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MANAGEMENT OF NEW PRODUCTION REACTOR WASTE STREAMS AT SAVANNAH RIVER (U)

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ABSTRACT

To ensure the adequacy of available facilities, the disposition of the several waste types generated in support of a heavy-water NPR operation at the Savannah River Site were projected through waste-treatment and disposal facilities expected after the year 2000. Volumes of high-level, low-level radioactive, TRU, hazardous, mixed and non-radioactive waste were predicted for early assessments of environmental impacts and to provide a baseline for future waste-minimization initiatives. Life-cycle unit costs for disposal of the waste, adjusted to reflect waste management capabilities in the NPR operating time frame, were developed to evaluate the economic effectiveness of waste-minimization activities in the NPR program.

INTRODUCTION

In September 1992, the Department of Energy announced plans to delay further design of the New Production Reactor (NPR) until 1995. As the first DOE materials-production reactor proposed for construction and operation in many years, the NPR presented a unique opportunity for innovation in waste-management practice. If the reactor was sited at the Savannah River Site (SRS), moreover, the waste-processing procedures supporting an NPR operation would have to be compatible with existing and near-term projected general site facilities.[1] Planning for site support of the NPR at SRS proceeded with recognition of the importance of waste management practice on reactor sizing, design, and costing and with systematic implementation of waste-minimization objectives, using cost analyses to optimize waste-generation and processing alternatives.

The purpose of this report is to present the strategy developed in the NPR program to ensure cost effective management of waste streams from SRS facilities supporting a heavy-water NPR design.

NPR SUPPORT FACILITIES

A heavy-water NPR operation at SRS would be supported by site facilities providing a full range of fuel cycle capabilities.[2] Fuel and target fabrication facilities would be provided for manufacturing high-enriched uranium-aluminum fuel tubes and lithium-aluminum target elements charged to the reactor for tritium-production operations. Chemical reprocessing facilities currently are available for recovering and recycling of enriched uranium from spent fuel. Product-extraction and purification facilities are provided for recovering tritium from irradiated targets. Supporting these operations is a complex of waste-management facilities including large, carbon-steel storage tanks for receiving high-level, radioactive-waste (HLW) effluents from the fuel reprocessing operations, and the Defense Waste Processing Facility (DWPF) for converting the aqueous waste to a solid, glass form. The fuel-cycle support facilities, as well as the reactor operation, generate several types of secondary waste that also must be processed for disposal through SRS's waste management system.

In addition to the existing waste-management facilities, projected modes of NPR operation could require new facilities to accommodate spent-fuel disposal without reprocessing for recycling enriched uranium. In accordance with DOE directives, a down-sized NPR was being designed to be compatible with direct spent-fuel disposal in a geologic repository. Support facilities for direct disposal would include replacing existing fuel-reprocessing and aqueous HLW management facilities with additional capabilities for interim storage and conditioning of the spent fuel prior to transport to a national waste repository. The storage facility would provide for dry storage of the spent fuel, pending availability of the repository. The conditioning facility would treat and package the spent fuel to meet criticality and safeguard requirements for repository emplacement. In the following representations of NPR support facilities, the interim storage and conditioning facilities are included as primary fuel-cycle operations, producing additional secondary waste of the several types generated by other support facilities.

SRS WASTE MANAGEMENT OPERATIONS

SRS facilities supporting NPR operations could produce a variety of waste types. These include liquid high-level radioactive waste, liquid low-level radioactive waste, solid low-level radioactive waste (low and intermediate activity levels), transuranic waste, hazardous waste, mixed waste containing both radioactive and hazardous components, and non-radioactive, non-hazardous (sanitary) waste. All of these waste are generated and managed at SRS in accordance with DOE Orders and federal, state and local regulations. In addition, improvements are being planned and made to the waste-management systems that are required to process and dispose of these waste. This section of the report identifies SRS's waste-management operations that would be impacted by the NPR utilizing a proposed heavy-water reactor (HWR) design and describes the waste-management facilities expected to be available after the year 2000. Summary charts, showing the flow of several waste types generated in support of a representative NPR operation, are presented in Figures 1 and 2.

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Liquid High-Level Waste

Liquid high-level waste generated in fuel- and target-reprocessing operations are stored, treated, and converted to solid form in a complex series of waste-management operations at SRS.[2,3] Since spent-fuel reprocessing was expected to be phased out of SRS operations by the time of NPR startup, it was assumed that no incremental HLW would be generated by NPR operation.

Liquid Low-Level Waste

Liquid low-level waste (LLLW) generated by NPR operations would be processed in waste-treatment facilities in the reactor design. Facilities for routine cleanup of the D_2O reactor moderator and the fuel-storage pool water, and for incidental liquid leaks and spills collected in building sumps typically would be required. These cleanup facilities, utilizing ion-exchange technology, for example, would generate solid radioactive waste for onsite disposal, as well as purified effluents for reuse or discharge into the environment.

The LLLW streams generated in NPR support facilities would be produced primarily in fuel- and target-fabrication operations before reactor irradiation and during the spent-fuel storage and conditioning/packaging operations after irradiation. The waste streams from the storage and packaging operations generally would result from evaporator overheads and wash solutions that contained low but measurable quantities of radioactive and chemical materials. In the case of the materials-fabrication operations, the waste also would contain low-radioactivity aqueous sludges and concentrates that result from processing unirradiated uranium.

Two treatment facilities are used to process the LLLW streams from supporting facilities. The first facility, called the Liquid Effluent Treatment Facility (LETF), is located in the materials-fabrication area and receives waste water from M-Area buildings. The LETF uses conventional methods of pH adjustment, flocculation, precipitation, filtration, and evaporation to separate a decontaminated effluent stream from the low-level radioactive-waste constituents. The radioactive concentrate would be disposed of onsite as a low-level waste, either directly or mixed with cement components to form a concrete solid (Saltstone).

The second facility, called the F- and H-Effluent Treatment Facility (F/H ETF), services the chemical-processing operations in those areas, using filtration, reverse osmosis, and ion-exchange equipment to remove impurities from low-level wastewater discharges. It is assumed this facility would be used to process the LLLW from spent-fuel storage and conditioning/packaging operations. The wastewater streams are processed to reduce radioactive and chemical concentrations to the very low levels that allow release to onsite streams in accordance with NPDES permits. The concentrated waste stream from the F/H ETF would be processed for final disposal as sludge or saltstone in onsite, low-level waste vaults.

Solid Low-Level Radioactive Waste

Solid low-level waste (SLLW) is processed as low-and intermediate-activity materials, producing radiation exposures less than or greater than 200 mr/hr, respectively. The low-activity waste, which can contain minor alpha activity as well as beta-gamma activity contamination, typically consists of small pieces of equipment, contaminated protective clothing, and other job-control items. The intermediate-activity waste includes reactor hardware, ion-exchange resins and filters, spent-melt crucibles from tritium-recovery operations, and failed equipment from other processes. In future operations, the non-hazardous SLLW will be placed in a new low-level Solid Waste Disposal Facility (SWDF), using subsurface, concrete vaults to minimize the escape of radioactivity into the environment.

Treatment activities used to reduce the volumes of SLLW requiring disposal include compaction and incineration. Compactable, low-activity waste is compressed into carbon-steel disposal containers (B-25 boxes), using two large-scale compactors located in M-Area and F-Area facilities. Combustible waste, including burnable liquids and solids, will be incinerated in a Consolidated Incineration Facility (CIF) scheduled for completion in 1994. The CIF will process combustible hazardous waste (HW) and mixed waste (MW), as well as SLLW.

The CIF is a full-scale facility for volume reducing and detoxifying SLLW, HW, and MW.[4] Waste to be burned include drummed liquids, sludges, and solids, as well as boxed job-control waste. Up to 1000 m^3/yr of liquid waste and 16,000 m^3/yr of solid waste will be processed. Incinerator ash and offgas scrubber slurries will be immobilized in cement-based or other solid waste forms, producing residual solids about 13% (7% ashcrete and 6% scrubber solids) of input SLLW volumes. The residual incinerator solids must be placed in HW/MW vaults, described in a subsequent section.

The SWDF to which uncompacted or compacted SLLW is directed has below-grade concrete vaults to provide the groundwater protection required by DOE Orders.[5] The SLLW is consigned to the facility according to the classifications designated tritium-contaminated intermediate-activity waste, other intermediate-activity waste, long-lived (greater than 30 year half-life) waste, and other low-level radioactive waste. The intermediate-activity tritium waste will be stored for at least 120 years to permit decay (about 10 half-lives) before disposal. The long-lived waste will be stored in an above-ground building on a concrete pad until a final-disposal method, such as geologic disposal, is developed for these wastes. Each SWDF vault will provide approximately 30,000 m^3 disposal space for solid LLW. Vault space would be provided to accommodate current SRS and incremental NPR requirements as needed.

Transuranic Waste

Solid transuranic (TRU) waste generally is produced in the fuel- and target-reprocessing facilities, including the primary/separations canyons and related lines for solidifying recovered actinide products. As such, the NPR would not be expected to generate significant incremental volumes of TRU waste.

Mixed and Hazardous Waste

Hazardous and mixed waste (HW/MW) typically consists of contaminated oils and scintillation fluids, tritium-contaminated mercury, lead-shielding materials, organic-contaminated soils, and heavy-metal-containing process sludges. Incinerable components of HW and MW (except PCBs) will be processed in the CIF, with incinerator ash and scrubber slurry stabilized in solid form for disposal in the vaults of the Hazardous Waste/Mixed Waste Disposal Facility (HW/MWDF).[1] The non-incinerable components will be sorted and packaged in a treatment building prior to final disposal in HW/MW vaults. The HW/MW treatment building will use prescribed treatments to convert non-incinerable waste into an acceptable form for final, onsite disposal. The above-grade

HW/MW vaults will be re-enforced, concrete structures with double liners and leakage-collection systems which are specified by the Resource Conservation Recovery Act regulations. The HW/MW vaults, each with a capacity of about 3500 m^3, to contain 740 m^3, of HW/MW before stabilization, will be provided to accommodate ongoing SRS and incremental NPR disposal needs. The space requirements will include provisions for disposing of the incinerator ash and scrubber solids from SLLW HW and MW processed in the incinerator.

Non-Radioactive Waste

Construction, operation and maintenance activities for the NPR would generate non-hazardous and non-radioactive waste (NRW). This waste typically consists of office material, paper, plastic, and glass. The SRS Sanitary Landfill handles all solid, NRW onsite in accordance with sanitary landfill operational requirements.

SRS's landfill currently is closing an area that has been filled within the last few years, and the site's Waste Management Operations has received approval to construct and operate a new interim facility. This interim facility will be able to handle SRS waste for approximately the next four years. Design work is being undertaken to construct a state-of-the-art sanitary landfill to meet SRS's needs beyond 1996.

The landfill also will accept special waste as defined in the S.C. Solid Waste Policy and Management Act of 1991 and outlined in the SRS Sanitary Landfill Waste Acceptance Criteria - Waste Analysis Plan. Generally, this is waste other than hazardous waste that is difficult or dangerous to handle and requires unusual management. Examples of special waste are pesticides, contaminated soils or debris from a cleanup, and containers or drums.

SRS's demand for a sanitary landfill will drive the construction and operation of the new sanitary landfill whether or not the NPR is built.

Availability of Waste Management Facilities

A review of waste-management projects indicated there is a high probability that the most critical facilities needed to support NPR operations after year 2000 would be available. These facilities include the F/H ETF, the SWDF, and the HW/MWDF. The CIF also will be provided with high priority. Although the NPR should have no impact on DWPF processing of HLW, this facility is expected to be available for processing existing HLW inventories in waste storage tanks. The availability of a Transuranium Waste Facility (TWF) for repackaging and shipping previously-generated and stored TRU waste to the Waste Isolation Pilot Plant (WIPP) in New Mexico is less certain. However, a critical part of the Waste Certification Facility (WCF), which processes most of the newly-generated TRU wastes currently is in operation.

NPR WASTE VOLUMES

Volumes of each waste type generated in fuel-cycle activities that would support NPR operations were projected for several reactor designs. Principal emphasis was given to designs using HWR technology at 100% historical production capacity of existing SRS reactors and at various downsized ratings between 25-50% of historical reactor capacity. A representative design under consideration just prior to the decision to stop the NPR work provided 31% of the historical SRS reactor capacity. The fuel assembly used in this reactor would be a three-tube assembly of aluminum-clad cast and coextruded uranium-aluminum (U-Al) fuel containing high-enriched U-235, with concentric inner and outer target aluminum-clad tubes of lithium-aluminum (Li-Al) alloy for product tritium generation. Operating the reactor under long-exposure (deep burn) conditions to minimize spent-fuel generation typically would produce 110 fuel assemblies per year, for which intermediate-term storage and conditioning/packaging would be required before final disposition in a geologic repository.

Long-term storage facilities with the capacity for 40 years of reactor operation would need space for about 6000 assemblies, including allowances for failed assemblies, emergency core discharges, and sprint outputs. The conditioning/packaging facility, assumed to operate for 10 years after the interim storage period, would be sized to process the stored spent fuel for geologic disposal at a rate of about 100 packages per year (assuming six assemblies/package). The tritium targets would be processed as discharged from the reactor, to recover product tritium by conventional operations.

The NPR's impact on the volume of waste processed in SRS waste-management facilities was projected by reference to historical waste-processing experience. The volume of waste generated in support of a full-sized (100% capacity) NPR was assumed equivalent to that generated by one existing reactor on tritium production. Waste volumes produced by the down-sized reactor designs were reduced by appropriate scaling factors. Waste-volume projections for the 31%-capacity-reactor design are included in the flow charts for processing liquid and solid waste in Figures 1 and 2. Comparisons of the NPR-processing requirements with the capacities of the SRS waste-management facilities, as summarized in the following table, showed the waste-management facilities to be readily capable of processing the incremental NPR waste generated.

LIFE CYCLE WASTE DISPOSAL COSTS

Unit-cost estimates for handling, treating and disposing of SRS waste in the post-2000 time frame of NPR operation were derived to support NPR development. The costs were projected for the NPR's waste from the time of generation through final disposal. The waste-disposal costs were used to compare life-cycle costs of candidate NPR designs and to evaluate the economic impacts of waste-minimization measures incorporated into these designs.

The NPR waste costs, derived from a 1992 compilation of SRS waste-cost projections,[6] were presented in a format potentially useful for specific waste forms of interest to the NPR program. The costs distinguished specific treatment and disposal options through which the NPR waste could be processed, allowing optimization of process alternatives. Total costs assigned included both relatively invariant fixed-cost components, and variable-cost components dependent on the quantities of waste processed. The variable costs, combined with annual input volumes of waste processed, provided incremental unit costs of changes in waste volumes processed. Such incremental-unit costs are applicable particularly to evaluations of the economic impacts of waste-minimization programs that affect existing SRS facilities. The total-unit costs, including the allocations of fixed-cost components, appear used most appropriately in design optimizations of new waste-generating (including reactor) and processing facilities.

The NPR waste costs, applicable to the liquid- and solid-waste volumes generated in support of a 31%-capacity HWR in Figures 1 and 2, are summarized in the following table.

Comparisons of the unit costs for alternative treatments of SRS waste indicated the following trends:

- Unit costs generally increased in the order of LLLW, NRW, SLLW, MW, and HW. Waste types with lower incremental costs (LLLW, NRW) benefited from the relatively large volumes of waste processed, in contrast to the low-volume waste (HW, MW) that requires special handling. The HW disposal costs reflected somewhat higher operating expenses which currently are budgeted for the emerging technologies involved.

- The unit costs of disposing of compacted SLLW significantly were lower than those of either uncompacted or incinerated waste. The cost of processing solid LLW through incineration concurrent with hazardous and mixed waste was increased compared to compaction due to the higher operating costs of the incinerator and the required disposal of the resulting ash/scrubber solids in the relatively high cost HW/MW vaults. The unit costs for disposal of hazardous and mixed wastes with incineration were less than the costs of disposal of these wastes without incineration.

Note that HLW or TRU waste costs were not included in these projections because it was assumed that spent fuel discharged from the reactor would not be reprocessed chemically to recover enriched uranium, and therefore, these waste types would not be generated.

SUMMARY

1. Existing and projected SRS capabilities for managing a variety of waste types produced in support of defense-reactor production operations provided a comprehensive foundation for developing an optimized NPR waste-management strategy.

2. Reactor fuel-cycle activities for which current facilities are provided include fuel and target fabrication, product tritium recovery, fuel reprocessing, and related waste-management operations. Projected suspension of fuel reprocessing for recycling enriched uranium would impose new requirements for interim storage and conditioning/packaging of NPR spent fuel before disposal in a geologic repository.

3. NPR waste types for which SRS facilities would be available after the year 2000 included, in addition to spent fuel for repository disposal, liquid low-level radioactive waste, solid low-level radioactive waste, hazardous and mixed waste, and non-radioactive, non-hazardous (sanitary) waste. Due to the suspension of fuel-reprocessing operations to recover enriched uranium and the elimination of plutonium production from the NPR program, no impact of NPR operation on liquid HLW or solid TRU waste treatment and disposal facilities was projected.

4. The incremental volumes of waste generated in support of NPR operations, based on historical SRS waste generation and appropriate scaling factors for down-sized NPR designs, were projected to assess environmental impacts. The NPR waste volumes were demonstrated to be well within the capacity of existing and planned facilities for treatment and disposal of the waste.

5. Life-cycle unit costs for waste disposal, adjusted from current practice to reflect waste-management operations in the NPR operating time frame, were developed and tabulated for use in economic evaluations of alternative NPR design, operations, and support facility utilization parameters. The cost compilations provided, in addition to measures of economic incentives for NPR waste minimization initiatives, bases for optimization of waste-treatment options applicable to NPR support activities.

6. The early development of strategies for optimized disposal of waste generated in support of NPR operation at SRS sets the stage for continued development of cost-effective innovations in waste-management practice for new and existing site operations.

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TABLE I. COMPARISON OF NPR PROCESSING REQUIREMENTS WITH CAPACITIES OF SRS WASTE MANAGEMENT FACILITIES

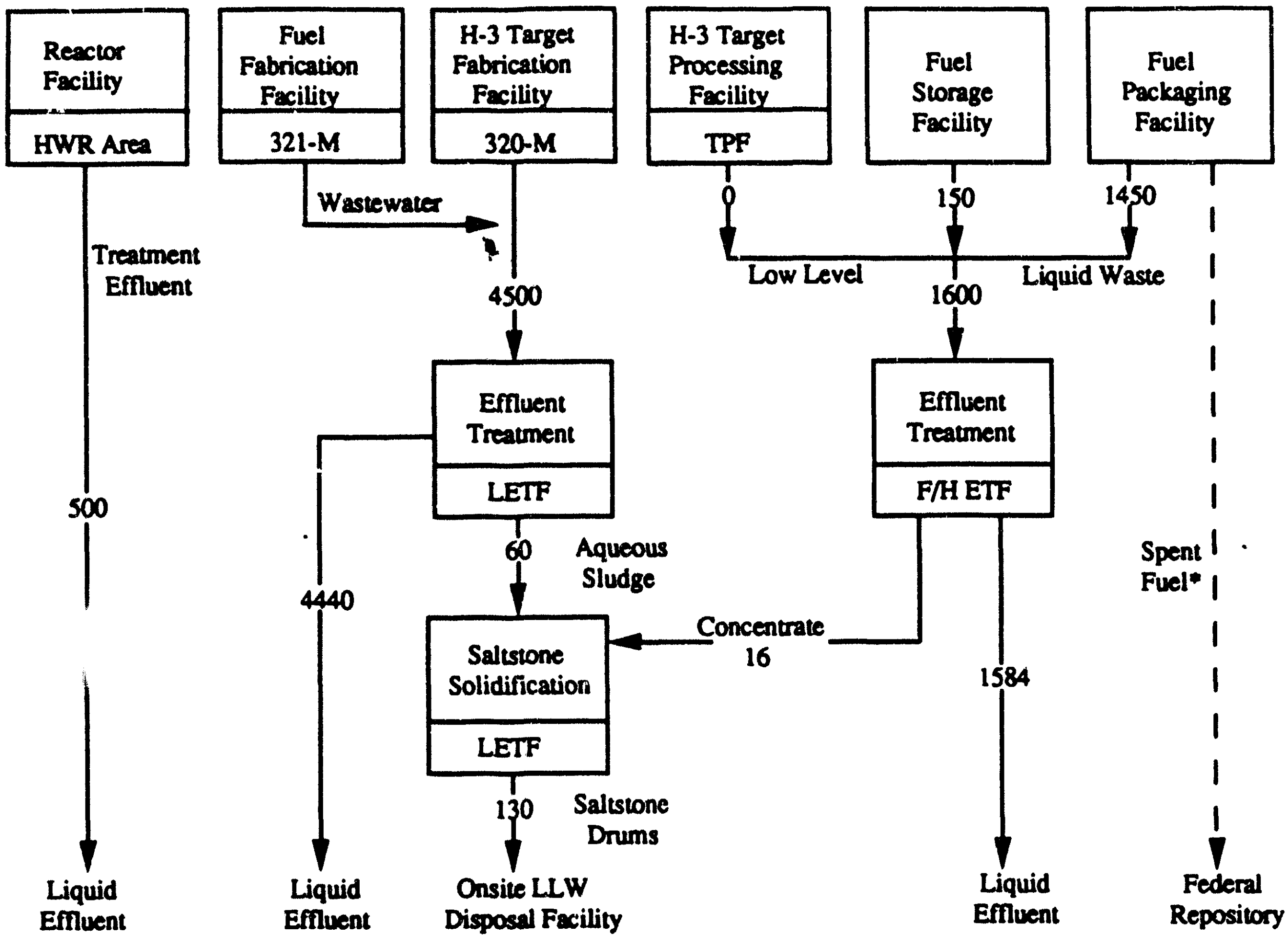
FACILITY	CAPACITY, m^3/yr	NPR WASTE VOLUME, m^3/yr 100% DESIGN	31% DESIGN
Effluent Treatment Facilities			
- LETF	120,000	25,000	4,500
- F/H ETF	130,000	14,000	1,600
Consolidated Incineration Facility (CIF)	17,000	1,800	1,000
Solid Waste Disposal Facility (SWDF)	As needed (up to 30,000 m^3 per vault)	3,350	1,850
Hazardous/Mixed Waste Disposal Facility (HW/MWDF)	As needed (3500 m^3 per vault containing 740 m^3 waste each)	500	275

TABLE II. WASTE COST COMPARISONS

TYPE WASTE AND TREATMENT	PROJECTED WASTE VOL, m^3/yr	UNIT COST, $/$m^3$ TOTAL	INCREMENTAL
LLLW (H/F ETF)	1,600	351	98
SLLW			
Uncompacted	1,600	1,215	759
Compacted	1,400	773	300
Incinerated	900	2,831	854
HW			
Incinerated	17	68,515	8,422
Non-Incinerated	10	98,303	21,296
MW			
Incinerated	60	34,286	4,099
Non-Incinerated	20	64,053	16,953
NRW	5,500	157	113

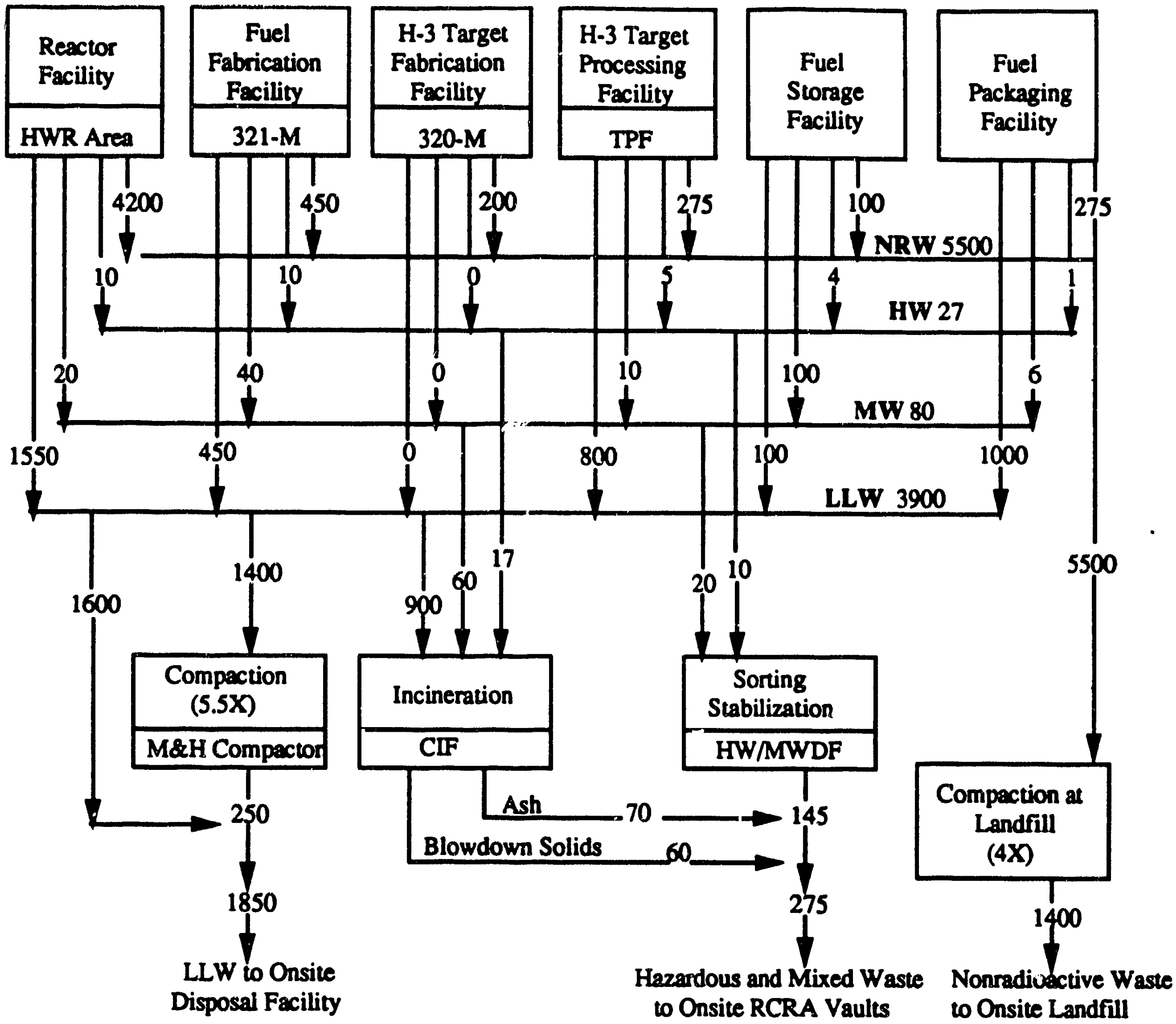
LLLW - Liquid Low-Level Waste
SLLW - Solid Low-Level Waste
NRW - Non-Radioactive/Non-Hazardous Waste
HW - Hazardous Waste
MW - Mixed Waste

Figure 1. Summary of Liquid Radioactive Waste Generation and Treatment Volumes (m^3/yr) for 31%- Size HWR-NPR at the Savannah River Site H-3 Production



*Spent fuel consigned to Federal Repository after long-term interim onsite storate - volume to be determined.

Figure 2. Summary of SolidWaste Generation and Treatment Volumes (m^3/yr) for 31%- Size HWR-NPR at the Savannah River Site H-3 Production



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