

THE TWO-PHASE FLOW SEPARATOR EXPERIMENT BREADBOARD MODEL: REDUCED GRAVITY AIRCRAFT RESULTS

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Life support systems in space depend on the ability to effectively separate gas from liquid. Passive cyclonic phase separators use the centripetal acceleration of a rotating gas-liquid mixture to carry out phase separation. The gas migrates to the center, while gas-free liquid may be withdrawn from one of the end plates. We have designed, constructed and tested a breadboard that accommodates the test sections of two independent principal investigators and satisfies their respective requirements, including flow rates, pressure and video diagnostics. The breadboard was flown in the NASA low-gravity airplane in order to test the system performance and design under reduced gravity conditions. In this poster, the test sections are identified by the respective PI's institution, Dynaflow, Inc., and Case Western Reserve University (CWRU).

Diagnostics: pressures and void fraction at various locations; video (regular and high-speed) of the test section and development tube; gas core diameter; bubble size distribution in Dynaflow's liquid exit chamber via acoustic bubble spectrometer (see ABS hydrophones in fig. 3-left).

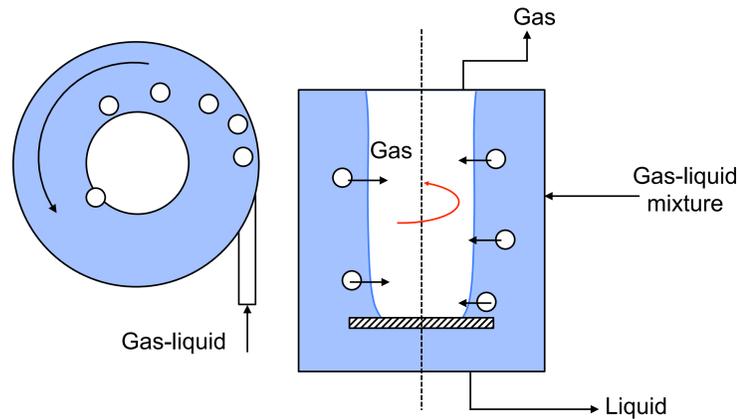


Fig. 1: Schematic of a cyclonic phase separator. The gas-liquid mix (pumped by the process equipment) enters tangentially into the cyclonic separator. The momentum of the injected mixture gives rise to a rotating fluid layer, most of which is in rigid-body motion.

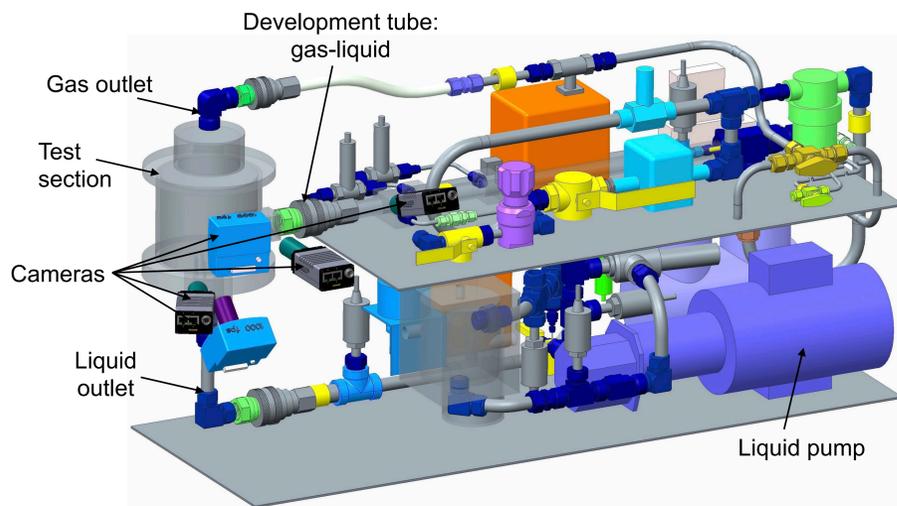


Fig. 2: Computer model of the breadboard flight rig showing key components. The breadboard was designed to fit in the ISS Fluids Integrated Rack.

Dynaflow

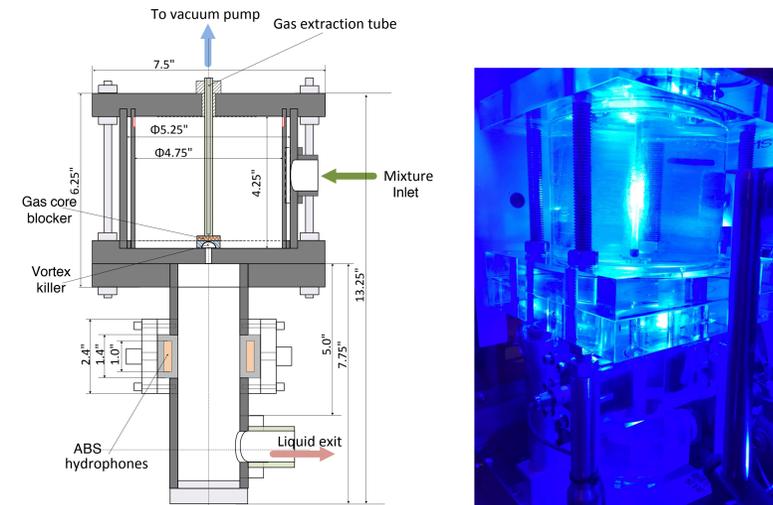


Fig. 3: Dynaflow test section. Left: schematic; right: under operation in the lab. Light glow along axis is formed by tiny gas bubbles congregating around the gas extraction tube.

Test matrix philosophy: Gather data of gas extraction ability as a function of gas flow rate, for several fixed liquid flow rates. When gas flow becomes too high, the gas core diameter grows, causing some gas to leak around the gas core blocker (see left schematic above) and leave through the liquid exit.

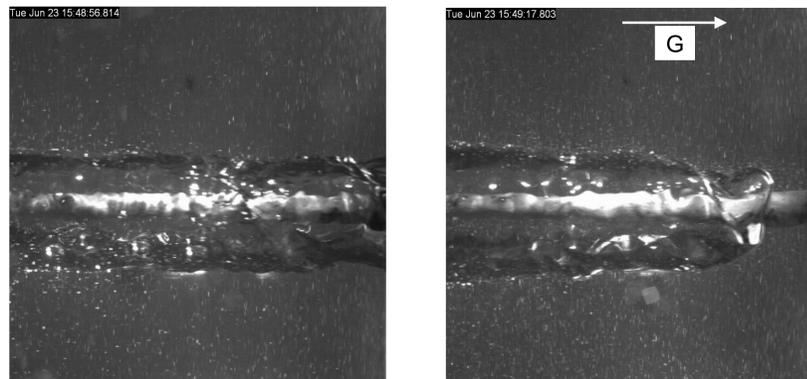


Fig. 4: Example of stable gas core in low gravity. $L=9.45$ l/min (2.5 gpm), $G=0.5$ slpm, frame rate =1000 fps. The gas core develops around the membrane tube through which gas is exhausted. Left: normal operation. Right: gas core starts to rise by the action of buoyancy at the beginning of high-g pull-up; arrow shows direction of gravity. Field of view is approximately 5 cm.



Fig. 5: Overall view of same case as above. This view is closely synchronized with the right image above. Field of view is approximately 18 cm left to right.

CWRU

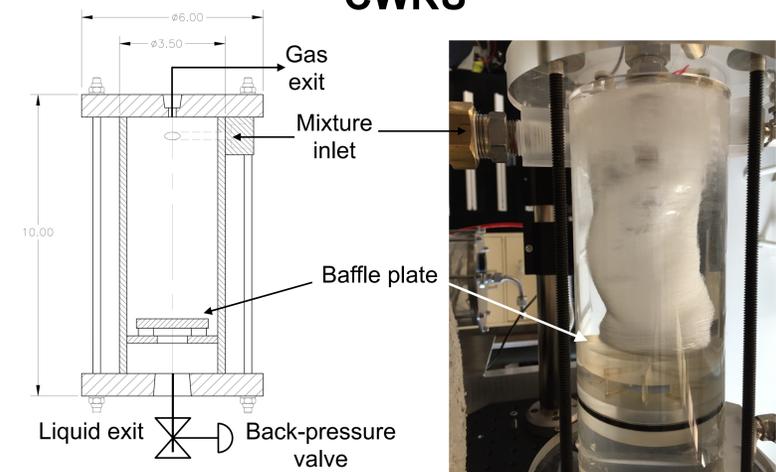


Fig. 6: CWRU test section. Left: schematic. Right: under operation in the lab. Liquid-gas rotating layer forms on the wall; gas bubbles migrate toward central gas core; all-liquid phase flows between baffle plate and cylinder wall.

Test matrix philosophy: Gather data of gas core stability boundaries in reduced gravity as a function of gas and liquid flow rates, and liquid back-pressure valve positions (all-open and 35-degrees closed). The more closed the valve, the higher the gas flow needed to sustain a gas core. For a given liquid flow rate, the more the valve is closed, the higher the gas flow needed to sustain a gas core.

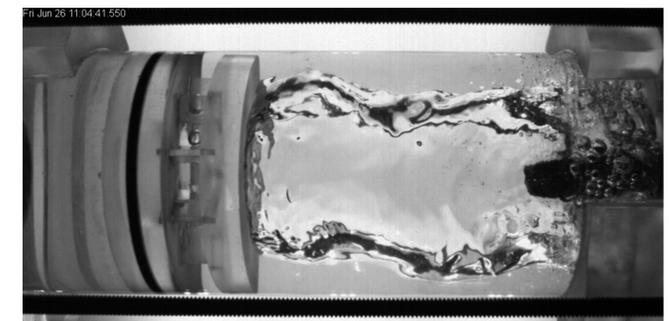


Fig. 7: Example of stable gas core in low gravity. $L=6.05$ l/min (1.6 gpm), $G=2.5$ slpm, liquid back-pressure valve 35 deg closed.



Fig. 8: Example of unstable gas core in low gravity. $L=6.05$ l/min (1.6 gpm), $G=10$ slpm, liquid back-pressure valve 35 deg closed. Because the gas flow rate is high, the gas core pressure increases, making the gas core diameter larger. This causes gas to leak around the baffle plate into the liquid outlet. If, on the contrary, the liquid pressure is too large (due to high liquid flow rate, e.g.) then the gas core would shrink and collapse, and the test section would become flooded.