APPENDIX B: WORKSHOP PRESENTATION:
REPORT ON MULTIPHASE FLOW PANEL

Discussion of Priorities

Priority Ratings
- enabling technology if not solved, don’t or can’t go.
  • Severeley Limiting enabling technology but other systems can be used, but a steep price
  • Enhancements
    – safety and reliability
    – weight savings
    – cost savings
  • Communication: Analysis, modeling, existing resource awareness can overcome difficulties.

Method of Testing
- space-flight experiment (SF)
- ground-based reduced gravity testing (GB)
- normal gravity testing,
- analysis/modeling
- review of existing space-flight / ground-based data for its appropriateness.
Critical Issues
Reduced Gravity Instabilities

• Flow/phase splitting through Parallel flow paths (system level)
• Phase Accumulation and release within Flow System Components
  Transient Operations
  – Startup/Shutdown
  – Changes in Set Point Operation
  – Variable gravity over sustained time periods
    • 1 – g prior to launch & after landing
    • 1g during launch / landing
    • μg, Martian, and Lunar
    • Variable gravity – sloshing

Critical

• Phase separation, distribution and control
  – Control-- pick components, get in game
  – (not phase change part)
  – Take best tool, best data, design experiment to test (evaporator/condenser system) (one really pertinent example!)

• Critical heat flux in transient and oscillating flows (recovery)
  Take best tool, best data, design experiment to test (one really pertinent example!) Run transients
  Evaporator/(not a system)

Density wave oscillations in multiphase systems
  Take best tool, best data, design experiment to test (evaporator/condenser system) (one really pertinent example!)

• Gravitationally insensitive evaporators/condensers
  – (same system)

• Scale-up
  – Do other scales (same idea)
  – Components
Severely Limiting Phase Separation

• Active Separators based on Centrifugal concept. Unstable operations at flooding conditions
• Multiphase (gas-liquid?) pump

Severely-Limiting Phase Change

• CHF is not a problem unless some other instability initiates a flow interruption.
  – Recovery from dryout by quenching hot surface because of
    • Exceeding CHF due to other flow instability
    • Hydrodynamic rupture of liquid film at slow slugging/wave frequencies
  – High power density: Spray cooling.
Severely Limiting

- Flow Splitting and Combining
- Packed Beds
  - Mass and Heat transfer coefficients
  - Phase Distribution and accumulation
- Mass transfer in various systems
- Noncondensibles

Enhancements

Passive Phase Separation
- Inertial Driven
  - Cyclonic devices
  - Tees/manifolds

Phase Change
- Surface Enhancements
- Surfactants & Engineered Fluids
Likely Problems in reduced gravity – Solve through Analysis and Awareness. Maybe look at existing data

- Ledinegg/Pumped Loop Instability
- Pressure Drop Oscillations
- Density Wave Oscillations

Phase Separation
- Bubble removal from rotating tanks through Needle suction

Flow Through Components
- Valves
- Pumps
  - Single phase – avoid cavitation
Methods of Resolution

- ISS
  - Fluids Integrated Rack
  - Microgravity Science Glovebox
  - Express rack
  - other
- Ground-based Reduced Gravity Facilities
- Normal Gravity Testing and Modeling
- Long duration partial/micro gravity

13-May-2003

- Liquid Supply
- Means of supplying vapor or gas
- Plumbing consisting of valves, tubing, accumulators, etc.
- Test article(s)
- Sensors – pressure, temperature, flowrate, flow regime
- Data Acquisition and Control System
- Ability to remotely change operational settings.
- Highly desired are Flow Visualization Sections, preferably high speed camera
  - Power, heat sink
  - Ground control

13-May-2003
MULTIPLE TEST SECTIONS

Two-Phase Flow Facility (TFFy)

- Parallel flow channels with multiple evaporators.
  - Flow through splitting manifold into the parallel channels
  - Parallel channels could focus on different aspects of boiling, namely critical heat flux and quenching,
- Assess slugging phenomena on active separation device(s)
- *Packed Bed hydrodynamic characterization*

2008 Space Flight
2003 – 2008
Ground – Based \( \mu G \) Facilities

- Flow splitting and mixing tees and manifolds (airplane)
- Component separation (air-water, e.g., fuel cells)
- Cryogenic (??)
- Phase Change
  - determine wetting characteristics of solid-liquid combinations and strategies (additives) to modify/control the wetting and spreading.
  - Conduct testing for rewetting/quenching of hot surfaces
  - Investigate the effects of wetting characteristics of a condensing surface
- Passive two phase flow separation techniques
  - Drainage of condensate with refrigerators from their "cold plates."
  - drainage of waste water, including urine from rat cages
  - continue bubble removal schemes for bioreactor
  - Propellants
- Initiate investigations of the effectiveness of techniques using acoustic, electric field, surfactants and surface enhancement for 1-g and low-g
  - (To alleviate CHF problems)

13-May-2003

2003 – 2008
Other

- Evaluate current two-phase system designs for known and appropriate normal gravity instability mechanisms.
- Continue and complete development of mechanistic models for nucleate pool boiling
  - Design tools/handbook
  - Flow boiling

13-May-2003
2009 – 2015
Space Flight

• Continue parallel channel instability tests
• Demonstration/validation of scaling
• Conduct phase change experiments for CHF, Quenching & Spray cooling
• Conduct phase change experiments on condensation to determine condensation heat transfer coefficient in microgravity
• Conduct ISS experiments on liquid-gas flows in packed beds (mass transfer, reactions)

2009 – 2015
Ground – Based µG Facilities

• Conduct experiments for pool and flow boiling for the effect of boiling enhancement techniques.
• Conduct advanced phase separator tests for a wide variety of concepts, including passive methods.
• Exotic materials and fluids,
• Nuclear power components
• Setting up for the next grand and glorious project
• Electrical and electroacoustic manipulation of interfaces and fluids
2009 – 2015

Other

• Bio power sources
• Nano-scale prototypes for power/etc
• Designed surfaces for heat transfer
• Combined comprehensive modeling effort for multiphase heat transfer and flow leading to user design code.

2016 ++

• Space Flight
  – Phase change and heat transfer with exotic materials
  – High and low pressure and temperature experiments
  – Large scale system demonstrations
• Ground – Based $\mu$G Facilities
  – Detailed verification of the comprehensive computation package.
• Other
  – two phase design and operations manuals
  – software package development?.

13-May-2003