Proposal for E-Cat Replication

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Introduction

A couple of years ago I attempted to replicate Celani's experiments using H_2 + NiCu wire, with no conclusive results. However, much of the apparatus can readily be repurposed for an E-cat experiment, particularly the calorimeter and control/monitoring electronics.

Original Cell Design and Modifications for E-Cat

The original cell consisted of concentric fused quartz tubes utilizing Conflat hardware for feedthroughs and H_2/Vacuum connections. Machined aluminum end caps with Viton O-rings maintain vacuum or pressure. The entire cell operates in an insulated enclosure through which air is blown and is monitored via closed-loop thermal mass flow calorimetry.

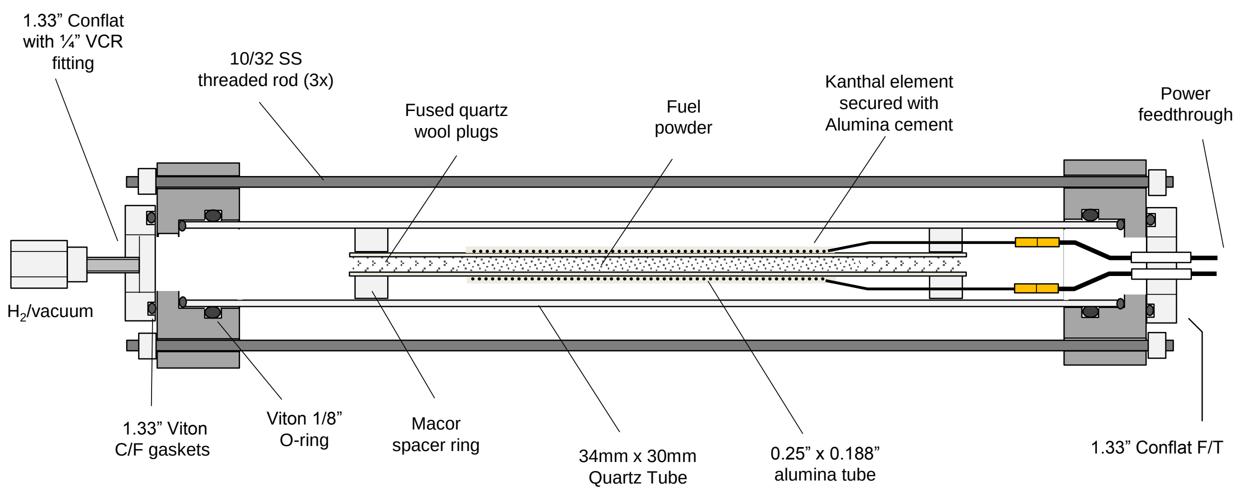


Figure 1: Diagram of E-Cat Cell

I propose to replace the Ni wire and inner quartz tube with an alumina tube, wound with Kanthal wire held in place by alumina cement. The alumina tubing shall contain a mixture of Ni powder and metallic Li (and perhaps Al powder as well). H_2 shall be introduced in gas form from an external source. The ends of the alumina tube shall be plugged with fused quartz wool to keep the metals inside, but still permit H_2 diffusion into the Ni/Li. Cell temperature will be monitored via a narrow field IR thermometer. Fused quartz in essentially transparent in the 2.0-2.4 um range used by the IR thermometer and can tolerate much higher temperatures than borosilicate glass.

Why not use $LiAlH_4$? Aluminum lithium hydride is a hazardous material. Metallic lithium is not quite as hazardous, since it oxidizes only slowly in air. There are advantages to maintaining an external source of H_2, rather than relying on the decomposition of $LiAlH_4$, in particular the ability to control independently the Li/H_2 ratio.

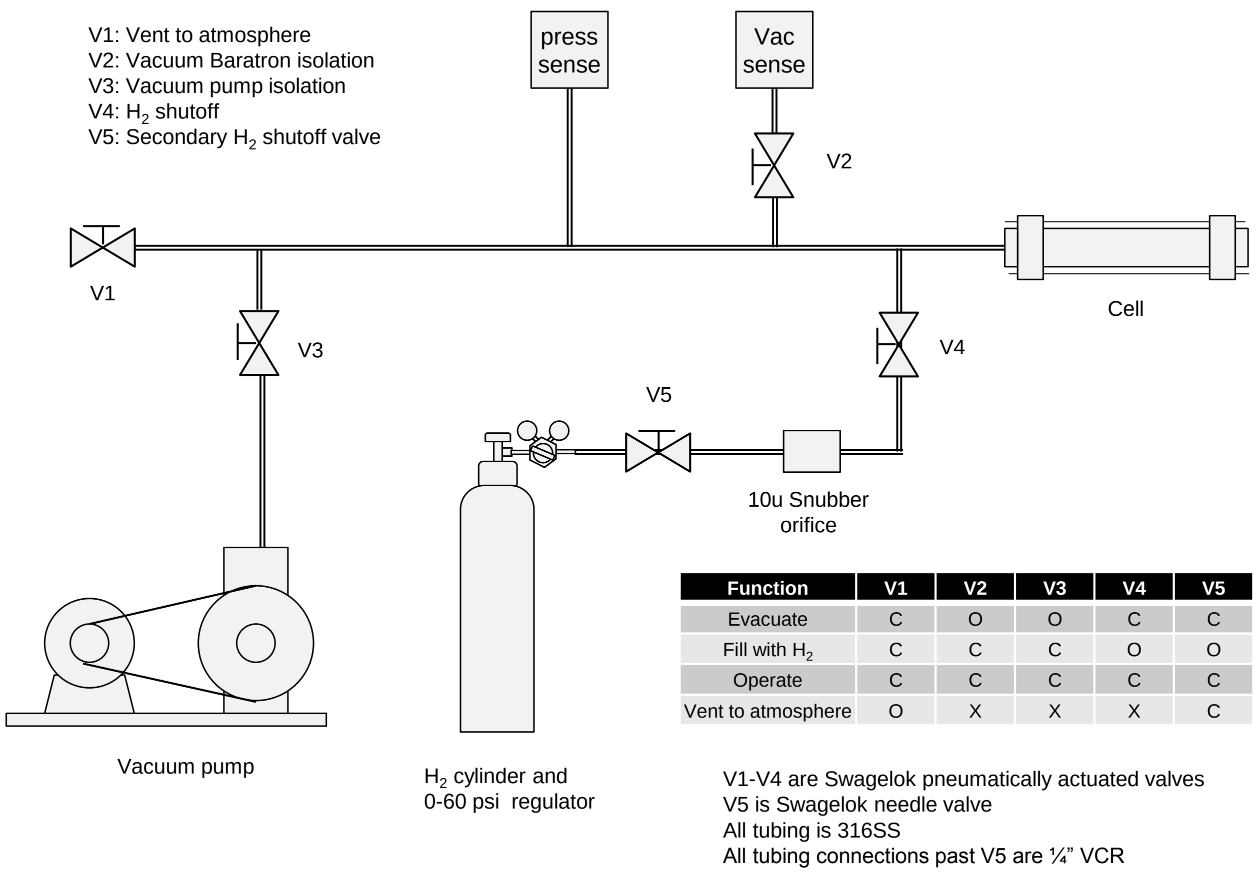
Having a vacuum source is important. It permits evacuation of atmospheric gas from the cell prior to the introduction of H_2 and makes H_2 loading of the Ni powder easier since the H_2 will naturally fill the vacancies in the Ni powder to whatever pressure is set. This is a pressure driven, rather than a diffusion driven, process.

Aluminum, which occurs as a byproduct of the thermal decomposition of $LiAlH_4$, may provide a benefit by virtue of its ability to reduce oxides of lithium and act as a scavenging agent. For that reason I plan to include a few percent by weight of powdered Al into the Ni powder.

H_2 and Vacuum

In the Celani experiment the apparatus was designed to accurately monitor both pressure and vacuum. H_2 and vacuum pressures are monitored by a pair of Baratrons accurate to better than 1%. Sudden overpressure events can be monitored and shut down before reaching dangerous levels. Additionally, the relatively large cell volume provides space for gas expansion, a much larger volume than a typical closed E-cat cell.

All gas and vacuum connections are through VCR fittings that have been brazed to 316SS tube. Ni or Cu washers are used in the VCR fittings to achieve a gas tight seal under either pressure or vacuum and at temperatures up to 300C. To my knowledge, no other commercially available technology can operate under both pressure or vacuum conditions at elevated temperatures. VCR fitting are much less leak prone than Swagelok ferrule-type fittings because there is only a single, replaceable metal-to-metal seal.



Function	V1	V2	V3	V4	V5
Evacuate	C	O	O	C	C
Fill with H_2	C	C	C	O	O
Operate	C	C	C	C	C
Vent to atmosphere	O	X	X	X	C

Figure 2: Hydrogen/Vacuum System

As illustrated above, the apparatus provides the ability to evacuate the cell as well as to pressurize it to a specified value. If desired, a sixth valve could be added at the cell’s input, thereby allowing a loaded cell to be removed from the H_2 feed and operated in isolation.

Calorimetry and Power Control

Most E-cat replication attempts have suffered from poor calorimetry methodology. While a COP >3 is easily detected, that does not provide an excuse for sloppy technique. Having spent a couple of years learning from my mistakes, I'm hopefully now in a position to know most calorimetry pitfalls and how to avoid them.

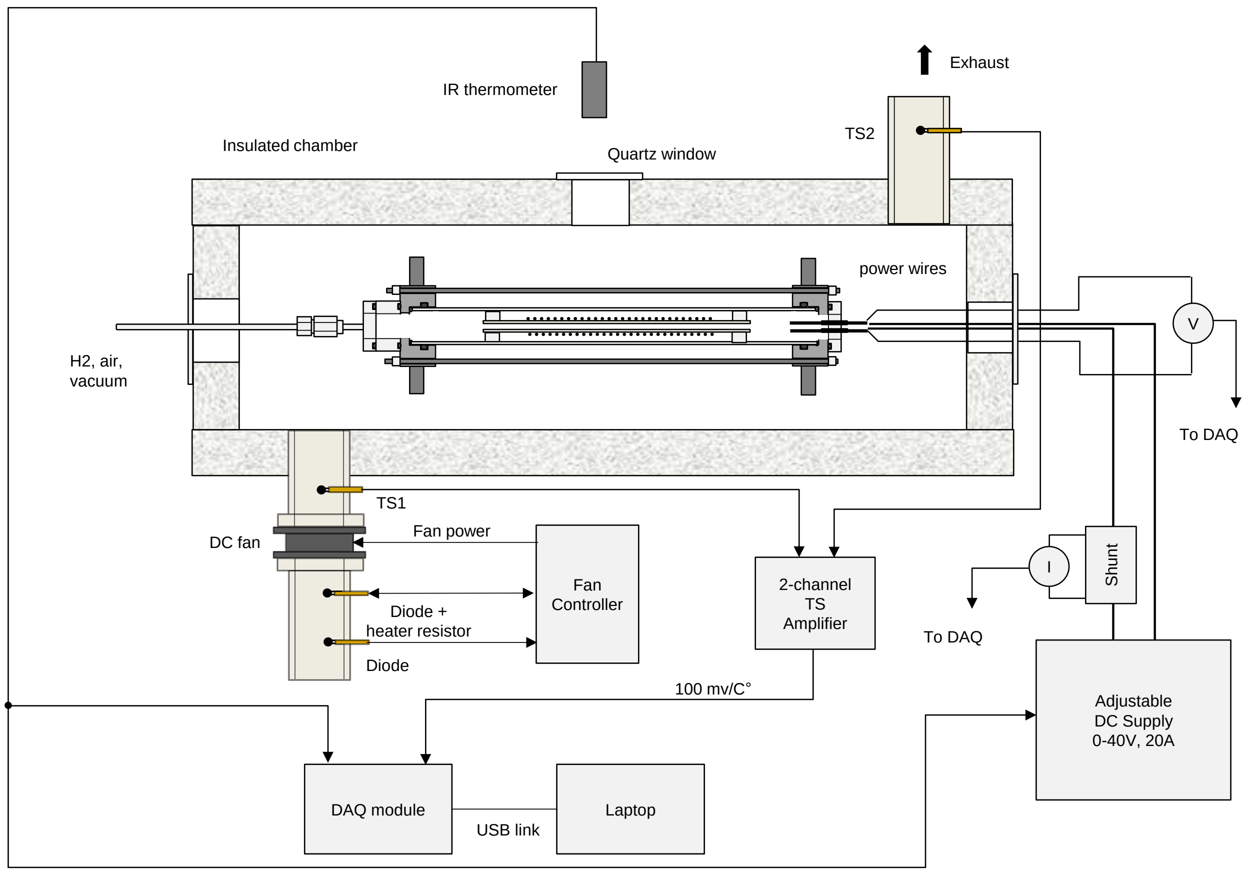


Figure 3: Calorimeter and Power Control/Monitoring

Airflow calorimetry is used to monitor the cell's thermal output. The key to making this method accurate is a closed loop control for the fan controlling the airflow. A pair of diodes, one of which is thermally bonded to a heater resistor, is located in the input port and sees air at the ambient temperature. Both diodes are forward biased, and a diode's junction voltage decreases with the junction temperature rise in a predictable way. The fan controller monitors the junction temperatures of the two diodes and attempts to maintain a fixed voltage (and therefore temperature) difference between the two diode junctions by adjusting the fan speed. Doing so is equivalent to maintaining a fixed thermal mass flow through the calorimeter. Calibration measurements of temperature vs. applied power show a nearly straight line, crossing through the origin, for power levels up to 200 watts (equivalent to a 40 °C rise). These results differ from the case where the fan is run at a fixed voltage, where the plot is not linear. Obviously, I plan on recalibrating once the E-cat cell is completed, and calibration will go up to the maximum anticipated cell operating temperature.

Air temperature rise between inlet and outlet ports is monitored by a pair of semiconductor temperature sensors generating 10 mV per degree C. The output of these sensors is scaled by a factor of 10 via a pair of instrumentation amplifiers that also guarantee good noise rejection. The output of the amplifiers is fed to a DAQ module that connects to a PC running a data acquisition program.

Power to the cell is provided by an 800 watt DC supply. Voltage is measured at the thermal boundary by means of a second pair of wires. Current is measured by means of a precision shunt. Overall power measurement accuracy has been verified by a 5 digit lab voltmeter, and the accuracy is better than 0.1%. The power supply has an external voltage programming option such that its output voltage can be controlled by the IR thermometer output. With this capability it is possible to maintain a fixed cell temperature for varying COP values.

For the Celani experiment I used a thermocouple bonded to the inner tube. At E-Cat operating temperatures thermocouples are expensive and difficult to use. As an alternative I plan to use a narrow field IR thermometer and will calibrate it with an optical pyrometer. This calibration method reduces the errors caused by uncertainties in calculating alumina emissivity. A quartz window into the insulated chamber provides the necessary transparency in the 2.0-2.4 um wavelength that the IR thermometer employs.

Photographs of Apparatus

The first photo shows a partially assembled cell. The left side has a VCR inlet for H_2 or vacuum. The right side has a Conflat electrical feedthrough that will eventually connect to the Kanthal A1 wire wound on the alumina tube. Macor spacers center the alumina tube and provide some amount of thermal insulation for the ends of the cell. Three sections of threaded rod, secured with knurled nuts, provide an easy means of assembly and disassembly. Overall cell dimensions are approx. 14” x 2.5”. Hydrogen is an excellent thermal conductor, so I do not anticipate problems with getting heat out of the alumina tube to the surface of the quartz envelope.

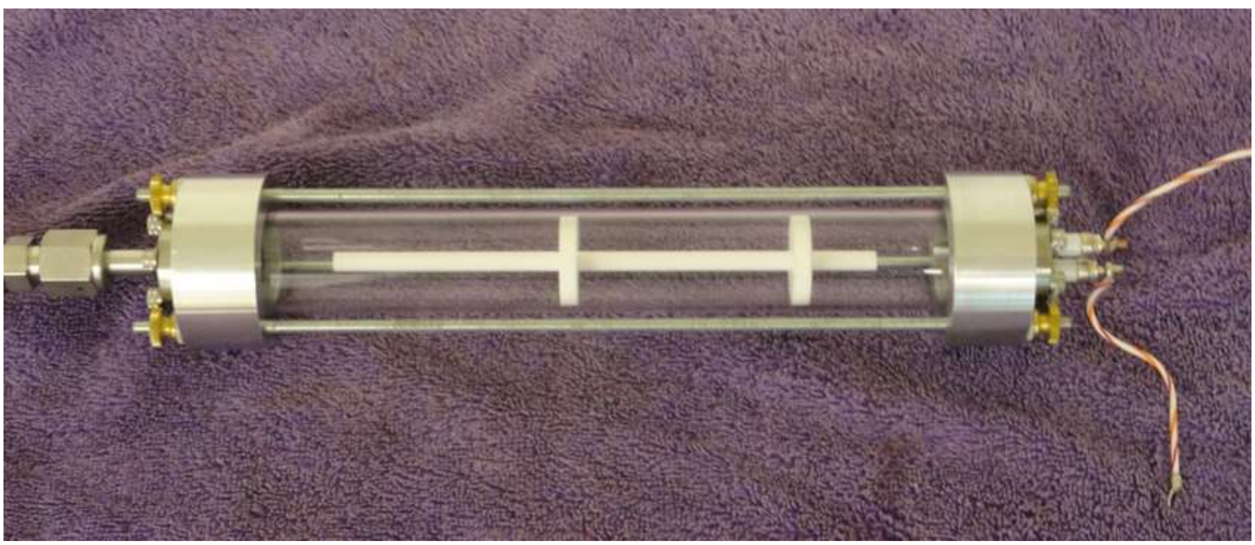


Figure 4: Partially Completed Cell

Gas and vacuum controls are shown in the photograph below. The cylindrical objects with nylon tubing coming out of the top are pneumatically operated Swagelok valves, and the four switches are pneumatic. The other two cylindrical objects with wires are pressure or vacuum Baratrons. They connect to a Vacuum General controller that provides a DC output signal that is proportional to the pressure or vacuum reading, so vacuum or pressure readings can be fed into the DAQ module, if desired.

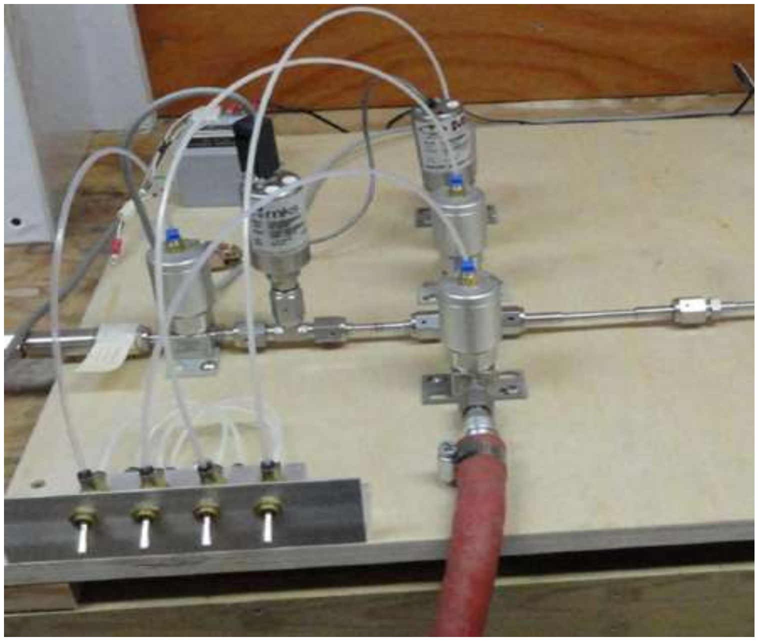


Figure 5: Gas and Vacuum Manifold and Valves

Figure 6 shows the calorimeter chamber with the top removed. The digital meters monitor inlet and outlet air temperatures, and the third meter measures the thermocouple output. As stated earlier, the E-cat experiment will not use a thermocouple to measure cell temperature.

Figure 6: Calorimeter Chamber and Monitoring meters

Next Steps

Some of the control electronics such as the fan controller need to be redesigned to drive a higher amperage fan. The original apparatus used thermistors to monitor inlet and outlet temperatures. As mentioned earlier, these will be replaced with IC temperature sensors that are more accurate.

Once the electronics are built, then I'll wind and secure the Kanthal wire onto the alumina tube and perform power vs. air temperature rise calibration with ~1.5 atm. H_2 in an empty alumina tube. That will give a baseline. Then we'll see what happens when the alumina tube is loaded with H_2 plus Ni/Al/Li/Al_2O_3. The last compound is included to prevent the Ni from sintering. Alumina powder can also be used as a "dilution agent" to reduce the energy density of the Ni/Li and may be used as a means of preventing runaway conditions.

Comments and suggestions are welcome.

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