Chairman's Overview

I have been following thermoelectrics since using this technology for thermal control on a spacecraft in the 1960's. In the past, a number of major companies have initiated thermoelectric programs and then dropped them. These include Westinghouse, Texas Instruments, Gulf Atomics, Borg-Warner, Melcor, the 3-M Company, and Teledyne in the US. In Japan, Yamaha, Sumitomo, Aisin (Honda), Technisco, and others have been involved in thermoelectrics. In Germany, BASF has been involved in this field. A number of Russian companies have also been active. They all seemed to come to the conclusion that large-scale use of thermoelectrics required a significant improvement in the figure of merit (ZT) from the current value of about one that bulk semiconductors seem to have been limited to since approximately 1950. These low ZT thermoelectric materials were limited to niche markets for which companies like Hi-Z Technologies, Marlow Industries and Amerigon have developed commercially viable devices.

Managing the Department of Energy's (DOE) Low Emission 55 percent efficient (LE-55) diesel engine development programs with Caterpillar, Cummins and Detroit Diesel rapidly identified for me that a path to obtain major engine efficiency improvement was to convert the available energy in the exhaust gas to useful work. Only about a third of the energy in the fuel ends up as output shaft work while another third is lost in the exhaust gas. DOE contracted with Hi-Z to develop a 1 kW thermoelectric generator which would augment the conventional alternator and eventually grow to a power level sufficient to replace it. This project provides experience in developing thermoelectrics for a vehicular application. The development of thermoelectric vehicle seat heater/cooler systems by Amerigon shows that thermoelectrics can successfully compete in the automotive market.

A thermodynamicist looking at a thermal map of a diesel engine sees many opportunities for high efficiency thermoelectrics. The most obvious opportunity is to utilize 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 Seebeck effect devices to provide additional electric power. These would nicely complement the beltless or more electric engines currently under development. In fact, the beltless engine concept is currently the highest priority program in the European Union (EU). 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. Thermoelectric heating could supply the necessary heat for this purpose. Peltier heating or cooling could maintain the catalysts for NO_x reduction at a temperature sufficient to provide optimum conversion efficiency. Heating the catalyst to the light off point with gasoline engines before engine starting could eliminate emissions from the cold start. This could be achieved by fast heating thermoelectrics 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 would be extended if the battery temperature were kept within a narrow band. Devices to detect objects in the vehicle's path require Peltier cooling. In the hotter areas of the country, inexpensive thermoelectrics 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) would use systems based on the Peltier effect. These would be equally or more efficient, but cheaper than conventional systems and would eliminate Refrigerant 134 leakage which has 1000 times the greenhouse gas effect as CO_2. Naval

applications could include using thermoelectrics 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 water-tightness. During nuclear, biological, or chemical attack conditions wherein the ships are all buttoned up to prevent introduction of airborne radiation particles, HVAC thermoelectrics could provide a reasonable comfort level for the sailors on station.

Initiation of a new major, i.e., well-funded, program to accelerate the development of high efficiency thermoelectrics can be done in a number of ways. We are currently developing a 5-year plan with an in-depth discussion of potential applications which would result when the Program is successful. The degree of difficulty is outlined. This would lead to a Request for Proposals (RFP) for investigators to determine their approaches. Measurement techniques will have to be developed and accepted as a tool to determine advances with thin-film or nanowire devices. Capabilities at the national labs should contribute to this program. Teaming arrangements with industry, academia and national labs will be encouraged. A parallel effort on an application will be undertaken to help define the problems (e.g., effective heat transfer). The Program will be coordinated with work being sponsored by the Defense Advanced Research Projects Agency (DARPA) and the Office of Naval Research (ONR).

Three months after this workshop, Hi-Z and Pacific Northwest National Laboratory (PNNL), using high rate sputtering, developed multi-layer quantum well devices with a figure of merit (ZT) of 4. This represents an improved efficiency which is 400% of that for current-art bulk semiconductors. It is desirable that such a breakthrough in the achieved efficiency should be rapidly exploited to take advantage of its tremendous potential for reducing petroleum consumption, emissions, and greenhouse gases from diesel engines used in transportation and stationary applications.

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