Energy 109: Thermoelectrics

Prof. Ken Johnson

Several readers of these episodes disagreed with my approach of using a 'worst case' example of a private residence solar cell electrical power generation system as the sole source of power (ENERGY 108: SOLAR CELLS II [1]), saying I did that just to make those systems look bad from a cost standpoint. My purpose in all these articles is to turn the cold light of Truth on to all these schemes for 'saving the planet', which involve building some miraculous power generation system that often violates the rules of Nature and the Laws of Thermodynamics . . . and produces electrical power at up to 10 times the cost of conventional fossil fueled or nuclear power plant outputs. They apparently were not only proponents of these 'planet savers' but believed in them enough to purchase one, because they were told many stories about grants, tax breaks/deferments, etc. I could have used an averaging approach (of $/kWhr) to these systems if there were enough in existence, but alas there are only four I know of, who stated very meager data, making meaningful averages impossible.

Unfortunately, for about the last fifty 50 years, we taxpayers have paid out billions, through loans, grants, tax credits, and deductions pushed through Washington by a small cadre of environmentalists who have not one iota of scientific proof or facts that fossil/nuclear fueled power plants are in any way causing permanent harm to the environment. The Federal Government presently offers purchasers of photovoltaic systems (PVs) a 30% tax credit and my State offers a 10% tax credit. So much for economic advantages of 'private' enterprise produced home photovoltaic energy systems . . . but I will continue collecting data on them.

The users seem to rely on the word of one failed presidential candidate politico, whose hoax about global warming has made him a multimillionaire . . . while ignoring a petition from about 40,000 degreed scientists, engineers, meteorologists, and technologists, knowledgeable in the subject, who say there little to no scientific proof that CO_2 from fossil fuel combustion is related to increased global temperatures. The "little" proof is that an increase in global temperature causes an increase in CO_2 (instead of the other way around) in the atmosphere through the process of increasing the oceans temperatures, prompting a release of the CO_2

dissolved in them. Further, there has been no damage from the claimed excess of CO_2 produced by any source (see my episode titled: Are Fossil-Fuel CO_2 Emissions a Problem? , February, 2010).

All the home system owners, I know of, have the Power Grid available to provide most of their energy and an agreement that their local utility will purchase any excess energy generated by the customer (a government requirement). Two users claimed they sell back “almost as much energy as they buy” but don’t say how much they are paid for their excess energy on ‘sell back’. In checking my local utility, I was told that arrangement is correct, however, they only pay the customer what they normally pay their regular Grid providers. In our area, that is presently \$0.029/kWhr. Compare that to the \$0.12/kWhr the customer must pay for power bought from them . . . and there is an initial \$50 connection/meter fee. These rates are set by a public utility commission. A huge advantage of private systems that connect to the Grid is they do not incur the cost of batteries to store energy for night-time or cloudy day use. It may be of interest, that in our area, of the about 18,000 utility subscribers, 24 of them have PVs and 1 has PVs and a wind turbine. The utility neither sells nor recommends any particular system brands, but they must meet the necessary Underwriter Lab’s certs.
.
I have some empathy for those homeowners who bought their photovoltaic systems to avoid the ever increasing “rolling brown-out” conditions (mostly in California) from power shortages. However, those conditions are mostly being caused by government moratoria on conventional power plant construction in some states many years ago, trying to mollify and gain political support from environmentalists. But without a battery storage system, the private system is of not much use during Grid power outages in evening hours and are of limited use otherwise.

I will continue to collect data on operating residential solar power systems and periodically report on my findings . . . but for now, let’s talk about power generation using Thermoelectric devices (TEs).

During the 19th Century, a number of scientists: Faraday, Seeback, Peltier, Thomson (Lord Kelvin), etc. were trying to relate the principles of thermodynamics (study of heat) and electrodynamics (study of electricity). Out of these studies came several significant relationships. One was just discussed in this Energy series, i.e. Photovoltaics (Solar Cells). Another was the ‘cooling’ semiconductor junction (called the Peltier Effect), which led to the ‘solid state’ refrigerator. A third was labeled the ‘thermoelectric’ or Seeback Effect, where it was observed that bringing two dissimilar metals together in a junction (by welding, soldering, or just twisting wires made of the metals together), and heating the junction produced a small electromotive force (emf) or ‘voltage’ across the junction. This led to their use as very accurate contact temperature indicators. Although the emf was very small (on the order of microvolts), by putting a number of heated junctions in series, a significant measurable direct current (dc) voltage could be obtained. The junctions became known as ‘thermocouples’ (T/C) and over the years, metallic alloys were developed to accentuate the emf into readily measurable outputs and tables were developed for various metal combinations over a range of temperatures. Some of the elemental metals chosen were: copper, iron, nickel, and platinum (to cover various temperature ranges and corrosive environments). Some alloys were developed for use in T/Cs, including: “alumel” (aluminum, nickel, chromium, & silicon), “chromel” (chromium & nickel), “constantan” (copper & nickel), “nicrosil” (nickel & silver), and an alloy of platinum and rhodium, called “p-rh”. Common combinations used to make T/Cs are given standard letter designations like: iron/constantan (Type J) or copper/constantan (Type T). There are issues of ‘Reference Junctions’ that must be addressed when using them for temperature measurements and it must be remembered that the connection of two dissimilar metals creates an emf across that junction. Most of those issues are automatically taken care of by modern day temperature readout instruments that include Reference Junctions (also called ‘Cold’ junctions) within the instrument. Some are also capable of working with most of the common T/C types, by means of a simple rotary selector switch.

Remote temperature measurement with thermocouples is the most common use of Seeback junctions, but they are frequently used as a power source. Probably the most common of these is in the safety gas shutoff systems in every gas appliance (clothes dryers, water heaters, space heaters, furnaces, etc.) that uses a gas pilot light for igniting the main burner. A thermocouple is mounted in a position to be heated by the pilot light. Its output is connected to the coil (making a ‘Cold’ or ‘Reference’ junction) of the spring loaded, normally closed, safety solenoid valve, which has a manual operating push button. Gas is turned on to the appliance by the main manual valve but is prevented from getting to the burner and pilot light by the safety solenoid valve. The manual push button on that valve is then pushed to hold the safety valve open and the pilot light can be lit. After several seconds the thermocouple is heated, generating a few millivolts supply to the safety valve solenoid coil. With a large number of turns on the valve solenoid coil, enough milliamp-turns are provided to hold the solenoid valve open when the manual button is released. If for any reason the pilot light goes out, the thermocouple quickly cools, stopping the current flow and the spring closes the safety shutoff valve.

If a number of thermocouples are placed in series, the individual connections wind up as alternating ‘hot’ and ‘cold’ junctions. If all the ‘hot’ junctions are placed in a hot stream of air or water, and the ‘cold’ junctions are kept in a cold or cool environ, usable high wattage dc voltages can be generated. This principle has been used in several undeveloped countries in making kerosene lamps, for illumination, with hundreds and even thousands of serial T/Cs with their hot junctions above the lamp flames in the chimneys and the cold junctions in the base of the lamp. These ‘thermoelectric’ devices provide illumination as well as enough voltage and wattage to operate a small radio.

Thermoelectrics are commonly used in providing electrical power for space probes. Batteries have a short useful life/charge and Photovoltaics (Solar Cells) are only viable in the inner reaches of the Solar System, so some other source of energy must be used for long term explorations away from the Sun. The most common are small atomic ‘piles’ made with low level radiation nuclear materials, active enough to generate sufficient ‘heat’ to energize thermoelectrics, but not hot enough to cause nuclear fission. In order to avoid spreading hazardous nuclear materials in the case of launch rocket failure, the nuclear pile is not fully assembled until the probe is well on its way to outer space. They are much like nuclear weapons not being 'armed' until they have been released from an aircraft or in the case of missiles, re-entered the atmosphere on their way to the target.

One other Thermoelectric has been recently receiving some attention and that is the 'Thermionic'. They work on about the same principle as the vacuum tube where the filament heats the cathode (a metal plate) to a high enough temperature to 'boil' electrons off its surface, which are attracted to the positively charged 'plate'. In between, is the 'grid' whose voltage can be varied to control the rate at which the electrons traverse to the plate. Thermionics generally involve heating semi-conductors and hence getting more electron flow (electricity) much easier.

In my estimation, the amount of "green" power producible by Thermoelectrics is minute in comparison to other methods, hence rates about a '1' on the power scale. On the other hand, having worked a number of years as a Test Engineer where accurate, wide range remote temperature sensing was a necessity . . . and their use as safety flame detectors, I would give thermocouples a '10' for versatility and usefulness.

Prof. Ken Johnson, Ret.

The preceding is the opinion of the author and not that of ECN.

Ken Johnson is a Registered Professional Engineer, retired Aerospace Engineer, and retired Professor of: Mechanical Engineering, Thermodynamics, Fluid Mechanics, and Metrology. He has awards/commendations from: AIAA, ASEE, ECPD, FMC, FPI, FPS, HR-Textron, MSOE, and NASA. He resides in a high desert area of New Mexico.