Search for excess heat in metal cathodes exposed to pulsed hydrogen plasma

Rick Cantwell[1], Matt McConnell[1], Tom Claytor[2]

[1]Coolescence, LLC, Boulder CO USA,

rick@coolescence.com

[2]Guest Scientist, Los Alamos National Laboratory

Background

- Claytor[1]
  - Report tritium
    - 1500-2500 V, 150-250 torr, > 5 A/cm^2
- Karabut[2]
  - Report excess heat, nuclear products
    - 100-500 V, 3-10 torr, > 10-100 mA/cm^2

1. Claytor, et. al. "*Tritium Production from Palladium Alloys*", ICCF-7, 1998, p. 88
2. Karabut, et. Al. "*Nuclear product ratio for glow discharge in deuterium*", Phys. Lett. A. 1992, p. 265

Background

Recently, simple thermometry experiments suggest possible excess heat using mixed H +D with Ni cathode[3]

- Plasma produces a greater temperature rise than same power delivered into a calibration resistor
- Excess power depends on H:D ratio in gas
- Excess power depends on cathode material

3. Claytor, Private conversation, September 2011

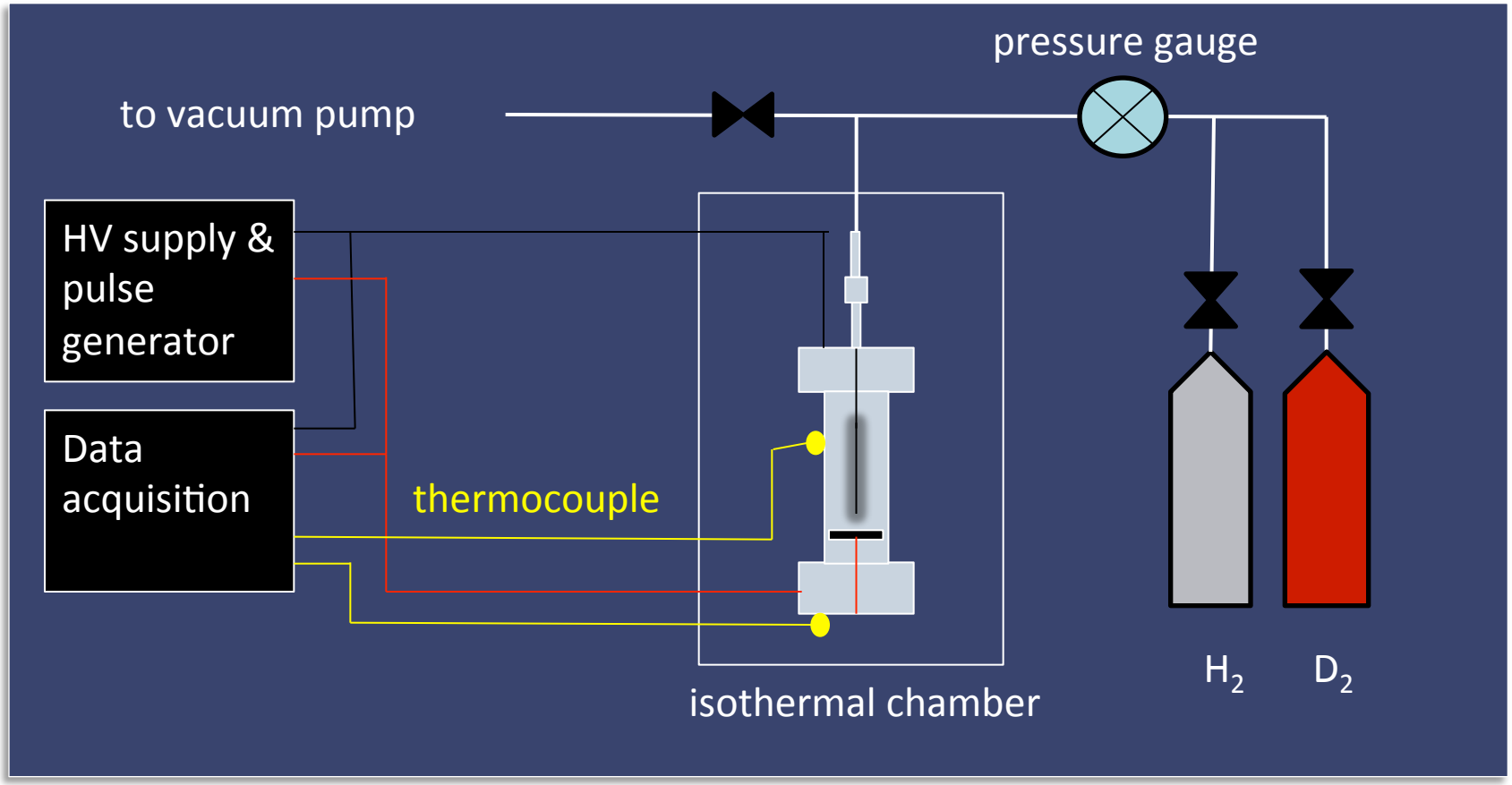
Research Objective

- Do we see excess heat in H/D plasma?
- Does excess heat depend on H:D ratio?
- Does excess heat depend on cathode material?

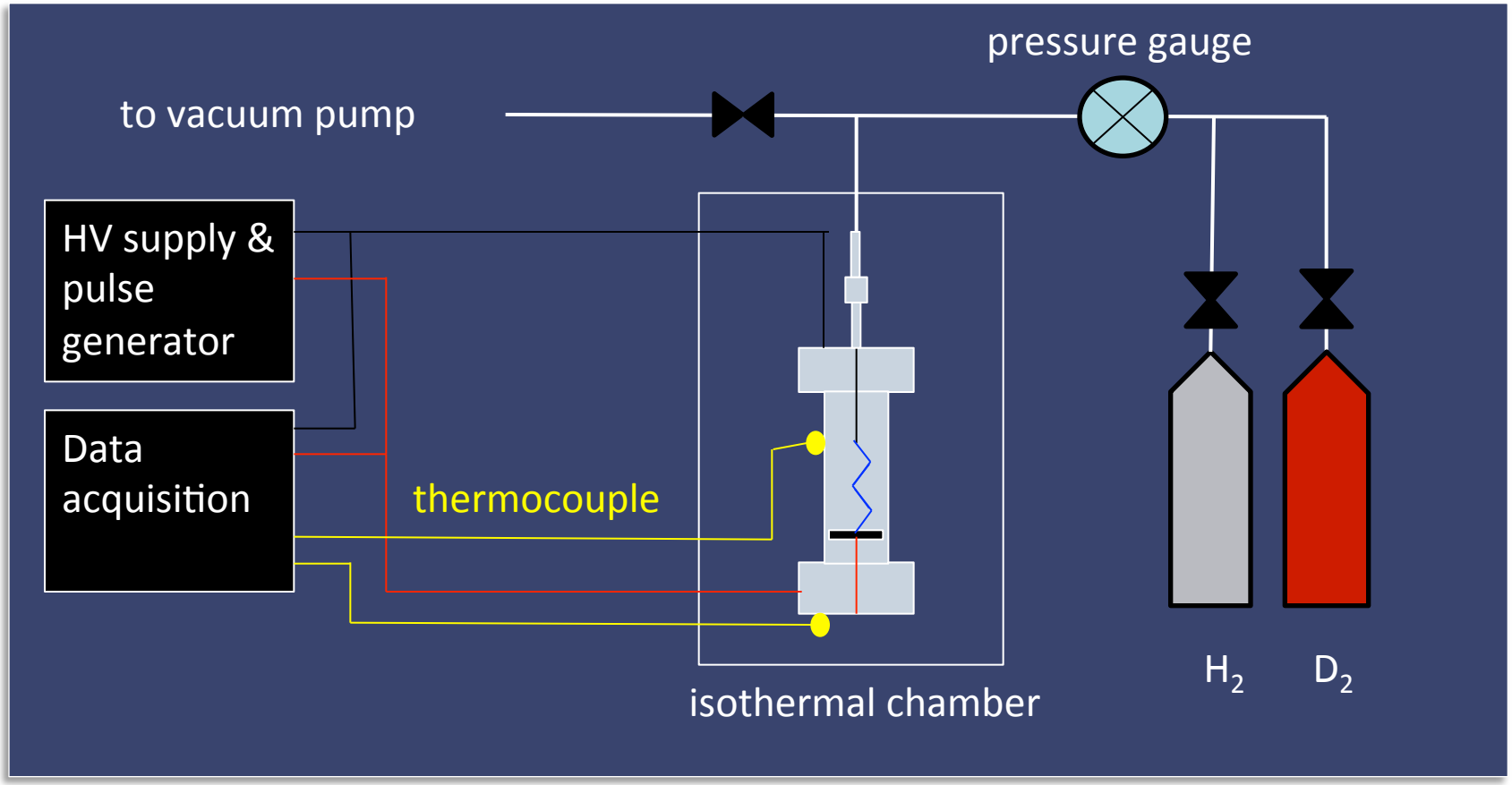
Experiment #1: Goal

- Look for excess heat using thermometry
  - Run cell in isothermal enclosure
  - Look how T and P change when power is applied to cell
  - Compare plasma changes to resistor changes under similar conditions

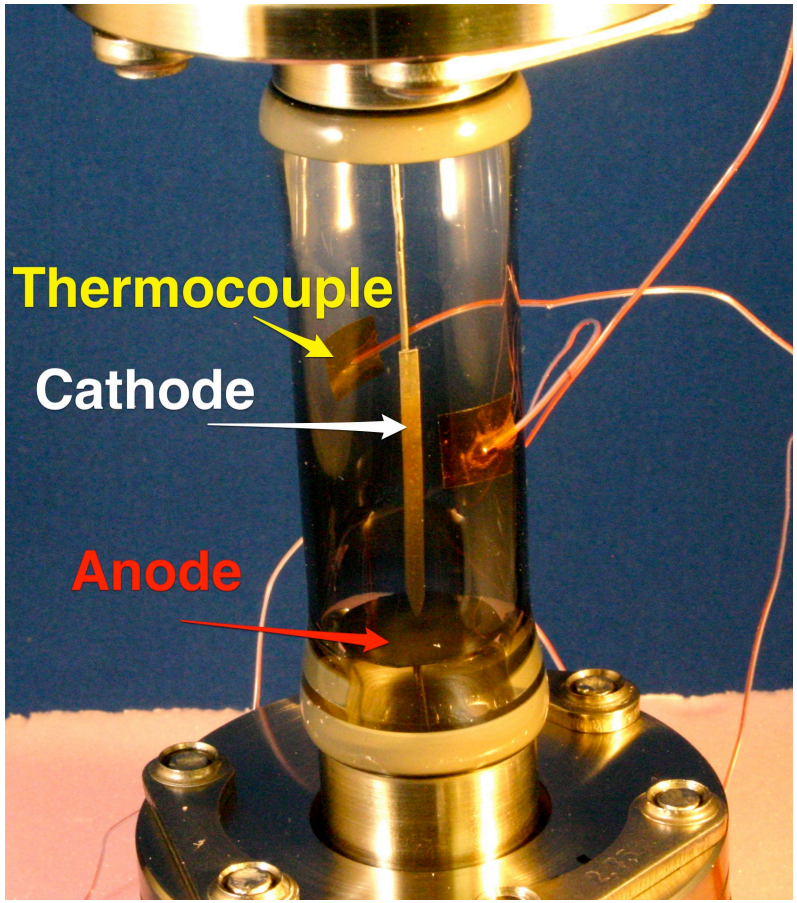
Block diagram: Operation



Block diagram: Calibration



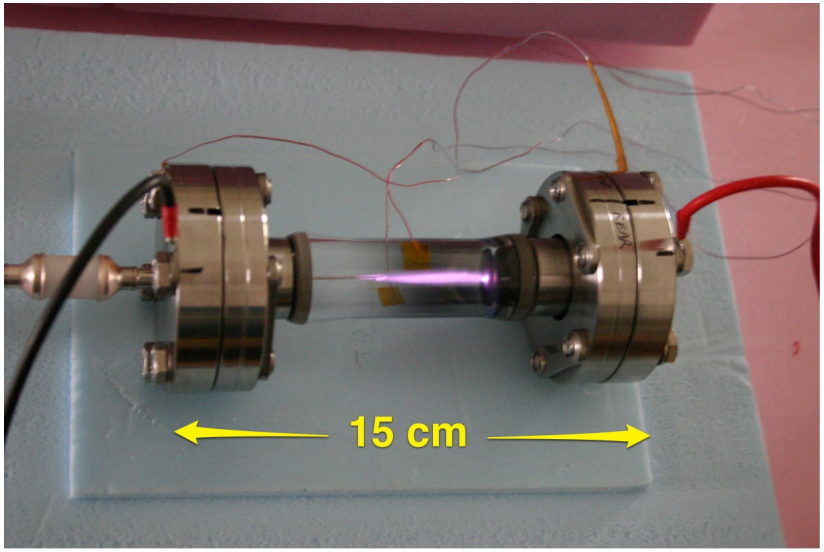
Plasma cell

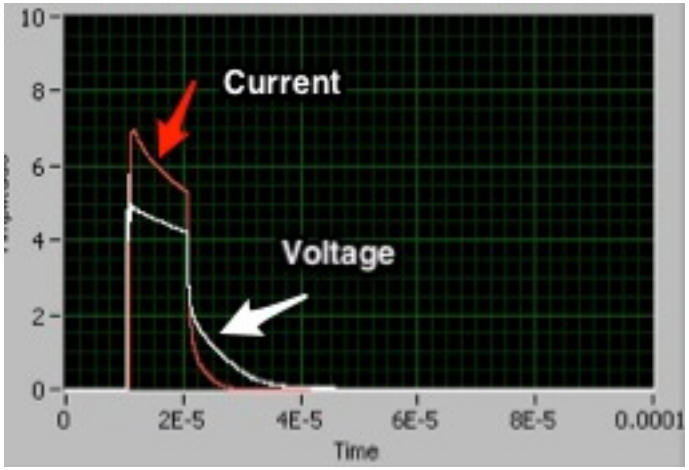


- Cathode: 2 x 40 mm
- Anode: 18 mm dia. Ni mu-metal alloy
- Cathode-Anode spacing: 1-3 mm
- 45 cm^3 volume
- CF 2.75 flanges
- Thermal time constants
  - 4 min center
  - 40 min flanges

Plasma characteristics

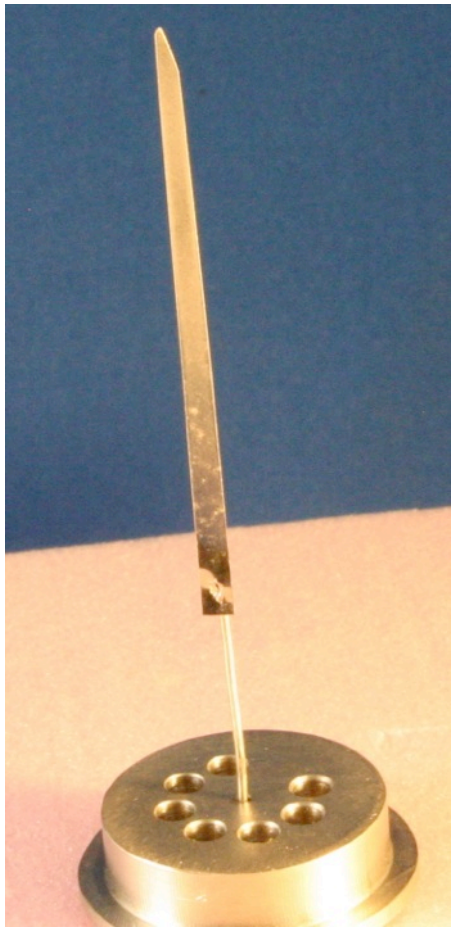
- 150-250 torr
- 900-1300 volts, 5-10 amps
- 5-20 µs pulse @ 50-100 Hz
- Constant power operation
- Sample V &I @ 14-bit, 100 M-sample/sec



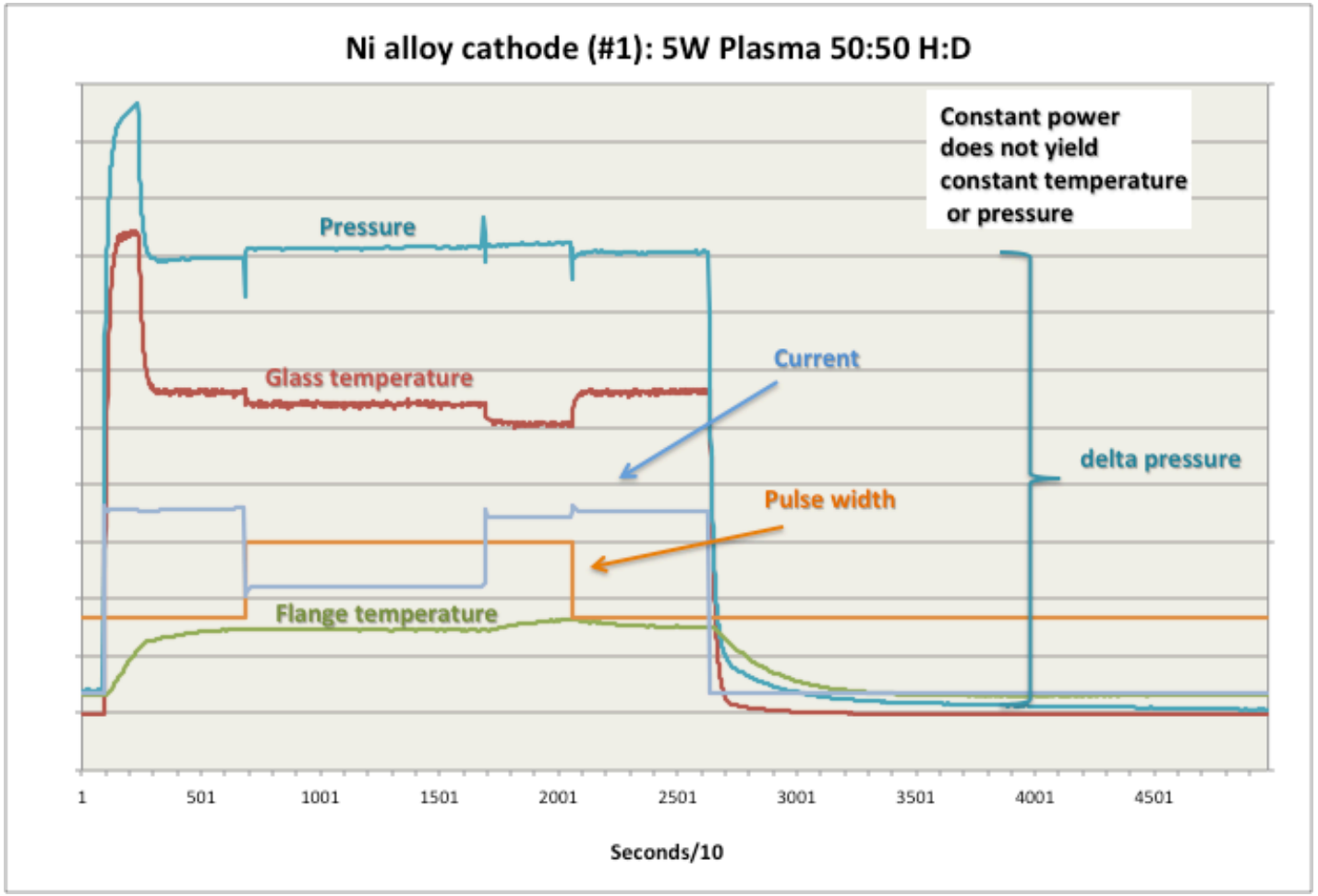


Cathode Materials

- Ni alloy (Nickel mu-metal: 80%Ni, 16% Fe, 4% Mo)
- Ni
- Pd
- Zr



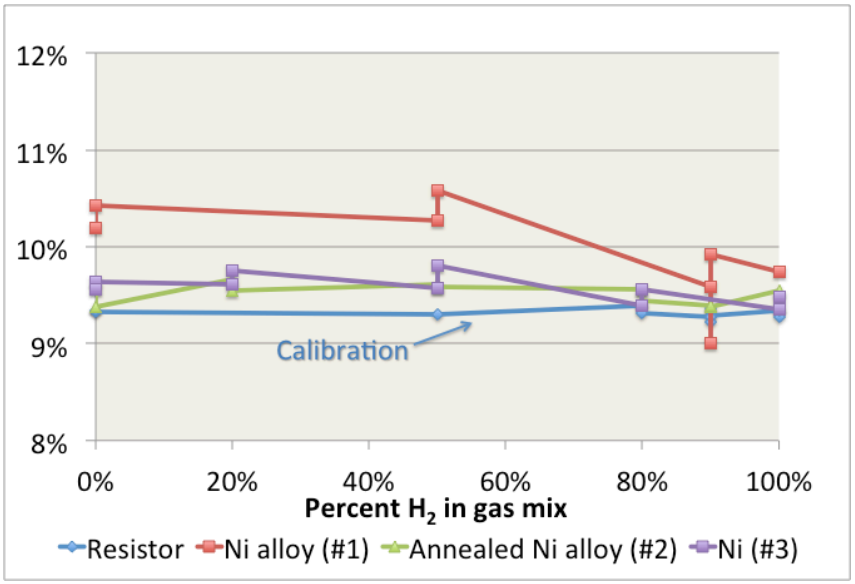
Typical run in isothermal chamber



Thermometry & pressure results

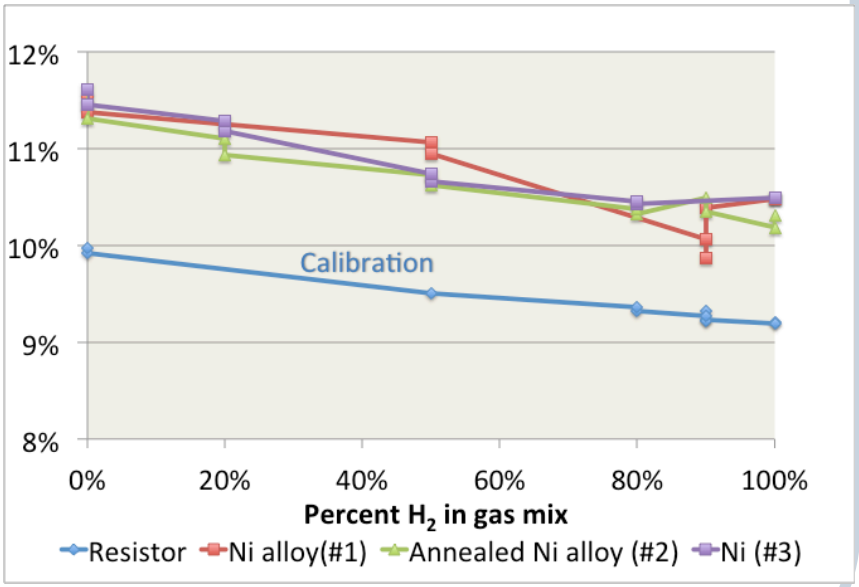
Normalized delta absolute temperature

$(T_{5W} - T_{0W})/T_{0W}$



Normalized delta pressure

$(P_{5W}-P_{0W})/P_{0W}$

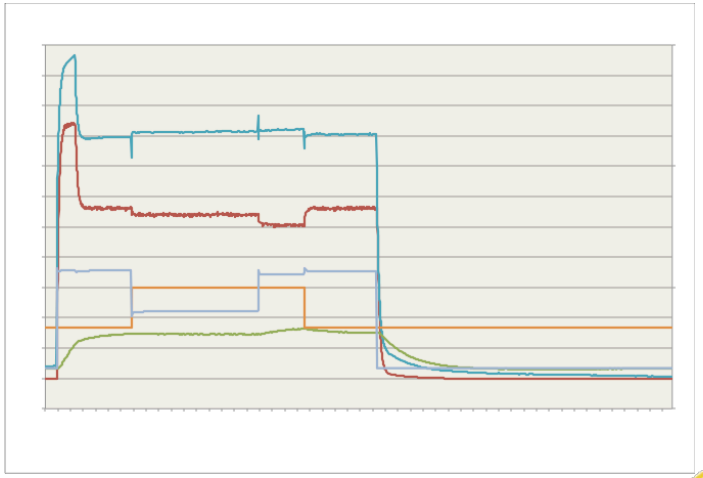


Conclusions from thermometry runs

- Excess Heat:
  - Possible 2-5%
- H:D ratio effect:
  - Not observed
- Cathode material effect:
  - Ni alloy may show excess heat

More Conclusions

- Neither ΔP nor ΔT are adequate proxies for heat output
  - Temperature & pressure sensitivity to plasma condition
  - ΔP greater for plasma
- **Need a calorimeter!**

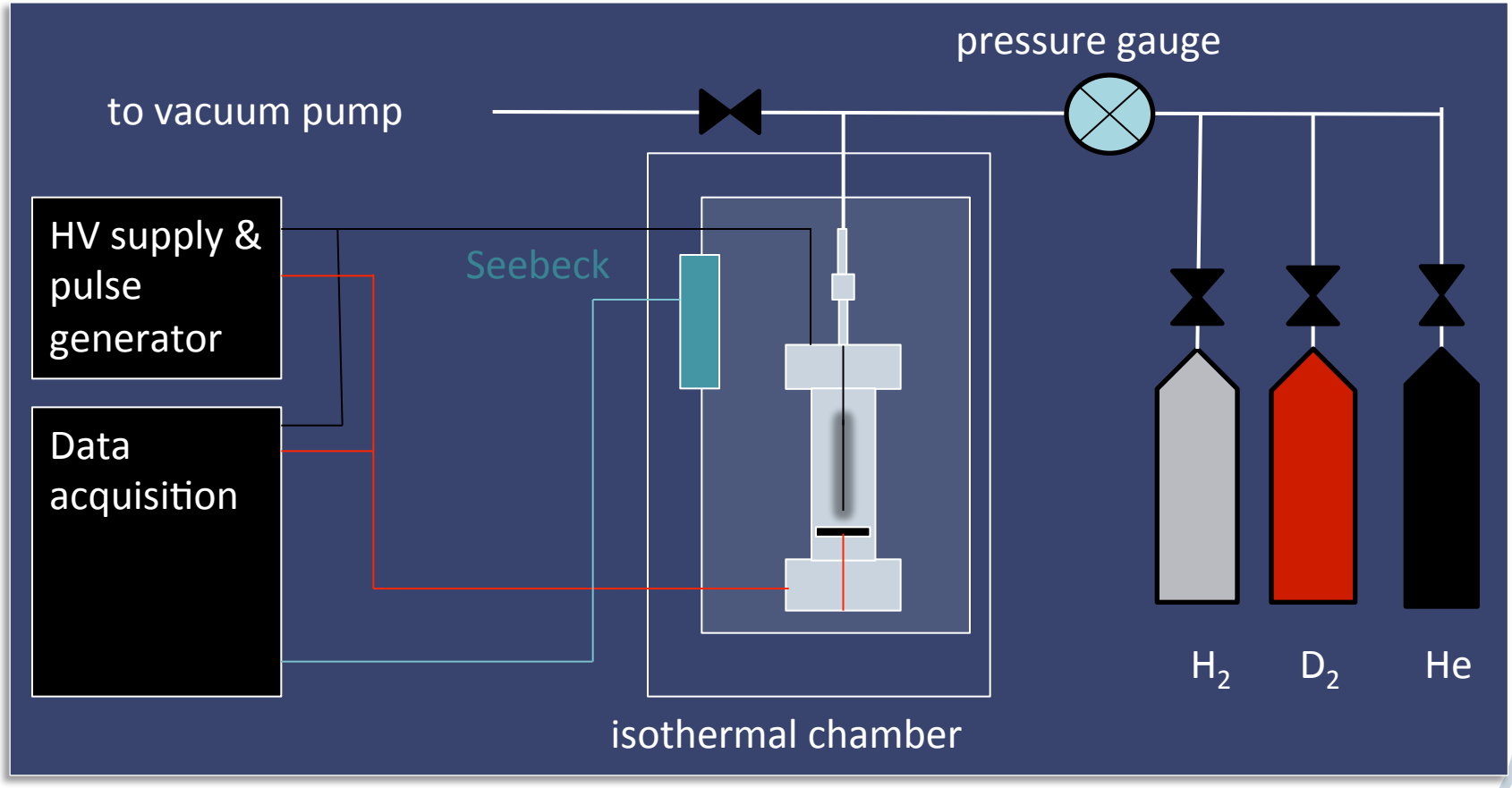


Experiment #2: Goals

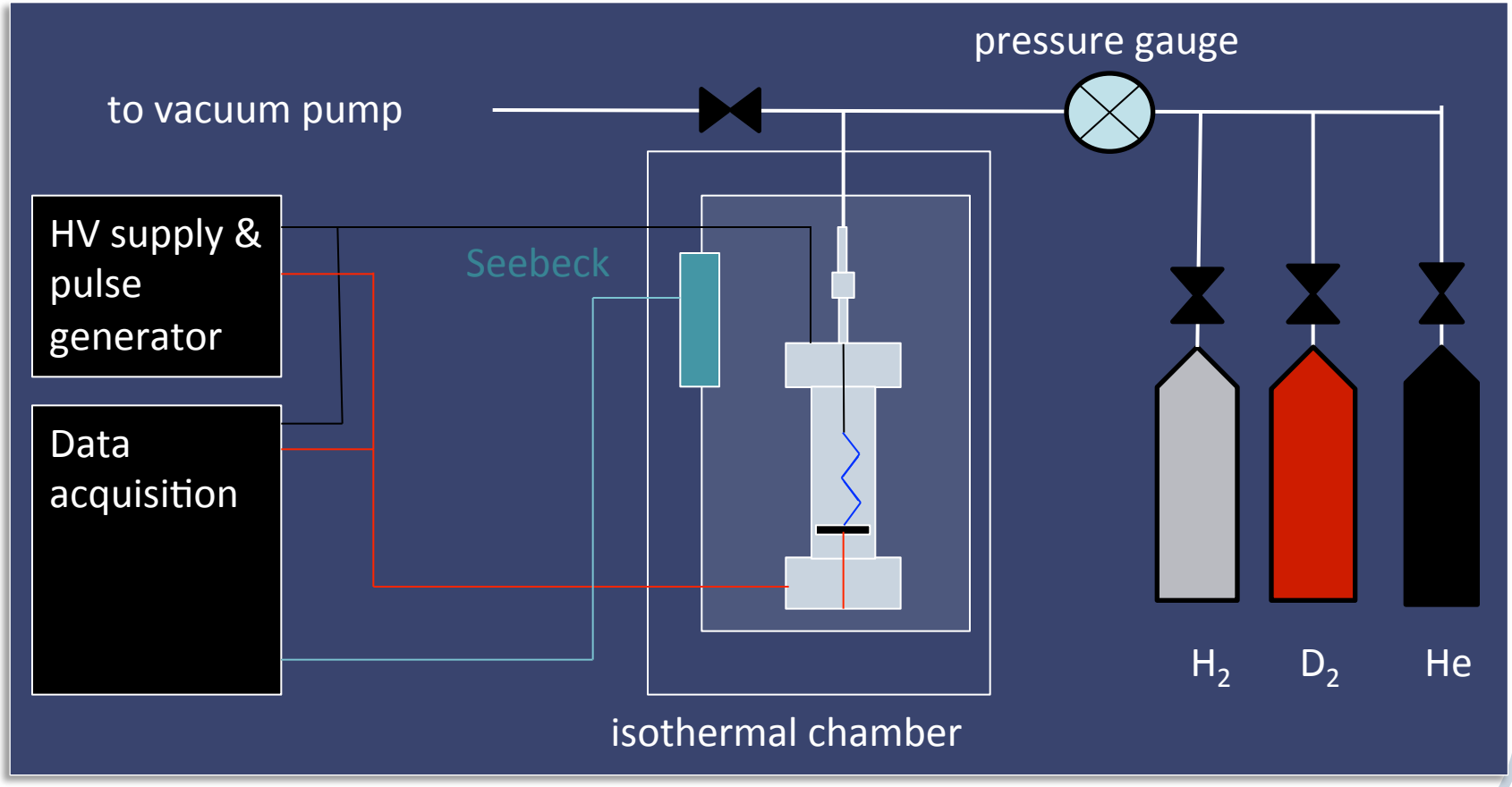
- Design calorimeter to look for excess heat
  - Sensitivity < 50 mW
  - Long term drift < 50 mW
  - Repeatability < 50 mW

  - 50 mW ➛ 0.9% at 5.5W input

Calorimeter: Operation

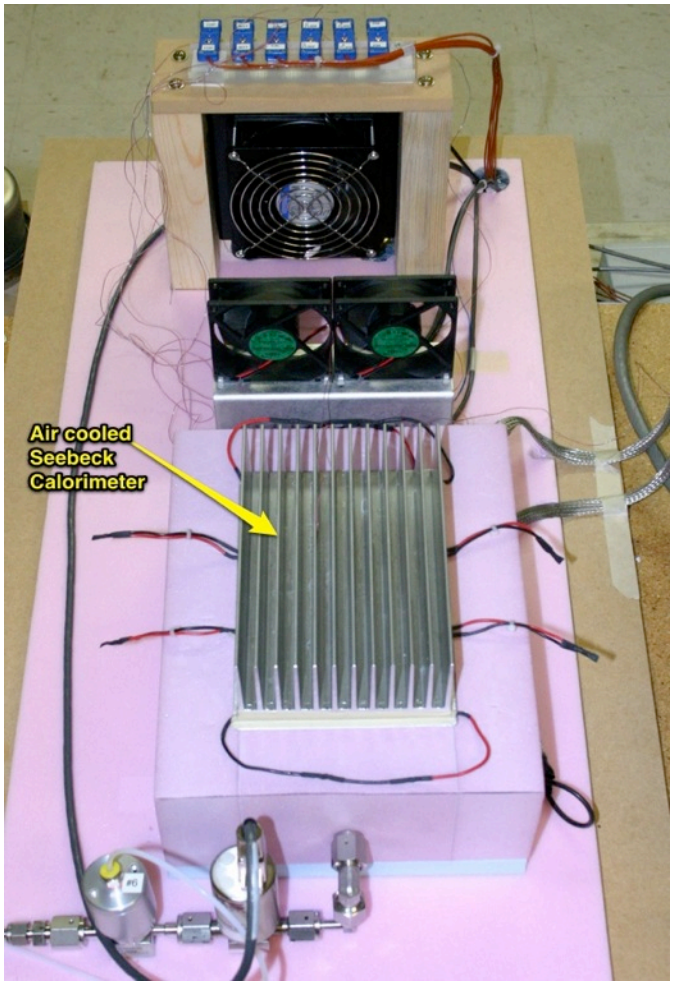


Calorimeter: Calibration



Calorimeter construction

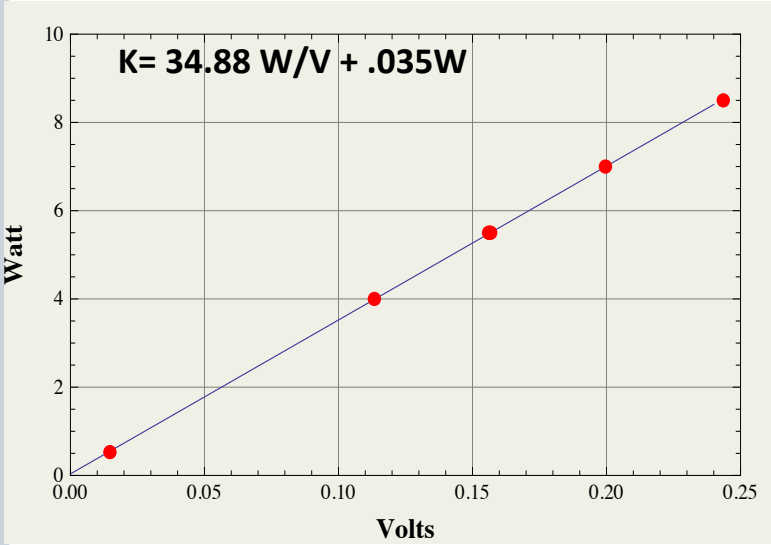
- Air cooled Seebeck[4,5]
  - 5 insulated sides
  - TEMs under heat sink
  - Small fan inside calorimeter
- Operated inside isothermal box
- Built from EPF sheets (2 inch pink foam)



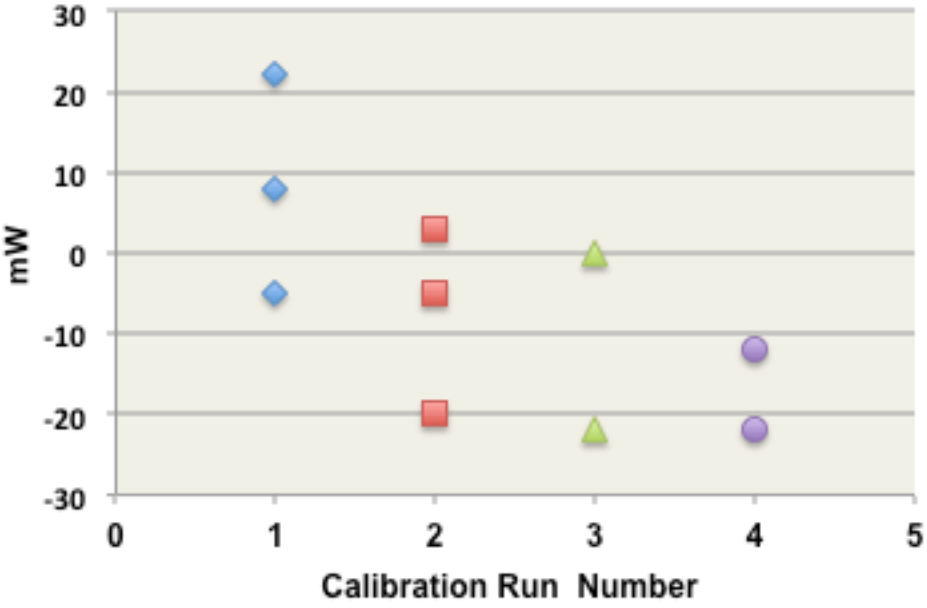
4. Knies, et. al. "*Differential Thermal Analysis Calorimeter at the Naval Research Laboratory*", ICCF-15, 2009, p.11
5. Letts & Hagelstein, "*Modified Szpak Protocol for Excess Heat*", ACS 2010

Calorimeter performance

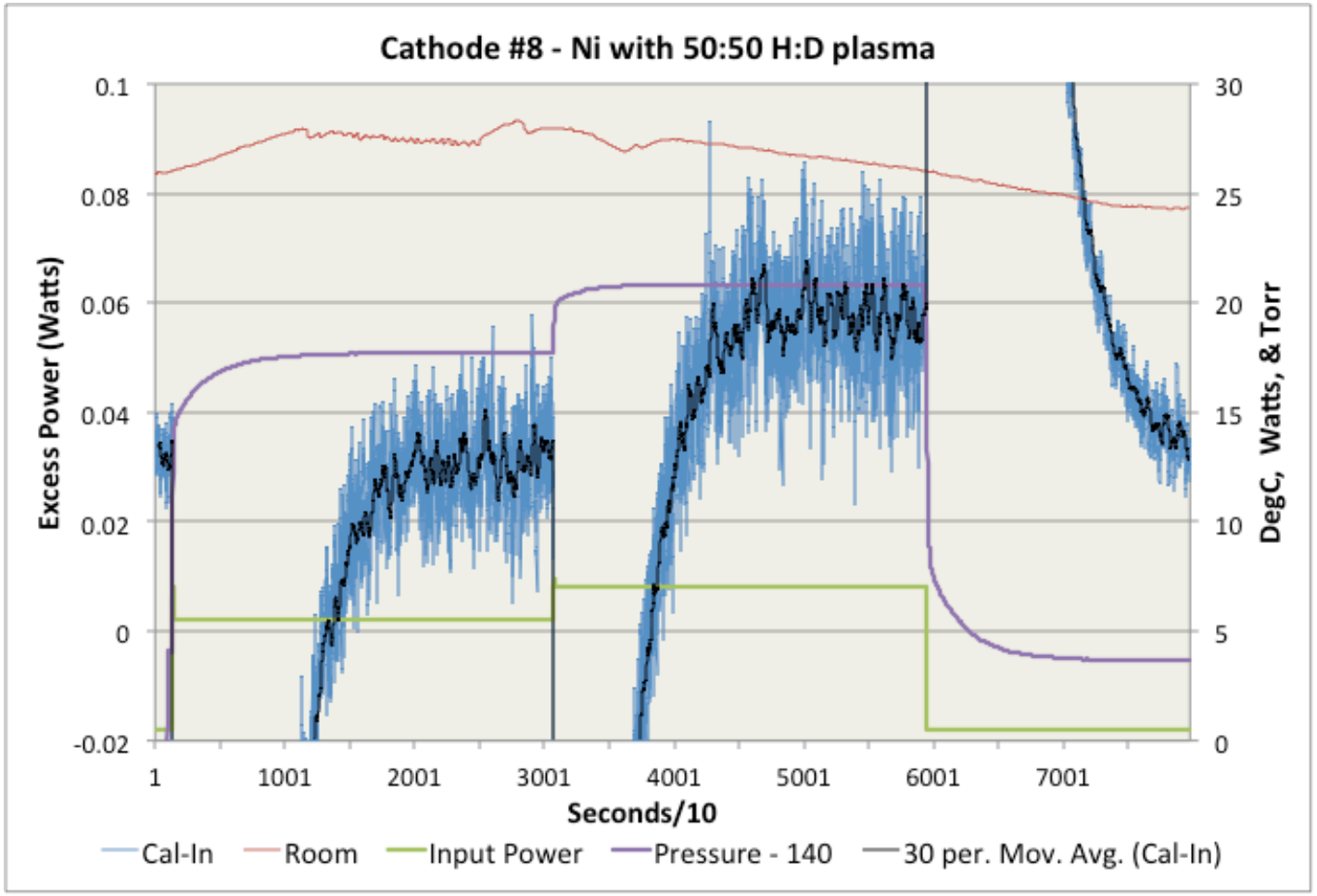
Input Power vs. Seebeck Voltage



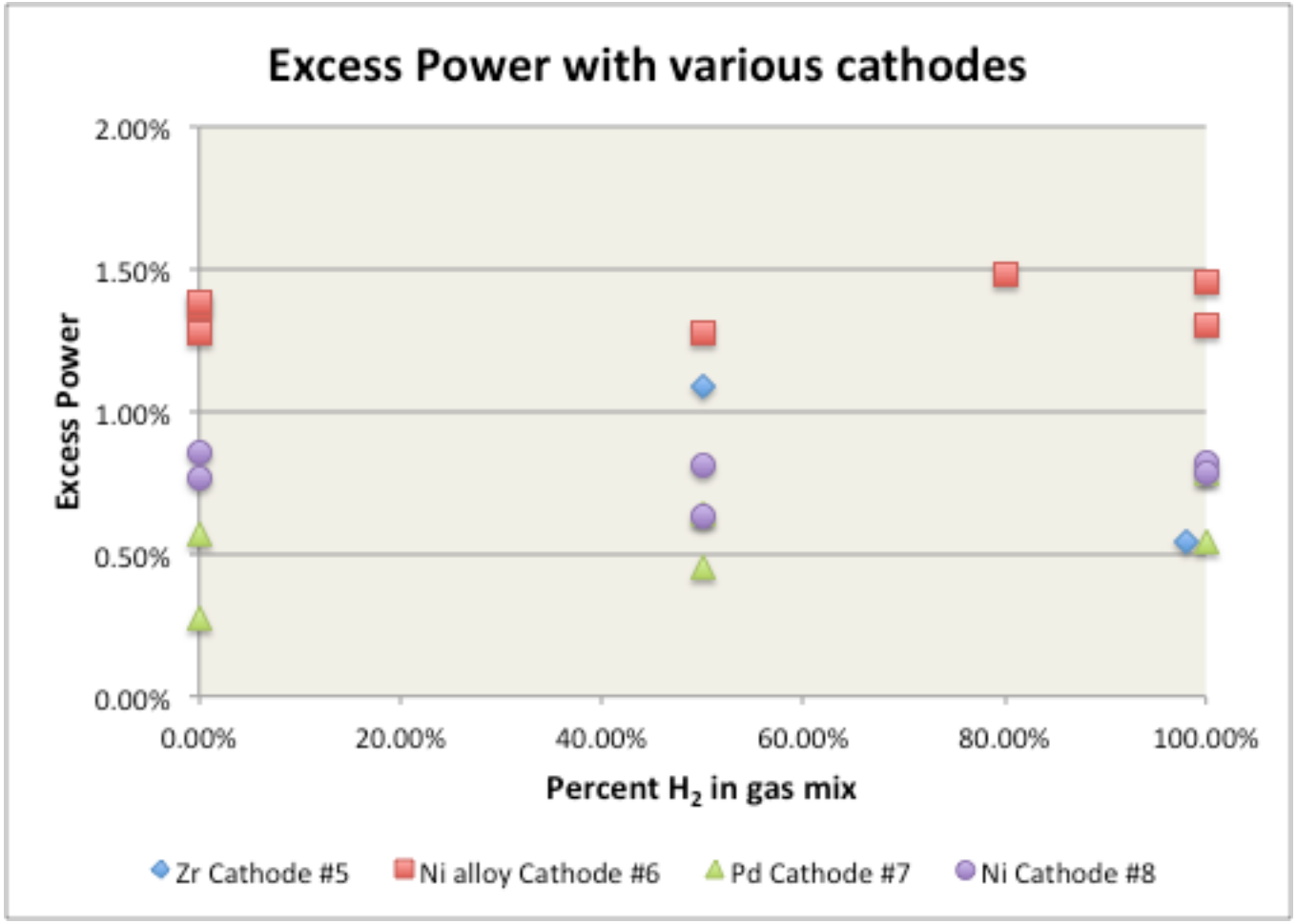
Resistor calibration - residual



Typical run in calorimeter

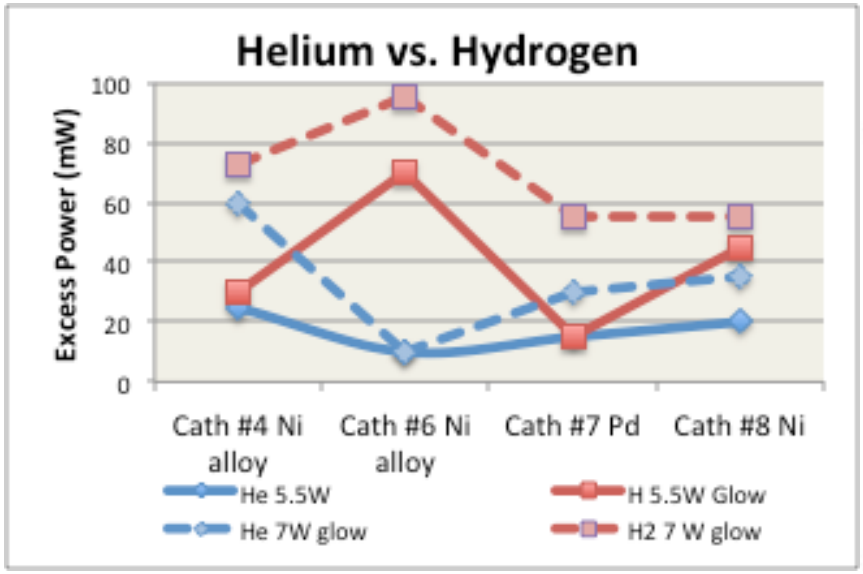


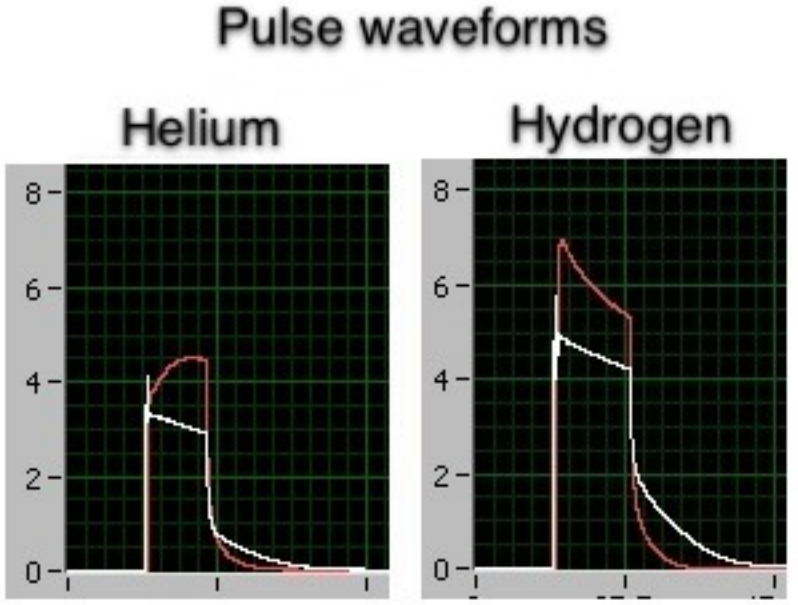
Calorimeter results



Helium as a control?

- Suggests less excess power with helium
- However, not consistent

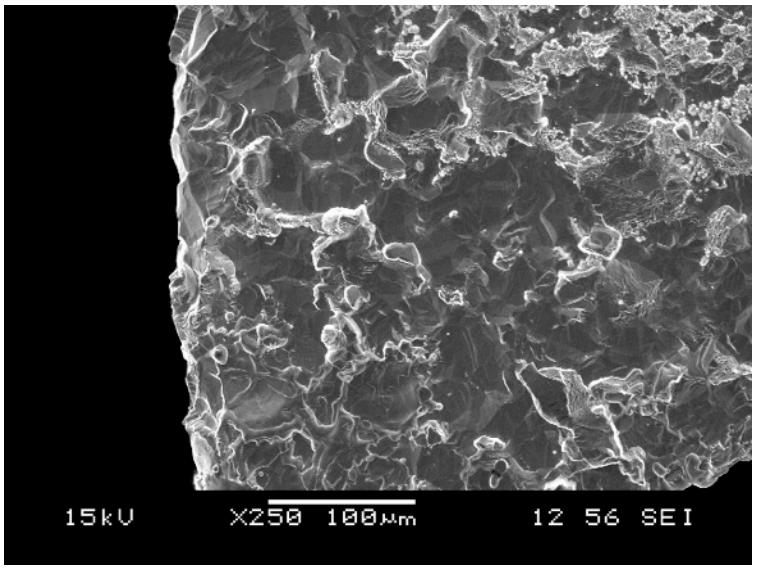




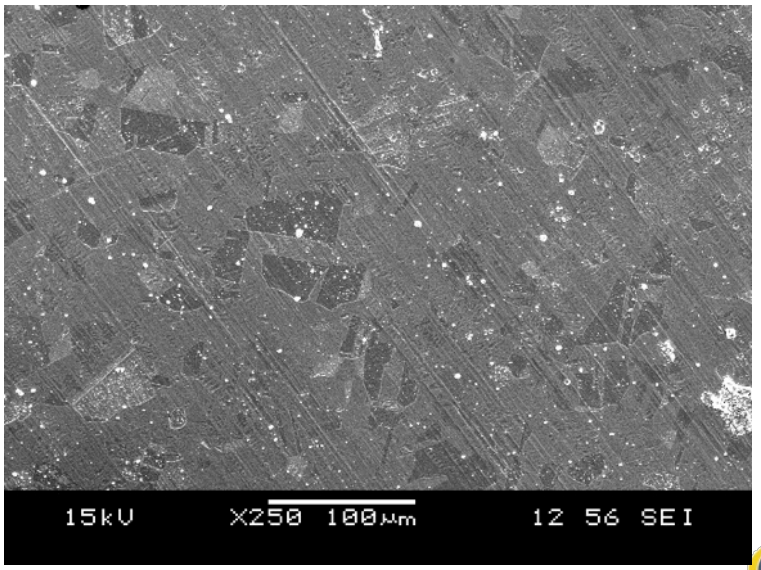
Cathode environment

- Surface erosion at tip
- Little damage at far end

Cathode tip after ~40 hours plasma



Back-end of cathode



Conclusions

- Excess heat?
  - Nothing greater than 2-3%
  - Possible small effect on some cathodes
- Isotope effect?
  - Not seen
- Cathode material effect?
  - Maybe Ni alloy

Future work

- Have we run the same experiment?
  - Analyze gas from cell for tritium
- Do we have any measurement artifacts?
  - Look for better control
  - Additional tests of power measurements
- Look for ways to increase effect
  - Anode-cathode separation distance
  - Other materials