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Revision 0

Process Options Description for Steam Reforming Flowsheet Model of INEEL Tank Farm Waste

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DISCLAIMER

ABSTRACT

Technical information is provided herein that is required for development of a steady-state process simulation of a baseline steam reforming treatment train for Tank Farm waste at the Idaho National Engineering and Environmental Laboratory (INEEL). This document supercedes INEEL/EXT-2001-173, produced in FY2001 to support simulation of the direct vitrification treatment train which was the previous process baseline. A process block flow diagram for steam reforming is provided, together with a list of unit operations which constitute the process. A detailed description of each unit operation is given which includes its purpose, principal phenomena present, expected pressure and temperature ranges, key chemical species in the inlet stream, and the proposed manner in which the unit operation is to be modeled in the steady state process simulation. Models for the unit operations may be mechanistic (based on first principles), empirical (based solely on pilot test data without extrapolation), or by correlations (based on extrapolative or statistical schemes applied to pilot test data). Composition data for the expected process feed streams is provided.

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FIGURES

TABLES

ACRONYMS

FS	Flowsheet
FY	Fiscal Year
INEEL	Idaho National Engineering and Environmental Laboratory
INTEC	Idaho Nuclear Technology and Engineering Center (at INEEL)
LLW	Low Level Waste
MB	Mass Balance
PM	Particulate Matter
SR	Steam reformer (or Steam Reforming)
TFA	Tanks Focus Area
TFF	Tank Farm Facility
TTP	Technical Task Plan
V/L/S	Vapor/Liquid/Solid
WIPP	Waste Isolation Pilot Plant

Process Options Description for Steam Reforming Flowsheet Model of INEEL Tank Farm Waste

1. PURPOSE

The purpose of this document is to provide the technical information that is required for the development of a basic steady-state process simulation of the steam reforming treatment train for Tank Farm waste at the Idaho National Engineering and Environmental Laboratory (INEEL). INEEL considers simulation to have an important role in the integration/optimization of treatment process trains for the High Level Waste (HLW) Program. During FY2001 this project involved a joint Technical Task Plan (TTP ID77WT31, Subtask C) between the Savannah River Site (SRS) and the INEEL. However, as a result of DOE redirection of INEEL's development program away from vitrification the SRS work scope supporting simulation of INEEL's treatment process has been eliminated.

2. SCOPE

This document provides information needed for process simulation engineers to construct and link unit operation models in a commercial process simulator to represent the treatment train for the steam reforming of SBW. The information supplied is of a mid- to high-level nature and consists of the following:

1. A list of specific unit operations, their probable operating conditions and constraints, and applicable modeling approaches for FY-2002 (see Tables 1–4);

2. One potential process configuration of the steam reforming treatment train showing the component unit operations and their interdependencies via stream connections (see Figure 1); and

3. Stream compositional makeups (see Table 5–9).

Low-level information, such as assumed species partition fractions or separation efficiencies, is not detailed in this document because it is not required for the construction and verification of the simulation package. This document is focused only on a steady-state simulation of steam reforming treatment of Tank Farm waste to be assembled in FY-2002. In addition, per the current assumed scope of activities by the HLW program at INEEL, the treatment of solid calcine will be separate from treatment of Tank Farm waste and will neither be modeled as part of this effort nor will it be included within the scope of this document. Tank Farm waste includes sodium bearing waste (SBW), newly generated liquid waste (NGLW), tank heels, and tank solids.

3. JUSTIFICATION

The reason for building a simulation model for steam reforming in a commercial process simulator is to provide mass balance accounting to support INEEL HLW Program planning. Modeling of INEEL SBW treatment processes has been done in the past using linked EXCEL spreadsheets which lack a physical properties database. The objective for FY-2002 is to continue the transition away from the spreadsheet-based simulation toward a full-fledged commercial simulation software package with thermodynamic simulation capability based on a physical properties database. This package will be used to perform basic mass and heat balances on individual unit operations and around the entire treatment train. Having an integrated model with a thermodynamic database will increase the ability of INEEL engineers to assess system-wide impacts of changes to individual unit operations.

A process simulation capability is expected to facilitate process design and thus reduce life-cycle schedule and cost for the SBW treatment project, which is imperative given the 1995 Settlement Agreement commitments and shrinking DOE budgets. The fact that funding may not be available for an integrated pilot plant demonstration of the treatment train increases the likely role of process simulation. Refinements to the physical properties database and unit operation models are planned during out-years to support future optimization efforts and detailed design of SBW treatment.

Simulation results will be used by engineers and scientists to develop high-level recommendations for DOE-ID and INEEL program managers regarding the treatment of Tank Farm waste. As such, it is expected that technical personnel will be the primary end-users of the simulation results, and program management will be an indirect end-user.

4. SUMMARY

Treatment of SBW stored in the Tank Farm Facility (TFF) at the Idaho Nuclear Technology and Engineering Center (INTEC) at the INEEL is a priority for the Department of Energy under the 1995 Settlement Agreement with the State of Idaho. Several options to treat this waste for disposal have been considered. During FY2001 Bechtel BWXT Idaho was directed to develop a vitrification flowsheet for SBW. However, this direction was altered at the start of FY2002 and vitrification has been supplanted with other treatment options. One option currently under DOE consideration is stream reforming (SR) of the SBW followed by packaging of the solid product for disposal at WIPP. Because steam reforming is now considered a major contender for treating the waste, the focus of this TTP was changed at the direction of TFA from vitrification to steam reforming, and simulation efforts have been re-targeted to support the latter option.

An essential first step in developing any process is to establish a flowsheet (FS) and mass balance (MB). The FS/MB describes the expected behavior of all sub-processes together with the assumptions, requirements, inputs, constraints, and known facts about the process on which the calculations in the MB are based. Thus, the flowsheet and its supporting data provide a design basis for conceptual design. The main objectives in generating the FS/MB are as follows:

a. Identify all required process input and output streams;

b. Track components of interest in the input streams through the process, partitioning them among possible output streams from the unit operations constituting the overall process;

c. Describe where each component exits the process--i.e., how much of each input component leaves in each of the output streams.

d. Describe the form (or forms) in which each input component leaves the process--i.e., what chemical compounds are formed.

e. Determine stream flowrates and properties needed for equipment sizing.

f. Determine heating and cooling requirements.

The above information constitutes a basis for process design. The MB is used to assess the adequacy of the process in transforming the inputs into the desired outputs and allows the characteristics of the output streams (e.g., flow rates, compositions, temperatures, pressures, etc.) to be compared with the process requirements. The MB is also used to provide performance specifications used to select and size the unit operations (e.g., required throughputs, required separation or reaction efficiencies, required temperatures, etc.). Both these uses of the MB assume that the information provided in items a–f above is credible for the assumed inputs and unit operations. If the underlying information is not credible then the resulting process design may not be viable.

The information required in items a–f above may be generated using any combination of the following modeling methods:

Mechanistic. Accurate models based on first principles are used to simulate the unit operations and the underlying physical and chemical phenomena. The models for the process unit operations are based on the assumed input streams and provide realistic and credible predictions for items a–f without the need for testing.

Empirical. Partitioning and chemical behavior associated with each unit operation are assumed constant and independent of operating conditions and stream compositions. Data from bench/pilot/full scale tests is directly incorporated in *ad hoc* fashion to force consistency between model predictions and experimental measurements. The information produced for items a–f will be credible to the extent that the assumed performance parameters are truly independent of variation in operating conditions. Information generated using this method offers the highest credibility (albeit at the highest cost) when the scale of pilot testing approaches that of the actual production system. However, the credibility is low if pilot testing is performed only at a reduced scale (and correspondingly reduced cost), since scale effects may not then be recognized and duly accounted for.

Correlation. Empirical test data is used to formulate semi-mechanistic models that capture the influences of key operating parameters on system performance. These models are used to predict partitioning and chemical transformations in the actual system from pilot scale measurements. Such models range from simple linear regressions to statistical models and engineering correlations based on dimensional analysis. The credibility of the resulting predictions for items a–f is usually between that of the Mechanistic method and the Empirical method applied with only subscale test data.

A commercial simulator will be used to generate the MB for treatment of SBW, and the model will be updated (as needed) from time to time. In modeling the behavior of the overall process, each unit operation (or subprocess) will be represented in some fashion by one of the above modeling methods [Mechanistic, Empirical, or Correlation]. The choice of the method will be made based on the following considerations:

- What are the requirements for the process? (e.g., component "C1" of the SBW feed must leave the process in output streams "S1" and "S2", in form "Z", below a concentration of "x");

- What information should the MB provide in determining whether the process requirements are met? (e.g., the concentration of component "C3" in output stream "S4" is "x" which satisfies requirement "R1");

- What predictive capabilities does the simulator have that are applicable to the preceding bullet;

- What empirical data will be available? (e.g., what scale(s) and type(s) of testing will be performed that will provide performance data for each component of the offgas system over a representative range of inputs.)

The above considerations have led to tentative conclusions regarding how the SR process will be modeled. The rationale underlying these conclusions is captured in Tables 1–4, below. Table 1 lists the component unit operations for the current baseline SR process shown in Figure 1. The numbers in the process boxes in the figure refer to the unit operations as listed in Table 1. For each unit operation Table 1 includes the information listed below and refers to supporting information in Tables 2–4:

Purpose: The function of the unit operation in the overall process scheme

Op Range: The range of temperature and pressure over which the unit operation may be expected to operate within the process

Phases: Physical phases (gas, solid, etc.) expected to be present in the streams entering and/or leaving the unit operation

Phenomena: Basic phenomena that occur in the unit operation and that determine its performance. The phenomena are shaded, indicating that they are described more fully in Table 3.

Needed info: Information about the inputs/outputs of a unit operation which are of interest for (a) assessing whether the process requirements will be satisfied, and (b) designing or specifying the equipment for the unit operation

Species of int: Key chemical species in the input stream(s) to the unit operation which are expected to be altered in some way (e.g., extracted, changed chemical form, etc.) by the unit operation

Related req'ts: Process requirements likely to be impacted by the unit operation. The process requirements are shaded, indicating that they are described more fully in Table 2.

Model descr: Entries describe how the needed information will be obtained from the process simulator. The following information is given:

- A brief description of the tasks the model is to perform,

- Specific capabilities of the process simulator that will be used. These capabilities are shaded, indicating that they are taken from Table 4.

[Note: Table 4 describes the simulator capabilities to be employed in the FY2002 SR process model. For each simulator capability the table indicates which of the three modeling methods is used (Mechanistic, Empirical, or Correlation). None of the simulator capabilities listed in Table 4 employ the Correlation method because the needed correlative information is currently unavailable. This method is likely to be employed in the future, however, once the required data is generated.]

Representative compositional makeups of the expected feed streams for the process are given in Tables 5–9. The compositional data provided corresponds to the information needed to assess whether process requirements are met and to choose target disposal sites for all waste products.

Table 9 also gives additional assumptions that will be employed in the simulation beyond what is provided in Table 1.

Table 1. Unit Operation Descriptions.

1. SBW Tank	
Purpose:	Mix SBW (1-3 tank wastes, including UDS)
Op Range:	10-33ºC, ambient pressure
Phases:	Aqueous, solid
Phenomena:	Solid/liquid chemical equilibrium
	Salts form from combinations of species of interest (and minor species in feed). Soluble complexes of F-, Cl- form with spe
Needed info:	(1) Composition of feed to Mixing Tank, (2) Average concentrations of H+, Cl- and HF in tank for corrosion rate estimates Identities and quantities of solids likely to precipitate (these may include Al, As, Fe, F, Mo, Na, NO3, P, PO4, SO4, SiO2, Z Patterson (1999)]) for assessment of blending scenarios and required equipment/piping sizing (blending equipment needed
Species of int:	HF, H, Cl, Al, Fe, F, Mo, Na, K, NO3, P, PO4, SO4, Zr
Related Req'ts:	Feed Blending, Corrosion Allowance, Prevention of Criticality
Model descr:	Blended composition of tank to next downstream component calculated as pass through using measured concentrations of s tanks. Mixing is assumed perfect. (Use "Mass Accounting" model.). Concentrations of H+, Cl- and HF and precipitation of s thermodynamics. (Use "V/L/S Equilibrium" model.)
2. Mixing Tank	
Purpose:	Mix SBW purge with sugar/carbon/other reductant
Op Range:	25-100ºC, ambient pressure
Phases:	Aqueous (inorganic and organic), solid, gas
Phenomena:	Vapor/liquid chemical equilibrium
	N2, NO, NO2, HNO3, O2, H2O equilibrate chemically and phasically (gas/liquid). Gas phase chemical equilibration of H2 Temperature dependence of equilibrium limits. Potential net heat release from reactions affects temperature if heat/cooling d reduction to volatile forms (H2SO4/SO2/SO3/H2S).
Needed info:	(1) Composition of feed to SR vessel, (2) Average concentrations of H+, Cl- and HF in tank, (3) Vapor phase generation ra
Species of int:	N2, NO, NO2, HNO3, O2, H2O, H2, H+, Cl-, HF; CO, organic reductant; H_2SO_4/SO_2/SO_3/H_2S
Related Req'ts:	Feed Blending, Corrosion Allowance, Prevention of Criticality
Model descr:	Blended composition of feed to next downstream component calculated as a pass through using measured concentrations of tanks. Mixing is assumed perfect. (Use "Mass Accounting" model.). Concentrations of H+, Cl- and HF and vapor generatio calculated from thermodynamics. (Use "V/L/S Equilibrium" model.)
3. Steam Reformer	
Purpose:	Evaporate water; reduce nitrates to N2, O2; convert dissolved solids into a solid product suitable for packaging and disposa
Op Range:	500-700ºC, ambient pressure
Phases:	Aqueous (inorganic and organic), solid, gas
Phenomena:	Finite-rate homogeneous chemical reaction, Gas phase chemical equilibrium, Interphase heat transfer with one phase dispe stream reformer offgas particulates, Steady state single-phase mixing with volumetric sources
	Gas phase chemical equilibrium of N2, NO, NO2, HNO3, O2, H2, H2O, C, CO2, CO, HCs (decomposition products from Some reactions kinetically limited (e.g., oxidation of CO, HCs. Evaporation of water from droplets and coated bed material dependence of equilibrium limits. Heat release/absorption from oxidation reactions, water-gas shift reaction. Reduction of forms (H_2SO_4/SO_2/SO_3/H_2S). Evolution of particle-laden offgas with particles formed from bed material and dissolved solic

Table 1. (continued).

	Needed info:	(1) Composition, flow rate, temperature of offgas (concentrations of H_2O, HCl, Cl_2, H_2, O_2, NO_x, HCs, HF, CO, CO_2, Hg HgO), (2) Generation rates, compositions of fines and product solids, (3) Feed rates of additives (sugar, carbon, air, steam)
	Species of int:	Ionic, gaseous, nitric acid
	Related Req'ts:	Cl Emissions, CO Emissions, Corrosion Allowance, F Emissions, H_2S Emissions, HC Emissions, Hg Emissions, Semivolati Low Volatile Metals Emissions, NO_x Emissions, SO_x Emissions, PM Emissions, RCRA Components of Primary Waste, R Rad in Secondary Wastes, Rad in Process Streams, RCRA Metals in Secondary Waste, TRU in Primary Waste, TRU in Se Volatile Rad Emissions, Nonvolatile Rad Emissions
	Model descr:	Gas and solid compositions, and required additive rates calculated from thermodynamic model assuming a specified reform "V/L/S Equilibrium" model. and "Mass Accounting" models.). Correct some reactions to reflect available data for species m (e.g., CO,) (Use "Specified Reaction" model.). Separate solids products from thermodynamic calculation into product and fi pilot scale data (Use "Specified Separation" model.).
4.	**Cyclone**	
	Purpose:	Gross solids separation from gas stream leaving steam reformer
	Op Range:	400 – 700ºC, 5 – 12 psia
	Phases:	Solid, gas
	Phenomena:	Particle collection by sedimentation, Steady state heat exchange between a fluid and its boundary
		Entering gas cooled by contact with device surfaces which are exposed to ambient air. Solid particles in fluid extracted acco diameter.
	Needed info:	(1) Composition and temperature of gas exiting, (2) Extraction rate and composition of solids extracted
	Species of int:	Solids leaving steam reformer, gas (N_2, NO, NO_2, O_2, CO_2, CO, H_2, H_2O)
	Related Req'ts:	Convert SBW to Solid, Limit HEPA Changeouts
	Model descr:	Assume prescribed separation of product and fines from inlet gas stream. Gas composition is a pass through. (Use "Specifi "Mass Accounting" models.)
5.	**Ceramic Filter**	
	Purpose:	Collect majority of mass of particulate in off-gas directly out of steam reformer
	Op Range:	300 – 700ºC, 5 – 12 psia
	Phases:	Gas, solid
	Phenomena:	Particle removal from gas by filtration
		Larger product solid particles from reformer.
	Needed info:	(1) Solids loading rate on ceramic filters, (2) Composition of solids collected on ceramic filters and of fines passing throug mass loading in effluent gas, (4) Effluent gas composition
	Species of int:	Gas leaving steam reformer (N_2, O_2, Ar, CO, CO_2, H_2O, NO_x), solids species from melter offgas
	Related Req'ts:	Convert SBW to Solid, Low Volatile Metals Emissions, Nonvolatile Rad Emissions, PM Emissions, Semivolatile Metals E Secondary Wastes, Limit HEPA Changeouts
	Model descr:	Assume specified separation of product and fines from inlet gas stream. PM compositions are pass throughs of fines and pr Fractions of fines and product particles collected based on pilot data, gas composition is a pass through. (Use "Specified Se Accounting" models.)

Table 1. (continued).

6. Spray Quench

Purpose:	Rapid cooling of gas stream with partial removal of PM
Op Range:	100 – 700ºC, 5 – 12 psia
Phases:	Aqueous, gas, solid
Phenomena:	Particle collection by sedimentation, Vapor/liquid chemical equilibrium, Interphase heat transfer with one phase disperse, l entrainment in a gas stream Some solids in influent gas extracted to liquid. Acid gas capture and dissociation (HNO3, H2SO4, HF, and HCl). Aqueous HgCl2, Hg2Cl2). Aqueous dissolution of soluble solids from steam reformer. Partitioning of NO2, HNO3, CO2, CO, Hg, H HCl, HF, H2SO4, SO2, SO3 between gas and aqueous phases. Heat transport between aqueous and gas phases. Vaporizati entrainment in offgas going to downstream equipment.
Needed info:	(1) Composition and temperature of gas exiting (including mass of entrained liquid), (2) Composition and temperature of l Composition of solids exiting in gas and liquid streams
Species of int:	Gas (N2, NO, NO2, O2, CO2, CO, H2, Hg, H2S), near-neutral pH aqueous (NO3-, Cl-, F-, H+, H2O, SO4-2, H2SO4, solul reformer
Related Req'ts:	Cl Emissions, Corrosion Allowance, Prevention of Criticality, F Emissions, Hg Emissions, Semivolatile Metals Emissions, Emissions, Volatile Rad Emissions, Nonvolatile Rad Emissions, PM Emissions, Rad in Secondary Wastes, Rad in Process Metals in Secondary Waste, SOx Emissions, TRU in Secondary Wastes, Limit HEPA Changeouts
Model descr:	Separate an assumed fraction of solid particles from inlet gas stream into liquid and match to test data. (Use "Specified Sep Adiabatic thermal and chemical equilibration of gas and liquid phase based on inlet gas and liquid temperatures. Neglect t Liquid composition from inlet scrub composition augmented with soluble solids (and UDS) extracted from gas. Gas compo vapor/liquid equilibrium. (Use "V/L/S Equilibrium" and "Mass Accounting" models.)

7. Submerged Bed /Packed Bed/Caustic Scrubber

Purpose:	Cool and/or scrub gas with liquid, solids separation
Op Range:	70 – 100ºC, 5 – 12 psia
Phases:	Aqueous, gas, solid
Phenomena:	Particle collection by sedimentation, Vapor/liquid chemical equilibrium, Two-phase flow with heat transfer, Liquid droplet stream, Finite-rate homogeneous chemical reaction Solids loading in effluent gas. Acid dissociation (HNO3, H2SO4, HF, and HCl). Aqueous Hg speciation (Hg^o, HgCl2, Hg2 NO2, HNO3, CO2, CO, Hg, HgCl2, HgCl, H2O, HCl, HF, H2SO4, SO2, SO3 between gas and aqueous phases. Heat transp & gas phases. Vaporization/condensation of water. Droplet concentration in offgas going to downstream equipment.
Needed info:	(1) Composition and temperature of gas exiting (including mass of entrained liquid), (2) Composition and temperature of li Composition of solids exiting in gas and liquid streams
Species of int:	Effluent gas from upstream scrubber (could contain N2, NO, NO2, O2, CO2, CO, H2, H2O, HCs, Cl2, SO2, SO3, HF, HCl aqueous (Na+, NO3-, Cl-, F-, OH-, CO3-2, HCO3-, H2O, SO3-2, SO4-2, HgCl2, HgCl, Hg+2, cations from dissolved solid
Related Req'ts:	Cl Emissions, Corrosion Allowance, Prevention of Criticality, F Emissions, Hg Emissions, Semivolatile Metals Emissions, Emissions, Volatile Rad Emissions, Nonvolatile Rad Emissions, PM Emissions, Rad in Secondary Wastes, Rad in Process Metals in Secondary Waste, SOx Emissions, TRU in Secondary Wastes, Limit HEPA Changeouts
Model descr:	Separate an assumed fraction of solid particles from inlet gas stream into liquid and match to test data. (Use "Specified Sep Adiabatic thermal and chemical equilibration of gas and liquid phase based on inlet gas and liquid temperatures. Neglect th Liquid composition from inlet scrub composition augmented with soluble solids (and UDS) extracted from gas. Gas compo vapor/liquid equilibrium. (Use "V/L/S Equilibrium" and "Mass Accounting" models.)

Table 1. (continued).

8. HEME (high efficiency mist eliminator, demister)	
Purpose:	Collect liquid scrub droplets remaining in offgas prior to final HEPA filtration and Hg removal in GAC columns. Collect s particles from offgas.
Op Range:	50-175ºC, 5 – 12 psia
Phases:	Gas, liquid
Phenomena:	Vapor/liquid chemical equilibrium, Mist removal Acid dissociation (HNO3, H2SO4, HF, and HCl). Aqueous Hg speciation (Hgo, HgCl2, HgCl). Partitioning of NO2, HNO3 HgCl2, HgCl, H2O, HCl, HF, H2SO4, SO2, SO3 between gas and aqueous phases. Vaporization/condensation of water
Needed info:	(1) Composition of gas exiting (including entrained liquid and solids), (2) Composition of liquid exiting, (3) Composition of and liquid streams
Species of int:	Effluent gas from upstream scrubber, scrub liquid from upstream scrubber
Related Req'ts:	Cl Emissions, Corrosion Allowance, Prevention of Criticality, F Emissions, Hg Emissions, TRU in Secondary Wastes, Lim
Model descr:	Assume separation factors for key solid species of interest and entrained liquid and adjust to agree with pilot data. Compos product solid particles are pass throughs (Use "Mass Accounting" model.). Concentrations of acid gases (HF, Cl-, SOx) and (elemental Hg in separate liquid phase) calculated from thermodynamics. Composition of liquid from pass through of enter by dissolution of soluble solids and acid gases extracted from offgas. (Use "V/L/S Equilibrium" model.)
9. Scrub Collection Tank	
Purpose:	Accumulate scrub solution for recirculation through scrubbers, quenchers, etc. Equilibrate pH in entering streams and prov scrubber blowdown liquid for downstream treatment processes.
Op Range:	10-33ºC, ambient pressure
Phases:	Aqueous, gas
Phenomena:	Gas/liquid/solid equilibrium, Salts associated with combinations of ions from the major & minor species lists above. Soluble complexes of F-, Cl-.
Species of int:	Liquids from primary and secondary (caustic) scrubbing operations (H+, OH-, H2CO3, HCO3-), vent gas (CO2, H2O, N2, from entering liquid streams and precipitates from chemical equilibration)
Needed info:	(1) Composition (including radionuclides, H+, OH-, carbonates) and temperature of scrub liquor fed to scrubbers, quenche UDS, TDS concentrations in scrub liquor, (3) Compositions of solids in liquid streams drawn from the tank.
Related Req'ts:	Corrosion Allowance, Prevention of Criticality,RCRA Metals in Secondary Waste, TCLP for Secondary Waste, TRU in Se
Model descr:	Thermodynamic chemical and phase equilibration of entering liquid streams. (Use "V/L/S Equilibrium" and "Mass Accoun
10. Solid/Liquid Separator	
Purpose:	Separate high-rad solids from quench purge solution that is to be treated and disposed as LLW
Op Range:	20 – 100ºC, 5 – 12 psia
Phases:	Liquid, solid
Phenomena:	Liquid , Particle collection by sedimentation, Particle impingement due to inertia
Needed info:	(1) Solids composition, (2) Liquid composition and solids concentration
Species of int:	Liquid (scrub liquor--Na+, K+, Al+3, OH, Na2CO3, water, NO3-, HCl, H2SO3, H2SO4, HF, H+, OH-), solids in scrub liq reformer
Related Req'ts:	Liquids in Wastes, Rad in Secondary Wastes, Rad in Process Streams, TRU in Secondary Wastes, Waste Form Disposabili
Model descr:	Assume specified separation of solids from inlet liquid stream. Solid and liquid compositions are pass throughs of liquid a stream. (Use "Specified Separation" and "Mass Accounting" models.).

Table 1. (continued).

11. Acid Fractionator (distillation column)

Purpose:	Recover HNO3 from evaporator overheads
Op Range:	90 -- 115ºC, 10 -- 12 psia
Phases:	Gas, liquid
Phenomena:	Vapor/liquid chemical equilibrium
Needed info:	(1) Gas composition after extraction of HNO3 and other acid gases, (2) Fractionator liquid effluent composition
Species of int:	HNO3, HCl, HF, H2O, Hg, HgCl2, H2SO4, SO2, SO3
Related Req'ts:	Cl Emissions, Corrosion Allowance, F Emissions, H2S Emissions, Hg Emissions, NOx Emissions, SOx Emissions
Model descr:	Concentrations of HNO3, NOx, Cl-, sulfur species, and HF in gas and liquid phases calculated from thermodynamics. Othe throughs (Use "V/L/S Equilibrium" and "Mass Accounting" models.).

12. Condenser

Purpose:	Reduce offgas temperature to extract condensable species (primarily H2Oand/or Hg) to liquid phase for recycle, storage or Reduce gas volume
Op Range:	15 – 100ºC, 5 – 12 psia
Phases:	Gas, liquid
Phenomena:	Vapor/liquid chemical equilibrium, Steady state heat exchange between a fluid and its boundary, Steady state heat exchang in a heat exchanger
Needed info:	(1) Gas exit composition, flow rate, and temperature, (2) Condensate composition, flow rate, and temperature, (3) cooling l temperature of coolant
Species of int:	Gas (H2O), liquid (H2O)
Related Req'ts:	Corrosion Allowance, Limit HEPA Changeouts
Model descr:	Condensation of water vapor and associated cooling duty calculated from thermodynamics. (Use "V/L/S Equilibrium" and ' models.)

13. Evaporator/Salt Dryer

Purpose:	Remove part or all H2O from SBW feed or scrubber blowdown by evaporation to gas phase.
Op Range:	25 – 150ºC, 10 – 12 psia
Phases:	Aqueous, gas, solid
Phenomena:	Gas/liquid/solid equilibrium, Two-phase flow with heat transfer, Steady state heat exchange between two fluids in a heat e Evaporation of water from evaporator feed. Partitioning of NO2, CO2, Hg, HNO3, HCl, HF, H2O, H2SO4, Hg, HgCl2, H between evaporator bottoms and overheads. Precipitation of nitrate, sulfate, chloride, fluoride, phosphate salts. Scaling depo [Schindler (1998)]. Soluble complexes of F- and Cl- with Al+3, Cr+3, Fe+3, Zr+4, H2BO3.
Needed info:	(1) Gas (overheads) exit composition, flow rate, and temperature, (2) Bottoms (liquid or solid) exit composition, flow rate, Presence or absence of solid precipitates (including scaling deposits), (4) Composition of solids leaving with bottoms.
Species of int:	Gas (N2, O2, CO2, CO, H2, Hg, HgCl2, HCl, H2SO4, HF, NOx), aqueous (Cl-, F-, H+, H2O, SO4-2, Hg^{o}, Hg+2, HgCl2, ca solids in feed), solid (UDS in feed, scaling deposits[CaCO3, SiO2], precipitates formed by over concentration of the feed)
Related Req'ts:	Cl Emissions, F Emissions, Hg Emissions, Corrosion Allowance, Prevention of Criticality
Model descr:	Evaporation of water vapor and associated heating duty as well as precipitation of solids from phasic and chemical equilibriu is a pass through. (Use "V/L/S Equilibrium" and "Mass Accounting" models.)

Table 1. (continued).

14. Thermal Catalytic Oxidizer	
Purpose:	Remove most hydrocarbons (HCs), CO, and H2 generated upstream in steam reformer from off-gas by converting to CO2 a emission limits
Op Range:	800-1100ºC, 5 – 12 psia
Phases:	Gas
Phenomena:	Gas phase chemical equilibrium, Finite-rate heterogeneous (or catalytic) chemical reaction HC/CO oxidation reactions, Hg speciation between Hgo, HgO, and HgCl2
Needed info:	(1) CO, HCs, H2S concentrations in exit gas, (2) Hg concentration and speciation, (3) Exit gas temperature
Species of int:	Gas - N2, O2, CO2, CO, H2, HCl, Hg, HgCl, HgCl2, HgO, H2S, various HCs (set of plausible species includes: methane, propane, butane, formaldehyde, acetone, benzene, toluene, butadiene, naphthalene [Soelberg (2001)]
Related Req'ts:	CO Emissions, H2S Emissions, HC Emissions, NOx Emissions, SOx Emissions, Hg Emissions
Model descr:	Concentrations of CO, H2, NOx, SOx, H2S, HCs and gas temperature calculated from thermodynamic equilibrium assuming (Use "V/L/S Equilibrium" model.). Adjust thermodynamically calculated species concentrations to reflect empirical data. (U Reaction" and "Mass Accounting" models.)
15. Mercury Amalgamator	
Purpose:	Treat condensed elemental Hg from the offgas by BDAT (amalgamation) for disposal.
Op Range:	15 – 30ºC, 12 psia
Phases:	Liquid, solid
Phenomena:	Mercury amalgamation
Needed info:	(1) Mass of amalgam produced, (2) Excess of second amalgamating element produced
Species of int:	Liquid (Hg^o), solid (Zn, Cu, Sn or other suitable amalgamating metal, amalgam)
Related Req'ts:	Waste Form Disposability, TCLP for Secondary Waste
Model descr:	From an assumed proportion of the mass of Hg to the mass of the second amalgamating element calculate the resulting mas Reaction" and "Mass Accounting" models.)
16. Mercury Removal by GAC Adsorption	
Purpose:	Remove Hg & organics
Op Range:	100-200ºC, ≈ 5 psia (subatmospheric)
Phases:	Gas, solid
Phenomena:	Adsorption Adsorption of Hg^o, HgCl2, I-129, and organics from the offgas prior to stack release
Needed info:	(1) Concentrations of Hg, I-129, and organic species in offgas, (2) Consumption rate of GAC
Species of int:	Hg species, iodine, trace organics, other gas species
Related Req'ts:	Waste Form DisposabilityWaste Form DisposabilityWaste Form Disposability Hg Emissions, HC Emissions, Volatile Rad
Model descr:	Assume a loading ratio (mass GAC/total mass adsorbed) and apply this to a stoichiometric reaction between Hg, I, and HCs produces spent (i.e., fully-loaded) GAC as a product. Adjust the loading ratio as necessary to reflect empirical data, and to competing reactions for GAC adsorption sites as indicated by test data. (Use "Mass Accounting" and "Specified Reaction"

Table 1. (continued).

17. Gas Heater	
Purpose:	Raise or lower offgas temperature to satisfy downstream equipment constraints (e.g., to prevent wetting of HEPA filters)
Op Range:	150-200ºC, 5 – 12 psia
Phases:	Gas
Phenomena:	Steady state heat exchange between two fluids in a heat exchanger Exit temperature of heated offgas
Needed info:	(1) Gas exit temperature and dewpoint, (2) Heating/cooling duty
Species of int:	Gas (N_2, O_2, Ar, CO_2, H_2O)
Related Req'ts:	Limit HEPA Changeouts
Model descr:	Calculate heating/cooling from specific heats of gaseous components and desired exit temperature, calculate dewpoint from partial pressure and thermodynamic relation between temperature and saturation pressure. (Use "V/L/S Equilibrium" and " models.)
18. HEPA Filter Ba nk/Prefilter	
Purpose:	Collect all particulate remaining in off-gas prior to discharge to the atmosphere
Op Range:	20 – 100ºC, 5 – 12 psia
Phases:	Gas, solid
Phenomena:	Particle removal from gas by filtration
Needed info:	(1) Concentrations of PM, semivolatile metals, low volatile metals, nonvolatile rad, volatile rad, Hg, Cl, HCs, CO, dioxins/f Mass loading rate of HEPA filters, (3) Rad concentration in loaded HEPA filters
Species of int:	Gas (N_2, O_2, Ar, CO_2, H_2O, NO_x), solids species from melter offgas
Related Req'ts:	Low Volatile Metals Emissions, Semivolatile Metals Emissions, Volatile Rad Emissions, Nonvolatile Rad Emissions, PM Secondary Wastes, Rad in Process Streams, TRU in Secondary Wastes
Model descr:	Filters assumed to remove only particulates and specified separation factors used to determine quantity of PM removed from particulate compositions. Concentrations of gaseous species are pass throughs. (Use "Specified Separation" and "Mass Acc
19. BFW Treatment and Steam Generator	
Purpose:	Generate steam for steam reformer from recovered water
Op Range:	60-100°C, 12-15 psia
Phases:	Gas, liquid
Phenomena:	Adsorption, Degassing of Liquid Removal of alkalinity by ion exchange; mechanical degasification
Needed info:	(1) Concentrations of TDS, PO_4^{3-}, CO_3^{2-}, HCO_3^-, OH^-, SO_3^{2-}, SiO_2, (2) Total Fe and SiO_2 in recovered condensate, (3) sorbents
Species of int:	Dissolved gases (CO_2, O_2) dissolved salts (PO_4^{3-}, CO_3^{2-}, SO_3^{2-}, Fe^{3+}) solids (SiO_2), organics
Related Req'ts:	Corrosion Allowance
Model descr:	Filters assumed to remove only particulates and specified separation factors used to determine quantity of PM removed from particulate compositions. Concentrations of gaseous species are pass throughs. (Use "Specified Separation" and "Mass Acc

Note: Unit operation 10 may be excluded if the is not a significant difference in the activity levels of the scrub blowdown liqui

Table 2. Process requirements.

REQUIREMENT NAME	DESCRIPTION
Feed Blending	Feeds to a unit operation must be blended and homogenized, maintaining all solids in suspension that are in
Convert SBW to Solid	Radioactive components of liquid SBW from the TFF must be converted into a solid form suitable for direct
Corrosion Allowance	Materials of construction must accommodate expected corrosion rates.
Prevention of Criticality	Criticality limits on aggregations of fissionable species must not be exceeded.
NOx Emissions	NOx emissions above 40 T/yr are considered "significant" by the state and subject to regulation. Since nitrat produce about 1,300 T of NOx it is expected that a NOx concentration limit would be imposed on stack emi
SOx Emissions	SO_2 emissions above 40 T/yr are considered "significant" by the state and subject to regulation. Since the tot produce about 14 T of SO_2 it is assumed unlikely that any limit on SO_2 emissions would be imposed.
H2S Emissions	H_2S emissions above 10 T/yr are considered "significant" by the state and subject to regulation. Since the tot produce about 7.1 T of H_2S it is assumed unlikely that any limit on H_2S emissions would be imposed.
Cl Emissions	HCl and Cl_2 are regulated by MACT. The total Cl concentration must be less than 75 ppmv
F Emissions	Fluoride (F) in SBW could be released in the offgas. F emissions exceeding 3 T/yr is considered "significant regulation. Since SBW has more than 6 T of fluoride, fluoride in stack gas would likely be regulated below a
Hg Emissions	Hg in stack off-gas is regulated by MACT. The total Hg concentration must be less than 40 µg/dsm^3.
Volatile Rad Emissions	Volatile radionuclide emissions in stack off-gas are regulated by NESHAPs to specific limits.
Nonvolatile Rad Emissions	Non-volatile radionuclide emissions in stack off-gas are regulated by NESHAPs to specific limits.
Semivolatile Metals Emissions	Pb and Cd are considered semivolatile metals and are regulated by MACT to below 100 µg/dm^3.
Low Volatile Metals Emissions	Sb, As, Cr, and Be are considered low-volatility metals and are regulated by MACT to below 55 µg/dsm^3.
CO Emissions	CO is regulated by MACT to less than 100 ppmv.
HC Emissions	Total hydrocarbons (HCs) is regulated by MACT to less than 10 ppmv.
PM Emissions	Particulate matter (PM) is regulated by MACT to less than 0.015 gr/dsm^3.
TCLP for Secondary Waste	RCRA metals in secondary waste must satisfy TCLP leaching limits.
RCRA Metals in Secondary Waste	Concentrations of RCRA metals in secondary wastes disposed at Hanford must satisfy limits imposed by the
Rad in Secondary Wastes	Concentrations of radionuclides in secondary wastes disposed at LLW or LLMW disposal sites must be belov category) of waste disposal.
TRU in Primary Waste	Concentrations of TRU radionuclides in wastes disposed at WIPP must be at least 100 nCi/gm and in wastes must be at most 10 nCi/gm.
TRU in Secondary Wastes	Concentrations of TRU radionuclides in wastes disposed at WIPP must be at least 100 nCi/gm and in wastes must be at most 10 nCi/gm.
Liquids in Wastes	Water must be removed from all waste streams (SBW liquid, tank and heel solids, NGLW), preparatory to p
RCRA Components of Primary Waste	Identities and maximum potential concentrations of RCRA components in the primary waste product must b
Rad in Primary Waste	Identities and maximum potential concentrations of radionuclides in the primary waste product must be dete
Rad in Process Streams	Identities and maximum potential concentrations of radionuclides in the process streams must be determined

Table 2. (continued).

REQUIREMENT NAME	**DESCRIPTION**
Limit HEPA Changeouts	Spent HEPA filters constitute an additional waste stream that must be treated and disposed. Changeout of H burden. Both considerations dictate that the sole function of HEPA filters should be to polish the final offgas be used as a primary particulate removal device. Thus, the bulk of offgas fine particulates must be removed system, and moisture in the offgas entering the HEPA banks must be prevented from condensing and wettin
Waste Form Disposability	All waste streams from the process must be converted to waste forms which satisfy the acceptance criteria a

Table 3. Phenomena in unit operations.

Adsorption
This involves physical (reversible) and chemical (usually irreversible) adsorption.
Aerosol growth by condensation and agglomeration
This involves the coupling of three fundamental phenomena: - Homogeneous nucleation of particles (liquid or solid) from a supersaturated gas - Heterogeneous nucleation/condensation of vapor from a supersaturated gas on an existing aerosol - Agglomeration growth of an aerosol under the influences of shear and Brownian diffusion An aerosol containing a condensable vapor is cooled to a saturation ratio above 1.0. The vapor changes phase to liquid or solid, either through homogeneous r condensation on pre-existing particles. All particles grow by collision and agglomeration through the mechanisms listed above. As a result of the particles' gro deposition tendency change.
Degassing of Liquid
A liquid that is supersaturated with one of more soluble gases equibrates to saturation. This involves the following phenomena: - Vapor/liquid equilibrium - Growth/coalescence of bubbles within the liquid - Rising of bubbles in the liquid under the action of buoyant and viscous forces
Finite-rate heterogeneous (or catalytic) chemical reaction
Chemical species present in a fluid (gas or liquid) diffuse to the surface of a second phase (liquid or solid), react at a finite rate, and are consumed to form othe Concentrations of all affected species change in the mixture with time as they are produced or consumed and diffuse to and from the bulk fluid at finite rates. T (continuum) aspects of the underlying fundamental phenomena are collapsed into a lumped-parameter form that is assumed applicable throughout the reactio
Finite-rate homogeneous chemical reaction
Chemically reacting species present in a fluid (gas or liquid) mix by convection and diffusion, react at a finite rate, and are consumed to form other chemical s affected species change in the mixture with time as they are produced or consumed and diffuse to and from the bulk fluid at finite rates. The multi-dimensional underlying fundamental phenomena are collapsed into a lumped-parameter form that is assumed applicable throughout the reaction region.
Gas/liquid/solid equilibrium
This involves coupling several phenomena: - Chemical equilibrium in each of the three phases All species in the three phases reach thermodynamic equilibrium at the temperature and pressure of the mixture quickly relative to the time step of the simulati species and the intraphase equilibria are solved simultaneously. The activities of all solid species are assumed to have a value of one.
Gas phase chemical equilibrium
A gas mixture has had sufficient time for all species in the mixture to reach thermodynamic equilibrium at the temperature and pressure of the mixture.
Generation of stream reformer offgas particulates
A heated, reacting, fluidized bed elutes a particle-laden gas mixture. The particles are formed from attrition of bed material, growth of bed particles from coati followed by evaporation of water and possible chemical reaction of dissolved solids in the feed.

Table 3. (continued).

Interphase heat transfer with one phase disperse

A liquid and a gas phase flow into a finite mixing volume at different temperatures and intermingle. Heat flows from the higher-temperature phase to the lowe each phase to exit at a different temperature from its inlet. If water is present in either the liquid or the gas phase, condensation and/or evaporation may occur r flow rates of the two phases. The impact on mass flow rates from phase change of species other than water are assumed negligible. Heat may be exchanged wi of the mixing volume.

Liquid droplet entrainment in a gas stream

Gas flowing alongside (or through) a liquid in a mixing region entrains a portion of the liquid as droplets in the gas. The particle loading in the gas phase is thu rate of the liquid stream is reduced.

Liquid filtration

A mixture of a liquid with suspended particles undergoes solid/liquid separation by passing through a filter medium. Particles are trapped by the filter mediur liquid by one or more of the following mechanisms:

- Sieve effect of filter medium
- Sieve effect of accumulated filter cake

The second mechanism results in increasing particle collection efficiency as solids accumulate in or on the filter. It also results in increasing pressure drop acrc flow resistance. In the cross-flow variant of liquid filtration the filter cake is continually scoured from the filter surface by the liquid, which flows parallel to th case the liquid flow parallel to the filtering surface is generally many times greater than the flow of filtrate through the filter.

Typically, the details of the fundamental processes described are not modeled. Particle collection efficiencies as functions of particle size are provided by the fi testing with standard colloidal solutions.

Mercury amalgamation

An element (generally Ag, Zn, Cu, or S) is mixed with elemental Hg resulting in the formation of a durable, non-leachable solid mixture (or amalgam.) of the

Mist removal

A gas laden with liquid droplets forced to flow tangentially into a cylindrical vessel and then parallel to the cylindrical axis through a fine mesh structure (usu or an inert material such as fiberglass, Kevlar, etc.). Larger liquid droplets impinge on the cylindrical wall due to centrifugal force. Smaller droplets follow the structure where most are collected by one or more of the following mechanisms:

- Sieve effect
- Brownian diffusion within gas phase to liquid boundary

The second mechanism occurs by virtue of the mesh structure being coated with a layer of liquid. The gas bubbles through the liquid layer after being disperse through the mesh. As the gas bubbles pass through the liquid layer the finest particles can diffuse to the spherical surfaces of the bubbles and be collected by th being below what would be collected by the sieve effect.

Typically, the details of the fundamental processes described may not all be modeled. Overall particle collection efficiencies may typically be provided by HE of particle size, mesh fineness, and gas/liquid and flow ratio.

Particle collection by sedimentation

Solid particles suspended in a fluid (gas or liquid) migrate through the fluid under the action of a body force (e.g., gravity, centrifugal force, etc.) in a collectin packed bed scrubber tank, cyclone, centrifuge, etc.) onto a collecting surface. (In a packed bed gas scrubber the surface would be the liquid on the surface of t particle concentration in the fluid decreases as the fluid passes through the collecting device.

Particle impingement due to inertia

Particles (solid or liquid) in a flowing fluid move under the influence of the fluid viscous force and inertia of the particles themselves. When the flow path of th particle trajectories may result in impingement on a flowfield boundary. Extraction of the particles from the fluid and material deposition on the boundary resu

Table 3. (continued).

Particle removal from gas by filtration

This involves the coupling of three fundamental phenomena:

- Viscous single-phase flow with volumetric sources
- Brownian diffusion of particles from bulk gas to a sink
- Particulate removal by sieve action

A gas containing an aerosol is forced through a fibrous medium. Particles in the gas move with the gas by advection and within the gas by Brownian diffusion. medium is assumed to be a sink for particles (i.e., zero particle concentration in the gas exists at the surface) and the particles diffuse toward the medium by vi gradient. As the gas move through the medium the concentration of particles is depleted according to the total residence time and diffusion behavior of the gas.

Typically, the details of the fundamental processes above are not all modeled. Overall particle collection efficiencies are typically provided by filter medium v size (and sometimes pressure drop through the fiber).

Solid/liquid chemical equilibrium

In a liquid mixture all species present in the liquid phase react to form compounds as a result of a specified set of reactions. In addition, electrolytes dissociate species. The species within the liquid phase reach thermodynamic chemical equilibrium at the temperature and pressure of the mixture (this assumes that suffi equilibration of all reactions). Species in the liquid phase will (in general) include ionic and molecular species in solution as well as soluble complexes.

Dissolved species in the liquid remain in solution if it is thermodynamically favorable to do so. Otherwise, separate solid phases precipitate, each composed of forms of the corresponding species (molecular or ionic) in solution. Such precipitation continues until the species in the solid and liquid phases reach thermody temperature and pressure of the mixture.

The phasic and chemical equilibrium are perfectly coupled. If some species precipitate from solution, the change to their concentrations in solution is instantly of the liquid mixture.

Steady state heat exchange between a fluid and its boundary

This involves the coupling of two fundamental phenomena:

- Viscous single-phase flow with volumetric sources
- Heat transfer at a fluid boundary

A moving fluid at one temperature flows next to a solid boundary at a different temperature. Heat flows between the fluid and the boundary by two paths: (a) bulk fluid and the boundary, and (b) via conduction between the viscous sublayer and the boundary. The fluid temperature in the sublayer is determined by he to the region near the boundary. This intrafluid transport is driven by velocity and thermal gradients. The boundary is assumed to have sufficiently high therm can be treated as an infinite sink at constant temperature.

Typically, the details of the fundamental processes above are not all modeled. Macroscopic models have been developed which correlate the heat transfer rate with macroscopic parameters (e.g., Re, Pr, etc.)

Steady state heat exchange between two fluids in a heat exchanger

This involves the coupling of three fundamental phenomena:

- Viscous single-phase flow with volumetric sources
- Heat transfer at a fluid boundary
- Conduction heat transfer through a solid wall

Two moving fluids at two different temperatures flow through passageways which are separated by a solid boundary. By virtue of the temperature gradient be the warmer to the colder through the solid wall which separates them. Heat flows between the bulk fluids and the wall via radiation and at the wall/fluid interf and thermal gradients within the fluids are established and heat is transported from the bulk fluids to the viscous sublayers next to the wall by conduction and

Typically, the details of the fundamental processes above are not all modeled. Macroscopic models have been developed which correlate the heat transfer rate macroscopic flow parameters (e.g., Re, Pr, etc.)

Table 3. (continued).

Steady state single-phase mixing with volumetric sources
Chemical species present in one or more homogeneous streams flow into a mixing volume and mix before leaving in a single, blended stream. Mixing occurs a at finite rates. Chemical species diffuse through the mixture and are produced or consumed by volumetric sources (e.g., chemical reactions). The composition spatially and temporally according to the mixing and volumetric sources within the mixing volume.
Two-phase flow with heat transfer
Liquid flow and vapor flow in the same space and undergo phase change with water the principal specie moving between the phases. Heat transfer between th gas may influence the evaporation or condensation of water. The dynamics of the flow (e.g., the effective friction factor and pressure drop in pipe flow, the eff heat transfer coefficients, etc.) are influenced by the presence of the second phase and by the phase changes.
Vapor/liquid equilibrium
In a liquid and gas mixture all species present reach a state of thermodynamic equilibrium between its gaseous and liquid forms is also achieved for each speci gaseous forms (this assumes that sufficient time is provided for full equilibration of all species between the liquid and gas phases).
Vapor/liquid chemical equilibrium
In a liquid/gas mixture all species present react to form a specified set of compounds as a result of a specified set of reactions. In addition, electrolytes dissocia and some species in the liquid phase will also form soluble complexes. The species within the liquid and gas phases reach thermodynamic equilibrium at the te mixture (this assumes that sufficient time is provided for full equilibration of all reactions). Equilibrium is simultaneously achieved for each specie between its (in the case of an electrolyte) between its molecular and dissociated forms. Effects of phase changes for each specie on concentrations in the liquid and gas pha intraphase chemical equilibrations.
Waste form properties as functions of processing parameters
A waste feed is transformed into a waste form (e.g., glass, grout, etc.) by a process (e.g., a glass melter, a grout mixing/casting/curing operation, etc.). The pro leaching rate of hazardous constituents, liquidus temperature, phases present, compressive strength, etc.) are completely determined by (a) the composition of t parameters. Because of this determinism the quantitative measures of the waste form properties can be predicted by some function of the composition variables (e.g., through multivariate linear regression of measured data, through thermodynamic equations, etc.).

Table 4. Process simulator modeling capabilities.

CAPABILITY	MODELING METHOD	DESCRIPTION
Mass Accounting	N/A	Elemental species present in input streams are tracked through the process such that for each rate (in all input streams) is accounted for in its total output mass flow rate (in all output stre each element among all output streams, chemical compounds, and phases is tracked.
V/L/S Equilibrium	Mechanistic	Within a component user-specified chemical species are formed from user-specified element between phases (V-vapor, L-liquid, S-solid) assumed to be present so as to achieve thermod and between the phases. All other specie present in the component's input streams are treate
Specified Reaction	Empirical	Designated chemical species present within a component, specified by the user, react accord stoichiometric coefficients and reaction extents are specified by the user.
Specified Separation	Empirical	Designated species, phases, streams, etc. present in the input streams to a component are div streams according to a user-supplied specification.

Table 5. Representative compositions of SBW (a) dilute SBW feed.[a]

		WM-187	WM-187	WM-187			WM-187	WM-187	WM-187
Evaporation in		2002	2003	2004			2002	2003	2004
		Mol/liter	Mol/liter	Mol/liter			Ci/liter	Ci/liter	Ci/liter
							Jan, 2016	Jan, 2016	Jan, 2016
H+		9.74E-01	8.19E-01	6.13E-01					
Al		6.04E-02	5.48E-02	3.76E-02		Th-231	7.81E-09	7.25E-09	2.38E-09
Sb		2.09E-06	2.30E-06	1.83E-06		Th-234	7.81E-09	7.25E-09	2.38E-09
As		6.88E-07	8.14E-07	2.79E-07		Pa-233	1.08E-06	1.00E-06	3.29E-07
Ba		7.52E-06	6.68E-06	4.91E-06		Pa-234m	7.81E-09	7.25E-09	2.38E-09
Be		7.59E-07	9.37E-07	4.73E-07		U-232	6.91E-10	7.97E-10	2.57E-10
B		1.77E-03	1.32E-03	1.01E-03		U-233	9.01E-11	1.04E-10	3.35E-11
Br		3.15E-06	1.54E-06	1.14E-06		U-234	1.62E-07	1.20E-07	7.13E-08
Cd		2.49E-04	9.88E-05	1.69E-04		U-235	3.08E-09	2.20E-09	1.58E-09
Ca		3.36E-03	2.80E-03	1.37E-03		U-236	4.49E-09	1.71E-09	2.32E-09
Ce		2.71E-06	3.95E-06	1.22E-06		U-237	1.29E-09	1.49E-09	4.80E-10
Cs		4.37E-06	4.94E-06	1.48E-06		U-238	3.42E-09	2.99E-09	1.21E-09
Cl		2.06E-03	1.29E-03	1.40E-03		Np-237	1.08E-06	1.00E-06	3.29E-07
Cr		3.18E-04	6.85E-04	3.04E-04		Np-239	7.81E-09	7.25E-09	2.38E-09
Co		3.96E-05	3.94E-05	3.14E-05		Pu-236	4.20E-11	3.90E-11	1.28E-11
Cu		4.19E-05	1.00E-04	4.50E-05		Pu-238	1.26E-04	1.17E-04	4.47E-05
F		1.42E-02	8.70E-03	5.64E-03		Pu-239	2.01E-05	1.87E-05	7.66E-06
Gd		1.06E-05	5.94E-05	1.59E-05		Pu-240	3.90E-06	3.62E-06	1.19E-06
I		9.26E-07	8.13E-07	3.88E-07		Pu-241	5.11E-05	4.74E-05	1.55E-05
Fe		2.40E-03	3.54E-03	1.68E-03		Pu-242	2.94E-09	2.73E-09	8.95E-10
La		2.26E-06	2.56E-06	7.68E-07		Am-241	1.98E-05	1.84E-05	8.26E-06
Pb		1.75E-03	7.71E-04	5.50E-04		Cm-244	3.90E-07	3.62E-07	1.19E-07
Li		2.05E-05	2.36E-05	1.36E-05					
Mg		4.68E-04	7.24E-04	3.59E-04		H-3	2.58E-06	1.94E-06	6.32E-07
Mn		1.13E-03	1.15E-03	8.32E-04		Se-79	1.62E-07	1.51E-07	4.93E-08
Hg		1.87E-03	8.71E-04	5.89E-04		Sr-90	1.41E-02	1.31E-02	4.21E-03
Mo		1.48E-04	1.36E-04	8.67E-05		Y-90	1.41E-02	1.31E-02	4.21E-03
Nd		7.50E-06	8.48E-06	2.54E-06		Zr-93	8.11E-07	7.53E-07	2.47E-07
Np		4.24E-06	4.79E-06	1.44E-06		Nb-93m	6.91E-07	6.41E-07	2.10E-07
Ni		1.56E-04	3.05E-04	2.04E-04		Nb-94	4.20E-07	3.90E-07	1.28E-07
Nb		1.56E-08	3.94E-06	1.05E-06		Tc-99	3.12E-06	4.57E-06	1.46E-06
NO3		1.28E+00	1.10E+00	8.22E-01		Sn-126	1.53E-07	1.42E-07	4.66E-08
Pd		7.38E-07	9.75E-07	2.93E-07		Sb-125	1.33E-07	1.64E-07	5.40E-08
PO4		1.05E-04	7.44E-05	3.40E-04		Sb-126m	1.53E-07	1.42E-07	4.66E-08
Pu		9.62E-07	1.09E-06	4.20E-07		I-129	1.98E-08	1.84E-08	7.69E-09
K		9.53E-03	9.24E-03	6.62E-03		Cs-134	1.35E-07	8.64E-08	2.69E-08

a. As of early March, 2002, all waste in the INTEC Tank Farm had been concentrated. Dilute and partially concentrated waste generated in the future will be collected in Tank WM-187. Current plans call for evaporation of waste in Tank WM-187 once per year from 2002 through 2007 and then in 2011. Table 5a shows projected compositions of waste in WM-187 that will be sent to the HLLWE in 2002, 2003 and 2004.

Table 5(a). (continued).

		WM-187	WM-187	WM-187			WM-187	WM-187	WM-187
Evaporation in		2002	2003	2004			2002	2003	2004
		Mol/liter	Mol/liter	Mol/liter			Ci/liter	Ci/liter	Ci/liter
							Jan, 2016	Jan, 2016	Jan, 2016
Pr		2.09E-06	2.37E-06	7.09E-07		Cs-135	3.30E-07	3.07E-07	1.01E-07
Rh		9.17E-07	1.04E-06	3.11E-07		Cs-137	1.38E-02	1.28E-02	4.20E-03
Rb		2.04E-06	2.31E-06	6.83E-07		Ba-137m	1.30E-02	1.21E-02	3.96E-03
Ru		4.77E-06	9.58E-06	2.72E-06		Pm-146	3.60E-09	3.35E-09	1.10E-09
Sm		1.44E-06	1.63E-06	4.88E-07		Pm-147	2.04E-06	1.90E-06	6.21E-07
Si		2.25E-04	3.09E-04	1.58E-04		Sm-151	1.14E-04	1.06E-04	3.47E-05
Na		9.22E-02	8.19E-02	7.73E-02		Eu-152	4.81E-07	4.46E-07	1.46E-07
Sr		4.11E-06	7.45E-06	2.18E-06		Eu-154	1.70E-05	1.69E-05	5.33E-06
SO4		2.85E-03	2.92E-03	2.08E-03		Eu-155	4.03E-06	2.16E-06	9.14E-07
Ti		3.09E-06	4.35E-06	2.20E-06		Co-60	9.46E-07	8.11E-07	3.37E-07
U		2.73E-05	3.60E-05	1.76E-05		Ni-63	1.05E-05	9.76E-06	3.20E-06
V		2.25E-05	6.44E-06	4.45E-06					
Y		1.72E-06	1.95E-06	5.85E-07		TOC, g/l	8.55E-02	7.74E-02	6.16E-02
Zn		5.86E-04	4.34E-04	3.28E-04		UDS, g/l	3.94E-01	4.79E-01	3.43E-01
Zr		2.02E-03	7.10E-04	7.86E-04		Gallons	120,000	120,000	120,000

a. As of early March, 2002, all waste in the INTEC Tank Farm had been concentrated. Dilute and partially concentrated waste generated in the future will be collected in Tank WM-187. Current plans call for evaporation of waste in Tank WM-187 once per year from 2002 through 2007 and then in 2011. Table 5a shows projected compositions of waste in WM-187 that will be sent to the HLLWE in 2002, 2003 and 2004.

Table 5. (continued) Representative compositions of SBW (b) concentrated feed.[b]

	WM-180	WM-188	WM-189			WM-180	WM-188	WM-189
Gallons	276,000	275,200	279,900			mol/liter	mol/liter	mol/liter
					Mn	1.48E-02	1.64E-02	2.03E-02
					Hg	2.12E-03	5.44E-03	2.86E-03
TOC, g/l	0.212	0.424	0.396		Mo	2.02E-04	4.06E-04	5.68E-05
UDS, g/l	0.246	3.738	3.988		Nd	1.50E-05	4.19E-05	2.81E-05
					Np	1.66E-05	1.63E-05	1.39E-05
	mol/liter	mol/liter	mol/liter		Ni	1.54E-03	4.32E-03	5.67E-03
H+	1.06	2.99	2.51		Nb	1.63E-05	6.61E-06	1.97E-07
					NO3	5.57E+00	6.50E+00	6.84E+00
Al	6.96E-01	5.83E-01	6.62E-01		Pd	2.46E-05	5.15E-06	3.52E-06
Am	7.60E-08	9.65E-08	1.08E-07		PO4	1.44E-02	4.53E-03	7.07E-03
Sb	6.69E-05	8.08E-06	2.83E-06		Pu	5.53E-06	5.58E-06	5.17E-06
As	5.24E-04	4.41E-05	3.27E-05		K	2.06E-01	1.57E-01	2.10E-01
Ba	5.85E-05	8.85E-05	1.05E-04		Pr	4.20E-06	1.17E-05	7.85E-06
Be	8.15E-06	2.18E-06	8.83E-07		Pm	1.53E-09	4.27E-09	2.87E-09
B	1.29E-02	2.31E-02	2.80E-02		Rh	1.84E-06	5.12E-06	3.44E-06
Br	1.53E-07	6.18E-06	9.14E-07		Rb	3.64E-06	1.07E-05	7.05E-06
Cd	7.92E-04	6.33E-03	8.86E-03		Ru	1.31E-04	3.79E-05	1.71E-05
Ca	4.95E-02	5.98E-02	7.11E-02		Sm	2.88E-06	8.03E-06	5.39E-06
Ce	4.96E-05	2.36E-05	1.72E-05		Se	1.53E-04	3.04E-06	1.73E-06
Cs	8.12E-06	2.44E-05	1.64E-05		Si	3.17E-07	3.27E-03	4.09E-03
Cl	3.15E-02	2.32E-02	3.06E-02		Ag	5.55E-06	2.08E-05	2.02E-05
Cr	3.52E-03	6.14E-03	6.77E-03		Na	2.16E+00	1.35E+00	1.84E+00
Co	2.02E-05	1.73E-04	1.14E-04		Sr	1.25E-04	2.91E-05	1.81E-05
Cu	7.32E-04	9.17E-04	1.13E-03		SO4	7.34E-02	4.51E-02	5.69E-02
Dy	3.15E-10	8.78E-10	5.90E-10		Tc	2.82E-06	9.71E-06	5.27E-06
Eu	3.09E-09	1.01E-08	9.01E-09		Te	1.45E-06	4.04E-06	2.72E-06
F	4.98E-02	1.13E-01	1.10E-01		Tb	1.07E-09	2.97E-09	2.00E-09
Gd	1.86E-04	7.52E-05	1.82E-06		Tl	4.29E-05	1.00E-05	1.42E-05
Ge	4.45E-09	2.53E-08	9.74E-09		Th	9.39E-11	2.62E-10	1.76E-10
In	6.74E-07	1.88E-06	1.26E-06		Sn	4.31E-05	2.31E-06	6.75E-07
I	5.86E-07	3.89E-06	3.16E-06		Ti	6.07E-05	5.07E-05	6.45E-05
Fe	2.28E-02	2.61E-02	2.68E-02		U	3.54E-04	5.22E-04	5.67E-04
La	4.54E-06	1.26E-05	8.49E-06		V	9.69E-04	1.26E-04	1.50E-04
Pb	1.37E-03	4.63E-03	1.61E-03		Y	3.46E-06	9.63E-06	6.47E-06
Li	3.56E-04	3.53E-04	4.61E-04		Zn	1.10E-03	1.93E-03	1.49E-03
Mg	1.26E-02	8.18E-03	1.03E-02		Zr	6.64E-05	1.78E-02	2.10E-02

b. From C. M. Barnes, "Updated Sodium Bearing Waste Compositions for Treatment Simulations," *INEEL Interoffice Memorandum, CMB-08-02*, April 15, 2002.

Table 5(b). (continued).

	WM-180	WM-188	WM-189			WM-180	WM-188	WM-189
	Ci/liter	Ci/liter	Ci/liter			Ci/liter	Ci/liter	Ci/liter
	Jan, 2016	Jan, 2016	Jan, 2016			Jan, 2016	Jan, 2016	Jan, 2016
Tl-208	3.35E-10	1.13E-09	6.55E-10		Cm-243	1.02E-08	3.45E-08	2.00E-08
Pb-211	2.76E-11	9.29E-11	5.40E-11		Cm-244	2.71E-06	1.75E-06	1.02E-06
Pb-212	9.46E-10	3.19E-09	1.85E-09		Cm-245	1.46E-10	4.91E-10	2.85E-10
Bi-211	2.76E-11	9.29E-11	5.40E-11		Cm-246	9.46E-12	3.19E-11	1.85E-11
Bi-212	9.46E-10	3.19E-09	1.85E-09		H-3	1.02E-05	1.33E-05	1.03E-05
Po-215	1.58E-11	5.31E-11	3.08E-11		Be-10	1.46E-12	4.91E-12	2.85E-12
Po-216	9.46E-10	3.19E-09	1.85E-09		C-14	5.91E-11	4.04E-06	1.16E-10
Po-218	6.31E-12	2.12E-11	1.23E-11		Se-79	2.13E-07	7.17E-07	4.16E-07
Rn-219	2.76E-11	9.29E-11	5.40E-11		Rb-87	1.42E-11	4.78E-11	2.78E-11
Rn-220	9.46E-10	3.19E-09	1.85E-09		Sr-90	9.72E-03	5.63E-02	3.12E-02
Rn-222	6.31E-12	2.12E-11	1.23E-11		Y-90	9.72E-03	5.63E-02	3.12E-02
Ra-223	2.76E-11	9.29E-11	5.40E-11		Zr-93	1.06E-06	3.58E-06	2.08E-06
Ra-224	9.46E-10	3.19E-09	1.85E-09		Nb-93m	9.07E-07	3.05E-06	1.77E-06
Ra-226	6.31E-12	2.12E-11	1.23E-11		Nb-94	5.52E-07	1.86E-06	1.08E-06
Ac-225	1.89E-13	6.37E-13	3.70E-13		Tc-98	1.26E-12	4.25E-12	2.47E-12
Ac-227	2.76E-11	9.29E-11	5.40E-11		Tc-99	1.04E-05	1.92E-05	9.30E-06
Th-227	2.72E-11	9.16E-11	5.32E-11		Ru-106	5.91E-11	1.74E-10	9.34E-11
Th-228	9.46E-10	3.19E-09	1.85E-09		Rh-102	1.89E-11	6.37E-11	3.70E-11
Th-229	1.89E-13	6.37E-13	3.70E-13		Rh-106	5.91E-11	1.74E-10	9.34E-11
Th-230	4.72E-10	1.59E-09	9.22E-10		Pd-107	7.88E-09	2.66E-08	1.54E-08
Th-231	1.02E-08	3.45E-08	2.00E-08		Cd-113m	8.67E-07	2.92E-06	1.70E-06
Th-234	1.02E-08	3.45E-08	2.00E-08		In-115	4.73E-17	1.59E-16	9.25E-17
Pa-231	4.73E-11	1.59E-10	9.25E-11		Sn-121m	2.72E-08	9.16E-08	5.32E-08
Pa-233	1.42E-06	4.78E-06	2.78E-06		Sn-126	2.01E-07	6.77E-07	3.93E-07
Pa-234m	1.02E-08	3.45E-08	2.00E-08		Sb-125	2.44E-07	1.08E-06	9.72E-07
Pa-234	1.30E-11	4.38E-11	2.54E-11		Sb-126m	2.01E-07	6.77E-07	3.93E-07
U-232	2.10E-09	9.16E-09	9.11E-09		Sb-126	2.80E-08	9.43E-08	5.47E-08
U-233	2.74E-10	1.20E-09	1.19E-09		Te-125m	5.91E-08	1.99E-07	1.16E-07
U-234	9.14E-07	1.36E-06	1.33E-06		I-129	1.33E-08	8.87E-08	7.24E-08
U-235	2.38E-08	3.49E-08	3.60E-08		Cs-134	5.05E-08	6.80E-07	5.93E-07
U-236	3.75E-08	5.20E-08	6.14E-08		Cs-135	4.34E-07	1.46E-06	8.48E-07
U-237	3.93E-09	1.71E-08	1.70E-08		Cs-137	2.16E-02	6.11E-02	3.55E-02
U-238	2.38E-08	4.07E-08	4.02E-08		Ba-137m	1.71E-02	5.75E-02	3.34E-02
Np-237	4.98E-07	3.52E-06	2.42E-06		Ce-142	1.46E-11	4.91E-11	2.85E-11
Np-238	3.51E-11	1.18E-10	6.86E-11		Ce-144	2.88E-12	8.19E-12	4.06E-12
Np-239	1.02E-08	3.45E-08	2.00E-08		Pr-144	2.88E-12	8.19E-12	4.06E-12
Pu-236	5.52E-11	1.86E-10	1.08E-10		Pm-146	4.73E-09	1.59E-08	9.25E-09
Pu-238	5.94E-04	7.04E-04	6.49E-04		Pm-147	2.68E-06	9.03E-06	5.24E-06
Pu-239	9.89E-05	9.14E-05	7.38E-05		Sm-151	1.50E-04	5.05E-04	2.93E-04
Pu-240	5.12E-06	1.67E-05	9.16E-06		Eu-150	5.52E-12	1.86E-11	1.08E-11
Pu-241	6.70E-05	2.86E-04	2.07E-04		Eu-152	6.31E-07	2.12E-06	1.23E-06
Pu-242	3.86E-09	4.23E-08	1.04E-08		Eu-154	1.93E-05	1.02E-04	7.49E-05
Am-241	8.97E-05	1.03E-04	1.00E-04		Eu-155	1.30E-05	2.20E-05	1.86E-05
Am-242m	7.09E-09	2.39E-08	1.39E-08		Ho-166m	2.25E-11	7.57E-11	4.39E-11
Am-242	7.09E-09	2.39E-08	1.39E-08					
Am-243	1.02E-08	3.45E-08	2.00E-08		Co-60	8.29E-07	1.09E-05	1.15E-05
Cm-242	5.91E-09	1.99E-08	1.16E-08		Ni-63	2.21E-05	5.91E-05	4.90E-05

Table 6. Representative composition of suspended solids in SBW[a]

	Wt %			Ci/g solids
Aluminum	5.85		Am-241	3.1E-7
Antimony	0.004		Co-60	3.6E-8
Arsenic	<7.1E-4		Cs-134	2.6E-7
Barium	0.0034		Cs-137	2.6E-4
Beryllium	<1.9E-4		Eu-154	4.3E-7
Boron	<0.051		I-129	0
Cadmium	0.018		Np-237	3.4E-9
Calcium	0.43		Pu-238	8.8E-5
Cerium	0.0043		Pu-239	1.3E-5
Cesium	0.052		Sb-125	3.4E-6
Chromium	0.068		Total Sr	6.2E-5
Cobalt	<0.0015		Tc-99	2.4E-8
Copper	0.014		U-234	4.3E-9
Gadolinium	0.008		U-235	8.9E-11
Iron	2.01		U-236	1.7E-10
Lead	0.052		U-238	3.8E-11
Lithium	<0.016			
Magnesium	0.14			
Manganese	0.16			
Mercury	<0.89			
Molybdenum	0.036			
Nickel	0.028			
Niobium	<1.0			
Palladium	<0.076			
Phosphorus	5.43			
Potassium	1.47			
Ruthenium	0.036			
Selenium	<0.13			
Silicon	2.09			
Silver	0.005			
Sodium	7.82			
Strontium	0.0022			
Sulfur	0.51			
Thallium	<0.14			
Tin	0.21			
Titanium	0.096			
Uranium	0.035			
Vanadium	<0.001			
Zinc	0.02			
Zirconium	2.8			
Chloride	0.091			
Fluoride	0.0033			
Nitrate	43.4			

a. Composition of WM-180 suspended solids; from J. D. Christian, *Composition and Simulation of the WM-180 Sodium-Bearing Waste at the Idaho Nuclear Technology and Engineering Center* , INEEL/EXT-2001-00600, May 2001.

Table 7. Representative compositions of heel solids from SBW Tanks.[a]

	WM-182	WM-183	WM-188		WM-182	WM-183	WM-188
	mg/kg	mg/kg	mg/kg		mg/kg	mg/kg	mg/kg
Al	21,880	24,911	35,406	Sr	9	11	
Sb	14	32	33	SO_4	33,240	13,647	
As	281	56	351	S	8,743	2,849	
Ba	127	24	12,542	Tc		0	
Be	1	1	0.2	Tl	17	14	783
B	150	182	482	Sn	4,072	1,466	
Cd	325	142	1,189	Ti	650	711	
Ca	1,765	1,868	5,630	U	4.62E+01	1.93E-01	
Ce	21	20		V	13	11	6
Cs	42	9		Zn	179	148	126
Cl	2,015	1,308		Zr	101,470	34,867	64,844
Cr	552	949	1,341	Total	467,177	500,167	157,952
Co	9	9	9	TOC			12
Cu	298	166					
F	14,800	4,373			mCi/g	mCi/g	mCi/g
Gd	53	170		Am-241	8.46E-04	2.45E-04	2.11E-04
Fe	4,476	17,967	5,769	Sb-125	5.77E-02	2.90E-03	1.12E-02
Pb	369	274	647	Cs-134	6.64E-03	5.89E-04	7.97E-03
Li	6	4		Cs-137	4.50E+00	8.68E-01	2.44E+00
Mg	410	434		Co-60	2.14E-04		6.30E-04
Mn	565	740	758	Cm-244	2.84E-06		
Hg	310	324	1,566	Eu-154	1.48E-03	7.56E-04	5.43E-04
Mo	2,495	694	2,518	I-129	2.22E-07	9.03E-08	9.51E-04
Ni	309	417	427	Np-237	1.68E-06	1.76E-06	2.85E-06
Nb	1,279	623	5,101	Nb-95			3.68E-03
NO_3	70,720	174,955		Pu-238	1.93E-02	4.00E-03	7.56E-03
Pd	5,766	1,444		Pu-239	1.47E-03	1.25E-03	4.30E-04
PO_4	97,806	139,740		Sr-90	2.29E-01	1.82E-01	5.46E+00
P	9,586	4,607	16,422	Tc-99	2.63E-03	3.29E-05	4.49E-03
K	7,050	10,900		H-3	1.15E-05		
Ru	829	2,126	273	U-234	2.40E-06	3.30E-06	2.00E-05
Se	91	13	1,720	U-235	2.61E-07	9.29E-08	1.97E-07
Si	43,920	35,344		U-236	3.05E-07	3.40E-08	2.07E-07
Ag	65	220	9	U-238	3.83E-08	6.91E-08	1.18E-07
Na	30,400	21,400					

a. From C. M. Barnes, *Feed Composition for the Sodium-Bearing Waste Treatment Process*, INEEL/EXT-2000-01378 Revision 1, July, 2001.

Table 8. Representative compositions of NGLW.[a]

MLLW & LLW NGLW			
	moles/liter		Ci/liter
H+	5.12E+00	H-3	6.05E-09
Al	1.43E-01	Co-60	3.62E-08
Sb	1.52E-04	Sr-90	4.92E-04
As	9.90E-07	Y-90	4.92E-04
Ba	2.43E-05	Nb-94	6.86E-08
Be	5.05E-06	Tc-99	7.86E-10
B	1.94E-03	Ru-106	1.08E-10
Cd	6.77E-05	Rh-106	1.08E-10
Ca	1.02E-03	Sb-125	1.11E-07
Cr	1.21E-03	I-129	1.64E-07
Co	1.08E-05	Cs-134	1.34E-08
Cs	2.20E-07	Cs-137	5.32E-04
Cu	6.01E-04	Ce-144	3.03E-11
Fe	2.44E-03	Pr-144	2.52E-11
Pb	1.25E-04	Eu-152	8.63E-08
Hg	2.56E-04	Eu-154	4.25E-06
Mn	8.21E-03	Eu-155	8.17E-08
Ni	4.70E-04		
K	1.22E-02	U-232	6.50E-11
Se	7.14E-07	U-234	1.15E-08
Ag	1.53E-05	U-235	3.02E-10
Na	1.26E-01	U-236	4.81E-10
Tl	2.60E-07	U-238	3.34E-10
U	9.11E-05	Np-237	2.05E-08
V	1.36E-05	Pu-238	6.20E-06
Zn	3.30E-03	Pu-239	8.41E-07
Zr	1.51E-03	Pu-240	9.86E-08
Cl	1.05E-03	Pu-241	1.78E-06
F	5.88E-02	Pu-242	1.80E-10
SO4	1.82E-02	Am-241	9.33E-07
NO3	5.64E+00		
PO4	2.70E-04	Total TRU	8.09E-06
TOC, g/liter	9.97E+00		
UDS, g/liter	6.95E+00		

TRU NGLW			
	moles/liter		Ci/liter
H+	4.01E+00	Co-60	2.37E-08
Al	8.48E-03	Sr-90	1.44E-03
Sb	6.08E-05	Y-90	1.44E-03
As	1.20E-03	Tc-99	2.60E-09
Ba	1.20E-04	I-129	5.78E-07
Be	5.40E-07	Cs-134	1.32E-08
Cd	7.76E-06	Cs-137	1.76E-03
Cr	4.39E-04	Ba-137m	1.65E-03
Co	2.88E-06	Eu-152	1.59E-08
Cs	7.26E-07	Eu-154	7.85E-07
Cu	3.32E-05	Eu-155	2.15E-07
Pb	2.17E-05		
Hg	5.55E-05	U-232	1.98E-10
Mn	1.06E-03	U-234	3.50E-08
Ni	1.84E-04	U-235	9.19E-10
K	1.17E-02	U-236	1.47E-09
Se	1.98E-06	U-238	1.02E-09
Ag	6.88E-06	Np-237	6.25E-08
Na	5.78E-02	Pu-238	1.89E-05
Tl	6.42E-07	Pu-239	2.56E-06
U	1.40E-05	Pu-240	3.00E-07
V	2.90E-06	Pu-241	5.44E-06
Zn	2.71E-04	Pu-242	5.48E-10
Cl	3.74E-03	Am-241	2.84E-06
F	4.00E-03		
SO4	3.95E-03	Total TRU	2.47E-05
NO3	4.10E+00		
TOC, g/liter	1.45E+00		
UDS, g/liter	7.53E-01		

a. From C. M. Barnes, "NGLW Volumes and Compositions for Treatment Study," *INEEL Interoffice Memorandum, CMB-07-02 Rev.2,* April 9, 2002.

Table 9. Miscellaneous mass balance assumptions.

Feed Evaporators	• Batch process terminates when solution reaches a specific gravity of 1.33
Acid Fractionator	• Bottoms stream is 12 M nitric acid
SBW Feed Rate	• 960,000 gal of SBW processed in 3 years and 200 operating days/year
Reformer	• 600^{o}C operating temperature • 12 psia operating pressure • Feeds: Granular sugar equivalent to two times the amount required to react with the acid in the SBW to produce CO_2 and H_2O; carbon and oxygen rates such that off-gas is 1% H_2 and reformer is adiabatic; steam such that off-gas is 84% H_2O • 0.5% carry-over of all feed species into reformer off-gas • 1% carry-over of Al_2O_3, SiO_2 and Fe_2O_3, 19% carryover of all other reformer solid products into the offgas • Sufficient silica and alumina additives to result in 80% of the Na in the waste producing sodium nephaline, $Na_2O \cdot Al_2O_3 \cdot 2SiO_2$, with the remainder of the sodium in the ash as carbonate • Reformer ash product contains 4% carbon
Quench Rate	• Rate such that quench liquid is 20 wt % total solids
Caustic Scrubber	• 5 liters caustic quench per m^3 gas
Caustic Scrub Blowdown	• 0.5%
Condenser	• Temperature set so that effluent water rate equal to water in the SBW feed plus water formed from sugar decomposition • 4% entrainment
HEME	• 100 % efficiency removing entrained water
Oxidizer preheater	• 1000^{o}C temperature
Oxidizer	• Oxygen rate based on 20% excess of the stoichiometric requirement to completely oxidize all CO, H_2O and H_2S
Oxidizer effluent cooler	• Temperature 105^{o}C
GAC Bed	• 99.9% Hg removal efficiency

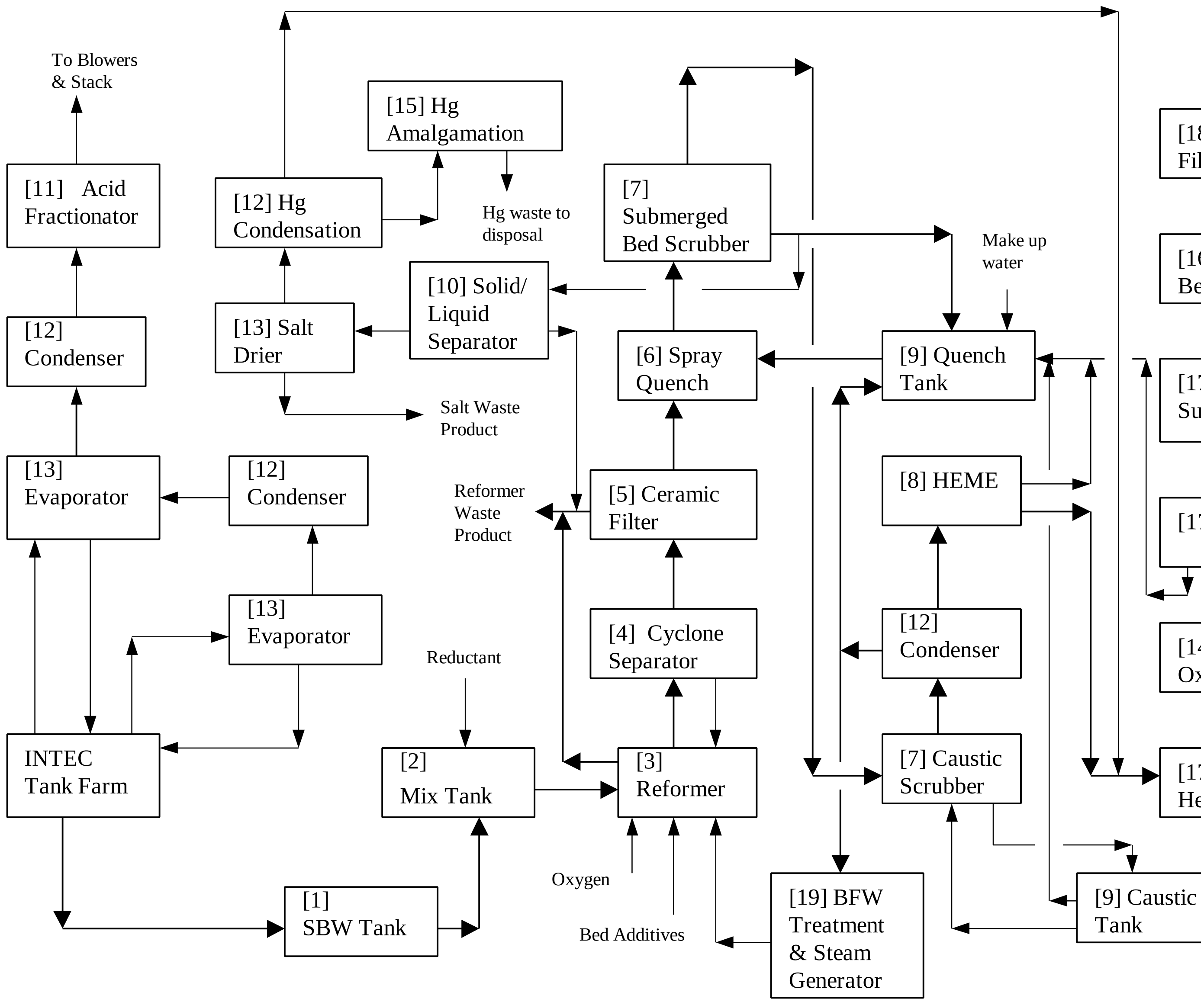

Figure 1. Process Configuration.

5. REFERENCES

Barnes, C.M. (2000a), File named "Dir Vit Unit Operations.doc, " An attachment to Lotus Notes memo to D.D. Taylor of INEEL, 10/19.

Barnes, C.M. (2000b), *Feed Composition for Sodium-Bearing Waste Treatment Process*, INEEL/EXT-2000-01378, Revision 0, October, pp. 12-16.

Patterson, M. (1999), *Light Duty Utility Arm Deployment in Tank WM-188*, INEEL/EXT-99-01302, December.

Schindler, R. E. (1998), *Evaporation of Blends of HLLWE Condensate with CPP-603 Basin Water*, INEEL Letter to F.S. Ward, SCHI-26-98, November 18, p.9.

Soelberg, Nick (2001), Personal communication to D.D. Taylor of INEEL, January 18.