MASTER

CRYOTRAP CHECKOUT TEST REPORT

NTO-R-0159

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1.0 INTRODUCTION

This report presents the results of an evaluation of the data acquired during the checkout of the LN₂ Cryotrap System, performed on 30 September 1968, and 4 October 1968.

1.1 TEST OBJECTIVES

The primary objectives of the test were: 1) to determine the operational capabilities and structural integrity of the cryotrap; 2) to demonstrate the capability of either RV-2848 or RV-3090 to prevent overpressurization of the control drum actuator bellows.

1.2 TEST PROCEDURE

The detailed test procedure is presented in NTO-FAC-TOP-0007, "Procedure for Cryotrap Test". The official operational copy of the procedure is in the ETS-1 FOSS files. The various test phases, which are presented in Table 1, were: cryotrap proof and leak check; LN₂ heat exchanger fill and chill; control drum supply system He flow tests; and the RV-3090, RV-2848 and combined RV-3090/RV-2848 relief valve tests.

1.3 TEST LIMITS AND REQUIREMENTS

- a. The chiller exit gas temperature must be maintained below 175°R during flow to the control drums.
- b. The pressure at the control drum actuator port must be maintained at 200 ± 10 psig.
- c. The actuator inlet pressure should not exceed 260 psig.
- d. The supply system should be capable of supplying 0.073 pps of helium (0.05 pps of GH₂) at temperatures between 430°R and 560°R. The supply system should be capable of supplying 0.062 pps helium (0.0425 GH₂) to the TPCV; therefore, the total helium flowrate requirement is .135 pps (0.093 pps GH₂).
- e. Maximum allowable leakage between PRV-403 and PRV-200 is 10^{-5} scc/sec with the system pressurized to 900 psig.

1.4 SYSTEM FUNCTION

1.4.1 Cryotrap Assembly

The cryotrap was designed to remove any trace quantities of compressor oil, water or other impurities from the engine control drum actuator

TABLE 1
TEST SUMMARY TABLE

Date	Test Description	Range Time Span Seconds	Comments
30 Sept. 1968	1150 psig Proof Pressure Test of system between PRV403 and PRV200	46010 to 46324	There was no evidence of system damage.
	300 psig Pressure Test of system between PRV200 and PRV703	46499 to 46821	There was no evidence of system damage.
	900 psi Leak Test of system upstream of PRV403	47352 to 47497	All significant leaks were eliminated.
	200 psi Leak Test of system between PRV200 and PCV703	49661 to 50021	All significant leaks were eliminated.
	Initial Fill and Chill of LN ₂ Chiller	56595 to 58600	Approximately 80 gallons were used to initially fill and chill the chiller.
	Flow Test No. 1	60084 to 60325	Reached steady-state flow of 0.123 pps, DP703 = 72%, (TE570) _{Final} = 212°R, (TT571) _{Final} = 141°R, TE535 = 537°R.
	Flow Test No. 2	60448 to 60557	Reached steady-state flow of 0.034 pps, DP703 = 72%, (TE570) _{Final} = 214°R, TT571 _{Final} = 142°R, TE535 = 537°R.
	Flow Test No. 3	60820 to 61021	Maintained steady-state flow of 0.078 pps, DP703 = 61%, TE570 _{Final} = 206°R, TE571 _{Final} = 141°R, TE535 = 536°R.
	Flow Test No. 4	61228 to 61521	Maintained flows of .080 and .038 pps at DP703 at 62% and 44%, respectively, TE570 _{Final} = 201°R, TT570 = 142°R, TE535 = 536°R
	RV-3090 Test	62145 to 62170	The relief valve maintained pressure below 270 psig and reseated at 240 psig, TE570 _{Final} = 228°R, TT571 _{Final} = 147°R.
	Flow Test No. 5	65205 to 65405	Maintained steady-state flowrate of .077 and .127 pps with PCV703 at 61% and 73%. TE570 _{Final} = 231°R, TT571 = 143°R, TE535 _{Final} = 535°R.

TABLE 1 (Continued)

Date	Test Description	Range Time Span Seconds	Comments
30 Sept. 1968	RV-2848 Test	65630 to 65652.2	RV-2848 initially opened at 60 psig, then allowed the pressure to increase to 280 psig. The inlet pressure then varied between 270 psig and 160 psig. The valve re-set at 240 psig. $TE570_{Final} = 223^{\circ}R$, $TT571 = 147^{\circ}R$.
	Flow Test No. 6	70271 to 71041	Maintained steady-state He flowrates of .071 and .027 pps at PCV-703 settings of 60% and 38%. $TE570_{Final} = 218^{\circ}R$, $TT571_{Final} = 143^{\circ}R$, $TE535 = 532^{\circ}R$.
	RV-2848/RV-3090 Combined Test	71239.9 to 71263.2	RV-2848 opened at 80 psig and maintained the pressure at 80 psig. The valve re-seated at 63 psig. $TE570_{Final} = 227^{\circ}R$, $TT571_{Final} = 154^{\circ}R$.
	Repeat of RV-2848/RV-3090 Combined Test	71853.7 to 72101	RV-2848 opened at 80 psig and maintained the pressure at 80 psig and re-seated at 58 psig.
4 Oct. 1968	Slow pressurization of system up to RV2848/RV3090	72268 to 72307	The pressure downstream (PT478) of PRV-200 was increased slowly and a relief valve opened at 262 psig; however, pressure then decreased to 80 psig and the relief valve then re-seated at 59 psig.
	Repeat of RV-2848/RV-3090 Relief Valve Test	52278.7 to 52295	RV-2848 opened at 60 psig then maintained the pressure at 80 psig and re-seated at 80 psig.
	Slow pressurization to determine if relief valves are rate sensitive.	53028 to 53070	The RV-2848/RV-3090 inlet pressure (PT478) was increased from 80 psig to the relief set pressure of 260 psig. Both relief valves maintained 260 psig and re-seated at 240 psig.

supply gases (GH_2 or GHe). These contaminants might otherwise be condensed in the chilled reactor control drum actuators and block the Servo valve bleed orifices.

1.4.2 Pressure Relief System

A dual pressure relief system has been installed downstream of PRV-200 to prevent overpressurization (> 275 psia) of the bellows assembly in the Servo valve of each control drum actuator.

1.5 SYSTEM DESCRIPTION

Figure 1 is a schematic of the GH_2 and GHe control drum and TPCV actuator supply systems. The significant data related to the primary system components are presented in Table 2. The cryotrap was installed in the 201 GH_2 line immediately upstream of PRV-200 and is comprised of two major subsystems: the recuperator and the LN_2 heat exchanger. The ambient gas enters and is cooled in the recuperator, then passes thru the LN_2 chiller where the gas is cooled below 175°R , and then passes through the recuperator where it is warmed to a minimum of 430°R before re-entering the normal flow path. The detailed description of the LN_2 heat exchanger and the recuperator is presented below:

1.5.1 LN_2 Heat Exchanger Description

The chiller assembly consists of a 16-inch diameter by 44.7-inch long cylindrical can which houses a 41-foot long coil assembly made from $3/4"$ x 0.065 wall 304 stainless tubing. The volume of the chiller less the coil volume is 5.1 cu. ft. The nominal coil diameter is 12 inches and the assembly has approximately 13 coils with a 1.5-inch pitch.

The chiller is externally insulated with type AA1702 polyurethane foam with a density of 2 lbs/ft³. The insulation is approximately 4 inches thick in the bottom, 6 inches thick in the sides and 6 inches thick on the top. The liquid level ΔP transducer (PD852) has ports located 12.5 inches and 44.5 inches from the bottom of the cylinder. The K/A^2 value for the filter cannot be accurately determined from available data. The filter has an operating pressure of 1500 psig, operating temperature range of 65°R to ambient, minimum element collapse ΔP of 3600 psid, a filtration capability of 10 normal (98% removal) and 25 absolute (100% removal) and a rated flow of .33 pps of He.

1.5.2 Recuperator Description

The recuperator is a 20-foot long by 2.2-foot high by 1.4-foot wide rectangular aluminum enclosure which houses a heat exchanger assembly. The heat exchanger consists of an inner and an outer concentric tubing assembly. The warm gas enters the inner tubing, which is $3/4"$ O.D. by 0.049-inch wall stainless tubing, and is prechilled by the cold chiller exit gas. The cold chiller gas is warmed up when the gas flows through

SCHEMATIC OF THE GH₂ AND GHe SUPPLY SYSTEMS TO THE DRUMS AND TPCV ACTUATORS

FIGURE 1

TABLE 2
COMPONENT DATA SUMMARY

Component Description	MFg.	Model No.	Size	(Cv) Max. Flow Capacity	Operating Temp.	Pressure Rating ASA	Set Pressure
RV3090	Ladewig	11034-S-FF	3 x 4 with 2½" dia. seat	4.7 pps of GH ₂ @ 250 psig	Ambient	150 lb.	250 psig
RV2848	Skyvalve	IRVA-3201	2"	5.5 pps of GH ₂ @ 250 psig (Cv = 90)	Ambient	150 lb.	237 psig
PRV-200	Grove	450-K6 T 760	2"	12	Ambient	1500 lb.	-
PRV-403	Grove	450-K8 T 844	2"	20	Ambient	1500 lb.	-
PRV-402	Grove	450-K8 T 849	2"	20	Ambient	1500 lb.	-
RV3480	Ladewig	2123-C-FF	2" x 3" 1½" dia. seat	30,000 SCFM of Air	Ambient	1500 lb.	1650 psig
RV3481	Anderson Greenwood	2-6625-501 2-	3/4" x 1"	138 SCFM	Cryogenic	150 lb.	55 psig
CHV-3485	Annin	4590	1"	7.6	Cryogenic	1500 lb.	-
CHV-3489	Security	919-L	2"	92	Ambient	150 lb.	-
CHV-3486	Pacific	6-1100-10T RJ(16169)	2"	-	Cryogenic	150 lb.	-
CHV-3482	Annin	4590	2"	35	Ambient	1500 lb.	-
CHV-3484	Security	999-L	2"	70	Ambient	900 lb.	-
CHV-3483	Flowmatics	E-909-17	3/4"	4.5	Ambient	1500 lb.	-
CHV-2333	Security	919-L	1½"	50	Ambient	150 lb.	-
CHV-3091	Annin	1590	4"	195	Ambient	150 lb.	-
PCV-703	Annin	4560	1"	4.8 P	Ambient		-
FE-430 (1)	Flow Technology	FT-32C-40GB	2"	N/A	Ambient	1500 lb.	-

- (1) The flowmeter was changed and the new calibration curve slope (K) is 1540 cycles/actual cu. ft. The flowmeter equation is $W(\text{pps}) = 2.422 \times 10^{-4} \times F_m \times \text{PI615}/\text{TE535}$ where F_m is the turbine meter output in cps, PI615 is the flowmeter inlet pressure in psia and TE535 is the flowmeter inlet gas temperature in °R.

the annulus between the inner and outer tubing, which is $1\frac{1}{4}$ " x 0.095 wall. The recuperator heat exchanger tubing run is approximately 225 feet long and is made of twelve 18.1-foot straight tubing runs connected by twelve 7.5-inch diameter 180° tube bends. The volume of the wall tubing is approximately .52 cu. ft. and the annulus volume is approximately .86 cu. ft. The volume in the rectangular housing is filled with type AA1702 polyurethane foam with a density of 2 lbs/cu. ft.

2.0 SUMMARY TEST RESULTS

- 2.1 The capability of the cryotrap assembly to cool the control drum supply gas to temperatures low enough ($< 175^{\circ}\text{R}$) to condense out undesirable contaminants was demonstrated. The cryotrap LN_2 heat exchanger (chiller) exit gas temperature was maintained below 145°R during the steady-state flow periods. This temperature was maintained at He flowrates ranging from 0.027 pps to 0.127 pps and chiller LN_2 levels as low as 60%. The gas temperature at the FE-430 turbine flowmeter varied between 538°R and 530°R during the entire test series. The acceptable temperature range is 430°R to 560°R . The cryotrap is adequate for XE testing.
- 2.2 The performance of RV-3090 during the individual RV-3090 test was acceptable. The relief valve maintained the line pressure between 269 psig and 258 psig during the flow test. Some pressure oscillations (± 7 psi) were noted during the test; however, these are characteristic of this type of relief valve. The relief valve reseated at 241 psig. This relief valve is adequate for XE testing.
- 2.3 The capability of RV-2848, which is a back pressure control type relief valve, to limit the pressure below the maximum allowable pressure of 275 psi, was demonstrated under conditions which simulated a PRV-200 failure during the initial system setup operations. The valve maintained the pressure between 80 and 100 psi during the combined relief valve tests. The ability of this relief valve to maintain the actuation system pressure at 237 psi was not demonstrated. The relief system was capable of maintaining the system pressures at 268 psig during a malfunction which simulated a pressure increase rate of 340 psi/sec from an initial system pressure of 232 psig. Significant pressure oscillations (225 ± 55 psi) were evidenced downstream of PRV-200 during the individual RV-2848 relief valve test. This behavior was not acceptable for this valve; however, the valve did not exhibit this characteristic when tested with RV-3090 during later tests. Post-test disassembly of the relief valve revealed a defective O-ring in the RV-2848 pilot valve; however, the test on 4 October 1968 showed that replacement of this O-ring did not affect the characteristic of the valve to open at significantly lower pressures (80-100 psi) than the set pressure (237 psi) and to maintain the pressure at 80 to 200 psig when subjected to rapid pressure increases (~ 1000 psi/sec).

The valve is rate sensitive; however, this characteristic may not affect the relief valve performance under more realistic failure mode, which will be simulated during planned future testing.

- 2.4 The LN₂ usage during the initial chill and fill of the 5.1 cu. ft. chiller and during various flow conditions was determined. The usage during the 0.71 pps flow tests varied between 509 lbs/hr and 600 lbs/hr. The chiller would have to be replenished every 13 to 14 minutes to maintain the level between 50 and 100% full. The no-flow boil-off rate was related to chiller level and increased significantly above the 75% level due to the increased heat conduction paths and inadequate initial chill of the top of the LN₂ heat exchanger. The interaction between the chiller and the LN₂ cooldown system was not determined because the 1-inch line between the two systems had not been plumbed in.
- 2.5 Some system pressure drop versus flow characteristics were determined and were consistent and in reasonable agreement with previous off-site test results.
- 2.6 There was no structural damage evidenced or any system problems encountered during the proof pressure tests.

3.0 TECHNICAL DISCUSSION

3.1 SYSTEM PROOF PRESSURE AND LEAK TESTS

The system proof pressure and leak tests were accomplished per NTO-FAC-TOP-0007. There was no evidence of any damage to the Facility between PRV-403, CHV-3484 and PRV-200 when the system was subjected to a proof pressure of 1150 psig for 5 minutes. There was no evidence of damage when the system downstream of PRV-200 was pressurized to 300 psig for 5 minutes.

The system between PRV-403 and PRV-200 was pressurized to 900 psig and all of the significant leaks were eliminated. The pressure at PT618 remained essentially constant when the supply was cut off by closing RSV-868 and 904 psig locked up between PRV-403 and PRV-200. A 200 psig leak test of the system downstream of PRV-200 was conducted and all of the significant leaks were eliminated.

3.2 INITIAL FILL AND CHILL OF LN₂ CHILLER ASSEMBLY

The initial fill and chill of the LN₂ chiller was accomplished using an LN₂ trailer, which was pressurized to 35 psig during the entire test. During engine testing, the LN₂ to the chiller will be supplied from the 225-LN-4 line which is the main LN₂ supply line from V-3601.

A one-inch tubing run with an RSV and check valve will connect the LN₂ system with the chiller fill line. The theoretical chiller volume versus level transducer (PD852) indication relationship is shown in Figure 2. Approximately 80 gallons (10.7 cu.ft.) were used to initially chill and fill the 5.1 cu. ft. chiller. The LN₂ was allowed to boil off for 6.85 minutes. The level changed from 89% to 58% or the loss rate was 4.85%/min (726 lbs/hr). The chiller was refilled and the LN₂ was again allowed to boil off for 5 minutes. The level changed from 87% to 71% or the loss rate was 3.2%/min (480 lbs/hr). The test data revealed that the no-flow boil-off rate is related to the LN₂ level in the chiller. The data related to no-flow boil-off is shown in Figure 3. The reason for the rapid increase in boil-off rate above 78% is the inadequate chilldown of the top of the chiller and the presence of heat conduction paths into the top of the chiller. The chiller would have to be refilled to take care of no-flow boil-off at 30 to 40 minute intervals if the level were maintained between 22.25 inches (50%/.27 psid) and 35.6 inches (80%/.64 psid) during future tests. The total expected test usage will be discussed in a later section of this report. The boil-off rate quoted from the previous cryotrap test data was 280 lbs/hr or 1.86%/min.

3.3 He FLOW TESTS

Six (6) He flow tests were conducted during the cryotrap checkout test on 30 September 1968. The pertinent data related to these flow tests is presented in Table 3. Figures 4 thru 13 are Cal-comp plots of the pertinent parameters versus range time. After the initial chill and fill of the LN₂ heat exchanger, the system between PRV-402/PRV-403 and PRV-200 was purged by flowing He through the cryotrap assembly and out through the vent valve (RSV-881). This operation insures that all of the gas will have been exposed to cryotrap filtration before flow is established to the control drum actuators. Flow through RSV-881 was maintained for 1.3 minutes. Extrapolation of the LN₂ heat exchanger pressure drop data indicated that the flow through the vent line was approximately .50 pps or an integral flow of 39 lbs. The 39 lbs represented approximately 74 volume displacements, which is much more than adequate for pre-purging the system up to PRV-200.

The data evidenced that the flowrate through the cryotrap was excessively high during the pre-purge phase at 300 psig. The chiller exit gas temperature (TT571) attained a steady-state value of 361°R during this purge phase. The desired temperature is 175°R. Therefore, it is recommended that the pre-purge be conducted with only 25 to 50 psig established at PT618.

Vent valve RSV-881 was closed and 200 psig was established between PRV-200 and PCV-703. Flow was initiated when PCV-703 was opened as shown in Figure 4. The maximum allowable He flowrate at 200 psig

Differential Pressure - PD852, psid

CHILLER DIFFERENTIAL PRESSURE (PD852) VS CHILLER INVENTORY

100% Full = 250 lbs at
48 lbs/cu.ft.
100% Full = 5.1 cu.ft.
100% Full = 44.5 inches
78.5% Full = 35 inches

FIGURE 2

Boil-off Rate - % Volume/Minute

BOIL-OFF RATE VS CHILLER INVENTORY

FIGURE 3

$\frac{1\% \text{ volume}}{\text{minute}} = 150 \text{ lbs/hr}$

TABLE 3

FLOW TEST SUMMARY TABLE

Flow Test No.	He Flowrate Steady- state (pps)	Flow Time @ Steady- state Flow (Minutes)	Initial LN ₂ Level (%)	Final LN ₂ Level (%)	Initial/Final Inlet Gas Temperature TE570 (°R)	Initial/Final Chiller Exit Gas Temperature TT571 (°R)	Initial/Final FE430 Inlet Gas Temperature TE535 (°R)	PT618 Cryotrap Outlet Press. (psig)	Cryotrap delta-P Avg. (psid)	Chiller delta-P PD855 (psid)
1	.123	4.5	83	73	251/209	143/141	535/538	748	108	5.1
2	.034	1.6	85	83	228/214	148/142	538/537	847	10	.4
3	.078	2.84	79.5	72.5	233/206	149/141	536/536	810	47	2.0
4A	.080	1.72	84.2	80.5	218/204	146/131	538/536	812	45	2.0
4B	.038	1.42	84.5	70.5	204/201	141/142	536/536	847	11	.53
5A	.071	.88	78	75.5	342/270	152/144	535/535	837	38	1.8
5B	.127	.78	75	72.5	260/230	144/143	535/535	773	102	5.0
6A	.071	2.67	76	67	329/231	152/142	534/533	848	34	1.7
6B	.027	7.84	66.5	59	232/218	143/143	533/532	878	4	.21

CRYOTRAP C/O TEST 30 SEPT '68

CRYOTRAP C/O TEST 30 SEPT 68

1 - PD852.. - PSID

FLOW TEST No. 1

FIGURE 5

-14-

Aug 5

14

CRYOTRAP C40 TEST 30 SEPT 68

1 - 11576.1
2 - 11571.1
3 - 11595.1

1 - RANKINE
2 - RANKINE
3 - RANKINE

FLOW TEST NO. 2
($VV_{He} = 0.034$ pps)

FIGURE 6

-15-

CRYOTRAP C/O TEST 30 SEPT 68

CRYOTRAP C/O TEST 30 SEPT 68

CRYOTRAP C/0 TEST 30 SEPT 68

CRYOTRAP C/O TEST 30 SEPT 68

1 - PD652 - PSID

FLOW TEST NO. 4

FIGURE 10

-19-

Fig 11A ✓

Fig 11B

CRYOTRAP C40 TEST 30 SEPT 68

CRYOTRAP C/O TEST 30 SEPT 68

CRYOTRAP C/O TEST 30 SEPT 68

1 -x- PD852.. -x- PSID

POST RV-2848 FLOW TEST

FIGURE 13

-22-

CRYOTRAP AND CHILLER PRESSURE DROP VERSUS He FLOW

Data corrected to
average system
pressure of 850 psia.

FIGURE 14

was 0.125 pps based on the maximum allowable FE-430 RPM limit of 1340. A more typical flow initiation is shown on Figure 9. The flow control valve (PCV-703) was adjusted to 61%, which corresponds to an actuator flow of 0.080 pps which is close to the maximum specified actuator flowrate of .072 pps. PRV-200 was operated to attain 200 psig between PRV-200 and PCV-703. This technique demonstrated that the actuator supply pressure could be established without excessively overspeeding the turbine flowmeter FE-430. It is to be noted that FE-430 failed during past facility testing; therefore, caution should be exercised to prevent overspinning. The maximum flowmeter speed attained was 1380 cps which is acceptable for this flowmeter on a transient basis.

As shown in Table 3, the chiller exit gas temperature was maintained well below the maximum limit of 175°R after flow was initiated during all of the flow tests. Even during the relief valve tests, when the flowrate through the chiller was higher, the chiller exit gas temperature remained below 160°R.

The requirement that the actuator supply gas temperature shall be between 430°R and 560°R was met. There was no temperature sensor located at the outlet of the recuperator; however, there is a sensor (TE535) located downstream at the FE-430 inlet. The gas temperature at the flowmeter inlet varied between 538°R and 530°R during the test. A heat balance of the LN₂ chiller during Flow Test No. 6 (0.027 pps) was made to determine the characteristics of the chiller. The total LN₂ boil-off rate was 144 lbs/hr during the 7.84 minute flow period. Approximately 83 lbs/hr could be attributed to normal heat leak into the chiller based on Figure 3; therefore, 61 lbs/hr was being used to cool the helium from 218°R to 143°R. The cooling down of the helium requires a heat rejection rate of 9100 btu/hr; therefore, the LN₂ was vaporized and the vapor reached approximately 390°R. This temperature is reasonable since the liquid level was between 67% and 59% during this test. The GN₂ temperature during the third flow test ($W_{GHe} = 0.078$ pps) was calculated to be 240°R and appears to be reasonable since the liquid level varied between 79.5% and 72.5% during this test. It is expected that the LN₂ usage rate will increase with hydrogen flowing through the cryotrap since the equivalent flowrate ratio (W_{GH_2}/W_{GHe}) is .684, whereas, the specific heat ratio ($CPH_2/CPHe$) is 2.71. The LN₂ boil-off rate was 800 lbs/hr during the hydrogen flow tests conducted at San Ramon, California.

The system drop data is plotted on Figure 14, which is a plot of the chiller pressure drop (PD853) and the system pressure drop versus He flow. The pressure drops have been normalized to a common reference pressure of 850 psia. The system pressure drop is the difference between the initial system no-flow pressure (PI618) and the PRV-200 inlet pressure (PI618) during steady-state flow periods. The validity of this approach is based on the assumption that PRV-403 maintained the pressure immediately downstream at the initial set pressure.

3.4 RELIEF VALVE TESTS

The dual pressure relief valves, RV-2848 and RV-3090, were installed in the control drum actuation line downstream of PRV-200 per ECR-727-241, entitled "Additional Relief Capability for Control Drum Actuation System", dated 17 October 1967. RV-2848 was designed to act as a back pressure regulator with the capability of controlling the pressure to the control drum actuators to an acceptable value (237 psi) even if PRV-200 failed full open. RV-3090 is a conventional type relief valve that provides a redundant pressure relief capability in the system. A relief valve test was incorporated in the cryotrap checkout test to demonstrate that the relief system could prevent a failure which, on the basis of present information, could lead to catastrophic results. RV-3090, which is a Ladewig, Model 11034-S-FF, 3" x 4" conventional spring loaded relief valve with a 2½" diameter seat, was tested first. RV-3090 was adjusted to initially crack at 250 psig. Figure 15 is a section drawing of the relief valve. It is to be noted that the force on the poppet is balanced by the spring on the vent side and there are no pressure feedbacks or pilot valve to assist the valve operation. The test procedure for the relief valve test was as follows: PRV-403 was adjusted to regulate 900 psig at PT-618; RSV-880 was closed; then PRV-200 dome pressure was locally adjusted between 400 and 550 psig to insure that the PRV would be full open during the test and RV-2848 was blanked off from the system. RSV-877 was closed because the rapid pressurization of the volume downstream of RSV-877 might result in overspinning of flowmeter FE-430. The test was conducted in this manner to expose the relief valves to a worst case condition. When RSV-880 was opened to initiate the test, the pressure (PT478) between PRV-200 and RSV-877 increased at approximately 1360 psi/sec from 0 psig to 270 psig as shown in Figure 16. RV-3090 maintained the line pressure (PT478) between 269 psig and 258 psig during the flow period. The 269 psig is 7 psig higher than the maximum desired of 263 psig; however, since this relief was intended to serve as a backup to RV-2848, this slight overpressure was not objectionable. RV-3090 reseated at 241 psig when the PRV-200 regulated pressure was decreased from 525 psi, as shown in Figure 17. The flow through RV-3090 stopped at approximately 62170.97 seconds. The system upstream of PRV-200 charged up to the PRV-403 pre-test set pressure of 870 psig when RV-3090 reseated. Figure 18 is a parameter time plot of other pertinent data.

The subsequent relief valve test was performed in the same manner except that RV-3090 was blanked off and RV-2848 was in line. Figure 19 is a sketch of RV-2848, which is a 2-inch, Model IRVA-3201, relief valve, manufactured by the Skyvalve Corp. The relief valve incorporates a pilot valve which is a pressure feedback to the downstream side (piston end) of the main poppet and serves to balance the main poppet. The pressure is maintained in the downstream side of the poppet so as to maintain the sensed inlet pressure at a preset value (237 psig).

RV-3090

FIGURE 15

UNIT 2 PLOT - 8

1	-	PT618..	-	PSIG
2	-	PT478..	-	PSIG
3	-	PT616..	-	PSIG

PT003 = 1192 psig

FIGURE 16

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PG 16

PRESSURE. 1011

$$\frac{dp}{dt} = 1360 \text{ psi/sec}$$

PD853 = 30 psid

2145.0

62146.0

62147.0
RANGE TIME-SECS.

62148.0

2149.0

62150.0

CRYOTRAP C/O TEST 30 SEPT 68

UNIT 2 PLOT 7

UNIT 2 PLOT 6

FIGURE 18

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RV-2848 SKYVALVE RELIEF VALVE

FIGURE 19

When RSV-880 was opened, the PRV-200 downstream pressure (PT478) increased at approximately 1000 psi/sec until the pressure reached 60 psig as shown in Figure 20. RV-2848 opened and the pressure decreased to 50 psig. The pressure began to increase from 50 psig to 115 psig, which was a breakpoint. The pressure then increased rapidly to 275 psig, then decreased to 200 psig. The valve cycled at 8 cps based on the dynagraph data. The digital data is subject to aliasing and does not reflect the real frequency. The dynagraph record is presented in Figure 21. As shown in Figure 22, the cryo-trap maintained the chiller exit gas temperatures below 155°R after flow was established. RV-2848 reseated at approximately 230 psi as shown in Figure 23.

Initially, the pressure on both sides of the relief valve poppet assembly was 0 psig and the valve was closed due to the spring force on the poppet. When the line pressure is increased, the pilot valve or multiplier assembly increases the pressure correspondingly on the downstream side (piston end) of the poppet assembly, which has a larger area, to maintain a net balancing force. Evidently, the pilot valve has an inherent lag characteristic which resulted in significant delays in the pressure buildup on the downstream side of the poppet when the line pressure was increased rapidly; thus, allowing the valve to go fully open.

The oscillatory behavior of RV-2848 during the individual test was not satisfactory for this valve since the valve was intended to maintain the actuator pressure at 237 psi.

Both relief valves, RV-3090 and RV-2848, were tested together and the pertinent system parameters are plotted in Figures 24 and 25. The pressure downstream of RSV-880 increased to 90 psig and remained between 80 and 90 psig until PRV-200 was closed. Apparently, with 90 psig at the inlet of the relief valve, there is enough pressure drop through the pilot valve so that the pressure on the downstream side of the poppet cannot build up to close the poppet. Figure 26 is a plot of the system pressures during a subsequent test phase designed to determine the slow pressurization characteristics of the relief valve. The pressure did build up to 267 psig before a relief valve opened and decreased the pressure 85 psig. The valve reseated at 65 psig when PRV-200 was closed. A post-test investigation of the relief valve revealed that there was a faulty O-ring in the pilot valve which may have influenced the behavior of RV-2848. A subsequent test in the valve lab verified the 90 psig relief pressure of RV-2848. Also, there is an orifice in the inlet line to the pilot valve which restricts the flow to the pilot valve and decreases its response. The O-ring was replaced.

A combined relief valve test was repeated on 4 October 1968 to determine the valve characteristics with the replaced O-ring. The RV-2848 characteristics were the same as during the 30 September test, as shown in Figure 27. RV-2848 maintained the pressure at 90 psig during the fast

UNIT 2 PLOT 9

PLBT 9

PRESSURE, POLIS

FIGURE 20

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RV-2848 Test
 Cryotrap Test 30 Sept. 1968
 FIGURE 21
 -33-

CRYOTRAP C/O TEST 30 SEPT 68

UNIT 2 PLOT 10

18570.. 3 RANKINE
2 TT571.. 3 RANKINE
3 TE535.. 3 RANKINE

RELIEF VALVE, RV-2848, TEST

FIGURE 22

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CRYOTRAP C/O TEST 30 SEPT. 68.

UNIT 2 PLOT 10

CRYOTRAP C/O TEST 30 SEPT 68

UNIT 2 PLOT 43

1	---	PT6184.	---	PSIG
2	---	PT4784.	---	PSIG
3	---	PT615.	---	PSIG

COMBINED RV-3090/RV-2848 TEST

FIGURE 24

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CRYOTRAP C/O TEST 30 SEPT 68

UNIT 2 PLOT 13

COMBINED RV-3090/RV-2848 TEST

FIGURE 25

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CRYOTRAP CVO TEST 30 SEPT 68

UNIT 2
PL01 14

PRESSURE, PSIG

CRYOTRAP C/O TEST 4 OCT 68 RV2848/RV3090 TEST

1	-*	PT618..	-*	PSIA
2	-*	TE570..	-*	RANKINE
3	-*	TT571..	-*	RANKINE
4	-*	PT478..	-*	PSIA
5	-*	PD853..	-*	PSID

UNIT 1
PLOT 1
RV2848/RV3090 TEST
UNITS

pressure ramp test; however, the relief valves did perform acceptably during a subsequent slow ramp test from 85 psig, as shown in Figure 28. A relief valve opened at 280 psig and the pressure was maintained at 268 psig during the flow test and reseated at 237 psig. It is concluded that the behavior of RV-2848 under rapid pressure increase conditions is related to its inherent operational characteristics.

Evaluation of the test data evidences that the two relief valves do limit the system pressures to acceptable levels (< 280 psi) when the system pressures are increased rapidly during a worst case malfunction simulation. The system pressures downstream of PRV-403/PRV-402 would be limited to 90 psig with the current relief system if a failure occurred before the control drum actuator supply system was pressurized rapidly to 200 psig.

The individual performance characteristics of RV-2848 are unacceptable due to the 225 ± 55 psi oscillations.

The vendor has recommended that a $1/4$ " tubing run be installed from the line downstream of PRV-200 to the external sensing port in the pilot valve. This modification should improve the response of the valve as well as the steady-state characteristics. This recommendation has been implemented and tests are planned to verify the performance of the modified RV-2848 relief valve.

Since the capability of the relief valves to limit the pressure to acceptable levels has been demonstrated, the fast pressure ramps should not be repeated; however, a malfunction at operating conditions should be simulated. The pressure upstream of PCV-200 should be regulated to 900 psig and then PRV-200 used to establish 200 psig at PT-478 with the system open to the on-mark connector below the TSA. PRV-200 and RSV-880 should be closed. The PRV-200 dome pressure should be locally increased to 400 psi or higher to ensure that PRV-200 will open fully. RSV-880 will be opened to simulate a PRV-200 malfunction. A spool shall be installed in place of FE-430 during the test to avoid damage to the flowmeter. Also, the initial cracking pressures of RV-2848 should be re-determined and adjusted, if necessary, to 237 psig. This test will more closely simulate a probable failure and will subject the relief valves to a more realistic but less severe environment. It is recommended that the two tests be performed with RV-2848 only and RV-2848/RV-3090 on the line. The results of this future test will be reported in an addendum to this report.

Figures 29 thru 32 are photographs of the cryotrap assembly located on the 3857 foot level at ETS-1. Figures 33 thru 38 are photographs of various components and hardware related to the cryotrap and control drum actuation system, and Figure 39 is a photograph of the unit being prepared for shipment.

CRYOTRAP C/O TEST 4 OCT 68 RV2848/RV3090 TEST

UNIT 2 PLOT 1 RV2848/RV3090 TEST UNITS

PT618.. * PSIA
 PT478.. * PSIA
 PD853.. * PSID
 TE570.. * RANKINE

FIGURE 28
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CRYOTRAP INSTALLATION - ETS-1

FIGURE 29

CRYOTRAP INSTALLATION - ETS-1
FIGURE 30

CRYOTRAP INSTALLATION - ETS-1

FIGURE 31

CRYOTRAP INSTALLATION - ETS-1

FIGURE 32

PRV-200 AND RELIEF VALVES
CONFIGURATION

FIGURE 33

PRV-402/PRV-403 INSTALLATION

FIGURE 34

FE-430 AND GF-432 INSTALLATION

FIGURE 35

RELIEF VALVES RV-2848, RV-3090
INSTALLATION

FIGURE 36

CHILLER FILTER, GF-462

FIGURE 37

CHILLER COILS

FIGURE 38

CRYOTRAP PRIOR TO SHIPMENT

FIGURE 39

4.0 RECOMMENDATIONS

- 4.1 Re-run the individual RV-2848 and combined RV-2848/RV-3090 relief tests with the normal operating pressure of 200 psi established between RSV-880 and the on-mark connector at Station 0.00. The test will also verify the adequacy of the installation of the new RV-2848 external sensing line. A spool piece should be installed to replace FE-430 during the next test series. The recommended test is discussed in detail in Section 3.0.
- 4.2 Relocate PT-618 downstream of CHV-3482 and CHV-3484 or install a new pressure 0-2000 psig pressure transducer in the proposed location. This pressure transducer will provide the console operator with more meaningful system data concerning PRV-402 or PRV-403 operation.
- 4.3 Install a .163 inch diameter square edge orifice in the RSV-881 vent line to limit the system purge flow, if a low pressure (25 to 50 psig) cannot be established initially at PT-618 with PRV-403 or PRV-402.
- 4.4 If scheduler considerations preclude the conduct of additional tests, either of the two following actions are recommended in order of preference:
 - a. Remove RV-2848 from the system because RV-2848 operation was erratic and RV-3090 was capable of limiting the pressure to acceptable limits, or
 - b. Set up RV-3090 to relieve at 240 psi and RV-2848 to relieve at 250 psig; therefore, RV-3090 will be the prime relief and RV-2848 will be the backup.
- 4.5 Change the PD-852 and PD-853 ranges from 0-5 psid and 0-200 psid to 0-2 psid and 0-100 psid, respectively.

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ETO Operations Analysis

CRYOTRAP CHECKOUT TEST REPORT

NTC-R-0159

Addendum No. 1

Additional testing of the control drum actuation system relief valves RV-2848 and RV-3090 was accomplished on 22 October 1968. The purpose of the tests were: 1) to demonstrate the capability of RV-2848 (with a new external sensing line) and RV-3090 to protect the control drum actuators against overpressure during a PRV-200 malfunction under simulated system operational conditions; and 2) to determine the effect of the new RV-2848 external sensing line on the response of the relief valve during rapid pressurization.

The initial test conditions for the first test were: 900 psig was established between RSV-880 and PRV-402; 185 psig was established between RSV-880 and Station 42.89, and PRV-200 was open fully. RSV-880 was opened and the system pressure (PT478) increased from 185 psig to 260 psig and controlled the system pressure between 250 and 260 psig during the test. The valve was set up to crack open between 230 and 240 psig and maintain the system pressure below 275 psi; therefore, the relief valve performance was as expected. This test conclusively demonstrated the capability of the control drum actuator relief valve system to maintain the drum and TPCV actuation pressure below 275 psi during a system malfunction simulating an operational condition; therefore, the facility portion of the control drum actuation system, which was operated during the Cryotrap Checkout Test, is ready for XE testing.

A second test was conducted to determine the effect of the new external sensing line, which is installed between the main 2" actuator supply line and the RV-2848 pilot valve, on the relief valve performance during rapid pressurization.

The initial conditions for the second test were: 900 psig was established upstream of RSV-880 and PRV-402, the small volume between RSV-880 and RSV-877 was at 0 psig, and PRV-200 was open fully. RSV-880 was opened to initiate the test. The system pressure (PT478) increased from 0 psig to 85 psig and remained at 85 psig for approximately 8 seconds and then increased to 260 psig. The relief valve (RV-2848) maintained the pressure between 250 and 260 psig. Apparently, the relief valve is still rate-sensitive and cannot respond immediately to rapid pressure increases; however, this characteristic is not objectionable. The primary point is that the relief valve system could protect the system adequately even during the failure mode simulated during the rapid pressurization test.

There was no evidence of oscillatory behavior of either RV-2848 or RV-3090 during either test.

No additional testing is recommended since all of the primary objectives of the cryotrap and control drum actuator system checkout have been met.