



Advanced Stirling Convertor (ASC) Technology Maturation in Preparation for Flight

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Abstract

The Advanced Stirling Converter (ASC) is being developed by an integrated team of Sunpower and National Aeronautics and Space Administration's (NASA's) Glenn Research Center (GRC). The ASC development, funded by NASA's Science Mission Directorate, started as a technology development effort in 2003 and has since evolved through progressive converter builds and successful testing to demonstrate high conversion efficiency, low mass, and capability to meet long-life Radioisotope Power System (RPS) requirements. The technology has been adopted by the Department of Energy and Lockheed Martin Space Systems Company's Advanced Stirling Radioisotope Generator (ASRG), which has been selected for potential flight demonstration on Discovery 12. This paper provides an overview of the status of ASC development including the most recent ASC-E2 converters that have been delivered to GRC and an introduction to the ASC-E3 and ASC flight converters that Sunpower will build next. The paper also describes the technology maturation and support tasks being conducted at GRC to support ASC and ASRG development in the areas of converter and generator extended operation, high-temperature materials, heater head life assessment, organics, nondestructive inspection, spring fatigue testing, and other reliability verification tasks.

Introduction

National Aeronautics and Space Administration (NASA) requires a next-generation Radioisotope Power System (RPS) that minimizes the use of the very limited plutonium fuel for a variety of projected missions that cannot be performed with photovoltaic power systems. The National Research Council's Radioisotope Power Systems (RPS) Committee (2009) recommended that "NASA and DOE should complete the development of the Advanced Stirling Radioisotope Generator (ASRG) with all deliberate speed...put final-design ASRGs on life test as soon as possible (to demonstrate reliability on the ground) and pursue an early opportunity for operating an ASRG in space (e.g., on Discovery 12)." This recommendation resulted in part from the continued advancements of the Advanced Stirling Converter (ASC), two of which are used on each ASRG to efficiently convert the heat from the plutonium source into electrical power. Sunpower, Inc., has been developing the ASC since 2003 under contract to NASA Glenn Research Center (GRC) and with technical support from GRC (Wong, 2006; Shaltens, 2007).

The key technologies in the ASC that enable high efficiency and low mass are the hydrostatic gas bearings, a moving-magnet linear alternator, high-frequency operation, high-temperature hot-end materials and fabrication processes, and high-temperature high-porosity regenerators. Initially, the ASC was a technology development project with a goal of demonstrating high conversion efficiency, which was accomplished with the initial non-hermetic Frequency Test Bed (FTB) and ASC-1 laboratory prototype converters that demonstrated, respectively, 36 percent efficiency (80 We, 650 °C/30 °C) and 38 percent efficiency (88 We, 650 °C/90 °C) (Wood, 2007; Wong, 2008). Sunpower then developed hermetic sealing and processing techniques while building the ASC-0 and ASC-1HS converters that had IN718 (for operation up to 650 °C) and MarM-247 (for operation up to 850 °C) heater heads, respectively (Wilson, 2008). Based on these successful performance demonstrations, NASA Headquarters provided direction to accelerate ASC technology development to transition towards flight implementation. In response, the ASC project was modified to include direct technical support from GRC focused on high-

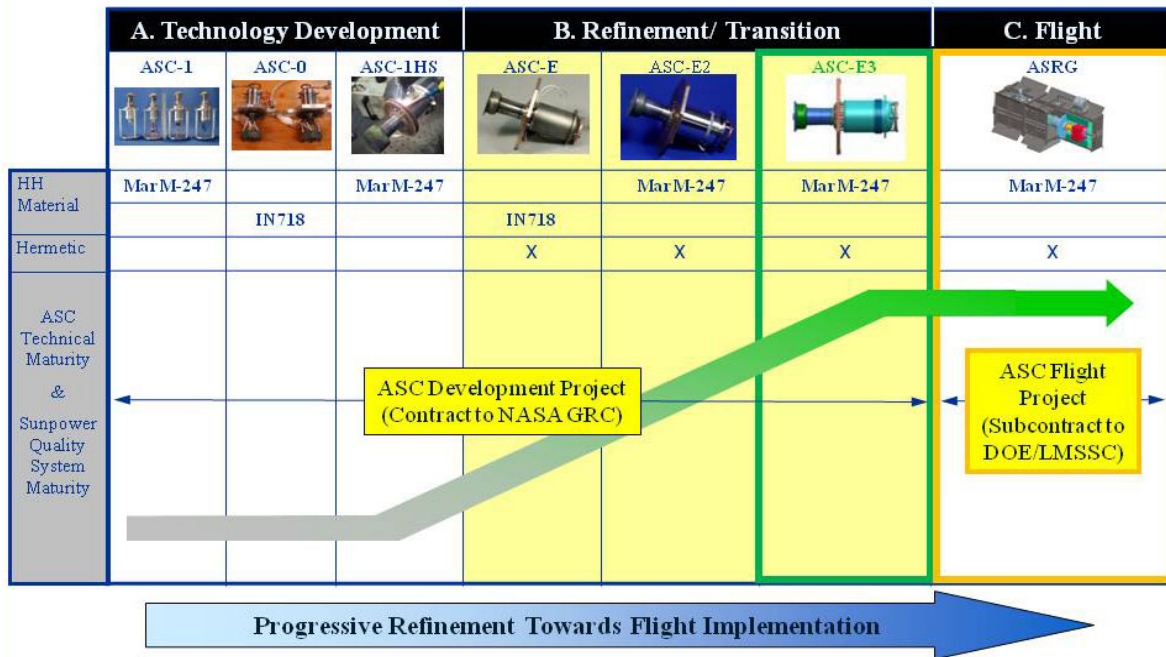


Figure 1.—Sunpower ASC convertor evolution from technology development to flight.

temperature materials, structures, organic materials, magnet aging, launch vibration simulation, electromagnetic interference (EMI) characterization, modeling, and reliability assessment, all aimed at reducing risk and enhancing reliability of the ASC. Additionally, the Department of Energy (DOE) and Lockheed Martin Space Systems Company (LMSSC) adopted the ASC as part of the ASRG. To transition the ASC from technology development to flight, the general plan illustrated in Figure 1 was developed to advance the technology with several progressive convertor designs. Completion of the technology development and transition to flight are part of Sunpower’s development contract with GRC, whereas flight hardware development and production are part of Sunpower’s subcontract to the DOE and Lockheed Martin ASRG contract. Each successive build includes design, processing, and hardware refinements, and in some cases newly defined requirements. To expedite demonstration of the ASRG system, Sunpower and GRC developed the ASC–E and worked collaboratively with Lockheed Martin to develop the product specification requirements for the ASC, including generator interfaces and preliminary flight requirements. In addition to some design changes, the ASC–E build, which uses an IN718 heater head, also required greater quality assurance rigor, documentation, and the incorporation of additional processing and testing including a workmanship-level vibration test of each completed hermetic convertor performed at GRC. In October 2007, two ASC–E convertors plus a spare were delivered on schedule as Government Furnished Equipment to DOE and Lockheed Martin for integration onto the ASRG Engineering Unit.

While the ASC–E convertors represented a major advancement of the technology, the ASC required further development to prepare for flight. It was recognized that, due to evolving requirements, refinement of the design, and a need to continue to mature the quality system at Sunpower, two additional generations of ASC convertors were needed. The ASC–E2 design would be built under a new formal Quality Management System, and would implement several reliability- or flight-requirements-driven design changes. The ASC–E2 convertors were recently completed and delivered by Sunpower to GRC.

After completing the ASC–E2, Sunpower is now developing the ASC–E3 that is intended to conclude the technology transition phase by completing limited design refinements and production development and demonstrating repeatability. The original intent as illustrated in Figure 1 was that Phase A.—Technology Development and Phase B.—Refinement and Transition would have been completed by

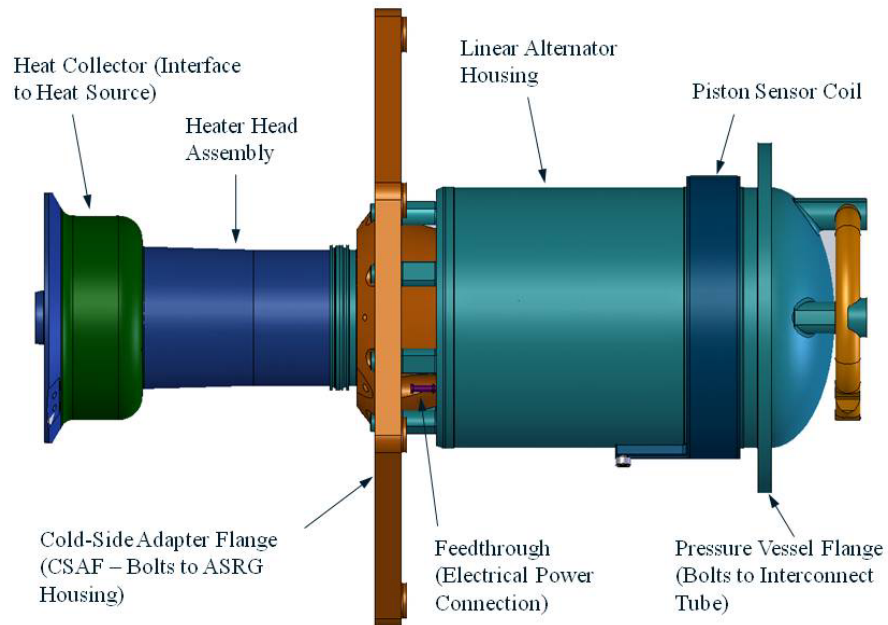


Figure 2.—Sunpower advanced Stirling convertor (ASC–E3/–F) with external interfaces.

Sunpower under contract to GRC prior to handoff to Lockheed Martin for Phase C.—Flight Production. In reality, the technology maturation plan has been compressed and Sunpower has recently started developing the ASC–E3 convertors for GRC and is, in parallel, developing the ASC–F flight convertors for Lockheed Martin. The intention is that the ASC–E3 and ASC–F convertors would be identical and will be built to the same design documentation. An illustration of the latest ASC–E3/–F is shown in Figure 2, with callouts for the primary exterior parts including the interfaces with the ASRG generator such as the heat collector that interfaces with the General Purpose Heat Source (GPHS), the Cold-Side Adapter Flange (CSAF) that bolts to the radiator generator housing, the power feedthrough, the piston sensor, and a flange on the pressure vessel that allows the structural mounting of a pair of ASC convertors back-to-back onto a common interconnect tube.

To date, Sunpower has delivered under the GRC development contract 22 ASC convertors with multiple units of each of the following designs: ASC–1, ASC–0, ASC–1HS, ASC–E, and ASC–E2. Of these convertors, many of which are on extended 24-hr/7-day week operation at GRC, a total of over 140,000 hr of operation have been accumulated as of December 2010, including the leading pair of ASC–0 convertors that each have over 22,000 hr, and another pair of ASC–0s that accumulated 15,000 hr in a thermal vacuum environment. Also, a pair of ASC–E convertors is currently operating in the ASRG Engineering Unit and has accumulated over 13,000 hr at GRC.

Nomenclature

| | |
|------|--|
| ASC | Advanced Stirling Convertor |
| ASRG | Advanced Stirling Radioisotope Generator |
| BOM | Beginning of Mission |
| CCB | Configuration Control Board |
| CSAF | Cold-Side Adapter Flange |
| CT | Computed Tomography |
| DOE | Department of Energy |
| EMI | Electromagnetic Interference |

| | |
|-------|---|
| EOM | End of Mission |
| ERB | Engineering Review Board |
| FEA | Finite Element Analysis |
| FTB | Frequency Test Bed |
| GPHS | General Purpose Heat Source |
| GRC | Glenn Research Center |
| ILS | Internal Limit Sensor |
| LMSSC | Lockheed Martin Space Systems Company |
| NASA | National Aeronautics and Space Administration |
| NRA | NASA Research Announcement |
| RPS | Radioisotope Power System |

ASC-E2 Convertor

The ASC-E2 is based on the ASC-E with several design changes that were determined by trade studies conducted by the GRC, Sunpower, and Lockheed Martin team. The changes included a new heater head design that uses MarM-247 rather than the IN718 used on ASC-E to increase reliability margin and offer higher temperature operation and improve performance. Another development task under the ASC-E2 build was the development of an electron beam (E-Beam) weld to bond the convertor to the CSAF for heat rejection and structural mounting to the generator. Additionally, to improve reliability of the convertor, a new Internal Limit Sensor (ILS) for piston stroke monitoring was selected for implementation to eliminate two feedthroughs in the pressure vessel and improve robustness of the piston assembly. Beyond these design changes, an emphasis of the ASC-E2 build was to increase the design rigor and to develop a new quality management system to prepare Sunpower as an eventual hardware supplier for flight nuclear systems. The ASC-E2 build was kicked off in November 2007, shortly after delivery of the ASC-E convertors. The Preliminary Design Review was held in January 2008, and the Critical Design Review was held July 2008. Some of the accomplishments of the ASC-E2 project are highlighted below.

Heater Head Assembly Development

One of the accomplishments of the ASC-E2 build was the development of a new heater head assembly that uses MarM-247 with the capability of operating up to 850 °C. The design of the heater head assembly takes into account thermal and structural interfaces with the GPHS and generator, launch load requirements, and life and reliability requirements. For the ASC-E2, a new team of vendors led by Refrac Systems was selected to produce the new heater head assembly and displacer assembly. The heater head assembly's functions include efficient transfer of heat from the GPHS into the convertor helium working gas, hermetic containment of the pressurized helium, structural support of the convertor under flight load conditions, and resistance to creep deformation while at high temperatures while maintaining high reliability over the 17-year life. Development of the heater head assembly, shown in Figure 3, was completed through a collaborative process with Lockheed Martin defining flight requirements, Sunpower leading the design, GRC leading the materials evaluation and reliability and life assessment, and Refrac providing manufacturing and processing expertise. After completion of trade studies, and several design iterations, the design of the ASC-E2 heater head assembly was completed using a composite of high-strength MarM-247 and high-thermal-conductivity nickel. Demonstration of the many processes needed to complete this long lead component was completed with a variety of hardware trials, culminating in a representative ASC-E2 trial heater head. Additional accomplishments related to the heater head are described below in section "GRC Technical Support."



Figure 3.—ASC-E2 production heater head assemblies.

Electron Beam Weld Development for CSAF Bond

For the ASC-E2, an E-Beam weld was developed to bond the CSAF to the convertor, specifically to the external rejector on the transition assembly. E-Beam weld was selected as a result of a trade study that evaluated the advantages of a metallurgical bond in comparison to the shrink fit used on the earlier ASC-E design. The E-Beam weld is unique from other welding processes due to its high aspect ratio of weld depth to weld width, as well as its relatively low energy resulting in minimal thermal distortion and minimal heating of the components. The functional requirements of this CSAF weld are to transfer reject heat from the convertor through the rejection assembly to the ASRG housing radiator and to help support the structural loads transmitted between the convertor and the ASRG. The E-Beam weld development effort for the ASC-E2 was completed through optimization of the weld conditions and penetration depth, minimization of weld distortion, and weld structural requirements verification. Four sets of weld trial articles varying in geometry from simple trial parts to fully representative ASC-E2 production parts were used to complete the E-Beam weld development. Successful welds were verified at penetration depths greater than the required E-Beam weld depth. Post-weld inspection and assessment of the welds determined that weld distortion results were acceptable and that they did not negatively affect fit or functionality. The structural requirements were verified to have been met through analysis by GRC. Driven by budget and schedule considerations for the ASC-E2, a simpler single-material CSAF was used. The E-Beam weld details have been provided to Lockheed Martin who is currently qualifying the E-Beam weld for the flight CSAF design that includes material to enhance thermal conductivity.

Materials “Master Buy”

Considerable effort is going into evaluating the reliability and performance of the ASC at the convertor level, component level, and basic material property level. To ensure consistency of materials, to minimize batch-to-batch variation, to ensure relevance of the data being gathered to the flight convertors, and to ensure continued availability of materials for the ASC-E2 and future builds, a “master buy” of critical materials was purchased and placed under bonded storage at Sunpower. These materials, some of which have a long delivery time and do not have a shelf life, are planned to be used for convertors to be built in the foreseeable future including the ASC-E3 and ASC-F. Materials include MarM-247, Udimet 720, magnets, regenerator material, fasteners, and feedthroughs.

ASC–E2 Configuration Management, Processing, and Testing

Configuration management of the ASC–E2 was the responsibility of the ASC–E2 Engineering Review Board (ERB) that was led by GRC and included membership from Sunpower and Lockheed Martin. All design documentation, process documents, and any nonconformances were reviewed and approved by the ERB. ASC–E2 assembly techniques and processes were based on heritage ASC–E and other Sunpower convertor and cryocooler builds. Convertor processing was performed at Sunpower in a clean assembly area utilizing flow benches, dedicated tools, and climate control. The standard subassembly and assembly vacuum bakeout processes were performed to remove the bulk of any potential outgassing contaminants from organics as well as any residual contaminants from atmospheric exposure. Purge and fill processing with ultra-pure helium further ensured that the working gas and internal surfaces of the convertor had minimal contamination. Convertor checkout tests were performed immediately before and after each critical process to confirm the process did not adversely affect performance (Wilson, 2008). Additional tests were performed throughout the build cycle to ensure integrity of the convertors and to verify performance requirements. Convertor Characterization Testing was performed early in the assembly and production phase to assess general characterization of the convertor operating behavior. Workmanship vibration testing, completed at NASA GRC, was performed after each hermetically sealed convertor was completed to confirm build quality and structural integrity. Verification of convertor performance prior to delivery was achieved with the Convertor Final Performance Test, which operated at Beginning-of-Mission (BOM) and End-of-Mission (EOM) conditions defined in the ASC–E2 Product Specification.

GRC Technical Support

In addition to managing the Sunpower ASC development contract, GRC has also made significant technical contributions to the ASC. For the ASC–E2 build, GRC directly supported Sunpower by providing the sintered oxidation-resistant regenerators, supporting design and analysis of the heater head and structural analysis of the convertor, conducting MarM-247 casting preparations, conducting workmanship vibration testing of each completed convertor, and maintaining configuration control of the design through the ERB. Further, GRC conducts analyses and tests to reduce risk and address the reliability of the ASC for use on applications that require a 17-year operating life. GRC has assembled a laboratory including autonomous test stands for conducting 24-hr/7-day week extended operation testing of multiple Sunpower ASC convertors, an essential part of establishing long life and reliability. Additionally, GRC continues testing and analyses that are specific to the Sunpower ASC design including investigation of high-temperature materials, structural life assessment, organic materials, modeling, system dynamic modeling, magnet evaluation, electromagnetic interference (EMI) characterization, launch vibration testing, and reliability assessment.

ASC Reliability Assessment

During the initial development phase of the ASC, Sunpower maintained a task to address ASC reliability with GRC providing technical support based in past experience. As the project has shifted towards system integration and flight, LMSSC has taken on the leadership for overall reliability of the ASRG generator including the ASC. GRC and Sunpower continue to play key roles in the efforts coordinated through the ASRG Reliability Working Group, whose intent is to mitigate risk and maximize reliability in meeting the 17-year-life requirement for the ASRG (Schreiber, 2009). Support in the ASC and ASRG life and reliability effort is ongoing through a variety of support tasks at GRC.

Heater Head Life Assessment

NASA GRC is responsible for the reliability and creep life assessment of the ASC heater head. The combined analytical and experimental assessment undertaken by GRC ensures high reliability of the heater head for its 17-year design life. This effort includes a series of uniaxial creep tests on MarM-247 samples that comprise the same chemistry, microstructure, and heat treatment processing as the heater head itself (Krause, 2008). Finite Element Analysis (FEA) to predict mean value creep strain was then performed, followed by a probabilistic analysis. The final phase of the heater head life assessment effort is to validate the preceding methodology with accelerated benchmark creep testing. Over 9400 hr of accelerated testing has been completed to date on an ASC-E2 bare shell heater head test article measuring creep at high pressure and temperature to generate substantial creep strains in short time durations. This ongoing testing directly supports the use of the MarM-247 at high temperatures for improved convertor efficiency. Accelerated testing and analysis will continue until tertiary creep is evident by higher creep rates. Testing is about to commence on an ASC-E2 “full-up” heater head assembly with heat collector while an ASC-E3 full-up heater head prototypical test will initiate in fall 2011.

Organics

A variety of organic materials are used in the ASC convertors as adhesives, potting compounds, electrical insulation, and structural bonding. The ASC-E2 has 11 types of organics with most residing in the area of the linear alternator (Schreiber, 2009). Recent advancements made in support of ASC and ASRG development involve the thermal stability assessment of organic materials, the evaluation of thread lockers and fasteners, and radiation testing to include component gamma irradiation, gamma in situ outgassing, reactor neutron irradiation, and the combined effects of radiation and thermal exposure. Radiation testing was conducted at either the coupon/component level or the subsystem hardware level, and is critical to the ASC to verify that the organic materials are not susceptible to radiation-induced degradation from the GPHS or the surrounding space environment during flight. Additional support tasks include epoxy tests to assess thermal aging behavior and magnet bond strength and continued evaluation of adhesives and thread lockers.

Heater Head Non-Destructive Inspection/Evaluation (NDI/NDE)

GRC is developing a very high resolution non-destructive inspection (NDI) method capable of detecting and characterizing surface and volumetric flaws within the heater head. After assessing several NDI methods, it was determined that Microfocus X-Ray Computed Tomography (CT) would be the most applicable for inspection and evaluation of the ASC heater head primarily due to the resolution and sensitivity capabilities of the CT system that is suited for inspection of the heater head, especially in the thin wall section. This technique employs tomography created by computer processing. Digital geometry processing is used to generate a three-dimensional image of an object from a large series of two-dimensional x-ray images taken around a single axis of rotation (Herman, 2009). While still in development, the CT trials using a representative MarM target with manufactured flaws indicates the inspection resolution needed to screen out critical flaw sizes is achievable. GRC is currently optimizing the procedure of post processing the CT data, and this method is expected to be used on the forthcoming ASC-E3 heater heads and potentially the flight heater heads as well.

Heater Head Lateral Load Test

Achieving flight status for the ASC-E2 mandates that the convertors satisfy design as well as flight requirements to ensure reliable operation during launch. To meet some of these requirements, GRC performed a series of mechanical tests simulating the operational pressure, axial mounting force, thermal conditions, and axial and lateral launch vehicle acceleration loadings that will be experienced by an ASC-E2 heater head assembly during an ASRG launch. These mechanical tests were conducted in



Figure 4.—ASC–E2 heater head installed in the lateral load test setup.

accordance with the Lockheed Martin specifications, and are collectively referred to as “lateral load tests” since a primary external load lateral to the heater head longitudinal axis was applied in combination with the other loading conditions. An ASC–E2 heater head shown in Figure 4 was used in the test to qualify the heater head analysis and to provide validated test results to meet launch requirements.

To enable reliable prediction of the heater head’s structural performance, GRC completed Finite Element Analysis (FEA) computer modeling for the stress, strain, and deformation that will result during launch. The predicted force and deflection data was used during the actual test to corroborate the experimental results. After demonstrating that the heater head did not yield under flightlike loads, the test continued with increased lateral loading until the heater head yielded, establishing a lateral load capacity 2.9 times greater than expected during launch. This test result validated the capability of the heater head to meet the launch load requirements with sufficient margin. The ASC–E2 heater head lateral load test is discussed in greater detail by Cornell (2010).

Displacer Spring Fatigue Testing

In order to evaluate the ASC–E2 displacer spring, GRC is performing analysis based on displacer spring fatigue testing as well as gigacycle testing of the spring materials. The fatigue analysis will quantify the fatigue strength and associated uncertainties, and enhance reliability assessment of the displacer spring for the long life required of the design. To date, the displacer spring fatigue testing at Sunpower at accelerated high stress levels has resulted in springs with over 2 billion cycles with no spring failures. This component-level testing of the planar spring will help validate design life by the extrapolation of high stress, low cycle count test results to the low stress, high cycle count design conditions. However, the planar spring life assessment requires further testing in the gigacycle fatigue range to verify and properly evaluate the processed material’s durability for the long-term life requirement of tens of billions of low stress cycles without degradation. This testing will be performed on samples with equivalent production spring processing at prototypical and near-prototypical stress levels, and at high frequencies for accelerated test results that simulate the required 17-year operating life.

ASC–E2 Completion and GRC Test Plan

The first ASC–E2 convertor delivered to GRC was the ASC–E2 #2, which was completed by Sunpower and delivered in February 2010. The second convertor, the ASC–E2 #1, was delivered in April 2010, and was paired with ASC–E2 #2 to complete EMI testing in August 2010. These two convertors have currently accumulated nearly 4500 total hr in GRC’s Stirling Research Lab as of December 2010, and will continue extended operation testing to contribute to the reliability database of ASCs.

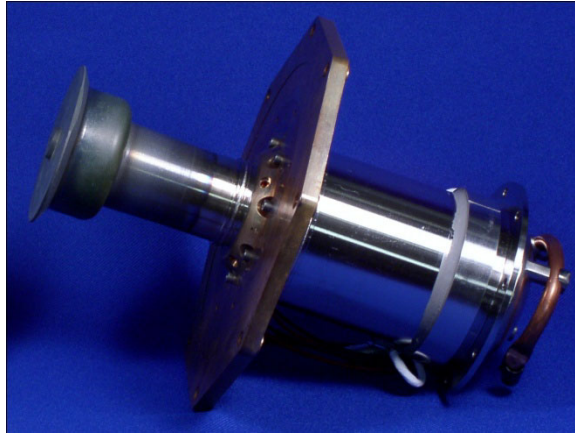


Figure 5.—Hermetically sealed ASC-E2 #6 convertor.

The second pair of convertors, ASC-E2 #3 and #4, which were delivered in April 2010, is the first pair to incorporate an E-Beam weld to bond the CSAF to the transition assembly to improve reliability of the joint. The E-Beam weld processing details were transferred to Lockheed Martin for verification using the flight-design CSAF. Performance Testing of ASC-E2 #3 and #4 at Sunpower indicated the convertors met the ASC Product Specification in terms of output power at the reference temperatures. GRC performed acceptance testing on this pair and then the convertors were provided to Lockheed Martin for ASRG controller developmental testing.

ASC-E2 #5 and #6, which were fully compliant under the new Sunpower Quality Project Plan, were delivered to GRC on July 2010 for installation into GRC's Stirling Research Lab. These convertors have recently initiated extended operation testing and have accumulated hundreds of hours to date. A photo of the completed hermetically sealed ASC-E2 #6 is shown in Figure 5 prior to delivery from Sunpower.

The fourth pair of convertors, ASC-E2 #7 and #8, were completed and delivered to GRC on August 2010. These convertors will be used for durability testing, during which some of the components will be stressed beyond nominal conditions. The purpose of the durability tests is to experimentally demonstrate the existing margins within the ASC-E2 design. The tests will consist of: 1) repeated starting and stopping of the convertor to accentuate any issues associated with contact before the gas bearings that support the piston and displacer become fully established, 2) random vibration with above nominal piston amplitude to create a number of controlled contact events to simulate potential contact during launch, 3) a controller switchover or other event that would temporarily disable control allowing a limited number of contact events, and 4) exposing the convertor to a large static g-load to simulate either reentry and landing on a planetary surface or a boost thruster during a mission to determine how the convertor would respond. Unlike the preceding ASC-E2s that use a hermetically sealed pressure vessel, a removable test pressure vessel was installed on ASC-E2 #7 and #8 to allow for inspection of the convertors after each test (Orti, 2011). These tests are not intended to cause damage that would shorten the life of the convertors, as they will transition into extended operation at the conclusion of durability testing.

Path Forward: ASC-E3 and ASC-F Flight UNITS

The ASC-E3 build will take place in parallel with the ASC-F (flight) build with the initial two pairs of ASC-E3 units leading the flight units by months. This provides a unique opportunity to use the ASC-E3 as pathfinders for the design and process changes that are required for flight. To maximize similarity between the two builds, the ASC-E3 will be built using the flight documentation. A Joint Configuration Control Board (CCB) with membership from GRC, DOE, Lockheed Martin, and Sunpower has been formulated and has the responsibility to review and approve Sunpower ASC design documentation to maintain configuration control for the ASC-F build managed by DOE and Lockheed Martin and the GRC-managed ASC-E3 build. The ASC-E3 project was initiated in October 2010 and

successfully passed a Long Lead Production Readiness Review for manufacture of the heater head, displacer, and transition assemblies. The ASC–E3 will focus on manufacturing, quality, and process control refinements along with design modifications to address new system integration and anticipated mission requirements. The goal of the project is to establish the viability of the technology for flight and complete the transition of the ASC from a technology development effort to a flight hardware build to support the ASRG.

Conclusion

The current Advanced Stirling Convertor (ASC)–E3 build is the culmination of the Sunpower and National Aeronautics and Space Administration (NASA) Glenn Research Center ASC technology development effort. The early convertors (Frequency Test Bed (FTB), ASC–1, ASC–0, and ASC–1HS) were developmental units, each of which progressively advanced the technology through design refinements, improved processing methods, and demonstrated feasibility, temperature capability, and break-through performance. Meanwhile, the ASC–E, recently completed ASC–E2 convertors, and the next-generation ASC–E3 convertors are part of transitioning the technology out of the development phase and into the flight application stage. While some limited production development is still needed and some technical challenges await, the current outlook is excellent for the ASC to exactly fulfill the objectives of the ASC project, which is to provide NASA with a power conversion technology that enables a reliable high-efficiency, high-specific-power Radioisotope Power System. Integrated into the Advanced Stirling Radioisotope Generator (ASRG), the ASC could enable NASA missions as early as 2016 while minimizing the fuel requirements and maximizing the specific power.

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| 14. ABSTRACT The Advanced Stirling Convertor (ASC) is being developed by an integrated team of Sunpower and National Aeronautics and Space Administration's (NASA's) Glenn Research Center (GRC). The ASC development, funded by NASA's Science Mission Directorate, started as a technology development effort in 2003 and has since evolved through progressive convertor builds and successful testing to demonstrate high conversion efficiency, low mass, and capability to meet long-life Radioisotope Power System (RPS) requirements. The technology has been adopted by the Department of Energy and Lockheed Martin Space Systems Company's Advanced Stirling Radioisotope Generator (ASRG), which has been selected for potential flight demonstration on Discovery 12. This paper provides an overview of the status of ASC development including the most recent ASC-E2 convertors that have been delivered to GRC and an introduction to the ASC-E3 and ASC flight convertors that Sunpower will build next. The paper also describes the technology maturation and support tasks being conducted at GRC to support ASC and ASRG development in the areas of convertor and generator extended operation, high-temperature materials, heater head life assessment, organics, nondestructive inspection, spring fatigue testing, and other reliability verification tasks. | | | | | |
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