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1	1	Proj. Design Eng.	<i>LA Rodgers</i>	3/22/00	LA Rodgers X3-85						
1	1	Cog. Eng.	<i>M.T. Husain</i>	3/22/00	MT Husain X3-74						
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1	1	Engineer	<i>RV Filkowski</i>	3/22/00	RV Filkowski X3-85						

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System Review Of Safety Function Components For The Design Of The Cask/MCO Helium Purge System – Project A.5/A.6

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

Project Hanford Management Contractor for the
U.S. Department of Energy under Contract DE-AC06-96RL13200

Fluor Hanford
P.O. Box 1000
Richland, Washington

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System Review Of Safety Function Components For The Design Of The Cask/MCO Helium Purge System – Project A.5/A.6

B. S. Lew
Fluor Hanford

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Prepared for the U.S. Department of Energy
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Fluor Hanford
P.O. Box 1000
Richland, Washington

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Key Words: Helium Purge System (HPS), lower flammability limit (LFL), Cask/Multiple Canister Overpack (MCO).

Abstract: The design of the Cask/Multiple Canister Overpack (MCO) Helium Purge System (HPS) is assessed for the appropriate designated safety function classification of its components. The purpose of this review is to determine appropriate safety function classifications for the system's components or to identify actions to be taken to reasonably assure that the system/component safety function(s) will be performed as intended. This review also includes consideration that the HPS would perform consistent with its analytical assumptions and basis in HNF-2833, Rev. 0.

SYSTEM REVIEW OF SAFETY FUNCTION COMPONENTS FOR THE DESIGN OF THE CASK/MCO HELIUM PURGE SYSTEM

1.0 PURPOSE AND INTRODUCTION

The design of the Cask/Multiple Canister Overpack (MCO) Helium Purge System (HPS) is assessed for the appropriate designated safety function classification of its components. The purpose of this review is to determine appropriate safety function classifications for the system's components or to identify actions to be taken to reasonably assure that the system/component safety function(s) will be performed as intended. This review also includes consideration that the HPS would perform consistent with its analytical assumptions and basis in HNF-2833, Rev. 0. This review is conducted consistent with intent of Hanford HNF-PRO-704, Table 5 (Reference 1); Spent Nuclear Fuel (SNF) Project AP EN-6-027-01 (Reference 2); and ENG-DI-003, Rev. 0 (Reference 3), Sections 5.2, 6.4.1 (Steps 2 and 3), Table 1, Figures 4, 5 and 6, Attachment A-2, Appendices E and F.

2.0 SYSTEM DESCRIPTION AND OPERATION

HNF-SD-SNF-FRD-025 (Reference 4) and SNF-4889 (Reference 5) describe the HPS, its design and its proposed operation. The Cask/MCO assembly was constructed with no provision for a flow-through purge and a programmatic decision was made to avoid the cost and complexity of an "vacuum/backfill" system. Therefore, the HPS was designed to dilute oxygen concentrations within the Cask/MCO assembly via a series of feed/pressurization and vent/purge cycles prior to establishing the final backfill conditions. The oxygen concentrations in the Cask/MCO are to be reduced to, or below, 1.6 volume percent during normal operations, in accordance with the Functions and Requirements (F&R) document, HNF-SD-SNF-FRD-025 (Reference 4).

The HPS consists of helium supply bottles (located on the west outside wall of the K-Basins), piping, valves, pressure gages, vent pipe, and HEPA filters. The HPS will feed/vent the atmosphere in the Cask/MCO headspace with helium at approximately 30 psig. (See Figure 1, Piping and Instrumentation Drawing (P&ID)). The 30-psig pressure will be held for several minutes before the pressure is vented down to approximately 3 psig. This vent purge operation will be repeated several times in order to lower the oxygen concentration inside the Cask/MCO head's space below required oxygen concentrations levels, 1.6 volume percent.

A weather protected helium supply bottle rack [the bottles will be filled from the same quality helium specified for use in the Cold Vacuum Drawing Facility (CVDF) Design Requirements Document HNF-SD-SNF-DRD-002, Reference 6], will be installed on the outside west wall of the K Basins near the north west corner of the building. This rack will hold 2 bottles (one in use and one as a backup). One 249 standard cubic feet (scf) bottle of helium contains enough gas to perform approximately 4 to 5 Cask/MCO feed/vent cycles or 14 1/2 loaded casks.

The bottle rack is equipped with a manifold and supply pressure regulator (CLS-Reg-1) set at 80 psig. Downstream of CLS-Reg-1 is a second pressure regulating device set at 30psig. Immediately following CLS-PRV-1 is a 50 psig relief valve and a 65 psig rupture disk (the cask design pressure is 150 psig).

A 1/4 inch or 3/8 inch tubing will be routed from the helium supply, along the inside building wall and under the walkway, to the Cask/MCO loading station, where an electrically operated supply valve is located. Following the valve will be a 'T' with one side going to the cask connection and the other side to the system exhaust. Solid tubing will be routed to a specific location where a section of flexible tubing with a Hanson quick disconnect will provide the connection to the cask.

The exhaust portion of the system consists of a pressure-indicating transmitter close to the 'T'. A back pressure valve set at 3 psig, a electrically operated exhaust valve, and two canister HEPA filters. The system will exhaust approximately two to three cubic feet of the air/helium gas mixture per feed/vent cycle near the Basin ceiling.

Controls for this system consist of a selection-position switch and a pressure indicator integrated into one of the Cask/MCO loading control closures.

3.0 SYSTEM AND COMPONENT FUNCTIONS AND DESIGNATED CLASSIFICATIONS

HNF-SD-SNF-FRD-025 (Reference 4) and SNF-4889 (Reference 5) provide the system and component function of the HPS, along with their designated classifications. The overall function of the HPS is to preclude flammable gas mixtures within the Cask/MCO assembly while it is being transferred from the basin to the CVDF. The oxygen concentrations in the Cask/MCO are to be reduced to, or below, 1.6 volume percent during normal operations, in accordance with the F&R document, HNF-SD-SNF-FRD-025. (Reference 4) This is accomplished by feeding and venting the air in the Cask/MCO headspace with helium to dilute its oxygen concentration. The oxygen-limited atmosphere is necessary since generation of hydrogen within the Cask/MCO can not be controlled to be within its lower flammability limit (LFL) when the Cask/MCO is shipped.

Secondly, Chapter 5 of SAR 3L (Reference 8) and Technical Safety Requirement (TSR) document (Reference 9) have administrative controls which specify that the cask/MCO be pressurized to 2-3 psi. This is to preclude the ingress of air into the internal volume of the cask/MCO and the evolution of flammable gas mixtures within the Cask/MCO assembly while it is being transferred from the basin to the CVDF. A function of the HPS is to measure the pressure of the cask/MCO prior to its departure from the K Basins.

3.1 CLASSIFICATIONS AND FUNCTIONS

The HPS is classified as a general service (GS) system. However, two items are to be classified as safety significant; the 65 psig rupture disk and the Cask/MCO purge pressure-indicating system.

The rupture disk is designated safety significant to assure that the cask internal pressure will be below the CVDF vent system design pressure of 150 psig. In addition, the rupture disk (actuates at 65 psig) protects the cask by ensuring that the cask design pressure (150 psig) is not exceeded. The purge pressure indicating system (PIT and PG) is designated Safety Significant (with appropriate TSR controls). These functions were to assure that the cask is feed/purged with helium (pressurized to a sufficient feed pressure, ~30 psi, and purged to a sufficient vent pressure, ~3 psi) to a sufficient cask/MCO exit pressure, ~2-3 psi. These are safety-significant functions for shipping and CVDF.

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3.2 PROPOSED OPERATIONS

Feed/vent operations are started with the operator pressing and holding a control switch to the purge position until the pressure in the Cask/MCO reaches 30 psig. The operator then releases the control switch to the purge position, notes that the pressure holds at 30 psig, and logs the pressure on the appropriate data sheet. The operator allows the pressure to stay at 30 psig for at least 2 minutes. At this time, the operator presses and holds the control switch to exhaust position until the pressure gage indicates 2.5 psig. The operator logs the feed/vent cycle is completed and performs the cycle for a total of five times, consistent with the analytical basis in HNF-2833, Rev. 0 (Reference 7) and in HNF-SD-SNF-OCD-001, Rev. 4 (Reference 10).

TABLE 1: DESIGNATED SAFETY SIGNIFICANT FUNCTIONS

Component	Function	Mode	Safety Class	Comment
HPS	Feeds/vents the Cask/MCO with sufficient volumes of an inert helium gas to preclude flammable gas mixtures within the Cask/MCO assembly by limiting the oxygen concentration in the Cask/MCO atmosphere below LFL concentrations	Active	GS	Overall system function
PT-430-1 pressure transmitter	<ul style="list-style-type: none"> - Measures Cask/MCO pressure during feed and cycles to be consistent with analytical bases, HNF-2833 - Measures Cask/MCO exit pressure prior to departure from K Basins, consistent with TSR administrative controls, HNF-SD-SNF-TSR-001 and HNF-SD-SNF-OCD-001, Rev 4 	Active	SS	Designated safety-significant function for shipping and CVDF
PI-430-1 Pressure indicator	Measures Cask/MCO pressure during feed and cycles to be consistent with analytical bases, HNF-2833	Active	SS	Designated safety-significant function for shipping and CVDF
CLS-V-8 Rupture disk-	Actuates at 65 psig to assure that the cask internal pressure is below the CVDF vent system design pressure of 150 psig	Active	SS	designated safety significant not exceed cask internal design pressure, 150 psig

4.0 FUNCTIONAL AND FAILURE MODES ASSESSMENT

HPS components were assessed consistent with HNF-PRO-704, Table 5 (Reference 1) and ENG-DI-003, Rev. 0 (Reference 3), Sections 5.2, 6.4.1 (Steps 2 and 3), Table 1, Figures 4 and 5, Attachment A-2, Appendices E and F. The HPS is assessed in a top down approach to determine which HPS components perform or support the HPS system functions. This review also considers whether the HPS performance is consistent with its analytical basis in HNF-2833, Rev. 0. Each system component's active and passive functions are reviewed to determine their role in performing/supporting the overall HPS system functions. Since this was a relatively simple system, it was not necessary to review individual sub-systems and their components. In this case, it was necessary to only review the system's individual components which perform/support the specific HPS feed and vent system functional cycles.

Similarly, a simple failure modes and effect analysis was performed for the system by viewing the system using a bottom up approach. From the component level, credible component failure modes were identified that could affect the system or individual component's to perform their intended functions. The active or passive functions of components were identified and assessed. Component failure modes that could affect component level functions that support the system functions were identified. Failure modes of helium lines by corrosion, mechanical impacts or natural phenomena; by electrical failures; and by component electrical or mechanical failures were considered by engineering judgement.

To address such failure modes, mitigating actions were identified or the failure modes were assessed for the impact on component functions or on overall system functions. This actions included making the component whose failure could affect a safety significant function as safety significant or recommend other mitigative compensating actions which provide reasonable assurance that system or component safety significant functions would perform as intended.

4.1 ASSESSMENT OF ACTIVE FUNCTIONS

4.1.1 Helium Supply

The supply of helium gas is provided by dual gas bottles from a bottle station using an automatic bottle change over manifold (CLS-Reg-1). These bottles provide ~250 ft³ of gas at a maximum of 2200 psi for a redundant and backup source of helium supply for HPS. The supply and quality requirements for the supply of the helium bottles is assumed to be provided by the same supplier of helium gas bottles to CVDF and CSB. This should assure the same high helium purity gas quality to the HPS as need by CVDF and CSB applications for 99.97% purity from helium supply gas bottles. The system supply purity is designated at 99.5% purity to the HPS. The impact of He purity to the HPS on the number of feed/vent cycles is discussed below. Maximum gas pressure from the bottles through the manifold is 2200 psi.

The piping from the station manifold to the pressure regulator is GS. This GS piping is rated at 150 psi and provides a passive boundary pathway to the HPS components. Failure of this GS piping from CLS-Reg-1 to CLS-PRV-1 or to CLS-SOV-1 on the function of the system and to component is considered in Section 4.2.1.

TABLE 2: HPS COMPONENT ACTIVE AND PASSIVE FUNCTIONS-HE SUPPLY

Component	Function	Mode	Safety Class	Comment	FMEs*
Helium tank gas bottles	Provide ~250 ft ³ of gas at maximum 2200 psi for a redundant and backup source of helium supply	Active	GS	Supplied as SS or SC to other SNF Project Facilities	Possible
CLS-Reg-1 Manifold	<ul style="list-style-type: none"> - Performs automatic bottle change over between the two (2) bottles in the station - pressure regulation from gas bottle pressure to 80 psig 	Active	GS	Provides operational flexibility and He gas pressure regulation	Possible
Helium gas purity	Assure high purity of HPS helium gas supply, consistent with the helium gas purity requirements at CVDF and CSB for 99.97% purity from the gas bottle source	Passive	GS	Supply & quality reqt's of the helium bottles to be same as to CVDF and CSB	Yes
Piping	Provides a passive boundary pathway of gas from the bottles to the HPS components	Passive	GS	Commercial grade piping is rated at 150 psi	Possible

* If GS, does the component have a significant failure mode and effect that could impact critical system or component functions or affect worker safety? If possible, failure mode and effects evaluation is assessed in Section 4.2

4.1.2 Pressure Regulation and Overpressure Protection

The GS pressure regulator (CLS-PRV-1) steps down the gas pressure from maximum 2200 psi to 80 psig and CLS-PRV-1 steps down the pressure from 80psig to 30 psig. Pressure is indicated by GS pressure instrumentation (PI-430-1). Failure of GS piping and the GS pressure instrumentation (PI-430-1) downstream of CLS-PRV-1 to CLS-SOV-1 on the function of the system and/or components is considered in Section 4.2.2.

Downstream of CLS-PRV-1 are GS pressure relief valve (CLS-SRV-1), a SS rupture disk (CLS-V-8) and GS pressure indication (PI-430-3). GS pressure relief valve (CLS-SRV-1) vents to atmosphere at 50psig and is a mechanical relief type valve with commercial grade rating of stamped 50psi for pressure control. Since an SS rupture disk is downstream of this valve whose function is to provide pressure relief below the set point of the rupture disk, its pressure relief function is not a critical function of the system. CLS-V-8 is an SS rupture disk specified to ASME Section VIII, Div. 1 at +/- 10%. It vents to atmosphere and provides reasonable assurance that it will perform its intended safety significant function (to provide pressure relief at 65 psig +/- 10% and thereby protect HPS overpressure of the Cask/MCO system) during HPS performance. GS pressure indication (PI-430-3) is a bourdon tube type indicator and has commercial grade readings from 0 to 100 psig. Since the system does not rely on this indication for any of its functions, this indication is not a critical function of the system. Failure of GS CLS-SRV-1 and GS PI-430-3 on the function of the system and/or components is considered in Section 4.2.2.

TABLE 3: HPS COMPONENT ACTIVE AND PASSIVE FUNCTIONS- PRESSURE REGULATION AND OVERPRESSURE PROTECTION

Component	Function	Mode	Safety Class	Comment	FMEs*
CLS-Reg-1 Pressure regulator	Steps down the gas pressure from the bottles at maximum 2200 psig to 80 psig	Active/ Passive	GS	He gas bottles are supplied with high purity req'ts to other SNF Project Facilities	Possible
CLS-PRV-1	Steps down the gas pressure from 80 psig to 30 psig	Active/ Passive	GS	High quality commercial grade item	Not Likely
PI-430-1	Provides secondary pressure indication on the down side of the regulator	Active	GS	~30 psig	Not Likely
Piping	Provides a passive boundary pathway of gas to the HPS components	Passive	GS	- Commercial grade piping is rated at 150 Psig - ~30 psig	No
CLS-SRV-1 Pressure valve	Actuates at 50 psig and is designated GS to assure that the cask internal pressure will be below the CVDF vent system design pressure of 150 psig. Functions such that the rupture disk will not need to be actuated	Active	GS	Actuates at a setpoint 15 psig lower than the rupture disk	Not Likely
CLS-V-8 Rupture disk	Actuates at 65 psig +/- 10% and is designated SS to assure that the cask is not over pressurized	Active	SS	Cask pressure limit is 150 psig	SS
PI-430-3 / CLS-V-2	Indicates gas pressure on the down side of the regulator. Provides secondary indication to PI-430-1 down stream of CLS-SOV-1	Active PI/ Passive valve	GS	Manually operated valve to be open for pressure indication	Not Likely

* If GS, does the component have a significant failure mode and effect that could impact critical system or component functions or affect worker safety? If possible, failure mode and effects evaluation is assessed in Section 4.2

4.1.3 Helium Supply to the Cask/MCO during the Feed Cycle

GS valve CLS-SOV-1 is a normally closed valve; GS valve CLS-SOV-2 is a normally open valve; and the port/quick-connect valve, Quick Disconnect, on the Cask/MCO lid is closed. During the HPS helium supply to the Cask/MCO during the feed cycle, CLS-SOV-1 is powered to be open; CLS-SOV-2 is powered to be closed; and port/quick-connect valve, Quick Disconnect, on the Cask/MCO lid is opened. The pressure in these lines is verified by SS pressure transmitter, PT-430-1, and SS pressure indicator, PI-430-1. This fills the lines

downstream of CLS-SOV-1 and up steam of CLS-SOV-2 with helium to the GS port/quick-connect valve, Quick Disconnect, on the Cask/MCO lid. This fills the Cask/MCO volumes with helium to 30 psi.

PT-430-1 and PI-430-1 are SS pressure transmitter and a SS pressure indicator, respectively. These provide pressure indication of the pressure in the HPS line-Cask/MCO volume with reasonable assurance that they will perform their its intended safety significant function (to indicate pressure and thereby confirm to the analytical basis of HNF 2833, Rev. 0) during HPS performance.

GS valves CLS-SOV-1 and CLS-SOV-2 are electrical powered direct lift type valves with commercial grade ratings of greater than 150psi for valve control. These valves are energized to change position for the system to perform its intended function. Quick Disconnect is a manual valve with passive pressure boundary functions. A failure of GS components CLS-SOV-1, CLS-SOV-2 and Quick Disconnect on the function of the system and/or components is considered in Section 4.2.3.

TABLE 4: HPS COMPONENT ACTIVE AND PASSIVE FUNCTIONS- HELIUM SUPPLY TO THE CASK/MCO DURING THE FEED CYCLE

Component	Function	Mode	Safety Class	Comment	FMEs*
CLS-SOV-1 normally closed valve	Normally closed valve is energized Open for helium feed to the Cask/MCO	Active	GS	CLS-SOV-1, CLS-SOV-2 & HS-430-2 must perform their function for the HPS to feed the Cask/MCO	Possible
CLS-SOV-2 normally open valve	Normally open valve is energized Closed for helium feed to the Cask/MCO	Active	GS		Possible
HS-430-2	Provides power to CLS-SOV-1 & CLS-SOV-2 to change their position for helium feed cycle	Active	GS		Possible
CLS-SRV-1 Pressure valve	Actuates at 50 psig and is designated GS to assure that the cask internal pressure will be below the CVDF vent system design pressure of 150 psig. Functions such that the rupture disk will not need to be actuated	Active	GS	Actuates at a setpoint 15 psig lower than the rupture disk	Not Likely
CLS-V-8 Rupture disk	Actuates at 65 psig and is designated SS to assure that the cask is not over pressurized	Active	SS	Cask pressure limit is 150 psig	SS
PI-430-3 / CLS-V-2	Indicates gas pressure on the down side of the regulator. Provides secondary indication to PI-430-1 up stream of CLS-SOV-1	Active PI/ Passive valve	GS	Manually operated valve to be open for pressure indication	Not Likely

TABLE 4: HPS COMPONENT ACTIVE AND PASSIVE FUNCTIONS- HELIUM SUPPLY TO THE CASK/MCO DURING THE FEED CYCLE

Component	Function	Mode	Safety Class	Comment	FMEs*
Quick Disconnect quick-connect valve	Connection of flexible hose off of the HPS to the Cask/MCO lid	Manual	GS	Manually operated on the Cask/MCO lid	Not Likely
PT-430-1 Pressure transmitter	Measures Cask/MCO pressure during feed and cycles to be consistent with analytical bases, HNF-2833	Active	SS	Designated safety-significant function for shipping and CVDF	SS
PI-430-1 Pressure indicator	- Measures Cask/MCO pressure during feed and cycles to be consistent with analytical bases, HNF-2833 - Measures Cask/MCO exit pressure prior to departure from K Basins, consistent with TSR administrative controls, HNF-SD-SNF-TSR-001 and HNF-SD-SNF-OCD-001, Rev 4	Active	SS	Designated safety-significant function for shipping and CVDF	SS
PI-430-4 / CLS-V-3	Indicates gas pressure on the down side of the CLS-SOV-1. Provides secondary indication to PI-430-1 down stream of CLS-SOV-1	Active PI / Passive valve	GS	Manual valve to be open for pressure indication	Not Likely
CLS-V-5 Hand valve	Provides low point for system drainage	Manual	GS	Manually operated, but should procedurally checked to be closed prior to HPS usage	No
CLS-V-1 Hand valve	Provides manual isolation capability for maintenance and inspection	Manual	GS	Manually operated, but should procedurally checked to be open prior to HPS usage	No
Piping	Provides a passive boundary pathway of gas to the HPS components.	Passive	GS	- Commercial grade piping is rated at 150 psig. - ~30 psig	No

* If GS, does the component have a significant failure mode and effect that could impact critical system or component functions or affect worker safety? If possible, failure mode and effects evaluation is assessed in Section 4.2

As described above, the supply and quality requirements for the supply of the helium bottles is assumed to be provided by the same supplier of helium gas bottles to CVDF and CSB. This should assure the same gas quality to the HPS consistent with the helium gas purity requirements

of 99.97% purity from the gas supply bottles to the CVD and CSB facilities. Given potential supply line and other supply system connections to the HPS, the helium supply purity to the HPS is assumed to be 99.5% purity. The analytical basis for four (4) feed/purge cycles to achieve minimum O₂ requirements in the cask/MCO of less than 2% with 100% helium supply to the HPS system is in HNF-2833, Rev. 0. However, the oxygen concentration requirements in the Cask/MCO are to be at or below, 1.6 volume percent during normal operations (HNF-SD-SNF-FRD-025, Reference 4) and using a requirement for helium supply purity of 99.5% to the HPS. The impact of He purity of 99.5% to the HPS on the number of feed/vent cycles to satisfy this limit is small and can be seen in Appendix A. However, the results of the HNF-2833 Rev. 0 were already close to limits in satisfying its requirements of being below 2 volume percent with 100% helium supply. The impact of the 99.5% He purity and the change of 2 to 1.6 volume percent changes the number of feed/vent cycles to achieve 1.6 volume percent oxygen with 99.5% He purity is five (5), see Appendix A. This is consistent with the fuel product specification document, HNF-SD-SNF-OCD-001, Rev. 4, which states greater than or equal to 5 cycles with the upper pressure greater than or equal to 27 psig and the bottom pressure between 1 and 3 psig.

4.1.4 Cask/MCO Atmosphere Release from the Cask/MCO during the Vent Cycle

GS valve CLS-SOV-1 is a normally closed valve; GS valve CLS-SOV-2 is a normally open valve; and the port/quick-connect valve, Quick Disconnect, on the Cask/MCO lid is closed. During the HPS venting of the Cask/MCO atmosphere volume during the vent cycle, CLS-SOV-1 is not energized and is normally closed; CLS-SOV-2 is not energized and is normally open; and port/quick-connect valve, Quick Disconnect, on the Cask/MCO lid is opened or remains open. The pressure in these lines is verified by SS pressure transmitter, PT-430-1, and SS pressure indicator, PI-430-1. This operation vents the lines downstream of CLS-SOV-1 and up stream of CLS-SOV-2 of the Cask/MCO atmosphere down to 3 psi. Failure of GS components CLS-SOV-1, CLS-SOV-2, PI-430-4, PDI-430-5 and piping on the function of the system and/or components is considered in Section 4.2.4.

PT-430-1 and PI-430-1 are SS pressure transmitter and a SS pressure indicator, respectively. These provide pressure indication of the pressure in the HPS line-Cask/MCO volume with reasonable assurance that they will perform their its intended safety significant function (to indicate pressure and thereby conform to the analytical basis of HNF 2833, Rev. 0) during HPS performance.

GS valves CLS-SOV-1 and CLS-SOV-2 are electrical powered direct lift type valves to change from their normal position with commercial grade ratings of 150psi for valve control and mechanical spring force to return to their normal position. For the HPS vent cycle function, these valves are not energized and in their normal position. The failure of these valves to concurrently be in their normal position on demand will affect the HPS ability to perform its function during the vent cycle. However, it is reasonable that the valves will be in their normal position when not energized, since this is not an active function to be in their normal position.

**TABLE 5: HPS COMPONENT ACTIVE AND PASSIVE FUNCTIONS - CASK/MCO
ATMOSPHERE RELEASE FROM THE CASK/MCO DURING THE VENT CYCLE**

Component	Function	Mode	Safety Class	Comment	FMEs*
CLS-SOV-1 normally closed valve	Normally closed valve is Closed helium vent to the Cask/MCO	Passive	GS	CLS-SOV-1, CLS-SOV-2 & HS-430-2 must not be energized for the HPS to vent the Cask/MCO	Not Likely
CLS-SOV-2 normally open valve	Normally open valve is Open for helium vent to the Cask/MCO	Passive	GS		Not Likely
HS-430-2	Not energized for vent cycle	Passive	GS		Not Likely
Quick Disconnect Quick-connect valve	Connection of flexible hose off of the HPS to the Cask/MCO lid	Manual	GS	Manually operated on the Cask/MCO lid	Not Likely
PT-430-1 Pressure transmitter	Measures Cask/MCO pressure during feed and cycles to be consistent with analytical bases, HNF-2833	Active	SS	Designated safety-significant function for shipping and CVDF	SS
PI-430-1 Pressure indicator	Measures Cask/MCO pressure during feed and cycles to be consistent with analytical bases, HNF-2833	Active	SS	Designated safety-significant function for shipping and CVDF	SS
CLS-V-7	Regulates pressure to 3 psig to assure feed/venting is consistent with analytical basis, HNF-2833	Active	GS	Vents to atmosphere via two (2) HEPA filters	Not Likely
PI-430-4 / CLS-V-3	Indicates gas pressure on the up stream of Quick Disconnect. Provides secondary indication to PI-430-1.	Active	GS	Designated safety-significant function for shipping and CVDF	GS
CLS-V-5 Hand valve	Provide low point for system drainage	Manual	GS	Manually operated, but should procedurally checked prior to HPS usage	Not Likely
Piping	Provides a passive boundary pathway of gas to the HPS components. Recommend pressure data recorder to assure consistency with analytical basis, HNF2833, where pressure does NOT reduce <3psig due to losses in pressure boundary integrity.	Passive	GS	- Commercial grade piping is rated at 150 psig - ~30 to ~3 psig	No

TABLE 5: HPS COMPONENT ACTIVE AND PASSIVE FUNCTIONS - CASK/MCO ATMOSPHERE RELEASE FROM THE CASK/MCO DURING THE VENT CYCLE

Component	Function	Mode	Safety Class	Comment	FMEs*
PDI-430-5 / CLS-V-4	Indicates differential gas pressure across HEPA filters CLS-HEPA-F-1 and CLS-HEPA-F-2	Active PI/ Manual valve	GS	Manually operated valve to be open for pressure indication	Not likely
CLS-HEPA-F-1 & CLS-HEPA-F-2 HEPA filters	Filter potential radiological particulates from the Cask/MCO prior to release of Cask/MCO atmosphere to the environment	Passive	GS	Max credible releases from the HEPA filters should be evaluated to determine their safety class to worker safety	Possible

* If GS, does the component have a significant failure mode and effect that could impact critical system or component functions or affect worker safety? If possible, failure mode and effects evaluation is assessed in Section 4.2

4.1.5 Measure Cask/MCO Pressure Prior to Departure from K Basins

GS valve CLS-SOV-1 is a normally closed valve; GS valve CLS-SOV-2 is a normally open valve; and the port/quick-connect valve, Quick Disconnect, on the Cask/MCO lid is closed. During the cask/MCO pressure measurement of the Cask/MCO atmosphere volume prior to departure from K Basins, CLS-SOV-1 is not energized and is normally closed; CLS-SOV-2 is energized and is closed; and port/quick-connect valve, Quick Disconnect, on the Cask/MCO lid is opened or remains open. The pressure in these lines to the cask/MCO is measured by SS pressure transmitter, PT-430-1, and SS pressure indicator, PI-430-1. This operation uses a closed system of the lines downstream of CLS-SOV-1 and up stream of CLS-SOV-2 of the Cask/MCO. Failure of GS components CLS-SOV-1, CLS-SOV-2, PI-430-4, PDI-430-5 and piping on the function of the system and/or components is considered in Section 4.2.4.

PT-430-1 and PI-430-1 are SS pressure transmitter and a SS pressure indicator, respectively. These provide pressure indication of the pressure in the HPS line-Cask/MCO volume with reasonable assurance that they will perform their its intended safety significant function (to indicate exit pressure in the cask/MCO in compliance with TSR administrative controls, HNF-SD-SNF-TSR-001 and HNF-SD-SNF-OCD-001, Rev 4) during HPS performance.

GS valves CLS-SOV-1 and CLS-SOV-2 are electrical powered direct lift type valves to change from their normal position with commercial grade ratings of 150psi for valve control and mechanical spring force to return to their normal position. For the HPS pressure measurement function, CLS-SOV-1 is not energized and is normally closed; CLS-SOV-2 is energized and is closed. The failure of these valves to be in these positions on demand will affect the HPS ability to perform its measure function. However, it is reasonable that CLS-SOV-1 will be in its normal position when not energized, since this is not an active function to be in their normal position. Failure of CLS-SOV-2 to energize and close will cause the cask/MCO to depressurize to atmospheric pressure. In this case, CLS-SOV-2 will need to be repaired and a feed or feed/purge cycle will need to be performed to re-pressurize the cask/MCO to 2-3 psig.

TABLE 6: HPS COMPONENT ACTIVE AND PASSIVE FUNCTIONS - CASK/MCO PRESSURE MEASUREMENT OF THE CASK/MCO PRIOR TO DEPARTURE FROM K BASINS

Component	Function	Mode	Safety Class	Comment	FMEs*
CLS-SOV-1 normally closed valve	Normally closed valve is Closed for pressure measurement of Cask/MCO	Passive	GS	CLS-SOV-1 (closed) must not be energized and CLS-SOV-2 must be energized for the HPS to measure Cask/MCO pressure	Not Likely
CLS-SOV-2 normally open valve	Normally open valve is Closed for pressure measurement of Cask/MCO	Passive	GS		Not Likely
HS-430-2	None for pressure measurement	None	GS		No Impact
Quick Disconnect Quick-connect valve	Connection of flexible hose off of the HPS to the Cask/MCO lid	Manual	GS	Manually operated on the Cask/MCO lid	Not Likely
PT-430-1 Pressure transmitter	Measures Cask/MCO pressure consistent with TSR administrative controls, HNF-SD-SNF-TSR-001 and HNF-SD-SNF-OCD-001, Rev 4	Active	SS	Designated safety-significant function for shipping and CVDF	SS
PI-430-1 Pressure indicator	Measures Cask/MCO pressure consistent with TSR administrative controls, HNF-SD-SNF-TSR-001 and HNF-SD-SNF-OCD-001, Rev 4	Active	SS	Designated safety-significant function for shipping and CVDF	SS
CLS-V-7	None for pressure measurement	None	GS	CLS-SOV-2 is closed	No Impact
PI-430-4 / CLS-V-3	Indicates gas pressure on the down stream of Quick Disconnect . Provides secondary indication to PI-430-1.	Active	GS	Designated safety-significant function for shipping and CVDF	GS
CLS-V-5 Hand valve	Provide low point for system drainage	Manual	GS	Manually operated, but should procedurally checked prior to HPS usage	Not Likely
Piping	Provides a passive boundary pathway of gas to the HPS components. Recommend pressure data recorder for data to comply with TSR administrative controls, HNF-SD-SNF-TSR-001 and HNF-SD-SNF-OCD-001, Rev 4	Passive	GS	- Commercial grade piping is rated at 150 psig - ~30 to ~3 psig	No

TABLE 6: HPS COMPONENT ACTIVE AND PASSIVE FUNCTIONS - CASK/MCO PRESSURE MEASUREMENT OF THE CASK/MCO PRIOR TO DEPARTURE FROM K BASINS

Component	Function	Mode	Safety Class	Comment	FMEs*
PDI-430-5 / CLS-V-4	None for pressure measurement	None	GS	CLS-SOV-2 is closed	No Impact
CLS-HEPA-F-1 & CLS-HEPA-F-2 HEPA filters					
PDI-430-5 CLS-V-4 CLS-V-6					

* If GS, does the component have a significant failure mode and effect that could impact critical system or component functions or affect worker safety? If possible, failure mode and effects evaluation is assessed in Section 4.2

4.2 ASSESSMENT OF FAILURE MODES

The following documents the failure modes and effects of the failures of different components in the HPS. In this analysis, only one single failure was assumed (with other components, including GS components, assumed to function as designed) and components designated SS classification were not considered to fail.

4.2.1 Failures in Helium Supply

Failures in the GS components which perform helium supply and pressure step involve the He-TK-1 or He-TK-2 gas bottles, CLS-Reg-1 manifold, CLS-PRV-1 regulator, PI-430-1 pressure instrument or GS piping from CLS-Reg-1 to CLS-PRV-1 or to CLS-SOV-1.

Failures in the GS components up stream of the Regulator (CLS-PRV-1) involve He-TK-1 or He-TK-2 gas bottles or CLS-Reg-1 manifold. Failure in these components would impact the ability of the HPS to provide helium pressure and, depending on their specific failure mode, may impact worker safety in the local areas around the gas bottle station. However, the current design has the gas bottle station outside of the basins area and located where workers are not generally located. As such, worker safety is not impacted by failures in these components and these components are not classified to safety significant for worker safety.

TABLE 7: HPS COMPONENT FMEA-HE SUPPLY

Component	Credible Failure*	Function	Failure Mode(s)**	Effect on System Functions	Comment
Helium Gas bottles	Possible	Provide ~250 ft ³ of gas at maximum 2200 psi for a redundant and backup source of helium supply	bottle valve failures lead to missiles	- Impact supply of He - worker safety	- ~maximum 2200 psig - bottle supplier same as CVD & CSB
CLS-Reg-1 Manifold	Possible	Performs automatic bottle change over between the two (2) bottles in the station	fracture of manifold valves, piping or connections	- Impact supply of He	HPS inoperable until repaired
Helium gas purity	Possible	Assure high purity of HPS helium gas supply, ~99.5%	low purity of He	- potential contamination of Cask/MCO - inconsistent with HNF-833	Should use same supplier / contact as CVDF & CSB
Piping	Possible	Provides a passive boundary pathway of gas from the bottles to the HPS components	brittle fracture	- Impact supply of He	- ~maximum 2200 psig - HPS inoperable until repaired

* If GS, does the component have a significant failure mode and effect that could impact critical system or component functions or affect worker safety? If possible, failure mode and effects evaluation is assessed in Section 4.2

** See Table 4 of Eng-DI-003, Rev 0, for a list of typical failure modes

4.2.2 Failures during Pressure Regulation and Overpressure Protection

Failures in components down stream of the Regulator, CLS-PRV-1 are assessed with CLS-SOV-1 closed and CLS-SOV-1 open. With CLS-SOV-1 open, the failures of the CLS-PRV-1 regulator during Pressure Regulation and Overpressure Protection, and during Helium Supply to the Cask/MCO during the Feed Cycle are similar to Failures in Helium Supply and Pressure Step down in regard to their impact on the Cask/MCO. As such, these are discussed in this Section.

CLS-SOV-1 Closed

With CLS-SOV-1 closed, failures in these components would interrupt helium supply and pressurization to 30 psig up stream of CLS-SOV-1.

Failure of the regulator would pressurize this part of the HPS to the pressure in the gas bottles, or at a maximum to 2200 psi. The effect of this pressurization is mitigated by the GS CLS-SRV-1 at 50 psig. In the event of CLS-SRV-1 failure to actuate, the SS rupture disk (CLS-V-8) at 65

psig mitigates this pressurization. With CLS-SOV-1 closed, failure of the regulator does not impact the Cask/MCO. With CLS-SOV-1 closed, failure of CLS-SRV-1 to open when required or to open when not required does not impact the Cask/MCO. Similarly, with CLS-SOV-1 closed, failures of PI-430-1 pressure instrument to not correctly indicate pressure or structurally fail to the atmosphere does not impact the Cask/MCO. With CLS-SOV-1 closed, failures of GS piping from CLS-Reg-1 to CLS-PRV-1 or to CLS-SOV-1 does not impact the Cask/MCO and only affect the ability of the HPS to reliably perform its function.

TABLE 8: HPS COMPONENT FMEA- PRESSURE REGULATION AND OVERPRESSURE PROTECTION CLS-SOV-1 CLOSED

Component	Credible Failure*	Function	Failure Mode(s)**	Effect on System Functions	Comment
CLS-Reg-1 Pressure regulator	Possible	Steps down the gas pressure from the bottles at maximum 2200 psi to 80 psig	Active failures of pressure measure/indication by mechanical or electrical failures or passive failures by loss of pressure integrity	- Cask and HPS system design pressure is exceeded - worker safety	High purity helium gas supply is assume the same as CVD & CSB
CLS-PRV-1 Pressure device	Possible	Steps down the gas pressure from 80psi to 30 psig	Flow and pressure control	- Loss of system pressure - ingress of air	Make repairs and re-perform feed/purge cycles
PI-430-1	Not Likely	Indicates secondary pressure indication on the down side of the regulator	Instrument failure by mechanical failure	Loss of secondary pressure indication	- ~30 psig - repair PI-430-1
Piping	No	Provides a passive boundary pathway of gas to the HPS components	Loss of pressure integrity by brittle fracture	- Impact supply of He	- ~30 psig - HPS inoperable until repaired
CLS-SRV-1 Pressure valve	Not Likely	Actuates at 50 psig	Fracture or corrosion of valve internals or body causes valve to not open as intended	CLS-V-8, rupture disk, protects Cask/MCO from exceeding design pressure on failure of CLS-SRV-1	Repair CLS-SRV-1

TABLE 8: HPS COMPONENT FMEA- PRESSURE REGULATION AND OVERPRESSURE PROTECTION CLS-SOV-1 CLOSED

Component	Credible Failure*	Function	Failure Mode(s)**	Effect on System Functions	Comment
PI-430-3 / CLS-V-2	Not Likely	Indicates gas pressure on the down side of the regulator. Provides secondary indication to PI-430-1 up stream of CLS-SOV-1	Instrument failure or mechanical failure	Loss of secondary pressure indication	- CLS-V-2 must be open - ~30 psig - repair PI-430-3

* If GS, does the component have a significant failure mode and effect that could impact critical system or component functions or affect worker safety? If possible, failure mode and effects evaluation is assessed in Section 4.2

** See Table 4 of Eng-DI-003, Rev 0, for a list of typical failure modes

CLS-SOV-1 Open

A failure of these components with CLS-SOV-1 open is the same system configuration as failures during helium supply to the Cask/MCO during the feed cycle. As such, these are discussed in this section with valve CLS-SOV-1 open. With CLS-SOV-1 open, failures in these components would not over pressurize the Cask/MCO, since the SS rupture disk (CLS-V-8) at 65 psig mitigates this pressurization. However, failure of (a) CLS-SRV-1, (b) PI-430-1, (c) GS piping, or (d) GS instrumentation (PI-430-3 or PI-430-4) by opening/failing to the atmosphere could interrupt helium supply and could affect maintenance of pressure at 30 psig in the Cask/MCO during the feed cycle. Failures of this nature would be immediately recognized by the operator and lead to shutdown of gas supply at the manifold or the bottles with impacts to the Cask/MCO expected to be minimal and simply be re-processed for air purging by another (or repaired) HPS. Such failures would affect the ability of the HPS to reliably perform its function.

With CLS-SOV-1 open, failures of PI-430-1 pressure instrument to not correctly indicate pressure does not impact the Cask/MCO. SS components PT-430-1 and CLS-V-7 were not considered to fail.

GS valves CLS-SOV-1 and CLS-SOV-2 are electrical powered direct lift type valves with commercial grade ratings of 150psi for valve control. These valves are energized to change position for the system to perform its intended function. Failure of these valves to concurrently change position on demand (due to failure in the mechanics of the valve to change position or a power failure) will affect the HPS ability to perform its function during its feed cycle. These valves and their power supply should be further studied to determine if they should be upgraded in quality to provide reasonable assurance that these valves will perform their helium feed function on demand.

Quick Disconnect is a manual valve with passive pressure boundary functions. Failure of Quick Disconnect to perform its passive boundary function was not considered credible and not considered to impact the HPS' or its component's functions.

TABLE 9: HPS COMPONENT FMEA- PRESSURE REGULATION AND OVERPRESSURE PROTECTION CLS-SOV-1 OPEN

Component	Credible Failure*	Function	Failure Mode(s)**	Effect on System Functions	Comment
CLS-SOV-1 normally closed valve	Possible	Normally closed valve is energized Open for helium feed to the Cask/MCO	<ul style="list-style-type: none"> - mechanical failure of the SV - electrical failure of the SV 	Loss of HPS to perform helium feed cycle	<ul style="list-style-type: none"> - CLS-SOV-1, CLS-SOV-2 & HS-430-2 must perform their function for the HPS to feed the Cask/MCO - Repair inoperable components - multiple failure modes
CLS-SOV-2 normally open valve	Possible	Normally open valve is energized Closed for helium feed to the Cask/MCO			
HS-430-2	Possible	Provides power to CLS-SOV-1 & CLS-SOV-2 to change their position for helium feed cycle			
CLS-SRV-1 Pressure valve	Not Likely	Actuates at 50 psig	Fracture or corrosion of valve internals or body causes valve to not open as intended	CLS-V-8, rupture disk, protects Cask/MCO from exceeding design pressure on failure of CLS-SRV-1	Repair CLS-SRV-1
PI-430-3 / CLS-V-2	Not Likely	<ul style="list-style-type: none"> - Indicates gas pressure on the down side of the regulator. - Provides secondary indication to PI-430-1 upstream of CLS-SOV-1 	Instrument failure by mechanical failure	Loss of secondary pressure indication	<ul style="list-style-type: none"> - CLS-V-2 must be open - ~30 psig - repair PI-430-3
Quick Disconnect Quick-connect valve	Not Likely	Connection of flexible hose off of the HPS to the Cask/MCO lid	Mechanical or corrosion failure of connection	Loss of ability to connect HPS to Cask/MCO	<ul style="list-style-type: none"> - manual valve - ~30 psig - HPS inoperable until repaired - consider pre-op test to assure pressure boundary

TABLE 9: HPS COMPONENT FMEA- PRESSURE REGULATION AND OVERPRESSURE PROTECTION CLS-SOV-1 OPEN

Component	Credible Failure*	Function	Failure Mode(s)**	Effect on System Functions	Comment
PI-430-4 / CLS-V-3	Not Likely	<ul style="list-style-type: none"> - Indicates gas pressure on the down side of the CLS-SOV-1. - Provides secondary indication to PI-430-1 down stream of CLS-SOV-1 	Instrument failure by mechanical failure	Loss of secondary pressure indication	<ul style="list-style-type: none"> - CLS-V-3 must be open - ~30 psig - repair PI-430-4
CLS-V-5 Hand valve	No	Provide low point for system drainage			<ul style="list-style-type: none"> - consider pre-op test to assure pressure boundary - consider pre-op system configuration inspections
Piping	No	Provides a passive boundary pathway of gas to the HPS components.			<ul style="list-style-type: none"> - consider pre-op test to assure pressure boundary - consider pre-op system configuration inspections

* If GS, does the component have a significant failure mode and effect that could impact critical system or component functions or affect worker safety? If possible, failure mode and effects evaluation is assessed in Section 4.2.

** See Table 4 of ENG-DI-003, Rev. 0, for a list of typical failure modes.

4.2.3 Failures during Helium Supply to the Cask/MCO during the Feed Cycle

Failures during helium supply to the Cask/MCO during the feed cycle are discussed in Section 4.2.2 with valve CLS-SOV-1 open.

4.2.4 Failure during Cask/MCO Atmosphere Release during the Vent Cycle

Failure of GS components during Cask/MCO atmosphere release from the Cask/MCO during the Purge Cycle could release potentially radiological material from the Cask/MCO and/or affect the ability of the HPS to perform the vent cycle consistent with its analytical basis, HNF-2833. The failure modes and effects of GS valves CLS-SOV-1 and CLS-SOV-2 valves on intended HPS functions during the vent cycle are discussed in Section 4.1.4.

TABLE 10: HPS COMPONENT FMEA- CASK/MCO ATMOSPHERE RELEASE FROM THE CASK/MCO DURING THE VENT CYCLE

Component	Credible Failure*	Function	Failure Mode(s)**	Effect on System Functions	Comment
CLS-SOV-1 normally closed valve	Not Likely	Normally closed valve is Closed helium vent to the Cask/MCO	- Failure modes which leave the valve in its normal position	HPS can not perform it vent function on a loss of pressure boundary	<ul style="list-style-type: none"> - Most failure modes, including electrical failures, should leave these valves in a position for the HPS to vent the Cask/MCO - valves not energized for vent cycle
CLS-SOV-2 normally open valve	Not Likely	Normally open valve is Open for helium vent to the Cask/MCO	- loss of pressure boundary failure by mechanical impacts or corrosion		
HS-430-2	Not Likely	Not energized for vent cycle	- electrical failures - loss of power		
Quick Disconnect valve	Not Likely	Connection of flexible hose off of the HPS to the Cask/MCO lid	Mechanical or corrosion failure of connection	<ul style="list-style-type: none"> - Loss of ability to connect HPS to Cask/MCO - loss of pressure boundary 	<ul style="list-style-type: none"> - manual valve - ~3 psig - HPS inoperable until repaired - consider pre-op test to assure pressure boundary
CLS-V-7	Not Likely	Actuates at 3 psig to assure feed/venting is consistent with analytical basis, HNF-2833	Mechanical or corrosion failures	May lead to inconsistencies with HNF-2833	<ul style="list-style-type: none"> - actuates at ~3 psig - HPS inoperable until repaired
CLS-V-5 Hand valve	Not Likely	Provide low point for system drainage	Mechanical or corrosion failures	- loss of pressure boundary	<ul style="list-style-type: none"> - consider pre-op test to assure pressure boundary - consider pre-op system configuration inspections
Piping	No	Provides a passive boundary pathway of gas to the HPS components.			<ul style="list-style-type: none"> - consider pre-op test to assure pressure boundary - consider pre-op system configuration inspections

TABLE 10: HPS COMPONENT FMEA- CASK/MCO ATMOSPHERE RELEASE FROM THE CASK/MCO DURING THE VENT CYCLE

Component	Credible Failure*	Function	Failure Mode(s)**	Effect on System Functions	Comment
PDI-430-5 CLS-V-4 CLS-V-6	Not likely	Indicates differential gas pressure across HEPA filters, CLS-HEPA-F-1 and CLS-HEPA-F-2	Instrument failure by electrical or mechanical failure	Loss of secondary pressure indication	- CLS-V-4 must be open - ~30 psig - repair PDI-430-5
CLS-HEPA-F-1 & CLS-HEPA-F-2 HEPA filters	Possible	Filter potential radiological particulates from the Cask/MCO prior to release of Cask/MCO atmosphere to the environment	- loss of filter capability	- worker safety	- Max credible releases from the HEPA filters should be evaluated to determine their safety class to worker safety - programmatic controls & inspections to assure operation
CLS-HEPA-F-1 CLS-HEPA-F-1	Possible, if not regularly checked	Filter radioactive particulates from the vented gas flow	Plugged filter by particulate overload	Back pressure by plugged filter(s)	HEPAs should be routinely checked and replaced

* If GS, does the component have a significant failure mode and effect that could impact critical system or component functions or affect worker safety? If possible, failure mode and effects evaluation is assessed in Section 4.2.

** See Table 4 of ENG-DI-003, Rev 0, for a list of typical failure modes.

4.2.5 Failure during Measurement of Cask/MCO Pressure

For the HPS pressure measurement function, CLS-SOV-1 is not energized and is normally closed; CLS-SOV-2 is energized and is closed. The failure of these valves to be in these positions on demand will affect the HPS ability to perform its measure function. However, it is reasonable that CLS-SOV-1 will be in its normal position when not energized, since this is not an active function to be in their normal position. Failure of CLS-SOV-2 to energize and close will cause the cask/MCO to depressurize to atmospheric pressure. In this case, CLS-SOV-2 will need to be repaired and a feed or feed/purge cycle will need to be performed to re-pressurize the cask/MCO to 2-3 psig. The failure modes and effects of GS valves CLS-SOV-1 and CLS-SOV-2 valves on intended HPS functions during the vent cycle are discussed in Section 4.1.4.

4.3 Consistency With Analytical Basis, HNF-2833

On initial HPS startup, air may, for numerous reasons, leak back into HPS lines after previous use of the HPS. While it is expected that HPS piping volumes will be small, the flexible hose volumes adjacent to the quick disconnect valve may be significant. To assure consistency with the assumptions in the analytical basis, HNF-2833, the HPS system could be blown down with helium to assure filling the flexible hose volumes with helium gas prior to initiating feed/vent helium gas processing a Cask/MCO. Similarly, since 100% pure helium was used in the analysis, HNF-2833, a sufficiently high purity, such as 99.97%, of helium should be used. Further, the K Basin TSRs current will control that the cask/MCO will be slightly pressurized to 2-3 psi prior to departure from K Basins to CVDF. This pressure tolerance requirement leads to a 2.5psig target pressure with a +/- 0.5 psig. To satisfy this pressure tolerance requirement, this will likely require that the final He purge pressure be targeted to 2.5 psig.

To provide an analytical basis consistent with HNF-2833, excel spreadsheet analyses were modified to account for these differences. Appendix A calculates oxygen concentrations for one to five feed/purge cycles for feed pressures to 30psig and vent pressures to 2.5 psig. These calculations indicate that five feed/purge are needed to achieve calculated oxygen concentrations in the cask/MCO below 1.6% volume concentration.

5.0 RECOMMENDATIONS

This review has developed several insights into the design and operation of the HPS. These lead to certain recommendations for the HPS design and operation. As discussed above, a blow down of line volumes with helium at system startup would clear air out of these lines after long HPS shutdowns. This would provide more assurance that HPS operation is consistent with the analytical bases described in HNF-2833.

As discussed in Table 4 above, manual valves (CLS-V-1, CLS-V-5 and CLS-V-6) should be checked for position prior to system operation.

Another recommendation is the use of a data recorder on the pressure feed and purge cycles. This would facilitate data collection and confirm of consistency with the assumptions in the analytical bases in HNF-2833.

The backpressure valve may need to be small to provide better pressure and flow control during the purging cycles. After HPS system shakedown and startup testing, the need for a smaller valve may need to be considered. A smaller valve may provide sufficient flow and pressure control to satisfy the 2-3 psig cask/MCO pressurization prior to departure from the K Basins. This need may be mitigated by new analysis results expected in a revised SARP indicating a updated pressure range of 5psig +/- 3 psig prior to departure from K Basins.

6.0 SUMMARY AND CONCLUSIONS OF ASSESSMENT

A review of the design and operation of the HPS as described in the P&ID, Figure 1, was performed. This review focused on system and component level functions, failure modes and failure effects to identify component safety classification consistent with HNF-PRO-704 (Reference 1). SS components identified by this review are in Table 1. The basis for identifying these components as having SS functions is described in this report. Items were selected as SS safety classifications, which perform active functions consistent with worker and facility SS functions or fail in such a manner to affect the performance of SS functional components to perform their SS function.

7.0 REFERENCES

1. HNF-PRO-704, Table 5, *Hazards and Accident Analysis Process*, Project Hanford Management System, Richland, Washington.
2. AP EN-6-027-01, Spent Nuclear Fuel Project Administrative Procedure, *Design Verification Process*, Project Hanford Management System, Richland, Washington.
3. ENG-DI-003, Rev. 0, SNF Project Engineering Desk Instruction, *Commercial Grade Item Upgrade Dedication Process Requirements and Implementation Instructions*, Project Hanford Management System, Richland, Washington.
4. HNF-SD-SNF-FRD-025, Rev. 2, *K Basin Cask Transport Facility Modifications, Project A.5/A.6, Functions and Requirements Document*, October 5, 1999, Richland, Washington.
5. SNF-4889, Rev. 0, Cogema Engineering Corporation, *Cask/MCO Helium Purge System Concept Design Report*, October 4, 1999, Richland, Washington.
6. HNF-SD-SNF-DRD-002, *CVDF Design Requirements Document*, Richland, Washington.
7. HNF-2833, Rev. 0, Cogema Engineering Services, *Inert Gas Requirements for Cask Loading*, Richland, Washington.
8. WHC-SD-WM-SAR-062, Rev. 3L, *K Basins Safety Analysis Report 3L*, October 1999, Richland, Washington.
9. HNF-SD-SNF-TSR-001, *K Basins Technical Safety Requirements*, Richland, Washington.
10. HNF-SD-SNF-OCD-001, Rev. 4, *Fuel Performance Specification*, Richland, Washington.

APPENDIX A

**IMPACT OF 99.5% HELIUM PURITY, 1.6% OXYGEN VOLUME
CONCENTRATION LIMIT AND 2.5 PSIG PURGE PRESSURE
ON THE NUMBER OF FEED/VENT CYCLES**

**CONSISTING OF 4 PAGES
INCLUDING COVERSHEET**

APPENDIX A:

IMPACT OF 99.5% HE PURITY, 1.6% OXYGEN VOLUME CONCENTRATION LIMIT
AND 2.5 PSIG PURGE PRESSURE ON THE NUMBER OF FEED/VENT CYCLES

Figure A-1: Number of Feed/Vent Cycles vs. O₂ in the Cask/MCO for 99.5% He Purity, 1.6% Oxygen Volume Concentration Limit And 2.5 Psig Purge Pressure

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APPENDIX A

Table A-1: SpreadSheet Results
(from 99.5% He Purity, 1.6% O₂ concentration and 2.5 psig purge pressure HNF-2833,
Spreadsheet File)

Pressurize - Bleed Cycle Concentration Prediction with Helium Purity at 99.5%

	liters	liters	ft3
Region 1 = Cask Void	V ₁ = 15.0	15.0	0.53
Region 2 = MCO Void	V ₂ = 15.9	15.9	0.56

For Cycle 1

p ⁰ =	0	psig =	14.7 psia
y ₁ ⁰ =	0	y ₂ ⁰ =	0
		y _p =	0.995

For Cycle 1

Initial Helium		Pressure to, psig	Helium		Air		Oxygen		Bleed to	2.5 psig =		17.2 psia			
y ₁	y ₂		y ₁	y ₂	ya1	ya2	yO1	yO2		ya1	ya2	yO1	yO2	VolAvg O2	VolAvg O2
0	0	8	0.5879	0.1282	0.4121	0.8738	0.0865	0.1835	0.1364	0.4706	0.1282	0.5294	0.8738	0.1112	0.1835
0	0	10	0.6528	0.1663	0.3472	0.8337	0.0729	0.1751	0.1254	0.4982	0.1663	0.5018	0.8337	0.1054	0.1751
0	0	12	0.7034	0.2047	0.2966	0.7953	0.0623	0.1670	0.1161	0.5181	0.2047	0.4819	0.7953	0.1012	0.1670
0	0	14	0.7437	0.2409	0.2583	0.7591	0.0538	0.1594	0.1081	0.5336	0.2409	0.4664	0.7591	0.0979	0.1594
0	0	16	0.7762	0.2747	0.2238	0.7253	0.0470	0.1523	0.1011	0.5466	0.2747	0.4534	0.7253	0.0952	0.1523
0	0	18	0.8028	0.3063	0.1972	0.6937	0.0414	0.1457	0.0950	0.5581	0.3063	0.4419	0.6937	0.0928	0.1457
0	0	20	0.8249	0.3355	0.1751	0.6645	0.0368	0.1395	0.0896	0.5687	0.3355	0.4313	0.6645	0.0906	0.1395
0	0	25	0.8660	0.3999	0.1340	0.6001	0.0281	0.1260	0.0784	0.5925	0.3999	0.4075	0.6001	0.0856	0.1260
0	0	30	0.8940	0.4637	0.1060	0.5463	0.0223	0.1147	0.0698	0.6142	0.4637	0.3858	0.5463	0.0810	0.1147
0	0	35	0.9138	0.4991	0.0862	0.5009	0.0181	0.1052	0.0629	0.6342	0.4991	0.3658	0.5009	0.0768	0.1052
0	0	40	0.9283	0.5377	0.0717	0.4623	0.0151	0.0971	0.0572	0.6527	0.5377	0.3473	0.4623	0.0729	0.0971
0	0	50	0.9478	0.5997	0.0522	0.4003	0.0110	0.0841	0.0485	0.6855	0.5997	0.3145	0.4003	0.0660	0.0841

For Cycle 2

For Cycle 2

Initial Helium		Pressure to, psig	Helium		Air		Oxygen		Bleed to	2.5 psig =		17.2 psia			
y ₁	y ₂		y ₁	y ₂	ya1	ya2	yO1	yO2		ya1	ya2	yO1	yO2	VolAvg O2	VolAvg O2
0.4706	0.1282	8	0.6986	0.2411	0.3014	0.7589	0.0633	0.1594	0.1127	0.5823	0.2411	0.4177	0.7589	0.0677	0.1594
0.4982	0.1663	10	0.7590	0.3139	0.2410	0.6881	0.0506	0.1441	0.0986	0.6175	0.3139	0.3825	0.6881	0.0603	0.1441
0.5181	0.2047	12	0.8019	0.3778	0.1981	0.6222	0.0416	0.1307	0.0873	0.6443	0.3778	0.3557	0.6222	0.0747	0.1307
0.5336	0.2409	14	0.8340	0.4337	0.1660	0.5663	0.0349	0.1189	0.0780	0.6668	0.4337	0.3332	0.5663	0.0700	0.1189
0.5466	0.2747	16	0.8588	0.4826	0.1412	0.5174	0.0297	0.1086	0.0702	0.6866	0.4826	0.3134	0.5174	0.0656	0.1086
0.5581	0.3063	18	0.8764	0.5256	0.1216	0.4744	0.0255	0.0996	0.0636	0.7045	0.5256	0.2955	0.4744	0.0620	0.0996
0.5687	0.3355	20	0.8943	0.5634	0.1057	0.4366	0.0222	0.0917	0.0579	0.7210	0.5634	0.2790	0.4366	0.0586	0.0917
0.5925	0.3999	25	0.9229	0.6404	0.0771	0.3596	0.0162	0.0755	0.0467	0.7571	0.6404	0.2429	0.3596	0.0510	0.0755
0.6142	0.4637	30	0.9416	0.6986	0.0584	0.3014	0.012267	0.063293	0.0386	0.7872	0.6986	0.2128	0.3014	0.044992	0.063293
0.6342	0.4991	35	0.9543	0.7437	0.0457	0.2583	0.0096	0.0538	0.0323	0.8123	0.7437	0.1877	0.2583	0.0384	0.0538
0.6527	0.5377	40	0.9633	0.7793	0.0367	0.2207	0.0077	0.0463	0.0276	0.8335	0.7793	0.1665	0.2207	0.0350	0.0463
0.6855	0.5997	50	0.9747	0.8312	0.0253	0.1688	0.0053	0.0354	0.0208	0.8666	0.8312	0.1334	0.1688	0.0280	0.0354

For Cycle 3

For Cycle 3

Initial Helium		Pressure to, psig	Helium		Air		Oxygen		Bleed to	2.5 psig =		17.2 psia			
y ₁	y ₂		y ₁	y ₂	ya1	ya2	yO1	yO2		ya1	ya2	yO1	yO2	VolAvg O2	VolAvg O2
0.5823	0.2411	8	0.7818	0.3486	0.2382	0.6514	0.0500	0.1368	0.0946	0.6568	0.3486	0.3432	0.6514	0.0721	0.1368
0.6175	0.3139	10	0.8157	0.4416	0.1843	0.5584	0.0387	0.1173	0.0791	0.6968	0.4416	0.3032	0.5584	0.0637	0.1173
0.6443	0.3778	12	0.8531	0.5180	0.1469	0.4820	0.0309	0.1012	0.0670	0.7285	0.5180	0.2715	0.4820	0.0570	0.1012
0.6668	0.4337	14	0.8905	0.5908	0.1195	0.4192	0.0251	0.0880	0.0574	0.7553	0.5908	0.2447	0.4192	0.0514	0.0880
0.6866	0.4826	16	0.9013	0.6331	0.0987	0.3689	0.0207	0.0771	0.0497	0.7785	0.6331	0.2215	0.3689	0.0466	0.0771
0.7045	0.5256	18	0.9175	0.6768	0.0825	0.3232	0.0173	0.0679	0.0433	0.7989	0.6768	0.2011	0.3232	0.0422	0.0679
0.7210	0.5634	20	0.9303	0.7138	0.0697	0.2862	0.0146	0.0601	0.0380	0.8169	0.7138	0.1831	0.2862	0.0384	0.0601
0.7571	0.6404	25	0.9524	0.7841	0.0476	0.2159	0.0100	0.0453	0.0282	0.8537	0.7841	0.1463	0.2159	0.0307	0.0453
0.7872	0.6986	30	0.9658	0.8329	0.0342	0.1671	0.007172	0.0361	0.0216	0.8813	0.8329	0.1187	0.1671	0.024919	0.0361
0.8123	0.7437	35	0.9744	0.8677	0.0256	0.1323	0.0054	0.0278	0.0159	0.9025	0.8677	0.0975	0.1323	0.0205	0.0278
0.8335	0.7793	40	0.9800	0.8933	0.0200	0.1067	0.0042	0.0224	0.0136	0.9188	0.8933	0.0812	0.1067	0.0170	0.0224
0.8666	0.8312	50	0.9866	0.9271	0.0134	0.0729	0.0028	0.0153	0.0092	0.9418	0.9271	0.0582	0.0729	0.0123	0.0153

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APPENDIX A

Table A-1: SpreadSheet Results (continued)

For Cycle 4

Initial Helium		Pressure to, psig	Helium		Air		Oxygen		Bleed to		2.5 psig =		17.2 psia		VolAvg O2
y1	y2		y1	y2	ya1	ya2	yO1	yO2	y1	y2	ya1	ya2	yO1	yO2	
0.6568	0.3486	8	0.8038	0.4436	0.1962	0.5564	0.0412	0.1169	0.0801	0.7123	0.4436	0.2877	0.5664	0.0804	0.0894
0.6968	0.4416	10	0.8533	0.5472	0.1467	0.4528	0.0308	0.0951	0.0638	0.7561	0.5472	0.2439	0.4628	0.0612	0.0738
0.7285	0.5180	12	0.8871	0.6273	0.1129	0.3727	0.0237	0.0783	0.0517	0.7906	0.6273	0.2084	0.3727	0.0440	0.0616
0.7553	0.5808	14	0.9114	0.6900	0.0886	0.3100	0.0186	0.0651	0.0425	0.8189	0.6900	0.1811	0.3100	0.0380	0.0519
0.7785	0.6331	16	0.9292	0.7397	0.0708	0.2603	0.0149	0.0547	0.0353	0.8424	0.7397	0.1576	0.2603	0.0331	0.0442
0.7989	0.6768	18	0.9427	0.7795	0.0573	0.2205	0.0120	0.0463	0.0296	0.8623	0.7795	0.1377	0.2205	0.0289	0.0378
0.8169	0.7138	20	0.9530	0.8119	0.0470	0.1881	0.0099	0.0395	0.0251	0.8791	0.8119	0.1209	0.1881	0.0254	0.0326
0.8537	0.7841	25	0.9697	0.8696	0.0303	0.1304	0.0064	0.0274	0.0172	0.9110	0.8696	0.0690	0.1304	0.0187	0.0232
0.8813	0.8329	30	0.9791	0.9063	0.0209	0.0937	0.004398	0.019676	0.0122	0.9328	0.9063	0.0672	0.0937	0.014106	0.018676
0.9025	0.8677	35	0.9848	0.9305	0.0154	0.0695	0.0032	0.0146	0.0091	0.9481	0.9305	0.0519	0.0695	0.0109	0.0146
0.9188	0.8933	40	0.9879	0.9470	0.0121	0.0530	0.0025	0.0111	0.0069	0.9591	0.9470	0.0409	0.0530	0.0086	0.0111
0.9418	0.9271	50	0.9915	0.9669	0.0085	0.0331	0.0018	0.0070	0.0044	0.9730	0.9669	0.0270	0.0331	0.0057	0.0070

For Cycle 4

For Cycle 5

Initial Helium		Pressure to, psig	Helium		Air		Oxygen		Bleed to		2.5 psig =		17.2 psia		VolAvg O2
y1	y2		y1	y2	ya1	ya2	yO1	yO2	y1	y2	ya1	ya2	yO1	yO2	
0.7123	0.4436	8	0.8352	0.5257	0.1648	0.4743	0.0346	0.0996	0.0680	0.7566	0.5257	0.2434	0.4743	0.0611	0.0696
0.7561	0.5472	10	0.8815	0.6331	0.1185	0.3669	0.0249	0.0770	0.0517	0.8026	0.6331	0.1974	0.3669	0.0416	0.0597
0.7906	0.6273	12	0.9123	0.7118	0.0877	0.2882	0.0184	0.0605	0.0401	0.8378	0.7118	0.1622	0.2882	0.0341	0.0506
0.8189	0.6900	14	0.9335	0.7705	0.0665	0.2295	0.0140	0.0482	0.0316	0.8654	0.7705	0.1346	0.2295	0.0283	0.0482
0.8424	0.7397	16	0.9487	0.8149	0.0513	0.1851	0.0108	0.0389	0.0252	0.8874	0.8149	0.1126	0.1851	0.0239	0.0315
0.8623	0.7795	18	0.9596	0.8491	0.0404	0.1509	0.0085	0.0317	0.0204	0.9051	0.8491	0.0949	0.1509	0.0199	0.0260
0.8791	0.8119	20	0.9676	0.8757	0.0324	0.1243	0.0068	0.0261	0.0167	0.9195	0.8757	0.0805	0.1243	0.0169	0.0216
0.9110	0.8696	25	0.9800	0.9205	0.0200	0.0795	0.0042	0.0167	0.0106	0.9450	0.9205	0.0550	0.0795	0.0115	0.0167
0.9328	0.9063	30	0.9863	0.9465	0.0137	0.0535	0.002581	0.011238	0.0072	0.9610	0.9465	0.0390	0.0535	0.008192	0.011238
0.9481	0.9305	35	0.9897	0.9623	0.0103	0.0377	0.0022	0.0079	0.0051	0.9713	0.9623	0.0287	0.0377	0.0060	0.0079
0.9591	0.9470	40	0.9917	0.9724	0.0083	0.0276	0.0017	0.0058	0.0038	0.9781	0.9724	0.0219	0.0276	0.0048	0.0058
0.9730	0.9669	50	0.9938	0.9833	0.0064	0.0167	0.0014	0.0035	0.0025	0.9859	0.9833	0.0141	0.0167	0.0030	0.0035