Energy 110: Fuel Cells

Prof. Ken Johnson

This episode will continue looking at various so-called “green” energy sources with regard to how ‘green’ they are, the state of their technology, and possible economic impact on their users as well as on the non-user taxpayers.

One bright light came shining through since the 2010 election. Although the market trading value of ‘carbon credits’ has been steadily declining since Climategate, after that election they took a real nosedive and now have been dropped by the trading firms as being virtually worthless, but Mr. Gore has made his millions and can retire to his new multimillion dollar mansion in CA. Unfortunately he leaves behind many souls who lost their shirts in that market, victims of his ‘the sky is falling’ sales rhetoric. It is conceivable that could result in a fraud investigation, similar to the Madoff fiasco. Let us hope it is the death knell of the Anthropogenic (human caused) Global Warming scam that has been victimizing the world’s population for the last three decades. From a technology standpoint, the extreme over-reaction produced by the scam appears to have stimulated an interest in unusual, uneconomical, and even bizarre energy conversion systems, as long as the term “green” or “renewable” is applied. Most of these systems have been around for decades and even centuries, periodically receiving scientific inquiry, feasibility studies, development, and even uneconomical production with the taxpayers footing the bill to the tune of billions of dollars. The ‘fuel cell’ (FC) is one of these. Their development has come a long way since the first one was assembled in 1801, attributed to Humphrey Davy, but still have a long way to go to reach a sustainable supply of energy at a reasonable price to the consumer.

They are conceptually relatively simple devices, similar to a ‘fluid battery’ with a ‘fuel’ being fed by pressure thru a porous electrode plate to a chamber containing a liquid ‘electrolyte’. On the other side of the chamber is another porous electrode plate which is exposed on its outside to an ‘oxidizer’ being fed in at low pressure. The electrical ‘load’ is connected between the two electrodes. The fuel side electrode contains a catalyst which knocks an electron off the fuel molecule, ‘ionizing’ it and the electrons collect on that electrode, making it a ‘cathode’ of a battery. The ionized fuel molecules pass thru the electrolyte (which allows ions to

pass, but not free electrons), on thru the porous oxidizer side electrode, and combine with the oxidizer. To do that, it needs an electron, which it gets from the oxidizer side electrode, having traveled thru the load and making that electrode into an anode, completing the 'battery'; a perfect example of "direct energy conversion", bypassing a 'thermal' process and hence the Carnot Efficiency Law. There is a discharge of waste product to contend with, in the form of an oxide compound of the fuel,.

In actual practice, there is also a large amount of heat generated, which lowers its efficiency of chemical energy to electrical energy conversion to considerably less than 100%. The goal over the centuries has been to increase that efficiency or even hold it at that level using less expensive materials in the electrodes than platinum (Pt) and less expensive/more common fuel/oxidizer combination than pure hydrogen (H2)/oxygen (O2) . . . that combination producing water (H2O) as a 'waste' product. You can understand why there is such interest by the environmentalists in FCs, however they seem never to consider the costs of the hardware, nor where there was a cheap source of H2 or how one could safely dispense it and carry large quantities in a vehicle. (Remember the Hindenberg?)

Half a century ago, fuel cells in this country probably reached the height of their notoriety during the early days of manned space exploration, being used as the electrical power generator for relatively long term operations in space, where batteries, which are heavy and require recharging, were impractical. Their major use probably began on NASA's Apollo 'Man on the Moon' Program, where they were used as the primary electrical power for the Saturn 5 rocket and Command Module (CM) systems, as well as to maintain charge on the batteries of the Lunar Excursion Module (LEM) during the trip to the Moon. The 'fuel' used by these cells was gasified liquid hydrogen and the 'oxidizer' was gasified liquid oxygen. Both were stored as liquids in separate cryogenic tanks. I believe there were three separate systems of tanks and cells . . . and supplied the breathing oxygen for the crew, as well as propellants for maneuvering rocket engines.

You may remember those famous words from Apollo 13 on their way to the Moon: "Houston, we've had a problem here", when one of the oxygen tanks exploded, wiped out two of the fuel cell systems and damaged the third. Thru some creative engineering, Houston was able to set up the crew in the LEM, using its batteries for heat and communication, shutting down the remaining CM fuel cell, which had only a small amount of oxygen left, to save it for electrical power to maneuver on a path around the Moon, back to Earth, and reenter safely. The Hollywood movie "Apollo 13" was an excellent dramatization of the event.

The proponents of FC powered vehicles received a real boost in 1959 when the Allis-Chalmers Company (A-C) unveiled their 15 kW FC powered farm tractor, demonstrating it to a bevy of international newsmen by plowing a field near their plant in West Allis, WI, (a suburb of Milwaukee). They later demonstrated a golf cart, fork lift, and marine craft, all powered by FCs. Then several years later, General Motors (GM) hit the papers with their Electrovan, a fuel cell powered GMC 'Handi(cap)van' in 1966. It was dubbed (erroneously) as the 'first fuel cell powered vehicle', failing to recognize the A-C tractor of 7 years earlier. Since then, there

have been a whole plethora of FC powered autos, most using H2 as fuel, O2 as an oxidizer, a hydroxide electrolyte, and platinum based electrodes. Obviously the main drawback is economics, because of the costs of platinum and H2. Then there are the 100 years of research which have not improved that situation much. Other electrode materials have been tried and some work, but not very well.

The O2 has been obtained from the normal atmosphere, but because of the high percentage of nitrogen (N2) with the O2, massive amounts of air must be supplied . . . and there is a long term effect on the electrodes. The source of H2 is primarily by electrolysis of water with electricity, with the advantage of getting O2 along with the H2. However, as it turns out, it requires more electricity to make the H2 than is obtained from the fuel cell converting it back to water (H2O). This is ‘entropy’ at work. Other fuels have been tried but the main disadvantage is the byproducts of those tend to coat the cathode, gradually lowering the electrical output to near zero, sometimes in a matter of a few hours. The A-C cells supposedly used propane as a fuel, but there isn’t much info available on its effect on the electrodes and some researchers think the cell fuels where actually propane spiked with hydrogen. And that GM van had so much equipment in it, there was barely room for 2 occupants.

There is an FC devotee website at: http://hydrogencarsnow.com [1] and Wikipedia” has a large ‘Fuel Cell’ site, but one can really only trust the information from their comprehensive Bibliography entries, because they have some very biased editors, as was recently revealed.

Back to the A-C tractor event, I was living in that area at the time, having just fulfilled a contract as a consultant engineer (known as a ‘job-shopper’ in those days) at the AC Spark Plug (ACSP) Inertial Guidance Division of General Motors (yes, they do make things other than car parts). They were supplying inertial (gyro) guidance systems for the Thor IRBM, Titan ICBM, Mace Cruise Missile, and Boeing 747 airliners. They also had just received a contract to supply Apollo’s LEM moon landing guidance system. I had been working as a Test Engineer/Data Analyst on the flight test programs of those missiles for several years and decided I needed a change of pace, so I applied for a teaching position at a local private engineering college, the Milwaukee School of Engineering (MSOE), located in downtown Milwaukee (yes, the nearby brewery Hospitality Rooms with free samples were favorite lunch ‘brown-bagging’ spots).

MSOE had very strong ties to the myriad industries, in that “Machine Shop of the Nation”, who supplied not only financial support, as corporate owners of MSOE, but through an advisory board, constantly reviewed the curricula of the school to keep their 9 Associate Degree, the 4 Baccalaureate, and 1 Master Degree programs up to date with industrial trends, so as to keep the graduates ‘shovel ready’ and able to step directly into productive roles at their employer’s facilities. Where’s the relevancy of all this, you might ask. Well, Allis-Chalmers (A-C) was one of those corporate owners, along with many other large companies such as: Allen-Bradley, Square D, Ladish, Nordberg, AC Spark Plug, Cutler Hammer, Falk Corp., etc., who contributed funds, provided plant tours for classes, and a source of a great deal of surplus equipment, raw materials, etc. to continually upgrade our laboratory

facilities.

These labs were an essential part of a good technical education . . . and so it was, one day several years later, that a van from Allis-Chalmers pulled up to the back door of our Heat-Power Laboratory (I had just been put in charge of that Lab) and unloaded a whole array of what was purported to be fuel cell related parts and equipment. Our glee gradually diminished to disappointment when after unpacking all the boxes, we found no FCs, only a few machined aluminum stack end and interface plates but no electrodes or containers of electrolyte. There was a prototype of a US Army field generator (28VDC/100A) they had been working on . . . but no cells were in it. It was planned to operate on gasoline or diesel fuel with a peroxide oxidizer. A query to A-C revealed:

1) They had closed down their FC research and thought we could use the test equipment.
2) No FCs or electrodes were included because of their high salvage value.
3) They suggested their projection of the future of FCs would not warrant MSOE setting up an expensive educational lab test unit.

So, another ‘green’ dream bit the dust. It is a great concept for a power plant, producing two necessities of modern life: electrical power and water . . . however, at prohibitive monetary and “Available Energy” costs . . . and after over a half century of concentrated private and government research efforts, there is no promise of substantially reducing those costs. 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.

Links:
[1] http://hydrogencarsnow.com