PNNL-11095

UC-810

Project Technical Information

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JUN 12 1996
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Hanford Waste Vitrification Plant Capacity Increase Options

D. E. Larson

April 1996

**Prepared for
the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830**

**Pacific Northwest National Laboratory
Richland, Washington 99352**

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UNITED STATES DEPARTMENT OF ENERGY

under Contract DE-AC06-76RLO 1830

Printed in the United States of America

Available to DOE and DOE contractors from the

Office of Scientific and Technical Information, P.O. Box 62, Oak Ridge, TN 37831;
prices available from (615) 576-8401.

Available to the public from the National Technical Information Service,
U.S. Department of Commerce, 5285 Port Royal Rd., Springfield, VA 22161

The document was printed on recycled paper.

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1.0 INTRODUCTION

Studies are being conducted by the Hanford Waste Vitrification Plant (HWVP) Project on ways to increase the waste processing capacity within the current Vitrification Building structural design. The Phase I study (Shah, 1993) on remote systems concepts identification and extent of capacity increase was completed. The study concluded that the HWVP capacity could be increased to four times the current capacity with minor design adjustments to the fixed facility design, and the required design changes would not impact the current "footprint" of the Vitrification Building. A further increase in production capacity may be achievable but would require some technology development, verification testing, and a more systematic and extensive engineering evaluation. The primary changes included a single advanced melter with a higher capacity (stirred or high temperature melter), new evaporative feed tank, offgas quench collection tank, ejector venturi scrubbers, an additional inner canister closure station, a smear test station, a new close-coupled analytical facility, waste hold capacity of 400,000 gal, the ability to concentrate out-of-plant HWVP feed to 90-g/L waste oxide concentration, and limited changes to the current base slab construction package (primarily in-cell service embeds and floor supports for the modified equipment).

To complement these studies, Pacific Northwest Laboratory (PNL) has considered simplified HWVP processes and design modifications that could achieve major waste processing capacity increases within the current structural design of the Vitrification Building. This report identifies, describes, and contains a preliminary evaluation of such modifications. The results are relevant to and available to support the capacity increase studies being performed by the HWVP Project Phase II studies.

2.0 OBJECTIVES

The objective of this study is to identify vitrification process improvements that can, with reasonable economy, substantially increase the HWVP waste processing capacity using the current structural design (i.e., "footprint") of the Vitrification Building.

The primary difference between this study and the Phase 1 study (Shah, 1993) is the bases used. This study allows the use of technological innovations on other processes and equipment equivalent to employing a modified melter concept such as the stirred melter or the high temperature melter. Only process and equipment technologies are considered which are demonstrated or which require only modest verification testing/development. The ability must exist to implement these technologies within the time it would take to implement an advanced melter in the HWVP. Key special and service requirements of these technologies such as in-bed piping need to be identified for initial HWVP construction to facilitate implementation of the modifications with minimal facility impact.

3.0 CONCLUSIONS AND RECOMMENDATIONS

The following conclusions and recommendations are a result of this study.

CONCLUSIONS:

- The HWVP glass processing capacity may be substantially increased within the existing "footprint" of the HWVP by reasonable extensions of existing technologies which could take up to five years to develop and implement. The approaches considered are indicated in the RECOMMENDATIONS.
- Implementing the simplified high capacity flowsheet will significantly enhance process performance and increase plant feed preparation capacity.
- Impacts of capacity increase on related HWVP operations not addressed in this study include waste/effluent handling, analytical support, canister handling and services which need to be addressed further. The conclusions from the Phase 1 study (Shah, 1993) may apply to results of this study.

RECOMMENDATIONS:

- Within study guidelines, the following HWVP modifications should be considered for implementation in the order indicated to significantly increase HWVP capacity.
 - Install advanced high capacity melter (high temperature stirred)
 - Maximize HWVP feed concentration received in plant (90 g/l of WO used in this study and is included in Phase I study) and perform process waste recycle concentration in SRAT or SME as appropriate to minimize overall time cycle.
 - Implement simplified high capacity flowsheet using an alternative reductant and direct process frit (dry) addition to the melter.
 - Maximize HWVP feed processing slurry concentrations

These combined changes could conceptually increase the HWVP capacity to over 500 kg/h of glass, not including idle times.

- Alternatively, if the HWVP feed concentration cannot be increased adequately, the heat transfer area in the SRAT/SME/DWTT can be significantly increased by converting the cooling coils to heating duty and placing cooling jackets on the tanks. The incentive to perform waste recycle concentration in the SRAT may not exist. This heat transfer modification for capacity increase should be beneficial under any circumstances if foaming and/or entrainment are not rate limiting. If the plant feed concentration cannot be increased significantly, the glass production capacity can conceptually be increased to about 500 kg/h without idle time by implementing this modification with the others.
- Increasing the batch sizes to the maximum by reducing the heel appears attractive in terms of capacity increase for the minor effort involved, included in Phase II study.
- Performing the SRAT and SME processes in one tank to enable operation of two parallel feed preparation systems (one in SRAT and one in SME) increases processing capacity. This is included in the Phase II study together with adding a third SRAT/SME vessel for further parallel operations.

4.0 STUDY BASES

The bases used for this study are as follows:

- The current design "footprint" of the HWVP Vitrification Building will not change.
- Technology changes will only be considered that are modest extensions of existing technologies and require limited development (i.e. can be readily implemented in the HWVP with a five year delay from 1999 with modest development funding).
- The current HWVP facility, equipment, and process design will be used to the maximum extent practicable and economical.
- The HWVP waste processing capacity will be maximized.
- Complementary bases and suppositions used for the Phase 1 studies (Shah, 1993) are appropriate for this study.
- Reference Flowsheet - Time/Motion Diagram: Fluor Daniel, Inc., No Date, "Time/Motion Diagram, Feed Receipt, Feed Preparation, Melter Feed, Radioactive Process Waste Collection System, 220 lb/hr Glass Production," H-2-123041, 2 Sheets is used as the basis for this study although not fully current. This reference was used as the bases for the previous capacity increase study (Shah, 1993). Use of this bases facilitates compatibility of study results.

5.0 PROCESS MODIFICATIONS OPTIONS

The simplified high capacity flowsheet is described in this section. A feed preparation process time-cycle is also presented and analyzed for flowsheet evaluation and comparison with the current reference and Phase 1 study time cycles. Some additional process modifications which may be beneficially added to HWVP are discussed. A process flow diagram of the simplified high capacity flowsheet is shown in Figure 1.

5.1 SIMPLIFIED HIGH CAPACITY FLOWSHEET DESCRIPTION

The NCAW is pumped from the tank farm to the Slurry Receipt and Adjustment Tank (SRAT). The pumping rate is maximum until the tank is filled to the operating level. Tank heating for boiling is initiated as soon as the coils are covered, and heating is continued to achieve and maintain a maximum boil off rate with acceptable de-entrainment (assume 10 gpm water boil off rate). The waste receipt rate in the tank is decreased to match the boil off rate and maintain the tank operating level. Waste receipt and concentration continues until the total amount of waste is received and the desired concentration is reached. The waste is then cooled to transfer temperature, sampled if deemed necessary (assumed no sampling for this study), and transferred to the SME.

Before the process waste addition, the SME contents are heated and concentration initiated to provide tank space for the waste recycle and obtain the final desired concentration. In the SME, the desired amount of canister decontamination waste containing Decontamination Waste Treatment Tank (DWTT) concentrated waste and treated waste recycle is added to the concentrated HWVP feed. On obtaining the final desired waste concentration and contents cooling, a sample can be taken to determine the reductant addition requirements and waste composition (assumed for time cycle analyses); or reductant requirements and waste composition can be determined from individual tank content analyses prior to transfer to the SME eliminating the need to wait for SME sample analyses, or reductant requirements and waste composition

Figure 1. Hanford Waste Vitrification Plant Simplified High Capacity Process Flow Diagram

can be determined from previous experience with each stream added and periodic sampling eliminating the need to wait for SME sample analyses. The reductant is then added. The mixed waste may then be sampled to determine that the correct reductant adjustments have been made (this is assumed unnecessary in this study and not included in the time cycle analyses). The SME contents are then transferred to the Melter Feed Tank (MFT).

From the MFT, feed is pumped to the melter. No samples are needed from this tank except if needed for archive or waste form qualification.

In the melter, dry frit is added in an appropriate ratio to the melter feed to form an acceptable glass. The melter is stirred and operated at a temperature up to 1500°C to increase the melt rate (for time cycle analyses assume not capacity limiting, assume about 9X current waste processing capacity). The increased temperature provides much more flexibility in formulating glass while providing a highly durable product.

If the melter offgas generation rate and composition are such that the cell cannot accommodate the appropriately sized SBS, a quench tank and ejector venturi scrubber would be necessary to serve the same function as indicated in the Phase 1 study (Shah, 1993). For this study, it was assumed that the quench tank and ejector venturi scrubber are used. The condensate from the catch tank is recycled to the process waste treatment system as appropriate. The treated melter condensate waste solids are recycled to the vitrification process.

The balance of the vitrification flowsheet is the same as the reference design case.

Canisters, process waste/effluent, and samples will be generated at a substantially higher rate than in the design case. The design analysis in the Phase 1 study (Shah, 1993) applies, and the results are applicable.

5.2 MAJOR CHANGES TO THE CURRENT FLOWSHEET

With notable exceptions, the simplified high capacity flowsheet uses the same process equipment as the current reference flowsheet which is described in Appendix A. The principle changes in the current reference flowsheet are as follows.

- The reductant is changed from formic acid to one that does not generate significant hydrogen or ammonia. There are no chemical reactions (see exception below) on reductant addition that limit the reductant addition rate or require a digestion period. The only potential reductant, if used in the acid form, chemical reactions on addition is neutralization which could lead to CO₂ and NxOy generation if the slurry pH is allowed to decrease below about eight. Potential reductants are butyric acid, citric acid, and tartaric acid and their sodium forms together with sugar and starch. Sugar is used in the West Valley vitrification process.
- The glass forming frit (fresh process frit) is directly added as a dry component to the melter. Current German vitrification technology employs this step. In addition to simplifying the flowsheet, the potential problem of melter feed rheology change due to frit solubility may be avoided. There is some potential that the canister decontamination frit recycle still may affect melter feed properties.
- The melter used is a high temperature stirred melter. It is assumed that this melter has a waste processing capacity well above four times the current reference melter capacity based on considerations made in the Phase 1 study (Shah, 1993). High temperature and stirred melter technology are currently under development by the Department of Energy at Hanford and Savannah River Plant respectively. The high temperature stirred melter would implement the advantages of the high temperature melter of high waste loading, increased glass formulation flexibility, and increased processing rate together with the stirred melter which increases capacity throughput. The concept is a high temperature melter with a stirrer in the tank. This approach is a modest extension of the individual melter technologies which has not been currently tested and may provide some materials performance challenges.

Implementing these changes may have a cascading effect such that one change may necessitate the need for other changes to make the process operate effectively. Thus, the impacts of the recommended changes need to be considered in greater detail to assure satisfactory overall process performance.

Other significant changes to feed preparation, that were considered in the Phase I study and further considered here and the Phase II study include the option to maximize the concentration of the HWVP feed. The concentration of the HWVP feed received has such a major impact on the feed preparation time cycle that the concentration needs to be maximized within the constraints of cost/benefit of other options as considered in this study. Other alterations include parallel feed preparation operations and increasing batch sizes.

Other beneficial process changes that should be evaluated, but are not included in this study are the following:

- Routing the canister decontamination waste back to the tank farm to be combined with the HWVP feed for concentration and recycle. This action would further simplify the process and eliminate an internal plant recycle stream which adds process operations complexity. Also the evaporation load on the plant would be decreased. If the decontamination solution is non-transuranic and low in radionuclides, the condensate can be sent directly to the tank farm as low level waste. A line, if not available, would have to be provided from the plant to the tank farm to enable recycle to the HWVP feed for concentration.
- The Submerged Bed Scrubber (SBS) may be operated at an elevated temperature to retain the water as a gas through the High Efficiency Mist Eliminator (HEME). Then the gas temperature is decreased for water condensation. The non-transuranic and very low radionuclide content condensed solution can then be routed directly to the tank farm after neutralization for treatment as low level waste. This process modification, in effect, adds additional evaporation capacity to the plant and reduces the feed preparation or the waste treatment time cycle. To implement this modification a condenser-condensate collector would have to be installed.

- The melter may be made with a sloped bottom and include a routine-use bottom drain. The sloped bottom and bottom drain would allow solids settling in the melter to be periodically flushed from the melter into the canister. This would extend the life of the melter if limited by solids accumulation. A review would have to be performed to ascertain if a melter with an adequately sloped bottom and bottom drain would fit into the existing HWVP cell and the changes needed to accommodate these melter modifications. Overflow pouring would be retained. These options are being included in part in current studies.
- The flexibility to accommodate a larger canister need be considered. This would lead to the production of fewer canisters that would have to be handled in the HWVP, shipped, and handled by the repository.
- The filled canister decontamination process should be reassessed. Using the Ce+4 decontamination process being employed at the West Valley Demonstration Project should be considered in addition to other approaches. Frit blasting for canister decontamination may have several drawbacks in slurry handling including ability to obtain representative samples, plugging pipes and fittings such as Purex nozzles, and maintaining the frit in suspension in addition to cost, complexity and reliability. Current indications are that the Ce+4 process time cycle for a single unit may not be compatible with high capacity HWVP and multiple units would be needed.

5.3 PROCESS TIME CYCLE ANALYSES

The process time cycle analyses are performed in this section to determine the capacity of the simplified high capacity flowsheet. The feed preparation time cycles developed are those for the SRAT and SME which are capacity limiting with an advanced melter such as the stirred, high temperature melter that has a capacity up to nine times the current design capacity. The SRAT and SME time cycles for the reference flowsheet are in Appendix A. The SRAT and SME time cycles for the simplified high capacity flowsheets are included in Tables 1 and 2. There should be no limitations for the MFT operating at a capacity compatible with the melter capacity study range. This melter capacity assumption is similar to that used in the Phase 1

study (Shah, 1993). The time cycle analyses do not include process idle times which for final process analyses need to be included.

The basis for the time cycle analyses is one melter feed batch. The assumptions used in generating the time cycles in Tables 1 and 2 are provided below:

- The MFT batch size: 6090-gal (current design)
- Feed concentration to HWVP: 25 g/L of waste oxides (WO) (current design)
- Concentrated waste slurry concentration: 125 g/L of WO (current design)
- The waste loading in the glass is 25 wt% on an oxide bases (current design).
- One canister contains 3630 lb (1650 kg) glass (current design).
- One melter feed batch produces 7 canisters
($[6090 \times 3.785 \times 125] / [1,650,000 \times 0.25]$) (current design).

The time cycle analyses impacts on HWVP capacity are shown in Table 3. For the reference case with the DWPF melter the plant capacity with the melter limiting capacity is 100 kg/h of glass. If an advanced melter is installed that has a capacity up to nine times the DWPF melter then, without idle time, the HWVP capacity is 150 kg/h of glass. The SRAT processing requirements becomes limiting. If the simplified high capacity flowsheet is used in conjunction with the advanced melter without idle times the HWVP capacity becomes 215 kg/h of glass.

To substantially further increase HWVP capacity, additional heat transfer capacity for evaporation and cooling whether in or out of the plant is required for boiling and cooling. Additional analyses to further increase the HWVP capacity are discussed in the next section.

TABLE 1. SIMPLIFIED HIGH CAPACITY FLOWSHEET REFERENCE MODIFICATION - SRAT TIME CYCLE

Process Step Number	Process Step Description	Process Step Time, h	Cumulative Process Time, h
0	SRAT batch heel (0 gal batch volume)	0.0	0.0
1	Receive HWVP feed at 100 gpm (25 g WO/l, 6090 gal incl 120 gal flush)	1.25	1.25
2	Heat tank contents to boiling (7780 gal, 123°F → 214°F)	1.8	3.05
3	Concentrate tank contents at evaporation rate of 10 gpm while receiving additional feed volume (23,460 gal; final batch volume, excluding heel, 6030 gal)	40.0	43.05
4	Cool tank contents for transfer (7720 gal, 214°F → 123°F)	9.7	52.75
5	Transfer concentrated feed to SME at 100 gpm (121 g WO/l, 6090 gal; incl 60 gal flush/prime water)	1.25	54.00

Reference: H-2-123041, Sh 1/2

TABLE 2. SIMPLIFIED HIGH CAPACITY FLOWSHEET REFERENCE MODIFICATION -
SME TIME CYCLE

Process Step Number	Process Step Description	Process Step Time, h	Cumulative Process
0	SME batch heel (0 gal batch volume)	0.0	0.0
1	Receive concentrated feed from SRAT at 100 gpm (121 g WO/l, 6090 gal incl 60 gal flush/prime water)	1.25	1.25
2	Heat tank contents to boiling (7780 gal, 123°F → 214°F)	1.1	2.35
3	Concentrate tank contents at evaporation rate of 10 gpm to allow chemical addition for melter feed makeup. During concentration add the following for melter feed makeup: (4192 gal evap).	7.0	9.35
3a	As room available, receive RWCT process waste recycle at 100 gpm. Assume canister decontamination waste including DWT concentrate transferred to RWCT in two batches. Assume: i. Receive spent frit slurry at 100 gpm, includes DWT concentrate (g WO/l, 2025 gal incl. prime/flush water) and reheat to 214°F ii. Repeat i	(0.5) (0.5)	
3b (or 7)	Receive reductant from cold chemical makeup at 10 gpm (0-g WO/l). Assume the reductant volume is the same as formic acid, 142 gal	(0.25)	
4	Cool tank contents for sampling, chemical adjustment, and transfer to the MFT (7780 gal, 214°F → 123°F)	11.1	20.45
5	Sample tank contents	0.5	20.95
6	Analytical hold time	8.0	28.95

Process Step Number	Process Step Description	Process Step Time, h	Cumulative Process
8	Chemical adjustment (as required)	2.0	30.95
9	Transfer melter feed to MFT at a rate of 100 gpm (200 g W0/l, 6110 gal, incl prime/flush water)	1.25	32.2

TABLE 3. HWVP WASTE PROCESSING CAPACITY

<u>Modifications</u>	<u>Available Melter Feed Rate, kg/h</u>
Current Flowsheet (Shah, 1993):	
Reference flowsheet	100
No idle time (Includes Advanced Melter)	150
Melter feed concentration: 600 g WO/l	120
Increase batch volume size: 7280 gal	120
Combination of no idle time, increase melter feed concentration (600 g WO/l), and increase batch volume size	216
(Increase feed concentration 0.09 kg WO/l with no idle time, SME cycle limit.): (11,640 kg/50.2 h, SME cycle limit) This case not in (Shah, 1993).	232
Simplified high capacity flowsheet with no idle time: (11,640 kg/54 hr, SRAT cycle limit)	215
Parallel operated SRAT/SME with no idle time using simplified high capacity flowsheet (eliminate 9.7 h SRAT cool and 1.25 h SRAT transfer): 2[11,640 kg/(54 h - 10.95 h + 32.2 h - 1.25 h)]	315
Simplified high capacity flowsheet using three steam coils and cooling jacket on SRAT and SME: (See Appendix C)	310
Parallel operated SRAT/SME using three steam coils and cooling jacket on SRAT/SME with no idle time using simplified high capacity flowsheet: 2[11,640 kg/(37.5 h - 10.95 h + 24.7 h - 1.25 h)]	465

<u>Modifications</u>	<u>Available Melter Feed Rate, kg/h</u>
Simplified high capacity flowsheet with no idle time and increased feed concentration (0.09 kg WO/l): (11,640 kg/32.2 hr, SME cycle limit), See Appendix C for SRAT cycle.	361
Simplified high capacity flowsheet with no idle time, increased feed concentration (0.09 kg WO/l), and waste recycle concentration performed in SRAT: (11,640 kg/(54 h - 40 h + 3.6 h + 7.0 h, SRAT cycle limit)	473
Parallel operated SRAT/SME using three steam coils and cooling jacket on SRAT/SME with no idle time using simplified high capacity flowsheet, and increased feed concentration (0.09 kg WO/l): (2[11,640 kg/(37.5 h - 1.25 h - 5.1 h - 28.6 h + 3.63 h + 24.7 h - 1.25 h)])	785
Simplified high capacity flowsheet using three steam coils and cooling jacket on SRAT/SME with no idle time and increased process slurry concentration (175 g/l of WO): [(11,640 kg)(175 g/l / 125 g/l)] / (54 h + 0 h - 0.5 h - 4.6 h), Appendix C for SRAT cycle.	333
Simplified high capacity flowsheet with no idle time, increased feed concentration (90 g/l WO), and increased process slurry concentration (175 g/l of WO): [(11,640 kg/h)(175 g/l / 125 g/l)] / (32.2 h - 5.3 h + 0.3 h, SME cycle limit)	610

5.4 ADDITIONAL OPTIONS ANALYSES

The essential factor in addition to flowsheet simplification (i.e. reducing the number of process steps) to obtain a major capacity increase is water management. The HWVP capacity can be increased by a factor of about two by flowsheet simplification and using an advanced melter. Increasing the capacity by a factor of up to five in waste processing capacity requires an effective increase in slurry evaporation and cooling capacity. There are also effective methods to increase melter feed batch size which will also modestly increase the HWVP capacity by up to 20 percent which are discussed in the Phase 1 study (Shah, 1993), see Table 3, and performing parallel feed preparation processes in the SRAT and SME even further increases plant capacity.

Methods to effectively and substantially increase HWVP heat transfer capacity which are included in this study are as follows. Convert the single cooling coils in the SRAT/SME/DWTT into coils that can be used for heating and place a cooling jacket on each tank. This option is analyzed in Appendix C. As shown in Table 3 by using three heating coils in the tanks and placing a 7-ft. high cooling jacket on each tank the plant capacity without idle time and the simplified high capacity flowsheet may be increased to 310 kg/h of glass.

A major effective increase in SRAT evaporation rate can also be achieved by increasing the HWVP feed concentration from the tank farm (Shah, 1993). The waste concentration to the HWVP can be increased by installing evaporation capacity in the HWVP tank farm lag storage or modified pretreatment steps. The Phase 1 study (Shah, 1993) indicated that the HWVP feed concentration could be increased from 25 g/L of W0 to 90 g/L which would decrease the SRAT evaporation time from 40 h to about 4 h at the nominal evaporation rate which would result in a SRAT capacity increase to 360 kg/h of glass without idle time and using the simplified high capacity flowsheet. If the flowsheet is further modified by performing the process waste recycle concentration in the SRAT the HWVP capacity can be further increased to 470 kg/hr of glass.

Another step in simplifying the flowsheet and increasing the capacity using the simplified high capacity flowsheet is to perform the SRAT and SME processes in one tank and in parallel. The SRAT and the SME would be used and operate in parallel. This approach eliminates the series step of cooling the SRAT contents and transferring the contents to the SME. Implementing this approach without any lag times and using the simplified high capacity flowsheet would result in a capacity increase to 315 kg/h of glass.

Combinations of using an advanced melter, the simplified high capacity flowsheet, increasing effective HWVP evaporation capacity, and operating SRAT and SME as parallel feed preparation systems can be used in combination and with approaches in the Phase 1 study (Shah, 1993) including increasing batch volume size and increasing process stream concentration. These combinations could increase the HWVP capacity to well over 400 kg/h of glass without idle times. The latter two options should be closely considered since their implementation reduces the analytical load per kilogram of glass produced.

Increasing the process waste concentration to between 150 g/l of WO to 200 g/l of WO (use 175 g/l of WO) increases the effective SRAT/SME/MFT batch size by about 40 vol.%. The slurry concentration is limited to about 175 g/l of WO due to the significant increase in viscosity which will limit slurry transfer rates, agitation, and sampling. This option is most attractive when combined with an increase in heat transfer capacity. Using the simplified high capacity flowsheet and additional tank heat transfer area together with the increased process slurry concentration will result in the glass processing capacity being increased to 333 kg/h of glass. If the HWVP feed concentration is increased to 90 g/l of WO with the simplified flowsheet and the increased concentration is used, the SME time cycle becomes limiting and the glass processing capacity is increased to about 610 kg/h of glass.

Operating the SRAT and SME in parallel to perform the simplified high capacity flowsheet and increasing the heat transfer areas in each tank further increases the HWVP capacity to 465 kg/h of glass excluding idle time.

If the combination of options is employed to use the simplified high capacity flowsheet, parallel SRAT/SME feed preparation systems, increased HWVP feed concentration, and increased SRAT/SME/DWTT heat transfer areas without idle times then the HWVP capacity could be increased to 785 kg/h of glass.

Increasing the SRAT/SME/MFT batch size from 6100 gal to 7280 gal will further increase processing capacity. The Phase 1 study (Shah, 1993) indicates that this modification could increase capacity to 120 kg/h of glass. Increasing the slurry concentration to 175 g/l of W0 will also modestly increase the HWVP capacity where used.

The glass process capacities indicated here are for comparative purposes. Actual values for plant production need to include delay times between steps and a more definitive engineering analyses.

6.0 FACILITY AND EQUIPMENT IMPACTS

Impacts of implementing the simplified high capacity flowsheet on the facility and equipment are discussed in this section. The simplified flowsheet was defined such that it would have no major impacts on the Vitrification Building structure. Facility modifications required for other process modifications assessed in this study are also discussed. This study identifies major equipment modifications needed to obtain a feed processing capacity increase of four to five times the current design capacity. Subsequent more detailed studies will be necessary to adequately define all plant implementation impacts.

Simplified high capacity flowsheet implementation will require the following major system modifications:

- The current melter would be replaced by an advanced melter, such as the stirred, high temperature liquid fed ceramic melter (SHLM), with the capability for controlled dry frit feeding. Routine bottom draining would be an asset for flexibility and keeping melter bottom clean. A high capacity melter is needed for any HWVP capacity increase scenario.
- Changing the reductant from formic acid to some other organic may require minor facility and equipment changes. Depending on the reductant selected, whether liquid or a solid requiring dissolution, there may be some chemical makeup and transport modifications needed. There is the possibility that eliminating the use of formic could lead to equipment simplification related to ammonia and hydrogen control along with hazards control for formic acid. Depending on which tank, SRAT or SME, or both that the reductant is added to, some minor piping modifications may be needed. Since the reductant would likely be added at a rate up to 20 gpm, the transport system would likely have to be increased in capacity.
- To increase the concentration of the process feed slurries (study: 175 g/l of WO) in conjunction with the simplified flowsheet no facility/equipment modifications are required. Some assessment is needed to assure that the process slurry composition and concentration selected is compatible with equipment performance.

To substantially further increase the HWVP capacity to attain a 4X or 5X capacity other modifications are needed as indicated in previous sections. These modifications are subsequently discussed.

- The modification which would be most beneficial to increasing HWVP capacity is increasing the concentration of the HWVP feed received to whatever is the maximum practical from the tank farm or pretreatment. The required changes would not impact the current HWVP design. This capability would likely affect other future Hanford waste management facilities. This option should be further investigated for implementation. This approach would greatly benefit the current HWVP design compatibility with high capacity flowsheets by alleviating water and waste management in the plant.
- SRAT/SME/DWTT heat transfer system modifications are needed to increase the heating heat transfer capacity by 40% and double the cooling capacity. The cooling coil in each tank would have services modified to accommodate heating duty. The ability of the system to retain cooling capability if desired would be desirable flexibility. A cooling jacket would be installed on each tank. The condenser heat transfer capacity would have to be increased commensurate with the increase in heat transfer capacity. The services and instrumentation need to be assessed for compatibility with the capacity increases.
- To accommodate parallel operation of the SRAT and SME as independent and parallel feed preparation systems; services, routes, and instrumentation to enable all of the required steps are needed.
- There is also significant incentive to maximize the feed preparation batch sizes. There are many minor modifications which can be easily implemented to accomplish this goal and should be pursued. Many of modifications are treated in the Phase 1 study (Shah,1993) and are being further pursued by WHC/Fluor in the Phase 2 study. These modifications will not be treated here.

Implementation of primary changes discussed above will have secondary process affects which, depending on the changes made, will require additional facility modifications. The major areas of secondary impact are canister handling, waste/effluent handling, and analytical support. The majority of

these impacts are a direct result of the capacity increase and are only modestly impacted by which of the above modifications are implemented. These secondary effects are treated in the Phase 1 study (Shah, 1993) and are being addressed in the Phase 2 study in progress. Primary changes that would significantly mitigate secondary impacts are increasing HWVP feed concentration to the plant, increasing process feed slurry concentration, increasing batch size, and increasing canister size.

7.0 DEVELOPMENT REQUIREMENTS

The system modifications selected for this study are extensions or modifications of existing technologies that would take up to five years or less to verify for HWVP implementation. No significant increases in the currently planned development budgets are envisioned for developing the modifications. The following discussion indicates system development requirements with basic required development times and preliminary budgets for HWVP implementation. The full budget and time indicated are not needed to determine if the system modifications are feasible for HWVP implementation.

The following development is needed:

- New reductant: A new reductant such as citric acid, tartaric acid, or butyric acid is needed. Studies are necessary to determine amount needed per batch and chemistry/rheology characteristics including any reactions such as gas generation that may affect processability and affect the waste processing rate in the melter, and affects on slurry properties for pumping and agitation.
 - Projected Budget: \$2M
 - Schedule: 2 yrs
- Melter feed makeup and properties: The new melter feed makeup/preparation procedure should be tested. The associated high concentration slurry processing properties need to be assessed for pumping, agitation, melter feeding, heat transfer, and process performance in the laboratory and on an engineering scale. A large-scale integrated demonstration would be performed. The large scale demonstration would include increased tank heat transfer if implemented.
 - Projected Budget: \$3M
 - Schedule: 3 yrs
- Stirred, High Temperature Liquid Feed Melter With Controlled Direct Dry Frit Feeding (And Routine Bottom Draining): The current High Temperature and Stirred Melter programs would be consolidated to demonstrate the melter concept. Some development has already been performed and is discussed in the Phase 1 report (Shah, 1993). The direct frit feed and bottom drain systems may be an adaptation of the

systems being used by the Germans. Also, melter empty-out systems are in current U.S. melter designs. Verification of the routine operation of a bottom drain valve and over flow such as used by the Germans would be demonstrated. Bottom draining would facilitate the removal of any solids buildup in the melter. A stirred, high temperature melter further challenges melter materials performance due to temperature and flow conditions. Other areas of development testing would include system component testing and integrated system testing, materials testing, electrode operations/life, component volatility, processing capacity, waste loading, glass quality, process control, equipment operations/reliability, and glass formulation.

- Projected Budget: \$15M
- Schedule: 5 yrs

These costs include budget to demonstrate the modifications described and replace related equivalent development areas. Not included in these costs are items already in the existing development budgets. As a result of further evaluation and engineering analyses other development items may be identified.

8.0 ALTERNATIVE EVALUATION

Evaluating the simplified high capacity flowsheet and other process/equipment modifications consists of qualitatively indicating advantages, disadvantages, cost impacts, and schedule impacts in regard to study bases and objectives. Each major modification is individually considered in Table 4. Combinations of modifications oriented toward meeting study objectives are not included in Table 4. However, selected combinations of modifications which are anticipated to be attractive were previously indicated in Table 3. No one modification considered here will achieve a 4X or 5X capacity increase. Each modification provides a significant capacity increase, but when combined with other modifications results in major capacity increases up to 5X or more. None of the modifications proposed has a direct major impact on the Vitrification Building "footprint."

The high capacity melter is needed in any capacity increase scenario since the melter is currently capacity limiting. A melter capacity increase of up to 9X would be appropriate so that the melter does not again become capacity limiting. The melter should be flexible to handle the a wide variety of feed compositions at high capacity while producing a high quality glass at high waste loadings (high temperature and stirred). Normal bottom draining in conjunction with a sloped bottom is an operating life extension feature. Direct process frit feeding is an approach to significantly simplify SME processing, reduce the SME time cycle, and reduce waste water generation.

Once the melter capacity limit is removed, SRAT processing becomes capacity limiting. The SRAT time cycle limit can be removed by significantly increasing the HWVP feed concentration which has no HWVP impacts. In lieu of the concentration increase, a variety of modification combinations can be used to make the SRAT time cycle non-limiting. Then additional decreases in the SRAT and SME time cycles further increase HWVP capacity. Without further study to determine the cost and related benefit returns including any secondary effects, there is significant uncertainty in ranking modifications. A significant case could be made to pursue all of the modifications indicated.

Within study guidelines and modifications evaluation (Table 4), the author judges that implementation of the modifications should be pursued in the following order:

- Install high capacity melter,
- Maximize HWVP feed concentration to plant,
- Use alternative reductant,
- Implement direct dry process frit feeding to the melter,
- Maximize process feed slurry concentrations,
- Increase batch sizes,
- Increase SRAT/SME/DWTT heat transfer areas, and
- Perform parallel feed preparation processes.

TABLE 4. COMPARISON OF CAPACITY INCREASE MODIFICATIONS

Modification	Advantages	Disadvantages	HWVP Schedule Impact	HWVP Cost Impact
1. Change reductant to: butyric acid, tartaric acid, citric acid, or sugar	<ul style="list-style-type: none"> • Eliminate following SRAT steps. <ul style="list-style-type: none"> - Cool to 190°F (2h) - Add formic acid (6h) - Reheat to boiling and reflux (4h) - Sample (0.5h) - Analyses hold (8h) - Chemical adjustment (as required [2h]) (Reductant add and sampling moved to SME, $\Delta = 22.5h$) • Eliminate hydrogen generation and associated HWVP safety mitigation requirements (SRAT/SME condenser/vent system modifications) • Eliminate ammonia generation and associated HWVP safety mitigation requirements (new vessel vent scrubber) • Eliminate safety hazards and HWVP requirements associated with handling formic acid 	<ul style="list-style-type: none"> • Requires modification of reductant makeup/addition system. Handling capacity would be increased from 2 gpm up to 20 gpm. 	< 1 yr	Minor (potential capital cost savings)

Modification	Advantages	Disadvantages	HWVP Schedule Impact	HWVP Cost Impact
<p>2. Advanced melter: high temperature stirred melter with controlled direct frit addition.</p> <p>Note: High capacity melter (high temperature melter or stirred melter) required to make capacity increase viable.</p>	<ul style="list-style-type: none"> • Eliminate following SME steps with direct frit add: <ul style="list-style-type: none"> - Cool to 125°F (8.4h) - Sample (0.5h) - Heat to boiling (1.1h) - Concentrate at 10 gpm boilup (3h) - Add fresh frit (1h) - Add trim chemicals, reheat to boiling, and reflux (as required) (2h) • Concentrate recycle steps compressed by adding waste and reductant during boiling (2h) (Δ cycle = 18h with above) • A stirred high temperature melter would use the high capacity advantages of the stirred melter with the high capacity, high waste loading, and glass formulation flexibility of a high temperature melter. • Dry frit feeding reduces waste generation 	<ul style="list-style-type: none"> • Development and design program may be required to provide controlled direct frit (dry) feed system to melter (more detail-engineering study needed to assess technology availability from Germans and applicability to HWVP) • Associated study may be required to assure product quality is not affected 	< 3 yrs	Modest for direct frit feed increment

Modification	Advantages	Disadvantages	HWVP Schedule Impact	HWVP Cost Impact
3. Increase SRAT/SME/DWTT heating (40%) and cooling (90%) heat transfer area	<ul style="list-style-type: none"> Reduce time for heating and cooling steps in SRAT/SME SRAT: Δ time, h Step: 2 heating 0.5h 3 boiling 11.4h 4 cooling 4.6h 16.5h SME: Δ time, h 2 heating 0.3h 3 boiling 0.2h 4 cooling 5.2h 7.5h Provides additional heat transfer area in DWTT to meet increased load from capacity increase. Need assessment to see if adequate to meet increased waste handling requirements. 	<ul style="list-style-type: none"> Requires minor HWVP design changes: - convert SRAT/SME/DWTT cooling coil to heating service. - Add cooling jackets to SRAT/SME/DWTT Assess heating (and may be cooling) characteristics of tank to see if increase in heat transfer area performs as projected. 	Minor	Modest
4. Maximize concentrated feed concentrations in HWVP (125g/l of WO to 175g/l of WO used for study)	<ul style="list-style-type: none"> Has effect of increasing batch size by 40% and decreasing the time needed for processing per gallon in SRAT and SME except for initial SRAT receiving and feed concentration and steps that are a function of the waste in the tanks. Minimizes analytical requirements per gallon of feed No impacts on HWVP facility and equipment 	<ul style="list-style-type: none"> Minor amount of development testing would have to be performed to determine what is the maximum concentration the process equipment can handle 	None	None

Modification	Advantages	Disadvantages	HWVP Schedule Impact	HWVP Cost Impact
5. Maximize concentration of HWVP feed transferred to HWVP (study: 25g/l of WO → 90 g/l of WO)	<ul style="list-style-type: none"> Reduces time for SRAT feed concentration step by about 36.4h which is time cycle limiting. Enables performance of SME process waste concentration steps to be performed in SRAT so not as to be time cycle limiting: SME: Δ time, h Step 2 heating -1.1h Step 3 boiling -7.7h Step 4 cooling <u>-11.1h</u> -19.9h This modification requires no facility modifications in HWVP. If want to perform SME steps in SRAT some routing modifications will be required. Significantly decreases waste condensate handling from SRAT. 	<ul style="list-style-type: none"> Need to assess impacts on tank farm and/or pre-treatment programs. 	None directly	None directly
6. Perform SRAT and SME feed preparation process in SRAT and SME, parallel feed preparation operations.	<ul style="list-style-type: none"> Eliminates process operations in SRAT and SME. SRAT: Δ time, h Step 4 cooling -9.7h 5 transfer <u>-1.25h</u> -10.95h SME: Step 1 receive -1.25h SRAT slurry <u>-1.25h</u> 	<ul style="list-style-type: none"> Requires HWVP design changes to assure routings are provided to enable completely parallel feed preparations in SRAT and SME 	< 1 yr	Modest

Modification	Advantages	Disadvantages	HWVP Schedule Impact	HWVP Cost Impact
7. Maximize process batch size in SRAT and SME (study uses 6100 gal → 7200 gal, 18% increase)	<ul style="list-style-type: none"> Decreases the time needed for processing per gallon in SRAT and SME except for initial SRAT receiving and feed concentration and steps that are a function of the waste in the tanks. Phase I study (Shah, 1993) indicates that there would be a 20% increase in plant capacity). There would be an improvement that would likely be somewhat < 10% increase. Minimizes analytical requirements per gallon of feed. 	<ul style="list-style-type: none"> SRAT and SME design and equipment modifications would have to be made such as modifying the pump intake and intake locations to enable the larger batch volume. 	Minor	Minor

9.0 REFERENCES

Shah, K. R., August 1993, "Hanford Waste Vitrification Plant Increased Production Capacity Evaluation (Phase I)," WHC-SD-HWV-ES-046, Westinghouse Hanford Company, Richland, WA 99352

APPENDIX A
CURRENT FLOWSHEET DESCRIPTION AND TIME CYCLES

SLURRY RECEIPT AND ADJUSTMENT TANK TIME CYCLE
Current Flowsheet

Process Step	Process Step Description	Step Duration (h)	Time at Start (h)	Time at end (h)
0	SRAT heel	0.0	0.0	0.0
1	Receive feed slurry at 100 gal/min	11.25	0.0	1.25
2	Heat to boiling	1.8	1.25	3.05
3	Concentrate at 10 gal/min boilup while receiving controlled rate transfer at 5 to 12 gal/min	40.0	3.05	43.05
4	Cool to 190°F	2	43.05	45.05
5	Add formic acid	6	45.05	51.05
6	Reheat to boiling and reflux	4	51.05	55.05
7	Cool to 125°F	9.7	55.05	64.75
8	Sample	0.5	64.75	65.25
9	Analysis hold	8	65.25	73.25
10	Chemical adjustment (as required)	2	73.25	75.25
11	Transfer to SME at 100 gal/min	1.25	75.25	76.5
12	SRAT idle	39	76.5	115.5
0	SRAT heel	0	115.5	115.5

SME = Slurry mix evaporator

SRAT = Slurry receipt and adjustment tank

SLURRY MIX EVAPORATOR TIME CYCLE
Current Flowsheet

Process Step	Process Step Description	Step Duration (h)	Time at Start (h)	Time at end (h)
13	SME heel	0	0	0
14	Receive SRAT transfer	1.25	0	1.25
15	Heat to boiling	1.1	1.25	2.35
16	Concentrate at 10 gal/min boilup	4.5	2.35	6.85
17	Receive RWCT transfer	1	6.85	7.85
18	Concentrate at 10 gal/min boilup	3.5	7.85	11.35
19	Cool to 125°F	8.4	11.35	19.75
20	Sample	0.5	19.75	20.25
21	Heat to boiling	1.1	20.25	21.35
22	Concentrate at 10 gal/min boilup	3	21.35	24.35
23	Add fresh frit	1	24.35	25.35
24	Add trim chemicals, reheat to boiling, and reflux (as required)	2	25.35	27.35
25	Cool to 125°F	11.1	27.35	38.45
26	Sample	0.5	38.45	38.95
27	Analytical hold	8	38.95	46.95
28	Chemical adjustment (as required)	2	46.95	48.95
29	Transfer to MFT at 100 gal/min	1.25	48.95	50.2

30	SME idle	65.3	50.2	115.5
13	SME heel	0	115.5	115.5

NFT = Melter feed tank

RWCT = Recycle waste collection tank

SME = Slurry mix evaporator

SRAT = Slurry receipt and adjustment tank

பெயர் - ம. சி. சி.

- ① CONT. START, ELIAT TO MCTY
(17.28 MINS)
- ② START SMC SAMPLE PUMP &
DRAW SAMPLE (18.30 MINS)
- ③ ANALYZE SMC SAMPLE (18.30 MINS)
- ④ CHEMICAL ADJUSTMENT, AS
REQUIRED (18.30 MINS)
- ⑤ SLACK TIME PRECEDING
PUMP-OUT (18.45 MINS)
- ⑥ TRANSFER 100% CAL TO SMC &
100 GPM (CIRCULATING) OF
PRIME/FLUSH WATER. APPLY
VOLUME CORRECTION FACTOR
(18.55 MINS)
- ⑦ STOP SMC TO GIVE 1719 CAL
CONDENSER AND 32 CAL VENT
LESS. APPLY VOLUME
CORRECTION FACTOR (19.00 MINS)
- ⑧ ADD 2312 CAL FRESH FWT &
40 GPM (19.00 MINS)
- ⑨ ADD 2312 CAL FRESH FWT AND
4 REFUEL (19.10 MINS)
- ⑩ CONT. START ELIAT TO MCTY
(19.10 MINS)
- ⑪ START SMC SAMPLE PUMP &
DRAW SAMPLE (19.20 MINS)
- ⑫ ANALYZE SMC SAMPLE (19.30 MINS)
- ⑬ CHEMICAL ADJUSTMENT, AS
REQUIRED (19.30 MINS)
- ⑭ OPTIONAL: START SMC SAMPLE
PUMP, DRAW SAMPLE AND
ANALYZE (19.30 MINS)
- ⑮ SLACK TIME PRECEDING
PUMP-OUT (19.35 MINS)
- ⑯ TRANSFER BATCH 02 (21.11 CAL) CAL
TO CONDENSER PRIME/FLUIDS TO
MCT & 100 GPM (19.35 MINS)
- ⑰ SAMPLE & ANALYZE MCT FWD
SUBSEQUENT CONTROL OF MCT,
NO MCT HOLD (19.38 MINS)
- ⑱ CONTINUOUS FEED OF POLYMER
& 2.00 GPM (20.00 MINS)
- ⑲ 2193 CAL TO VENT AND RECEIVE
2193 CAL PRIME/FLUSH WATER.
AVERAGE MCT DRAWING
RATE = 3.972 GPM MCT
PROCESSING BATCH 02

18. IT IS ASSURED THAT DURING SAMPLING OF THE PROCESS FLOW, 83 HOUR WILL BE ACQUIRED TO START THE SAMPLING PLAN AND TO ESTABLISH SAMPLE LINE CIRCULATION BEFORE A REPRESENTATIVE SAMPLE MAY BE DRAWN.

19. THIS DIAGRAM PRESENTS A SPECIFIC PLANT EQUIPMENT OPERATING SCHEDULES BASED ON THE ASSUMPTIONS GIVEN IN CALCULATION AND ALTERNATE OPERATING SCHEDULES WOULD ALSO BE POSSIBLE IF THE UNDERLYING ASSUMPTIONS WERE TO BE REVISED.

20. THE INDICATED VOLUMES FOR PROCESS STREAMS AND TANK CONTENTS ARE BASED ON AN ASSUMED 100% OPERATING TEMPERATURE.

21. THE PROCESS LIQUID VOLUMES SHOWN ON THIS DIAGRAM WERE TAKEN FROM THE 228 LBS/HR CASE MATERIAL BALANCE.

22. THE TWO PLISTS WILL BE REOILED DURING THE COURSE OF A SINGLE TRANSFER FROM THE TANK FARM, SCHEDULED TO OCCUR EVERY OTHER PLANT BATCH U.S. EVERY 224 HOURS.

23. AS SHOWN BY THIS DIAGRAM, THE PLIST THAT, THE 800 MT WILL OPERATE SIMULTANEOUSLY PROCESSING SEPARATE BATCHES OF FEED SLURRY. THIS PERMIT THE PLIST TO ACHIEVE 228 LBS/HR CASE PRODUCTION THROUGH CORRESPONDING TO A 1153 MT BATCH INTERVAL EVERY 224 HOURS. TOTAL OF 1933 HOURS WILL ELAPSE BETWEEN THE RECEIPT OF A GIVEN 800 MT BATCH TO THE PLIST AND THE TRANSFER OF THAT BATCH IN PROCESSED FORM TO THE MT.

CHECKING RELEASE

REC. _____ DATE _____
CFO _____

U.S. DEPARTMENT OF ENERGY
Nuclear Operations Office
DC - ACC-SCALDISDOR

**S FLUR DWELL DC
ADVANCED TECHNOLOGY SYSTEM**

TIME/MOTION DIAGRAM
FEED RECEIPT, FEED PREPARATION
HELTER FEED, RADIOACTIVE
PROCESS WASTE COLLECTION SYSTEM
220 LB/HR GLASS PRODUCTION

HANDLED WASTE VITRIFICATION PLANT

8-743 6-37 3701

EX NOT REC'D

M-2-(1955) 1 : 2 3

5

17. EVAPORATORS TANKS (E-1, E-2 & E-3) ARE ASSIGNED TO EXPERIENCE WYTH LOSSES ONLY DURING BOILING, NON-BOILING TANKS (E-4, E-5, E-6, E-7, E-8, E-9, E-10 & E-11) ARE ASSIGNED TO EXPERIENCE CONTINUOUS LOSSES TO VENT DURING THE COURSE OF A PLANT BATCH
18. IT IS ASSUMED THAT DURING SAMPLING OF THE PROCESS TANKS, 4.5 HOURS WILL BE REQUIRED TO START THE SAMPLE PUMP AND TO ESTABLISH SAMPLE LINE CIRCULATION BEFORE A REPRESENTATIVE SAMPLE MAY BE DRAWN.
19. THIS DIAGRAM PRESENTS A SPECIFIC PLANT EQUIPMENT OPERATING SEQUENCE BASED ON THE ASSUMPTIONS GIVEN IN CALCULATION NO. 10-22. ALTERNATE OPERATING SEQUENCES WOULD ALSO BE POSSIBLE IF THE UNDERLYING ASSUMPTIONS WERE TO BE REVISED.
20. THE INDICATED VOLUMES FOR PROCESS STREAMS AND TANK CONTENTS ARE BASED ON AN ASSUMED 125°F OPERATING TEMPERATURE.
21. THE PROCESS LIQUID VOLUME DOWN ON THIS DIAGRAM WERE TAKEN FROM THE 228 LBS/HR CASE MATERIAL BALANCE.
22. THE TWO RESTARTS WILL BE REQUIRED DURING THE COURSE OF A SINGLE TRANSFER OF THE TANKS. RESTARTS TO OCCUR EVERY OTHER PLANT BATCH WILL, EVERY 231 HOURS.

[illegible]

GENERAL NOTES:

APPENDIX B

APPLICABLE GERMAN VITRIFICATION TECHNOLOGY STATUS

FOREIGN TRAVEL REPORT

KARLSRUHE, GERMANY

ML Elliott

GA Jensen

July 1993

Pacific Northwest Laboratory

Richland, Washington

B.1

analyses of samples from the Research-Scale Melter (RSM) at PNL. Some of the RuO_2 crystals analyzed by SEM/EDX also had a Rh peak, indicating a mixture of Rh_xO_y and RuO_2 .

The next topic covered was the formation of platinum metal alloys and oxides with increasing temperature. Prof. Pentinghaus predicted that ruthenium oxidized to RuO_2 at 500°C , rhodium oxidizes to Rh_2O_3 at 550°C , and palladium metal and tellurium metal alloy at 800°C . He also predicted that ruthenium and rhodium oxides combine at approximately 1000°C and rhodium metal alloys with the palladium/tellurium alloy at 1000°C .

KfK tried to predict the oxidation state by ^{57}Fe Mössbauer spectrum. The results indicated that most of the iron in the glass was in the Fe^{+3} state. It was unclear if this can be quantified.

June 17 - Further Review of Draft ESM Report

On the morning of June 17, Mr. Elliott, Dr. Roth, and Mr. Grünewald finished the review of the suggested changes made to the document by Mr. Elliott. These were only general changes to the text. The more specific changes were not planned until the next day. Many of the changes were re-edited with suggestions made by Mr. Grünewald and Dr. Roth.

QA Review by Dr. Jensen

Dr. Jensen completed a quality assurance surveillance of the records of Mr. Grünewald. Everything was found to be acceptable and the QA form sent by B.D. Slonecker of PNL was completed. This form is shown in Appendix D.

Tour of V-W1

On June 17, Dr. Roth and Mr. Karlheinz Weiß gave Mr. Elliott and Dr. Jensen a tour of the V-W1 vitrification facility. This is a hot cell mock-up where testing is being done for the Chinese. KfK and several other companies are transferring LFCM technology to China as part of a joint project started in 1991³. The first step of the project is the completion of a full-scale mock-up vitrification facility in China in 1994. This mock-up, the VPM (Vitrification Plant Mock-up), is scheduled for operation in

³Grünewald, W., G. Roth, W. Tobie, and S. Weisenburger. 1993. "Progress Achieved in HLW Vitrification Techniques at INE." Paper in preparation for the 1993 International Conference on Nuclear Waste Management and Environmental Remediation, Prague, Czechoslovakia.

1995. The melter for this mock-up was designed and built at KfK. It is being tested in V-W1 before being shipped to China. The melter is an enlarged version of the K-6' melter. It has a glass surface area of 1.4 m² and a design feed rate of 65 L/h. This corresponds to a glass production rate of 38.4 kg/hr. As in the K-6' melter, the frit beads (1-2 mm diameter) are discontinuously added to the melter through a separate line. The beads are fed in three batches of 3.75 kg for each airlift batch of simulant. The beads are metered using a strain gauge and hopper system. The feed line from the hopper to the melter is approximately 60° to the horizontal. Although the Chinese HLW does not contain high concentrations of noble metals, the melter is designed for concentrations of noble metals in the glass up to 1 wt%.

The feed and off gas systems in V-W1 are very similar to the VA-WAK except all of the piping is put through remote penetrations into the hot cell mock-up. The mock-up has full remote crane and manipulator access and good viewing windows. The control system for this melter is new. Dr. Roth designed a Windows™ based data acquisition system that is much different than those previously used at INE.

The first run on the Chinese melter in V-W1 ran for approximately four weeks. The system worked well. The feed nozzle had been removed after the run and had very little feed splattered on it. The bottom drain operated fine. It has a two zone induction coil, but they only use the top and bottom taps. The first time that they use it they need to heat it up for one to two hours before pouring. After the first pour, they leave it idling at a low power (just enough to stop it). The off gas line from the melter is kept clean with Blasters similar to those used on the ESM. The blasters are essentially air cannons and they tested them using both 4 bar (58 psi) and 7 bar (102 psi) air pressure. The pipes started to become fouled using only 4 bars of pressure so they switched back to the 7 bar air.

As an interesting note, KfK is now ordering their frit beads from a source in China. They previously ordered it from a European supplier but found the Chinese supplier to be cheaper and the frit was of a higher quality.

June 18 - Final Review of Document

On the last day of the PNL visit, Mr. Elliott and Dr. Jensen met with Mr. Grünewald for a detailed review of the draft ESM report. Mr. Elliott gave Mr. Grünewald an electronic copy of the edited document with all of the comments made by reviews as well as changes made during the KfK visit.

A final review of the document was done by going over each reviewer's comments individually. Approximately one half of the comments could be skipped because they had already been mentioned in previous meetings. Some were reviewed again to stress the importance of the specific comments. Individual comments were made by Don

APPENDIX C
CALCULATIONS

Option: Increase SRAT/SME/DWTT Heating/Cooling Heat Transfer Area By Converting Coil To Heating Coil And Installing Cooling Jacket On Tank

Ref: D.E. Larson, February 1989, "HWVP Technical Manual", HWVP-89-IVJ0010100A, pg 2-31

Current heat transfer area: SRAT/SME
Heating: 340 ft²
Cooling: 140 ft²

Revised heat transfer area: SRAT/SME
• Make cooling coil heating coil
• Install a 7-ft high cooling jacket on Tank: $RD L = 3.14(12.5\text{ ft}) 7\text{ ft} = 264\text{ ft}^2$

Ratio of revised to reference heat transfer areas

$$\text{Heating: } \frac{140 + 340}{340} = 1.4$$

$$\text{Cooling: } \frac{264}{140} = 1.9$$

Assume (Need Check): Services can provide 40% more steam and 90% more cooling water to tank for heating/cooling service. Associated condensers can be modified to provide 40% more cooling capacity by increasing length, number of tubes, and/or cooling water flow (See Hydrogen Mitigation Studies for Condenser Changes)

Maintain cooling coil configuration so can be used for heating or cooling

Heat Transfer related changes would have the following impacts on time cycles

Table - SRAT

Step	Modifications
2	New Step Time: $\frac{1.8 \text{ h}}{1.4} = 1.3 \text{ h}$
3	New Step Time: $\frac{40 \text{ h}}{1.4} = 28.6 \text{ h}$
4	New Step Time: $\frac{9.7 \text{ h}}{1.9} = 5.1$

Change in Cycle Time

Step	Change
2	$1.8 \text{ h} - 1.3 \text{ h} = 0.5 \text{ h}$
3	$40.0 \text{ h} - 28.6 \text{ h} = 11.4 \text{ h}$
4	$9.7 \text{ h} - 5.1 \text{ h} = 4.6 \text{ h}$
	<hr/>
	16.5 h

New SRAT Cycle Time, No Lag Time

$$54.00 \text{ h} - 16.5 \text{ h} = 37.5 \text{ h}$$

SME time would also be reduced

Table - SME

Step	Modification
2	New Step Time: $\frac{1.1 \text{ h}}{1.4} = 0.8 \text{ h}$
3	New Step Time: $\frac{7.0 \text{ h}}{1.4} = 5.0 \text{ h}$
4	New Step Time: $\frac{11.1 \text{ h}}{1.9} = 5.9 \text{ h}$

Change in Cycle Time

Step	Change
2	$1.1 \text{ h} - 0.8 \text{ h} = 0.3 \text{ h}$
3	$7.0 \text{ h} - 5.0 \text{ h} = 2 \text{ h}$
4	$11.1 \text{ h} - 5.9 \text{ h} = 5.2 \text{ h}$
	<hr/>
	7.5 h

New SME Cycle Time No Lag Time

$$32.2 \text{ h} - 7.5 \text{ h} = 24.7 \text{ h}$$

Modified Capacities, No Lag Time

$$\text{SRAT} = \frac{11,640 \text{ kg}}{37.5 \text{ hr}} = 310 \text{ kg/h}$$

$$\text{SME} = \frac{11,640 \text{ kg}}{24.7 \text{ h}} = 471 \text{ kg/h}$$

Option: Increase HWVP Feed Concentration
From 0.025 kg WO/L to 0.09 kg WO/L

Reference Flowsheet

Feed required to make MFT batch
at 0.09 g WO/L

$$\frac{0.025 \text{ g WO/L}}{0.09 \text{ g WO/L}} (6090 \text{ gal} + 23460 \text{ gal}) = 8208 \text{ gal}$$

Water evaporated to make MFT batch
at 0.09 g WO/L

$$8208 \text{ gal} - (6090 \text{ gal} - 6030) = 2178 \text{ gal}$$

Time to evaporate 2178 gal

$$\frac{2178 \text{ gal}}{10 \text{ gpm} (60 \text{ m/h})} = 3.63 \text{ h}$$

Time to process on batch of MFT with
reference flowsheet and no idle time

$$\text{SRAT Time Cycle} = 76.5 \text{ h} - 40 \text{ h} + 3.6 \text{ h} \\ = 40.1 \text{ h}$$

SME Time Cycle becomes limiting
at 50.2 h

$$\text{Processing Capacity} = \frac{\text{Ref. } 11,640 \text{ kg}}{50.2 \text{ h}} = 232 \text{ kg/h}$$

$$\text{Simpl. H.C. } \frac{11,640 \text{ kg}}{32.2 \text{ h}} = 361 \text{ kg/h}$$

Option: Increase SRAT/SME/MFT
Feed Slurry Concentration from 125 g/l
of WO to 175 g/l of WO in conjunction
With Flowsheet Simplification and
Evaporation Capacity Increase

The limiting cycle time is the SRAT
cycle time (See Tables 1 and 2). The
SME cycle is only affected a minor
amount.

The impacts are 40 percent more feed
will have to be concentrated in the
HWVP and the feed concentration will
have to be increased from 125 g/l of
WO to 175 g/l of WO

Change cooling coil to heating coil
in SRAT/SME/DWTT

Evaporation Time: (Tbl —)

$$\left(\frac{40 \text{ h}}{1.4} \right) \left(\frac{175 \text{ g/l WO}}{125 \text{ g/l WO}} \right) = 40 \text{ h}$$

Increase feed concentration to
90 g/l of WO (See 90 g/l of WO option)

$$3.63 \text{ h} \left(\frac{175 \text{ g/l WO}}{125 \text{ g/l WO}} \right) = 5.08 \text{ h}$$

Change cooling coil to heating coil
in SRAT/SME/DWTT. Based
on above batch cycle time would
not change but the feed
concentration would be increased
by 40%. Thus the processing rate
would be

$$\frac{(11,640 \text{ kg/h})(175 \text{ g/l WO}/125 \text{ g/l WO})}{54 \text{ h} + 0 \text{ h Evap} - 0.5 \text{ h Ht} - 4.6 \text{ h Cool}} = \frac{16296}{48.9}$$

$$= 333 \text{ kg/h glass}$$

If the HWP feed concentration is increased to 90 g/d WO the SRAT time cycle becomes

$$54h + (-40h + 5.1h) + (-0.5h \text{ h.t.}) + (-4.6h \text{ cool}) = 14h$$

And the SME time cycle becomes limiting

In the SME time cycle assume the dots not change with slurry concentration.

Assume waste volume is not cons/batch
This is very conservative.

Cycle Time

$$32.2h = 5.26h + 0.3h + \text{boiling time} + \text{no change, increased by waste balance}$$

$$= 26.6h$$

Glass processing rate

$$\frac{(11,640 \text{ kg/h}) (175 \text{ g/d WO} / 125 \text{ g/d WO})}{26.6h}$$

$$= 612 \text{ kg/h} \approx 610 \text{ kg/h}$$

$$26.6h$$