TRW

IN-STEP Two-Phase Flow (TPF) Thermal Control Experiment

Flight Experiments Technical Interchange Meeting

6 October 1992

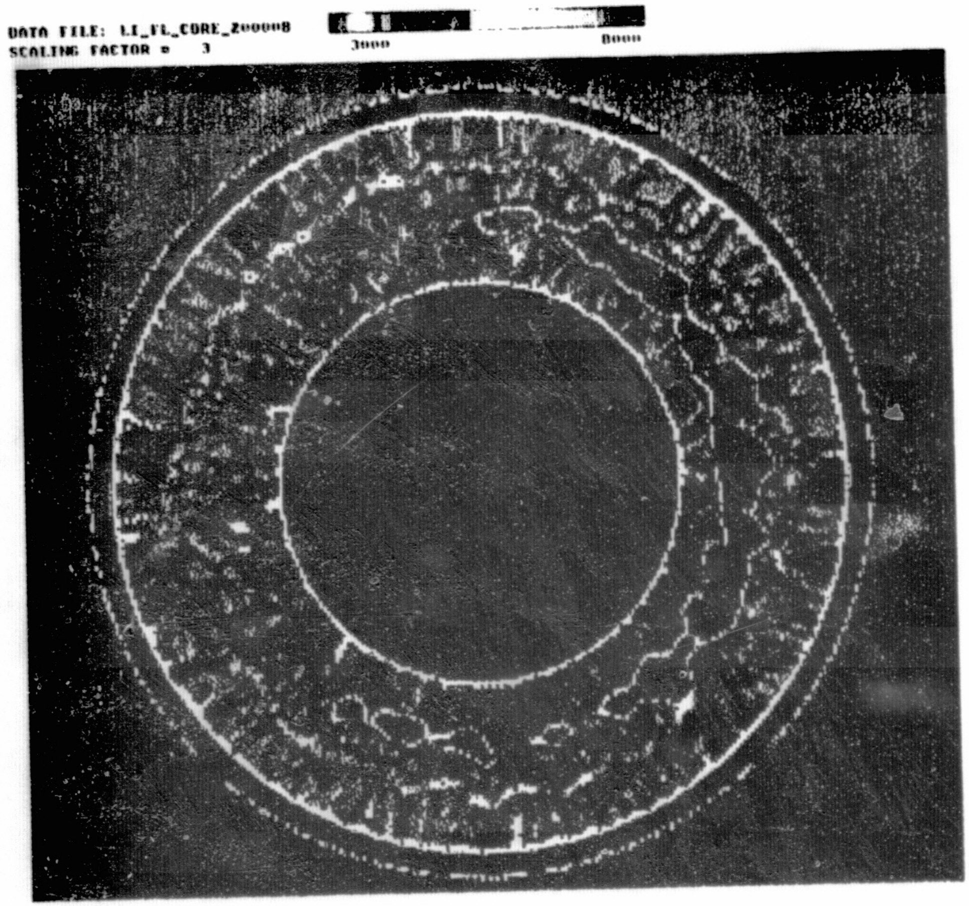
Jeff Nienberg, Program Manager

THERMAL ENERGY STORAGE (TES) FLIGHT PROJECT

EXPERIMENTAL CONDITIONS

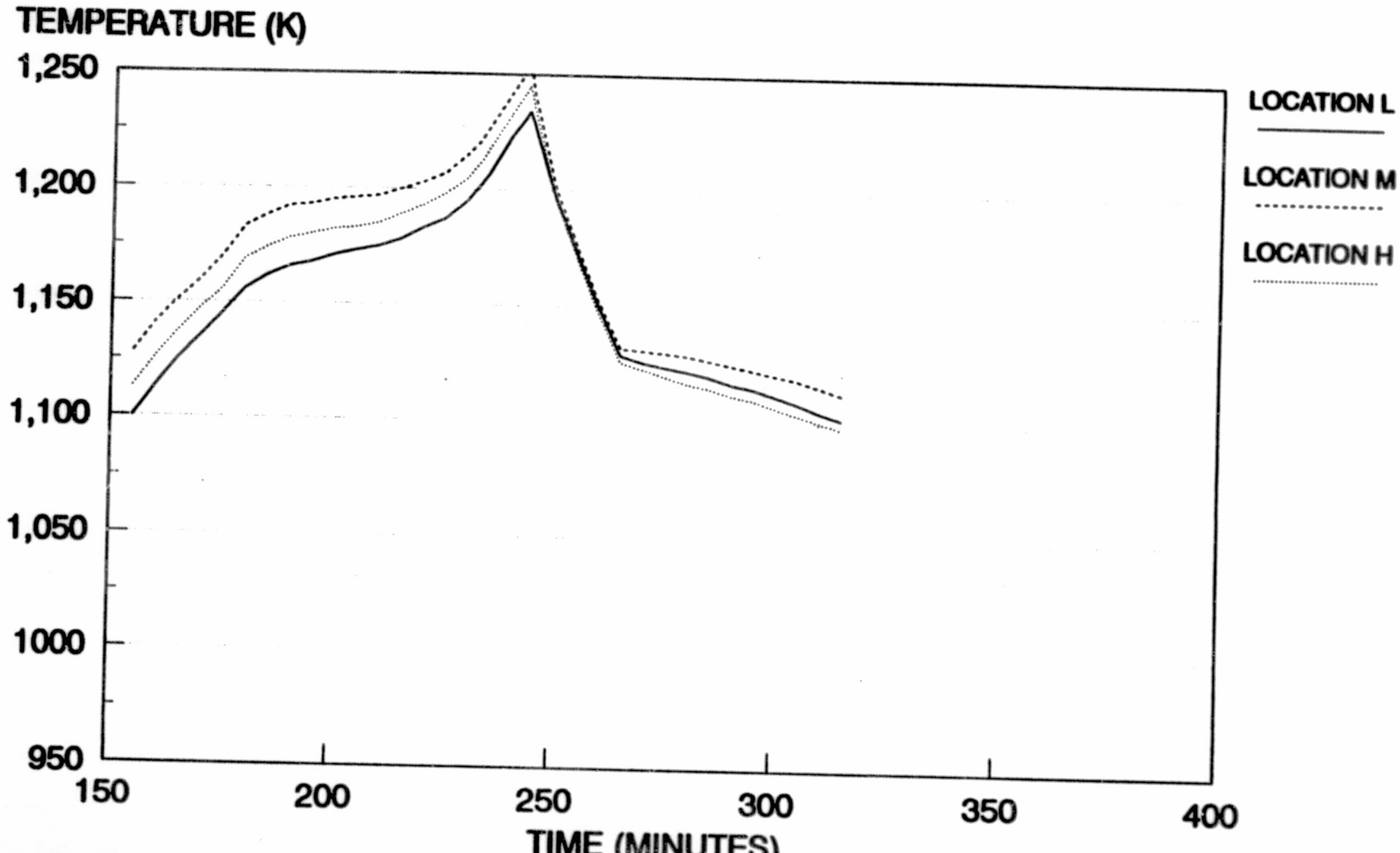
EXPERIMENT	GEOMETRY	TES	WETTING CONDITIONS
1	ANNULAR	LiF	WETTING
2	ANNULAR	LiF/CaF_2	WETTING
3	WEDGE	LiF	WETTING
4	WEDGE	LiF	NON-WETTING

THESE EXPERIMENTS ENCOMPASS THE SIGNIFICANT VARIABLES AFFECTING VOID BEHAVIOR AND LOCATION


DATA FILE: LI_FL_CORE_200008
SCALING FACTOR = 3
3000
8000

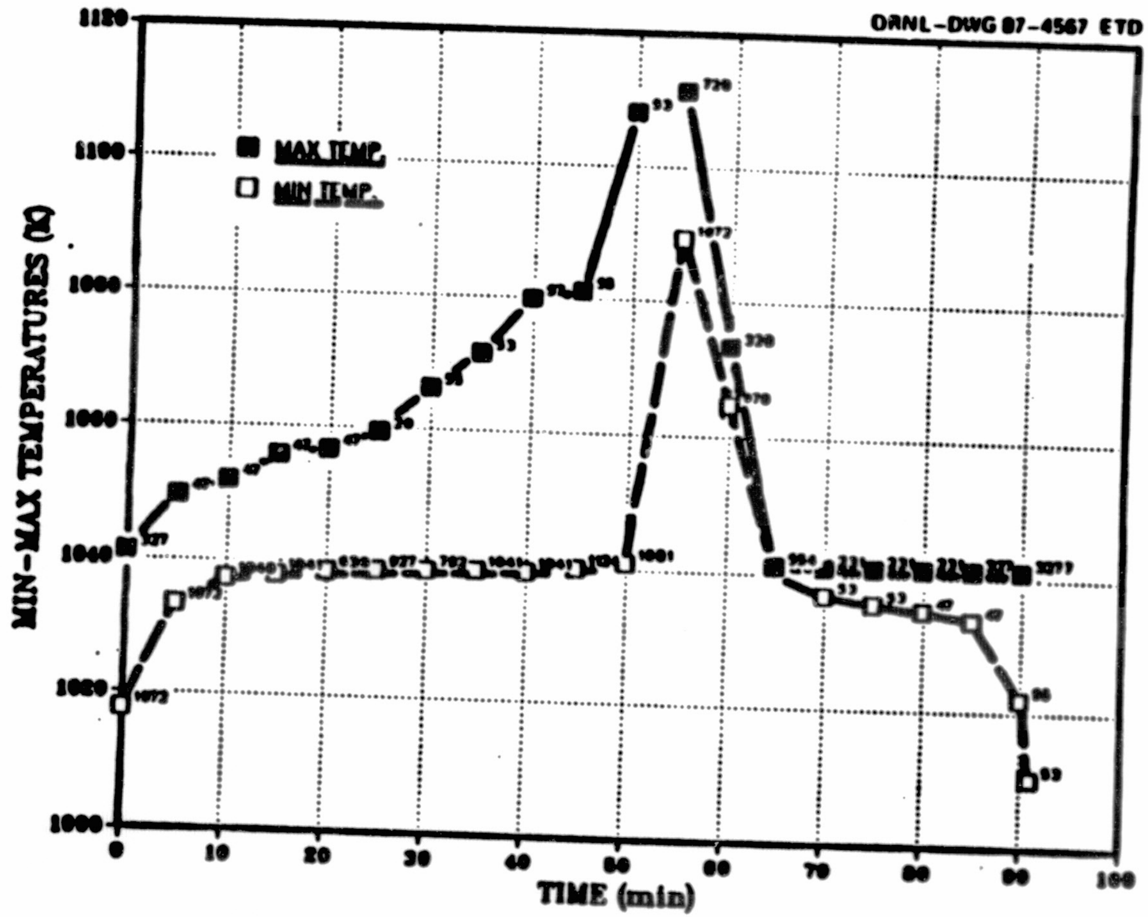
CANISTER TEMPERATURE, 1-g

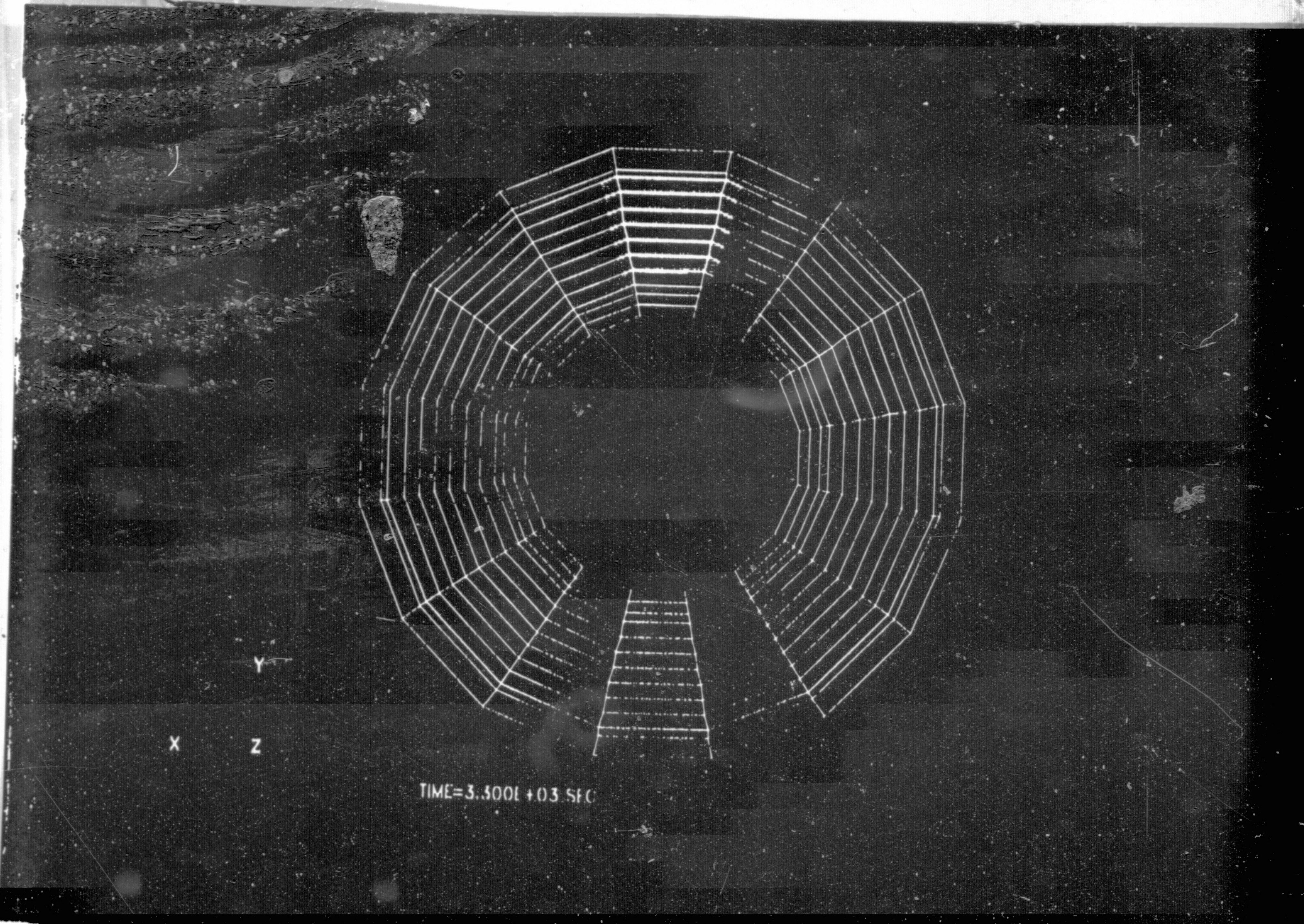
CANISTER 0-degrees



D. NAMKOONG

TEMPERATURE HISTORY, 1-g




Y
X
Z
TIME=3.300E+03 SEC

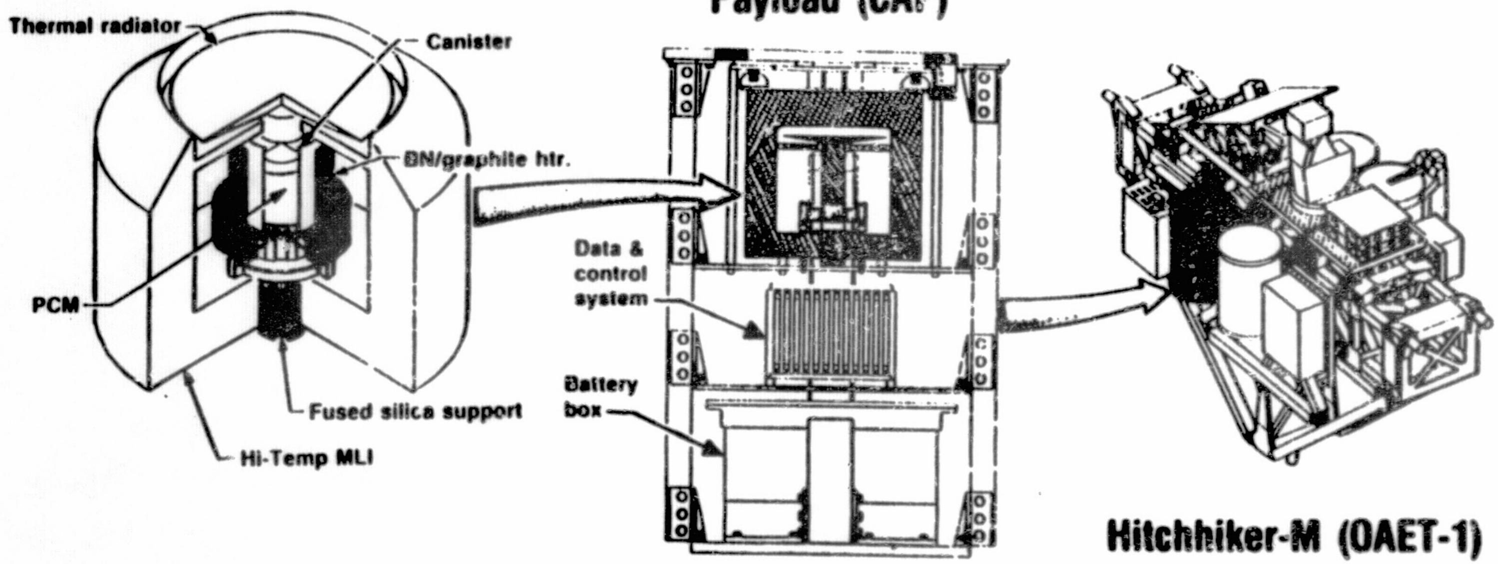
ACCOMPLISHMENTS

IDENTIFIED AND RESOLVED CRITICAL TECHNOLOGY ISSUES FOR TEST EXPERIMENTS 1 & 2

THERMAL ENERGY STORAGE TECHNOLOGY EXPERIMENT

TES-1 experiment section

Complex Autonomous Payload (CAP)



Hitchhiker-M (OAET-1)

DEVELOP IN-SPACE EXPERIMENTS TO CHARACTERIZE VOID SHAPE AND LOCATION IN LIF-BASED PHASE CHANGE MATERIALS IN DIFFERENT ENERGY STORAGE CONFIGURATIONS REPRESENTATIVE OF ADVANCED SOLAR DYNAMICS SYSTEMS

PM/PS: A.J. Szaniszlo

PI: D. Namkoong
SSC: Sverdrup

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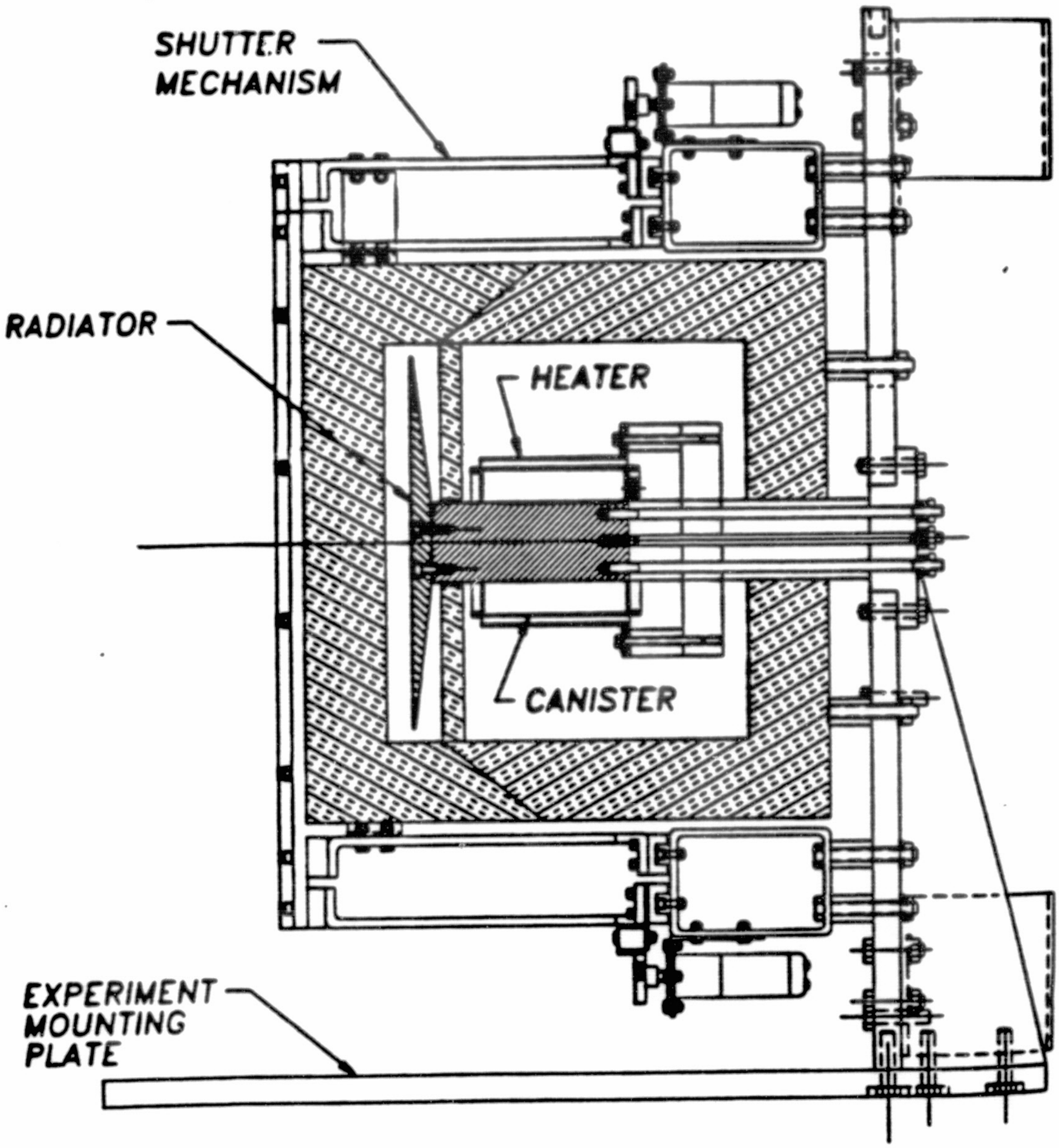


THERMAL ENERGY STORAGE (TES) EXPERIMENT

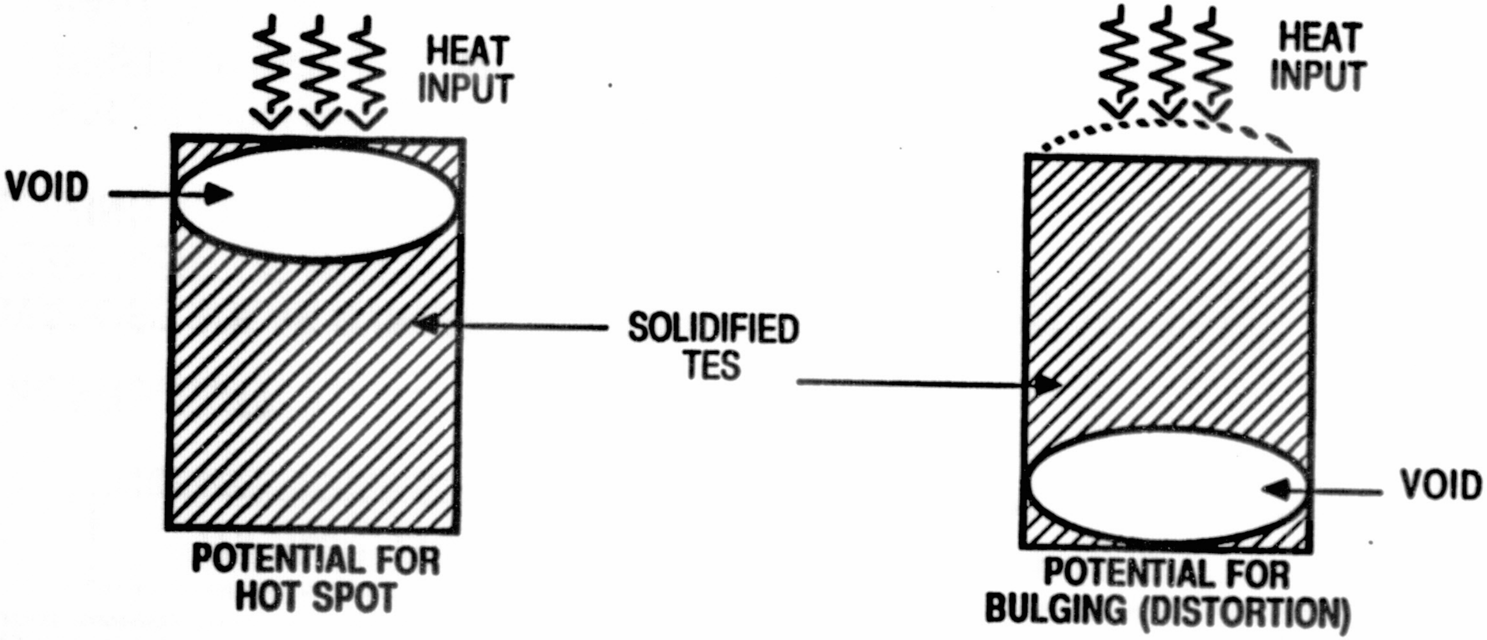
THERMAL ENERGY STORAGE (TES) FLIGHT PROJECT

NORVEX PROGRAM FEATURES

TIME STEPS	IMPLICIT
GEOMETRY	R-Θ-Z
GRAVITY	• 0-G • 1-G, ARBITRARY DIRECTION • CAN PROGRAM VARIABLE G(T)
CANISTER HEAT FLUX	INTEGRATED
VOID LOCATION	MOVING BOUNDARY NAVIER-STOKES
MELT FRONT	"ENTHALPY" METHOD, 3D
RADIANT H.T.	TWO GROUPS • TRANSPARENT • STRONG ABS
VOID H.T.	VAP/COND
STRESS CODE	ADINA
LIFETIME ESTIMATE	ASME CODE

THERMAL ENERGY STORAGE (TES)

VOLUME CHANGE WITH PHASE CHANGE -
IMPACT ON VOID BEHAVIOR IN MICROGRAVITY



THERMAL ENERGY STORAGE (TES) FLIGHT PROJECT

WHY THE PROJECT?

ADVANCED SOLAR DYNAMIC SYSTEMS REQUIRE BETTER TECHNICAL ASSESSMENT OF THERMAL ENERGY STORAGE (TES) SALTS UNDERGOING FREEZING AND THAWING

- SOLAR DYNAMIC SYSTEMS DESIGNED FOR SUN-SHADE ORBITAL MISSIONS INCLUDE TWO PHASE STORAGE OF ENERGY AS INTEGRAL PART OF RECEIVER
- LACKING DATA OF TES SALTS UNDERGOING FREEZE/THAW IN MICROGRAVITY, SOLAR DYNAMIC RECEIVERS HAVE BEEN DESIGNED CONSERVATIVELY -- HEAVIEST COMPONENT OF SYSTEM
- ADVANCED SOLAR DYNAMIC SYSTEMS ARE BASED ON LIGHTER WEIGHT, BETTER PERFORMANCE COMPONENTS

CONCLUSION:	NEED FOR ANALYTIC - EXPERIMENTAL BASIS TO DEVELOP CAPABILITY FOR ADVANCED SOLAR RECEIVER/TES DESIGNS

Two-Phase Flow Experiment

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Background

Program sponsored by NASA GSFC, Thermal Engineering Branch

Part of the NASA/OAST In-Space Technology Experiments (IN-STEP) Program

TRW completed experiment definition (phase A) in August 1989

Engineering development phase (phase B) initiated July 1992

- Preliminary design of flight experiment
- Breadboard test and characterization of thermal control system (TCS)
- Non-Advocate Review

Flight development phase (Phase C/D)

- Final Design
- Experiment Fabrication and Assembly
- Environmental Testing
- Flight Operations and Post-Flight Analysis

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Background (cont.)

Experiment configured for NASA Hitchhiker Shuttle Payload System

Two-phase thermal control system consists of

- Capillary pumped loop (CPL)
- Heatpipe radiator
- Two-phase flow heat exchanger (TPFHX)

Two-Phase Flow Experiment

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Schedule

Phase B	Start	July 1992	
	PDR	April 1993	
	NAR	June 1993	
Phase C/D	Start	Sept 1993	
	CDR	Jan 1994	
	Delivery	April 1995	
	Flight	July 1995	(OAST-3)
	Post-Flight	Oct 1995	

Two-Phase Flow Experiment

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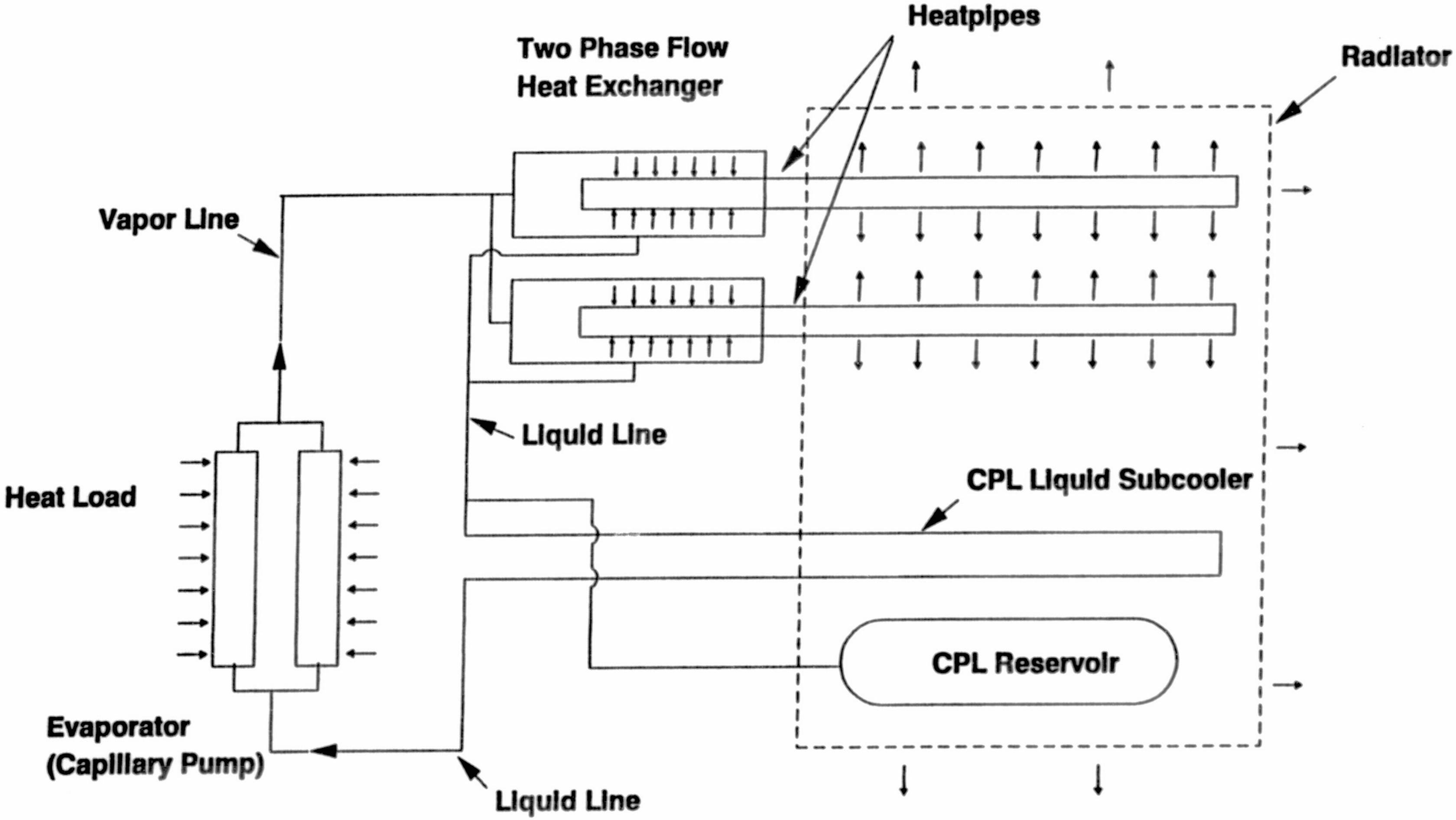
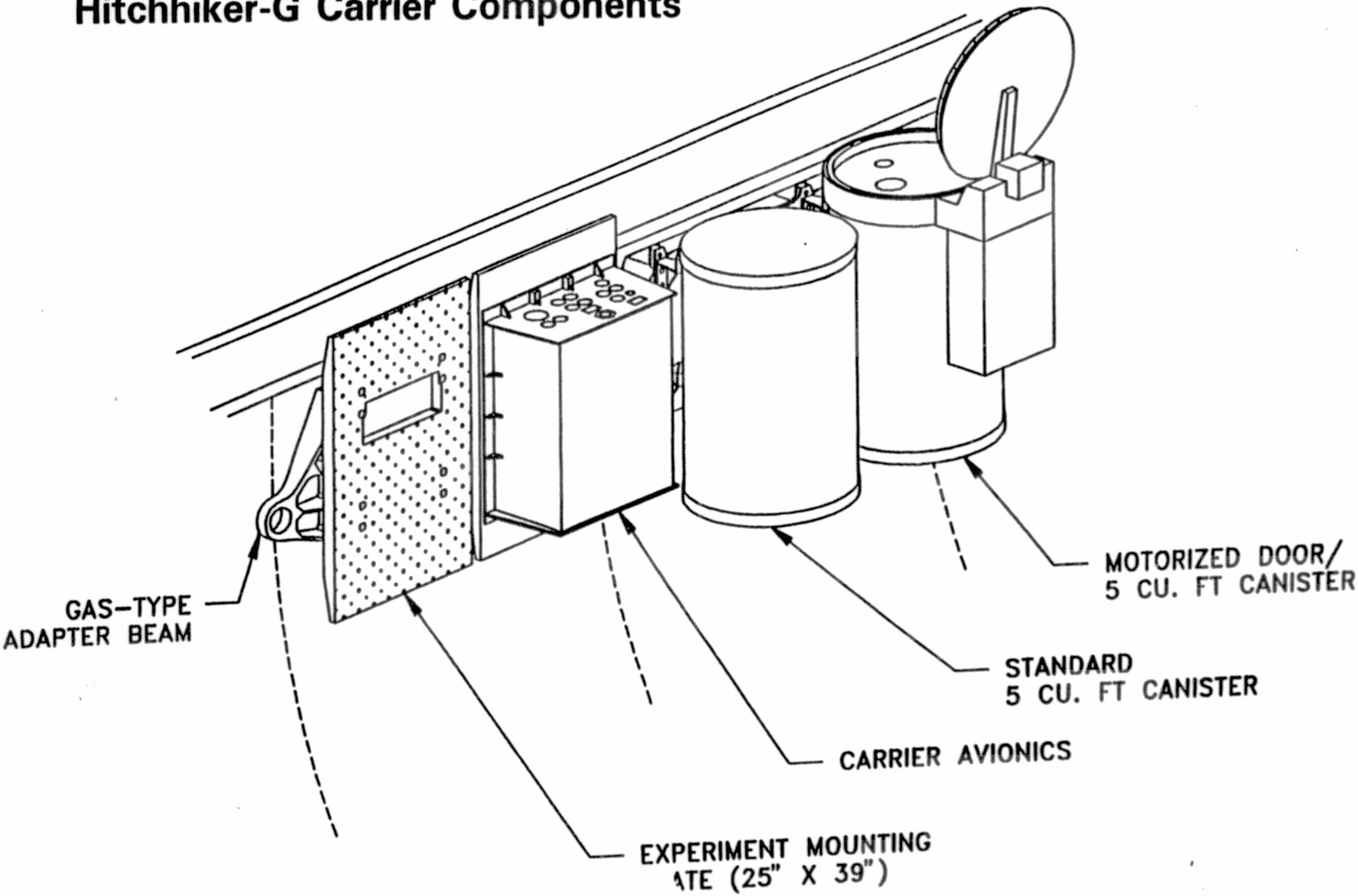
Thermal Control System Schematic



Two-Phase Flow Experiment

Hitchhiker-G Carrier Components



Two-Phase Flow Experiment

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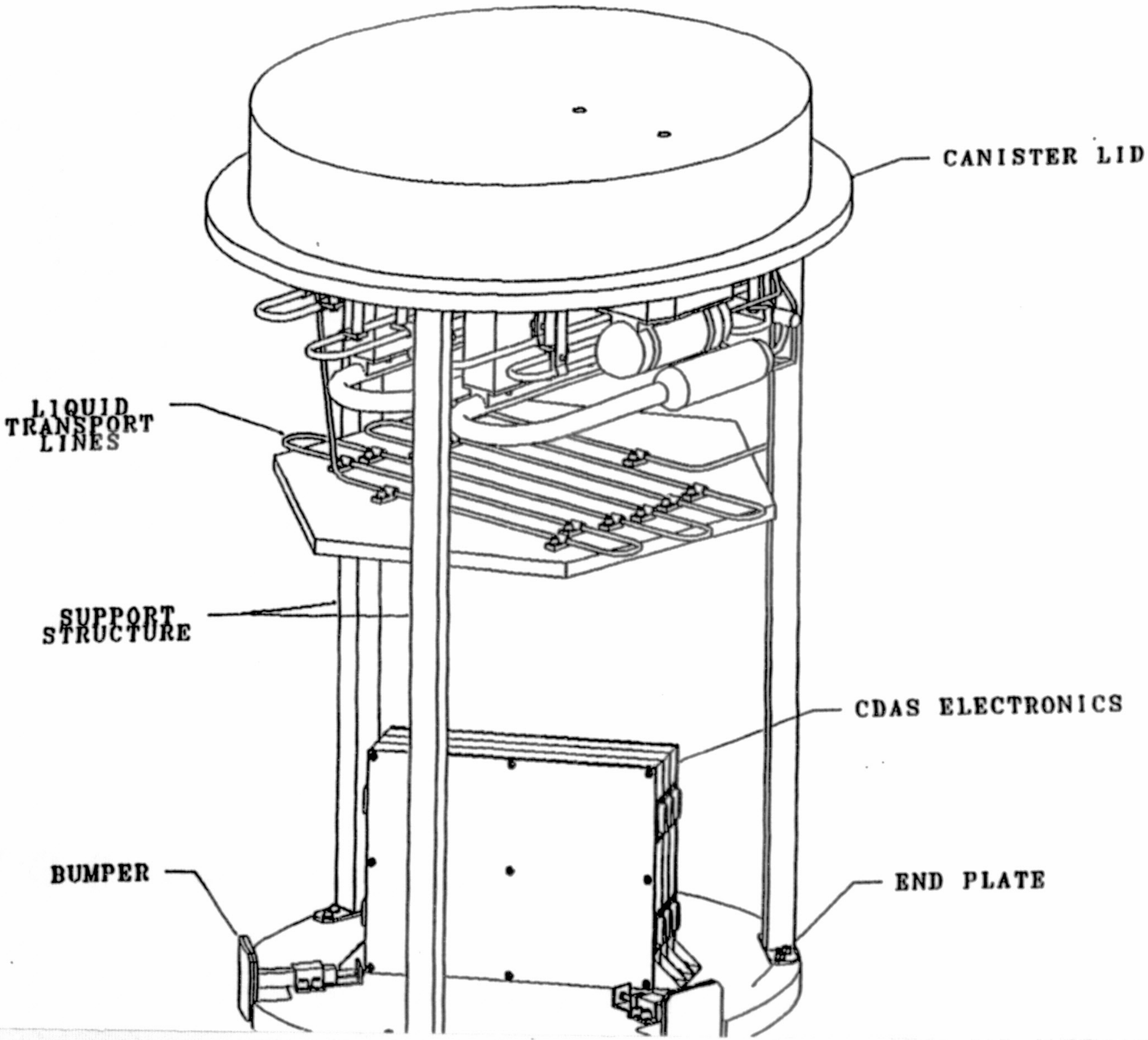
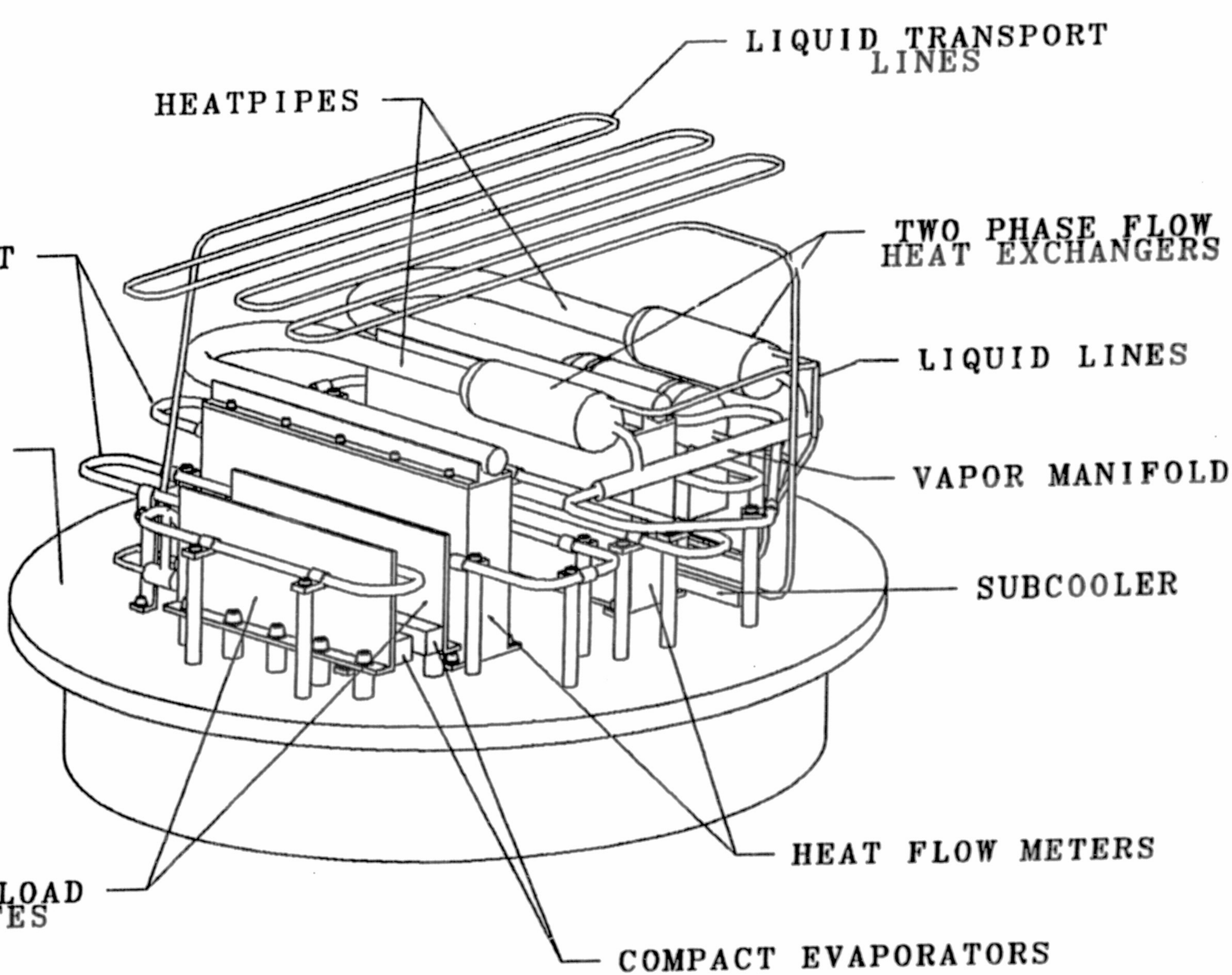
Flight Experiment Payload



Two-Phase Flow Experiment

Thermal Control System Mechanical Design



Flight Experiment Thermal Design Approach and Test Plan

Canister lid serves as the thermal control system heatsink and radiator with added weight to provide a high thermal capacity

Experiment instrumented with thermistors to measure temperatures required for determining the heat transfer coefficients in all components

Heat flux meters integral with the heatpipe condenser saddles will measure the heat load through the individual heatpipes

Reservoir controlled at constant temperature

Test plan includes power cycling at various levels, heat sharing, and induced deprime

Command and Data Acquisition (CDAS) system will provide

- Real time data and command capability
- Temperature measurement accuracy of $\pm 0.1\,^{\circ}C$
- Bus voltage measurement

Two-Phase Flow Experiment

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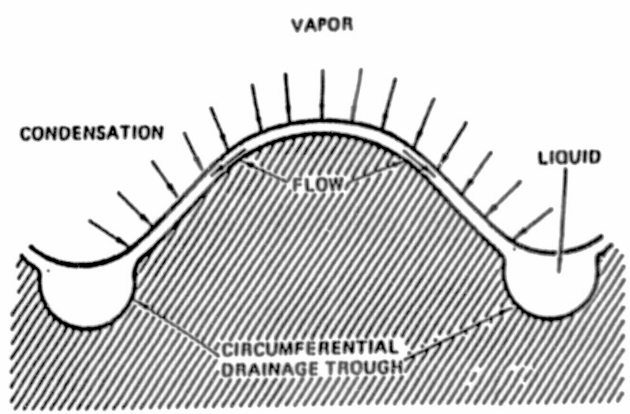
Two-Phase Flow Heat Exchanger (TPFHX)

A small temperature drop in the heat exchanger between the capillary pumped loop and the heatpipe radiator is critical for an efficient thermal control system

Gregorig condensation grooves balance capillary and viscous forces producing a thin constant film thickness for a high condensation heat transfer coefficient



Theory predicts condensation "h" values that are an order of magnitude greater than for typical condenser sections in heatpipes

Verification requires microgravity environment of space since capillary forces which determine liquid flow patterns are dominated by gravity during ground testing

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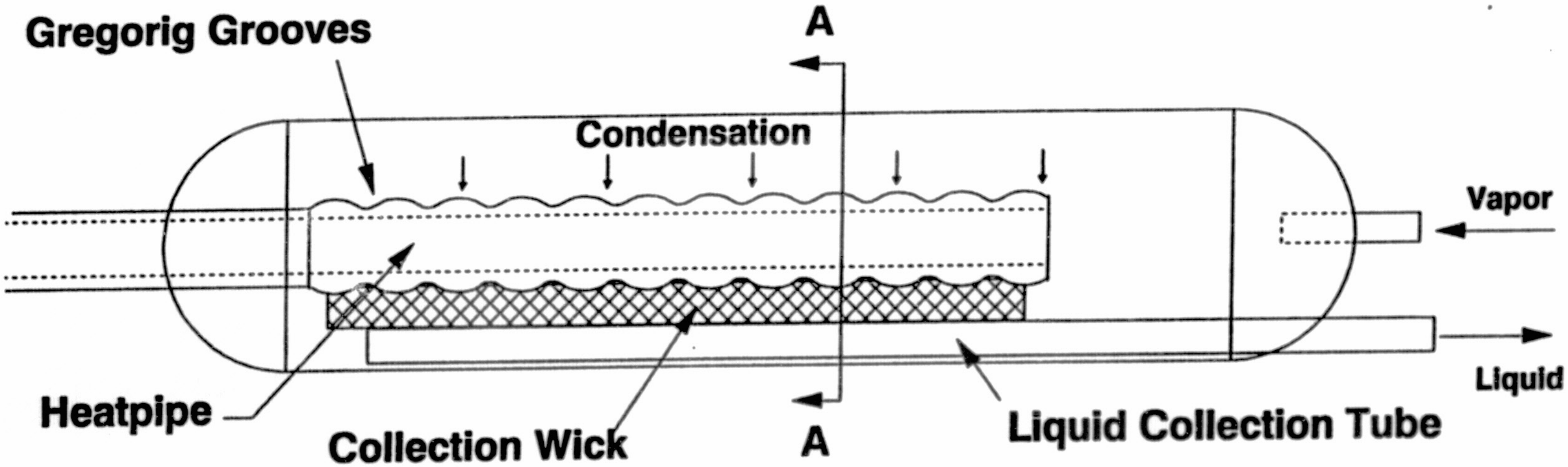
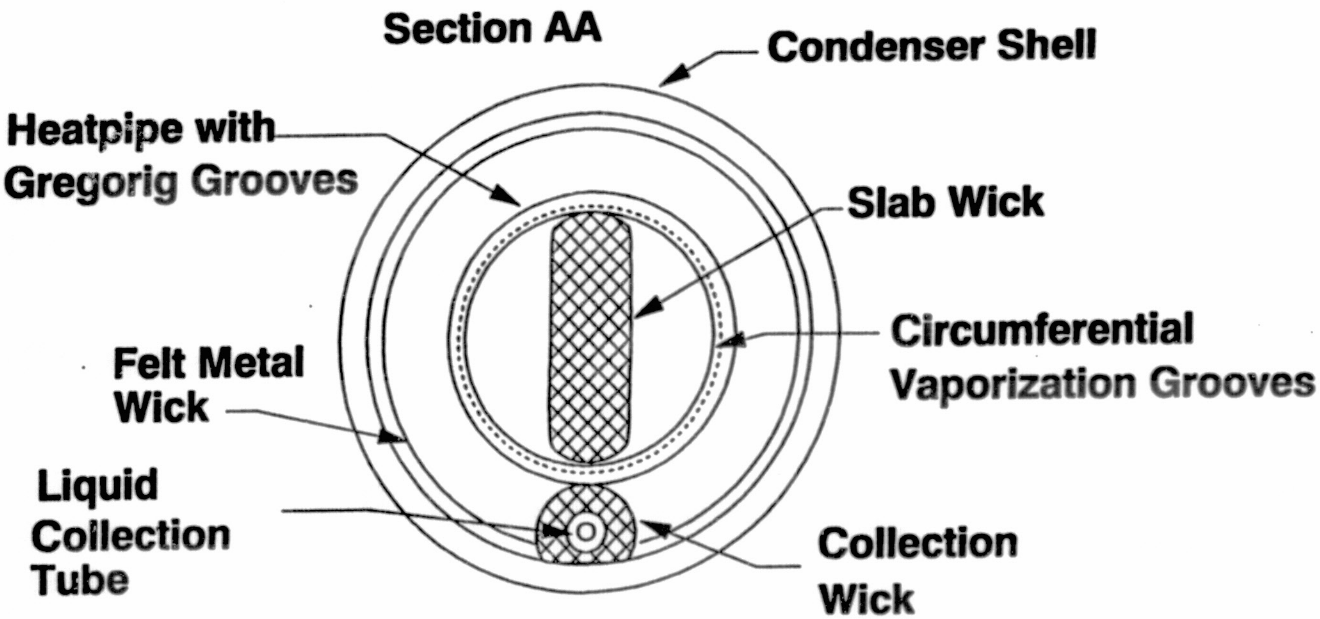
Two-Phase Flow Heat Exchanger (TPFHX)





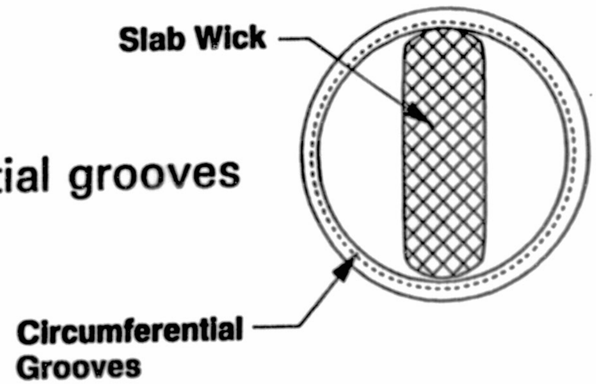
Radiator Heatpipes

Incorporating two heatpipe designs will maximize the performance data obtained from the flight experiment

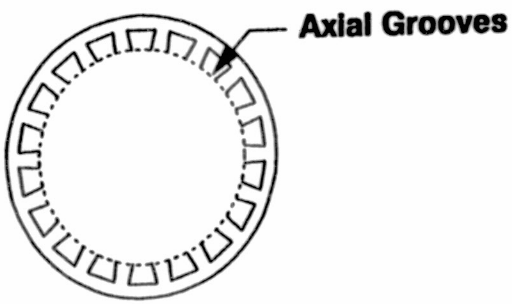
Design emphasis will be placed on achieving improved evaporation heat transfer coefficients, "h"

Candidate designs include

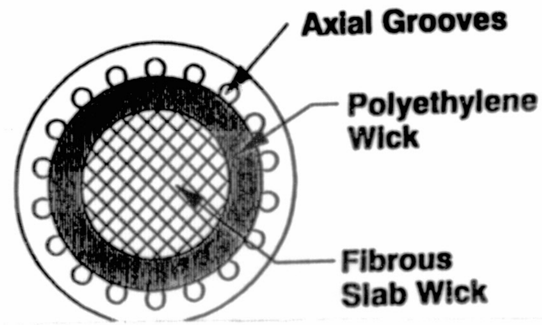
- Slab wick heatpipe with high density circumferential grooves (200 grooves/inch)



- Axial groove heatpipe

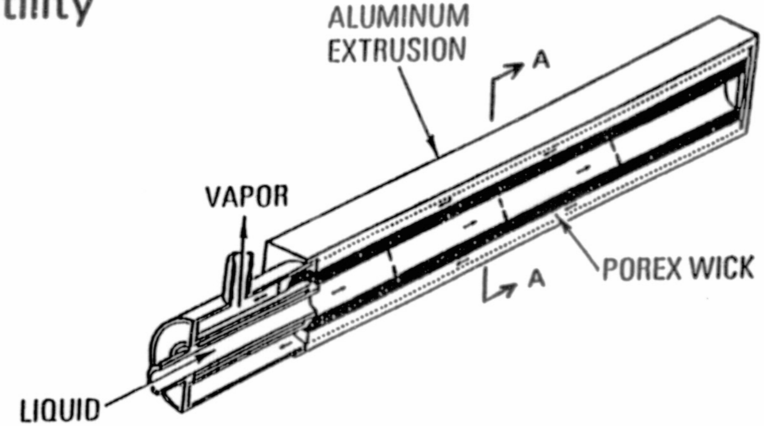


- Inverted meniscus heatpipe under development at TRW

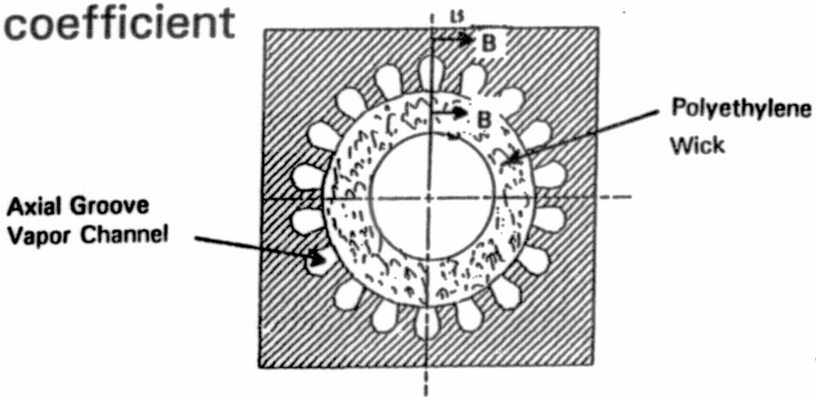


TRW Compact Evaporator Pump

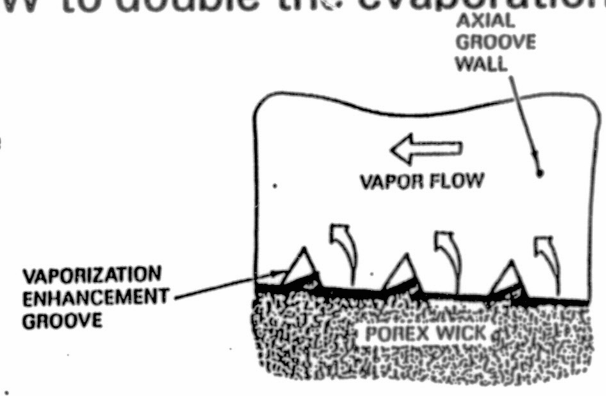
Compact mechanical design with liquid and vapor outlet at same end enhances integration versatility



Vaporization Enhancement Grooves (VEGs) machined onto the lands (flats) of evaporator extrusion have been shown by TRW to double the evaporation heat transfer coefficient



Section AA



SECTION BB

Can be verified in flight experiment by incorporating VEGs in one of the two evaporator pumps and comparing performance

Two-Phase Flow Experiment

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Thermal Math Model of Thermal Control System

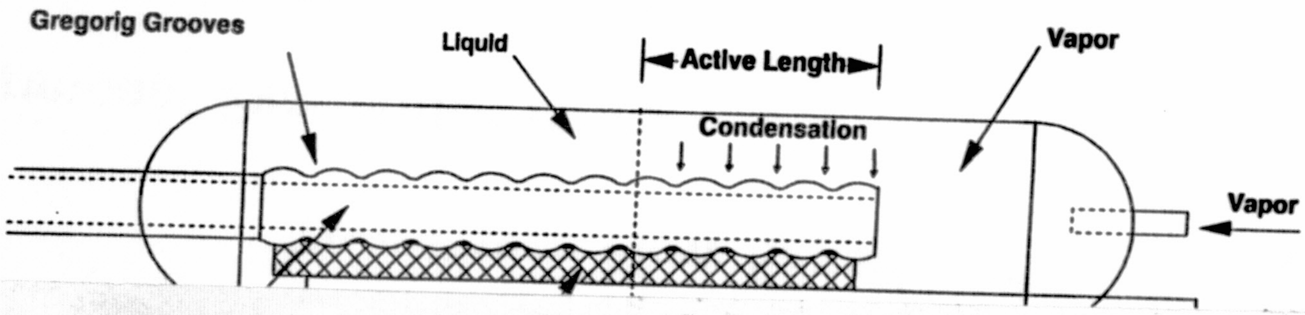
Uses SINDA Thermal Analyzer Program

Developed to assist in component sizing and to simulate experiment operational conditions

Includes: two CPL evaporator pumps, TPFHX, subcooler, CPL reservoir, heat flow meters, canister lid

Predicts transient temperature response of all components and the active length of the heat exchanger condenser

- Active length is a function of the CPL heat load and the sink temperature
- When the active length reaches the total condenser length the TPFHX becomes overdriven, i.e., CPL vapor blows by the TPFHX liquid collection wick (undesirable)



Two-Phase Flow Experiment

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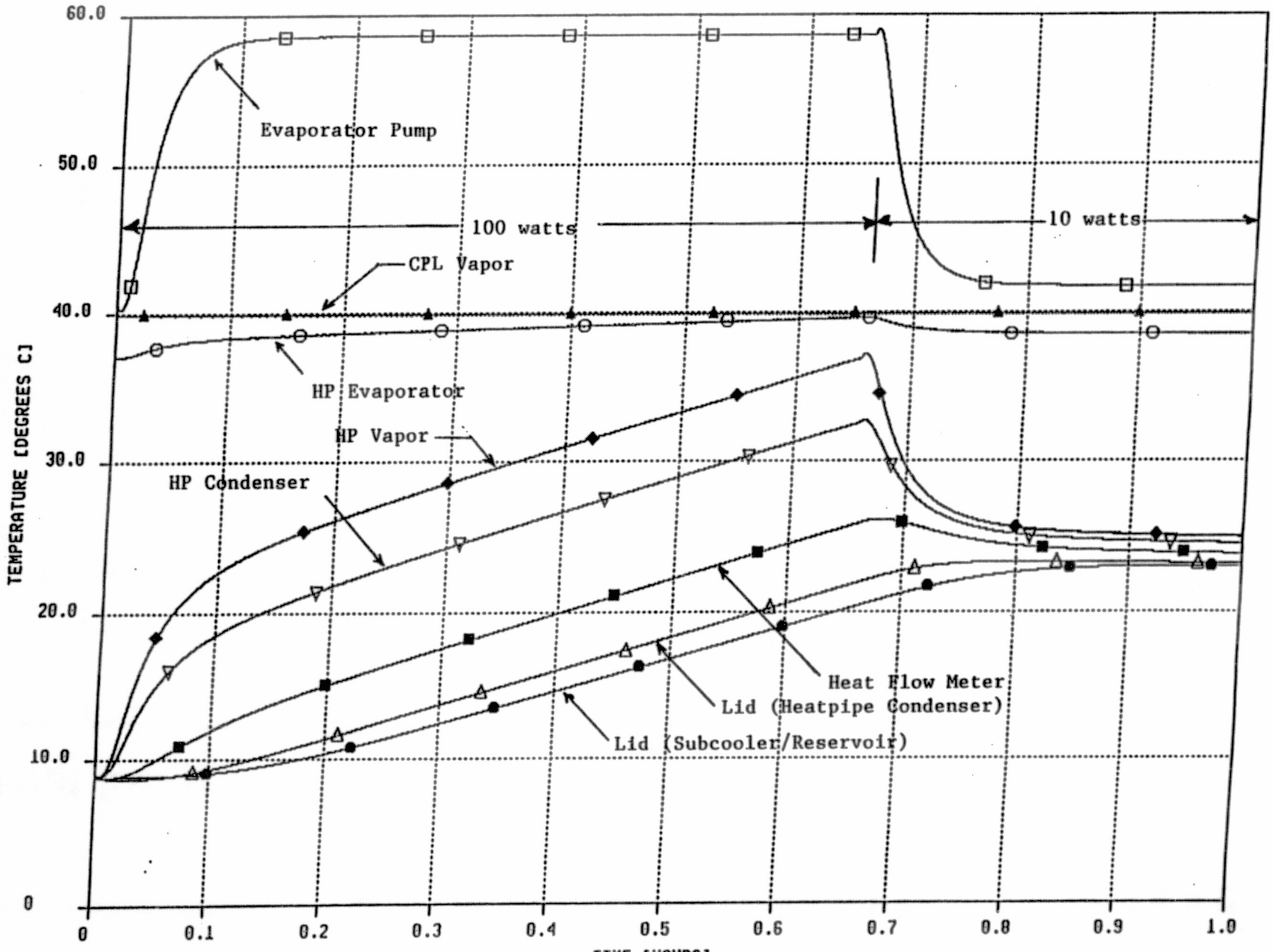
Evaporator Pump-to-Lid Temperatures



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Two-Phase Flow Experiment

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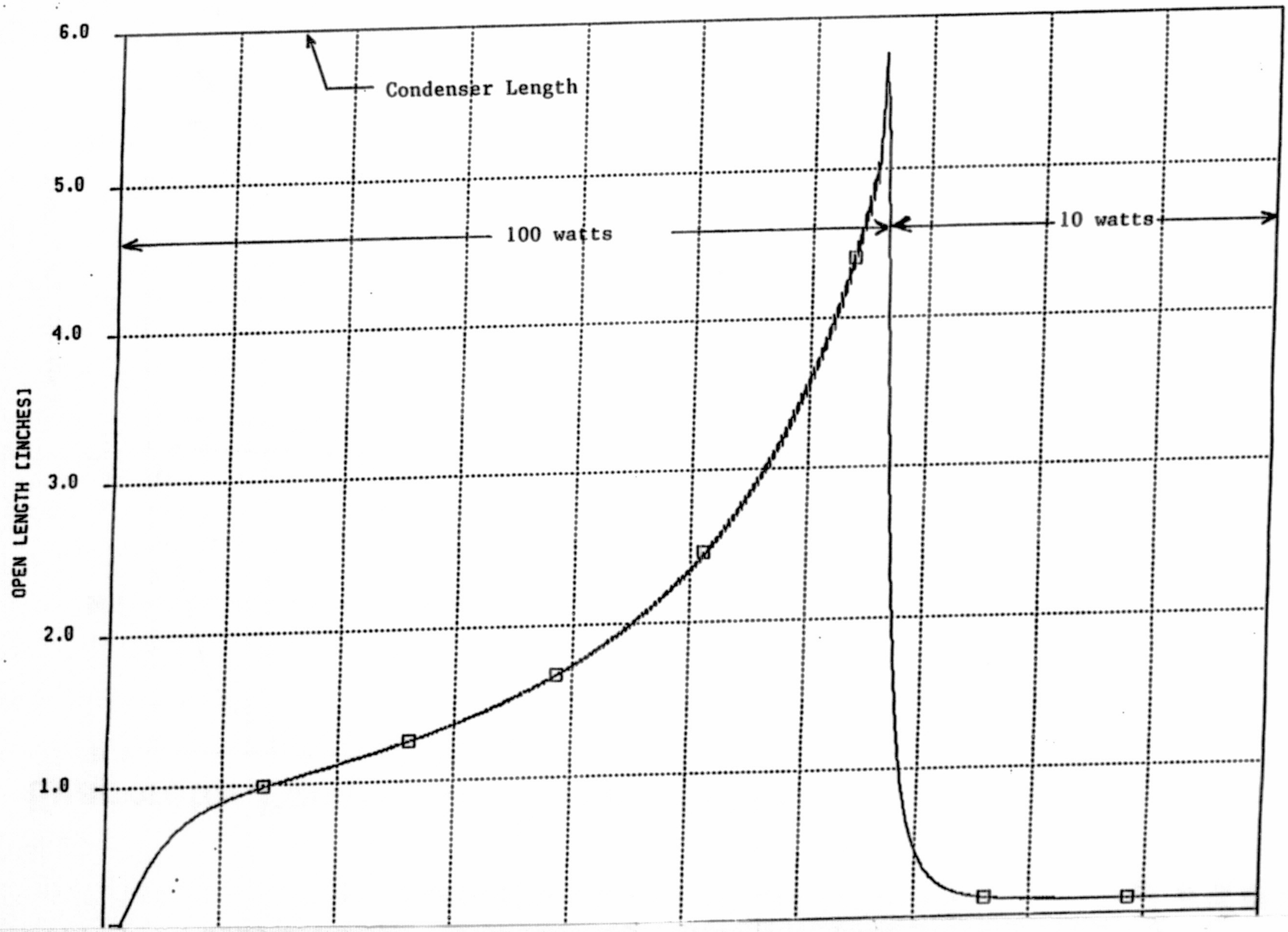
Heat Exchanger Condenser Open Length



One-G Measurement of Condensation "h" on Gregorig Grooves

Purpose is to bound the expected zero-g values for condensation heat transfer coefficient on gregorig-grooved surfaces

Existing hardware has been modified and incorporated into the test setup

Measurements will be made at several power levels with the grooves facing up and with the grooves facing down

- Gravity will enhance the heat transfer in "up" orientation and retard heat transfer in the "down" orientation

Liquid inventory in the condensation chamber will also be varied

Preliminary data has been taken and is currently under analysis

Two-Phase Flow Experiment

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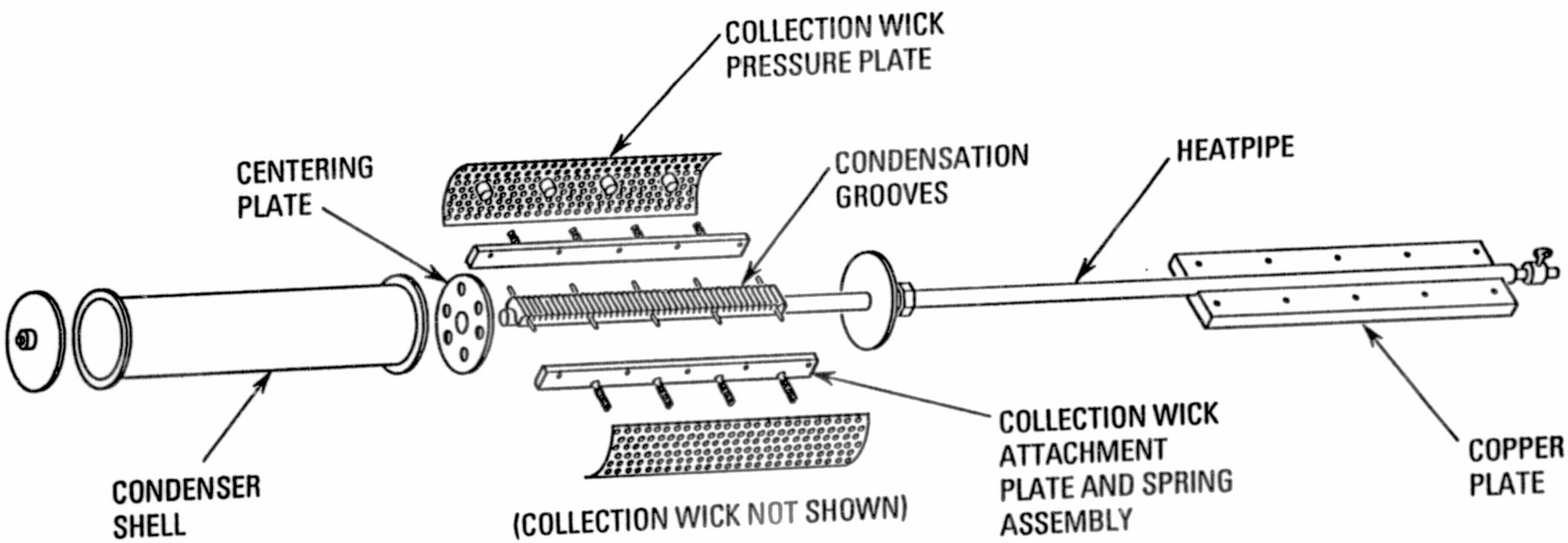
Exploded View of One-G Test Apparatus



Two-Phase Flow Experiment

Cross-Sectional View of condensation Chamber