Tank Pressure Control Experiment/Thermal Phenomena
TPCE/TP

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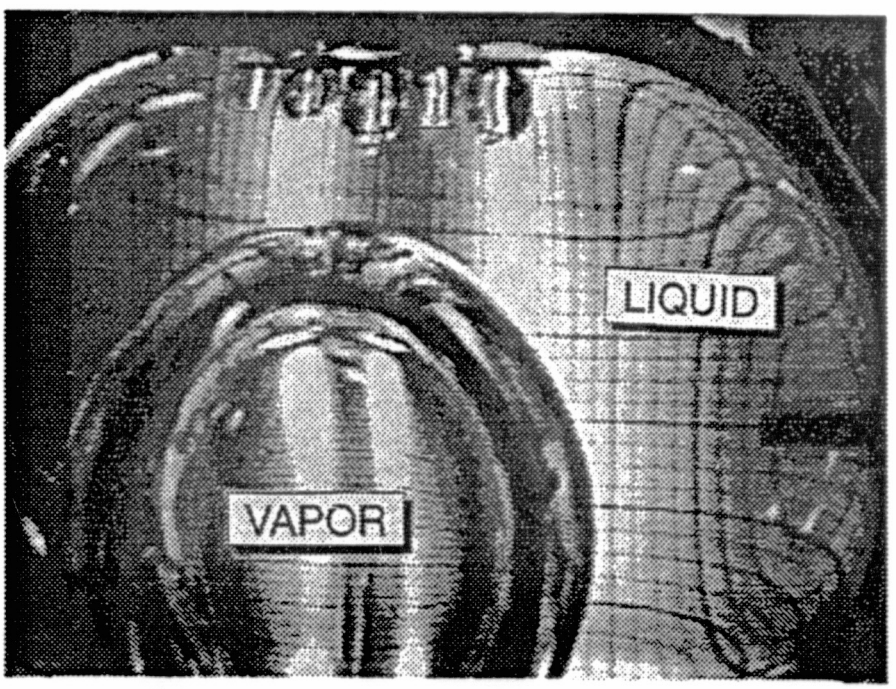
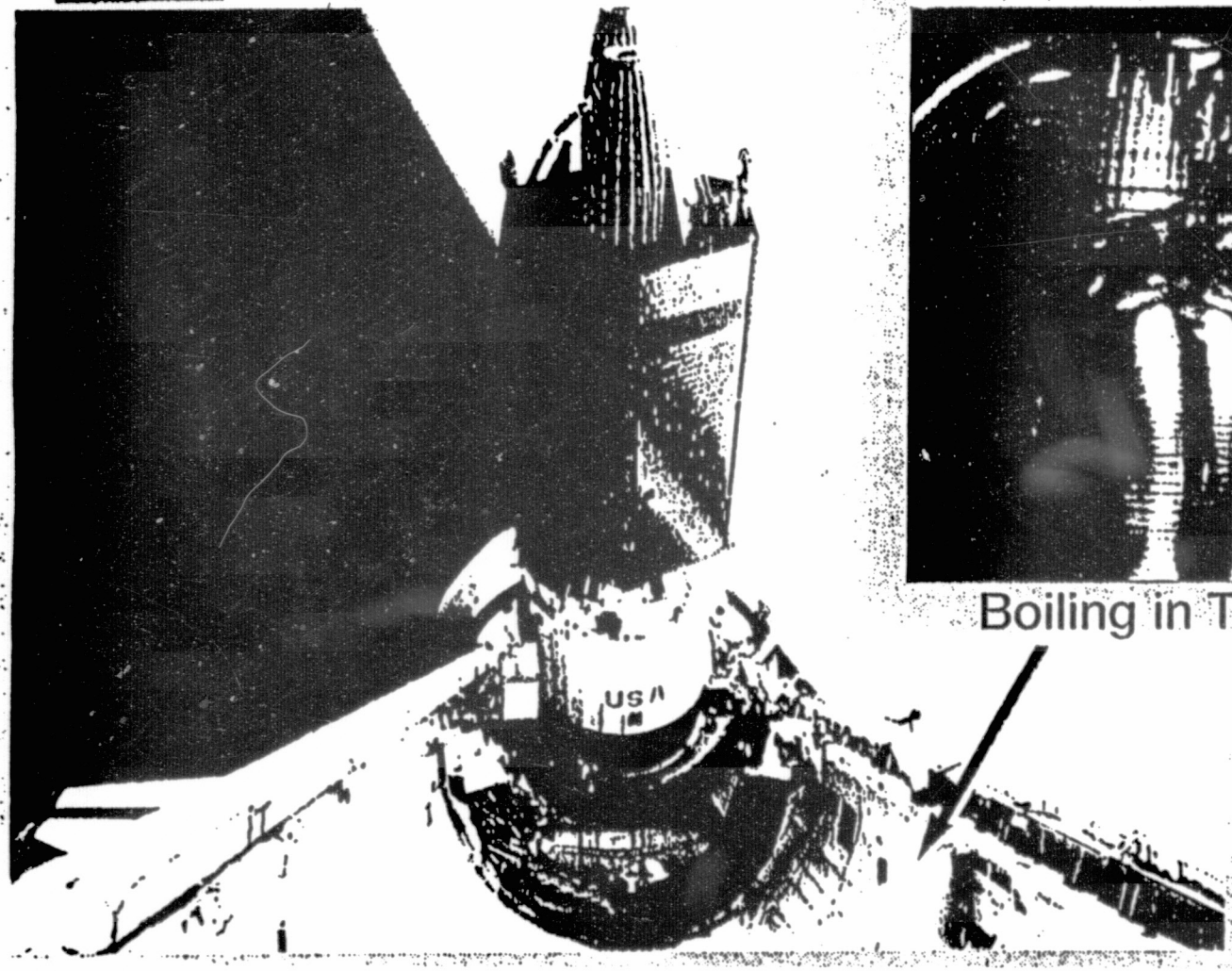
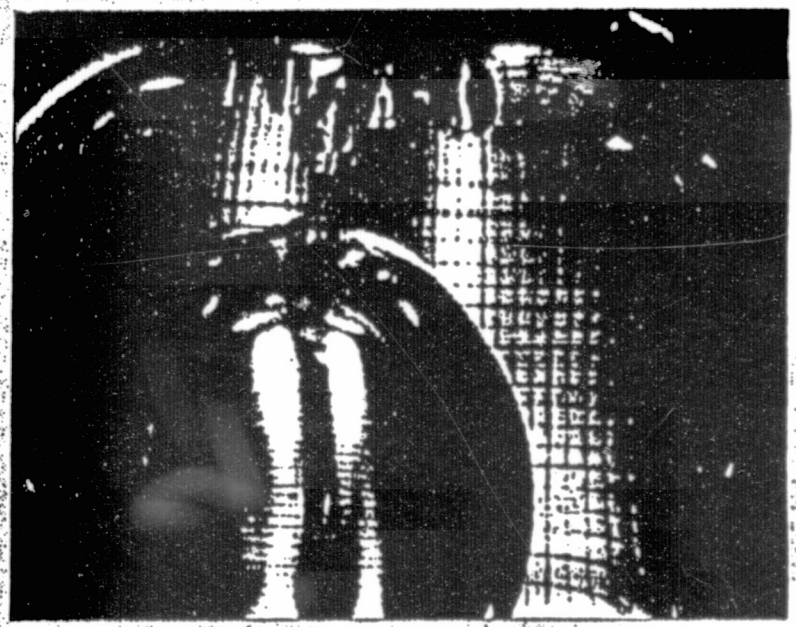


Flight Experiments Technical Interchange Meeting
October 5-9, 1992
Monterey, California

IN-STEP

TPCE/TP is a reflight of TPCE which flew successfully on STS-43 (August 1991)





Boiling in TPCE freon tank

CD-92-61081

TANK PRESSURE CONTROL EXPERIMENT:THERMAL PHENOMENA

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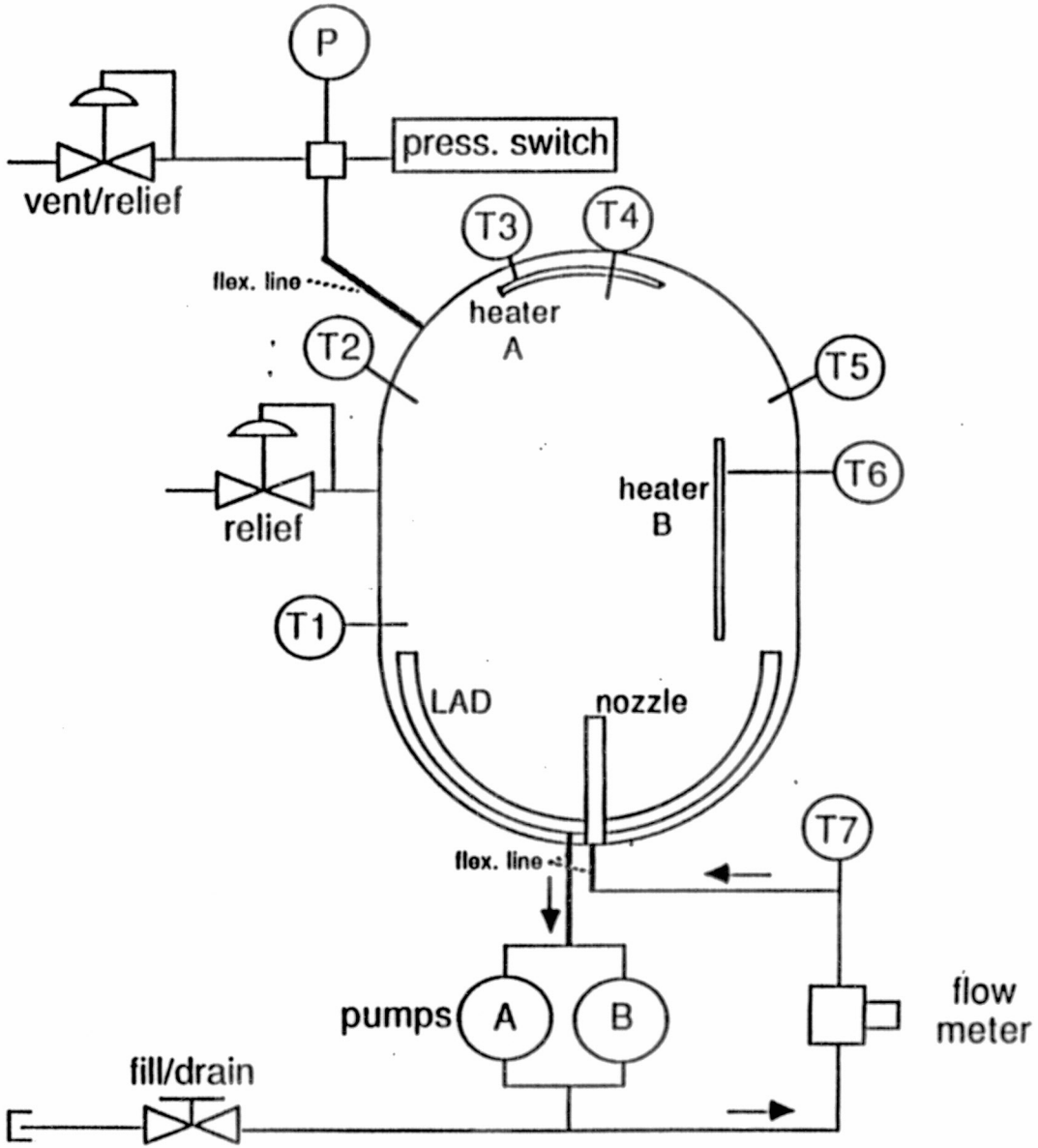
Abstract

The "Tank Pressure Control Experiment/Thermal Phenomena (TPCE/TP)" is a reflight of the tank pressure control experiment (TPCE), flown on STS-43 in a standard Get-Away special (GAS) container in August 1991. The TPCE obtained extensive video and digital data of the jet induced mixing process in a partially filled tank in low gravity environments. It also provided limited data on the thermal processes involved. The primary objective of the reflight of TPCE is to investigate experimentally the phenomena of liquid superheating and pool nucleate boiling at very low heat fluxes in a long duration low gravity environment. The findings of this experiment will be of direct relevance to space based subcritical cryogenic fluid system design and operation.

SCHEMATIC OF TANK PRESSURE CONTROL EXPERIMENT (TPCE) HARDWARE



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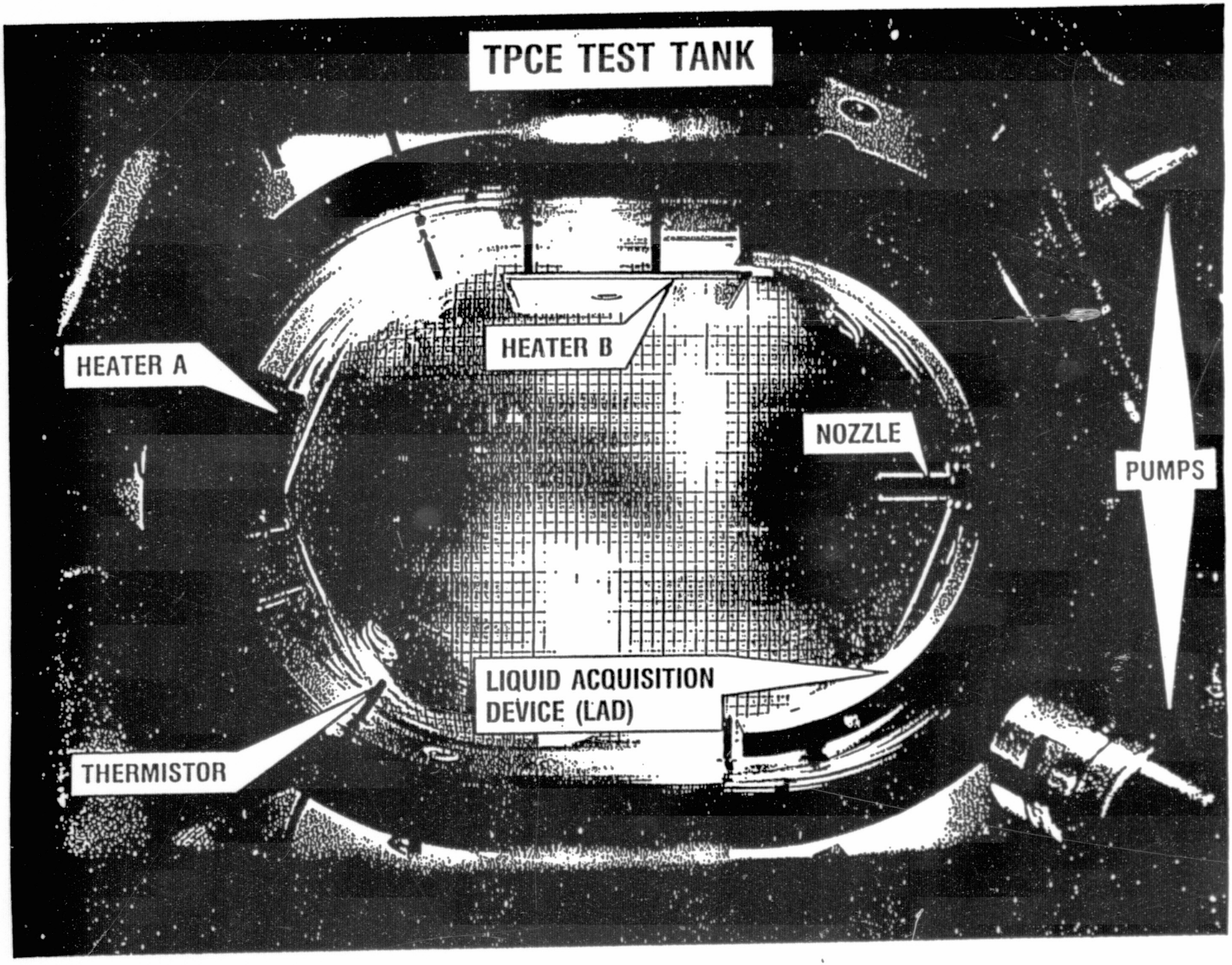
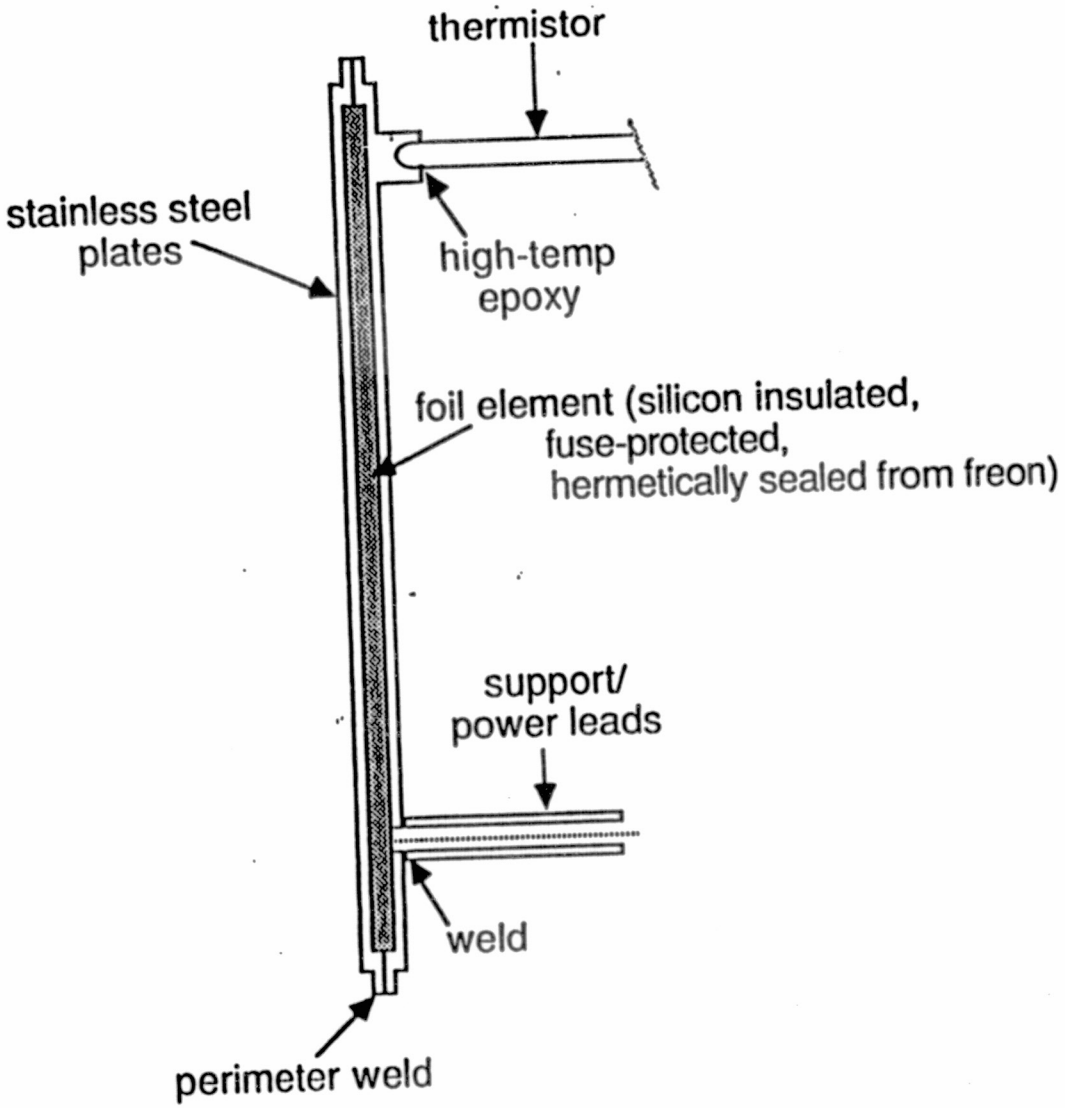

TPCE TEST TANK
HEATER A
HEATER B
NOZZLE
PUMPS
LIQUID ACQUISITION DEVICE (LAD)
THERMISTOR

HEATER ASSEMBLY



OBSERVATION OF BOILING PROCESS IN LOW-G

- FLUID: FREON 113
- HEATER: FLAT HEATING SURFACE(10.16cm x 6.35cm)
- HEAT FLUX: 0.1 TO 0.15 Watt/cm^2
- LIQUID SUBCOOLING: 3 TO 4^o c
- LIMITED VIDEO OBSERVATION OF BUBBLE INCEPTION, GROWTH AND DEPARTURE
- EXTENDED (10 min.) LOW-G DATA

SOME OBSERVATIONS OF TPCE DATA DURING HEATING PHASE

- FLIGHT DATA SHOW SIGNIFICANT PRESSURE FLUCTUATION

- AN INITIAL PERIOD OF ABOUT 1 TO 2 MINUTES RESULTED IN NO PRESSURE CHANGE, FOLLOWED BY PRESSURE SPIKES OF VARYING MAGNITUTES AND THEREAFTER SOMEWHAT REGULAR PRESSURE FLUCTUATION.

- HEATER SURFACE TEMPERATURE EXCEEDED THE FLUID SATURATION TEMPERATURE BY ABOUT 3 TO 8C. A SIGNIFICANT DIFFERENCE BETWEEN GROUND AND FLIGHT DATA.

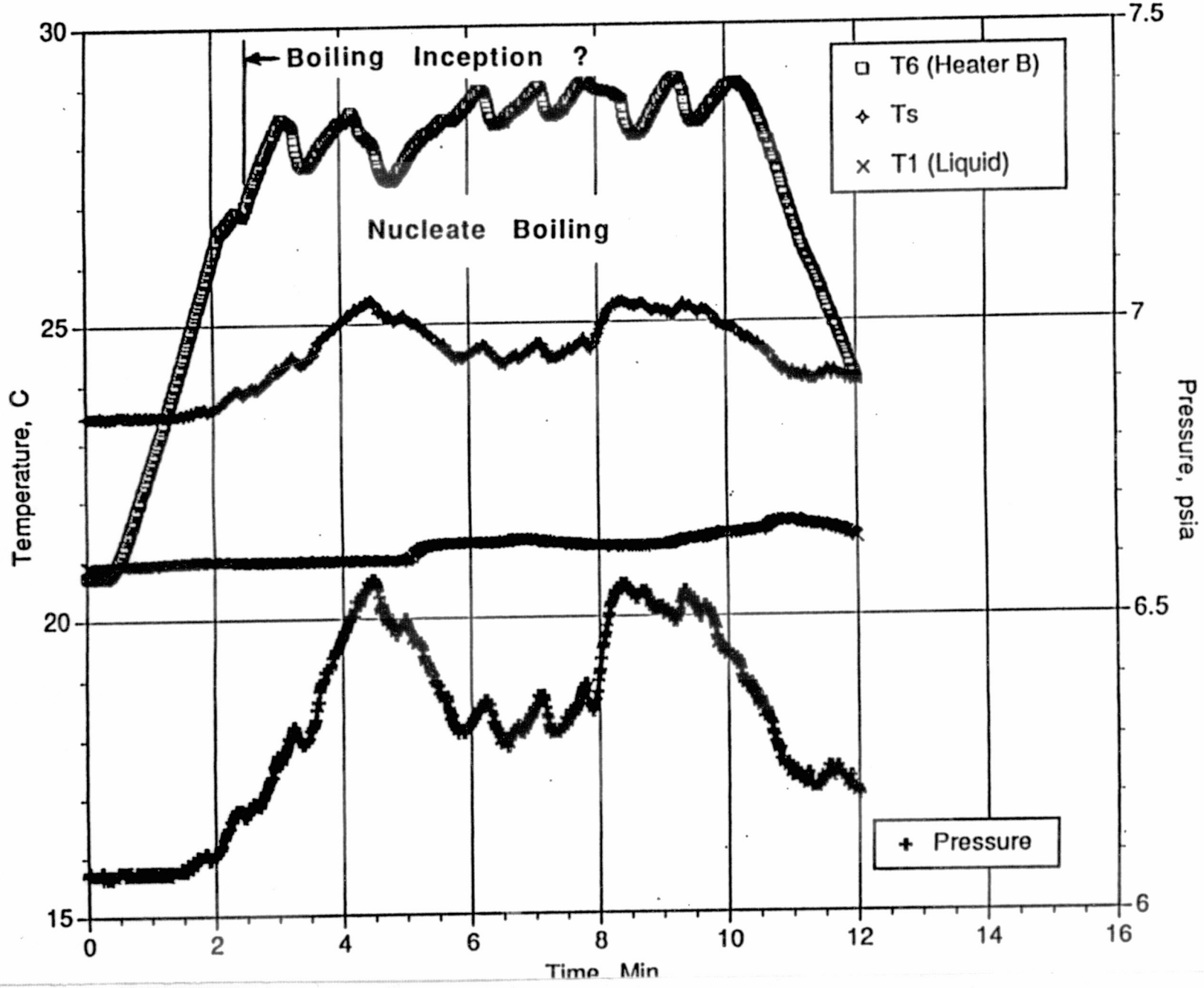
-HEATER TEMPERATURE AND TANK PRESSURE HISTORIES SUGGEST THAT BOILING OCCURRED AND NUCLEATE BOILING CONTINUED DURING THE HEATING PERIOD. VIDEO CAMERA SHOWS SOME LIMITED EVIDENCE OF THIS BUT MISSED INTERESTING PHASE BETWEEN 2 AND 10 MINUTES.

• IN SOME TEST RUNS WITH "HEATER-A" ON THE TANK PRESSURE DID NOT CHANGE FOR ABOUT SIX MINUTES OF HEATING.

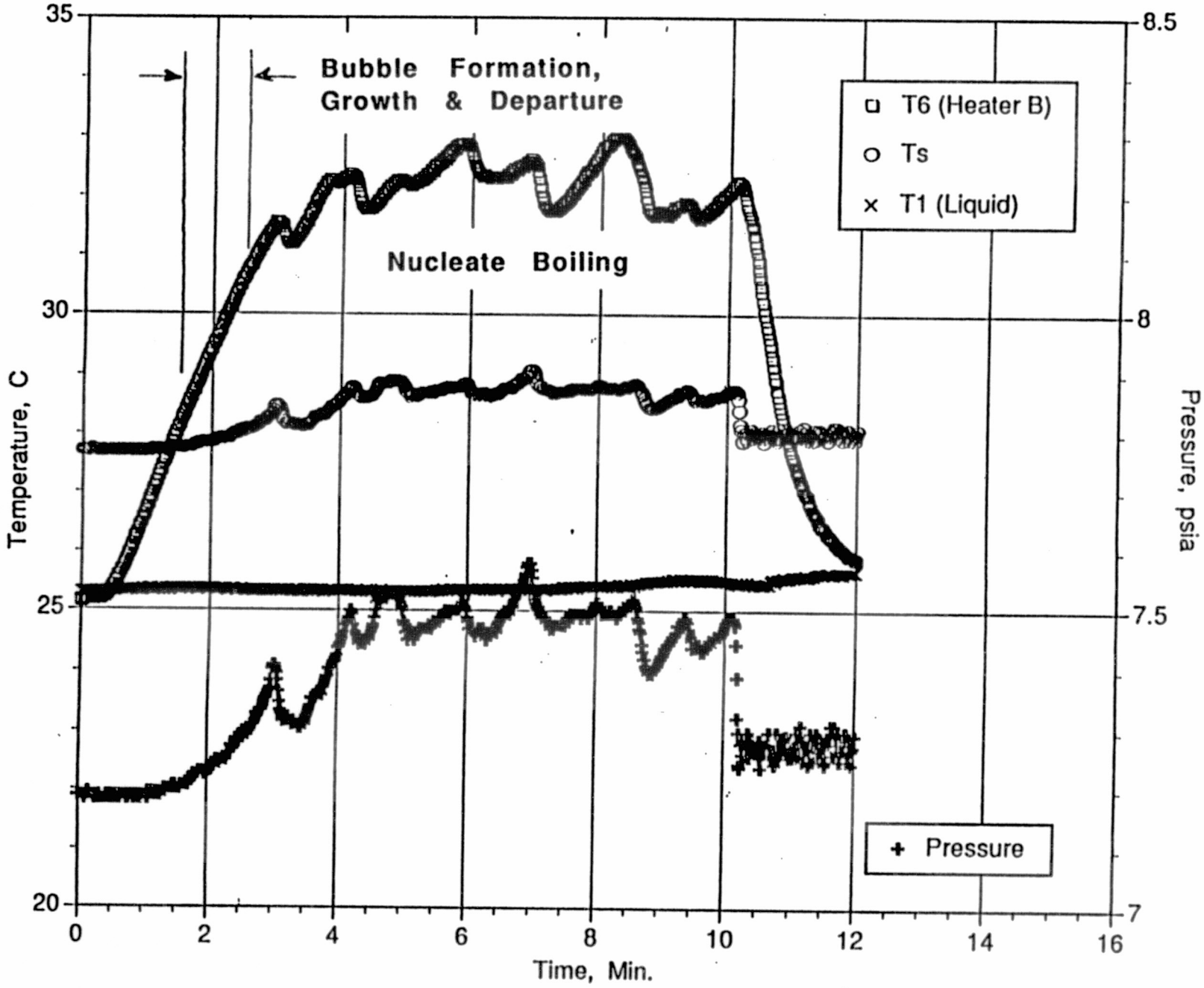
-HEATER SURFACE TEMPERATURE EXCEEDED THE SATURATION TEMPERATURE BY 12 TO 14C.

- THE SUPERHEATING PERIOD WAS FOLLOWED BY EITHER VIOLENT BOILING OR FLASHING OF SUPERHEATED LIQUID. THIS IS EVIDENCED BY PRESSURE SPIKES OF ABOUT 1.4 TO 2.0 PSI IN LESS THAN 0.3 SECOND.

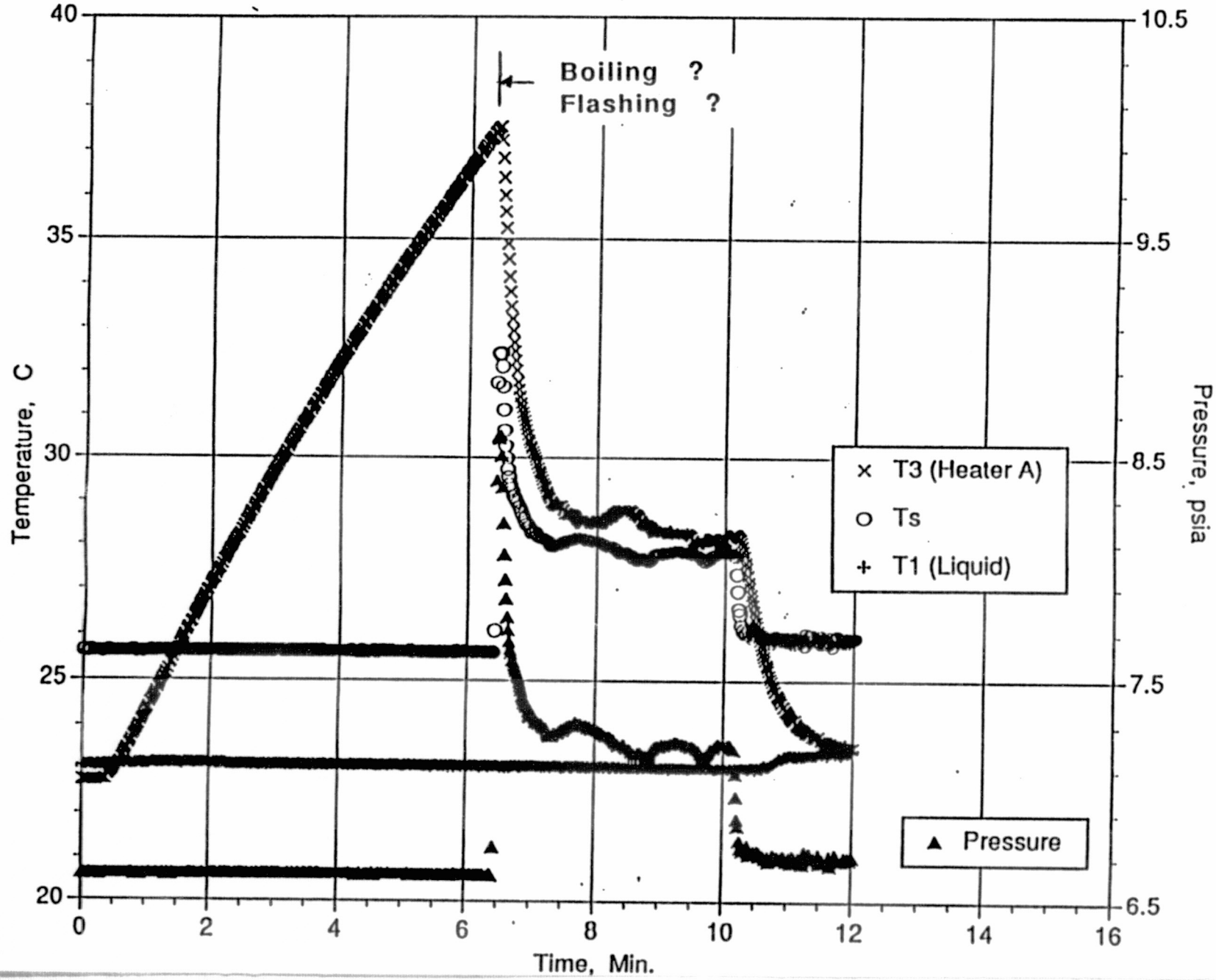
Heater and Liquid Temperatures and Tank Pressure as a Function of Time for
Run No. 03 with Heat Flux Equal to 0.14 watt/cm2



Heater and Liquid Temperatures and Tank Pressure as a Function of Time for Run No. 37 with Heat Flux Equal to 0.10 watt/cm2



Heater and Liquid Temperatures and Tank Pressure as a Function of Time
for Run No. 13 with Heat Flux Equal to 0.12 watt/cm2



TPCE CONCLUSIONS

- **FLIGHT RESULTS:**
  - VIDEO AND DIGITAL DATA ON JET INDUCED MIXING PROCESS FOR PRESSURE CONTROL, POOL BOILING, AND LIQUID SUPERHEAT PHENOMENA

- **FINDINGS:**
  - FLUID MIXING AND VAPOR CONDENSATION IN LOW-G ARE ACHIEVED WITH CONSIDERABLY LOWER JET FLOW RATE THAN IN 1-G
  - LOW-G DATA MAY LEAD TO METHOD TO EXTRAPOLATE LOW-G PERFORMANCE FROM 1-G DATA
  - PRESSURE SPIKES OCCUR IN LOW-G DUE TO HIGH LIQUID SUPERHEAT AT LOW HEAT FLUX. THIS REPRESENTS A POTENTIALLY HAZARDOUS CONDITION FOR LONG TERM STORAGE OF SUBCRITICAL CRYOGENIC FLUID IN SPACE; FURTHER STUDY/EXPERIMENT IN LONG DURATION LOW GRAVITY ENVIRONMENT IS NEEDED

OBJECTIVES OF REFLIGHT OF TPCE (TPCE/TP)

- FOR A GIVEN HEAT FLUX AND LIQUID SUBCOOLING APPROACHING ZERO
  - OBTAIN EXPERIMENTAL DATA ON MAXIMUM SUSTAINABLE LIQUID SUPERHEAT
  - OBSERVE AND CHARACTERIZE THE LOW-G BOILING PROCESS
- DETERMINE SELF-PRESSURIZATION RATE OF NEARLY SATURATED LIQUID
- DETERMINE PRESSURE DECAY RATE AND CHARACTERIZE DIRECT CONTACT CONDENSATION OF VAPOR FOR LOW JET FLOW RATE MIXING PROCESS
  - DETERMINE QUANTITATIVE CRITERIA OF LOW FLOW RATE

RATIONALE FOR REFLIGHT

- HIGH LIQUID SUPERHEATING OBSERVED AT SUCH LOW HEAT FLUX IS OF PARTICULAR IMPORTANCE TO CRYOGENIC FLUID STORAGE AND TRANSFER. UNDERSTANDING OF LIQUID SUPERHEATING PROCESS WILL HELP TO:
  - ELIMINATE HAZARDOUS CONDITION DURING STORAGE
  - DEVELOP ALTERNATE METHOD FOR TANK PRESSURIZATION
- A VISUAL OBSERVATION OF BOILING AND LIQUID SUPERHEATING PHENOMENA COUPLED WITH TEMPERATURE AND PRESSURE MEASUREMENT WILL PROVIDE USEFUL INFORMATION TO MODEL THESE PROCESSES

EXPERIMENTS WITH EXTENDED HEATING PERIOD AND COMPLETE VIDEO COVERAGE ARE REQUIRED

RATIONALE FOR REFLIGHT (CONTINUED)

- TPCE USED NONCONDENSIBLE PRESSURANT (HELIUM) TO AVOID PUMP CAVITATION PROBLEM
  - RESULTED IN LIQUID SUBCOOLING OF ABOUT 5 ^{o}C
  - ANTICIPATED TO HAVE NEGLIGIBLE EFFECT ON CONDENSATION RATE OF VAPOR; REFLIGHT WILL VERIFY
- SUBCRITICAL CRYOGENIC FLUID IN SPACE ENVIRONMENT WILL ALWAYS BE AT NEARLY SATURATED CONDITION; HOWEVER, EXTRAPOLATION OF TPCE RESULTS TO NEARLY SATURATION CONDITION IS NOT STRAIGHTFORWARD AND OBVIOUS

EXPERIMENTAL DATA WITH NO NONCONDENSIBLES IN THE ULLAGE AND LIQUID SUBCOOLING APPROACHING ZERO ARE REQUIRED

PROPOSED EXPERIMENT

- FLUID: FREON 113
- LIQUID SUBCOOLING: LESS THAN 2 °C
- HEATING TIME: 10 TO 40 MINUTES
- LIQUID FILL LEVEL: 85 PERCENT SAME TPCE
- VIDEO: DURING THE ENTIRE HEATING PHASE FOR SELECTED TESTS
- JET FLOW RATE: IN THE RANGE OF 0.0 TO 0.5 GPM
- SOME MIXING TESTS WITH NO HEATING
- MEASUREMENTS, ACCURACY AND DATA RATE: SAME AS TPCE

A TEST MATRIX INCORPORATING THE ABOVE CHANGES AND WITHIN THE CONSTRAINTS OF THE SAME TOTAL POWER DISSIPATION AND TOTAL VIDEO TIME IS SHOWN IN TABLE 1

TABLE 1

TEST MATRIX (TPCE/TP)

RUN NO.	HEATER	HEATING TIME:MIN	CAMERA	VIDEO TIME:MIN	JET FLOW RATE, GPM	MIXING TIME MIN	SETTLING TIME:MIN	PRINCIPAL OBJECTIVE/FOCUS
1	OFF	0.0	A	12.0	0-0.5	6	20	FLOW TRANSITION CRITERIA
2	B	10.0	A	12.0	0.1	10	20	BOILING, VAPOR CONDENSATION, MIXING, STRATIFICATION
3	B	10.0	A	12.0	0.2	10	20	
4	B	10.0	A	12.0	0.3	10	20	
5	OFF	0.0	B	12.0	0-0.5	6	20	FLOW TRANSITION CRITERIA
6	A	10.0	B	12.0	0.1	10	20	LIQUID SUPERHEATING, PRESSURE SPIKES, BOILING, CONDENSATION
7	A	10.0	B	12.0	0.2	10	20	
8	A	10.0	B	12.0	0.3	10	20	
9	OFF	0.0	A	12.0	0-0.5	6	20	FLOW TRANSITION CRITERIA
10	B	18.0	A	20.0	0.2	10	20	SAME AS 2 TO 4 FOR LONGER HEATING TIME
11	B	18.0	A	20.0	0.0	10	20	
12	A	18.0	B	20.0	0.3	10	20	SAME AS 6 TO 8, EFFECT OF SUB-COOLING ON VAPOR COND. RATE
13	A	18.0	B	20.0	0.1	10	20	
14	OFF	0.0	B	12.0	0-0.5	6	20	FLOW TRANSITION CRITERIA
15	A&B	18.0	A	20.0	0.4	10	20	BOILING AT LOWER HEAT FLUX
16	A&B	18.0	B	20.0	0.4	10	20	
17	A	40.0	OFF	---	0.4	30	20	HEATER ON DURING MIXING: HOMOGENOUS PRESSURE RISE
18	B	40.0	OFF	---	0.4	30	20	
19	A&B	40.0	OFF	---	0.4	10	20	LONGER HEATING WITH NO VIDEO
20	B	40.0	OFF	---	0.2	10	20	
21	A	40.0	OFF	---	0.3	10	20	