WVST 87/209

Failure Modes and Effects Analysis of the West Valley Nuclear Services Vitrification System

J. H. Westsik, Jr.
T. V. Vo
F. A. Graf, Jr.
J. M. Perez, Jr.
?. H. Fisher

July, 1987

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

Pacific Northwest Laboratory
Richland, Washington 99352

ABSTRACT

A Failure Modes and Effects Analysis (FMEA) was performed to identify design changes and other corrective actions to improve the system integrity and operational performance of the West Valley Demonstration Project vitrification system. The FMEA includes descriptions of the failure modes and causes of those failures, possible effects of the failures, qualitative estimates of the probability and severity of the failures, and possible corrective actions. Nineteen items were identified as having a high failure frequency or a medium failure frequency with lengthy repair times. An additional thirty items were identified whose failures could be mitigated or eliminated by design modifications or additional monitoring. Recommendations for improving these items are provided. An effort was also made to quantify the failure rates and repair times to prioritize the important components and to estimate the vitrification system's availability.

1.0 INTRODUCTION

The West Valley Demonstration Project (WVDP) is being conducted to demonstrate removal and solidification of the high-level liquid wastes stored at the now defunct, Western New York Nuclear Service Center fuel reprocessing facility at West Valley, New York. From 1966 to 1972, Nuclear Fuel Services, Inc. operated the facility, during which time approximately 640 tons of nuclear fuel were reprocessed. As a result of these activities, 560,000 gallons of neutralized high-level liquid waste (HLLW) and 12,000 gallons of acidic THOREX waste were generated. In 1981, West Valley Nuclear Services Inc. (WVNS, a subsidiary of Westinghouse Electric Inc.) was established to implement the WVDP. The current schedule calls for the vitrification system to begin radioactive operation in FY 1991 and operate for approximately two years to vitrify all of the HLLW on site.

The West Valley Support Task of the Nuclear Waste Treatment Program at the Pacific Northwest Laboratory (PNL) is providing technical support to the WVDP. One activity undertaken by PNL in FY-1987 has been to complete a Failure Modes and Effects Analysis (FMEA) of the vitrification system within the Component Test Stand (CTS) at West Valley.

A FMEA is typically performed to identify design changes and other corrective actions that can be made to improve the reliability and safety of the system analyzed. The FMEA includes descriptions of 1) the failure modes and causes of those failures, 2) possible effects of the failures, 3) the probability of the failure, 4) the severity of the failure, and 5) possible corrective actions (Bjoro date unknown, Blanchard and Fabrycky 1981). A FMEA is directed toward equipment and equipment design and does not include the effects of human actions. It is usually performed early in the design process.

Section 2.0 of this report describes the approach, assumptions, format and methodology used in the performance of the FMEA. Section 3.0 discusses the results of the analysis. Section 4.0 lists the conclusions and recommendations developed as a result of performing the FMEA. The functional block diagram, FMEA worksheets, and a review of the Fussell-Vesely Importance measure are included as appendices.

2.0 FAILURE MODES AND EFFECTS ANALYSIS DESCRIPTION

A Failure Modes and Affects Analysis (FMEA) is a systematic, logical process for identifying equipment failure modes for a plant, system, subsystem or component. It inductively determines the effects that such failures will have on the desired operational characteristics of the system being analyzed. For example, a desired characteristic of a typical process system is its ability to maintain production. The most useful outputs of a FMEA are the assessment of the design adequacy of the system to perform its intended function, and an increased understanding about the physical and functional interrelationships of the multiplicity of parts in the system. The FMEA assists the designer in evaluating the inherent strengths and hidden flaws in the design and identifying those potential design improvements which will improve reliability, minimize maintenance requirements, and maximize operational effectiveness.

For the West Valley Demonstration Project FMEA, primary emphasis was placed on evaluating the ability of the system to continue the vitrification process under component failure conditions and recommending methods to minimize the impacts of these failures from the standpoints of system integrity and operational performance. The FMEA was conducted in part to provide guidance for the development of interlocks and alarms to be implemented on the distributed control system at WVNS.

Four steps were completed in performing the FMEA (Bjoro). First, a Functional Block Diagram was prepared to show the interfaces among the major equipment components of the vitrification system in the CTS. Second, the actual Failure Modes and Effects Analysis was performed and documented on the FMEA worksheets. Third, a corrective action report was prepared that identified the equipment components whose failures would most impact the safe, efficient operation of the plant. Fourth, this final report summarizing the FMEA was prepared.

FUNCTIONAL BLOCK DIAGRAM

The Functional Block Diagram (FBD) shows graphically the interfaces between the individual components of the vitrification system. Each piece of equipment is represented by a block, and lines connecting the blocks represent pipes and flow paths between pieces of equipment.

The FBD developed for the WVNS vitrification system can be found in Appendix A. Major equipment components included the Concentrator Feed Makeup Tank (CFMT), the Melter Feed Tank (MFT), the melter, the turntable, and the off-gas treatment system including the Submerged Bed Scrubber (SBS), the off-gas dryer, dual trains of High-Efficiency Mist Eliminators (HEMEs), preheaters, HEPA filters, and a single trench heater. Auxiliary equipment including instrumentation, pumps, jets, agitators, valves, and services are also shown on the FBD. The diagram is based on our understanding of the vitrification flowsheet as defined in the following paragraphs.

To vitrify the wastes, the WVDP will decant and decontaminate the supernatant from the 8D-2 neutralized waste to remove the Cs-137 via ion exchange onto a zeolite. The loaded zeolite will then be blended with the solids fraction of tank 8D-2 and the THOREX waste in tank 8D-4. These activities will be conducted outside the CTS and are therefore outside the scope of this FMEA.

The waste will then be pumped into the CTS where the waste will be concentrated and then blended with glass forming chemicals, recycle and decontamination wastes, and sugar to adjust the glass redox potential. Following verification that the melter feed composition is within acceptable limits, the slurry will be transferred to the melter feed tank and metered to the slurry-fed, Joule-heated, ceramic melter.

The slurry-fed melter (SFM) has been designed to process the slurry at a feed rate ranging from 90 to 150 L/h. The design basis glass production rate is 45 kg/h. Currently, the equivalent glass oxide concentration in the feed slurry is approximately 350 g/L. As the glass is produced, it will be transferred into stainless steel canisters positioned beneath the melter by an enclosed turntable. Once filled, the canisters are allowed to cool in the turntable prior to being removed for closure and decontamination. The off gases generated during processing will include steam, decomposition gases, and entrained particulate and volatile matter. The off-gas treatment system will remove the particulate and condensable matter for recycle back to the melter. NO_x will also be stripped from the off-gas stream in the 01-14 Building prior to releasing the remaining noncondensable gases to the plant stack.

The Functional Block Diagram was prepared from this understanding of the process and from Process and Instrumentation Diagrams (P&IDs), hydraulic diagrams, and nozzle and jumper layout drawings. Several updates to the FBD were made as the equipment design evolved (January 30, 1987 was the nominal cutoff date for incorporating changes in the FBD).

FMEA WORKSHEETS

To guide the performance of the FMEA, a worksheet was devised so that the necessary information would be obtained. The choice of the format for the FMEA worksheets was made based on the successful experience with performing FMEAs on similar systems. Minor modifications were made to the initial format to make it more compatible with the WVDP configuration. The present format contains the major headings necessary to cover all aspects of the type of output required for this project. The FMEA worksheets are included in Appendix B. The entries under each of the ten columns of the FMEA worksheets are explained below.

- Item: This column contains the name of the component being analyzed.
- Failure Mode: In this column, the credible ways in which the item can fail are listed. In many instances, there are several failure modes to be considered (i.e., valves can "fail to operate", "fail open", "fail closed", or "rupture") and each failure mode must be listed separately on the FMEA. In general, the failure modes of a component describe the manner in which it cannot perform its intended function.
- Failure Mechanism: In this column, the fundamental causes potentially responsible for the particular failure mode being investigated are described. For example, if the failure mode of a pump is defined as "fails to operate", failure mechanisms attributable may be "loss of

power", "broken drive belt", "seizure", etc. Each failure mechanism for each failure mode must be listed separately on the FMEA.

- Failure Effect, System Level: The expected behavior of the next higher level portion of the subsystem being investigated which results from the failure of the identified item is entered in this column. For example, if the ADS pump on the Melter Feed Tank "fails to operate" due to "seizure", the system level effect is that feed will cease being transferred to the melter.
- Failure Effect, Plant Level: In this column, the expected behavior of the overall plant due to the failure of the item under consideration is presented. In the case of the previous example, however, the effect at the plant level is to let the melter idle until the pump is repaired or replaced. Thus, glass production is halted during this maintenance action time. If there is no immediate effect, this is stated and further explanations may be entered in the Remarks column as appropriate.
- Method Of Detection: This column lists any sources which can provide the operating personnel with information which would make them aware of the failure. This could be a significant entry in the FMEA, because a failure may be inconsequential if detected immediately, but may become a problem if the ability to detect the failure is delayed very long. In the case of the WVDP, it is expected that the onset of failures that would lead to unacceptable periods of plant downtime will be adequately alarmed to alert the operating personnel to the situation.
- Recovery Action: In this column, the steps necessary to recover from the failure are described. For a system in which the operations are in series (i.e., failure of any component of the system fails the entire system), there is usually no recourse but to repair or replace the failed item. However, if there is a redundant path available, such as the dual off-gas treatment lines, which would mitigate the effects of the failure until the repairs are completed, this is stated.
- Failure Frequency: This column contains a semi-quantitative estimate of how often the item is expected to fail; this can be expressed as the

"failure frequency", or "number of failures per unit of time". For this analysis, there were three levels of failure frequency: "high", "medium" and "low" (H, M, L). A "high" failure frequency was defined as being at least one failure every six months, a "medium" failure frequency as being at least one failure occurring between 6 months and two years, and a "low" failure frequency as having no expectation of failures before two years of system operation.

- Repair Time: This column contains a semi-quantitative estimate of the time it will take to repair or replace the failed item. For this analysis, there were three levels of mean-time-to-repair, "high", "medium", and "low" (H, M, L). A "high" repair time was defined to be greater than one week; a "medium" repair time was defined to be between one day to one week; and a "low" repair time was defined to be less than one day.
- Remarks/Recommendations: Comments in this column may clarify the entries in any of the other columns, provide recommendations for design modifications which appear desirable to improve the system operations, or provide any other information which seems appropriate to the further clarification of the item under consideration.

The analytical approach taken was to carefully examine each system component (indicated as "Item" on the FMEA) that appeared on the functional block diagram to determine the consequences (indicated as "Effect" on the FMEA) of a failure in that component, particularly relative to glass production and/or system integrity. All legitimate modes in which that component could fail were also identified, and for each failure mode, the mechanism(s) that could cause such a failure mode were defined. The effects of these failures, at both the subsystem level and at the plant level, were identified as well as method(s) for detecting that this failure had occurred, the action that needed to be taken to recover from the failure (i.e., repair, replace, use redundant path, etc.), and semi-quantitative estimates of failure frequency and repair times. In many cases, special consideration had to be given to qualifying conditions, such as the impact of multiple simultaneous failures, assumptions, and recommendations. These considerations were noted under the Remarks/Recommendations heading on the FMEA.

Assumptions

Prior to initiating the FMEA and during the performance of the FMEA, it was necessary to make certain assumptions regarding system characteristics which were as yet not completely defined. Examples of the types of assumptions that needed to be made involved system operating philosophy, operating methods, and equipment configurations. These assumptions are important to the understanding of the results of the FMEA, since an incorrect assumption could significantly change the outputs from the FMEA. Following is a list of these assumptions which were felt to be important to the conduct of the FMEA.

- Human-errors due to test and maintenance, equipment installation, etc., were not considered in this analysis.
- Common-cause failure effects (e.g., redundant systems, external events) and component aging degradation were not considered.
- Operator recovery actions were not considered.
- It was assumed that neither of the redundant paths of the off-gas system was a primary path, i.e., that when a failure occurred in a primary path, the secondary path would only be used until the primary path was operational again. The operating philosophy will be to use one path until a failure occurs in it, and, after switching to the second path, continue using that path until a failure occurs in it. By this time, the failure in the first path would be repaired and the first path would again be available for operation.
- It was assumed that, under normal operations, the melter would be operating continuously while the feed preparation process would be operating in a batch processing mode.
- It was assumed that equipment failures which had no impacts on safety or plant operations, i.e., equipment which is useful but not mandatory to successful operations, could be repaired or replaced at a later time during a shutdown required for other reasons.

Analysis Methodology

A consistent and meaningful FMEA can only be achieved through a coordinated effort on the part of the preparers. The ultimate FMEA is one in which each participant prepares a FMEA for the entire system being analyzed and, in a meeting of all participants, the various inputs from each preparer are evaluated in detail for each FMEA item entry. Available resources seldom permit this sort of in-depth analysis, as is the case for the WVDP FMEA. The methodology used in the WVDP FMEA was to assign selected portions of the system to each of the participants. However, during the performance of the WVDP FMEA, frequent meetings were held among all the participants to clarify, critique and recommend improvements to each entry in the FMEA.

In addition to the detailed review by the preparers, an independent technical review was performed. Two vitrification system experts (a PNL staff member and a private consultant) reviewed the completed worksheets. Their comments and recommendations were addressed and incorporated in the worksheets.

CORRECTIVE ACTION REPORT

The Corrective Action Report was prepared in response to the findings of the FMEA. The purpose of the report was to identify the vitrification system equipment components whose failure would most impact the successful or efficient operation of the plant. The criteria used for selection included: 1) items having a high failure frequency, 2) items having a medium failure frequency in conjunction with a high or medium repair time, and 3) FMEA items that could be mitigated or eliminated through design changes or additional monitoring equipment. Also included in the Corrective Action Report were estimates of the system availability (based on a two year operational lifetime) and a list of recommendations for minimizing or eliminating the impacts of equipment failures on successful plant operations. Since the transmittal of the Corrective Action Report to WVNS[(a)], revisions to the FMEA

(a)Letter to Jim Pope from John Carrell, WVST 87/141, April 30, 1987.

worksheets based on comments from reviewers have changed some items in the Corrective Action Report. The changes are reflected in the next section of this final report.

3.0 DISCUSSION OF RESULTS

For the WVDP FMEA, there were approximately 115 separate items in the system that were examined for their unique failure modes to determine their impact on system performance and integrity. Approximately 200 separate failure modes were attributed to these items and, when multiple failure mechanisms which caused specific failure modes to occur were considered, approximately 300 entries were included in the FMEA. The FMEA worksheets showing the failure modes and their associated failure mechanisms for each item are presented in Appendix B.

Nineteen items from the FMEA worksheets were identified as having a high failure frequency or a medium failure frequency with a high or medium repair time. An additional thirty items were identified whose failures could be mitigated or eliminated by design modifications or by incorporation of additional monitoring instrumentation. Tables 1 and 2, revised from the Corrective Action Report, list these items and recommended corrective actions. The plant's reliability could be improved by all or a combination of the following: performing periodic preventive maintenance or testing on the item, improving on the design of the item itself or of ancillary equipment, or instituting clearly defined operating procedures/philosophy documentation which will mitigate the effects of the failed item.

An effort was also made to quantify the failure rates and recovery/replacement times of the nineteen key items in Table 1 in order to estimate their impact on plant availability. Though the FMEA itself used only qualitative values (High, Medium or Low) for these characteristics, failure and repair experience from similar projects as well as engineering judgement were employed to provide specific numerical estimates. The quantitative estimates used for this availability analysis are shown in parentheses in Table 1.

The Fussell-Vesely (FV) Importance measure was used for this quantitative analysis (Lambert 1973). The FV Importance measure is the fraction of the total system unavailability to which an event, component, or subsystem contributes. The objective of this evaluation is to identify and

TABLE 1. Failure Items Having a High or Medium Failure Frequency

Item	Failure Mode	Failure Mechanism	Failure Frequency	Repair Time	Comments/Recommendations
ADS Pump (Sh# 3 of 49)	Pumping rate falls off	Pump screen plugged	H (1/wk)	L (0.25 h)	The entrance to the ADS pump chamber is expected to periodically become plugged with solids. This will require the pump to be cleared by backflushing the pump with water into the feed tank. It is recommended that the pump be routinely flushed and/or a flow meter be installed in the melter feed line to observe the slurry flow stability.
Level Indication (Sh# 7 of 49)	No level indication	Dip tubes plugged	H (1/wk)	L (0.25 h)	The reliability of dip tubes in high solids-containing slurries is very poor. Although operation of the melter and feed systems can be continued in the wake of failed or plugged dip tubes, process models relying on their operation may not allow process operation without proper dip tube operation. The use of humidified gas and the availability of water for flushing the tubes is strongly recommended.
Feed Nozzle (Sh# 17 of 49)	Slurry pluggage in feed nozzle	Oversized feed particle or gradual scale buildup	H (1/wk)	L (0.25 h)	A feed line flow meter and feed line pressure transducer are recommended to allow early detection of a possible feed nozzle pluggage in order to allow for early detection and identification of the source of the problem. The feed line and nozzle could then be flushed to either recover from the pluggage or to clean the feed line prior to shutdown and nozzle cleanout.
Glass/Plenum Thermowells (Sh# 18 of 49)	Loss of signal	T/C well failure	H (4/y)	L (1 d)	The glass thermocouple well can be expected to fail. Therefore, it should be placed on a routine replacement schedule to assure adequate instrumentation for process control. How often it should be replaced should be dictated by plant experience but it should be with a 3 to 9 month period.
Glass/Plenum Thermowells (Sh# 18 of 49)	Loss of signal	• T/C failure • T/C wire junction failure	H (4/y)	L (1 d)	Single or even multiple failures should not require an interruption of melter operation. However, the requirements for WFQ process model data needs to be considered as possibly having more strict requirements.
TV System (Sh# 18 of 49)	Obstruction of tip aperture	Salt deposits, or impinged glassy material	H (4/y)	L (8 h)	A reliable method of periodically cleaning the tip is recommended. Loss of one or both camera images should not require immediate cessation of slurry feeding to the melter given that trained operators can interpret instrument data.

Item	Failure Mode	Failure Mechanism	Failure Frequency	Repair Time	Comments/Recommendations
Weight Factor/Specific Gravity (Sh# 19 of 49)	Faulty or interrupted signal	Connection failure	M (2/y)	M (2 d)	Melter monitoring capability will be decreased. The longer repair time is based on the fact that it may take a longer period of time to identify the source of the failure than to actually repair the failure. It is recommended that a pressure transducer be located in the air line at the melter to allow for a rapid identification of the source of the failure. It is also recommended that an operating procedure/philosophy clearly define the reliance on such information based on operating constraints and the need to maintain an adequate data base for WFQ.
Weight Factor/Specific Gravity (Sh# 19 of 49)	Faulty or interrupted signal	Dip tube failure due to corrosion or plugging	H (4/y)	L (1 d)	The corrosion of the dip tubes are recognized to be a high failure item which will require frequent replacement. The operation of the melter should therefore minimize its reliance on this system to lessen the impact of its failure on plant operations.
Glass Airlift System (Sh# 19 of 49)	Loss of lift air	Connection failure	M (2/y)	M (2 d)	The longer repair time is based on the fact that it may take a longer period of time to identify the source of the failure than to actually repair the failure. It is recommended that a pressure transducer be located in the air line at the melter to allow for a rapid identification of the source of the failure.
Glass Airlift System (Sh# 19 of 49)	Air lance fails	Corrosion /erosion	H (4/y)	L (8 h)	Although the corrosion/erosion of the airlift lance is significantly lower than the weight factor/specific gravity bubblers in the melter tank, it is still expected to fail. It is recommended that plant experience dictate whether an Inconel 690 tube is satisfactory or whether a platinum airlift tube should be considered.
Glass Airlift System (Sh# 19 of 49)	Overpressurization or underpressurization	Faulty signal /control	M (2/y)	M (3 d)	Design needs to assure that the air flow rate and pressure are controlled to prevent over pressurization of the lance through operator error or equipment failure. Failure could result in either a canister to be overfilled or the pluggage of the pour area.
Overflow Section Thermowells (Sh# 20 of 49)	Loss of signal	• T/C failure • T/C wire junction failure	H (8/y)	L (8 h)	The routine replacement of the thermocouples should be evaluated as a means of minimizing failure during operation. The operation of the melter overflow heaters can be provided by feedback on the heater power consumption. Again, however, the need for data for purposes of WFQ may require continuous thermocouple data. This requirement needs to be defined.

Item	Failure Mode	Failure Mechanism	Failure Frequency	Repair Time	Comments/Recommendations
Bottom Electrode (Sh# 21 of 49)	Electrode failure	Conductive sludge layer	M (2/y)	M (3 d)	Highly dependent on noble and precious metal inventory and glass chemistry. Alarm electrode high current and temperature limits. If melter replacement required, a high repair time would occur.
Overflow Section Heaters (Sh# 25 of 49)	Loss of Power	Heater electrical lead(s) fail	M (2/y)	M (3 d)	Design should assure that a failed electrical connection at the heaters will be electrically isolated and will not be able to establish a ground short.
Overflow Section Heaters (Sh# 25 of 49)	Heater failure	Thermal shock/ fatigue	H (4/y)	M (2 d)	Design should assure that heater fragments will not obstruct trough/pour area. Plant procedures should establish the minimum number of heaters that are required to sufficiently heat the overflow area before replacement of the heater insert section is required.
Off-Gas Nozzle Film Cooler (Sh# 26 of 49)	Corrosion	Salt attack	M (2/y)	M (2 d)	Failure will lead to pluggage of the off-gas jumper. Ability to detect failure is recommended. Should consider inspection/replacement of the film cooler when melter is idled for routine maintenance.
Off-Gas Nozzle Film Cooler (Sh# 26 of 49)	Weld failure	Corrosion/ thermal cycling	M (1/y)	M (2 d)	Same comment as above.
Off-Gas Nozzle Film Cooler (Sh# 26 of 49)	Pluggage	Accumulated solids	H (7/wk)	L (0.1 h)	Routine cleaning of the film cooler entrance, using a remote device, is recommended.
Glass Pour Area Discharge Cone (Sh# 27 of 49)	Plugs	Glass accumulation	M (2/y)	M (3 d)	Monitoring of the glass stream with a TV camera is recommended.

TABLE 2. Failure Items Based on Design Areas and/or Instrumentation Improvements

Item	FMEA Page	Comment/Recommendation
Air Purge Confirmation After Jet Transfer	12-16	Present approach is to open air purge valve and assume air flowed. If it did not, in some cases back-siphoning could occur. Need feed-back to control system that confirms that air purge actually occurred. Insert orifice plate in-line downstream from air valve and pressure tap to sense air flow so that control system can confirm.
ADS Sample Pump	4,8	Need to assure that the circulated flow has been running sufficiently to achieve a homogeneous stream that is similar to the tank contents. Need flow sensor in recirculation loop to assure that pump is operating as required.
Radiation Monitor Downstream of HEPA Filter	45	If a HEPA filter is breached, downstream contamination will occur. A single radiation monitor before the trench heater would indicate severity of the problem. If not already existing, an additional gamma radiation monitor downstream of both redundant off-gas legs is recommended to sense any spread of radiation past HEPAs.
Radiation Monitor in Closed Loop Cooling System	10	Monitor for any contamination in coolant. Install radiation monitor on CLCW system outside of cell.
Closed Loop Cooling System	10	Make manual water make-up automatic loop to ensure water level is maintained in the loop.
Airlift Air Supply	19	A solenoid valve is recommended to prevent inadvertent air flow to air lift.
Condenser. Coolant leaks	34	Condenser coolant could leak into condenser undetected and end up in either Tanks 8D-1, 8D-2, or 8D-4. Include closed loop cooling system level monitoring in process control system.

Item	FMEA Page	Comment/Recommendation
Off-Gas System Isolation Valves	40,46	Need to ascertain position of valves (open or closed). Add position switches to valves to indicate open or closed position. Incorporate into process control system.
Melter Feed System	17	The ADS pump should be monitored to determine its performance and detect feedline pluggage. Add melter feed flow meter to monitor feed flow to melter.
Glass Overflow	27	To indicate glass accumulation in pour area. Add a remote viewing system to monitor glass pour stream.
SBS Recir- culating Tank Packed Bed	36	If the bed support fails and the bed drops down into the receiver tank, there will be no way to know that it happened. Need means to ascertain that the bed is still intact and in place if impacts of such a failure are unacceptable.
Off-Gas System Dryer	39	An electrical circuit monitoring system is recommended to warn of an impending failure of the heater and subsequent excess condensation in the HEME. Add monitoring of the heater electrical circuit.
Air Purge Valve Solenoid (Air to Jacket on CFMT). Does not open on power-up.	5	Monitor air purge service.
Pressure Let- down Valve Low Pressure Loop. Pressure remains high in rest of loop.	10	Controller logic needed to obtain shared flow to other demands.
TV System. Obstruction of tip aperture.	18	Method of routinely cleaning tip of assembly recommended.
Glass/Plenum Thermowells. Loss of signal.	18	Ceramic liner inside thermowell is recommended to minimize corrosion.

Item	FMEA Page	Comment/Recommendation
Inner Refractory Cooling System. Loss of temperature indication.	24	Exit air temperature monitor should be replaceable.
Shell Cooling. Loss of water.	26	Back-up air cooling should be available in case of loss of water cooling.
Shell Cooling. Rupture of shell.	26	Design of shell cooling system should prevent isolation of melter jacket that could lead to steam pressurization.
Off-gas Vent Line. Solids plug water drain.	28	Drain should be sized so as to prevent this event.
Condenser Outlet and Drain. Solids plug liquid outlet.	33	Capability to jumper in a back-flush if ever needed is recommended.
Control Valves in CLCW System. Fails to open.	10	All CLCW system valves should be designed to fail open.
TV System. Loss of cooling.	18	Valves in air lines should be designed to fail open.
Melter Electrodes. Loss of cooling.	20	Valves in air lines should be designed to fail open.
Off-gas Nozzle Film Cooler. Loss of air.	25	Valve(s) in air line should be designed to fail open if compatible with operating control.
Shell Cooling. Loss of water.	26	Valves in water line should be designed to fail open.
Shell Cooling. Loss of air.	27	Valves in air line should be designed to fail open.
Connection to Melter. Expandable bellows fails.	28	Valve in air line should be designed to fail open.

Item	FMEA Page	Comment/Recommendation
Access Port. Water seal fails.	29	In-cell water supply valve should be designed to fail open. Water regulator valve should be set to operate in-cell valve full open as standard operating procedure.
Weigh System. Air cooling fails.	29	In-cell air valve should be designed to fail open.

to prioritize the components that dominate the total system failure, given that component failure occurred.

The nineteen high and medium failure rate items from Table 1 were ranked according to their unavailabilities, as shown in Table 3. The results indicated that an upper bound on the plant availability is 0.83, which means that the plant would be expected to be fully operational 83% of the time and down for repairs 17% of the time as a direct result of equipment failures.

An analysis of the important component measure shows which of the component failures dominate the total system's availability. Table 3 lists, in decreasing order of magnitude, the results of the FV Importance measure for components in Table 1. Two comments must be made concerning this table. First, the items identified in the table as having high unavailability will have a high impact on the plant's availability; e.g., Overflow Section Heater has a highest unavailability at $2.39 * 10^{-2}$ and its FV Importance (I^{FV}) is 0.134. This is the highest value of I^{FV} for all the components listed in Table 3. Second, this data contains only the components/ subsystems that have either a high or medium failure frequency combined with a medium or high repair time. As a result this is not considered a comprehensive analysis. It must be emphasized that these calculations are based on crude estimates of failure frequencies and repair times. A more comprehensive treatment is recommended for future study. More details and sample calculations of the FV Importance evaluation can be found in Appendix C.

TABLE 3. Component Unavailability and its Associated Fussell-Vesely Importance Measure

Item	Failure Mode	Unavailability(a)	I^{FV} Measure(b)
• Overflow Section Heaters	Heater failure (thermal shock/fatigue)	$2.39*10^{-2}$	1
• Overflow Section Heaters	Loss of power	$1.64*10^{-2}$	2
• Glass Airlift System	Over/under pressurization	$1.64*10^{-2}$	3
• Glass Pour Area Discharge Cone	Plugs	$1.64*10^{-2}$	4
• Glass/plenum Thermowells	Loss of signal (T/C failure)	$1.20*10^{-2}$	5
• Glass/plenum Thermowells	Loss of signal (well failure)	$1.20*10^{-2}$	6
• Weight Factor/Specific Gravity	Faulty signal (connection failure)	$1.10*10^{-2}$	7
• Bottom Electrode	Electrode failure	$1.10*10^{-2}$	8
• Weight Factor/Specific Gravity	Faulty signal (diptube failure)	$1.10*10^{-2}$	9
• Glass Airlift System	Loss of lift air	$1.10*10^{-2}$	10
• Off-gas Nozzle Film Cooler	Corrosion	$1.10*10^{-2}$	11
• Overflow Section Thermowells	Loss of signal	$7.94*10^{-3}$	12
• Off-gas Nozzle Film Cooler	Weld failure	$5.50*10^{-3}$	13
• Off-gas Nozzle Film Cooler	Plugged	$4.20*10^{-3}$	14
• Glass Airlift System	Air lance fails	$4.00*10^{-3}$	15
• TV System	Obstruction of tip aperture	$3.97*10^{-3}$	16
• ADS Pump	Pumping rate falls off	$1.45*10^{-3}$	17
• Level Indication	No level indication	$1.45*10^{-3}$	18
• Feed Nozzle	Slurry pluggage	$1.45*10^{-3}$	19

(a) These quantitative calculations are provided for perspective. Moreover, the numerical values presented in this report are highly uncertain, and should be interpreted cautiously.
(b) Ranked in descending order of magnitude of the calculated I^{FV} values.

4.0 CONCLUSIONS AND R

Based on the information generated in th Analysis, the following conclusions regarding th of the WVDP are presented:

- There are no equipment items in the WVNS vitri both a high failure rate (> 2/y) and high repai Nineteen items were identified with a high failur failure rate (> 0.5/y) and a high or medium (< 1 w Thirty additional items were identified whose failur gated or eliminated by design modifications or additio Recommendations for improvements are described in detail Tables 1 and 2.

- The availability analysis indicates that the vitrificatio operating availability will be approximately 80% as a resu equipment failures. This analysis is based on the nineteen iten aving a high failure frequency or a medium failure frequency with medium or long repair times and uses semi-quantitative estimates for the failure frequencies and repair times. Therefore, the analysis should not be considered rigorous.

- The largest contributors to system unavailability are the overflow section heaters which represent approximately 36% of the unavailability. The second largest contributors are the glass/plenum thermowells which represent approximately 14% of the unavailability. The results of the availability analysis are summarized in Table 3.

This FMEA was limited in scope to the vitrification system proper within the Component Test Stand at WVNS. Thus, some failures and effects that could effect production were not addressed. In particular, the loss of cranes, manipulators, and other handling and transportation equipment should be evaluated. The loss of services (power, instrument air, steam, water, etc.) was examined for each piece of equipment. The system-wide effects of the loss of services should be addressed.

When detailed cell-layout drawings are available, a technical review by experienced remote facility operators should be conducted. One product of the review would be quantitative estimates of the failure rates and repair times. This additional information could then be used for an in-depth analysis of the reliability of the WVNS vitrification system.

5.0 REFERENCES

Bjoro, E. F. Procedure for Performing a Failure Mode and Effects Analysis (Revised). U.S. Department of Energy, Washington, D.C.

Blanchard, B. S., and W. J. Fabrycky. 1981. System Engineering and Analysis. Prentice-Hall, Inc., Englewood Cliffs, NJ 07632.

Lambert, H. E. 1973. Fussell-Vesely Importance Measure. UCID-16238, Lawrence Livermore Laboratory, Livermore, California.

APPENDIX A

FMEA FUNCTIONAL BLOCK DIAGRAM

<u>REFERENCES FOR FUNCTIONAL BLOCK DIAGRAM</u>

<u>Prints</u>

West Valley Nuclear Services Company, Inc. Drawing No. 900E705.

Sheet	1	Abbreviations and Legend	Rev 0
	2	Concentrator Feed Makeup Tank	Rev B
	3	Melter Feed Hold Tank 63-11-011N Process and Instrumentation	Rev D
	4	Waste Header-Vitrification Cell Process and Instrumentation Diagram	Rev C
	5	Sample Pumps and Samplers for V-01 & V-11 Process and Instrument Diagram	Rev D
	6	FHT ADS Pump 63G-11 Process and Instrument Diagram	Rev B
	7	Internal Melter Thermocouples	Rev 0
	8	Melter Cooling System	Rev 1
	9	Melter Pneumatic Instrumentation	Rev 0
	10	Melter & Heater Power Supply & Controls	Rev 0
	12	Turntable	Rev 8
	13	Turntable Seal	Rev 0
	14	Primary Scrubber Scrub Section	Rev 0
	15	Primary Scrubber Receiver Tank	Rev 0
	16	Glass Level Detector System	Rev 0
	19	CTS Vessel Vent System	Rev B
	21	Melter Off-gas System Pre-heater and HEMES P&ID	Rev B
	22	Vessel Vent Off-gas Filters and Heaters Process and Instrument Diagram	Rev B

Prints (continued)

(No drawing number)

Off-gas System Hydraulic Elevation Diagram — Rev 0

(No drawing number)

Pit Area Hydraulic Diagram — Rev 0

PNL-250-1 Sheet 1

Concentrators V-01 & V-11 Nozzle & Jumper Layout

Other References

Siemens, D. H., W. O. Heath, D. E. Larson, S. N. Craig, D. N. Berger and R. W. Goles. April 1985. High-Level Radioactive Waste Vitrification Process Equipment Component Testing. PNL-5394, Pacific Northwest Laboratory, Richland, Washington.

Siemens, D. H., M. M. Beary, S. M. Barnes, D. N. Berger, R. A. Brouns, C. C. Chapman, R. M. Jones, R. D. Peters, and M. E. Peterson. March 1986. Design and Operating Features of the High-Level Waste Vitrification System for the West Valley Demonstration Project. PNL-5780, Pacific Northwest Laboratory, Richland, Washington.

Holton, L. K., Jr., Compiler. June 1985. Design Features of the Radioactive Liquid-Fed Ceramic Melter System. PNL-5393, Pacific Northwest Laboratory, Richland, Washington.

APPENDIX B

FMEA WORKSHEETS

PROGRAM: WEST VALLEY DEMONSTRATION PROJECT

SYSTEM: STEAM JET CONTROL SYSTEM

PREPARED BY: Frank Graf

Item	Failure Mode	Failure Mechanism	Failure Effect System Level	Failure Effect Plant Level
Cell sump to waste header (North or South)	Vent valve fails open	Solenoid fails	Loss of steam motive power. No transfer	Minor
	Steam supply valve fails closed	Same	No steam for jet. No transfer	Same
	Air supply valve fails closed	Same	No purging possible	No back siphoning likely
	Block valve upstream of jet fails closed	Same	No transfer	Minor

See Sheet 49 for failu

Item	Failure Mode	Failure Mechanism	Failure Effect System Level	Failure Effect Plant Level
Turntable to waste header jet	Vent valve fails open	Solenoid fails	Loss of steam motive power. No transfer	Cannot pump out turntable
	Steam supply valve fails closed	Same	No steam for jet. No transfer	Same
	Air supply valve fails closed	Same	No purging possible	No back siphoning likely
	Block valve upstream of jet fails closed	Same	No transfer	Cannot pump out the turntable

REVISION #: 2
DATE: July 1987
DRAWING NUMBER: DFMEA-1 REV 3

ANALYSIS WORKSHEET

SHEET: 12 : of: 49

Method of Detection	Recovery Action	Failure Frequency	Repair Time	Remarks/Recommendations
Monitor cell sump level	Replace solenoid. Use other sump in meantime	L	L	There are two cell sumps. One will therefore be available
Same	Same	L	L	
Same	Same	L	L	Need confirmation that air purge really occurred
Same	Same	L	L	
e analysis of jet itself				
Monitor turn-table level	Replace solenoid	L	L	
Same	Same	L	L	
Same	Same	L	L	Need confirmation that air purge really occurred
Same	Same	L	L	

SI APERTURE CARD

Also Available On Aperture Card

8911010071-01

PROGRAM: WEST VALLEY DEMONSTRATION PROJECT

SYSTEM: CLOSED-LOOP COOLING WATER SYSTEM

PREPARED BY: Frank Graf

Item	Failure Mode	Failure Mechanism	Failure Effect: System Level	Failure Effect: Plant Level	C
Backup steam turbine pump	Does not startup	• No steam • Bearings seize	No water flow during electric-driven pump failure	• Stop glass production • melter refractory overheats • SBS liquid boils	Fl ar ir
Heat exchanger (cooler)	Loss of cooling	Cooling power pump fails	Melter, turntable V-001 and V-011, SBS, vessel vent condenser lose cooling source	Vessel vent condenser fails to condense CFMUT vapor, pressurizes vent system diverting steam to offgas dryer which will pass steam to HEME. HEME will pass steam to HEPA's melting them and causing breaching. Could also pressurize melter by back-pressuring the SBS offgas system. Glass production stopped. Possible uncontrolled glass discharge from mel	M v c t

ANALYSIS WORKSHEET

REVISION #: 2
DATE: July 1987
DRAWING NUMBER: FMEA-1 REV 3

SHEET: 11 : of: 49

Method f Detection	Recovery Action	Failure Frequency	Repair Time	Remarks/Recommendations
ow meters d temperature dicators	Use air coding on melter jacket	L	L	Refer to Sheet 25, loss of water cooling on melter shell; page 35, loss of cooling for SBS. Should check out backup pump monthly
nitor vessel nt condenser olant water mperature	If no redundant pump available	L	L	The status of the cooling tower pump should be on the distributed control system. If redundant pumps are available, means to switch over from pump to pump should be available from the CTS control room

er

SI APERTURE CARD

Also Available On Aperture Card

8911010071-02

PROGRAM: WEST VALLEY DEMONSTRATION PROJECT

SYSTEM: CLOSED-LOOP COOLING WATER SYSTEM

PREPARED BY: Frank Graf

Item	Failure Mode	Failure Mechanism	Failure Effect: System Level	Failure Effect: Plant Level
Electric circulation pump	No circulation	Motor failed, coupling failed	Loss of cooling to SBS, melter, V-011, V-001, vessel vent condenser and turntable	Stop glass production
Pressure let-down valve for low pressure loop	Pressure remains high in rest of loop	Valve mechanical or electrical failure	None	None
Hold tank level instrumentation	Dip tube plugs	Salt buildup	Level unknown	None if other monitor points verify circulation flow
Control valve to any source	Valve fails open	Ruptured diaphragm	Excess cooling to loop with failed valve, others are starved	Stop feeding melter
System leak	Pipe or tank leak	Corrosion/ weld failure	Loss of coolant	Stop glass production
	Inleakage into loop while pump off	Same	Contaminated coolant	Spread of contaminated coolant outside cel

REVISION #: 2
DATE: July 1987
DRAWING NUMBER: FMEA-1 REV 3

ANALYSIS WORKSHEET

SHEET: 10 of: 49

Method of Detection	Recovery Action	Failure Frequency	Repair Time	Remarks/Recommendations
lowmeter on irculated flow	Switch to steam turbine pump. Replace failed motor	L	L	Steam turbine is the backup. Building SOP's should include use of turbine pump
Pressure loop	Replace valve	L	L	High-pressure loop normally runs 50 psig, low-pressure loop runs 35 psig. Melter jacket can take 50 psig. Pump curve should be checked to see what shut-off pressure could be expected Need controller logic to obtain shared flow to other demands during problems
	--			
Level reading goes off scale at high end	Blow down dip tube	L	L	System does not have automatic level makeup
Flow readings on all loops on the CLCWS	R/R valve	L	L	Valves should all fail open
Coolant flow rates	Add makeup water	M	L	No level input to control system from hold tank. Needs a level control loop
None	Drain coolant and dispose of it, reduce corroded parts	L	L	Need radiation monitor on cooling loop to monitor for contaminated coolant

SI
APERTURE
CARD

8911010071-03

Also Available On
Aperture Card

FAILURE MODES AND EFFECTS A

PROGRAM: WEST VALLEY DEMONSTRATION PROJECT

SYSTEM: SAMPLE STATION

PREPARED BY: Frank Graf

Item	Failure Mode	Failure Mechanism	Failure Effect: System Level	Failure Effect: Plant Level	of
Sample container	Sample container does not come out of sampler	Sample container jammed	No sample	Glass production stops when acceptable feed is exhausted	No
Spray rinse valve	No spray	Valve does not open due to failed SV	No rinsing of outside of sample	Same	Con sur con
Miscellaneous parts	Mechanical parts fail	Wear	No sampling	Same	Non

NALYSIS WORKSHEET

Method Detection	Recovery Action	Failure Frequency	Repair Time	Remarks/Recommendations
sample	Repair sampling	L	L	Sample station must be in view
tainer face taminated	Replace SV that supplies air to rinse water supply valve	L	L	Sample station must be in view
c	R/R ADS sample pump	L	L	Sample station must be in view

SI
APERTURE
CARD

Also Available On
Aperture Card

8911010071-04

FAILURE MODES AND EFFECTS

PROGRAM: WEST VALLEY DEMONSTRATION PROJECT

SYSTEM: MELTER FEED TANK (V-011)

PREPARED BY: Frank Graf

Item	Failure Mode	Failure Mechanism	Failure Effect: System Level	Failure Effect: Plant Level	of
ADS sample pump	Fails to pump slurry	Cylinder jammed with valve closed	No sample, cannot proceed with the batch	Glass production stopped until ADS sample pump repaired	No
	Same	Cylinder jammed with valve open	No sample, air blows into tank	Same	Sam
	Same	Air vent solenoid valve fails in supply position	No slurry circulation	Same	Sam
	Same	Air vent valve fails in vent position	Pump chamber fills but cannot pump due to loss of motive air	Same	No
	Same	Pressure ratio relay fails	Higher pressure on pump than desired	No immediate effect	Hi si co
	Same	Worn mechanical parts	No pumping	Glass production stopped until pump replaced	No
	Same	Screen plugged	Same	Glass production down until screen flushed	No

REVISION #: 2
DATE: July 1987
DRAWING NUMBER: FMEA-1 REV 3

NALYSIS WORKSHEET

SHEET: 4 : of: 49

Method Detection	Recovery Action	Failure Frequency	Repair Time	Remarks/Recommendations
sample	Replace ADS pump top assembly	L	L	Need means of indicating that sample pump is working
e	Same	L	L	Same
e	Same	L	L	Same
e	Same	L	L	Same
gher pressure gnal to the ntrol system	None required	L	L	Pump rate will be higher which would have minor effect on system
ne	Replace ADS sample pump	L	L	Same
ne	Water flush ADS sample pump	M	L	Need means to measure pumping rate

8811010071-05

PROGRAM: WEST VALLEY DEMONSTRATION PROJECT

SYSTEM: MELTER FEED TANK (V-011)

PREPARED BY: Frank Graf

Item	Failure Mode	Failure Mechanism	Failure Effect: System Level	Failure Effect: Plant Level	O
ADS Pump	Fails to pump slurry	Cylinders jammed with valve in closed position	Loss of feed, air goes to melter	Loss of feed to melter, glass production stopped	Me te in in tr st V-
	Same	Cylinders jammed with valve open	Loss of feed flow, air bleeds into feed tank	Same	Sa
	Same	Air vent solenoid valve fails in air supply position	Loss of feed, air alternately goes to melter and feed tank as 2-way valve cycles	Same	M t r 1
	Same	Air vent solenoid valve fails in vent position	Pump chamber fills but cannot pump due to loss of motive air	Same	S
	Loss of air pressure control	Pressure ratio relay fails	Delay in feeding until relay replaced	Stop glass production. Loss of feed control. Possible melter pressurization	
	Pumping rate falls off	Pump screen plugged	Shut down ADS feed pump	Stop glass production	
Pump	Same	Valve seats wear, rods wear, pivot bushing wear	Lower feed rate	Lower glass production rate	

ANALYSIS WORKSHEET

REVISION #: 2
DATE: July 1987
DRAWING NUMBER: FMEA-1 REV 3

SHEET: 3 : of: 49

Method Detection	Recovery Action	Failure Frequency	Repair Time	Remarks/Recommendations
lter plenum mperature crease dicates at feed has opped. sual	Replace cylinder assembly on top of pump	M	L	Air accumulator and orifice limit air flow upon failure
me	Same	M	L	Same
lter vapor mperature se indicates oss of feed	Same	M	L	Same
ame	Replace pump assembly	M	L	Fails safe because air vents to vent header
elter pressure ndicator	Replace ratio relay	L	L	Air pressure would increase up to PRV setpoint. Air flow limited by restrictive orifice upstream
Same	Water flush pump	H	L	Feed line flow monitor recommended
Same	When pumping rate cannot be increased sufficiently to compensate, replace pump	M	L	Need a flow indication for the feed. Can increase pumping rate to compensate for some wear

PROGRAM: WEST VALLEY DEMONSTRATION PROJECT

SYSTEM: MELTER FEED TANK (V-011)

PREPARED BY: Frank Graf

Item	Failure Mode	Failure Mechanism	Failure Effect: System Level	Failure Effect: Plant Level
Jet recycle back to CFMUT	Jet does not work	Jet dip leg plugged	Cannot recycle back to CFMUT	Glass production interruption
Agitator	Shaft fails to turn	Motor failed	Solids settle out	Same
	Same	Coupling disengaged	Same	Same
	Same	Shaft breaks	Same	Same
Demister	Plugs off or high ΔP	Water spray control valve fails or nozzle plugs	Shutdown boil-down cycle	Potential delay to processing
Glass former addition	Cannot add glass former	Control valve failed close or I/P transmitter failed	Cannot makeup batch when this tank is in backup service	Melter glass production interrupted
Chemical/ HNO_3 Addition	Valve failed shut	Diaphragm or solenoid failure	Cannot makeup batch	Same

REVISION #:	2
DATE:	July 1987
DRAWING NUMBER:	FMEA-1 REV 3
SHEET:	2 : of: 49

S ANALYSIS WORKSHEET

Method of Detection	Recovery Action	Failure Frequency	Repair Time	Remarks/Recommendations
Monitor levels in CFMUT and feed tank	Remove and clean. Replace if necessary	L	M	
Monitor motor amps	Replace motor	L	M	
Monitor motor amps	Remove and replace agitator drive	L	M	
Same	Same	L	M	Will require special tool to retrieve broken shaft from tank. The resuspension of the solids in the [illegible] may be a question
ΔP across filter	Repair water spray valve and increase flow until ΔP returns to normal. Replace demister if required	L	L	Normally boildown is done in CFMUT
Monitor level, check chemical feed tanks	Remove and repair valve	L	L	
Monitor level check chemical makeup tanks	Remove and repair valve	L	L	No means of flow indication at control room

FAILURE MODES AND EFFECTS A

PROGRAM: WEST VALLEY DEMONSTRATION PROJECT

SYSTEM: MELTER FEED TANK (V-011)

PREPARED BY: Frank Graf

Item	Failure Mode	Failure Mechanism	Failure Effect: System Level	Failure Effect: Plant Level	of
Steam supply to tank coils	Steam supply valve fails shut	Ruptured diaphragm	Cannot boil down a batch for melter feed	Can run melter with unconcentrated feed. Glass production will be low	Ste
	Steam condensate valve fails	Same	Same	Same	Ste ind
	Solenoid valve on steam supply valve fails	Solenoid burned out	Same	Same	Sam
	Solenoid valve on steam condensate fails	Same	Same	Same	Sam
Internal coils	Corrosion	Minor rupture of corroded pipe section	Dilutes batch with steam condensate	Glass production stopped	V-0 in
	Same	Major rupture of corroded pipe section	Steam will not condense in feed tank	Will overload vent condenser. Could pressurize the melter resulting in uncontrolled glass discharge	Ve pr ta in
Feed tank	Leaks	Corrodes through tank wall, weld failure	Terminate feed to melter	Melter on idling until new feed tank acquired	Ca
Cold water supply valve or return valve	Cooling water stays on	Fails open	Cooling water on until hand valved out	No delay unless feed tank used as concentrator	Co f

REVISION #: 2
DATE: July 1987
DRAWING NUMBER: FMEA-1 REV 3

NALYSIS WORKSHEET

SHEET: 1 : of: 49

Method Detection	Recovery Action	Failure Frequency	Repair Time	Remarks/Recommendations
m flowmeter	R/R steam valve	L	L	Feed tank is only used as a concentrator when CFMUT is out of service. Repair time short
m flow icator	R/R valve	L	L	Same
e	R/R solenoid	L	L	Same
e	R/R solenoid	L	L	Same
ll level creases	Feed tank is out of service until coil replaced	L	M	Does not require heating as feed tank. Could possibly valve off leaky coil and run as feed tank only
nt system essure, feed nk pressure dicators	Shut off steam to feed tank	L	M	Valve out steam coil. The feed tank is only used as a concentrator to back up the CFMUT
ll sump level	Repair or replace tank	L	M	Can use CFMUT as a feed tank intermittently if a feed loop is installed
oling water ow meter	Replace valve	L	L	

SI APERTURE CARD

8911010071-08

Also Available On Aperture Card

FAILURE MODES AND EFFECTS A

PROGRAM: WEST VALLEY DEMONSTRATION PROJECT

SYSTEM: CONCENTRATOR FEED MAKEUP TANK

PREPARED BY: Frank Graf

Item	Failure Mode	Failure Mechanism	Failure Effect: System Level	Failure Effect: Plant Level	of
ADS sample pump	Fails to pump slurry	Cylinders jammed with valve closed	No sample. Cannot proceed with batch	Glass production stopped when feed exhausted	Vis sam
	Same	Cylinders jammed with valve open	No sample, air blows into CFMUT tank	Same	Sam
	Same	Air vent SV fails in air supply position	No slurry circulation	Same	Sa
	Same	Air vent SV fails in vent position	Pump chamber fills but cannot pump due to loss of motive air	Same	Sa
	Same	Screen plugged	Cannot sample	Melter down after acceptable feed exhausted	Sa
	Same	Worn parts	Same	Same	S
	Same	Pressure ratio relay fails	Higher pressure on pump than desired	No immediate effect	P t s
	High pump rate	Pressure ratio relay fails	None	None	P t s

REVISION #: 2
DATE: July 1987
DRAWING NUMBER: FMEA-1 REV 3

NALYSIS WORKSHEET

SHEET: 8 : of: 49

Method Detection	Recovery Action	Failure Frequency	Repair Time	Remarks/Recommendations
ual/no ple	Replace pump top assembly	L	L	Need means to verify that ADS sample pump is pumping slurry
e	Same	L	L	Same
e	Same	M	L	Same
ue	Same	M	L	Same
me	Water flush screen	M	L	Need means to determine pumping rate
me	R/R ADS sample pump	L	L	Same
ressure signal o control ystem	Remove and replace ratio relay when convenient	L	L	Flow rate will be uncontrollably higher
ressure signal o control ystem	Remove and replace ratio relay	L	L	

SI
APERTURE
CARD

Also Available On
Aperture Card

8911010071-09

FAILURE MODES AND EFFECTS

PROGRAM: WEST VALLEY DEMONSTRATION PROJECT

SYSTEM: CONCENTRATOR FEED MAKEUP TANK

PREPARED BY: Frank Graf

Item	Failure Mode	Failure Mechanism	Failure Effect: System Level	Failure Effect: Plant Level	of
Glass former addition	Cannot add glass former	Control valve failed closed or I/P failed	Cannot make up batch	Glass production interrupted after exhausting feed supply	Tar doe inc
Heel removal equipment	Cannot pump heel	Jet plugged	Cannot pump heel to 8D-2 Tank	None	Nor
Feed transfer jet	Feed will not transfer	Jet plugged	Cannot transfer feed to feed tank	Glass production stops after feed exhausted	Ta
Heating and cooling jacket	Corrosion	Ruptures jacket	Cannot concentrate a feed batch	Same	Ce in
CFMUT tank	Tank leaks	Corrosion/ weld failure	CFMUT out of use	Can use feed tank but rate of glass production cut in half	Ce
Level instrument	Dip tube corrodes, level drifts	Corrosion of end of dip tube will overflow to seal pot V-003 and thence to the waste header	Overfill tank	Minor. Will recycle back to 8D tanks	I d d W o l s i
Thermowell	Corrodes	Both T/Cs fail	No temperatures control during operation	None. Spare thermowell available	T g r

Method Detection	Recovery Action	Failure Frequency	Repair Time	Remarks/Recommendations
k level s not rease	R/R valve or I/P relay	L	L	Flow meter on line would verify the flow and provide totalization capability
e	Remove and clean jet and suction line	L	M	Level will be below dip tubes so heel may not be sensed by the dip tubes
k levels	Same	L	M	Plugged dip tubes
ll sump level creases	Use feed tank as concentrator until CFMUT repaired or replaced	L	H	Feed tank could also be used for CFMUT. However, this then slows down glass production
ll sump level	Replace tank if early in campaign. If not, complete campaign at reduced production rates	L	H	
dicated nsity would ift lower. en tank verflows, evel in V-003 eal pot would ndicate high	Install new dip tube	L	L	Heel is larger as dip tube corrodes. Batch-to-batch consistency in question
emperature oes to maximum ange	Replace thermowell and T/Cs when convenient	L	L	Change out thermowell when it is convenient. Use spare in meantime

FAILURE MODES AND EFFECTS

PROGRAM: WEST VALLEY DEMONSTRATION PROJECT

SYSTEM: CONCENTRATOR FEED MAKEUP TANK

PREPARED BY: Frank Graf

Item	Failure Mode	Failure Mechanism	Failure Effect		of
			System Level	Plant Level	
Jet to V-011 (contd)	No air purge	No air	Siphons out V-001 to waste storage tanks	Loss of prepared feed	Tan
Agitator	Fails to turn	Motor has open circuit	Cannot mix, solids settle	Melter down after exhausting feed supply	Mon amp
	Same	Shaft breaks	Same	Same	Sam
	Same	Coupling disengaged	Same	Same	Red dra
Demister	Plugs off on high ΔP	Water spray fails during evaporation cycle	• CFMUT tank pressurizes • Seal pot pressurizes	Same	Spr flo CFM
	Demister plugged	Cannot wash solids off	High ΔP. Reduced boildown rate	Batch preparation time increased	ΔP den
Chemical added to CFMUT	Valve does not open	Valve fails shut	Batch makeup held up	Melter down after current, feed supply exhausted	Un is ma un ad th ba us CF ri ro on

NALYSIS WORKSHEET

Method Detection	Recovery Action	Failure Frequency	Repair Time	Remarks/Recommendations
level	Monitor feed tank air pressure signal	L	L	Need air purge confirmation
tor motor	Remove and repair drive motor	L	M	
	Same	L	M	Need special tools to retrieve the broken shaft
uced ampere w on motor	Remove and repair agitator	L	M	Need alarm for low amps on drive motor
ay nozzle w meter UT pressure	Shutdown steam supply to jacket of CFMUT	L	L	• Alarm demister spray water flow • Interlock ΔP with steam flow
across ister	Remove demister and replace	L	M	May need chemical added to demister pot
nown. There no flow er to measure chemical ed. Assume t normal ch tanks are d elsewhere. MUT level e would be gh estimate y	R/R	L	L	Could use chemical added flowmeter to verify flow and to totalize it into the melter

FAILURE MODES AND EFFECTS

PROGRAM: WEST VALLEY DEMONSTRATION PROJECT

SYSTEM: CONCENTRATOR FEED MAKEUP TANK

PREPARED BY: Frank Graf

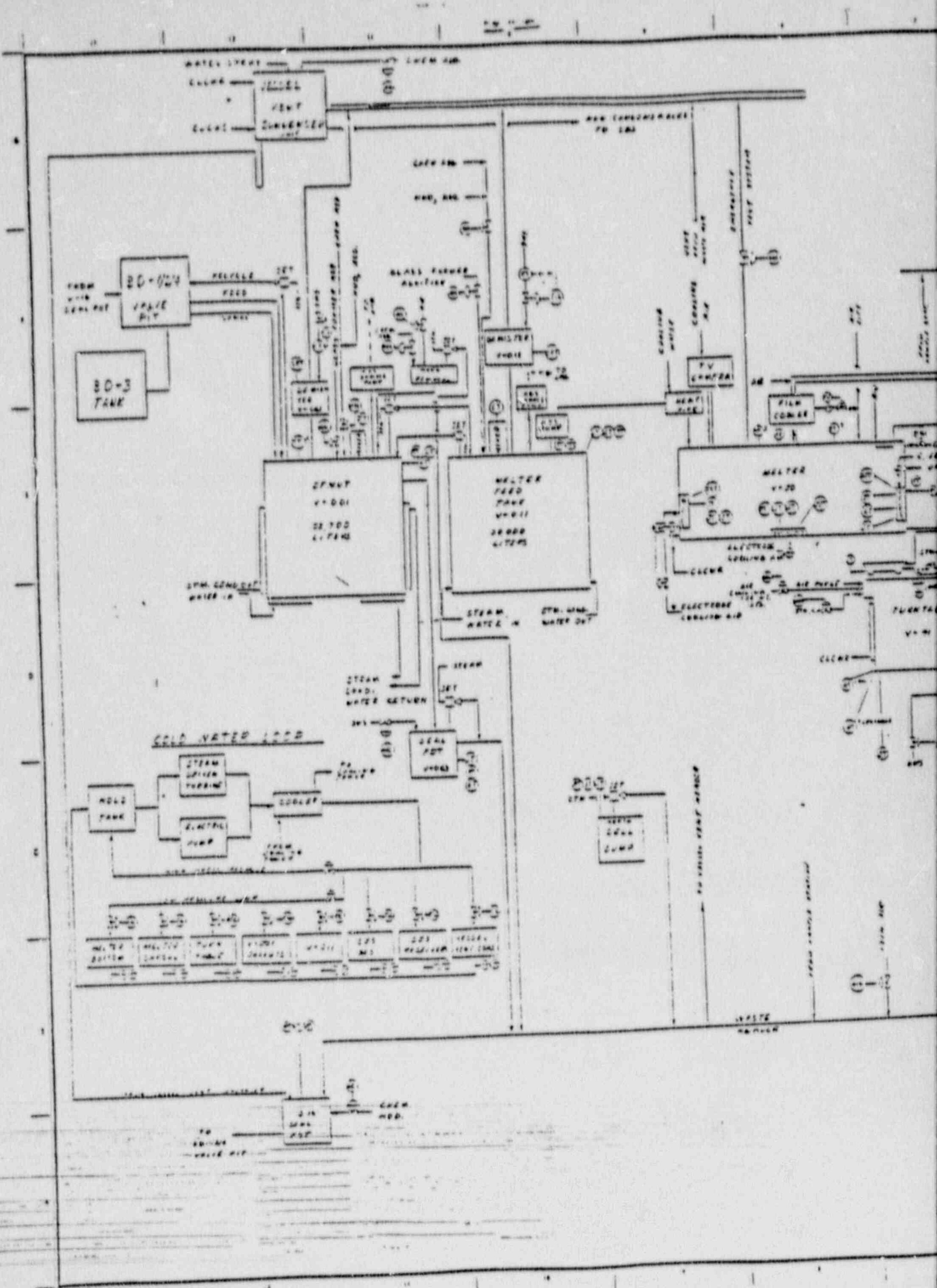
Item	Failure Mode	Failure Mechanism	Failure Effect: System Level	Failure Effect: Plant Level	of
Steam supply to either tank jacket (upper or lower)	No steam	Steam supply or condensate valve failed shut	Cannot concentrate a batch	Glass production stopped after current supply exhausted	Ste met tem
	Same	Solenoid valve on steam condensate failed or steam trap plugged	Same	Same	Sam
Cold water supply or return valves or SV on CWR	Fail open	Valves fail open. Water continues to flow	Cannot heat up CFMUT to boil down and concentrate a batch of feed	Same	Co met
Air pressure reducer on air purge to steam line to tank jackets	Valve fails to regulate air down from 100 psig	Diaphragm breaks air pressure is 100 psig unregulated	None	None	St wi
Air purge valve solenoid (air to jacket)	Does not open on power up	Solenoid valve failed	Cannot purge steam	Minor	Sc ma
Jet to 8D-1/2/4 valve pit	Submerged jet will not pump	Jet suction plugs	Loss of recycle back to 8D-1/2/4 tanks for heel	Minor. Assumed it is only used occasionally	V- do wh
Jet to V-011	Same	Same	Cannot replenish feed tank	Same	V V i

REVISION #: 2
DATE: July 1987
DRAWING NUMBER: FMEA-1 REV 3

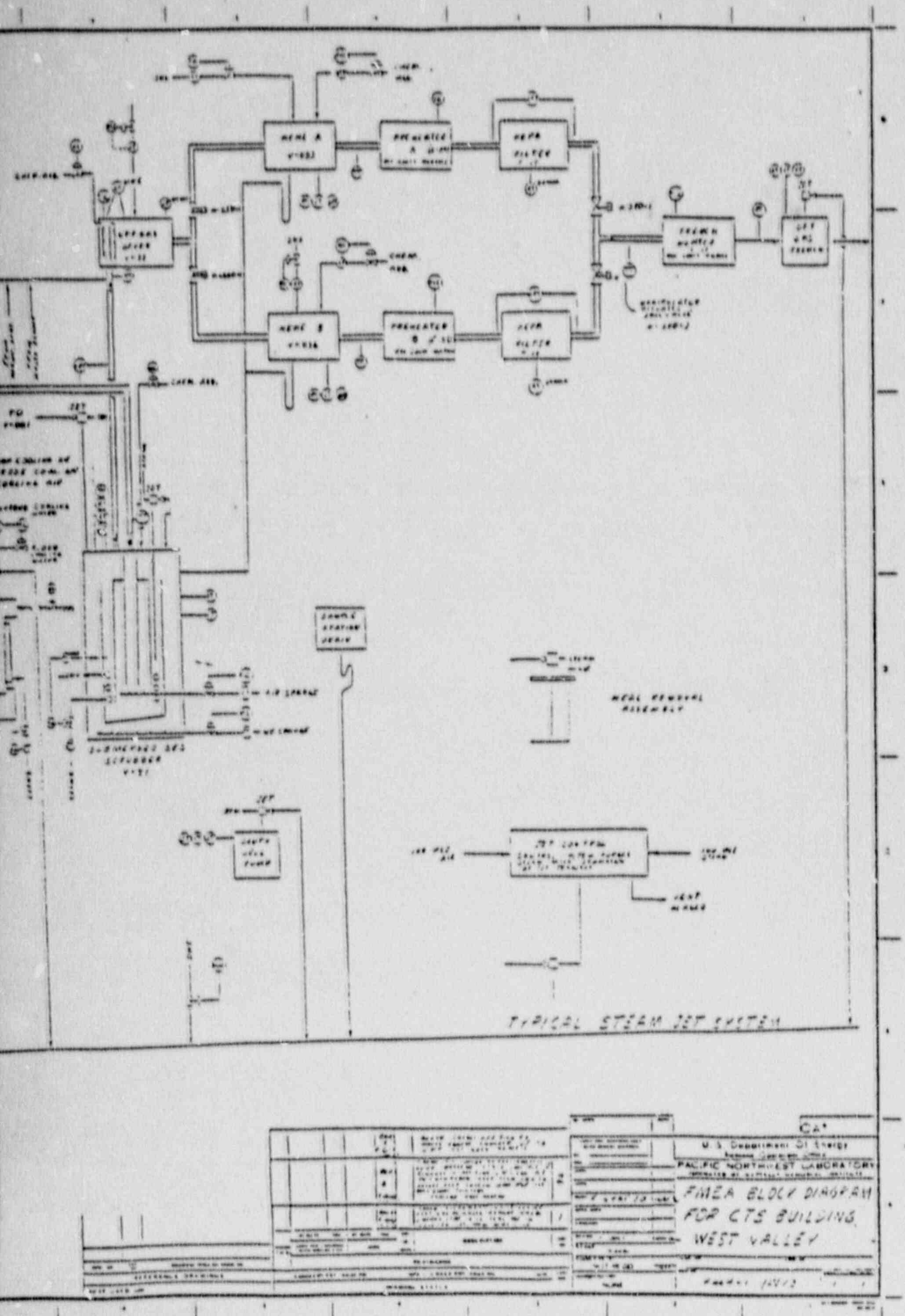
NALYSIS WORKSHEET

SHEET: 5 : of: 49

Method Detection	Recovery Action	Failure Frequency	Repair Time	Remarks/Recommendations
m flow- r tank erature	Repair steam valve	L	L	Minor problem. Valve is outside of cell
	R/R solenoid valve and/or steam trap	L	L	Same
water flow er	R/R valve and/or solenoid valve	L	L	Same
am pressure h steam off	R/R reducer valve	L	L	Same
am hammering develop	Replace solenoid valve	L	L	Monitor air purge flow
001 level s not drop n jet is on	Back flush line	L	L	With agitation in tank, unlikely to occur
001 and 011 level strumentation	Same	L	M	



BD-3
TANK
VALVE
PIT
MELTER
FEED
TANK
LITERS
MELTER
COLD WATER LOOP
HOLD
TANK
ELECTRIC
PUMP
STEAM
WATER IN
STEAM
COND.
WATER RETURN
SEAL
POT
CHEM
ADD.
WASTE
HEADER



SI
APERTURE
CARD

Also Available On
Aperture Card

8911010071 - 13

FAILURE MODES AND EFFECTS A

PROGRAM: WEST VALLEY DEMONSTRATION PROJECT

SYSTEM: STEAM JET CONTROL SYSTEM

PREPARED BY: Frank Graf

Item	Failure Mode	Failure Mechanism	Failure Effect: System Level	Failure Effect: Plant Level	of
CFMUT to feed tank	Vent valve fails open	Solenoid burned out	Loss of steam motive power in jet. No transfer	Glass production stops after exhausting feed	Low duri V-00 leve chag
	Steam supply valve fails closed	Same	No steam to run jet	Same	No s pres
	Air supply valve fails closed	Same	No purging	Can siphon back from feed tank to CFMUT	Moni tank
	Valve upstream from jet fails closed	Same	No steam to jet. Cannot transfer	Same	Same

See Sheet 5, 7 for failure a

Item	Failure Mode	Failure Mechanism	Failure Effect: System Level	Failure Effect: Plant Level	of
SBS recirculation tank to SBS receiver	Vent valve fails open	Solenoid burned out	Loss of steam motive power for jet. No jet transfer	No immediate problem. SBS will plug up in time. Glass production must stop prior to reaching high ΔP	Mon and pre
	Steam supply valve fails closed	Same	No steam to operate jet	Same	Sam
	Air supply valve fails closed	Same	No purging. Can siphon back from receiver to scrub section	Will siphon back more dilute slurry than was transferred	Mon
	Block valve upstream from jet fails closed	Same	No transfer possible	Shut down feed to melter	Mo pr

See Sheet 35 for failure

REVISION #: 2
DATE: July 1987
DRAWING NUMBER: FMEA-1 REV 3

ALYSIS WORKSHEET

SHEET: 13 : of: 49

Method Detection	Recovery Action	Failure Frequency	Repair Time	Remarks/Recommendations
pressure ng jetting 1 and V-011 ls do not e	Replace solenoid valve	M	L	
team sure	Same	M	L	
tor levels	Same	M	L	Need a confirmation back to the control system that air purge cycle occurred
	Same	M	L	
nalysis of jet itself				
tor level steam ssure	Replace solenoid valve	M	L	
e	Same	M	L	
itor levels	Same	M	L	Need confirmation that air purging really occurred
itor steam essure	Same	M	L	
nalysis of jet itself				

SI APERTURE CARD

Also Available On Aperture Card

8911010071 - 14

FAILURE MODES AND EFFECTS A

PROGRAM: WEST VALLEY DEMONSTRATION PROJECT

SYSTEM: STEAM JET CONTROL SYSTEM

PREPARED BY: Frank Graf

Item	Failure Mode	Failure Mechanism	Failure Effect: System Level	Failure Effect: Plant Level	of
SBS to CFMUT	Vent valve fails open	Solenoid burned out	Loss of steam pressure, jet will not work	Glass production interrupted	Stea
	Steam supply valve fails closed	Same	Cannot transfer between SBS and to CFMUT	Same	No s pres
	Air supply valve fails closed	Same	Cannot air purge	Can siphon back from CFMUT to SBS	Moni and tank
	Block valve upstream from jet fails closed	Same	No transfer possible	Same	Moni pres

See Sheet 37 for failure an

Item	Failure Mode	Failure Mechanism	Failure Effect: System Level	Failure Effect: Plant Level	of
CFMUT to BD tank valve pit	Vent valve fails open	Solenoid valve	Loss of steam motive power to jet. No transfer	Minor. Assumed it is only used occasionally	Low dur V-0 doe
	Steam supply valve fails closed	Same	No steam for jet. No transfer	Same	Sam
	Air supply valve fails closed	Same	No purging possible	Minor	Mon lev
	Valve upstream of jet fails closed	Same	No transfer	Same	Sam

See Sheet 5 for failure an

NALYSIS WORKSHEET

REVISION #: 2
DATE: July 1987
DRAWING NUMBER: FMEA-1 REV 3

SHEET: 14 : of: 49

Method Detection	Recovery Action	Failure Frequency	Repair Time	Remarks/Recommendations
m pressure	Replace solenoid	M	L	
tream sure	Same	M	L	
tor SBS CFMUT levels	Same	M	L	Need confirmation that air purging really occurred
tor steam sure	Same	M	L	
alysis of jet itself				
pressure ng jetting l level not change	Replace solenoid	L	L	
e	Same	L	L	
itor tank els	Same	L	L	Need confirmation back to control system that air purging occurred. Both siphoning possible
e	Same	L	L	
alysis of jet itself				

SI
APERTURE
CARD

Also Available On
Aperture Card

8911010071-15

FAILURE MODES AND EFFEC

PROGRAM: WEST VALLEY DEMONSTRATION PROJECT

SYSTEM: STEAM JET CONTROL SYSTEM

PREPARED BY: Frank Graf

Item	Failure Mode	Failure Mechanism	Failure Effect: System Level	Failure Effect: Plant Level
V-011 to V-001 jet	Vent valve fails open	Solenoid fails	Loss of steam motive power to jet. No transfer back to CFMUT	Minor
	Steam supply valve fails closed	Same	No steam for jet. No transfer	Same
	Air supply valve fails closed	Same	No purging. Possible back siphoning of tank V-001 to V-011	Same
	Valve upstream of jet fails closed	Same	No transfer	Same

See Sheet 2 for fail

Item	Failure Mode	Failure Mechanism	Failure Effect: System Level	Failure Effect: Plant Level
V-001 heel removal to waste header jet	Vent valve fails open	Solenoid fails	Loss of steam motive power to jets. Cannot remove heel from V-001 (CFMUT tank) to waste header	Minor
	Steam supply valve fails closed	Same	No steam for jet. No transfer	Same
	Air supply valve fails closed	Same	No purging possible	Minor
	Block valve upstream of jet fails closed	Same	No transfer	Same

See Sheet 7 for fa

REVISION #: 2
DATE: July 1987
DRAWING NUMBER: FMEA-1 REV 3

...TS ANALYSIS WORKSHEET

SHEET: 15 : of: 49

Method of Detection	Recovery Action	Failure Frequency	Repair Time	Remarks/Recommendations
Monitor steam pressure. No level change	Replace solenoid	M	L	Only used occasionally
Same	Same	M	L	
Same	Same	M	L	Need confirmation that air purging occurred
Same	Same	M	L	
...re analysis of jet itself				
Monitor steam pressure. No level change	Replace solenoid	L	L	Only used at end of a campaign
Same	Same	L	L	
Same	Same	L	L	Need confirmation that air purging actually occurred. Both siphoning unlikely
Same	Same	L	L	
...ilure analysis of jet itself				

FAILURE MODES AND EFFECTS A

PROGRAM: WEST VALLEY DEMONSTRATION PROJECT

SYSTEM: STEAM JET CONTROL SYSTEM

PREPARED BY: Frank Graf

Item	Failure Mode	Failure Mechanism	Failure Effect: System Level	Failure Effect: Plant Level	of
V-003 seal pot to waste header	Vent valve fails open	Solenoid fails	Loss of steam motive power to jet. No transfer	Minor	Moni pres No l
	Steam supply valve fails closed	Same	No steam for jet. No transfer	Same	Same
	Air supply valve fails closed	Same	No purging possible	Back siphoning unlikely. However, can continue to siphon out all contents of the seal pot thus opening up a path for overhead vapor to flow to the waste header and thence back to the turntable	Mon pot
	Block valve upstream of jet fails closed	Same	No transfer	Cannot dump seal pot to waste header	Mon pot

Method Detection	Recovery Action	Failure Frequency	Repair Time	Remarks/Recommendations
tor steam sure. evel change	Replace solenoid	L	L	Rarely would be used
	Same	L	L	
tor seal level	Same	L	L	Need confirmation that air purging actually occurred. Need automatic water makeup to seal pot
itor seal level	Same	L	L	

FAILURE MODES AND EFFECTS

PROGRAM: WEST VALLEY DEMONSTRATION PROJECT

SYSTEM: MELTER (V-20)

PREPARED BY: J. M. Perez, Jr.

Item	Failure Mode	Failure Mechanism	Failure Effect: System Level	Failure Effect: Plant Level	of
Feed Nozzle	Slurry pluggage in feed nozzle	Loss of cooling to nozzle causing it to overheat	Loss of feed to melter	Interrupts melter operation	• M f t s c
	Same	Oversized feed particle, or gradual scale buildup	Same	Same	Sar
Feed Nozzle Cooling system	Fails to keep feed nozzle cool	Interruption of radiator air cooling supply	• SO_2 overpressure • Interrupt feed slurry flow to melter	Same	• •
	Same	Failure of radiator	• SO_2 loss • Interrupt feed slurry flow to melter	Same	SO mc
	Same	Failure of SO_2 supply lines	Same	Same + SO_2 gas will be vented to the cell	Sa
	Same	Corrosion of feed nozzle outer wall	Same	• Interrupts melter operation, • SO_2 (gas) vented into melter plenum	S

NALYSIS WORKSHEET

REVISION #: 2
DATE: July 1987
DRAWING NUMBER: FMEA-1 REV 3

SHEET: 17 : of: 49

Method Detection	Recovery Action	Failure Frequency	Repair Time	Remarks
lter istrumenta- on will ense loss f feed	Drain/flush feed line, repair/replace SO_2 radiator, and clear/ replace feed nozzle	M	L	Recommend feed line flow meter be added
e	Drain/flush feed line, and clear/replace feed nozzle	H	L	• Feed nozzle changeout may require SO_2 radiator changeout • Feed line flow monitor recommended to allow early direct detection
ir flow/ ressure onitor O_2 pres- ure monitor	• Shut down feed system • Repair air supply failure • Reinstall feed nozzle/ cooling system	L	M	Need to assure maximum SO_2 pressure is acceptable
2 pressure nitor	• Shut down feed system • Replace feed nozzle/ cooling system	L	L	
me	Same	L	L	SO_2 (gas) to cell should not pose a safety risk
me	Same	M	L	SO_2 (gas) to plenum should not pose a safety risk

SI
APERTURE
CARD

Also Available On
Aperture Card

8911010071-18

FAILURE MODES AND EFFECTS AN

PROGRAM: WEST VALLEY DEMONSTRATION PROJECT

SYSTEM: MELTER (V-20)

PREPARED BY: J. M. Perez, Jr.

Item	Failure Mode	Failure Mechanism	Failure Effect: System Level	Failure Effect: Plant Level	of [
TV System	Loss of cooling	Loss of air	• Reduce melter monitoring/control capability • Camera/lens system would be damaged	None	• Ai mo • Ca te mo • Qu TV
Failure of lens assembly	Same	Loss of air	Same	None	Same
	Lens failure	Loss of air cooling	Same	None	Sam
	Same	Radiation effects	Same	None	Qua TV
	Same	Fouling of lens	Same	None	Sam
	Obstruction of tip aperture	Salt deposits, impinged glassy material	Same	None	Gr su of
	Steam cleaning failure	Loss of steam/ connection	Same	None	St se
	Camera failure	Loss of power	Same	None	Lo s
Glass/plenum thermowells	Loss of signal	• T/C failure • T/C wire junction failure	Reduces melter monitoring/ control	None	T
	Same	T/C well failure	Same	Stop feeding during replacement	L r

ethod Detection	Recovery Action	Failure Frequency	Repair Time	Remarks/Recommendations
flow nitors mera/lens mperature nitors ality of image	• Restore air supply • Repair/ replace camera/lens assembly	L	M	• If air source failure results in both plenum-viewing cameras losing cooling, temporary interruption of melter operation may be considered • Valves should fail open
	Replace camera/ lens assembly	M	L	Corrosion of external assembly housing is the primary concern due to corrosive plenum environment
e	Same	L	L	
lity of image	Same	L	L	Minimize through selection of optimum lens material
e	Same	M	L	High quality air without oils or dirt is essential
dual or dden loss image	Activate lens cleaning device if available; otherwise replace camera/lens assemble	h	L	Method of routinely cleaning tip of assembly is strongly recommended
eam flow nsors	Repair steam service	M	L	
ss of gnal	Repair power service	M	L	
/C signal	Determine source of failure and correct	H	L	• Minimize with use of Type B T/C, consider Pt-sheath and compatible T/C well materials • Consider ceramic liner in T/C well to minimize corrosion
oss of umerous T/C ndications at same time	Replace T/C well and T/C's	H	L	• Melter has two thermowells with 7 T/Cs each. Three T/Cs in each thermowell are used for temperature control

8911010071 - 19

PROGRAM: WEST VALLEY DEMONSTRATION PROJECT

SYSTEM: MELTER (V-20)

PREPARED BY: J. M. Perez, Jr.

Item	Failure Mode	Failure Mechanism	Failure Effect: System Level	Failure Effect: Plant Level	M of D
Weight factor/ specific gravity	Faulty or interrupted signal	Air supply interrupted	Reduces melter monitoring/ control	Interrupt feeding to replace	Suppl press flowr
	Same	Connection failure	Same	Same	Line not "
	Same	Transmitter failure	Same	Same	Loss signa
	Same	Dip tube failure due to corrosion or plugging	Same	Same	Same
Glass airlift system	Loss of lift air	Failure of control valve	• Glass pouring by natural overflow only • Cannot completely fill canister before canister change	Interrupt melter operation	Supp flov
	Same	Connection failure	Same	Same	Lin not
	Same	Supply interrupted	Same	Same	Su pr fl
	Air lance fails	Corrosion/ erosion	Same	Same	Ca fa

ethod etection	Recovery Action	Failure Frequency	Repair Time	Remarks/Recommendations
y air ure and/or ate	Determine source of failure and correct	L	L	
pressure normal"	Troubleshoot connections and transmitters and correct	M	M	
of l	Same	L	L	
	Replace dip tubes	H	L	• Repair time dependent on number of other jumpers that have to be cleared to replace dip tubes • Current experience indicates that dip tubes will experience high corrosion/erosion rates that will result in gradual signal drift • If only one dip tube system in melter, need to interrupt feeding to replace
ly air wrate	Determine source of failure to correct	L	L	• Plant needs to establish procedure for canister filling and rotation in event air lift is inoperable • Recommend pressure monitor for proper control
e pressure "normal"	Same	M	M	Pressure transducer at melter flange connection is recommended to monitor lance pressure
pply air essure and/or owrate	Same	L	L	
nister weight ctor	Replace air lance	H	L	Platinum air lance would have much better durability

PROGRAM: WEST VALLEY DEMONSTRATION PROJECT

SYSTEM: MELTER (V-20)

PREPARED BY: J. M. Perez, Jr.

Item	Failure Mode	Failure Mechanism	Failure Effect System Level	Failure Effect Plant Level
Glass airlift system (contd)	Overpressurization	Faulty signal/ control	Overfill canister	Interrupt melter operation
	Same	Same	Plug pour area	Same
	Underpressurization	Same	Same	Same
Overflow section thermowells	Loss of signal	• T/C failure • T/C wire junction failure	Overflow section heaters switched to manual control/ reduces monitoring and control	None
	Same	T/C well failure	Same	Interrupt melter operation to replace
Electrodes	Loss of cooling	Air source failure	Glass would migrate further into refractory, higher corrosion rate of the electrodes would occur	Threat to melter service life
	Same	Cooling channel failure	Same	Same

Method of Detection	Recovery Action	Failure Frequency	Repair Time	Remarks/Recommendations
anister weight actor	Remove turn-table thimble and clear glass from it; remove glass from canister neck inside and outside areas	M	M	Air control should limit maximum air pressure and flow
T/C readings, canister weight factor, level monitor	Remove pour area insert	M	M	Visual monitoring of the pour stream before it enters the canister is recommended
Same	Same	M	M	Same
T/C signal	Determine source of failure and correct	H	L	See comments for item: glass/plenum thermowells
Rapid failure of multiple T/Cs	Replace T/C well and T/Cs	M	L	
Air pressure and flow sensors	Repair failure and resume air cooling	L	L	• Plant should establish operational procedure to minimize damage to the melter or threat to melter service life • Shell cooling would prevent glass migration to the shell • Valve should fail open
Drop in air pressure ΔP, ΔT and Δ flow	• Stop cooling air • Replace melter if continued operation is not possible	L	H	Critical area, alarm/monitoring recommended for cooling system

FAILURE MODES AND EFFECTS

PROGRAM: WEST VALLEY DEMONSTRATION PROJECT

SYSTEM: MELTER (V-20)

PREPARED BY: J. M. Perez, Jr.

Item	Failure Mode	Failure Mechanism	Failure Effect: System Level	Failure Effect: Plant Level	C
Electrodes (contd)	Loss of cooling	Control loop failure	Same	Same	S
	Electrical failure	Bus bar/cable failure	Interrupt melter operation	Could require cold restart	L
	Same	Transformer failure	Interrupt melter operation	Interrupt melter operation	L t
	Electrode failure	Corrosion	Stop melter operation	Plant put on standby to replace melter	E t c
	Same	Corrosion due to DC voltage	Stop melter operation	Plant put on standby to replace melter	S
Bottom electrode (only)	Electrode failure	Nonconductive sludge layer	Bottom electrode fails to pass current causing cooling of glass	Reduced glass production rate, or interrupt operation if melter replacement required	
	Same	Conductive sludge layer	High current flow increases electrode temperature leading to failure, alloying noble and precious metals accelerate corrosion	Same	

Method of Detection	Recovery Action	Failure Frequency	Repair Time	Remarks/Recommendations
me	Repair control loop	L	L	Failure of loop should never be allowed to terminate air flow
ss of current	Replace cable and clamps as required	L	L	Low repair time if preparations were made to change out at early indications of failure
ss of electrode power	Repair/replace transformer	L	H	• High repair time if spare is not on hand • Glass would freeze unless system allows idling with remaining system
lectrode electrical and ooling monitors	Replace melter	L	H	Electrode face thickness conservatively sized to allow for corrosion
ame	• Adjust/repair power system • Replace melter	L	H	• Electrodes should be inspected for signs of preferential corrosion due to DC voltage following cold testing • Systems available to routinely monitor for DC voltage should be considered if justified
• Electrode voltage, resistance measurements	• Reduce electrode power, evacuate sludge from melter floor • Possible requirement to replace melter	L	H	For melter replacement if required • Method of removing sludge may be required if glass chemistry allows excessive sludge production
Electrode-to-electrode resistance measurement	Same	M (1)	M (2)	(1) highly dependent on noble and precious metal inventory and glass chemistry • alarm electrode high current and temperature limits (2) for melter replacement, if required, a high repair time would occur

FAILURE MODES AND EFFECTS A

PROGRAM: WEST VALLEY DEMONSTRATION PROJECT

SYSTEM: MELTER (V-20)

PREPARED BY: J. M. Perez, Jr.

Item	Failure Mode	Failure Mechanism	Failure Effect System Level	Failure Effect Plant Level	of
Glass tank refractory	Brick collapse	Wall warpage/ shifting	Stop operation	Replace melter	Refr T/C TV
	Same	Corrosion of lower level bricks	Same	Same	Same
Electrical short to shell	Glass migration	Brick collapse	Stop operation	Replace melter	T/C tro cal in-
	Same	Brick corrosion	Same	Same	Sam
	Same	Loss of electrode cooling	Same	Same	Sa
	Same	Breakdown of bus bar electrical isolation	Same	Same	El po gr
	Same	Shift in melter internals forces bus bar against shell	Same	Same	S
	Electrode short to shell	Electrical insulation breakdown	Same	Same	S

Method Detection	Recovery Action	Failure Frequency	Repair Time	Remarks/Recommendations
actory , In-melter	Remove glass and replace melter	L	H	Melter designed to allow for joint expansion
	Same	L	H	Melter designed conservatively to allow for maximum expected brick corrosion
and elec- de electri- monitors/ melter TV	Remove glass and replace melter	L	H	• Shell cooling would also have to fail to allow electrical path to shell to be maintained for any significant period of time • Alarm electrode resistance measurement to cut power if resistance drops below specific level
e	Same	L	H	Same
e	Resume cooling if possible. See Item: Electrodes p. 20	L	(1)	(1) Dependent on loss mechanism and response
ectrode tential to ound	Pull melter from wall and possibly replace isolation packing. Otherwise, replace melter	L	H	Isolation design is conservative
ame	Replace melter	L	H	Melter design allows for brick expansion
ame	Same	L	H	Recommend monitor shell voltage to ground

PROGRAM: WEST VALLEY DEMONSTRATION PROJECT

SYSTEM: MELTER V-20

PREPARED BY: J. M. Parez, Jr.

Item	Failure Mode	Failure Mechanism	Failure Effect: System Level	Failure Effect: Plant Level	M of D
Glass discharge riser	Inoperable	Collapse/fatigue	Stop operation	Interrupt plant operations	Inabi disch
	Same	Sludge plugs riser	Same	Same	Same
	Efficiency drops (Gradual deterioration)	Corrosion	Discharge rate versus glass tank level changes	None	Disch versu tank
	Failure of backup riser/ discharge section	Sludge accumulation or refractory failure	Stop operation	Interrupt plant operations	Same
Lid Assembly	Nozzles/Flanges	Warpage	Higher inleakage	Increased non-condensible flow to the off-gas system	Visua flow monit
	Same	Solids pluggage	Stop operation	Interrupt plant operations	Inab remo inst flan
	Same	Corrosion	Stop operation	Possible melter replacement	Visu melt age
Inner refractory cooling system	Corrosion	Glass contact (1)	Stop airflow	Possible melter failure (2)	Air ance pres
	Same	Salt contact	Same	Same	Same

thod tection	Recovery Action	Failure Frequency	Repair Time	Remarks/Recommendations
ity to rge glass	Switch to back-up discharge riser	L	M	If riser collapses into glass tank, melter may require replacement
	Same	L	M	Removal techniques should allow further melter use
rge rate glass evel	Switch to backup riser when corrosion becomes excessive	L	M	No direct measurement possible
	Replace melter	L	H	
, off-gas rate or	Place additional packing to seal flange	L(1)	H(2)	(1) Problems should be detected and corrected during cold testing (2) Customized sealing apparatus or unit required to be fabricated
lity to e or ll mating e/device	Mechanically clean out nozzle	M	L	
l, high- r inleak- low	Repair nozzle if possible, remove nozzle from service, replace melter if catastrophic	L(1)	M-H(2)	(1) Assumes corrosion resistent material (2) Depends on nature of failure
mass bal- air line sure change	• Stop or reduce air flow if detrimental • Replace melter if required	L	H	(1) Would require failure of dam wall (2) If glass migrates from tank to overflow area, melter operation may be compromised
	Same	L	H	Path for salts to migrate from melt tank or overflow area without condensing must exist

FAILURE MODES AND EFFECTS

PROGRAM: WEST VALLEY DEMONSTRATION PROJECT

SYSTEM: MELTER V-20

PREPARED BY: J. M. Perez, Jr.

Item	Failure Mode	Failure Mechanism	Failure Effect: System Level	Failure Effect: Plant Level	O
Inner refractory cooling system (contd)	Mechanical failure	Thermal stress	Same	Same	Sa
	Loss of air	Air supply fails	Halt operation (1)	Interrupts glass production	Sa
	Loss of temperature indication	Failed T/C(s) junction	Loss of monitoring ability	None	L s
Overflow section dam	Corrosion	Glass contact	Possible glass penetration into overflow area (1)	Possible melter failure (2)	N
	Same	Salt contact	Same	Same	
	Mechanical failure	Thermal stress	Partial or total collapse of tank refractories	Require melter replacement	
Lid refractory	Loss of refractory	Thermal stress	Interrupt melter operation (1)	Possible melter failure (1)	
	Same	Failure of metal clips holding refractory support bricks	Same	Same	

ANALYSIS WORKSHEET

REVISION #: 2
DATE: July 1987
DRAWING NUMBER: FMEA-1 REV 3

SHEET: 24 : of: 49

Method of Detection	Recovery Action	Failure Frequency	Repair Time	Remarks/Recommendations
ne	Same	L	H	Melter design allows for expansion
me	Determine source of failure and repair	L	L	• (1) Circumstances may require temporary lowering of glass and overflow temperatures, operating procedure required • Valve(s) should fail open
ss of gnal(s)	Determine source of failure and repair/replace	M	L	Exit air temperature monitor should be replaceable. Panel T/Cs (if existing) replacement optional
one	None--replace melter if glass migration into overflow occurs and is not acceptable (2)	L	H(2)	(1) Requires failure of the inner refractory cooling panel(s) (2) If (1) occurs and significant glass migrates from tank to overflow section requiring melter replacement
one	Same	L	H	
n-melter viewing of glass tank	Same	L	H	Melter design allows for expansion
• Possible with in-melter viewing system • Lid surface T/C(s) (2)	If catastrophic replace melter	L	H	(1) If catastrophic failure (2) If they exist • Melter design should minimize possibility for thermal stress
Same	Same	L	H	

SI APERTURE CARD

Also Available On Aperture Card

8911010071 · 25

FAILURE MODES AND EFFECTS

PROGRAM: WEST VALLEY DEMONSTRATION PROJECT

SYSTEM: MELTER V-20

PREPARED BY: J. M. Perez, Jr.

Item	Failure Mode	Failure Mechanism	Failure Effect: System Level	Failure Effect: Plant Level	_/
Overflow section heaters	Loss of power	Heater electrical lead(s) fail	Interrupt melter operation	Interrupt glass production	El po zo tu
	Same	Electrical supply to bus bar fails	Same	Same	Sa
	Heater failure	Thermal shock	Same	Same	Sa
Overflow trough	Becomes misaligned	Weld/refractory failure	Interrupt melter operation	Interrupt glass production	G e
	Same	Corrosion	Same	Same	S
Overflow refractory	Collapses	Thermal/mechanical stress	Same	Same	S
Off-gas nozzle film cooler	Loss of air	Supply failure	Interrupt melter operation	Interrupt glass/canister production	A S
	Same	Control valve failure	Same	Same	
	Same	Connection failure	Same	Same	

REVISION #: 2
DATE: July 1987
DRAWING NUMBER: FMEA-1 REV 3

ANALYSIS WORKSHEET

SHEET: 25 : of: 49

Method of Detection	Recovery Action	Failure Frequency	Repair Time	Remarks/Recommendations
ectrical wer monitors, ne tempera- re indication	Replace heater assembly if temperature of zone cannot be maintained	M	M	Should determine if the failure of a single heater lead will be detected by V, R, I indicators
me	Determine source of fail- ure and repair/ replace	L	M	
me	Replace heater assembly if temperature of zone cannot be maintained	H	M	Should determine that heater fragments would not plug trough or pour area
ass ceases to ter canister	Switch to backup overflow section	L	M	If backup not available, melter replacement required with high repair time
ame	Same	L	M	
ame	Same	L	M	Minor failure could result in trough or pour area being obstructed
ir flow/pres- ure monitor	Determine source of fail- ure and repair/ replace	L	L-M	Valve(s) should fail open if com- patible with operating control
Same	Same	L	L	
Same	Same	L	M	

SI
APERTURE
CARD

Also Available On
Aperture Card

8911010071-26

PROGRAM: WEST VALLEY DEMONSTRATION PROJECT

SYSTEM: MELTER V-20

PREPARED BY: J. M. Perez, Jr.

Item	Failure Mode	Failure Mechanism	Failure Effect System Level	Plant Level	of
Off-gas nozzle film cooler (contd)	Loss of steam	Supply loss	Interrupt melter operation	Stop Glass Production	Same
	Same	Connection failure	Same	Same	Same
	Corrosion	Salt attack	Same	Same	Same
	Weld failure	Corrosion/thermal cycling	Same	Same	Same
	Pluggage	Accumulated solids	Same	Same	Mel ΔP
Shell cooling	Loss of water	Supply failure	Same	Same	Coo and mon
	Same	Connection failure	Same	Same	Sa
	Shell rupture	Channel blocked or line closed off	Steam generation ruptures jacket	Same	Sa

Method Detection	Recovery Action	Failure Frequency	Repair Time	Remarks/Recommendations
	Same	L	L	Valve(s) should fail open if compatible with operating control
	Same	L	L	
	Replace film cooler assembly	M	M	Failure would lead to eventual pluggage of nozzle
	Same	M	M	Same
ter-to-SBS monitor	Same	H	L	Routine cleanout procedure is recommended
ling flow temperature itors	• Initiate backup air cooling • Determine source of failure and repair/replace	L	M	• Assumes backup air cooling available • Recommend procedure for glass idling temperature and response sequence • Shell temperature must be kept below critical temperature to prevent warpage • Valves should fail open • Electrode cooling should be suspended at times when water to jacket is lost and air cooling is required
me	Determine source of failure and repair/replace	L	M	
me	Replace melter	L	H	• In-cell repair possible for small leaks • Design and procedures should prevent isolation of melter jacket. Consider rupture disk

PROGRAM: WEST VALLEY DEMONSTRATION PROJECT

SYSTEM: MELTER V-20

PREPARED BY: J. M. Perez, Jr.

Item	Failure Mode	Failure Mechanism	Failure Effect: System Level	Failure Effect: Plant Level
Shell cooling (contd)	Shell failure	Corrosion	Cooling ability lost	Same
	Same	Weld failure	Same	Same
	Loss of air	Supply failure	Shell warpage may damage melter	Same
	Same	Connection failure	Same	Same
Trough cooling air	Loss of air	Supply failure	Possible glass movement into trough	Same
	Same	Control valve failure	Same	Same
	Same	Connection failure	Same	Same
Glass pour area discharge cone	Plugs	Glass accumulation	Interrupt melter operation	Same

TS ANALYSIS WORKSHEET

Method of Detection	Recovery Action	Failure Frequency	Repair Time	Remarks/Recommendations
Same plus sump alarm of liquid present	Same	L	H	Minimized by proper materials selection
Same plus sump alarm of liquid present	Same	L	H	
Cooling flow and temperature monitors	Replace melter if shell damaged; otherwise, determine source of failure and repair/replace	L	H	Assumes water cooling lost and air cooling in use • Glass temperature held at minimum acceptable temperature to minimize shell temperature • Air cooling readiness should be routinely assured • Valves should fail open
Same	Same	L	H	
Zone temperature indications and cooling flow monitors	Determine source of failure and repair/replace	L	M	
Same	Same	L	M	
Same	Same	L	M	
Canister weight factor and gamma level	Remove discharge cone and clear/replace	M	M	Would not pinpoint cause, significant amount of glass would collect in the cone prior to identifying the problem. A method for detecting the glass stream is recommended

PROGRAM: WEST VALLEY DEMONSTRATION PROJECT

SYSTEM: TURNTABLE V-41

PREPARED BY: J. M. Perez, Jr.

Item	Failure Mode	Failure Mechanism	Failure Effect System Level	Failure Effect Plant Level
Connection to melter	Vent to melter plugs	Air purge fails and salts and/or particulate plug line	Melter and turntable operate at ΔP	Interrupt glass production
	Expandable bellows fails	Air supply fails	Unable to seal turntable to melter: excessive air inleakage	Interrupt glass production
	Same	Fatigue cracks develop	Same	Same
Shell cooling	Loss of water	Supply fails	• Will affect canister cooling history • Higher internal temperature may affect mechanical operation	May interrupt glass production
	Same	Connection failure	Same	Same
	Jacket fails	Corrosion	Same	Same
Off-gas vent line	Seal pot fails	Water supply fails	Melter gases may be drawn into turntable and increase contamination of canister walls	No immediate impact
	Same	Solids plug water drain	Water collection in or around turntable possible	Same

Method of Detection	Recovery Action	Failure Frequency	Repair Time	Remarks/Recommendations
ΔP measurement between melter and turntable	Repair/replace jumper and restore air purge	L	M	
Visual, turn-table/melter ΔP	Re-establish air supply	L	M	Valve should fail open
Same	Retract turntable and replace bellows	L	M	
Water flow/ temperature monitors	Determine source and repair/replace	L	M	• Operating procedure required to specify turntable internal temperature limits for operation • Valves should fail open
Same	Same	L	M	
Same plus sump liquid alarm	Replace turntable	L	H	
Water flow monitor	Determine failure and replace/repair	L	L	Plant procedure required defining operating under this condition
Same	Replace seal pot	L	L	Drain should be oversized to prevent this event

FAILURE MODES AND EFFECTS A

PROGRAM: WEST VALLEY DEMONSTRATION PROJECT

SYSTEM: TURNTABLE V-41

PREPARED BY: J. M. Perez, Jr.

Item	Failure Mode	Failure Mechanism	Failure Effect System Level	Failure Effect Plant Level	of
Access port	Water seal fails	Water supply fails	Adequate seal not maintained, air inleakage may require stopping melter operation	No immediate impact	Wate mon
	Same	Seal drain plugs	Same	Same	Sam
Turntable Drive	Carousel will not rotate	Motor fails	Cannot rotate canister	Interrupt glass/canister production	Mot mon
	Same	Linkage fails	Same	Same Visual	
	Same	Bearings freeze	Same	Same	No inc (e of po
	Same	Mechanical failure	Same	Same	Sa

ethod etection	Recovery Action	Failure Frequency	Repair Time	Remarks/Recommendations
flow or	Determine failure and replace/repair	L	L	In-cell valve should operate 100% open so that fail open action does not impact operation
	Repair drain	L	L	
power tor	Replace motor assembly	M	L	
	Replace linkage assembly	L	M	
irect cation mination other sibilities)	Remove turntable lid and inspect. Repair/replace turntable	L	H	
e	Same	L	H	

SI
APERTURE
CARD

Also Available On
Aperture Card

FAILURE MODES AND EFFECTS A

PROGRAM: WEST VALLEY DEMONSTRATION PROJECT

SYSTEM: TURNTABLE V-41

PREPARED BY: J. M. Perez, Jr.

Item	Failure Mode	Failure Mechanism	Failure Effect: System Level	Failure Effect: Plant Level	of
Weigh system	Loss of signal	Load cell fails	Gamma detection becomes only method for canister level monitoring	None	Sig ind
	Same	Electrical connection fails	Same	Same	Sam
	Mechanical failure	Pivot assembly fails	Same	Same	No mea
	Air cooling fails	Supply fails	Same	Same	Air mor
	Same	Piping connection fails	Same	Same	Sar
Steam service	Loss of steam	Control valve fails	Steam not available	Same	St mo
Water service	Loss of water	Same	Water cooling not available	Same	Wa mo

NALYSIS WORKSHEET

Method Detection	Recovery Action	Failure Frequency	Repair Time	Remarks/Recommendations
al cation	Replace load cell assembly	L	M	Plant procedure required to define operational response in case of load cell failure
e	Determine failure and repair/replace	L	L	
direct surement	Replace pivot assemble	L	M	
flow itor	Repair air source	L	L	In-cell valve should fail open
e	Determine failure and repair/replace	L	M	
am flow itor	Replace valve	L	M	
er flow nitor	Same	L	M	

SI
APERTURE
CARD

Also Available On
Aperture Card

8911010071-31

FAILURE MODES AND EFFECTS A

PROGRAM: WEST VALLEY DEMONSTRATION PROJECT

SYSTEM: MELTER V-20

PREPARED BY: Frank Graf

Item	Failure Mode	Failure Mechanism	Failure Effect: System Level	Failure Effect: Plant Level	of
Emergency vent valve	Fails in open position	Stuck open due to heatup from hot melter off gases	Cannot shut valve	Stop glass production. Loss of pressure control on melter	Mon vacu
	Same	Solenoid in air supply burns out	Same	Same	Sam
	Same	Airline to activator broken or pinched off	Same	Same	Vis ins
	Same	Activator jammed	Same	Same	Sam
Emergency vent valve	Fails to open when needed	Valve stuck shut	Cannot vent melter during overpressure. Could discharge glass into both discharge ports	Stop glass production. Melter overpressurization can blow seals and contaminate cell	Mon pr
	Valve does not open	Solenoid burned out on motive power air line	Same	Same	Sa di ex
	Same	Airline to activator broken or pinched off	Same	Same	Vi in
	Air pressure reducer to pneumatic activator fails	Ruptured diaphragm	50 psig to activator may jam the valve open or closed	Same	Vi ai PR ra
	Valve does not open	Activator jammed	Cannot vent melter during overpressure	Same	

Method Detection	Recovery Action	Failure Frequency	Repair Time	Remarks/Recommendations
tor melter um	Remove and replace	L	M	Valve tolerances may have to be opened up. Valve may close when cooled down after feeding stops. Recommend exercising valve occasionally
	Remove and replace solenoid	M	L	
al ection	Remove and replace airline	L	L	
	Remove and replace valve	L	L	
tor melter ssure	Remove and replace valve	L	M	Will probably fail shut. Needs to be activated occasionally
e but cannot tinguish ct cause	Remove and replace solenoid valve	L	L	
ual pection	Remove and replace airline	L	L	Manipulator can damage tubing
ually check gauges on in valve k	Remove and replace pressure reducing valve	L	L	
	Remove and replace valve	L	M	

PROGRAM: WEST VALLEY DEMONSTRATION PROJECT

SYSTEM: SEAL POT V-003

PREPARED BY: Frank Graf

Item	Failure Mode	Failure Mechanism	Failure Effect: System Level	Failure Effect: Plant Level	[illegible]
Jet	Unable to pump seal pot	Jet [illegible]ion blo[illegible]	Seal pot will overflow to waste header and then back to 8D tanks	Prepared feed lost back to 8D tanks	H s V
Water addition to seal pot	Level rises	Water addition control valve leaks	Seal pot will overflow to waste header and then back to 8D tanks	Increases future boildown requirements	S a
Level indication	No level indication	Dip tube plugs	None	None	S 1
Same	Same	Transmitter fails	None	None	
Water seal	Loss of seal	Evaporation or leak	Vapor bypasses to waste header	Condensables can reach turntable and condense	

SYSTEM: SEAL POT D-16

Item	Failure Mode	Failure Mechanism	Failure Effect: System Level	Failure Effect: Plant Level
Pressure transmitter	Output fails to zero	Electronics failure	No seal pot pressure signal	
Density transmitter	Same	Same	No seal pot density	Minor
Density dip tube	No air purge to create backpressure	Tip of dip tube salts over	Same	Same
Weight factor transmitter	Output fails to zero	Electronic board failure	No indication of seal pot level	Can bypass vapor to waste header and thence to turntable if liquid seal is lost

Method of Detection	Recovery Action	Failure Frequency	Repair Time	Remarks/Recommendations
gh level in al pot, -011 level	Remove and clean jet	L	L	Upset mossbalance program. Its an unmetered stream
al pot level nd V-011 level	Hand valve out water supply and remove and repair control valve	L	L	
eal pot evel input	Blow down dip tubes	H	L	
ame	Remove and repair transmitter	L	L	
Seal pot level indication	Add water to seal pot	M	L	Automate makeup of water to seal pot suggested
Monitor pressure input	Remove and replace pressure transmitter	L	L	
Monitor density input	Remove and repair density transmitter	L	L	
Same	Back flush dip tube	L	L	
Weight factor transmitter indication	Use DWS purge on seal pot until the transmitter is repaired	L	L	Need automatic response to failed transmitter to prevent loss of seal level

FAILURE MODES AND EFF

PROGRAM: WEST VALLEY DEMONSTRATION PROJECT

SYSTEM: VESSEL VENT CONDENSER

PREPARED BY: Frank Graf

Item	Failure Mode	Failure Mechanism	Failure Effect System Level	Failure Effect Plant Level
Control valve or I/P transmitter	• Transmitter fails to zero output • control valve fails open	• Diaphragm ruptures • Electronic circuit fails	Control valve fails wide open in either case	May rob cooling water from other areas--especially melte jacket and SBS
Cooling water return temperature element	T/C fails	Open junction	Temperature controller would call for more cooling if upscale burn out occurs	Same
Temperature transmitter	Fails upscale	Electronic circuit fails	Same	Same
Condenser outlet	Liquid outlet plugged	Solids accumulate	Reduces condenser capacity as condensate backs up to gas outlet	Will drain to SBS and thence back to CFMUT
Condenser drain 80 inch loop	Plugs	Solids buildup	Same	Same
Noncondensible off-gas pressure control valve	Valve fails open	Diaphragm ruptures	High negative pressure at CFMUT would increase boilup rate, suddenly overcome the condenser and push hot vapors over to the SBS	Shut down CFMUT boildown operation

CTS ANALYSIS WORKSHEET

REVISION NUMBER: 2
DATE: July 1987
DRAWING NUMBER: FMEA-1 REV 2

SHEET: 35 : of: 49

Method of Detection	Recovery Action	Failure Frequency	Repair Time	Remarks/Recommendations
Flowmeter in cooling loop	Replace I/P or control valve	L	L	Need means to prevent one cooling loop's failure from reducing flow to the critical loops
Flowmeter	Remove and replace T/C	L	L	Same
Same	Repair transmitter	L	L	Same
ΔP across condenser	Back flush	L	L	Need back flush capability. Could create a closed loop that would keep filling up the CFMUT as it tried to evaporate down
Same	Flush loop	L	L	Need back flush capability
Monitor condenser pressure	Replace jumper with control valve in it	L	L	The steam to the CFMUT should be cut off automatically

FAILURE MODES AND EFFECTS

PROGRAM: WEST VALLEY DEMONSTRATION PROJECT

SYSTEM: VESSEL VENT CONDENSER

PREPARED BY: Frank Graf

Item	Failure Mode	Failure Mechanism	Failure Effect: System Level	Failure Effect: Plant Level	O
Condenser Body	Coolant leaks to vent side	Corrosion	Increased flow down condenser drain system to 8D- 1/2/4 tanks	None to CTS process	Non
Closed loop cooling water supply valve	Valve fails open	Diaphragm ruptures	Increased flow to condenser	Robs cooling capacity from other items such as melter, SBS, etc.	Lo me
Pressure relief valve on cooling water supply	Fails to relieve pressure	Diaphragm failure	Higher cooling water pressure	Change loads on cooling loops	No

REVISION NUMBER: 2
DATE: July 1987
DRAWING NUMBER: FMEA-1 REV 3

ANALYSIS WORKSHEET

SHEET: 34 : of: 49

Method Detection	Recovery Action	Failure Frequency	Repair Time	Remarks/Recommendations
e known	Replace vessel vent condenser	L	M	Recommend monitoring of closed-loop cooling system tank level. May want to bring BD tank levels into DCS
op flow ter	Remove and repair valve	L	L	Need automatic response to prevent excessive load switching on CLCWS and to be able to maintain some minimum heat load pickup from the melter jacket
ne	Remove and repair valve	L	L	

PROGRAM: WEST VALLEY DEMONSTRATION PROJECT

SYSTEM: SUBMERGED BED SCRUBBER V-31

PREPARED BY: J. M. Westsik, Jr.

Item	Failure Mode	Failure Mechanism	Failure Effect: System Level	Failure Effect: Plant Level	of
Recirculation tank cooling coil	Loss of cooling	Corrosion of coil	Lower off-gas exit temperature	Potential contamination of cold water loop. Increase volume of liquid to treat. Stop glass production to repair	Liq tur and lev rap De vol wa
	Same	Leak at valves, jumpers	Higher off-gas exit temperature	Water on cell floor. Stop feed to melter to locate and repair leak	Lic dec lic tu De vo wa Ce le
Recirculation tank jet	Failure to transfer	Plug of jet or dip leg	Eventually plug tank with solids	Eventually plug tank with solids, forcing feed to melter to be stopped	No le cu
Recirculation tank air sparge	Loss of sparging	Plug of air vents	Incomplete agitation, solids accumulation	Stop feed to melter when replacing sparger	No no le me
	Same	Leak at valves jumpers	Same	Same	No le me
Recirculation tank level detection	Loss of measurement	Plug of dip legs, leak at jumpers, transmitter fails	Cannot tell if liquid level is dropping leading to loss of scrubbing, over loading other off-gas system components	When other systems over loaded, stop feed to melter	Lo me pr i i

ANALYSIS WORKSHEET

REVISION NUMBER: 2
DATE: July 1987
DRAWING NUMBER: FMEA-1 REV 3

SHEET: 35 : of: 49

Method Detection	Recovery Action	Failure Frequency	Repair Time	Remarks/Recommendations
uid tempera- e decreases liquid el increases idly. rease of ume in cold er loop	• Turn off cooling water to SBS • Achieve cooling via dilution • Replace coils	L	H	Need to determine if adiabatic operation is acceptable
uid level reases and uid tempera- e increases. rease in ume of cold er loop. l sump els	Turn off cooling water. Locate and repair leak	L	M	Alarm sump levels
change in vel of recir- ation tank	Replace jet	L	M	See Sheet 14 for steam-jet control system analysis
air flow, change in vel asurement	Replace sparger	L	M	Can probably continue to operate without sparge
change in vel asurement	Locate and repair leak	L	M	
ss of asurement, essure crease supply line	Replace dip legs, locate and repair leak, repair transmitter	L	M	If only one leg plugs, can still get level indication. Also can monitor pressure drop across bed

FAILURE MODES AND EFFECTS

PROGRAM: WEST VALLEY DEMONSTRATION PROJECT

SYSTEM: SUBMERGED BED SCRUBBER V-31

PREPARED BY: J. H. Westsik, Jr.

Item	Failure Mode	Failure Mechanism	Failure Effect: System Level	Failure Effect: Plant Level	o
Recirculation tank thermowell	Loss of temperature measurement	Thermocouple burnout, poor contacts	TC used in controlling cooling water flow	None	Los re te me
Recirculation tank vessel	Leak	Corrosion	Loss of scrubbing, overloading other off-gas system components	Potential release to stack, stop glass production	Ch le in dr in re
Recirculation tank packed-bed vessel	Loss of packing	Corrosion or weld failure leading to packing falling into recirculation tank	Inefficient scrubbing, overloading other off-gas system components	Potential release to stack, stop glass production	In of ti ti do co (H
	Packing plugged	Excess solids in scrub solution	No off-gas treatment from melter	Stop glass production	Hi dr sc
Receiver tank cooling coil	Loss of cooling	Corrosion of coil	Jet transfers inefficient if cooling water turned off	Stop glass production. Potential contamination of cold water loop. Initially larger volume of liquid to treat; then, when cooling water off, none	Li t a i r d v c
	Same	Leak at valves, jumpers	Jet t[illegible]nsfers inefficient unless solution cooled	Water on cell floor. Stop glass production to repair	I l t i c

ANALYSIS WORKSHEET

Method Detection	Recovery Action	Failure Frequency	Repair Time	Remarks/Recommendations
s of sonable perature surement	Replace TC and/or connectors	L	L	Failure of TC should lead to maintenance level of cooling flow to coils. Transmitter should have upscale T/C burnout feature
nge in vel, change pressure op, increase level of ceiver tank	Replace tank	L	H	
creased rate contamina- on, deposi- on on wnstream mponents EME)	Replace packed-bed vessel	L	M	No immediate means to detect
gh pressure op across rubber	Flush packing with water, replace packed-bed vessel	L	M	
quid tempera- re decreases d liquid creases pidly, crease of lume in ld water loop	Turn off cooling water, replace SBS	L	H	Need to determine if adiabatic operation is acceptable
ncrease in iquid tempera- ure, decrease n volume of old water loop	Turn off cooling water, locate and repair leaks	L	M	

SI
APERTURE
CARD

Also Available On
Aperture Card

PROGRAM: WEST VALLEY DEMONSTRATION PROJECT

SYSTEM: SUBMERGED BED SCRUBBER V-31

PREPARED BY: J. H. Westsik, Jr.

Item	Failure Mode	Failure Mechanism	Failure Effect: System Level	Failure Effect: Plant Level	O[illegible]
Receiver tank cooling coil (contd)	Control valve fails open	Plugs, corrosion	Cannot control flow	None	Lo co er dr
Receiver tank jet	Failure to transfer	Plug of jet or dip leg	Fill tank with solution	Stop glass production	No ta
Receiver tank air sparge	Loss of sparging	Plug of air vents	Incomplete agitation	Stop feed to melter when when replacing sparger	No no ta me
		Leak at valves or jumpers	Same	None	No ta me
Receiver tank level detection	Loss of measurement	Plug of dip legs, leak at jumpers, transmitter fails	Cannot tell liquid level	None	Lo me
Receiver tank	Loss of temperature signal	Thermocouple burnout, poor connectors	TC used to control cooling water flow	None	L r t m
Receiver tank vessel	Leak	Corrosion	Receiver tank catches over-flow from recirculation tank, may require frequent transfers to maintain level below leak point. This will also impact plant	Water leak to cell floor. Stop glass production to repair	[illegible]

NALYSIS WORKSHEET

Method Detection	Recovery Action	Failure Frequency	Repair Time	Remarks/Recommendations
s of flow trol, temture in SBS ps	Replace valve	L	L	
change in k level	Replace jet	L	M	
air flow, change in nk level asurement	Replace sparger	L	H	Can probably continue to operate without sparge
change in nk level asurement	Locate and repair leaks	L	M	
ss of asurement	Replace dip legs, fix leaks, make jet transfers on a conservative schedule, replace transmitter	L	M	
oss of easonable emperature easurement	Replace TC and/or connectors. Can run cooling loop in manual during repairs	L	L	Failure of TC should lead to maintenance level of cooling flow to coils
hange in level f tank. ell sump evels increase	Operate out of recirculation tank. Replace SBS	L	H	

FAILURE MODES AND EFFECTS

PROGRAM: WEST VALLEY DEMONSTRATION PROJECT

SYSTEM: OFF-GAS SUBSYSTEM

PREPARED BY: F. Fisher

Item	Failure Mode	Failure Mechanism	Failure Effect: System Level	Failure Effect: Plant Level

The off-gas subsystem is designed to eliminate undesirable radioactive particulates in the gases emanating from the melter. After passing through the submerged bed scrubber and into the off-gas dryer and being heated there, the off gas passes through a bank of HEME and HEPA filters (and another dryer in front of the HEPA) before passing through the trench heater and into the trench. The off gas is further cleaned in the 01-14 building prior to release to the atmosphere. The HEME-heater-HEPA filter bank is designed for redundant operation, which is controlled by opening or closing ball valves at either end of the two banks.

In this analysis, only one side of the redundant paths is considered. The other path will have identical characteristics. In all cases, if both paths are in a failed state, glass production must be halted until at least one path is operating satisfactorily.

REVISION NUMBER: 2
DATE: July 1987
DRAWING NUMBER: FMEA-1 REV 3

ANALYSIS WORKSHEET

SHEET: 38 of: 49

Method of Detection	Recovery Action	Failure Frequency	Repair Time	Remarks/Recommendations

SI
APERTURE
CARD

Also Available On
Aperture Card

8911010071-39

FAILURE MODES AND EFFECTS

PROGRAM: WEST VALLEY DEMONSTRATION PROJECT

SYSTEM: OFF-GAS DRYER (V-32)

PREPARED BY: F. Fisher

Item	Failure Mode	Failure Mechanism	Failure Effect: System Level	Failure Effect: Plant Level	O
Off-gas dryer (V-32)	Fails to heat	Heating coils burn out	Allows excessive moisture in the off-gas to HEME	Glass production halted until dryer back on line	Te in dr lo he dr
	Same	Short or open in electrical supply lines	Same	Glass production halted until problem is located and corrected	Sa
	Overheating of coils	Solids or corrosion scale accumulate on coils	Same	Same	Sa
	Chemical added. Valve fails shut	Ruptured diaphragm, transmitter failure	Cannot flush demister pad	Reduced off-gas flow	P a d
	Thermocouple failure	T/C failure. T/C wire junction failure	Same. Cannot control temperature	Same	L

REVISION NUMBER: 2
DATE: July 1987
DRAWING NUMBER: FMEA-1 REV 3

ANALYSIS WORKSHEET

SHEET: 39 : of: 49

Method Detection	Recovery Action	Failure Frequency	Repair Time	Remarks/Recommendations
perature icator on er shows . Also ter current ops	Remove and replace dryer heating coils as appropriate (See Remarks)	L	M	• redundant heater coils can be switched in and corrective action delayed until more convenient time • Recommend electric circuit monitoring device be installed
he	Locate, isolate and repair short or open	L	M	Same
me	Remove and replace dryer heating coils	L	M	Same
ressure drop cross the emister	Repair valve	M	L	May have to stop glass production during repair if melter vacuum cannot be maintained
oss of signal	Replace T/C	L	L	

SI
APERTURE
CARD

Also Available On
Aperture Card

8911010071 - 40

PROGRAM: WEST VALLEY DEMONSTRATION PROJECT

SYSTEM: OFF-GAS VALVE

PREPARED BY: F. Fisher

Item	Failure Mode	Failure Mechanism	Failure Effect: System Level	Failure Effect: Plant Level	
Valve (HV-330-1) (HV-360-1)	Fails open	Seizure or plugging	One or the other valve would be normally open and attempts to close it made only if maintenance action were required downstream. Off gas would continue to flow through area requiring maintenance	Glass production halted while valve is replaced	Di pr V- ir cc f i v p i
	Fails closed	Seizure or plugging	This valve is closed when maintenance has been performed downstream and the redundant path is in operation. Reopening will be attempted when maintenance is required in the redundant path. If unable to open, off gas will continue to flow in path requiring maintenance	Glass production halted while valve is replaced	D p V f f
	Leakage	Worn seats, stem wear	Air in-leakage to off-gas stream	Glass production halted until valve is replaced	

ANALYSIS WORKSHEET

Method Detection	Recovery Action	Failure Frequency	Repair Time	Remarks/Recommendations
fferential essure on 033 or V-036 dicates ntinued ow of off-gas HEME. Also sual valve sition dicator	Remove and replace valve	L	M	• Back end valve (OH-390-1 or -2) on this leg of the filter bank can be closed and redundant path opened. This will permit the delay of the replacement of the failed valve until a more convenient time • Valve position indicators are recommended • Need flowmeter in each path to assess leakage
ifferential ressure on -033 or V-036 ndicates no low of off gas	Remove and replace valve	L	M	
Increased pressure drop valve across HEME	Remove and replace valve	L	M	Alarm on pressure may be appropriate

FAILURE MODES AND EFFE

PROGRAM: WEST VALLEY DEMONSTRATION PROJECT

SYSTEM: HEME

PREPARED BY: F. Fisher

Item	Failure Mode	Failure Mechanism	Failure Effect: System Level	Failure Effect: Plant Level
HEME (V-033 or V-036)	Loss of filtration	Filter clogged	Restricted off-gas flow through HEME. Maximum ΔP achieved	Stop glass production if redundant line not available
	Loss of DWS	Nozzles clogged	HEME eventually clogs	Stop glass production if redundant line not available
	HEME fills with water	Seal loop plugs due to glass fines	Overflow of liquid in HEME to other downstream vessel. Possibly short out preheater	Same
	Same	Drain to SBS clogs due to glass fines	Same	Glass production halted until drain is operating properly

CTS ANALYSIS WORKSHEET

Method of Detection	Recovery Action	Failure Frequency	Repair Time	Remarks/Recommendations
Differential pressure increase will be indicated on ΔP transmitter	Open chemical additive valve initially to try to unclog filter. If unsuccessful, switch in redundant path--remove and replace filter	M	L	• Alarm on ΔP may be appropriate • Gradual increase expected. Can correct before HEME becomes plugged
Flow meter DWS line will indicate loss of flow	Open chemical additive valve to try to unclog filter. Switch in redundant path. Remove and replace HEME filter	L	L	
Same	Switch in redundant path. Remove and replace HEME	L	M	
Pressure transmitter and level transmitter will indicate problem	Close valves at bottom of both HEMEs. Unbolt drain and attempt to clear the clog. If unsuccessful, replace drain line	L	M	

8811010071-42

FAILURE MODES AND EFFECTS

PROGRAM: WEST VALLEY DEMONSTRATION PROJECT

SYSTEM: OFF-GAS SUBSYSTEM

PREPARED BY: F. Fisher

Item	Failure Mode	Failure Mechanism	Failure Effect: System Level	Failure Effect: Plant Level	of
Off-gas dryer DWS flow control valve	Fails to operate on demand	Valve sticks	Insufficient DWS to V-32 demister, which will eventually clog	Glass production halted until valve is operating properly	Lev wil pro
HEME DWS flow control valve	Fails to operate on demand	Valve sticks	Insufficient DWS to V-033 or V-036 HEME which will eventually clog	Stop glass production if redundant line not available	Le wi pr
HEME chemical additive flow control valve	Fails to operate on demand	Valve sticks	Insufficient additive to HEME will eventually clog HEME. This additive is not required very often	No effect	Pr mi wi pr
Differential pressure sensors on off-gas dryer (V-32)	Fail to display proper ΔP	a) Too high	Decrease in ability to monitor off-gas flow	Glass production halted until cause of overpressure is determined and corrected	Vi ti su
	Same	b) Too low	Same	Same	S

REVISION NUMBER: 2
DATE: July 1987
NALYSIS WORKSHEET
DRAWING NUMBER: FMEA-1 REV 3

SHEET: 42 : of: 49

Method Detection	Recovery Action	Failure Frequency	Repair Time	Remarks/Recommendations
el indicator l indicate blem	Remove and replace valve	L	L	This valve is located outside of the containment area
el indicator l indicate blem	Switch in redundant path. Remove and replace valve	L	L	Same
ssure trans-ter on HEME l indicate blem	Switch in redundant path. Remove and replace valve	L	L	This valve is located outside the containment area
sual inspec-on of pres-re gauge	Troubleshoot the equipment to verify that sensor is giv-ing erroneous signal. Remove and replace	L	L	This equipment is outside the contaminant area
me	Same	L	L	Same

SI
APERTURE
CARD

Also Available On
Aperture Card

8911010071 - 43

FAILURE MODES AND EFFECTS A

PROGRAM: WEST VALLEY DEMONSTRATION PROJECT

SYSTEM: HEME

PREPARED BY: F. Fisher

Item	Failure Mode	Failure Mechanism	Failure Effect: System Level	Failure Effect: Plant Level	of
Pressure transmitter on HEME	Fails to display proper pressure	a) Too high	Decrease in ability to monitor off-gas flow	Glass production stopped if redundant line not available	Visu tion sure
	Same	(b) Too low	Same	Same	Sam
Level density transmitter on HEME	Fails to display proper level	a) Dip tube plugs	Level density indication too high	Glass production stopped if redundant path not available	Flo ind
	Same	Circuit board fails	Zero level indication	Same	Sam

ALYSIS WORKSHEET

ethod etection	Recovery Action	Failure Frequency	Repair Time	Remarks/Recommendations
l inspec- of pres- gauge	Valve in redundant path. Troubleshoot the equipment to verify that sensor is giving erroneous signal. Remove and replace	L	L	This equipment is outside the containment area
	Same	L	L	Same
alarm cator	Valve in redundant path. Troubleshoot the equipment to verify that sensor is giving erroneous signal. Remove and replace	L	L	Same
e	Same	L	L	Same

SI
APERTURE
CARD

Also Available On
Aperture Card

FAILURE MODES AND EFFECTS

PROGRAM: WEST VALLEY DEMONSTRATION PROJECT

SYSTEM: PREHEATER (E-34, E-37)

PREPARED BY: T. V. Vo

Item	Failure Mode	Failure Mechanism	Failure Effect: System Level	Failure Effect: Plant Level	of
Preheater (E-34, E-37)	Fails to preheat the off gas	a) Electric heater element fails short/ open circuit • material filter defect • T/C failure	• Low temperature in preheater • potential condensation on HEPA	Stop glass production if redundant path not available	• T l p • p y c t
	Same	b) Preheater housing fails: corrosion mechanical damage	• Low temperature in preheater • potential condensation on HEPA filter • cannot maintain melter vacuum if excessive inleakage	Same	• •
	Thermocouple fails	T/C junction failure, extension wire failure	• Low temperature same in preheater • potential condensation on HEPA filter • potential overheating of HEPA	Same	L t i

NALYSIS WORKSHEET

Method Detection	Recovery Action	Failure Frequency	Repair Time	Remarks/Recommendations
emperature ow in reheater reheater oltage or urrent ndicators	• Valve in redundant path • replace heater elements	L	L	• Repair time is low due to the availability of spare heater elements in the housing
Surveillance loss of vacuum in upstream components	• Valve in redundant path • replace preheater housing	L	M	
ss of emperature dication	Valve in redundant path and replace T/C	L	L	Heater can be controlled manually if T/C fails. Past history will dictate controller setting. Heater has redundant thermocouples

FAILURE MODES AND EFFECTS A

PROGRAM: WEST VALLEY DEMONSTRATION PROJECT

SYSTEM: HEPA FILTER A (T-35)

PREPARED BY: T. V. Vo

Item	Failure Mode	Failure Mechanism	Failure Effect: System Level	Failure Effect: Plant Level	of
HEPA filter (T-35, T-38)	Filter element breached	• Material defect • excessively high temperature/pressure/radiation • plugged with particulate or water	Contaminate system downstream	Stop glass production if redundant path not available	• C a • h a d
	Filter housing	Corrosion mechanical damage	• Primary loop of off-gas system fails • melter vacuum cannot be maintained	Same	Lo va
Radiation detector	Fails to operate	• Power surge • calibration error • defective materials • wiring/electronics failure	Loss of monitoring device cannot assess HEPA performance	Same	Lo
Differential pressure transmitter (ΔPT)	Fails to operate	• Power surge • calibration errors • wiring/electronics failure	Same	Same	L

NALYSIS WORKSHEET

REVISION NUMBER: 2
DATE: July 1987
DRAWING NUMBER: FMEA-1 REV 3

SHEET: 45 : of: 49

Method Detection	Recovery Action	Failure Frequency	Repair Time	Remarks/Recommendations
hange in ΔP cross HEPA igher radi-tion levels ownstream	• Valve in redundant path • replace filter assembly • assess downstream contamination level	L	L	• Replace HEPA filter as a complete assembly. Individual filter elements in the assembly will not be replaced • turn off the preheater prior to HEPA replacement • may have to stop glass production if significant contamination. Need radiation detector downstream to monitor off gas beyond HEPA filter
melter cuum	• Valve in redundant path • replace housing	L	M	• Turn off the preheater prior to HEPA replacement
ss of signal	• Valve in redundant path • diagnose the causes and replace/ repair detector	L	L	
oss of signal	• Valve in redundant path • diagnose the causes and replace/ repair instrumentation	L	L	Can use upstream and downstream pressure taps to estimate pressure drop

PROGRAM: WEST VALLEY DEMONSTRATION PROJECT

SYSTEM: VALVE (M-390-1 and -2)

PREPARED BY: T. V. Vo

Item	Failure Mode	Failure Mechanism	Failure Effect: System Level	Failure Effect: Plant Level
Valve (H-390-1 and-2)	Fails open	Seizure or plugging	Possible contamination on back of HEPA filter	Stop feeding until valve fixed
	ails closed	Same	Loss of redundant system	Same
	Inleakage	Worn seats, stem	Loss of vacuum in upstream components	Same

REVISION NUMBER: 2
DATE: July 1987
DRAWING NUMBER: FMEA-1 REV 3

...CTS ANALYSIS WORKSHEET

SHEET: 46 : of: 49

Method of Detection	Recovery Action	Failure Frequency	Repair Time	Remarks/Recommendations
• Will not close. Pressure indication from upstream components	Stop feeding and replace with new valve	L	L	• This failure mode can be detected only when the valve is on demand, e.g., need to close the valve but it will not close
• Will not open. Pressure indication from upstream components	Same	L	L	• This failure mode can be detected only when the valve is on demand • In all cases, installing valve position indicators are recommended
Small leaks are hard to detect. Larger leaks will cause loss of vacuum	Same	L	L	

FAILURE MODES AND EFFECTS

PROGRAM: WEST VALLEY DEMONSTRATION PROJECT

SYSTEM: TRENCH HEATER (E-39)

PREPARED BY: T. V. Vo

Item	Failure Mode	Failure Mechanism	Failure Effect: System Level	Failure Effect: Plant Level	of
Trench heater (E-39)	Fails to heat the off gas	a) Electric heater element fails: • short/open circuit • material defect	Low temperature in trench heater • possible condensation on system	Stop glass production	• L • t
	Same	b) Trench heater housing fails: • mechanical failure	• Low temperature in trench heater • possible condensation • melter vacuum cannot be maintained	Same	• • •
	Thermocouple fails	T/C junction failure, extension wire failure	• Low temperature in preheater • potential condensation in trench	Same	Lo pe in

REVISION NUMBER: 2
DATE: July 1987
DRAWING NUMBER: FMEA-1 REV 3

ALYSIS WORKSHEET

SHEET: 47 : of: 49

Method Detection	Recovery Action	Failure Frequency	Repair Time	Remarks/Recommendations
w tempera- re in the ench heater ench ater rrent/ ltage dicators	• Stop feeding • replace heater elements	L	L	Repair time is low due to the availability of spare heater elements in the heater.
rveillance w tempera- ure in rench heater oss of acuum in ostream omponents	Remotely remove/replace trench heater from VF cell	L	M	Stop feeding until the trench heater is repaired/replaced
s of tem- ature ication	Replace thermocouple	L	L	Should have automatic switch over to redundant T/C

8911010071-48

PROGRAM: WEST VALLEY DEMONSTRATION PROJECT

SYSTEM: OFF-GAS SYSTEM

PREPARED BY: F. Fisher

Item	Failure Mode	Failure Mechanism	Failure Effect System Level	Failure Effect Plant Level
Master/Slave manipulator	Fails to operate	All possible mechanisms	No effect if rest of plant equipment is operating satisfactorily	If a failure in the off-gas system occurs and it is required to valve-in the redundant HEME-HEATER-HEPA filter bank, glass production must be halted until manipulator can operate the appropriate valve
Vacuum pumps in off-gas system	Fails to maintain required vacuum levels	All possible pump/blower failures	Flow of off-gas essentially stopped	Glass production halted until required vacuum levels are attained
Vacuum pumps in off-gas system	Fails to maintain required vacuum levels	Failure of vacuum control	Off-gas flows too quickly through off-gas system	Glass production halted until normal vacuum pressure can be attained

TS ANALYSIS WORKSHEET

REVISION NUMBER: 1
DATE: June 1987
DRAWING NUMBER: FMEA-1 REV 2

SHEET: 48 : of: 49

Method of Detection	Recovery Action	Failure Frequency	Repair Time	Remarks/Recommendations
Attempts to operate manipulator are unsuccessful	Replace manipulator	H	L	
Loss of vacuum	Repair or replace vacuum pumps/blowers	M	M	Alarms should be installed to warn of this condition
High vacuum	Repair or replace vacuum pumps, control system	L	M	Same

s

SI
APERTURE
CARD

Also Available On
Aperture Card

8911010071-49

FAILURE MODES AND EFFECTS A

PROGRAM: WEST VALLEY DEMONSTRATION PROJECT

SYSTEM: CELL SUMPS (North or South)

PREPARED BY: F. Graf

Item	Failure Mode	Failure Mechanism	Failure Effect System Level	Failure Effect Plant Level	of
Jet to waste header	Steam supply valve failed	Ruptured diaphragm	No jet transfer from one of the sumps	None. Other sump available	Sum jet pre
Same	Jet does not transfer	Plugged jet	Same	Same	Sum
Level instrumentation	Loss of level indication	Dip tube plugs	No level indication	None. Other sump's level indication can be used in interim period	Sum ind
Same	Same	Transmitter fails	Same		Sa
Density instrumentation	Loss of density signal	Dip tube plugs	Loss of density indication	Minor. Level indication probably close enough. Also, other sump could yield information	De ti
	Same	Transmitter fails	Same	Same	Sa

NALYSIS WORKSHEET

Method Detection	Recovery Action	Failure Frequency	Repair Time	Remarks/Recommendations
p level and stream ssure	Remove and repair steam supply valve	L	L	
p level	Flush jet	L	L	
p level ication	Back flush dip tubes	M	L	
re	Remove and repair transmitter	L	L	
nsity indica- on lost	Blow down dip tubes	M	L	
me	Remove and repair transmitter	L	L	

APPENDIX C

IMPORTANT COMPONENTS OR SUBSYSTEMS RANKING

APPENDIX C

IMPORTANT COMPONENTS OR SUBSYSTEMS RANKING

This appendix presents the methodology used to rank the importance of the components that have either a high failure frequency or a medium failure frequency combined with a medium or high repair time. The objective of this evaluation is to identify which components dominate the system unavailability, given that component failure has occurred.

The components/subsystems "importance" was calculated using the Fussell-Vesely (FV) Importance measure (Lambert 1973)[a]. The FV Importance measure (I^{FV}) is defined as the fraction of the total system unavailability to which an event, component, or subsystem contributes.

$$I_i^{FV} = \frac{Q_i}{Q_s} \tag{1}$$

Q_i is defined as the probability of the component or subsystem failure exists at time t. This is either the probability of component or subsystem failure or the probability of a particular system hazard at time t, depending on the definition of the failures. In general, Q_i is defined as

$$Q_i = (1-e^{-\lambda t}) \text{ for nonrepairable component}$$

$$= \frac{\lambda_i}{\lambda_i + \mu_i} \left[1-e^{-(\lambda_i + \mu_i)t}\right] \text{ for repairable component} \tag{2}$$

where λ_i = component i failure rate (per unit time)

μ_i = component i repair rate (per unit time)

t = time

Similar to Q_i, the total system unavailability, Q_s, is defined as

$$Q_s = \sum_i Q_i \tag{3}$$

(a) Lambert, H. E. 1973. "Fussell-Vesely Importance Measure." Report No. UCID-16238, Lawrence Livermore Laboratory, Livermore, California.

For illustration purpose, the calculations of I^{FV} for the ADS pump (first item in Table 1 of this report) is detailed in the next few paragraphs. The frequency of ADS pump failure was estimated to be 1/wk or 1/168 hr = 0.006 per hour. The repair time for the ADS pump was estimated to be 0.25 hr which translates to a repair rate of 1/0.25 hr or 4 per hour. From equation (2), the ADS pump unavailability is

$$Q_{ADS} = \frac{0.006}{0.006 + 4}\left[1-e^{-(0.006 + 4)(2*8760)}\right]$$

$$= 1.45*10^{-3}$$

where time t is assumed to be 2 years, the operating life of the WVDP plant.

The unavailability of the other 18 components listed in Table 1 were calculated in the same manner. The contribution of these 19 unavailabilities were then summed to obtain the total system unavailability, Q_s, as described in equation (2). The resulting value of Q_s was $1.70*10^{-1}$.

Therefore, from equation (1), the FV Importance measure for the ADS pump was determined as follows

$$I^{FV}_{ADS} = \frac{1.45*10^{-3}}{1.70*10^{-1}} = 0.0085$$