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Research Article

Total Calorimetry (“From the Wall”) in a Brillouin Reactor

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Abstract

Brillouin Energy (BEC) has continued performing calorimetry measurements on the metal (*e.g.* Ni)/ceramic/Cu coated ceramic tube (catalyst) in a H_2 atmosphere with nanosecond pulses applied across the coatings. The Energy Research Center (ERC) has been examining and verifying BEC’s calorimetry for over 5 years. Over 2000 runs were performed on over 300 different catalyst tubes using different stimulation parameters. A new reactor system has been designed and implemented using only mass flow calorimetry. This has led to more reliable and understandable thermal outputs, making it easier to determine when over-unity results are seen. Some over-unity results are described in this paper. The temperature of the outer nickel layer has been estimated using the temperature coefficient of resistance method. Future plans for even better calorimeters are described.

Keywords: Excess energy, Mass Flow Calorimetry, Nickel, Hydrogen gas, Pulse stimulation

1. Introduction

Since 2012, first SRI International (SRI) and later the Energy Research Center (ERC) have been performing tests on several different versions of Brillouin Energy Corp.’s low-energy nuclear reactors (LENR) [1]. At SRI we operated these reactors independently to attempt to verify results that Brillouin has found with these reactors and others like them. We have also monitored and advised Brillouin on the results from identical reactors operated by Brillouin in their own laboratory. This paper reports on the verification and validation of results [2] recently obtained in Brillouin’s laboratory. Brillouin has indicated that it has designed the control systems in its reactors to drive the underlying physics of LENR, as described in its Controlled Electron Capture Reaction (CECR) hypothesis [3]. The CECR hypothesis explains how BEC believes that their reactors generate controlled LENR reaction heat. This study did not attempt to prove or disprove Brillouin’s CECR hypothesis.

The systems tested and described in this report consist of three parts: catalysts; reactors; and calorimeters. The catalysts are the reactive components of the system. The reactors provide the environment and stimulation that causes the catalysts to produce reaction heat. The calorimeter is used to measure the thermal efficiency and absolute heat

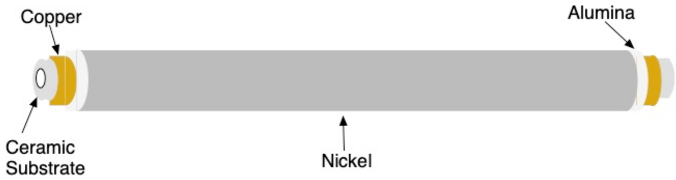

Figure 1. Diagram of typical catalyst tube.

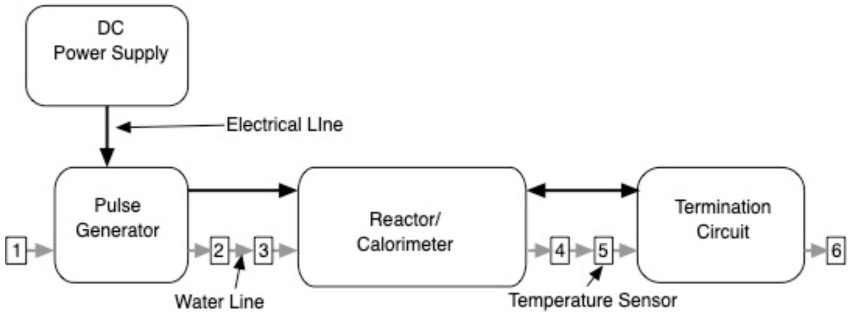

Figure 2. Diagram of mass flow water and pulse stimulation lines.

produced by the catalyst-reactor system. The calorimeter was designed by both SRI and Brillouin personnel to be perfectly matched to the reactor. The reactors and calorimeters have been re-designed since the last report at ICCF22.

Brillouin's new design utilizes three mass flow calorimeters (MFC) operating in series, in which constant flow rate water is passed through a chamber surrounding the catalyst/reactor, as well as chambers surrounding the pulse generator (PG) components and the impedance matching termination (IM) circuits. The inlet and outlet temperatures of all three calorimeters are measured along with the water's flow rate. The water flowed first through the PG's calorimeter, then through the IM's calorimeter before flowing though the reactor's calorimeter. In this way the mass flow rate was constant in all three calorimeters. Different types of fast rise time pulse stimulations were applied to the catalyst tube as input power. This mass flow calorimetry allowed us to analyse all power entering or affecting the catalyst as well as all power emanating from the catalyst based on simple Newtonian calculations. Each calorimeter was calibrated using a tube with a non-reactive Nichrome® coating replacing the active Ni coating.

2. Experiment

2.1. Reactor Design

The catalyst consists of metal and ceramic coatings applied to a ceramic substrate, an example of which is shown in Figure 1. Generally, these coatings alternate between a hydrogen-absorbing metal and an insulating ceramic. All of the layers are porous, allowing the gas(es) in the reactor chamber access to all coatings. A schematic diagram of the reactor/calorimeter system is shown in Figure 2. The reactor/calorimeter is mounted inside a glass vacuum cylinder. The system is generally operated in the vertical direction. The substrate diameter is $\sim$6.4 mm, and the coatings are 50 to 250 μm thick.

2.2. Measurement

The catalyst is stimulated by sending pulses between the outer layer and the inner copper layer. The nature of the pulses is such that its current travels primarily on the surface of the outer metal coating in contact with the ceramic (the "skin effect") [4]. This effect is caused by the very fast rise time of the pulses and is dependent on the magnetic permeability of the metal. Although the skin effect is present on both surfaces of a metal, in a multi-layer system the greatest current is passed at the interface with the greater dielectric [1], in this case the ceramic.

The stimulation power imparted to the catalyst is not measured directly. However, the DC power sent to the pulse generator is measured every cycle., usually ten seconds The pulse is generated by a proprietary Q-Pulse board and delivered to the catalyst with a termination circuit that helps match the catalyst tube load impedance to that of the pulse board output. The shape of the voltage pulse at both ends of the catalyst tube is measured and recorded using a high-speed oscilloscope whenever a stimulation parameter is changed, generally every hour.

The pulse width presently used is from $\sim$ 30–10,000 ns with a voltage duty cycle of approximately 100%. The current is only high during the pulse's fast rise time due to the "skin effect" leading to a much smaller power duty cycle. An example of this pulse design, which Brillouin refers to as a "Q Pulse". More detail on the pulse trains are shown here [3]. All catalysts are measured using a "Hi-Pot" tester before use. Any catalyst that shows measurable current when 500V is passed between the two metal layers is rejected. Any voltage breakdown would reduce the possibility of the current pulse passing the complete length of the catalyst. As such, capacitive discharge is avoided.

The thermal output power is measured using mass flow calorimeters in each of the reactor, the pulse generator and the termination device. The latter two powers are considered parasitic thermal losses. Hence, stimulation parameters and conditions are generally chosen to optimize the amount of thermal output measured in the reactor, while minimizing the losses from the other two components. Referring to Figure 2, Water flows in series through all three components while input and output temperatures are measured from each component.

After the mass flow calorimetry water exits the system, it is cooled back to room temperature by flowing through an air-liquid heat exchanger with an electric fan. The system utilizes both an ultrasonic volumetric flow meter and an electronic balance to determine the water's flow rate. An electronic diverter valve sends the water flow to the electronic balance for approximately 120 seconds once an hour. The flow rates from both methods are recorded and saved to disk. The output power from each calorimeter is calculated and saved as well as that of all temperatures and flow rates, allowing for also calculating that power post experiment. The data acquisition system with a photograph of the graphical interface has been described earlier [2].

2.3. Calibration

Calibrating via joule heating using the single layer Nichrome® coated tube, is supplemented by stimulating three-layer catalyst with the nickel outer layer replaced with Nichrome®. Also, several stimulation methods on regular catalyst tubes were tried to find one that can act as a blank (no excess power) using similar pulse power input [2]. Calibrations are performed using pulses (or DC power) that impart the power necessary to cover the desired temperature range. These calibration methods are compatible with the data collection's software's calculation designed for the high duty cycle Q pulse square waves and do not require hardware changes.

The system can keep the internal catalyst temperature constant at its set point or deliver constant total power. When controlling temperature using different gases, the catalyst substrate temperature is held constant regardless of the gas. Using DC stimulation of a single-layer Nichrome® coated tube in H_2 gas, 98% of the electrical input shows up as heat in the reactor. The other 2% shows up as thermal losses in the connector board substituting for the pulse generator board.

2.4. Operation

Since the thermal time constant of the reactor is approximately 15 minutes, the input power is controlled in one-hour steps. During this time the power can be held constant by explicitly commanding all three parameters, pulse amplitude, width, and repetition rate. Often the pulse width is calculated to maintain 100% duty cycle when the amplitude and repetition rate are commanded. In addition, either the width or repetition rate is chosen and the other is determined by the software to maintain at requested input power. The steady-state stimulation method is operated in MFC mode, where the computer usually keeps the pulse power constant. The system can also operate so that the output power or the catalyst temperature is held constant. The total output power includes the stimulation power and the power due to reaction heat (i.e. LENR power).

The sheath containing the catalyst is usually operated with a static fill of hydrogen gas held at constant pressure up to 15 bar. The temperature of the catalyst, using at least one thermocouple inserted in its central annular space, is measured ranging from 100°C to 600°C.

The power delivered to the Q-pulse generator board, is held constant as chosen by the program's front panel or the sequence file. Generally, the pulse amplitude (voltage) and pulse width are chosen. The repetition rate is adjusted automatically to maintain the chosen pulse power or temperature. The actual pulse power is not measured directly but is assumed to be equal to the power provided by the DC power supply. Both pulse amplitude and repetition rate are scanned to look for trends in thermal efficiency relative to these parameters.

3. Results and Discussion

Several different runs have been performed over the past few months to find the tube with the greatest output power relative to input power. In some runs the pulse amplitude and repetition rate are commanded explicitly. In other runs one of these parameters is commanded and the system is commanded to adjust the other parameter to maintain a chosen power for at least one hour. The data from the last five minutes of that hour is averaged to determine the steady state efficiency of each of the three calorimeters. The purpose is usually to maximize the output power/input power ratio (CoP) from the tube in the reactor to emulate operating a steam generator. Occasionally a run is performed to maximize the total output efficiency from the sum of all three calorimeters to emulate a device that uses the hot water directly.

Figure 3 shows an example of a typical constant pulse amplitude (160 v) run plotting the output thermal powers from each calorimeter respectively over the DC input power versus pulse repetition rate. The power is ramped in one-hour steps from ∼250 W to 330 W by commanding repetition rate steps from 250 to 287 kHz. The total output power over DC power is shown in red, shows that 100% of the DC input power is collected by the sum of all three calorimeters. The jacket (reactor) calorimeter collected ∼ 86%, with ∼10% lost by the pulse generator board (PCB), and ∼ 4% lost in the termination board (IM).

Figure 4 shows the results of a different run using the same catalyst and reactor as in Figure 3 plotted versus time. The repetition rate was held at 279 kHz while stepping the voltage from 90 to 215 v. In this run the output from the reactor is nearly equal to the input power and the total output power is over 110% when including the parasitic losses. There was no obvious trend in pulse amplitude in this run.

Figure 5 shows an early attempt to estimate the actual temperature of the nickel coating using its temperature coefficient of resistance. The absolute resistance in blue across the lower X-axis is plotted against the thermocouple temperature on the Y-axis. The nickel temperature is estimated via a lookup table using the known resistance versus temperature of nickel in H_2 determined by calibration run outside of the reactor is plotted across the upper X axis, again versus the thermocouple temperature.

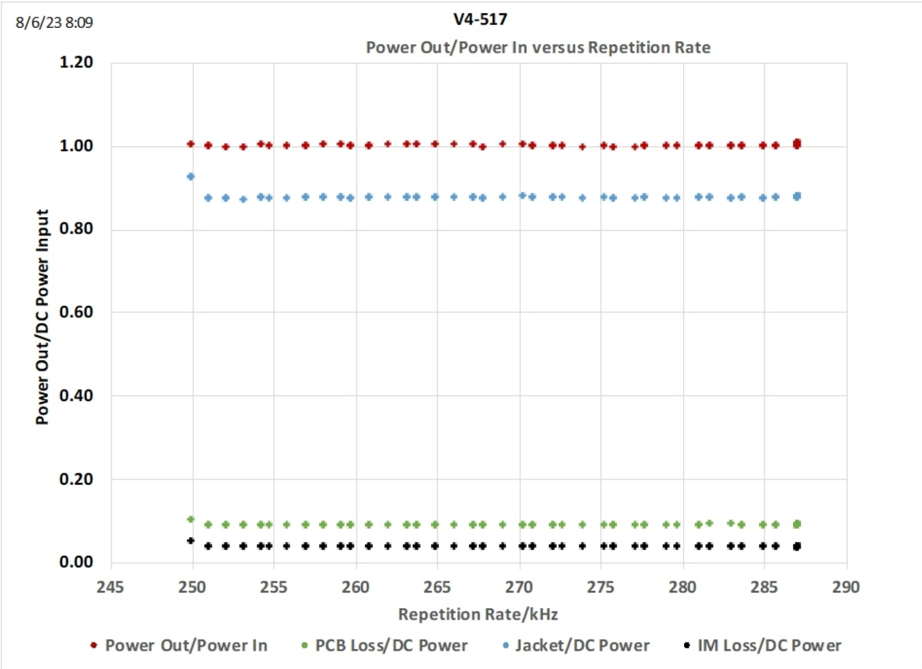

Figure 3. Input and output powers versus time during a typical. experiment.

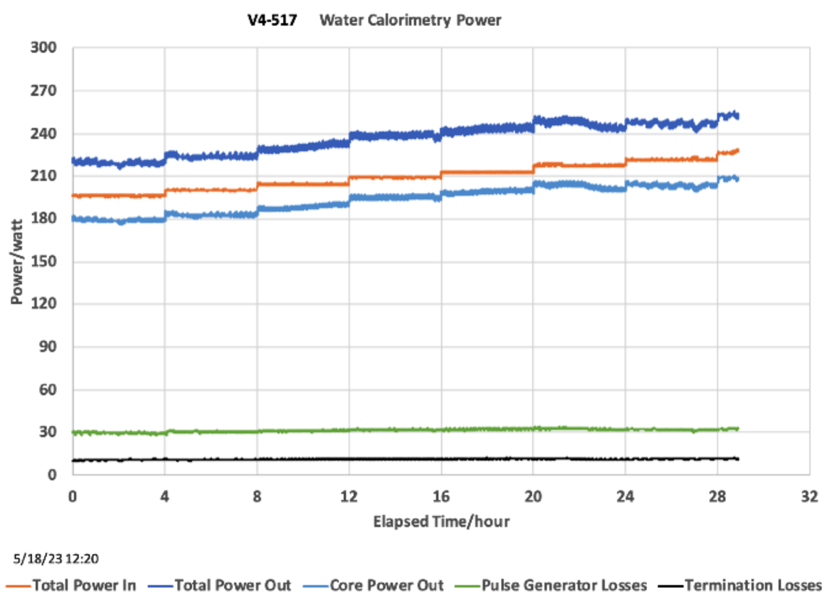

Figure 4. Input and output powers versus time from the same catalyst and reactor as in Figure 3.

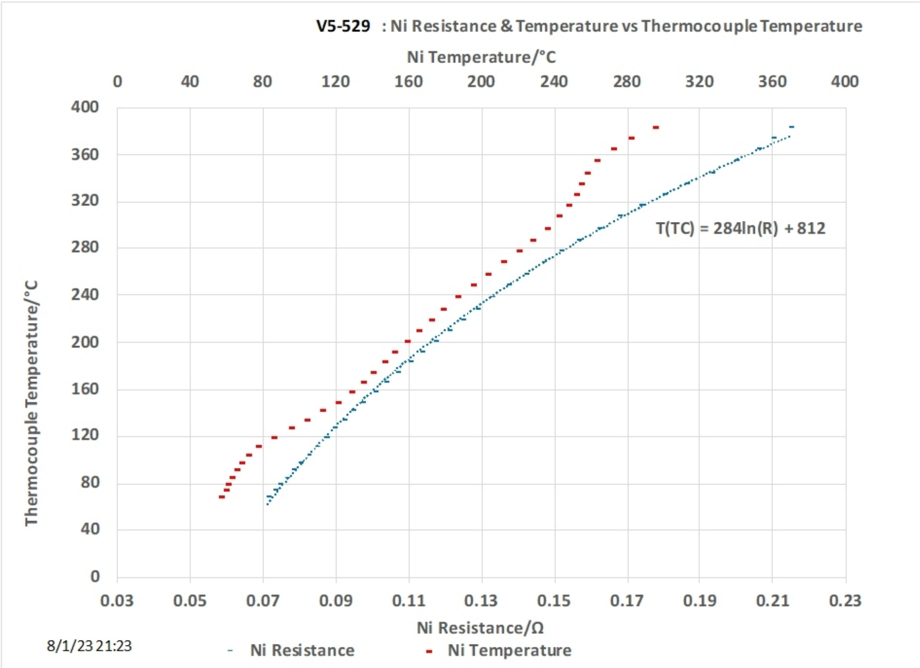

Figure 5. Nickel resistance and calculated temperature versus thermocouple temperature.

4. Conclusions

LENR can produce thermal power when hydrogen-absorbing, catalytic metal-coated substrates are stimulated using fast rise-time pulses. Several runs have shown over unity total output power when compared to input electrical power. Since the efficiency of DC power supplies can be very high, we consider these over-unity numbers to be equivalent to that relative to ratios using wall power as input power.

The catalyst tubes consist of a ceramic substrate coated with three layers of copper/ceramic/nickel. All experiments were operated in H_2 gas from 200°C to 600°C. Thermal measurements were performed using pulse power stimulation. These runs were performed using three mass flow calorimeters operated in steady-state input power mode, while the software kept either the input power or the temperature constant. The main calorimeter is that in the reactor. To account for thermal losses, mass flow calorimeters also measure the thermal power dissipated by both the pulse generator board and the impedance-matching termination board. Six different reactors have been used for these runs.

Calibrations runs comparing all thermal output to all electrical power input have been performed showing up to 100% efficiency of different reactors when using a ceramic tube coated with one layer of Nichrome®. In addition, three-layer (copper/ceramic/Nichrome) tubes have been used to determine the efficiency of the pulse generator board and the impedance-matching termination board.

Over 2000 runs were performed on over 300 different catalyst tubes using different stimulation parameters. Using newly designed and implemented mass flow calorimetry, these results are more reliable and/or understandable than results presented earlier. The results presented here are some of the higher CoPs seen over this time period. Many of the tubes tested showed much lower CoPs due to materials issues.

Estimates of the outer nickel's temperature have been calculated from its resistance on one reactor. We anticipate performing this is all future reactors. A new reactor prototype is running where the outer vacuum jacket is part of the actual reactor, eliminating the need for an external Dewar cylinder. We hope to replace the volumetric flow meter and occasional mass flow measurements with real-time mass flow measurements throughout each run.

Acknowledgements

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