Benchmark Calibration Tests Completed for Stirling Convertor Heater Head Life Assessment

A major phase of benchmark testing has been completed at the NASA Glenn Research Center (http://www.nasa.gov/glenn/), where a critical component of the Stirling Radioisotope Generator (SRG) is undergoing extensive experimentation to aid the development of an analytical life-prediction methodology (ref. 1). Two special-purpose test rigs subjected SRG heater-head pressure-vessel test articles to accelerated creep conditions, using the standard design temperatures to stay within the wall material's operating creep-response regime, but increasing wall stresses up to 7 times over the design point. This resulted in well-controlled "ballooning" of the heater-head hot end. The test plan was developed to provide critical input to analytical parameters in a reasonable period of time.

The SRG is being developed for multimission use, including the electric power supply for long-duration deep-space missions (ref. 2). For this application, the heater head must endure high temperatures at low stress levels for a long time. These conditions impose an operation-limiting mechanism of material creep--a slow, gradual increase in the pressure-vessel diameter that reduces system performance because of internal dimensional tolerances. Because the SRG must operate for more than 10 years, testing the heater head at the low design-wall stress alone would likely cause high scatter of the very small magnitude creep strains in the short term. This would be of limited value in providing a robust life-prediction tool. Therefore, the test articles' stress levels were raised by increasing test pressures to accelerate the creep results. In addition, although creep-limited components have been designed satisfactorily using material properties generated from traditional uniaxial tests, the heater head is subjected to a highly biaxial state of stress. To supplement the ongoing uniaxial creep tests on flight heat Inconel 718 material (ref. 3), researchers designed the benchmark test program to experimentally evaluate the response to this specific biaxial stress condition.

Three-month test of IN 718 heater head at 650 °C (1200 °F) with induction heater coils and diametral extensometer quartz glass probes.

Long description of figure. Closeup photograph of an approximately 50-millimeter- (2-inch-) diameter cylindrical heater head under test at 650 °C (1200 °F). The specimen is glowing (exaggerated by time-lapse photography) throughout the hot domed end because of resistance to the current induced by a surrounding induction heater coil.

The completed calibration testing included three shorter term, high-stress benchmark tests conducted on geometrically simplified test vessels fabricated from a heat of flight material: the test conditions caused rapidly increasing creep strains in 1 to 3 months (see the photograph). A fourth test was performed on a flight prototype design test article; this extended the test duration to 6 months. Glenn researchers plan to conduct two additional tests of test articles fabricated to flight prototype specifications at design operating pressure for 1 year or more. One of these tests will be with a “full-up” specimen with structurally significant attachments. It will be conducted with additional externally applied axial stress to duplicate actual flight loading.

The test facility is located at Glenn’s Life Prediction Branch’s (http://www.grc.nasa.gov/WWW/LPB/) Structural Benchmark Test Facility. The test stand includes two independently operated test rigs with argon-pressurization systems capable of 3000 psig. Two 3-kW induction power supplies provide even heating and temperature profiling. A custom data acquisition and control system is employed to safely conduct tests and record results.

The benchmark testing was performed for Glenn’s Thermal Energy Conversion Branch (http://www.grc.nasa.gov/WWW/tmsb/) and Power and Propulsion Office (http://space-power.grc.nasa.gov/ppo/) as part of an in-house project supporting the development of the SRG. NASA's Office of Space Science provided funding for this effort. Lockheed Martin and Stirling Technology Company are developing the SRG110 for the Department of Energy, which is managing the overall SRG project.

References

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