BASELINE FLOWSHEET GENERATION FOR THE TREATMENT AND DISPOSAL OF IDAHO NATIONAL ENGINEERING AND ENVIRONMENTAL LABORATORY SODIUM BEARING WASTE

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ABSTRACT

The High-Level Waste (HLW) Program at the Idaho National Engineering and Environmental Laboratory (INEEL) must implement technologies and processes to treat and qualify radioactive wastes located at the Idaho Nuclear Technology and Engineering Center (INTEC) for permanent disposal. This paper describes the approach and accomplishments to date for completing development of a baseline vitrification treatment flowsheet for sodium-bearing waste (SBW), including development of a relational database used to manage the associated process assumptions.

A process baseline has been developed that includes process requirements, basis and assumptions, process flow diagrams, a process description, and a mass balance. In the absence of actual process or experimental results, mass and energy balance data for certain process steps are based on assumptions. Identification, documentation, validation, and overall management of the flowsheet assumptions are critical to ensuring an integrated, focused program. The INEEL HLW Program initially used a roadmapping methodology, developed through the INEEL Environmental Management Integration Program, to identify, document, and assess the uncertainty and risk associated with the SBW flowsheet process assumptions. However, the mass balance assumptions, process configuration and requirements should be accessible to all program participants. This need resulted in the creation of a relational database that provides formal documentation and tracking of the programmatic uncertainties related to the SBW flowsheet.

The Technical Baseline Database (TBDB) for SBW Vitrification has been established to manage the elements of the baseline. The focus of the TBDB is on the design basis elements (DBEs), which include uncertainties in process requirements, basis, and assumptions. This database also enables the tabulation of other vital information linked to the assumptions; for example, bases for assumptions, development tasks needed to validate assumptions, and technical resources relevant to the assumptions. The primary purpose of these efforts is to validate the assumptions through experimental results and operational data, thus mitigating or minimizing technical risk. Validation of the DBEs will eventually resolve the uncertainties.

INTRODUCTION

The term *sodium-bearing waste* (SBW) refers to the liquid waste now stored in the Idaho Nuclear Technology and Engineering Center (INTEC) Tank Farm. SBW was generated primarily from laboratory, decontamination, and other operational processes at INTEC. These wastes are not raffinates resulting from uranium recovery from spent fuel reprocessing activities at INTEC (formerly the Idaho Chemical Processing Plant). About 3,800 cubic meters of SBW are currently stored at INTEC. In the past, portions of SBW were thermally converted to a dry granular form (calcine) at the calcination facilities at INTEC by blending with the raffinates from spent fuel reprocessing. However, calcination was terminated in June 2000. Under the terms of the 1995 Settlement Agreement (1) and other Consent Orders between the DOE Idaho Operations Office (DOE-ID), the State of Idaho, and the Department of the Navy, use of the tanks at INTEC must cease by 2012; all SBW is to be calcined (i.e., treated) by 2012; and all HLW is to be treated to a "road ready" condition by 2035. To treat the SBW and the calcine, DOE-ID is considering the treatment options described in the draft environmental impact statement (EIS) (2) evaluating various alternatives and their associated impacts. A decision management team consisting of senior DOE managers with strong nuclear waste technical and regulatory backgrounds will advise DOE Headquarters and DOE-ID on the preferred alternatives to include in the final EIS and record of decision (ROD).

WIR Issue

Disposition of the SBW depends on whether it is classified as HLW or waste incidental to reprocessing (WIR). Recent program planning has been based on the assumption that the SBW is HLW. Classifying the waste as HLW dictates a particular disposal path, which ends in the national monitored geologic repository. This path, in turn, determines the required final waste form. Current waste acceptance criteria for HLW require that the contaminants be immobilized in borosilicate glass, using a vitrification process. To clarify the waste classification, INEEL's HLW Program has developed a WIR determination. Nuclear Regulatory Commission review and issuance by DOE of the WIR determination for SBW is planned for June 2002. If the SBW is determined to be WIR, rather than HLW, a different disposal location would be selected. In that case, the disposal location would likely be the Waste Isolation Pilot Plant (WIPP) in New Mexico, and the waste acceptance criteria would be significantly different. Different disposal options considered in the draft EIS accommodate a ruling for SBW as either HLW or WIR.

Evolution of SBW Vitrification as the Baseline

In December 1999 DOE-ID requested that Bechtel BWXT Idaho, LLC (BBWI) examine the waste processing options in the draft EIS and recommend a process for treating the SBW. A broad-based BBWI Core Team was assembled to leverage work performed over the prior 5–7 years. Based on recommendations of this team (3) and concurrence by DOE-ID, Raytheon was contracted to perform a pre-conceptual design for a SBW treatment process that would remove radioactive cesium from the SBW and generate a contact-handled TRU grout to be disposed of at WIPP.

While the Raytheon study was underway in the summer of 2000, DOE-ID requested that the Tanks Focus Area (TFA) convene a review team of national experts to independently assess the technical alternatives bounded by the Draft EIS with regard to SBW treatment. The review team recommended Direct Vitrification as the SBW treatment option (4), with Cesium Ion Exchange as a backup option.

BBWI prepared, in late summer of 2000, a SBW technology roadmap (5) to define development work that must occur to resolve the key uncertainties in SBW disposition for three treatment alternatives: Direct Vitrification, Cesium Ion Exchange, and Solvent Extraction. The Roadmap was reviewed by the TFA and recommendations were made.(6) On the basis of continuing review by DOE of the treatment options in the EIS, the recommendations by the TFA, and SBW technology roadmap, DOE redirected BBWI development efforts for FY2001 toward Direct Vitrification of SBW and away from Cesium Ion Exchange.(7)

Genesis of Roadmap Uncertainties

The results of the roadmapping sessions at the end of FY 2000 were reviewed internally by BBWI management and incorporated into a roadmap report.(5) The roadmap detailed development work needed for each of three alternatives under consideration for treatment of SBW, namely, Cesium Ion Exchange, Solvent Extraction, and Direct Vitrification. It identified potential failure modes, safety issues, and engineering needs associated with each of these alternatives. Development activities were identified that would address one or more of these issues or needs. A schedule for these activities was prepared that placed uncertainties having the greatest impacts early in the schedule. Milestones for each of the activities were included in the schedules. The issues associated with Direct Vitrification were listed as data needs, evaluations needed for decisions regarding processing options, and general concerns regarding safety, operability, viability, etc., that should be answered before detailed design of a processing facility commences. A list of 67 uncertainties was drafted. The list was created to encapsulate the issues in a more succinct form and facilitate work planning aimed at resolving the issues.

Flowsheet Development

A fundamental part of the process flowsheet is the mass balance. It is based on the expected behavior of the sub-processes, on assumed processing requirements, feeds, operating conditions, constraints, etc. It drives the selection and performance specifications of the unit operations. During development of a process, many of the assumptions of the mass balance are not based on demonstrated performance or test data. It is therefore necessary to identify the assumptions that most affect the mass balance and validate them prior to proceeding with detailed design.

Concurrent with the start of development activities, the mass balance for the SBW Vitrification Feasibility Study (8) was modified to incorporate new information and to better represent the evolving process configuration. In addition, in light of their critical role, the assumptions used in generating the mass balance were identified and documented.

Need for a Managed Technical Baseline

The original need for a managed baseline became evident in discussions about the assumptions used in the mass balance calculations. Since many of these assumptions were not validated, there was disagreement among individuals with differing perspectives. Thus, BBWI decided that the mass balance assumptions should be codified and made accessible to all program participants. In addition, they recognized that the assumptions should be tied to the uncertainties and that the development activities should focus on validation (or updating) of the assumptions and resolution of the uncertainties. Finally, they recognized that the mass balance assumptions should be a unifying factor in the efforts of those participating in development activities, flowsheet development and engineering studies.

The idea of using the mass balance assumptions to integrate the programmatic efforts suggested the creation of a relational database. This would enable tabulation of other information linked to the assumptions (e.g., bases for assumptions, development tasks needed to validate assumptions, identification of personnel knowledgeable about assumptions and their bases, links to documents containing relevant information, etc.). It would also facilitate documenting issues and questions raised relative to the assumptions and "threading" them to create a rationale for modifying or validating each assumption. These considerations were presented to management, who approved the creation of the database, which was named the "Technical Baseline Database" (TBDB) for SBW vitrification. Input was then solicited from all high-level waste program participants on its design.

One of the suggestions offered was that the database include process functional requirements. The suggestion was accepted and generalized to broaden the application of the database. Thus, the assumptions for the process mass balance, together with the process functional requirements, and all other data that will ultimately be part of the design basis for the SBW vitrification process, were lumped together conceptually to form the central entity contained in the TBDB, called a design basis element (DBE).

Each DBE is a concise statement about a specific element of the SBW vitrification process (e.g., "The efficiency of $HgCl_2$ scrubbing in an acid venturi scrubber is 85%"). Generally, the information in the statement is necessary to establish the functional requirements of the process, to define the mass balance, to configure the process, or to design individual unit operations. Thus, a DBE is a statement of what is required, currently known, or assumed regarding a specific element or aspect of the flowsheet. Some of the DBEs (generally mass balance assumptions) relate directly to the roadmap uncertainties. Others (e.g., process functional requirements) are not tied directly to the uncertainties.

The statements in the DBEs are accepted as fact *for the moment* so that design activities can proceed (e.g., calculation of mass balances, selection of candidate unit operations, etc.). However, if the validity of the DBE can be questioned or has not yet been demonstrated, the DBE must be validated at some point. If the DBE is changed as a result of validation, it may be necessary to modify the process design before the process is pronounced viable and worthy to advance to the next stage of design.

The TBDB was constructed using Microsoft Access and has been partially populated. In a nutshell, it contains (a) technical data and process requirements needed to define the flowsheet and mass balance (contained in the DBEs), (b) the basis for each DBE, (c) the validation plan and status of each DBE, (d) specific tasks required to validate each DBE, (e) the unit operations whose designs are impacted by each DBE, (f) the personnel responsible for validation tasks and design of the unit operations, (g) issues raised regarding each DBE, and (h) the disposition of each of these issues.

PROCESS BASELINE DESCRIPTION

Process Requirements, Basis, and Assumptions

A major objective of the High-Level Waste program during FY 2001 was to establish a process baseline.(9) To do this, a number of high-level assumptions were made as a starting point to define process requirements. Assumed regulatory and process requirements for the TBDB are listed in Table I.

Table I. Assumed Process Baseline Requirements

Regulatory	Process
The SBW glass waste form produced must comply with all acceptance criteria for disposal at Yucca Mountain.	All liquid wastes in the Tank Farm will be treated, including suspended solids, but excluding heels and heel solids, to one or more waste forms disposable in one or more permanent disposal facilities. Liquid wastes include SBW and liquid wastes generated in the future.
Secondary wastes must comply with all waste acceptance criteria for at least one target disposal site. Specific disposal sites for secondary wastes have not been selected as of this writing. However, the list of candidate disposal sites includes WIPP, Nevada Test Site, Envirocare of Utah, and mixed/low level disposal sites at the Hanford reservation.	The process must produce no "orphan" waste streams (i.e., waste streams that cannot be disposed of in an established or a planned permanent disposal facility).

RCRA—The waste vitrification facility will operate as a licensed RCRA treatment facility and will be required to comply with all State of Idaho and Federal regulations applicable to such facilities.	The primary waste form to be produced is borosilicate glass produced in a joule-heated melter. The glass will contain the bulk of the radioactive elements contained in the treated wastes and will comply with all Waste Acceptance Criteria (WAC) for Yucca Mountain.
Clean Air Act—The IWVF will be required to comply with the provisions of the Clean Air Act of 1970 and all amendments thereto. In particular, it is assumed that the facility will be required to comply with maximum achievable control technology (MACT) standards. It will also comply with any additional requirements imposed by the state beyond those of the federal statutes. In addition, the facility will be required to obtain a permit to construct from the State of Idaho Department of Environmental Quality, and a Permit to Operate, defining operating conditions, emission limits, control equipment, and reporting requirements necessary for compliance.	Liquid wastes from the process must not be returned to storage in the current Tank Farm.
	The process must be operable in such a way that ensures that workers and the public are not exposed to levels of radiation or hazardous materials above established limits discussed in various DOE Orders (e.g., 420.1, 435.1, 440.1A).
	The design of the SBW treatment facility shall be such that modifications for future treatment of calcine can be made in a cost-effective manner consistent with ALARA practices.

Process Basis

The mass balance for the vitrification facility is based on a waste feed rate of 100 gal/hr. This feed rate is intended to provide mass balances that can easily be adjusted up or down as design studies evaluate different processing schedules. The feed rate also coincidentally corresponds to processing the entire volume of waste projected to be present at 2012 in a 2-year schedule.

The SBW vitrification mass balance for waste from Tank WM-180 is based on a waste loading of 20% in the glass waste form. Waste loadings for the other waste tanks and the total waste case are based on 0.306 wt% sulfur in the glass waste, which corresponds to the sulfur loading for glass produced from waste in the INTEC tank with the highest sulfur content (Tank WM-180). The waste loadings for the different wastes are subject to change as the glass formulation envelope is refined.

Many other assumptions that underlie the process flowsheet are contained within the DBEs.

Process Description

Process flow diagrams and a complete mass balance for the baseline configuration have been generated. The principal waste feed to the process is concentrated liquid from the INTEC Tank Farm. The projected liquid waste volume to be processed is 3,700 cubic meters (10,11), containing suspended solids at an estimated average concentration of 2.7 g/l, free acid at 2.4 Molar (M), Al^{+3} at 0.56 M, Cl^- at 0.024 M, Hg^{+2} at 0.0037 M, NO_3^- at 5.9 M, Na^+ at 1.5 M, PO_4^{+3} at 0.0072 M, and SO_4^{-2} at 0.051 M. Sucrose solution (67 wt%) is added as a reductant in the ratio of 33 g sugar/mole NO_3. A glass frit containing 65% SiO_2, 15% B_2O_3, 10% Fe_2O_3, 5% Li_2O, and 5% CaO is also blended with the waste feed before being fed to the melter.

The current baseline incorporates the following principal unit operations:

Feed Preparation. Sodium-bearing waste is transferred from the INTEC Tank Farm to the SBW work off tank. Glass frit is received from the supplier and stored in a hopper. A solution of 67% sucrose is also received from the supplier and stored in a heated tank. Glass frit is weighed and conveyed to a SBW Mix Tank, and a sugar solution and SBW are pumped to the melter feed mix tanks. A portion of the scrub purge, containing undissolved solids, dissolved solids, and dissolved acid gases and other volatile species captured by the acid scrub system, is also added to the melter feed mix tanks. The melter feed mix tanks are cooled with chilled water to minimize the reaction of sucrose with nitric acid contained in the SBW and scrub purge. The SBW mix tanks are also agitated to maintain the frit and waste solids in suspension and to maintain a uniform composition. When one of the SBW mix tanks reaches a specified level, the feed is stopped and the tank is sampled. Following verification that the feed composition falls within certification limits, the slurry is transferred to the melter feed tank. The melter feed mix tanks are sized to provide sufficient holding time for sample analysis while maintaining the design melter feed rate.

Melter Feed Tank. The melter feed tanks are heated with steam to initiate evaporation of water from the feed slurry. Reaction between sugar and nitric acid is also expected, producing NO_x, CO, water, and heat. The solid/liquid slurry and the gases and vapors produced in the melter feed tank are transferred by two separate lines to the melter.

Melter. The melter is joule-heated, similar to those used at the Defense Waste Processing Facility at the Savannah River Site and the West Valley Demonstration Project. In joule-heated melters, an electric current is passed through molten glass. The internal electrical resistance of glass generates the heat required to maintain the glass temperature and evaporate water. The melter will operate at a nominal glass temperature of 1150°C. The melter is refractory lined, and power is supplied to Inconel 690 electrodes. The melter is also equipped with heaters in the melter plenum. The plenum heaters are used to start the melter and to boost the evaporation of water from the feed.

In the melter, all water in the melter feed volatilizes and leaves the melter in the off-gas. Sugar and nitrates react and decompose to NO_x, N_2, CO, CO_2, H_2 and steam. Nearly all mercury in the feed will volatilize; a portion of the halides and other volatile species in the feed will form gases and be contained in the melter off-gas. A small amount of solids from the feed and molten solids will also be entrained in the off-gas leaving the melter.

Canister Handling. Empty canisters will be transferred into the facility by flatbed truck or forklift. The canisters will be off-loaded, unpackaged, and checked for compliance and cleaned if necessary. A forklift mounted canister-handling device is then attached to the canister, and it is transferred to the canister elevator. The forklift canister handling device is removed and the elevator lowered to the basement floor. The canister is then removed from the elevator and into the clean canister storage area via cranes. Cranes move the canisters from the storage area into the melter cell and into position on the melter canister turntable. The canister is then rotated into the melter tapping mating position. Heated glass taps on the side of the melter allow transfer of molten glass into a canister. When a canister is greater than 80% full, as monitored by weight or thermal imaging, the tapping operation ceases for canister changeout.

When a canister is full, the tapper-to-canister shroud is withdrawn and the canister is rotated. Cooling, which began during the fill cycle, continues as the canister remains on the canister turntable. When the canister reaches the initial position, a crane transfers it to a cooling area. When cooling is complete, the canister is transferred to the weld cell for remote welding of the canister closure lid. After the weld has passed inspection, the canister is moved to the decon cell for decontamination, and then to the smear cell to determine if external contamination is at acceptable levels. Canisters meeting the external contamination criteria are then moved to the interim storage complex.

Film Cooler. Off-gas from the melter enters a film cooler to minimize solids deposition on off-gas piping walls. The film cooler is a double walled pipe designed to introduce a stream of air, steam or air/steam mixture axially into the off-gas through a series of slots in the inner wall. The injected air and steam cool the melter off-gas to below the softening point of the entrained solids (~400^{o}C) and maintain gas velocities above 60 ft/s to minimize deposits in the line. Additional air is added to the off-gas downstream of the film cooler via a pressure control valve to maintain a steady pressure in the melter. The gas exiting the film cooler will have a temperature of about 350^{o}C. After the addition of pressure control air, the off-gas temperature will be about 330^{o}C.

Quench Tower. The off-gas then enters a quench tower for cooling to its saturation temperature, about 80^{o}C. The cooled scrub solution is sprayed into the quench tower to cool the off-gas. Large-diameter (>10 μm) particles entrained in the off-gas are mostly removed in the quench tower by the scrub solution. The makeup scrub solution is water. However, as the scrub solution contacts the off-gas, NO_2 is absorbed by the water, producing nitric acid, and additional acidity is gained from capture of a portion of the HCl and HF in the off-gas.

Venturi Scrubber. Smaller particulate solids contained in the off-gas are removed in the scrubber immediately downstream of the quench tower. The present flowsheet assumes a venturi scrubber; other types of scrubbers could be evaluated in later studies. The venturi scrubber removes particulate and soluble gases from the off-gas by forcing intimate contact of gas and liquid. The scrub solution is sprayed perpendicular to the gas flow into a neck region of the scrubber. The high velocity of the gas facilitates atomization of the water by a shearing action. A knockout drum, often an integral part of the venturi scrubber, removes the bulk of the liquid from the gas/liquid stream.

High-Efficiency Mist Eliminator. The high-efficiency mist eliminator (HEME) captures a high percentage of the remaining entrained water and entrained solids not removed by the venturi scrubber. The HEME employs a single large cylindrical packed fiber bed. Off-gas enters the central annulus of the bed and passes radially though a series of screens holding the filter medium of fiberglass or polypropylene fibers. Water droplets and small (submicron) particulate and aerosols in the gas are collected on the filter media via inertial impaction, direct interception and brownian movement capture. The water droplets, particulate and aerosols, coalesce, and drain to the bottom of the unit. Water is sprayed onto the inner face of the fiber bed to minimize the accumulation of particulates on the bed.

When the pressure drop in the bed reaches a predetermined maximum level, the filter media is considered loaded and is replaced with new media.

High-Efficiency Particulate Air Filters. Off-gas from the high-efficiency mist eliminator is heated before entering a bank of high-efficiency particulate air (HEPA) filters. Heating the gas is required to avoid condensation in the HEPA filters that could degrade their performance. HEPA filters are glass fiber media folded multiple times. The filters are secured in a sealed housing with inlet and outlet isolation dampers and test ports. A HEPA filter train consists of a pre-filter followed by two HEPA filters in series. The HEPA filter bank consists of four trains in parallel. HEPA filters are designed for 99.97% removal of 0.3 μm particles, although the American National Standards Institute only allows 99.9% removal to be assumed for the first filter and 99% for a second filter in series. HEPA filters are replaced when the differential pressure across the HEPA reaches a predetermined limit.

NO_xidizer. Following HEPA filtration, the off-gas exits from the hot cell and is treated to remove NO_x, acid gases, and mercury. A three-stage combustion process is used to destroy NO_x contained in the off-gas. In the first stage, a propane direct-fired burner brings the off-gas to a temperature of 1200–1400°C. Additional fuel is introduced into the gas stream through the burner or through injection parts to create reducing conditions for conversion of NO_x to N_2 plus steam. The design residence time is about two seconds. The products of combustion from the first stage and inert gases in the off-gas are cooled in the second stage to a temperature of 760–870°C by injection of water. Air is introduced into the cooled off-gas, and the unburned hydrocarbons, CO, and H_2 are oxidized in the third stage of the combustor. Combustion in the third stage is controlled with minimal excess air (oxygen) to minimize reformation of NO_x. The temperature varies based on the amount of fuel available (CO, H_2 and hydrocarbons) in the off-gas for combustion. Propane is supplied to the burner of the first stage through a standard burner control train. An additional burner may be installed on the third stage for startup or to maintain a minimum temperature, however, during normal operation fuel flow to the third stage is zero.

Caustic Scrubber. Effluent from the combustor is cooled, and acid gases are removed in a quench scrubber using a dilute caustic solution. Caustic is used to achieve high-efficiency removal of HCl and SO_2, in order to minimize emissions of these gases, and HI, to minimize the collection of ^{129}I on the downstream GAC bed. A small amount of CO_2 and the trace amount of NO_2 present in the off-gas are also removed by the caustic solution. Caustic quench/scrub solution is fed to the quench tower from a collection tank. Losses of caustic and water from the quench/scrub solution are replaced by supplying the collection tank with 4 molar makeup caustic.

Demister, Mercury Removal, and Final HEPA Filtration. Entrained liquid in the caustic quench tower effluent gas is removed by a demister. The off-gas is then heated to avoid condensation in downstream equipment. Mercury is removed from the heated off-gas by passing the gas through a bed of sulfur-impregnated activated carbon. The off-gas then passes through a second bank of HEPA filters and is released to the atmosphere via the stack.

Acid Scrub Tank. Liquid from the quench tower, venturi scrubber and HEME are collected in the acid scrub tank. Makeup water is added to the scrub tank to replace losses due to evaporation and purging of the scrub solution. The acid scrub tank is designed as a solid liquid separator to concentrate solids captured from the off-gas in the quench tower and venturi scrubber. The concentrated solids are recycled to the melter, while liquid scrub solution is recycled to the quench tower and venturi scrubber. A small portion of the scrub solution is purged to a treatment system consisting of a solid filter, an ion exchange column to remove cesium, and a grouting system.

Cs Ion Exchange Columns. The scrub purge liquid is filtered in a cartridge filter. The filtered scrub purge is then neutralized by the addition of caustic in the acid scrub neutralization tank. Neutralization is required in order to achieve high removal of cesium by the downstream ion exchange sorbent. Cesium is removed in the ion exchange columns in order to reduce the radiation field of the waste. UOP IONSIV IE-95, an alkali metal alumino silicate, is used as the ion exchange media. Being inorganic, no degradation of the ion exchange media is expected in a high-radiation field. Spent sorbent is collected and stored for treatment by vitrification in a later vitrification campaign.

Grouting. The cesium-free scrub purge is then combined with the purge from the caustic scrub system in the effluent storage tank and stored for batching in the grout system. The combined scrub is first conditioned in preparation for grouting. Additional sodium hydroxide is added, if required, to the combined scrub to obtain a pH of 11 to 12. Calcium hydroxide is also added to complex free fluoride. Following a sufficient hold period for the solution to reach equilibrium, the conditioned effluent is transferred to the grout mixer, and blast furnace slag and Portland cement are added in a ratio of 9 kg slag:1 kg cement. The grout mixture is stirred for about 30 minutes and then discharged to 210-liter or 270-liter drums. The drums of grouted waste are then decontaminated, surveyed and labeled, and sent to interim storage. Fig.1. depicts the overall process block flow diagram.

The results of the mass balance indicate that treatment of the entire projected SBW inventory should produce about 620 m^3 of glass (515 4.5-m tall canisters) and 520 m^3 of grout having radionuclide concentrations well below the Hanford Category 3 LLW limits. Approximately 54 m^3 of granular activated carbon and 5.2 m^3 of UOP Ionsiv IE-95 sorbent will be required. A total of 6.3 m^3 of spent HEPA filters will be produced. Expected contaminant levels in the off-gas are 0.2-0.3 ppmv SO_2, 1 ppmv CO, 0.5-1.5 ppbv Hg, 0.02-0.03 ppmv HCl, and 7×10^{-10} g/m^3 particulate. Total radioactivity in the off-gas released is expected to be less than 4×10^{-7} Ci/m^3, with virtually all the radioactivity from ^{3}H. The estimated Hg concentration corresponds to about 8–26 μg/dsm^3, which is less than the MACT standard for new sources (45 μg/dsm^3).

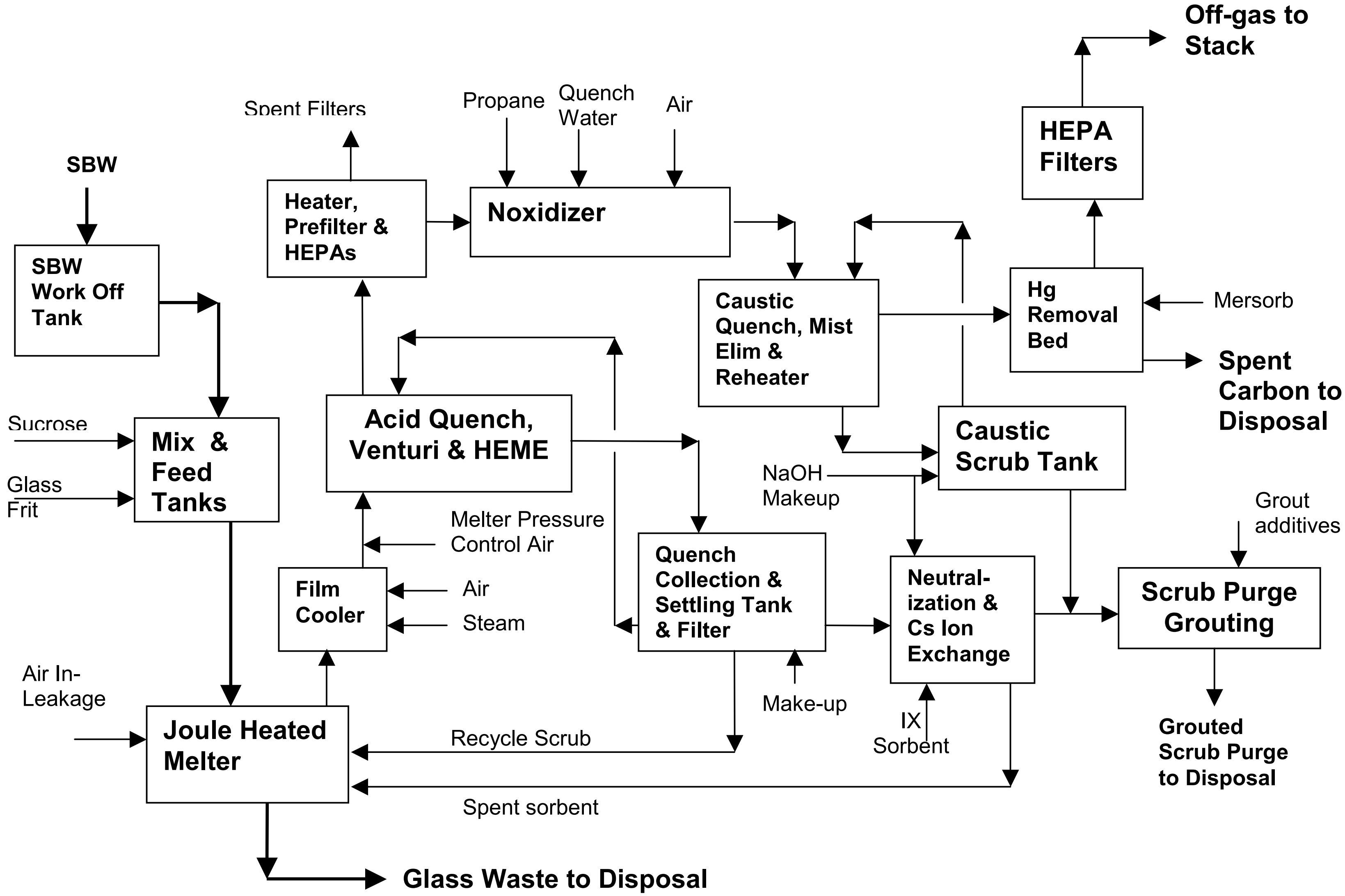

Fig. 1. SBW Vitrification Process Block Flow Diagram

PROCESS UNCERTAINTIES

Development Work Completed In FY 2001

Development work completed in FY 2001 included the following items. Details of these activities are published in formal reports listed in the References section.

A cold simulant for concentrated SBW in WM-180 was prepared and used in crucible and pilot-scale melter tests. (11, 12)

Sampling was performed on wastes that will become part of the vitrification facility feed. Analyses for these samples have been completed or requested. (10)

Two series of melt rate experiments have been performed on WM-180 simulants at the Reduced Scale Melter (RSM) facility at PNNL. Data were collected on glass melt rate, alternative reductants, off-gas characterization, fate of sulfates, and operational issues (e.g., melter off-gas duct plugging). (13, 14)

Two series of pilot-scale melter tests were performed in the EV-16 facility at Clemson. Data similar to those collected in the RSM tests were gathered, but from a larger-scale melter. The second test at Clemson was terminated early due to the National events of September 11, 2001. (15, 16)

Tests were performed at INTEC on commercial GAC products to measure removal efficiencies for elemental and oxidized forms of mercury. Removal efficiencies in excess of 99% were consistently obtained. (17)

Sixty-four glass formulations were made and tested in a compositional variation study to obtain data for predicting glass characteristics as a function of composition. (18)

Development Work Needed Beyond FY 2001

Additional work on waste characterization, performance of process unit operations, integrated processing effects, waste form qualification, and process requirements definition is needed to validate the DBEs that constitute the technical baseline. Issues in the DBEs identified as having the highest priority and to which attention and effort should be focused in the near term include the following:

- Waste feed characterization (I-129 and noble metals concentrations, suspended solids composition range, representativeness of cold simulants, volume and composite SBW composition)
- Granular activated carbon performance (toxicity characteristic leaching procedure, effects of competing species on Hg removal efficiency)
- Off-gas scrubbing (acid gas and mercury partitioning, scrubbing efficiency of venturi scrubber for solids)
- Secondary waste treatment (need for extracting Sr-90 from scrub purge)
- Melter performance (DFs for all species of concern, fate of sulfate, waste loading in glass, composition envelope for acceptable glass feed)
- Requirements definition (disposal requirements for Hg-containing wastes, applicability of MACT requirements, safety requirements for blended feed during abnormal shutdown).

CONCLUSIONS (PATH FORWARD)

The primary function of the original Roadmap was to identify technical uncertainties, provide a logical sequence (schedule) for resolving the uncertainties, and provide an initial estimate of the resources required. It has been utilized to guide work planning processes for Fiscal Years 2001 and 2002. Discussions within INEEL management have deemed that it is appropriate to transition from the Roadmap to a Risk Management Plan directed by DOE Order 413.3, Program and Project Management for the Acquisition of Capital Assets. The primary reasons for the transition being an avoidance of cost and that a Risk Assessment Report, assumed to be generated in Fiscal Year 2002, will sufficiently manage the technical uncertainties. The Risk Management Plan will guide:

- Identification of technical risks in the SBW vitrification program
- Prioritization of development tasks according to their risk levels.

The Risk Management Plan will be applied to accomplish each of these two tasks in FY 2002, and the results will be documented in a Risk Assessment Report. The SBW Vitrification Roadmap will also be integrated with the Risk Assessment Report so those future development tasks can be prioritized and planned in accordance with established risk management practices. Plans to validate all DBEs in the technical baseline should be formulated with specific development tasks that would be required.

DOE Environmental Management is conducting a "top-to-bottom" thorough review of cleanup and closure tasks as of this writing. It is entirely possible that vitrification may not become the preferred alternative for SBW treatment and disposal in the EIS Record of Decision. In this case, a similar methodology for preparing and managing the baseline flowsheet is recommended.

REFERENCES

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