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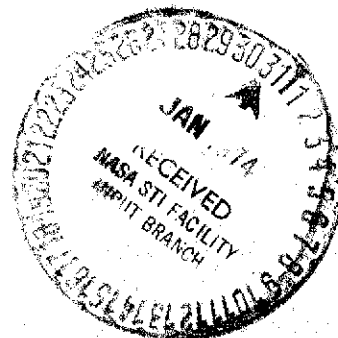
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CIRCADIAN PERIODICITY EXPERIMENT Final
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NORT 73-320

SKYLAB S071/S072
CIRCADIAN PERIODICITY EXPERIMENT
FINAL REPORT NOVEMBER 1973

Prepared Under Contract NAS 2-6897
for
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Ames Research Center
Moffett Field, California 94035

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INTRODUCTION

This report spans the Circadian rhythm hardware activities from 1965 through 1973. In the first section is a brief history of the programs leading to the development of the combined Skylab S071/S072 Circadian Periodicity Experiment (CPE). S071 is the Skylab experiment number designating the Pocket Mouse Circadian Experiment, and S072 designates the Vinegar Gnat Circadian Experiment. During early development the two experiments were conceived to be independent, but common features lead to their marriage into a single experiment package to save duplicate support functions.

The design, fabrication, integration, and qualification testing of two CPE packages, under Contract NAS-2-5850, during the period March 1970 through October 1971 is briefed in Section I, including reference to previous descriptive reports listed in Appendix II.

The main body of this report describes the continuing effort on Contract NAS-2-5850 from November 1971 to May 1972 and the activities on support Contract NAS-2-6897 from May 1972 through September 1973, including the final design modifications and checkout of the CPE, integration testing with the Apollo service Module CSM 117 at North American Downey, and the launch preparation and support tasks at Kennedy Space Center.

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- II. CPE Program Documentation.
- III. Pocket Mouse & Vinegar Gnat Humidity Conditions
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1.0 CIRCADIAN RHYTHM HARDWARE HISTORY AND EVOLUTION

During the period from 1965 through 1969 two sets of hardware were built and tested to evaluate and verify the design of the equipment for sustaining the little desert pocket mouse (*Perognathus Longimembris*) and monitoring the daily rhythms (Circadian Rhythms) of body temperature and activity.

The goal in mind was the production of an experiment package to be flown in earth orbit under conditions of constant darkness and a constant temperature of approximately 20°C for a minimum of 21 days to determine the effect of weightlessness on the Circadian Rhythm.

Independently, two sets of hardware were built and tested to evaluate methods of monitoring the Circadian Rhythm of Vinegar Gnat (*Drosophila*) eclosion (hatching) in the space environment to determine if weightlessness would prove to be a perturbing factor.

Subsequently, a single combined experiment package was built to support and monitor both the pocket mice and the vinegar gnats in space.

Table 1-1 shows a chronology of the hardware programs and the paragraphs following briefly review the activities on the early contracts and on the design, fabrication, integration, and qualification testing of the combined S071/S072 experiment packages.

Further details of the background programs are available in the documents listed in Appendix I "Documentation from Previous Circadian Programs" and Appendix II "CPE Program Documents".

Table 1-1. Chronology and History of Pocket Mouse and Vinegar Gnat Circadian Periodicity Experiment Hardware

<u>Contract</u>	<u>Period</u>	<u>Hardware Involved</u>	<u>Evaluation & Test</u>
NAS-W 1191	1965 & 1966	<u>Pocket Mouse Design Verification Model</u> Pocket mouse enclosure (Six mouse tubular construction) Environmental Control System Circadian Data System	Extensive performance evaluation with biology and in simulated environments of vibration and vacuum
NAS-2 5094	1967 & 1968	<u>Vinegar Gnat Design Verification Model</u> Single sealed vinegar gnat enclosure for 144 pupae with manual eclosion readout system	V.G. survival and eclosion testing and vibration testing
	1968 & 1969	<u>V.G. Laboratory Development Model</u> Two V.G. enclosures with data monitoring and record console	Performance with biology and vibration (Used by principal investigator for biology evaluation)
NAS-2 5093	1968 & 1969	<u>P.M. Lab Evaluation Model</u> Flat cylinder P.M. enclosure for six mice with lab air circulated for conditioning. Data monitor and record console included.	Performance with biology and vibration tests (Used by principal investigator in animal testing)
NAS-2 5850 & NAS-2 6897	1970 Thru 1973	<u>Space Flight Circadian Experiment</u> Two combined pocket mice/vinegar gnat circadian periodicity experiments (S071/S072) for flight on the Apollo Skylab Program	Development & functional evaluation & integration test, biology compatibility, environmental qualification, endurance runs, spacecraft integration test, prelaunch checkout, launch and ground test.

1.1 Pocket Mouse Design Verification Model

During 1965 and 1966 Northrop prepared specifications defining an experiment package to evaluate the effect of the weightlessness of orbital space environment on the Circadian rhythms of pocket mice. A prototype experiment package was then built to evaluate the design concepts. The experiment included a pocket mouse life support and environmental control system, with the animal enclosure and data monitoring system. The experiment was functionally checked with biology and environmental tests were conducted to verify the structural integrity of the unit and to verify continued acceptable performance of the experiment and biology. Test activities included endurance testing with biology, vacuum environment test, and vibration testing.

1.2 Vinegar Gnat Design Verification Model

During 1967-68, the first hardware designed toward sustaining vinegar gnat pupa in space environment and monitoring the eclosion periodicity was built up. The single sealed pupa enclosure provided control of temperature, humidity, and gas composition and monitored the eclosion of 144 pupae. The data readout was a "manual" system which visually indicated the eclosion count on a digital lamp display. The feasibility of monitoring the V.G. pupa eclosions with a red light scan and a light pipe/photo-resistor sensor was demonstrated, along with the survival of pupa in a closed system. The enclosure was subjected to vibration levels simulating those expected on the launch vehicle.

1.3 Vinegar Gnat Laboratory Evaluation Model

During 1967-68 an improved vinegar gnat circadian periodicity system was built. This system had two enclosures and a data monitor and record console. Each enclosure accommodated 180 pupae and numerous modifications were incorporated in the hardware. The evaluation model (enclosures and data monitoring unit) was subjected to rigorous integration testing, tests with live biology and vibration testing. The V.G. lab evaluation model was then turned over to the principal investigator at Stanford University where numerous vinegar gnat eclosion cycles were studied.

1.4 Pocket Mouse Laboratory Evaluation Model

During 1968-1969 a second Pocket Mouse Circadian system was built, consisting of a laboratory test console monitoring and recording data from a six cage animal housing assembly. The cages were flat cylinders wrapped around a central antenna. No environmental control system was provided with the unit, conditioning being provided by circulating lab air through the open loop system.

Integration testing was performed to determine that the performance complied with the requirements and to establish calibration values. An acceptance test was performed, and the units were subjected to vibration levels representing the expected transport dynamics. Following a post-vibration functional acceptance test, the P.M. lab evaluation model was delivered to the principal investigator at Northrop Corporate Laboratories. Several batches of mice were sustained and monitored to evaluate the merit of the new cage configuration and antenna/receiver for studying pocket mouse circadian periodicity.

1.5 Circadian Periodicity Flight Experiments Skylab S071/S072

From the experience gained from working with the design verification and evaluation hardware, the design specification for the flight hardware Circadian Periodicity Experiment was generated. This specification established the requirements for the performance, design, test, and qualification of the Skylab S071 and S072 combined pocket mouse/vinegar gnat assembly.

The initial program concept had established a requirement for the production of three experiment packages, one to be subjected to all qualification testing, and two others to be acceptance tested to serve as flightworthy end items. The program scope was later reduced to just two experiments with the qualification testing being distributed essentially equally between the two experiments.

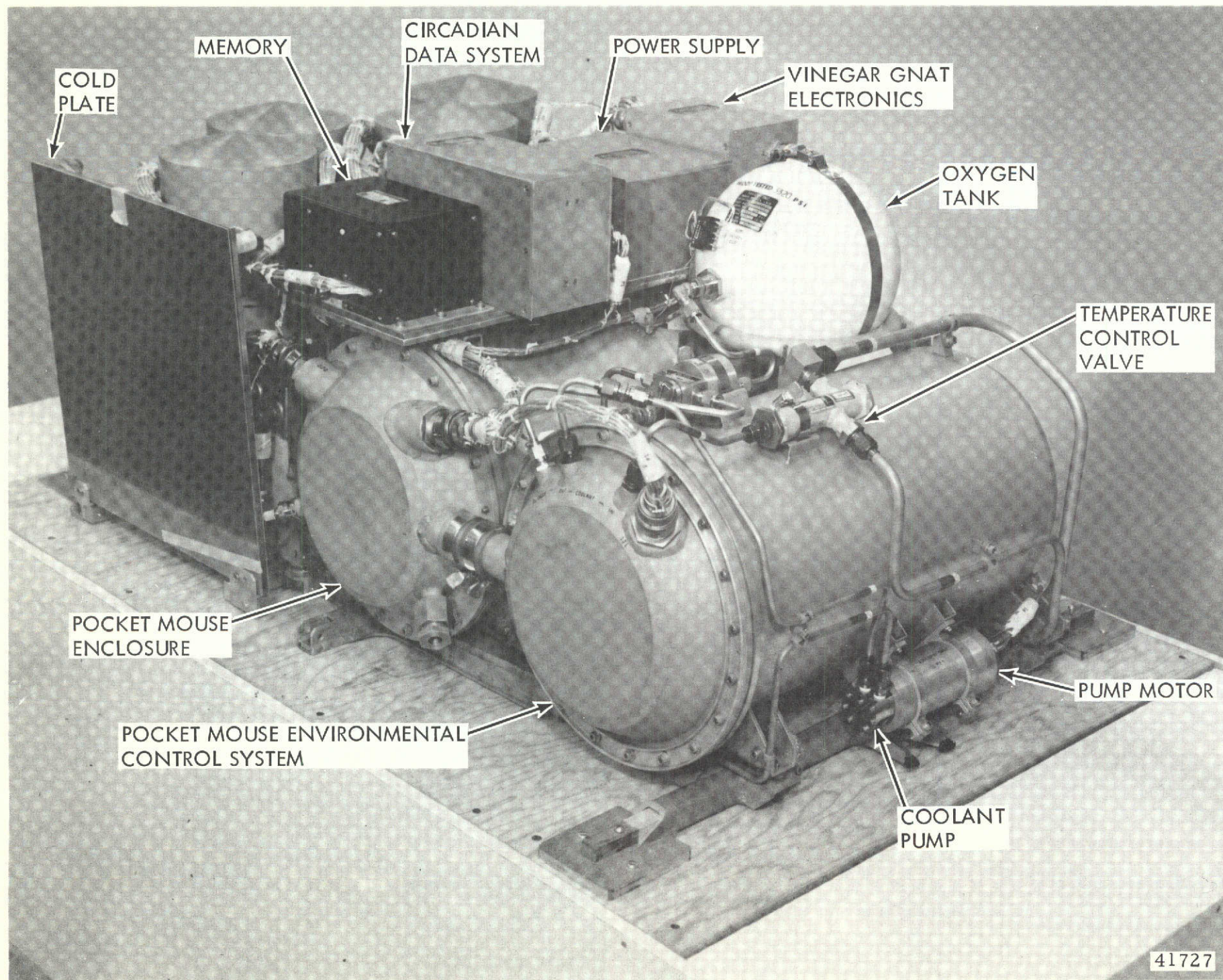
Activities on the CPE flight program were started on March 1970. A preliminary design review was conducted in May 1970 and critical design review concluded in August 1970. The first experiment package was assembled and available for the beginning of integration testing in February 1971,

and the second unit began integration testing the following month. Because only one command and monitor unit existed, there was some competition between the two units for the use of that one C&M during the period of integration, electromagnetic compatibility, and environmental qualification testing which followed.

Detailed accounting of the design, fabrication, and testing activities from March 1970 through October 1971 are contained in Development Status Report Series 70-348-1 through -18, the 67000702 Integration Test Data Sheets filed with the CPE Data Package, EMI Qualification Test Report NORT 71-244, System Environmental Test Report NORT 71-286, System Environment Test Report NORT 71-286, and System Environment Test Reports of Vibration and Shock NORT 71-291 and NORT 71-303.

1.6 Hardware Photographs

On the following pages, Figures 1-1 and 1-2 picture the Circadian Periodicity Experiment with the major elements identified. Figure 1-3 on page 8 shows the CPE mounted on the transportation container. Figure 1-4 on page 9 shows the two CPE in their thermal control blankets being powered, conditioned and monitored by the major CPE Ground Support Equipment (the Control and Monitor Console) during the endurance test period. The test and checkout cart, which is used for loading CPE fluids and gases, is shown in Figure 1-5 on page 10. An open vinegar gnat enclosure, with an empty vinegar gnat plate in place, but without the Potassium Hydroxide cup mounted at the center, is shown in Figure 1-6 on page 11. Page 12, Figure 1-7, shows a "practice run" mouse loading and Figure 1-8 shows the pocket mouse cage assembly being loaded into the enclosure. (The pocket mice are actually loaded in photo dark room conditions at their accustomed constant 20°C temperature to reduce disturbance of their circadian rhythms.)



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FIGURE I - I . CIRCADIAN PERIODICITY EXPERIMENT FRONT VIEW

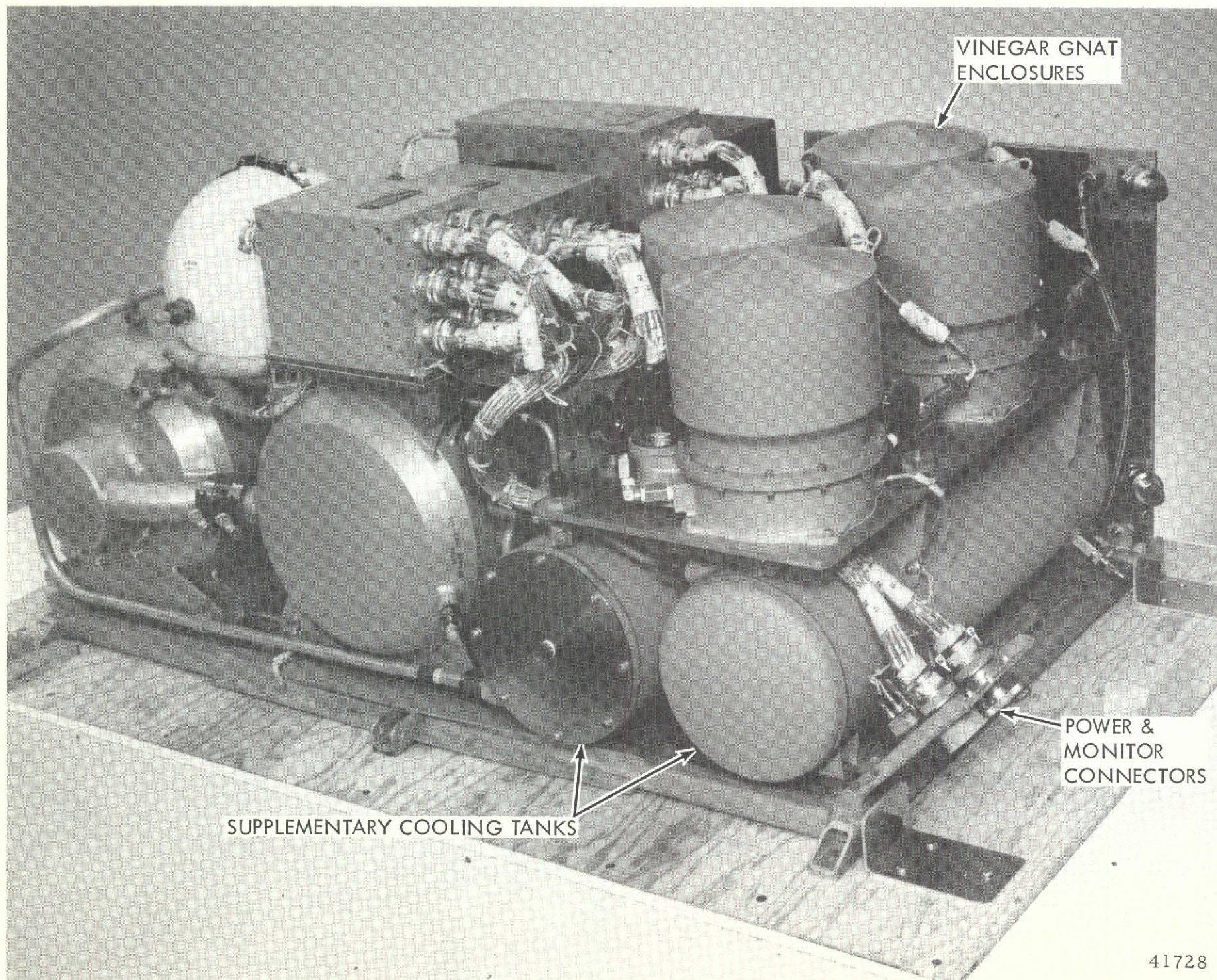


FIGURE I - 2 CPE REAR VIEW

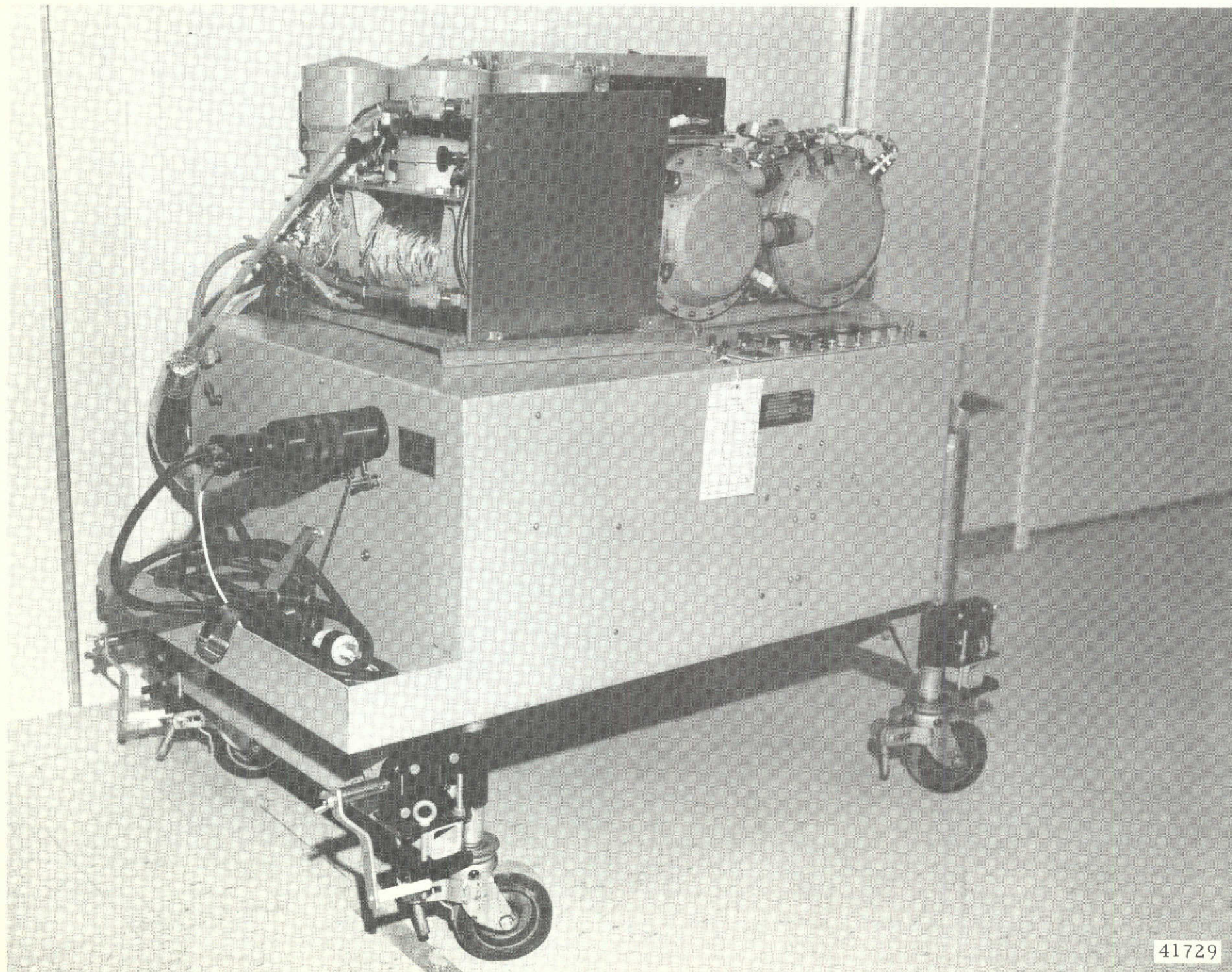


FIGURE I - 3 CPE TRANSPORTATION CONTAINER

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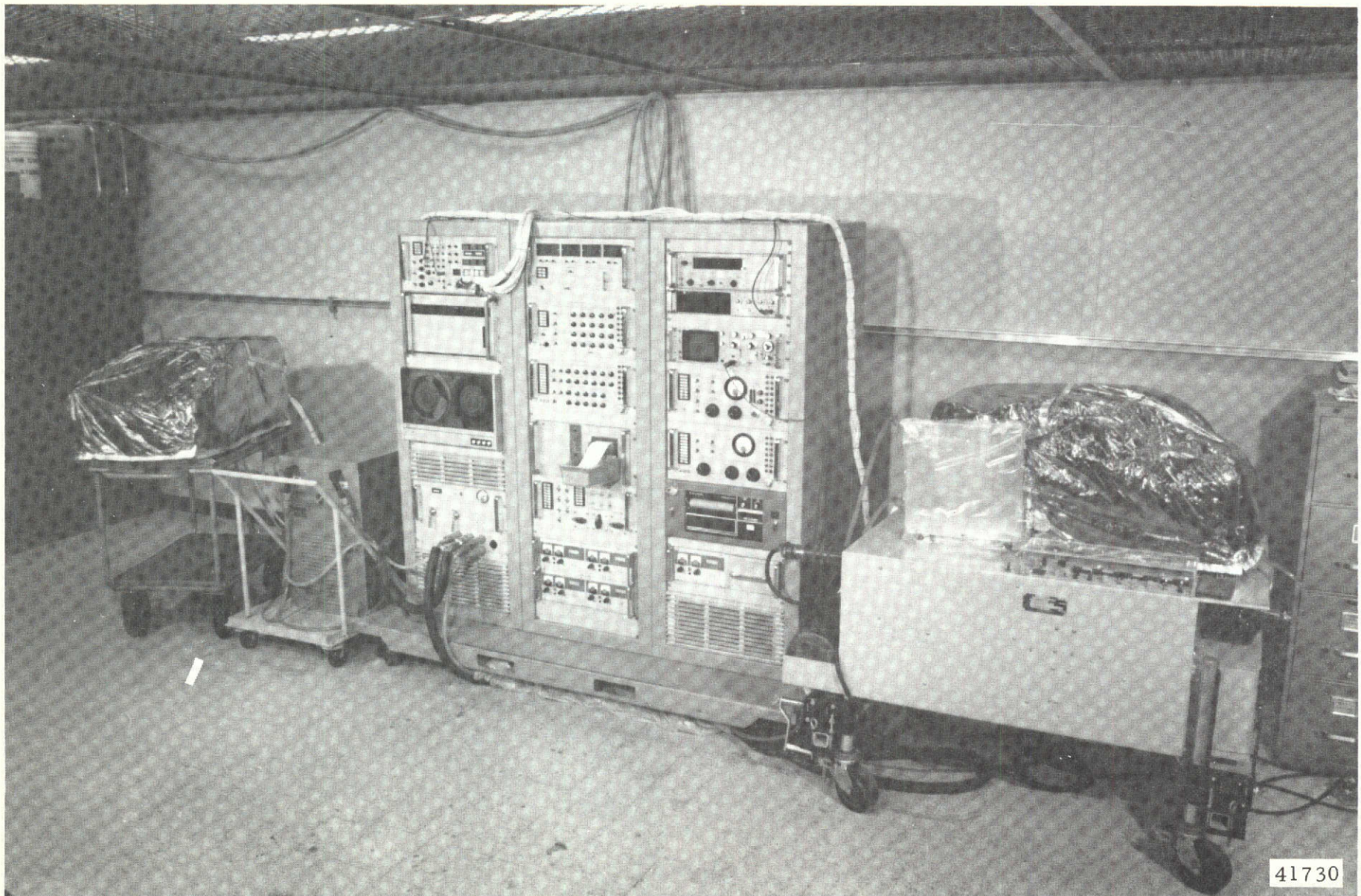


FIGURE I - 4 BOTH CPE BEING CONTROLLED FROM CONTROL & MONITOR UNIT DURING 21 DAY ENDURANCE TEST

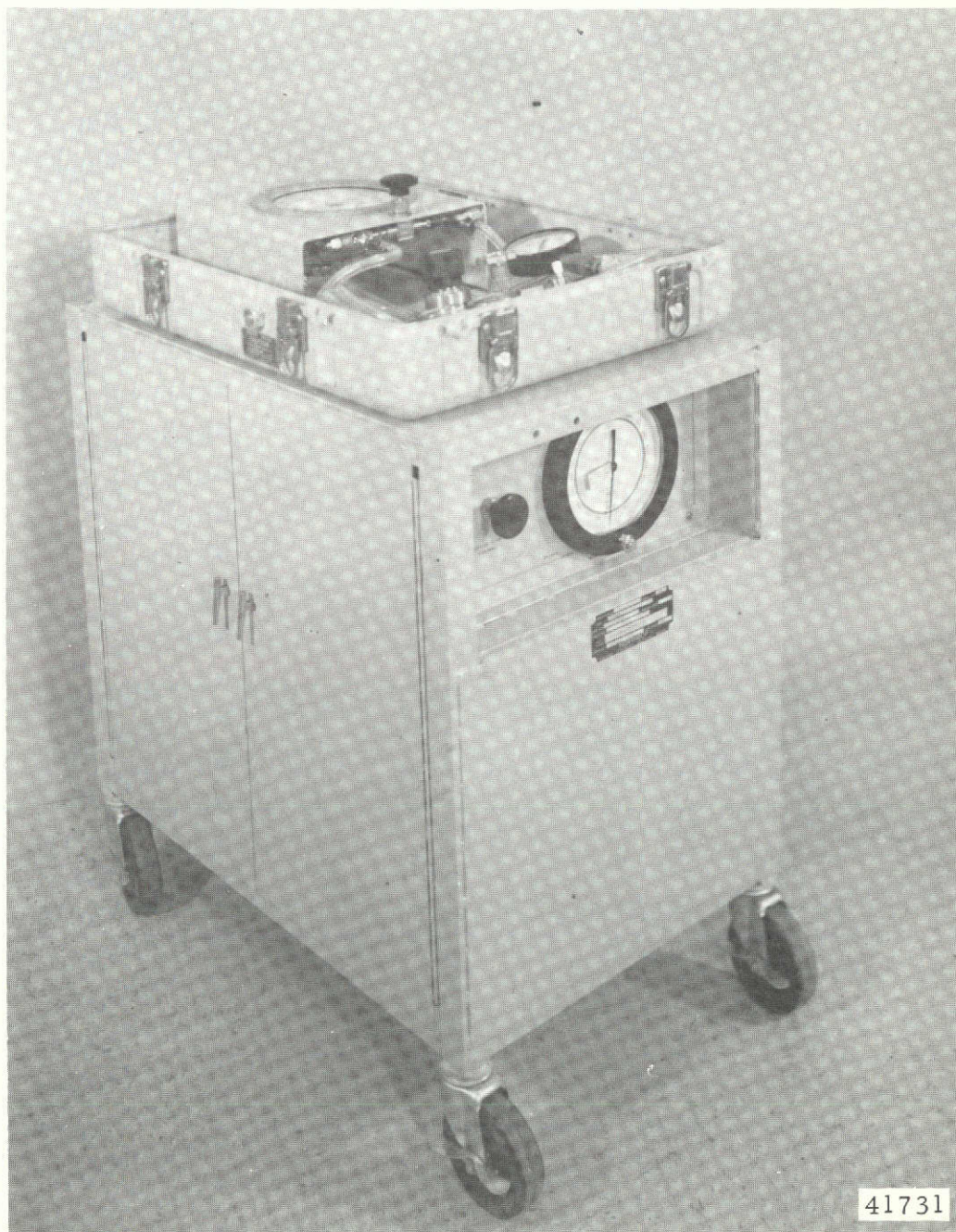


FIGURE I - 5 CIRCADIAN PERIODICITY TEST & CHECKOUT CART



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FIGURE 1 - 6 CIRCADIAN PERIODICITY EXPERIMENT VINEGAR GNAT ENCLOSURE

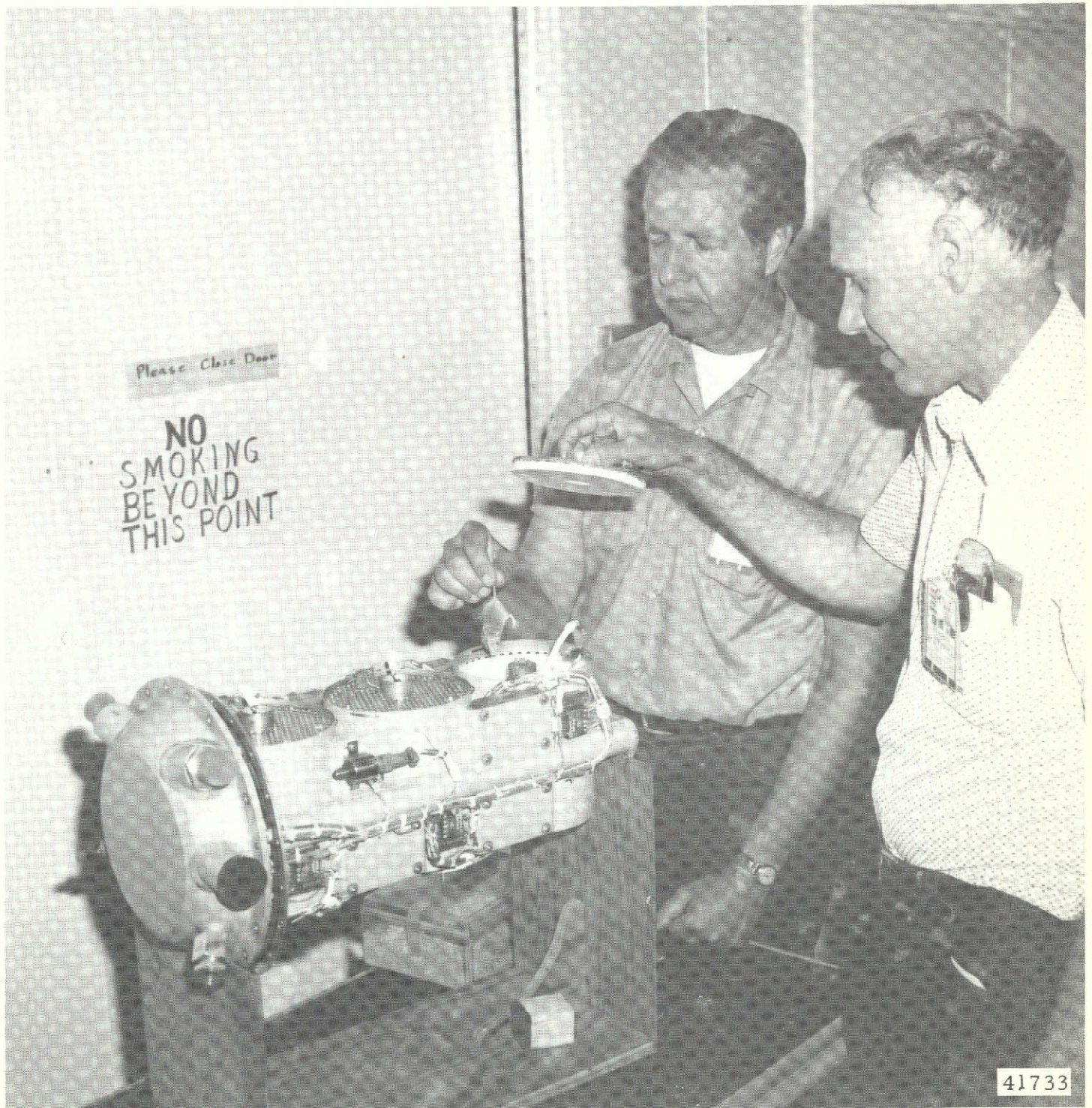


FIGURE I - 7 CPE POCKET MOUSE CAGE ASSEMBLY

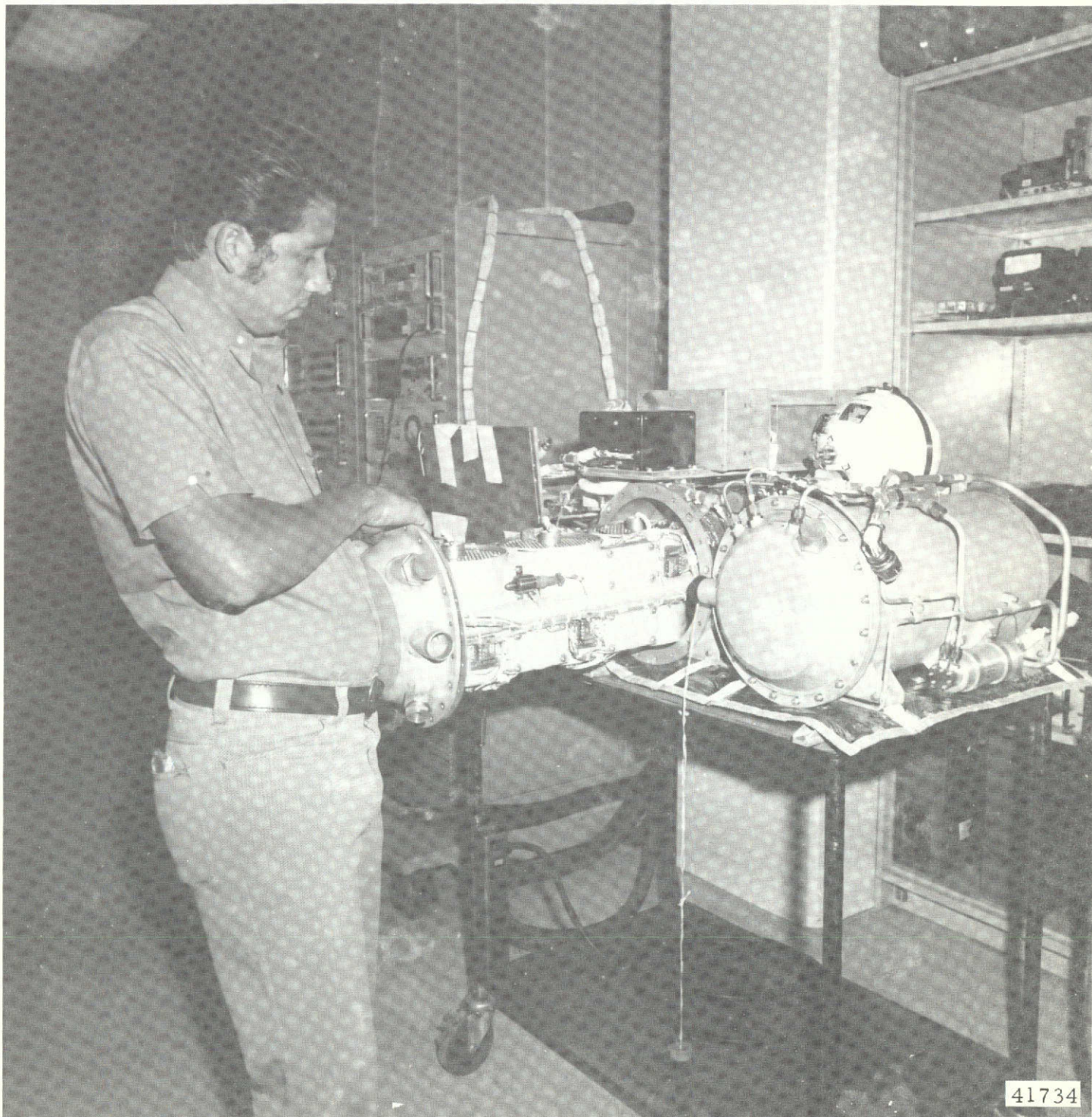


FIGURE I - 8 CPE POCKET MOUSE CAGE ASSEMBLY INSTALLATION

2.0 NORTH AMERICAN DOWNEY SPACECRAFT INTEGRATION

This section of this report picks up the activities on the Skylab S071/S072 Circadian experiments beginning with the mechanical fit check at North American Rockwell in Downey during November 1971 and continues through the Apollo system tests.

2.1 CPE/Apollo Mechanical Fit Check

During November 1971 the Circadian Periodicity Experiment #2 was delivered to North American Downey for a mechanical fit check. The CPE #2 was installed into Apollo Service Module CSM 117 using the NAR experiment lifting fixture. An interference between the lifting fixture and the CPE was observed when an attempt was made to attach the lifting yoke to the CPE frame. The interference was eliminated by removing the two shims on the mounting base of the CPE. (The CPE mounting base holes were subsequently spot faced flat to accommodate flat washers and eliminate the need for the shaped shims.)

The insertion of the CPE through the minimally sized access door required extreme care to avoid tearing the thermal control blanket; however, the CPE did go through and did fit the mounting shelf. The photo on the following page shows the CPE being installed in Apollo Service Module #117. The CPE cold plate was bolted to the CSM cold plate. (The mating foot print was not checked at this time because thermal grease had not been applied to the spacecraft cold plate. This will be discussed further in a later section.)

An electrical interface mismatch was encountered when it was discovered that the spacecraft electrical right angle connector had been clocked incorrectly and could not be connected to the CPE. The connector was re-clocked, and it then connected easily.

All other CPE/CSM mechanical interfaces were compatible. The CPE was returned to Northrop PV following mechanical fit check.

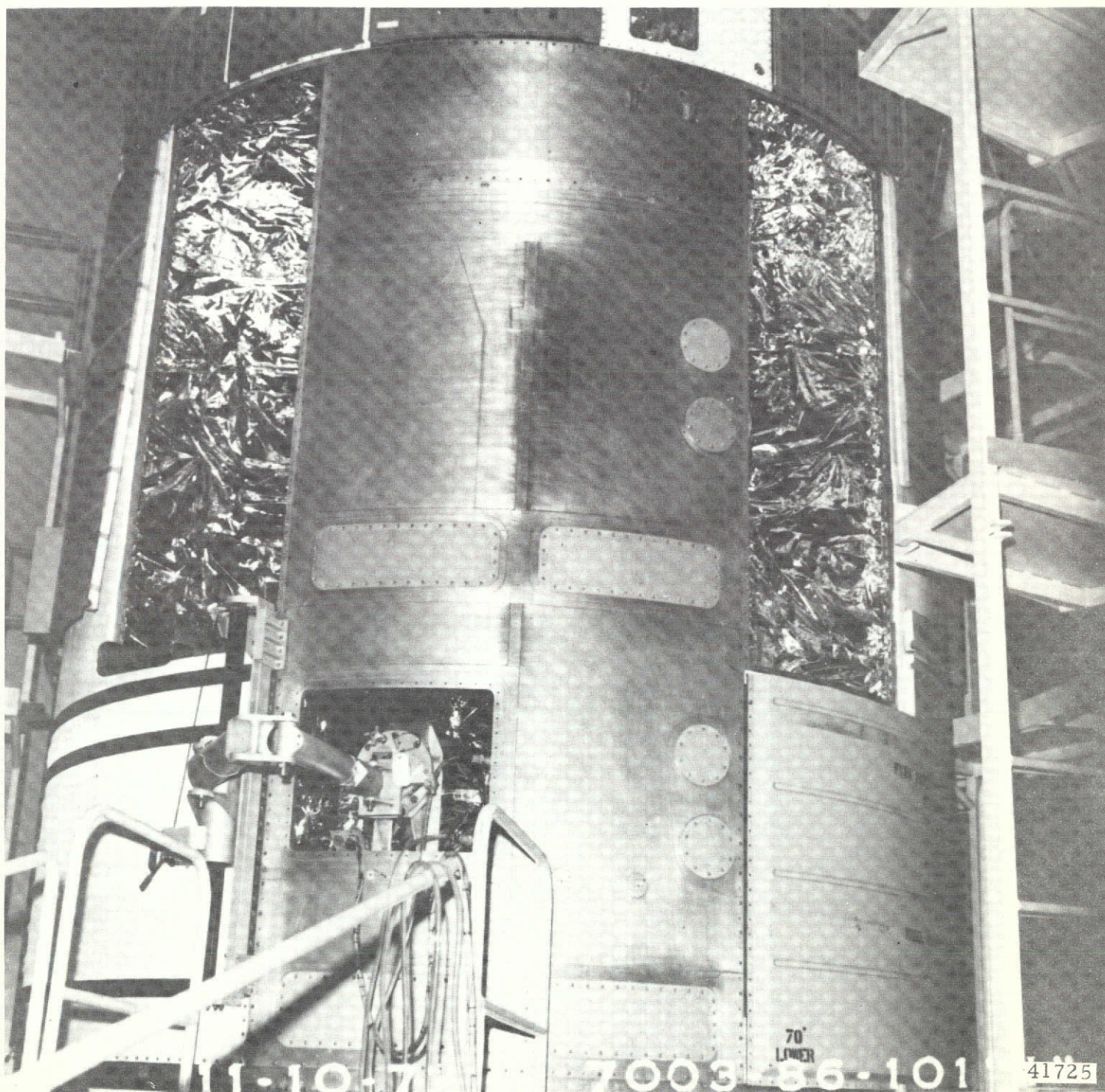


FIGURE II - I CPE BEING INSTALLED IN APOLLO CSM #117

2.2 Pre-Integration CPE Functional Test

During December of 1971 the CPE units were assembled with simulated biology installed and acceptance tested per TP67000701 prior to the delivery of CPE #1 to Downey for integrated functional testing with CSM 117. Both systems performed as required during the acceptance testing. The CPE #1 was then subjected to a special test to determine the thermal response to a 55 to 60°F CSM/CPE glycol coolant loop temperature. During this test a failure was encountered in the S/N 001 power supply when a secondary (-15 volt) regulator did not provide the proper output voltage. The power supply from CPE #2 was reassigned to CPE #1 and the TP67000701 and the special 55 to 60°F interface temperature tests were repeated with no discrepancies occurring. The test data are included in the data package, which is retained with the experiment.

CPE #1 was shipped to North American at Downey on 20 December 1971 for system tests with CSM 117. The tests were not scheduled to start until late in February 1972, and it was desired to have the CPE memory loaded with known information so the CPE #1 was returned to Northrop and powered up from the control and monitor unit, and 19 hours of data were recorded into the memory.

During the above operation, the CPE was cooled from the transportation container ice system to determine the ice use rate. The ice required to cool the system and operate for 60 minutes was approximately 50 pounds, and the ice required to keep the system cooled was 10 to 15 pounds per hour.

A sample of the CPE #1 water glycol cooling solution was taken following the data loading exercise and sent to NAR Downey for analysis. The sample proved to be very clean with no particulate contamination, and the inhibitors were still within the requirements of the procurement specification FS67000658, indicating that no corrosion was occurring within the CPE.

2.3 System Tests with Apollo Command Service Module (CSM)

During February 1972 CPE #1 was installed in the Apollo service module CSM #117 and operated with the CSM. Cooling was provided from the CPE transportation container for nominal operation to avoid pulling the spacecraft coolant loop below dewpoint temperature. All performance of the CPE was normal (with specification) except:

(1) The time code generator could not be updated properly from the transportation container and (2) the pocket mouse cage temperatures ran cooler than required. (See Sections 3.1.5, 3.1.7, and 3.1.8 for discussion of the resolution of these problems.

A separate cooling test conducted with the spacecraft operating at approximately 60°F demonstrated that the CPE return could be cooled to within 4°F of the spacecraft coolant input temperature. When the two cold plates were disengaged, it was discovered that approximately 15% of the surfaces were in contact and an investigation was made to determine a technique for installation to insure 50% or greater surface contact. A grease spreader with deeper serrations was made to put the grease on thicker and the plates were remated to verify adequate interface contact.

Integrated system tests were conducted with all CSM systems operating (including CPE) during April/May 1972. During these tests, no incompatibility was encountered between CPE and other systems, and the CPE operated in specification except as noted in the previous paragraph.

3.0 PROGRAM CONTINUATION AT NORTHROP PALOS VERDES

This section defines the activities occurring at Northrop Palos Verdes following the North American Downey integration tasks. The following tasks were accomplished from May through December 1972:

- Hardware modifications and recalibration
- Endurance and functional checkout
- Refurbishment and preparation for shipment to KSC

3.1 CPE Modifications

With the inception of NAS-2-6897, modified performance of the CPE was requested in two specific areas: (1) The pupa plates which had been controlled at two "warm" temperatures of 15°C and 20°C were required to be controlled at 20°C during the pupa development time, and (2) The circuits controlling the vinegar gnat temperature rise and the stimulus light "on" time were required to be latched so that in the event of a power interruption after initiate, the control would not reset and repeat. These mods were worked on the CPE. The performance evaluation demonstrated a need for further improvement and additional changes, as described in the following paragraphs, were incorporated.

3.1.1 V.G. Temperature Ladder and Stimulus Lamp Latch

Reason for Change

If a power interruption occurred following the illumination of the V.G. Stimulus Lamps, the state of the temperature ladder controller and also the Stimulus Light programmers was indeterminate. The result was normally a resetting of the electronics with a subsequent thermal excursion and also re-illumination of the Stimulus Lamps. This occurrence would compromise the V.G. experiment. ECP 54 was initiated to request a positive latch that would preclude this occurrence.

Change

Circuitry was designed (module 67300129 and schematics 67300128 and 67300053 sheet 2 zone 29F) that sensed the illumination of each set of Stimulus Lamps. Following the illumination of either set, a magnetic latching relay was energized with the resultant lock-out of that set of lamps and also a lock-up of the temperature ladder.

Results

Subsequent testing indicated that the new circuitry operated as designed and was impervious to power dropouts following Stimulus Lamp operation.

3.1.2 V.G. 20°C Ladder Control

Reason for Change

The initial design of the V.G. electronics specified that the four V.G. houses be held at 5°C until experiment initiation at which time two houses be raised to 15°C and the other two be raised to 20°C. The Principal Investigator requested that this be changed such that all four houses would be raised to 20°C and ECP50 was originated to accomplish this.

Change

The 15°C Control Module (67300075-1) was deleted, and the 20°C Control Module (67300072-1) was used to control all four houses. The 15°C Control Module housed both current and voltage references that were used by both the 15 and 20°C modules. Analyses of these references showed potential drift problems that could result in out of spec conditions. These references were redesigned and included in a new module (67300130) along with gain controls to accommodate the differences in the inputs of the four houses.

Results

The new circuitry operated as expected. The initial control settings of 5°C and 20°C, as well as the drifts in these settings, were improved from approximately $\pm 0.4^\circ\text{C}$ to approximately $\pm 0.1^\circ\text{C}$.

3.1.3 V. G. "Power On" Flip Flop

Reason for Change

Analysis of the V.G. electronics uncovered a potential operational problem involving the "Scan On" and "Pwr On" flip flops FF1A and FF1B, shown in zone 15B of 67300053 sheet 1. If, at initial power turn-on, these two flip-flops came on in opposite states, then subsequent operation would be such that the +5V switched power would be off when scans were being attempted. This would result in the loss of all scanning. The history of the system indicated that the flip-flops always came on in the same state. It was, nevertheless, decided to redesign the circuitry to preclude this occurrence.

Change

The change is described in E.O. 34196, and involves the gating of a data system timing pulse into the reset lines of the flip-flops.

Results

No change occurred in system operation.

3.1.4 Isolated +28V Power Reduction

Reason for Change

The isolated 28V line was an unregulated output of the power supply. Its load was comprised of the 10 watt cold plate bypass valve and also the 10W coil of the relay in the PM air heater circuitry. The line was highly noisy due to its unregulated nature and lack of filtering and also the power transfer to the loads was inefficient because of the normal operation of the switching regulator and preregulator in front of it.

Change

Several changes were made. The 10 watt heater relay was replaced with a 600 m watt relay (EO 34184). The 10 watt bypass valve was removed from the isolated 28 volt line and put on the raw power line with control coming via a 600 m watt relay on the isolated 28V line (EO 34186). Finally, the isolated 28V line was regulated (EO 34181).

Results

Peak power loading was reduced by approximately 12 watts and the noise on the isolated 28 volt line was virtually eliminated.

3.1.5 P.M. 30 Watt Heater

Reason for Change

System testing indicated that the 20 watt heater, under extreme conditions of low input voltage and low interface temperatures, would be insufficient to maintain the required 20°C P.M. air temperature.

Change

The heater was changed from 20 watts to 30 watts.

Results

Subsequent testing indicated that the duty cycle of the heater contained sufficient margin to accommodate all anticipated extremes in input power and temperature levels.

3.1.6 P.M. Activity Circuit Change

Reason for Change

System tests with biology indicated that the activity data was inconsistent from one receiver to another.

Change

Subsequent investigations indicated that the problem was caused by interaction between the three signals from the orthogonal receiving antenna system and also due to a lack of consistency in the gain of the various receivers. The solution was the standardization of gain and also the removal of activity data from two of the three receiver channels. The circuit changes are described in EO 32621 and EO 34203.

Results

Activity data from subsequent biology tests demonstrated an acceptable consistency between receivers.

3.1.7 TCG Advance Noise Filter

Reason for Change

Operation of the Manual TCG Advance control resulted in erratic counting in the TCG circuitry.

Change

A simple RC noise filter was added to the data system to reduce extraneous signals (See EO 32615).

Results

Erratic counting no longer occurs during operation of the Manual TCG Advance control. It is noted, however, that the transportation container sometimes generates false TCG advance signals when its AC power is turned on or off, and also when its pump is turned on or off.

3.1.8 P.M. Cage Temperature Sensor Relocation

Reason for Change

Biology tests indicated that some of the cage temperatures were not holding to the $20 \pm 0.5^{\circ}\text{C}$ spec. limit. It was noted that individual cage temperatures would occasionally increase for no apparent reason.

Change

Investigation determined that the location of the temperature sensing thermistors was such that the mice could affect their readings by positioning themselves sufficiently close to the thermistors. The solution was to move the thermistors to a different location, and this was done (E.O. 34164) to the thermistors in houses #2 and #5.

Results

Subsequent tests show that the cage air temperature, as measured in houses #2 and #5 stay well within the specification limit.

3.1.9 P.M. Telemeter Swamping Capacitor

Reason for Change

The RF carrier frequencies of the biotelemeters that are implanted in the mice were observed to drift excessively with time.

Change

Investigations indicated that the drift was due to changes in the interwinding capacitance of the telemeter transformer and was probably caused by either the movement of the windings due to moisture absorbed from the mouse or by changes in the dielectric constant due to the moisture.

Attempts were made to preclude the moisture by changing the encapsulant material, but they were unsuccessful. The final solution (EO 34170) was to add a swamping capacitor across the transformer. This capacitor is sufficiently large (500 pf.) to make any changes in interwinding capacitance negligible.

Results

Subsequent testing of six flight type telemeters in a water bath held at 40°C for a period of several months showed the RF carriers were stable and the temperature/pulse rate calibrations were also unchanged.

3.1.10 V. G. Eclosion Noise Filters

Reason for Change

During the November 1972 Endurance Test, it was noticed that on occasion the V.G. eclosion counts were noisy to the extent of up to ± 10 counts. Subsequent investigation indicated that when the light transmissibility of the pupae was such that the photo detectors were operating in their active region (rather than saturated or off) then the counting circuit was very susceptible to any type of electrical noise.

Change

The implemented change was the addition of a simple low pass RC filter in the pupae counting circuitry (Reference E.O. 34207).

Results

Subsequent testing indicates that the noise has been reduced to an occasional ± 2 counts.

3.1.11 V. G. Δ10 Minute Stimulus Lamps

Reason for Change

During the endurance tests of November 1972, it appeared that the second set of stimulus lamps in the Vinegar Gnat experiment did not illuminate following the VGI command. Subsequent analysis showed that when, and only when, the second set of stimulus lights was programmed to follow the first set by 10 minutes, they would actually illuminate 12 minutes later. Since this was two minutes after a V.G. data scan, there was no data indication that they actually did illuminate.

Change

An appropriate logic signal was brought out to the V.G. timing plug as described in E.O. 34205 to be used only when the time between the stimulus lamps is 10 minutes. Proper wiring of the timing plug is discussed in NORT 71-224A (November 1972), Volume III, Section 2.4.12D.

Results

The delta ten minute increment now operates properly and is recorded by the data scan as required. For other than the delta ten minute increment, the circuit remains unchanged from before, and hence there is no change in operation.

3.2 CPE Calibration Verification

All data channels of both CPE units were recalibrated or the existing calibrations were verified at the completion of the previously described modifications because many of the calibrations had been affected by the rework, and all deserved a calibration check due to the passage of time since initial calibration. All new calibration data were included in NORT 71-283A. The following table lists all CPE data channels and defines any changes encountered during hardware rework and the method used in calibration/verification on both CPE units.

Table 3.2 -1

CPE Calibrations

<u>Data Channel</u>	<u>Rework Change</u>	<u>Calibration/Verification Method</u>
Time Code	None	Verified 0 thru 143 continuous sequential counts in 24 hours.
Animal Activities (Six Channels)	None	All pocket mouse telemetry receiver activity counters were programmed thru 0 to 860 counts to verify 0 to 5 volt output with rate changes at 32 and 96 count amplitudes. The CDS analog to digital converter was checked to verify a 50 count per volt conversion.
Cage Temperatures 6 Chan and Oxygen Tank Temperatures & Dew Point Temperatures	Two new cage thermistors (cages 2 & 5)	The pocket mouse temperature indications were verified in three ways: (1) The CDS indications vs. the thermistor temperatures were calculated for the resistance values in the sensing circuits. (2) The calculated values were confirmed by placing precision resistors (equal to thermistor values for specific temperatures) into the sensing circuits, and (3) By checking against a standard temperature indicator after stabilization in a temperature controlled laboratory over night.
Mouse Body Temperature (6 Channels)	None	All P.M. receivers checked to verify one output pulse for each telemeter pulse in.
Vinegar Gnat Pupa Plate Temps (4 Enclosures)	Settings and controls changed	The GSE temperature sensing circuitry was calibrated by replacing the GSE thermistor with a precision resistor and varying the resistor to simulate various temperatures. The CPE temperature sensing circuit was then calibrated against the GSE readings.

Table 3.2-1 (Cont)

<u>Data Channel</u>	<u>Rework Change</u>	<u>Calibration/Verification Method</u>
Pocket Mouse Enclosure Pressures	None	Ranges extended and calibration completed by applying precisely measured pressures to the enclosures and printing out CDS indications.
CDS CAL Voltages	No Change	Verified no change in indication.
V.G. House Temperatures	No Change	Checked against a standard temperature indicator at 3 points after stabilization in temperature controlled lab over night.
Oxygen Tank Pressure	Transducer changed on System #2	Applied precisely measured pressures to the O ₂ tank and read CDS output
Memory Write Address	None	Verified linear increase in count from from 0 to 255 for 19.5 hours of continuous data system operation.
V.G. Lamp Status	Shifted because of reference volt- age modification	Placed opaque masks over all 12 sensors, then 11, then 10, etc. to calibrate the C.D.S. Out-put from 0 to 12 counts.
V.G. Popu- lation Count	New red lamp in- stalled but no change in count results	Calibration verified by use of above masks varying actual count from 0 to 180 and reading the CDS output indication.

3.3 Ground Support Equipment Modifications

The following paragraphs describe improvements implemented on the CPE Ground Support Equipment. The first five were recognized and implemented at Palos Verdes in the spring of 1972. The transportation container IR drop reduction change was made at Kennedy Space Center following the launch rehearsal checkout, which indicated a potential problem due to low voltage from the transporter.

3.3.1 C & M Stand-By Power

Reason for Change

When the CPE was being powered from the GSE C&M console, a potential problem existed. In the event of a 60 Hz power drop-out the CPE would perform certain resetting functions with the result that certain data and operating conditions would be lost. ECP 51 was generated to request the addition of battery powered stand-by operation to preclude this problem.

Change

A lead-acid battery was incorporated into the C&M power supply system such that two CPE systems could be run with the battery acting as a back-up power source in the event of a power drop-out. Existing power supplies in the C&M were modified to satisfy normal power requirements and also to insure full charge on the battery.

Results

Testing indicated that the back-up system worked properly and would sustain system operation during power failures exceeding three hours in duration.

3.3.2 Transportation Container TCG Pulse

Reason for Change

The TCG Manual Advance Command had two problems. It would occasionally issue two control pulses when one command was issued, and it was also highly sensitive to being triggered by extraneous noise signals.

Change

The change included adding a filter capacitor across the command switch contacts, increasing the one-shot period from 8 to 50 m sec, and the shielding of the signal line.

Results

Subsequent testing demonstrated that the double pulsing no longer occurs. The noise susceptibility was considerably reduced, but there is still a tendency for the circuit to trigger when the glycol circulating pump is turned on or off.

3.3.3 GSE Temperature Monitor Modifications

Reason for Change

The temperature monitoring circuits on both the C&M and the transportation container were demonstrating a drift in their temperature readings.

Changes

Analysis of the circuitry disclosed a highly unbalanced input impedance on the comparator op-amps which resulted in output error signals due to circuitry thermal drifts. This situation was corrected by balancing the input impedances. It was also discovered that noise on the output line was feeding back into the op-amp and causing error signals. This was corrected by the addition of filters. Additionally, there was a problem in the C&M (only) circuitry due to common mode voltages on the ground lines. The ground lines in the temperature monitor circuits were rearranged to reduce these common mode voltages.

Results

The above changes eliminated the drift in temperature readings on both the C&M and the transportation container. The common mode problem on the C&M was considerably reduced but not eliminated. Small errors (approximately 0.2°C) are present if the ± 6 and +15 volt supplies on the Data Processor panel are turned "on". Turning these supplies "off" eliminates the common mode problem.

3.3.4 Transportation Container Capacitor Bleed Resistors

Reason for Change

An electrical shock hazard existed because the input filters on the 60 Hz line had no discharge path after turning "AC PWR" off. If one were to unplug the 60 Hz power line and then touch the plug, he would be shocked.

Change

Bleeding resistors were added across the 60 Hz line filters.

Result

The shock hazard no longer exists.

3.3.5 Transportation Container Battery Charging Modifications

Reason for Change

During normal operation of the Transportation Container, it was observed that the Ni-Cad batteries had seriously overheated. Upon removal and testing of the batteries, it was discovered that they had all been damaged to varying degrees. It was necessary to refurbish all the batteries.

Change

The battery pack consists of six parallel batteries, one of which is regularly switched in and out. A current limiting ballast was added in series with this battery to prevent excessive currents. In addition to this, a second problem source was uncovered. The battery charging supply was voltage limited to 34 volts d.c. The gassing potential of a 22 cell ni-cad battery is 33 volts, thus the batteries were being overcharged, had water driven out of them, and overheated. The voltage limit on the battery charging power supply was, therefore, changed from 34 volts to 31.8 volts.

Results

Subsequent operation of the transportation container showed no degradation or heating in the batteries.

3.3.6 Transportation Container IR Drop Reduction

Reason for Change

When the CPE was powered by the batteries in the transportation container, there was a voltage loss of approximately 4 volts from the batteries to the CPE. After approximately 25% of the battery life had been consumed, the voltage at the CPE was not sufficient to maintain operation within the specified operating conditions.

Change

The change is delineated in KSC TPS Number GNOR-100-01-004 and consists primarily of replacing and shortening 20 ga wire runs with 14 ga wire runs in the transportation container and the 67500153 cable assembly.

Results

After the change, the voltage drop from the batteries to the CPE was approximately 1 volt and system operation could be maintained within specification for over 80% of the battery life (4 hours duration).

3.4 Endurance/Functional Test

With the completion of all CPE modifications and calibration verification described in the previous paragraphs, the two CPE units were cleaned, assembled, and prepared for a 21-day endurance run with biology. A Functional Acceptance Test (TP67000701) was run on each of the two experiments with no malfunctions occurring. The lithium hydroxide was conditioned, the canisters were loaded, and the coolant system was topped off. Biology was loaded into the two CPE units on 10 October 1972 at the Corporate Laboratories. Each experiment was transported in an operational mode from the Corporate Labs to Northrop Palos Verdes, where a 21-day endurance test was conducted.

3.4.1 Biology Loading

The biology loading at Corporate Labs was performed as a rehearsal of the planned loading sequence for launch preparation at Kennedy Space Center. However, gas samples were not taken during the loading for the endurance test.

The CPE biology loading flow chart on page 40 shows that the loading task began at 0800 and continued without break through 1800. Six men supported the task, and no substantial problems were encountered. The transporter carried each experiment from Hawthorne to Palos Verdes and provided power and cooling for a period of 60 minutes for each unit. All CPE and GSE functions were normal during loading and transfer.

3.4.2 Initial Thermal Interface (50°F Run)

Both CPE units were operated for the first several hours at 32°F, then the temperature of the coolant to the CPE cold plates was raised to 50°F and held at that temperature for three hours. All temperatures in the CPE units remained within specification during the three hour period. The coolant temperature was then reduced to 40°F for the remaining endurance period.

3.4.3 Twenty-One Day Run

With the exception of the problems discussed in Paragraph 3.4.5, the two CPE operating from the control and monitor unit performed as required. All Vinegar Gnat pupa plates controlled to within $\pm 0.2^{\circ}\text{C}$ both at the 5°C

CPE BIOLOGY LOADING
FOR ENDURANCE TEST

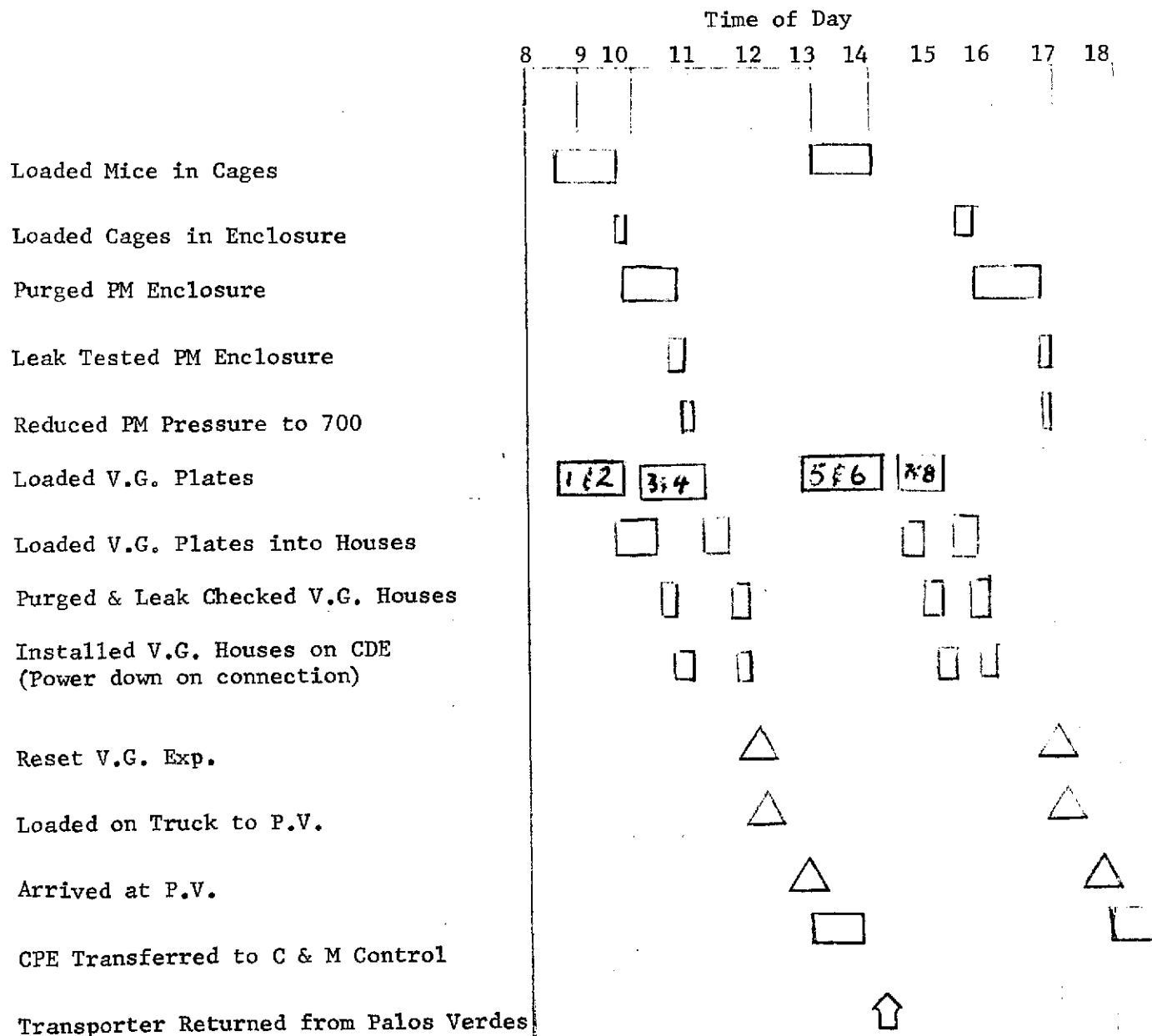


Figure 3.4-1

holding temperature and at the 20°C development temperature. The Pocket Mouse cages, measured by thermocouples #2 and #5, controlled at $20 \pm 0.2^\circ\text{C}$ at all times, and the dew point temperature controlled at $53 \pm 1.0^\circ\text{F}$. The Pocket Mouse enclosure pressure in both systems controlled at 700 ± 5 mm hg. The oxygen consumed during the 21 day period was only 25% of the total capacity as is shown by the plot of the oxygen supply tank pressure in Figure 3.4-2, page 42.

The Vinegar Gnat house pressures in system #1 appeared to decrease approximately 10 mm during the 21-day endurance period, and while it could not be ascertained if the small change was due to transducer tolerance or slight leakage, a subsequent "fine" mass spectrometer leak check indicated that one house had a small leak due to a hair laying across the seal. (Prior to flight at KSC, all houses were checked for leakage in a vacuum bell jar and careful seal inspection was implemented at closure after biology loading to assure that pressure would not be lost in a space mission.)

The vinegar gnat eclosion bursts encountered during the endurance period were well defined. A typical eclosion pattern is shown on page 43.

The total data was presented to the principal investigator for analysis, and the raw data are retained as Appendix IV to this report.

The pocket mouse temperature and activity data during the endurance period were excellent. All mice exhibited torpor temperature cycles and correlative activity cycles. Typical temperature/activity plot data are shown on page 14. The pocket mouse data were given to the principal investigator for analysis, and the raw data are also retained as Appendix IV to this report.

3.4.4 Examination of CPE After 21-Day Run

When the 21-day endurance run was completed, the units were shut down, the pocket mice removed (all 12 were found to be in excellent condition), and the hardware was examined. The pocket mouse cages were relatively clean with no indication of debris clogging air flow passage, and there was excess food to indicate the mice could be sustained for at least twice the 21-day period.

CIRCADIAN PERIODICITY EXPERIMENT

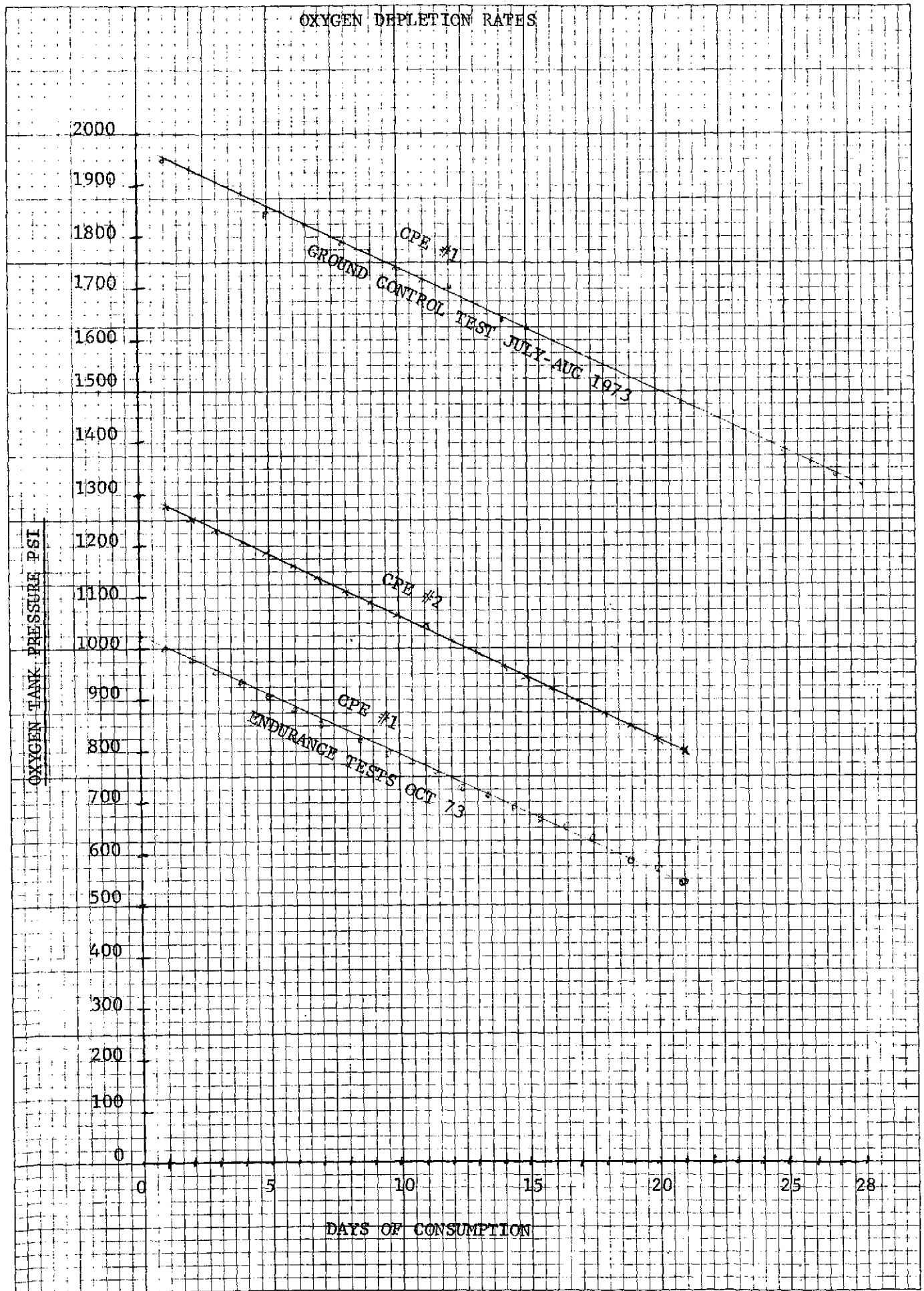


Figure 3.4-2

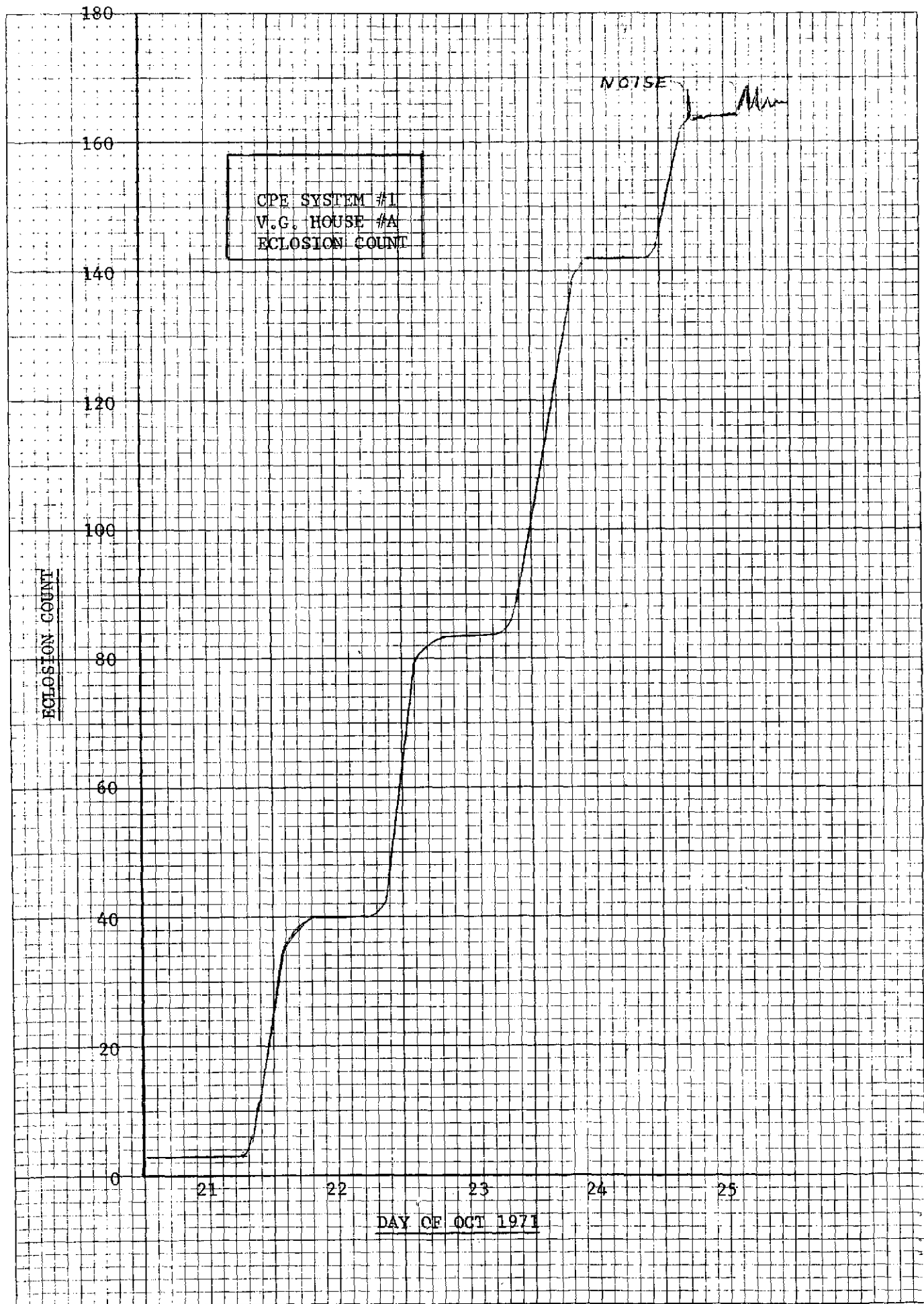
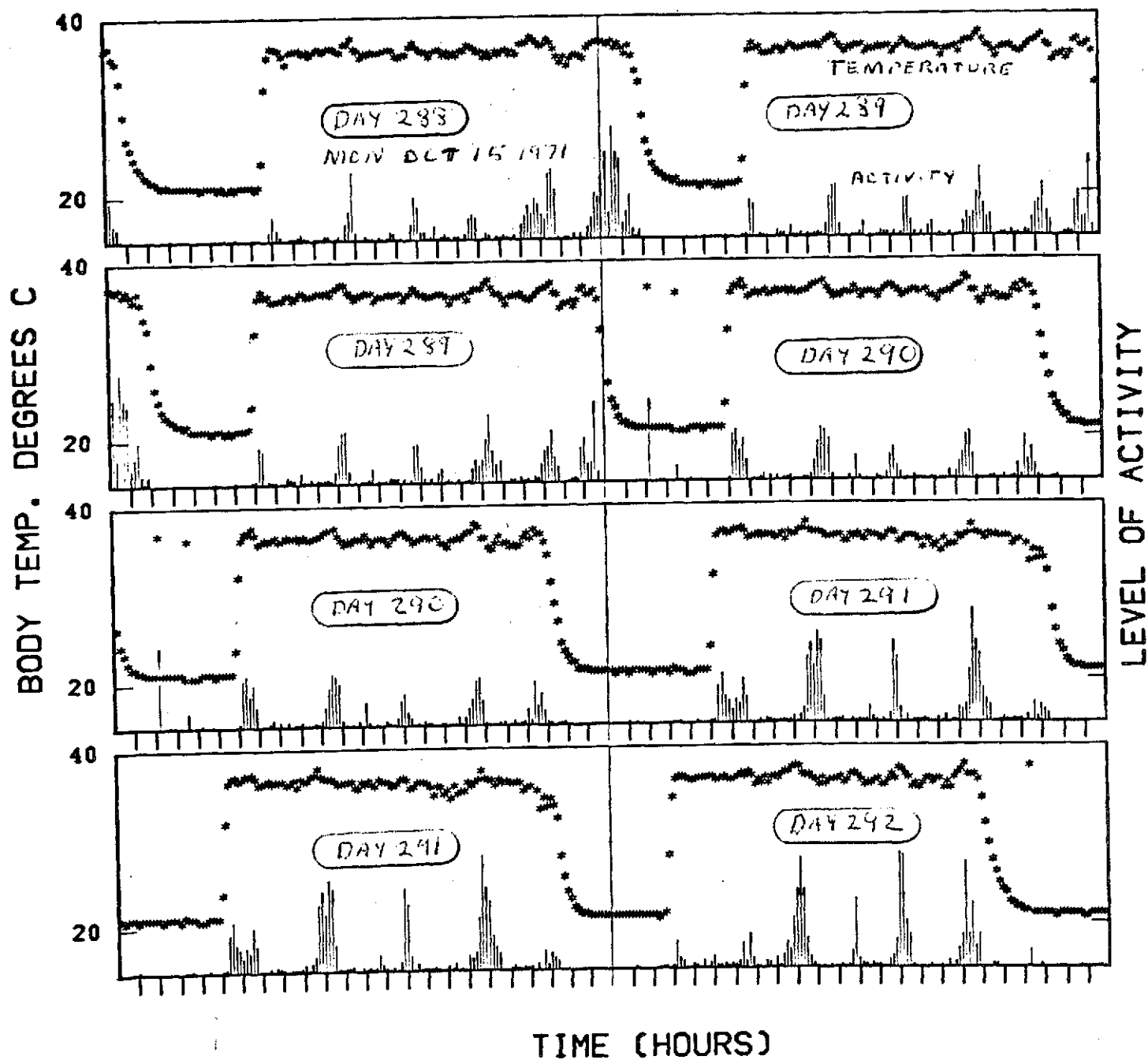


Figure 3.4-3



SYSTEM 2

CAGE 3

DAYS 288- 292

Figure 3.4-4

TYPICAL POCKET MOUSE TEMPERATURE AND ACTIVITY PLOT

The lithium hydroxide crystals in the canisters were found to be slightly encrusted and welded together, but with no apparent restriction to air flow, and an analysis of the LiOH beds indicated that only about 30% of the material had been converted to lithium carbonate, indicating that the canister can support a mission in excess of 50 days' duration. The moisture wicks were examined and found to have approximately .9 pounds of water in each. (A wick, tested to determine how much water it could hold, held 2.5 lb. of H₂O; thus the wick should be able to retain water for a mission twice the 21-day period.)

The vinegar gnat enclosures were opened and examined. The eclosed vinegar gnats were counted and compared with the final Circadian Data System count. The results are shown below:

Vinegar Gnat Final Eclosion Count

<u>System #1</u>	<u>House A</u>	<u>House B</u>	<u>House C</u>	<u>House D</u>
Final CDS Count	165	152*	175	164
Visual Count	171	173	176	173
<u>System #2</u>				
Final CDS Count	170	176	172	168
Visual Count	170	177	177	174

*One lamp off as explained by Paragraph 3.4.5 and Table 3.4-1.

The vinegar gnat enclosures had a strong "acid" smell when opened. (This odor has been observed after all eclosion cycles - including those run on control plates - and apparently is a product of the vinegar gnat development.)

The Potassium Hydroxide cups, originally loaded with 10 grams of solution, were found to be reduced to nominally 5 grams each, and the bases in each house were observed to contain water. This indicates that water migrates to the base of the enclosure because of the temperature gradient. Further discussion of the V.G. enclosure humidity is found in Appendix III.

3.4.5 Problems Encountered During Endurance Run

Several anomalies were encountered during the 21-day endurance run. Emergency corrections were made to compensate for those which affected CPE continued operation, and the 21-day runs on both experiments were completed with no interruption. The following table lists the problems encountered and describes those immediate measures taken to allow uninterrupted endurance testing plus the subsequent modifications to correct the causative faults.

Table 3.4-1

CPE SYSTEM PROBLEMS DURING ENDURANCE RUN

<u>Problem</u>	<u>Effect on Function/Temporary Fix</u>	<u>Cause & Corrective Action</u>
Lost Pocket Mouse Temperature Indicator from One Cage (Both Systems)	Lost only 1/6 PM data - no fix	Caused by dead battery in PM telemeter which had had battery installed for longer than should be. (Flight TIMS will have fresher batteries.)
Vinegar Gnat Eclosion Count Fluctuated during Eclosion Period (Both Systems)	Count variation did not appreciably deter eclosion period determination.	Filtering added. (See Paragraph 3.1.10.)
Second Set of Stimulus Lights Came on Two Minutes Late. (Both Systems)	Did not affect stimulus occurrence but the stimulus did not indicate by showing a high eclosion count indication.	Design change by EO 34205. Rewired the V.G. stimulus light programmer to allow the stimulus lights to occur 10 minutes apart. (See Paragraph 3.1.11)
GSE Dew Point Temperature Indication Error (System #2)	No effect on CPE function.	Thermistor found to have been damaged on installation - was replaced.
System #1 House #2 Shows Only 11 of 12 Scan Lamps and Eclosion Count is Low.	No effect in determining eclosion periods.	Scan lamp was found to have a short in the base and burned out its driver. Lamp and driver were replaced.
CPE #2 Glycol Pump Became Noisy.	Substitute pump was installed to avoid possibility of catastrophic failure. The test environment was not affected by change.	Pump bearing failed. (See para. 4.13 for further discussion.)
CPE #2 Dew Point Temperature Started to Raise Because Bypass Module Failed and Shunted the Coolant Flow Away from the Coldplate.	Disconnected the bypass module to incapacitate it and allow the coolant to flow the normal path.	The unencapsulated bypass module had collected condensate and shorted out. (This would not have happened in space; however the modules were encapsulated to avoid any possible moisture during ground use.)

3.5 CPE Refurbishment for Preparation for Shipment to KSC

Following the completion of the endurance testing, both CPE units were refurbished, including (1) clean-up after biology occupancy, (2) replacement of limited life items, and (3) correction of the faults encountered during the endurance test. Corrective measures for these faults are shown in Table 3.4-1. The units were then functionally checked per Functional Acceptance Test 67000701 and packaged for shipment to the launch site.

CPE Clean-Up

Clean-up of the CPE items was performed as follows:

<u>Items</u>	<u>Cleaning Method</u>
Pocket Mouse Cage Liners	The liners were removed from the cages and placed in a water alcnox (mild detergent used in hospitals) solution and left to soak overnight. All residue was then flushed with fresh water spray and by brushing with a nylon bristle brush. When small seeds were embedded in the pores of the liner, they were picked out with a sharp pointed tool. The liners were flushed with deionized/distilled water and dried before replacing in the cage assemblies.
Pocket Mouse ECS Gas Adsorption Canister	The canister was removed from the ECS, the lithium hydroxide poured out for analysis, and the carbon was thrown away. All elements of the canister, including the felt screens, were then washed in water and dried. (The washed filters were not used in the subsequent reassembly, however, as new felt filters were drawn from spares and used.)
Pocket Mouse Enclosure	The inside of the P.M. enclosure was cleaned merely by wiping out with a cloth dampened with distilled water. The outside of the CPE was wiped with an ethyl alcohol dampened cloth.
Vinegar Gnat Pupa Plates	The pupa plates were soaked for an hour in a boiling solution of water and alcnox. The plates were then brushed with a soft brush, then rinsed with distilled water and dried.

<u>Items</u>	<u>Cleaning Method</u>
Vinegar Gnat Enclosures	<p>The opened enclosures were cleaned by first vacuuming as many dead flies as possible out with a small tube connected to a shop vacuum cleaner. Additional flies were removed by blowing out the enclosures with a gas stream from dry clean bottled nitrogen.</p> <p>(Additional clean up of any potentially volatile substances within either the V.G. enclosures or P.M. enclosures was affected when the CPE packages were subjected to eight hours of vacuum exposure.)</p>

Limited Life Item Replacement

The pocket mouse heater control relays (40M374 96-23) on Relay Boards 67200144 were replaced because the cycling rate of the heater control results in a number of actuations that would approach the 100,000 rating of the relay after the equivalent of 60 days of continuous operation.

The pocket mouse air blowers were changed because the original CPE refurbishment plan had called for the replacement of all "rotating machinery." However, the blower is rated for 5000 hours of continuous operation and under the ideal temperature pressure and clean environment in which it operates, it should be expected to operate far beyond the conservative 5000 hours rating which allows for some adverse conditions.

New glycol pumps were installed. (Inspection of the removed pumps showed no indication of wear and degradation.) The glycol pump motors were removed and returned to the supplier for refurbishment and checkout. (One of the two motors had developed noisy bearings during the endurance test - see comments on page 47 and also refer to the discussion on motors/bearings following a subsequent failure at KSC, on page 66.)

3.6 CPE Packaging and Shipment

The two Circadian experiments were packed in crates surrounded by 4 inches of urethane foam for their shipment to Kennedy Space Center. All the Ground Support Equipment was rolled on their own wheels and placed on the air ride temperature-controlled van used to transport them. All items were padded and tied in conventional furniture-moving style. The equipment arrived in excellent condition as is indicated in the subsequent paragraphs.

4.0 KENNEDY SPACE CENTER OPERATIONS

The Kennedy Space Center operations from January 1973 to August 1973 included receiving and inspection, GSE validation, preinstallation tests, maintenance activities, space craft integration and vacuum chamber tests. When the CPE hardware was received at Kennedy Space Center (KSC), receiving inspection tests were performed on the CPE Ground Support Equipment and the two experiment packages; first to verify that no physical damage had been inflicted by shipment, and second to verify that the equipment functioned as required.

4.1 Ground Support Equipment Physical Condition

The Ground Support Equipment (GSE) for the Circadian Experiment was shipped without crating. The units were tied down on the air ride moving van and wrapped with mover's blankets to prevent damage. All GSE arrived at KSC with no damage due to shipment.

4.2 CPE Physical Appearance on Arrival at KSC

The two Circadian Periodicity Experiments were packed in wooden crates and padded with four inches of urethane foam for the air ride truck trip to KSC. When the crates were opened at KSC, it was apparent from the wear at pressure points in the packing foam, that the CPE packages had bounced up and down during transit. The only effect on the CPE due to the bouncing motion was a scuffing of the tie lines on the flow direction tags on the glycol line to the interface cold plate. The ties were replaced. No other physical damage was encountered.

4.3 Ground Support Equipment Validation

Before the GSE was used at KSC to check the functional performance of the CPE, it was powered to verify that the proper voltages and commands were provided to the CPE. The temperature indicators on the GSE were also calibrated at this time.

The Control and Monitor Console (C&M) was checked by connecting the processor test board to the C&M/CPE connector and verifying the voltage on each output pin as the C&M was programmed through all possible control modes. Simulated thermistor resistance values were provided to the C&M temperature monitor circuits to verify the calibration accuracy. KSC test procedure GNOR-500-01-002 was written to accomplish the C&M validation.

CPE Transportation Container Validation was performed per KSC TPS GNOR-100-01-002. The transporter test board (6750034) was connected to the transporter output connector and measurements were made to verify the proper interface voltages to the CPE. The temperature indicating circuits in the transporter were then calibrated.

4.4 CPE Pre-Installation Test

The pre-installation tests (PIT) were performed on the CPE at Kennedy Space Center prior to testing with the Apollo Command Service Module to assure that the CPE were functioning as required. When the PIT was attempted on CPE #2 (during January 1973), a failure was encountered in the Circadian Data System which resulted in Discrepancy Record PM/VG-NOR-002-DR0001. (Investigation revealed an open weld in CDS welded module 67400108. The weld was near the surface of the encapsulated module and repair was made by removing encapsulant to expose the weld, rewelding, and reencapsulating.)

Pre-installation testing was performed on CPE #1 (PM/VG-NOR-001-002) to replace CPE #2 for the early integrated system testing. The PIT consisted of operating the CPE through all possible functional modes with the Control and Monitor Unit and the transportation container, and included the conduction of the functional performance TP67000701.

The coolant pump from CPE #2 had to be transferred to CPE #1 before the PIT could be performed because the pump from CPE #1 was being refurbished and no spare was available. With the coolant pump replaced, CPE #1 passed the PIT with no discrepancies and was made available for installation on the Apollo Command Service Module for altitude testing.

Further PIT for CPE #2 was deferred until the 67400108 module was repaired and a refurbished coolant pump was available. The PIT (PM/VG-NOR-02-008) was then conducted with no further problems, and CPE #2 was available for the integrated test and launch rehearsal.

4.5 Altitude Tests (CPE #1)

The Circadian Experiment #1 was installed in CSM #117 within the altitude chamber. The installation and transfer was made from the CPE transporter in simulation of launch handling, and the transporter was used to provide cooling to the CPE cold plate during sea level checkout of the CPE. Operation of the CPE was normal and within specification during the sea level check.

Two periods of altitude testing were conducted; the first being unmanned, and the second manned (without and with astronauts). During the unmanned altitude test, the CPE performed within specification requirements; however, the Pocket Mouse oxygen storage tank pressure was observed to be decreasing at a rate of approximately 10 PSI per hour. (Later investigation disclosed that a leak existed in the A-N fitting on the low pressure oxygen regulator. The leak was corrected by installing a soft aluminum crush seal in the fitting.)

During the manned altitude tests, the CPE Data System developed a fault, which caused the loss of real-time data. The main memory data were still available, and all other CPE functions were normal, so this discrepancy did not void the altitude test results. (Further investigation of the failure revealed that a data system mini-memory module 67400218 was not functioning properly, and the fault was found to lie with a COSMOS CD4006 shift register which would not strobe data through the register. No specific cause for the defect could be discovered in the component when it was dissected. The Circadian Data System was repaired by replacement of the welded module.)

When the CPE cold plate was removed from the spacecraft cold plate following the altitude tests, the thermal interface footprint (as indicated by the thermal grease transfer) was less than 50%, and North American Rockwell initiated further investigation to increase the contact area. After modi-

fication of the trowel used to apply the grease, additional trials in mating resulted in approximately 70% surface contact between the plates. The procedure for grease application and plate attachment is contained in Rockwell procedure TCK-K-10004. (A subsequent complication in cold plate mating was encountered during launch vehicle installation rehearsal when the CPE cold plate was chilled with circulating ice water. This caused the plate to collect a film of water which could not be effectively wiped off and also cooled the thermal transfer grease on the service module plate on initial contact, thus causing an increase in grease viscosity, which reduced the spread and surface contact as the plates were bolted together. This problem was resolved by temporarily turning off the CPE/ground support coolant flow to let the plate warm so that it could be dried and bolted to the service module plate. This step was also included in the Rockwell installation procedure.)

4.6 Integrated Test and Simulated Installation for Launch (Launch Rehearsal)

CPE #2 was transported to and installed on the launch vehicle on the launch pad with the CPE operating in simulation of a launch installation sequence. The CPE, with simulated biology installed, was mounted on the transporter at the Circadian Laboratory. Power and coolant were provided from the transporter while the CPE was moved to the gantry and installed on the Service Module. (The CPE voltage supplied from the storage batteries dropped to below 24 volts during the two hours the experiment was drawing power from those batteries. Subsequently, the transporter was modified as described in Para. 3.3.6 to hold the voltage up at a higher level for a longer period.)

The CPE installation "rehearsal" was very slow and tedious, requiring over 24 hours to complete. Progress was delayed by the following problems:

1. Electrical power connector identified for use by CPE was occupied by other equipment, which needed to be changed over.
2. Electrical grounding terminal did not accommodate the CPE ground cable and had to be modified.

3. The facility gaseous nitrogen outlet, intended for CPE purge, was occupied and needed to be cleared.
4. Part of the experiment lifting fixture had been misplaced and could not be found for several hours.
5. The attach hardware was not available at the gantry and needed to be obtained.
6. Adhesive on the shims on the mount holes in the CPE, which interfered with the attach bolts, needed to be reamed out. This required documentation which required about six signatures, which took several hours of frantic effort to obtain.
7. The spacecraft cold plate had not been greased in advance, and problems were encountered coupling the wet cold plate of the CPE.
8. MIL spec naptha, which was required by the installation specification, was not available at KSC. (Procurement activities were proceeding before a deviation was written to allow use of the grade which was available at the gantry.)
9. Available torque wrenches would not fit in the space between the CPE and the interface cold plate. Smaller torque wrenches needed to be obtained.
10. Torquing of the cold plate attach bolts required several hours because the procedure called for first determining the "breaking" torque of the locking nuts, then tightening the bolts around the plate in very small increments above the measured breaking torques. This necessitated resetting the torque wrench for each bolt in turn to compensate for the different initial torque in the locking nuts.
11. One cold plate lock nut had less than the specified locking torque. Change out of the nut plate was contemplated until a deviation was written to allow installation as was.

The above problems, coupled with the necessity of having the authorized technicians to perform operations, authorized inspectors to witness the work, authorized NASA Quality Assurance Representatives to witness the witness and authorized contractor and NASA engineers to authorize procedure modifications, made of the installation rehearsal a recital in tedium. However, the functioning of the CPE during integrated tests with the launch vehicle were flawless, and the discoveries made during the installation heralded a quick and faultless installation for the actual launch since every possible hold-up had been encountered and resolved.

4.7 Launch Preparation and Biology Loading

The Circadian Periodicity Experiments and the Ground Support Equipment (GSE) were prepared for the launch in accordance with Test Procedures TP67000705, (CPE Preflight Preparation and Checkout Procedure) and TP6700706 (CPE Ground Support Equipment Preflight Preparation).

The GSE preparation included (1) a check to verify that all supplies and equipment required were available, (2) equipment calibration verification, and (3) battery servicing and charging. Functional performance of the GSE was assured by checkout with the CPE.

The CPE prelaunch preparation required approximately one month preceding the launch. The schedule of preparation and biology loading on page 56 shows the actual dates on which the events were accomplished. The procedures used to control the preparation are retained with the data packages for the experiments, and copies of these procedures are included with Appendix IV to this report. No major problems were encountered during the preparation. The lithium hydroxide conditioning created a surprise and required more time than had been anticipated (a discussion of this activity is included in Appendix III in the description of the pocket mouse humidity control).

The launch preparation activities flowed very smoothly, including the actual day of biology loading, which was one long, tiring day for the twelve participants. A major difference between the biology loading sequence at Kennedy Space Center and the loading for the endurance test earlier in California, was the gas sampling activity which was not done earlier. Two sample bottles of gas were taken from each vinegar gnat enclosure. While this required more time than was expected, the loading was completed within a ten-hour period with no problems encountered. Analysis of the initial gas samples discovered no undesirable contaminants.

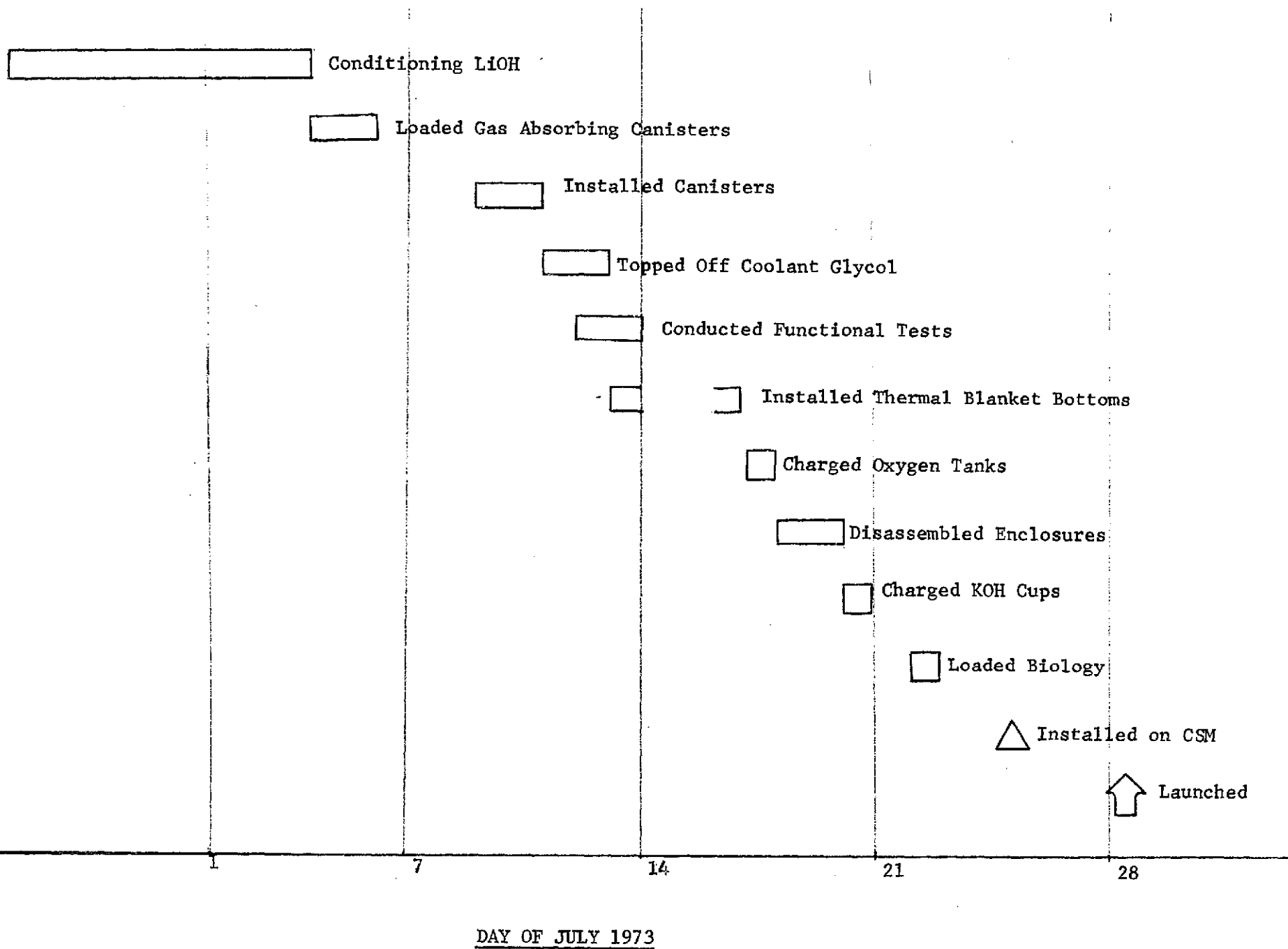


Figure 4.7-1 - CPE Launch Preparation and Biology Loading Schedule

4.8 Selection of Flight Unit

When both CPE were loaded with biology, the principal investigators considered them to be essentially equal, and no strong preference was voiced as to which experiment should fly. Both CP experiments operated in the laboratory for two days and the data from them scrutinized. All functions were proper and within specification, and the pocket mice in both systems appeared to be continuing their daily routines without interruption due to the CPE loading operations. One consideration for experiment selection was the fact that the coolant pump on system #1 appeared to be making a slight noise; as a result CPE #2 was elected for installation on the launch vehicle.

4.9 Spacecraft Installation

A time period of 16 hours was allowed for the installation of the CPE on the CSM #117. The CPE #2 was installed on the transportation container and preparations were made for the move in accordance with TP 67000705. The installation sequence proceeded with no holdup; as follows:

- The cooling loop was transferred to the transporter ice/water system.
- Power was transferred to the transporter battery.
- A final data dump was taken from the CPE and recorded by the control and monitor unit. Then the monitor cable was removed and the CPE thermal blanket closure was completed and the transporter protective cover installed.
- The unit was trucked to the gantry. (This operation required 45 minutes.) Temperatures monitored on the transporter panel remained precisely correct.
- The transporter was connected to gantry power and nitrogen purge.
- The CPE was installed in the CSM and bolted down within four hours from leaving the laboratory.

- The transporter coolant flow was turned off for 55 minutes to allow the CPE cold plate to warm and remain warm while the plate was attached to the CSM cold plate. (The CPE temperatures did not change during the coolant off period except for the dew point temperature which increased one degree centigrade.)
- The CPE was powered from the CSM nine hours after the lab exit and a normal data dump was made through the Kennedy ACE data link. All parameters were normal.
- The transporter coolant loop was purged and disconnected, and the cooling function transferred to the CSM glycol loop. The CPE cold plate quick-disconnect fittings were removed to allow the GSE portion of the CPE cold plate to vent.

This completed the installation and transfer of the CPE to the spacecraft.

4.10 Flight Performance (CPE #2)

The Skylab III launch occurred on 28 July 1973, three days after the installation of the CPE on the CSM #117. During the installation and the three days on the ground, the CPE functioned flawlessly with all temperatures and pressures being maintained within the close tolerance limits. The vinegar gnats were maintained at $5.0 \pm 0.1^{\circ}\text{C}$. The pocket mouse cage temperatures were maintained at $20 \pm 0.1^{\circ}\text{C}$. The pocket mouse enclosure pressure was controlled 715 ± 5 mm and the vinegar gnat enclosure pressure remained at 735 ± 5 mm. All parameters were normal and all data were recorded through the Kennedy A.C.E. data link. A copy of the data listing is retained in Appendix IV to this report.

The launch of the Skylab II occurred at nominally 1110 GMT 28 July 1973, and CPE data frame TCG #67 was recorded approximately 20 seconds later during the acceleration phase. The data were all normal. Ten minutes later, two mice that had been in torpor showed body temperatures that were increasing toward 36°C , and at 20 and 30 minutes after launch all mice showed greatly increased activities. (This minimal description of biology reaction is given to show how the CPE hardware was functioning; discussions of the pocket mouse "performance" is to be found in the Principal Investigator's Progress Reports on Contract NAS-2-5038, NRTC-68-53-21, and NRTC-68-53-22.)

The CPE #2 continued to function completely normal with all data being retrieved through the telemetry down link for 31 hours and 48 minutes from launch.

The vinegar gnat experiment had been initiated and the pupa plate temperatures raised to 20°C . The stimulus lights had lighted at the proper time. The pressures in the vinegar gnat enclosures were retained in space. At the time of launch the V.G. enclosure pressure indications showed a reduction of approximately 5 millimeters, and at the time of initiation an increase averaging 15 mm was observed. The pocket mouse enclosure pressure was controlling at 710 ± 5 mm and all parameters were encouragingly correct

until at GMT 18:58:30 a high current spike approximately 40 amps above the nominal line current of 24 amps occurred, and 3 seconds later the Circadian experiment data went dead (all zeros). The current spiking continued for a total period of four minutes, then dropped back to the nominally expected line level minus the CPE current of approximately 4 amps. The power switches to the CPE S071 and S072 experiments were turned off, then on again with no change being indicated in the current being drawn. After several hours with the power on to the CPE, there were no further data, and it was concluded that the CPE was non-operative, and the power switches were turned off.

The CPE, being mounted on the service module, was not retrievable for failure analysis; however, an extensive analysis was performed by an AMES Failure Review Board using spare components and components removed from the ground test CPE #1. The Failure Board concluded that the coolant pump power inverter (American Electronics SL6-4) was most probably the primary failure cause. Details of the FRB findings are to be reported by an Ames letter (date and number not known).

4.11 Ground Control Test on CPE #1

Following the selection of CPE #2 as the flight experiment, CPE #1 was maintained in operation in the Circadian laboratory at Kennedy Space Center and was monitored by the Control and Monitor Console. Even though the flight unit functioned for only 30 hours in space, the ground control test was continued for a total of 28 days from the day of biology loading for the purpose of establishing good baseline data in the event that a decision might be made later to fly the CPE #1 in a subsequent mission.

The pump motor which was noisy during the first few days after loading became noisier, and a decision was made to replace the motor with the spare. With the motor changed, the noise was eliminated. (The replacement pump, however, developed a slight noise by the end of the endurance period.) Additional discussion of the motor bearing failure is contained in paragraph 4.13.

The further performance of CPE #1 during the ground control test period was flawless. The contained Pocket Mice and Vinegar Gnats were sustained in good condition and exhibited very definite circadian rhythms.

The data were processed and presented to the principal investigators for analysis and copies of the data prints are maintained as part of Appendix IV to this report.

The experiment hardware was monitored round the clock during the ground control test. No emergencies or malfunctions occurred. An intentional facility power shutdown was encountered when the Kennedy electrical maintenance crew shut all power off to check and clean electrical equipment. The CPE operation was not affected as the C & M batteries sustained operation while the power to the C&M was transferred temporarily to an alternate power source, then back to normal power.

The oxygen consumed by the mice during the 28 day test reduced the supply tank pressure from 2000 psi to 1300 psi. The plot of oxygen use is shown on page 48 along with the oxygen use plots made during earlier endurance tests.

4.12 CPE Post Test Gas Analysis

Before shutting down the CPE gas samples were taken from each Vinegar Gnat enclosure and from the Pocket Mouse enclosure. In the V.G. samples, there was found to be no undesirable contaminants, but in the sample

taken from the pocket mouse house, carbon monoxide (CO) of a concentration exceeding 180 parts per million was found. A second gas sample was drawn from the pocket mouse enclosure, and a repeat test was made specifically to check for CO. The analysis report, included as page 63, shows 240 parts per million when measured in an infrared spectrophotometric analyzer. (The analyst was confident that the IR analysis more accurately measured carbon monoxide than the gas chromatography technique.)

The Merick Index of Chemicals and Drugs shows the maximum allowable concentration (MAC) of carbon monoxide for humans as:

MAC	Time and Effect
100 Parts/Million	• 8 hours = distress
400 Parts/Million	• 1 hour = distress
1000 Parts/Million	• 1 hour may cause unconsciousness
1000 PPM	• 4 hours may cause death

The principal investigator indicated that the Paraganathus Mouse's tolerance to carbon dioxide is not known, and the concentration encountered in the CPE did not seem to affect the circadian responses; however, a search was instituted for the CO source. No CO source could be identified until suspicion was cast on the charcoal placed in the gas canister for the purpose of absorbing methane and ammonia and other body-produced odors and noxious gases. Analysis of the gas in the containers holding the two types of charcoal (CA and AC) used in the canister is included as pages 64 and 65. It shows concentrations of 400 and 210 PPM CO, thus confirming that the charcoal was a source for carbon monoxide when used in a small closed system.

Mr. Barneby of Barneby-Cheny, supplier of the charcoal used, was consulted about the CO found in the charcoal. He stated that coconut shells are treated with very high temperature steam to make the activated charcoal and that in the process some carbon monoxide and some carbon dioxide are created. Residual CO would be expected in a small, closed volume with a relatively large charge of charcoal (approximately one pound of activated charcoal per two cubic feet volume in the CPE). Mr. Barneby suggested the CO residue could probably be reduced to a negligible level by baking in a vacuum. He suggested 200°C for 24 hours with a vacuum pressure below 10^{-5} Bar.

Figure 4.12-1
GAS ANALYSIS REPORT S071/072 EXPERIMENT

Sample Bottle # 001 Pressure 1 atm Source P/M House

Date, Time Rec'd 0900 8-20-73 Reported _____

1. Major Constituents % By Volume:

Nitrogen _____ Oxygen _____ CO₂ _____ Helium _____ Argon _____

2. Total Hydrocarbons _____ ppm

(Includes)

Acetone	_____	Freon 113	_____	Chloroform	_____
Isopropyl Alcohol	_____	Freon 114	_____	Methylene Chloride	_____
Benzene	_____	Methanol	_____	Dioxane	_____
MEK	_____	Ethanol	_____	Ethyl Acetate	_____
Freon 11	_____	m-Butanol	_____	2 - Methyl Butanone	_____
Freon 12	_____	Ethylene Glycol	_____	Methyl Chloroform	_____

3. Total Hydrocarbons: Aliphatics, Less CH₄ _____ mg/M³
Aromatics, Less Benzene _____ mg/M³

4. Low Limit Constituents in ppm

1, 1 Dichloroethylene	_____	Monochloroacetylene	_____	Trichloroethylene	_____
trans - Dichloroethylene	_____	Dichloroacetylene	_____	Formaldehyde	_____
cis - Dichloroethylene	_____	Carbonyl Fluoride	_____	Phosgene	_____

5. Ammonia _____ ppm 6. H₂S _____ ppm 7. SO₂ _____ ppm 8. CO 240 ppm

9. Other contaminants found:

Analysis for CO only - Confirmed presence of Carbon
monoxide by Infrared Spectrophotometer.

GAS ANALYSIS REPORT S071/072 EXPERIMENT

Sample Bottle # 007 Pressure 1 atm Source Type CA Charcoal Canister

Date, Time Rec'd 0900 8-22-77 Reported _____

1. Major Constituents % By Volume:

Nitrogen _____ Oxygen _____ CO₂ _____ Helium _____ Argon _____

2. Total Hydrocarbons: _____ ppm

(Includes)

Acetone	_____	Freon 113	_____	Chloroform	_____
Isopropyl Alcohol	_____	Freon 114	_____	Methylene Chloride	_____
Benzene	_____	Methanol	_____	Dioxane	_____
MEK	_____	Ethanol	_____	Ethyl Acetate	_____
Freon 11	_____	n-Butanol	_____	2 - Methyl Butanone	_____
Freon 12	_____	Ethylene Glycol	_____	Methyl Chloroform	_____

3. Total Hydrocarbons: Aliphatics, Less CH₄ _____ mg/M³
 Aromatics, Less Benzene _____ mg/M³

4. Low Limit Constituents in ppm

1, 1 Dichloroethylene	_____	Monochloroacetylene	_____	Trichloroethylene	_____
trans - Dichloroethylene	_____	Dichloroacetylene	_____	Formaldehyde	_____
cis - Dichloroethylene	_____	Carbonyl Fluoride	_____	Phosgene	_____

5. Ammonia _____ ppm 6. H₂S _____ ppm 7. SO₂ _____ ppm 8. CO 400 ppm

9. Other contaminants found:

Analysis by GC and IR

GAS ANALYSIS REPORT S071/072 EXPERIMENT

Sample Bottle # 001 Pressure 1 atm Source Type A C
Charcoal
Cannister

Date, Time Rec'd 0900 8-22-73 Reported _____

1. Major Constituents % By Volume:

Nitrogen _____ Oxygen _____ CO₂ _____ Helium _____ Argon _____

2. Total Hydrocarbons _____ ppm

(Includes)

Acetone _____	Freon 113 _____	Chloroform _____
Isopropyl Alcohol _____	Freon 114 _____	Methylene Chloride _____
Benzene _____	Methanol _____	Dioxane _____
MEK _____	Ethanol _____	Ethyl Acetate _____
Freon 11 _____	m-Butanol _____	2 - Methyl Butanone _____
Freon 12 _____	Ethylene Glycol _____	Methyl Chloroform _____

3. Total Hydrocarbons: Aliphatics, Less CH₄ _____ mg/M³
 Aromatics, Less Benzene _____ mg/M³

4. Low Limit Constituents in ppm

1, 1 Dichloroethylene _____	Monochloroacetylene _____	Trichloroethylene _____
trans - Dichloroethylene _____	Dichloroacetylene _____	Formaldehyde _____
cis - Dichloroethylene _____	Carbonyl Fluoride _____	Phosgene _____

5. Ammonia _____ ppm 6. H₂S _____ ppm 7. SO₂ _____ ppm 8. CO 210 ppm

9. Other contaminants found:

Analysis by GC and IR

4.13 Pump Motor Bearing Failures

The pump motor which failed in July 1973 on CPE #1 due to a noisy bearing, was the same motor which had failed in October 1972 during the endurance testing of CPE #2. Further investigation showed the probable cause of the failure to be an eccentric magnetic coupler (micropump 8383). The sketch below shows the configuration of the coupler and indicates that the female coupler was found to be running .007 inch eccentric. This caused high inertial loads on the bearing. The eccentricity may also have caused the coupler to rub against the stainless steel seal cup (scuff marks were observed on the seal and coupler), adding to the bearing loads. It is felt that this was the cause of the bearings failing both times in this same pump assembly. The spare pump, which replaced the above pump on CPE #1, and appeared to have a slight bearing noise at the end of the ground test period, had no coupler eccentricity. This further suggests bearing weakness. Replacement of the pump motor is recommended.

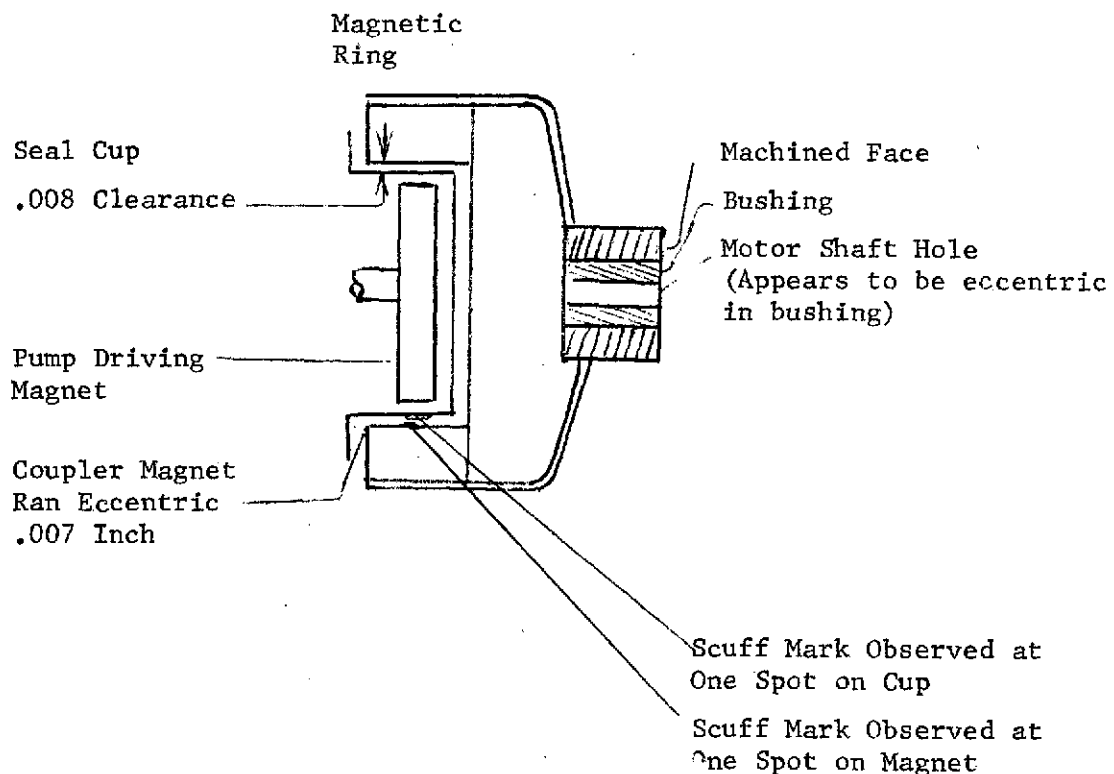


Figure 4.13-1
Coolant Pump Magnetic Coupler Assembly

4.14 Examination of CPE #1 After the Ground Control Test

When the pocket mouse enclosure was opened, all six mice were found in good condition. The cages were clean with approximately 50% of the food left. A photograph of the cages after the 28 day ground control run is shown on page 68, Figure IV-5.

The environmental control was opened and the assembly with the wet wick was weighed. Then the wick was dried out and the assembly was re-weighed. The difference in weight indicated that the wick had contained approximately 0.7 lb. of water. The gas absorption canister weighed 8.63 pounds compared to 8.49 when it was installed, indicating the lithium hydroxide had collected approximately .14 lb. H_2O .

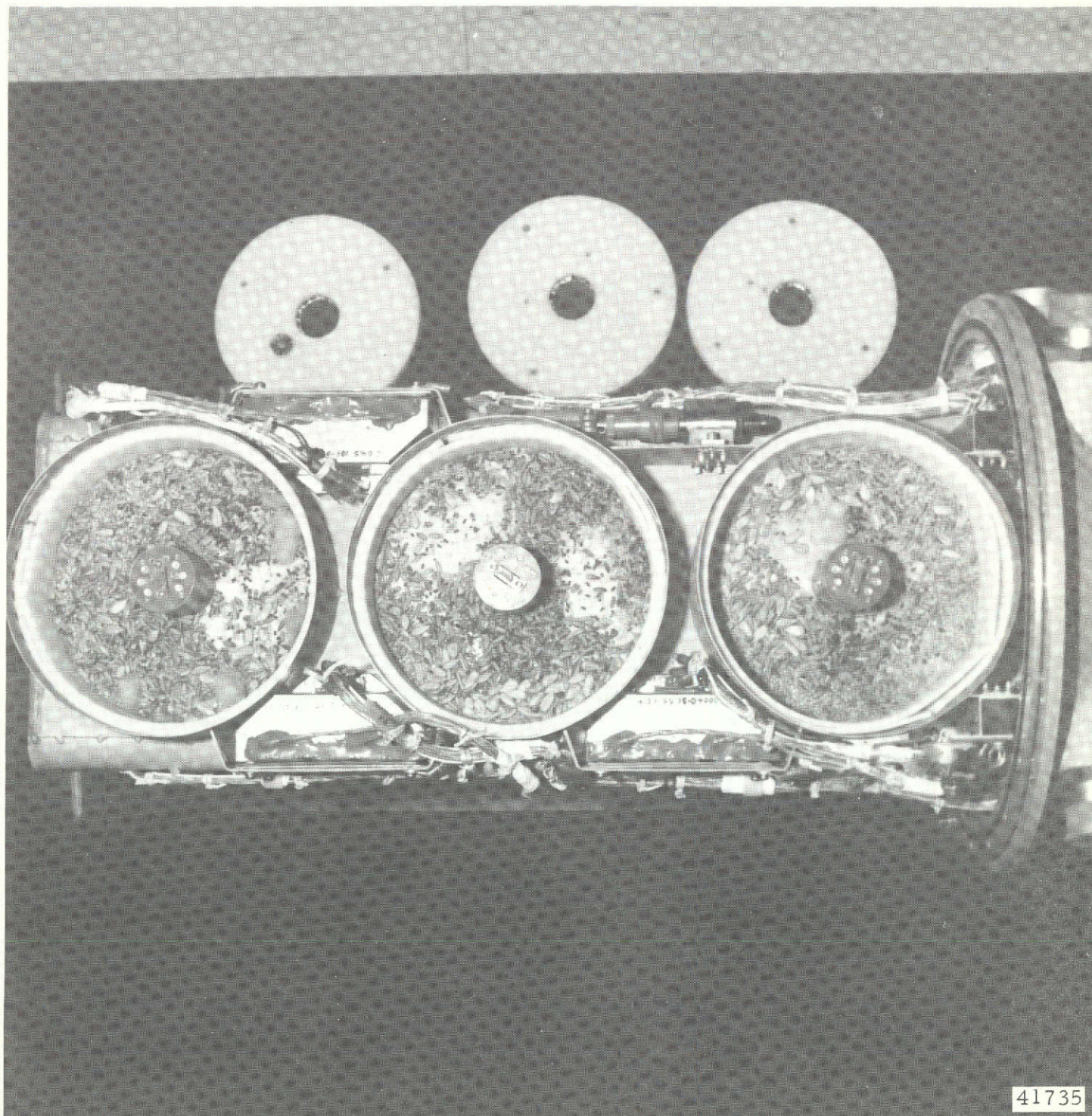
The lithium hydroxide, when removed from the canister, appeared to be adequately porous to allow air to flow freely through the bed though the crystals were slightly crusted and welded together.

The pupa enclosures, when opened, were clean. The same acid smell, which had been observed after previous runs, was noticed. The odor had been even stronger from the pupae on the control plates, which were laying directly on moisture-saturated paper towels. The pupa plates were examined to compare the visual eclosion count to the Circadian Data System count. The following table shows the close correlation between visual and CDS counts:

<u>V. G. Plate #</u>	<u>Visual Eclosion Count</u>	<u>CDS Final Count</u>
A	170	170
B	171	168
C	161	161
D	170	169

A photograph of the removed Plate C is shown on page 69, Figure IV-6.

The potassium hydroxide cups were weighed at the completion of the run, and each had approximately 5 grams of KOH solution, as expected and described in Appendix III.



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FIGURE IV - 5 POCKET MOUSE CAGES FOLLOWING GROUND CONTROL TEST

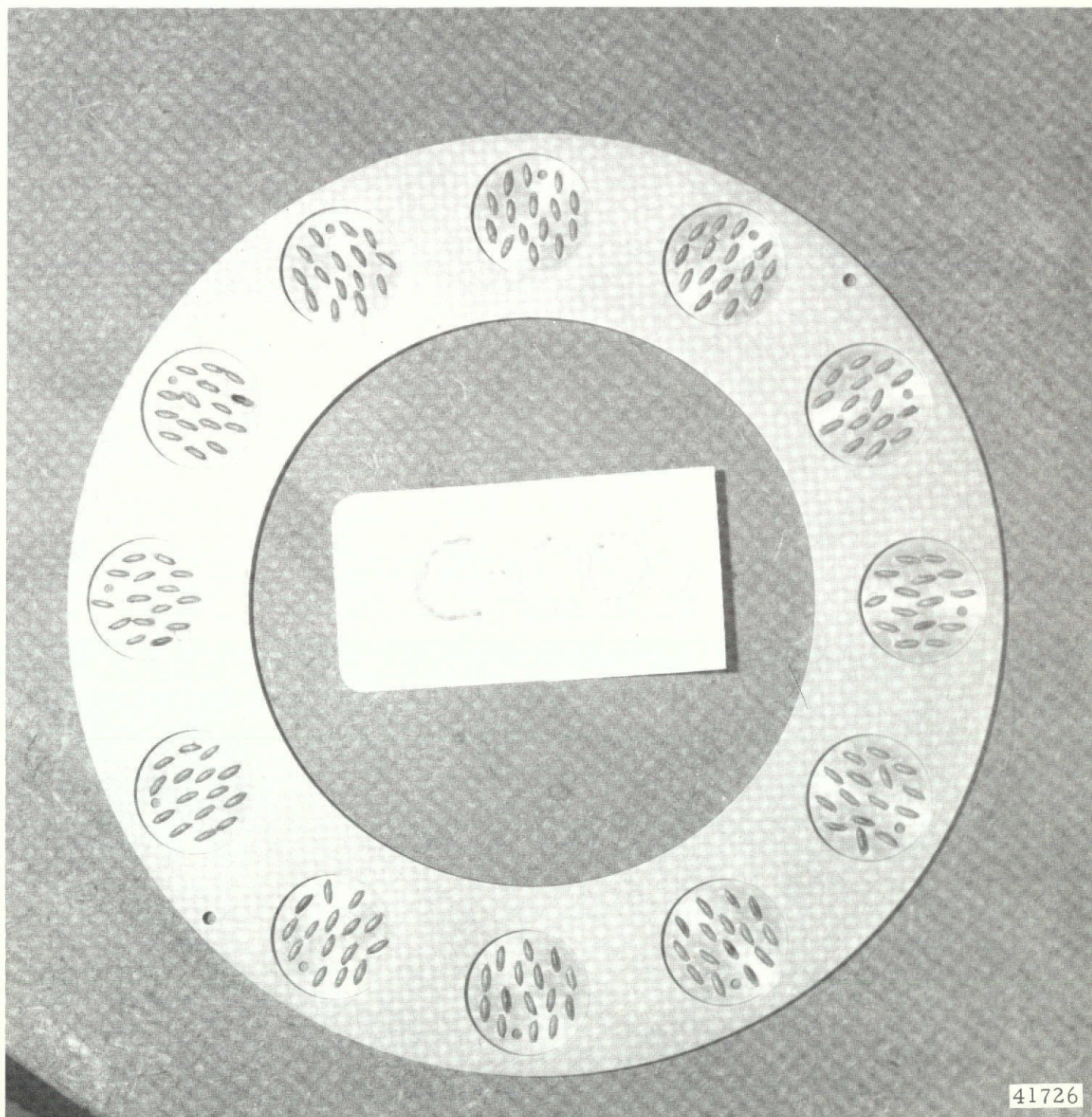


FIGURE IV - 6 VINEGAR GNAT PUPA PLATE AFTER GROUND CONTROL TEST

5.0 STORAGE CONFIGURATION AND REACTIVATION REQUIREMENTS

Configuration of the CPE #1 and Ground Support Equipment, following preparation for shipment and storage at Ames Research Center, and the steps required to ready the equipment for a subsequent use are defined in this section

5.1 C.P.E.

5.1.1 Storage Preparation (CPE S/N 001)

The preparation for storage as performed at KSC during August 1973 comprised the following operations:

- The P.M. cages were opened up and the cages, along with their liners, were washed with a mild detergent and rinsed with deionized water. They were then reinstalled in the CPE.
- The E.C.S. was opened and the LiOH and charcoal were removed. The wick was dried. The ECS components were scrubbed to remove any caustic residue, washed and flushed with deionized water, and finally replaced in the CPE (minus the LiOH and charcoal).
- The E.C.S. and P.M. assemblies were GN_2 purged and then sealed.
- The V.G. houses were opened and cleaned. The KOH cups were thoroughly cleaned, dried and reinstalled in the V.G. houses.
- The glycol lines, tank and coldplate were drained, flushed with deionized water, purged with GN_2 and then sealed.
- Protective aluminum covers were installed on both sides of the interface coldplate.
- The oxygen supply tank was bled to a pressure of 250 ± 50 psi.
- The thermal blanket was stored in its protective suitcase.
- All exposed connectors and fittings were capped.
- The CPE was installed on the transportation container and covered with a plastic dust cover.
- During October 1973 the glycol pump and its associated inverter were removed from the CPE for failure analysis purposes.

5.1.2 Reactivation Requirements (CPE)

The reactivation of the CPE for future operation should include the following:

- Install a new glycol pump and power unit.
- Charge the glycol system.
- Remove the power supply from the electronics coldplate, clean off the existing thermal grease and apply new grease.
- The heater relay (67200144) is approaching its life expectancy and should be replaced prior to any long-term test or flight.
- Install P.M. simulators if required.
- Install V.G. simulators if required.
- Install the thermal blanket if required.

Upon completion of the system reactivation, the test engineer shall determine what electrical test should be performed. At a minimum this should include the Functional Test Procedure TP67000701.

Before biology can be loaded and sustained, new materials will need to be obtained and conditioned for the pocket mouse environmental control system. Several cans of anhydrous lithium hydroxide are available, and they probably will be suitable for use if they have been kept sealed. Several bags of charcoal have been retained with the CPE supplies. However, the carbon monoxide content encountered in the charcoal and discussed in paragraph 4.12 suggests that some steps should be taken to obtain or create CO-free charcoal.

If a biology test is to be run, then the following operations are required:

- Disassemble the V.G. houses to allow the peltier coolers to be cleaned and regreased.
- Load the KOH cups and reassemble the V.G. houses.
- Clean the bottom of the V.G. houses, apply thermal grease and assemble on the V.G. coldplate.
- Install a new V.G. timing plug if required.
- Disassemble the E.C.S. Perform the appropriate conditioning on the LiOH, charcoal and wick. Install these in the E.C.S. and reassemble into the CPE.
- Charge the O₂ supply tank.

5.2 Control & Monitor Console (C&M)

5.2.1 Storage Preparation

The storage preparation performed on the C&M during August 1973 comprised two things. First, the glycol system was drained, flushed out with deionized water, and then purged with GN_2 . Second, the battery fuse inside the center console door was removed, bagged, and taped to the inside of the door. The batteries were fully charged prior to this occurrence.

5.2.2 Reactivation Requirements

The reactivation of the C&M for future operation should include the following:

- Remove the hp Digital Printer and have it serviced. There is presently a slippage in the paper drive mechanism.
- Remove the hp Coupler and have it serviced. Its clock sometimes counts erratically in the "unit-seconds" digit, and sometimes stops counting entirely.
- Charge the glycol system.
- Install the battery fuse and check the battery water level. Apply power to Bay 2, Power supply #1 and note two criteria. First, the supply current should exceed 2 amps for greater than 2 seconds. Second, note the voltage on the power supply. It must raise above 20 volts within 30 minutes from the time the supply is turned on.
- Two data processing problems have been observed and are described in paragraph 5.2.3. These problems should be resolved if the magnetic tape recording system is planned to be used. If not, they may be disregarded.

Upon completion of the system reactivation, an electrical test, similar to TPS GNOR-500-01-002 run at KSC, should be performed.

5.2.3 C & M Data Processing Problems

Two problems were observed in the data processing associated with the C&M console and are described below. Both problems occurred during the ground biology control test associated with the Skylab III experiment and troubleshooting was very limited because of the conflict between troubleshooting and the running of the test.

First Problem

An intermittent condition developed that resulted in the binary "ORing" of the 64 bit and the 128 bit of each data word. Thus, any data word that had either of those bits in a "1" state would be recorded as though they had both bits in the "1" state. This occurred on both the paper tape printouts and the magnetic tape, but would not occur when the C&M was operated in its "Memory Bypass" mode.

Preliminary investigation suggested that a short between pins 11 and 13 of I.C. Inverter 847-9 (reference schematic 67500524 sheet 1 zone 18G) in the C&M Data Processor Panel could cause the condition. This I.C. was replaced but no change in performance occurred.

A connector "extender" card was inserted in series with the J2 connector to the memory and the problem subsided. No further troubleshooting was attempted at that point because it was considered more important to have good data from the test than to run the risk of agitating the problem by continued troubleshooting.

A suggested starting point for a troubleshooting procedure would be as follows (this assumes the problem is present; if it isn't, then it can be aggravated by removing the extender card and also wiggling the various connectors). Simultaneously observe the waveforms at J02J-9 and J02J-10 (reference schematic 67500524 sheet 1, zone 23H). If they are identical (identical waveforms indicate the problem is present at that point), then return to a "Memory Bypass" mode and note the paper tape printouts. They should now be normal. If this is the case, then the problem is either in the J02J contacts or in the input circuitry to the GSE memory. If the waveforms at J02J-9 and 10 were not identical, then observe the

waveforms at J02J-12 and 14. If these waveforms are identical, then the problem is either in the GSE memory, the J02J connector, the wiring to the 847 and 848 inverters, or the inverters themselves. If the waveforms are not identical, then look at the waveforms at J02J-11 and 13. Identical waveforms indicate the problem is in the 847 and 848 inverters. If the foregoing procedure does not isolate the problem, then the original observation that the system never fails in a "Memory Bypass" mode was coincidental and a different troubleshooting procedure will be needed.

Second Problem

This problem was present during the entire test but was not recognized until the computer-processed mag tape data were analyzed. (Data on the digital paper printouts were correct in all cases.) The problem concerned only certain words in the 34 word data frames; namely words #5, 10, 15, 20, 25, 30 and 35. There was an apparent random dropping of some of the data bits for these words (e.g., a temperature reading might be 16.5 degrees instead of 20). There was approximately a 25% occurrence of the error on data words 5, 10, 15, 20, 25 and 30. The error rate on word #35 was considerably higher and indeed was 100% after TCG 6 of 5 August, at which time the data word always dropped its 100 bit and sometimes other bits besides. It was noted that while word #35 was consistently dropping its 100 bit, words 5, 10, etc., were maintaining their 100 bit. No troubleshooting was performed on the system.

The problem appears to be occurring in the GSE Data Processor after the binary to BCD conversion. This indicates that the data drop-outs occur either in the loading of the data registers FF931 through FF940 (reference schematic 67500525 sheet 2 zone 36B through 40B) or the buffers Q1 through Q11 (sheet 5 zone 102C through 107C) with the former being the most suspect. The registers are loaded by first opening the enable gates G931 through G940 and then clocking the FF931 through FF940 registers. Both the enabling signals and the clock signals are generated in a "divide by five" counter (FF840 through FF842, sheet 1, zone 30E). The characteristics of this counter are such that every fifth output pulse is slightly different from the preceding four and also that every 35th pulse is unique. These pulses are then time phased through the delay circuits associated with C810, C812, C813 and C828 (zone 26C).

Troubleshooting of this problem is made difficult because of the time lag between operation of the system and the time at which the mag tape is processed. One solution to this problem is to modify the hp 2547A Coupler to accept a typewriter output and thus have real time feedback of the system operation. A second solution is to assume that the problem is always present and just go ahead and troubleshoot. The troubleshooting procedure should include a comparison of the data gating signal (T/R DATA EN at pin 48 of gate G931-33) and the clocking signal (pin 45 of register FF931-36). The clocking signal must fall before the gating signal falls. If it doesn't, then that would account for the observed problem. In comparing these signals it would be desirable to trigger the scope such that only every fifth signal is observed. This can be accomplished by triggering from the output of gate G813-15 (zone 28C). For comparison, normal signals can be observed by triggering the scope from G809-14 through G812-14. Once the problem is observed it can be traced back to either marginal phase shifting due to problems with capacitors C810, C812, C813 and C827, or to a problem in the fifth pulse itself as observed at the output of G813.

5.3 Transportation Container (T.C.)

5.3.1 Storage Preparation

The preparation for storage as performed at KSC during August 1973 comprised the following operations:

- The four 1.5V carbon-zinc batteries were removed and discarded.
- The six ni-cad batteries were removed from the system, discharged, and a shorting bus applied across each cell of each battery. The batteries were then reinstalled in the T.C.
- The pressure was bled off of the GN_2 bottles.
- All exposed connectors and fittings were capped.

5.3.2 Reactivation Requirements

The reactivation of the T.C. for future operation should include the following:

- Remove the ni-cad batteries from the T.C. and remove the shorting busses from each cell on each battery. Reassemble the batteries into the T.C. After all the batteries are reconnected, turn the AC PWR to "ON", the TCG power switch to "OFF" and the battery switch to "OPERATE". (It is normal to hear a loud humming noise from the power supply at this time.) The "Battery Current" meter should indicate a charge rate of 15 ± 5 amps. The battery voltage, as monitored on the "D.C. Volts" voltmeter, will climb towards 32 ± 2 volts at which time the charging current will start to reduce. It will take 72 hours to insure full charge on the batteries; however, the batteries will be sufficiently charged for normal system operation after a 4 hour charge period.
- Install four new size AA 1.5V carbon-zinc batteries in the T.C. if required at this time.
- Charge the cooling system with water if required at this time.

- Charge the GN_2 bottles if required at this time.

Upon completion of the system reactivation, an electrical test, similar to TPS GNOR-100-01-001 run at KSC, should be performed.

APPENDIX I
DOCUMENTATION FROM PREVIOUS CIRCADIAN PROGRAMS

<u>Contract</u>	<u>Document Number/Date</u>	<u>Date</u>	<u>Title</u>
NAS W-1191	NSL 65-140	13 Aug 65	Model Spec for Biosat Package to Study Circadian Rhythms in Pocket Mice
"	NSL 66-86	Jun 66	Commodity Spec for Prototype Exp.
"	88	"	Test Summary " " "
"	89	"	Final Report " " "
NAS 2-5093	NORT 68-453	Mar 69	"Final" Technical Prog. Report Hdwe. Def.
NAS 2-5093	NORT 68-453 (-1 thru -8)	(1968-1969	Exp Hardware Definition for P/M (Technical Progress Report Series)
"	NORT 68-453 Amend. 1	Oct 69	Hardware Def. Final Progress Report
"	NORT 68-454	Dec. 68	Environmental Control Syst. Analysis
"	NORT 68-458	Mar 69	Hardware End Item Spec S071
"	NORT 68-459	"	" EIS CDS
"	NORT 68-460	"	Interface Spec CDS/AAP-SM
"	NORT 68-461	"	" " CDS/S-071
"	NORT 69-619	Oct. 69	PM Test Console Function TP
"	NORT 69-617	"	" " " Vibration TP
"	NORT 69-619	"	" " " Instruction Manual
NAS 2-5094	NORT 68-440	Sept. 68	Exp Reqmts Catalog - V.G.
	NORT 68-471	March 69	Hardware End Item Spec S-072
	NORT 68-472	"	Interface Spec S072/AAP-SM
	NORT 68-473	"	" " S072/CDS
	NORT 68-466	"	Final Technical Progress Report
	NORT 69-626A	Dec. 69	V.G. Lab Exp Functional Acceptance T.P.
	NORT 69-627A	"	V.G. " " Vibration T.P.
	NORT 69-628	"	V.G. " " Service Manual
	NORT 68-466 (Rev. 1)	Feb 70	Final Technical Progress Report

APPENDIX II

CPE PROGRAM DOCUMENTATION

The following list shows the documentation compiled during the period of action on Contracts NAS 2-5850 and NAS 2-6897 during the years 1970 through 1973. A file containing one copy of each listed report has been maintained with the Drawing Data File for CPE #1.

<u>NORT No.</u>	<u>Title</u>
70-300	Circadian Periodicity Program Proposal
70-306	Reliability Program Plan
70-306-1	Reliability Program Plan
70-306-2	Reliability Program Plan
70-309	Thermal and Environmental Control Analysis
70-313	Quality Assurance Program Plan/Contamination Control Plan
70-313A	Quality Assurance Program Plan/Contamination Control Plan
70-314	General Management Plan (Section of NORT 70-323)
70-315	Test Management Plan
70-316	Electromagnetic Compatibility Test Plan and Procedures
70-317	Logistics Plan
70-317-1	Logistics Plan
70-317-2	Logistics Plan
70-317A	Logistics Plan
70-318	Configuration Management Plan
70-318A	Configuration Management Plan
70-319	Manufacturing Plan
70-319A	Manufacturing Plan
70-321	Qualification Test Plan (Replaced by NORT 70-395)
70-321-1	Qualification Test Plan (Replaced by NORT 70-395)
70-322	Reliability Predictions
70-322A	Reliability Predictions
70-323	Management Plan
70-324	Functional Description
70-326	Mission Test Certification Report
70-326-1	Mission Test Certification Report
70-327	Reliability Test Plans, Specifications and Procedures
70-328	System Safety Program Plan
70-329	Experiment Hardware Support Requirements
70-329-1	Experiment Hardware Support Requirements
70-329-2	Experiment Hardware Support Requirements
70-329C	Experiment Hardware Support Requirements

<u>NORT No.</u>	<u>Title</u>
70-330	Failure Mode Effects and Criticality Analyses (FMECA)
70-330A	Failure Mode Effects and Criticality Analyses (FMECA)
70-330B	Failure Mode Effects and Criticality Analyses (FMECA)
70-331	Structural Analysis Report
70-331A	Structural Analysis Report
70-332	Measurements Lists
70-332A	Measurements Lists
70-332B	Measurements Lists
70-334-1	Parts and Materials Application Report
70-334-2	Parts and Materials Application Report
70-335	Process Specification List
70-335A	Process Specification List
70-335B	Process Specification List
70-335C	Process Specification List
70-336	Approved Parts, Devices and Materials List for the Apollo Applications Program
70-336-1	Approved Parts, Devices and Materials List for the Apollo Applications Program
70-336-2	Approved Parts, Devices and Materials List for the Apollo Applications Program
70-338	Parts Qualification Test, Specification and Procedure
70-339	Development Model "As Built" List
70-340	S071/S072 Experiment Intersystem/Interface Development
70-340A	S071/S072 Experiment Intersystem/Interface Development
70-341	Pocket Mouse Electronic Description
70-345	Preliminary Design Review
70-346	Preliminary Design Review Minutes
70-347	Preliminary Design Review Report
70-347 (Attach. A)	Reproductions of Selected Slides from Preliminary Design Review 19, 20 May 1970
70-348-1	Development Status Report for June 1970
70-348-2	Development Status Report for July 1970

<u>NORT No.</u>	<u>Title</u>
70-348-3	Development Status Report for August
70-348-4	Development Status Report for September
70-348-5	Development Status Report for October
70-348-6	Development Status Report for November
70-348-7	Development Status Report for the Month of December
70-348-8	Development Status Report for the Month of January 1971
70-348-9	Development Status Report for the Month of February
70-348-10	Development Status Report for the Month of March
70-348-11	Development Status Report for the Month of April
70-348-12	Development Status Report for the Month of May
70-348-13	Development Status Report for the Month of June
70-348-14	Development Status Report for the Month of July
70-348-15	Development Status Report for the Month of August
70-348-16	Development Status Report for the Month of September
70-348-17	Development Status Report for the Month of October
70-348-18	Development Status Report for the Month of November
70-354	Data Sheet for Ground Support Equipment
70-355	Vinegar Gnat Electromechanical Mechanization Study Report
70-356	Vinegar Gnat Cold Plate Thermal Study
70-357	Cage Airflow/Drag Analysis
70-358	Pocket Mouse Absorption Canister Test Plan/Canister Size Analysis
70-363	Power Interruption Effect Summary Study Report
70-364	GSE Preliminary Design Review Minutes
70-366	Test and Checkout Requirements for Experiments S071 and S072 at North American Rockwell and at Cape Kennedy
70-366-1	Test and Checkout Requirements for Experiments S071 and S072 at North American Rockwell and at Cape Kennedy
70-366-2	Test and Checkout Requirements for Experiments S071 and S072 at North American Rockwell and at Cape Kennedy
70-366-3	Test and Checkout Requirements for Experiments S071 and S072 at North American Rockwell and at Cape Kennedy
70-367	Design Compatibility Verification
70-368	GSE Design Review Report
70-369 (Draft)	Operator's Training Manual Welded Electronics Modules

<u>NORT No.</u>	<u>Title</u>
70-369	Operator's Training Manual Welded Electronic Modules
70-370	Antenna System Study
70-371	Outline of operating Maintenance and Handling Procedures
70-372	Acceptance Test Plan (Replaced by NORT 70-395)
70-372-1	Acceptance Test Plan (Replaced by NORT 70-395)
70-373	Biotelemeter Qualification and Acceptance Test Plan
70-373-1	Biotelemeter Qualification and Acceptance Test Plan
70-374	Spares Requirements List
70-375	Circadian Periodicity Experiments Program - Critical Design Review Booklet
70-378 (Draft)	Operator's Training Manual Soldered Electrical Connections
70-378	Operator's Training Manual Soldered Electrical Connections
70-379	Crew Hazardous Failure Study
70-382	Critical Design Review Minutes
70-385	Northrop Specification Index and Status for Circadian Periodicity Experiments Program
70-385-1	Northrop Specification Index and Status for Circadian Periodicity Experiments Program
70-386	Northrop Document Index and Status for Circadian Periodicity Experiments Program
70-387	Operator's Training Manual - Dye Penetration Inspection
70-388	Operator's Training Manual - Hardness Testing
70-389	CDR Design Review Report
70-393	GSE CDR Requirements
70-394	Experiments SO71/SO72 CDR Rid Closure Summary
70-395	Qualification/Acceptance Test Plan
70-395A	Qualification/Acceptance Test Plan
70-396	GSE Critical Design Review Report
70-397	New Technology Plan
70-398-1 to 14	Drawing Status Reports
70-401	Operator's Training Manual for Conformal Coating, Potting and Use of Adhesives
70-405	Inspection Station Layout, Station Procedural Index, and Product Flow Charts

<u>NORT No.</u>	<u>Title</u>
70-406-2	Non-Conformance Close-Out Report for the Month of December
70-406-3	Non-Conformance Close-Out Report for the Month of January
70-406-4	Non-Conformance Close-Out Report for the Month of February
70-406-5	Non-Conformance Close-Out Report for the Month of March
70-406-6	Non-Conformance Close-Out Report for the Month of April
70-406-7	Non-Conformance Close-Out Report for the Month of May
70-406-8	Non-Conformance Close-Out Report for the Month of June
70-406-9	Non-Conformance Close-Out Report for the Month of July
70-406-10	Non-Conformance Close-Out Report for the Month of August
70-406-11	Non-Conformance Close-Out Report for the Month of September
71-202	Control and Monitor Console Interface and Intraface Cabling Diagrams
71-202A	Control and Monitor Console Interface and Intraface Cabling Diagrams
71-214	CPE Holding Unit and Laboratory Monitoring Unit
71-222	Transportation Container Description and Operation
71-222A	Transportation Container Description and Operation
71-224	Operation and Maintenance Manual Circadian Periodicity Experiment SO/71 S072, Volumes I, II and III
71-228	Control and Monitoring Console-Description and Operation
71-238	Test and Checkout Cart Operating and Servicing Instructions
71-239	Loading Procedure - Potassium Hydroxide (KOH) Cup Assembly - Vinegar Gnat Experiment
71-244	Report of EMI Qualification Test on Circadian Periodicity Experiment System
71-280	Baseline Configuration
71-281	Actual Weight and Center of Gravity for the Flight Experiments
71-282	Acceptance Data Package Specification Index
71-283	CPE Calibration Data Report Systems No. 1 and 2
71-284	Numerical Drawing List
71-285	Drawing Offset List
71-286	System Environmental Test Report on CPE So71/S072 S/N 01 and S/N 02
71-289	Spares Status Report
71-290	Acceptance Data Package Northrop Document Index

<u>NORT No.</u>	<u>Title</u>
71-291	System Environment Test Report of Vibration and Shock Test on the Circadian Periodicity Experiment S071/S072
71-296	Configuration Inspection Report
71-303	System Environment Test Report of Vibration and Shock Tests for Experiment S071/S072, S/N 02
71-307	Vibration Test Report on the CPE Memory Core
72-287-1	Quarterly Progress Report July 1972
72-287-2	Quarterly Progress Report October 1972
72-287-3	Quarterly Progress Report January 1973
72-287-4	Quarterly Progress Report April 1973
72-317	New Technology Summary (NAS-2-5093)
No #	CDS Subsystem Troubleshooting/Confidence T.P. (TP6740000)
(Date 2/5/71)	

Specifications

FS50640100	Buffing Aluminum Alloys
67000000	End Item Specification for Apollo Applications Program Experiments on Circadian Periodicity - Part I
67000000	CPE Flight Hardware EIS - Part II
67000001	End Item Specification for Biotelemeter on Circadian Periodicity - S072
67000002	End Item Specification for GSE on Circadian Periodicity S071/S072
67000050	Thermoelectric Device, Modified - Vinegar Gnat Experiment (Altered Item Drawing)
67000051	Socket, Lamp, Modified - Vinegar Gnat Experiment (Altered Item Drawing)
PS67000056	Cold Plate, Vinegar Cooling - CPE
PS67000150	Seal ECS & Housing Animal Enclosure PME
67000151	Specification, Heat Exchanger, Pocket Mouse ECS
PR67000154	Reservoir, Oxygen - PME
PS67000155	Filter O ₂
FS67000156	Regulator, High Pressure - PM Exp.
PS67000157	Regulator, Low Pressure - PM Exp.
67000163	Specification, Feed Thru, Electrical Pocket Mouse Experiment
PS67000164	Heater, ECS PME
67000165	Pump Coolant - PME
PS67000168	Valve O ₂ Charging - PME
PS67000173	Interface Coldplate
PS67000174	Electronic Coldplate
PS67000177	Control Valve - Interface Coldplate - CPE
PS67000178	Blower/Power Supply - PM ECS
TP67000178	Sig - 4 Pump Inverter Environmental Test Procedure
67000182	Bellows, Supplementary Cooling System - CPE
67000253	Oscillator, Tuning Fork - Circadian Data System
PS67000259	Component Parts for CDS Power Supply
PS67000301	Oscillator, 16 KHz Procurement Specification
67000507	Screen Spec. Thermistor 44015
FS67000508	Screen Spec. Transistor NS6214
67000509	Screen Spec. Capacitor, Solid Tantalum C332

Specifications

FS67000510	Screen Spec. Battery, Miniature Y-1404
FS67000511	Screen Spec. SCP-380501K Ceramic Capacitor
FS67000512	Screening Spec. - 44204 Thermistor
FS67000513	Screening Spec. - 44031 Thermistor
FS67000514	Screening Spec. 2N3376 Field Effect Transistor
FS67000515	Screening Spec. 10R4 Diode (Isolfilm)
FS67000516	Screening Spec. 10R2 Diode (Isolfilm)
FS67000517	Screening Spec. 2N5038 Transistor
PS67000519	Screening Spec. Tests - Micro Connectors - Mod Series
PS67000520	Screening Spec. for S7B Thermo Ribbon Sensor
PS67000521	Bendix Scintilla Div. PT "CE" Connectors
PS67000522	Procurement and Screening Tests - ITT Cannon D*MA Series Connectors (Non-Magnetic) Gold Plated Shell
PS67000523	Deutsch DL Series, Class 6, Electrical Connector
PS67000524	Screening Tests MIL-C-83723 Electrical Connectors
PS67000525	Screening Spec. for Photo Sensor
PS67000526	2N3045 Dual Transistor Screening Specification
PS67000527	Screening Spec. Sig. 4 Inverter Burn-In
PS67000601	Flat Pack Inspection Criteria - Specification for Signetics
PS67000602	Process Specification for Loading Gas Canister with Lithium Hydroxide and Charcoal
67000656	Drawing Tree - Circadian Periodicity Experiment
67000657	Specification Tree - Circadian Periodicity Experiment
FS67000658	Preparation of 62.5/37.5% Inhibited Ethylene Glycol - Water Solution
FS67000659	Process Bulletin for Assembly of PM Biotelemeter - CPR
TP67000661	Specification - Acceptance Test Procedure for Philamon Tuning Fork Oscillator
TP67000663	GSE Data Processor/CDS Flight Hardware - Compatibility Test Procedure
TP67000664	Compatibility Test Procedure, GSE V.G. Simulator/Circadian Exp. Pkg.
TP67000666	Compatibility Test Procedure for VG Tester/Circadian Experiment Pkg.
TP67000667	Compatibility Test Procedure for Transportation Container - CPE, GSE

Specifications

TP67000668	Compatibility Test Procedure for GSE Pocket Mouse Tester - CPE
F-303	Blind Nut Installation Process Specification
TP67000701	System Functional Test Procedure - S071/S072
TP67000702	System Qualification/Acceptance (Integration) Test Procedure - CPE
TP67000703	System Electromagnetic Compatibility Qualification Test Procedure - CPE S071/S072
TP67000704	System Environmental Test Procedure - CPE S071/S072
TP67000705	CPE S071/S072 Preflight Preparation and Checkout Procedure
TP67000706	CPE S071/S072 GSE Preflight Preparation
TP67000801	Biotelemetry Acceptance Test and Calibration Procedure
PS67000860	Cleaning Procedure for Circadian Periodicity Experiment

TEST REPORTS

<u>Identifying No.</u>	<u>Description</u>
7433 205 (2 copies)	Circadian Periodicity Exp. Assembly Flight Unit #1 Resonant Search - Ames Research Center
7433 206	Analyses of Gas Samples Taken from the Exp. Enclosures in S071/S072 Flight Unit 2 at start of the Thermal/ Vacuum/Endurance Test from Analytical Research Labs., Inc.
7433 212 and 7433 213	Atmospheric Analysis of Vinegar Gnat and Pocket Mouse Enclosure, Flight System #2 from Analytical Research Labs., Inc.

APPENDIX III

POCKET MOUSE AND VINEGAR GNAT HUMIDITY CONDITIONS

A. VINEGAR GNAT

The vinegar gnat enclosures are sealed houses containing sufficient air to provide oxygen for the eclosing "hatching" flies and also for the adults during the several days of continued eclosion.

Carbon dioxide generated by the pupa and flies is removed by reaction with a potassium hydroxide (KOH) solution in a small teflon cup attached to the pupa plate holder. The KOH solution also releases water into the enclosure to maintain a humidity suitable for the developing pupae. The original solution placed in the cup is 10 grams of water with one gram of KOH. This solution should be expected to maintain a relative humidity of approximately 95%. (Figure III-1 shows the expected RH for two $\text{LiOH}/\text{H}_2\text{O}$ solutions.)

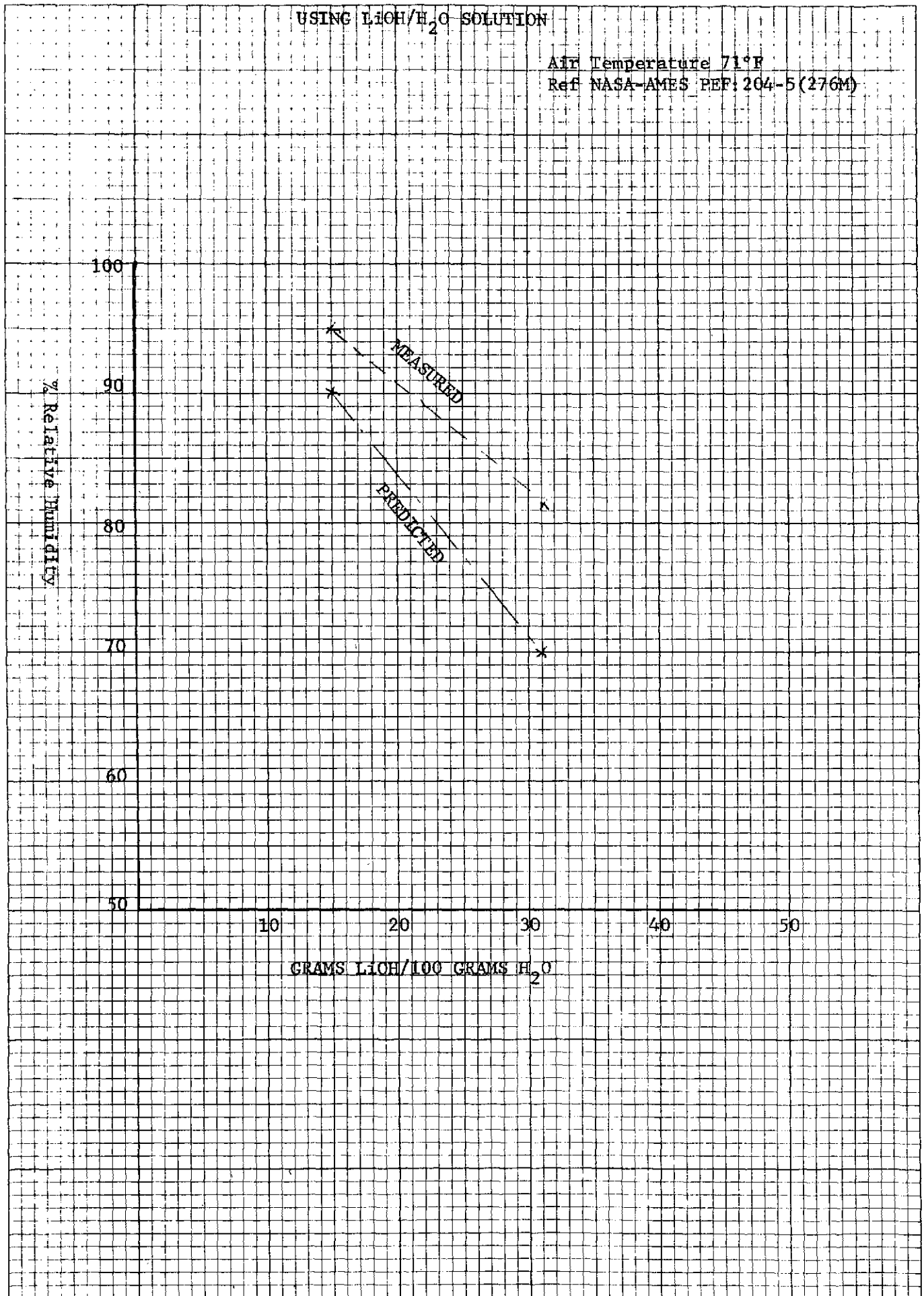
With the plate at 20°C (68°F) a 95% RH represents a partial pressure of .32 psi. The base of the V.G. enclosure, however, is held at a nominal temperature of 54°F. The saturation pressure for 54°F is .21 psi, which is 62% of the saturation pressure at 68°F. Thus the water vapor partial pressure in the V.G. enclosure remains at a constant .21 psi and the relative humidity is between 100% at the coolest spot on the enclosure wall and 62% at the surface of the pupa plate controlled at 68°F.

B. POCKET MOUSE ENCLOSURE

The relative humidity of the pocket mouse enclosure is controlled by reducing the circulated atmosphere temperature to 52°F (.20 psi H_2O saturation) to remove excess moisture. The air is then reheated to a mouse comfortable 68°F, where .20 psi partial pressure of water represents 60% of the 68°F saturation pressure of .32 psi or a relative humidity of 60%.

The lithium hydroxide severely affected the relative humidity control in the P.M. enclosure as it was originally used in the anhydrous state (no water in the crystal). Because the LiOH was a very effective desiccant, most of the water was taken out of the air while passing through the LiOH bed, and the air returned to the mouse house had a relative humidity below 15% for many days until enough water had been generated by the mice to satisfy the thirsty LiOH .

Figure III-1
ATMOSPHERIC RELATIVE HUMIDITY CONTROL



EUGENE DIETZGEN CO.
MADE IN U. S. A.

NO. 340R-10 DIETZGEN GRAPH PAPER
10 X 10 PER INCH

To enable the Pocket Mouse Environmental Control System to more effectively control the mouse enclosure, the lithium hydroxide was preconditioned by the addition of water to the anhydrous crystals to form monohydrate (one molecule H_2O for each molecule LiOH). The addition of a mole of H_2O (18 lb/mole) to a mole of LiOH (24 lb) increases the weight of the crystal by 75% and also expands the crystal size slightly. It was expected that the LiOH bed in monohydrate form would not act as a desiccant and would thus allow water vapor to pass through the bed. However, LiOH is able to retain more than one mole of water per mole of LiOH before allowing a relative humidity approaching 60% to pass. Figure III-1 shows the relative humidity encountered in a bed of LiOH during the conditioning phase. One batch of LiOH was conditioned to approximately 1.1 mole H_2O /Mole LiOH as indicated in the figure. When the bed reached 100% monohydrate, the differential temperature across the bed was reducing rapidly and the crystals were still solid; however, when the conditioning was continued to 110% H_2O / LiOH , the crystals were soft (slushy), and it was concluded that it would be impractical to attempt to load the canister with LiOH in this form for concern that the crystals would pack into a nonporous mass through which air could not pass. Thus the monohydrate crystals were used.

Figure III-2 shows the expected relative humidity in the pocket mouse enclosure for a period of 28 days when starting with a canister packed with 5.8 lb. of monohydrate LiOH . Approximately .25 pounds of water would be required to bring the bed to a condition of 1.1 mole H_2O /Mole LiOH and water is generated and released at the rate of approximately .05 lb. per day. Calculations then show that the bed should reach a condition to control RH at 60% within approximately 5 days. The actual relative humidity in the enclosure has not been measured, and these calculated values describe the predicted RH encountered. The finding of approximately one pound of water in the moisture wick at the end of a 28 day period further confirms the prediction.

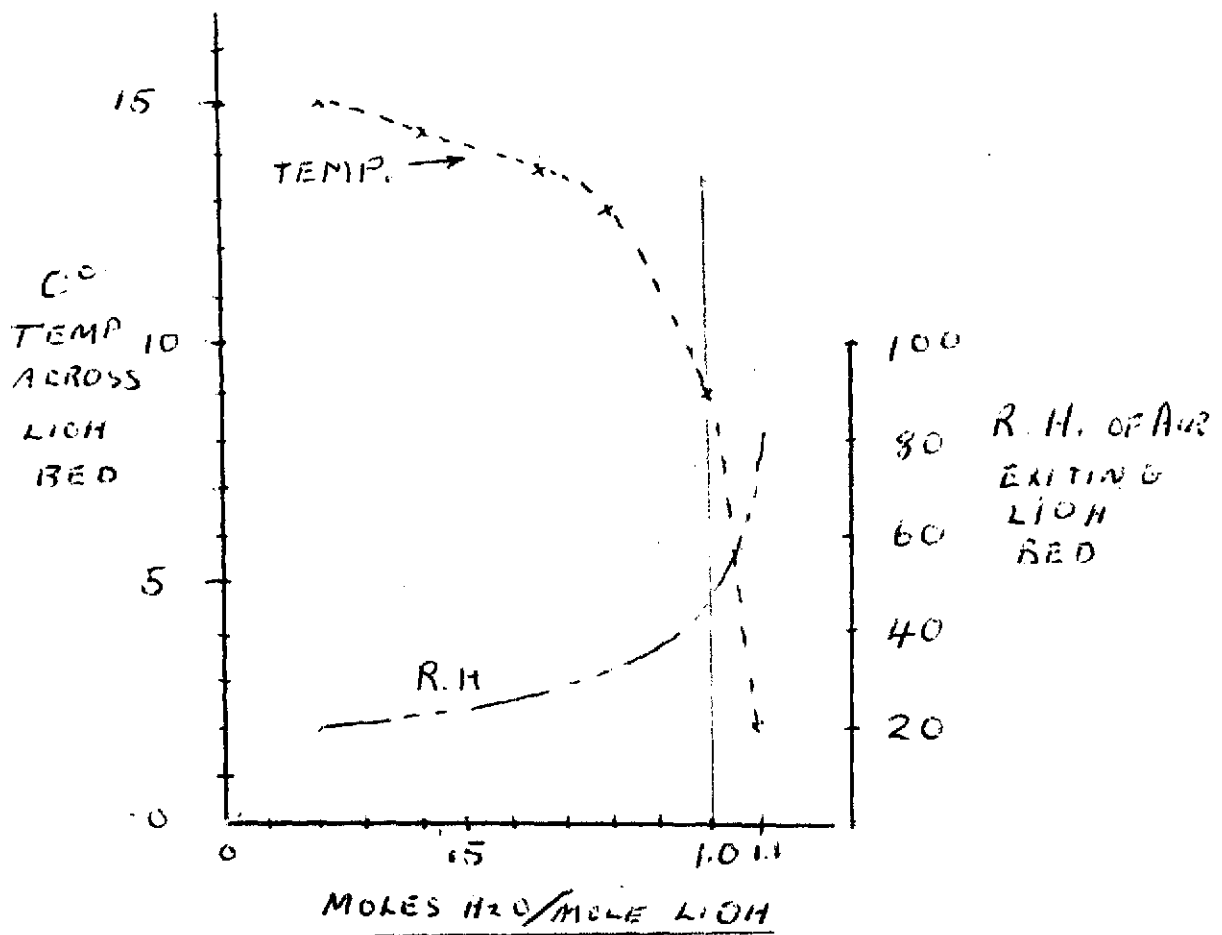


FIGURE III-1 LIOH CONDITIONING

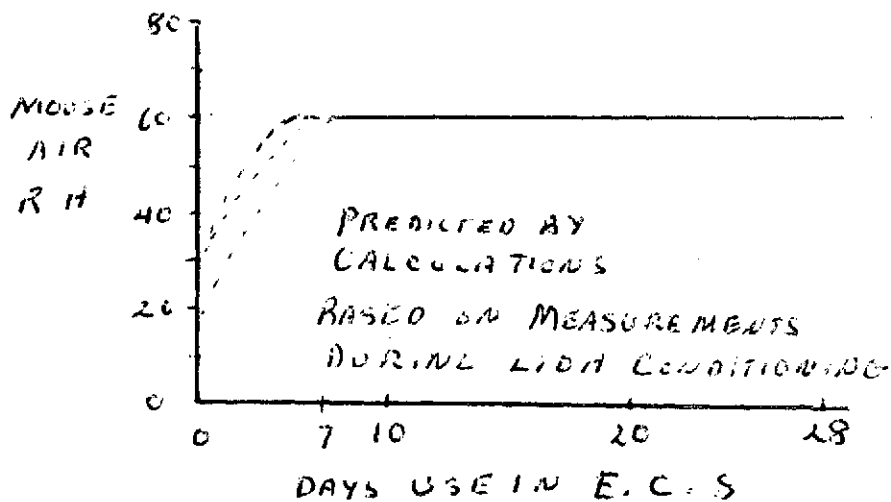


FIGURE III-2 POCKET MOOSE AIR HUMIDITY

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APPENDIX IV
TEST DATA FILE

A copy of data collected during the CPE tests at Northrop, Rockwell, and KSC is retained as an appendix of this report for reference purposes. The data includes the following:

CPE #2 Thirty-Hour Flight Data Listing - Skylab Tapes/ NORT Reduced
CPE #2 Prelaunch Data - ACE Printout
CPE #1 Ground Test Data - C & M Tape KSC CIF Reduced
CPE #1 Ground Test Data - CIF 9 Track Dump
CPE #1 Ground Test Data - Paper Printout
CPE #1 Ground Test Data P.M. Temp & Activity Plot
CPE #2 KSC Integration June 73 - A.C.E. Print
CPE #1/KSC Altitude Test May 73 - A.C.E.
CPE #1 & #2 - Endurance Oct 72 - Northrop Computer Listing
TPS FM/VG-NOR-001-010, CPE #1 Preflight Preparation TP6700705
TPS FM/VG-NOR-002-012, CPE #2 Preflight Preparation TP6000705