FINAL REPORT

Cryopumping-Cryosorption Array System

For a 3' x 3' Vacuum Facility

Contract No. NAS 5-5881

for

Goddard Space Flight Center
Greenbelt, Maryland

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FINAL REPORT

1.0 INTRODUCTION

This report summarizes the results of tests performed on the cryopumping - cryosorption array system supplied under contract NAS 5-5881.

The report is specifically concerned with the test results and their analysis as related to system performance. Details of system operation as well as background information on theoretical aspects of cryogenic pumping are included only where necessary for logical presentation. The reader is directed to the system Operating Instructions or the Acceptance Test Procedure for supplemental information.

2.0 SUMMARY

1. The overall design and performance of the supplied cryopumping - cryosorption system was proven to be satisfactory and within the requirements of NASA specification GSFC P-322-06-64.

2. Ultimate system pressures in the high 10^{-14} to low 10^{-13} Torr range were attained during the testing period. These pressures were attained after a relatively mild system bakeout of 12 hours at 200 - 230°C.

3. Pumping speeds for hydrogen gas exceeded the specified array value based on a 0.16 sticking coefficient for the adsorbent panels. This sticking coefficient is consistent with the indicated panel temperatures of 18 - 21°K.

4. Satisfactory thermal performance was demonstrated while operating a 50 watt heat load inside the test volume.

5. The vacuum integrity of the system with its associated flanges and interface connections was satisfactorily demonstrated by bagged helium mass spectrometer leak tests.

6. The overall cleanliness of the system and the integrity of the bonded sieve panels was successfully demonstrated when no traceable contaminants were found.

3.0 DISCUSSION

3.1 General Configuration

The supplied array concept and configuration consists of two vertically oriented cryogenically cooled concentric cylinders surrounding a shielded cryosorption pumping system. The supplied hardware was installed in an existing 3 ft. by 3 ft. vacuum facility located in Building 10 at Goddard Space Flight Center, Greenbelt, Maryland. The outer cylinder is cooled with liquid nitrogen and is supplied with a removable, flanged head located at the top end of the cylinder. The cylindrical shroud is flanged to mate with the baseplate on the GSFC facility. The primary functions of this element are to serve as an integral vacuum vessel, thus minimizing inleakage to the internal vacuum spaces, and to act as a heat sink for absorption of radiant energy from the room temperature chamber enclosure. In addition, the liquid cooled walls act as cryopumping surfaces for higher boiling species, i.e., H_2O, CO_2, etc.

The inner cylinder is cooled with helium gas and serves the same qualitative functions as the liquid nitrogen shroud only at a lower temperature level. The shielded internal cryosorption pumping array is attached to a removable plate which forms the top end of the helium shroud. The plate-array assembly is attached to and removed with the liquid nitrogen shroud head during disassembly. The lower end of the helium shroud contains an open port (8 inch diameter). The area extending on both sides of the port to a diameter of 10 inches is machined to a flat surface to mate with the GSFC supplied vacuum valve plate seal.

The cryosorption pumping array consists of an upper and lower adsorbent panel-baffle assembly. The total effective projected array area is a minimum of 8.0 square feet. Four adsorbent panels are provided as two sandwich assemblies, located at the top and bottom of the helium shroud. The panels facing the work zone are shielded with optically tight chevron baffles. The panel facing the top plate of the shroud is unshielded since all molecules approaching this surface must first make at least one collision with the helium shroud. The panel facing the lower pumping port is also shielded with optically tight chevron baffles.

All electrical and cryogenic feedthrough penetrations servicing the supplied nitrogen and helium elements enter the system through an extension collar which is flange mounted between the 3 ft. x 3 ft. chamber and head units. Separate liquid nitrogen refrigeration circuits are supplied for the liquid nitrogen shroud and head. In addition, three individual helium circuits are routed to 1) cryosorption panels, 2) chevrons and top plate of helium shroud and, 3) helium shroud cylinder.

As indicated, the cryosorption pumping array (both upper and lower elements) is removed from the system as a single unit. A test object support stand is located between the upper and lower array elements and allows a free working volume 20 inches diameter by 20 inches deep.

3.2 In-House Leak Test

An in-house leak check of the system was conducted at the Linde Factory before shipping the system to NASA. The test procedure involved hot and cold thermal cycles on the system as described in Paragraph 2.11 of the Acceptance Test Procedure.

A leak developed in the helium array circuit during the first hot cycle test. This leak was repaired and with the helium mass spectrometer at maximum senstivity, no further leaks were detected in any of the tested circuits through the remainder of the in-house test cycle. It should be noted that the liquid nitrogen vessel itself was not leak checked during the in-house test program because suitable test equipment was not available.

3.3 Field Leak Test

Leak tests were performed on the complete system during and after final installation on the NASA baseplate. This procedure generally followed that outlined in Paragraph 2.12 of the Acceptance Test Procedure.

During installation testing, a relatively large leak was discovered in a weld seam area of the liquid nitrogen vacuum vessel. In addition a small leak was indicated in the No. 31 Pin on the D-2 power feed-through. The system was disassembled and the weld seam leak successfully repaired. The suspect feedthrough pin was removed and a plug welded in its place.

After reassembly the complete system was leak checked. The inner vacuum vessel and all the cryogenic tubing showed no leaks at maximum sensitivity of the mass spectrometer. The outer guard vacuum vessel showed no leaks at the maximum attainable sensitivity of 1×10^{-7} standard cc/sec. The system was then baked for 12 hours at an average temperature of 200°C. Subsequent leak checks at ambient temperature still showed no detectable leaks.

Because of equipment delays etc., the cryogenic leak test was not conducted until after the system had been opened once and baked for the second time. The cryogenic leak test showed no detectable leaks in any of the cryogenic circuits; however, a 1×10^{-6} Torr-liters/sec. leak was indicated between the guard vacuum and the inner volume. Later when the guard vacuum vessel was opened, small leaks were suspected in the G. E. cold cathode gauge, a flange joint on the gas in-bleed line, the liquid nitrogen vessel upper flange and the liquid nitrogen vessel to baseplate flange.

The G. E. guage was replaced and all the suspect joints except the baseplate flange were retorqued. A repeat leak check still showed positive; however, it was decided to proceed with the test program since the leak was protected by the guard vacuum and would not effect the overall system performance.

Upon completion of the acceptance test program, the system was disassembled and inspected. A misalignment of the aluminum wire gasket on the liquid nitrogen vessel flange was discovered in the vicinity of the G. E. gauge. It was decided that correct placement of the gasket plus re-torquing of the baseplate bolts would resolve the problem.

3.4 Performance Data

During the course of the acceptance test, the system was baked out and cold cycled a total of three different times. The first bakeout was in conjunction with the leak test and the first cooldown was a shakedown of the cryogenic refrigerant system. A third complete cycle was necessary because the second had to be aborted after difficulties were encountered with the inleak measuring equipment.

Performance data from the second and third test cycles are given in Tables 2 through 7. The data is identified as Run No. 1 or Run No. 2.

Table 2 lists the vacuum pressure versus time for the system. The guard vacuum pressure was measured by a hot filament, Bayard-Alpert type ionization gauge. A nude, hot filament, Bayard-Alpert ionization gauge was mounted inside the work zone. The intermediate vacuum space was monitored by a hot filament, Bayard-Alpert type ionization gauge that was mounted on the liquid nitrogen vessel head. Finally, a General Electric cold cathode, trigger discharge gauge was mounted on the liquid nitrogen vessel head with the tubulation extending into the work zone.

From the test data it is observed that the system pressure as read by the G. E. guage repeatedly reached the low 10^{-13} Torr range. No effort has been made to adjust or correct these readings for gauge sensitivity since a partial pressure analyzer was not used during the acceptance tests.

The bakeout data given in Table 3 shows that the hot gas heater system is capable of achieving bakeout temperatures in the desired 200°C. range.

Tables 5, 6, and 7 show the temperature profile of the gaseous helium refrigerated system. From the observed temperature readings, it is concluded that the Collins Cryostat used for the tests was marginal in the operation of the system. Temperatures average near 20°K whereas a cryosorption system of this type would be more effective if the panels could operate at temperatures below 15°K.

Overall, the system performed very well during both bakeout and cold cycle operation. The relatively high system pressures noted after the bakeout cycles can be attributed to the outgassing load imposed by great amounts of instrumentation wiring inside the vacuum areas. Once cryogenic cooling began, the system pressures dropped predictably into the base pressure range.

Output from the liquid nitrogen copper-constantan thermocouples was recorded directly on a Brown, self compensating, strip chart recorder. The gaseous helium copper-constantan thermocouple output was readout on a liquid nitrogen referenced Dymec Digital Voltmeter. Standard NBS conversion tables were used to record temperature in °K. Reading accuracy at the 20°K level was assumed to be ± 1°K.

3.5 Thermal Performance Test

The thermal performance test was conducted to insure an overall temperature uniformity while operating a 50 watt test load in the work volume.

A quartz iodine lamp was suspended in the work zone to provide the 50 watt load. The power to the lamp was regulated by measuring the voltage and current input.

The test was conducted during the first cooldown cycle after the system had stabilized. Readout data during the test is given on data sheet - Table 5. From this data it is concluded that thermal performance is within the specification requirements.

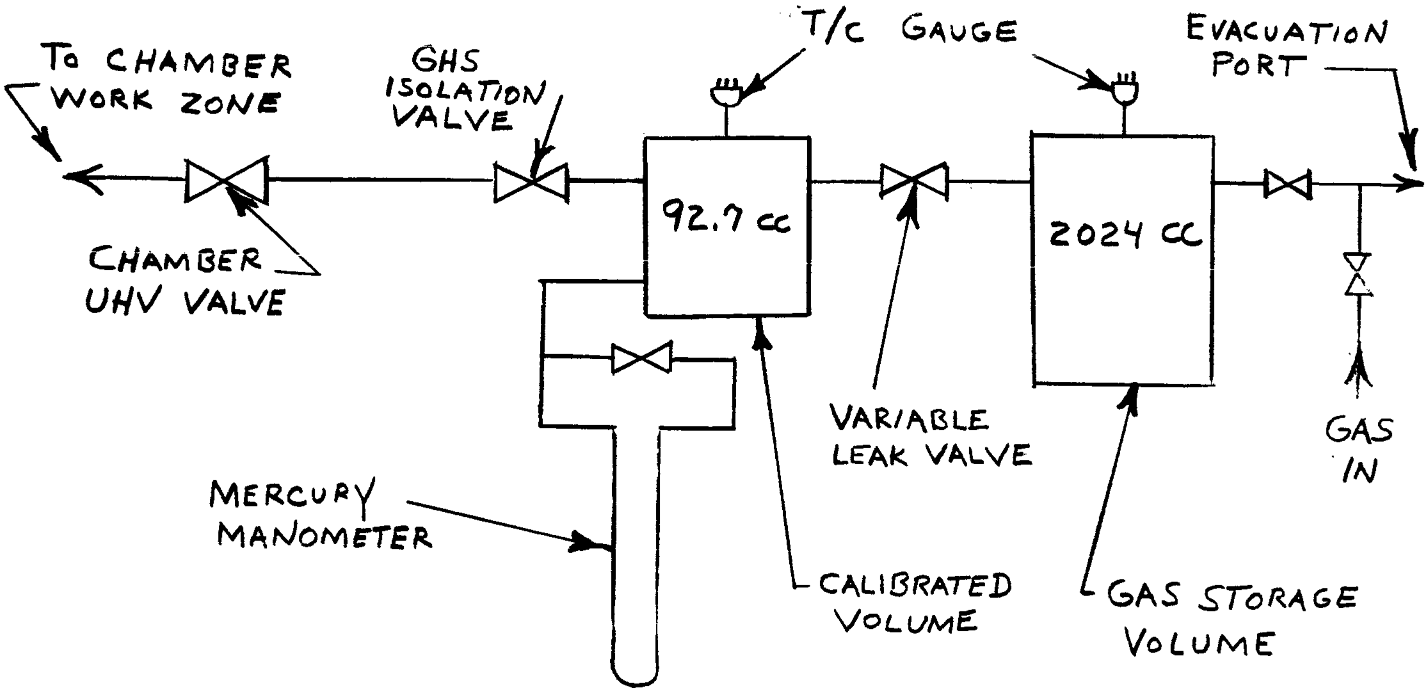
3.6 Pumping Speed Test

Hydrogen pumping speed tests were conducted to verify the predicted adsorbent panel performance. The test method involved measurement of system pressure as a function of time for a specific predetermined gas admission rate. For a more detailed description of the test, the reader is referred to the Acceptance Test Procedure. The specification requires that at 20°K, the adsorbent panels possess a pumping speed of 7,000 liter/sec. per sq. ft. for hydrogen. With 8 sq. ft. of panels and associated baffles, the total effective pumping speed in the work zone is estimated to be 33,000 liter/sec.

The NASA gas handling system was used for controlling and measuring the hydrogen inleak rate. It was originally intended to use a Linde supplied system; however, some difficulties were encountered with the variable leak valve and it was decided to use the NASA system.

The NASA gas handling system measures the change in pressure in a known volume (initially under vacuum) as atmospheric hydrogen gas is inleaked across a low conductance variable leak valve. The change in pressure is observed with a mercury manometer or with a calibrated thermocouple gauge.

A description of the NASA system is as follows:



The sequence of operation included the following steps:

1. The GHS (gas handling system) to the chamber UHV valve was evacuated with an independent pumping system to 10^{-5} Torr and charged to one atmosphere with hydrogen gas. This evacuating - flushing process was repeated twice.

2. The GHS was again evacuated to 10^{-5} Torr, and with the variable leak valve closed, the 2024 cc storage volume was charged with one atmosphere of hydrogen gas.

3. With the GHS still isolated from the chamber, the variable leak valve was opened and a leak rate was established to the small evacuated volume. Pressure change was monitored using the mercury manometer.

Time Minutes	Δh mm Hg	V-L Setting
0	0	63
55	34	
65	40	
85	52	

$Q_{300°K} = V \frac{\Delta h}{t}$ = Gas inleak rate

V = 92.7 cc

$Q_{300°K} = 9.5 \times 10^{-4} \frac{T\text{-}L}{Sec.}$

4. The chamber UHV isolation was opened and the line between the valve and the GHS was allowed to equilibrate with the vacuum system. Then the GHS ioslation valve was opened and the leak rate admitted to the chamber. Pressure time data was recorded using the G. E. cold cathode gauge and the nude hot cathode gauge. Pressure time data is given in Table I. The curve is shown in Figure 1.

From the data shown in Figure 1 it is observed that the system pressure increased whenever the nude gauge was turned on. The nude guage was not degassed because the 90 watt load would have been too great for the refrigeration system. In addition, the higher recorded pressures with the nude gauge could be due to a beaming effect because of its proximity to the inleak gas tube.

Pumping speed calculations are based on the pressures as measured by the G. E. gauge with corrections for gauge temperature and sensitivity for hydrogen gas.

$$S_{300°K} = \frac{Q_{300°K}}{k_{H_2} (P_{ss} - P_o) \left(\frac{300}{T_g}\right)^{1/2}}$$

$$Q = 9.5 \times 10^{-4} \frac{T\text{-}L}{Sec.}$$

$$P_{ss} = 4.5 \times 10^{-9} \text{ Torr}$$

$$P_o = 7.3 \times 10^{-11} \text{ Torr}$$

$$T_g = 83°K$$

$$k_{H_2} = 2.1$$

$$S_{300°K} = 53{,}000 \text{ liters/sec.}$$

3.7 Adsorbent Integrity

A clean, polished stainless steel plate was installed in the work volume of the chamber prior to starting the acceptance test. This plate was mounted horizontally parallel to and beneath the top adsorbent panel so as to collect any molecular sieve particles that become dislodged during the test program.

Upon completion of the test program, the plate was removed and analyzed by NASA personnel. No trace of sieve particles were found.

3.8 Equipment Status

In general, the vacuum equipment as supplied under the contract was proven to be suitable and practical for the application. Actual installation proceeded without major difficulty and with only a few equipment modifications.

The NASA supplied valve plate which is used to isolate the 10 inch diffusion pump system from the test volume, worked very well.

The cap screw bolts used on the liquid nitrogen vessel top and bottom sealing flanges were replaced with hex-headed bolts to facilitate torquing. Also a high temperature lubricant was used on the threads of all the stainless steel bolts in the guard vacuum to eliminate a seizing problem.

After initial alignment, the cryogenic feedthrough flanges were found to seal satisfactorily to the extension collar. The copper gaskets supplied per drawing A-611541 were found to seat better if the O.D. was reduced .030 inches.

The therocouple and power feedthrough except A-1 were wired as shown in the supplied drawings. This feedthrough was removed to accomodate the inleak equipment and at NASA's request was not re-installed.

LINDE - GSFC CRYOSORPTION SYSTEM

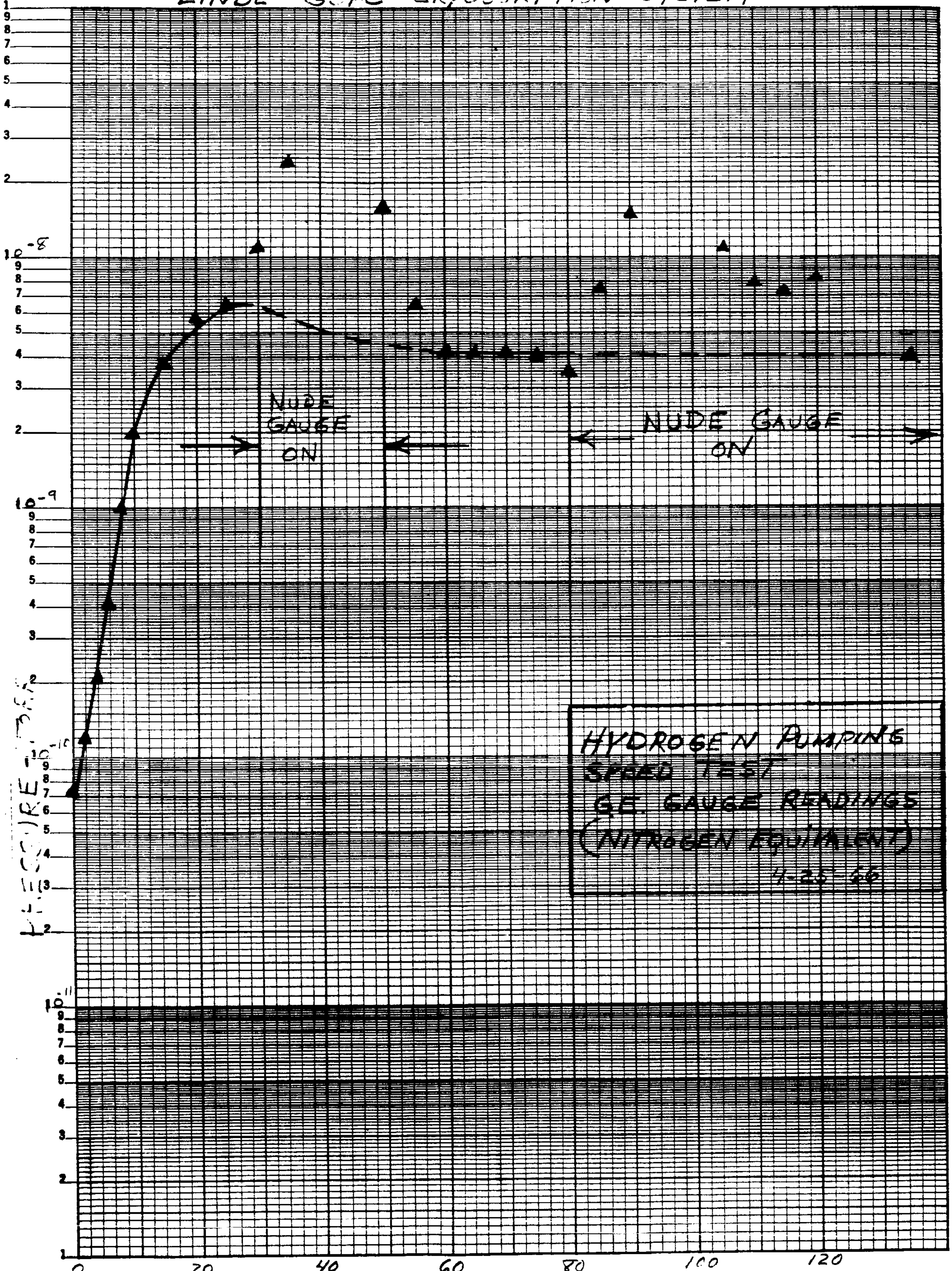


FIGURE 1

TABLE I

Time Minutes	Pressure Torr (G. E.)	Pressure Torr (Nude)	Remarks
0	3×10^{-12}		Opened UHV
0	7.3×10^{-11}		Admitt leak
1	9×10^{-11}		
2	1.2×10^{-10}		
4	2.2×10^{-10}		
6	4.3×10^{-10}		
8	1×10^{-9}		
10	2×10^{-9}		
15	3.8×10^{-9}		
20	5.8×10^{-9}		
25	6.5×10^{-9}		
30	1.1×10^{-8}	1.1×10^{-7}	Nude gauge ON
35	2.4×10^{-8}	1×10^{-7}	
50	1.6×10^{-8}	1×10^{-7}	Nude gauge OFF
55	6.4×10^{-9}		
60	4.1×10^{-9}		
65	4.2×10^{-9}		
70	4.5×10^{-9}		
75	4×10^{-9}		
80	3×10^{-9}		
85	7.6×10^{-9}	8×10^{-8}*	Nude gauge ON
90	1.5×10^{-8}	9.3×10^{-8}	
105	1.1×10^{-8}	3×10^{-8}	
110	8×10^{-9}	7.1×10^{-8}	
115	7.4×10^{-9}	7×10^{-8}	
120	8.4×10^{-9}	6.5×10^{-8}	
135	4×10^{-9}	3×10^{-8}	Close UHV

Hydrogen Leak Test Completed

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* Nude gauge not degassed.

LINDE - GSFC CRYOSORPTION PUMPING SYSTEM

VACUUM PERFORMANCE SYSTEM PRESSURE - TORR

RUNS # 1 + 2

RUN #																						
	DATE	4-18-66								4-19-66						4-20-66						
	TIME HRS	1000	1100	1200	1300	1400	1500	1600	1630	0800	1300	1400	1500	1600	0830	1000	1200	1400	1500	1600	1700	1800
1	GUARD VACUUM (GLASS)	5×10^{-5}	5.6×10^{-5}	5.3×10^{-5}	5.4×10^{-5}	5.0×10^{-5}	3.2×10^{-5}	3.2×10^{-5}	2.6×10^{-5}	3.5×10^{-5}	2.8×10^{-5}	2.8×10^{-5}	2.1×10^{-5}	2.1×10^{-5}	3.0×10^{-5}	3×10^{-5}	3×10^{-5}	2.8×10^{-5}	3×10^{-5}	1.1×10^{-5}	3.5×10^{-5}	2.8×10^{-5}
	NUDE (WORK ZONE)	$>10^{-4}$	3.1×10^{-4}	1.7×10^{-4}	1.0×10^{-4}	8×10^{-5}	6.8×10^{-5}	1.2×10^{-6}	4.1×10^{-7}	2.6×10^{-7}	2.4×10^{-7}	2.4×10^{-7}	2.4×10^{-7}	2.5×10^{-7}	2.7×10^{-7}	2.8×10^{-7}	3×10^{-7}	2×10^{-7}	1.6×10^{-7}	5×10^{-10}	3.8×10^{-10}	3.0×10^{-10}
	GLASS (LN$_2$ CHAMBER)	$>10^{-4}$	7.2×10^{-5}	4.2×10^{-5}	3.2×10^{-5}	2.9×10^{-5}	2.3×10^{-5}	2.2×10^{-6}	9.0×10^{-7}	3×10^{-7}	2.2×10^{-7}	2.2×10^{-7}	2.7×10^{-7}	2.4×10^{-7}	2.5×10^{-7}	2.3×10^{-7}	2.4×10^{-7}	2.3×10^{-7}	1.6×10^{-7}	5.8×10^{-9}	1×10^{-8}	1.1×10^{-7}
	GE (INTO WORK ZONE)	3.5×10^{-4}	1.6×10^{-4}	9.0×10^{-5}	5.3×10^{-5}	4.2×10^{-5}	3.2×10^{-5}	1.2×10^{-6}	4.2×10^{-7}	9.2×10^{-8}	6×10^{-8}	4.4×10^{-8}	4.4×10^{-8}	4.5×10^{-8}	1.8×10^{-8}	5×10^{-8}	5×10^{-8}	3×10^{-8}	[illegible]	2×10^{-12}	1.1×10^{-12}	1.4×10^{-13}
		HEAT ON						HEAT OFF				LN$_2$ ON	OUTGAS GAUGES			CRYOSTAT ON [illegible]				CLOSE VALVE PLATE		
	DATE	4-20-66						4-21-66														
	TIME HRS.	900	2000	2100	2200	2300	2400	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100	1200	1300	1700	1900
1	GUARD VACUUM (GLASS)	3×10^{-7}	3.2×10^{-7}	2.6×10^{-7}	2×10^{-7}	1.8×10^{-7}	2×10^{-7}	2×10^{-7}	2×10^{-7}	2×10^{-7}	2×10^{-7}	2×10^{-7}	2×10^{-7}	1×10^{-7}	2×10^{-7}	2×10^{-7}	2.4×10^{-7}	1.6×10^{-7}	1.6×10^{-7}		2×10^{-7}	2×10^{-7}
	NUDE (WORK ZONE)	3.4×10^{-10}	3.4×10^{-10}	3.5×10^{-10}	5×10^{-10}	5×10^{-10}	5×10^{-10}	5×10^{-10}	5×10^{-10}	5×10^{-10}	4×10^{-10}	5×10^{-10}	5×10^{-10}	5×10^{-10}	5×10^{-10}	5×10^{-10}	4×10^{-10}	3×10^{-10}	5.4×10^{-10}		5.1×10^{-9}	1×10^{-8}
	GLASS (LN$_2$ CHAMBER)	1×10^{-8}	4.4×10^{-9}	7.8×10^{-9}	1.8×10^{-9}	2.5×10^{-9}	3.5×10^{-9}	2.6×10^{-9}	2.5×10^{-9}	8×10^{-9}	2×10^{-9}	1.5×10^{-9}	3×10^{-9}	1.4×10^{-9}	4×10^{-9}	1.1×10^{-9}	1.1×10^{-9}	7×10^{-10}	6×10^{-10}		1.3×10^{-9}	1.6×10^{-9}
	GE (INTO WORK ZONE)	6.2×10^{-13}	6×10^{-13}	4.6×10^{-13}	2.7×10^{-13}	1.5×10^{-13}	1.4×10^{-13}	1.0×10^{-13}	1.0×10^{-13}	5×10^{-10}	2×10^{-12}	1×10^{-12}	1×10^{-13}	4×10^{-13}	2×10^{-13}	2.8×10^{-13}	6×10^{-14}	6×10^{-14}	3.8×10^{-13}		1×10^{-10}	8×10^{-11}
				FLOW TO PANELS							RETRIGGER G.E.							PUMP OUT LEAK LINE		START PUMPING SPEED RUN (LARGE LEAK)	50 WATT LOAD ON	
	DATE	4-21-66		4-22-66								4-26-66						4-27-66				
	TIME - HRS.	2000	2100	0900								1600		0840	0930	1000	1045	1100	1245	1400	1500	1700
1	GUARD VACUUM	2×10^{-7}	1.8×10^{-7}	2.8×10^{-5}				START RUN #2				1.5×10^{-4}		3.4×10^{-5}	2.6×10^{-5}	2.6×10^{-5}	1.8×10^{-5}	1.9×10^{-5}	2.5×10^{-5}	2.6×10^{-5}	2.7×10^{-5}	3×10^{-5}
	NUDE (WORK ZONE)	9×10^{-9}	7.8×10^{-8}	1.4×10^{-6}										6.1×10^{-7}	2.9×10^{-7}	2.4×10^{-7}	1.9×10^{-7}	2.2×10^{-7}	2.7×10^{-7}	2.1×10^{-7}	3×10^{-7}	4.6×10^{-7}
	GLASS (LN$_2$ CHAMBER	3×10^{-9}	1.8×10^{-9}	5.4×10^{-7}								3.7×10^{-4}		8.6×10^{-7}	2.8×10^{-7}	1.7×10^{-7}	1.6×10^{-7}	1.6×10^{-7}	1.8×10^{-7}	2.6×10^{-7}	2.4×10^{-7}	2.7×10^{-7}
	GE. (INTO WORK ZONE)	3×10^{-11}	4×10^{-11}	1.4×10^{-7}										1.6×10^{-6}	4.5×10^{-7}	2.6×10^{-7}	1.6×10^{-7}	1.2×10^{-7}	1×10^{-7}	1.2×10^{-7}	1.2×10^{-7}	2×10^{-7}
			START WARM-UP									BAKEOUT	HEAT OFF 0740 HRS.		LN$_2$ FLOW ON					START CRYOSTAT		
	DATE	4-27-66										4-28-66										
	TIME HRS	1800	1900	2000	2100	2200	2300	2330	2400	0100	0200	0300	0500	0700	0900	1000		1620				
2	GUARD VACUUM	3×10^{-5}	3.4×10^{-5}	3.0×10^{-5}	3.4×10^{-5}	3.6×10^{-5}	2.8×10^{-5}	5.3×10^{-7}	5×10^{-7}	4×10^{-7}	4.8×10^{-7}	5×10^{-7}	4.8×10^{-7}	4×10^{-7}	3.8×10^{-7}	3.7×10^{-7}						
	NUDE (WORK ZONE)	4.6×10^{-7}	4.4×10^{-7}	4.6×10^{-7}	4.3×10^{-7}	5×10^{-8}	1.7×10^{-9}	1.1×10^{-9}	1.1×10^{-9}	1×10^{-9}	7×10^{-10}	9×10^{-10}	8×10^{-10}	1.5×10^{-10}	6×10^{-10}	5.8×10^{-10}						
	GLASS (LN$_2$ CHAMBER)	2.7×10^{-7}	2.4×10^{-7}	2.4×10^{-7}	2.4×10^{-7}	1.6×10^{-7}	1.4×10^{-8}	5×10^{-9}	6×10^{-9}	5.8×10^{-9}	6×10^{-9}	4.2×10^{-9}	4.8×10^{-9}	1.4×10^{-9}	1×10^{-9}	1×10^{-9}						
	GE. (INTO WORK ZONE)	1.8×10^{-7}	1.7×10^{-7}	1.6×10^{-7}	1.5×10^{-7}	1.5×10^{-9}	1×10^{-12}	1.3×10^{-12}	1×10^{-12}	2.8×10^{-10}	2.8×10^{-11}	1×10^{-11}	1.3×10^{-12}	1×10^{-12}	1×10^{-12}	6.6×10^{-13}						
								VALVE PLATE CLOSED		RE-TRIGGER GE	FLOW TO PANELS						START PUMPING SPEED TEST	TEST COMPLETE START WARM-UP				

TABLE 2

LINDE-[illegible] CRYOSORPTION PUMPING SYSTEM

BAKEOUT CYCLE-TEMPERATURES °C

RUN #1 — 4-18-66

T/C #	TIME HRS →	1000	1100	1200	1300	1400	1500	1600	1630
1	UPPER He CHEV.	125	197	219	230	237	242	172	123
2	" " "	130	199	220	230	237	243	170	121
3	" " PANEL	172	219	234	242	248	*255	199	160
4	LOWER " "	135	202	221	232	238	248	172	127
5	" He CHEV.	169	215	230	238	243	237	104	73
6	" " "	162	210	228	227	242	238	118	80
[illegible]	He SHROUD BOT.	133	183	201	210	216	201	127	96
13	" " MID	85	155	183	197	205	203	164	132
17	" " TOP	77	151	180	195	203	202	174	143
21	He COVER	132	190	209	220	226	227	173	133
23	" "	120	184	205	216	223	217	167	127
25	" " OUTLET	[illegible]	175	197	208	215	192	173	133
26	" CHEV. INLET	245	>250	>250	>250	*255	194	48	35
29	" SHROUD "	248	>250	>250	>250	*255	162	44	32
30	OUTLET	120	170	187	196	202	152	133	100
32	LN2 SHROUD OUTLET	65	111	134	150	162	168	147	125
33	" " BOT.	162	187	192	195	197	202	94	65
34	" "	158	183	189	193	196	204	99	69
36	" " LOWER	55	106	130	147	160	169	154	131
40	MID.	36	73	100	121	138	150	150	139
44	" " TOP	22	62	87	107	127	142	145	137
49	" " COVER	50	95	118	135	145	149	137	121
50	" "	45	85	109	125	140	145	137	125
5[illegible]	COVER OUTLET	43	80	102	120	133	140	134	124
	Remarks	START HEATER @ [illegible] °F					HOT GAS FLOW STARTED TO HELIUM CHEVRON & SHROUD @ 1405 HRS.	ALL HEAT OFF @ 1505 HRS. CONTINUE COLD GAS FLOW TO ALL EXCEPT He PANELS	

ALLOW SYSTEM TO RETURN TO AMBIENT OVER NIGHT

RUN #2 — 4-26-66 / 4-27-66

T/C #	TIME HRS →	1530 (4-26-66)	1625 (4-26-66)	0740 (4-27-66)	0900	0940	1000	1100	1300	1400
1	UPPER He CHEV.	60	167	229	172	122	123	123	100	84
2	" " "	68	169	229	167	122	125	121	100	81
3	" " PANEL	115	194	231	137	124	125	122	100	83
4	LOWER " "	70	175	235	165	116	117	117	100	83
5	" He CHEV.	124	186	232	120	107	113	117	86	82
6	" " "	112	184	232	128	105	113	119	86	82
[illegible]	He SHROUD BOT.	86	150	212	132	114	115	101	56	47
13	" " MID	66	124	208	172	136	132	111	68	54
17	" " TOP	38	126	208	175	139	135	113	69	54
21	He COVER	85	160	207	147	132	127	109	70	57
23	" "	72	153	221	153	130	127	109	70	57
25	" " OUTLET	62	145	219	159	132	119	76	67	43
26	" CHEV. INLET	234	225	224	50	83	92	85	20	16
29	" SHROUD "	228	224	236	45	65	73	59	23	14
30	OUTLET	81	137	233	138	107	101	67	50	18
32	LN2 SHROUD OUTLET	55	145	199	152					
33	" " BOT.	84	143	175	96					
34	" "	19	56	191	102					
36	" " LOWER	28	50	191	159					
40	MID.	26	35	174	159					
44	" " TOP	24	32	166	157					
49	" " COVER	31	54	161	143					
50	" "	32	56	160	145					
5[illegible]	COVER OUTLET	33	48	159	145					
	Remarks	HEATER ON @ 1500 HRS SET AT 6[illegible]°F INLET		HEATER OFF - CLOSE PANEL VALVE	START LN2 FLOW TO NITROGEN SYSTEM				START AMBIENT TEMP. He GAS THRU He CIRCUITS	START HELIUM CRYOSTAT

TABLE [illegible]

LINDE - GSFC CRYOSORPTION PUMPING SYSTEM

RUN # 1 — LIQUID NITROGEN SYSTEM COLD CYCLE TEMPERATURES °C

T/C #	TIME HRS.	4-19-66 1100	4-19-66 1500	4-19-66 1600		4-20-66 0800	1000	1200	1400	1500	1700	1900	2100	2300	4-21-66 0100	0300	0500	0700	1000	1500	1900
31	INLET - SHROUD	-186	-188	-188		-186	-185	-185	-185	-185	-185	-186	-18[illegible]	-186	-185	-185	-186	-185	-186	-186	-185
32	OUTLET - SHROUD	-27	-190	-190		-190	-188	-190	-189	-189	-190	-190	-190	-190	-190	-190	-190	-190	-190	-186	-189
33	SHROUD BOTTOM	-147	-164	-165		-162	-160	-160	-162	-162	-163+	-166	-162	-163	-162	-164	-162	-163	-163	-165	-167
[illegible]	" "	-177	-185	-184		-180	-179	-178	-177	-179	-179	-182	-178	-179	-178	-178	-179	-179	-179	-181	-185
[illegible]	" "	-24	-182	-186		-185	-184	-184	-185	-186	-186	-186	-186	186	-186	-187	-185	-185	-189	-185	-186
[illegible]	" "	-41	-178	-186		-186	-184	-184	-185	-186	-187	-186	-186	-186	-186	-187	-185	-185	-184	-185	-188
[illegible]	SHROUD MIDDLE	-28	-179	-186		-186	-185	-186	-187	-187	187	-186	-187	-187	-187	-188	-187	-187	-189	-186	-186
[illegible]	" "	-37	-179	-186		-186	-185	-185	-187	-187	-187	-186	-187	-187	-187	-188	-187	-187	-189	-188	-187
[illegible]	" "	-70	-184	-188		-188	-186	-186	-187	-187	-187	-186	-187	-187	-187	-188	-187	-187	-188	-189	-187
40	" "	-20	-178	-184		-185	-184	-184	-185	-185	-185	-186	-185	-185	-185	-186	-185	-185	-186	-184	-185
[illegible]	SHROUD TOP	+2	-143	-164		-183	-182	-182	-184	-184	-185	-185	-184	-184	-184	-185	-184	-184	-186	-184	-185
[illegible]	" "	+4	-116	-154		-175	-173	-174	-176	-177	-178	-178	-179	-178	-178	-179	-178	-178	-179	-180	-179
[illegible]	" "	-29	-155	-175		-183	-182	-182	-184	-184	-184	-184	-184	-183	-184	-184	-184	-184	-185	-182	-184
[illegible]	" "	-20	-165	-175		-185	-183	-183	-184	-184	-184	-184	-184	-184	-184	-185	-184	-184	-186	-184	-186
[illegible]	SHROUD COVER	-150	-167	-176		-178	-172	-175	-177	-179	-178	-180	-190	-186	-190	-190	-191	-191	-192	-190	-191
[illegible]	" "	-120	-153	-169		-173	-164	-170	-175	-177	-177	-179	-190	-190	-191	-191	-192	-192	-191	-191	-192
[illegible]	" "	-169	-180	-182		-184	-179	-180	-184	-186	-185	-186	-187	-192	-187	-186	-187	-187	-188	-186	-187
[illegible]	" "	-161	-172	-176		-181	-179	-180	-182	-184	-182	-182	-182	-184	-183	-181	-184	-186	-185	-182	-184
[illegible]	" "	-167	-173	-175		-179	-175	-178	-180	-182	-181	-182	-182	-183	-182	-181	-183	-183	-184	-181	-182
[illegible]	" "	-166	-173	-179		-183	-183	-183	-185	-186	-185	-184	-186	-186	-185	-185	-186	-186	-185	-180	-184
[illegible]	INLET - COVER	-185	-185	-185		-179	-183	-181	-182	-181	-182	-183	-181	-183	-180	-180	-180	-181	-182	-180	-182
[illegible]	OUTLET - COVER	-174	-185	-186		-183	-184	-181	-186	-185	-183	-184	-185	-185	-184	-185	-184	-186	-185	-184	-186

LN_2 FLOW STARTED 1315

LN_2 ON OVERNIGHT

HELIUM CRYOSTAT ON @ 0840

LN_2 OFF @ 2100
TEST COMPLETE

TABLE 4

LINDE - GSFC CRYOSORPTION PUMPING SYSTEM

RUN # 1 — GASEOUS HELIUM SYSTEM - COLD CYCLE TEMPERATURES - °K

T/C #	TIME - HRS	1000	1200	1400	1500	1600	1700	1800	1900	2000	2030	2100	2200	2300	2400	0100	0200	0400	0600	0800	0900	1000
		4-20-66														4-21-66						
* 1	UPPER - CHEVRON	>200	155	92	55	32	18	16	16	16	17	16	18	18	14	18	20	19	18	16	15	15
2	" "	↓	155	91	58	34	24	22	25	20	22	21	24	25	24	22	23	25	25	20	23	22
* 3	" PANEL	↓	>200	170	135	120	85	71	48	26	19	19	20	21	20	22	20	20	21	18	21	19
4	LOWER "	↓	185	145	120	100	72	59	44	35	16	16	18	18	18	18	18	17	17	15	18	16
5	" CHEVRON	185	125	76	48	25	18	14	16	11	6	12	16	16	15	13	12	13	13	13	15	11
6	" "	185	130	82	56	38	30	25	28	24	24	22	25	26	26	26	26	25	25	23	26	22
7	SHROUD BOTTOM	200	150	100	64	27	23	20	22	20	22	18	21	19	19	20	18	19	20	19	14	19
8	" "	>200	165	105	64	26	22	20	22	20	22	20	19	17	16	20	18	19	20	18	18	19
9	" "	↓	165	105	63	22	20	14	16	9	18	16	15	12	12	16	14	13	14	12	12	13
10	SHROUD MIDDLE	↓				OPEN CIRCUIT																
11	" "	↓	175	110	71	25	22	20	18	20	19	17	18	17	16	16	16	14	14	12	12	16
12	" "	↓				OPEN CIRCUIT																
13	" "	↓	175	110	72	25	22	20	18	18	20	16	19	18	15	18	18	13	12	12	10	16
14	" "	↓	175	110	72	27	25	24	20	21	24	20	22	21	19	21	21	18	17	13	14	19
15	" "	↓	180	115	74	25	20	20	20	18	21	18	20	19	17	18	18	17	15	13	14	17
16	" "	↓	180	125	75	25	19	20	20	15	19	18	20	19	17	18	18	18	15	14	14	16
17	SHROUD TOP	↓	180	125	75	22	18	15	16	14	18	16	19	18	16	17	16	17	15	13	13	13
18	" "	↓	180	125	76	25	20	15	20	17	19	16	21	18	17	18	18	18	16	15	14	17
19	SHROUD COVER	↓	165	98	59	34	32	30	30	30	29	28	30	29	30	30	30	30	28	28	27	29
20	" "	↓	155	92	54	26	25	20	20	17	17	18	21	18	18	18	17	19	17	16	16	17
21	" "	↓	165	100	58	27	25	23	22	23	20	19	18	20	15	20	20	20	18	15	19	13
22	" "	↓	165	99	57	27	26	25	22	22	22	20	20	19	16	21	21	20	18	15	21	18
23	" "	↓	165	97	57	27	25	23	22	21	20	19	17	16	17	21	20	19	17	15	19	17
24	" "	↓	165	100	59	30	28	26	23	24	24	22	22	22	22	24	20	20	20	18	23	21
25	OUTLET - COVER	↓	165	100	59	29	26	26	25	23	23	18	22	25	22	23	21	20	18	18	23	21
26	INLET - CHEV.	145	105	71	48	27	26	27	27	19	26	23	26	23	25	26	25	21	23	23	26	25
27	OUTLET - PANEL	>200	170	105	68	36	31	25	29	17	23	23	25	21	23	25	23	22	21	22	26	21
28	INLET - PANEL	>200	165	115	54	63	62	89	91	115	23	22	24	23	22	23	22	21	19	20	20	19
29	INLET - SHROUD	150	105	75	51	32	25	27	29	28	28	28	30	28	29	29	29	28	26	27	28	27
30	OUTLET - "	>200	165	105	72	33	29	30	30	29	28	28	30	28	29	29	29	28	27	28	29	27
		CRYOSTAT ON @ 0830								REFRIGERANT TO PANELS @ 2015												

* T/C REVERSED FROM THAT SHOWN ON C-61215

(sheet 1) TABLE 5

LINDE - GSFC CRYOSORPTION PUMPING SYSTEM

RUN #1

GASEOUS HELIUM SYSTEM - COLD CYCLE TEMPERATURES - °K

T/C #	TIME - HRS	1100 (4-21-66)	1200	1300	1400	1500	1600	1645	1730	1800	1900	2000	2100	0900 (4-22-66)
1	UPPER CHEVRON	15	19	19	19	27	17	14	19	19	19	19	24	90
2	" "	23	22	26	23	30	22	16	27	26	26	27	30	100
3	" PANEL	18	21	21	19	29	19	16	22	22	19	24	27	100
4	LOWER "	11	17	19	15	48	18	12	19	19	16	21	25	80
5	" CHEVRON	11	12	14	12	45	13	12	16	16	12	16	20	80
6	" "	21	22	26	24	44	26	20	28	29	28	28	32	85
7	SHROUD BOTTOM	11	18	19	19	43	19	20	19	19	19	19	22	100+
8	" "	11	19	20	19	27	19	21	23	19	19	19	22	100+
9	" "	11	18	16	16	26	16	16	23	16	12	16	18	100+
10	SHROUD MIDDLE				OPEN	CIRCUIT								
11	" "	12	18	16	16	24	16	16	26	18	16	16	16	100+
12	" "				OPEN	CIRCUIT								
13	" "	14	14	15	16	21	17	11	27	19	16	16	17	100+
14	" "	18	21	19	19	20	19	19	28	20	19	19	20	100+
15	" "	16	19	15	16	19	19	17	28	19	18	17	19	100+
16	" "	16	19	12	11	19	19	17	28	19	18	14	19	100+
17	SHROUD TOP	15	17	11	10	19	19	14	27	18	16	11	17	100+
18	" "	17	19	12	13	21	19	16	28	19	17	18	19	100+
19	SHROUD COVER	28	29	27	27	30	28	28	35	29	29	28	30	125
20	" "	17	18	15	18	21	16	13	27	23	16	19	19	125
21	" "	14	14	18	17	22	19	17	30	16	12	18	25	125
22	" "	14	14	19	19	25	21	20	30	18	17	18	26	125
23	" "	11	13	20	19	18	20	19	30	18	17	17	26	125
24	" "	19	19	24	23	21	22	21	35	19	22	19	27	125
25	OUTLET - COVER	19	19	23	21	19	22	19	35	21	22	21	26	150
26	INLET - CHEVRON	22	22	26	24	21	26	20	34	24	26	26	26	150
27	OUTLET - PANEL	20	19	24	21	19	22	18	30	22	22	23	26	150
28	INLET - "	19	20	19	19	18	21	17	30	19	21	21	25	125
29	" SHROUD	27	28	28	26	26	28	23	35	27	26	27	30	>200
30	OUTLET "	28	28	29	27	27	29	24	30	27	28	28	30	>200

← 50 WATT LOAD ON → (1645–2100)

NUDE GAUGE ON 2000 - 2100 HRS

SYSTEM OFF @ 2100

(sheet 2) TABLE 5

LINDE - GSFC CRYOSORPTION PUMPING SYSTEM

RUN #2 — LIQUID NITROGEN SYSTEM - COLD CYCLE TEMP. °C

T/C #	TIME HRS	0900 (4-27-66)	1000	1100	1300	1400	1500	1730	2100	2300	0300 (4-28-66)	0600	1400	1600
31	LN_2 SHROUD INLET	+152	-178	-181	-185	-185	-185	-184	-185	-189	-189	-190	-189	-188
32	" " OUTLET	-	>100	-12	-185	-188	-189	-188	-190	-193	-194	-194	-194	-193
33	" " BOTTOM	+96	-25	-148	-155	-180	-151	-159	-164	-168	-168	-169	-164	-168
34	" " "	102	-44	-170	-180	-182	-178	-178	-180	-184	-184	-185	-184	-183
35	" " "	-	+86	-90	-180	-182	-182	-184	-186	-190	-190	-190	-190	-190
36	" " "	+159	>100	-48	-180	-183	-183	-184	-186	-190	-190	-190	-190	-190
37	LN_2 SHROUD MIDDLE	-	>100	-21	-180	-183	-184	-185	-187	-191	-191	-190	-190	-190
[illegible]	"	-	>100	-32	-180	-183	-183	-183	-187	-190	-190	-190	-190	-190
[illegible]	"	-	+88	-76	-183	-185	-185	-185	-188	-191	-191	-191	-190	-190
[illegible]	"	+159	>100	-4	-178	-180	-182	-183	-185	-189	-189	-188	-189	-189
41	LN_2 SHROUD TOP	-	>100	+42	-152	-166	-173	-180	-184	-188	-188	-188	-188	-188
42	" " "	-	>100	+52	-139	-154	-164	-170	-177	-181	-182	-182	-183	-182
43	" " "	-	>100	-8	-178	-176	-179	-181	-184	-188	-187	-188	-188	-189
44	" " "	+157	>100	0	-180	-176	-179	-182	-185	-188	-188	-188	-189	-188
45	LN_2 SHROUD COVER	-	+83	-150	-180	-171	-172	-175	-180	-185	-194	-194	-194	-193
46	" "	-	+8	-130	-155	-169	-160	-168	-177	-185	-195	-196	-196	-196
47	" "	-	-138	-170	-175	-178	-177	-180	-184	-190	-192	-191	-192	-191
48	" "	-	-68	-152	-169	-172	-175	-178	-182	-186	-188	-187	-190	-190
49	" "	+143	-86	-160	-169	-171	-174	-176	-180	-185	-187	-187	-188	-189
50	" "	+145	-120	-153	-170	-177	-180	-185	-186	-189	-190	-189	-190	-190
51	LN_2 COVER INLET	-	-175	-178	-181	-180	-182	-181	-182	-186	-186	-185	-184	-186
52	" OUTLET	+145	-158	-178	-182	-182	-184	-184	-185	-189	-189	-189	-189	-188

LIQUID NITROGEN FLOW STARTED 0940

START AMBIENT TEMP HE GAS THRU GHE CIRCUIT

START GHE CRYOSTAT

LN_2 FLOW OFF 1620 TEST COMPLETE

TABLE 6

LINDE - GSFC CRYOSORPTION PUMPING SYSTEM

RUN #2 — GASEOUS HELIUM SYSTEM - COLD CYCLE TEMPERATURES °K

T/C #	TIME HRS. →	1900 (4-27-66)	2100	2200	2300	2400	0100 (4-28-66)	0200	0300	0500	0700	0800	0900	1000	1100	1130	1200	1300	1400	1500	1600
* 1	UPPER CHEVRON	170	100	65	35	29	22	20	20	18	19	17	17	12	17	17	17	13	15	18	18
2	" "	165	100	68	40	30	27	26	24	25	24	23	22	17	22	26	19	16	19	19	23
* 3	" PANEL	200	175	150	125	105	82	25	23	23	22	21	17	17	21	26	19	11	19	19	21
4	LOWER "	180	145	120	100	80	62	20	18	15	17	16	10	16	11	21	16	10	13	13	16
5	" CHEVRON	135	77	58	32	18	15	16	14	14	15	12	12	10	11	19	11	10	11	11	13
6	" "	145	88	63	43	32	30	29	26	25	27	26	23	21	21	25	19	18	24	22	20
7	SHROUD-BOTTOM	155	120	78	41	22	22	21	19	16	19	19	19	19	17	22	18	19	19	18	21
8	" "	165	115	81	39	22	21	19	18	16	19	19	19	19	12	22	16	18	19	18	19
9	" "	160	120	80	40	18	16	15	15	12	13	12	15	13	10	17	11	13	16	12	16
10	SHROUD-MIDDLE		OPEN CIRCUIT																		
11	" "	180	125	89	43	19	16	17	16	15	14	12	16	13	12	16	13	16	17	16	18
12	" "		OPEN CIRCUIT																		
13	" "	175	125	91	46	19	14	17	17	16	17	11	13	16	12	16	16	17	17	16	18
14	" "	180	130	92	44	22	17	19	19	15	17	13	17	17	18	17	16	17	19	17	19
15	" "	185	130	97	45	18	16	20	19	15	15	13	15	17	16	19	17	16	17	18	19
16	" "	175	135	97	45	14	17	18	16	13	15	13	16	17	16	17	16	16	18	18	19
17	SHROUD TOP	200	135	97	44	16	16	17	15	13	14	11	15	16	13	17	17	13	18	16	17
18	" "	195	135	97	45	18	17	17	17	15	17	16	17	17	16	18	16	17	18	18	17
19	SHROUD COVER	175	115	73	43	30	28	27	29	26	27	28	28	28	28	29	24	27	28	28	29
20	" "	160	105	67	35	15	18	17	18	15	15	13	17	16	16	19	12	15	18	17	18
21	" "	180	110	74	41	21	23	18	22	19	20	23	13	17	19	21	16	16	22	18	16
22	" "	180	110	72	40	21	23	19	22	21	20	23	17	19	21	17	18	16	22	19	16
23	" "	160	110	71	39	18	23	18	22	20	19	22	18	22	19	16	19	16	21	19	21
24	" "	175	110	75	40	25	27	23	25	25	25	26	24	21	24	23	19	18	26	21	23
25	OUTLET COVER	175	110	74	38	25	25	22	18	23	22	21	22	24	22	20	21	18	23	26	21
26	INLET - CHEVRONS	115	77	56	34	26	26	24	24	26	25	16	26	21	26	26	24	21	27	26	24
27	OUTLET - PANEL	140	115	93	59	35	31	23	21	20	22	21	23	22	22	22	22	18	24	24	21
28	INLET - PANEL	185	120	59	63	50	49	22	21	17	20	19	19	24	19	22	19	12	21	19	21
29	INLET - SHROUD	115	81	93	[illegible]	30	29	29	29	27	28	28	28	24	24	29	28	22	29	28	27
30	OUTLET - SHROUD	150	120	87	45	31	28	29	29	27	28	28	28	26	24	28	27	27	27	27	26

HELIUM TO PANELS @ 0115 HRS.

TEST COMPLETE @ 1620 HRS. CRYOSTAT OFF

* T/C [illegible] AS [illegible] C-611515

TABLE 7