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Isoperibolic Hydrogen Hot Tube Reactor Studies

INTERIM PROGRESS REPORT
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SRI International Project P21429

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EXECUTIVE SUMMARY

Introduction

In August 2012, SRI International (SRI - https://www.sri.com), was contracted by Brillouin Energy Corp. (Brillouin – http://brillouinenergy.com) to perform independent studies of Brillouin's low energy nuclear reaction (LENR) reactors, as well as advise on related Brillouin LENR research. We have operated these reactors to observe, monitor, analyze, advise on, and independently verify Brillouin's LENR evolving research & development work, test systems, and test results. This report documents the most recent results obtained in SRI's laboratory, as well as verification and validation of results obtained in Brillouin's laboratory over the course of the past nine months. Brillouin indicates 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, which is how it believes its reactors generate controlled LENR Reaction Heat. This Report does not attempt to prove or disprove Brillouin's CECR Hypothesis.

The systems tested and described in this report consist of three parts – cores, reactors and calorimeters. The cores are the reactive components of the system. The reactors provide the environment and stimulation that causes the cores to produce LENR reaction heat. The calorimeter is used to measure the thermal efficiency and absolute heat produced by the core-reactor system. The calorimeter was designed by both SRI and Brillouin personnel to be perfectly matched to the reactor for accuracy of measurement, whose results are described in this report.

SRI has brought over 75 person-years of calorimeter design, operation, and analysis experience to this process. We have used our expertise in LENR calorimetry – the ability to measure input and output power in the form of electricity or heat (energy balance power gain), to validate the results that are summarized in this Interim Progress Report. Brillouin's system design relies upon compensation calorimetry, which is an accepted method of examining the variables that affect power gains.

Experimental

Since the start of SRI's independent advisory and experimental verification and validation role in August 2012 to date, Brillouin has developed its uniquely fabricated, hydrogen "gas-based" reactors, known as its "Hydrogen Hot Tube" (HHT), in order to prove its Hypothesis that it can generate controlled LENR Heat on demand for potential industrially useful applications. During this time, Brillouin has run many experiments at its headquarters lab in Berkeley, as well as experiments at SRI, producing at various times a wide range of tell-tale indications of actual LENR Reaction Heat in its HHT reactor test systems.

SRI has aided in the evaluation of the effectiveness of the two gas mass flow calorimeters used with Brillouin's first generation (GEN1) HHT reactor using ConFlat® fittings. We have also been instrumental in the design and development of the isoperibolic (IPB) calorimeter used to measure and validate the energy balance of Brillouin's second generation IPB HHT reactors. Brillouin had two identical IPB systems built, calibrated and tested at Brillouin's lab. A 3rd identically built IPB HHT is presently completing its final calibration tests and is anticipated to come online before the end of 2016.

Between the end of September and the beginning of October 2016, Brillouin further de-constructed and transported one of its first two IPB HHTs down to SRI in Menlo Park, and subsequently reconstructed the system, in order to allow SRI to run this IPB HHT independently. The transferred IPB HHT has since been used for the past two months to complement the experiments being performed at Brillouin.

The design of the Brillouin IPB HHT involves a conventional resistive heater used to maintain a constant temperature in the reactor while adding additional proprietary electrical "Q" pulses to the system to stimulate the specially designed core to yield LENR Heat. This becomes evident if the total output heat measured is greater than that from the heater and the Q-pulse power imparted to the core. Upon generating a positive LENR coefficient (excess heat), the system reduces the heater power input, by an amount equal to the excess heat difference, required to maintain the pre-set temperature. By this compensation calorimetry method, the measurements of net input and output power are carefully measured to within 5% accuracy to assure an exact calculation of the LENR coefficient.

SRI has closely followed and advised on the evolution of Brillouin's system design and materials and as such we are highly familiar with the history of their efforts to build and advance their test systems, test protocols, manufacturing techniques, specifications and core components. We closely studied Brillouin's test data generated from extensive testing of their two IPB HHTs, especially over the past nine months since the beginning of March 2016, which is the period during which they have produced their most advanced and comprehensive test results to date.

Results

We report here on the most recent nine months of extensive testing in Brillouin's two original IPB HHTs operated at its Berkeley laboratory, and in the past two months, with the second unit having been further situated at SRI. Brillouin has manufactured five identical metallic cores and has consecutively tested each one of them in its two IPB HHTs, seemingly producing the same controlled heat outputs repeatedly.

Since its reconstruction and calibration, I have been able to corroborate that the IPB HHT system moved to SRI continues to produce similar LENR Reaction Heat that it produced up in its Berkeley laboratory at Brillouin. Together with my prior data review, it is now clear that these very similar results are independent of the system's location (Berkeley or Menlo Park) or operator (Brillouin's or SRI's personnel). This transportable and reproducible reactor system is extremely important and extremely rare. These two characteristics, coupled with the ability to start and stop the reaction at will are, to my knowledge, unique in the LENR field to date.

The results described in this report suggest that Brillouin can now produce repeatable, small scale LENR reaction heat on the order of up to several watts of power, on a fully controlled basis, on demand. Brillouin has posited that this specific heat production is being generated from its CECR process, based on its interpretation of the precise calorimetric measurements of the input and output power in its two IPB HHTs. This joint effort has generated extensive test data, which suggest that both of the IPB HHTs have produced similar LENR heat outputs, regardless of which system is being run, and using various different core materials (key components), so long as they are run the same way each time.

Using different batches of the same materials and standard industrial processing techniques, processed to a proprietary set of customized specifications, Brillouin has produced relatively identical components for its HHT systems, including its test cores, which recently have consistently produced these same results.

In my extensive review of the test data generated from both IPB systems, from test runs made continuously at Brillouin's Berkeley Lab in the past nine months though the date of this report, the test data showed and continues to show that LENR heat outputs up to several watts were repeatedly produced from positive coefficients in the range of 1.2X to 1.45X, depending on various factors. We feel that the calorimetry was studied exhaustively and validated to an extremely high level of accuracy (see further discussion and test data review below). In addition, I have continued to run the IPB HHT system that was transported to SRI for the past nine weeks, and it has continued to produce same kind of results.

After reviewing Brillouin's IPB HHT test data and performance characteristics of reactors operated at both Brillouin and SRI, especially over the past nine months, and using SRI's extensive experience in LENR calorimetry, we have found that Brillouin's reactor test systems appear to be producing small scale

LENR heat outputs - reaction heat, which translates to LENR coefficients of performance (COP) between 1.2 and 1.45 for stimulations designed to produce excess power - while finding COP's of 1.00 to 1.05 with stimulation not expected to produce excess power such as at a 600°C temperature. A representative sample of these coefficients summarized in Table E.1, include those coefficients generated both before and after transportation of the IPB HHT to SRI.

At least one core, having undergone special material processing explained in the technical section, has produced COP's of 1.91 and 2.08. Several other test runs were above 1.5 or 1.6. However, these higher output results have so far been not as reliably repeatable. As core construction continues to improve and more protocols and parameters are tested and refined, we expect to see more of the higher COP's. Regardless, the test results summarized herein are the basis for the conclusions in this Interim Progress Report, because of the extensive analysis they have been put through, including their repeatability and their accuracy. Brillouin and SRI are continuing to expand these test results with additional test core materials and data outputs at this time.

Table E.1 Summary of coefficients of performance (COP) of recent experiments

Temperature/°C	Pulse Width/ns	COP
300	150	1.41
250	150	1.44
300	150	1.21
600	150	1.03*
300	300	1.28
600	150	1.01*
300	150	1.43

* These cores have been shown not to produce Reaction Heat at 600°C.

Conclusions

The LENR coefficients of performance (COPs) that have been produced in the Brillouin IPB HHTs in 2016, and the related power output levels of a couple or several Watts, especially since March of 2016, are admittedly low and small-scale. However, it would be a mistake to discount them, in light of the accuracy of their calorimetry, the consistent repeatability of their production, their controllability, and the refinement of their manufacturing techniques, specifications, and components, all leading to the same repeated results as verified independently. The transportability of the system is also a remarkable achievement from an independent review basis. While these achievements are still being produced in a test laboratory at bench scale, they are uniquely pointing to an engineering pathway to evolve an actual commercial design. I know of no other independently verified results of this kind in the field today.

These results demonstrate:

- That the repeatability and the consistency of the system output are similar, regardless of in which reactor, the core is being operated and which core components of a given design are being used, interchangeably.
- To our knowledge, this is the first time in the LENR field that an independent examination of an entity's reactor, i.e. Brillouin's IPB HHT, is clearly demonstrating the production of a verifiable and repeatable LENR heat output with positive COPs, which are consistently initiated and uninitiated on command using system design control mechanisms.

- In addition, Brillouin has invented and built a LENR reactor system that has been shown to be transportable from its own laboratory while showing the same positive results in its new laboratory. The unit was transported from the Brillouin laboratory to SRI, for purposes of independent operation, verification, and validation and produced similar excess power in both locations.

In summary, when using cores constructed from similar metal compositions and constructed to the same industrial specifications, the Brillouin IPB HHT LENR reactor has shown groundbreaking results that are potentially:

- Controllable on demand
- Reproducible
- Transportable
- Generated from multiple system components, made from relatively identical metallic compositions, manufactured to the same industrial specifications, producing the same LENR heat output results

Side note: The above positive COP results were primarily produced at operating temperatures of 300°C. The ultimate operating temperature of an HHT commercial system is primarily related to the COP produced, and other engineering factors, and is not in itself a limiting factor per se. In fact Brillouin has had success using similar reactors and cores operating at up to 700°C, which is a much more desirable operating range for the commercial HHT systems that Brillouin anticipates building.

INTRODUCTION

Since August 2012, SRI has been performing tests on two different versions of Brillouin Energy Corp.'s low energy nuclear reactors (LENR) under SRI project P21429. We have operated these reactors to independently attempt to verify results that Brillouin has found with these reactors and type of reactors. We have also monitored and advised Brillouin on the results found in reactors operated by Brillouin in their own laboratory. This report documents the results obtained by studies in SRI's laboratory, as well as verification and validation of results obtained in Brillouin's laboratory over the past nine months. 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, which is how it believes its reactors generate controlled LENR Reaction Heat. This study did not attempt to prove or disprove Brillouin's Controlled Electron Capture Reaction (CECR) Hypothesis.

The systems tested and described in this report consist of three parts – cores, reactors and calorimeters. The cores are the reactive components of the system. The reactors provide the environment and stimulation that causes the cores to produce reaction heat. The calorimeter is used to measure the thermal efficiency and absolute heat produced by the core-reactor system. The calorimeter was designed by both SRI and Brillouin personnel to be perfectly matched to the reactor, whose results are described in this report.

SRI has brought over 75 person-years of calorimeter design, operation, and analysis experience to this process. We have used our expertise in low energy nuclear reaction (LENR) calorimetry – the ability to measure input and output power in the form of electricity or heat (energy balance power gain), to validate the results that are summarized in this Report. Brillouin's system design utilizes compensation calorimetry, where the core and reference temperatures are held constant by varying the input heater power while applying different types of stimulation which also input power to the reactor/calorimeter.

EXPERIMENTAL

Design

The cores consist of a metal substrate, which in some configurations includes a heater and thermocouple, with several spray-coated layers. Generally, these coatings alternate between a hydrogen-absorbing metal and an insulating ceramic. One example is shown in Figure 1. Other designs may have more or less layers. All of the layers are porous, allowing the gas(es) in the reactor chamber access to all coatings. There is a heater and thermocouple in the center of the core. The power to the heater is measured directly from the voltage and current supplied by the direct current (DC) power supply.

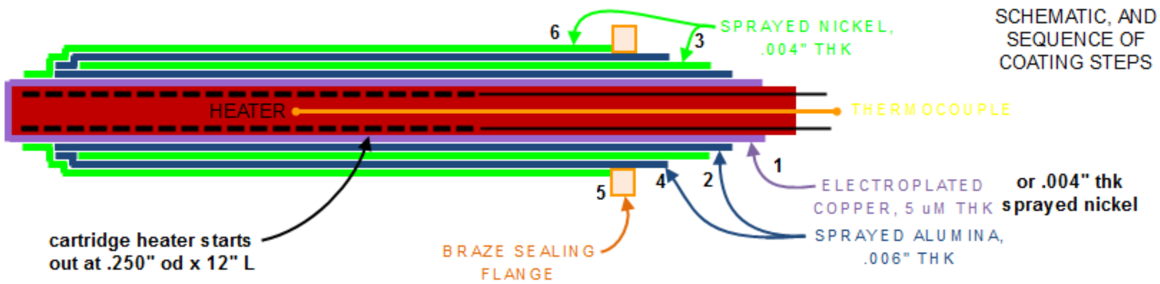

Figure 1. Example of Brillouin's fourth generation Hydrogen Hot Tube Cores

A photograph of the reactor/calorimeter system is shown in Figure 2. The system is contained in an acrylic container filled with argon gas to minimize the probability of a hydrogen-oxygen reaction from any H_2 that might leak from the system. A schematic diagram of the reactor/calorimeter system is shown in Figure 3. In a traditional isoperibolic calorimeter

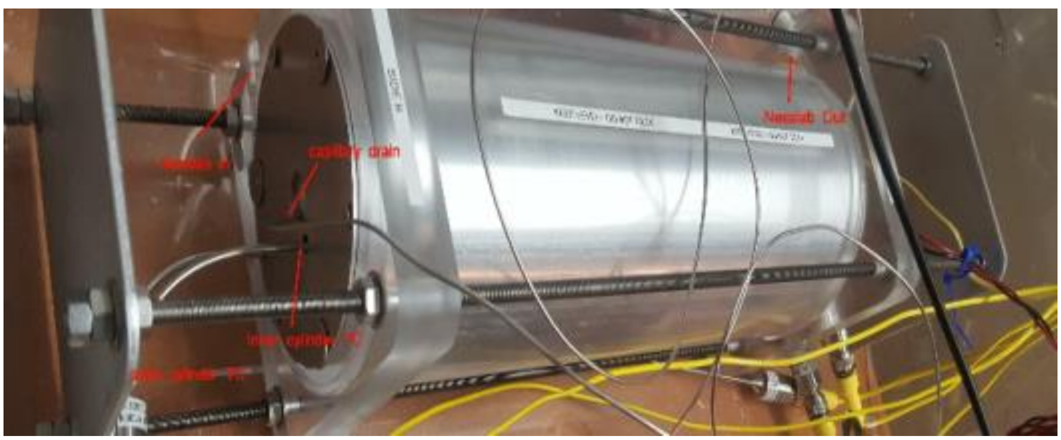

Figure 2. Photograph of the reactor/calorimeter system

the reactor temperature is distributed along a massive thermal block (inner block) surrounded completely by a thick insulating layer, which itself is surrounded by another thermally conductive metal mass (outer block). This latter block is kept at a constant reference temperature.

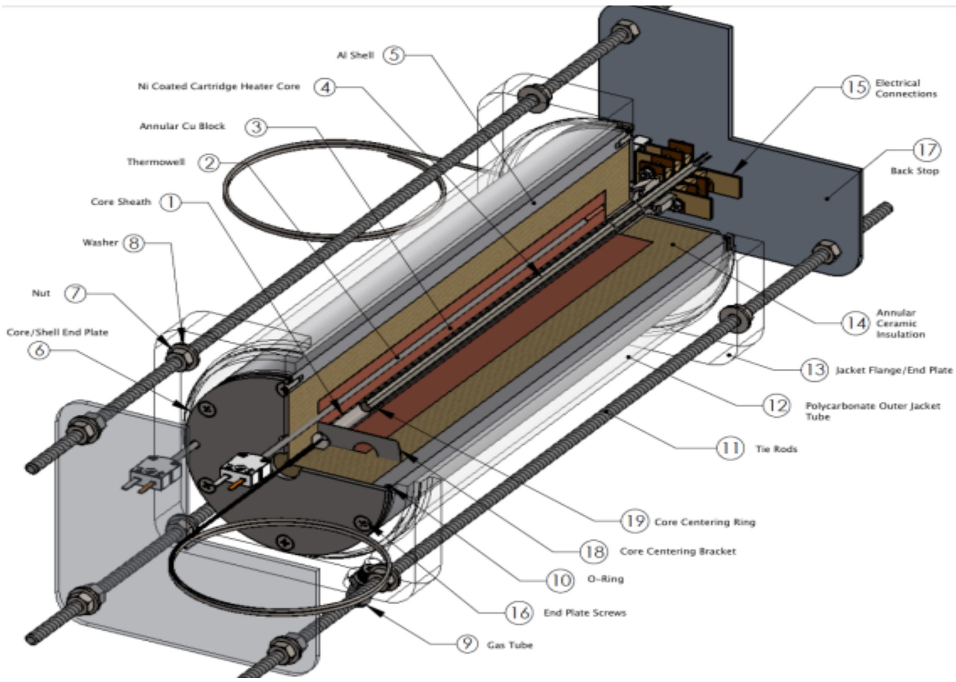

Figure 3. Schematic diagram of the isoperibolic hydrogen hot tube reactor/calorimeter

Referring to the labeled parts of Figure 3, the core (4) is centered in and insulated from a metal sheath (1). This core/sheath combination together with the electrical connections (15) comprise the reactor. An annular copper block (3) is in intimate contact with the reactor sheath and contains a thermowell (2) and thermocouples and acts as the inner block. This copper block is surrounded by an annular ceramic insulator (14). Surrounding this insulator is an aluminum shell (5) with thermowell and thermocouples. This shell, kept at constant temperature by flowing temperature-controlled water between it and the outer acrylic sleeve (12), serves as the outer block. Argon gas is circulated through the chamber outside of the calorimeter.

Measurement

The outer active layer is stimulated by sending pulses through the outer layer or layers and returning electrically through the innermost layer. The nature of the pulses is such that its current travels primarily on the surface of the metal in contact with the ceramic (the “skin effect”). This effect is caused by the very fast rise time of the pulses. An example of this pulse design, which Brillouin refers to as a “Q Pulse”, is shown in Figure 4. The pulse width is from ~80 – 1000ns with a duty cycle of less than 1%. This example shows a pair of pulses with alternating polarity, although same polarity pulse trains have also been used.

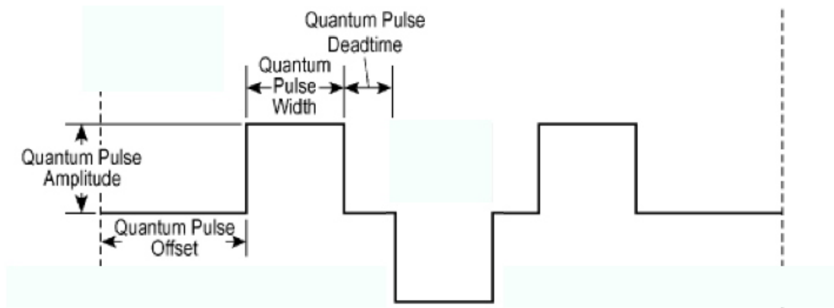

Figure 4. Example of Brillouin's "Q Pulse".

The stimulation power imparted to the core is measured using a circuit shown in Figure 5. The pulse is generated by a proprietary Q Pulse board and delivered to the core using series and termination resistors which help match the load impedance to that of the pulse board output. Using a high speed oscilloscope, the voltage across the end of the core nearest the pulse board is measured as well as the voltage across the opposite end of the core across the termination resistor (Zterm). Zterm also acts as a current measuring resistor. The root mean square (rms) voltage across Zterm is then converted to the rms current.

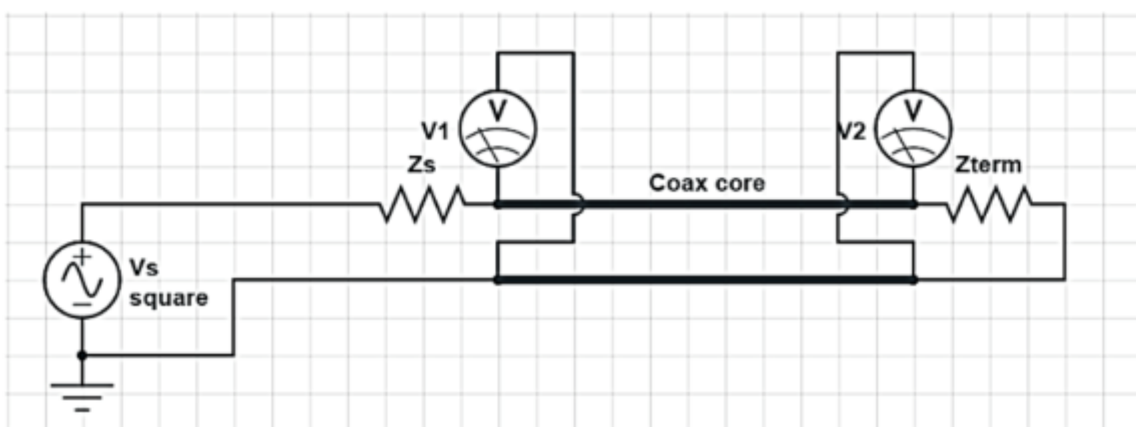

Figure 5. Pulse power measurement circuit

The voltage across the core is determined using the method shown in Figure 6. Figure 6a shows the two voltage traces being aligned in a way that minimizes the time difference. This overestimates the power imparted to the core since any phase lag between voltage and current would impart less input power. This voltage difference is shown in the upper plot of Figure 6. The current is shown in the middle graph and the product of these two (power) is shown in the lower plot. It has been shown that the power calculation is essentially the same (within measurement error) whether it is calculated by multiplying the current and voltage plots point by point or by multiplying the calculated rms voltage by the rms current.

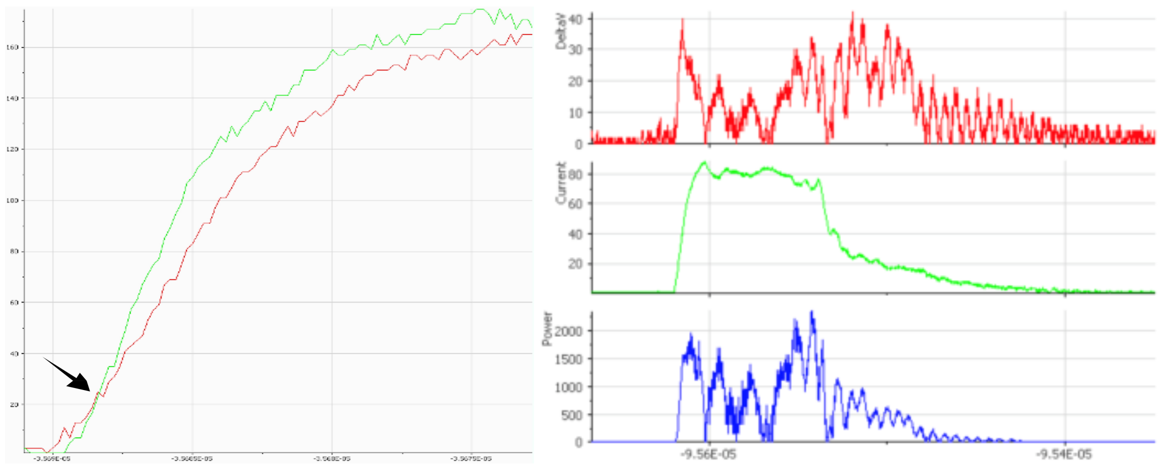

Figure 6. Measurement of the voltage drop across the core

In compensation calorimetry the heater power is varied to keep the core at constant temperature, which generally keeps the inner block at a constant temperature. The difference between the heater power with and without stimulation determines the effect of the stimulation. If this difference is greater than the stimulation that reaches the core, then energy is being produced in the core. Approximately 50 different parameters are collected allowing for calculation of Reaction Power (the power produced by the process induced by the pulse stimulation). Several calculation methods are possible from these parameters. In the Analysis section we describe the two used in this report.

Operation

Figure 7 shows a screenshot from the specially-designed proprietary automation and data collection computer program used to control and collect results from the IPB reactor/calorimeter system. The program has several panes allowing for control of temperature, pressure, pulse voltage, pulse power, pulse width, and pulse repetition rate and gas composition. The program also collects the heater power, the pulse power at the generator as well as at the core, all temperatures, water flow rates and gas pressure. Hydrogen and oxygen concentration in the argon blanket are also measured and collected. In all approximately 50 different parameters are collected and stored every 10 seconds. A sequence file can be used to automatically change any or all of these parameters at specified intervals over a multi-day or multi-week period.

The sheath containing the core is operated with a static fill of hydrogen, helium, or argon gas held at constant pressure up to 10 bar. The temperature of the core is held constant using its embedded heater and thermocouple and controlled from 200°C to 600°C. The outer block temperature is held at 25°C by constant temperature water flowing from a Neslab® chiller.

The power emanating from 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. Only a minor fraction of this power reaches the core as most of it is lost as heat in the electrical components and the transmission line. Of that reduced power only a portion of it influences the heater power as explained in the “Measurement” subsection above. The actual pulse power is measured directly via the methodology presented above.

Operating in power compensation mode, the computer keeps the inner core temperature constant in its set point. When power is imparted from the Q-pulse the heater power is reduced to compensate and maintain a constant temperature. Hence the core temperature, and the inner and outer block temperatures are all held constant.

First operating in He gas, a sequence was operated from 200°C to 600°C in 50°C intervals. At each temperature a given DC power was applied to the coating on the core. This process was then repeated but applying constant power pulses varying pulse width at each temperature. Finally, both automated sequences were repeated in hydrogen gas.

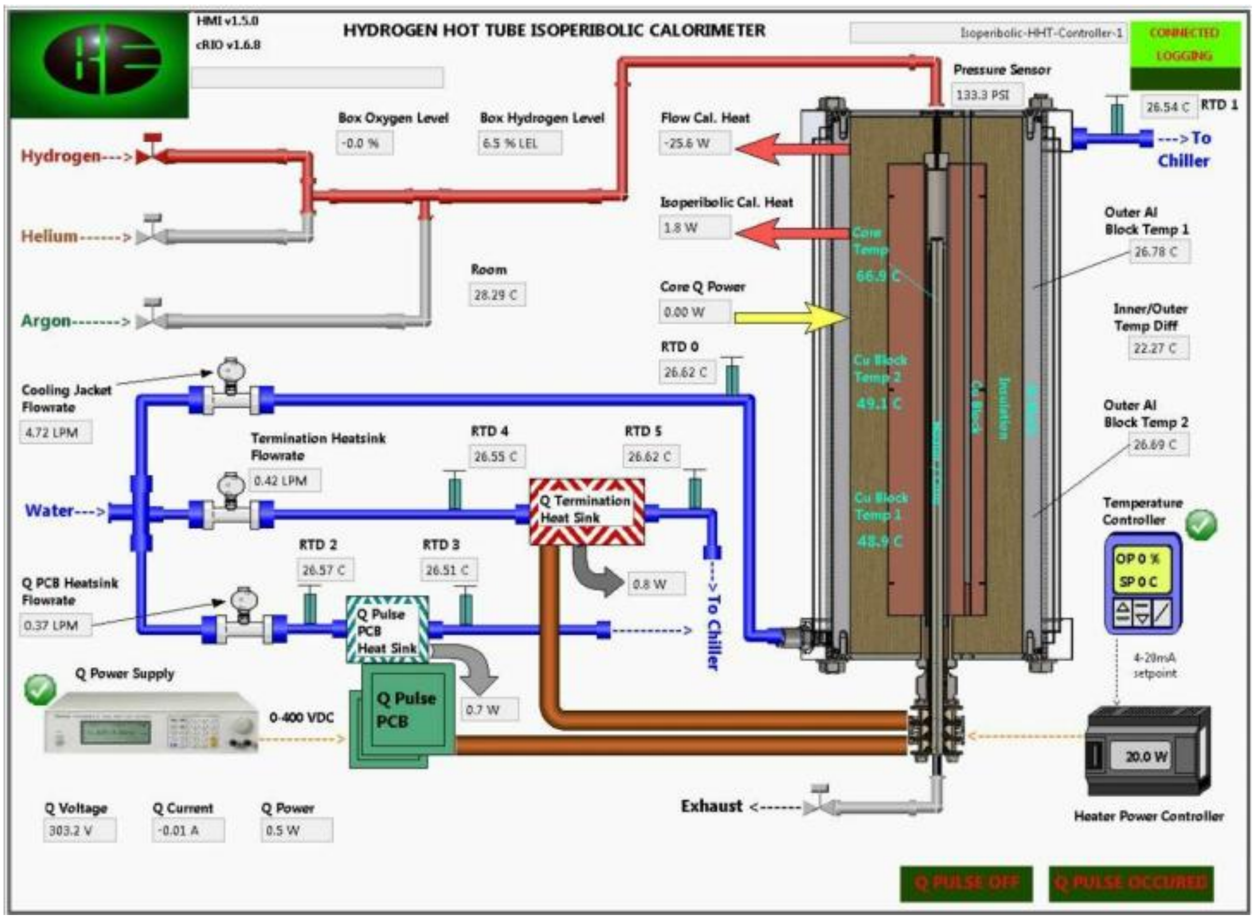

Figure 7. Screenshot of the automation and data acquisition computer program in operation

ANALYSIS

Method A

In our IPB design only a fraction of the stimulation power is imparted to the core heater control because the heater/thermocouple combination is only in contact with approximately half of the core's length. The actual fraction imparted to the core is determined by resistively heating the core's coatings using different powers sourced from a well-measured DC power supply and measuring the heater's response at different temperatures. At each temperature, a linear function ($P_{drop} = m*P_{coating} + b$) is determined between the power imparted to the core's coating via resistive heating and the power reduction in the internal heater necessary to maintain temperature. Representative linear coefficients at different temperatures are shown in Table 2.

Table 2. Correlation of power imparted to the core's internal heater by resistively heating its coating:

($P_{drop} = m*P_{coating} + b$)

Temperature/°C	m	b
150	0.41	0.07
200	0.44	0.10
250	0.48	0.07
300	0.51	0.06
350	0.55	0.01
400	0.56	0.03
450	0.57	0.03
500	0.57	0.07

The basic calorimetric calculations are shown in Equations 1 through 4 when the isoperibolic calorimeter operates in heat flow mode. Heat flow (Q_{flow}) is measured using k_{flow}, which is determined via calibration and the temperature difference between the inner and outer blocks. Heat loss (Q_{loss}) represents the heat loss to air that is not accounted for in (Q_{flow}) and is also determined via calibration. The output heat (Q_{out}) is the sum of (Q_{flow}) and (Q_{loss}). The input heat is the sum of power applied to the heater (Q_{heater}) and the amount of heat experienced by the heater from the pulse (Q_{pulse}). Hence the heat due to the reaction ($Q_{reaction}$) is the difference between the output and input heats.

$$Q_{reaction} = (Q_{flow} + Q_{loss}) - (Q_{heater} + Q_{pulse}) \quad \text{Equation 1}$$

$$Q_{flow} = k_{flow}(T_{core} - T_{outer}) \quad \text{Equation 2}$$

$$Q_{loss} = k_{los}(T_{core} - T_{air}) \quad \text{Equation 3}$$

$$Q_{out} = Q_{flow} + Q_{loss} \quad \text{Equation 4}$$

We use the subscripts 1 to mean operation without Q power and 2 to mean operation with Q power. In power compensation mode, we compare the heater power imparted to the core with and without Q pulses applied. Because T_{core}, T_{outer}, T_{air} are held constant in this mode Q_{flow} and Q_{loss} are the same with and without Q power. As such Equation 4 cannot be used to calculate

Q_{out} in power compensation mode. The difference between $Q_{reaction1}$ and $Q_{reaction2}$ is shown in Equation 5. When Q pulses are not applied Equation 6 defines Q_{pulse} and $Q_{reaction}$ to be zero. This simplifies equation 5 to that shown in Equation 7 where ΔQ_{heater} is the difference between the heater applied with and without Q pulses and ΔQ_{out} is output power with and without Q power. The empirical determination of ΔQ_{out} is shown in Equations 8 through 10.

$$Q_{reaction2} - Q_{reaction1} = (Q_{flow2} - Q_{flow1}) + (Q_{loss2} - Q_{loss1}) - (Q_{heater2} - Q_{heater1}) - (Q_{pulse2} - Q_{pulse1}) \quad \text{Equation 5}$$

Without Q pulse: $Q_{pulse1} = Q_{reaction1} = 0W$ Equation 6

$$Q_{reaction} = (Q_{heater1} - Q_{heater2}) - Q_{pulse} + (Q_{out2} - Q_{out1}) = \Delta Q_{heater} - Q_{pulse} + \Delta Q_{out} \quad \text{Equation 7}$$

Replacing pulses with DC power through the core to emulate the physical source of the heat, as described in the measurement subsection, allows us to determine the amount of Q pulse power that affects the core heater power when $Q_{reaction} = 0$. Rearranging Equation 7 where $Q_{heaterDC}$ is the heater power when DC power is applied to the core coating, Equation 8 allows us to calculate ΔQ_{out} at different applied DC powers (Q_{DC}). Finding the linear fit parameters from the plot of ΔQ_{out} vs Q_{DC}, Equation 9 shows us the relationship between applied DC power (Q_{DC}) and the DC power output to the environment (ΔQ_{out}), which cannot be measured directly.

The same equation can be used to find ΔQ_{out} with Q power applied substituting (Q_{pulse}) for Q_{DC}.

$$\Delta Q_{out} = Q_{DC} - (Q_{heater} - Q_{heaterDC}) \quad \text{Equation 8}$$

Since $\Delta Q_{out} = m(Q_{DC}) + b$ then $\Delta Q_{out} = m(Q_{pulse}) + b$ Equation 9

Equation 10 shows the calculation of $Q_{reaction}$ when operating in power compensation mode where $\Delta Q_{heater} + \Delta Q_{out}$ would equal Q_{pulse} (or Q_{DC}) when $Q_{reaction}$ =0. Equation 11 defines our effective coefficient of performance for the power compensation mode for our isoperibolic calorimeter system.

$$Q_{reaction} = \Delta Q_{heater} - Q_{pulse} + \Delta Q_{out} \quad \text{Equation 10}$$

$$COP = (\Delta Q_{heater} + \Delta Q_{out})/Q_{pulse} = (\Delta Q_{heater} + m(Q_{pulse}) + b)/Q_{pulse} \quad \text{Equation 11}$$

Method B

The second method of analyzing the calorimetry is more direct in that instead of calculating the power loss by the calorimeter it determines the amount of heater power compensation (HPC) for different amounts of DC calibration power. In fact, this method is analogous to the traditional isoperibolic calorimeter analysis except that it substitutes heater power compensation for the temperature difference. In order to calculate $Q_{reaction}$ as output power minus input power, Method B compares the heater power compensation (HPC) from DC calibration to that from pulse stimulation. Using this DC calibration the relationship between input power and HPC is determined so that with input pulse power the HPC can be used to back calculate the power from the pulse imparted into the core.

First the linear relationship between HPC and DC power (Q_{DC}) is found by fitting a linear equation to HPC vs Q_{DC} when Q_{DC} is varied across the range of Q_{pulse}. These linear coefficients are then applied to measured Q_{pulse} to calculate HPC(DC), the amount of HPC expected as if the pulse power were DC power. Q_{reaction} is then calculated as shown in Equation 12, where HPC(Q) is the actual HPC measured when the pulse is applied. Equation 13 is then used to calculate COP.

$$Q_{\text{reaction}} = \text{HPC(Q)} - \text{HPC(DC)} \qquad \text{Equation 12}$$

$$COP = Q_{\text{reaction}}/Q_{pulse} = (\text{HPC(Q)} - \text{HPC(DC)})\,/Q_{pulse} \qquad \text{Equation 13}$$

The linear slope coefficient is similar to the value “m” used in Method A. Method A uses the fit to determine the input power lost to the environment and Method B uses the fit to determine the percentage of input power that interacts with the core’s heater and thermocouple. Table 3 shows the values for “M”, the linear fit coefficient from Method B.

Table 3. List of linear fit coefficients determined and employed in Method B:

Temperature/°C	“M”
150	0.45
200	0.47
250	0.50
300	0.53
350	0.57
400	0.58

RESULTS

Figure 8 plots the input and output powers versus time for a pulse sequence operated at 600°C as the pulse length is varied from 100 to 300 and back to 100 ns while maintaining constant Q power. Note that the heater power is invariant with pulse length. Calculation shows that the reduction in heater power (power compensation) is essentially equal to the Q power that reaches the heater (i.e. no $Q_{reaction}$).

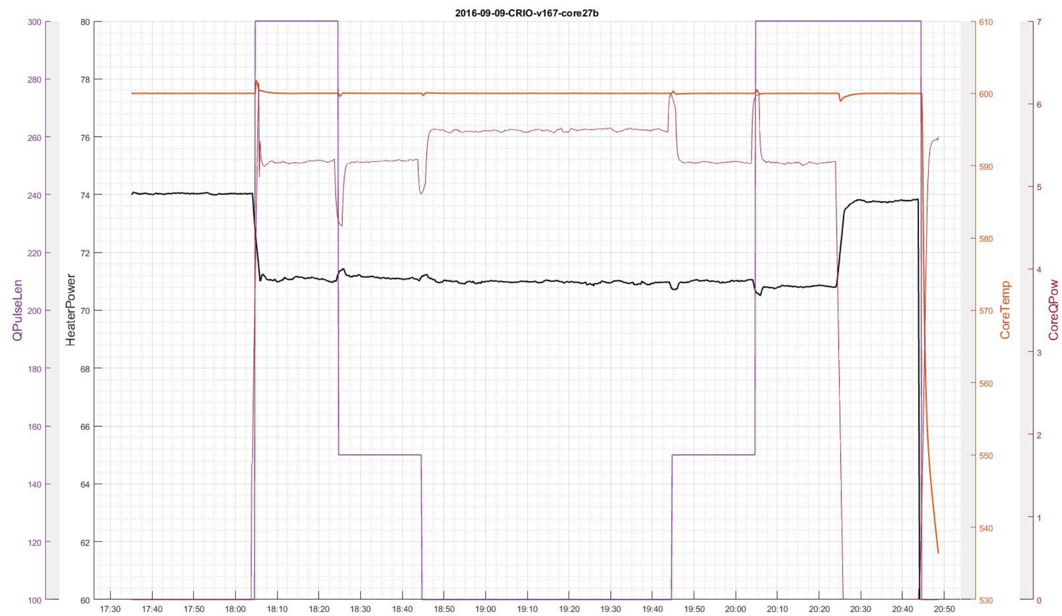

Figure 8. Effect of varying pulse length at constant power on heater power compensation at 600°C

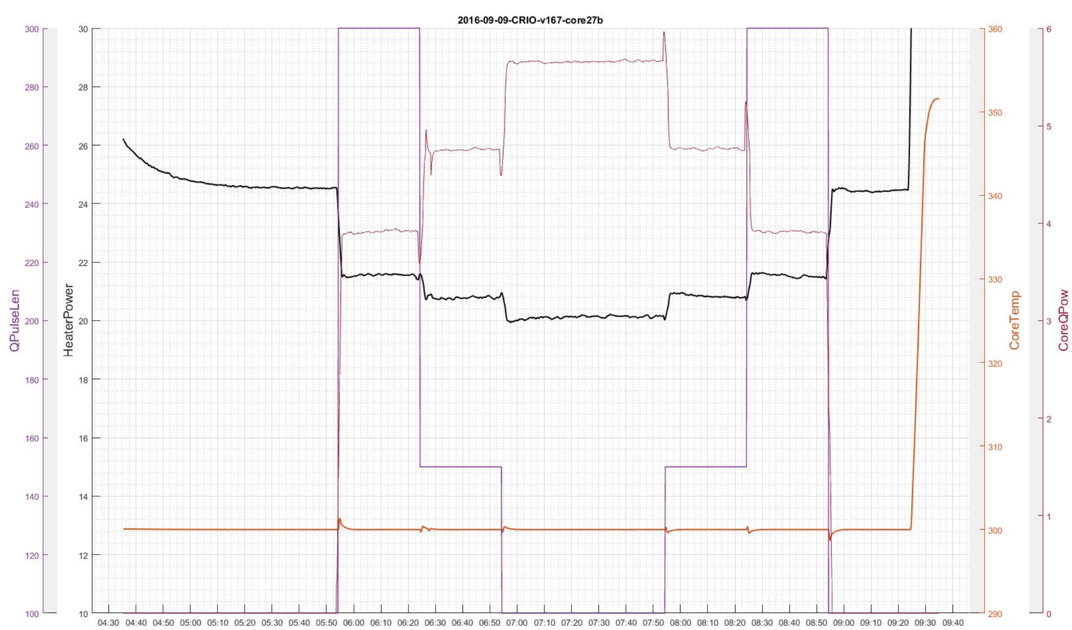

Figure 9. Effect of varying pulse length at constant power on heater power compensation at 300°C

Figure 9 plots the same sequence operated at 300°C. Note that the power compensation amount is very dependent on the pulse length. Although the total pulse power from the generator is constant the pulse power measured at the core does vary with pulse length. Still, the magnitude of the power compensation is a greater percentage of the pulse power at 100ns than at 300ns. Calculations show that at 300ns the $Q_{reaction}$ is quite small but is of much greater magnitude at 100ns. Table 4 summarizes the COP results from a single run calculated using Method A. Table 5 summarizes the COP results from six such runs.

Table 4. Summary of COP calculations from a Q pulse length run similar to that shown in Figure 9:

EXPERIMENT RUN DETAILS						
IPB2 STUDIES ROH, Core 27b Ni/Pd, in H2, CRIO-v167						
Operator	Roger H.	Roger H.	Roger H.	Roger H.	Roger H.	Roger H.
Date	09/17/16	09/17/16	09/17/16	09/17/16	09/17/16	09/17/16
DUT	IPB2	IPB2	IPB2	IPB2	IPB2	IPB2
ΔQout calibration	IPB2 28B H2	IPB2 28B H2	IPB2 28B H2	IPB2 28B H2	IPB2 28B H2	IPB2 28B H2
PULSE SYSTEM PARAMETERS						
Pulse Width	100	100	100	100	100	100
REACTOR GAS	H2	H2	H2	H2	H2	H2
Qvoltage, Chroma, VDC	300	300	300	300	300	300
Q generator type	Half-H	Half-H	Half-H	Half-H	Half-H	Half-H
Core Temp Setting (celsius)	**150**	**200**	**250**	**300**	**350**	**400**
Pi-Filter QPOW Setting	50.00	50.00	50.00	50.00	50.00	50.00
COP MEASUREMENT VALUES						
Measured pulse power across core oscope (Q_pulse)	**3.75**	**4.31**	**5.00**	**5.66**	**4.94**	**4.51**
Heater power - no pulses (Q_heater)	9.06	13.70	18.77	24.43	30.57	37.72
Heater power - with pulses (Q_heater)	7.24	11.13	15.30	20.12	27.48	34.94
Delta heater power (ΔQ_heater)	**1.83**	**2.58**	**3.47**	**4.31**	**3.08**	**2.77**
m (for Q_k equation)	0.55	0.55	0.49	0.49	0.42	0.42
b (for Q_k equation)	-0.04	-0.04	0.03	0.03	-0.02	-0.02
Q_k = m*Q_pulse + b (Q Power dissipated under heat spreader)	2.02	2.32	2.46	2.78	2.04	1.87
COP = (ΔQ_heater + Q_k) / Q_pulse	**1.02**	**1.14**	**1.19**	**1.25**	**1.04**	**1.03**

Table 5. Summary of COP calculations from six Q pulse runs similar to that shown in Figure 9:

Temperature/°C	Pulse Width/ns	COP
300	150	1.41
250	150	1.44
300	150	1.21
600	150	1.03
300	300	1.28
600	150	1.01
300	150	1.43

It is important to note in Table 4 that the runs performed at 300°C showed COP significantly greater than 1.0 while those at 600°C are essentially 1.0 within experimental error. This can possibly be explained as the Pd inner layer totally de-loading its hydrogen as we have seen before at this temperature and the Ni, although retaining hydrogen traverses its Curie point, changing its electrical and chemical properties. Similar results have been seen from more than 50 runs performed over this period.

Recently Method B was used to calculate COP from some more recent runs similar to that shown in Figure 9. As shown above operating above 600°C usually does not yield any reaction heat. Recent runs were operated only up to 400°C. Table 6 summarizes $Q_{reaction}$ and COP calculated from recent runs analyzed using Method B.

Table 6. $Q_{reaction}$ and COP from recent runs calculated using Method B:

Temperature/°C	$Q_{REACTION}$ @ 100ns/W	$Q_{REACTION}$ @ 150ns/W	COP @ 100ns	COP @ 150ns
150	0.73	0.88	1.24	1.33
200	0.99	1.15	1.30	1.40
250	1.18	1.51	1.33	1.47
300	1.91	2.08	1.47	1.58
350	1.41	1.65	1.37	1.48
400	1.06	1.42	1.29	1.42

There are many more test runs that occurred with Brillouin's IPB HHTs, which can be analyzed using these and other methods but the COP's found in those tests are very similar to the runs that were examined and summarized in this Report.

CONCLUSIONS

Low energy nuclear reactions (LENR) can produce thermal power when Ni, and other metal, coated tubes are stimulated using fast rise-time pulses. These experiments operated in H_2 or He gas from 200°C – 600°C. The exact same procedure was performed in each gas. Comparative thermal measurements were performed between heater-only power and heater and pulse power.

These runs were performed in isoperibolic calorimeters operated in power compensation mode, where the heater adjusts its power to keep the inner and outer temperature-difference constant. Over 100 runs were performed on five different Ni-coated cores. Three additional cores were also tested for other experimental purposes. COP's from 1.0 to over 2.0 were measured depending on stimulation conditions. Recent test runs have not averaged above 1.5, although the core's coating composition and metallurgy are still being optimized. Better calorimetry is regularly being optimized and implemented.

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