Thermoelectrics
Chairman's Overview

The High Efficiency Thermoelectrics (HETE) workshop held in San Diego, California, during February 17-20, 2004, whose proceedings are documented on this CD, was a follow-on event to another such workshop held during March 2002. Comparing the presentations from these two workshops, it is evident that numerous advances continue to be made in this important field, the most recent being the development of 2-D Quantum Well Thermoelectric with a ZT value approaching 4! It should be noted, however, that there is considerable controversy on how to measure properties of nano thickness materials.As larger devices evolve, it would be perhaps better understood by engineers if these were gauged as a percentage of the Carnot efficiency achieved across a temperature difference.

I have been following thermoelectrics (TE) since using this technology for thermal control on a spacecraft in the 1960's. Over the years, I have seen a number of major players first initiate and then drop TE projects. For example, in the U.S., such companies included Westinghouse, Texas Instruments, Gulf Atomics, Borg-Warner, Melcor, the 3-M Company, and Teledyne. In Japan, Yamaha, Sumitomo, Aisin (Honda), Technisco, and others were involved in TE. In Germany, it was BASF. A number of Russian companies were also active. However, eventually, they all seemed to conclude that large-scale commercialization had to await a significant improvement in the figure of merit ("ZT") from the then prevailing value of about one. Bulk semiconductors appeared to have been limited to that value since approximately 1950. However, a few companies (such as Hi-Z Technologies, Marlow Industries, Teledyne and Amerigon) did develop commercially viable thermoelectric devices, limited to niche markets.

DOE contracted with Hi-Z to develop a 1 kW thermoelectric generator for class 7 & 8 trucks and a 325 watt unit for light trucks to augment the conventional alternator and eventually to grow a unit to replace it. The development of TE vehicle seat heater/cooler systems by Amerigon proves that TE can successfully compete in the automotive market.

An engineer looking at a thermal map of a diesel engine sees great opportunities for high efficiency TE to recover a significant amount of the almost 60 per cent of the energy in the fuel that ends up as waste heat. The most obvious opportunity would be to use the available energy in the exhaust gas. There are also sufficient temperature differences (delta-T's) available at the radiator, exhaust gas recirculation (EGR) loop, turbocharger compressor discharge, and lube oil cooler for high efficiency TE devices to convert heat directly to electricity. These would complement the belt-less or more electric engines currently under development. Alternatively, the electric power generated could be absorbed by a integrated starter/motor/generator to assist the engine develop torque.

Peltier devices for heating or cooling (depending on the polarity of the DC power) could find use with particulate (PM) traps, when operation has not heated the trap adequately for regeneration, or oxidation, of the trapped soot. TE heating could supply the necessary heat for this purpose. Peltier heating or cooling could maintain the catalysts for NOx reduction at a temperature sufficient to provide optimum conversion efficiency.

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Heating the catalyst to the light off point with gasoline engines before engine starting could eliminate or dramatically reduce emissions from the cold start. This could be achieved by fast heating thermoelectric devices, which could be triggered by opening the driver-side door. These applications could improve engine efficiency with an attendant reduction in petroleum use and/or reduced engine emissions.

Battery life could be extended if its temperature were maintained within a narrow band. Radar devices to detect objects in the vehicle's path require Peltier cooling to stay within a limited temperature band. In warmer parts of the country, inexpensive TE devices could cool the dash, steering wheel, etc. Drink holders could be cooled/heated with Peltier devices. In addition, numerous power stations, industrial processing, or manufacturing plants have low-grade heat available, which currently gets released to the atmosphere. High ZT values can raise the refrigeration coefficient of performance (COP) to a level where household refrigerators and heating, ventilation, and air conditioning (HVAC) could use systems based on the Peltier effect. These would be equally or more efficient, but cheaper than, conventional systems and would eliminate the refrigerant R-134A leakage, which has 1800 times the greenhouse gas effect as CO2. Naval applications could include using TE for submarine HVAC, which would reduce noise and lead to a stealthier submarine. Thermoelectric HVAC units in compartments could eliminate ducting and piping which compromises watertight integrity. During nuclear, biological, or chemical attack conditions wherein the ships are buttoned up to prevent introduction of airborne radiation particles, HVAC TE could provide a reasonable comfort level for the sailors on station. Thermoelectric units could provide cooling under the body armor of soldiers and marines in the extreme heat encountered in the Middle East

DOE is enthusiastic about the initiation of a new, program to accelerate the development of high efficiency TE. We recently issued a Request for Proposals (RFP) to move the high efficiency TE from the lab to commercial applications in surface transportation applications. Teaming arrangements with industry, academia and national labs have been encouraged. This effort is built upon the excellent work sponsored by the Defense Advanced Research Projects Agency (DARPA) and the Office of Naval Research (ONR), particularly their Multiple University Research Initiative (MURI) program for HETE.

The recent exciting breakthroughs in the TE conversion efficiencies should be rapidly exploited to take advantage of the tremendous potential for reducing petroleum consumption, emissions, and greenhouse gases from heat engines used in transportation and stationary applications. The proceedings reported on this CD detail the incremental, but very important, research efforts currently ongoing to achieve that end.

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