S	ENGINEERING CHANGE NOTICE	1. ECN 638717 Proj. ECN
Page 1 of <u>2</u>		

2. ECN Category (mark one) Supplemental ☐ Direct Revision ☒ Change ECN ☐ Temporary ☐ Standby ☐ Superseded ☒ <i>9/15/99</i> Cancel/Void ☐	3. Originator's Name, Organization, MSIN, and Telephone No. David J Braun, FONW, B4-47, 376-6510	4. USQ Required? ☒ Yes <i>PFP-99-014</i> ☐ No	5. Date 6/15/99
	6. Project Title/No./Work Order No. Letter Report Seismic Shutdown System Failure Mode and Effect	7. Bldg./Sys./Fac. No. 234-5 Z/99B	8. Approval Designator <i>SS SP R44/99</i>
	9. Document Numbers Changed by this ECN (includes sheet no. and rev.) WHC-SD-C053-RPT-001 <i>Rev D 6/25/99</i>	10. Related ECN No(s). N/A	11. Related PO No. N/A
12a. Modification Work ☐ Yes (fill out Blk. 12b) ☒ No (NA Blks. 12b, 12c, 12d)	12b. Work Package No. N/A	12c. Modification Work Completed N/A Design Authority/Cog. Engineer Signature & Date	12d. Restored to Original Condition (Temp. or Standby ECNs only) N/A Design Authority/Cog. Engineer Signature & Date

13a. Description of Change This FMEA now covers more equipment than it originally did. It has been expanded to include the Laboratory Prototype Calcliner. Replace all pages of document WHC-SD-C053-RPT-001 with the attached new pages. The revised document was a failure modes and effects analysis of the HVAC Supply Fan Seismic Shutdown System. With the changes attached, the document will become a failure modes and effects analysis for both the ventilation and laboratory prototype calciner seismic shutdown system. In addition, an appendix has been added that to the document that contains an analysis of the expected seismic response of some of the laboratory calciner non-seismically rated valves.	13b. Design Baseline Document? ☐ Yes ☒ No
---	--

Supersede 9/15/99
~~Interim~~
Supersede ECN 638717

For WHC 822 PFP-99-014

ECN.SeismicShutdownFMEA

14a. Justification (mark one) Criteria Change ☒ Design Improvement ☐ Environmental ☐ Facility Deactivation ☐ As-Found ☐ Facilitate Const. ☐ Const. Error/Omission ☐ Design Error/Omission ☐	14b. Justification Details New design information is presented in the Appendix which provides a seismic failure analysis of some of the laboratory prototype calciner isolation valves as non-seismically qualified components. The revisions to the FMEA will bring the analysis up to date with additions to the PFP Seismic Shutdown Systems.
--	---

15. Distribution (include name, MSIN, and no. of copies) Roger Keck, T4-20, 2 copies Dave Braun, B4-47, 1 copy Kenneth Fein, B4-46, 1 copy Al Ramble, T5-54, 1 copy Jim Shapley, T4-46, 1 copy Frank Powell, T2-12, 1 copy <i>B4-09</i> JB WIT, T5-47, 1 copy Central Files, B1-07, 1 copy DOE/RL Reading Room, H2-53, 1 copy	RELEASE STAMP <div style="border: 2px solid black; padding: 10px; display: inline-block;"> JUN 28 1999 DATE: _____ STA: <i>5</i> <div style="display: inline-block; text-align: center;"> HANFORD RELEASE </div> <div style="display: inline-block; text-align: center; margin-left: 20px;"> ID: </div> </div>
--	--

ENGINEERING CHANGE NOTICE

Page 2 of 2

1. ECN (use no. from pg. 1)

638717

16. Design Verification Required

☐ Yes
☒ No

17. Cost Impact

ENGINEERING

Additional ☐ \$ N/A
Savings ☐ \$ _____

CONSTRUCTION

Additional ☐ \$ N/A
Savings ☐ \$ _____

18. Schedule Impact (days)

Improvement ☐ N/A
Delay ☐ _____

19. Change Impact Review: Indicate the related documents (other than the engineering documents identified on Side 1) that will be affected by the change described in Block 13. Enter the affected document number in Block 20.

SDD/DD	☐	Seismic/Stress Analysis	☐	Tank Calibration Manual	☐
Functional Design Criteria	☐	Stress/Design Report	☐	Health Physics Procedure	☐
Operating Specification	☐	Interface Control Drawing	☐	Spares Multiple Unit Listing	☐
Criticality Specification	☐	Calibration Procedure	☐	Test Procedures/Specification	☐
Conceptual Design Report	☐	Installation Procedure	☐	Component Index	☐
Equipment Spec.	☐	Maintenance Procedure	☐	ASME Coded Item	☐
Const. Spec.	☐	Engineering Procedure	☐	Human Factor Consideration	☐
Procurement Spec.	☐	Operating Instruction	☐	Computer Software	☐
Vendor Information	☐	Operating Procedure	☐	Electric Circuit Schedule	☐
OM Manual	☐	Operational Safety Requirement	☐	ICRS Procedure	☐
FSAR/SAR	☐	IEFD Drawing	☐	Process Control Manual/Plan	☐
Safety Equipment List	☐	Cell Arrangement Drawing	☐	Process Flow Chart	☐
Radiation Work Permit	☐	Essential Material Specification	☐	Purchase Requisition	☐
Environmental Impact Statement	☐	Fac. Proc. Samp. Schedule	☐	Tickler File	☐
Environmental Report	☐	Inspection Plan	☐		☐
Environmental Permit	☐	Inventory Adjustment Request	☐		☐

20. Other Affected Documents: (NOTE: Documents listed below will not be revised by this ECN.) Signatures below indicate that the signing organization has been notified of other affected documents listed below.

Document Number/Revision

Document Number/Revision

Document Number/Revision

N/a

N/a

N/a

21. Approvals

Signature	Date
Design Authority _____	
Cog. Eng. <u>Roger Keek</u> <u>6/24/99</u>	<u>6/24/99</u>
Cog. Mgr. <u>[Signature]</u> <u>6-24-99</u>	<u>6-24-99</u>
QA <u>[Signature]</u>	
Safety <u>Donald A. Cameron</u> <u>6/24/99</u>	<u>6/24/99</u>
Environ. _____	
Other _____	
OSR - Jeff King <u>[Signature]</u> <u>6/24/99</u>	<u>6/24/99</u>

Signature	Date
Design Agent _____	
PE <u>[Signature]</u> <u>FDNW</u> <u>6-23-99</u>	<u>6-23-99</u>
QA _____	
Safety _____	
Design _____	
Environ. _____	
Other _____	
Author - David Braun	
Author Mgr - Brit Hey	
DEPARTMENT OF ENERGY	
Signature or a Control Number that tracks the Approval Signature	

ADDITIONAL	

Letter Report Seismic Shutdown System Failure Mode and Effect Analysis

R. D. Keck

Babcock and Wilcox Hanford Company, Richland, WA 99352
U.S. Department of Energy Contract DE-AC06-87RL10930

EDT/ECN: 638717

UC: 515

Org Code: 15510

Charge Code: 100750

B&R Code: EW7002010

Total Pages: 28

Key Words: HVAC, Ventilation, Seismic, Shutdown, Authorization Basis,
Safety Envelope, OSR, Failure Modes

Abstract: The Supply Ventilation System Seismic Shutdown ensures that the 234-5Z building supply fans, the dry air process fans and vertical development calciner are shutdown following a seismic event. This evaluates the failure modes and determines the effects of the failure modes.

MATHCAD is a registered trademark of Mathsoft, Inc. Cambridge, Massachusetts

TRADEMARK DISCLAIMER. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof or its contractors or subcontractors.

Printed in the United States of America. To obtain copies of this document, contact: WRC/BCS Document Control Services, P.O. Box 1970, Mailstop H6-08, Richland WA 99352, Phone (509) 372-2420; Fax (509) 376-4989.

Release Approval

6/28/99
Date

Approved for Public Release

LETTER REPORT

SEISMIC SHUTDOWN SYSTEM FAILURE MODE AND EFFECT ANALYSIS

PROJECT C-053

INTRODUCTION

The Plutonium Finishing Plant (PFP) Seismic Shutdown System, is shown on drawings H-2-78073, H-2-78074, H-2-78075, H-2-78076, H-2-26538, H-2-99550, H-2-99554, H-2-99554, and H-2-95625. It is designed to shut down certain designated ventilation system equipment, actuate the existing manual shutdown system and shutdown the Laboratory Prototype Calcliner when an earthquake of intensity greater than a selected magnitude occurs. This analysis was performed to identify all the significant faults that may be anticipated to occur in the seismic shutdown system. Appropriate provisions shall be included in the design to ensure that none of these faults will prevent the system from shutting down the designated equipment when a sufficient seismic event occurs.

In addition, an analysis of the seismic response of some of the valves in the laboratory prototype calciner has been included in Attachment B.

SUMMARY AND CONCLUSIONS

All the components of the shutdown system have been examined to ascertain the effect on the system of their failures. None of the failure modes analyzed demonstrates any single fault that would prevent the system from shutting down the designated ventilation equipment or 10L Calcliner in case of a seismic event. Wherever a component failure could prevent shutdown of the fans, at least one redundant component has been provided to ensure that the required shutdown function will occur.

The analysis presented in Attachment B shows that the likelihood of failure of the laboratory prototype calciner filter isolation solenoid valves combined with the frequency of the design basis seismic event is beyond extremely unlikely with the present arrangement of non-seismically qualified valves. Another section of the Attachment shows that the likelihood of back flows from the accumulator through two non-seismically qualified check valves and a non-seismically qualified solenoid valve is also beyond extremely unlikely. Therefore, in both cases, the design does not require the placement of seismically qualified valves.

UNCERTAINTIES AND RECOMMENDATIONS FOR FURTHER STUDY

When installation is complete, a periodic testing plan should be created to detect invisible failures in redundant components.

REFERENCES

Attachment A	Data Sheets
Attachment B	Probabilistic Assessment Air Backflow Preventers for Laboratory Prototype Calciner
ECN-652825	Engineering Change Notice 652825
ECN-652967	Engineering Change Notice 652967

ATTACHMENT A

Data Sheets

FAILURE MODES AND EFFECTS ANALYSIS

SYSTEM	COMPONENT IDENTIFICATION	FUNCTION	FAILURE MODE	FAILURE MECHANISM	EFFECT ON SYSTEM	METHOD OF FAILURE DETECTION	REMARKS
HVAC Supply Fan and Laboratory Calciner Seismic Shutdown	Trip Relays K1, K2, K3, K4	Deenergize fan breakers and actuators manual shutdown system	Contact fails closed	Contact welded shut	Fans will be shutdown by redundant accelerometer system	Testing	Testing should be performed at a time when fans may be shutdown
HVAC Supply Fan and Laboratory Calciner Seismic Shutdown	Trip Relays K1, K2, K3, K4	Deenergize fan breakers and actuators manual shutdown system	Relay deactuated	Coil burned out	Affected fans shutdown	Indicator lights, airflow instrument	Fails Safe
HVAC Supply Fan and Laboratory Calciner Seismic Shutdown	Trip Relays K1, K2, K3, K4	Deenergize fan breakers and actuators manual shutdown system	Contact fails open	Burned contact	Affected fans shutdown	Indicator lights, airflow instrument	Fails Safe
HVAC Supply Fan and Laboratory Calciner Seismic Shutdown	Uninterruptible Power Supply UPS-1 UPS-2	Supplies electrical power to system	Partial or total loss of output power	UPS fault	Shutdown of all fans	UPS alarm, indicator lights, airflow instrument	Fails Safe Static and manual bypasses are available
HVAC Supply Fan and Laboratory Calciner Seismic Shutdown	Uninterruptible Power Supply UPS-1 UPS-2	Supplies electrical power to system	Power restoration	UPS fault	Accelerometer and relays will momentarily reenergize. Fans and air dryers will not restart.	Indicator lights	Fails Safe Fans and air dryers must be manually restarted
HVAC Supply Fan and Laboratory Calciner Seismic Shutdown	Control Power Conduit and Wire CN1157, CN1158	Carry control power to main supply fan breakers and contactors	Short circuits	Conduit crushed	Main Supply Fans will shutdown upon loss of voltage to relays	Visual Inspection	Fails Safe
HVAC Supply Fan and Laboratory Calciner Seismic Shutdown	Control Power Conduit and Wire CN1157, CN1158	Carry control power to main supply fan breakers and contactors	Open circuits	Conduit severed	Main Supply Fans will shutdown upon loss of voltage to relays	Indicator lights, airflow instrumentation, visual inspection	Fails Safe

SYSTEM	COMPONENT IDENTIFICATION	FUNCTION	FAILURE MODE	FAILURE MECHANISM	EFFECT ON SYSTEM	METHOD OF FAILURE DETECTION	REMARKS
HVAC Supply Fan and Laboratory Calciner Seismic Shutdown	Control Power Conduit and Wire CN1160, CN1161 CN1162, CN1163, CN1164, CN1165, CN1168, CN1169	Carry control power to Stage 2 Process Fan breakers and contactors	Short circuits	Conduit crushed	Stage II Fans will shutdown	Visual Inspection	Fails Safe
HVAC Supply Fan and Laboratory Calciner Seismic Shutdown	Control Power Conduit and Wire CN1160, CN1161 CN1162, CN1163, CN1164, CN1165, CN1168, CN1169	Carry control power to Stage 2 Process Fan breakers and contactors	Open circuits	Conduit severed	Stage II Fans will shutdown	Indicator lights, airflow instrumentation, visual inspection	Fails Safe
HVAC Supply Fan and Laboratory Calciner Seismic Shutdown	Indicator Conduit and Wire CN1166, CN1208 CN1211, CN1218	Carry alarm and status signals to HVAC control room.	Short Circuits	Conduit crushed	Disable affected Alarm contacts	Visual inspection, testing	Does not affect shutdown function.
HVAC Supply Fan and Laboratory Calciner Seismic Shutdown	Indicator Conduit and Wire CN1166, CN1208 CN1211, CN1218	Carry alarm and status signals to HVAC control room.	Open circuits	Conduit severed	Disable affected alarm contacts	Visual inspection, testing	Does not affect shutdown function.
HVAC Supply Fan and Laboratory Calciner Seismic Shutdown	Plant Electrical System PNLBD EP-1 XFMR TI CN1140, CN1200 CN1201, CN1205 CN1210	Supply electrical power to Shutdown System.	Loss of output power	System fault	None.	Indicator Lights, annunciate	UPS will maintain shutdown system.

SYSTEM	COMPONENT IDENTIFICATION	FUNCTION	FAILURE MODE	FAILURE MECHANISM	EFFECT ON SYSTEM	METHOD OF FAILURE DETECTION	REMARKS
HVAC Supply Fan and Laboratory Calciner Seismic Shutdown	Outdoor Indicator Light Power Pack Shutdown Warning Light Strobe Power Supply Accelerometer Remote Unit	Verify fans are shutdown.	Failure to illuminate.	Lamp burned out; battery dead	None.	Testing	Does not affect shutdown function.
HVAC Supply Fan and Laboratory Calciner Seismic Shutdown		Sense vibration	Loss of signal	Electrical component failure	Fans will be shutdown by redundant accelerometer	Alarm annunciate	
HVAC Supply Fan and Laboratory Calciner Seismic Shutdown	Accelerometers Electric Support Equipment Accelerometer No. 1 Accelerometer No. 2	Excite accelerometers, condition signal inputs, actuate fan shutdown.	Malfunction of signal converter, logic gate frozen high or low, micro-processor failure, transistor state frozen	Electronic component failure	Fans will be shutdown by redundant accelerometer system.	Testing	
HVAC Supply Fan and Laboratory Calciner Seismic Shutdown	Bypass Switches SS 1 SS 3	Bypass accelerometer during testing to avoid false shutdown of system	Contact fails closed	Contact welded	Fans will be shutdown by redundant accelerometer contact.	Testing	
HVAC Supply Fan and Laboratory Calciner Seismic Shutdown	Bypass Switches SS 1 SS 3	Bypass accelerometer during testing to avoid false shutdown of system	Contact fails closed	Contact burned	Fan will shutdown during test	Indicator lights, airflow instrn	Fails Safe
HVAC Supply Fan and Laboratory Calciner Seismic Shutdown	Seismic Shutdown Control Panel Power Conduit and Wires CN1146, CN1147 CN1206	Energize shutdown system.	Short circuits	Conduit crushed	Power loss to seismic shutdown control panel will cause fan shutdown.	Visual inspection	Fails Safe

SYSTEM	COMPONENT IDENTIFICATION	FUNCTION	FAILURE MODE	FAILURE MECHANISM	EFFECT ON SYSTEM	METHOD OF FAILURE DETECTION	REMARKS
HVAC Supply Fan and Laboratory Calciner Seismic Shutdown	Seismic Shutdown Control Panel Power Conduit and Wires CN1146, CN1147 CN1206	Energize Shutdown system.	Open circuits	Conduit severed	Power loss to seismic shutdown control panel will cause fan shutdown.	Indicator Lights, airflow instrn.	Fails Safe
HVAC Supply Fan and Laboratory Calciner Seismic Shutdown	Accelerometer Unit DCA 333 Power Switch	Energized DCA 333 unit.	Off Position	Operator error	Disable accelerometer fans shutdown by redundant system.	Visual inspection	Administrative controls
HVAC Supply Fan and Laboratory Calciner Seismic Shutdown	Accelerometer Unit DCA 333 Trigger Switch	Testing DCA 333 Unit	Off position	Operator error	Disable trigger signal fans shutdown by redundant system.	Visual inspection	Administrative controls
HVAC Supply Fan and Laboratory Calciner Seismic Shutdown	Accelerometer Calibration	Set trip level.	Set above specification	Earthquake undetected	Fan shutdown by redundant system.	Testing	Administrative controls.
HVAC Supply Fan and Laboratory Calciner Seismic Shutdown	Accelerometer Control Conduit and Wires CN1148, CN1449	Carry alarm signals from accelerometer to seismic shutdown control panel.	Short circuits	Conduit crushed	Fans will be shutdown by redundant accelerometer	Visual inspection, testing.	
HVAC Supply Fan and Laboratory Calciner Seismic Shutdown	Accelerometer Control Conduit and Wires CN1148, CN1149	Carry alarm signals from accelerometer to seismic shutdown control panel.	Open circuits	Conduit severed	Fans will be shutdown.	Visual inspection, indicator lights airflow instrn.	Fails Safe
HVAC Supply Fan and Laboratory Calciner Seismic Shutdown	Test Switches SS 2 SS 4	Simulate accelerometer operation to test trip relays and fan control circuits.	Contact fails closed	Contact welded	System operation normal	Testing	Testing should be performed at a time when the fans may be shutdown.

SYSTEM	COMPONENT IDENTIFICATION	FUNCTION	FAILURE MODE	FAILURE MECHANISM	EFFECT ON SYSTEM	METHOD OF FAILURE DETECTION	REMARKS
HVAC Supply Fan and Laboratory Calciner Seismic Shutdown	Test Switches SS 2 SS 4	Simulate accelerometer operation to test trip relays and fan control circuits.	Contact fails open	Contact burned	Fans will be shutdown	Airflow instrm.	Fails Safe
HVAC Supply Fan and Laboratory Calciner Seismic Shutdown	Accelerometer Power Conduit and Wire CN1171, CN1172	Energize accelerometer.	Short circuits	Conduit crushed	AC power loss to accelerometer with subsequent trip of relays K1 through K6.	Visual inspection	
HVAC Supply Fan and Laboratory Calciner Seismic Shutdown	Accelerometer Power Conduit and Wires CN1171, CN1172	Energize accelerometer	Open circuits	Severed conduit	AC power loss to accelerometer with subsequent trip of relays K1 through K6.	Visual inspection	
HVAC Supply Fan and Laboratory Calciner Seismic Shutdown	Accelerometer Interconnecting Conduit	Provide DC power to accelerometer (DCA 333) and carry trigger signal to output relay.	Short circuits	Conduit crushed	DC power loss to accelerometer (DCA 333) and interrupt trigger signal. Fans will be shutdown by redundant accelerometer	Visual inspection	
HVAC Supply Fan and Laboratory Calciner Seismic Shutdown	Accelerometer Interconnecting Conduit	Provide DC power to accelerometer (DCA 333) and carry trigger signal to output relay	Open circuits	Severed conduit	DC power loss to accelerometer (DCA 333) and interrupt trigger signal. Fans will be shutdown by redundant accelerometer.	Visual inspection	
HVAC Supply Fan and Laboratory Calciner Seismic Shutdown	Trip Relays K5, K6	Deenergize Pilot Relays JY-AZ-1B, JY-AZ-2B	Contact fails closed	Contact welded shut	Power to calciner will be shutdown by redundant pilot relay	Testing	Testing should be performed at a time when calciner is shutdown
HVAC Supply Fan and Laboratory Calciner Seismic Shutdown	Trip Relays K5, K6	Deenergize Pilot Relays JY-AZ-1B, JY-AZ-2B	Relay deactuated	Coil burned out	Power to calciner shutdown	Pilot indicator lights, loss of power to calciner	Fails Safe

SYSTEM	COMPONENT IDENTIFICATION	FUNCTION	FAILURE MODE	FAILURE MECHANISM	EFFECT ON SYSTEM	METHOD OF FAILURE DETECTION	REMARKS
HVAC Supply Fan and Laboratory Calciner Seismic Shutdown	Trip Relays K5, K6	Deenergize Pilot Relays JY-AZ-1B, JY-AZ-2B	Contact fails open	Burned contact	Power to calciner shutdown	Pilot indicator lights, loss of power to calciner	Fails Safe
Laboratory Calciner Seismic Shutdown	Laboratory Calciner Seismic Shutdown System Conduit and Wires CN1227, CN1228, CN1229, CN1230	Carry shutdown signals from Seismic Shutdown Control Panels #1 & #2 to Control Panel TBX-AZ	Short circuits without grounding to conduit	Conduit crushed	Function of one accelerometer negated, other accelerometer still functional	Visual inspection, testing.	Fails Safe
Laboratory Calciner Seismic Shutdown	Laboratory Calciner Seismic Shutdown System Conduit and Wires CN1227, CN1228, CN1229, CN1230	Carry shutdown signals from Seismic Shutdown Control Panels #1 & #2 to Control Panel TBX-AZ	Short circuits with grounding to conduit	Conduit crushed	Loss of Power to Panelboard AZ, with subsequent loss of Air Supply, Heater Power, Backflush Power, Lighting, etc. to Laboratory Calciner	Visual inspection, testing.	Fails Safe
Laboratory Calciner Seismic Shutdown	Laboratory Calciner Shutdown Conduit and Wires CN1227, CN1228, CN1229, CN1230	Carry shutdown signals from Seismic Shutdown Control Panels #1 & #2 to Panelboard AZ	Open circuits	Conduit severed	Loss of Power to Panelboard AZ, with subsequent loss of Air Supply, Heater Power, Backflush Power, Lighting, etc. to Laboratory Calciner	Visual inspection, indicator lights airflow instrumentation.	Fails Safe
Laboratory Calciner Seismic Shutdown	Laboratory Calciner Seismic Shutdown System Conduit and Wires P1A, P1B	Carry electrical power from Panelboard PB to TB-AZ1 and TBX-AZ	Short circuits with grounding to conduit	Conduit crushed	Loss of Power to Panelboard AZ, with subsequent loss of Air Supply, Heater Power, Backflush Power, Lighting, etc. to Laboratory Calciner	Loss of electrical power to Laboratory Calciner, Visual inspection	Fails Safe
Laboratory Calciner Seismic Shutdown	Laboratory Calciner Seismic Shutdown System Conduit and Wires P1A, P1B	Carry electrical power from Panelboard PB to TB-AZ1 and TBX-AZ	Open circuits	Conduit severed	Loss of Power to Panelboard AZ, with subsequent loss of Air Supply, Heater Power, Backflush Power, Lighting, etc. to Laboratory Calciner	Loss of electrical power to Laboratory Calciner, Visual inspection	Fails Safe

SYSTEM	COMPONENT IDENTIFICATION	FUNCTION	FAILURE MODE	FAILURE MECHANISM	EFFECT ON SYSTEM	METHOD OF FAILURE DETECTION	REMARKS
Laboratory Calciner Seismic Shutdown	Control Transformer, CT-AZ	Step-down electrical power from 480 to 120 VAC	Short circuit	Insulation failure	Loss of Air Supply, Heater Power, Backflush Power, Lighting, etc. to Laboratory Calciner	Loss of Power to calciner	
Laboratory Calciner Seismic Shutdown	Control Transformer, CT-AZ	Step-down electrical power from 480 to 120 VAC	Open circuit	Connection failure	Loss of Air Supply, Heater Power, Backflush Power, Lighting, etc. to Laboratory Calciner	Loss of Power calciner, testing	
Laboratory Calciner Seismic Shutdown	Pilot Relays JY-AZ-1B, JY-AZ-2B	Transfer signal from Seismic Shut Down Panel to Power Contactor Relays	Contact fails closed	Relay Contact welded	System shutdown due to double contingency	Testing	Testing should be performed at a time when calciner is shutdown.
Laboratory Calciner Seismic Shutdown	Pilot Relays JY-AZ-1B, JY-AZ-2B	Transfer signal from Seismic Shut Down Panel to Power Contactor Relays	Contact fails open	Relay Contact burned	Loss of power to Panelboard AZ	Pilot lights for Power Contactor Relays	Fails Safe
Laboratory Calciner Seismic Shutdown	Selector Switches SS-AZ-1, SS-AZ-2	Reset Pilot Relays JY-AZ-1B, JY-AZ-2B	Switch fails closed	Switch fails in closed position	Reset of pilot relay upon power restoration	Testing	
Laboratory Calciner Seismic Shutdown	Selector Switches SS-AZ-1, SS-AZ-2	Reset Pilot Relays JY-AZ-1B, JY-AZ-2B	Switch fails open	Switch fails in open position	Pilot relay can not be reset after reset of seismic switches	Testing	Double contingency
Laboratory Calciner Seismic Shutdown	Power Contactor Relays JY-AZ-1A, JY-AZ-2A	Open electrical circuit to Panelboard AZ	Relay Contacts fails closed	Relay Contacts welded	System shutdown due to double contingency	Testing	Testing should be performed at a time when calciner is shutdown.
Laboratory Calciner Seismic Shutdown	Power Contactor Relays JY-AZ-1A, JY-AZ-2A	Transfer signal from Seismic Shut Down Panel to Power Contactor Relays	Relay Contact fails open	Relay Contacts burned	Loss of power to Panelboard AZ	Pilot lights for Power Contactor Relays	Fails Safe
Laboratory Calciner Seismic Shutdown	Calciner Air Supply Solenoids valves A, B	Shutdown of air supply to calciner	Solenoid valve fails closed	Coil failure	Loss of air to calciner	Loss of air to calciner injector nozzle	May result in clogging of inlet nozzle of calciner

SYSTEM	COMPONENT IDENTIFICATION	FUNCTION	FAILURE MODE	FAILURE MECHANISM	EFFECT ON SYSTEM	METHOD OF FAILURE DETECTION	REMARKS
Laboratory Calcliner Seismic Shutdown	Calcliner Air Supply Solenoids valves A, B	Shutdown of air supply to calcliner	Solenoid valve fails open	Valve sticks open	No effect	Testing	Double contingency
Laboratory Calcliner Seismic Shutdown	Power Indicator Lights PL-AZ-1 PL-AZ-2	Indicate power on to Panelboard AZ	Burned out	Failure of light element	No effect	Backup Power Indicator Lights	

ATTACHMENT B

**PROBABILISTIC ASSESSMENT OF
AIR BACKFLOW PREVENTERS FOR
LABORATORY PROTOTYPE CALCINER**

Abbreviations and Acronyms

F	frequency
FSAR	Final Safety Analysis Report
H _v	fragility factor
P	probability
P _{cvr}	random probability of failure of check valve
P _{cvs}	probability of failure of check valve under seismic conditions
P _{solr}	random probability of failure of solenoid valve
P _{sols}	probability of failure of solenoid valve under seismic conditions
PFP	Plutonium Finishing Plant

TABLE OF CONTENTS

1.0 INTRODUCTION.....	B-4
2.0 OFF-GAS FILTERS PROBABILISTIC ANALYSIS	B-5
3.0 INJECTOR NOZZLE PROBABILISTIC ANALYSIS.....	B-7
3.1 Check and Solenoid Valve Seismic Failure Probabilities.....	B-7
3.1.1 Check and Solenoid Valve Fragility Factor	B-7
3.1.2 Check Valve Seismic Failure Probability.....	B-8
3.1.3 Solenoid Valve Seismic Failure Probability.....	B-8
3.2 Random Failure Probability of Valves	B-8
3.2.1 Check Valves Failure Probability	B-8
3.2.2 Solenoid Valve Failure Probability.....	B-9
3.3 Check and Solenoid Valve Failure Rate Due to Seismic Event	B-9
4.0 REFERENCES.....	B-10

LIST OF FIGURES

Figure 1 Laboratory Prototype Calcliner Schematic.....	B-11
Figure 2 Mathcad Worksheet I.....	B-12
Figure 3 Mathcad Worksheet II.....	B-13
Figure 4 Mathcad Worksheet III	B-14
Figure 5 Mathcad Worksheet IV	B-15

1.0 INTRODUCTION

A seismic event has the potential to result in a pressurization of the calciner chamber. This can occur due to compressed air flowing from the accumulator tank into the chamber portion of the calciner through the inlet nozzle or the pulse airflow system for the three calciner off-gas filters. As shown in Figure 1, four solenoid-operated valves are located downstream of the accumulator tank to control airflow into the three-calciner off-gas filters. Upstream from the calciner injector nozzle and rotameter is an electrically operated solenoid valve. There are two backflow preventer check valves upstream from the accumulator tank.

There are two sequence of events by which the calciner chamber can become pressurized after a seismic event occurs. Frequencies are calculated for each of the following sequence of events:

- Calciner Pressurization Through Off-Gas Filters From Accumulator Tank
- Calciner Pressurization Through Injector Nozzle From Accumulator Tank

2.0 OFF-GAS FILTERS PROBABILISTIC ANALYSIS

A seismic event has the potential to result in a pressurization of the calciner due to the filter back-pulse air flowing from the accumulator tank into the filter chamber portion of the calciner. Four solenoid-operated valves are involved in providing back-pulse air to the three calciner off-gas filters and are located downstream of the accumulator tank. The configuration can be represented as follows:

The first valve downstream of the accumulator tank supplies air to the three back-pulse air valves servicing the calciner off-gas filters. Each off-gas filter is supplied back-pulse air by one solenoid-operated valve. Each of these four solenoid-operated valves normally close if electrical power is removed, and actuation of the seismic shutdown system is designed to de-energize all of the solenoid valves.

In order to pressurize the calciner through the off-gas filters during a seismic event, three conditions must be satisfied. These conditions are:

- A seismic event occurs,
- The first solenoid-operated valve (valve A) fails to close upon actuation of the seismic shutdown system, and
- At least one of the three off-gas filter back-pulse air solenoid-operated valves (valves B, C or D) is open at the time of the seismic event and fails to close when electrical power is removed.

The frequency of this event (i.e., pressurizing the calciner through the off-gas filters) is calculated by examining the likelihood of each condition listed above. The first solenoid valve downstream of the accumulator during calciner operation is energized in the open position to provide airflow to the calciner off-gas filter pulse valves. The rate of a solenoid-operated valve failing to change state (close in this case) is given as 2.83×10^{-3} /demand in AIChE 1989. This

value is the mean rate for a failure for the generalized condition of no change of position on demand.

The percent of time that a single filter back-pulse air solenoid-operated valve is open is calculated to be 1.67×10^{-2} . This calculation is based on the programmed cycling of these valves. Each of the off-gas filter valves is cycled open for a maximum of one second each minute to provide a back-pulse of air to the filter and no two valves are open at the same time. Therefore, a back-pulse valve is open less than 2% of the time (i.e., $1\text{s}/60\text{s} = 0.0167$). Conversely, it also means that a back-pulse valve is normally closed 98% of the time. It is assumed that a back-pulse valve that is closed will remain closed (very low likelihood of spurious opening). For conservatism, it will be assumed that if a back-pulse valve is open when an earthquake occurs it will remain open. This assumption is not applied to solenoid valve A based on its different function (one time shutoff rather than continuous cycling).

Therefore, the probability of air continuing to be supplied to the calciner given a demand to isolate the airflow is:

$$P\{T\} = P\{A\} \cdot [(P\{B\} + P\{C\} + P\{D\})]$$

Where $P\{A\}$ is the failure probability of valve A and $P\{B, C, \text{ and } D\}$ is the fraction of time back-pulse valve is open times the probability of failure which is assumed to be one. $P\{T\}$ is the probability. Therefore:

$$P\{T\} = 2.83 \times 10^{-3} \cdot (3 \cdot 1.67 \times 10^{-2} \cdot 1) = 1.42 \times 10^{-4}$$

The frequency of a seismic event of concern is $1 \times 10^{-4}/\text{yr}$ based on the PFP FSAR (HNF 1995).

Combining these values shows that the annual probability of pressurizing the calciner through the off-gas filters is:

$$\text{Annual probability} = (\text{seismic event}) \cdot (\text{combined failure probability of solenoid valves})$$

$$1 \times 10^{-4} / \text{yr} \cdot P\{T\} = 1.42 \times 10^{-8} / \text{yr}$$

This value is clearly well below the category of "beyond extremely unlikely" events and is considered incredible.

3.0 INJECTOR NOZZLE PROBABILISTIC ANALYSIS

A probabilistic analysis was performed to determine the frequency of the pressurization of the calciner from the accumulator tank through the injector nozzle of the calciner during and after a seismic event. This analysis accounts for the failure of two air back-flow-preventer check valves and one solenoid operated valve in the Laboratory Prototype 10L Calciner during a design basis seismic event. The scope of this portion of the probabilistic analysis includes failures of both the check and solenoid valves from random and seismic induced failure modes.

The methodology and results of the PFP Laboratory Prototype Calciner probabilistic analysis of the backflow preventer valves are presented in this section. The calculations for this analysis were performed in Mathcad^{3.0}. The listing of the program is provided in Figures 2 through 5 and will be referred to through out this section.

3.1 Check and Solenoid Valve Seismic Failure Probabilities

3.1.1 Check and Solenoid Valve Fragility Factor

This section describes the methodology used to calculate the probability of failure of both check valves and solenoid valve due to a seismic event. The methodology was obtained from (NUREG 1985) and is associated with the SAFEGURAD Program. The SAFEGUARD Program was undertaken to demonstrate reliability of power and process equipment used in hardened radar installations under shock conditions.

There are two analytical methods presented in (NUREG 1985) for determining fragility factors for components under shock conditions. Methodology A (pg. 4-13) was selected for the valves that are being evaluated. The data used in the evaluation was obtained from Table 7, pg. 4-14 under the generic category "Small miscellaneous valves". The seismic event intensity and frequency used in the calculations was obtained from the PFP FSAR (FDH 1995).

The fragility factor for the backflow preventer check valves and solenoid valve was determined to be:

$$H_V = 10.2$$

A fragility factor of one or greater certifies that this technique can be used in estimating the probability of failure of these valves under seismic conditions. The Mathcad worksheet used in the calculation is provided in Figure 2. This factor can be used in determining the probability of failure under seismic conditions for both the check valves and solenoid valve. These calculations are covered in the next two sections.

3.1.2 Check Valve Seismic Failure Probability

Based on Method A of (NUREG 1985) and a calculated fragility factor of greater than one (Section 3.1.1), a probability of failure of each check valve under seismic conditions was conservatively estimated to be:

$$P_{cvs_i} = 2.3 \times 10^{-2}$$

The Mathcad worksheet used in the calculation is provided in Figure 3.

When more than one component is used to insure reliability of a system function, a common mode failure of identical components must be accounted for. In this case a standard Beta Factor Model (NUREG 1982) was used to conservatively estimate the probability of this mode of failure. The beta factor used to estimate the failure probability was conservatively taken to be one. The resulting common mode failure probability was conservatively estimated to be:

$$P_{cvsc} = 2.3 \times 10^{-2}$$

The Mathcad worksheet used in the calculation is provided in Figure 3.

The seismic induced failure probability of both backflow preventer check valves due to a seismic event accounting for independent and common mode failures is:

$$P_{cvs} = 2.35 \times 10^{-2}$$

3.1.3 Solenoid Valve Seismic Failure Probability

Based on Method A of (NUREG 1985) and a calculated fragility factor of greater than one for "small miscellaneous valves" (Section 3.1.1), a probability of failure of the solenoid valve under seismic conditions was conservatively estimated to be:

$$P_{cvs_i} = 2.3 \times 10^{-2}$$

The Mathcad worksheet used in the calculation is provided in Figure 3.

3.2 Random Failure Probability of Valves

3.2.1 Check Valves Failure Probability

The random failure probability for check valves was obtained from (AICHE 1989). The demand failure probability of "Fails to Close on Demand" is:

$$P_{cvri} = 2.2 \times 10^{-3}$$

The Mathcad worksheet used in the calculation is provided in Figure 4.

When more than one component of the same type and manufacture is used to insure reliability of a system function, a common mode failure of identical components must be accounted for. In this case a standard Beta Factor Model (NUREG 1982) was used to conservatively estimate the probability of this mode of failure. The beta factor used to estimate the failure probability was conservatively taken to be one. The resulting common mode failure probability was conservatively estimated to be:

$$P_{cvrc} = 2.2 \times 10^{-4}$$

The Mathcad worksheet used in the calculation is provided in Figure 4.

The random failure probability of both backflow preventer check valves due to a seismic event accounting for independent and common mode failures is:

$$P_{cvr} = 2.25 \times 10^{-4}$$

3.2.2 Solenoid Valve Failure Probability

The random failure probability for solenoid valve was obtained from (AIChE 1989). The demand failure probability of "Fails to Close on Demand" is:

$$P_{solr} = 2.83 \times 10^{-3}$$

The Mathcad worksheet used in the calculation is provided in Figure 4.

3.3 Check and Solenoid Valve Failure Rate Due to Seismic Event

The failure rate of backflow preventer check valves and solenoid valve to prevent air flow into the 10L Calciner during and after a seismic event is a combination of random failures of the valves, common mode failures, and seismically induced failures. The Mathcad worksheet used in this calculation is provided in Figure 5. The seismically induced failure rate for this combination of valves is:

$$\begin{aligned} F_s &= f_s \cdot \{P_{cvs} + P_{cvr}\} \cdot \{P_{sols} + P_{solr}\} \\ &= (1 \times 10^{-4}) \cdot \{2.35 \times 10^{-2} + 2.25 \times 10^{-4}\} \cdot \{2.3 \times 10^{-2} + 2.83 \times 10^{-3}\} \\ &= 6.14 \times 10^{-8} \end{aligned}$$

This value is clearly in the category of "beyond extremely unlikely" events. No further analysis of this sequence of events is performed.

4.0 REFERENCES

- NUREG/CR-3558, 1985, *Handbook of Nuclear Power Plant Seismic Fragilities*, Lawrence Livermore National Fragilities, Lawrence Livermore National Laboratory, Livermore, California.
- FDH, 1995, *Plutonium Finishing Plant Final Safety Analysis Report*, WHC-SD-CP-SAR-021, Rev. 0-J, September 1995, Westinghouse Hanford Company, Richland, Washington.
- AIChE, 1989, *Guidelines for Process Equipment Reliability Data with Data Tables*, Center for Chemical Process Safety of the American Institute of Chemical Engineers, New York, New York.
- NUREG/CR-2300, 1982, *PRA Procedures Guide*, American Nuclear Society and the Institute of Electrical and Electronics Engineers, U.S. Nuclear Regulatory Commission.
- NUREG/CR-3558, 1988, *Procedures for Treating Common Cause Failures in Safety and Reliability Studies*, Pickard, Lowe, and Garrick, Inc., U.S. Nuclear Regulatory Commission, Electric Power Research Institute.

Figure 1. Laboratory Prototype Calciner Schematic

Figure 2. Mathcad Worksheet 1

PFP 10L CALCINER - BACKFLOW PREVENTOR VALVES SEISMIC FAILURE EVALUATION

I. SEISMIC FRAGILITY FACTOR

**Factors: Lower Bound Fragility Factors, Small miscellaneous Valves (Ref. 1, pg 4-13) -
 Used in generating a conservative estimate of Fragility Factor for seismic event**

$f_{1lower} := 8.00$	Achieved lower acceleration level of test
$f_{2lower} := 0.85$	Similarity of component to be qualified to tested component
$f_{3lower} := 0.70$	Similarity of test conditions to actual expected conditions of component to be qualified
$f_{4lower} := 1.00$	Performance of tested component
$E := 0.20$	Seismic event intensity level (g)
$f_s := 1 \cdot 10^{-4}$	Seismic Event Frequency for the specific intensity (Ref. 2)
$\sigma := 0.05$	Standard Deviation - assumed to be 0.05 g

Fragility Factor (Ref 1, pg 4-13): For the backflow preventor valves of the 10L Calciner the fragility factor is:

$$H_v := \frac{f_{1lower} \cdot f_{2lower} \cdot f_{3lower} \cdot f_{4lower}}{[E + 3 \cdot \sigma]}$$

Fragility Factor Equation

$$H_v = 10.2$$

10L Calciner Fragility Factor

Figure 3. Mathcad Worksheet 2

II. SEISMIC VALVE FAILURE PROBABILITIES

CHECK VALVES

If the fragility factor is above one the component is assigned a 97.7% (3 sigma) or greater probability of survival from the seismic event. Based on this calculation each check valve is assigned a seismic demand failure probability of:

$$p_{cvsi} := 1 - 0.977 \quad \text{Check valve failure probability due to Seismic Event}$$

$$p_{cvsi} = 2.3 \cdot 10^{-2}$$

COMMON MODE Failure - Beta Factor Model (Ref 4, pg 5-51)

The Beta Factor is estimated from Table IV.4.4-1 of Ref 5, pg 168. All of the mean Beta Factors in this table are below one tenth. A conservative value of one-tenth is assumed for the random failure of the check valves.

$$\beta_o := 1 \cdot 10^{-0} \quad \text{Random Seismic Beta Factor (Assumption)}$$

$$p_{cvsc} := \beta_o \cdot p_{cvsi} \quad \text{Seismic Common Mode Failure Probability}$$

$$p_{cvsc} = 2.3 \cdot 10^{-2}$$

Failure probability of both backflow preventer check valves due to seismic event accounting for independent and common mode failures.

$$p_{cvs} := p_{cvsi}^2 + p_{cvsc}$$

$$p_{cvs} = 2.35 \cdot 10^{-2} \quad \text{Total seismic failure probability of both check valves, "Fail to Close on Demand"}$$

SOLENOID VALVE

Based on the fragility factor calculated above for small valves above the solenoid valve is assigned a 97.7% (3 sigma) or greater probability of survival from the seismic event. Based on this calculation the solenoid valve is assigned a seismic demand failure probability of:

$$p_{sols} := 1 - 0.977 \quad \text{Solenoid Valve failure probability due to Seismic Event}$$

$$p_{sols} = 2.3 \cdot 10^{-2}$$

Figure 4. Mathcad Worksheet 3

III. RANDOM VALVE FAILURE PROBABILITIES

CHECK VALVES

Random failure probability for Check Valves (Ref 3, pg 198):

$P_{cvri} := 2.2 \cdot 10^{-3}$
 Random failure probability for check valve,
 "Fails to Close on Demand"

COMMON MODE Failure - Beta Factor Model (Ref 4, pg 5-51)

The Beta Factor is estimated from Table IV.4.4-1 of Ref 5, pg 168. All of the mean Beta Factors in this table are below one tenth. A conservative value of one-tenth is assumed for the random common mode failure of the check valves.

$\beta_p := 1 \cdot 10^{-1}$
 Random Beta Factor

$P_{cvrc} := \beta_p \cdot P_{cvri}$
 Common Mode Failure Probability

$P_{cvrc} = 2.2 \cdot 10^{-4}$

Failure probability of both accumulator check valves accounting for independent and common mode failures.

$P_{cvi} := P_{cvri}^2 + P_{cvrc}$

$P_{cvi} = 2.25 \cdot 10^{-4}$
 Total non-seismic failure rate of both check valves,
 "Fail to Close on Demand"

SOLENOID VALVE

Random failure probability for Solenoid Valve (Ref 3, pg 202):

$P_{solr} := 2.83 \cdot 10^{-3}$
 Random failure probability for solenoid valve,
 "Fails to Close on Demand"

Figure 5. Mathcad Worksheet 4

IV. TOTAL FAILURE RATE OF CALCINER BACKFLOW VALVES

Probability of failure of Backflow Preventer Check Valves and Solenoid Valve to prevent air flow into 10L Calcliner during and after a seismic event.

Frequency of Event = Seismic Event Frequency * Probability of Failure of Check Valves due to (Seismic Event + Random Failure)*Probability of Solenoid Valve due to (Seismic Event + Random Failure)

$$F_s := f_s \cdot [p_{cvs} + p_{cvr}] \cdot [p_{sols} + p_{solr}]$$

$$F_s = 6.14 \cdot 10^{-8}$$

- References:
1. NuReg/CR-3558, 1985, Handbook of Nuclear Power Plant Seismic Fragilities, Lawrence Livermore National Fragilities, Lawrence Livermore National Laboratory, Livermore, California.
 2. WMC, 1995, Plutonium Finishing Plant Final Safety Analysis Report, HNF-SD-CP-SAR-021, Rev. 0-J, Westinghouse Hanford Company, Richland, Washington.
 3. AIChE, 1989, Guidelines for Process Equipment Reliability Data, New York, New York.
 4. NuReg/CR-2300, 1982, PRA Procedures Guide, American Nuclear Society.
 5. NuReg/CR-4780, 1988, Procedures for Treating Common Cause Failures in Safety and Reliability Studies.