LONG DURATION EXPOSURE FACILITY (LDEF) LOW TEMPERATURE HEAT PIPE EXPERIMENT PACKAGE (HEPP) FLIGHT RESULTS

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SUMMARY

The Low Temperature Heat Pipe Flight Experiment (HEPP) is a fairly complicated thermal control experiment that was designed to evaluate the performance of two different low temperature ethane heat pipes and a low-temperature (182°K) phase change material. A total of 390 days of continuous operation with an axially grooved aluminum fixed conductance heat pipe and an axially grooved stainless steel heat pipe diode was demonstrated before the data acquisition system's batteries lost power. Each heat pipe had approximately 1 watt applied throughout this period. The HEPP was not able to cool below 188.6°K during the mission. As a result, the preprogrammed transport test sequence which initiates when the PCM temperature drops below 180°K was never exercised, and transport tests with both pipes and the diode reverse mode test could not be run in flight. Also, because the melt temperature of the n-heptane PCM is 182°K, its freeze/thaw behavior could not be tested.

Post-flight thermal vacuum tests and thermal analyses have indicated that there was an apparent error in the original thermal analyses that led to this unfortunate result. Post-flight tests have demonstrated that the performance of both heat pipes and the PCM has not changed since being fabricated more than 14 years ago. This paper presents a summary of HEPP's flight data and post-flight test results.

INTRODUCTION

A schematic of the HEPP is presented in Figure 1. This system contains an axially grooved aluminum constant conductance heat pipe (CCHP) and a stainless steel axially grooved liquid trap diode heat pipe (DHP). Both heat pipes use ethane as the working fluid for operation in the range of 150 to 250°K. The condenser of each heat pipe is thermally coupled to a radiant cooler system. A phase change material (PCM) canister is integrated with the radiator to provide temperature stability at its 182°K melting point. The PCM is n-heptane and it is used to provide a 27 watt-hr latent heat capacity for constant temperature operation during transport tests. Data acquisition and data recording were provided by an Experiment Power Data System (EPDS) which was integrated with the HEPP in Tray F12.

Power to the HEPP's electronics module was provided by a Direct Energy Transfer (DET) Power System which included a 12-ampere-hour, 28 VDC Nickel Cadmium battery, four solar array panels and power system electronics. The DET was installed into Tray H1 and connected by power cables to the HEPP in Tray F12. Analysis of the flight data shows that the power system provided nominal operation without any anomalies over the 390 days of recorded data. Nominal DET operation was also demonstrated prior to deintegration from LDEF at KSC. A detailed discussion of this system is presented in Reference 1.

In addition, five sets consisting of a total of 65 thermal control coating samples were attached to trays F12, H1 and F9 for evaluation with the HEPP. Flight results for these samples are presented in Reference 2.

The LDEF and its extended mission provided a unique opportunity for the long term evaluation not only of the ethane heat pipes but also of the various space flight subsystems that were needed to support the HEPP. This paper summarizes results obtained for the heat pipes, the PCM, the HEPP's electronics module and instrumentation, and the EPDS.

EXPERIMENT DESCRIPTION

A schematic of the total HEPP Experiment System is presented in Figure 2. The structural support of the HEPP is provided by a welded stainless steel tubular assembly. A primary radiator and specular shield surfaces, fabricated from aluminum and coated with silver teflon and vapor deposited aluminum respectively, are fastened to this frame. The cooler's radiator/shield configuration is designed to minimize parasitic heat inputs from the sun, earth and spacecraft while maximizing radiation to space. Thermal isolators are employed at all structural mounting locations and multi-layer insulation (MLI) blankets cover the experiment components and all inboard surfaces.

The HEPP assembly also includes an electronics module for signal conditioning and power sequencing, kapton foil heaters and platinum resistance temperature sensors (PRTs). The HEPP and its EPDS were flown in Tray F12. The HEPP EPDS also recorded

Figure 1. Low Temperature Heat Pipe Experiment Package (HEPP)

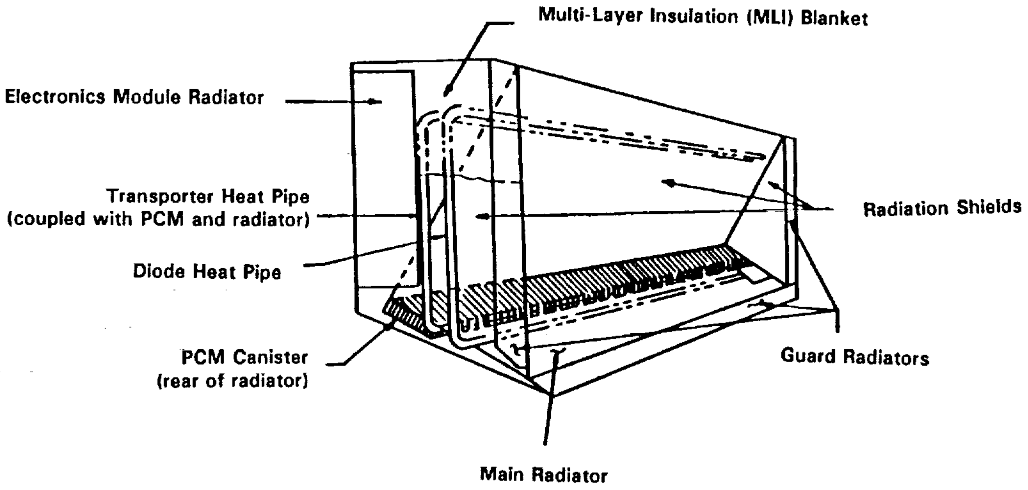
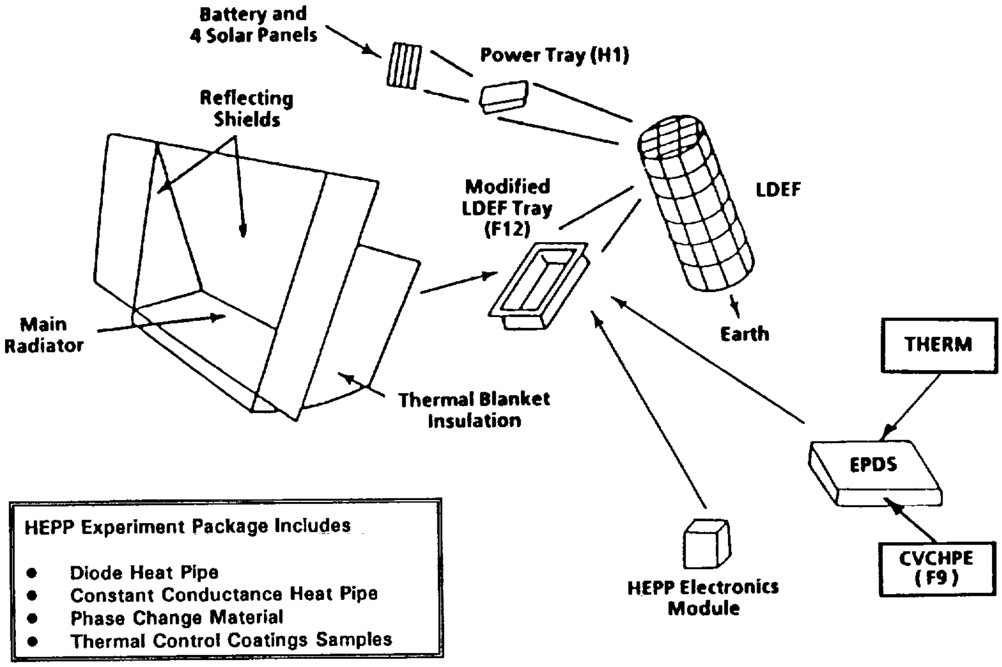


Figure 2. HEPP System Description



HEPP Experiment Package Includes

- Diode Heat Pipe
- Constant Conductance Heat Pipe
- Phase Change Material
- Thermal Control Coatings Samples

temperature data from six thermocouples and two thermistors from the THERM (P0003)[3] and 6 thermistors from the CVCHPE (A0076)[4] experiments. Figure 3 provides an electrical block diagram for the HEPP and its interfaces with THERM and CVCHPE. HEPP subsystems and components are summarized in Table 1.

COMPONENT DESCRIPTION

Constant Conductance Heat Pipe (CCHP)

The CCHP is an axially grooved design which was extruded from 6063 aluminum alloy. The grooved tubing was originally developed for the ATS-F heat pipe program and has well defined performance characteristics.[5] This heat pipe was selected to demonstrate the application of low cost, high reliability axially grooved heat pipe technology in the low temperature and cryogenic ranges. The CCHP is charged with ethane and will operate in the 120° to 270°K range. It has a predicted "0-g" heat transport capability of 33-watt-meters at 180°K. A design summary of the CCHP is presented in Table 2.

Thermal Diode Heat Pipe

The thermal diode heat pipe which was furnished by the NASA-Ames Research Center employs a liquid trap to accomplish shutdown in the reverse mode. It consists of cold forged axially grooved stainless steel tubing charged with ethane. The stainless steel provides a high strength, low thermal conductance envelope which minimizes axial conduction effects during reverse mode shutdown. A reservoir is attached to the evaporator end of the pipe and it contains a stainless steel wire mesh core which acts as a liquid trap during shutdown. A design summary of the diode heat pipe is presented in Table 3.

PCM Canister

The phase change material (PCM) canister is located on the underside of the experiment's main radiator and is thermally coupled to both heat pipes and the radiator. The heat dissipation capability of the radiator at the nominal test temperature (182°K) is substantially less than the heat loads associated with the maximum heat transport limits of either pipe. The PCM canister was included to provide a constant temperature heat sink during transport tests by absorbing up to 27 W-hr of latent energy through its melting process.

The n-heptane PCM material is contained within a Tungsten Inert Gas (TIG) welded aluminum rectangular box which is filled with a partially expanded aluminum honeycomb core. The high conductance of the honeycomb in combination with its large contact area with the PCM results in a high thermal diffusivity which provides good response with

Figure 3. HEPP Electrical Block Diagram

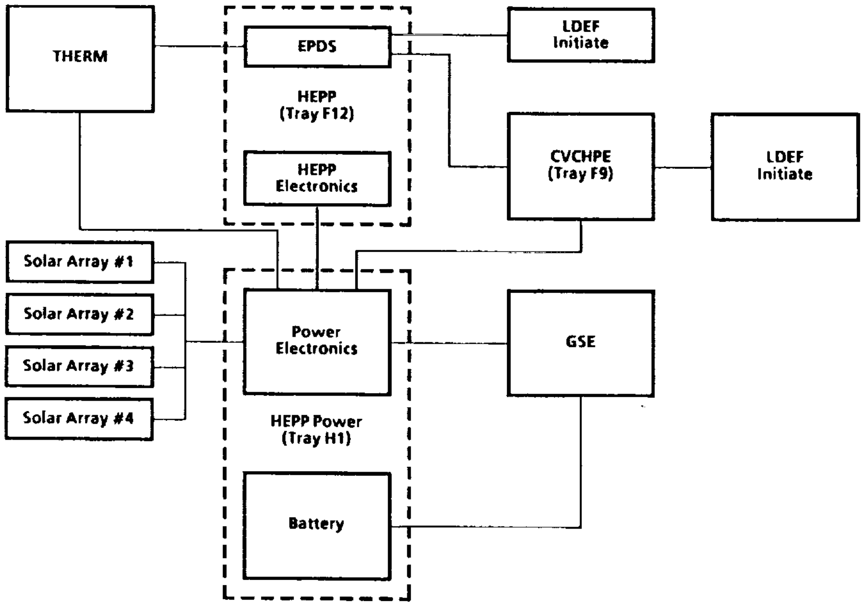


Table 1. HEPP Subsystems and Component Summary

THERMAL

1. Ethane/Aluminum Axially Grooved Heat Pipe.
2. Ethane/Stainless Steel Axially Grooved/Liquid Trap Diode Heat Pipe.
3. n-Heptane/Aluminum Phase Change Material Canister.
4. Low Temperature Radiator/Shield System Including Silver Teflon and VDA Optical Surfaces.
5. Platinum Transducers (28 PRTs) and Nichrome Ribbon and Kapton Foil Resistance Heaters.
6. MLI Blankets, Velcro Fasteners, Phenolic Snaps and Fasteners.
7. Bonding Compound for PRTs and Tape for Blankets, G-10 Fiberglass and Thermal Isolators.
8. 65 Thermal Control Samples.

ELECTRICAL

1. Electronics Module Including Signal Conditioning and Power Sequencing Command Logic.
2. EPDS Including Lithium Battery, Data Acquisition, Power Conditioning and Magnetic Tape Recorder.
3. HEPP DET System Power Supply
    - Nickel Cadmium Battery
    - Solar Array (4 Panels)
    - Power Conversion & Conditioning Electronics
4. Current and Voltage Sensors, Connectors and Harnesses.

MECHANICAL

1. HEPP Stainless Steel Tubular Structure.
2. DET Honeycomb Baseplate and Bond Materials.
2. LDEF Trays (F12 & H1)

Table 2. Constant Conductance Heat Pipe (CCHP) Design Summary

Wick Configuration	ATS Extruded Axial Groove (27 Grooves)	
Material	Ethane	
Working Fluid	6063 Extruded Aluminum	
Operating Temperature Range	120° - 270°K	
Geometry	in.	cm
O.D.	5/8	1.59
Lengths		
Overall	50.8	129.0
Evaporator	6.0	15.2
Adiabatic	26.8	68.1
Condenser	18.0	45.7
Effective	38.8	98.6
Internal Pressure @ 27°C	630 psia	
Burst Safety Factor @ 27°C	7.1	
Transport Capacity (0-g)	33 W-m @ 180°K	
Conductance	5.0 W/°C	

Table 3. Liquid Trap Diode Heat Pipe Design Summary

Wick Configuration		
Heat Pipe	Axially Grooved (20 Grooves)	
Liquid Trap Reservoir	30 Mesh Cylindral Slab, 100 Mesh Bridges, Circumferentially Grooved Wall	
Material	Stainless Steel	
Working Fluid	Ethane - 9.0g	
Operating Temperature Range	120° - 270°K	
Geometry	in.	cm
Heat Pipe O.D.	413	413
Heat Pipe Lengths		
Overall	46.85	46.85
Evaporator	4.0	4.0
Adiabatic	24.45	24.45
Condenser	18.40	18.40
Effective	35.65	35.65
Reservoir O.D.	1.00	2.54
Reservoir Length	4.00	10.16
Internal Pressure @ 70°C	815 psia	
Burst Safety Factor @ 70°C	9.5	
Transport Capacity (0-g)	16.4 W-m @ 180°K	

Table 4. PCM Canister Design Summary

Canister - Construction	TIG Welded 6061-T6 Aluminum Assembly
Core	3/16-in. Cell by 0.002-in. Thick 5052 Aluminum Honeycomb
Adhesive	Hysol Ea 934
PCM	753-g of n-heptane
Heat Storage Capacity	27 W-hr
Minimum Thermal Conductance	8 W/°C
Total Weight	2.73 Kg (6.02 lb)

minimum temperature drops across the canister. The PCM design is summarized in Table 4 and Reference 6.

Radiant Cooler System

The main radiator uses silver teflon ($\alpha/\epsilon = 0.12/0.76$) as its optical coating. This radiator is oriented parallel to the earth's limiting ray to eliminate direct albedo inputs. For the LDEF's average orbital altitude (225 nautical miles) the radiator was tilted 71° with respect to the earth's normal.

The main radiator is partially surrounded by shields that were fabricated from aluminum sheet and coated with vapor deposited aluminum (VDA) which has optical properties of $\alpha/\epsilon = 0.13/0.04$. These specular shields increase the radiator's net heat rejection by reducing direct inputs from the sun and spacecraft and by minimizing reflected albedo as well as reflected and direct infrared inputs. Auxiliary guard radiators, which are integral flanges extending from the shields, are coated with silver teflon to reject heat conducted from the shields and effectively reduce shield temperatures. This further reduces infrared inputs to the main radiator.

Structure

The support structure for the HEPP is a welded assembly of 0.5-inch diameter stainless steel tubing which is attached to a 0.69-inch thick aluminum baseplate in four (4) places by fiberglass isolators. This frame supports the radiator and shields, the heat pipes, and PCM canister. Thermal isolators are used at all attachment locations to minimize conductive parasitics.

Insulation

Multi-layer insulation (MLI) blankets cover all inboard surfaces of the HEPP and where possible completely envelop the heat pipes and PCM canister. The blankets consist of 14 layers of 1/3 mil double aluminized Kapton separated by Dacron cloth. One milsingle-sided aluminized Kapton is used for the external layers of the blankets with the Kapton side out. Velcro was used to attach the blankets to the various surfaces.

Instrumentation

The HEPP was instrumented with 28 platinum resistance (500 ohm) thermometers (PRTs) to measure temperatures throughout the experiment. Three of these measured battery temperatures in Tray H1. Nichrome ribbon heaters or Minco Kapton foil heaters were installed to provide electrical heat loads to the evaporators of each heat pipe, and to the main radiator to raise its temperature for diode reverse mode tests. The heaters were attached to the surfaces using Kapton tape. Voltages and currents were also measured to provide battery performance data and to determine applied heater power throughout the mission.

Power and Electronics

Power for the experiment is provided from two separate sources. A standard LDEF Experiment Power and Data System (EPDS) uses lithium batteries to power the data acquisition and recording portions of the experiment. Power for the experiment heaters, signal conditioning, command sequencing and execution of the experiment logic is provided to the HEPP electronics module by the DET which is mounted in a separate tray on the space viewing end of the LDEF.

EXPERIMENT OBJECTIVES

Primary objectives for the HEPP in their order of precedence can be summarized as follows:

1. Record temperature data for the HEPP, CVCHPE and THERM experiments.
2. Demonstrate long-term low temperature heat pipe operation (180-250°K).
3. Evaluate low-temperature heat pipe start-up from near super-critical conditions.
4. Determine heat pipe transport limits and thermal conductances.
5. Evaluate diode heat pipe reverse mode shutdown and restart.
6. Evaluate the low temperature PCM canister's performance including energy storage capacity, freeze/thaw characteristics, subcooling effects and thermal conductance.
7. Evaluate the thermal performance of a heat pipe/radiant cooler system.

Secondary objectives included:

8. An evaluation of the effect of the Flight Environment on 65 thermal control samples, MLI blankets and solar cells.
9. An evaluation of long-term nickel-cadmium battery performance.
10. An evaluation of the long term effect of the flight environment on electronics, instrumentation, and thermal and mechanical interfaces and subsystems.

Achievement of the first three objectives represents the minimum success criterion for the HEPP.

FLIGHT RESULTS

Operation of the HEPP commenced upon deployment of the LDEF when the HEPP radiator system began to cool down. Also, upon deployment of the LDEF, its initiate is activated and simultaneously power from the DET is transferred to the HEPP electronics module which was preprogrammed to apply 1.2 watts and 1.0 watt to the evaporator heaters of the diode, and CCHP, respectively. This is the HEPP's long term forward mode and also its default mode. During this mode, data is collected every 112 minutes. This mode of operation was exercised immediately to insure that minimum success was achieved. Unfortunately, with the 2.2 watts applied the PCM never cooled below 192°K and the programmed sequence for transport tests and diode reverse mode shutdown and restart could not be executed. These tests were to be performed after the PCM had frozen and its temperature dropped below 180°K. This temperature was selected consistent with the PCM's 182°K melt temperature so that the PCM would freeze and then it's heat of fusion would provide a constant temperature heat sink for the heat pipe transport tests.

Post flight thermal analyses and thermal vacuum tests confirmed that there was an apparent error in the original thermal model that resulted in overestimating the HEPP radiator's cooling capacity. Time and resource constraints prohibited conducting TV tests with the HEPP after its radiator and shields had been modified for flight aboard the LDEF. This test might have uncovered the problem and the flight program sequence adjusted to accomplish all objectives.

Fortunately, minimum success was achieved and good complete data for the first 390 days was obtained for the HEPP and THERM. Temperature data for the CVCHPE was also obtained for its first 45 days of operation until its thermistor circuit battery lost power. In addition to accomplishing the first three objectives, the thermal performance of the heat pipe radiant cooler system was evaluated and correlated with an updated thermal model. Also, all secondary objectives were accomplished with extensive data obtained. Preliminary results for the DET and thermal control samples are published in References 1 and 2.

Heat Pipe Flight Data

Figures 4 and 5 show the transient cycling of the evaporator and condenser sections of the CCHP and the DHP, respectively. The temperature cycling is due to changes in the external environment that affect the net cooling capacity and correspondingly the temperature of the HEPP radiator. The temperature drops across each heat pipe are shown in Figure 6. These results show that both heat pipes are nearly isothermal with continuous operation over the range of 192°K to 260°K throughout the 390 days of recorded data. In flight, the diode evaporator's temperature drop is less than 1°C whereas ground tests show more than a 15°C temperature drop at the diode's evaporator when it is "dried-out" at an adverse tilt. A 10°C drop was observed in the CCHP when it was "dried-not" with 1.0 watt applied versus the average 0.6°C drop recorded in flight.

Figure 4A. CCHP Evaporator - Location A

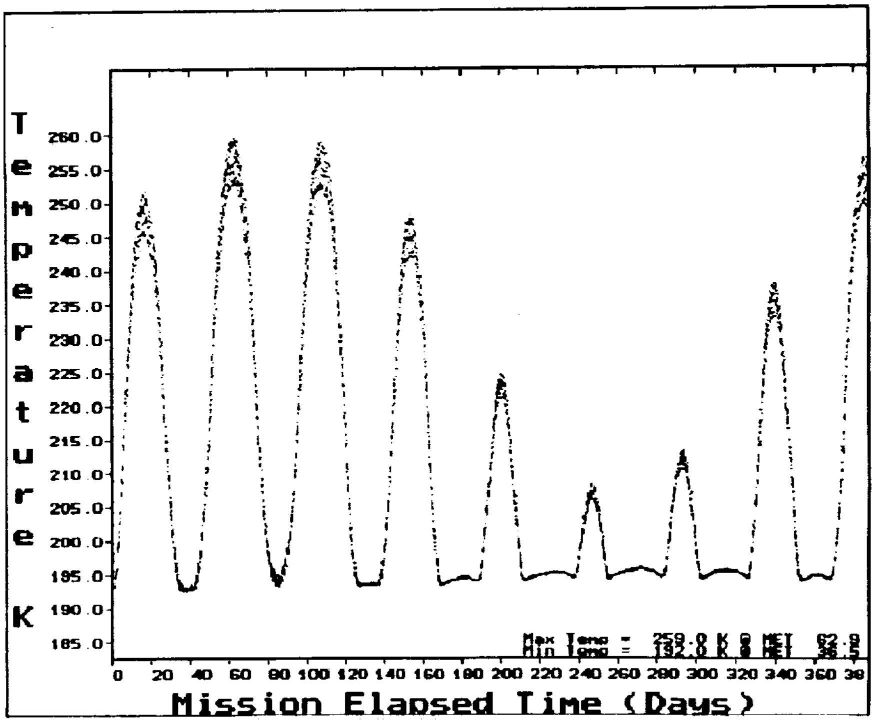


Figure 4B. CCHP Condenser - Location C

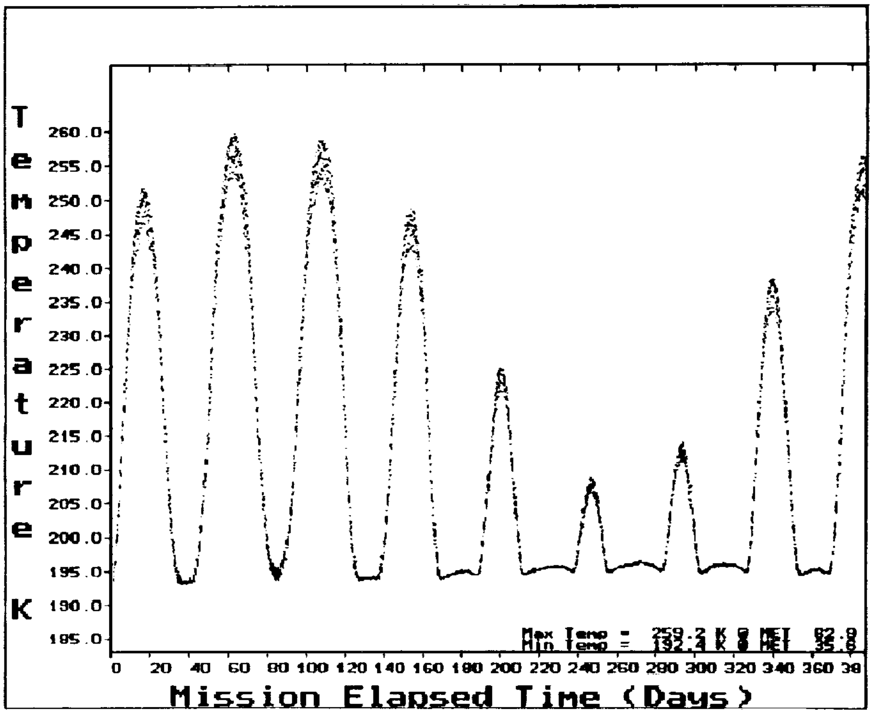


Figure 5A. Diode Evaporator - Location A

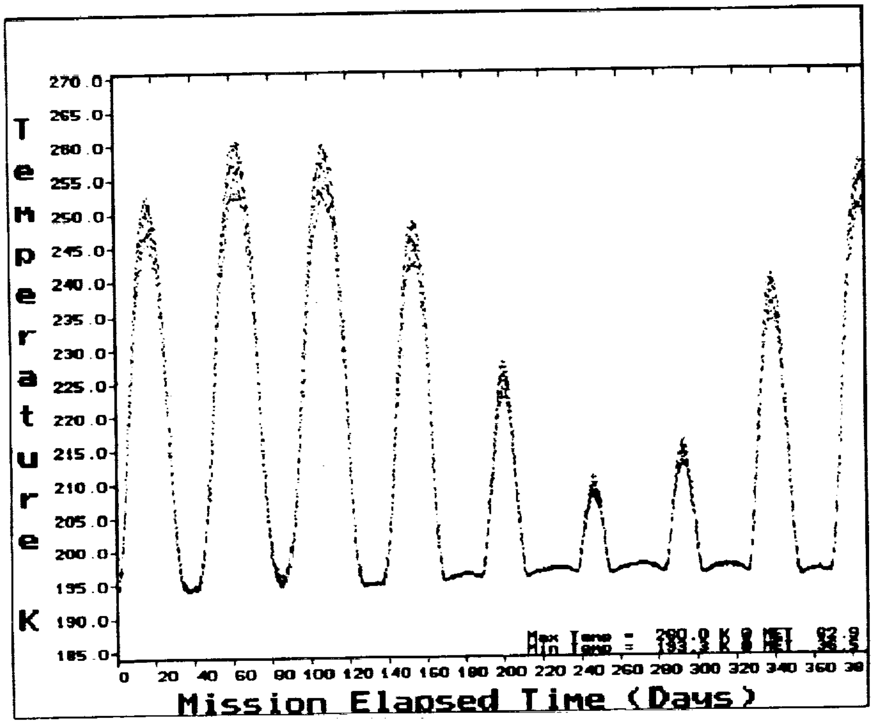


Figure 5B. Diode Condenser - Location C

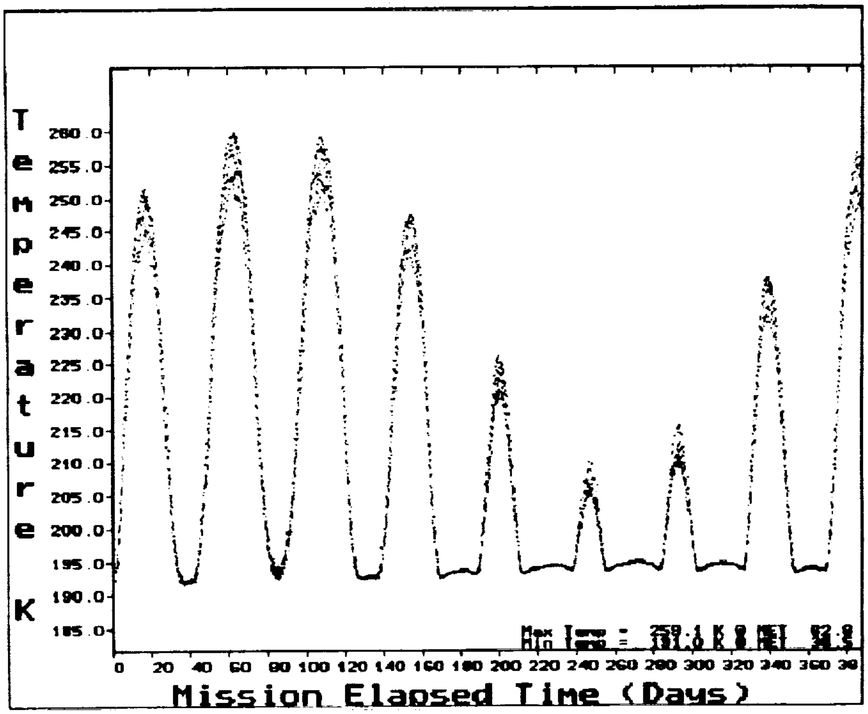


Figure 6A. CCHP Temperature Drops vs Mission Time at Maximum and Minimum Beta Angles

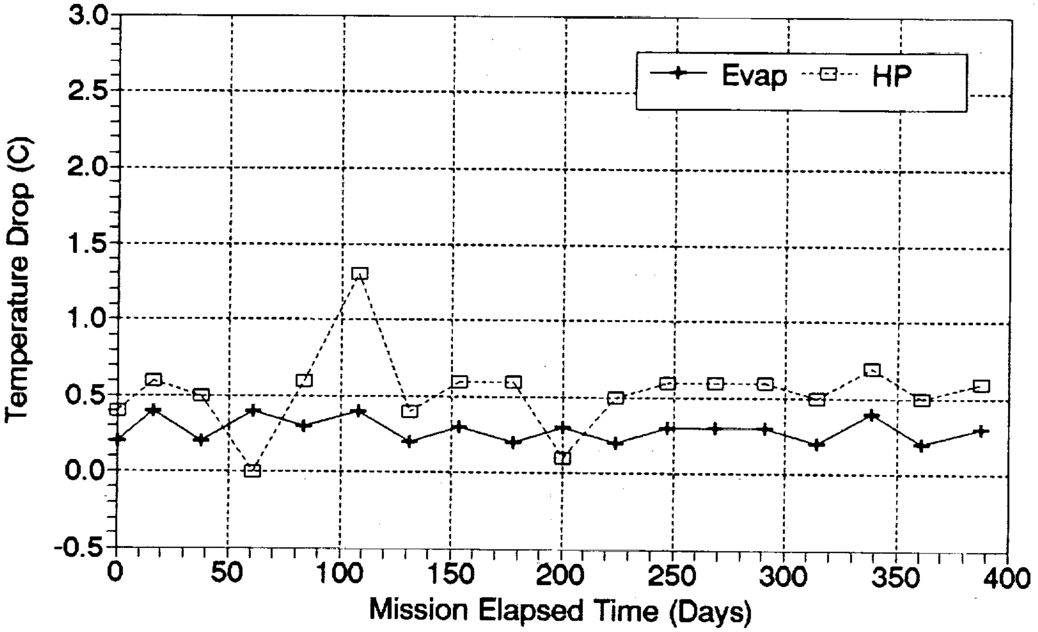
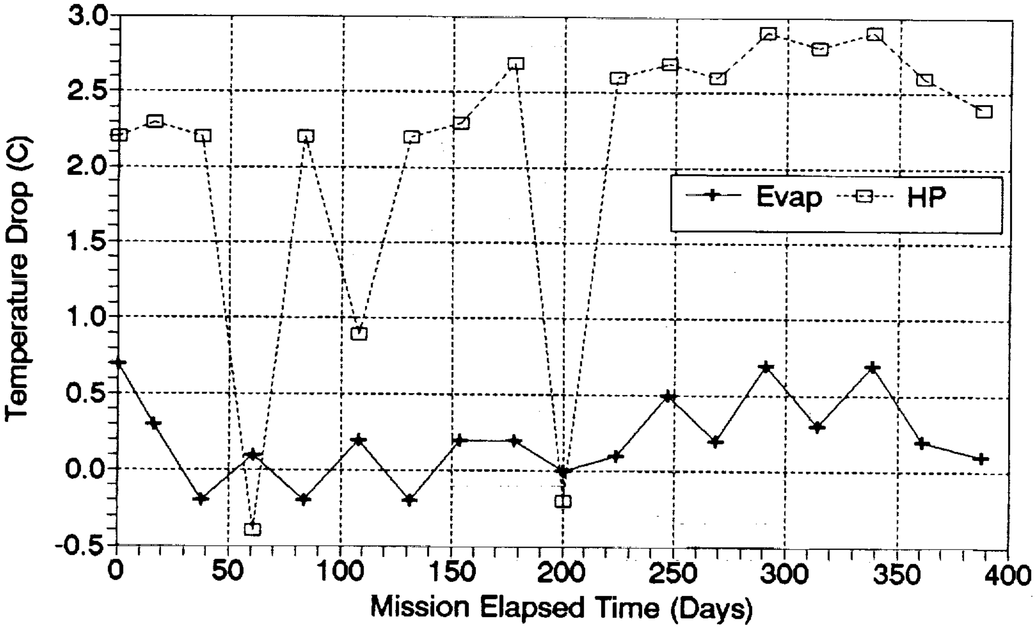


Figure 6B. Diode HP Temp. Drops vs Mission Time at Maximum and Minimum Beta Angles



Radiator and PCM temperatures are shown in Figure 7. These temperatures are essentially the same since the PCM is attached directly to the HEPP radiator as are the condenser sections of each heat pipe. The temperature cycling corresponds directly to the orbital variations in the solar heat flux that occur throughout the mission.

In addition to demonstrating successful long term low power heat pipe operation, the HEPP demonstrated successful performance of the electronics module, and associated instrumentation. The HEPP's EPDS and its Magnetic Tape Memory (MTM) and lithium batteries also performed without any difficulty. The HEPP's DET battery and solar arrays also performed as designed.

POST FLIGHT RESULTS

HEPP/CVCHPE/THERM/LDEF Integrated Test Results

A functional test was conducted with the HEPP (Trays F12 and H1), the CVCHPE (Tray F9), and the THERM integrated with the LDEF prior to Deintegration at KSC. Before conducting this test, the lithium batteries in each experiment were disconnected and GSE NiCad cells were connected with GSE harnesses. The HEPP NiCad flight battery which is contained in Tray H1 was discharged and recharged two days earlier. The Integrated Test is basically a functional check of the various electrical subsystems for each experiment.

The following is a summary of the results obtained from analysis of the HEPP NiCad battery data and the Integrated Test data.

1. All electronics systems including the EPDS, HEPP's Electronics Module, and the DET's electronics functioned properly.
2. All HEPP power profiles were executed indicating that the experiment heaters were in working condition and that the preprogrammed test sequence could have been executed.
3. All telemetry was within calibration for the ambient temperature operation.
4. The flight battery was essentially at 0 voltage across each of the 18 cells. It recharged rapidly (within 30 hours) and uniformly across each cell. The third electrode "came on" within approximately 12 hours after each cell had reached 1.4 volts.
5. The HEPP relay latched on when the third electrode reached a pressure of 250 psi which was consistent with its pre-flight behavior.
6. The temperature data for the heat pipes indicated that they still contained an ethane fluid inventory.
7. Each of the solar arrays was illuminated individually with a high intensity halogen lamp at the conclusion of the Integrated Test. An increase in the battery voltage was observed when each array was illuminated which indicated good overall array performance.

Figure 7A. Main Radiator - Location C

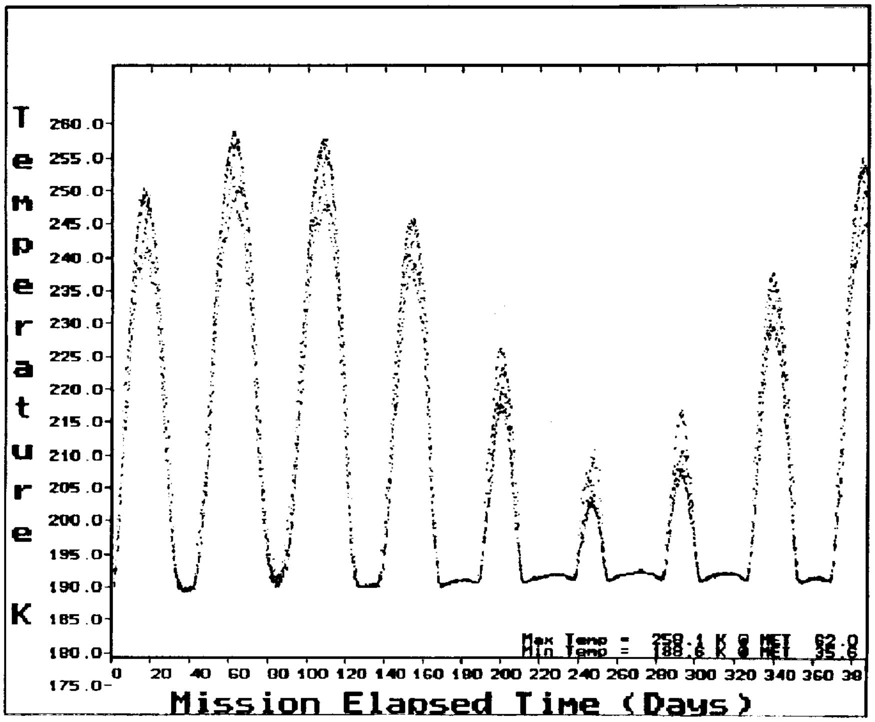
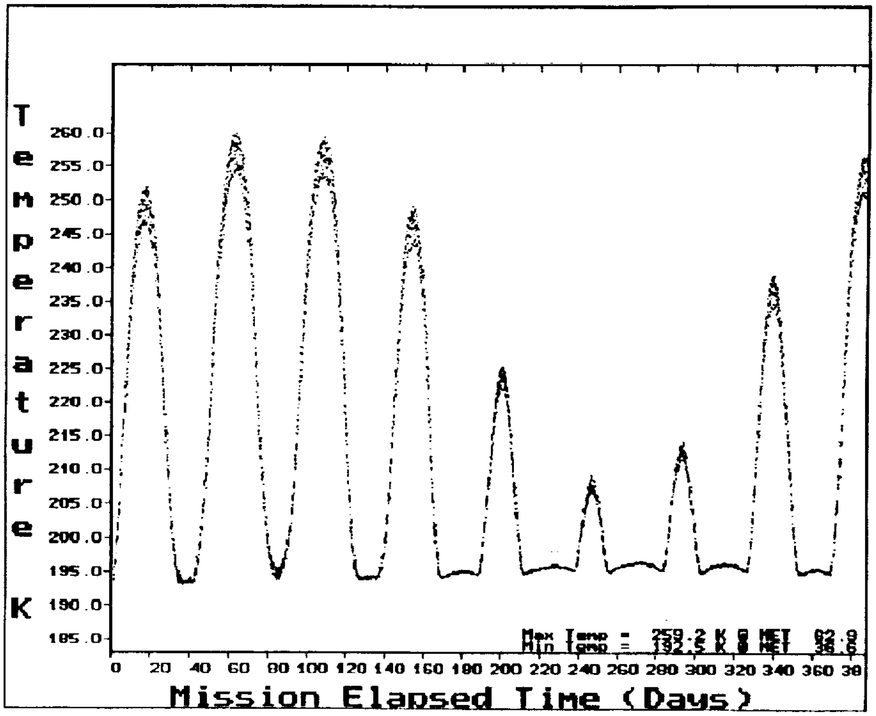


Figure 7B. PCM - Location C



8. Data recording through the EPDS was demonstrated with an alternate flight recorder. The flight MTM had been removed approximately one month earlier to transcribe the flight data. This component was determined to be in good operating condition and the recorded flight data was complete and had good quality.

In summary, all HEPP electrical systems were functioning properly after retrieval. Visual observations and the Integrated Test data indicated that the mechanical and thermal integrity of the HEPP were also intact.

Thermal Vacuum Tests

The HEPP was removed from its LDEF tray and installed into a test fixture that was fabricated to conduct thermal vacuum (TV) tests. This fixture included a liquid nitrogen cold plate to simulate the HEPP's radiation in deep space. Electrical heaters were attached to permit simulation of external solar, infrared and albedo inputs. A Ground Test Set was used to replace the EPDS and operate the HEPP electronics module. Tests were conducted in the large chamber in the Optical Coating Laboratory at Goddard Space Flight Center. Once the fixture was installed into the chamber its tilt was adjusted so that the two heat pipes which are coplanar were at an adverse tilt with the evaporator leg located above the condenser leg. The TV tests were conducted to accomplish the following objectives:

1. Simulate flight conditions and obtain transient cooldown temperature data for comparison with the flight data and correlation with thermal models.
2. Measure the heat transport capability of each heat pipe at two adverse elevations for comparison with pre-flight data.
3. Observe the freeze/thaw characteristics of the PCM canister and compare with pre-flight data.

A comparison of flight and TV test data is given in Figure 8 for the HEPP's radiator which is less than 1°K cooler than the PCM temperature. This data is for the "Long Term Forward Mode" of operation. This corresponds to the Flight Mode with 1.2 watts applied to the DHP and 1.0 watts applied to the CCHP. Flight data is for the first 36 hours of HEPP operation after LDEF deployment. These temperatures were the coldest that the HEPP ever achieved. The transient cooldown and steady state temperatures are essentially identical with the lowest temperature being 192.5 °K both in flight and in the TV test. Since the updated thermal model had correlated flight data, the close match of the TV test and flight data tends to imply that the updated model is correct.

The difference between the updated simplified model and the original thermal model appeared to be that the radiative parasitics from the LDEF's interior were not properly coupled to the HEPP's radiator and shields in the original model. This resulted in these parasitics having an insignificant effect on the HEPP radiator's predicted net cooling capacity. The net effect is that a higher heat rejection rate at a given radiator temperature and faster cooldown were predicted with the original thermal model. This condition was simulated in the TV tests by cooling the chamber walls with liquid nitrogen to eliminate parasitic input from the chamber. When the Long Term Forward Mode was repeated, the result was that the radiator and PCM cooled to below the freezing temperature of the

Figure 8. Comparison of Flight Data to TV Data for Radiator Cooldown- Long Term Forward Mode

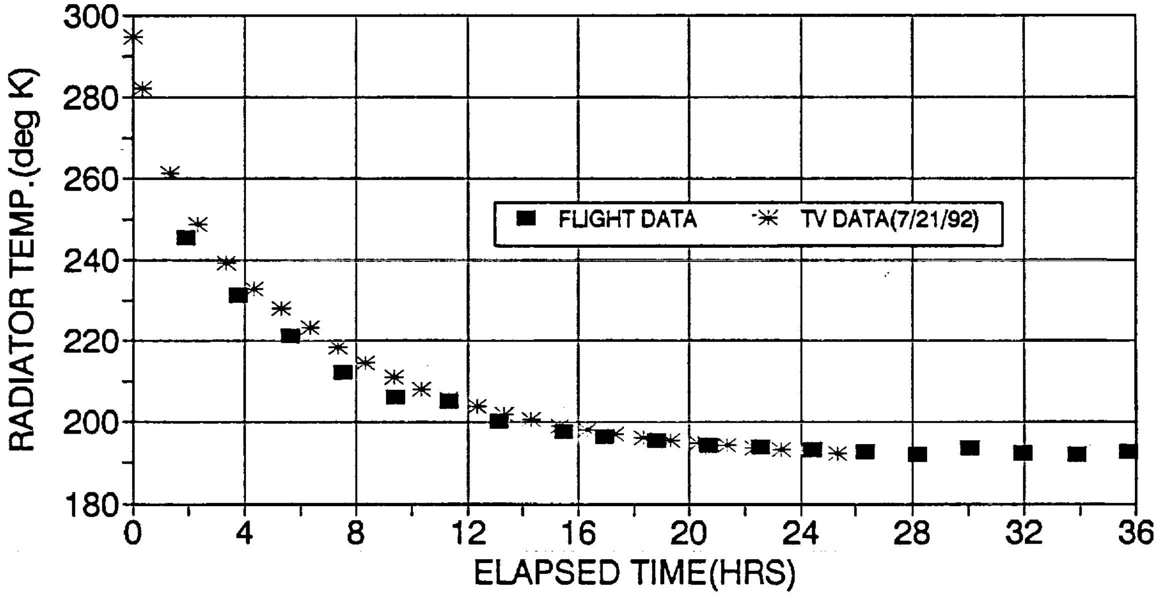
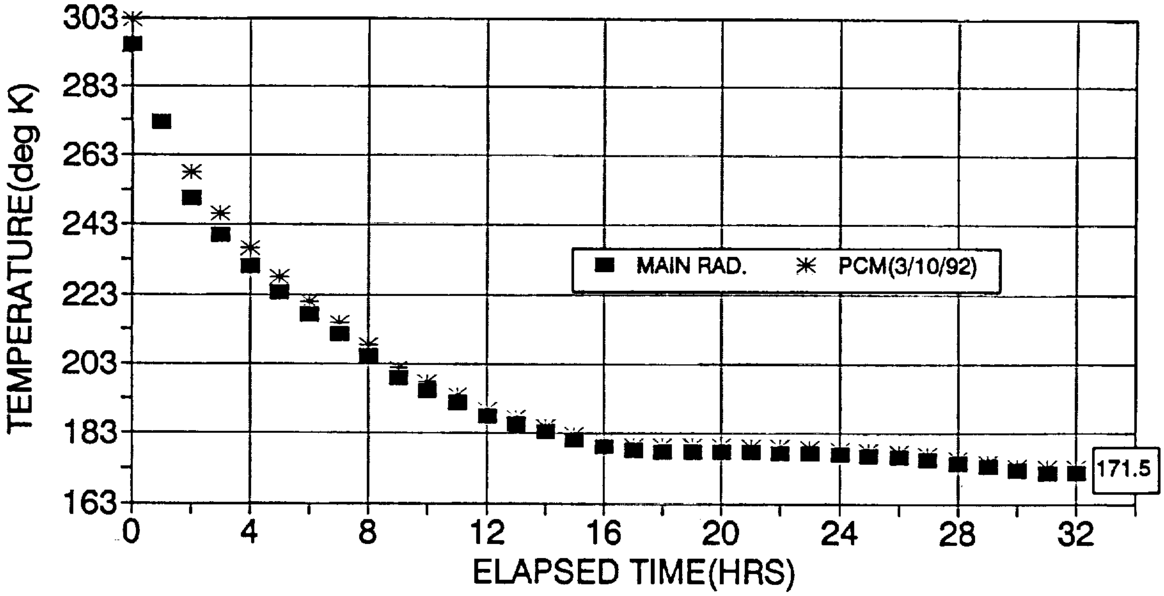


Figure 9. Long Term Forward Mode Cooldown with Cold Plate and Chamber Shroud LN Cooled



PCM as shown in Figure 9. These results are exactly as predicted with the original thermal model and tend to substantiate where the error occurred. Cooldown to 171.5°K was achieved after 32 hours prior to discontinuing the test.

The results of this test can be used to evaluate the PCM behavior. They show that the PCM freezes at 181.5°K. This is only 1°K higher than was measured 15 years prior and is well within the accuracy of the instrumentation. Also, freezing occurred for a total of 11.5 hours which corresponds to 57 watt-hours of energy based on the radiator's net heat rejection capacity at 181°K. The heat pipes were transporting 2.2 watts into the radiator at this time or 25.3 watt-hours of energy. The 31.7 watt-hours difference corresponds to the latent heat given up by the freezing of the PCM. This is approximately 20% higher than the energy predicted based on the 753 grams of n-heptane that are in the PCM canister but is well within the accuracy of the thermal estimate. The 31.7 watt-hours also corresponds exactly to thermal vacuum test results obtained in 1977. When the transport tests were conducted, the PCM melted at 181.5°K which again corresponds to its original melting temperature. In summary, the post flight thermal vacuum test results shown in Figure 9 demonstrate that the n-heptane canister is behaving almost exactly as it had 15 years ago. Also, there has been no apparent loss of n-heptane due to leakage over this period.

The results of the post flight heat pipe transport tests are shown in Figure 10 and Table 5. Again, the Long Term Forward Mode is exercised in ground tests for a one to one comparison with the flight data. Figure 10 compares the temperature drops across each heat pipe as a function of time from the start of cooldown. Also shown in Figure 10 are the temperature responses of each evaporator. Flight data again is for the first cooldown cycle so that heat pipe priming can be evaluated. The temperature drop and evaporator data show that the CCHP is primed and can carry the 1 watt heat load on the ground and in flight. The negative temperature drop in flight is instrumentation error which is less than 0.5°K.

The data for the diode heat pipe shows that it was fully primed by the time the first flight data point was recorded and the DHP had cooled to approximately 250°K. In the TV test however, which was conducted at an adverse tilt of 4.0 mm, the DHP was not fully primed until it had cooled to 220°K. Similar results were obtained in component tests with the DHP in 1978. A maximum evaporator temperature gradient of 42°K had occurred due to the 1.2 watt heat load prior to the DHP's priming. This same temperature drop would have occurred in flight if the DHP were not operating properly. Once primed, the ground and flight temperature drops are virtually identical at 1.1°K.

Table 5 summarizes the results of post flight transport tests that were conducted with each heat pipe at adverse tilts of approximately 2.4 and 4.0 mm. These tests were conducted by cooling the system and freezing all of the PCM and then using the pre-programmed test sequence with the electronics module and the flight heaters. This allows the transport tests to be conducted at a constant temperature of approximately 182°K. The CCHP held 25.2 watts and "Dried Out" at 29.5 at the 2.4 mm tilt. The theoretical maximum transport is 24 watts at this tilt and the 182°K test temperature. Component tests in 1977 verified the theoretical prediction. The slightly higher performance that is now being exhibited is probably due to the inability to accurately establish the tilt in systems tests.

Figure 10a. Comparison of CCHP Temperature Drop Between Flight & TV Test Data (4 mm Tilt)

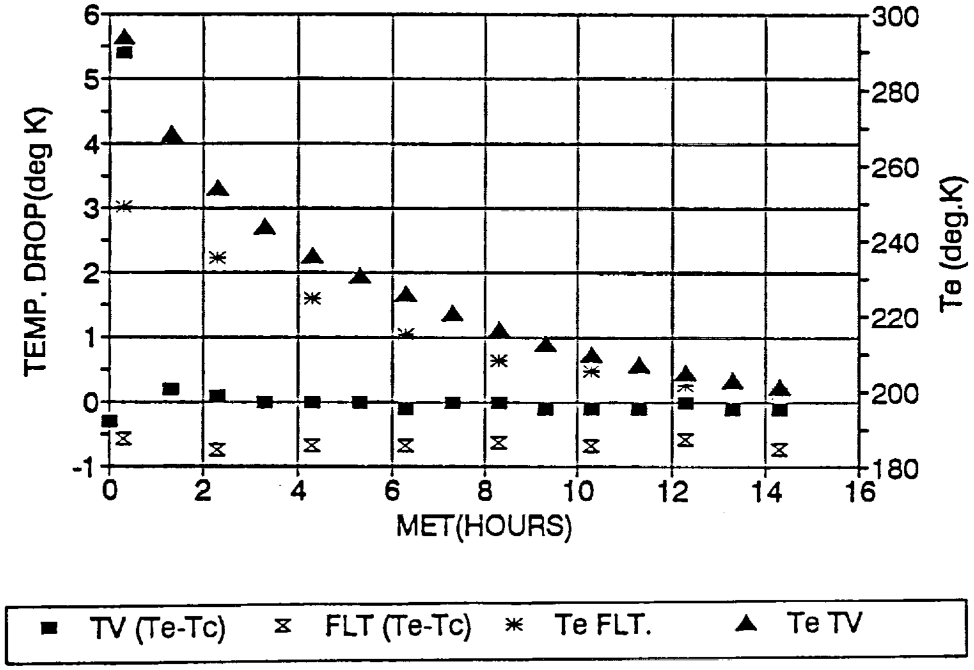
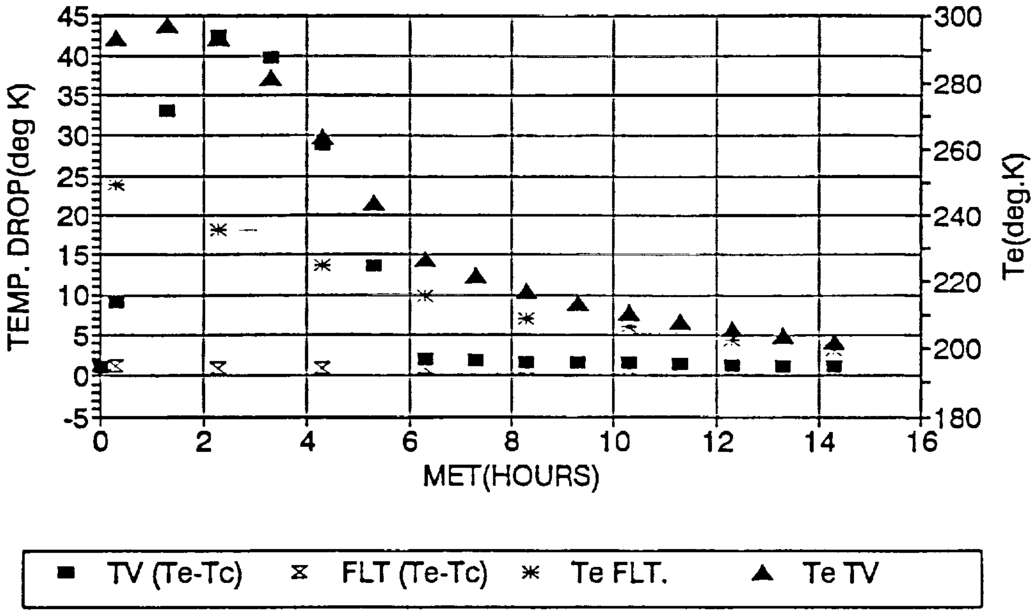


Figure 10b. Comparison of DHP Temperature Drop Between Flight & TV Data (4 mm Tilt)



The lowest power in the pre-programmed sequence is 21.4 watts and this caused immediate "Dry Out" of the CCHP at the higher tilt. The theoretical transport is 17 watts at this tilt. In any case, the data at the lower tilt indicates that the CCHP is still performing properly.

The transport test results for the diode heat pipe show that it held 14.9 watts and "Dried-Out" at 16.6 watts. The theoretical transport for these test conditions which was verified by component tests is 12.5 watts. Again, the higher test result is probably due to the inability to accurately measure the tilt in systems tests. The results from the DHP transport test at the 4.0 mm adverse tilt show that it held 7.3 watts and "Dried-Out" at 8.5 watts. The theoretical transport for this tilt is 8.0 watts. Again, we can say that the diode heat pipe appears to be working properly since being fabricated 14 years ago.

Table 5. Summary - Post Flight Transport Test Data

	6/10/92 PRE ELEV @ 2.2 MM POST ELEV @ 2.8 MM		7/10/92 PRE ELEV @4.0 MM POST ELEV @ 4.0 MM	
	POWER (W)	DTe(deg K)	POWER (W)	DTe(deg K)
CONSTANT CONDUCTANCE HEAT PIPE * DENOTES DRY OUT	0.0 25.2 29.5 2.0 2.0	0.0 6.6 30.0* 32.0 1.2	21.4	DRY OUT
DIODE HEAT PIPE * DENOTES DRY OUT	0.0 8.5 11.0 14.9 16.6 0.7	0.0 4.7 6.7 5.8 9.0* 3.2	0.0 7.3 8.5 0.8	0.0 4.2 8.0* 3.5

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