Contract No. NAS9-18021
DRL NO. T-2226
Line Item No. 20
DRD No. MA-183TJ

FINAL REPORT, TEST PROGRAM, HELIUM II ORBITAL RESUPPLY COUPLING

December 20, 1991

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BALL AEROSPACE SYSTEMS GROUP, BALL CORPORATION

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Prepared by:

William S. Hyatt

William S. Hyatt
Senior Test Engineer

Approved by:

Harold G. Carrington
Program Manager

BALL AEROSPACE SYSTEMS GROUP, BALL CORPORATION

[redacted]

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DEFINITIONS

CTF - Cryogenic Test Fixture

DAS - Data Acquisition System - IBM PC compatible computer based system for compiling, displaying, starting and formatting critical system test data from the CTF and the Thermal Mismatch Fixture

GHe - Gaseous Helium

HEPA Filter - High efficiency particulate air "cleanroom" filter

Helium II - (He II) - Superfluid liquid helium, boiling temperature = 2.177°K or lower

LHe - Liquid Helium, normal boiling temperature at Boulder, Colorado altitude = 4.0°K

LN_2 - Liquid Nitrogen, normal boiling temperature = 77°K

MLI - Multilayer Insulation - thermal radiation blankets which, in a vacuum, reduce thermal radiation heat flow

MOOG Inc. - MOOG Incorporated, Space Products Division, East Aurora, N.Y. 14052

SCCS - Standard cubic centimeters per second

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SUMMARY

The full scope of this program was to have included development tests, design and production of custom test equipment and acceptance and qualification testing of prototype and protoflight coupling hardware. This program was performed by Ball Aerospace Systems Division, Boulder, Colorado until its premature termination in May 1991.

Development tests were performed on cryogenic face seals and flow control devices at superfluid helium (He II) conditions. Special equipment was developed to allow quantified leak detection at large leak rates up to 8.4×10^{-4} SCCS.

Two major fixtures were developed and characterized: The Cryogenic Test Fixture (CTF) and the Thermal Mismatch Fixture (Glovebox).

The CTF allows the coupling hardware to be filled with liquid nitrogen (LN_2), liquid helium (LHe) or sub-cooled liquid helium when hardware flow control valves are either open or closed. Heat leak measurements, internal and external helium leakage measurements, cryogenic proof pressure tests and external load applications are performed in this fixture. Special reusable MLI closures were developed to provide repeatable installations in the CTF.

The Thermal Mismatch Fixture allows all design configurations of coupling hardware to be engaged and disengaged while measuring applied forces and torques. Any two hardware components may be individually thermally preconditioned within the range of 117°K to 350°K prior to engage/disengage cycling. This verifies dimensional compatibility and operation when thermally mismatched. A clean, dry GN_2 atmosphere is maintained in the fixture at all times.

The first shipset of hardware was received, inspected and cycled at room temperature just prior to program termination.

RESULTS, CONCLUSIONS AND RECOMMENDATIONS

The Helium II Orbital Resupply Coupling Test Program was canceled just as the first coupling set - manufactured by MOOG Aerospace Group, Space Products Division - was installed in the thermal mismatch fixture for its first test sequence. As a consequence of this cancellation, program results are limited to early development test results and the fabrication and checkout of the deliverable test fixtures.

Results, plus any conclusions or recommendations, are included in the main body of the report after description of each test or fixture.

EARLY DEVELOPMENT EFFORTS

Premature cancellation of this test program prevented significant end item testing from being completed. This report addresses those portions of the program which were completed. These include two major development tests, development of a device which allows quantification of large helium leaks, the design, fabrication and characterization of two major test fixtures and the writing of 6 detailed test procedures.

Development Test for Cryogenic Face Seals

Test Description:

Operation of the coupler within its leakage specifications requires that the concentric face seals employed outside the flow control devices meet a $1x10^{-4}$sccs maximum leak rate requirement at 2°K. MOOG Inc. fabricated a face seal development test fixture for evaluation of candidate seals. The final selection seal design was shipped to Ball Aerospace for testing at LN2 (77°K), LHe (4.0°K) and He II (2°K) conditions.

Initial test anomalies required some fixture rework to achieve meaningful, repeatable results. Leakages were of such large magnitude when cold that an external splitter assembly was developed as described in a separate following section.

Results:

Figure 1 is a graphical presentation of leak rate vs. pressure results for the candidate single face seal. This seal almost met specifications for maximum allowable leak rate when tested at ambient temperature. As the test temperature was reduced, performance deteriorated greatly. Helium II temperature performance could not be plotted on this graph. Extrapolated leakage from one data point at Helium II conditions suggests performance more than 7000 times worse than the maximum allowed.

Conclusion:

The candidate seal, as installed in the provided test fixture, exhibited inadequate performance for its proposed application.

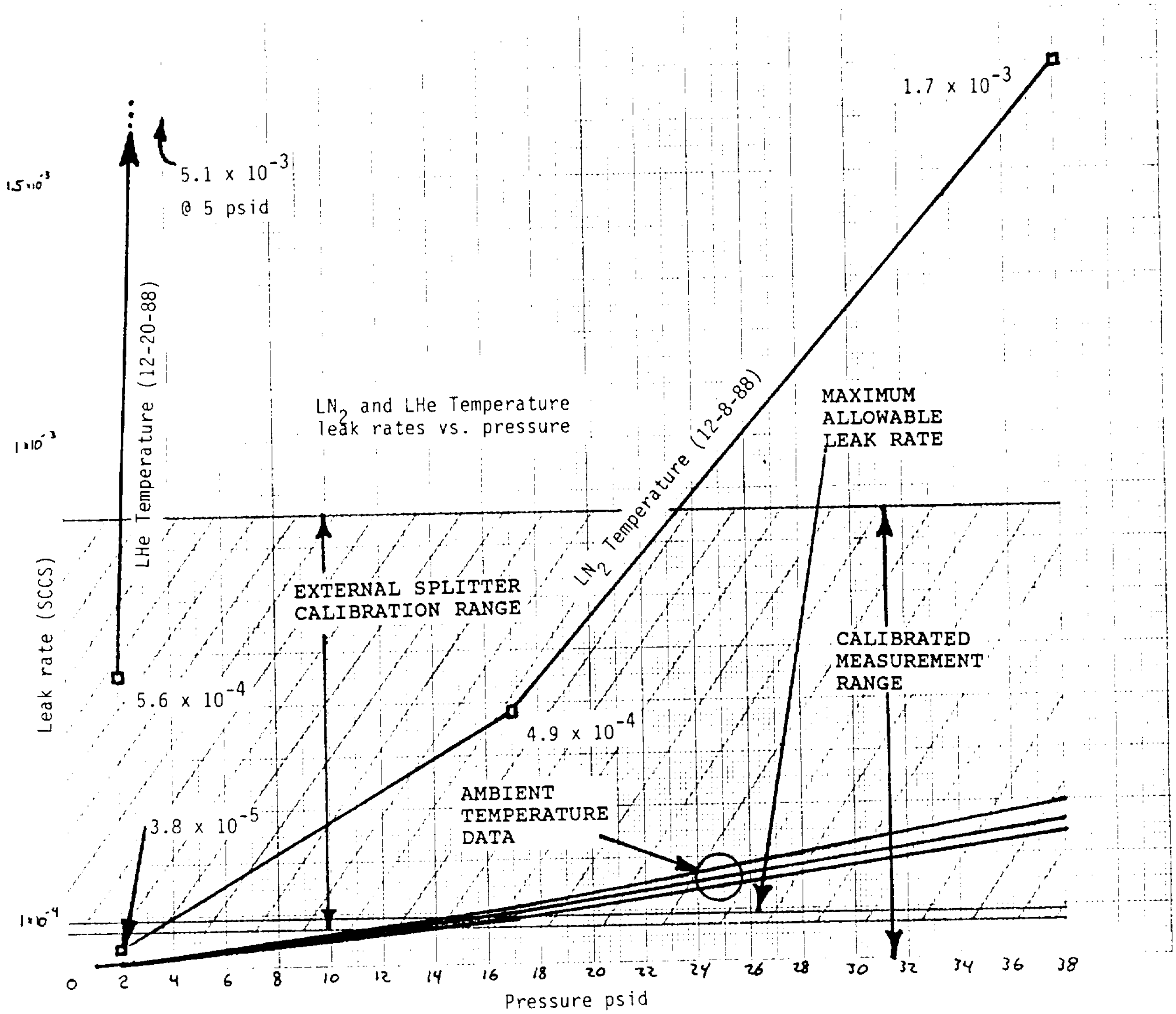


Figure 1. Face Seal Leakage Rates at Three Temperatures

Recommendations:

The sealing surfaces in the test fixture had a polished textured surface. They appeared to have been polished before the surface was adequately leveled. These areas require rework.

The test seal had two parallel depressions or scratches across the sealing surface. This seal should have been replaced with a good seal.

The design of this fixture, immersed in Helium II, creates an isothermal environment across the seal. The coupling will usually have a thermal gradient with higher temperature on the low pressure side of the seal creating conditions for thermomechanical pumping. Addition of a small heater and temperature diodes on each side of the seal would have allowed investigation of the effects of thermal gradient on seal performance.

Development Test for Cryogenic Flow Control Valve Seal

Test Description:

When not engaged, each coupling half's flow control valve is closed. Maximum allowed leakage past each closed ball is $1x10^{-4}$sccs up to 20 psid. This was a test of the final configuration of ball size and seal type used by MOOG Inc. in the coupling.

MOOG Inc. supplied the test ball and seal already installed in a test fixture. No documentation was provided with the test article or fixture.

The test fixture was configured such that GHe was introduced at various pressures on the appropriate side of the ball and a vacuum, generated by a mass spectrometer helium leak detector, was plumbed to the low pressure side of the ball. Leakage vs. pressure differential data was recorded at 295°K, 77°K, 4.0°K and 1.8°K.

At no time during this test was the ball preload altered or the ball moved on its seat.

Results:

Twenty five different tests were run on this configuration. Many tests were repeat runs to establish stability trends with accumulated thermal cycles and to investigate apparent data scatter. Leakage was great enough to require use of the external splitter assembly.

Data scatter settled out quite well considering the numerous variables which had to be controlled in this test.

Reference A summarizes the results from this test.

Conclusion:

For the one ball/seal combination and assembly tested, specified maximum allowable leak rates were not exceeded at ambient temperature or at LN2 temperature. LHe temperature and below resulted in leakage 20 or more times greater than the maximum allowed.

Recommendations:

This test would be a better predictor of performance if a statistically significant number of ball/seal assemblies were tested. Also, the questions of sealing repeatability and preload/leak relationships could be investigated by a planned matrix of teardowns and reassemblies with different preloads over the range expected in coupling assemblies.

External Splitter Assembly

Most mass spectrometer helium leak detectors are limited to maximum quantified leak rates of approximately $1x10^{-5}$sccs. Larger leaks can be identified and located but not quantified. This program is unique in that large leaks of $1x10^{-4}$sccs and greater had to be quantified.

The external splitter assembly was developed at Ball to satisfy this measurement requirement. The splitter, along with its calibrated leak, is shown in Figure 2.

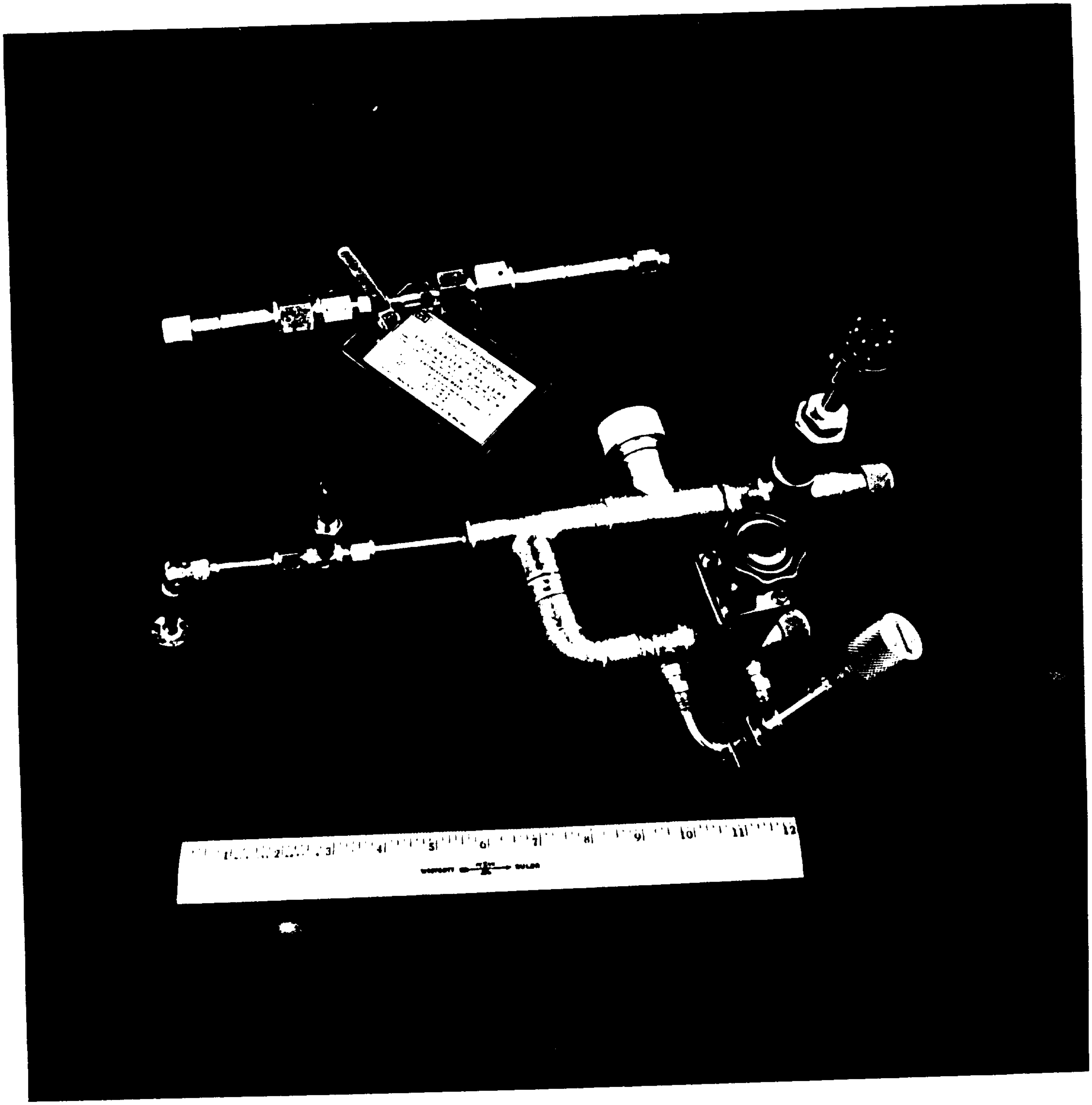


Figure 2. External Splitter Assembly with Calibrated Leak

Theory of Operation:

The splitter divides incoming large leaks through adjustable internal openings (manual valves). Using a pretest calibration procedure-detailed in reference B - the valves are adjusted to split the large leak such that approximately .1% of the total flow enters the mass spectrometer. The other 99.9% is drawn off by a mechanical vacuum pump and exhausted to a vent. An error curve is generated over the range of the calibration leak used. In this case, the resulting calibrated range is 7.0×10^{-5}sccs, to 8.6×10^{-4}sccs. This system is designed to function when the entire gas flow being pumped and measured is GHe.

Results:

When used with an Alcatel ASM51 leak detector, the splitter showed excellent stability as evidenced by pre- and post-test calibration checks over an 8 to 10 hour day.

Graphs of leak rate vs. Δpressure showed excellent linearity.

Conclusions:

Used within the limits of the calibrated error curve leak rates, the external splitter assembly provided a reliable means of quantifying large leaks beyond the normal range of most helium mass spectrometer leak detectors.

CRYOGENIC TEST FIXTURE

Performance Requirements:

The majority of performance testing for the resupply coupling hardware will be conducted in the cryogenic test fixture (CTF). This one fixture provides the following capabilities:

- Mounting interfaces accept all design combinations of coupling halves, Type II flight cover, Type I holding fixture and individual cold seal leak test fixture.
- Any design combination of coupling halves and individual cold seal leak test fixture can be filled with LN2 or LHe. Flow control devices may be open or closed during fill operations.
- LHe cryogen loads may be subcooled by vacuum pumping to any sub-atmospheric pressure down to 10 torr. Final pressure is automatically maintained.
- The Type I coupling is counterbalanced above its center of gravity while mounted in the CTF to eliminate gravity caused loads at the engagement interface.
- Specified external loads and moments may be applied to the Type I transfer line outer jacket interface.
- Specified displacements may be applied at the coupling mini-conflat cryogen flow interfaces while at ambient or cryogenic temperatures.
- Proof pressure tests may be performed at LN2 temperatures (77°K) and above.
- Leakage or permeation rates may be measured as follows:
  - warm seals as a unit.
  - cold seals as a unit.
  - individual cold seals.
  - closed flow control devices.
  - individual glass-epoxy thermal isolators.
  - internal sources (welds) into the guard vacuum.
  - External sources (welds) into the guard vacuum.

- The coupling halves may be engaged and disengaged while at LHe temperature and at ambient. The halves may not be separated to the extent that warm seal integrity is lost while cryogenic.
- Heat leak into engaged coupling halves may be measured while filled with LHe or subcooled LHe.
- A class 10,000 cleanliness environment is maintained at all times around any hardware while installed in the fixture.
- Analog signals of system temperature, cryogen liquid level, pressure and boiloff rates support a P.C.-based Data Acquisition System (DAS).
- Rapid system cooldown allows the CTF to be used for repeated thermal cycle testing between 4°K and 295°K.

CTF Configuration Description

Many of the CTF system parts are visible in either Figure 3 or Figure 4. Most system components are also represented in Figure 5. This configuration description section is a listing of all major components with an explanation of each part's function or purpose. Circled locator numbers in the text match with those on the illustrations. Detailed operation specifics are provided in individual test procedures.

Two LN2 shielded LHe/He II dewars ① are mounted above and on both sides of the centrally located test hardware ②. Each dewar connects to the hardware under test through flexible vacuum jacketed transfer lines ③. The dewars may be filled with cryogen individually or both may be filled from one side if connected to an open coupling or coupling simulator.

Vents ④ are routed symetrically from the tops of each dewar to a common tee ⑤ then through two heat exchangers ⑥, a controlled vacuum valve ⑦ and a 300 CFM mechanical vacuum pump ⑧. A flow transducer ⑨, positioned in a manually valved shunt, measures the exhaust flow of the vacuum pump during heat leak testing.

Various valves and ports facilitate backfilling, pressurization, purging and pressure measurements.

The LHe cryogen fill is subcooled by reducing the system pressure with a 300 CFM mechanical vacuum pump. Once attained, system pressure is automatically maintained with a closed loop pressure control system comprised of a 0-1000 torr pressure transducer ⑩ , a butterfly throttle valve ⑦ and a vacuum valve controller ⑪ . System pressure can be maintained anywhere from 10 torr to atmospheric pressure within ±.5 torr.

Two high vacuum pump stations ⑫ & ⑬ acquire and maintain 10^{-7} torr pressure in the guard vacuum spaces of the two dewars and their common transfer lines. A third high vacuum pump station ⑭ evacuates the vent cavity between coupling halves.

Each pump station is equipped with a custom manifold providing a pressurization/backfill port and a port for connection to a helium mass spectrometer leak detector.

A one degree of freedom mounting system ⑮ provides support for any design combination of hardware along the Y and Z axes while allowing free motion in the X axis direction. This accommodates cycling the coupling halves while mounted in the CTF. A one "g" suspension is provided for the Type I coupling while in the CTF. This suspension eliminates unwanted interface loads and moments.

External test loads and moments are applied at a single interface bracket ⑯ . One bracket location is sufficient because the coupling is symmetrical in rotation about the X axis.

Internal test deflections are applied to the internal mini-conflats in two orthogonal directions both of which are perpendicular to the X axis. Displacement is provided by vacuum micrometer feedthrus each mounted to a warm mini-conflat ⑰ . Coupling rotational symmetry about the X axis allows any deflection test requirement in the Y and Z axes to be satisfied by these two interfaces.

A built-in HEPA filter ⑱ and enclosure provides continuous class 10,000 flow in the volume surrounding hardware under test and in the staging area downstream of the test interfaces.

The individual leak test manifold (not shown) connects to the (MOOG supplied) individual leak test fixture. This permits all necessary combinations of pressure and vacuum to be applied across each cold seal for leak testing. Tests can be run at any temperature from subcooled LHe to ambient.

Reusable MLI cuffs (not shown) are specially designed MLI assemblies fastened with velcro patches. They cover the otherwise unshielded mini-conflat connections on the coupling flowlines. The velcro allows the cuffs to be repeatedly installed with negligible changes in thermal performance.

The lowheat simulator ⑲ is shown mounted in place of an engaged coupling. This unit provides a full flow connection between the two dewar transfer lines (as does an engaged coupling). The calculated total heat leak of this simulator including two MLI cuffs is less than 50 mw. For comparison, the predicted heat leak of the engaged coupling is approximately 1600 mw.

Liquid level sensors ⑳ (readout unit marked). The liquid level probes are permanently mounted inside each dewar. They indicate approximate percentages of liquid when filled with LHe or He II.

There are 11 temperature sensors in this system as shown. A maximum of 12 sensors are possible. Four sensors indicate temperatures of the inlets and outlets of the dewar LN2 shields. Four indicate temperatures of the tops and bottoms of the dewar P.V.'s. The remaining four, two associated with each dewar, can be connected to instrumented couplings to indicate internal temperatures. All temperature sensors are calibrated silicone diodes.

CTF Development Results

The CTF has been thoroughly characterized during its development phase. Its operation has proven to be trouble-free, reliable and repeatable. Heat leak performance data was obtained for the system while mated to the low heat leak simulator. This was done both in a flow-through and in a one-ended configuration. System heat leak performance must be re-established once the CTF is operational in its new location.

System cooldown with a two-ended configuration is rapid, requiring less than 45 minutes. This capability eliminated the need to design and fabricate a dedicated thermal cycle fixture.

Internal flow tube temperatures in the coupling vicinity while operating the system at 20 torr pressure do not reach lambda point. This is a result of a high effective l/a ratio in the transfer line segments.

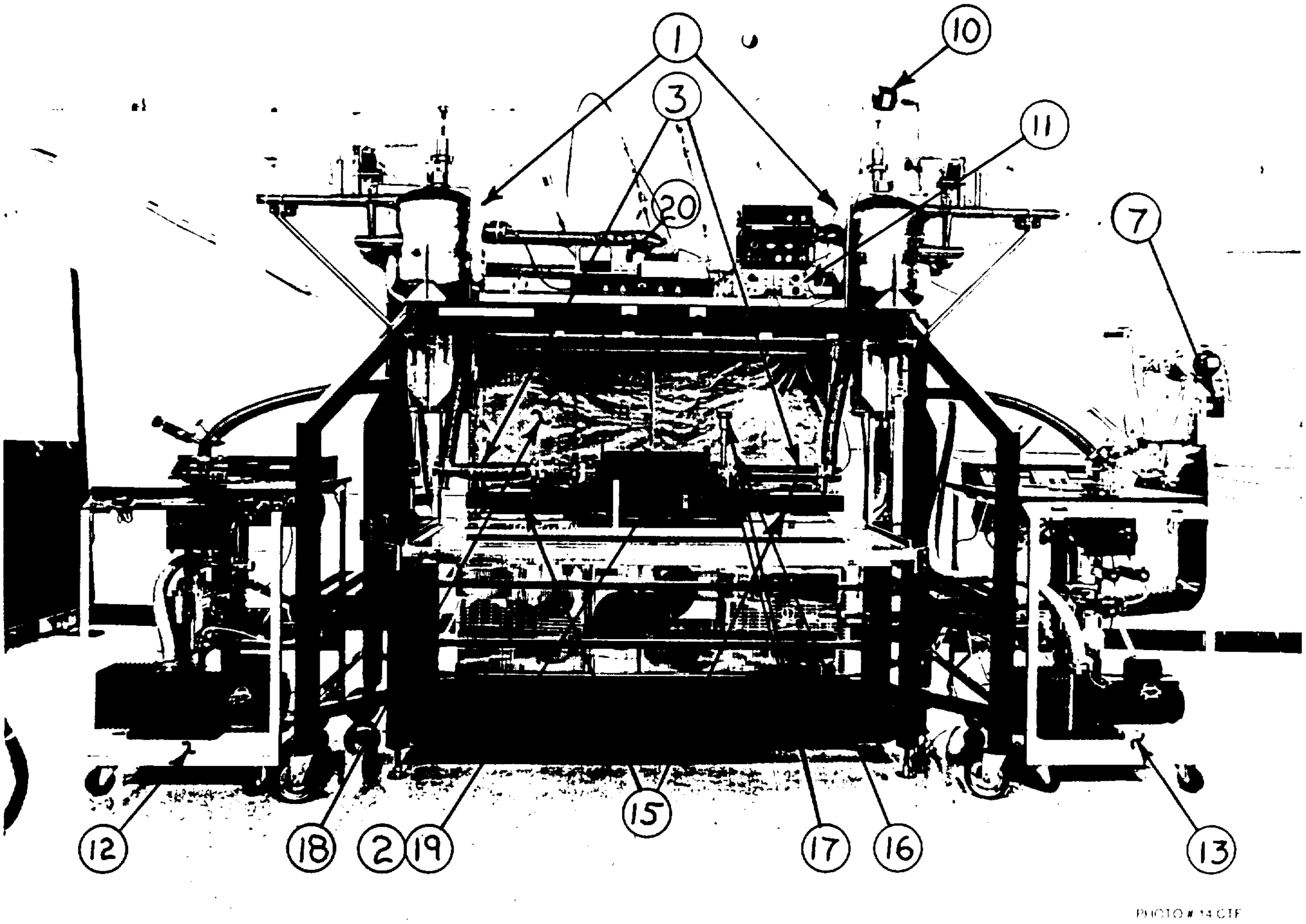
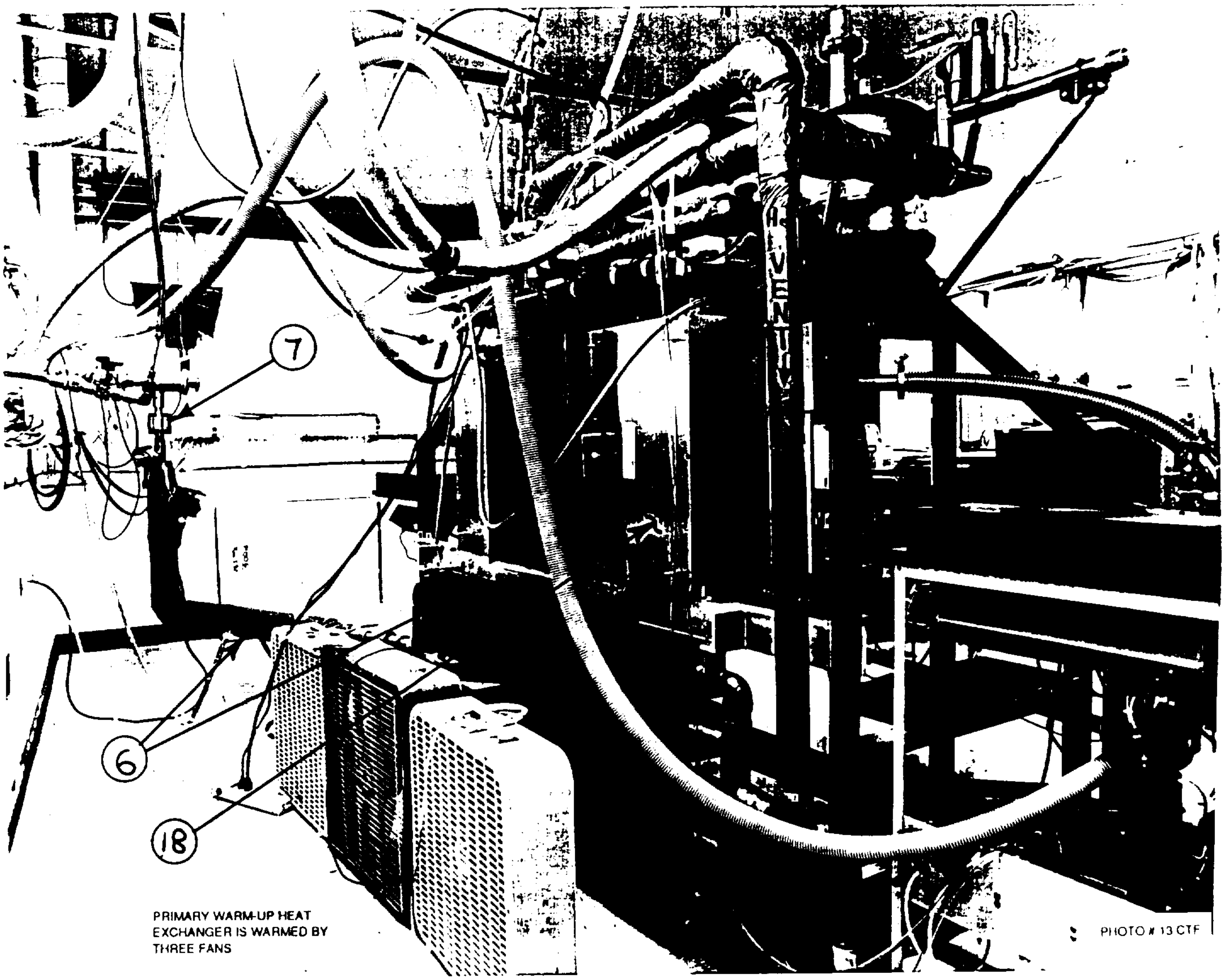


Figure 3. Cryogenic Test Fixture (front view)



PRIMARY WARM-UP HEAT EXCHANGER IS WARMED BY THREE FANS

Figure 4. Cryogenic Test Fixture (rear view)

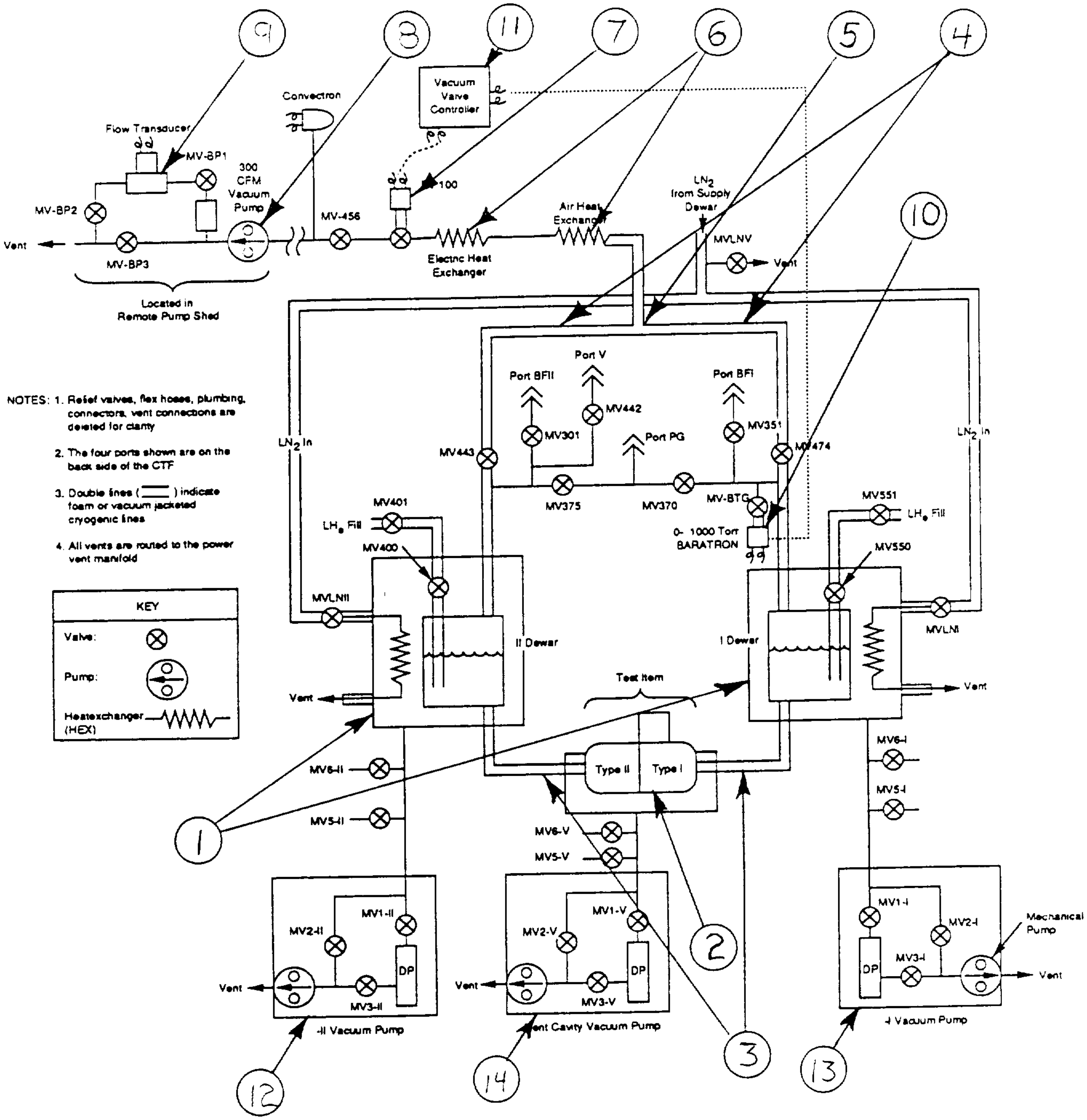


Figure 5. Cryogenic Test Fixture Schematic

THERMAL MISMATCH FIXTURE

Performance Requirements:

All resupply coupling hardware tests not performed in the Cryogenic Test Fixture are conducted in the Thermal Mismatch Fixture. This fixture provides the following capabilities:

- Mounting interface for the Type II coupling and for the Type I Holding Fixture.
- Thermal pre-conditioning for any combination of two mating hardware items to any temperature from 117°K (-250°F) to 350°K (+171°F) prior to manual docking and engagement.
- Measurement and recording of manually applied forces during docking and undocking operations.
- Maintaining a class 10,000 cleanliness environment inside the fixture at all times.
- Support for a PC based data acquisition system with analog thermocouple signals. The resulting data to be used for test control and for post-test data reduction.

Thermal Mismatch Fixture Configuration Description

The Thermal Mismatch Fixture features two thermal preconditioning chambers (ovens) either attached to or inside a cleaned clear lexan glovebox assembly. The overall configuration is illustrated in Figure 6. A flow schematic appears in Figure 7.

The inner oven①, shown in the open position in Figure 8 and represented in the closed position in Figure 7, is mounted on a slide table restrained by a 50 lb-force load cell. The slide table incorporates a mount②designed to accept either a Type II coupling half or a Type I Holding Fixture.

The outer oven ③ opens at both ends. The outer door allows loading hardware into the oven. The inner door provides primary access to the interior of the fixture. All hardware under test enters and exits the fixture through the outer oven.

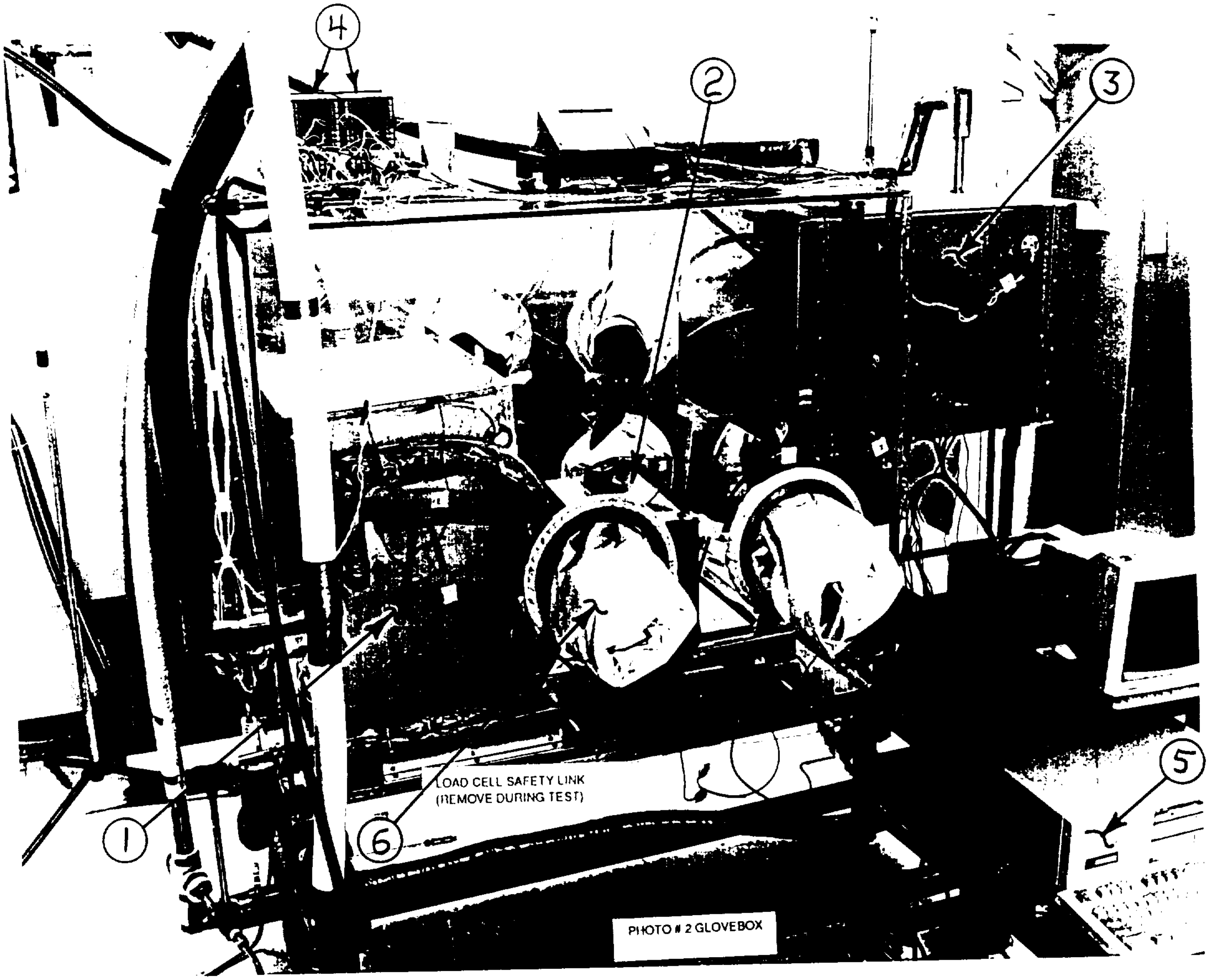
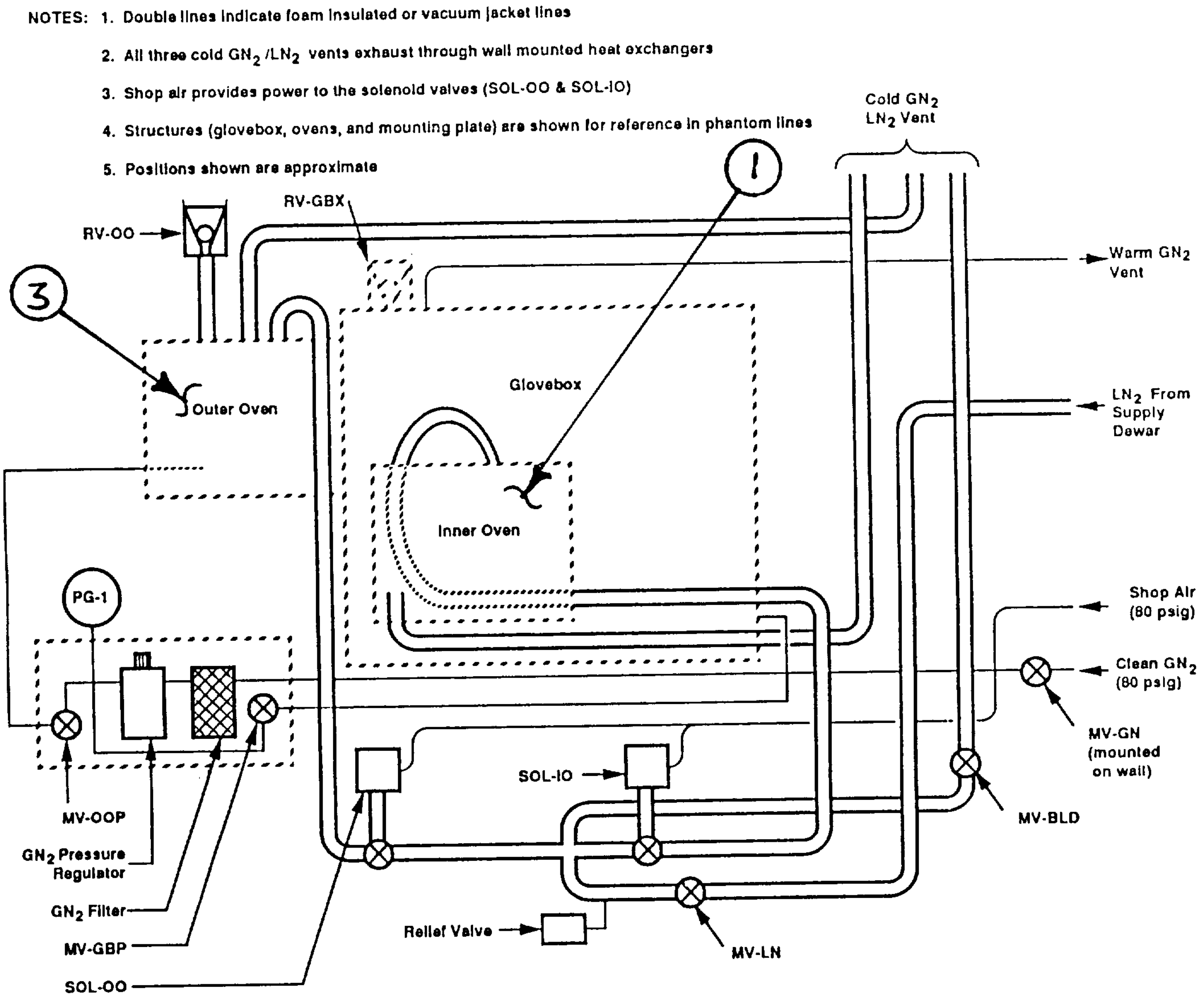


Figure 6. Thermal Mismatch Fixture (exterior view)



NOTES:
1. Double lines indicate foam insulated or vacuum jacket lines
2. All three cold GN_2 /LN_2 vents exhaust through wall mounted heat exchangers
3. Shop air provides power to the solenoid valves (SOL-OO & SOL-IO)
4. Structures (glovebox, ovens, and mounting plate) are shown for reference in phantom lines
5. Positions shown are approximate

Figure 7. Thermal Mismatch Fixture Schematic

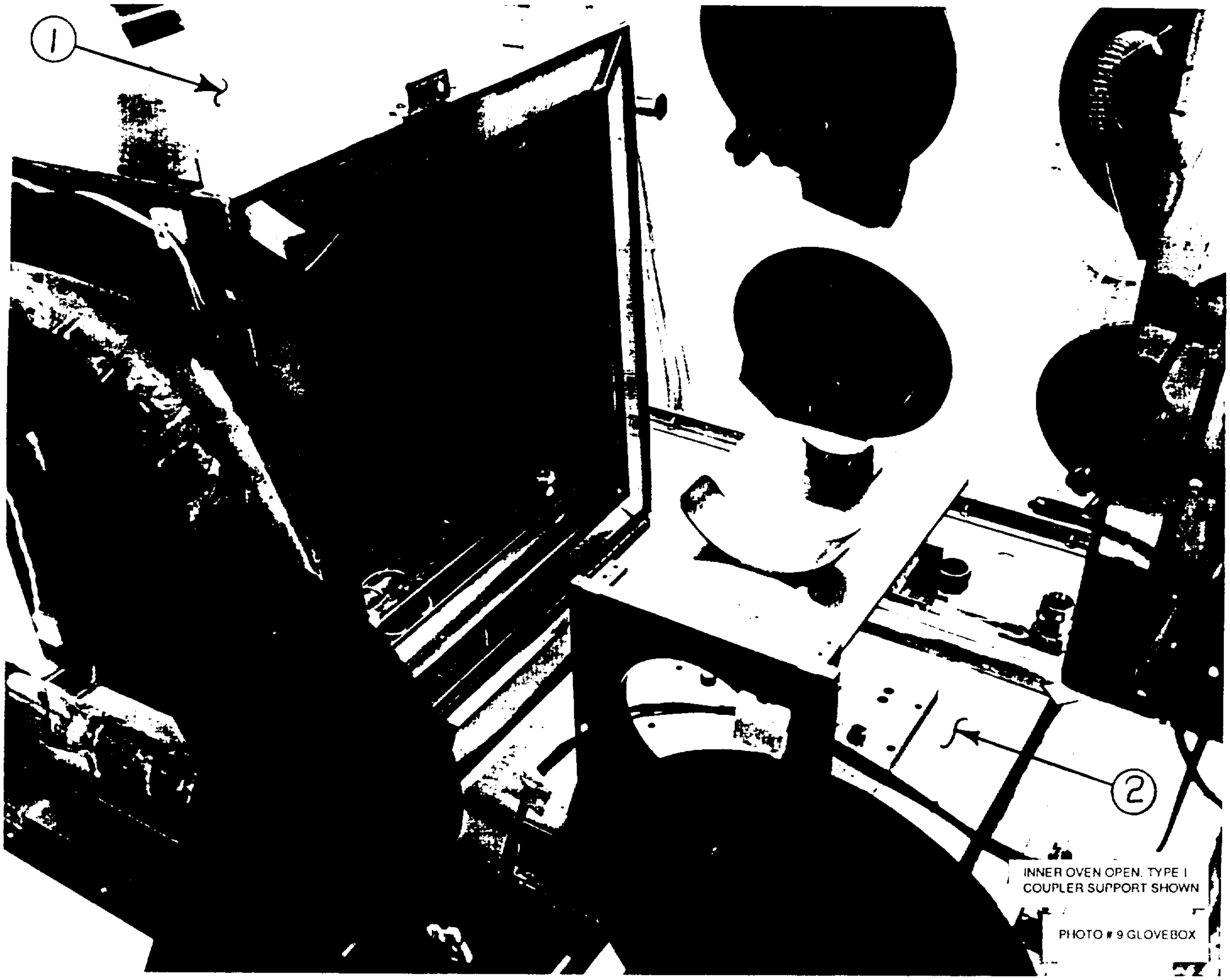


Figure 8. Thermal Mismatch Fixture (slide table)

Both ovens have provisions for electric heating and for sacrificial shielded spray LN2 cooling. Temperature control is provided by dedicated LFE programmable controllers ④. Typical thermal performance plots for the two ovens appear in Figures 9 and 10.

A maximum of 10 thermocouple channels are installed to support the Data Acquisition System ⑤. Typical uses of the channels are demonstrated by the channel labels on the DAS screen display in Figure 12.

The interiors of the ovens and the glovebox were carefully cleaned during final assembly. A positive pressure 7 micron filtered dry GN2 purge was continuously maintained in the fixture until it was shipped after program termination. All hardware introduced into the fixture was verified clean prior to entering. All LN2 used for cooling (system verification only) was filtered at 7 microns.

Three pairs of cryogenic gloves ⑥ were strategically placed to allow all required test and maintenance functions. Cuff extensions made of beta cloth were added to the gloves. Figure 8 shows earlier rubber gloves which could not be adequately cleaned and did not provide cryogenic protection.

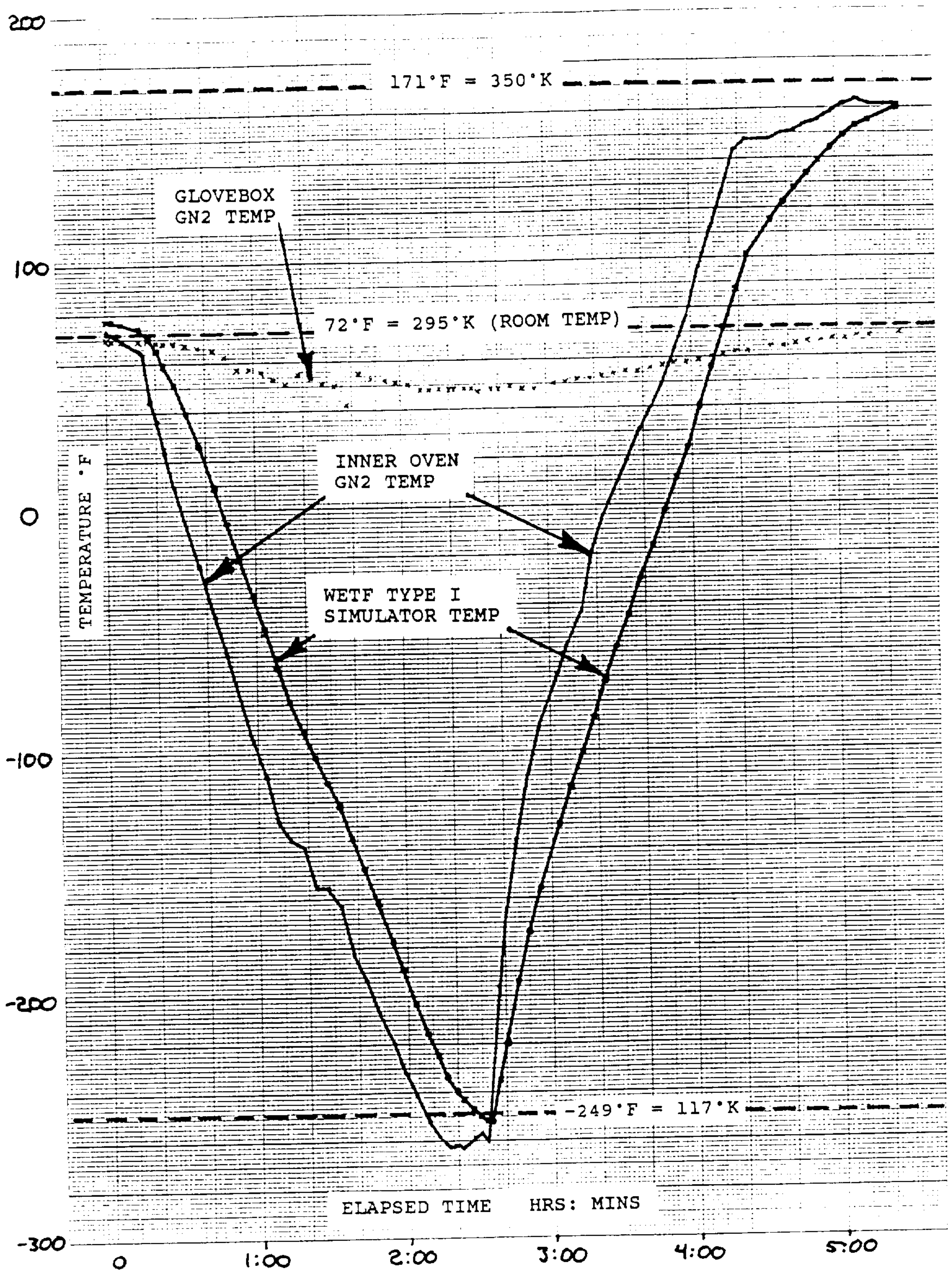


Figure 9. Thermal Mismatch Fixture Performance - Inner Oven

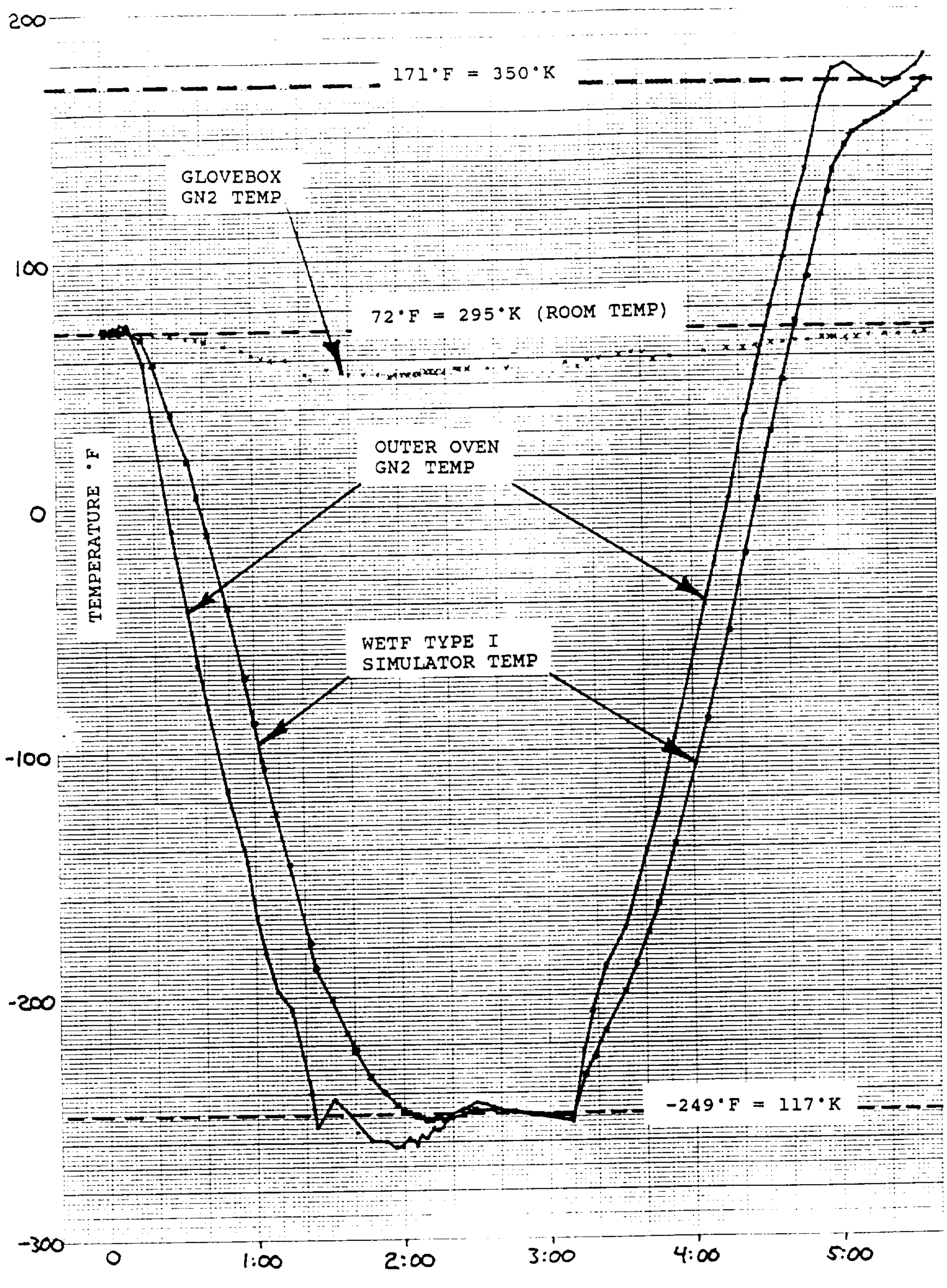


Figure 10. Thermal Mismatch Fixture Performance - Outer Oven

DATA ACQUISITION SYSTEM

The Data Acquisition System (DAS) performs two primary functions: a real time display of test parameters and storage of all data for future review. The DAS is based on a 80286 Compaq P.C.. Custom software was written at BASG to accept, display and record test parameters on both the CTF and the Thermal Mismatch fixture. The programs were shipped to NASA already loaded on the P.C. hard drive.

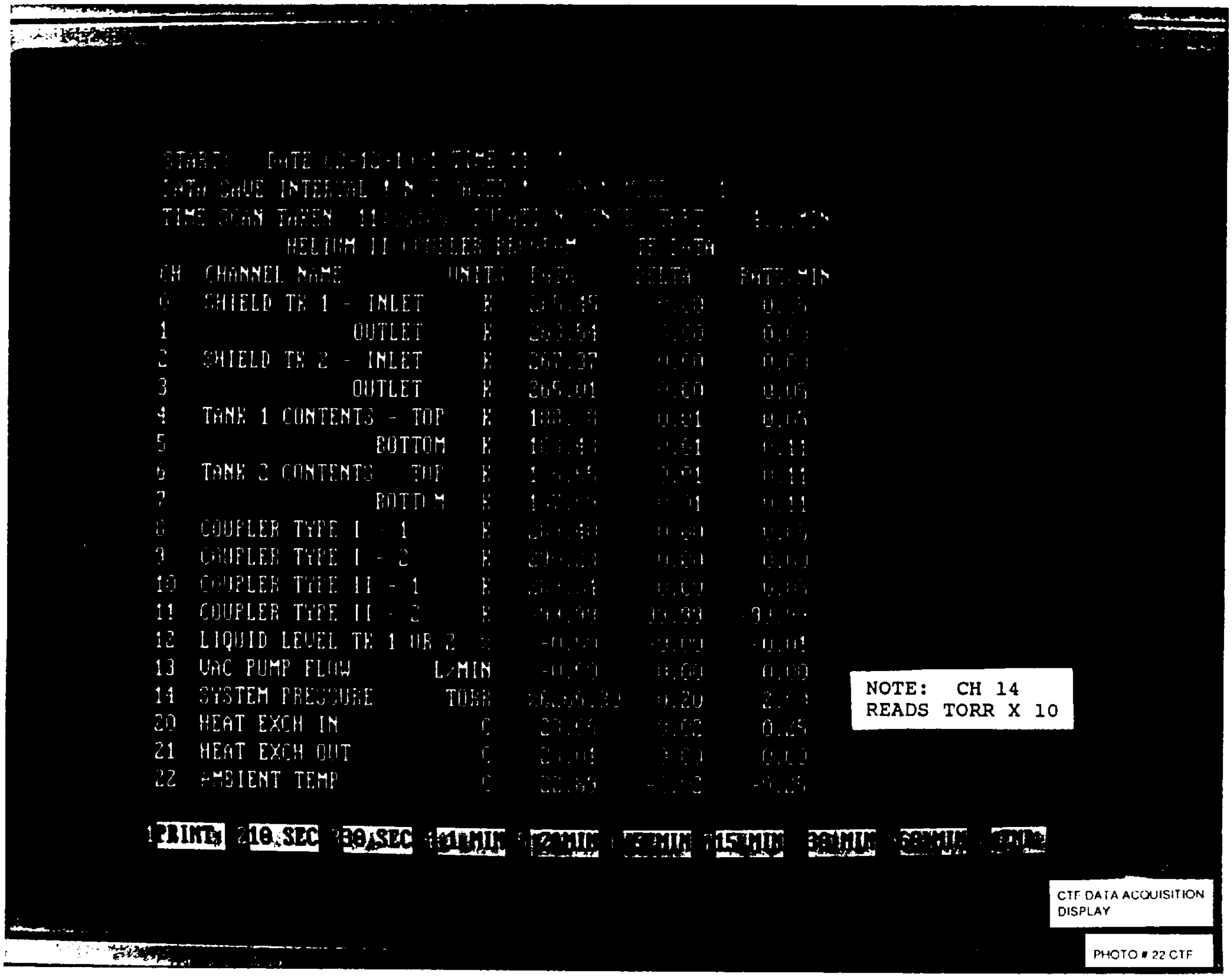
The software controls the other essential hardware part of the DAS system, a 3497A Hewlett Packard Datalogger.

When used with the CTF, the software (filename CTFDAST) sequentially commands the datalogger to apply 100 ma constant current to each of twelve silicone diode temperature sensors, read the resulting voltage across the diode, curve fit the voltage to a calibration curve and store the resulting temperature. After reading the twelve diodes, analog d.c. voltages from the liquid level gauge controller, the GHe flow transducer controller and the vacuum pressure controller are all read through the datalogger, converted to proper units and stored. Finally, the datalogger reads three thermocouple voltages and, after curve fitting, stores these values.

Having completed collecting and storing all 18 data channels, the information is displayed in a screen update as shown in Figure 11. The above process repeats every six seconds.

The display format is mostly self explanatory. All data is stored as a unique file on the hard drive. After the file is closed (end of test run), the file can be manipulated as desired to produce graphs or other output forms.

A simpler program (filename GBXDAS) performs a similar function with the DAS and the Glovebox. The only inputs are ten thermocouples. A typical information display is shown in Figure 12. This scan updates every three seconds.



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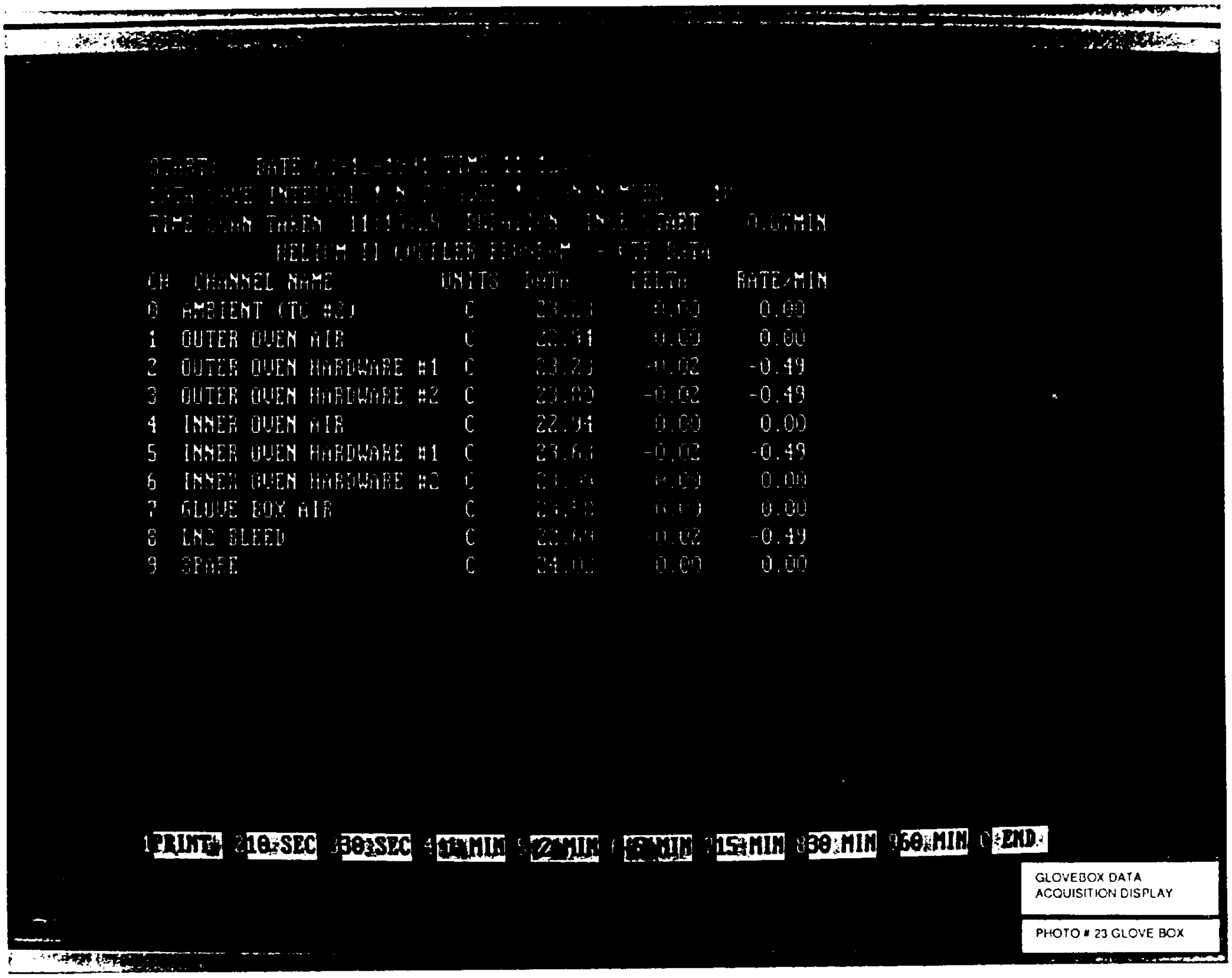
CH  CHANNEL NAME            UNITS  [illegible]  DELTA        RATE/MIN
0   SHIELD TK 1 - INLET      K     [illegible]  [illegible]  [illegible]
1                 OUTLET     K     [illegible]  [illegible]  [illegible]
2   SHIELD TK 2 - INLET      K     267.37       [illegible]  [illegible]
3                 OUTLET     K     265.01       [illegible]  0.05
4   TANK 1 CONTENTS - TOP    K     [illegible]  0.01         [illegible]
5                   BOTTOM   K     [illegible]  [illegible]  [illegible]
6   TANK 2 CONTENTS   TOP    K     [illegible]  [illegible]  [illegible]
7                   BOTTOM   K     [illegible]  [illegible]  [illegible]
8   COUPLER TYPE I - 1       K     [illegible]  [illegible]  [illegible]
9   COUPLER TYPE I - 2       K     [illegible]  [illegible]  [illegible]
10  COUPLER TYPE II - 1      K     [illegible]  [illegible]  [illegible]
11  COUPLER TYPE II - 2      K     [illegible]  [illegible]  [illegible]
12  LIQUID LEVEL TK 1 OR 2   [illegible]  [illegible]  [illegible]  [illegible]
13  VAC PUMP FLOW         L/MIN    [illegible]  [illegible]  [illegible]
14  SYSTEM PRESSURE        TORR    [illegible]  [illegible]  [illegible]
20  HEAT EXCH IN             C     [illegible]  [illegible]  [illegible]
21  HEAT EXCH OUT            C     [illegible]  [illegible]  [illegible]
22  AMBIENT TEMP             C     [illegible]  [illegible]  [illegible]
```

NOTE: CH 14 READS TORR X 10

CTF DATA ACQUISITION DISPLAY

PHOTO # 22 CTF

Figure 11. Data Acquisition System - CTF Display



```
START:   DATE [illegible] TIME [illegible]
[illegible] INTERVAL [illegible]
TIME SCAN TAKEN  11:1[illegible]  [illegible]  START   [illegible]MIN
         HELIUM II [illegible]
CH  CHANNEL NAME          UNITS  DATA     DELTA    RATE/MIN
0  AMBIENT (TC #2)          C    23.[illegible]   0.00     0.00
1  OUTER OVEN AIR           C    [illegible]    0.00     0.00
2  OUTER OVEN HARDWARE #1   C    23.2[illegible]  -0.02    -0.49
3  OUTER OVEN HARDWARE #2   C    23.[illegible]   -0.02    -0.49
4  INNER OVEN AIR           C    22.94    0.00     0.00
5  INNER OVEN HARDWARE #1   C    23.6[illegible]  -0.02    -0.49
6  INNER OVEN HARDWARE #2   C    [illegible]    0.00     0.00
7  GLOVE BOX AIR            C    [illegible]    [illegible]     0.00
8  LN2 BLEED                C    2[illegible]   -0.02    -0.49
9  SPARE                    C    24.[illegible]   0.00     0.00

1PRINT 210 SEC 330 SEC 41 MIN 52 MIN 6[illegible] MIN 715 MIN 830 MIN 960 MIN 0END
```

Figure 12. Data Acquisition System - Thermal Mismatch Fixture Display

PROCEDURES

The acceptance test procedures are organized in six volumes. Document numbers are 171547 through 171552. Each volume addresses a major acceptance test requirement as below:

171547	Baseline Performance, Ambient
171548	Cover Cycling (Thermal Mismatch)
171549	Coupling Cycling (Thermal Mismatch)
171550	Warm Engagement and Heat Leak
171551	Cryogenic Proof Pressure
171552	Cold Engagement and Heat Leak

All procedures were written in draft form prior to receipt at Ball of the first coupling hardware. The intent was to upgrade the procedures to final release status after gaining experience with the hardware in the test fixtures. Early termination prevented this.

All pre-test redlines have been inserted in the Baseline Performance procedure. The other five procedures remain in draft form.

EXPERIENCE WITH HARDWARE AT BALL

A detailed description of all operations at Ball with the four delivered hardware items is contained in the respective Test Cert. Log for each item. The document numbers appear here:

Cert. Log #	Hardware Description	Hardware P/N
2500A	Type I Coupling Half S/N 001	A99846-1
4727A	Type II Coupling Half S/N 001	A99820-1
4728A	Type II Cover	B41487
4729A	Type I Holding Fixture S/N 001	B41494

Summary:

A condensed summary is presented here of all operations with the four coupling hardware items while at Ball.

Type I Coupling Half:

The Type I coupling was first routed to a clean room environment for an incoming receiving inspection and comparison with the (MOOG Inc.) pre-ship inspection. The following types of discrepancies were noted:

- Contamination both particulate and film was found in numerous locations.
- Some fasteners were loose or missing.
- One external dimension was out of tolerance.
- Soft seals were visibly deformed.
- There were rough edges on the engagement threads.
- Wires used to connect to temperature sensor diodes were crushed and insulation was damaged.

The wire damage was repaired and the fasteners and contamination discrepancies were repaired, to the extent directed by NASA, prior to starting test.

One socket-type wire connector was found to be missing during the inspection. In an attempt to find the socket, or at least confirm that it had not lodged in the coupling MLI insulation, the engaged Type I and Type II couplings were x-rayed. The socket was not found. Significant internal misalignment was noted from the x-ray photos.

Various operations prior to formal start of acceptance testing totaled four engagement cycles. It was noted that each successive cycle required more input torque to complete. The fourth cycle required 21% more input torque than the first cycle.

During testing per the acceptance test procedure - Ambient Engagement - the gearbox lock mechanism failed after 4 1/2 of the planned 5 cycles. The lock mechanism was removed from the gearbox to allow test resumption. An additional 2 1/2 cycles were performed after this repair.

Type II Coupling Half:

The following discrepancies were found on the Type II coupling during receiving inspection:

- Numerous exterior dents, dings and scratches were noted.
- Both external clocking "ears" showed heavy wear.
- Particulate contamination was visible on exterior surfaces.
- There were areas of greasy, sticky contamination.
- Loose fibers were noted on the thermal isolator tubes.
- There was a major discrepancy when compared with MOOG supplied drawings.
- The polished cold seal surfaces exhibited a texture similar to that noted on the development test fixture.
- One temperature sensor wire was slightly pinched.
- A ring of screws installed at the flange-to-body interface were one-half the required length.

At NASA direction, the short screws were replaced with correct length hardware and contamination was removed where possible and appropriate. The remaining discrepancies were not corrected.

No operational problems were experienced with the Type II coupling during pretest operations or during the early ambient engagement tests. The same cycles were performed on the Type II as with the Type I.

Type I Holding Fixture:

This hardware was only inspected. Some minor contamination was noted but not corrected. No cycles were put on this hardware.

Type II Cover:

Some minor damage and contamination were discovered during receiving inspection. The contamination was removed at NASA direction. This cover was used for one cycle during installation of the Type II coupling half in the Thermal Mismatch Fixture.

Ball

Memorandum

April 17, 1989

TO: Rich Schoenberg

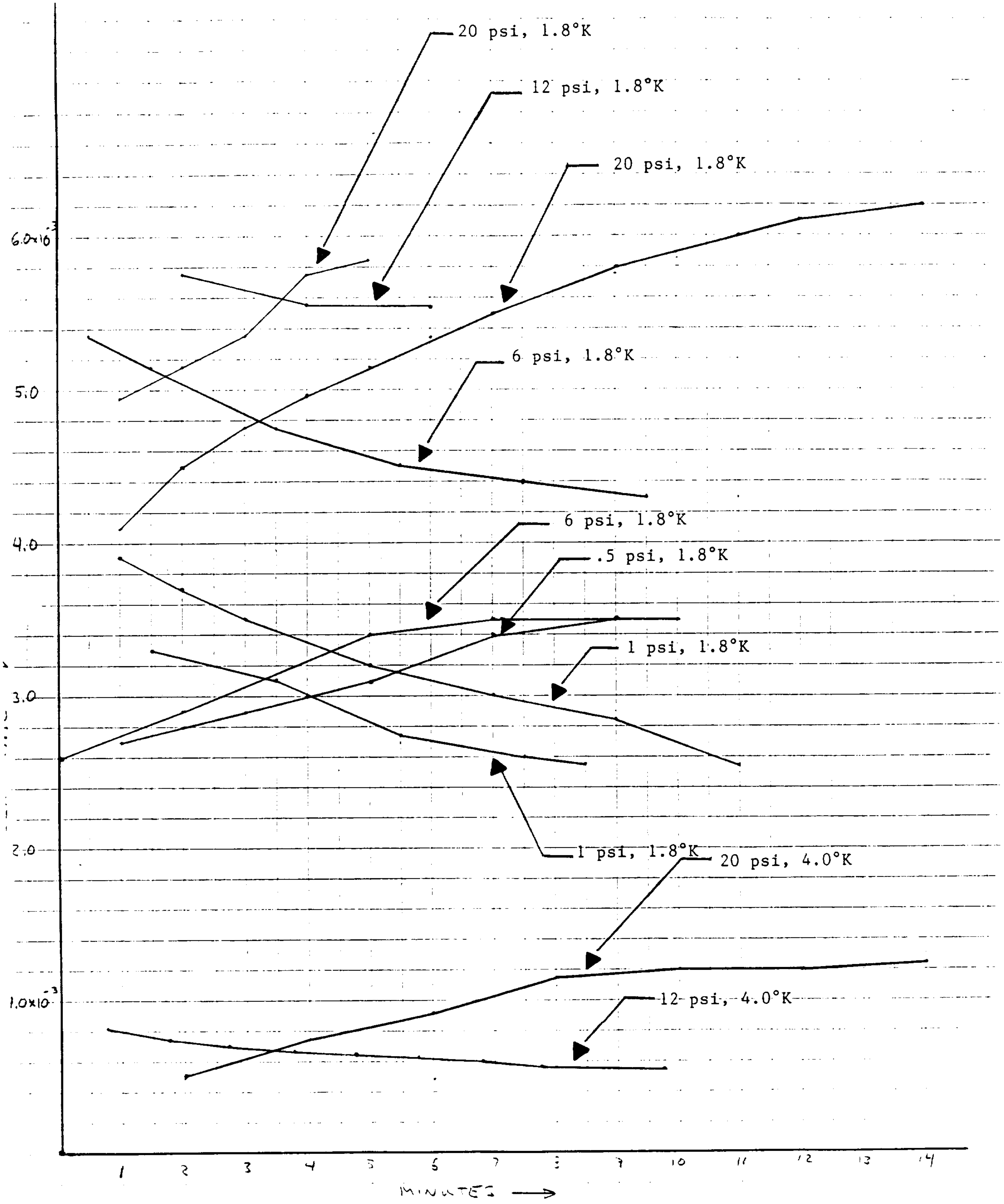
FROM: Bill Hyatt

SUBJECT: Test Results from Cryo Testing of MOOG Flow Control Valve Ball-and-Seat Configuration

Rich - Here are the results from last weeks tests at LH_e and He II temperature.

Page 1 is a graphical representation of leak data vs. time.

Page two is a table of estimated final leak rates after stabilization. Time prevented waiting for full stabilization.

20 psi, 1.8°K
12 psi, 1.8°K
20 psi, 1.8°K
6 psi, 1.8°K
6 psi, 1.8°K
.5 psi, 1.8°K
1 psi, 1.8°K
1 psi, 1.8°K
20 psi, 4.0°K
12 psi, 4.0°K
6.0×10⁻³
5.0
4.0
3.0
2.0
1.0×10⁻³
1
2
3
4
5
6
7
8
9
10
11
12
13
14
MINUTES →

Temperature	Pressure Δ P = PSIA	Estimated Trial Leak Rate (SCCS)
1.8 °K	.5	3.6×10^{-3}
1.8 °K	1.0	2.0×10^{-3}
1.8 °K	6.0	3.6×10^{-3}
1.8 °K	12.0	5.5×10^{-3}
1.8 °K	20.0	7×10^{-3}
4.0 °K	12.0	5×10^{-4}
4.0 °K	20.0	1.5×10^{-3}
77 °K	20.0	2.7×10^{-5}
77 °K	12.0	1.6×10^{-5}
77 °K	2.0	2.6×10^{-6}
295 °K	20.0	2.8×10^{-5}
295 °K	12.0	1.9×10^{-5}
295 °K	2.0	3.7×10^{-6}

TABLE I

Summary of Flow Control Valve Development Tests 4-12-89 thru 4-14-89

Reference B:
External Splitter Assembly
Operating Instructions

Aerospace Systems Division
P.O. Box 1062, Boulder, Colorado 80306-1062 (303) 939-4000 TWX 910-940-3241 Telex 45-605 Cable BAREC

November 29, 1989

National Aeronautics and Space Administration
Lyndon B. Johnson Space Center
Houston, TX 77058

Attention: Rich Schoenberg, EP-4

Subject: Operating Instructions for the Gross Leak "Splitter"

Dear Rich:

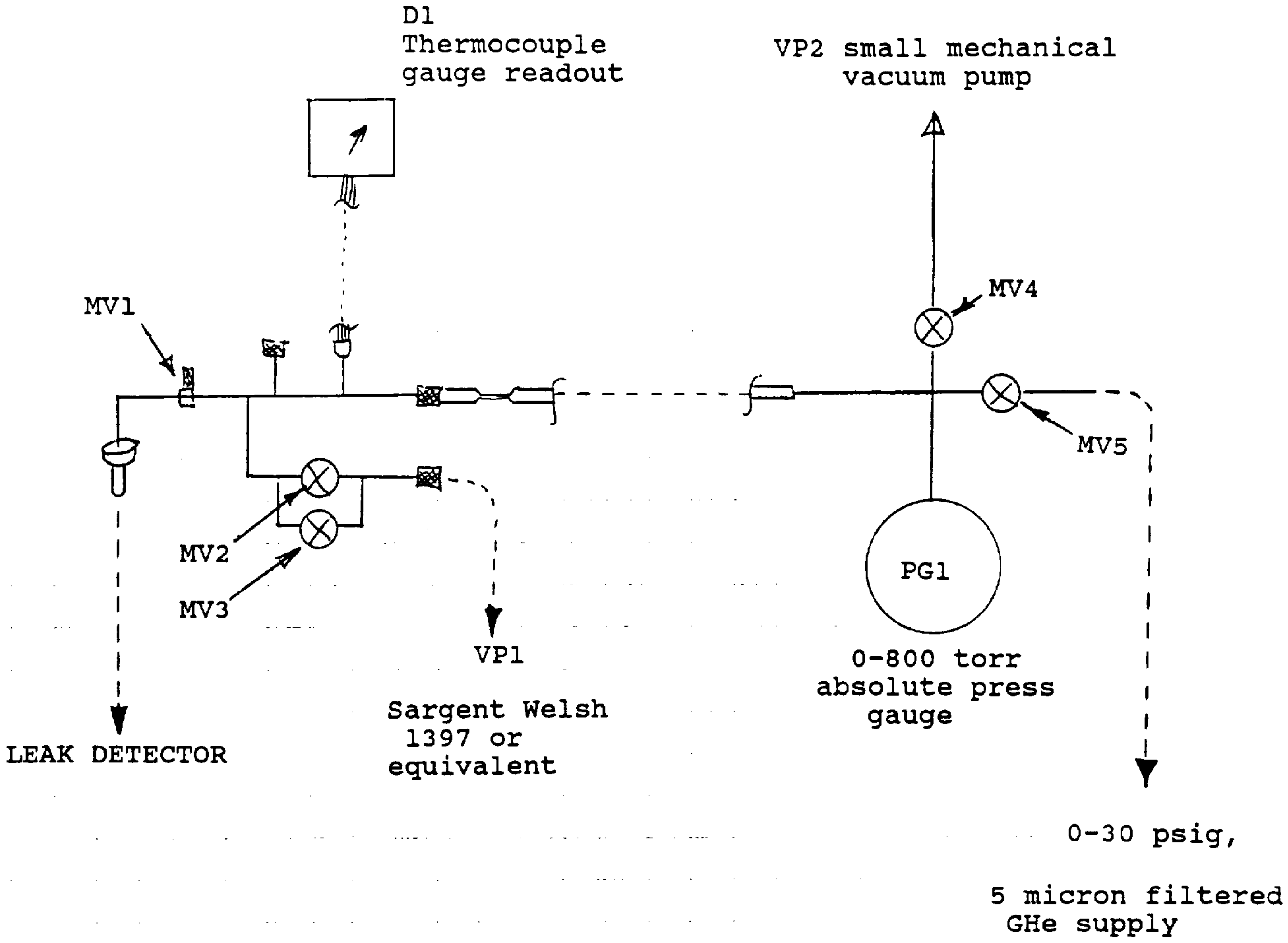
Enclosed is a schematic and procedure to use when setting up and getting comfortable with operation of the external splitter. I have put this together from memory, so there may be a few holes, but not many. Call any time for clarifications.

Notes:

1. Calibration must be performed before taking test data and confirmed after taking test data without shutting down leak detector or vacuum pumps in the meantime.
2. Warmup times in the procedure are important, particularly for VP1 and the leak detector.
3. Do not ever loosen the cajon fittings on the gross leak.
4. The extra hole in the splitter body must be plugged. An ion gauge tube is the correct diameter.
5. The entire system must be kept clean inside. Do not solvent flush the splitter without removing all elastomers including inside the brass valve. The splitter has never been solvent flushed and I would prefer this not be done.
6. All external surfaces must be leak checked after the system is assembled.
7. Do not tighten MV3 more than necessary to lightly seat.
8. Do not touch MV1 unless necessary. If necessary, do not change more than ≃1/100 of a turn total from its as-shipped position. This valve is sensitive.
9. Do not solvent flush the gross leak.

Calibration Procedure:

1. Configure with calibrated gross leak per schematic.
2. Close MV2, MV3 (gently), MV4 and MV5.
3. Start VP1 and let warm up at least 10 hours to achieve stable temperature and performance.
4. Warm up and calibrate leak detector in mid 10^{-7} scc/sec GHe range using a good calibrated leak. Pay attention to temperature correction factors.
5. Attach splitter to leak detector port.
6. Start VP2 and let warm up at least 1 hour.
7. Start leak detector cycle (creates vacuum downstream of MV1).
8. Open MV2 (creates vacuum inside splitter) until D1 shows 50-100 micron pressure.
9. Open MV3 to "50" (of possible 175) graduations (2 turns).
10. Close MV2.
11. Open MV4 until PG1 reads 1 torr or lower.
12. Close MV4, open MV5, pressurizing to 750 torr.
13. Close MV5, open MV4 until PG1 reads 1 torr or lower.
14. Repeat steps 12 and 13 each 2 more times. This establishes pure GHe in the system.
15. Open MV5 to establish 707 torr pressure.
16. After the leak detector stabilizes, adjust MV1 if necessary to establish a split ratio of approximately 1000 ÷ 1. This is achieved when the leak detector indicates about 8.6 x 10^{-7} scc/sec GHe leak rate. If the split ratio is in the range of 950 ÷ 1 to 1050 ÷ 1, don't attempt to adjust any closer. The valve (MV1) is very sensitive. Once set, don't touch or bump this valve. If bumped, all subsequent data will be suspect until a post-test calibration check confirms no change has occurred.



Schematic Notes:

1. MV4 and MV5 recommended valve: Whitey p.n. 1KS4.

2. Pressure Gauge: Wallace & Tiernan p.n. 61B-1D-0800.

3. All flexible lines (to small vacuum pump VP2, to GHe supply, to 0-800 mm (torr) pressure gauge PG1, and to and from the face seal test fixture) should be 1/4" s.s. hex line.

17. Open MV4 to establish 351 torr pressure.
18. Record leak detector output.
19. Open MV4 to establish 69 torr pressure.
20. Record leak detector output.
21. Open MV4 to establish 50 torr pressure.
22. Open MV5 to establish 69 torr pressure (the deliberate undershoot will show any system hysteresis).
23. Record leak detector output.
24. Open MV5 to establish 351 torr pressure.
25. Record leak detector output.
26. Open MV5 to establish 707 torr pressure.
27. Record leak detector output.
28. Generate a calibration error curve from the above data for leakage rates of 7.0×10^{-5} to 8.6×10^{-4} scc/sec GHe.

Data Collection:

Data can now be taken by substituting the face seal test fixture for the calibrated gross leak.

W.S. Hyatt

W. S. Hyatt
Senior Test Engineer

cc: Landon Moore

WH.kb