TANK PRESSURE CONTROL EXPERIMENT (TPCE)

Flight Experiments Technical Interchange Meeting
October 6, 1992

Mike Bentz
Boeing Defense & Space Group
Seattle, WA
TANK PRESSURE CONTROL EXPERIMENT

OVERVIEW

• Tank Pressure Control Experiment (TPCE) is a small self-contained STS payload
• Objective is to test jet mixer for cryogenic fluid pressure control
• Flown on STS-43 in August 1991
• Demonstrated reliable pressure control with low-energy mixer
• Reflight scheduled for late October on STS-52
TANK PRESSURE
CONTROL
EXPERIMENT

PROJECT ORGANIZATION

- Sponsored by In-Space Technology Experiments Program (In-STEP)
- Managed by NASA Lewis Research Center
- Design, fabrication, flight data analysis by Boeing Defense & Space Group
- STS integration managed by NASA Goddard Space Flight Center
PROJECT PHILOSOPHY

- Quick-response, relatively low-cost experiment
- GAS carrier chosen for ease of integration, manifesting
- Class D Modified approach used for hardware development
  - minimum cost
  - commercial-grade components
  - reduced product assurance requirements (except safety)
  - extra system-level testing to assure of flight readiness
RISK MANAGEMENT APPROACH

- Designed with redundancy where most beneficial
- Designed for minimal requirements on Orbiter and crew
- Based designs and components, where possible, on those used on prior payloads
- Tested prototype in low-g on Lewis Learjet Microgravity Test Facility
- Performed five complete Mission Simulation tests prior to delivery
**Problem:**

Storage of cryogens for long durations in low-g requires efficient and reliable control of tank pressure.

Active jet mixing is leading candidate for pressure control but energy addition results in boiloff penalty. Low-energy mixing requires in-space test.

**Objectives:**

- Determine jet mixing effectiveness in realistic low-g environment, as measured by ability of jet to:
  - penetrate vapor bubbles and reach all tank regions
  - reduce pressure in minimum time / minimum energy
  - equilibrate fluid temperatures

- Provide data for development of analytical models
TANK PRESSURE
CONTROL
EXPERIMENT

APPROACH

- Refrigerant 113 simulates cryogens
- 0.5 cu-ft tank filled to 83% level
- Pressure raised by heating, then reduced by mixing
- 38 test runs to determine effect of flow rate, acceleration environment, heater location
- Packaged as an autonomous STS payload using GAS carrier
Note: For clarity, some components are not shown in their true orientations.
STS MISSION PLAN

- Secondary payload using Get-Away Special carrier
- Payload size: <200 lbm, 5.0 cu-ft
- Tank major axis aligned with Orbiter
  X-axis, mixer nozzle at aft end
- OMS burns will settle liquid at mixer end
- Tail-first Orbiter orientation during first
  sleeping period (8 hours)
- Payload activation by baroswitch during launch
- Test duration: approximately 27 hours
SUMMARY OF DATA - VIDEO

- Effects of acceleration environment
- Heating (pressure rise) phase
- Self-mixing behavior
- Mixing flow patterns
TANK PRESSURE
CONTROL
EXPERIMENT

NORMALIZED PRESSURE HISTORIES -
FOUR TYPICAL RUNS

\[ \Theta = \frac{P - P_i}{P_f - P_i} \]

TIME SINCE MIXER TURNED ON (MINUTES)

LOGARITHMIC PLOT

TIME SINCE MIXER TURNED ON (MINUTES)

Run 4 (1.7 l/min)
Run 16 (0.66 l/min)
Run 9 (0 l/min)
Run 10 (3.0 l/min)
Run 6 (1.0 l/min)
Run 1 (3.0 l/min)
PRESSURE REDUCTION TIME
VERSUS WEBER NO. & FLOW PATTERN
RESULTS AND CONCLUSIONS

- All objectives met or exceeded, no failures
- Data support thesis that low-energy jet is efficient pressure control device
  - Moderate velocities cause complete circulation, rapid pressure drop
  - Low velocities also cause reliable pressure drop with ~80% less energy added
  - Identified ranges of dimensionless jet momentum to be avoided
  - Generated large amount of digital and video data to support model development
- Identified potentially significant pressure rise phenomena requiring further study
- Payoff: Cryogen pressure control shown to be manageable problem
  - Boiloff mass due to mixing can be reduced to insignificant level