAGEMENT EXPERIENCE

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ABSTRACT

One of the main areas of both regulatory and public concern surrounding the cleanup at TMI-2 was the packaging, shipment, and disposal of radioactive waste. Through the end of 1989, approximately 183,200 cubic feet of radioactive waste was disposed of as a result of cleanup activities. To transport this volume to various disposal locations required in excess of 500 radioactive material shipments involving over 7,500 separate waste containers. The majority of these shipments required use of NRC certified shipping containers while the remainder were shipped by either flatbed or closed van trailers.

In order to provide a comprehensive documentation of the important aspects of the waste management activities resulting from the TMI-2 recovery program, GPU Nuclear Corporation (GPUN) and the Electric Power Research Institute (EPRI) established a program of Technology Transfer in the area of waste management. The report that was prepared as a result of this effort provides a historical perspective by documenting the volume and characteristics of the waste that was generated. The report also discusses numerous waste management problems identified during the cleanup, and solutions developed by the TMI-2 Staff in handling the problems that arose.

TMI-2 Waste Generation

One area of major concern for both regulators and the public surrounded the shipment and disposal of the radioactive waste generated as a result of the cleanup. Through the end of 1989, approximately 183,200 cubic feet of radioactive waste was shipped for direct disposal of as a result of these activities. The vast majority of this waste was sent to the commercial radioactive waste disposal site at Hanford, Washington. Beginning in late 1987, a small volume was also sent to the commercial disposal site at Barnwell, South Carolina. Prior to this time, the Barnwell Site was prohibited from accepting any TMI-2 accident generated waste by order of the Governor of South Carolina.

To transport this volume to the disposal sites required in excess of 500 radioactive material shipments involving over 7,500 separate waste containers. The majority of these shipments required use of Nuclear Regulatory Commission (NRC) certified shipping containers, while the remainder were shipped by either flatbed or closed van trailers.

Nearly 138,000 cubic feet of waste disposed of as a result of the cleanup was classified as dry activated waste (DAW). This included such material as paper, plastic, wood, metal, concrete and equipment which was generated as a result of decontamination activities within the TMI-2 plant. The remaining 45,200 cubic feet resulted from processing and/or reprocessing accident water or the solidification of sludges and other liquids which were generated during the cleanup.

Beginning in mid-1988, GPUN began to use the services of a supercompaction vendor to process some DAW. During the last half of 1988 and 1989, 7 shipments consisting of 163 boxes of unprocessed DAW were shipped for supercompaction. Since not all of this waste was processed for disposal before the end of the year, none of this volume is included in the 169,000 cubic feet of commercial disposal volume.

During the accident, large volumes of high specific activity water escaped from the primary coolant system and spread throughout the TMI-2 facility contaminating large areas of the plant and mixing with other water sources. In the post-accident cleanup and processing of this water, a large number of demineralizer process vessels were generated that were not acceptable for commercial disposal because of specific activity or waste form. To ensure that Three Mile Island did not become a long term waste storage location, the U.S. Department of Energy (DOE) agreed to accept for long term storage and eventual disposition accident generated waste that was not suitable for commercial disposal.

Between 1981 and 1988, 73 shipments containing 3,071 cubic feet of waste was transferred to the DOE. This material consisted of 19 highly loaded Submerged Demineralizer System (SDS) vessels which were used as part of DOE's High Level Waste Research & Development (R&D) Program, 50 EPICOR II Prefilter vessels used by the DOE as part of a High Integrity Container (HIC) Demonstration Program, and 3 Greater Than Class C SDS cartridge filter liners which were accepted for long term storage and ultimate disposal by the DOE. In addition, one shipment containing cartridge filters installed in the Makeup and Purification System prior to the accident was sent to the DOE for use in various R&D programs.

Of the waste volume shipped to commercial disposal sites subsequent to implementation of 10 CFR Part 61 in 1984, the following table summarizes the disposition by waste class:

Waste Class	Volume	Percent
Class A	82,738	92.7%
Class B	4,043	4.5%
Class C	2,389	2.7%
GTCC	112	0.1%

TMI-2 Waste Streams

During the TMI-2 accident a number of conditions resulted in the release of radionuclides from the reactor fuel. Once released, these radionuclides flowed with the water also released from the reactor vessel throughout the TMI-2 facility. As a result, the activity level varied in different levels and areas of the plant., and DAW taken from these different areas exhibited large variations in both specific activity and isotopic distribution.

Unlike normal operating reactor facilities, TMI-2 could not develop a single DAW waste stream but had to develop several standard waste streams for DAW based on location and the ratio of Cs^{137} to Sr^{90}. The standard DAW waste streams developed at TMI-2 included Normal Plant (Cs^{137} to Sr^{90}: 12 to 1), Reactor Building and Make-up and Purification System (Cs^{137} to Sr^{90}: 1.5 to 1), Defueling (Cs^{137} to Sr^{90}: 0.32 to 1), and Seal Injection.

Similarly, GPUN could not take the approach of identifying wet waste streams by the normal method of processing systems. At TMI-2, two main processing systems were in use. These systems were the Submerged Demineralizer System (SDS) and EPICOR-II liquid processing systems. During the course of the cleanup these systems went through numerous changes in configuration. The activity of the waste generated as a result of operations of these systems was dependent on many factors including the source of water being processed. Consequently, activity determinations for these wet wastes were a result of individual sampling of the influent and effluent of the water being processed through the demineralizer liner.

MAJOR ISSUES

High Sr^{90} Concentration

With implementation of 10 CFR Part 61, numerous special waste management problems were created at TMI-2. The largest problem was a direct result of the large concentration of Sr^{90} that resulted from the accident. Sr^{90} was a predominant isotope in the TMI-2 waste stream, and was exceeded only by Cs^{137} in concentration. Under 10 CFR Part 61, Sr^{90} had a very low Class A limit (0.04 curies/cubic meter). This caused large quantities of waste that were buried as ordinary waste under the old (pre-10 CFR Part 61) rules to now require stabilization. To meet this new challenge, GPUN was required to develop numerous waste streams based on the Cs^{137} to Sr^{90} ratio, perform selective packaging of dry waste, establish positive control over liquid processing and submit an exemption request to exceed 10 CFR Part 61 limits.

Because of the low concentration of Sr^{90} allowable in Class A waste, GPUN had to be extremely careful in the packaging of DAW. Numerous separate waste streams were required because of the different concentration of Sr^{90} throughout the plant. As part of Part 61 classification program, GPUN used a dose to curie conversion factor method. Conversion factors were developed for each standard waste stream based on the different isotopic distribution. Additional factors were developed considering the package size, waste density (i.e., compacted/noncompacted) and other appropriate factors.

Standard containers evaluated included 55 gallon drums, B-25 metal LSA boxes, and Ferralium HIC's in both the 50 cu.ft. and 190 cu. ft. versions. Since TMI-2 had a drum compactor for DAW, separate conversion factors were developed for 55 gallon drums based on whether the waste was compacted or not. For noncompacted waste, graphs were developed depending on container weight (related to waste density) which established the correct conversion factor to be used. Even with this large assortment of waste streams, special care had to be taken when new work or plant areas were started. Because of different Cs^{137} to Sr^{90} ratios many special waste curie estimates also had to be developed.

With the low allowable Sr^{90} level, GPUN was also not able to take advantage of such volume reduction techniques as supercompaction. Supercompaction of most TMI-2 waste would result in a change in waste class from Class A to Class B which would then require stabilization. In order to make the most effective use of the burial containers, GPUN turned to selective packaging. Selective packaging became an important practice at TMI not only because of the low Sr^{90} level for waste classification, but also because of the low Sr^{90} level for LSA transportation determination.

To insure regulatory compliance, a detailed approach was developed for use with selective packaging. This approach was developed after careful review of the NRC's Branch Technical Position paper on Waste Form, modifications made to that BTP by the burial site states, and conversations with both NRC and state officials. The key in the development of this approach was to do what was reasonable.

Sr^{90} concentrations not only caused a problem in DAW, but it also caused problems in the wet waste area. In 1981 with the introduction of the Submerged Demineralizer System, the Epicor II demineralizer system was reconfigured to process lower specific activity water. A process control program was developed to ensure that these portable demineralizers were kept below 1 microcurie/gram for isotopes with a half life greater than five years. This limit was the limit above which resins were required by the burial states to be solidified or placed in a HIC. With the implementation of 10 CFR Part 61, an added factor had to be considered in that the Sr^{90} Class A limit was 0.04 microcuries/cc.

Based on a previous analysis performed as a result of the proposed 10 CFR Part 61 limits published in the Federal Register, GPUN determined that restricting these Epicor II liners to this Sr^{90} level would result in ten times as many liners being generated. If solidification was chosen as the compliance method, an additional 20% to 30 % waste volume would be generated. Because of this increased burial volume, along with its associated cost, GPUN requested a variance first from the NRC prior to Part 61 implementation and then from the State of Washington after Part 61 became effective. Although the NRC rejected GPU's variance request prior to Part 61, the request was evaluated by the NRC staff. Using the same computer program used in developing the Part 61 limits, NRC determined that the Class A limit (if only the arid Hanford site was considered) would have been 24 microcuries/cc. In disapproving GPUN's request, it was suggested that an application be made directly to the State of Washington after Part 61 was implemented.

After implementation of 10 CFR Part 61, GPUN made a formal request to the State of Washington for a variance. The variance requested that for Epicor II resin liners that the Class A limit for Sr^{90} be increased to one (1) microcurie/cc instead of the current 0.04 microcurie/cc. GPUN chose this relatively low level because the Epicor-II liners would start to show chemical break hrough at about this level of Sr^{90}. The state sent the request to the NRC who act as Washington's technical advisor. At the same time, GPUN requested a variance from the requirements of 10 CFR Part 20.311 which required NRC licensees to classify waste in accordance with Part 61 prior to making shipments to a disposal site. The NRC returned this request stating that GPU should resubmit after an approval from the state was received. After a considerable review time by the NRC staff, a recommendation was made to the state to approve the request. Following this recommendation the State of Washington approved GPUN's variance. A variance was then again requested from the NRC as it related to 10 CFR 20.311 based on the Washington approval and was quickly received. As a result of these two variances, a considerable volume of waste was saved.

Barnwell Prohibition

On the basis of verbal conversations between GPU Nand the State of South Carolina in 1979, it was determined that the state did not want any waste from the TMI-2 accident buried in South Carolina. South Carolina's position was based upon three primary concerns. The state's main concern was the expectation of very large waste volumes resulting from cleanup operations at TMI-2. At the time, no one knew how much radioactive waste would be generated as a result of the cleanup effort. The next concern was in the area of TRU contamination within the waste from TMI. Since Barnwell was limited to less than 10 nanocuries per gram transuranics, and with the fuel failures at TMI-2, the state was concerned that additional TRU would end up at Barnwell.

The last concern was in the area of high specific activity waste expected from TMI-2. It was believed that as the cleanup progressed, large quantities of waste, higher in specific activity than most current utility waste, would be generated. It must be remembered that at this time (1979) there was no federal limit to define what waste was capable of being disposed of by shallow land burial.

The result of these concerns was a decision by the Governor of South Carolina to prohibit the disposal of TMI-2 accident generated waste at the Barnwell facility. The prohibition was only issued verbally, and GPU elected to comply with the wishes of the Governor. Waste generated from the operations of TMI Unit 1 and certain Pre-accident TMI-2 waste was not covered by this prohibition and shipments of these materials were disposed of at the Barnwell site.

Due to the ban on disposal at Barnwell, all Unit 2 waste generated as a result of the cleanup (prior to 1986) was disposed of only at the Hanford site. The Beatty site was never used because the State of Nevada let it be known that it also did not want any TMI-2 accident waste. Being limited to only one site did cause certain problems in disposal. The main impact was to greatly increase the cost of transportation, especially when shielded equipment was used. In some areas such as the flatbed shipment of LSA boxes, shipments to Hanford cost less overall due to the higher disposal charges at the Barnwell site.

In 1986 a new governor took office in South Carolina. Since the conversations with the previous governor, there had been some notable changes in the regulations for low level waste disposal. The NRC had published 10 CFR Part 61 which not only established a limit on what waste was suitable for commercial shallow land disposal, but also established a waste classification system with prescribed stability requirements based on waste class. In addition, Congress had established a national volume allocation program for all nuclear utilities in passage of the Low Level Waste Policy Amendments Act of 1985. Since most of the previous Governor's concerns had been addressed either through NRC or Congressional action, GPUN requested the state agency controlling the Barnwell site to permit GPUN to dispose of waste at Barnwell. Based on a review by this agency and their conversations with the new Governor's office, GPUN was allowed to dispose of low level radioactive waste at Barnwell. The first shipment consisting of 55 compacted drums departed TMI in August of 1987.

Stabilization Requirements at Hanford

10 CFR Part 61 affected TMI through its stability requirements. Until late 1987, GPUN was restricted to burial at the Hanford disposal site as discussed above. Although HIC's had been in use for some time at Barnwell, no HIC had been approved for use at Hanford. Because of the deeper burial depths at Hanford the HIC's which had been approved for Barnwell were not suitable, nor approved for use, at the Hanford site. With the waste forms generated at TMI, GPUN and the DOE worked with a commercial vendor to obtain the first licensed HIC authorized for burial at the Hanford site. Although this HIC license was of limited application in that it only approved the burial of 48 Epicor II prefilter liners, it did open the way for additional HIC's at a later date.

As a result of the accident, TMI-2's waste contained a high concentration of Sr^{90}. In addition, certain waste streams also contained a high concentration of TRU material. With the implementation of the waste classification system under 10 CFR Part 61, certain DAW generated at TMI-2 was either Class B or C and, therefore, required stabilization. The two authorized methods for stability were solidification/encapsulation or disposal inside a HIC. The first commercially submitted HIC application to the State of Washington was a metal container made of a specialty stainless steel alloy called Ferralium. These containers came in 50, 190, and 210 cubic foot sizes. Once the application was submitted for these containers, GPUN requested from the State, along with a few other plants, interim authority to use these containers for the disposal of Class B and C DAW while the application was being reviewed.

Interim authority was granted by the State of Washington for use of these containers. At first only the 50 cubic feet containers were approved. Interim authority was granted by the state only on a quarterly basis, for an allotted number of containers for each requesting utility. Interim authority had to be requested each quarter with a separate letter being issued by the State. This authority also stated the material that was authorized for each container under the interim authority. In addition, the State established a 25% of Class C limit on the containers. This limited GPUN to 25 nanocuries per gram of TRU which left certain waste that could not be disposed of under this interim authority. The first HICs packaged with DAW under this interim authority were shipped to Hanford in 1984.

In April 1988 the NRC had finished its review of the Techincal Evaluation Report for these High Integrity Containers. Based on its review the NRC concluded that these HIC's met or exceeded all of the requirements of 10 CFR Part 61 and the recommendations of the NRC Technical Position Paper on Waste Form. As a result of the NRC review and approval, these HIC became fully licensed HIC's not only at Washington but also at the other two sites in Nevada, and South Carolina. The 25% limit of Class C TRU limit was removed from the final license.

TRU Limits

10 CFR Part 61's impact on TMI-2 generated waste was not all negative. Part 61 did increase the total concentration of TRU authorized for commercial shallow land disposal. Prior to Part 61 a limit of 10 nanocuries/gram was place on TRU's. Part 61 increased that limit to 100 nanocuries/gram for most TRU's with higher limits for Pu-241 and Cm-242. This had a very beneficial effect on GPUN which had large TRU concentrations in certain waste streams. This beneficial effect was some what negated by Washington's failure to accept these new limits initially, and when the limits were accepted specific state approval was required for each package which exceeded the class A TRU limit (10 nCi/gm). This relief did however, allow GPUN to dispose of material commercially that would have had to go to DOE at considerable cost.

Greater Than Class C Waste

As a result of the Memorandum of Understanding between NRC and DOE that identified DOE's role in the acceptance of waste for which commercial disposal was not available, negotiations began with GPUN on contractual requirements for the acceptance by the DOE of waste that had no R&D value, but could not be disposed of at commercial facilities. This waste was termed "Abnormal Waste". A key principle of the MOU was that this type of material would be accepted on a cost reimbursable basis to the DOE, where GPUN would be responsible for all costs expended by the DOE in interim storage, monitoring, and ultimate disposal (including any required processing). From this contract, a process consisting of an initial payment to the DOE and the establishment of a trust fund that would be available for future expenses, was adopted.

Abnormal waste would be shipped to INEL for interim retrievable storage for an indefinite period. For purposes of planning it was assumed that this period would be 30 years. The DOE developed an interim storage plan which called for outside storage in a concrete containment shield on a concrete pad. The containment shield was sized to accept multiple drums and/or SDS vessels or a single 50 cubic foot liner. It was assumed that any abnormal waste would be packaged in one of these three types of packages.

Packaging operations were to be completed by GPUN and a safe and legal package would be presented to the DOE. As with most waste sent to the DOE, ownership of the abnormal waste would be transferred to the DOE at Three Mile Island and the DOE would be the shipper of record. However, all regulatory agencies would continue to hold GPUN solely, fully and legally responsible for regulatory compliance as it related to the packaging and delivery of the material to the carrier just as if GPUN was the shipper of record.

In determining an estimated cost for DOE to accept the abnormal waste, it was necessary to develop an anticipated volume of waste that would require DOE disposal. Based on the best information available at the time, it was estimated that approximately 300 cubic feet of abnormal waste would require DOE disposal. Certain costs such as the construction of the concrete pad and the concrete shield containers were not directly related to the volume of waste. GPUN paid these costs up front. Based on DOE's estimate, a cost of $13,300 (1984 dollars) per cubic foot of waste was to be charged to GPU Nuclear. (Note: this cost was based on the actual volume of waste material only, and not on the container volume). Part of the cost would be paid directly to the DOE and part would be placed into a trust fund to cover later expenses. Although GPUN wanted a maximum upper limit, none was provided by DOE. If the final cost exceeded the $13,300 per cubic foot cost, then GPUN would be required to makeup the difference. On the other hand if the total cost was less than $13,300, then the excess in the trust fund or in DOE's possession would be returned to GPUN.

At the time of these negotiations and subsequent contract, the DOE had no legal responsibility for Greater Than Class C Waste. With passage of the 1985 Amendment to the Low-Level Radioactive Waste Policy Act, Congress made the disposal of this material a federal responsibility and charged DOE with the responsibility for the transportation, interim storage and disposal of Greater Than Class C Waste generated by the commercial sector. In DOE's subsequent report to congress, as required by the Act, DOE estimated that the transportation, interim storage in a concrete shield on a concrete pad and the ultimate disposal of Greater Than Class C Waste would be only approximately $8,800 (in 1986 dollars).

SNM Accountability

One of the earliest problems that required a solution prior to fuel shipments was in the area of Special Nuclear Material (SNM) accountability. Under NRC regulations contained in 10 CFR Part 70, GPUN was required to account for all SNM (plutonium, U233 and U235) in its possession to the nearest gram weight. DOE had similar regulations on gram accountability for SNM in its possession. At most reactor plants this is a rather simple task. Almost all SNM is contained in sealed fuel pellets within the fuel rods. Using approved computer programs the amount of SNM which is created as a result of the reactor's operation can be accurately determined. At TMI-2 however, there was a large amount of damage to the fuel during the accident which resulted in the release of SNM from the protective cladding. This allowed the spread of SNM material throughout the plant and made gram accountability impossible.

Numerous options were therefore considered for SNM accountability. One of the most popular was "One Core, More or Less". Under this philosophy GPUN would transfer accountability to DOE as "one each core" with no effort to determine the quantity of SNM by gram weight in each shipment. Another option proposed conducting a detailed analysis using experimental equipment to determine the gram quantity of SNM contained in each spent fuel canister prior to its delivery to the DOE for shipment. Although this type of equipment had been used successfully by DOE in a laboratory environment, it had not been used in an operating facility under the restrictions imposed by such a field location. Another option suggested the DOE do a detailed analysis of each canister after its arrival at INEL. Transfer documentation (DOE/NRC Form 741) would be filled out after the fact based on this analysis. As with most recovery operations at TMI-2, the final proposed solution ended as a hybrid of the various possible technical alternatives.

Based on an NRC approved exemption to the requirements contained in 10 CFR Part 70, no formal SNM accountability on a gram basis would be required at the time of shipment. Each spent fuel shipment would be covered by a DOE/NRC Form 741 with all other required information which was available entered. After defueling operations were concluded, GPUN would conduct a Post Defueling Survey. The purpose of this survey would be to determine the total quantity of SNM that was left at TMI-2. This survey would use available state-of-the-art techniques and both the procedures for conducting the survey along with the survey results would be approved by the NRC. The results of this survey would then establish the quantity of SNM left at TMI-2.

Based on available computer programs such as ORIGIN, the total quantity of SNM on hand at the time of the accident could be determined. If the total quantity of SNM that remained at TMI-2 based on the post defueling survey plus the total quantity of SNM shipped to other licensees and covered by DOE/NRC Form 741's, plus the total quantity of SNM lost by radionuclide decay, was subtracted from the quantity of SNM on hand at the time of the accident based on ORIGN, then the result would be the total quantity of SNM transferred to the DOE as part of the core contract. This represented the philosophy that was finally agreed upon by DOE, NRC, and GPUN.

EPRI Report

An EPRI report was prepared during 1989 to consolidate the technical and operational radioactive waste information available at TMI-2 into a single, comprehensive summary document. Past shipping records were thoroughly reviewed in order to present definitive volumes of waste shipped since March 1979, operational performance of each liquid processing system was evaluated and many of the technical and regulatory influences on waste management activities at TMI-2 were documented.

The result is a single reference which contains details on the volumes, form, type and characteristics of radioactive waste shipped from TMI-2 from 1979 through 1989. Issues affecting TMI-2 waste disposal, such as disposal site availability, 10 CFR Part 61, interim storage and federal government research activities are addressed. Since cleanup activities at TMI-2 were not fully complete at the time of preparation, this report presents only an interim status of waste management activities. A final report documenting the complete decontamination and defueling of TMI-2 may be published at a later date.

The primary objective of this report is to provide comprehensive documentation on all the important aspects of radioactive waste management which have resulted from the TMI-2 Recovery Program. The March 1979 accident presented many unique problems to the waste management organization at TMI-2, many of which had not been previously experienced in waste management activities throughout the rest of the commercial nuclear industry. This report documents these difficult and unique problems and examines GPUN's solutions. In addition, this report provides a historical perspective to the recovery period by documenting the actual volumes and characteristics of radioactive waste that was generated.

To meet these objectives, the emphasis of this report has been to provide as much information as possible in the form of tabulated data, figures, chronological plots, and similar pictorial methods. In addition to providing raw data, this report provides a detailed analysis and interpretation of the data. Areas such as waste generation by type and source, packaging method, liquid processing system performance, interim storage, shipment methods, disposal, and the disposition of the damaged reactor fuel are presented. It is anticipated that the final report will be published by EPRI by mid-1990.