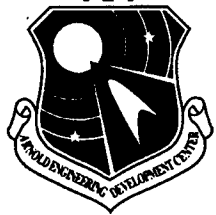


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INTERNATIONAL SPACE STATION PASSIVE AND ACTIVE COMMON BERTHING MECHANISM THERMAL CYCLE TEST

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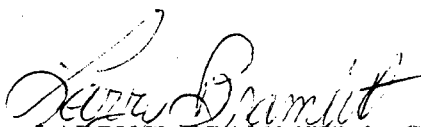
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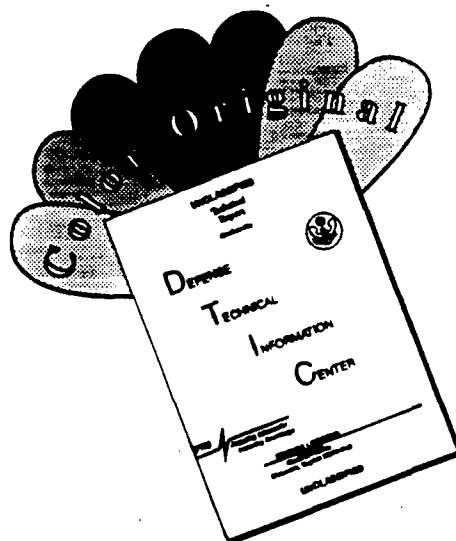

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PREFACE

The work reported herein was performed by the Arnold Engineering Development Center (AEDC), Air Force Materiel Command (AFMC) under Program Element 921E01 at the request of the NASA-Marshall Space Flight Center, Huntsville, AL. The Boeing Test Conductor was Kevin Wagner of Boeing Space and Missiles Group, Huntsville, AL. NASA Funding Manager was Randy Galloway of NASA-Marshall Space Flight Center, Huntsville, AL. Lt. Nick McKinzey and Robert W. Smith were the AEDC Air Force project managers. AEDC Project Engineer was Jimmy D. Sisco of Sverdrup Technology Inc. Test results were obtained by Sverdrup Technology, Inc., AEDC Group, testing contractor for the AEDC, AFMC, Arnold Air Force Base, TN. The tests were performed in 12V Thermal Vacuum Chamber from December 1, 1995 through April 3, 1996, under AEDC Project Number 2687.

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1.0 INTRODUCTION

The International Space Station Alpha Common Berthing Mechanism (CBM) thermal cycle test was conducted in the Arnold Engineering Development Center (AEDC) 12V Thermal Vacuum Chamber. The CBM is the primary mechanical interface for joining the International Space Station Alpha modules on-orbit. The CBM system consists of a pair of 6-ft-diam rings with the appropriate means to seal the joint upon mating. The first ring, called Active CBM (ACBM), houses the powered bolts which drive the two halves together. The second ring, called Passive CBM (PCBM), contains the seals which are energized when the two halves are mated. Each CBM is attached to its respective module with a sealed flange on a berthing plate. Both CBMs are in the developmental testing stage. AEDC's 12V Thermal Vacuum Chamber exposed the test hardware to the deep space thermal environment with the use of the 12V's Xenon solar simulator and internal liquid nitrogen (LN₂) cold wall liner.

The primary objective of this test project is to thermal cycle the active and passive Common Berthing Mechanisms developed under the NASA-MSFC/Boeing International Space Station Alpha program. Performance parameters validated by tests include: thermal model validation, test article temperature, gross heat flux evaluation, and seal integrity survivability. The 68-day test matrix included 54 hot and cold thermal cycles consisting of six different hardware configurations, each requiring separate pumpdowns. The chamber performance for this project included a vacuum of less than 1×10^{-5} torr and a background temperature of less than -250°F. The solar simulator provided an 8-ft-diam beam at 1.0 solar constant with ± 5 percent uniformity and less than 4 deg divergence. All chamber housekeeping data were acquired by AEDC. All test article thermal data were acquired on Boeing's data acquisition system.

This report does not include all the data obtained during the tests but describes the particulars of each test phase and presents some typical results from each phase. The equipment used to accomplish the test objectives is also discussed. All the data from the test program are contained in a data package released to Boeing Space and Missiles Test Group on April 10, 1996.

2.0 APPARATUS

2.1 TEST FACILITY

The 12V Chamber, also known as the Aerospace Environmental Chamber 12V, is located at Arnold Air Force Base, TN. The chamber was specifically designed for thermal balance testing of components and space vehicles. The Chamber (Fig. 1) is nominally a 12-ft-diam by 35-ft-tall vertical test chamber. Its outer vacuum shell is constructed of 304 stainless steel for low outgassing, and it is equipped with a LN₂ cooled floor and walls to simulate the thermal environment of space. A solar simulator that produces spectral radiation within the solar spectral band is also provided in 12V. The working volume within the chamber is nominally 10 ft diameter by 30 ft in length. The solar test volume on the chamber floor is 8 ft diameter by 8 ft tall.

Personnel access to the 12V chamber is through a 5-ft-diam hinged door opening in the east end of the chamber and through a 2.5-ft-diam opening near the top (southeast side). The width of the 5-ft-diam hinged door opening is somewhat restricted by the cryo-liner. Relatively large test articles can be installed by removing a 10-ft-diam bulkhead located at ground level, or by removing the 10-ft bulkhead on the top of the chamber. Installation of test hardware through the bottom of the chamber may require removal of some cryo-panels. Installation of the test article from the top of the chamber requires removal of a section of building roof, then the top chamber bulkhead. The solar simulator collimating mirror and its mount are removed as part of the chamber top. A large crane is used to remove the building roof and chamber bulkhead. The ISSA Passive and Active Common Berthing Mechanisms were installed and removed through the top opening. All hardware re-configurations were installed and removed through the 5-ft personnel access.

2.1.1 Pumping System

The chamber is evacuated with a combination of vacuum pumping components which includes a 750 ft³/min roughing pump and a 50,000 l/sec oil diffusion pump with LN₂ baffles and an angle valve. A 140 ft³/min mechanical pump and a 750 ft³/min Roots blower evacuates the diffusion pump foreline. Safety system interlocks automatically isolate the vacuum pump system from the chamber in case of power or cooling water failure, or if the foreline pressure exceeds normal limits. A 10-ft² cryo-cooled panel (cooled with 12K GHe) serves as a cryo-pump in the 12V chamber. Chamber pressure below 10⁻⁵ torr can be obtained without using the GHe-cooled cryo-pump if the chamber has no large vacuum or nitrogen leaks. The GHe cooled panel was used to compensate for test article outgassing and vacuum nitrogen leaks inherent to a system of this size.

2.1.2 Cryo-liner

The 12V chamber is completely lined with LN₂-cooled cryo-surfaces below the water cooled/heated collimating mirror (Fig. 2). The cryo-liner consists of upper and middle boiler zones, a lower zone of wall panels that surround the working test volume, an inspection platform that folds in the down position for a working platform or cold ceiling if needed, and a deeply grooved high-emissivity floor panel. Most panels are actively cooled with LN₂ flow from a pressurized storage tank. A few panels are cooled by conduction from contact with directly cooled panels. The panels in the upper and middle zones are cooled using a boiler principle. A LN₂ reservoir at the top of the panels is partially filled and floods the tubes that extend to the bottom of the panels. Supply and return are concentric tubes; LN₂ flows down the inner tube and a mixture of liquid and vapor flows back to the top of the reservoir. A vent in the reservoir removes the vapor from the system. Flow is increased as the heat load on the cryo-surfaces increases. All LN₂ zones return to a GN₂/LN₂ recovery tank where the liquid is pumped back into the main supply tank and the boil-off gas is used to regulate the tank pressure. Normal 12V LN₂ consumption is 2,000 gal for initial cooling, 200 gal/hour at steady state with no solar, and 300 gal/hour at steady state with 1 solar constant. Current LN₂ costs approximately 0.30 cents/gallon. Prior to the CBM test aluminized Mylar® multi-layer insulation (MLI) blankets were installed between all LN₂ panels and the chamber shell to reduce radiation exchange and lower the LN₂ consumption during the long test runs. As a result, the consumption rate was decreased to 1,800 gal for the initial cool down, 125 gal/hr at steady state without solar, and 180 gal/hr at steady state with 1 solar constant. This consumption rate produced an average cost savings of \$42,000 over the 60-day test period.

2.1.3 Solar Simulator System

The solar simulator consists of three basic components: lamp assembly with associated lamp housing, integrating lens unit, and collimating mirror. The lamp housing contains seven, 20-kW Xenon lamps and ellipsoidal collectors. Subsystems include water, electrical power, and air circulation. Each lamp is independently powered by a welding power supply with a nominal 45 vdc at 450 amp. A high-frequency and high-voltage igniter circuit is used to start each lamp. The lamps are operated at 17 to 19 kW to maximize the lamp warranty. Water lines are attached in a coil shape around the outside of the lamp collector to prevent overheating. Raw water circulates throughout the lamp housing walls for cooling purposes. The lamps are cooled by a closed-loop demineralized water system. Demineralized water is required for the prevention of short circuiting, heat erosion, and mineral build-up on the

electrodes. An air circulation system is used to remove ozone created by the lamps and provide additional cooling to the lamp housing.

The integrating lens unit contains an inlet lens, two planes of 19 hexagonal lens elements, and an outlet lens. Subsystems include air circulation and water cooling. The purpose of the integrating lens is to uniformly distribute the optical radiation of the lamps onto the test volume area.

The spherical collimating mirror is a 10-ft-diam single element, water-cooled, aluminum forge. The forge was ground, polished, and coated with nickel. The nickel surface is aluminized, which results in an average spectral reflectance of 87 percent. The function of the mirror is to uniformly reflect a collimated beam onto the test area.

The simulator will produce a continuous variable radiant flux of 0 to 2.3 solar constants. Recommended maximum power is 1.4 solar constants without monitoring the integrating lens assembly temperature with a scanning radiometer. Sunrise /sundown can be simulated with the support of a water-cooled shutter located in the lamp housing. The solar test volume area has a ± 5 -percent micro uniformity. The decollimation angle is ± 1.8 deg. The blackbody spectrum of the Xenon lamps is 5,900 K.

In an off-axis system, the line of sight of the test article is not perpendicular to the collimating mirror. Thus, the test article is prevented from "seeing itself" (reflection). The test article in an off-axis system only sees an apparent sun produced by the integrating lens. Better than ± 5 -percent micro uniformity has been measured. The uniformity over the test volume is a result of the integrating lens that distributes the radiant output of each lamp by splitting the beam into sectors and overlaying them into the test volume. Uniformity quality is primarily dependent on the number of integrating lens elements in the integrating lens. The solar simulator employs 4 of 7 lamps to obtain 1.0 solar constant. In the event of a lamp failure, an alternate lamp can be turned on to replace the loss in irradiance. The xenon solar simulator lamps and mirror were aligned prior to test. A solar spectrum and uniformity measurement of the solar beam were taken prior to the first pumpdown and after the test completion and are included in the final data package. The 12V solar spectrum is shown in Fig. 3.

2.2 TEST ARTICLE

The test article is composed of several components interconnected to make a whole. The passive common berthing mechanism included the hatch, node simulation can, node ring, alignment guides, cooling ring, and multi-layer insulation. The active common berthing mechanism, dependent upon which pumpdown included the hatch, node can, node ring, alignment guides, center disk, cooling ring, multi-layer insulation,

motor controllers, capture latch actuators, and deployable shields. The hatch was previously tested in the 12V chamber in FY92. Two aluminum I-beam stands covered with multi-layered insulation were constructed to support and rotate the test article. Teflon® shim stock was used to thermally isolate the stands from the 12V chamber floor. Two trunion pins, located 180 deg apart, were attached to a trunion bearing mounted on the top of each stand. The bearings allow the test article to rotate from horizontal to vertical (0-, 30-, 60-, 90-deg positions). A rotary hand wheel vacuum feedthrough was mounted on the outside with two 12-in. rods with universal joints attached to the rotating test article trunion pin. The universal joints were used to adjust for a 2-in. misalignment between the rotary feedthrough and test article. An approximate 40-lb counterweight was added to counteract the test article's shift in center of gravity as it was rotated.

2.2.1 Test Article Heaters

Motor control unit heaters were set at a constant 62 W to simulate the motor control unit heat sink. Can heaters were used to simulate the radiation heat sink of the node up on the CBM in space. The cooling ring represented structural thermal contact heat sink of the node wall. The guard heaters are resistive heaters applied to the trunion pins to provide a buffer between the test article and test article stands in which the test article rotates. All test article heaters are thin-film resistive-type heaters. The test article has two trunion pins connected 180 deg apart on the outside diameter of the test article. The shafts of the pins are attached to bearings mounted on the test article stands.

2.3 TEST-SPECIFIC HARDWARE

The 12V chamber port P-13 (normally used for vacuum gages and solar radiometers) was removed to allow a Boeing-supplied thermocouple feedthrough port. Port P-12 was removed and replaced by an instrumentation feedthrough port. Feedthroughs include one conflat for camera operation, four 14-pin Canon plug feedthroughs for Boeing's heater wires, one 7-pin feedthrough for solar radiometers, one convectron gage, and four ½-in. AN fittings for air/glycol cooling lines. Copper to stainless steel flex lines were installed in the chamber from port P-12 to the test article. The flex lines allowed the test article to be cooled with air and, later, glycol while enabling the test article to rotate. The lines were wrapped with 10 layers of MLI for the first four pumpdowns. The lines were wrapped with resistive wire heaters, aluminum foil, and then 10 layers of MLI to prevent glycol from freezing (-50°F) when not in use. Teflon strips were placed between the floor and copper lines for additional thermal isolation. Average temperature on the line at the floor level, when not used, was -180 °F. An RTE4000 circulation chiller with an added pre-ice bath provided the glycol

circulation. The flow rate varied, dependent upon the orientation of the test article. The circulator was primed with a vacuum pump to overcome the initial line head pressure. The cooling lines were held under a vacuum when not in use.

2.4 TEST INSTRUMENTATION

2.4.1 Test Facility Instrumentation

A Kaye Instruments Digi 4S data logger interfaced to a 128-channel ramp/scanner was used to measure the chamber housekeeping data. The data logger output was sent and stored on a personal computer (PC). The log interval was 5 minutes. All test data files were backed-up on 3-1/2-in. floppies and included in the final data package. Instrumentation was provided to measure vacuum levels and surface temperatures. Seven thermocouple vacuum gages were used to monitor vacuum level in the various components of the pumping system, vacuum guard system, and LN₂ vacuum jacket system. Chamber vacuum was measured, depending on the vacuum level, using a mechanical absolute vacuum gage, a thermocouple/convectron vacuum gage, Baratron gage, and three Bayard-Alpert ionization gages. All vacuum gage outputs were read from meter outputs and manually logged in the test operation log book.

Pressure in the chamber was measured with three Bayard-Alpert ionization gages and ranged from 3.5×10^{-5} to 3.1×10^{-6} torr during the first three pumpdowns and 3.5×10^{-6} to 3.1×10^{-7} torr during the remaining three pumpdowns. The pressure gage was mounted near the test article on the northeast chamber wall. Pressure as measured by a Bayard-Alpert gage, was on the order of 2.3×10^{-6} torr. A Bayard-Alpert gage mounted in the top of the chamber between LN₂ liner and chamber shell measured pressure on the order of 1.5×10^{-6} torr. The pressure as measured by a Bayard-Alpert gage mounted behind LN₂ liner and chamber shell at test article level close to the GHe cryo-panel was on the order of 5.7×10^{-7} torr.

Surface temperatures (LN₂ cooled) were measured using copper/constantan thermocouples that were read by a multi-channel data logger. The data logger converted the thermocouple outputs voltages to temperatures displayed in degrees Fahrenheit. Chamber hardware temperatures that were measured with thermocouples include all cryo-panels, collimating mirror, gaseous helium panel, test article cooling lines, integrating lens assembly, and diffusion pump heater. Table 1 identifies the data logger channel assignments. Figures 4a-i identify the LN₂ panel location corresponding to the thermocouple assignments. Each thermocouple location on the test chamber was verified by spraying a "Freeze Mist II" solution for a temperature response.

Solar simulator lamp voltages and currents were manually logged on an hourly basis or when a restart or current fluctuation occurred. The solar beam was monitored by two water-cooled Hy-Cal radiometers placed in the northwest side of the chamber. Each radiometer output was fed into a Preston 8300 XWB amplifier which was read by the Digi-Link ramp/scanner. Hy-Cal radiometers and Preston amplifiers were calibrated with the data system prior to testing. The solar spectrum and beam uniformity underwent calibration/certification using an Optronic scanner spectrometer. The spectrometer was calibrated using a NIST-calibrated lamp from AEDC's Precision Measurements Calibration Laboratory (PMEL). Calibration and certification documents can be obtained from PMEL.

A black-and-white CCD array video camera was installed in the 12V chamber to view the shadowing effects of the solar beam on the test article. The camera was placed in a 304 stainless steel atmospheric canister, 3 in. in diameter by 4 in. long, using a ½-in.-thick Plexiglas® window sealed by an O-ring for viewing and vacuum integrity. A 20-ft-long stainless steel flex line, 1-in. diam, was attached to the canister using an A-N fitting and to the P-12 port using a 2-3/4-in. conflat. A 14-v power line, a 75-ohm coaxial video line, a Type T thermocouple, and a 1/4 nylon tubing line were fed through the flex hose for camera operation. The nylon tubing served as a nitrogen purge to prevent the camera from overheating or freezing. The flex hose was wrapped with 10 layers of MLI for additional thermal protection. The camera employs a fixed focus lens (infinity at 6 in. with a 90-deg field of view (FOV). The wide FOV allowed the camera to be mounted 5 ft above and 5 ft east of the test article. The entire test article could be viewed in the horizontal or vertical position. A VCR was used to record the test article during rotation and at each rotation angle. An ND1 glass filter had to be installed to reduce the amount of incident light on the camera from the solar beam. The nitrogen purge was never used. The camera temperature lowered to 41°F for hot case and -6 °F for cold test runs.

2.4.1.1 Thermocouple Temperature Sensor Errors

A check was made of the data system by dipping a temperature sensor in liquid nitrogen at 730 torr and then in an ice bath. A major potential source of error with temperature sensors is from poor thermal contact. Differences up to 10 K have been observed. Most of the thermocouples with bad thermal contact were held down with tape. All of the thermocouples from noted inaccuracies from a previous test were either replaced or epoxied onto the LN₂ cryo-panel. The data logger has a 0.1°F resolution. The test required a background temperature of less than -250°F. Test average temperatures were maintained from -280 to -310°F.

2.4.2 Test Article Instrumentation

Boeing provided the instrumentation and data acquisition system associated with test article measurements. All of the CBM test article surface temperatures were recorded by a Hewlett Packard (HP) Vectra computer interfaced to a HP 3852A data acquisition/control unit with three HP3853A extended chassis. The HP 3852A remotely controlled eight HP 6024A 0-60 V / 0-10 A, 200 W autoranging DC power supplies which powered four heater zones on the berthing plate and powered four motor control heater zones. HP3852A also remotely controlled two HP6038A programmable power supplies which powered the guard heaters on the trunion pins. Boeing provided a 16-in. flange with two - 375 Douglas Type T passthroughs. Over 700 thermocouple terminations were welded and silver epoxied to the test article and read with the HP3852A. Thirty-minute profiles were printed on an HP III Laserjet printer. Each thermocouple location/connection on the test article was verified by spraying a "Freeze Mist II" solution for a temperature response. Boeing added two "loose" radiometer sensors in the chamber, one near chamber radiometers and the other on the test stand to monitor solar input. Boeing's test area, outside of the chamber, is shown in Fig. 5.

To minimize the effects of any possible power interruptions on tests (particularly on the long-term stability tests), a Boeing-supplied 208-V power distribution unit was powered from a 50-kW uninterruptible power supply. All data handling systems were tied to the distribution unit.

3.0 PROCEDURE

3.1 THERMAL-VACUUM TESTS

The thermal-vacuum test approach consisted of exposing the passive and active CBM's to low environmental pressures and then thermally cycling the CBM's using a combination of solar simulator, node simulator can heaters, center disk, berthing plate heaters, Mylar blankets, cooling ring, and cold thermal backgrounds. The testing was broken into six pumpdowns to determine test article response to different thermal conditions. A summaries of the pumpdowns are shown in Tables 2-7. The first pumpdown employed the passive CBM which provided the basis for additional thermal cycling tests.

3.2 THERMAL-VACUUM TEST PUMPDOWN #1

The passive CBM test article was loaded into the top of the 12V chamber and mounted in the Boeing-provided test stand. Boeing personnel connected and checked out approximately 700 test article thermocouples to the HP3852A data system in two days. Figure 6 shows the test article being installed in the 12V test chamber. Figure 7 shows the test article after the MLI had been installed before testing in the 12V test chamber. When the chamber was first pumped down, the chamber pressure gage indicated that a larger-than-normal amount of outgassing was present. The chamber experienced "burping effects" when the pressure rose and then backed down in a matter of seconds. This was believed to be the test article's 20-layer MLI blankets outgassing. Chamber pressures ranged from 3.5×10^{-4} to 3.1×10^{-6} torr during the initial outgassing phase and 3.5×10^{-5} to 3.1×10^{-6} torr during test. Thermal Cycle test #1 hardware configurations, heater settings, and start and stop times are listed in Table 2. The air cooling ring froze up during a thermal run, and disabled the unit. Upon test completion, the passive ring was removed and the active ring was installed.

3.3 THERMAL-VACUUM TEST PUMPDOWN #2

The first active CBM test included the hatch, active node ring, motor controls, berthing plate, node simulator can, MLI external blankets, and test stand. The active CBM clocking position remained at 0 deg in the test stand. Figure 8 shows the test article being installed in the 12V chamber and Fig. 9 shows the test article after installation. The black-and-white CCD array video camera was placed in the test chamber to record solar shadowing effects on the test article when in a rotated position. Chamber pressures ranged from 3.1×10^{-6} to 3.5×10^{-7} torr during test. Thermal Cycle

test #2 hardware configurations, heater settings, and start and stop times are listed in Table 3.

3.4 THERMAL-VACUUM TEST PUMPDOWN #3

Prior to the pumpdown, the active CBM was rotated to 45 deg in the test stand. Figure 10 shows the test article in the 12V test chamber. Thermal Cycle test #3 hardware configurations, heater settings, and start and stop times are listed in Table 4.

3.5 THERMAL-VACUUM TEST PUMPDOWN #4

Prior to the pumpdown, the active CBM was rotated to 0 deg in the test stands and the center disk (MLI to cover hatch) was added. Figure 11 shows the test article in the 12V test chamber. Thermal Cycle test #4 hardware configurations, heater settings and start and stop times are listed in Table 5.

3.6 THERMAL-VACUUM TEST PUMPDOWN #5

Prior to the pumpdown, the active CBM was rotated back 45 deg in the test stands and a flight capture latch actuator was installed. A wire resistant heater powered by an AC variac was added onto the glycol cooling lines to prevent line freezing. Figure 12 shows the test article in the 12V test chamber. Thermal Cycle test #5 hardware configurations, heater settings and start and stop times are listed in Table 6.

3.7 THERMAL-VACUUM TEST PUMPDOWN #6

Prior to the pumpdown, the active CBM remained at a 45-deg clocked position and the flight capture latch actuator was removed. The deployable covers with MLI were added to cover the active CBM. Figure 13 shows the test article in the 12V test chamber. Thermal Cycle test #6 hardware configurations, heater settings, and start and stop times are listed in Table 7. Upon test completion, the active CBM and test stands were removed and shipped back to NASA-MSFC Huntsville, AL. Figure 14 shows the test article being removed from the 12V test chamber. A final solar spectrum and uniformity measurements were recorded and included in the data package.

4.0 RESULTS AND DISCUSSION

4.1 DATA PRESENTATION

Within each hardware configuration, the tests were conducted in the order that best used the test time available. The data curves presented here are organized by test sequence of when the data were obtained. For reference, Tables 2-7 list all of the tests conducted and give the date when each was run and which hardware configuration and heaters applied were involved.

The data curves presented in this report are data recorded from the Boeing data acquisition system. The curves were generated on a PC using MS Excel software. Table 8 catalogs all of the chamber housekeeping data files that were produced each pumpdown test. All chamber housekeeping data files and AEDC CBM Test Log Books were contained in the data package and released to Boeing Space and Missiles Group, Huntsville, AL.

4.2 THERMAL-VACUUM TEST PUMPDOWN #1

All critical test article temperatures for the first four test runs during pumpdown #1 are shown in Fig.15. All chamber housekeeping data file names for this pumpdown are listed in Table 8. Any test chamber and test article problems that occurred during the thermal cycling test pumpdown #1 were recorded and stored in the AEDC CBM Test Log Book #1.

4.3 THERMAL-VACUUM TEST PUMPDOWN #2

All critical test article temperatures for test run 9 during pumpdown #2 are shown in Fig. 16. All chamber housekeeping data file names for this pumpdown are listed in Table 8. Any test chamber and test article problems that occurred during the thermal cycling test pumpdown #2 were recorded and stored in the AEDC CBM Test Log Book #2.

4.4 THERMAL-VACUUM TEST PUMPDOWN #3

All critical test article temperatures for test run 18 during pumpdown #3 are shown in Fig.17. All chamber housekeeping data file names for this pumpdown are listed in Table 8. Any test chamber and test article problems that occurred during the

thermal cycling test pumpdown #3 were recorded and stored in the AEDC CBM Test Log Book #3.

4.5 THERMAL-VACUUM TEST PUMPDOWN #4

All critical test article temperatures for test run 21 during pumpdown #4 are shown in Fig. 18. All chamber housekeeping data file names for this pumpdown are listed in Table 8. Any test chamber and test article problems that occurred during the thermal cycling test pumpdown #4 were recorded and stored in the AEDC CBM Test Log Book #4.

4.6 THERMAL-VACUUM TEST PUMPDOWN #5

All critical test article temperatures for test run 30 during pumpdown #5 are shown in Fig. 19. All chamber housekeeping data file names for this pumpdown are listed in Table 8. Any test chamber and test article problems that occurred during the thermal cycling test pumpdown #5 were recorded and stored in the AEDC CBM Test Log Book #5.

4.7 THERMAL-VACUUM TEST PUMPDOWN #6

All critical test article temperatures for test run 33 during pumpdown #6 are shown in Figure 20. A summary of all chamber housekeeping data file names for this pumpdown are listed in Table 8. Any test chamber and test article problems that occurred during the thermal cycling test pumpdown #6 were recorded and stored in the AEDC CBM Test Log Book #6.

5.0 CONCLUDING REMARKS

Based on results of the CBM operational tests, the following lessons learned should be noted:

1. Cold soak times were not affected by the off-axis mirror in the chamber. This was verified during the first pumpdown with rotation angles 0-, 30-, 60-, 90-deg test article data. The off-axis mirror did not affect the cooldown rate on large mass items. As a result, many thermal cycles were deleted.
2. Adding deployable shields with MLI blankets to the test article added considerable time to the cooldown cycle.
3. There were instances when the chamber pressure indicated heavy outgassing by rapid changes in ion gage readings during pumping and cooling of the chamber. All of these instances occurred when new and additional MLI and instrument simulator boxes were installed on the test article. Also, a steady liquid nitrogen leak in the upper boiler zone was present which limited usual base pressure. A gaseous cryo-panel (12 Kn) was employed to provide additional pumping capacity to overcome leaks and outgassing.
4. In as few as 6 hours after vacuum pumps are started, LN₂ steady-state temperatures (-300 °F) were achieved by a quick cooldown method. Pumping required two hours and cooling required 4 hours.
5. Adding MLI blankets between the 12V chamber LN₂ liner produced a \$42,000 cost savings over the 60-day test period.

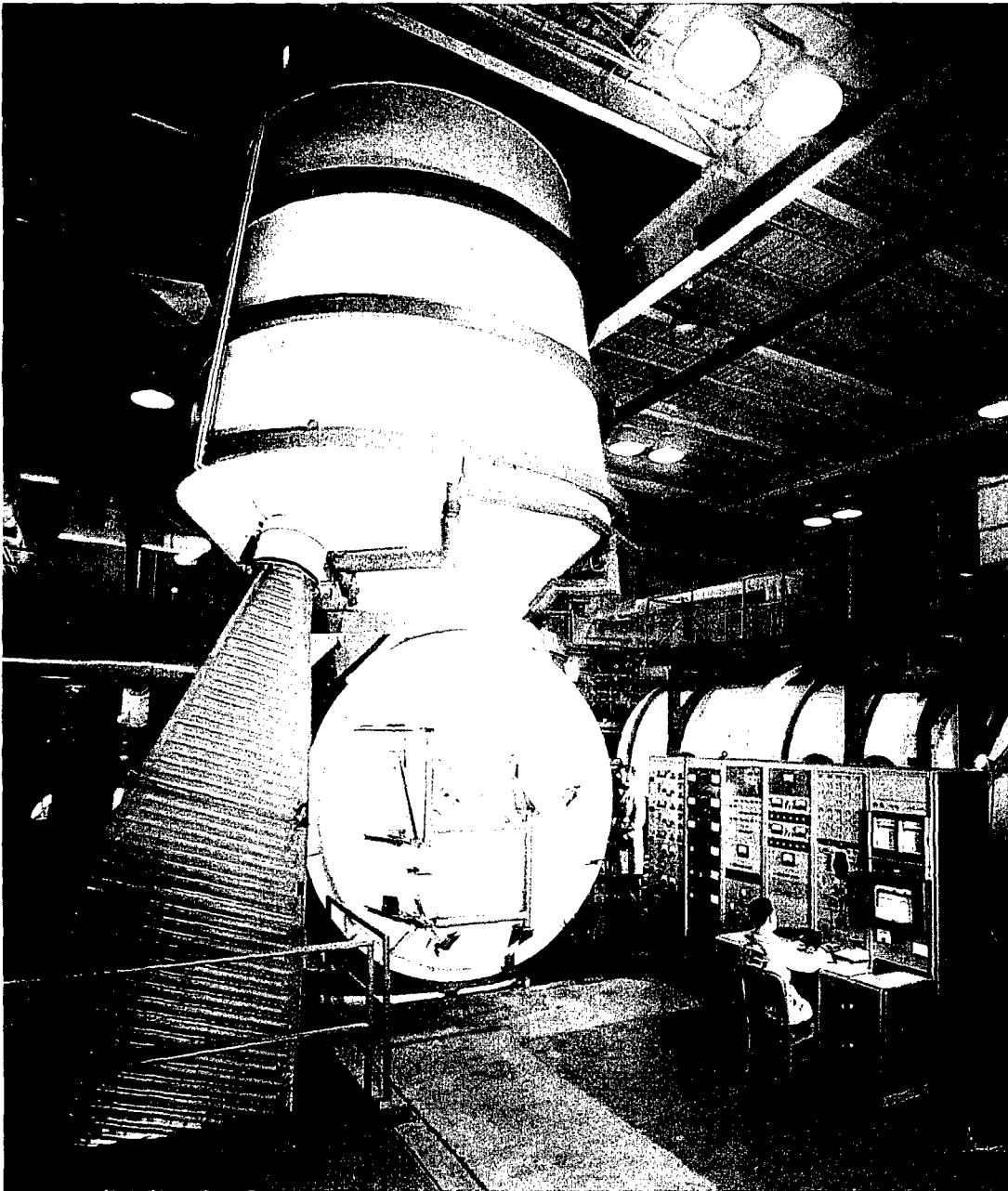


Figure 1. View of the Aerospace Chamber 12V.

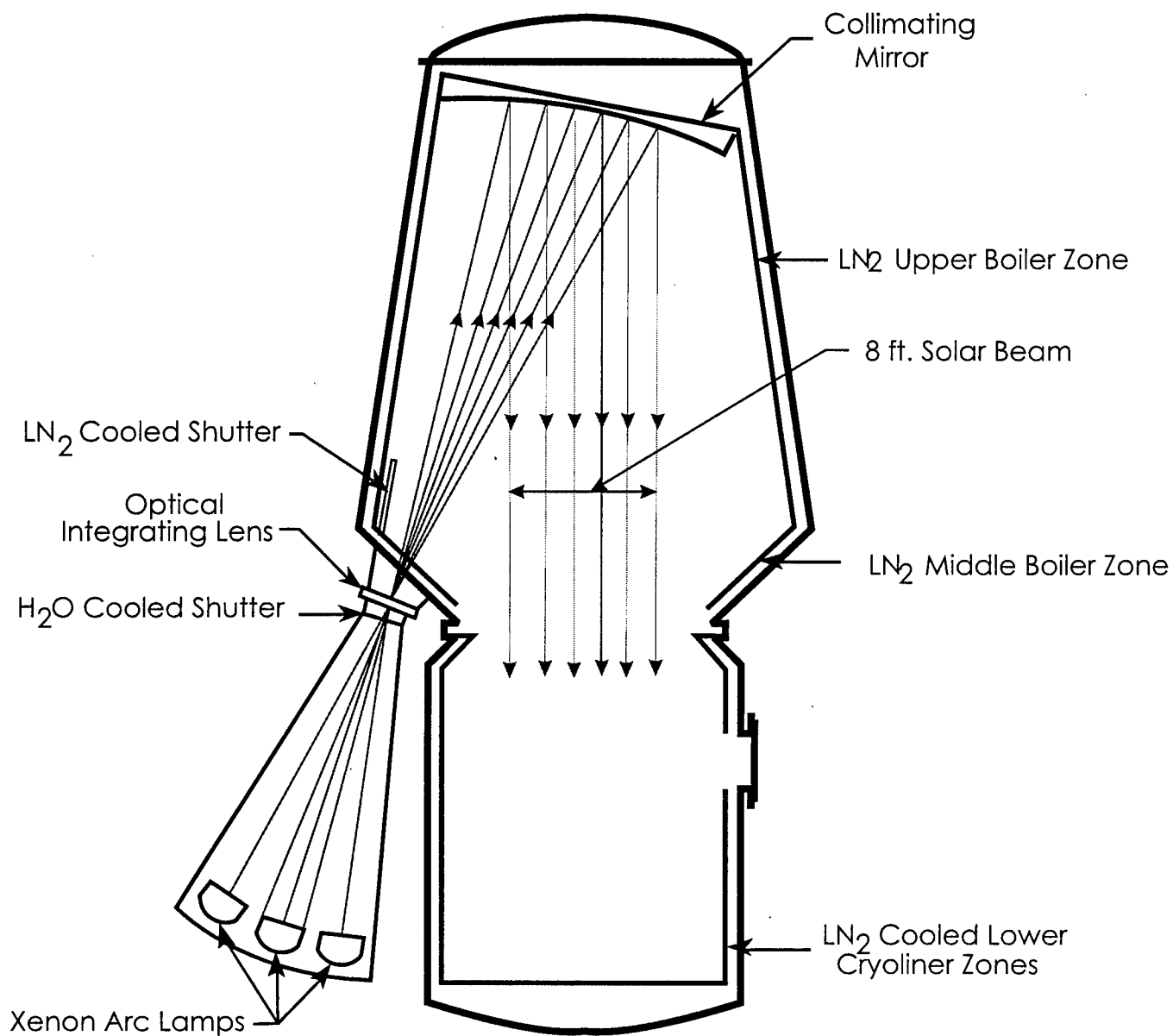


Figure 2. AEDC 12V Aerospace Chamber.

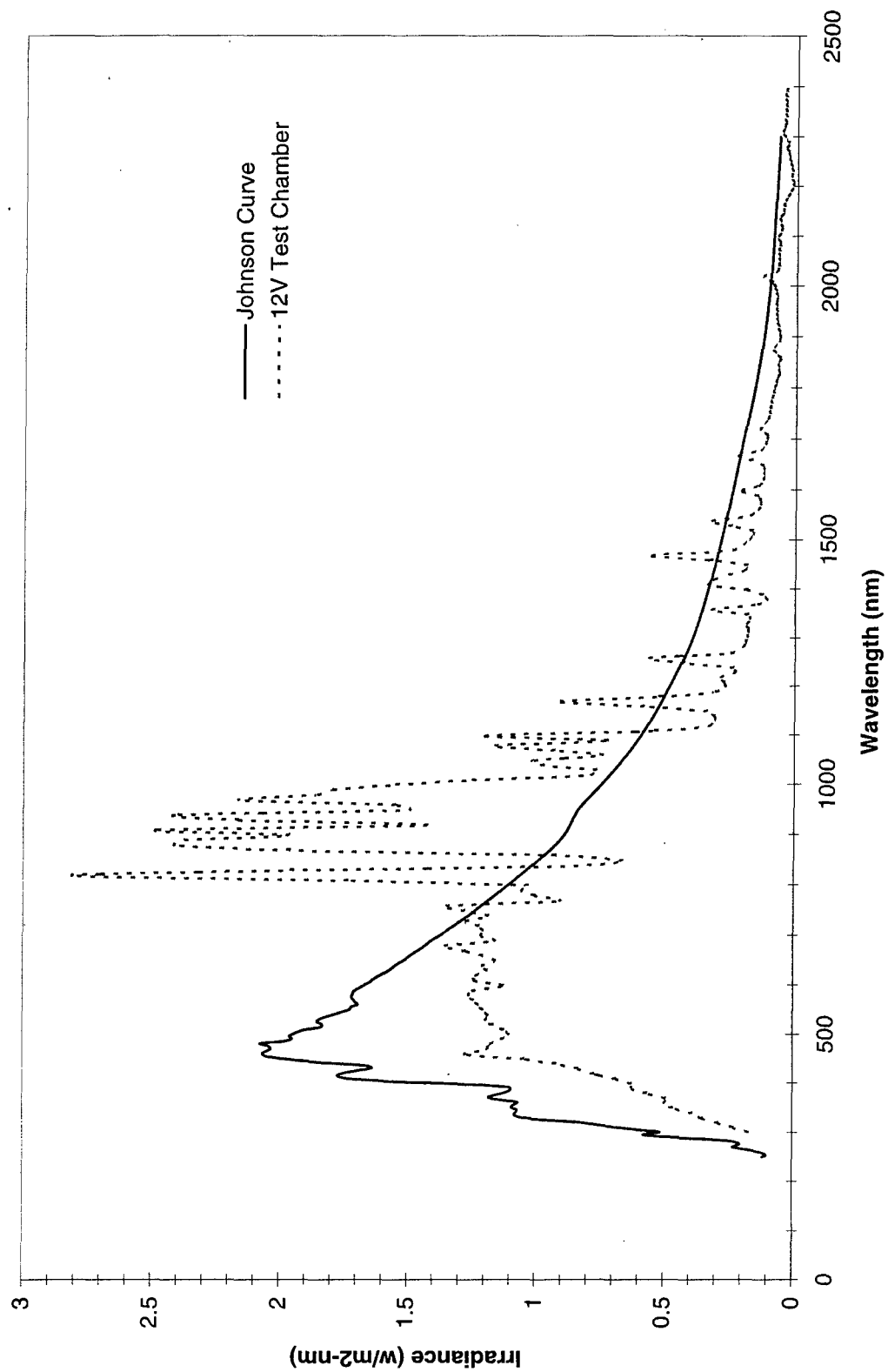
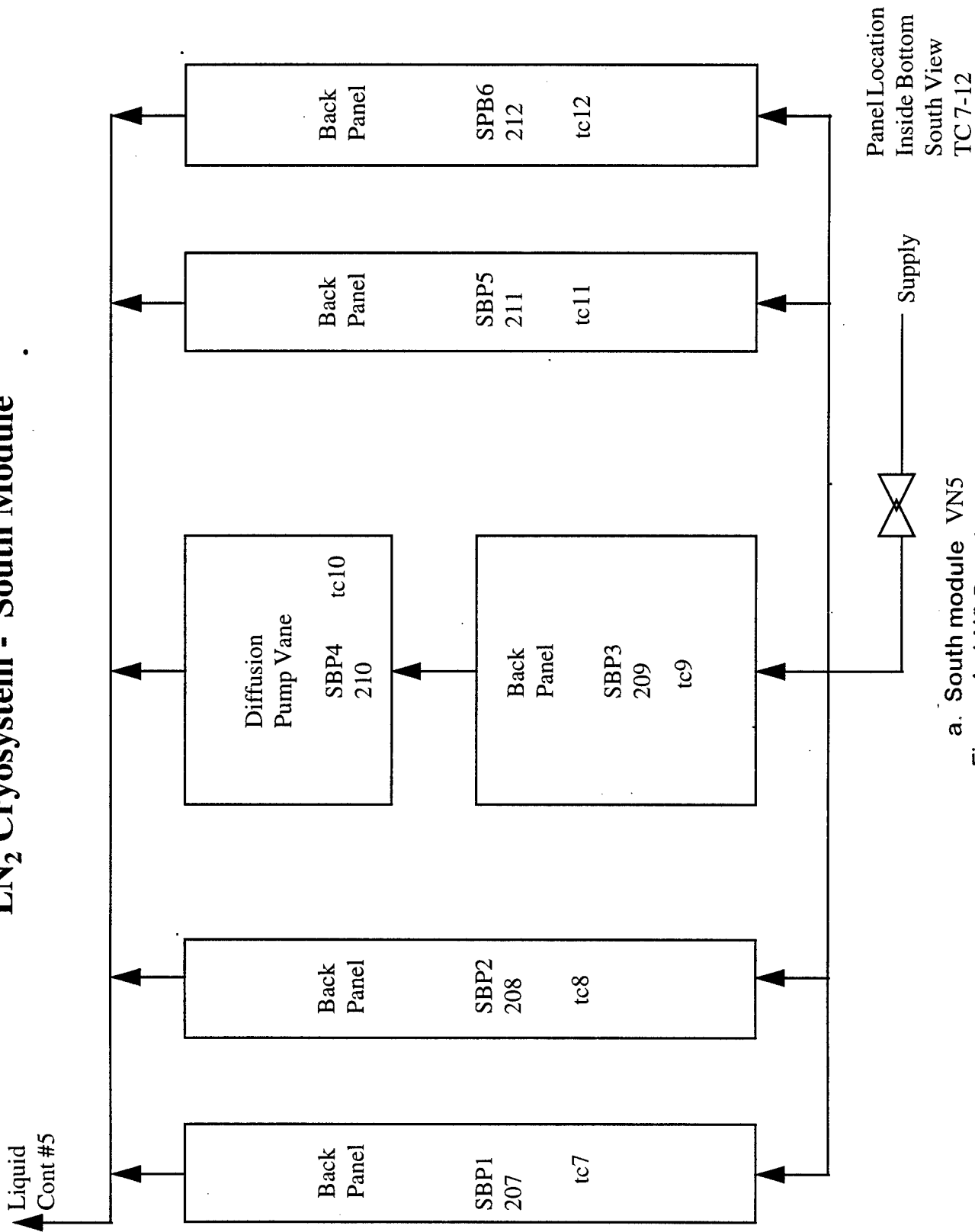


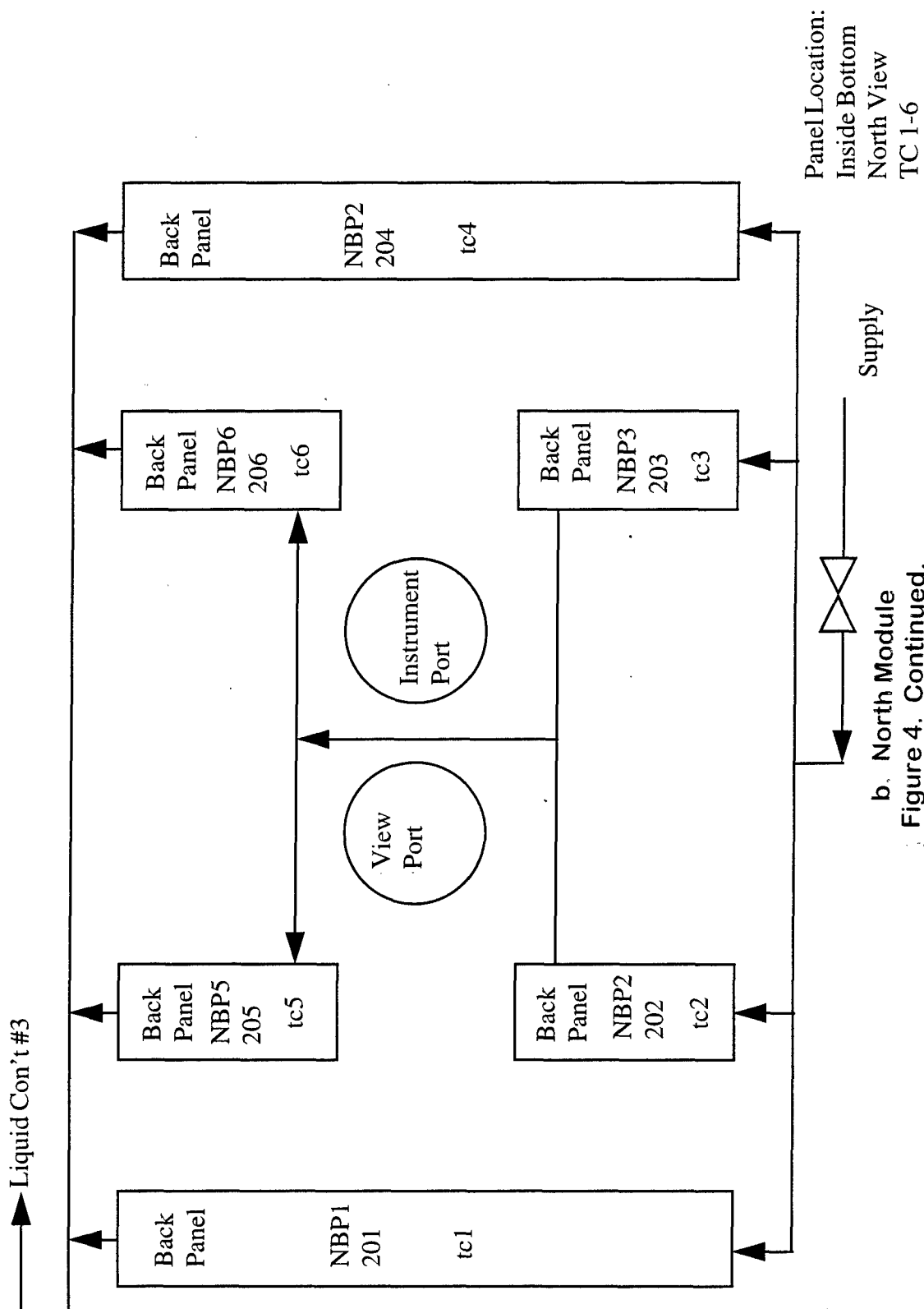
Figure 3. 12V Solar Spectrum.

LN₂ Cryosystem - South Module



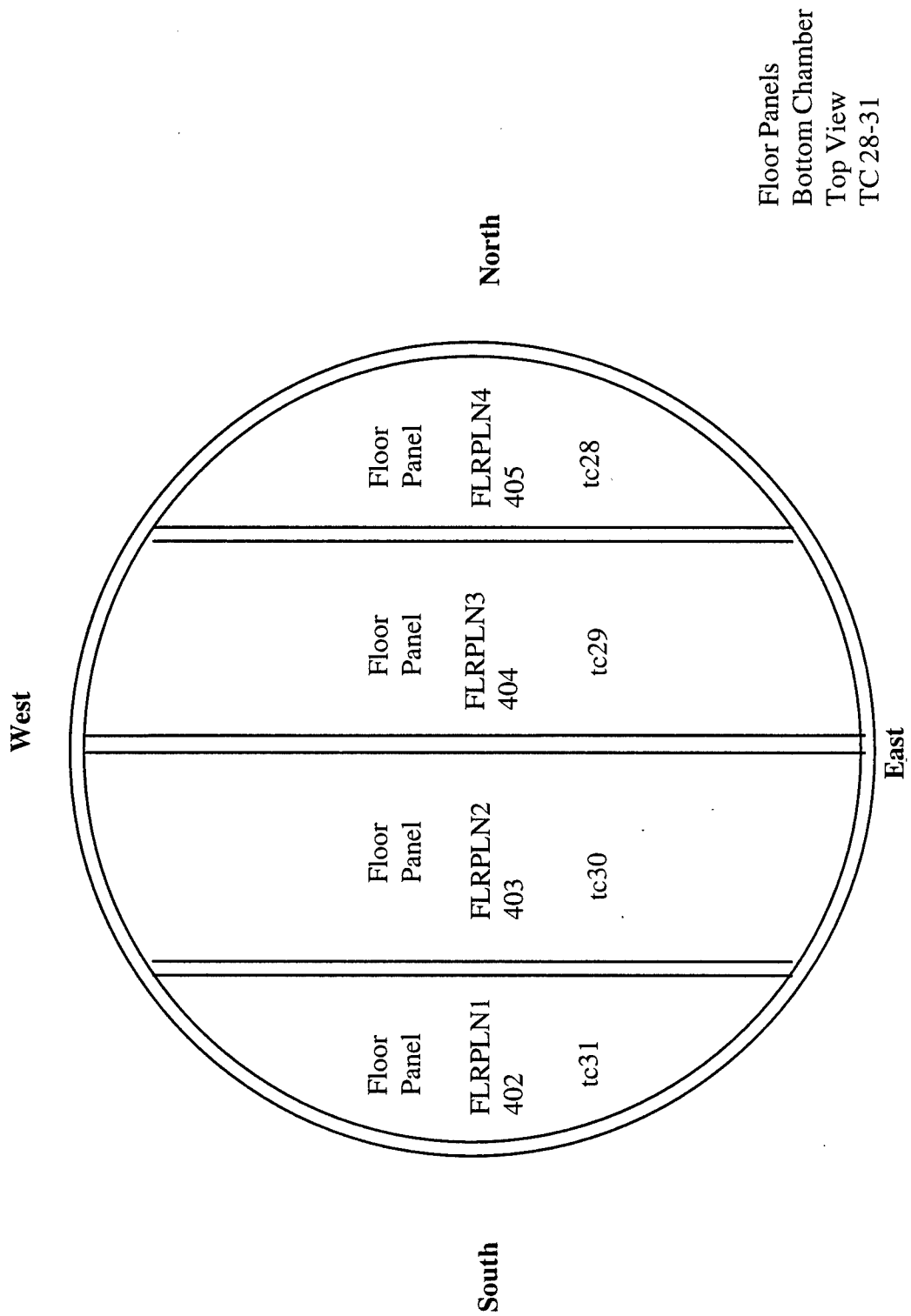
a. South module VN5
Figure 4. LN2 Panels.

LN₂ Cryosystem - North Module



b. North Module
Figure 4. Continued.

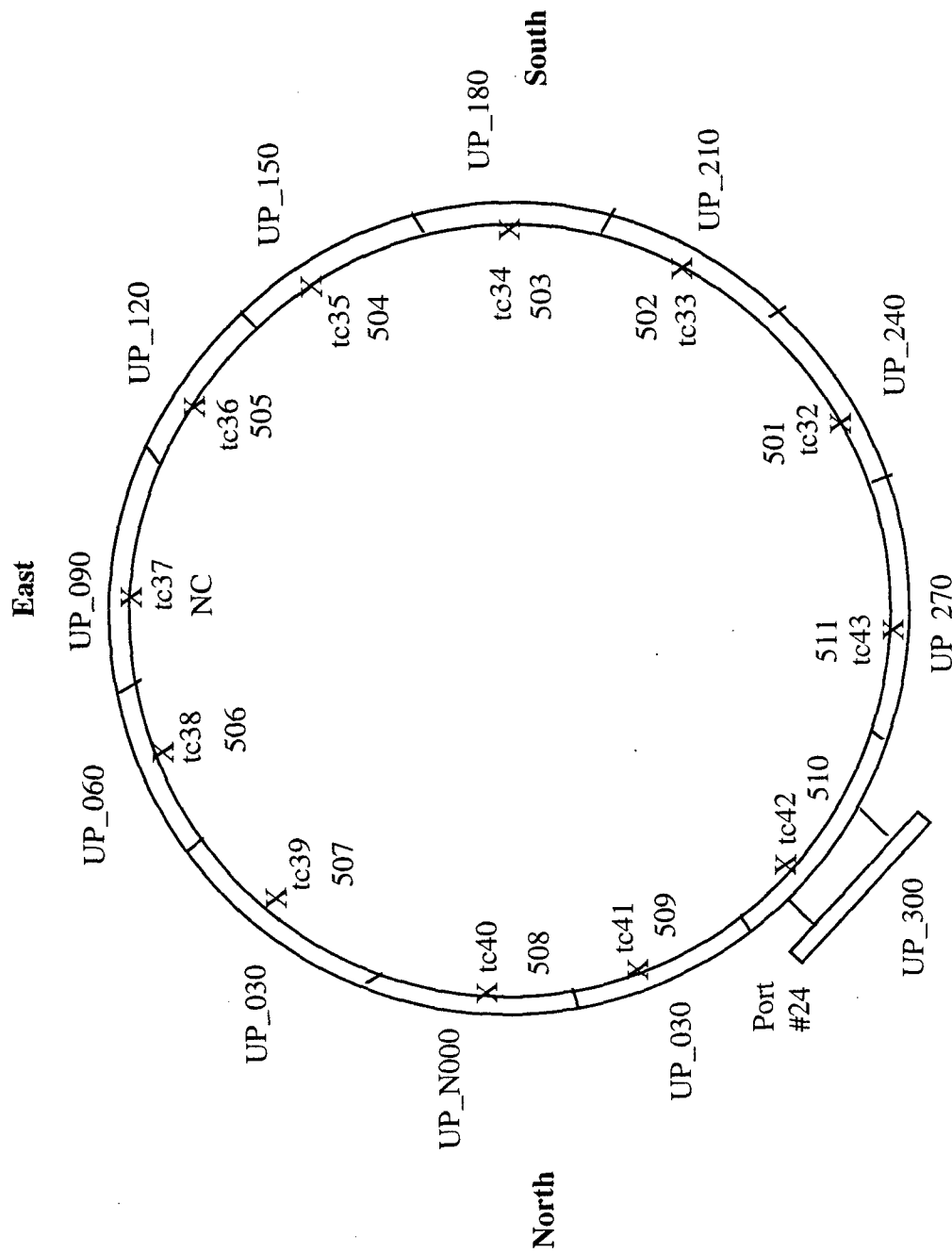
LN₂ Floor Panels - Bottom of Chamber



Floor Panels
Bottom Chamber
Top View
TC 28-31

c. Bottom of chamber
Figure 4. Continued.

Upper Chamber LN₂ Panels

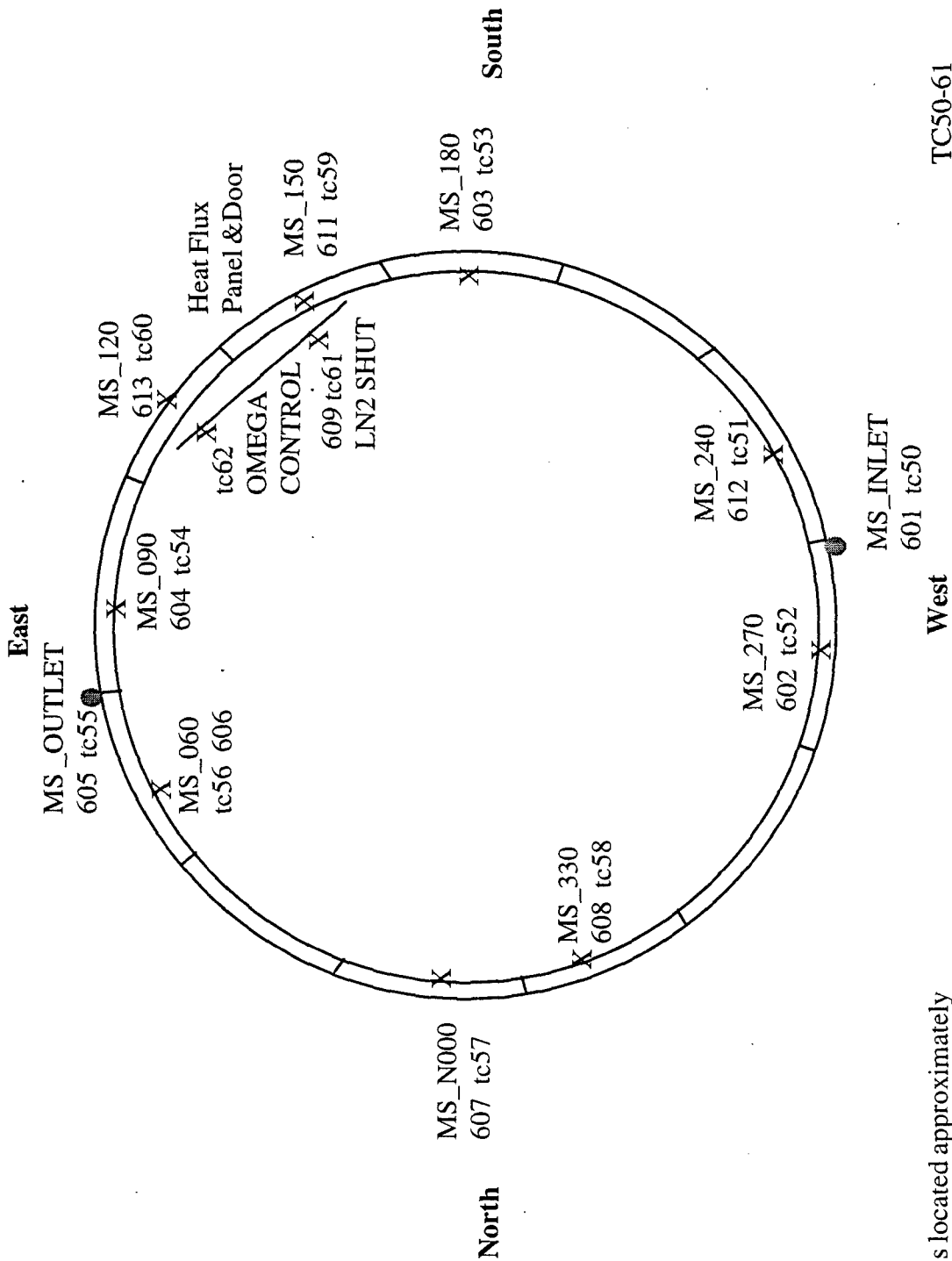


TC32-43
12V Upper level
Thru Port #24

TC's located approximately
in center of panels

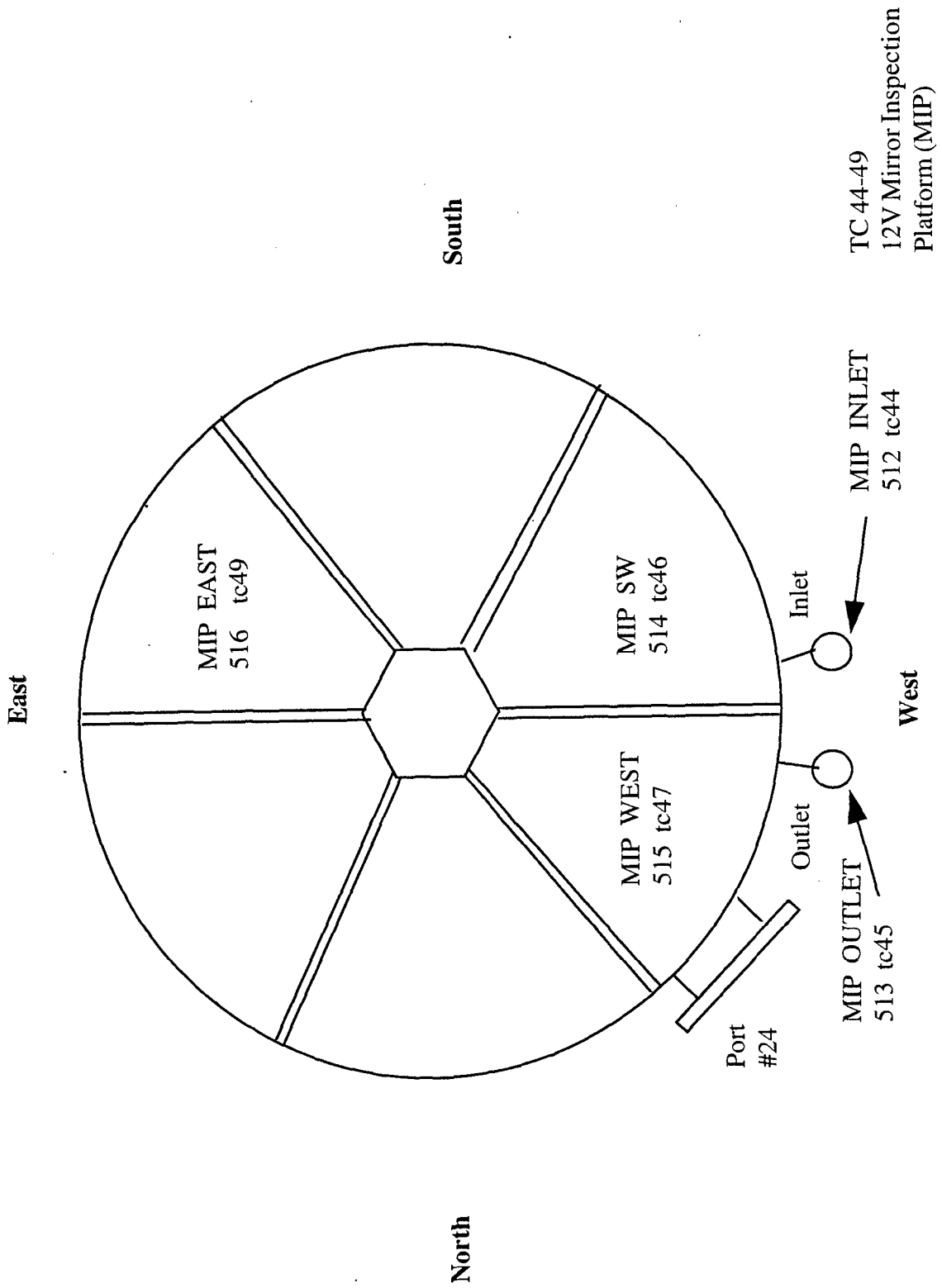
d. Upper Chamber
Figure 4. Continued.

Mid-Section Chamber LN₂ Panels



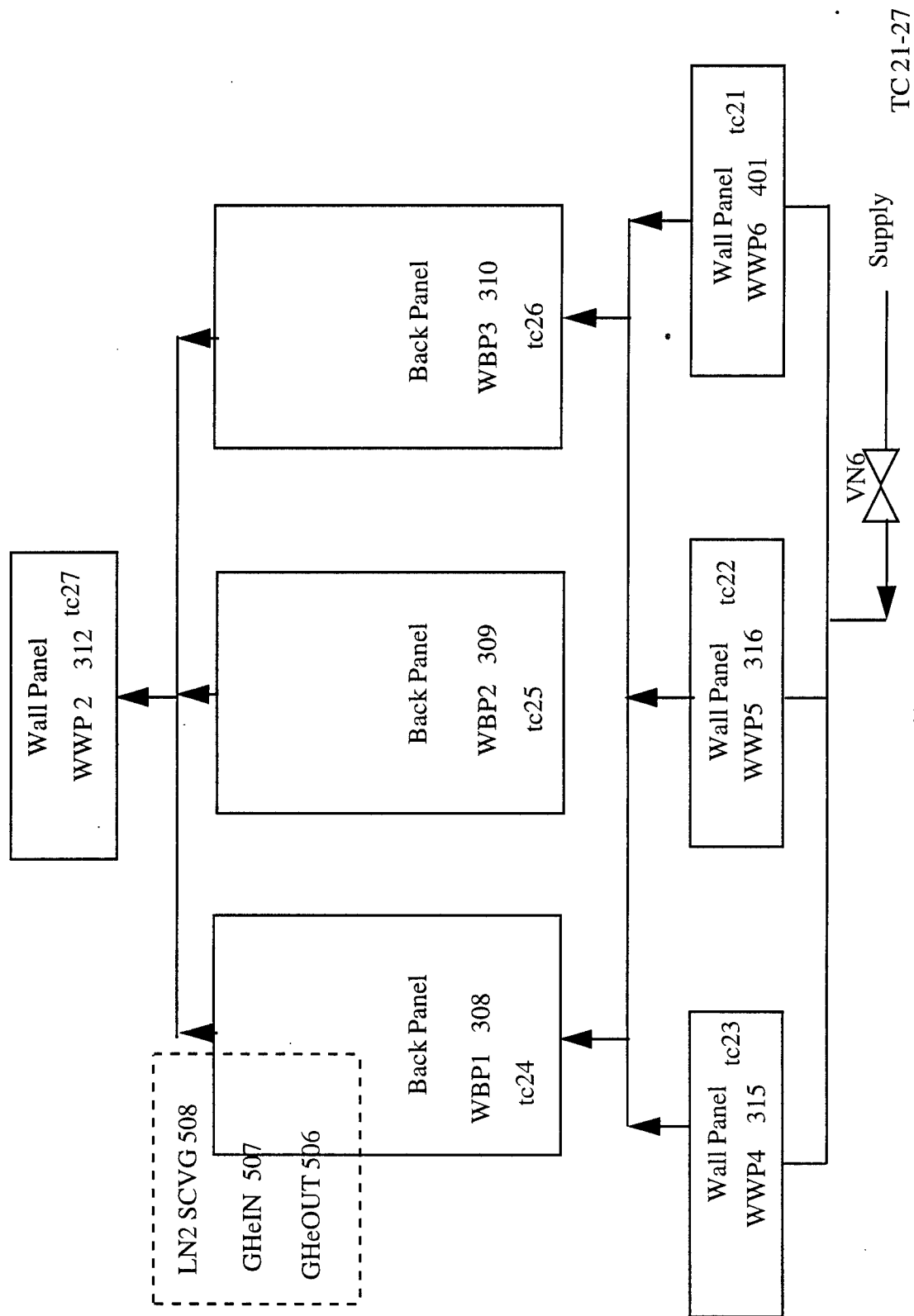
e. Mid-section
Figure 4. Continued.

LN₂ Mirror Shield - Top of Chamber



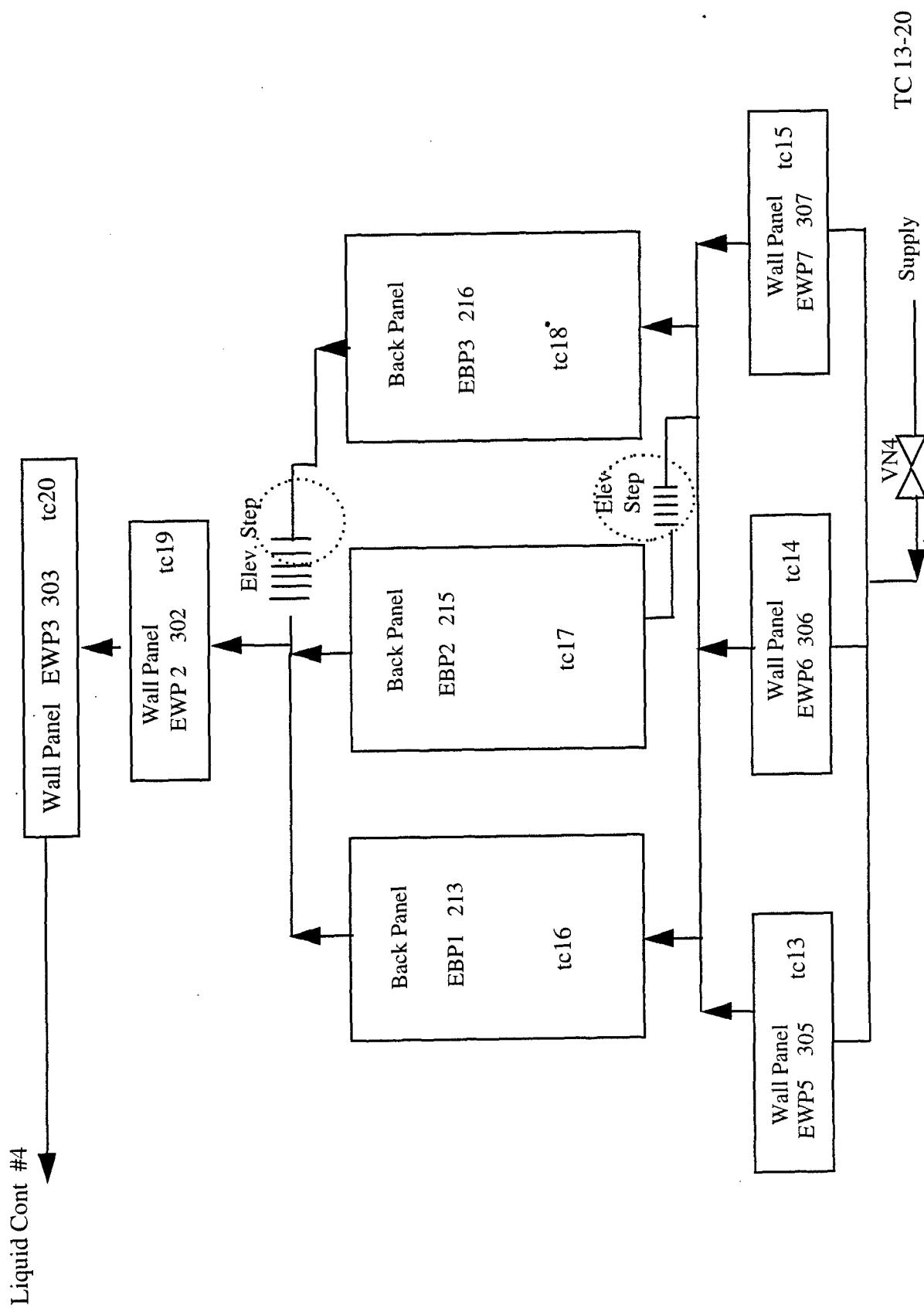
f. Mirror shield-top of chamber
Figure 4. Continued.

LN₂ Cryosystem - West Module



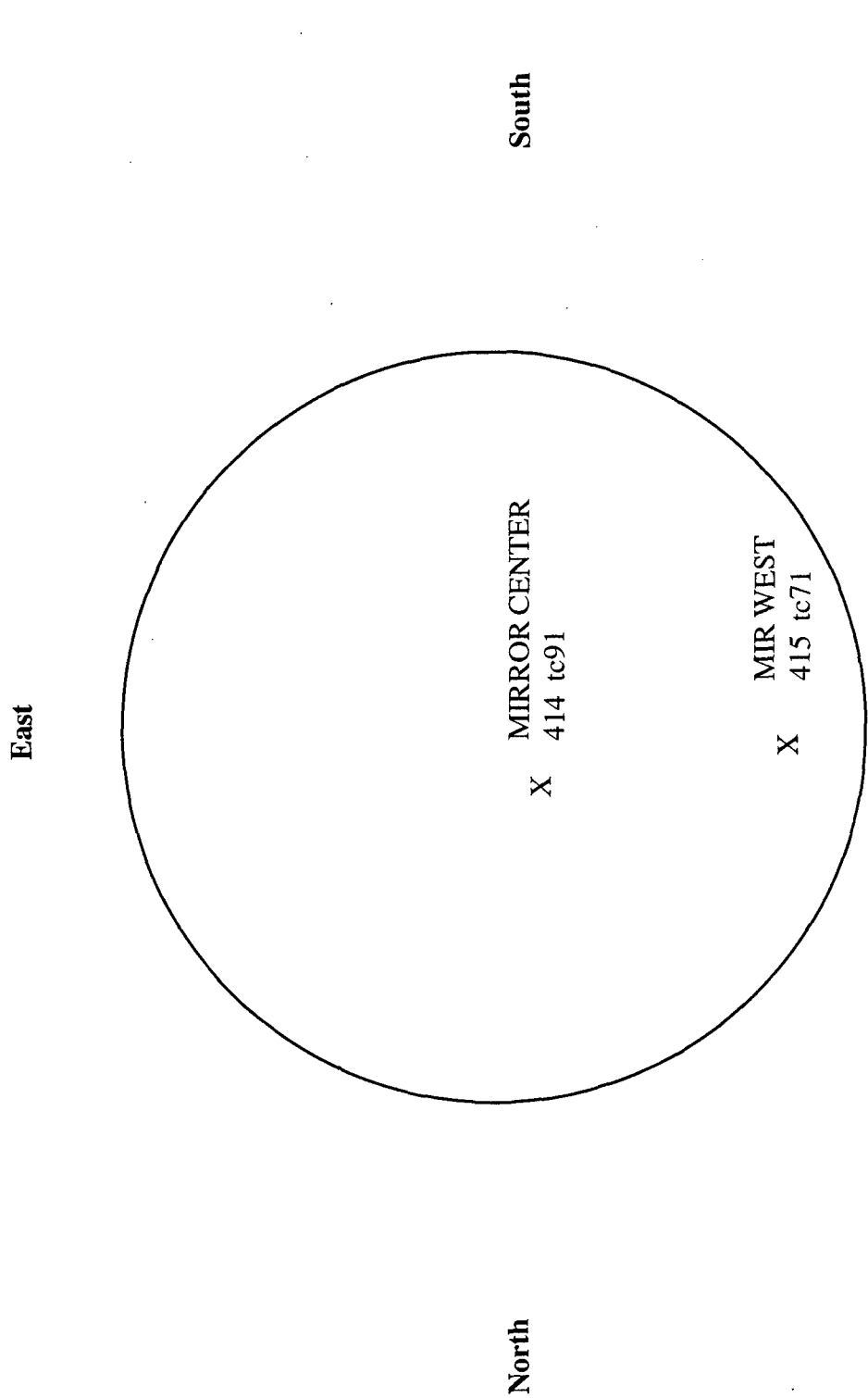
g. West module
Figure 4. Continued.

LN₂ Cryosystem - East Module



h. East module
Figure 4. Continued.

12V CHAMBER - MIRROR



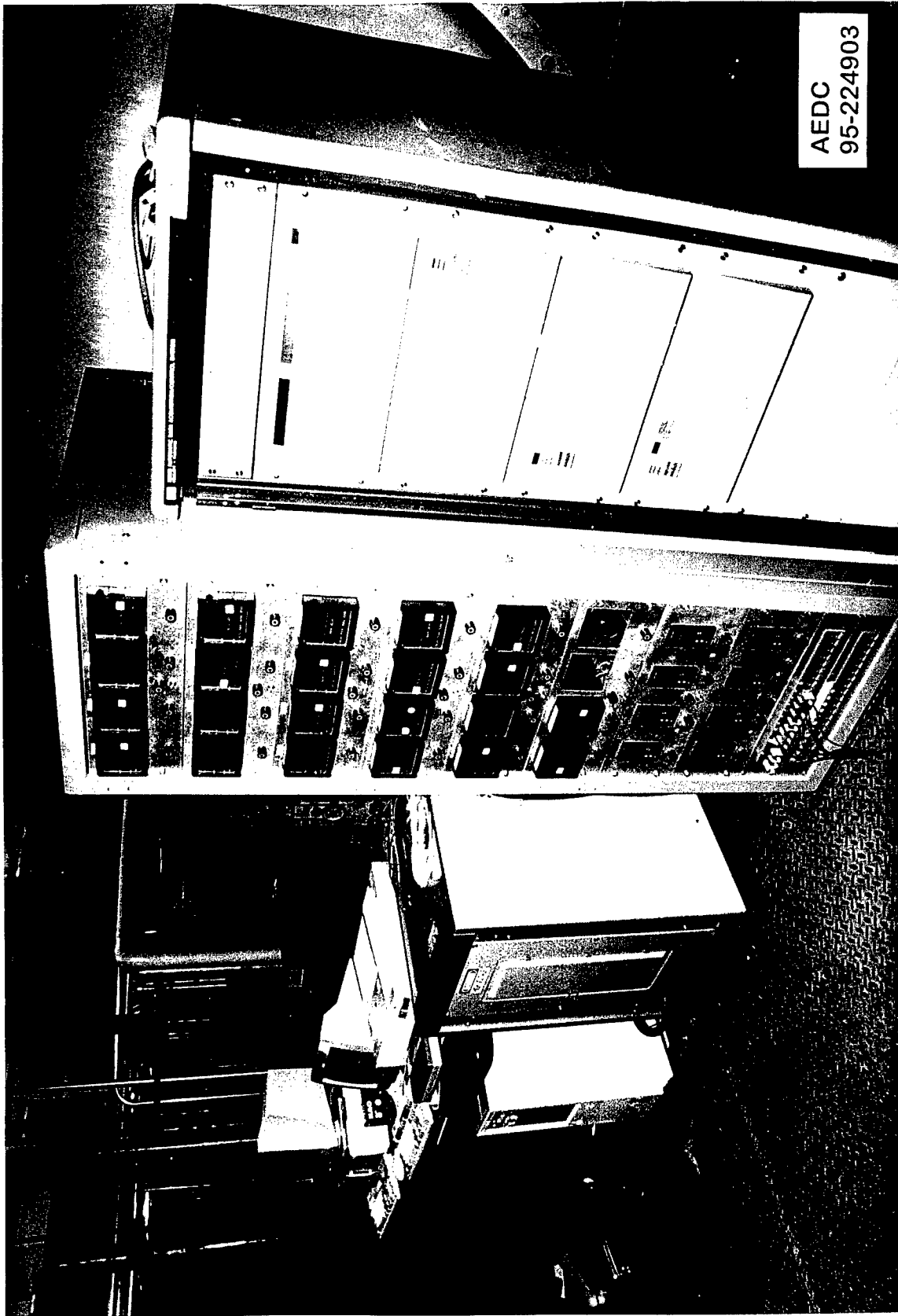


Figure 5. Boeing's Test Setup (Outside of Chamber).

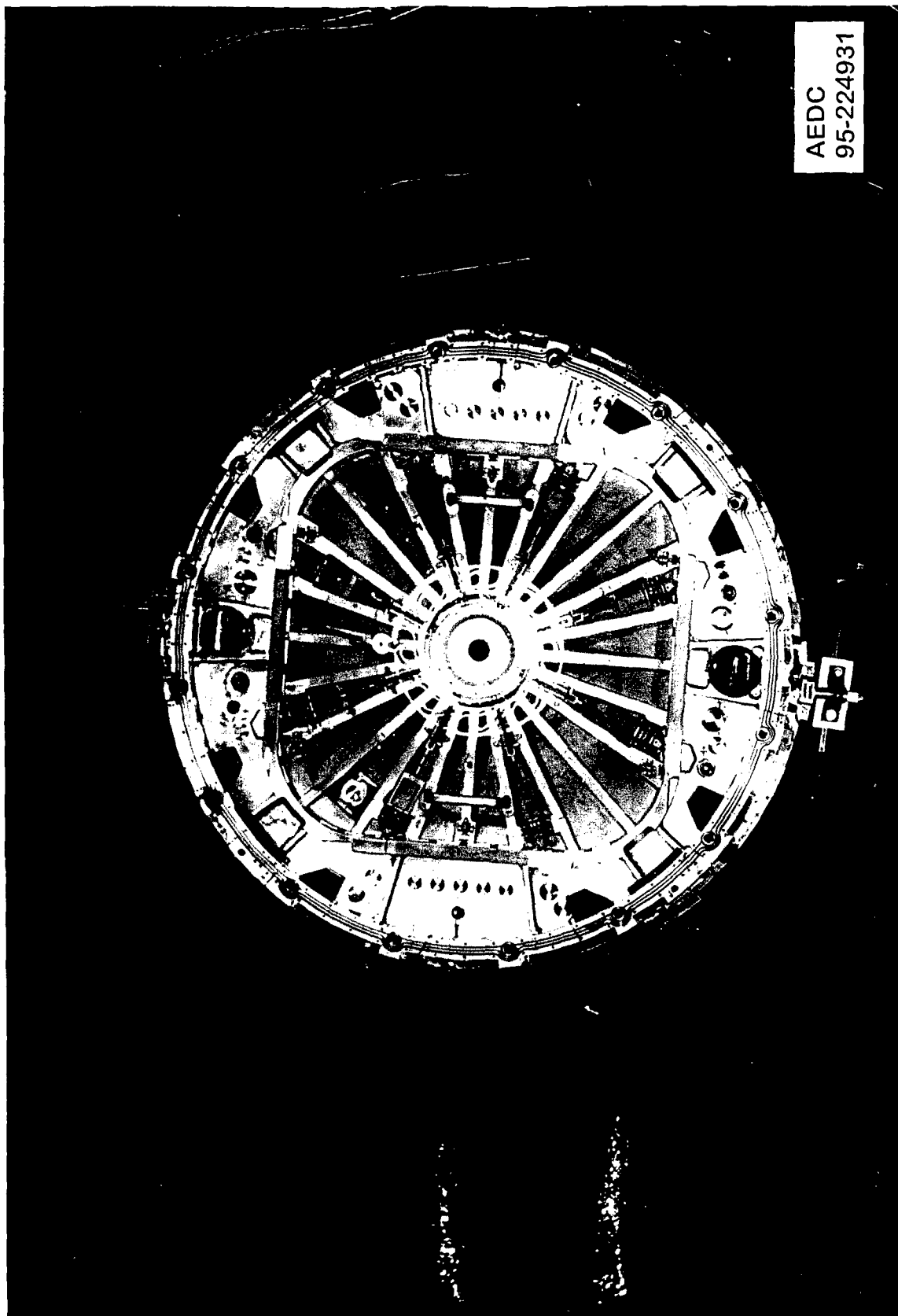


Figure 6. Photograph of Passive Test Equipment Installation.



Figure 7. Photograph of Passive Test Equipment Pumpdown #1.

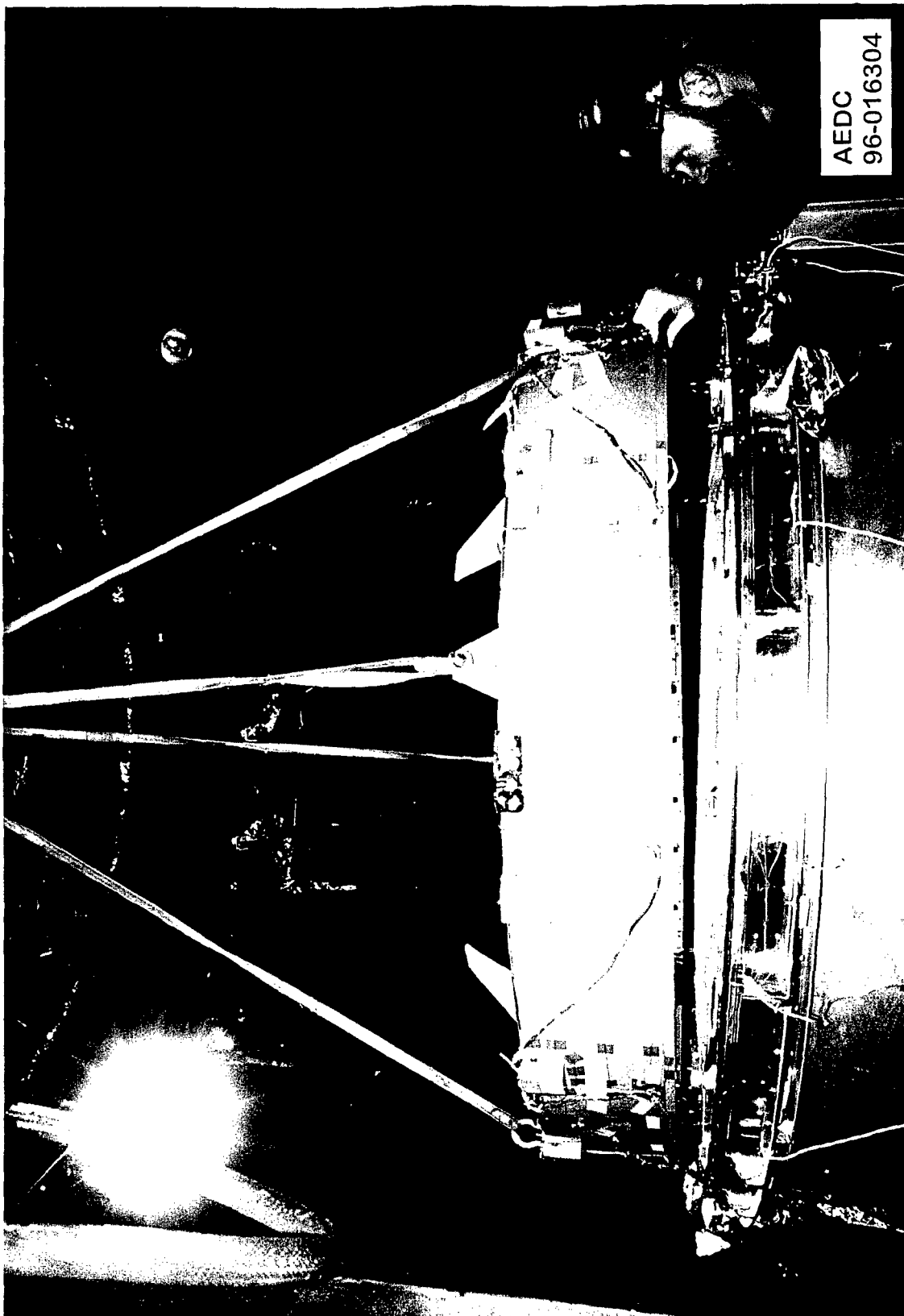


Figure 8. Photograph of Active Test Equipment Installation.

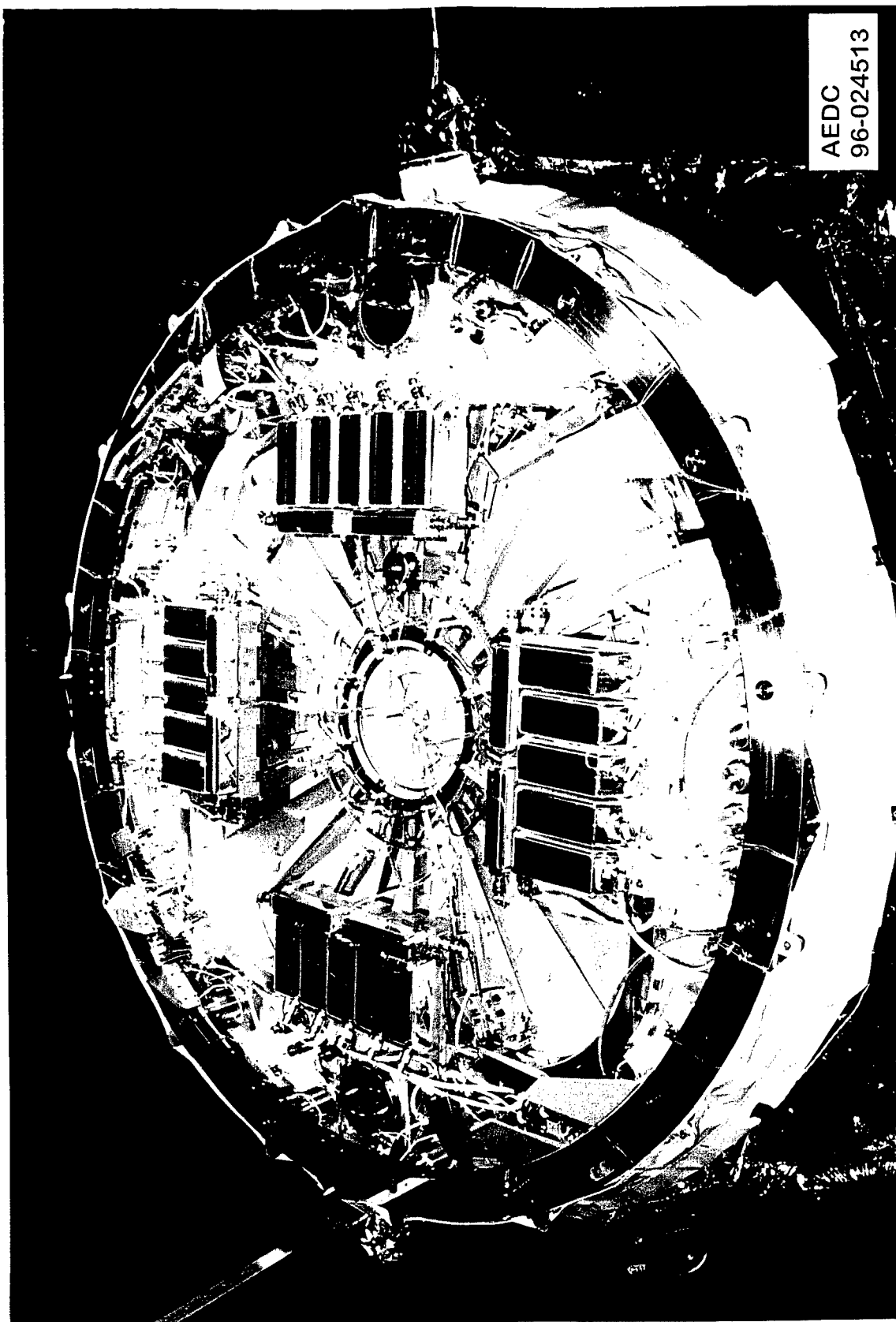


Figure 9. Photograph of Active Test Equipment Pumpdown #2.

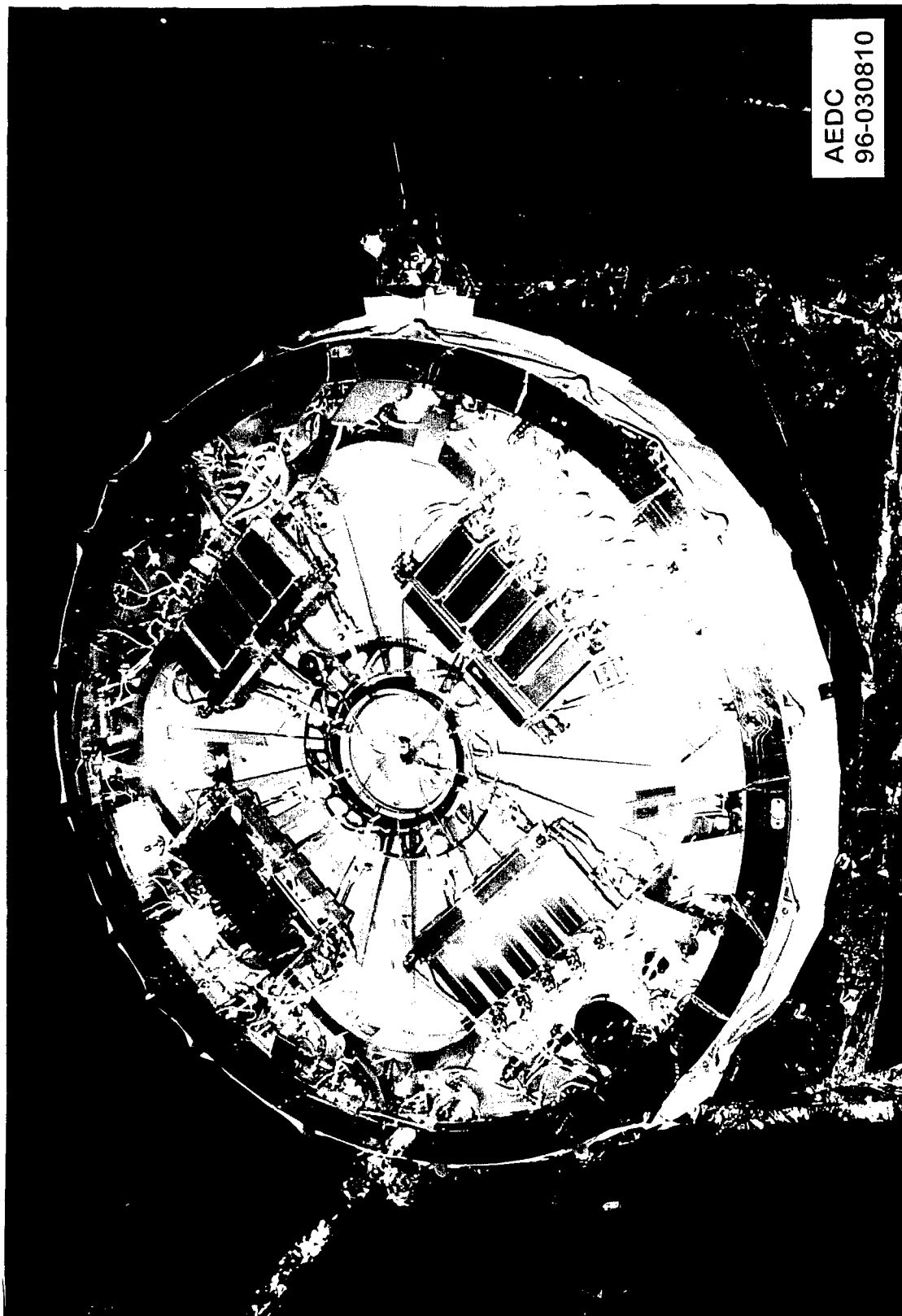


Figure 10. Photograph of Active Test Equipment Pumpdown #3.



Figure 11. Photograph of Active Test Equipment Pumpdown #4.

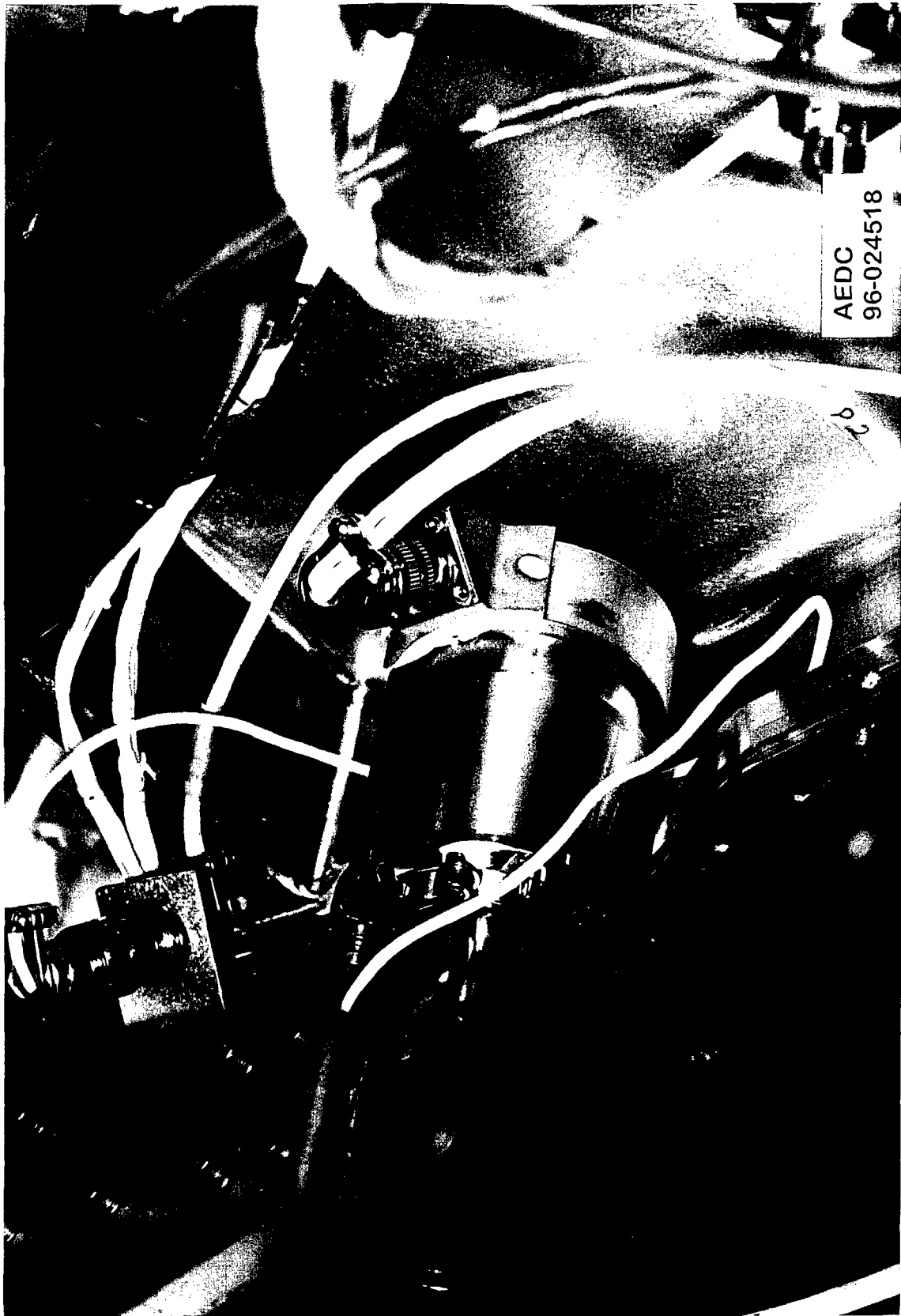


Figure 12. Photograph of Active Test Equipment Pumpdown #5.



Figure 13. Photograph of Active Test Equipment Pumpdown #6.

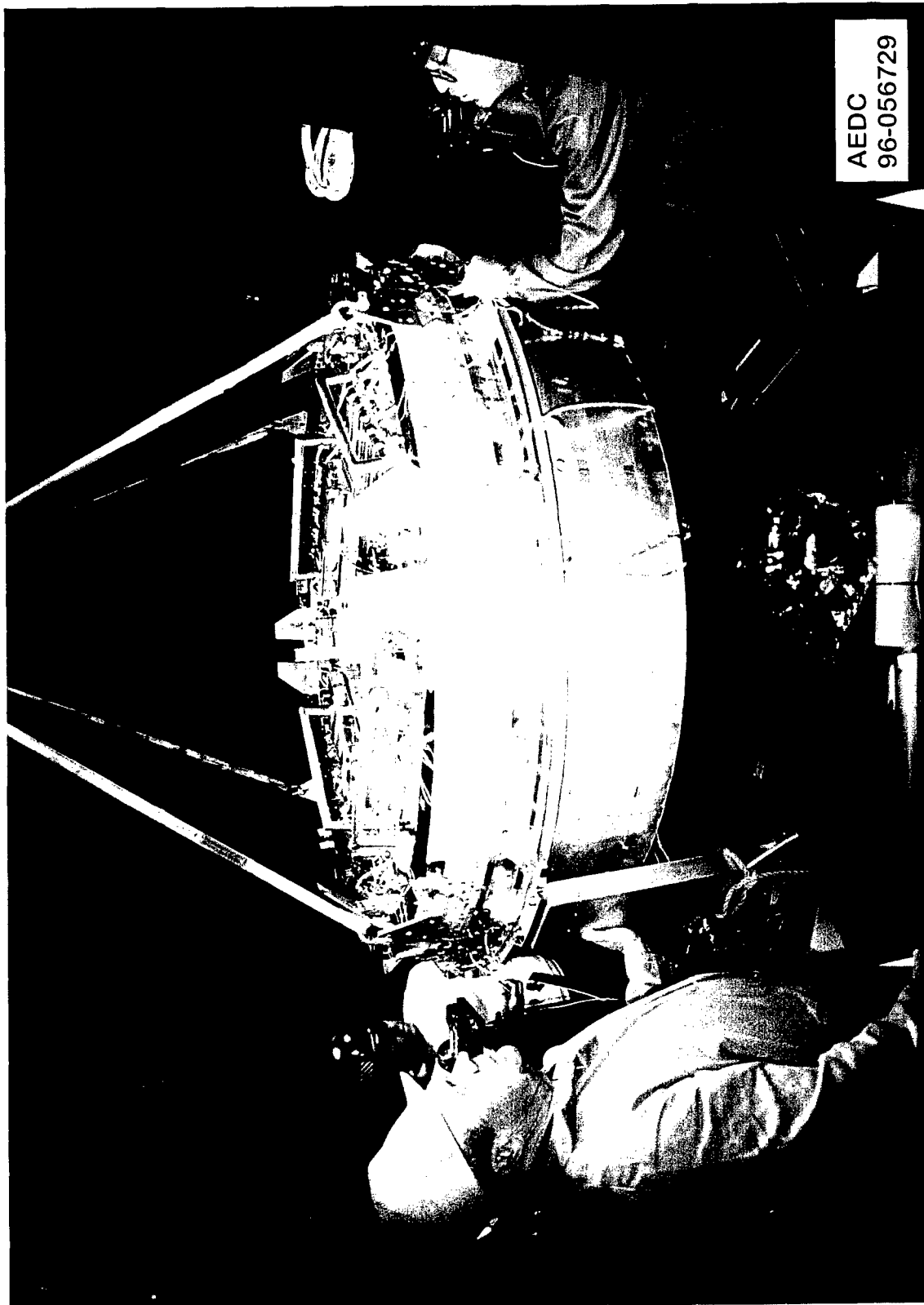


Figure 14. Photograph of Active Test Equipment Removal.

CBM Thermal Balance Test PCBM Configuration, Cold Cases, Runs 1 - 4

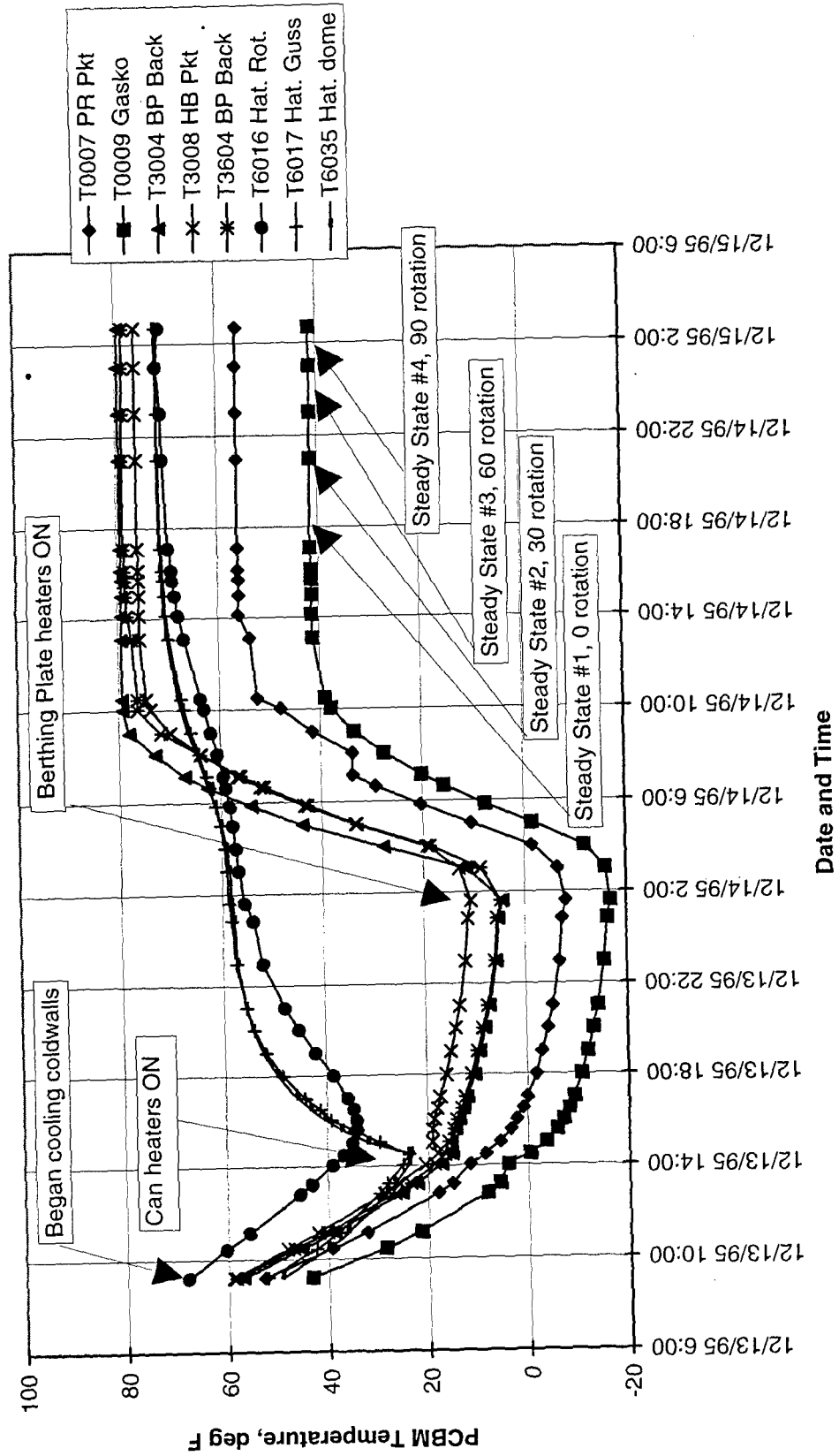


Figure 15. Pumpdown #1 Test Run 1-4, Thermal Cycle 1-4.

CBM Thermal Balance Test: ACBM Temps
Cold Case, Clock = 0, Rotn = 0
Para 7.1, Steady State #1

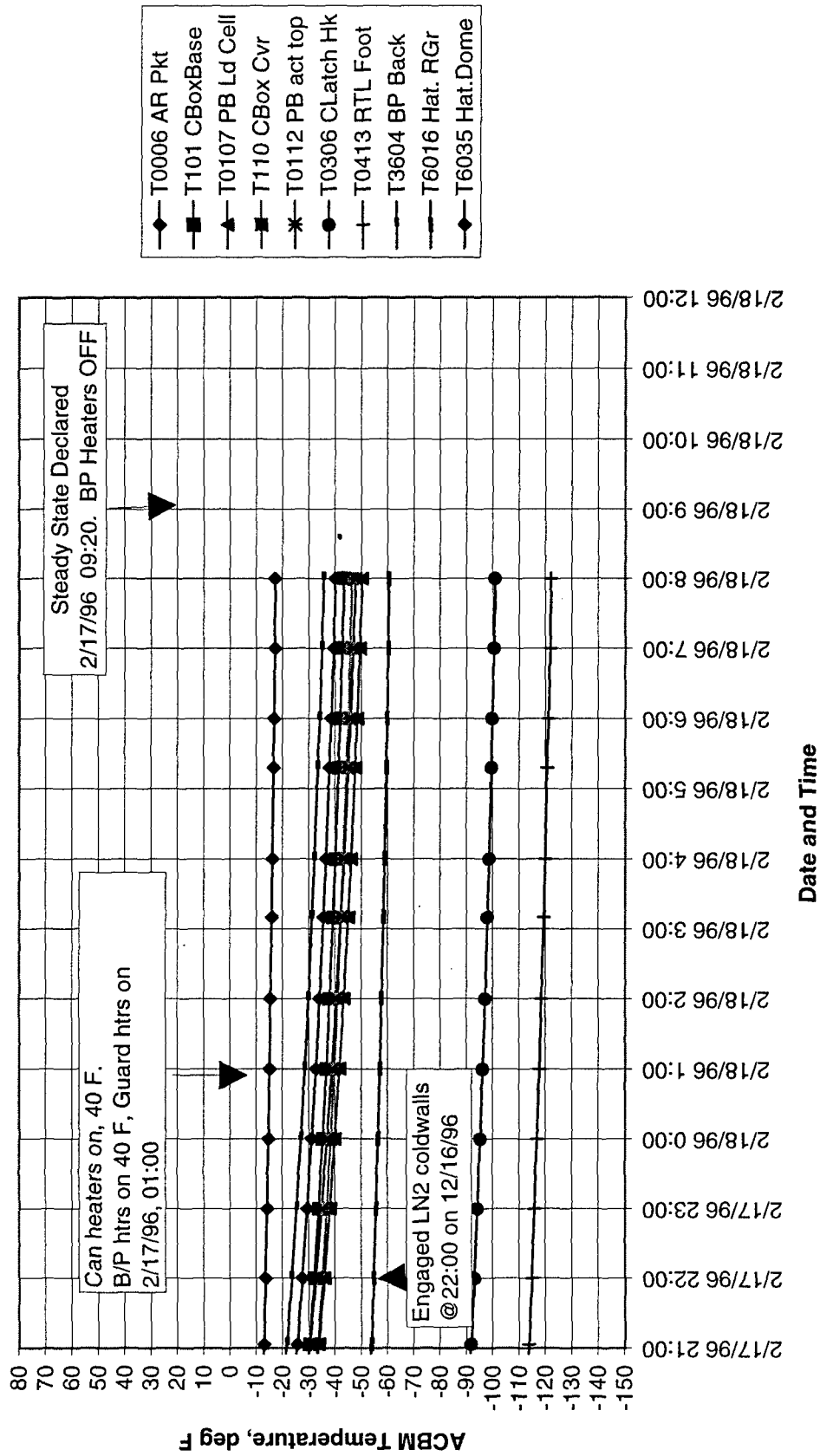


Figure 16. Pumpdown #2 Test Run 9, Thermal Cycle 10.

CBM Thermal Balance Test: ACBM Temps
Solar ON, Clock = 45 deg., Rotation = 30 deg.
Para. 7.10 (Step 11), Steady State #1, Ctrlr Htrs OFF, B/P Htrs OFF
Can @ 100, Glycol H/E: OFF

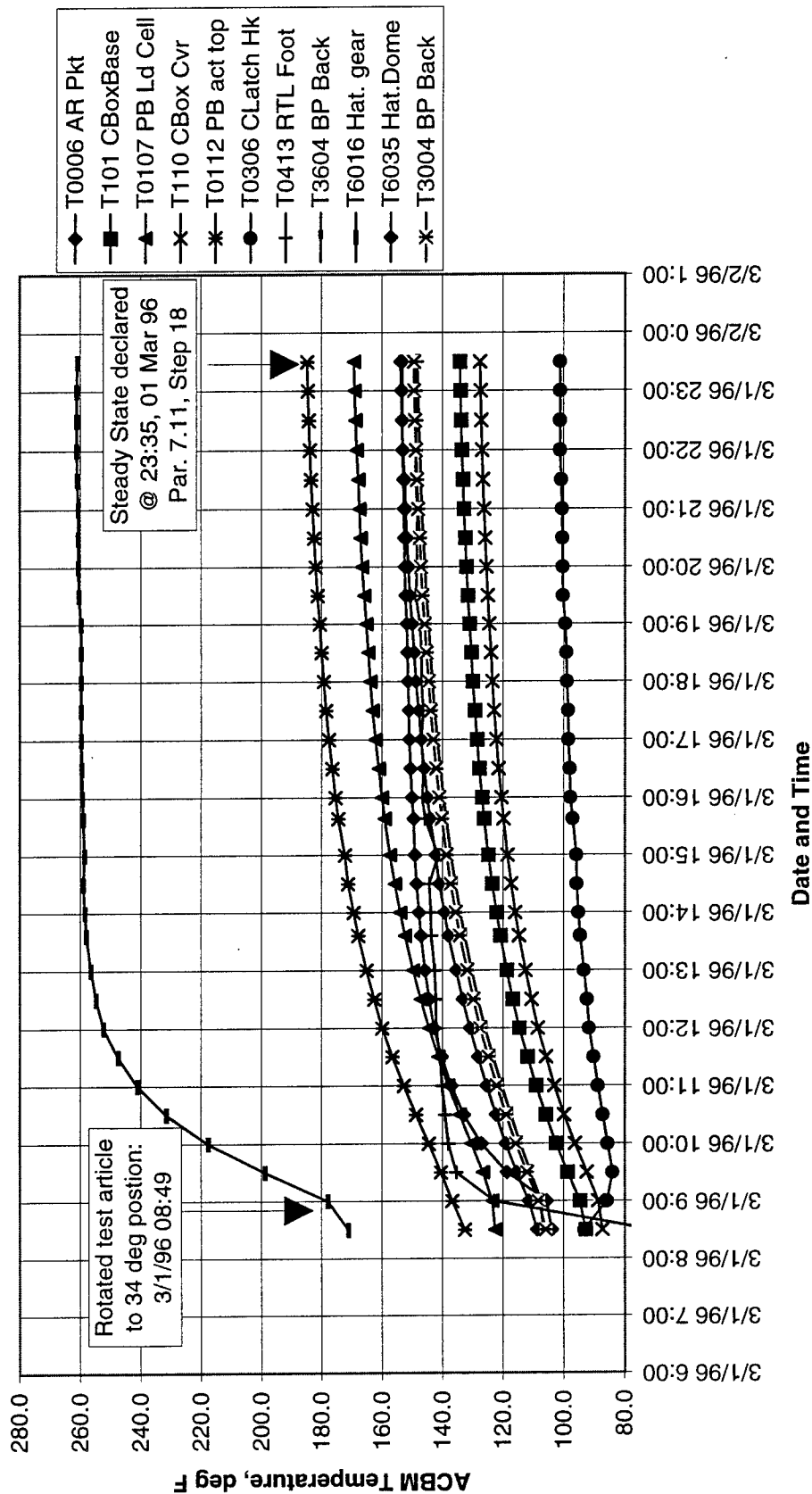


Figure 17. Pumpdown #3 Test Run 18, Thermal Cycle 24.

CBM Thermal Balance Test: ACBM Temps
Center Cover Installed, Cold Case, Clock = 0 deg., Rotation = 0 deg.
Para. 7.13 (Step 18), Steady State #1, Ctrlr Htrs OFF, B/P Htrs @40 deg
Can @40, Glycol H/E: OFF

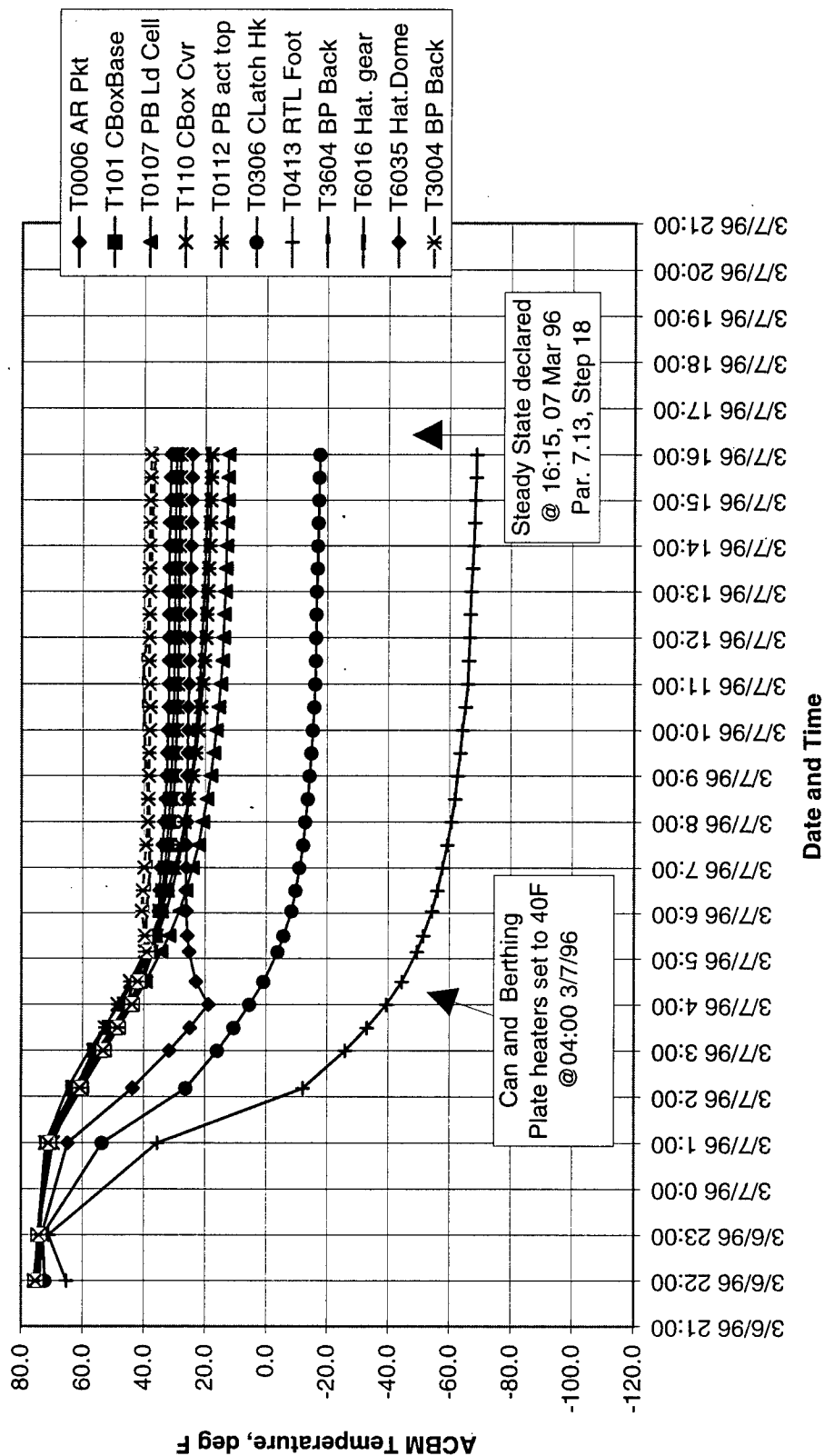


Figure 18. Pumpdown #4 Test Run 21, Thermal Cycle 28.

CBM Thermal Balance Test: ACBM Temps
 Center Cover Installed, Hot Case, Clock = 45 deg., Rotation = 30 deg.
 Para. 7.22 (Step 11), Steady State #1, Ctrlr Htrs OFF, B/P Htrs OFF
 Can @100, B/P (Glycol) H/E: OFF

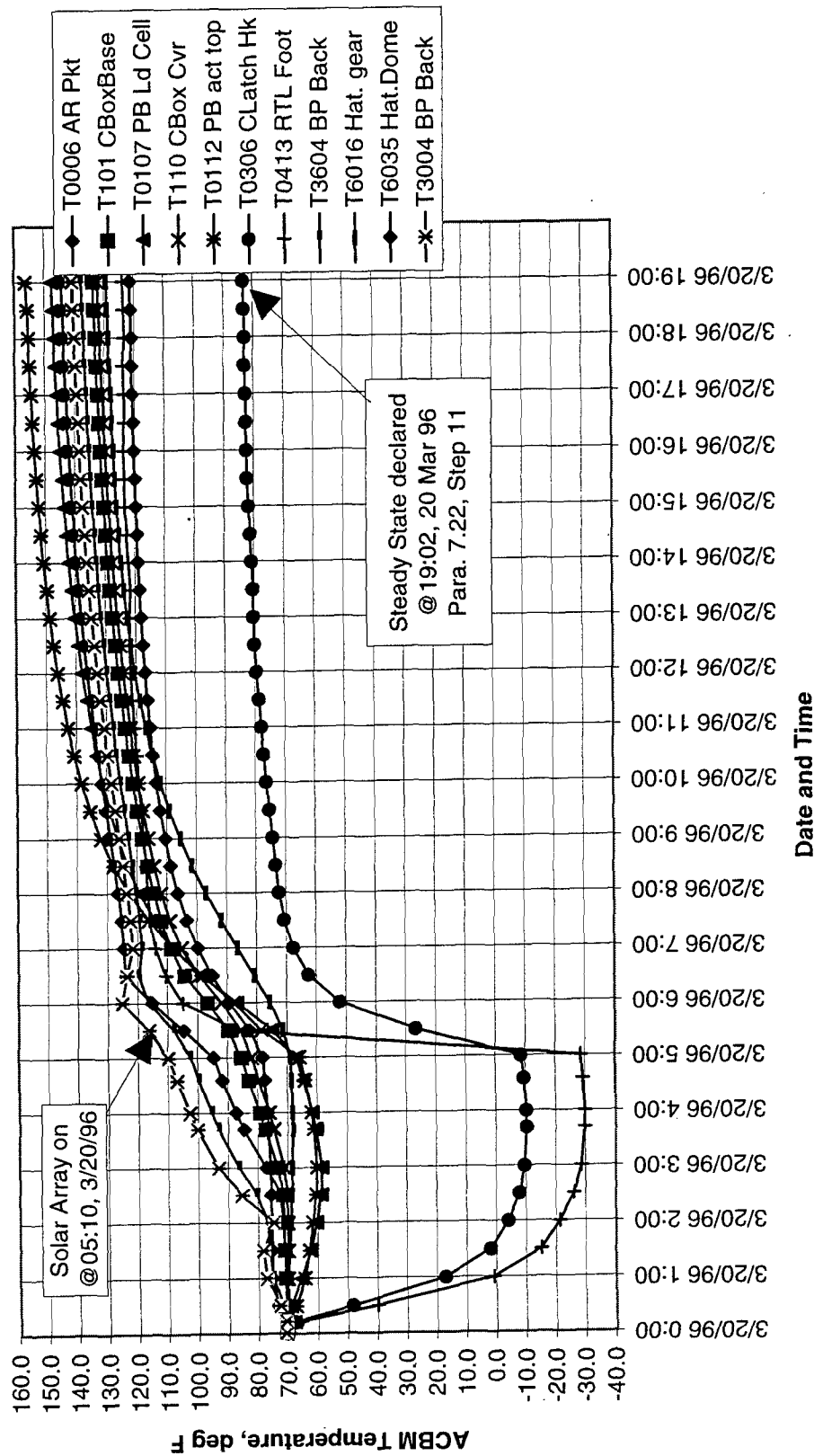


Figure 19. Pumpdown #5 Test Run 30, Thermal Cycle 42.

Figure 19. Pumpdown #5 Test Run 30, Thermal Cycle 42.

CBM Thermal Balance Test: ACBM Temps

Center & M/D Covers Installed, Cold Case, Clock = 45 deg., Rot. = 0 deg.
 Para. 7.25 (Step 18), Steady State #1, Ctrlr Htrs OFF, B/P Htrs @40
 Can @40, B/P (Glycol) H/E: OFF

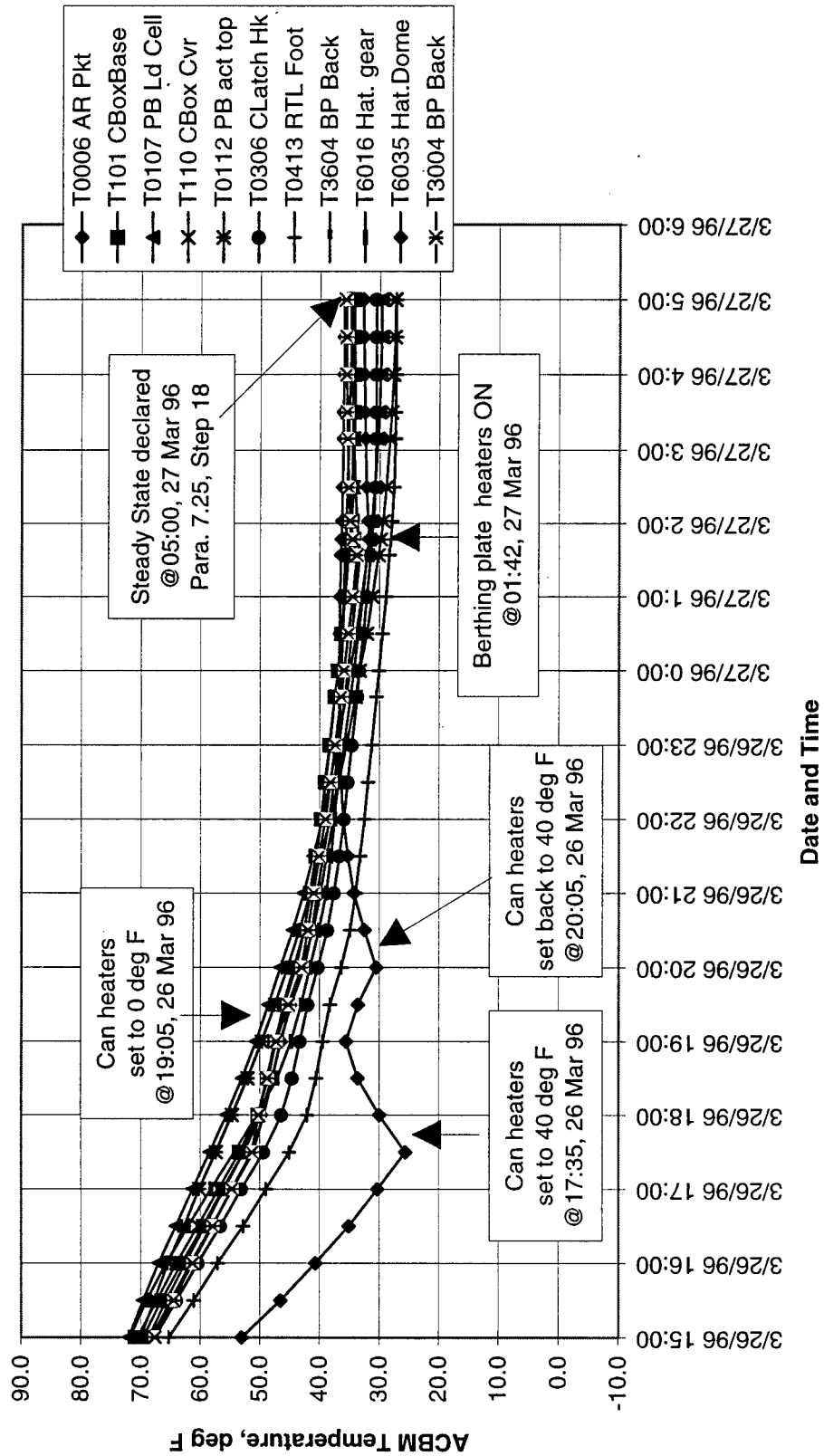


Figure 20. Pumpdown #6 Test Run 33, Thermal Cycle 45.

Table 1. Kaye Digi 4S Channel Assignments

Digi #	ID	TC Location	Digi #	ID	TC Location
102	LENS OUT	Lens H2O Disc	316	wwp5	West Wall Panel #5
103	LENS MNT	Lens mount	401	wwp6	West Wall Panel #6
104	RAD1 NOR	Radiometer 1 West Side-North	402	flrpln1	Floor Panel #1
105	RAD2 SOU	Radiometer 2 West Side - South	403	flrpln2	Floor Panel #2
106	LSHTR S	Lamp House Shutter - South	404	flrpln3	Floor Panel #3
107	LSHTR CT	Lamp House Shutter - Center	405	flrpln4	Floor Panel #4
108	LSHTR N	Lamp House Shutter - North	414	MIR CNTR	Mirror Center
109	18WP1DIS	18 wp1 Water Pump Discharge	415	MIR WEST	Mirror 1- edge
110	D LAMPS	Demineralized Water to Lamps	501	UP-240	Upper panel 240
111	D LAMPS	Demineralized Water to Lamps	502	UP-210	Upper Panel 210
112	18HE1DIS	18He1 Demin Water Heat Ex.	503	UP-180	Upper Panel 180 South
113	ION GAGE	ION Gage - Bottom	504	UP-150	Upper Panel 150
201	nbp1	North Back Panel #1	505	UP-120	Upper Panel 120
202	nbp2	North Back Panel #2	506	UP-060	Upper Panel 060
203	nbp3	North Back Panel #3	507	UP-030	Upper Panel 030
204	nbp4	North Back Panel #4	508	UP-N000	Upper Panel 000 North
205	nbp5	North Back Panel #5	509	UP-330	Upper Panel 330
206	nbp6	North Back Panel #6	510	UP-300	Upper Panel 300
207	sbp1	South Back Panel #1	511	UP-270	Upper Panel 270 West
208	sbp2	South Back Panel #2	512	MIP INLT	Mirror Inspection Panel LN2 Inlet
209	sbp3	South Back Panel #3	513	MIP OUT	Mirror Inspection Panel LN2 Outlet
210	sbp4	South Back Panel #4	514	MIP SW	Mirror Inspection Panel - SW
211	sbp5	South Back Panel #5	515	MIP WEST	Mirror Inspection Panel - West
212	sbp6	South Back Panel #6	516	MIP EAST	Mirror Inspection Panel - East
213	ebp1	East Back Panel #1	601	ms ln2 in	Mid-Section LN2 Inlet
215	ebp2 door	East Back Panel #2	602	ms- W,270	Mid-Section 270 West
216	ebp3	East Back Panel #3	603	ms-S180	Mid-Section 180 South
302	ewp2	East Wall Panel #2	604	ms-90	Mid-Section 090
303	ewp3	East Wall Panel #2	605	ms, ln2 out	Mid-Section LN2 Outlet
305	ewp5	East Wall Panel #5	606	ms-060	Mid-Section 060
306	ewp6	East Wall Panel #6	607	ms-N000	Mid-Section 000 North
307	ewp7	East Wall Panel #7	608	ms-330	Mid-Section 330
308	wbp1	West Back Panel #1	609	ln2 shutter, mid	LN2 Shutter - Middle
309	wbp2	West Back Panel #2	611	ms-150	Mid-Section 150
310	wbp3	West Back Panel #3	612	ms-240	Mid-Section 240
312	wwp2	West Wall Panel #2	613	ms-120	Mid-Section 120
315	wwp4	West Wall Panel #4			

Table 2. CBM Test Pumpdown #1
Passive Ring, No Center Disk, No Deploy Covers, Int. MLI Installed

Run No.	Solar (On/Off)	CAN On/Off Temp	B/P Heater On/Off Temp	Guard Heaters On/Off	Motor Control Heaters On/Off Power	Clock Position	Rotation	Start Time	Stop Time	Duration Hr:Min
1	Off	On/10/90 On/10/90	Off On	Off Off	Off Off	0 0	0 0	12/13/96 9:13 12/14/96 1:37	12/14/96 0:58 12/14/96 18:02	15:45 16:25
2	Off	On/70	On/70	Off	Off	0	30	12/14/96 19:01	12/14/96 21:35	2:34
3	Off	On/70	Off	Off	Off	0	60	12/14/96 22:08	12/15/96 0:00	1:52
4	Off	On/70	Off	Off	Off	0	90	12/15/96 1:00	12/15/96 2:00	1:00
5	Off On	On/40/70 On/70	Off Off	Off Off	Off Off	0 0	0 0	12/19/96 2:00 12/15/96 2:41	12/19/96 16:28 12/17/96 9:27	14:28 6:46
6	On	On/70	Off	Off	Off	0	30	12/17/96 9:27	12/17/96 16:59	7:32
7	On	On/70	Off	Off	Off	0	60	12/17/96 17:15	12/18/96 12:00	18:45
8	On	On/70	Off	Off	Off	0	90	12/18/96 1:00	12/19/96 1:00	24:00:00

Table 3. CBM Test Pumpdown #2
Active Ring, No Center Disk, No Deploy Covers, No Int. MLI

Run No.	Solar (On/Off)	CAN On/Off Temp	B/P Heater On/Off Temp	Guard Heaters On/Off	Motor Control Heaters On/Off Power	Clock Position	Rotation	Start Time	Stop Time	Duration Hr:Min
9	Off	On/40	On/40	On	Off	0	0	2/16/96 21:27	2/17/96 9:14	11:47
	Off	On/40	Off	On	Off	0	0	2/17/96 10:00	2/18/96 9:35	23:35
	Off	On/40	Off	On	On/62	0	0	2/18/96 10:03	2/19/96 3:00	16:57
	Off	On/70	Off	On	Off	0	0	2/19/96 3:13	2/19/96 13:32	10:19
10	Run Deleted									
11	Run Deleted									
12	Run Deleted									
13	On	On/70	Off	On	Off	0	0	2/19/96 18:00	2/20/96 15:00	21:00
	On	On/100	Off	On	Off	0	0	2/20/96 16:01	2/20/96 23:00	6:59
	On	On/100	On/100	On	Off	0	0	2/20/96 23:48	2/22/96 6:00	30:12:00
	On	On/100	On/100	On	On/62	0	0	2/22/96 7:00	2/22/96 13:00	6:00
	On	On/100	On/100	On	Off	0	0	2/22/96 14:00	2/22/96 20:00	6:00
	Off	On/100	Off	On	Off	0	0	2/22/96 21:00	2/23/96 20:00	19:00
14	On	On/100	Off	On	Off	0	90	2/23/96 20:51	2/24/96 2:00	5:09
15	On	On/100	On/100	On	Off	0	60	2/24/96 2:30	2/24/96 17:00	14:30
	On	On/100	Off	On	Off	0	60	2/24/96 18:00	2/25/96 2:47	8:47
16	On	On/100	Off	On	Off	0	30	2/25/96 3:00	2/25/96 16:00	13:00

Table 4. CBM Test Pumpdown #3
Active Ring, No Center Disk, No Deploy Covers, No Int. MLI

Run No.	Solar (On/Off)	CAN On/Off Temp	B/P Heater On/Off Temp	Guard Heaters On/Off	Motor Control Heaters On/Off Power	Clock Position	Rotation	Start Time	Stop Time	Duration (Hours)
17	Run Deleted									
18	On	On/100	Off	On	Off	45	30	3/1/96 9:00	3/1/96 23:30	14:30
19	On On	On/100 On/100	On/100 Off	On On	Off Off	45 45	60 60	2/29/96 13:00 2/29/96 23:01	2/29/96 22:30 3/1/96 8:30	9:30 9:29
20	Run Deleted									
3	On	On/100	On/100	On	Off	45	0	2/28/96 11:20	2/29/96 12:00	24:40:00

Table 5. CBM Test Pumpdown #4
Active Ring, Center Disk, No Deploy Covers, No Int. MLJ

Run No.	Solar (On/Off)	CAN On/Off Temp	B/P Heater On/Off Temp	Guard Heaters On/Off	Motor Control Heaters On/Off Power	Clock Position	Rotation	Start Time	Stop Time	Duration (Hours)
21	Off	On/40	On/40	On	Off	0	0	3/6/96 22:01	3/7/96 16:18	18:17
	Off	On/40	Off	On	Off	0	0	3/7/96 16:30	3/8/96 12:00	19:30
	Off	On/40	Off	On	On/62	0	0	3/8/96 12:38	3/9/96 6:00	17:22
	Off	On/70	Off	On	Off	0	0	3/9/96 6:30	3/9/96 15:00	8:30
22	Run Deleted									
23	Run Deleted									
24	Run Deleted									
25	On	On/70	Off	On	Off	0	0	3/9/96 15:33	3/10/96 16:20	24:47
	On	On/100	Off	On	Off	0	0	3/10/96 16:31	3/11/96 3:11	10:40
	On	On/100	On/100	On	Off	0	0	3/13/96 16:37	3/14/96 2:00	9:23
	On	On/100	On/100	On	On/62	0	0	3/14/96 12:30	3/14/96 23:00	10:30
	On	On/100	On/100	On	Off	0	0	3/14/96 23:30	3/15/96 8:00	8:30
	Off	On/100	Off	On	Off	0	0	3/15/96 8:30	3/16/96 6:00	21:30
26	On	On/100	Off	On	Off	0	30	3/13/96 0:30	3/16/96 16:00	87:00:00
27	On	On/100	On/100	On	Off	0	60	3/14/96 2:30	3/14/96 12:00	9:30
	On	On/100	Off	On	Off	0	60	3/12/96 7:16	3/13/96 0:00	16:44
28	On	On/100	Off	On	Off	0	90	3/11/96 6:31	3/12/96 6:30	23:59

Table 6. CBM Test Pumpdown #5
Active Ring, Center Disk, No Deploy Covers, No Int. MLI

Run No.	Solar (On/Off)	CAN On/Off Temp	B/P Heater On/Off Temp	Guard Heaters On/Off	Motor Control Heaters On/Off	Clock Position	Rotation	Start Time	Stop Time	Duration (Hours)
29	This Run deleted per handwritten change No.									
30	On	On/100	Off	On	Off	45	30	3/19/96 23:01	3/20/96 19:00	19:59
31	On On	On/100 On/100	On/100 Off	On On	Off Off	45 45	60 60	3/20/96 19:43 3/21/96 8:30	3/21/96 8:00 3/21/96 17:30	12:17 9:00
32	This Run deleted per handwritten change No.									

Table 7. CBM Test Pumpdown #6
Active Ring, Center Disk, Deploy Cover Closed, No Int. MLI

Run No.	Solar (On/Off)	CAN On/Off Temp	B/P Heater On/Off Temp	Guard Heaters On/Off	Motor Control Heaters On/Off Power	Clock Position	Rotation	Start Time	Stop Time	Duration (Hours)
33	Off	On/40	On/40	On	Off	45	0	3/26/96 15:00	3/27/96 5:02	14:02
	Off	On/40	Off	On	Off	45	0	3/27/96 5:13	3/27/96 17:00	11:47
	Off	On/40	Off	On	On/62	45	0	3/27/96 17:30	3/28/96 20:00	26:30:00
	Off	On/70	Off	On	Off	45	0	3/28/96 20:30	3/29/96 13:59	17:29
34	On	On/70	Off	On	Off	45	0	3/29/96 15:30	3/30/96 11:00	19:30
	On	On/100	Off	On	Off	45	0	3/30/96 11:39	3/31/96 8:30	20:51
	On	On/100	On/100	On	On/62	45	0	3/31/96 9:00	4/1/96 7:00	22:00
	On	On/100	On/100	On	Off	45	0	4/1/96 7:30	4/2/96 4:00	20:30
	Off	On/100	Off	On	Off	45	0	4/2/96 4:30	4/3/96 4:00	23:30

Table 8. Chamber Housekeeping Data File Names

TEST PUMPDOWN NO.	DATE DATA OBTAINED	DATA LABEL FILE	NOTES
1	12/21/92	CBM1A CBM1B CBM2A CBM2B	Passive test, 48 data channels in each file (A and B). Data runs were split into two runs limiting the size of the file (1 and 2). All files are in ascii format.
2	12/22/92	CBM3A CBM3B CBM4A CBM4B	Passive test, 48 data channels in each file (A and B). Data runs were split into two runs limiting the size of the file (3 and 4). All files are in ascii format.
3	12/22/92	CBM5A CBM5B	Passive test, 48 data channels in each file (A and B). All files are in ascii format.
4	1/9/93	CBM6A CBM6B CBM7A CBM7B	Passive test, 48 data channels in each file (A and B). Data runs were split into two runs limiting the size of the file (6 and 7). All files are in ascii format.
5	1/9/93	CBM8A CBM8B	Passive test, 48 data channels in each file (A and B). All files are in ascii format.
6	1/11/93	CBM9A CBM9B	Passive test, 48 data channels in each file (A and B). All files are in ascii format.