MAY 18 2000

ENGINEERING DATA TRANSMITTAL

1. EDT 629585

2. To: (Receiving Organization) Site-Wide SNF	3. From: (Originating Organization) Site-Wide SNF	4. Related EDT No.: N/A
5. Proj./Prog./Dept./Div.: W-518	6. Design Authority/Design Agent/Cog. Engr.: D.M. Johnson	7. Purchase Order No.: N/A
8. Originator Remarks:		9. Equip./Component No.: N/A
		10. System/Bldg./Facility: Drying & Inerting Syst
		12. Major Assm. Dwg. No.: N/A
11. Receiver Remarks:	11A. Design Baseline Document? ☐ Yes ☒ No	13. Permit/Permit Application No.: N/A
		14. Required Response Date: May, 18, 2000

15. DATA TRANSMITTED

(A) Item No.	(B) Document/Drawing No.	(C) Sheet No.	(D) Rev. No.	(E) Title or Description of Data Transmitted	(F) Approval Designator	(G) Reason for Transmittal	(H) Originator Disposition	(I) Receiver Disposition
1	SNF-6386	N/A	0	Preliminary Design Report	ESQ	2	1	

16. KEY

Approval Designator (F)	Reason for Transmittal (G)		Disposition (H) & (I)	
E, S, Q, D OR N/A (See WHC-CM-3-5, Sec. 12.7)	1. Approval 2. Release 3. Information	4. Review 5. Post-Review 6. Dist. (Receipt Acknow. Required)	1. Approved 2. Approved w/comment 3. Disapproved w/comment	4. Reviewed no/comment 5. Reviewed w/comment 6. Receipt acknowledged

17. SIGNATURE/DISTRIBUTION (See Approval Designator for required signatures)

(G) Reason	(H) Disp.	(J) Name	(K) Signature	(L) Date	(M) MSIN	(G) Reason	(H) Disp.	(J) Name	(K) Signature	(L) Date	(M) MSIN
2	1	Design Authority D.M. Johnson	[signature]	5/15/00	R3-11			Process Engineering			R3-86
		Design Agent				1	1	R.A. Sexton	[signature]	5-16-00	
		Cog. Eng.									
1	1	Cog. Mgr. R.L.McCormack	[signature]	5/18/00	R3-11						
1	1	QA D.W. Smith	Per E-mail [signature]	5/17/00	S2-48						
1	1	Safety L.J.Garvin	[signature]	5/18/00	R3-26						
1	1	Env. J.E.Turnbaugh	[signature]	5/16/00	X3-79						

18.	19.	20.	21. DOE APPROVAL (if required)
[signature] D.M. Johnson — 5/15/00 Signature of EDT Originator — Date	[signature] R.L.McCormack — 5/18/00 Authorized Representative for Receiving Organization — Date	[signature] R.L.McCormack — 5/18/00 Design Authority/ Cognizant Manager — Date	Ctrl No. ____ ☐ Approved ☐ Approved w/comments ☐ Disapproved w/comments

S

SNF-6386
Revision 0

Preliminary Design Report, Shippingport Spent Fuel Drying and Inerting System

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

SNF-6386
Revision 0
EDT 629585

Preliminary Design Report, Shippingport Spent Fuel Drying and Inerting System

Date Published
May 2000

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

Release Approval 5/18/00 Date

DATE: HANFORD RELEASE
STA: 4
ID: 2.
MAY 18 2000

SNF-6386, REV 0

25 pages.

SNF-6386 REVISION 0

PRELIMINARY DESIGN REPORT SHIPPINGPORT SPENT FUEL DRYING AND INERTING SYSTEM

May, 2000

Prepared for

Fluor Hanford
Richland, Washington

Prepared by: D. W. Jeppson **Date:** May 12, 2000

Reviewed by: O. L. Kruger **Date:** May 15, 2000

Approved by: D. M. Johnson **Date:** May 15, 2000

PRELIMINARY DESIGN REPORT, SHIPPINGPORT SPENT FUEL DRYING AND INERTING SYSTEM

Summary

A process description and system flow sheets have been prepared to support the design/build package for the Shippingport Spent Fuel Canister drying and inerting process skid. A process flow diagram was prepared to show the general steps to dry and inert the Shippingport fuel loaded into SSFCs for transport and dry storage. Flow sheets have been prepared to show the flows and conditions for the various steps of the drying and inerting process. Calculations and data supporting the development of the flow sheets are included.

Introduction

The Shippingport spent fuel stored in T Plant will be removed from the water storage pool, drained and loaded into SSFCs for drying, inerting, packaging, shipping to the Canister Storage Building (CSB), and dry storage (SNF-5809). There are 72 spent blanket fuel assemblies (BFAs) to be packaged. Four selected fuel assemblies will be loaded into each of 18 canisters for processing. The canisters are about 24 inches in diameter by about 160 inches long and have a void volume of about 38.7 ft^3. The BFAs will be selectively loaded into the canisters to minimize exposure of operating personnel working near the canister during the drying and inerting process. The high exposure BFAs will be loaded away from the drying and inerting port position and the lower exposure BFAs will be loaded under the port position. The shield plug is installed with a specific port having a plug valve for the drying and inerting process. Residual free water associated with the BFAs, estimated to be 2.5 liters nominally (HNF-3043 Rev 1, Attachment 1). Removal of larger volumes of water were evaluated during the design to verify that temperatures remain above freezing with a somewhat larger than bounding amount of water at more than twice the design flow rate; and to determine the drying times for the assumed bounding volume of water at the design flow rate (HNF 6381). The water will be removed by connecting the drying system to the drying and inerting port, evacuating the SSFC, backfilling with helium, evacuating a second time and backfilling with helium a second time. The hydrated water content of the BFAs is expected to be negligible. Pressure rebound testing will be used to insure water removal and provisions are provided for gas sampling if needed to assure satisfactory final conditions. The loaded canisters will be transported from T Plant to the CSB for closure welding and long-term interim storage.

Process Description

A drying and inerting process flow diagram for the removal of water from the loaded SSFC is shown in Figure 1. A system flow diagram is shown in Figure 2. The process flow diagram (Figure 1) shows the major steps required to remove water from the fuel and backfill with an inert gas in preparation for transport to and long term interim storage at the CSB. A minimum of two evacuation and backfill operations are performed to insure that the water and oxidants are removed to an acceptable level (SNF 5809 and NUREG 1536).

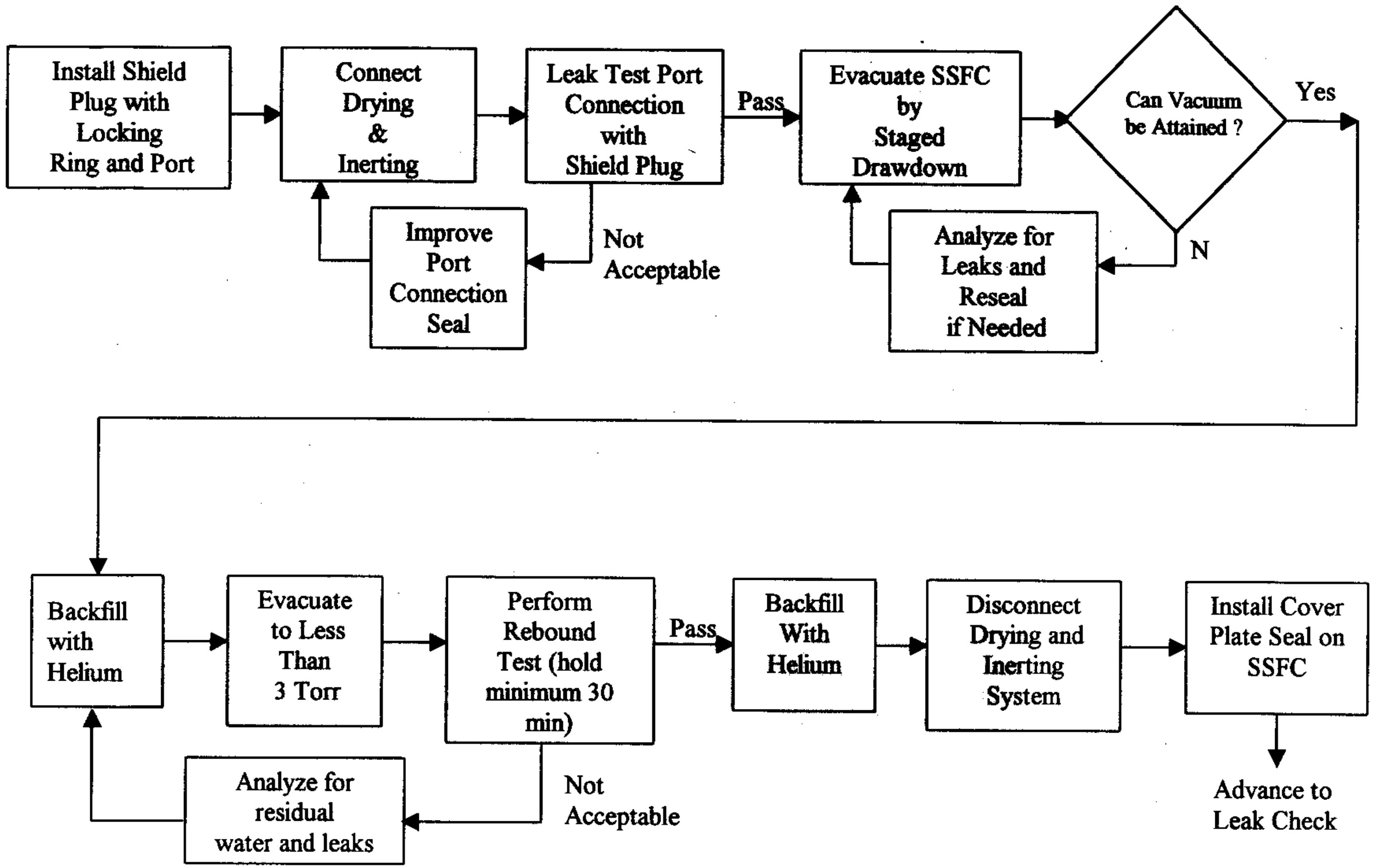


Figure 1 SSFC Drying and Inerting Process Flow

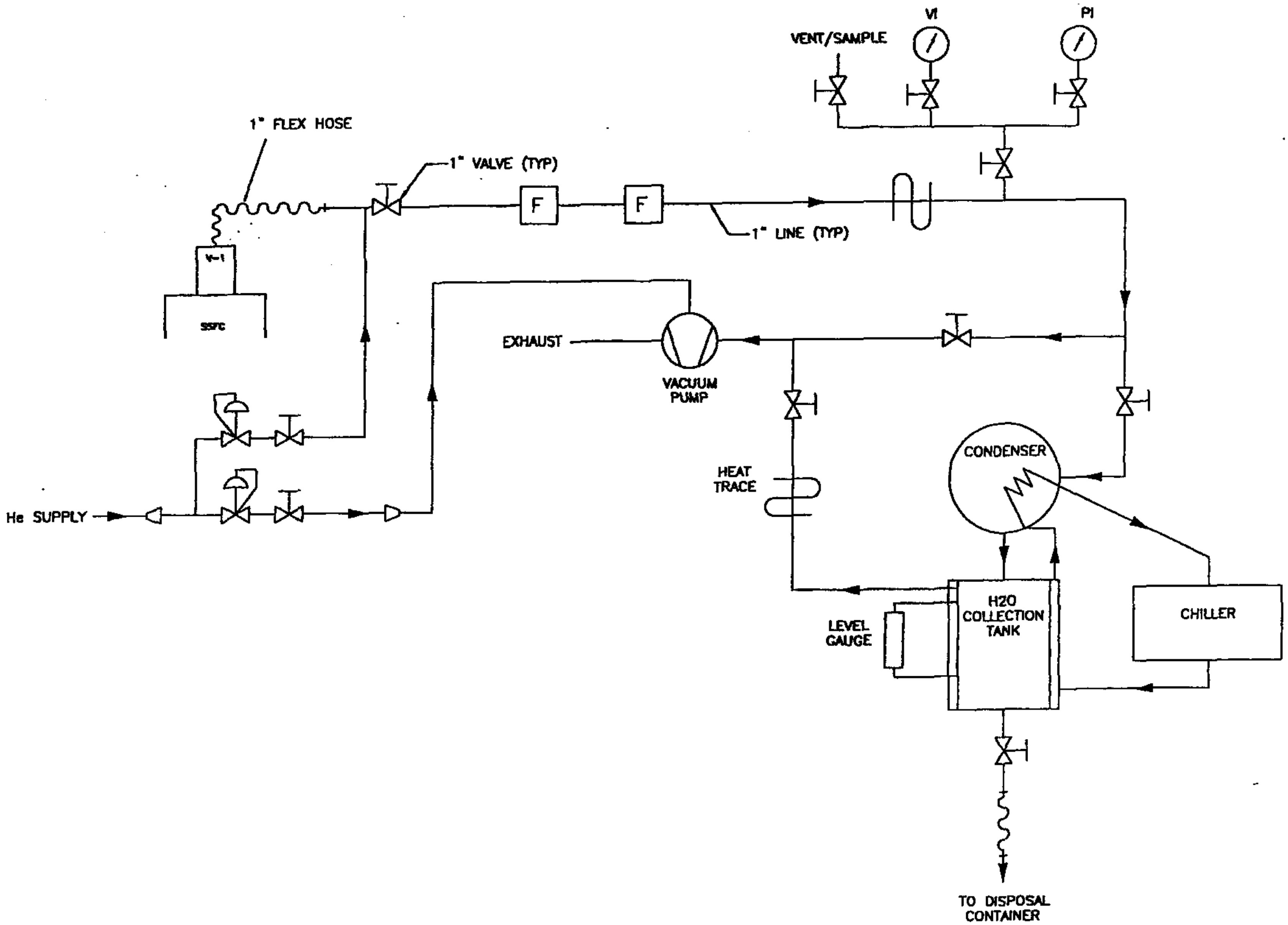


Figure 2 Drying and Inerting System Flow Diagram

SNF-6386
Rev 0

Leakage Test for Port Connector Seal
After four BFAs are loaded into a SSFC the loading guide is removed, the shield plug and locking ring are placed on the top of the canister and tightened down to make a seal with the canister. The cover plate over the ported plug valve is then removed. The drying and inerting flexible line is connected to the valve port. The port valve is in the closed position and the vacuum pump is turned on to draw a vacuum on the line to the SSFC with the condenser valved out. When the vacuum is established in the line, the vacuum pump isolation valve is closed and the line pressure monitored for inleakage. If inleakage is detected such that the pressure increases more than attributable to temperature change in about 15 minutes, additional leak testing will performed to determine which seal needs improvement prior to retesting for acceptability. When the leak test is satisfactory the SSFC is ready for water removal.

Initial SSFC Evacuation
When ready to start SSFC staged drawdown, the filters and hard run lines are heated to operating temperature and the chiller water flow to the condenser and collection tank is started. The vacuum system valving is lined up to allow the vacuum pump to draw a vacuum on the SSFC through the condenser. The SSFC ported plug valve and vacuum pump isolation valve are opened, the condenser is valved inline, and the condenser bypass valve is closed. The vacuum pump is then started and the SSFC is evacuated by staged drawdown. Ballast gas (helium) is bled into the vacuum pump for pump cooling and enhanced water removal in the lines and components during evacuation.

When the SSFC vacuum pressure reaches less than 10 torr absolute, the condenser bypass valve is opened and the two valves to the condenser are closed allowing the SSFC gases to go directly to the vacuum pump. The vacuum in the SSFC is reduced to less than 3 torr by continued vacuum pump operation.

Evacuation Evaluation
When the SSFC vacuum is drawn down to less than 3 torr the vacuum drying process is continued to the next step. If the SSFC vacuum of less than 3 torr cannot be obtained then evaluations are needed to determine if inleakage needs improvement or if a modified evacuation procedure is needed (eg. longer evacuation time or slower draw down time are needed, or proceeding to the helium fill and re-evacuation step). When resolution is reached appropriate action is taken to insure that the SSFC can be evacuated to less than 3 torr.

Second Evacuation and Rebound Test
When the first evacuation cycle has been completed, the valve to the vacuum pump is closed and the SSFC is backfilled with helium to atmospheric pressure. A second evacuation of the SSFC is conducted to insure the water has been removed and to verify that the SSFC is in satisfactory condition to perform a pressure rebound test. When the SSFC has been evacuated to less than 3 torr the valve to the vacuum pump is closed. A rebound test is conducted to verify that water has been removed from the BFAs by maintaining the vacuum of less than 3 torr for a 30 minute period with the SSFC isolated from the vacuum pump. Upon successful verification of dryness (negligible water), the SSFC is again backfilled with helium gas to a positive pressure of about 2 psig. A second rebound test and/or analysis for leaks and resealing of the system can be utilized, if needed to meet the rebound test value. A gas sampling provision is available to validate that

the cover gas purity requirement is met through the applied evacuation and rebound test procedure.

The shield plug port valve is then valved off and the vacuum and inerting system is disconnected from the SSFC. The port cover plate with sealing ring is installed over the plug valve. The SSFC is then ready for a leak check

Description of Drying and Inerting System

The SSFC drying and inerting system is designed to remove water and oxidants from the loaded canisters to allow sealing, shipping, and long term interim storage of the Shippingport BFAs in canisters. An equipment arrangement of the drying and inerting system is shown in Figure 3 and the piping and instrumentation diagram (P&ID) is shown in Figure 4. The drying and inerting system consists of a vacuum pump, condenser, two sintered metal filters in series, a connection to helium gas supply, and flexible line to allow connection of the system to the SSFC. The system has manual operated control valves and instrumentation as shown in Figure 4. The condenser and condensate collection tanks are cooled by a chiller as shown in Figures 2, 3, and 4. The condensate in the collection tank is drained to a transfer tank or other tank for eventual disposal or recycle to the storage pool.

The vacuum pump is rated at 35 SCFM and is capable of pumping down to less than 0.1 torr pressure. A ballast gas is supplied to the pump for cooling and enhanced moisture removal. A condenser with chilled liquid coolant is used to condense the water vapor from the SSFC. A water collection tank and a storage tank are included to collect the water and allow it to be periodically removed as needed.

Two sintered metal filters are included at the receiving end of the system to remove any particulates that may be entrained in the canister gases. The sintered metal filters are rated at greater than 99.97 % removal efficiency for particulate at 0.3 micron or greater in diameter. The clean filters have a pressure drop of 0.5 psi or less for a flow rate of 35 scfm. The sintered metal filters are heated above 120 °F to prevent the formation of liquid within the filters and housing.

Pressure instrumentation calibrated from about 15 psig to 0.1 torr is used to monitor the pressures.

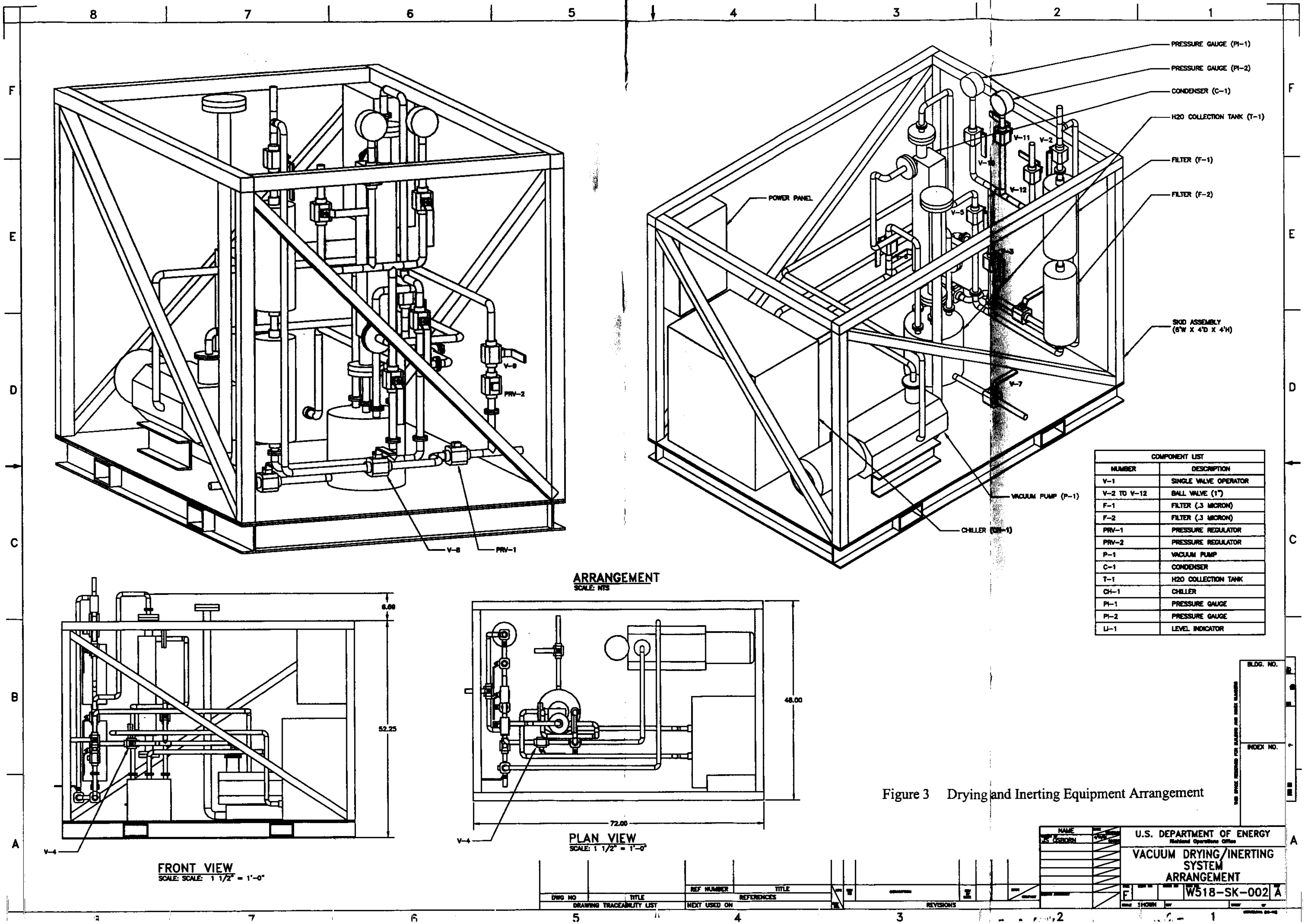


Figure 3   Drying and Inerting Equipment Arrangement

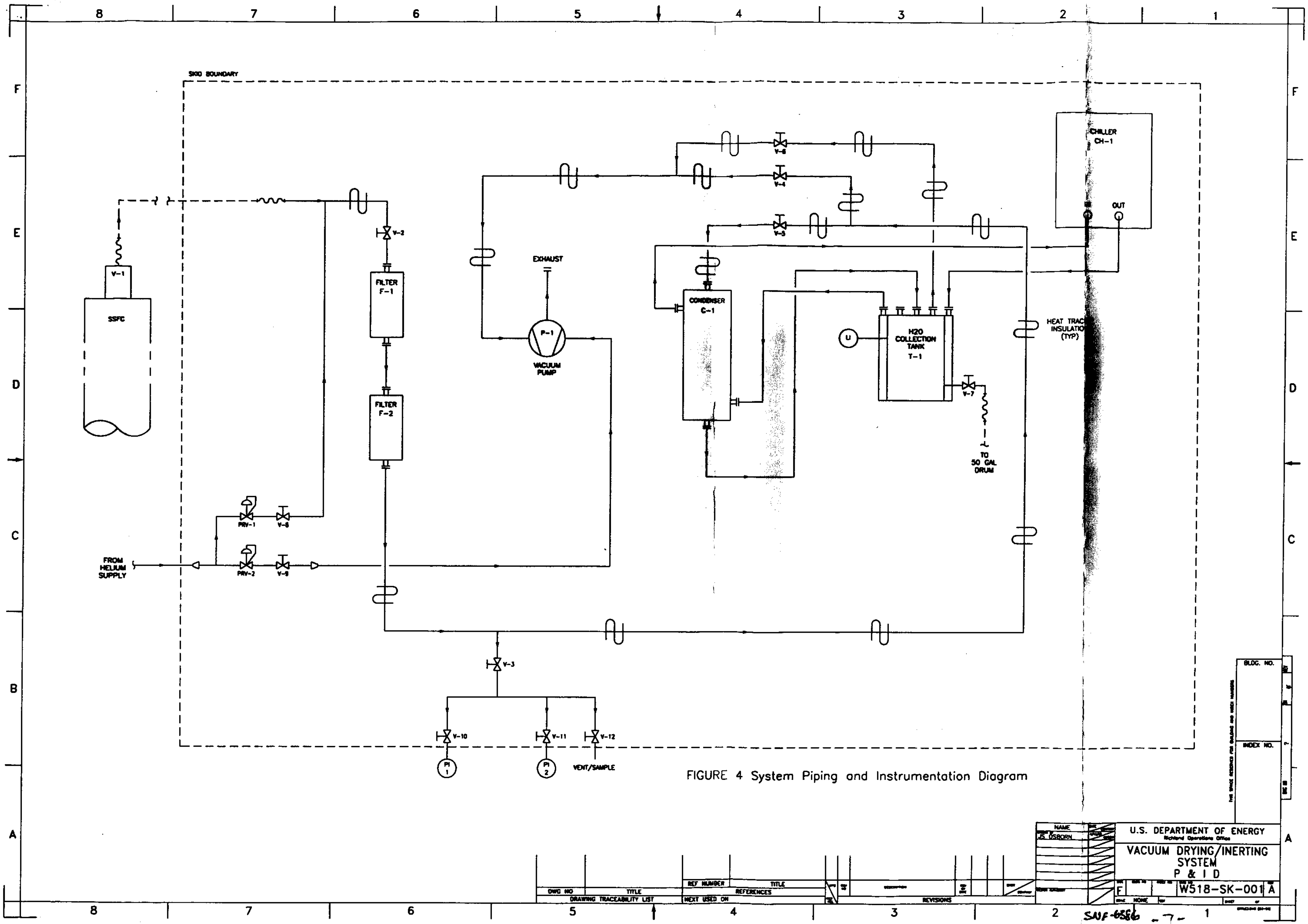


FIGURE 4 System Piping and Instrumentation Diagram

Flow Sheets

Flow sheets are presented for three stages of the vacuum drying process: bulk air removal, bulk water removal, and final end point. The vacuum pump is assumed to be rated at 35 scfm flow. Pump down curves were prepared for pumping down the SSFC at two flow rates using the HANSF code (SNF-3650, 1999 and HNF-63381, 2000). Inputs to the code cases were one at 30 cfm and one at 15 cfm with the conservative assumption of about 3 kg of water as shown in Figure 5. Times required for water removal were determined by the code to be about 3 hours for the 30 cfm case and 5.5 hours for the 15 cfm pump down case.

Conductance losses through the SSFC head, filters, vacuum lines and condenser were not modeled in these HANSF code runs. Estimated conductance losses were made for approximate piping and equipment in the vacuum system. Pressure drops through the SSFC head, piping, filters, and condenser are calculated based upon approximate characterization of anticipated equipment in the vacuum system. These pressure drops are listed in Table 1 for head penetrations of 0.6 inch diameter vertical, 1.0 inch diameter horizontal and the three port plug valve, the use of 1 inch diameter tubing, two sintered metal filters rated at 33 acfm with a pressure drop of about 0.25 psi each, and a condenser. Estimated conductance losses on effective pumping speed from the SSFC for the approximated vacuum pumping system is shown in Figure 6. Also included for comparison is the pumping speed for an assumed hypothetical case of no conductance loss from the SSFC.

From these approximated conductance loss determinations, the HANSF case of 15 cfm appears most applicable. More definite values can be determined as the equipment purchase orders are placed (e.g. filter conductance could vary based upon final filters selected).

Flow times, mass of water removed, and ending SSFC pressure for the three stages of the vacuum drying pump down are listed in Table 1 below. The system configuration for the various stages and estimated flow conditions are shown in Figures 7, 8, and 9.

Table 1 Approximate Time and Water Removal Quantity for Pump Down Stages

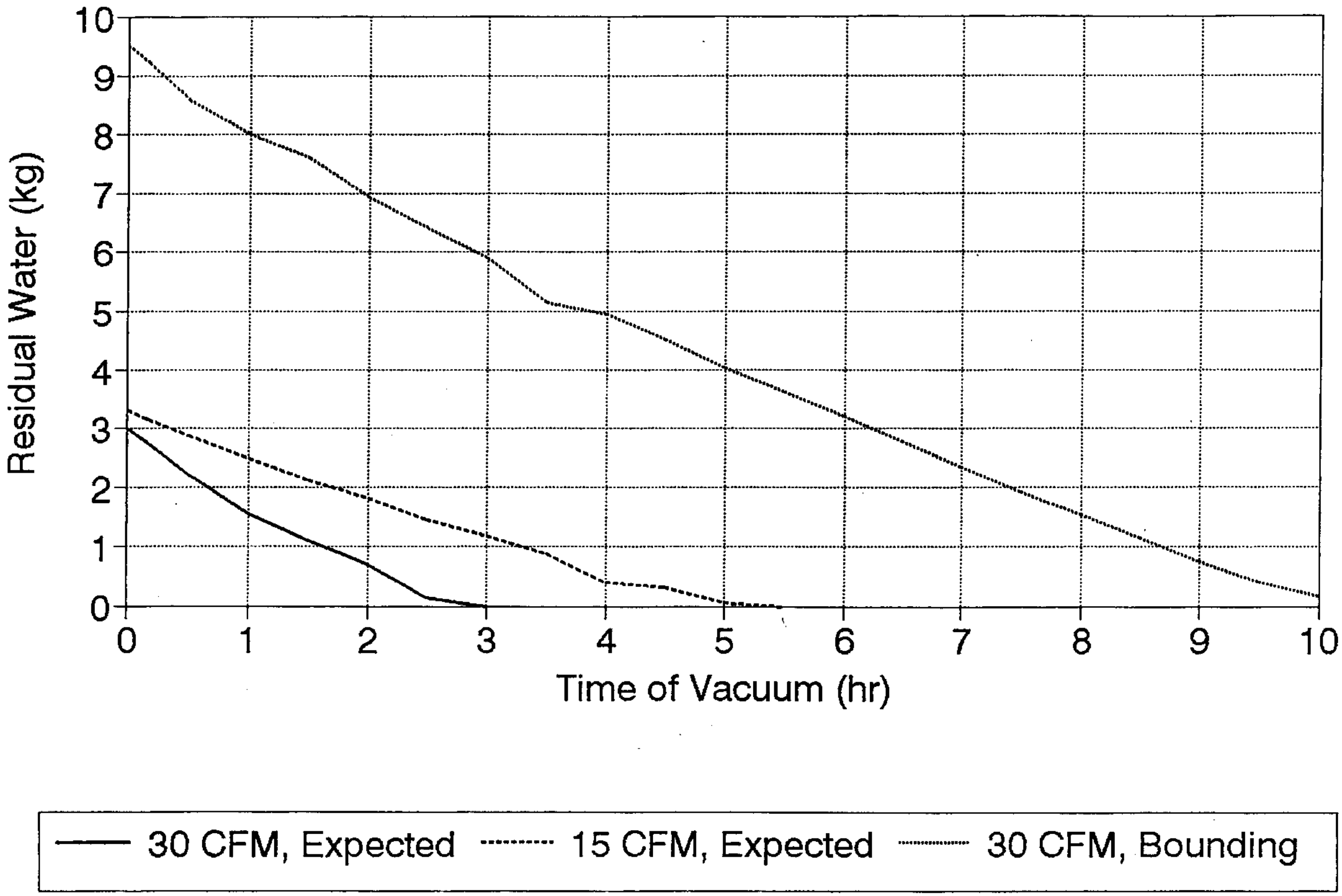
Stage	Approximate time (hr)	Mass Water Removed (kg)	Ending Pressure (Torr)
Bulk Air Removal	0.15	0.09	40
Bulk Water Removal	5.25	3.15	10
Final State	0.1	0.01	3.0 - 0.1
Total	5.5	3.25	NA

Calculations supporting the flow sheet stages are listed in Tables 2, 3, and 4 respectively. Calculations shown in Table 2 support the Bulk Air Removal stage and lists the SSFC starting pressure and temperature as atmospheric and 22 °C respectively. The 22 °C temperature was chosen to be conservatively low since the higher the canister fuel and gas temperature the more quickly the water is removed under vacuum. The initial SSFC temperatures is estimated to be near room temperature but could vary depending upon the time of year in which the SSFC loading occurs and holding time prior to processing.

Figure 5.

Liquid Water in SSFC During Vacuuming

Low decay power of 360 W

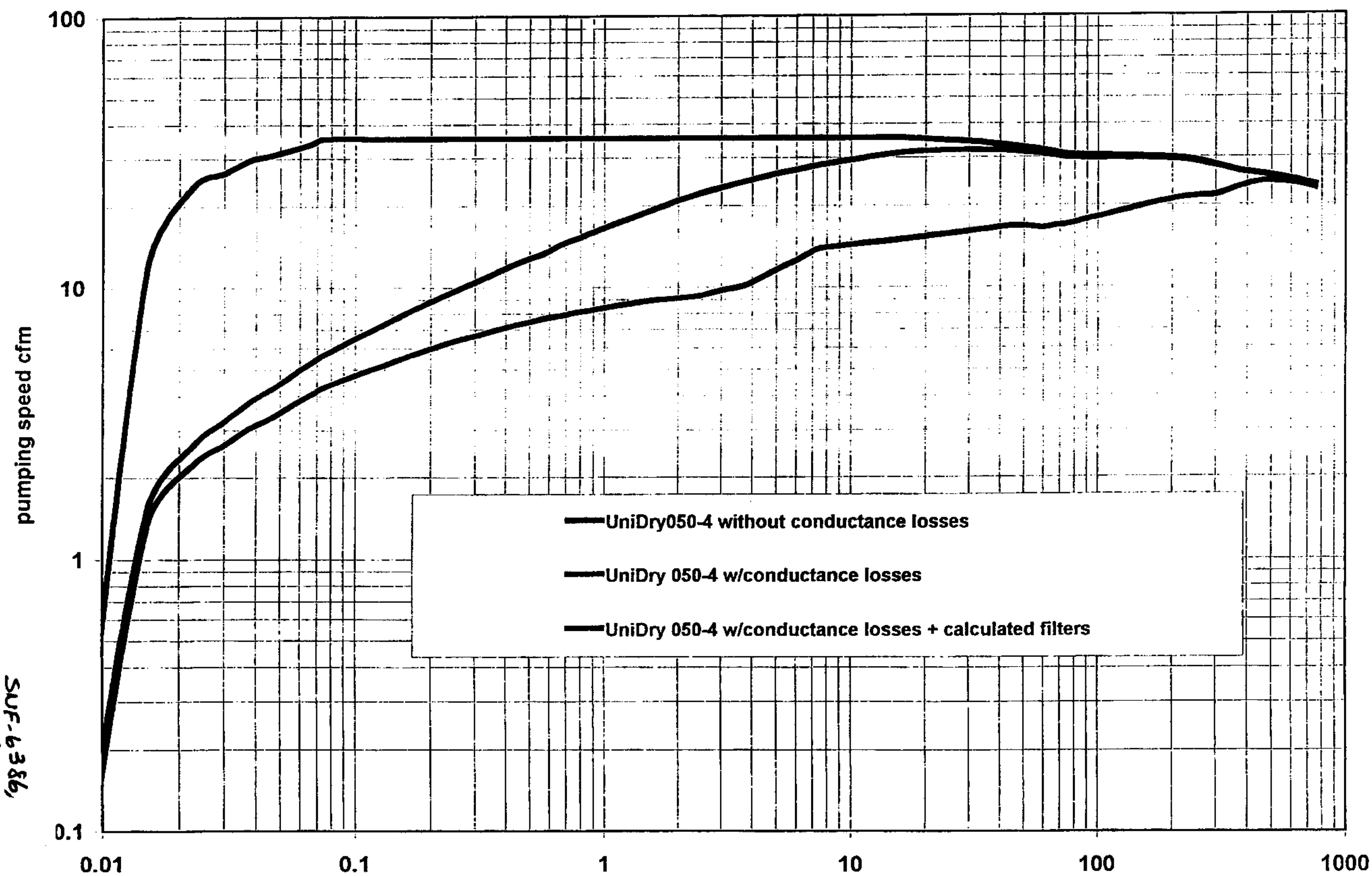


SNF-6386, R0

PFEIFFER VACUUM

Pumping Speed of UniDry 050-4 with conductance losses (35 feet 1"ID Line,3 x 1" valves, 7 x 1" elbows) and without conductance losses

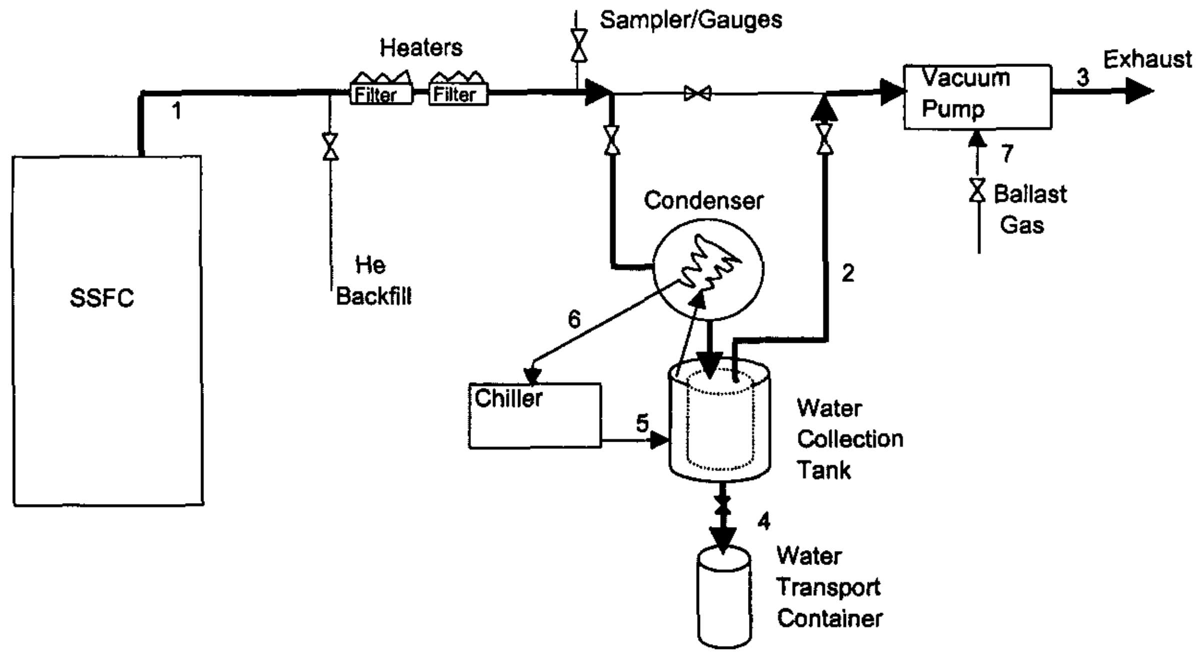
Figure 6.



Prepared by: Mike Trunca/Pfeiffer-Vacuum
Date: 3/28/00

SUF-6386, R0

Figure 7 SSFC Vacuum Drying - Stage 1 - Bulk Air Removal

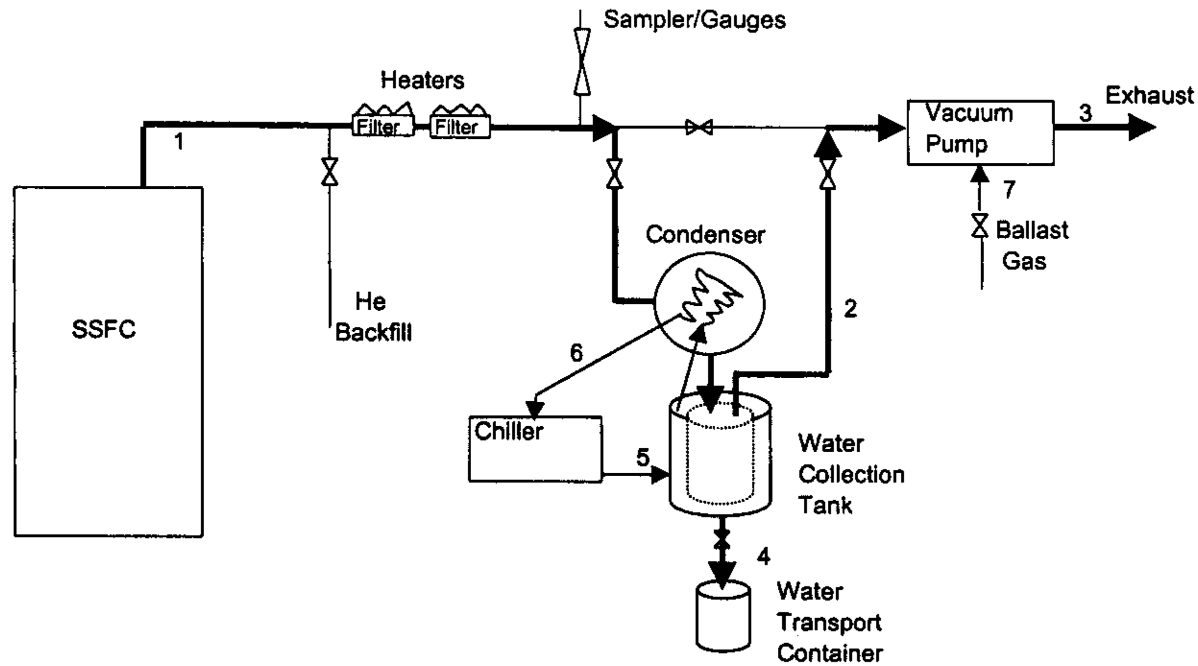


Stage 1 -- Bulk Air Removal 0.15 hr

Stream		1	2	3	4	5	6	7
	Units							
Temperature	°C	22	5	140	4	4	5	23
Pressure	mmHg	760 - 40	708 - 39	760	760			
Water Vapor	mol %	2.6 - 50	0.9 - 16.7	3.012				
Air	mol %	97.4 - 50	99.1 - 83.3	89.675				
Helium	mol %	0	0	7.313				100
Total	ave scfm	3.906	3.583	3.866				
water vapor	ave scfm	0.440	0.116	0.116				
air	ave scfm	3.466	3.466	3.466				
helium	ave scfm	0.000	0.000	0.283				0.28
Mass Flow Out								
water vapor	kg	0.090	0.024	0.024				
air	kg	1.139	1.139	1.139				
helium	kg	0	0	0.013				
water liquid	kg				0.066			

SNF-6386, R0

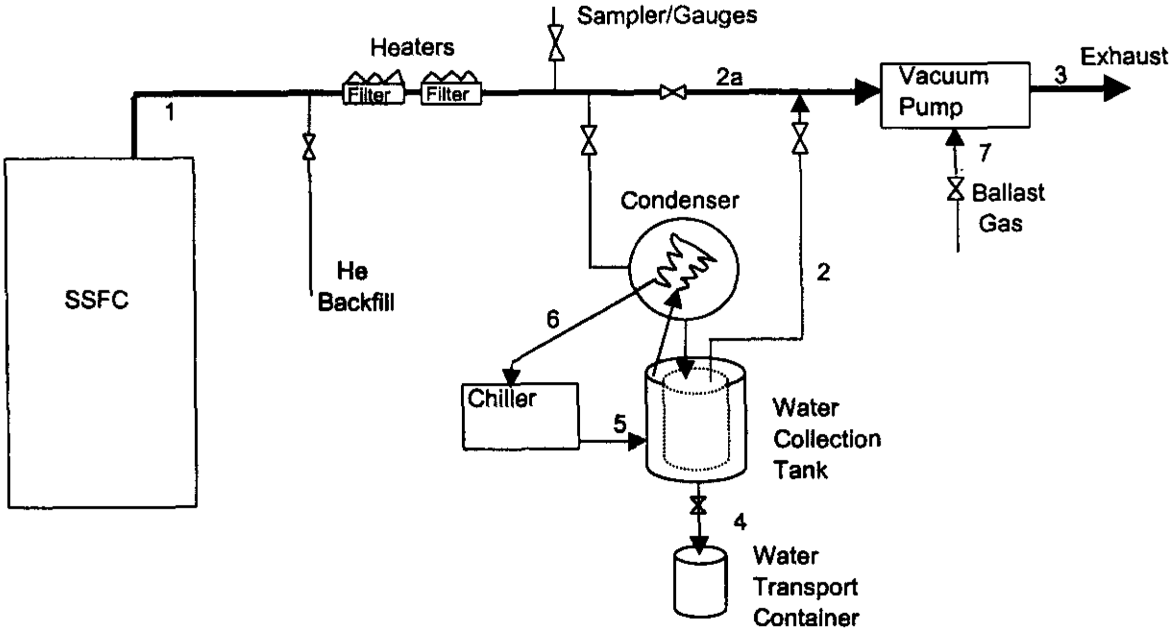
Figure 8 SSFC Vacuum Drying -- Stage 2 Flow Sheet -- Bulk Water Removal



Stage 2 -- Bulk Water Removal 5.25 hr

Stream		1	2	3	4	5	6	7
	Units							
Temperature	°C	22	4	140	4	4	5	23
Pressure	mmHg	40 - 10	39 - 9.8	760	760			
Water Vapor	mol %	50 - 100	16.7 - 100	1.758				
Air	mol %	50 - 0	83.3 - 0	0.947				
Helium	mol %	0	0	97.29				100
Total	ave scfm	0.442	0.00786	0.291				
water vapor	ave scfm	0.440	0.00511	0.00511				
air	ave scfm	0.00275	0.00275	0.00275				
helium	ave scfm	0	0	0.28				0.28
Mass Flow Out								
water vapor	kg	3.15	0.0366	0.0366				
air	kg	0.0316	0.0316	0.0316				
helium	kg	0	0	0.446				
water liquid	kg				3.11			
water liquid	gpm					4	4	

Figure 9 SSFC Vacuum Drying -- Stage 3 Flow Sheet -- Final State



Stage 3 -- Final State

Stream		1	2a	3	4	5	6	7
	Units							
Temperature	°C	22	40	140	4	3	5	23
Pressure	mmHg	10 to 0.1		760	760			
Water Vapor	ave mol %	100	100	0.335015				
Air	ave mol %	0	0	0				
Helium	ave mol %	0	0	99.66498				100
Total	ave scfm	0.00095	0.00095	0.283636				
water vapor	ave scfm	0.00095	0.00095	0.00095				
air	ave scfm	0	0	0				
helium	ave scfm	0	0	0.28				0.28
Mass Flow Out								
water vapor	kg	0.00013	0.00013	0.00013				
air	kg	0	0	0				
helium	kg	0	0	0.00849				
water liquid	kg				0.00013			
water liquid	gpm					4	4	

SNF-6386, R0

Table 2 Supporting Calculations for Flow Sheets Stage 1

		duration (hr)	pressure psia	pressure mmHg (torr)	temperature temp (°C)	absolute temp (K)	water vapor pres (torr)	mol fraction water	air pres (torr)	mol fraction air	volume (ft^3)	scf total (ft^3)	scf air start (ft^3)	scf air end (ft^3)	air ave flow rate (scfm)	air out (kg)	water out (kg)	water out rate (scfm)	helium flow rate (scfm)	Total gas flow (scfm)	water flow (gpm)
Stream 1																					
Bulk Air Removal-Init			14.7	760	22	295	20	0.0263158	740	0.974	35.58	32.93	32.06								
	End	0.15		40	22	295	20	0.5	20	0.500		1.73		0.867	3.47	1.14	0.090	0.440		3.91	
Stream 2																					
Gas flow from Condenser-Init				708.3	5	278	6.5	0.00918	701.8	0.991							av p 200 t	ave 9 min			
	End	0.15		39.0	5	278	6.5	0.1667	32.50	0.833					3.47	1.14	0.0238	0.116		3.58	
Stream 3																					
Vacuum Pump Discharge																					
		0.15		760	25	298	ave	ave	ave	ave											
	Average			760	25	298	22.89	0.0301	681.5	0.897					3.47	1.14	0.0238	0.116	0.283	3.87	
Stream 4																					
Condensate Drain																					
	Total	0.15															0.0662				0.00194
Chilled Water Flow																					
Stream 5	in	0.15			4																4
Stream 6	out	0.15			5																4
Stream 7																					
Helium Gas Flow																					
	Constant	0.15																	0.2826855		

Table 3 Supporting Calculations for Flow Sheets Stage 2

		duration (hr)	pressure	pressure	temperatu	absolute	water vap	mol fractio	air pres	mol fractio	volume	scf total	scf air	scf air end	air ave flo	air out	water out	ave water	helium flo	total gas	water flow
			psia	mmHg (tor	temp (°C)	temp (K)	pres (torr)	water	(torr)	air	ft^3	ft^3	start (ft^3)	ft^3	rate (scfm	(kg)	(kg)	rate (scfm	rate (scfm	flow (scfm	(gpm)
Stream 1																					
SSFC gas Properties-Init			0.77	40	22	295	20	0.5	20	0.5	35.58	1.733	0.867								
	End	5.25		10	22	295	10	1	0	0		0.433		0	0.00275	0.0316	3.15	0.440		0.442	
Stream 2																					
Gas flow from Condenser-Init				39.00	5	278	6.5	0.167	32.50	0.833											
	End	5.25		9.750	5	278	6.5	1	0	0					0.00275	0.0316	0.0366	0.00511		0.00786	
Stream 3																					
Vacuum Pump Discharge																					
		5.25		760	25	298															
				760	25	298									0.00275	0.0316	0.0366	0.00511	0.283	0.291	
Stream 4																					
Condensate Drain		5.25																			
																	3.11				0.00261
Chilled Water Flow																					
Stream 5	in	5.25			4																
Stream 6	out	5.25			5																4
																					4
Stream 7																					
Helium Gas Flow		5.25																	0.283		

Table 4 Supporting Calculations for Flow Sheets Stage 3

		duration (hr	pressure	pressure	temperatu	absolute	water vap	mol fractio	air pres	mol fractio	volume	scf total	scf air	scf air end	air ave flo	air out	water out	ave water	helium flo	total gas	water flow
			psia	mmHg (tor	temp (°C)	temp (K)	pres (torr)	water	(torr)	air	ft³	ft³	start (ft³)	ft³	rate (scfm	(kg)	(kg)	rate (scfm	rate (scfm	flow (scfm	(gpm)
Stream 1																					
SSFC gas Properties-Init			0.0132	10	22	295	10	1	0	0	35.58	0.433	0								
	End	0.1		0.1	22	295	0.1		0			0.00433		0	0	0	0.00013	0.00095	0	0.0010	
Stream 2																					
Gas flow from Condenser-Init				9.75	40	278	9.75	1	0	0			0		0	0	0.00013	0.00095		0.0010	
	End	0.1		0.0986	40	278	0.0986							0	0	0	0.00000	0.00000		0	
Stream 3																					
Vacuum Pump Discharge																					
		0.1		760	25	298															
				760	25	298									0	0	0.00013	0.00095	0.283	0.284	
Stream 4																					
Condensate Drain		0.1															0				0
Chilled Water Flow																					
Stream 5	in																				
Stream 6	out																				
Stream 7																					
Helium Gas Flow		0.1																	0.283		

SNF-6386, R0

Calculations for stage 1 (Bulk Air Removal) are listed in Table 2 and support the calculations for pumping the SSFC from atmospheric pressure down to 40 torr. The water vapor content of the SSFC gas was obtained from Perry's (1963) as a function of temperature assuming saturation. The flow rate of gas from the SSCF by the 33 cfm rated pump is estimated from Figure 6 which accounts for the conductance losses due to the filters, SSFC head restrictions, and other vacuum system components. For the initial Bulk Air Removal - Stage 1 the vacuum pump pumping speed is estimated to range from about 24 cfm at 760 torr to about 17 cfm at about 40 torr. Piepho (HNF-6381) reports from his HANSF modeling work that this reduction in pressure occurs within ten minutes for both the 30 cfm and 15 cfm cases that he modeled. The gas flow rate out of the canister is estimated from the difference in initial inventory of air and water vapor in the SSFC compared to the estimated amount at the 40 torr pressure. The water removal rate from the canister for a flow of 15 cfm was determined from the HANSF code to be about 0.6 kg per hour throughout the pump-down operation. The calculated flow rate in standard cubic feet, mass of air and water, and mole percent of gases are calculated as shown in Table 2 and are listed in the Figure 7 table for the streams of interest. Stream 2 constituents are calculated assuming that the SSFC gas is cooled in the condenser to 5 °C and all of the air continues to flow with the change in water vapor reduced to equilibrium at 5 °C. The initial and ending gas pressures of stream 2 for stage 1 were calculated from the pressure losses listed in Table 5 using the applicable flow rate. The average gas pressure out of the condenser was assumed to be about 200 torr as estimated from Figure 6. Stream 3 gases consist of the stream 2 gas plus the added ballast gas of 2.11 scfm helium being added to the vacuum pump as recommended by a vendor. The outlet temperature of the gases discharged from the vacuum pump is estimated to be about 140 °C as indicated by a vendor for this application. The water removed from the SSFC was calculated to be about 0.090 kg and the amount condensed and collected is calculated to be about 0.066 kg during stage 1.

Stage 2 calculations for Bulk Water Removal support the removal of water from the SSFC between the pressures of 40 torr and 10 torr for which water removal of about 0.6 kg/hour was noted by the HANSF calculations for the 15 cfm case by Piepho. Stage 2 calculations are listed in Table 3 and summarized in the Figure 8 table. The water removal time was determined to be about 5.25 hours as shown in Figure 5 which corresponds to a pumping speed of about 15 cfm for the pressure range of interest as shown in Figure 6 with conductance losses. The stream component calculations for stage 2 are shown in Table 3 and were performed in a similar way as for stage 1. The calculated water removed from the SSFC during stage 2 was 3.15 kg and 3.11 kg of this water was estimated to be collected as condensate.

Calculations for stage 3 final state are listed in Table 4 and summarized in the Figure 9 table. The condenser is by passed for this stage and only about 6 minutes is required to pump the SSFC pressure down to about 0.1 torr. The small amount of water vapor (~0.00013 kg) removed during this stage passes through the vacuum pump. The helium ballast gas is maintained and the calculations for this stage are similar to the other stages.

Table 5 SSFC Vacuum Drying System Pressure Drop Cases 4/17/00

Lines and fittings calculations based upon various diameter tubing calculations from Tables 3 and 4.

		30 SCFM		15 SCFM	
Case A	**System Components with 2 inch diam flex line**	equiv feet*	delta P, psi	equiv feet*	delta P, psi
	SSFC head penetration (0.609 inch dia hole 0.5 ft, 2 elbows)	3	0.381	3	0.095
	Two inch dia. flex tubing (25 ft) from SSFC to skid		0.006		0.002
	3 one inch dia. ball valves (assume same as tubing)	1	0.009	1	0.002
	10 one inch dia. Elbows ($K=14f_T$)	13	0.117	13	0.029
	2 one inch dia. Tees (branch flow $K= 60f_T$)	10.2	0.092	10.2	0.023
	6 inch dia. 0.3 micron filter (14.4 inch long)**		0.207		0.052
	6 inch dia. 0.3 micron filter (14.4 inch long)**		0.207		0.052
	10 ft length of one inch diameter tubing		0.090		0.001
	Condenser***		0.141		0.035
	Total **Total**		**1.249**		**0.291**
Case B	**System Components with one inch diam flex line**				
	SSFC head penetration (0.609 inch dia hole 0.5 ft, 2 elbows)	3	0.381	3	0.095
	One inch dia. flex tubing (25 ft) from SSFC to skid		0.225		0.056
	3 one inch dia. ball valves	1	0.009	1	0.002
	10 one inch dia. elbows	13	0.117	13	0.029
	2 one inch dia. tees	10.2	0.092	10.2	0.023
	6 inch dia. 0.3 micron filter (14.4 inch long)**		0.207		0.052
	6 inch dia. 0.3 micron filter (14.4 inch long)**		0.207		0.052
	10 ft length of one inch diameter tubing		0.090		0.022
	Condenser***		0.141		0.035
	Total **Total**		**1.468**		**0.367**
Case C	**System Components with one inch diam flex line**				
	SSFC head penetration (1.0 inch diam hole 1 ft, 2 elbows)	4	0.036	4	0.009
	All other same as Case B				
	Total **Total**		**1.123**		**0.281**
Case D	**System Components with two inch diam flex line and 1.0 inch head penetration**				
	All other same as Case B **Total** **Total**		**0.904**		**0.204**
Case E	**System Components with one inch diam flex line and smaller filters**				
	SSFC head penetration (0.609 inch dia hole 0.5 ft, 2 elbows)	3	0.190	3	0.095
	One inch dia. flex tubing (25 ft) from SSFC to skid		0.225		0.056
	3 one inch dia. ball valves	1	0.009	1	0.002
	10 one inch dia. Elbows	13	0.117	13	0.029
	2 one inch dia. tees	10.2	0.092	10.2	0.023
	3.5 inch dia. 0.3 micron filter (13.9 inch long)		1.325		0.331
	3.5 inch dia. 0.3 micron filter (13.9 inch long)		1.325		0.331
	10 ft length of one inch diameter tubing		0.162		0.022
	Condenser***		0.141		0.035
	Total **Total**		**3.586**		**0.926**

* Equivalent lengths of pipe in feet from Crane (Technical Publication 410) page A-29 and A-30. The equivalent lengths of components were estrimated from Crane and related to the pressure drop per foot of the respective line diameter.

** See filter calculation from vendor data

*** See condenser calculations form vendor data

Table 5 SSFC Vacuum Drying System Pressure Drop Cases (Continued)

Calculations to estimate pressure drops across proposed filters and condenser for 30 scfm and 15 scfm based upon vendor supplied ratings. Pressure drops across the filters and condensers at the desired flow rates were determined by ratioing the square of the velocities to the pressure drop value for the vendor supplied data to those for the desired flow rates.

	Filters	Condenser
A (6 " dia.)	0.25 psi at 33 acfm (vendor data)	0.0696 psi at 21.05 cfm (vendor data)
	0.207 at 30 acfm (Calculated)	0.141 at 30 cfm (calculated)
	0.052 at 15 acfm (calculated)	0.035 at 15 cfm (calculated)
B (3.5 " dia)	0.23 psi at 12.5 acfm (vendor data)	
	1.325 at 30 acfm (calculated)	
	0.331 at 15 acfm (calculated)	

Summary and Conclusions for Flow Sheet Development

Calculations for SSFC vacuum drying pressure drops for various tubing diameters, head penetrations, and filters are summarized in Table 5. Supporting calculations are shown in Tables 6 and 7. Consideration of flexible tubing (25 ft length) at two-inch diameter (Case A) and one-inch diameter (Case B) were compared with less than 0.1 psi difference for flow at 15 cfm. The minor difference in differential pressure indicates that one-inch diameter flexible tubing can be used without affecting the vacuum pump performance appreciably.

Consideration of size of vertical head penetration indicates the difference between the 0.609 inch diameter and one-inch diameter is less than 0.1 psi for flow of 15 cfm and can be tolerated.

The difference in differential pressure for the two sizes of filters (3.5 inches by 10 inches long and 6 inches diameter by 14.4 inches long) considered indicates that a significant difference in pressure drop occurs (0.66 Vs 0.1 psi respectively for flow of 15 cfm). The larger filters (6-inch diameter by 14.4 inches long) with the lower pressure drop are desirable.

References

1. Crane, 1979, Technical Paper No. 410, *Flow of Fluids Through Valves, Fittings, and Pipe*, New York, New York.
2. HNF-3043-Rev 1, 2000, *Performance Specification Fuel Drying and Canister Inerting System for Shippingport Pressurized Water Reactor (PWR) Core 2 Blanket Fuel Assemblies Stored within Shippingport Spent Fuel Canisters*, Fluor Hanford, Richland, Washington.
3. SNF-3650, Plys, M., 1999, *HANSF 1.3.2: Users's Manual, Rev. 2*, Fluor Daniel Hanford, Incorporated, Richland, Washington.
4. SNF-5809, Rev. 0, 2000, *Shippingport Spent Fuel Canister System Description*, Fluor Hanford, Incorporated, Richland, Washington.
5. NUREG-1536, *Standard Review Plan for Dry Cask Storage Systems*, US Nuclear Regulatory Commission.
6. Perry's *Chemical Engineering Handbook, Fourth Edition*, 1963, McGraw-Hill Book Company.
7. HNF-6381 Rev 0 , Piepho, M. G., 2000, Vacuum Drying and Thermal Simulations for Shippingport Fuel Assemblies in a Canister at T-Plant, Fluor Federal Services, Inc., Richland, Washington.
8. Trunca, M., 2000, Pumping Speed of UniDry 054-4 with Conductance Losses and Without Conductance Losses, Pfeiffer-Vacuum.

4/17/00
dwj

Table 6 SSFC Vacuum Drying Pressure Drop Calculations for 30 scfm air flow in line to SSFC vacuum pump
Pressure Drop Calculations for Alternative Tubing Lines Using the Darcy Formula

delta P= $pfLv^2/144D2g$

Flow in 2.0 inch inside diameter smooth tubing

flow area= 0.0218 ft^2

Where delta P = pressure drop pounds/square inch

p= density of air		v= mean velocity in feet per second	
f= friction factor		D= internal diameter, in feet	
L= length of pipe in feet		g=	32.2 ft/sec^2

R_e=123.9dvp/u	23728	u_{air}= 0.018 cp at 68 F per A-5 of Crane		
f=	0.0098	Page A-23 of Crane Flow of Fluids - Using R_e		
p=	0.0752 lb/ft^3	air @ 14.7 psia and 68 F	20 C	Crane A-8
L=	25 ft			
v=	22.92 ft/sec			
D=	0.1667 ft			
delta P_{25} =	**0.0063 lb/in^2**			

Flow in 1.0 inch inside diameter smooth tubing flow area = 0.005454 ft^2

R_e=	47453	
f=	0.011	Page A-23 of Crane Flow of Fluids - Using R_e
v=	91.67 ft/sec	
D=	0.0833 ft	
delta P_{25}=	**0.225 lb/in^2**	

Flow in 3/4 inch inside diameter smooth tubing

R_e=	63270	
f=	0.012	flow area= 0.003068 ft^2
v=	162.97 ft/sec	
D=	0.0625 ft	
delta P_{25} =	**1.034 lb/in**	

Flow in 0.609 inch smooth bore hole in cylinder head

R_e =	77909	flow area= 0.002023 ft^2
f=	0.013	
L=	0.5 ft	
v= ft/sec	247.14 ft/sec	
D=	0.05075 ft	
delta $P_{0.5}$ =	**0.0634 lb/in^2**	

4/17/00

dwj

Table 7 SSFC Vacuum Drying Pressure Drop Calculations for 15 scfm air flow in line
Pressure Drop Calculations for Alternative Lines Using the Darcy Formula

delta P= $pfLv^2/144D2g$

Flow in 2.0 inch inside diameter smooth tubing

flow area= 0.021815 ft^2

Where delta P = pressure drop pounds/square inch

p= density of air	v= mean velocity in feet per second
f= friction factor	D= internal diameter, in feet
L= length of pipe in feet	g= 32.2 ft/sec^2

R_e=Ren #	11864 123.9dvp/u	u_{air}=	0.018 cp at 68 F per A-5 of Crane		
f=	0.0098	Page A-23 of Crane	Flow of Fluids - Using R_e		
p=	0.0752 lb/ft^3	air @ 14.7 psia and 68 F		20 C	Crane A-8
L=	25 ft				
v=	11.46 ft/sec				
D=	0.1667 ft				
delta P_{25}	**0.0016 lb/in^2**				

Flow in 1.0 inch inside diameter smooth tubing flow area 0.005454 ft^2

R_e=	23726		
f=	0.011	Page A-23 of Crane	Flow of Fluids - Using R_e
v=	45.84 ft/sec		
D=	0.0833 ft		
delta P_{25}=	**0.0562 lb/in^2**		

Flow in 3/4 inch inside diameter smooth tubing

R_e=	31635	
f=	0.012	flow area= 0.003068 ft^2
v=	81.49 ft/sec	
D=	0.0625 ft	
delta P_{25}	**0.258 lb/in**	

Flow in 0.609 inch smooth bore hole in cylinder head

R_e =	38954	flow area= 0.002023 ft^2
f=	0.013	
L=	0.5 ft	
v= ft/sec	123.57 ft/sec	
D=	0.05075 ft	
delta $P_{0.5}$	**0.0159 lb/in^2**	

DISTRIBUTION SHEET

To	From	Page 1 of 1
Distribution	D. M. Johnson	Date 5/18/00
Project Title/Work Order SNF-6386 Rev 0, Preliminary Design Report, Shippingport Spent Fuel Drying and Inerting System		EDT No. 62~~0~~9585
		ECN No.

Name	MSIN	Text With All Attach.	Text Only	Attach./ Appendix Only	EDT/ECN Only
Ayers, W.S. (3 copies)	T3-28				
Carrell, R.D.	R3-11				
Ellis, M.W.	T3-28				
Garvin, L.J.III	R3-26				
Hagmann, D.B.	R2-89				
Hunter, J.A.	H1-19				
Jeppson, D.W.	H3-27				
Johnson, D.M.	R3-11				
Kasper, J.	T3-28				
Kruger, O.L.	R3-11				
McCormack, R.L.	R3-11				
Sexton, R.A.	R3-86				
Smith, D.W.	S2-48				
Turnbaugh, J.E.	X3-79				