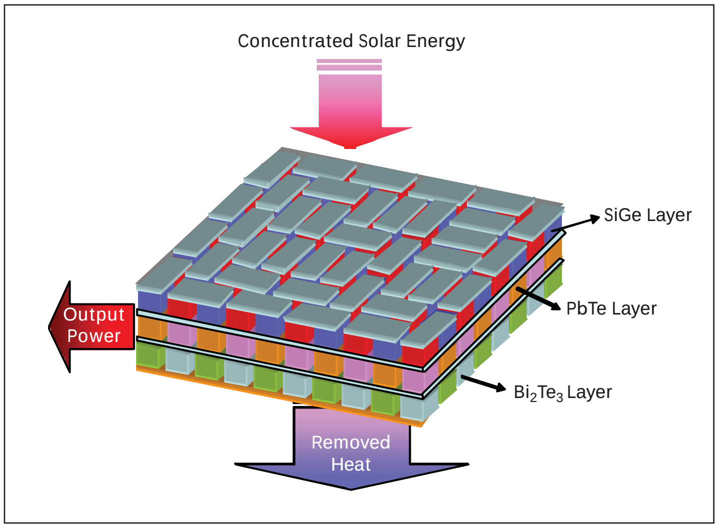
Green Design

Thermoelectric Energy Conversion Technology for High-Altitude Airships

Applications include surveillance for homeland security, and Earth observation for weather monitoring.

Langley Research Center, Hampton, Virginia

The High Altitude Airship (HAA) has various application potential and mission scenarios that require onboard energy harvesting and power distribution systems. The power technology for HAA maneuverability and mission-oriented applications must come from its surroundings, e.g. solar power. The energy harvesting system considered for HAA is based on the advanced thermoelectric (ATE) materials being developed at NASA Langley Research Center. The materials selected for ATE are silicon germanium (SiGe) and bismuth telluride (Bi_2Te_3), in multiple layers. The layered structure of the advanced TE materials is specifically engineered to provide maximum efficiency for the corresponding range of operational temperatures. For three layers of the advanced TE materials that operate at high, medium, and low temperatures, correspondingly in a tandem mode, the cascaded efficiency is estimated to be greater than 60 percent.



The **ATE Energy Conversion Device** consists of triple layers of p-n-junction arrays in a tandem mode. The first layer is built from the array of SiGe, while the second and third layers are built from PbTe and Bi_2Te_3, respectively, as regenerative cycles. Such an arrangement allows effective energy harvesting from a heat source.

The first layer is built from the array of SiGe, while the second and third layers are respectively built from PbTe and Bi_2Te_3 as regenerative cycles. Such an arrangement allows effective energy harvesting from a heat source. First, solar flux is concentrated and heats up the first layer, which is built with high-temperature SiGe. The unused thermal energy from the first layer is subsequently used by the second layer, which is built with mid-temperature PbTe. The third layer of Bi_2Te_3 uses the unused energy from the second layer to maximize the conversion of the energy that is otherwise dumped away. In this fashion, the ATE devices become more effective than solar cells because the performance of solar cells is monolithically tied to band-gap energy structure, so that they only couple with certain spectral lines.

For nighttime, the power required must be augmented from the onboard fuel cells, battery, and a rectenna array that is attached at the bottom surface of HAA. These systems combined provide at least a megawatt level of power for the intermittent operation.

Commercial applications include monitoring and controlling the ever-increasing complexities of aerial and maritime transportation and telecommunication networks. Military applications include close and persistent surveillance of adversarial elements, possibly controlling enemy infiltrations through open air and sea and shooting down enemy missiles during their boosting phase.

This work was done by Sang H. Choi, James R. Elliott, Glen C. King, Yeonjoon Park, Jae-Woo Kim, and Sang-Hyon Chu of Langley Research Center. Further information is contained in a TSP (see page 1). ***LAR-17213-1***

Combustor Computations for CO_2-Neutral Aviation

This method can be used to determine synthetic and biological fuels and blends.

John H. Glenn Research Center, Cleveland, Ohio

Knowing the pure component C_p^0 or mixture C_p^0 as computed by a flexible code such as NIST-STRAPP or McBride-Gordon, one can, within reasonable accuracy, determine the thermophysical properties necessary to predict the combustion characteristics when there are no tabulated or computed data for those fluid mixtures 3or limited results for lower temperatures. (Note: C_p^0 is molar heat capacity at constant pressure.) The method can be used in the determination of synthetic and biological fuels and blends using the NIST code to compute the C_p^0 of the mixture.

In this work, the values of the heat capacity were set at "zero" pressure, which provided the basis for integration to determine the required combustor properties from the injector to the combustor exit plane. The McBride-Gordon code was used to determine the heat capacity at zero pressure over a wide range of temperatures (room to 6,000 K). The selected fluids were Jet-A, 224TMP (octane), and C12. It was found that each heat capacity loci were form-similar. It was then determined that the results [near 400 to 3,000 K] could be represented to within acceptable engineering accuracy with the simplified equation $C_p^0 = A / T + B$, where A and B are fluid-dependent constants and T is temperature (K).

With this information, a model for JP8 was established using NIST Code STRAPP with a 12-component mixture. Selected pure components such as C12 and 224TMP have representations in both the McBride-Gordon and NIST codes, and were calculated and compared. A 12-component mixture was defined for JP8 and C_p^0 computed using the NIST code to 1,000 K. The simplified representation of the C_p^0 for JP8 was form-similar to Jet-A, C12, and 224TMP over the range of 400 to 3,000 K. This defined the ability to predict the C_p^0 for a variety of hydrocarbon mixtures using the NIST code to 1,000 K, and representing these data by the simplified C_p^0, which can then be extrapolated to 3,000 K within reasonable engineering accuracy. Knowing $C_p^0(T)$ results for enthalpy, entropy, and free energy can be determined and input into the combustion code.

The simplified form of the gas phase caloric equations generated using the NIST STRAPP code, the NASA McBride code, and a systematic curve-fitting methodology, work well within an established computational fluid dynamics (CFD) flow solver. Computed flow structure for the four fuels, using a trapped vortex combustor experimental rig as a test case, show strong similarities. This is true for the temperature as well as the CO and CO_2 mass fraction contours. Inspection of the mass-averaged combustor exit quantities, however, indicates that temperature differences may be sufficient to require reconsideration of turbine fueling schemes.

This work was done by Robert C. Hendricks of Glenn Research Center; Andreja Brankovic and Robert C. Ryder of Flow Parametrics; and Marcia Huber of the National Institute of Standards and Technology. Further information is contained in a TSP (see page 1).

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Innovative Partnerships Office, Attn: Steve Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-18453-1.