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Vol. 1

Final Programmatic
Environmental Impact Statement
related to decontamination and disposal of radioactive wastes resulting from March 28, 1979, accident Three Mile Island Nuclear Station, Unit 2

Docket No. 50-320

Metropolitan Edison Company
Jersey Central Power and Light Company
Pennsylvania Electric Company

U.S. Nuclear Regulatory Commission

Office of Nuclear Reactor Regulation

March 1981

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A Final Programmatic Environmental Impact Statement (PEIS) related to the decontamination and disposal of radioactive wastes resulting from the March 28, 1979, accident at Three Mile Island Nuclear Station, Unit 2 (Docket No. 50-320) has been prepared by the Office of Nuclear Reactor Regulation of the Nuclear Regulatory Commission in response to a directive issued by the Commission on November 21, 1979. This statement is an overall study of the activities necessary for decontamination of the facility, defueling, and disposition of the radioactive wastes. The available alternatives considered ranged from implementation of full cleanup to no action other than continuing to maintain the reactor in a safe shutdown condition. Also included are comments of governmental agencies, other organizations, and the general public on the Draft PEIS on this project, and staff responses to these comments.

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COVER SHEET AND ABSTRACT

1. Proposed Action and Location:

   DECONTAMINATION AND DISPOSAL OF RADIOACTIVE WASTES RESULTING FROM THE MARCH 28, 1979, ACCIDENT AT THREE MILE ISLAND NUCLEAR STATION, UNIT 2, LOCATED IN LONDONDERRY TOWNSHIP, DAUPHIN COUNTY, PENNSYLVANIA.

2. Messrs. Oliver Lynch and Paul Leech are the Project Managers for this statement. They may be contacted at the Three Mile Island Program Office, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555 or at 301-492-7258.

3. A Final Programmatic Environmental Impact Statement (PEIS) related to the decontamination and disposal of radioactive wastes resulting from the March 28, 1979, accident at Three Mile Island Nuclear Station, Unit 2 (Docket No. 50-320) has been prepared by the Office of Nuclear Reactor Regulation of the Nuclear Regulatory Commission in response to a directive issued by the Commission on November 21, 1979. This statement is an overall study of the activities necessary for decontamination of the facility, defueling, and disposition of the radioactive wastes. The available alternatives considered ranged from implementation of full cleanup to no action other than continuing to maintain the reactor in a safe shutdown condition. Also included are comments of governmental agencies, other organizations, and the general public on the Draft PEIS on this project, and staff responses to these comments.

SUMMARY

This programmatic environmental impact statement (PEIS) by the staff of the U.S. Nuclear Regulatory Commission (NRC) is an overall study of the activities necessary for decontamination of the facility, defueling, and disposition of the radioactive wastes which resulted from the accident on March 28, 1979, at Unit 2 of the Three Mile Island Nuclear Station (TMI-2). The following summary has been prepared by the staff for those who prefer to follow the main themes of the statement without referring to the technical descriptions, calculations, data, and other details that provide a basis for assessing the cleanup alternatives and their impacts.

In response to a directive issued by the Commission on November 21, 1979, to prepare this PEIS, the staff has reviewed the status of the contaminated facilities and their surroundings, surveyed the methods available to carry out the cleanup operations, and analyzed the impacts of the cleanup activities on the environment, members of the public, and plant workers. In summary, the staff has reached the following major conclusions and findings (see Section 12 for a complete listing):

- Full cleanup of the TMI-2 facilities should proceed as expeditiously as reasonably possible to reduce the potential for uncontrolled releases of radioactive materials to the environment.

- Existing methods are adequate, or can be suitably modified, to perform virtually all of the necessary operations without incurring environmental impacts that exceed acceptable limits; where special tools or methods are found necessary for operations such as defueling, engineering expertise is available to cope with such requirements.

- An early decision to decommission TMI-2 will have very little effect on the choice of alternatives for the cleanup tasks because most of the same tasks must be performed in order to remove and dispose of the damaged fuel.

- The time needed to complete the cleanup will be 5 to 9 years from the time of the accident.

- The most significant environmental impact associated with the cleanup will result from the radiation doses received by the entire work force from cleanup activities. These doses are estimated to be in the range from 2000 to 8000 person-rem.

- It is predicted that less than one additional cancer death attributable to exposure to radiation will occur among the entire work force engaged in cleaning up TMI-2. (The death rate from cancer among the U.S. population averages approximately 200 deaths per 1000 people.) Not more than two additional genetic defects are expected in descendents of exposed workers. (Among the U.S. population, approximately 60 genetic defects can be expected per 1000 people.)

- Throughout the cleanup, any anticipated releases to the environment must be controlled by the licensee in accordance with the staff's proposed effluent criteria to conform to the individual dose design objectives listed in 10 CFR Part 50, Appendix I, as mandatory limits. The total-body dose design objectives are 15 mrem/year from airborne particulate releases and 3 mrem/year from liquid releases. Implementation of the criteria in this manner is more stringent than for normally operating plants in recognition of the condition of TMI-2.

- Assuming the cleanup is conducted in accordance with the staff's proposed effluent criteria, the staff estimates that, for the entire cleanup, the cumulative total body dose to the maximum exposed individual offsite will range from 0.8 to 2.3 mrem for gaseous effluents.

- An individual offsite receiving the maximum estimated dose resulting from atmospheric releases during the entire cleanup (0.8 to 2.3 mrem) would incur an estimated increased risk of dying from cancer of between 1 in 2 million and 1 in 600,000, and an increased risk of a genetic effect to offspring over the next five generations of between 1 in 300,000 and 1 in 100,000.

- Assuming the cleanup is conducted in accordance with the staff's proposed effluent criteria, the total cumulative dose received by the entire population within a 50-mile radius of TMI-2 due to both gaseous and liquid releases would range from 10 to 30 person-rem for the entire cleanup. This is a small fraction (about .01%) of the background radiation dose received annually by the population from causes other than releases from TMI (annual population background radiation dose = 116 mrem/yr $\times$ 2.2 $\times 10^6$ people = 255,000 person-rems).

- The psychological distress caused by the accident and operations necessary to proceed with the cleanup has declined, but there is a potential for temporary increases in distress as various cleanup activities are undertaken.

- The contaminated accident-generated water in the reactor building basement (sump) and in the reactor primary system cannot be left in its present condition and location if the cleanup effort is to proceed. Removal of this contaminated accident water will reduce the airborne and direct radiation levels in the building sufficiently to permit other cleanup operations to be accomplished with greater safety.

- Treatment of the contaminated accident water will transform the entrained radioactivity from its current mobile state to a more manageable form by concentrating and immobilizing the activity by an appropriate process. The cleanup activity will eliminate the risks associated with leaving the contaminated accident water radionuclide inventory in the mobile unprocessed state.

- A decision on the ultimate disposal of the processed water can be deferred until after the water has been processed. Then, the concentration of radionuclides remaining in the water will be low enough for the water to be stored safely onsite until the disposal decision is made. Processing the water to immobilize most of the radionuclides and storage of the processed water will not foreclose any reasonable options for disposition of the water or concentrated wastes.

- The staff regards the transfer of high-specific-activity waste to facilities operated by the Department of Energy to be the most appropriate course of action for processing and final disposal of this material. In the interim, radioactive fuel and high-specific-activity wastes from TMI-2 must be packaged and will have to be stored at the site temporarily until a suitable disposal site is established elsewhere. No significant environmental effects are expected from these activities.

- The staff has concluded that TMI should not become a permanent radioactive waste disposal site. If the damaged fuel and radioactive wastes are not removed, the Island would, in effect, become a permanent waste disposal site. The location, geology, and hydrology of Three Mile Island are among the factors that do not meet current criteria for a safe long-term waste disposal facility. Removing the damaged fuel and radioactive waste to suitable storage sites is the only reliable means for eliminating the risk of widespread uncontrolled contamination of the environment by the accident wastes.

The staff has based its analysis on the licensee's plans,* where they are available, as well as on alternatives the staff has independently developed and assessed. The alternatives considered are, in general, dependent upon radiological and technological conditions encountered. Because the precise conditions of the reactor core and other parts of the system are not known, the staff has described and assessed probable or bounding situations. When more information becomes available, appropriate supplements to the PEIS will be issued if the affected operations are found to be significantly beyond the scope of these assessments.

The ultimate disposition of TMI-2 is of interest to the Federal, State, and local governments, as well as to the licensee and the public. However, the disposition of the facility--whether to decommission or restore it to a condition acceptable for licensed operation--is not within the scope of this PEIS. The March 28, 1979, accident and its associated environmental impacts also are not within the scope of this PEIS.

*The term "licensee" or "Met-Ed" in this document refers to Metropolitan Edison Company, the principal owner (50 percent) and operator of the plant, Jersey Central Power and Light Company, Pennsylvania Electric Company, each of which owns 25 percent.

S.1 The Situation

During the accident at TMI-2, the reactor coolant water level dropped, uncovering the upper portion of the reactor core. This produced temperatures in the core in excess of 2500°F, which may have had the following consequences:

- Reaction of possibly 50 percent of the Zircaloy fuel cladding tubes (in the uncooled upper core region) with the water vapor and steam, thereby causing the tubes to fail and exposing uranium oxide fuel pellets containing fission products.
- Possible melting and fusing together of various stainless steel parts on adjacent fuel assemblies, such as the top end fittings and spacer grids that are located along the fuel assembly.
- Cracking and crumbling and possibly melting of uranium oxide fuel pellets in the overheated section of the core.
- Possible damage, caused by overheating, of other reactor parts. It is possible that the overheating produced local distortions and warping of some of these components.

Small pieces of fuel and other radioactive material may have been carried from the core by the flow of coolant. Larger fragments may have settled out in parts of the primary coolant system, smaller particles may be in suspension, and some will be dissolved in the cooling water. Radioactive material also plated out, forming a thin layer on the inside surfaces of the coolant system components. Although the total quantity of radioactivity in these various forms is not known with any precision, the upper limit on total radioactivity currently in the reactor coolant system (exclusive of fuel) is estimated at about 140,000 Ci.

Some of the radioactive gases leaked out of the reactor coolant system along with a large amount of water. Some of these gases escaped to the environment, but substantial amounts of radioactive gases remained in the reactor building. Shortly after the accident, xenon and iodine gases accounted for most of the radioactivity in the reactor building atmosphere, but these decayed rapidly to nonradioactive forms. The radioactivity remaining in the reactor building atmosphere up to June 27, 1980, consisted almost entirely of an estimated 57,000 Ci of krypton (Kr-85) gas.** Following authorization by the Commission, the gas was purged to the outside atmosphere during the period June 28 to July 11, 1980. Subsequently, the building has been purged several times. The release of Kr-85 has not exceeded 100 Ci for any purge; as of December 1980, the amount purged was less than 15 Ci per month and is decreasing. Some of the purges were made in conjunction with entries into the reactor building.

Several hundred thousand gallons of highly contaminated water were released from the primary system when the reactor pressurizer relief valve stuck open early in the accident and the coolant overflow tank ruptured. Additionally, primary system coolant leaked from the letdown and makeup system into the auxiliary and fuel handling building (AFHB) contaminating the floors, walls, and storage tanks. About 700,000 gallons of contaminated water (termed sump water) are standing about 8 feet deep in the reactor building basement. This sump water contains about 500,000 Ci of radioactivity. There also are about 100,000 gallons of water containing an estimated 20,000 Ci still circulating in the reactor coolant system. At the present time, heat from the reactor is lost to the building and ultimately to the environment. Backup cooling systems are available if needed. Tritiated water and dissolved radionuclides of cesium and strontium are the dominant radioactive materials of concern in the accident water. The other radionuclides are in low concentrations.

Because the tanks then available for storing contaminated water were rapidly being filled, the necessity for decontaminating the radioactive water in the AFHB tanks and sumps was recognized soon after the March 28 accident. The use of a demineralizer system, designated as EPICOR II, was authorized for this purpose by the NRC on October 16, 1979, and cleanup of the water in the AFHB has been completed. This processed water is being stored on the site in accordance with direction of the Commission and an agreement among the NRC, the licensee, and the City of Lancaster. The processed water still contains tritium, which is not removed by the EPICOR II system.

**Analysis after completion of the purging showed that, if instrument errors and uncertainties in the building free volume are considered, the actual amount of Kr-85 purged was approximately 44,000 Ci.

A demineralizer system designed for decontaminating water containing higher levels of radioactivity than EPICOR II is under construction by the licensee for processing the water in the reactor building. This system, known as the submerged demineralizer system (SDS), and alternatives to SDS are evaluated in Section 7.1 of the PEIS. Approval by the NRC would be required before any of these systems could be placed in operation.

Exposed interior surfaces and equipment in the AFHB and the reactor building were contaminated during the accident. The AFHB was contaminated by primary coolant leakage from the makeup and letdown system, and the reactor building was contaminated by hot water and steam carrying radionuclides released to the building under pressure. The interior exposed surfaces of both buildings were coated with thin deposits (known as plateout) of radioactive material. Removal of the plateout in the AFHB began in April 1979 and about two-thirds of the interior surfaces had been decontaminated by September 1980. Very little has been accomplished since then because of the licensee's limited funds. The largest portion of the radioactive contamination in the AFHB was deposited in the sludge in the sump and several tanks in the auxiliary building. These radiation sources have not yet been removed.

Five entries into the reactor building for radiation mapping and damage assessment had been made by January 1981, but work on decontaminating the reactor building had not yet started.

No significant impacts have been identified as a result of the low-activity solid waste handling and shipment operations to date. Wastes shipped by truck to the commercial low-level disposal facility near Richland, Washington, have consisted of immobilized decontamination solutions, compacted trash and noncompactible solid materials. As of February 5, 1981, 2013 drums and 273 LSA boxes of low-level waste had been transferred off the island in 36 truck shipments.

An interim radwaste storage facility has been constructed onsite to store temporarily some of the higher activity wastes, such as the spent demineralizer beds from the water treatment systems. This storage facility will be used until the evaluation of alternatives for offsite disposal of these wastes has been completed and an appropriate one is selected.

S.2 Reasons for Cleanup

The cleanup operations will remove sources of potential radiation exposure that currently pose risks to the health and safety of station workers and the public. Radiation sources are present in the form of airborne contamination, wastewater contaminated by radioactive materials during the accident, plateout of radioactive material on building and equipment surfaces, contaminated sludge, contaminated filter cartridges and demineralizer resins, and damaged fuel. As long as water with radioactive substances in it is allowed to occupy sumps and tanks, there exists a small probability of leakage into the groundwater and subsequently into the Susquehanna River. The contaminated water is also a source of direct radiation to workers requiring access to the building to perform critical maintenance (e.g., repair of nuclear instrumentation) or other repair to maintain the reactor in safe shutdown condition.

The reactor has been in a safe shutdown state since April 1979. The primary system temperature is about 120°F, and the small and decreasing amount of decay heat still being generated is being lost to the building. A new forced circulation system for the primary coolant, the mini-decay heat-removal-system (MDHRS), has been installed but is not in use because loss of heat to the building has been shown to be adequate. As long as the damaged fuel in the reactor core is cooled and remains relatively undisturbed and surrounded by boron-rich coolant, there is essentially no chance that the nuclear chain reaction, which was abruptly stopped at the time of the accident, could start again. But, the staff believes that as time passes, there will be an increasing potential for failure of essential equipment. Even though improbable, if the core were accidentally to begin a chain reaction once more, radioactivity could be released to the reactor building. The amount of radioactivity released during an accidental recriticality would be much less than that released in the initial accident. Even so, timely removal of the damaged fuel to safe storage is a paramount objective of the cleanup of TMI-2.

The feasibility of partial cleanup alternatives in which the reactor building would be sealed with some or all of the radioactive sources left in place was examined. It was found that all such alternatives, including taking no action other than maintaining the reactor in safe shutdown condition, either would not eliminate the potential risks or would convert part of the TMI-2 site into a long-term or permanent waste repository.

The staff concluded that all of the cleanup operations must be performed whether TMI-2 is decommissioned or refurbished to generate electricity in the future. The environmental impacts would be essentially the same regardless of whether the cleanup alternatives were chosen on the assumption that the plant would be decommissioned or on the assumption that the plant would be refurbished and restarted. The differences are less than the uncertainties in the best estimates that can be made for these impacts on the basis of the information presently available.

Cleanup of the facility should proceed in a timely manner, not only to mitigate any risks to the physical health of workers and nearby residents, but also to complete those activities which can cause psychological distress for residents in the area. The sooner the cleanup process is completed, the sooner the sources of concern will cease to exist.

S.3 The Cleanup Operations

The cleanup comprises four fundamental activities: building and equipment decontamination; fuel removal and decontamination of the primary coolant system; treatment of radioactive liquids; and packaging, handling, storage and transportation of radioactive wastes. The current schedule for conducting these activities is indicated in Figure 1. Figure 2 illustrates how the wastes resulting from the cleanup activities, and from the accident itself, would be separated for eventual packaging and disposal.

The removal of unwanted radioactive contamination from materials and equipment is a familiar and routine operation for reducing radiation levels. Decontaminations of various types have been conducted since the 1940s and a considerable amount of experience and technology is available. These experiences illustrate that available techniques can be modified to suit the conditions at TMI-2. Applicable experience in removing damaged fuel and core components is limited, hence development of specific techniques will be required.

Building and Equipment Decontamination

Cleanup of the AFHB started with the general areas where contamination was relatively light and is proceeding to rooms (cubicles) containing tanks and other equipment which are more heavily contaminated. The methods in use are not essentially different from those used in the process of removing dirt from any surface except that care must be taken to protect workers from radioactive contamination, and more stringent methods must be used to remove most of the contamination. The methods used for decontaminating building and fixed equipment surfaces include washing with a high-pressure water jet, wet and dry vacuuming, and manual wiping. Clean surfaces are often protected by applying strippable coatings which are easily removed if the surface becomes recontaminated. Small demountable equipment items can be cleaned by electrochemical or ultrasonic techniques. The methods considered to be most practicable for removing the sludge that accumulated in the sump, pipes, tanks and other vessels containing water involve resuspension of the sludge in water by agitation to form a slurry which is pumped out and filtered.

As of September 1, 1980, the amount of labor by workers directly involved in the AFHB decontamination effort was about 500,000 person-hours. The average exposure rate for these workers generally allowed normal shift operation. Shielding is used to protect workers from the ambient radiation fields, and only a fraction of a worker's time on the job is actually spent in the radiation field. The staff estimates that a total of about 750,000 person-hours of work effort will be needed to decontaminate the AFHB.

The methods used for decontaminating the reactor building will be similar to those used in the AFHB, although the strategies will be different because the reactor building consists primarily of large open spaces, while the AFHB is divided into many small cubicles. Surface decontamination may be easier in the reactor building than in the AFHB because most of the reactor building surfaces are painted, whereas most of the surfaces in the AFHB are untreated concrete. The major tasks that must be coordinated and carried out are removal of the contaminated water from the basement, removal of the sludge and debris, and removal of the plateout from the building and equipment surfaces.

The staff estimates that decontamination of the reactor building (excluding any additional decontamination that might be required in connection with decommissioning or refurbishing

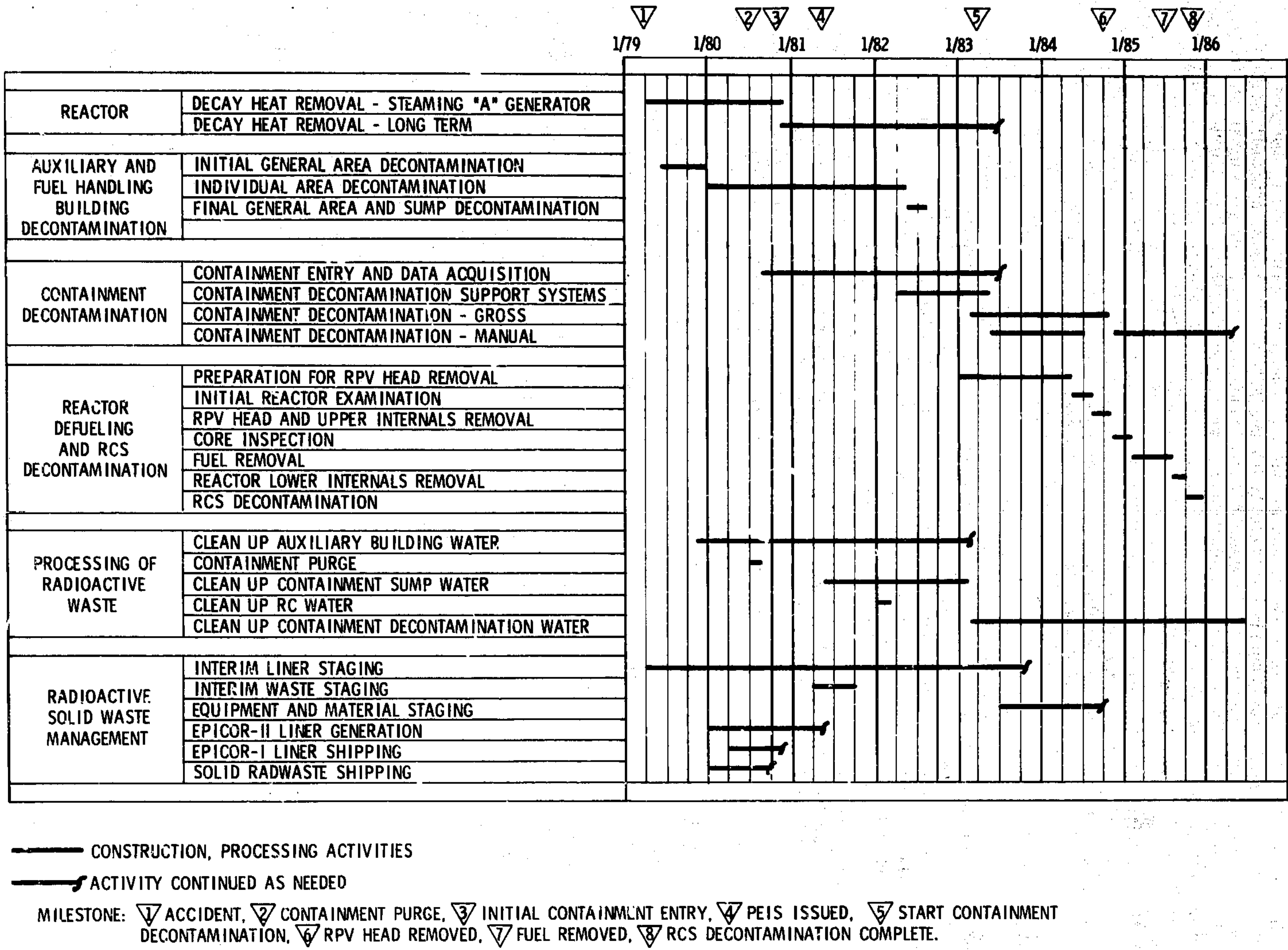

Figure 1. Licensee's Planning Schedule for TMI-2 Cleanup, Phase I and II. (Construction of support facilities not included.)

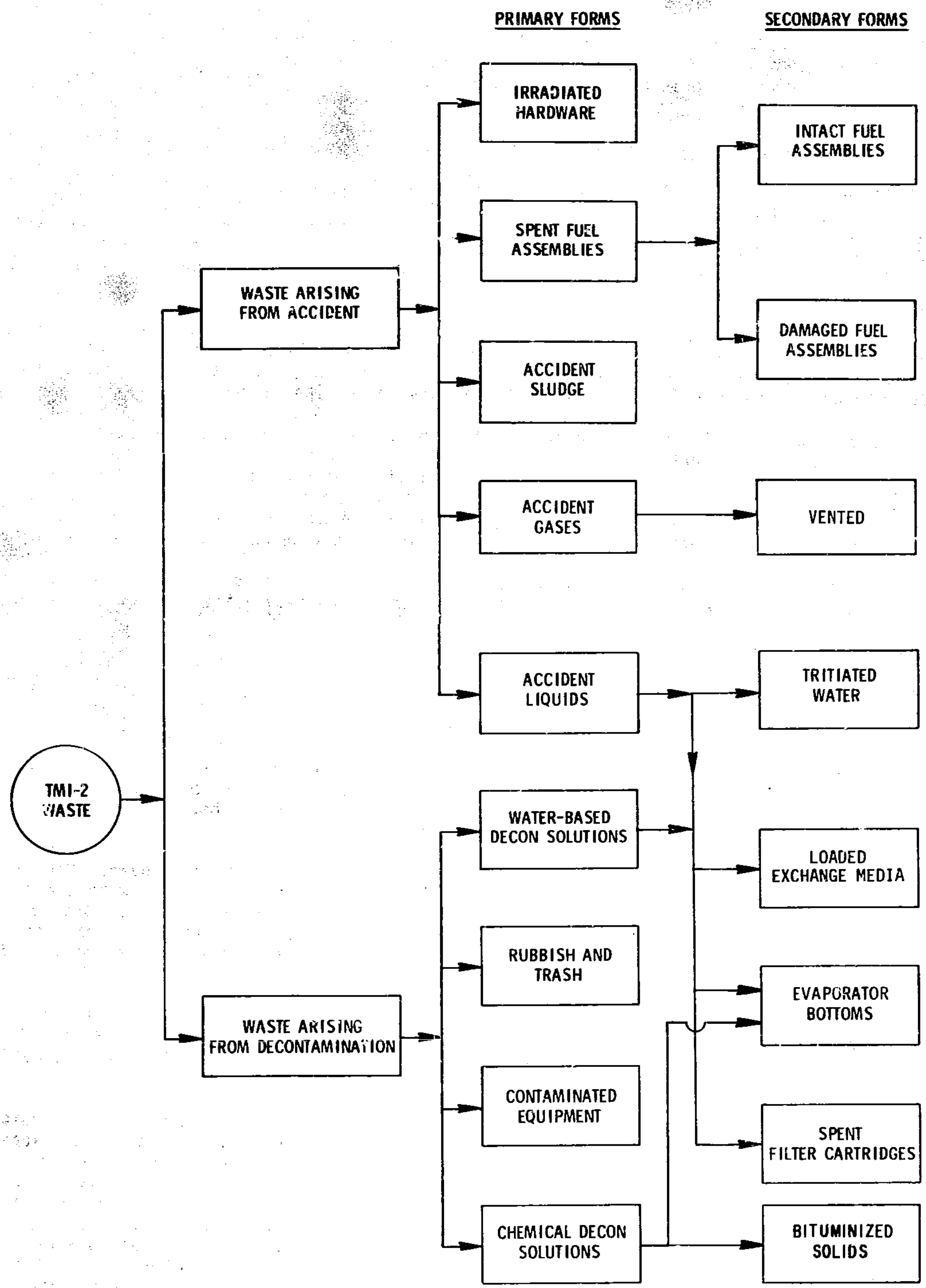

Figure 2. Characterization of TMI-2 Radioactive Waste.

operations) would require a work effort in the range of 300,000 to 900,000 person-hours. This includes both in-building and out-of-building time for workers with assignments that require entry into the building; it does not include support work by others with assignments that do not require entry.

Fuel Removal and Primary System Decontamination

The ultimate objective of the reactor defueling and primary system decontamination is to remove all fuel, damaged reactor parts, and radioactive plateout in the coolant system. Because the exact condition of the reactor core and some of the other reactor parts will not be known until thorough inspections have been performed, it is impossible to predict or plan the defueling and cleanup operations in complete detail at this time. However, the major steps and the order in which they will be conducted are reasonably certain.

The coolant system must first be connected to a cleanup system so that the coolant can be decontaminated. It also will be necessary to remove any additional radioactive materials released to the water during fuel removal operations. This could be done by continuously running the water through a cleanup system consisting of filters and demineralizers.

Obtaining access to the fuel requires removal of the reactor vessel head and components above the fuel. These tasks can be performed in much the same manner as during normal reactor refueling operations, namely by direct contact methods. If minimal warpage or mechanical damage occurred during the accident, these operations should proceed with relative ease. However, if warpage or mechanical damage is extensive, considerable difficulty could be encountered in fuel removal operations, and underwater cutting and machining operations might be needed.

The fuel will be moved under water to the spent fuel pool for interim storage. Some of the fuel assemblies may not be all in one piece. Operations necessary to remove the fuel assemblies are:

- Detailed inspection of the core.
- Removal of loose debris.
- Removal of fuel assemblies using special equipment.

During defueling, it is very important to maintain the boron concentration in the circulating water at the proper level in order to prevent reactor recriticality. Since some of the water treatment processes remove boron along with the radionuclides, boron may have to be added to the water during the defueling.

After the fuel has been removed, the support structure for the fuel must be removed. Normally, removal of the support structure is a straightforward procedure requiring hook up with the crane, lifting it out of the pressure vessel, and moving it to the fuel transfer canal. Because of the possibility that overheating has caused distortion and warping of the support structure, removing it may not be easy. Accordingly, planning allows for the contingency of having to remove this structure by cutting it into smaller pieces while still under water.

After removal of all the fuel from the reactor pressure vessel (hence removing of any further source of radioactivity which could recontaminate the system), the final step will be to clean out the residual radioactivity from the system. This would be accomplished by a method quite analogous to flushing the cooling system of an automobile.

The staff assumes that decontamination of the reactor building will be largely completed before fuel removal activities begin. Thus, during these activities the contribution to worker exposure from building background radiation should be small. The major contribution to worker exposure will be the general background of 2 to 3 mR/hr at the surface of the transfer canal water during underwater operations to disassemble the reactor. In addition, it will be necessary to work in radiation fields as high as 150 to 200 mR/hr in performing some of the hands-on activities. The staff has estimated the time-averaged field for a typical worker during the defueling activities over a work shift to be 10 mR/hr. While some persons will be working in higher average fields and others in lower fields, it is the staff's judgment that this average value is appropriate for estimating radiation exposures for workers performing the defueling and primary cooling system cleanup activities. A total of about 100,000 to 300,000 person-hours of effort will be required, depending upon the conditions found during inspection.

Treatment of Liquid Waste

Liquids involved in the TMI-2 decontamination will require further processing to permit their safe disposal in accordance with the staff's proposed use of the effluent criterion in 10 CFR 50 Appendix I as discussed in Section 1.6.3.2; these liquids include those directly generated during the March 28, 1979, accident (accident water) as well as liquids contaminated during the cleanup operations.

The accident-generated water in the reactor building sump and the primary system cannot be left in its present condition and location if the cleanup effort is to proceed. Some of the alternatives considered for disposition of this water involve its cleanup through the use of filtration, ion exchange, evaporation and bitumenization techniques. Others include transfer from its present location to onsite storage facilities or processing the water for transport and disposal at a low-level radioactive waste disposal facility. As decontamination solutions are generated, they too must be either cleaned up, stored, or processed and shipped offsite. The alternatives considered for accident-generated water and decontamination solutions are discussed below.

Long-term onsite storage of the unprocessed accident water involves transfer from its present locations in the reactor building and primary system to storage tanks. This water could be transferred to tanks within the reactor or auxiliary fuel handling buildings, if available, or to newly constructed exterior tanks. In either case, the storage tanks would have to be heavily shielded to reduce radiation levels in areas near the tanks. Storage of the accident water onsite would defer cleanup and complicate the cleanup operation without contributing to its end goals. For these reasons, long-term onsite storage of unprocessed accident water is not considered a reasonable alternative.

Direct immobilization involves mixing unprocessed accident water with a binder materal such as Portland cement or vinyl ester styrene for either temporary onsite storage or offsite shipment to a commercial shallow land burial facility. Immobilization of accident water with cement would take about 5 years, produce about 7400 cubic yards of concrete, and require about 1900 shielded shipments from the TMI-2 site. This was not considered suitable for unprocessed accident water but may be used for the relatively small quantitives of decontamination liquids.

Several processes and systems are available for treating the liquid to remove the contaminants. The following processes were considered: (1) filtration, (2) ion exchange, (3) evaporation, and (4) bitumenization.

Filtration is applicable to TMI-2 liquid wastes as an initial step in a process. It is not a appropriate treatment process by itself because much of the radioactivity is in solution and thus is not removed by filtering.

Ion exchange, the same process used in household water softeners, involves the removal of ionic species from an aqueous phase. The ion-exchange media considered for use at TMI-2 include inorganic zeolites and other minerals and organic resins. Ion exchange is appropriate for accident water and some decontamination solutions. It is not appropriate for treatment of chemical decontamination solutions because the chemical nature of these liquids would lead to rapid breakdown and plugging of ion-exchange media.

Evaporation would separate the water from the non-volatile radionuclides and other impurities dissolved in the liquid waste. Most of the contaminants are retained in the concentrated solution (or bottoms) while the relatively clean water vapor is condensed to liquid which requires further processing in an ion-exchange system. Additionally, the concentrated solutions would have to be immobilized in a solidification system. Evaporation is only appropriate for treatment of TMI-2 liquid wastes with low to moderate concentrations of dissolved solids and low radionuclide concentrations.

Bitumenization combines evaporation and immobilization in one step. The radionuclides are immobilized in an asphalt-like material (bitumen) and the vaporized water removed from the liquid waste is condensed for further treatment in an ion-exchange system. Bitumenization is only appropriate for TMI-2 liquids of low to moderate radioactivity concentration with at least 5 percent solids content by weight.