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ABSTRACT

The purpose of this paper is to introduce the concepts and needs associated with treatment of solid low-level waste (LLW) and to describe some of the treatment technologies that are being demonstrated and evaluated as part of the implementation of the Low-Level Waste Disposal Development and Demonstration (LLWDDD) Program strategy. According to the strategy, LLW has been divided into four classes. Class I consists of materials that, at the time of disposal, contain contaminants yielding a dose to man that is less than an allowable limit. Disposal would be in an industrial-type landfill. Class II, principally for disposal of short-half-life isotopes, provides engineered barriers that would contain the radionuclides, with the goal of zero release during a period of decay. Class III disposal, less well-defined than other disposal classes, is designed to accept wastes contaminated by long-half-life radionuclides that contain a soluble fraction that can be removed by leaching during the period of institutional control. Class IV, which includes all other wastes that are not acceptable for disposal on-site, may be treated to convert the majority of the material to a lower classification for disposal on-site.

Waste treatments are divided into four categories: (1) volume reduction; (2) conditioning to improve waste form performance; (3) segregation to achieve waste reduction; and (4) separation to remove radioactive (or hazardous) constituents. Two waste treatment demonstrations are described. In the first, volume reduction by mechanical means was achieved during the supercompaction of 300 55-gal drums of solid waste at ORNL. In the second demonstration, conditioning of waste through immobilization and packaging to improve the performance of the waste form is being evaluated.

The final section of this paper describes potential scenarios for the management of uranium-contaminated wastes at the Y-12 Plant in Oak Ridge and emphasizes where demonstrations of treatment technology will be needed to implement the scenarios. Separation and thermal treatment are identified as the principal means for treating these wastes.

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EVALUATION OF WASTE TREATMENT TECHNOLOGIES BY LLWDDD PROGRAM

INTRODUCTION

The Low-Level Waste Disposal Development and Demonstration (LLWDDD) Program, being conducted at the U.S. Department of Energy's Oak Ridge Operations (DOE/ORO) facilities, is demonstrating and evaluating waste management technologies to be incorporated into new facilities for treating, storing, and disposing of low-level wastes (LLW) in the 1990s.

The purpose of this paper is to introduce the concepts and needs associated with waste treatment and to describe some of the treatment technologies that are being demonstrated and evaluated as part of the implementation of the LLWDDD strategy.

CLASSIFICATION SYSTEM FOR LLW

The LLWDDD strategy for management of LLW includes four classes of waste of regulatory concern. These classes are described below to orient the reader to the special treatment requirements for each class of waste.

1. Class I consists of materials that, at the time of disposal, contain contaminants yielding a dose to man that is less than a specified allowable limit. Disposal would be in an industrial-type landfill.
2. Class II, principally for disposal of short-half-life isotopes, provides engineered barriers that would contain the radionuclides, with the goal of zero release during a period of decay. During the decay period, which would occur during institutional control by a responsible agency, intruder protection, as well as monitoring and needed treatment of potential releases, would be provided. Above-grade facilities (e.g., tumulus disposal) for low-activity waste and below-grade disposal units (e.g., silos) are being considered for managing Class II wastes.
3. Class III disposal, less well-defined than other disposal classes, is designed to accept wastes contaminated by long-half-life radionuclides that contain a soluble fraction that can be removed by leaching during the period of institutional control. Leachate would be monitored and treated as needed, and intruder protection might be required after institutional control ends for the insoluble fraction remaining at the disposal site.

4. Class IV includes all other wastes that are not acceptable for disposal on-site. Treatment of Class IV wastes would convert the majority of the Class IV material to a lower classification that is acceptable for disposal on-site, with a small residual requiring storage or shipment off-site.

CATEGORIES OF WASTE TREATMENT

The treatment technology demonstrations for LLW include any processing of waste to segregate; separate; package; isolate; immobilize; alter form; and reduce volume, toxicity, or hazardous nature in preparation for recycle, storage, or disposal. Waste treatments are divided into four categories:

1. volume reduction, usually by mechanical (supercompaction, shredding) or thermal (incineration, pyrolysis) means;
2. conditioning, by solidification, immobilization, or packaging, to produce a waste form for improved performance during storage or disposal;
3. segregation, by means such as monitoring, assaying/surveying, sorting, or administrative control measures at the point of generation, to achieve waste reduction; and
4. separation, by methods such as leaching, extraction, filtration, ion exchange, or biological processes, to remove or reduce the low-level constituents.

The following section describes two waste treatment demonstrations being conducted by the LLWDDD Program. The first, the application of supercompaction to 55-gal drums of solid waste, is an example of volume reduction by mechanical means. The second demonstration, having the objective of evaluating and applying waste form/packaging technologies available from the private sector, is an example of conditioning of waste to improve its performance during disposal. The final section of this paper describes potential scenarios for the management of uranium-contaminated wastes at the Y-12 Plant in Oak Ridge, Tennessee, and emphasizes where demonstrations of treatment technology will be needed to implement the scenarios. Separation and thermal treatment are identified as the principal means for treating these wastes.

SUPERCOMPACTION OF LLW DRUMS - A DEMONSTRATION OF VOLUME REDUCTION TECHNOLOGY

DOE/ORO facilities have large quantities of high-volume, low-activity, solid LLW being generated for which shallow-land burial is the primary means of disposal. Because available space for this method of disposal is being used up rapidly, volume reduction of solid wastes is being pursued vigorously as the most promising means readily available for extending the life of existing facilities and for reducing the scope of future facilities. A primary objective of this demonstration was to obtain cost and performance data for on-site supercompaction using a mobile supercompaction system.

In general, the presence of undetected liquids in containers of contaminated solid waste which will eventually undergo compaction is undesirable. The real-time-radiography (RTR) system used by Oak Ridge National Laboratory (ORNL), which is a continuous X-ray technique installed at the Waste Examination and Assay Facility, has been developed for examining and certifying that free liquids are absent from containers of waste. This system is shown in Fig. 1. All the drums used in the demonstration were examined by RTR prior to processing to eliminate those drums in which the presence of free liquids was indicated during the X-ray examination. An important objective of this demonstration was to evaluate the effectiveness of the RTR technique by observing the amount of liquids released during the compaction process.

The demonstration of supercompaction and grouting of 55-gal drums of solid LLW from ORNL was successfully completed between March 9 and 27, 1987, at the ORNL Solid Waste Storage Area 5 (SWSA-5). The subcontractor, US Ecology of Louisville, Kentucky, used its mobile supercompaction system operating at 2200 tons of compressive force. The mobile unit as set up at ORNL is shown in Fig. 2. During the demonstration, 300 drums were reduced in volume by a factor of approximately 6.7:1. A typical compacted drum (puck) is shown in Fig. 3.

During the crushing of the drums, it was found that absorbed liquids undetected by the RTR examinations were released and collected from 94 of the 300 drums in amounts varying from a fraction of a pint up to 3 gal. A total of about 60 gal of fugitive liquids was collected during the processing. However, contamination of the supercompaction unit was insignificant, and decontamination to meet Department of Transportation (DOT) standards

Fig. 1. Real-time radiography unit.

Fig. 2. Supercompaction unit set up at SWSA-5 site.

was carried out at the conclusion of the processing to the satisfaction of Martin Marietta Energy Systems and US Ecology.

Following supercompaction, the crushed drums were then placed in overpack containers and encapsulated by injecting the containers with a high-density, cement-based grout to fill all voids and produce a stable waste form. A steel reinforcing structure was placed around the stack of pucks to provide added stability to the final waste form. Grouting of an overpack is shown in Fig. 4. The final volume reduction factor of the compacted drums after grouting was about 2.9 to 1 for the forty-seven 125-gal overpacks produced.

About 40% of the 300 drums had uncompacted densities of 10–15 lb/ft^3. All uncompacted drums had densities less than 55 lb/ft^3. The compacted densities ranged from 30 to 270 lb/ft^3. About 66% of compacted drums had densities between 75 to 140 lb/ft^3. A volume reduction factor lower than 10 was obtained for drums whose uncompacted density was greater than 12 lb/ft^3. For drums with an uncompacted density lower than 12 lb/ft^3, a volume reduction factor of 10 to 30 was obtained.

No accidents, injuries, environmental releases, radiation releases, or worker exposures occurred as a result of the demonstration. Favorable publicity was generated by three local television news releases and in local newpaper coverage.

Three major conclusions resulted from the demonstration:

1. An improved system is needed for collecting fugitive liquids released during the compaction process. This improvement would significantly reduce delays in the operation to clean up liquids released to the drum press area.
2. The RTR system cannot detect absorbed liquids on such items as mop heads and absorbent materials, necessitating the segregation of these wastes from the dry materials.
3. Site-support costs for the demonstration were significant.

EVALUATION OF IMMOBILIZATION AND PACKAGING TECHNOLOGIES FOR PRIORITY DOE/ORO WASTE STREAMS

A three-phased program to select, demonstrate, and implement treatment and packaging technologies that are appropriately matched to four priority DOE/ORO waste streams is in progress. The three phases of the program are designed to begin with laboratory-scale evaluations and to proceed

Fig. 3. Typical compacted drum (puck).

Fig. 4. Grouting of an overpack.

through full-scale field processing of the wastes. In Phase I, samples will be obtained for testing and verifying waste forms and packages prepared by private sector suppliers using surrogate recipes for the priority waste streams. In Phase II, on-site, pilot-scale demonstrations would be conducted with actual wastes by private sector companies that successfully completed Phase I. In Phase III, full-scale treatment capabilities would be implemented on-site to process the priority waste streams using the most applicable technologies identified in the first two phases of the project.

Four priority waste streams have been identified in FY 1987:

1. Y-12 End Treatment Facility sludges containing heavy metals and spend uranium.
2. ORNL Wastewater Treatment Facility water-softening sludges with cesium, strontium, cobalt, and trace rare earths.
3. Sludges with heavy metals and chlorinated phenolics produced at the K-1232 facility from Y-12 wastewaters.
4. ORNL Wastewater Treatment Facility evaporator bottoms containing nitrates, cesium, strontium, and trace rare earths. This waste also includes Hg, As, Cr, Cd, Ba, Pb, and Ag compounds and may be classified as a transuranic (TRU) waste.

In carrying out this project, the testing protocols and performance criteria for the waste forms and packages will be established and applied, anticipating current and future regulatory issues and requirements. The testing requirements have been selected from statutory requirements of the U.S. Environmental Protection Agency, U.S. Nuclear Regulatory Commission, DOE, and DOT to address such issues as reactivity, corrosiveness, durability, leachability, and mechanical properties of the waste form. It is recognized that performance specifications will be determined by the environmental impact statement policy and pathways analysis, as well as by evolving disposal unit design requirements. An ultimate goal of the LLWDDD Program is to develop a model that integrates the waste form, packaging, and disposal unit so that these features can be optimized to achieve the most cost-effective scenario meeting dose restriction.

During Phase I of the project, the testing protocols have been divided into two categories. The first category consists of widely accepted, standardized tests to be performed by the private sector participants. The second category, involving tests that are developmental or require modifications and subjective interpretation, will be performed by the Waste Isolation Technology Group at ORNL.

TREATMENT SCENARIOS FOR URANIUM WASTES TO MEET THE LLWDDD CLASSIFICATION SYSTEM

Implementation scenarios for wastes containing long-half-life (LHL) constituents (uranium, thorium, and technetium) are presented in Figs. 5 to 8. These scenarios are presented to illustrate how treatments of these wastes to remove and concentrate the LHL constituents could convert most of the waste to a lesser classification status [shallow landfill (SLF) or Class I disposal], with a small residual to be handled as Class IV.

Figure 5 illustrates the undesirable scenario in which a uranium removal process would be necessary indefinitely for treating the leachate, requiring a commitment of resources for construction and long-term operation. The Figure 6 scenario, which assumes treatment to remove and concentrate the uranium for Class IV waste, would not likely require a comprehensive, long-term leachate treatment program. Figure 7 illustrates a possible flowsheet for liquid treatment of Class IV wastes by wet chemical means, producing a residual for off-site shipment or storage. The concept of chemical recovery for recycle makes this scenario attractive. Figure 8 combines the thermal treatment and the chemical treatment options for Class IV waste, with the objective of producing a minimum residual and a maximum amount of decontaminated material eligible for disposal in a lower classification. Demonstrations of technology thought to be needed to implement the scenarios are indicated in the figures.

ORNL DWG 87-895R

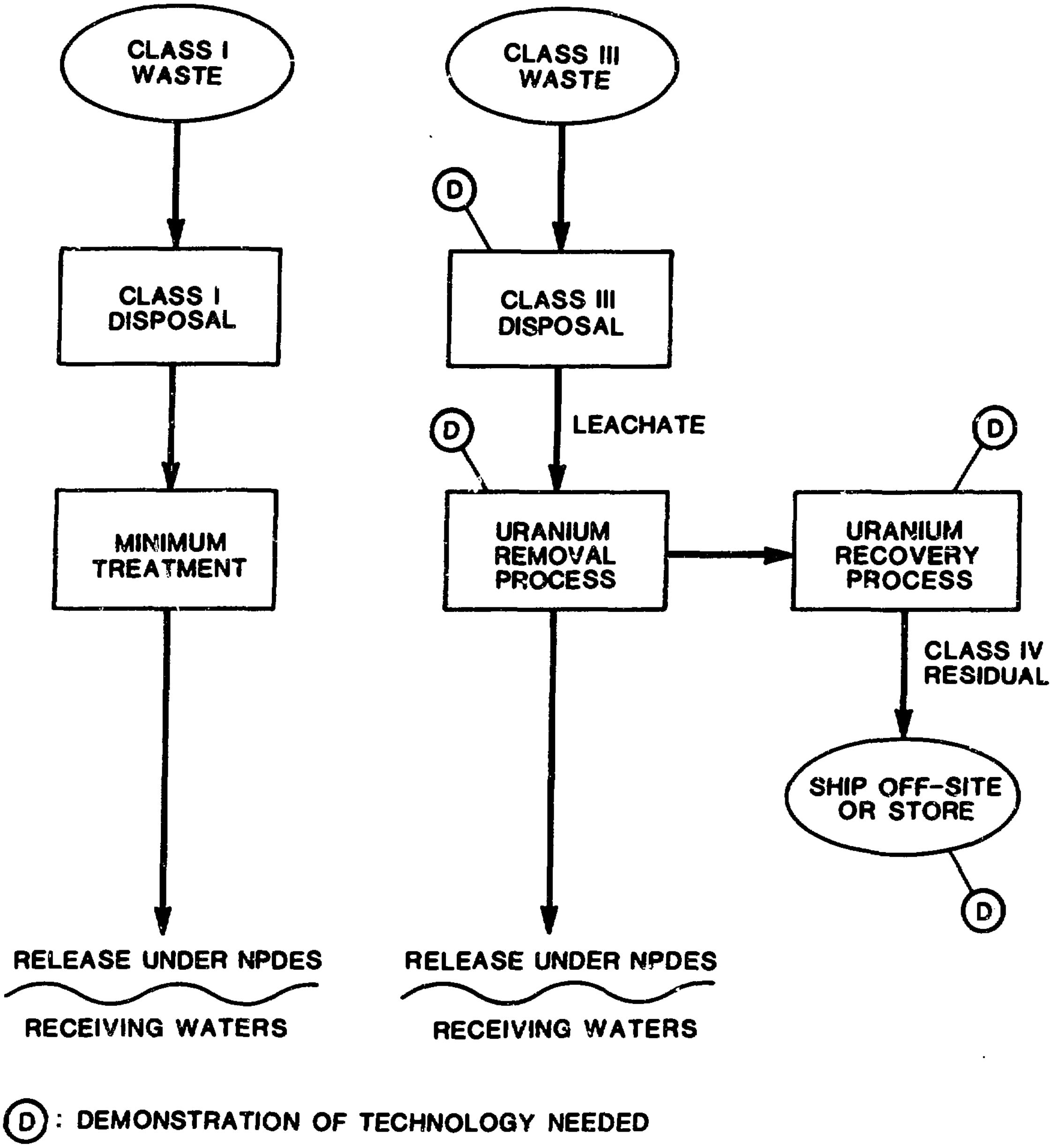

Fig. 5. Conceptual flowsheet for posttreatment after disposal of Class I and III long-half-life wastes.

ORNL DWG 87-894R2

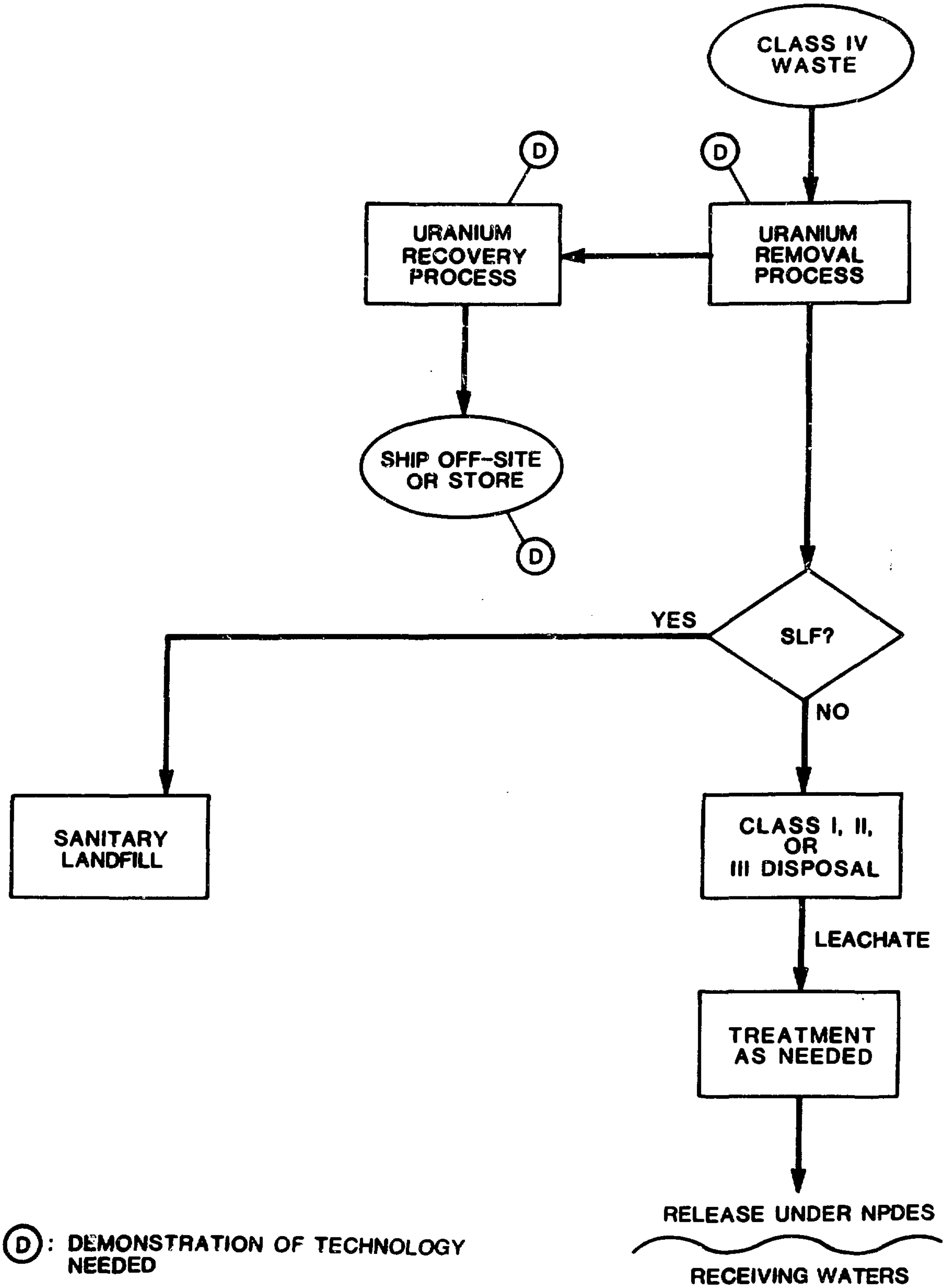

Fig. 6. Conceptual flowsheet for pretreatment of Class IV long-half-life wastes.

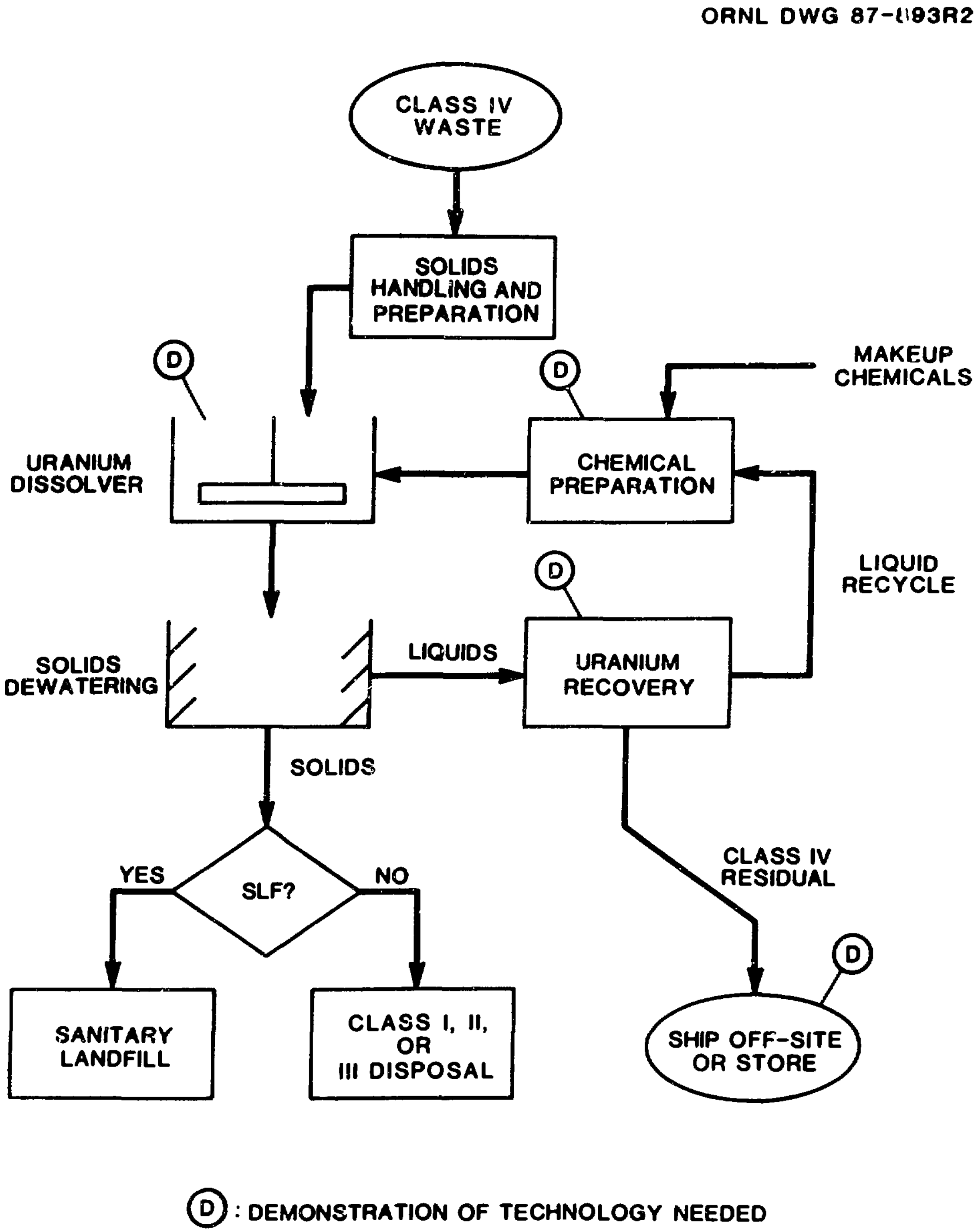

Fig. 7. Conceptual flowsheet for liquid treatment of Class IV uranium wastes.

ORNL DWG 87-892R2

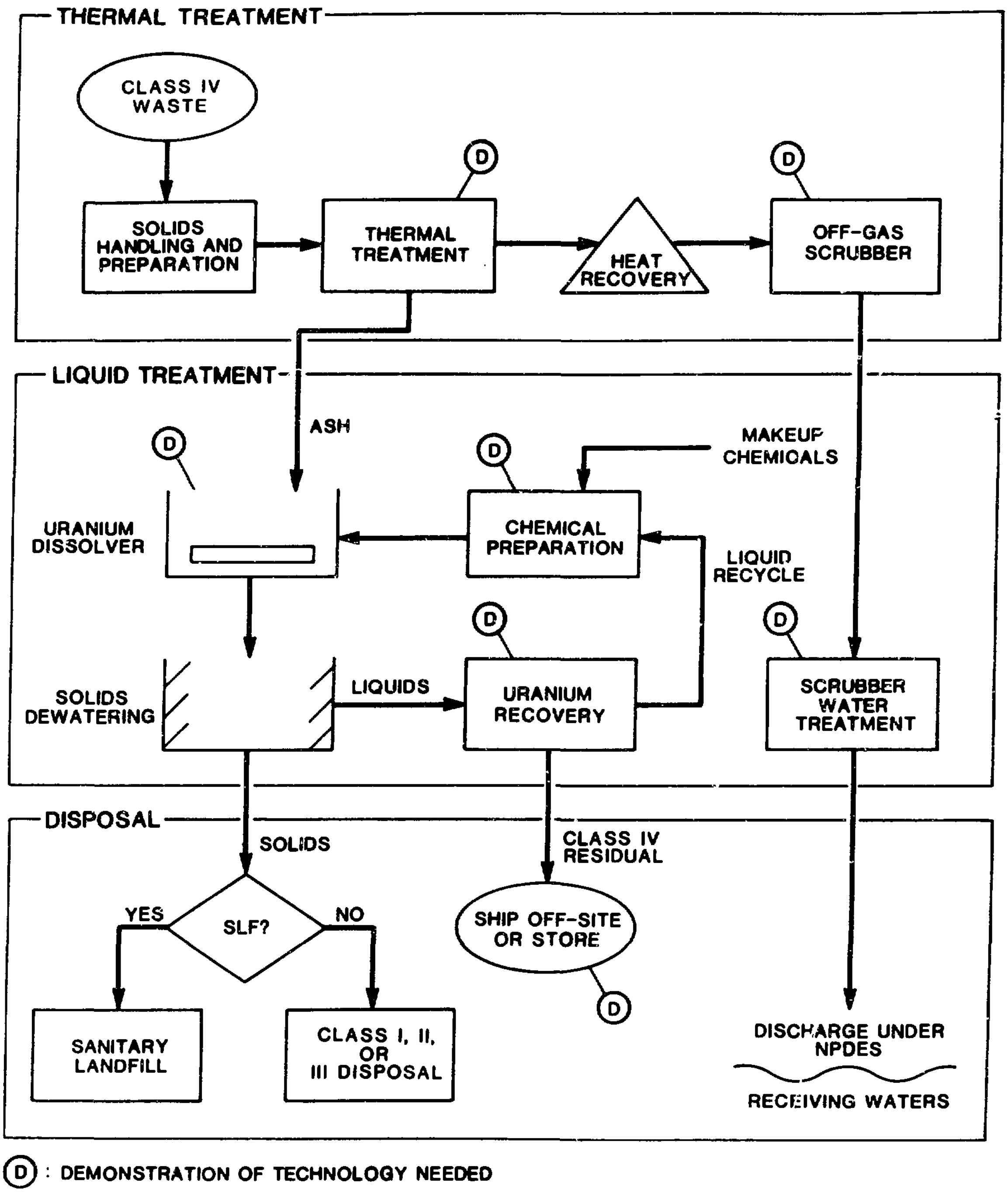

Fig. 8. Conceptual flowsheet for thermal treatment of Class IV uranium wastes.