Thermal Energy Storage Flight Experiment in Microgravity

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Presented at the NASA / DOD Flight Experiments Technical Interchange Meeting, Monterey, California

October 5-9, 1992
Heat Pipe Performance Experiment

Flight Experiments Technical Interchange Meeting

Sponsored by
Space Technology Interdependency Group
Flight Experiments Committee

October 5-9, 1992
Monterey, CA

George Fleischman
Hughes Aircraft Company
CRYOGENIC HEAT PIPE EXPERIMENT
FY 93 PLANS

• SUPPORT FLIGHT OPERATIONS
• REDUCE FLIGHT DATA AND RESOLVE ANY ANOMALIES
• PERFORM POST FLIGHT TESTS ON EXPERIMENT AND HEAT PIPES
• INCORPORATE RESULTS INTO GROOVE ANALYSIS PROGRAM AND SUBMIT TO COSMIC
• COMPLETE FINAL REPORT
CRYOGENIC HEAT PIPE EXPERIMENT
CURRENT STATUS

• DELIVERED TO KSC AND INSTALLED ON SHUTTLE
• FINAL INTERFACE VERIFICATION TEST COMPLETED
• ALL DOCUMENTATION COMPLETE
• LAUNCH DUE ON NOVEMBER 16, 1992
# CRYOHP INSTRUMENTATION

<table>
<thead>
<tr>
<th>TYPE</th>
<th>QUANTITY</th>
<th>LOCATION</th>
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<tbody>
<tr>
<td>Platinum Resistance Thermometers (PRTs)</td>
<td>26</td>
<td>13 each heat pipe system</td>
</tr>
<tr>
<td>Thermistors</td>
<td>24</td>
<td>UEP, EBP, pillars, heat pipe structure, cryo-coolers, electronics</td>
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<tr>
<td>Thermistors</td>
<td>9 (HH)</td>
<td>EBP, Canister, &amp; CECM Mounting Brackets</td>
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<tr>
<td>Pressure Transducers</td>
<td>1</td>
<td>Canister Internal Pressure</td>
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<tr>
<td>Current Monitors</td>
<td>13</td>
<td>CECM</td>
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<tr>
<td>Voltage Monitors</td>
<td>18</td>
<td>1 for bus voltage, 17 for temperature calibration</td>
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<tr>
<td>Heaters (Kapton foil)</td>
<td>11</td>
<td>4 per heat pipe, 3 survival</td>
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<tr>
<td>Thermostats</td>
<td>33</td>
<td>Tri-series circuit for each heater</td>
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</tbody>
</table>
HAC HEAT PIPE TRANSIENT COOLDOWN
TEST DATE: 04-09-92

TEMPERATURE (K)

TIME (HOURS)

\[ T_e = 82 \]
\[ T_t = 61 \]
HEAT PIPE - CONCEPT
SCHEMATIC -- CRYOHP OPERATION

Cryocoolers
Heat Out

Thermal Shunt

Kapton Foil Heaters
Heat In

Heat Pipe
CRYOHP OPERATIONS SCENARIO

ASCENT
- Vent to 2 PSIA
- Hitchhiker Avionics On
- Survival Heaters On
- Vent to $10^{-4}$ Torr or Less
- CRYOHP On
- Cooldown TRW Heat Pipe
  - Start Up
- Cooldown
  - Transport/Recovery
- Cooldown
  - Transport/Recovery/Minimum Temperature
- Cooldown Hughes Heat Pipe
  - Repeat
- Cooldown TRW Heat Pipe
  - Repeat - Total Five Cycles Each Pipe
- CRYOHP Off
- Descent

ORBIT
CRYOHP SUBSYSTEM IMPLEMENTATION

Cryogenic Coolers

Cryogenic Cooler/Heat Pipe Interface

Heat Pipes

Electronic Module

Bumper Assembly
CRYOHP DESCRIPTION (cont.)

- **Heat Pipes**
  - Two Independent Designs
  - Axially Grooved Aluminum Extrusion
    - TRW
    - Hughes

- **Cryo-Coolers**
  - Five Split Stirling Cycle Coolers
    - Hughes Model No. 7044H
      - 3.5 Watts Each @ 80K
      - Mounted to HH Canister UEP
      - Helium at 450 Psia Maximum
      - 95 W Power, 7.5 Amp Startup for 100 Millisecond Max.
CRYOHP DESCRIPTION

o Shuttle/HH Carrier Flight Experiment (Minus Avionics) Less Than 345 lbs

o HH Canister
  - Modified Upper End Plate (UEP)
    o Thermal Mass
    o Radiator
    o Flown on CPL/GAS and CPL/HH-1

o Uninsulated Top Plus Sides

o Vented Can (Valves in Lower End Plate (LEP))
  - 16 Psia Prior to Launch
  - 2 Psia Differential Pressure Relief Valves on Ascent
  - Solenoid and Butterfly Valves Provide Flight Vacuum

o HH Avionics
  - Provides Power, Signal, Command, and Data
  - 3 HH Ports Required
CRYOGENIC HEAT PIPE EXPERIMENT

OBJECTIVE

CONDUCT A SHUTTLE EXPERIMENT TO DEMONSTRATE THE RELIABLE OPERATION OF TWO OXYGEN HEAT PIPES IN MICROGRAVITY.

1. DEMONSTRATE STARTUP OF THE PIPES FROM THE SUPER-CRITICAL STATE.
2. MEASURE THE HEAT TRANSPORT CAPACITY OF THE PIPES
3. MEASURE EVAPORATOR AND CONDENSER FILM COEFFICIENTS
4. WORK SHUTTLE SAFETY ISSUES

APPROACH

✓ FLY TWO AXIALLY GROOVED OXYGEN HEAT PIPES ATTACHED TO MECHANICAL STIRLING CYCLE TACTICAL COOLERS
✓ INTEGRATE EXPERIMENT IN HITCHHIKER CANISTER
✓ FLY ON SHUTTLE AND CONTROL FROM GROUND
<table>
<thead>
<tr>
<th>CRYOGENIC HEAT PIPE EXPERIMENT</th>
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<tr>
<td>BACKGROUND</td>
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</tbody>
</table>

- No micro-gravity data available for oxygen or nitrogen heat pipes
- Poor wicking and low transport make 0-G extrapolation difficult
- Reliable start up from super critical temperature needs to be demonstrated
- Micro-gravity information on cryo (<100 K) heat pipes identified as critical technology need by NASA and the Air Force - 1988 Thermal Fluids in Space Workshop and in STEP 88 Workshop
- Oxygen and nitrogen pipes built and evaluated
# TES Flight Schedule

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<tr>
<th>Activities</th>
<th>FY 1990</th>
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<th>92</th>
<th>93</th>
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<td>Non Advocate Review</td>
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<td>Flight Experiment Review</td>
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<td>Launch</td>
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