CRYOGENIC HEAT PIPE EXPERIMENT
CRYOHP

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NASA GODDARD SPACE FLIGHT CENTER
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JUSTIFICATION – HEAT PIPE TECHNOLOGY

INVESTIGATION OF MICRO-GRAVITY EFFECTS ON HEAT PIPE THERMAL PERFORMANCE AND WORKING FLUID BEHAVIOR (IMEHP)

PERFORMANCE COMPARISON BETWEEN PREDICTIONS AND DATA (REF.: AIAA 77-747)

![Graph showing performance comparison between predictions and data for ammonia at different elevations.](image-url)
NASA IN-STEP HEAT PIPE PERFORMANCE (HPP)

40°C FREON HEAT PIPE GROUND TEST DATA

![Graph showing the relationship between Q (watts) and TILT (inches) with data points for F01 and F02.](image)
IN-STEP HEAT PIPE PERFORMANCE (HPP) EXPERIMENT

OBJECTIVES – SYSTEM LEVEL

- HOW DOES EXCESS LIQUID IN HEAT PIPES AFFECT SPACECRAFT THERMAL PERFORMANCE

- HOW DO SPACECRAFT ACCELERATIONS BETWEEN 0 AND 1-g AFFECT HEAT PIPE PERFORMANCE

- OBTAIN DATA FOR DESIGN IMPROVEMENTS IN SPACE HEAT PIPES:
  - LIGHTER WEIGHT, RELIABLE, AND MORE EFFICIENT SYSTEMS
  - HANDLING EXCESS LIQUID
  - START-UP AND REWICKING IN SPACE
IN-STEP HEAT PIPE PERFORMANCE (HPP) EXPERIMENT

TYPICAL SPACECRAFT ACCELERATIONS BETWEEN 0 AND 1-G:

- RENDEZVOUS AND DOCKING
- ASCENT/DESCENT
- ORBITAL MANEUVERING
- LUNAR BASE OR MARS MISSION
- SPINNING/DE-SPINNING
  - SPINNING S/C (e.g., INTERNATIONAL SOLAR TERRESTRIAL PLATFORM, ISTP–8 FT DIA. x 10 RPM)
- STABILIZATION (TRANSFER ORBIT, GEO-SYNCHRONOUS)
- SURVEILLANCE
- HARDENING
- THREAT AVOIDANCE
- SPACE DEBRIS
- MILITARY
IN-STEP HEAT PIPE PERFORMANCE (HPP) EXPERIMENT

APPROACH

- TWO (2) HEAT PIPE CONFIGURATIONS
  - FIXED CONDUCTANCE HEAT PIPES (FCHPs):
    AXIAL GROOVE DESIGN; MOST COMMON DESIGN
    SPECIFIED FOR COMMUNICATIONS, SURVEILLANCE,
    SCIENTIFIC, AND OTHER SPACECRAFT
  - VARIABLE CONDUCTANCE HEAT PIPES (VCHPs):
    POROUS WICK DESIGN; CURRENTLY BEING USED
    ON HUGHES HS-111 SPACECRAFT, AND PROPOSED
    FOR FUTURE MISSIONS

- HEAT PIPE WORKING FLUIDS/MATERIALS:
  - WATER/COPPER (16 EACH)
  - FREON – 113/ALUMINUM (2 EACH)
  - VARIOUS FILL FRACTIONS (90 TO 120 %)
IN-STEP HEAT PIPE PERFORMANCE (HPP) EXPERIMENT

APPROACH (CONTINUED)

- THERMAL PERFORMANCE
  - STATIC
  - SPIN
  - REWICKING
IN-STEP HEAT PIPE PERFORMANCE (HPP) EXPERIMENT

THERMAL PERFORMANCE MODEL
NASA IN-STEP HEAT PIPE PERFORMANCE (HPP) FLIGHT HEAT PIPES
NSTS Shuttle Orbiter Middeck Configuration
IN-STEP HEAT PIPE PERFORMANCE (HPP) MIDDECK MODULAR LOCKERS
# Heat Pipe Performance Experiment
## Weight and Power Summary

<table>
<thead>
<tr>
<th>Item</th>
<th>Quantity</th>
<th>Weight (lbs)</th>
<th>Orbital Power (watts)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat Pipe, Warmers,* and Thermostats**</td>
<td>14</td>
<td>10.9</td>
<td>&lt;60.0</td>
</tr>
<tr>
<td>Control/Motor Module</td>
<td>1</td>
<td>27.7</td>
<td>&lt;32.0</td>
</tr>
<tr>
<td>Safety Shroud, Quarter Pieces with Brownline Fittings</td>
<td>1</td>
<td>27.8</td>
<td></td>
</tr>
<tr>
<td>Data Loggers and Cables</td>
<td>2 ea</td>
<td>9.4</td>
<td></td>
</tr>
<tr>
<td>Batteries, Data Logger (Spares)</td>
<td>4</td>
<td>4.0</td>
<td></td>
</tr>
<tr>
<td>HPP Tool Kit***</td>
<td>1</td>
<td>~5.0</td>
<td></td>
</tr>
<tr>
<td>Crowmember Deerskin Gloves</td>
<td>1 pr</td>
<td>0.25</td>
<td></td>
</tr>
<tr>
<td>DC Power Cables</td>
<td>1</td>
<td>~1.0</td>
<td></td>
</tr>
<tr>
<td>35mm Film, Kodak 5017</td>
<td>2</td>
<td>0.41</td>
<td></td>
</tr>
<tr>
<td>VIU with Cables</td>
<td>1</td>
<td>2.71</td>
<td></td>
</tr>
<tr>
<td>Video Camcorder Assembly</td>
<td>1</td>
<td>3.3</td>
<td>9.6</td>
</tr>
<tr>
<td>Camcorder Videocassettes</td>
<td>12</td>
<td>2.0</td>
<td></td>
</tr>
<tr>
<td>Camcorder Batteries (Spares)</td>
<td>8</td>
<td>5.0</td>
<td></td>
</tr>
<tr>
<td><strong>Total Weight</strong></td>
<td></td>
<td><strong>99.2</strong></td>
<td>&lt;103.6</td>
</tr>
<tr>
<td><strong>Total Power</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*One (1) per heat pipe.

**Two (2) per heat pipe warmer.

***Includes spare circuit board interface assembly and motor amplifier board assembly.
Table 2. NASA Supplied Equipment Flown in HPP Lockers

<table>
<thead>
<tr>
<th>Item</th>
<th>JSC Part No.</th>
<th>Qty</th>
<th>Usage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Video Camera</td>
<td>SED33103370-301</td>
<td>1</td>
<td>Video Recording</td>
</tr>
<tr>
<td>2. Video Interface Unit</td>
<td>SED39121272-301</td>
<td>1</td>
<td>Camera Adapter</td>
</tr>
<tr>
<td>3. Video Cable</td>
<td>SED39122102-301</td>
<td>1</td>
<td>Camera Power/Signal</td>
</tr>
<tr>
<td>4. Deerskin Gloves</td>
<td>TBS</td>
<td>1 pr</td>
<td>Hand Protection</td>
</tr>
</tbody>
</table>
HI OH STOWAGE COMPARTMENT

MISSION/PAYLOAD SPECIALIST

WASTE MANAGEMENT COMPARTMENT

HPP Apparatus Mounted to Middeck Floor
STS-52 MISSION SPECIALIST
DR. T. JERNIGAN
Simple Closed Form Heat Pipe Models (Cotter's Equations):

\[ \Delta P_{\text{cap}} - \Delta P_{c} \geq \Delta P + \Delta P_{v} \]

Where:
- \( \Delta P_{\text{cap}} \) = Capillary Pressure Head
- \( \Delta P_{c} \) = Centrifugal Pressure Head Due to Rotation
- \( \Delta P \) = Liquid Pressure Drop
- \( \Delta P_{v} \) = Vapor Pressure Drop

Wick Capillary Pumping Based on Eninger's Approach for Fibrous Wicks:

\[ \Delta P_{\text{cap}} = 6.36 \frac{(1 - \varepsilon)}{\varepsilon} \frac{\sigma}{d_{w}} \]

Where:
- \( d_{w} \) = Wire Diameter
- \( \varepsilon \) = Wick Porosity
- \( \sigma \) = Surface Tension

*AIAA Paper No. 75-661
Wick Pressure Drop Based on Darcy's Equation:

$$\Delta P_l = \frac{\mu_l Q L_{\text{eff}}}{K_w A_w h_{fg} \rho_l}$$

Where:

- $K_w = \frac{d_w^2}{122} \frac{\varepsilon^3}{(1 - \varepsilon)^2}$
- $K_w =$ Wick Permeability
- $\mu_l =$ Liquid Viscosity
- $h_{fg} =$ Latent Heat of Working Fluid
- $Q =$ Heat Transport
- $L_{\text{eff}} =$ Effective Heat Pipe Length

Groove and Vapor Pressure Drops Based on Channel Flow:

- $\Delta P_{\text{cap}} = \frac{2 \sigma}{w_g}$
  - $w_g =$ Groove Width
- $\Delta P_{l,v} = \frac{2 (fRe)_{l,v} \mu_{l,v} Q L_{\text{eff}}}{(d_h^2)_{l,v} A_{l,v} \rho_{l,v} h_{fg}}$
  - $fRe =$ Constant (Laminar Flow)
  - $d_h = \frac{4A}{P_w}$
Centrifugal Force Due to Spinning:

\[ dF_c = r \omega^2 dm \]
\[ dF_c = \rho \omega^2 r A_w dh \]

Pressure Drop at Radius, \( r \), Due to Centrifugal Force on Element:

\[ \frac{dF}{A_w} = dp = \rho \omega^2 r dh \]
\[ r = L - h \]
\[ dp = \rho \omega^2 (L - h) dh \]

Pressure Drop at Radius, \( r \), Due to Centrifugal Force on Liquid column of Length, \( h \):

\[ \Delta P_c = \rho \omega^2 \int_0^h (L - h) \, dh \]
\[ \Delta P_c = \rho \omega^2 h \left( L - \frac{h}{2} \right) \]

\( r \) = Radius About Axis of Rotation
\( L \) = Heat Pipe Length
\( A_w \) = Wick Cross-Sectional Area
\( \rho \) = Liquid Density
\( \omega \) = Angular Velocity
IN-STEP HEAT PIPE PERFORMANCE (HPP) EXPERIMENT
HEAT PIPE THERMAL PERFORMANCE ANALYSIS

PRESSURE HEAD DIFFERENTIAL ARISING FROM FCHP ROTATION

- ΔP_{cap}
- (ΔP_{cap} - ΔP_c) @ FCHP Rotation Speed of 2 rpm

HEAT PIPE PARAMETERS:
- Working Fluid: Freon 113
- Fluid Pumping Medium: Axial Groove
- Operating Temperature: 80°C
- Heat Input: 20 W
- Gravitational Acceleration:
  - 0 g (1 g w/o tilt)

AXIAL HEAT PIPE LOCATION (INCHES)
# Description of Experimental Pipes

<table>
<thead>
<tr>
<th>Item</th>
<th>Fixed Conductance Heat Pipes (FCHPs)</th>
<th>Variable Conductance Heat Pipes (VCHPs)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Copper - Water</td>
<td>Aluminum - Freon</td>
</tr>
<tr>
<td>Outside Diameter (in.)</td>
<td>0.50</td>
<td>0.50</td>
</tr>
<tr>
<td>Wall Thickness (in.)</td>
<td>0.020</td>
<td>0.030</td>
</tr>
<tr>
<td>Active Length (in.)</td>
<td>17.0</td>
<td>17.0</td>
</tr>
<tr>
<td>Gas Reservoir</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Material</td>
<td>OFE Copper</td>
<td>6063-T6 Aluminum</td>
</tr>
<tr>
<td>Wick:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Description</td>
<td>25 axial grooves electro-discharge machined in envelop wall</td>
<td>40 axial grooves extruded in envelop wall.</td>
</tr>
<tr>
<td>Dimension (in.)</td>
<td>0.040 depth 0.034 width</td>
<td>0.035 depth x 0.017 width</td>
</tr>
<tr>
<td>Material</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Working Fluid</td>
<td>Triply Distilled Water</td>
<td>Freon-113</td>
</tr>
<tr>
<td>Nominal Fluid (gm)</td>
<td>7.7</td>
<td>8.8</td>
</tr>
<tr>
<td>Liquid Fill Fractions (%)</td>
<td>90,100,105</td>
<td>100</td>
</tr>
<tr>
<td>Weight per pipe, dry (lbm)</td>
<td>0.32</td>
<td>0.15</td>
</tr>
<tr>
<td>Quantity (Flight)</td>
<td>6</td>
<td>2</td>
</tr>
</tbody>
</table>

* Two (2) VCHPs will have non-condensable gas and four (4) will not. Reservoir has hemispherical end caps.

¹ OD x 2.5
Hughes

NASA IN-STEP
HEAT PIPE
PERFORMANCE (HPP)
FIXED
CONDUCTANCE
HEAT PIPE

CONNECTOR

PRT

BRACKET

THERMOSTAT

COPPER/WATER

FREON/AL

ø 0.500

25X 0.040

25X 0.034

25X 14.5°

25X 14.3°

ø 0.370

40X ø 0.440

40X 0.035

40X 0.017

40X 9.1°

40X 8.9°

Hughes NASA IN-STEP Heat Pipe Performance (HPP) Fixed Conductance Heat Pipe
Heat Pipe Pressure Characteristics

<table>
<thead>
<tr>
<th></th>
<th>Nominal Operating Pressure (PSIA) at 65°C</th>
<th>Maximum Design Pressure (PSIA) at 85°C*</th>
<th>Minimum Required Burst Pressure (PSIA)**</th>
<th>Calculated Burst Pressure (PSIA)</th>
<th>Safety Factor ***</th>
<th>Proof Pressure (PSIG)</th>
<th>Qty.</th>
</tr>
</thead>
<tbody>
<tr>
<td>FCHP Freon 113/Al 6063-T6</td>
<td>24.7</td>
<td>44.7</td>
<td>111.8</td>
<td>1149</td>
<td>26</td>
<td>223.5</td>
<td>2</td>
</tr>
<tr>
<td>FCHP Water/Copper</td>
<td>3.6</td>
<td>8.4</td>
<td>21.0</td>
<td>1667</td>
<td>198</td>
<td>42.0</td>
<td>6</td>
</tr>
<tr>
<td>VCHP Water/Copper</td>
<td>3.6</td>
<td>8.4</td>
<td>21.0</td>
<td>1129</td>
<td>134</td>
<td>42.0</td>
<td>6</td>
</tr>
</tbody>
</table>

* This pressure results from the temperature corresponding to the worst-case two-failure condition.

** This pressure corresponds to the MDP with a safety factor of 2.5

*** Based on the temperature corresponding to MDP (i.e. SF = calculated burst pressure/MDP)
<table>
<thead>
<tr>
<th>Component</th>
<th>Material</th>
<th>Max. Stress (kPa)</th>
<th>Ult. Stress (kPa)</th>
<th>Factor of Safety</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motor Mount</td>
<td>Steel</td>
<td>30.3</td>
<td>517</td>
<td>17.1</td>
</tr>
<tr>
<td>Screw A</td>
<td>Steel</td>
<td>3.69</td>
<td>75.8</td>
<td>20.6</td>
</tr>
<tr>
<td>Screw B Mount</td>
<td>Aluminum</td>
<td>120</td>
<td>517</td>
<td>4.3</td>
</tr>
<tr>
<td>Screw C</td>
<td>Steel</td>
<td>4.44</td>
<td>317</td>
<td>71.6</td>
</tr>
<tr>
<td>Heat Pipe Bracket DZUS</td>
<td>Steel</td>
<td>4.44</td>
<td>317</td>
<td>71.6</td>
</tr>
<tr>
<td>Fastener</td>
<td>Steel</td>
<td>6.25</td>
<td>317</td>
<td>50.7</td>
</tr>
<tr>
<td>Cruciform Arm Hinge Pin</td>
<td>Steel</td>
<td>21.7</td>
<td>193</td>
<td>8.9</td>
</tr>
<tr>
<td>(2)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fan Blade</td>
<td>Steel</td>
<td>43.1</td>
<td>65.5</td>
<td>1.5</td>
</tr>
<tr>
<td>Safety Shroud</td>
<td>Lexan</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
HPP EXPERIMENT FEATURES
PAYLOAD INTEGRATION

- Mechanical Integration
  - Modular Design Facilitates Assembly and Stowage (Nominal and Emergency)
  - Hardware Stows in Three Middeck Locker Drawers
  - HPP Complies with NSTS 21000-IDD-MDK Weight and c.g. Requirements
  - Total HPP Weight: 99.2 lbs (36 lbs Maximum in Single Locker)

- Electrical Integration
  - Total Orbiter DC Electrical Power Used by HPP: 104 Watts (Maximum)
  - Fuse (5 amp) at Payload/Orbiter Interface Protects Against HPP Failure
  - SSP-Provided Power Cord (15 ft Length) Connects HPP to Orbiter
  - Relay Prevents Inadvertant Activation Upon Power Cord Connection
HPP EXPERIMENT FEATURES
THERMAL, MECHANICAL DESIGN

• Thermal Design Features
  • Redundant Thermostats (Elmwood 3200) Mounted on Each Heat Pipe
    Preclude Overheating
  • Active Cooling Uses 35 CFM Fan (Pabst 8124 G) on Each Pipe
  • Aluminum and Lexan 9600 Safety Shroud Prevents Contact with
    Surfaces at Elevated Temperatures (up to 85°C)

• Mechanical Design Features
  • Heat Pipes Incorporate Large Safety Factors (\(P_{BURST}/P_{MAX} > 25\))
  • Rotating Structure Safety Factors Exceed 1.4 Ultimate
  • Collision Hazard Prevented by Safety Shroud, Internal Clutch, and Low
    Angular Momentum; Safety Factor Exceed 1.4 Ultimate
  • Design Contains no Fracture Critical Components as Defined by
    NHB8071.1 (19,307 Joules Criterion)
IN-STEP HEAT PIPE PERFORMANCE (HPP)
ELECTRICAL DESIGN

- Design Constraints
  - 115 Watt Power Limit
  - 28±4 VDC Power Supply From Spacecraft Bus
  - Specified Low Conductive and Radiative EMI

- Design Features
  - Switching Voltage Regulators Versus Analog for High Efficiency, Constant Output Regardless of Input Voltage Variation.
  - LCDs for Low Power Consumption
  - Each Controller Designed with Schottky Diode EMI Suppression
  - EMI Block Filter Installed on Input Line
  - Brushless DC Motor Used on Fans and Drive Mechanism

- Safety Features
  - Specified NASA Approved Circuit Breakers
  - Warmer/Fan Interlock
  - Dual Thermostats for Heat Pipe Over-Temperature Protection
  - Fail-Safe Start-up
  - Exclusive Operation of a Single Heat Pipe and Fan at Any Time
HEAT PIPE PERFORMANCE (HPP) THERMAL PERFORMANCE EXPERIMENT

- Total HPP Duration is 18 Hours not including Set-up and Restowage Time
- HPP Includes Three Types of Experimental Runs:
  1) Static Testing—at 0 RPM (no Rotation) Heat Pipes are Warmed at Increasing Power Levels Intil:
     a) Dryout Occurs;
     b) 40 W Maximum Power Level is Reached; or
     c) Heat Pipe Temperature Exceeds 85° C
  2) Spin Testing—at Warmer Power of 20 to 40 W, Spin Rates are Increased Until:
     a) Dryout Occurs; or
     b) 30 RPM Spin Rate is Reached
  3) Rewicking Testing – See Next Viewgraph
HPP REWICKING TEST TIMELINE

LEGEND:
- - - - Spin Rate
--- --- Power

Spin Rate (rpm)

Power (Watts)

Time (minutes)

0 10 20 30 40 50 60

70 60 50 40 30 20 10

1F1
2V1
3F2
4V2

70 60 50 40 30 20 10

- - - - Spin Rate
--- --- Power

Spin Rate (rpm)

Power (Watts)

Time (minutes)
## HPP TEST MATRIX

<table>
<thead>
<tr>
<th>RUN</th>
<th>TEST</th>
<th>HEAT PIPE</th>
<th>FLUID</th>
<th>POWER LEVEL</th>
<th>TEST INCREMENT</th>
<th>SPIN RATE</th>
<th>WARM TIME</th>
<th>RUN TIME</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>STATIC</td>
<td>1F1</td>
<td>Freon-113</td>
<td>8 → 16 W</td>
<td>2 W</td>
<td>0 RPM</td>
<td>15 min</td>
<td>90 min</td>
</tr>
<tr>
<td>A2</td>
<td>STATIC</td>
<td>2V1</td>
<td>Water/NCG</td>
<td>20 → 40 W</td>
<td>20 W</td>
<td>0 RPM</td>
<td>15 min</td>
<td>30 min</td>
</tr>
<tr>
<td>A3</td>
<td>STATIC</td>
<td>3F2</td>
<td>Freon-113</td>
<td>8 → 16 W</td>
<td>2 W</td>
<td>0 RPM</td>
<td>15 min</td>
<td>90 min</td>
</tr>
<tr>
<td>A4</td>
<td>STATIC</td>
<td>4V2</td>
<td>Water/NCG</td>
<td>20 → 40 W</td>
<td>20 W</td>
<td>0 RPM</td>
<td>15 min</td>
<td>30 min</td>
</tr>
<tr>
<td>B1</td>
<td>SPIN</td>
<td>1F1</td>
<td>Freon-113</td>
<td>6 W</td>
<td>2 RPM</td>
<td>2 → 8</td>
<td>10 min</td>
<td>40 min</td>
</tr>
<tr>
<td>B2</td>
<td>SPIN</td>
<td>2V1</td>
<td>Water/NCG</td>
<td>40 W</td>
<td>3 RPM</td>
<td>20 → 29</td>
<td>10 min</td>
<td>40 min</td>
</tr>
<tr>
<td>B3</td>
<td>SPIN</td>
<td>3F2</td>
<td>Freon-113</td>
<td>6 W</td>
<td>2 RPM</td>
<td>2 → 8</td>
<td>10 min</td>
<td>40 min</td>
</tr>
<tr>
<td>B4</td>
<td>SPIN</td>
<td>4V2</td>
<td>Water/NCG</td>
<td>40 W</td>
<td>3 RPM</td>
<td>20 → 29</td>
<td>10 min</td>
<td>40 min</td>
</tr>
<tr>
<td>C1</td>
<td>REWICK</td>
<td>1F1</td>
<td>Freon-113</td>
<td>5 W</td>
<td>N/A</td>
<td>50 RPM</td>
<td>20 min</td>
<td>20 min</td>
</tr>
<tr>
<td>C2</td>
<td>REWICK</td>
<td>2V1</td>
<td>Water/NCG</td>
<td>20 W</td>
<td>N/A</td>
<td>50 RPM</td>
<td>10 min</td>
<td>10 min</td>
</tr>
<tr>
<td>C3</td>
<td>REWICK</td>
<td>3F2</td>
<td>Freon-113</td>
<td>5 W</td>
<td>N/A</td>
<td>50 RPM</td>
<td>20 min</td>
<td>20 min</td>
</tr>
<tr>
<td>C4</td>
<td>REWICK</td>
<td>4V2</td>
<td>Water/NCG</td>
<td>20 W</td>
<td>N/A</td>
<td>50 RPM</td>
<td>10 min</td>
<td>10 min</td>
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<tr>
<td>D1</td>
<td>STATIC</td>
<td>1F3</td>
<td>Water</td>
<td>20 → 40 W</td>
<td>20 W</td>
<td>0 RPM</td>
<td>15 min</td>
<td>30 min</td>
</tr>
<tr>
<td>D2</td>
<td>STATIC</td>
<td>2V3</td>
<td>Water</td>
<td>20 → 40 W</td>
<td>20 W</td>
<td>0 RPM</td>
<td>15 min</td>
<td>30 min</td>
</tr>
<tr>
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</table>

**TOTAL** = 1100
HEAT PIPE PERFORMANCE (HPP)
THERMAL PERFORMANCE EXPERIMENT

- Four Heat Pipes are Mounted at Once in "Pinwheel"; Only One of the Four is Thermally Active at Any Time During the Flight

- Temperature Control is Maintained by Power Regulation Circuitry and by Fans Mounted on Rotating Platform

- Thermostatic Switches Mounted on Heat Pipes Prohibit Overheating

- Thin Film Warmers are Attached to the Evaporator Section of Pipes; Maximum Temperature (Inaccessible Surfaces) is 85°C

- Safety Shroud with Aluminum Sides, Lexan 9600 Top Provides Thermal and Collision Protection for Crew

- HPP Operation is Controlled from Raised Panel of "Control Module"

- Data Recorded Using Solid State Data Loggers and Videotape Recording of Control Module Panel Meters

- Orbiter Power Used for Warmers; Power and Data Transferred Through Slip Rings to HPP Rotating Platform

- HPP Attached to Middeck Floor Using Fittings Mounted to Seat Studs
IN-STEP HEAT PIPE PERFORMANCE (HPP) EXPERIMENT

OBJECTIVES – HEAT PIPE TECHNOLOGY

• HOW DOES HEAT PIPE PERFORMANCE IN SPACE DIFFER FROM PERFORMANCE ON THE GROUND?
  • GRAVITY DOMINATES IN GROUND TESTING
  • SURFACE TENSION DOMINATES IN MICRO-GRAVITY ENVIRONMENT
  • EFFECT OF UNDERFILL AND OVERFILL?

• OBTAIN QUANTITATIVE DATA FOR AXIAL GROOVE AND POROUS WICK HEAT PIPES IN A MICRO-GRAVITY ENVIRONMENT FOR:
  • COMPARISON WITH ANALYTICAL MODELS
  • COMPARISON WITH GROUND TEST DATA
  • COMPARISON WITH EXISTING FLIGHT DATA
Primary Objectives of HPP Middeck Experiment:

1) Obtain Quantitative Data on Thermal Performance of Heat Pipes in a Microgravity Environment for Comparison with Ground Testing

2) Develop an Increased Understanding of Heat Pipes Subjected to Accelerations in Space

3) Results will be Used to Improve Design of Spacecraft Thermal Control Systems

HPP Design Heritage Includes Hughes Fluid Dynamics Experiment (FDE), and Several KC-135 Experiments