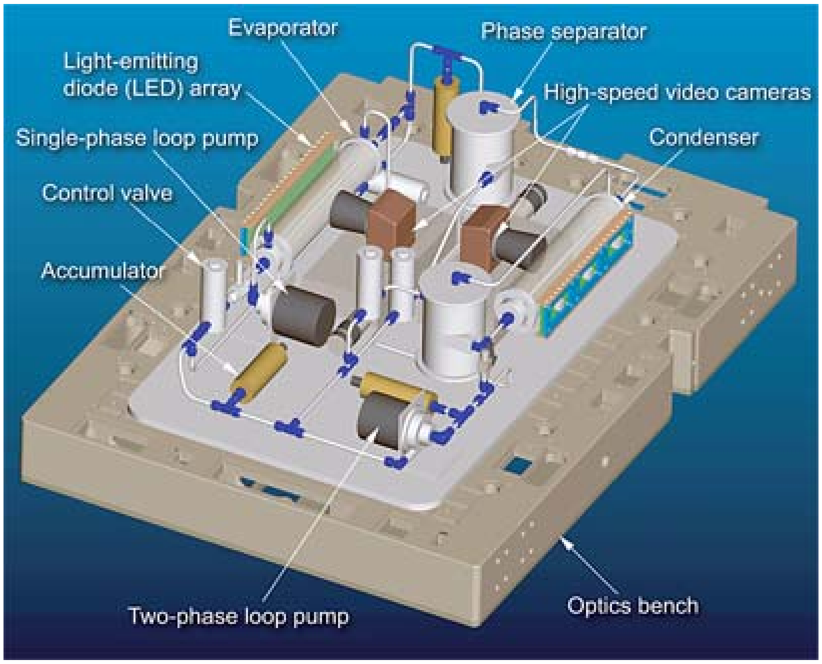
Two-Phase Flow Technology Developed and Demonstrated for the Vision for Exploration

NASA's vision for exploration will once again expand the bounds of human presence in the universe with planned missions to the Moon and Mars. To attain the numerous goals of this vision, NASA will need to develop technologies in several areas, including advanced power-generation and thermal-control systems for spacecraft and life support. The development of these systems will have to be demonstrated prior to implementation to ensure safe and reliable operation in reduced-gravity environments. The Two-Phase Flow Facility (TΦFFy) Project will provide the path to these enabling technologies for critical multiphase fluid products (refs. 1 and 2). The safety and reliability of future systems will be enhanced by addressing focused microgravity fluid physics issues associated with flow boiling, condensation, phase separation, and system stability, all of which are essential to exploration technology. The project--a multiyear effort initiated in 2004--will include concept development, normal-gravity testing (laboratories), reduced-gravity aircraft flight campaigns (NASA's KC-135 and C-9 aircraft), space-flight experimentation (International Space Station), and model development. This project will be implemented by a team from the NASA Glenn Research Center, QSS Group, Inc., ZIN Technologies, Inc., and the Extramural Strategic Research Team composed of experts from academia.

Two-phase systems (i.e., liquid and gas) for thermal-control and power-conversion systems rely on using the latent heat of vaporization of a working fluid to absorb and reject heat from the cycle. Typical components of two-phase thermal-control and power-conversion systems are a boiler-evaporator, phase separator(s), accumulator(s), a condenser, and a pump. Both the boiling and condensing processes can be affected by low-gravity conditions. The effects of gravity can alter such phenomena as bubble formation, liquid bridging, and carryover in the boiler. Conditions in the condenser that can be affected by the gravity level include the maintenance of interface control during the condensation process and the prevention of vapor carryover into the pump.

The TΦFFy project was conceived and initiated in 2004 to address two-phase issues in a reduced-gravity environment. During the first year, a project team was formed, experiment requirements were developed, and some reduced-gravity experiments were performed on NASA's KC-135 aircraft.

A space-flight experiment is being planned for future operations on the International Space Station. This experiment will include the operation of a single-fluid, two-phase closed thermodynamic loop testbed. A conceptual three-dimensional diagram of the TΦFFy experiment mounted in the Fluids Integrated Rack (a Glenn facility that will be launched to the International Space Station) is shown in the illustration. A low-boiling-point surrogate fluid will be selected on the basis of scaling analyses using preliminary designs for operational systems. Time scales on the order of minutes or hours will be required to bring a system such as this to a steady-state condition, and to run a series of experiments.



Three-dimensional conceptual model of the TΦFFy experiment mounted to the optics bench of the Fluids Integrated Rack in the International Space Station. The major components of the experiment are identified.

Long description of figure. Three-dimensional model showing two-phase loop pump, accumulator, control valve, single-phase loop pump, light-emitting diode (LED) array, evaporator, phase separator, high-speed video cameras, condenser, and optics bench.

In addition to the multiphase component space-operation demonstration, key measurements will include the flow regime, pressure drop, velocities, and quality. The data will be used to develop operational prototype components and to validate engineering correlations and new computational models. Three key products will result: (1) passive vortex-type phase separator technology will increase from technology readiness level 4 (TRL 4) to TRL 6, (2) flow boiler tube technology will increase from TRL 3 to 6, (3) high-flow-rate, multiphase thermodynamic cycle stable operation demonstration in reduced gravity will increase from TRL 4 to 6. The project will increase exploration-vision-enabling multiphase technology from TRL 4 to 6, will increase system safety, and will decrease development risks.

References

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2. Lahey, Richard T.; and Dhir, Vijay: Research in Support of the Use of Rankine Cycle Energy Conversion Systems for Space Power and Propulsion. NASA/CR--2004-213142, 2004. http://gltrs.grc.nasa.gov/cgi-bin/GLTRS/browse.pl?2004/CR-2004-213142.html

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http://www.nasa.gov/missions/solarsystem/explore_main.html

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