Introduction to Heat Measurements

The reported production of heat in an electrochemical cell of apparently non-chemical origin was a main feature of the first report by Fleischmann and Pons in 1989. Experiments to measure energy production have been a mainstay of the field since then. The last section described five different calorimeters for measuring heat with adequate sensitivity and good signal-to-noise ratios. Each type has been used in LENR experiments and measured heat from the Fleischmann-Pons Effect. This section deals with the results of such measurements, which were reported at ICCF-14. First, we provide a brief overview of the character and importance of heat measurements. Then, we preview the results provided in the papers of this section.

Most low energy nuclear reaction experiments aimed at heat measurements are done by measuring both the power input to the electrochemical cell and the power from the cell as a function of time. If the output power exceeds the input power, then the cell is said to produce “excess” or “anomalous” power. The integral of this excess power over the duration of the experiment gives the “excess energy” from the cell during its operation. There has been some confusion associated with the term “excess heat,” which is simply the difference between the output and input energies, and is often termed “anomalous” heat. Unknown chemical reactions can produce “excess heat”. It can be very challenging experimentally to establish that the heat is not from chemistry. In many FPE (LENR) heat experiments, the amount of excess heat seen, when normalized to the number of atoms in the sample, the volume of the sample or the mass of the sample in various units, is so large that known chemistry is excluded. Thus, excess heat in these experiments begs to be explained because of its anomalously large value.

The net (excess) absolute powers and energies from LENR cells have been modest in comparison to values routinely encountered in daily life. Incandescent light bulbs generally consume a few tens to a few hundreds of watts of power. Most LENR experiments have produced powers in or below this range of values. Those measurements did have good calibrations and signal-to-noise ratios, so there should be little concern about the reality of these relatively small values. Nevertheless, the measured powers to date are modest. The duration of the periods of power production are also not practical when contemplated for routine applications. They range from a few hours to a few weeks, with some few exceptions. And, the reproducibility and controllability of the power production is sorely wanting in almost all experiments. In short, the power production capabilities of LENR sources are now far from practical. Absent the most rudimentary quantitative theoretical understanding, it is not clear when power production at significant values, with adequate reproducibility and control will be available. Having a theory is, of course, not necessary, but engineering without good models becomes Edisonian in the development of systems with the attendant high cost in effort and time.

It is conceivable that useful energies could be produced even from small power sources. This is done increasingly in electronic systems, which “scavenge” energy from their environments and charge batteries for their occasional operational periods. Light, vibrational and even radio-frequency energy sources are employed commercially for ambient energy harvesting. The total excess energies from LENR experiments are also relatively small. There are some experiments that have produced excess heat energies exceeding mega Joules. While this sounds like a lot of energy, it is only enough to power a 100 watt light for about three hours. (Note a lead acid battery weighing about 15 kg would store this amount of energy.) It is likely that uses will be found for LENR sources with the current modest powers and energies. But, there is a significant need to scale up both the power and energy levels from LENR systems before they will be commercially significant, that is, sufficient for many applications.

These considerations might deflate hopes that LENR energy sources will ever prove to be widely useful. However, achievement of reproducibility and control, even without understanding, might lead to useful scaling up of the outputs. Once understanding is achieved, it is very possible that both scaling and optimization of LENR power and energy sources will follow. The histories of some technologies offer examples of dramatic scaling. The increase in the number of cars during the past century is one of them. In the past half century, the number of transistors on a single chip has grown from a few hundred to a half billion. In the past ten years, the number of phones in the world has also skyrocketed because of mobile phone technologies. There are 6.8 billion people living now and almost 5 billion mobile phones. Hence, it is reasonable to expect that LENR sources of power and energy will grow significantly in capabilities and, with that growth, increase in the numbers of applications.

Besides the chronic need for energy, especially in the face of rapid population growth, there are some reasons that compel interest in relatively small sources of nuclear energy. They include:

- Such small nuclear energy sources might be mobile, even to the point of powering personal electronic devices.
- Stationary, but still small LENR sources could be geographically distributed and, hence, relieve stress on power grids. They might power homes, for example.
- Experiments to date have shown that LENR energy sources do not produce dangerous radiation during operation, in stark contrast to current fission and hypothetical hot fusion sources, which require very heavy shielding.
- It is also known experimentally, that the operation of LENR sources does not produce significant radioactive waste materials, again in contrast to fission and hot fusion sources.
- LENR sources do not emit greenhouse gases during operation. Their production and the management of waste from defunct LENR sources could also be done in a “green” fashion.

There is a major question concerning the characteristics of the heat, which might be obtained from commercial LENR sources. If the temperatures put out by such sources are modest, notably below the boiling point of water, there will still be significant applications. Home water heaters provide one example. However, if temperatures of hundreds of degrees C are available, then efficient production of electricity becomes possible using currently available technologies.

In addition to these possibilities, there are emerging technologies for the direct production of electricity from thermal sources. The best known of these are devices based on thermoelectric materials. When these devices have a thermal gradient across their sides, they produce a voltage (power). The reverse is also true, that is, application of a voltage causes the devices to be heat pumps. There is a tremendous interest in making efficient thermoelectric devices because of refrigeration. Such devices could enable solid-state refrigeration, that is, cooling systems for homes and other places without compressors and working fluids. Such systems, which would not have moving parts, should require less maintenance and last longer than the present systems with their moving parts.

There is a newer technology for direct conversion of heat to electricity. It is called micro-gap thermo photovoltaics (MTPV). This technology is a relatively recent development and a long way from practical commercialization. The efficiency of both thermoelectric and MTPV technologies improves with operating temperatures and gradients. It could turn out that both commercial LENR sources, and either thermoelectric or MTPV materials, will be developed in the same time frames, and then mated for production of electricity from LENR power.

The papers on heat production presented at the conference and given on the following pages are research studies. They are not yet technology developments or engineering designs. However, these papers have three key features. First, they add to the considerable experimental database for the production of net power and energy by LENR. Second, results from these papers help point to the possibilities for practical LENR heat sources. So, finally, the range of potential applications for LENR sources becomes somewhat clearer.

The first paper by Cravens and Letts was commissioned to provide an overview of papers reporting excess heat results. They provide four “enabling criteria” for generation of excess energy. These are based on earlier experiments, and they appear to be necessary but not sufficient conditions for energy production by LENR.

The paper from Energetics Technologies reports some remarkable results. Their electrolytic experiments included both “SuperWaves” to drive the electrolysis and the presence of ultrasonic excitation. Excess powers as high as 34 watts were achieved. In the best case, the excess power was about 30 times larger than the input power to the experiment. The longest duration experiment gave excess power for 40 days. The largest excess energy was 3.5 MJ. In one case the ratio of the excess energy to the number of Pd atoms in the system was an incredible 27,000 eV/Pd. Specific excess powers of 70 W/gm Pd were measured. They compare favorable with fission fuel rod specific powers of 20 to 50 W/gm of U. This paper is one of the most important experimental papers in the field.

Swartz has prosecuted one of the most instructive experimental efforts on LENR over the years. One of his key discoveries is the existence of “optimal operating points” (OOP) for electrolytic LENR cells, which are expressed in terms of the output power vs. input power in his systems. In his analytical paper, he links the characteristics of OOPs to three sites within deuterium-loaded Pd where excess heat originates. Data from published experiments, in addition to his own measurements, is analyzed with a quasi-one-dimensional model.

Mizuno and Sawada have a university-industry collaboration, but their experiments are both very different and diverse compared to other papers at ICCF-14. They subjected a heavy oil (phenanthrene) to both high pressure and high temperatures in a reactor with a metal catalyst. Heat generation of 100 W was observed for several hours. Gamma rays were also measured, and a "reasonably significant" correspondence between heat generation and gamma emission was reported. Mass spectroscopy measurements after runs showed what appears to be ^{13}C.

Karabut and Karabut reported the results of both electrolysis and plasma (glow discharge) loading of Pd with deuterium. In the electrolysis experiments, controls with light water and Cu and Pd cathodes were performed. Both mass flow and heat capacity calorimetry were employed for the electrolytic experiments. Excess heat was observed for both electrolytic and plasma loading. In the case of plasma loading, excess powers in the range of 5-15 W were reported.

The experimental and analytical papers on production of excess power and heat, given at ICCF-14 and in this section, added considerably to the database and knowledge for LENR. Given the several types of loading, the many experimental parameters and the diversity of calorimeters, there remain numerous opportunities for LENR power and heat measurements. Both replication of reported experiments by other experimenters, and the performance of new types of experiments, are needed. More and better chemical analyses of materials both before and after experimental runs are also critically needed.