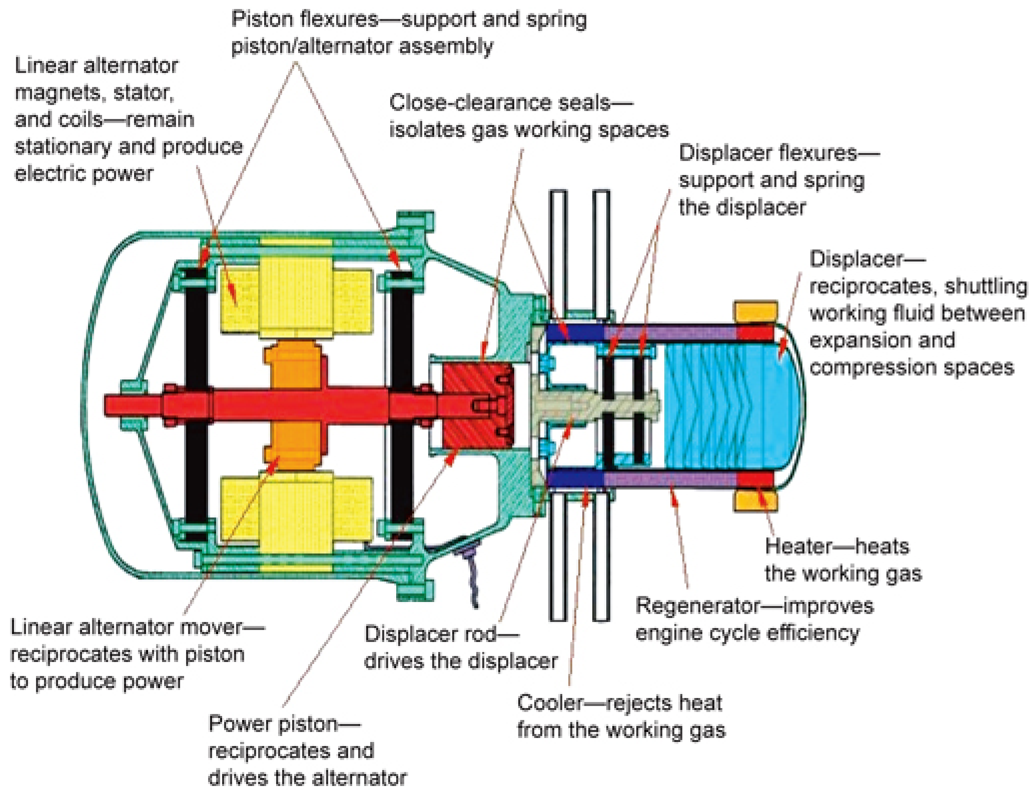
Reliability of the SRG110 Stirling Convertor Quantified



110-W Stirling Radioisotope Generator (SRG110)

Long description of figure. Illustration showing linear alternator magnets, stator, and coils (remain stationary and produce electric power); piston flexures (support and spring piston/alternator assembly); close-clearance seals (isolate gas working spaces), displacer flexures (support and spring the displacer); displacer (reciprocates, shuttling working fluid between expansion and compression spaces); heater (heats the working gas); regenerator (improves engine cycle efficiency); cooler (rejects heat from the working gas); displacer rod (drives the displacer); power piston (reciprocates and drives the alternator); and linear alternator mover (reciprocates with piston to produce power.

The NASA Glenn Research Center has been involved in the development of Stirling power-conversion technology and is currently providing technical support to the Department of Energy and Lockheed Martin, of Valley Forge, Pennsylvania, their system integration contractor, for the 110-W Stirling Radioisotope Generator (SRG110). Stirling radioisotope power-conversion technology is a potential candidate for future deep-space science and exploration missions. The SRG110 has a multifold increase in efficiency and would reduce the inventory of the radioisotope fuel by a factor of 4 in comparison to systems used to power past missions.

The SRG110 is a new radioisotope power system that will have to perform efficiently for up to 14 years; therefore, high reliability is of paramount importance. The SRG110 has five major subsystems: the heat source, the Stirling Convertor Assembly (SCA), the structure, the radiator, and the controller. The SCA is a free-piston device consisting of many components, materials, electronics, and heat exchangers, and it involves multiple disciplines. Critical components governing the performance and reliability of the SCA are the heater head, regenerator, displacer, flexures, fasteners, clearance seals, cooler, linear alternator (magnets, stators, and coils), and heat exchangers.

The design variables of different SCA components inherit uncertainties from the material behavior, the loads, the manufacturing and fabrication processes, component integration and the interfaces of components, and human factors. Conventional design approaches based on factors of safety (which do not quantify the reliability) have resulted in highly conservative, expensive designs. Glenn has pursued a more rational reliability approach: quantifying SCA reliability while meeting key mission objectives, such as flight qualification, certification, and mission success.

These efforts have addressed reliability of the heater head, the flexures, the linear alternator magnets, and the fasteners. Heater head reliability for long-term durability under sustained high-temperature loads and rare thermal excursions has been quantified and verified with the accelerated test data. Analysis has shown that the reliability is most sensitive to uncertainties in the creep behavior of the material. In addition, the reliability of the flexures for a fatigue life of 35 billion cycles during a mission has been evaluated, and the test data are being verified. Initial evaluation showed that the reliability of the flexures is most sensitive to variations in the piston stroke. Evaluation of the linear alternator magnets showed that the reliability of the generated voltage is most sensitive to uncertainties in the gap between the mover and the stator and to the magnetization properties of magnets. Sensitivity evaluation provides guidelines to improve reliability by identifying the variables to control during operation as well as tests to be performed for verification.

Evaluation of the reliability of other SCA components, as well as testing to provide quantification, is in process. We also plan to integrate the results of the SCA component reliability to quantify the reliability of the overall SCA, and to verify them with the test data that are being collected from the extended operation of the Stirling convertors.

Bibliography

Shah, Ashwin R.; and Schreiber, Jeffrey G.: Reliability Issues in Stirling Radioisotope Power Systems. NASA/TM--2004-213428 (AIAA-2004-5506), 2004.
http://gltrs.grc.nasa.gov/cgi-bin/GLTRS/browse.pl?2004/TM-2004-213248.html

Shah, Ashwin R., et al.: Reliability Based Life Assessment of Stirling Convertor Heater Head. Presented at the Space Technology and Applications International Forum (STAIF-2004), AIAA, Albuquerque, NM, 2004.

Find out more about this research at http://www.grc.nasa.gov/WWW/tmsb/

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