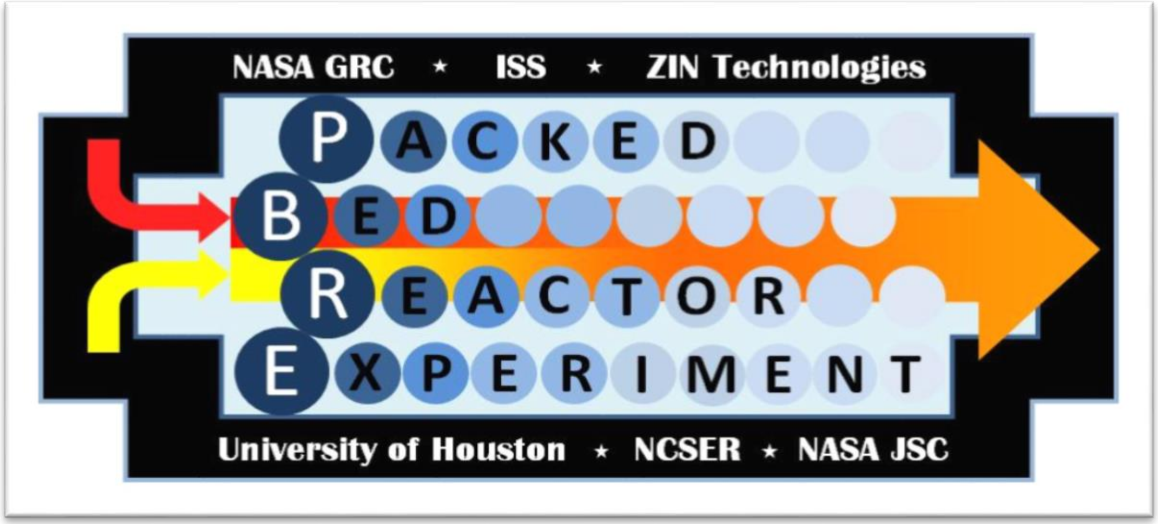
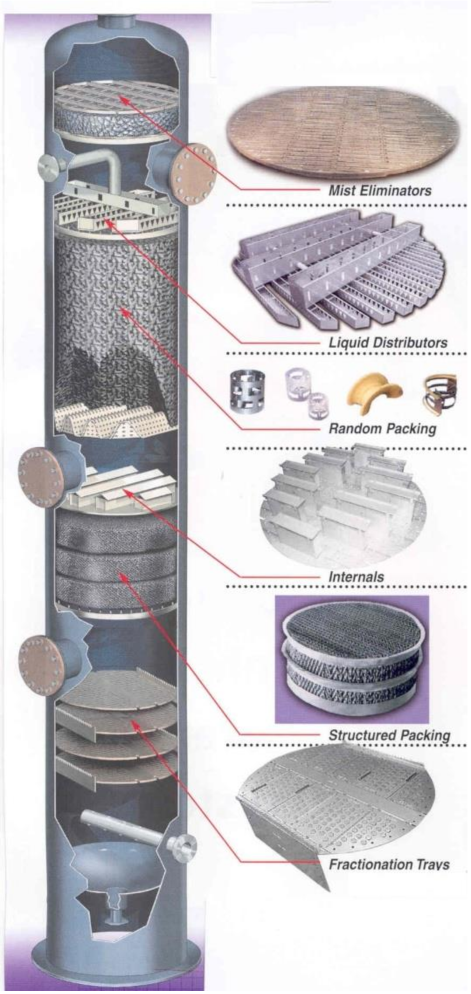


The Packed Bed Reactor Experiment (PBRE-2 and PBRE-WR)

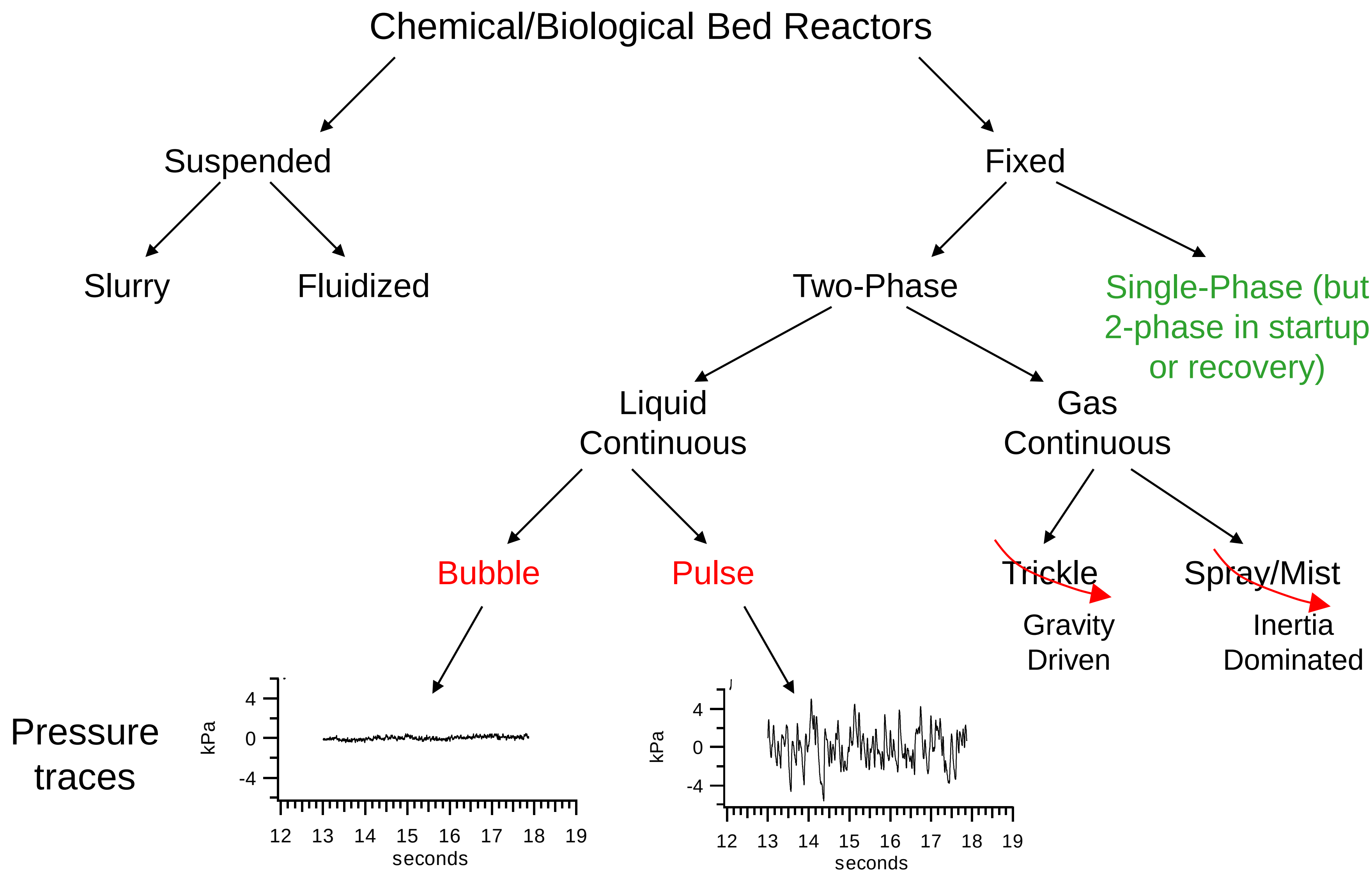
Brian Motil, NASA Glenn Research Center

Background

- PBR: chemical or biological reactor vessel filled with fixed solid particles, flowing any combination of gas and liquid reactants or products through the packing.
- Solid packing: various shapes and sizes, serves as support for catalyst or host for bio-growth material.
- PBR: most common type of reactor used in industry today (~80%).
- Advantages: higher throughputs, compact design, operational flexibility and minimal power consumption – excellent candidate for long-duration human space flight.
- Challenges: fouling, pressure drop, flow stability, flow regimes, catalyst degradation, scale-up, heat and mass transfer.
- Provides opportunity to purify/treat water in space (examples provided in later charts).

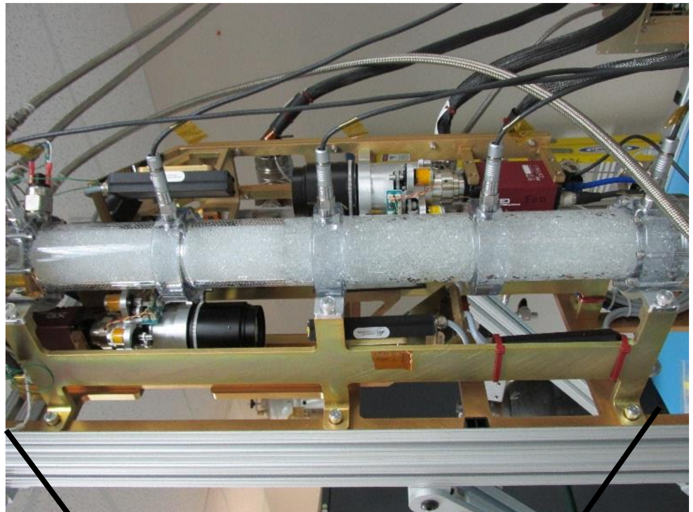


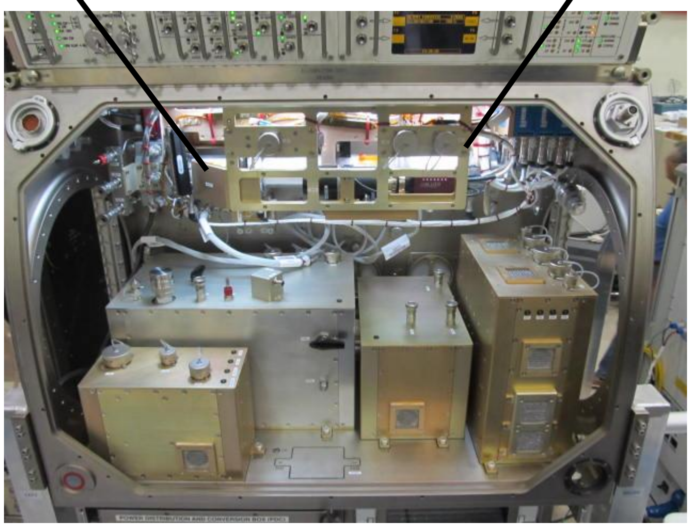
Types of Reactors



Packed Bed Reactor Experiment

Introduction





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Co-Investigator: Prof. Vemuri Balakotaiah, U. of Houston
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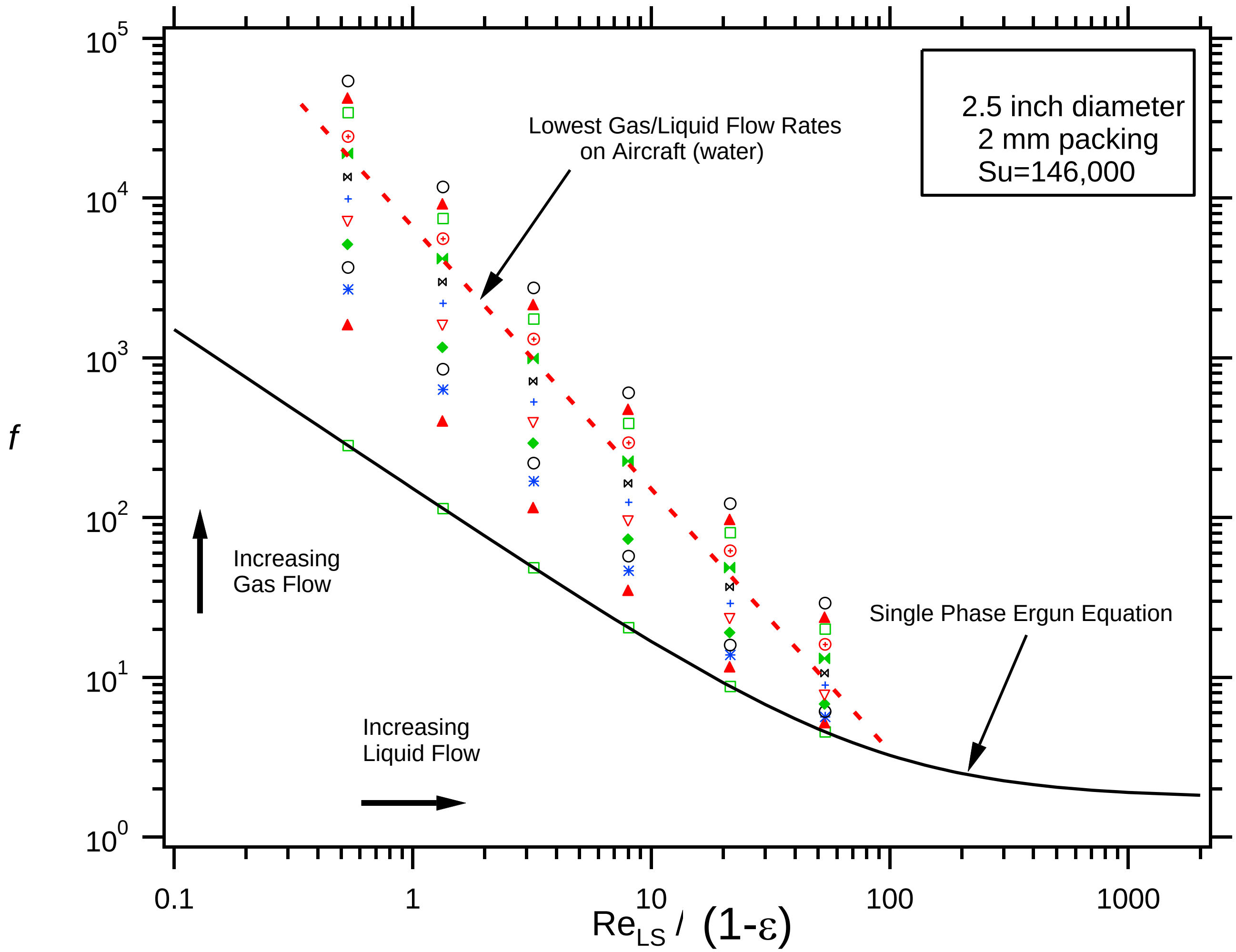
Project Manager: Robert Hawersaat, GRC
Project Scientist: Dr. David Chao, GRC

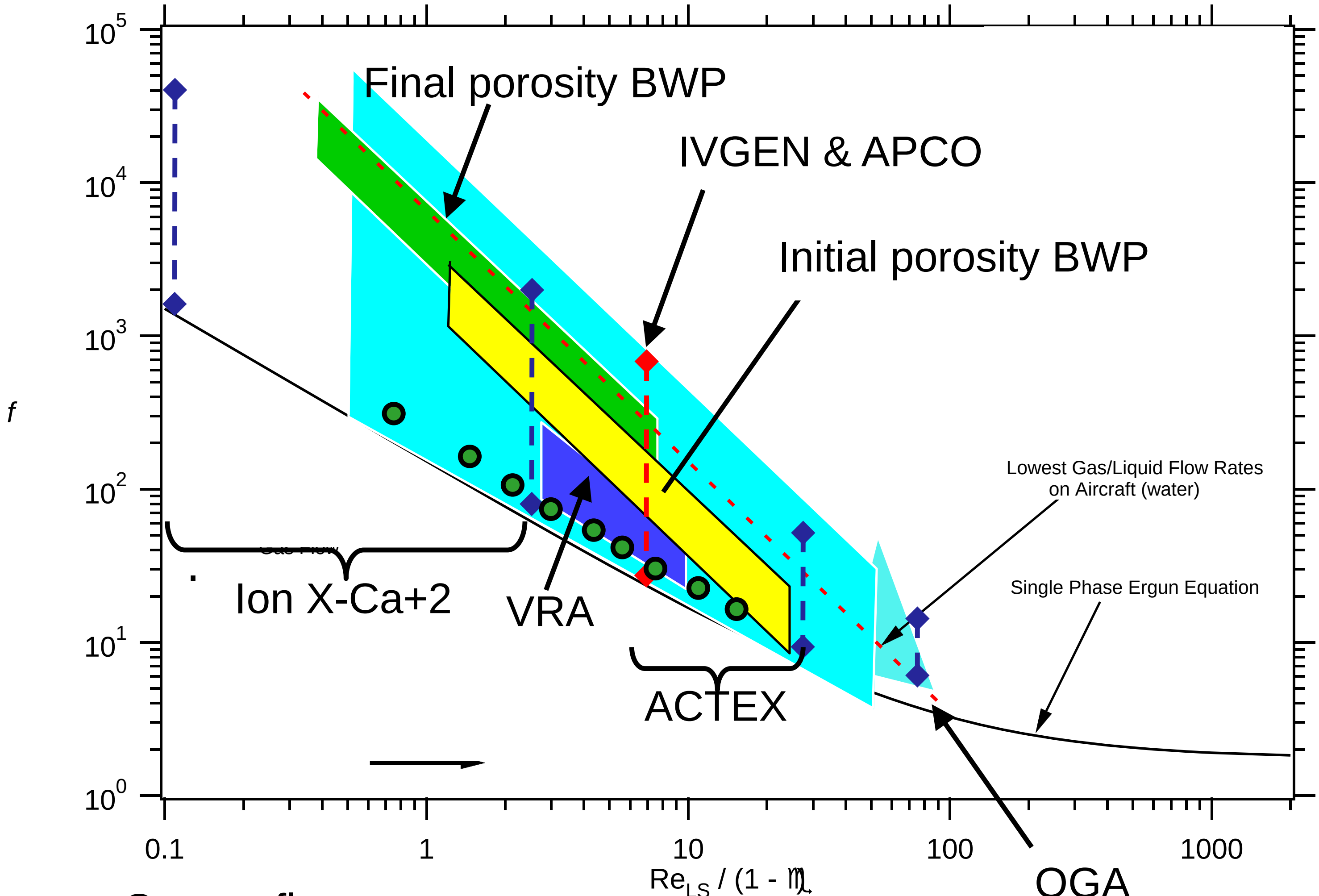
- Increment 61& 62 will provide the opportunity to re-fly the PBRE experiment within the Microgravity Science Glovebox.
- PBRE-1 completed ops in MSG (2/2017).
  - Included glass and Teflon packing.
  - Some hardware issues reduced some of the original science (mainly with high speed video) – has been resolved for re-flight.
- PBRE-2 will extend test matrix to different size packing.
- PBRE-WR will extend test matrix to different type of packing (alumina).

Investigation Goals & Objectives

- Investigate the role and effects of gravity on gas-liquid flow through porous media. Specific NASA applications include chemical and biological reactors for water revitalization as well as flows to deliver water and nutrients to plant systems.
- Develop/validate scaling laws and design tools for future fixed packed bed reactors in 0-g and partial-g environments, including start up and transient operations.
- Identify strategies to recover single phase beds from undesired gas bubbles.
- Provide test fixture for future two-phase flow components (e.g. membrane beds).
- Develop and validate gas holdup models such as B. Guo, D.W. Holder & L. Carter, Physics of Fluids (2004).
- By removing the influence of gravity in flow through porous media, study the effects of other important forces such as inertial, viscous and surface tension forces.

ISS Test Matrix





●: Startup flow rates

Packed Bed Reactor Experiment

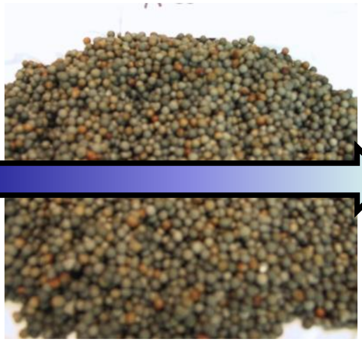
Measurement Approach

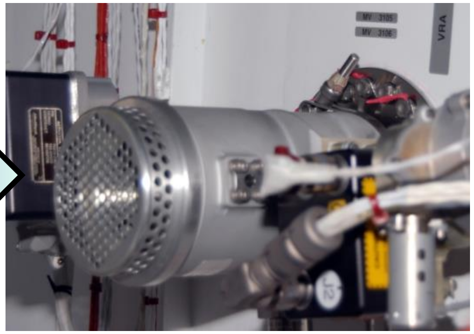
- Full range of gas (nitrogen) and liquid (water) flows anticipated in thermal and life support systems. Testing spans two orders of magnitude of Liquid and Gas Reynolds Number.
  - Gas flow: 0-1 kg/hr
  - Liquid flow: 0-150 liters/hr
  - Includes identification of minimum liquid flows to expel trapped gas pockets.
- Critical diagnostics and data collection. Capability to add/upgrade diagnostics.
  - 2 high speed video cameras
  - 5 high speed pressure transducers spaced evenly along column
- Interchangeable beds (up to 24 inches long by 5 inches in diameter).

Space Applications

Water Recovery Systems (WRS)

- Water Processor Assembly (WPA) uses a thermal catalytic reactor for oxidizing volatile organics
- Single-phase packed beds
  - Microbial Check Valve (MCV), an iodine addition system
  - Activated Carbon/Ion Exchange (ACTEX), an iodine removal system
  - WPA Multifiltration Beds use adsorbent and ion exchange media for removal of dissolved contaminants





Packed Bed Reactor Experiment

Space Applications

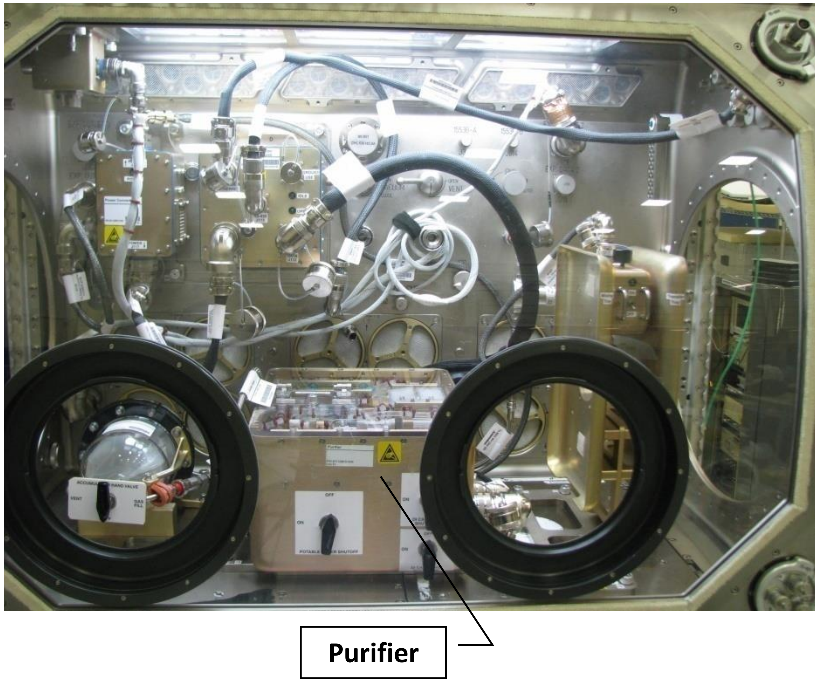
WRS Developing Technologies with Packed Beds/Membranes

- Direct Osmotic Concentration (DOC) System
  - Forward/Reverse Osmosis membranes: processes hygiene/laundry wastewater
  - Direct Contact Membrane Distillation: processes urine/humidity condensate
  - Aqueous-Phase Catalytic Oxidation: post-processing
- Biological Water Processors
  - Pretreatment: hollow-fiber membranes
  - Primary processors: packed beds

Packed Bed Reactor Experiment

Medical:

- IntraVenous Fluid GENeration (IVGEN): demonstrated a microgravity compatible water purification and pharmaceutical mixing system.
- Successfully flown in March, 2010.
- PBRE model was used to predict deionizing resin bed startup conditions and pressure drop.
- Required minimal liquid velocity to <u>clear bubbles from packed bed</u> and <u>minimal flow rate</u> to meet purified water production requirements.



Expected Results

- **PBRE-2**
  - Re-flight with smaller packing to increase pressure drop across column.
  - Obtain full set of video data to determine flow regimes (camera malfunction experienced on initial flight).
  - Validate pressure drop models with smaller packing size.

- **PBRE-WR**
  - Establish pressure drop and gas occlusion for various gas/liquid flow rates over the potential range for the reactor application
    - Data will subsequently be used to optimize reactor design
  - Establish pressure drop for gas/liquid flow rates consistent with PBRE-2 to develop correlation for different packing material