LMFBR SODIUM-BEARING WASTE PROGRAM - AN OVERVIEW

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INTRODUCTION

A viable nuclear economy will require the existence of a technology for the management of radioactive reactor wastes. Many of the waste management problems are generic in nature and common to all reactor types. However, in the case of the Liquid Metal Fast Breeder Reactor (LMFBR), the use of elemental sodium introduces a complication unique to this reactor system. The LMFBR experimental program produces radioactive scrap and waste that contain elemental sodium and also produces radioactive bulk sodium. These materials are not acceptable at reprocessing or disposal facilities because of the sodium-bearing contents.

Although much experience has been accumulated in the safe handling and storage of wastes containing elemental sodium, it is realized that interim storage is a short-term solution. It is, therefore, evident that as disposal and reprocessing facilities define their criteria for acceptance of waste and scrap, the only long-term solution would be one that encompasses the removal of the sodium from the material so as to allow (a) disposal of the nontransuranic (nonTRU) waste, (b) reprocessing of the recoverable scrap, and (c) long-term storage of transuranic (TRU) waste. Methods, therefore, need to be developed for removing the sodium from these materials such that the radioactive waste can be sent to disposal sites and scrap can be sent to reprocessing facilities. The resulting sodium must be converted to a form acceptable to disposal sites or purified for reuse. The United States Department of Energy (DOE) has established a Sodium Waste Technology (SWT) Program to develop and demonstrate such methods. This paper represents an overview of the SWT Program and the current phase of technologies being developed.

SODIUM WASTE TECHNOLOGY PROGRAM

The SWT Program was established to develop techniques and demonstrate treatment of sodium-bearing radioactive scrap and waste that have been and are being generated from LMFBR operations to provide potential solutions for generators of these materials. The tasks of the program are presented in Fig. 1. The program was structured to meet the following primary objectives:

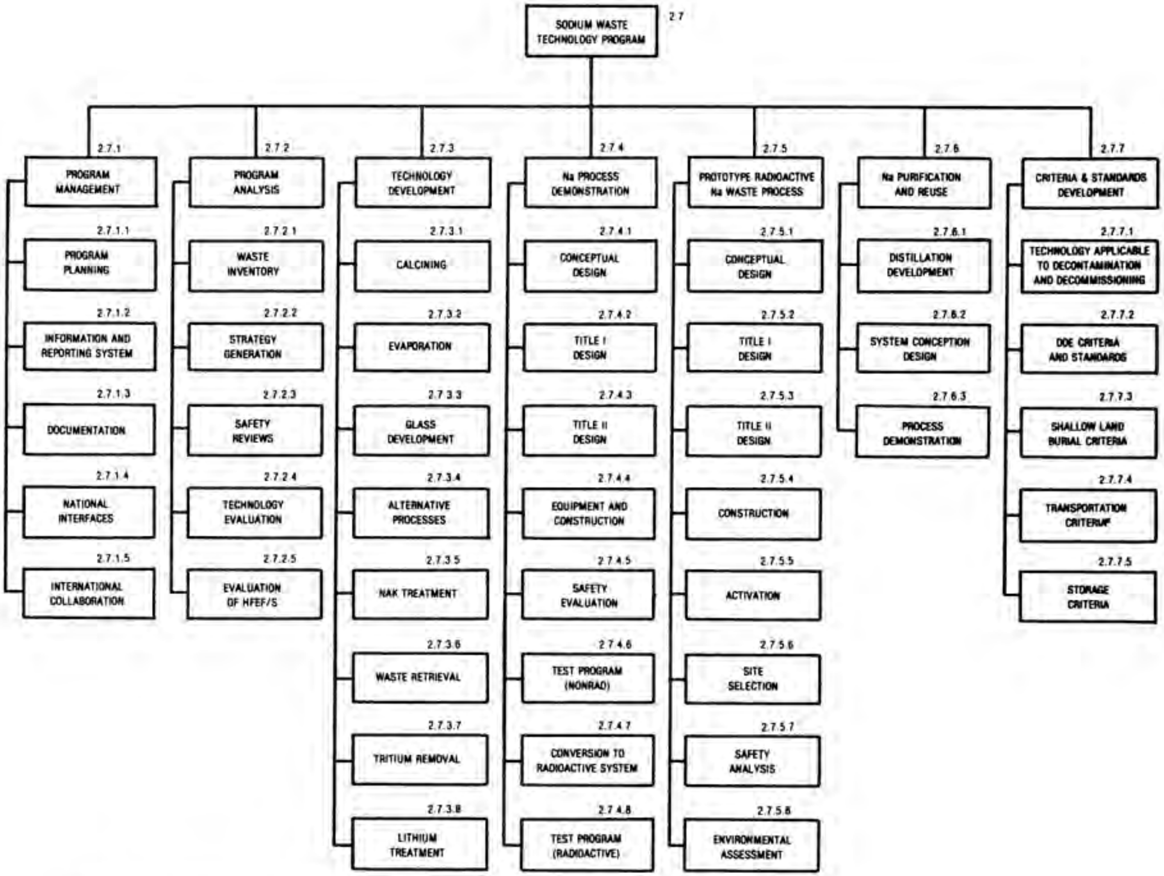

Fig. 1. Tasks and Sub-Tasks of Sodium Waste Technology Program.

1. Determine present quantities of this waste and scrap and estimate future production.

2. Evaluate sodium removal processes to meet safe disposal and scrap reprocessing requirements.

3. Evaluate processes to convert bulk elemental sodium to a form that meets requirements for safe disposal.

4. Purify sodium so that it can be reused in the reactor system, if desired.

5. Select and test the process in a full-scale, nonradioactive demonstration system.

6. Construct a prototype shielded facility to treat existing and future waste and scrap.

7. Develop generic solutions for waste and scrap from existing and future LMFBR's.

8. Apply techniques from this program to decontamination and decommissioning of LMFBR's.

Under DOE, the program is managed by the Argonne National Laboratory. During the initial phase, discussions were held with lead DOE Field Offices and Contractors in which the strategy of the program was discussed which included inventories, types of processes, and impact on the various sites. DOE-HQ established an international collaboration with the United Kingdom where experiences with waste sodium and NaK can be shared.

One of the first tasks was to conduct an inventory of sodium waste throughout the U.S. The majority of the sodium waste and scrap was determined to be in the Northwest with the largest portion of the sodium-bearing waste located at Argonne National Laboratory-West (ANL-W) on the Idaho National Engineering Laboratory (INEL) where the Experimental Breeder Reactor II (EBR-II) has been and is continuing to generate waste and scrap. Large quantities of bulk sodium from previous decommissionings are being stored by Rockwell-Hanford at the Hanford Site and at this same location the Fast Flux Test Facility (FFTF) is also expected to be producing sodium-bearing waste materials in the near future. This large inventory in the Northwest influenced later decisions made within the program, such as the location of the demonstration process, location of the prototype facility and transportation studies.

Process Selection

One of the initial tasks of the SWT Program was to select a process for removing sodium from waste materials so that the waste material could be sent to shallow land burial (nonTRU) or the waste repository (TRU). In selecting the process, the major considerations were minimization of liquid effluents, minimization of hydrogen generation, ability to remove sodium from cracks and crevices, compatibility with remote handling because of high radiation levels associated with some of the materials and the ability to convert the removed sodium to a stable, solid product. Potential processes considered were steam/moist nitrogen, alcohol, evaporation, concentrated caustic, heavy metal and burning. Several of these processes are internationally popular for removing sodium from reactor components which are to be reused in the reactor systems. However, most did not meet all of the requirements established by the program. For example, some factors that could limit the use of the alcohol processes are (a) the sodium content of the alcohol must be kept low, thereby requiring continuous regeneration of alcohol (by distillation) during the reaction, (b) the bottom product from the distillation must be further processed, and difficulties arise in reducing the product to a solid because of the presence of a variety of organic compounds, (c) disposal of liquid waste containing radioactive isotopes by landfill burial is not acceptable; therefore, disposal of the waste from the alcohol process presents a problem, and (d) alcohol is flammable.

The process selected for demonstration was a drain/evaporation process. This process best meets the original considerations and is the only one which will remove sodium from cracks and crevices in the material. This decision was reinforced by two independent studies performed by industrial organizations under contract which evaluated the melt/drain, steam/moist nitrogen and alcohol processes. The sodium, once removed from the waste or scrap material will be converted, in the demonstration, to sodium oxide using a rotary drum calciner. Laboratory tests were conducted on evaporation and calcination. These tests, in conjunction with design input from industry, resulted in the design criteria for these key components. Laboratory work has shown that it is possible for the calciner to produce sodium monoxide (Na_2O) with about 8-12 wt% of sodium peroxide (Na_2O_2) and about 0.16 wt% of elemental sodium. The demonstration process has been given the acronym MEDEC for MElt-Drain-Evaporation-Calcine.

Consideration is being given to converting the sodium oxide from the calciner to a glass as an option for final disposal. Battelle Pacific Northwest Laboratory is doing the development work on the glass utilizing an in-can melting technique. In-can melting was chosen since the calciner output is a batch process and more suitable for in-can melting rather than a continuous melter.

An alternate process to calcining is being evaluated. A one-step, wet-chemical process converts the elemental sodium to sodium chloride and immobilizes it in an inert matrix. The process utilizes an inert carrier in which elemental sodium has been dispersed with hydrochloric acid. Quadrex Corporation is performing the work in conjunction with United Technologies Corporation, who developed the proprietary process being used. The potential advantage would be to perform a conversion of sodium in a one step process versus calcination and glass.

Burning was considered as another alternative. Tests showed that the process resulted in much higher amounts of Na_2O_2 in the final product, the rate of reaction was difficult to control, the product was fluffy, and any interruptions in the process would result in difficulties in recovery. It is possible, however, that this method should be considered for treating large quantities of sodium from a decommissioning activity.

Process Demonstration

The MEDEC process consists of four discrete procedures. Each has been tested and demonstrated on a laboratory scale. However, all four have never been linked together in a single unit designed for continuous operation. Moreover, the wastes that are likely to be processed in the unit have not been previously considered for sodium removal and disposal; (e.g., primary cold traps), hence, the experience base for these items is limited. This is true not only for this method, but also for any other method that might be employed. Therefore, the MEDEC process utilizing full-scale equipment will be tested, using nonradioactive sodium components, during this fiscal year in a modified, single story, concrete slab on grade, structure, designated the Sodium Demonstration Facility. The entire building is utilized for the MEDEC demonstration test program. The operation of this facility will provide significant technical information for design and operation of a future shielded facility. In addition, operating experience and process verification essential to the program will be obtained. The process is shown schematically in Fig. 2.

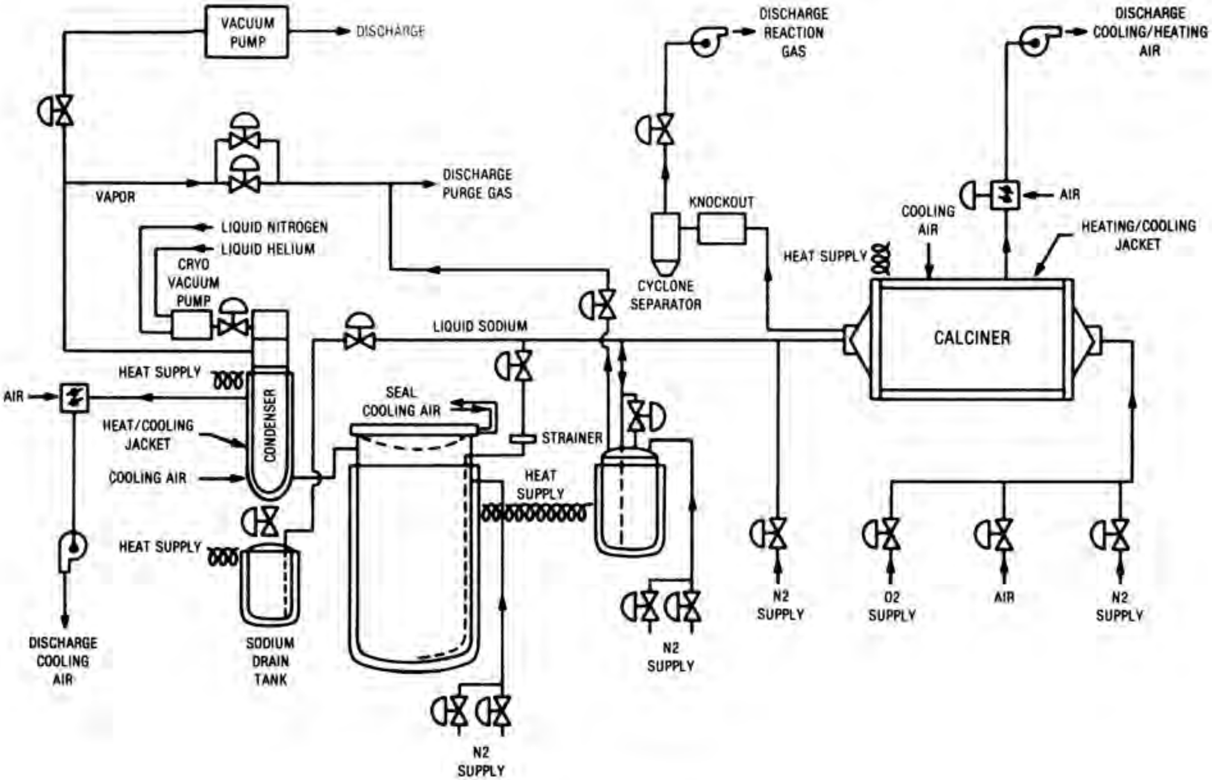

Fig. 2. Melt-Drain-Evaporation-Calcination (MEDEC) Process.

During this period of demonstration, progress which has started towards design efforts on a new shielded hot cell, designated the Prototype Radioactive Sodium Waste Process Facility (PRSWPF) will be enhanced. The PRSWPF facility will be designed and constructed to incorporate the full-scale MEDEC process equipment from the Sodium Demonstration Facility. In this facility, existing and future waste and scrap with radiation levels in the R/hr range will be processed, demonstrating the remote operation at the system and the capability of treating waste and scrap for disposal or reprocessing.

In the demonstration process, components to be cleaned of sodium are placed in the Melt/Evaporation (M/E) vessel. The components can contain bulk sodium and/or residual sodium film. For components containing sodium, the vessel is closed and sealed. The vessel is purged with nitrogen gas to displace oxygen from the vessel. The oxygen level in the gas is measured to verify completion of the purge. The components are heated to 400^o F to melt the bulk sodium. The melted bulk sodium drains to the vessel bottom and then can be transferred to the sodium storage tank. At the completion of the sodium transfer, the vessel and components are heated to 900^o F and the vacuum pump is started. Sodium and some impurities in the sodium will evaporate as the vacuum cycle continues. Non-condensible constituents such as hydrogen will be exhausted through the vacuum pump. The nitrogen pressurization and evacuation will be cycled until the sodium is removed.

The condenser removes the sodium and impurities from the vapor stream. The condenser temperature is controlled to maintain the sodium in liquid state. Upon completion of the evaporation cycle, the upper stage of the condenser will be heated to remove sodium. This sodium and the sodium removed by the condenser will then be transferred to the sodium storage tank. The M/E vessel is then purged with nitrogen and allowed to cool to room temperature. The vessel is then opened and the contents are removed. The sodium in all piping is kept liquid by heating the piping to 400^o F. After accumulation of a maximum of 300 gallons of sodium in the storage tank, the sodium is transferred to the calciner and converted to Na_2O. The calciner is initially charged with granular Na_2O either from a previous run or with commercially available Na_2O granules. The calciner bed is initially heated to 400^o F and sodium is injected into the rotating calciner bed in batch quantities of about 10 gallons. Oxygen is injected into the calciner until the sodium is converted to Na_2O. The bed is continuously regenerated by fracture and recoating of the particles. The heat of reaction is exothermic and the bed temperature is maintained in the range of 257^{o} F to 392^{o} F by air cooling of the calciner drum. The Na_2O product is removed from the calciner and is placed in containers for shipment or storage.

The test program will initially consist of removing sodium from simulated waste. Known quantities of sodium will be used to wet items of various configuration to simulate cracks and crevices on waste items. The items will be processed and the amount of sodium removed will be determined in the analytical laboratory. The program will progress to processing actual items containing nonradioactive sodium. These items will be disassembled or cut up and examined for any remaining sodium. The program will also test the ability to remove the sodium bonding from unirradiated EBR-II blanket elements and then demonstrate the ability to remove the sodium from an actual nonradioactive EBR-II cold trap.

After successful demonstration of the process, the facility will be modified for radioactive work and additional testing will be performed. This will include actual EBR-II and other low level waste presently in storage at ANL-W. Equipment will be added, if necessary, to convert the sodium to a final disposable product. The overall objective will be to treat low level waste such that the waste from which the sodium has been removed will be shipped to a disposal site and the resulting sodium will be converted to a form that is also acceptable at a disposal site.

Sodium Purification

The melt/drain/evaporation portions of the MEDEC process remove the sodium from various components and collects it in a holding tank where it has become, for all intents and purposes, bulk sodium. As previously noted there are also large quantities of radioactive bulk sodium from decommissioned reactors in storage. An active LMFBR program will require large quantities of sodium for initial fill; therefore, it may be more desirable to purify the waste sodium for reuse, rather than process it for disposal. It may also be desirable that sodium resulting from maintenance may be purified and reused as make-up. These decisions should be made by the operators of LMFBRs as to the cost effectiveness of the alternatives.

The SWT Program includes development work on the purification of sodium by distillation. Initial small scale pilot plant tests have shown that impurities (e.g., fission products) can be removed from the sodium. This testing will continue throughout this fiscal year so that design parameters can be established. As previously stated, the option of decontaminating sodium for reuse is being developed to provide options for LMFBR operators.

Shielded Facility

Since there are wastes and scrap that have radiation levels too high for contact operations, a remote handling facility is required. As previously noted, a shielded facility, to be located at the ANL-W site, is being considered. A location at the ANL-W site has been selected and the geotechnical work performed. Title I will be completed during the second quarter in FY 82 and additional work such as Titles II and III will be dependent upon future funding. A preliminary safety analysis report has been completed as well as an environmental assessment. Methods of removing existing waste with high radiation levels from present storage has been evaluated and will be tested in the future. Since tritium will be generated, methods of removing tritium are being evaluated and a cost-benefit analysis will be accomplished.

Criteria and Standards

An integral part of the SWT Program is the development of criteria and standards related to the handling and disposal of radioactive sodium and sodium-bearing radioactive waste. The overall purpose is to develop a set of generic standards which may be used by future LMFBRs for the handling of their waste. These standards could also be applied to the decontamination and decommissioning (D&D) plans for future LMFBRs. Over the shorter term, some of the standards and criteria are needed to dispose of the waste that presently exists. At present, the following are being developed.

1. Shallow Land Burial Criteria

Presently shallow land burial facilities prohibit the burial of elemental sodium. Since there are no data which establish the amount of sodium which may be safety buried, facilities are taking the conservative approach and prohibiting any sodium no matter how small the amount. The SWT Program has been performing tests utilizing a closed vessel which simulates the in-leakage of water to a waste container containing varying amounts of elemental sodium. Initial tests show that if the container contains readily-accessible sodium, the reaction does generate pressure and hydrogen and in some cases, small explosions.

However, tests are also showing that if the sodium is distributed around on surfaces which are not readily accessible, such as would be the case for sodium-wetted components from which much of the sodium had been removed, little if any reaction takes place. Atomics International-Rockwell is continuing this work for the SWT Program, and expects to develop criteria and verification procedures which will allow burial facilities to accept sodium-wetted waste which has been processed by some approved method.

2. Storage Criteria

Although sodium and sodium-bearing wastes have been stored for many years at ANL-W, Hanford and other locations with no problems, there are no defined storage criteria. The SWT Program has a task which will define the storage requirements for sodium and sodium-bearing waste which is being stored prior to processing or reuse. The approach being taken will define the storage criteria for newly generated waste, with each facility, who presently stores waste, making a determination how much retrofitting should be done for their material.

SUMMARY

The SWT Program has been established to develop methods, processes and criteria for disposing of sodium and sodium-bearing wastes and scrap which presently exist in the LMFBR experimental program and which will be generated from future commercial LMFBRs. Work is presently proceeding on demonstrating a process for removing the sodium from waste materials so that they can be disposed of in the same manner as other reactor wastes. Simultaneously, work is proceeding on the treatment of bulk sodium to provide the options of either reusing the sodium or converting it to a stable form for disposal as well as the development of generic standards for handling sodium wastes and scrap.

It is the intent of the SWT Program to solve the problems of LMFBR wastes such that these wastes will not adversely affect future government and commercial LMFBR operations.