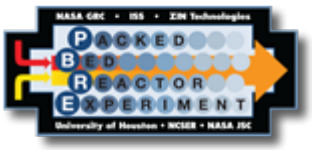
Packed Bed Reactor Experiment (PBRE)



A critical unit operation used with many of the leading water reclamation and air revitalization technologies for advanced life support systems is the fixed packed bed reactor. Examples of systems currently under development or in use in space that take advantage of this type of reactor include the Volatile Removal Assembly (VRA), the Aqueous-Phase Catalytic Oxidation (APCO) system, the Microbial Check Valve (MCV), the Activated Carbon/Ion Exchange (ACTEX), and the IntraVenous Fluid GENeration (IVGEN) system. However, despite the many applications, there is very little understanding of how the reduced gravity environment affects the performance and reliability of the reactors. This is especially critical when the reactor involves simultaneous gas and liquid flows. The Packed Bed Reactor Experiment (PBRE) is designed to specifically resolve these technology gaps. The expected outcome of this research effort is to develop a set of guidelines and tools to enable engineers to reliably design and operate fixed packed bed reactors for microgravity as well as the lunar and Martian environments.

The PBRE ISS flight experiment will provide critical hydrodynamic information for a project which also includes reduced gravity aircraft and ground-based (1-g) testing. The main objective is to develop and validate macroscopic equations that can be used in partial and microgravity conditions to accurately predict flow pattern transitions; pressure drops; and chemical and biological transport rates in gas-liquid flows through randomly packed beds. The hydrodynamic investigations will focus on the transitions between flow regimes (i.e., bubbly-to-pulse flow transition) and the associated pressure gradients for each flow regime over the range of relevant test parameters (e.g., liquid flow rates, gas flow rates, and particle sizes). These design tools will provide important information for specific water reclamation and air revitalization technologies for advanced life support systems.

The PBRE is being developed under the Space Flight Systems Development and Operations Contract, through the collaboration of ZIN Technologies and the National Aeronautics and Space Administration (NASA) Glenn Research Center (GRC), the International Space Station (ISS), the University of Houston, the National Center for Space Exploration Research (NCSER) and NASA Johnson Space Center (JSC). The success of the PBRE project is crucial to the development of technologies which will maintain the well-being of crew members participating in extended space missions.

Recent Updates

Achievements for the week ending: March 18, 2021

The Packed Bed Reactor Experiment – Water Recovery (PBRE-WR) completed a series of tests in the Microgravity Science Glovebox on the International Space Station.

Tests were performed on the International Space Station studying gas-liquid flows through Alumina packing. PBRE-WR was the fourth type of packing tested in the PBRE flow loop and was the first to test a realistic-type of packing (versus idealized packing better suited for modeling). Operation of the experiment was very successful over a three-week period, meeting all the science test objectives.

Test points completed included 312 different flow conditions at steady state; 133 test conditions to examine bubble removal strategies; 18 series of test conditions to examine the effects of hysteresis; and finally, 63 test points at steady state with an extended time duration to examine slow accumulation of gas bubbles in the column.

Objective

• Investigate the role and effects of gravity on gas-liquid flow through porous media.

• Outcome will be the development of design and operational guidelines for gas-liquid Packed Bed Reactors in partial and microgravity conditions.

Relevance/Impact

• Directly aligns with high priorities from the NRC Decadal survey on Biological and Physical Sciences and crosses over to other technologies.

• AP-2: Provides a study of a critical multiphase flow component for life support systems.

• TSES-6: Provides a fundamental study in porous media under microgravity conditions.

• Porous media are critical components in life support systems; thermal control devices; fuel cells; and biological and chemical reactors.

Development Approach

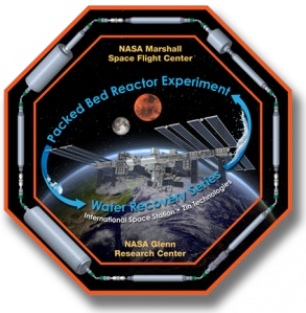
• Completed extensive (but time-limited) low-G aircraft tests.

• Engineering model hardware and Proto-flight unit.

• Video and data downlinked to the ground for evaluation.

• Develop on-orbit replaceable test section to extend experiment capabilities. Enables flexibility for future development of porous media components/devices.

Packed Bed Reactor Experiment - Water Recovery Series (PBRE-WRS)



Objectives:

Investigate role and effects of gravity on hydrodynamics of gas-liquid flow through porous media. Develop/validate scaling laws and design tools for future packed bed reactors in zero-g and partial-g environments, including start up and transient operations. Identify strategies to recover single-phase beds from undesired trapped gas bubbles.

Experimental Approach:

- Control variables: gas and liquid flow rates.
- Diagnostics: Temperatures, pressures, video images.

Relevance/Impact:

Directly aligns with high priorities from the NRC Decadal survey on Biological and Physical Sciences (1) and the NRC 2000 report on Microgravity Research in Support of Technologies for the Human Exploration and Development of Space and Planetary Bodies (2):

- AP-2: Provide study of a critical multiphase flow component for life support systems.
- TSES-6: Provide a fundamental study in porous media under microgravity conditions.

Two-phase components are critical to life support and thermal control systems.

Project Development Approach:

- PBRE-WR2 Series, return PBRE flight hardware, clean, modify and relaunch.
- **Redesign Cradle and operate: 8 Test Section inserts:**
- PBRE-WR-BF: Brine Filter
- PBRE-WR-UF: Urine Filter
- PBRE-WR-PF: Purge Filter
- PBRE-WR-Check Valve
- PBRE-WR-Orifice 1 through 4
- Work with PI Team at MSFC and PBRE team to develop PBRE-WR Series Science Requirements Document (SRD)

PBRE-WRS – Test Module – Redesign Status

Accomplishments/Progress

–The PBRE-WRS Engineering Requirements Document (ERD) was reviewed by the Science Team (PI, Co-I and PS) comments were provided. Comments were incorporated.

Publications

–International Conference on Environmental Systems (ICES) publication planned upon completion of flight experiment

–PBRE 1-2 data analysis publication (in discussion)

Issues/Concerns

–Potential Optics Updates, discuss with PI

- Assess possibility to have camera position and light bars adjustable:

–Per SOW: “Provisions will be made to adjust the camera and light bar positions for each test section. Associated brackets will be fabricated and installed as needed.”

- Assess current camera’s capability to be adjusted for different focal lengths.

Contact Information:

- PI: Jill Williamson (MSFC)
- Co-I: Colton Caviglia (MSFC)
- Project Manager: Jennifer Wetzel (GRC)
- Project Scientist: Tyler Hatch (GRC)
- Current Grant Period of Performance: N/A
- Scheduled or Actual operations dates: December 2023
- Last task book update: N/A
- Final report due: December 2024