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

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Talk describes our effort to find excess heat in metal-hydrogen plasma

Work is on going

Conclusions are still preliminary and therefore tentative

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

Claytor tritium since early 90's

  High current, high pressure

  This work in this pressure/current/voltage regime

Karabut variety of effects since '92

  Low pressure, lower current

  Reference only – this work does not attempt to replicate Karabut

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

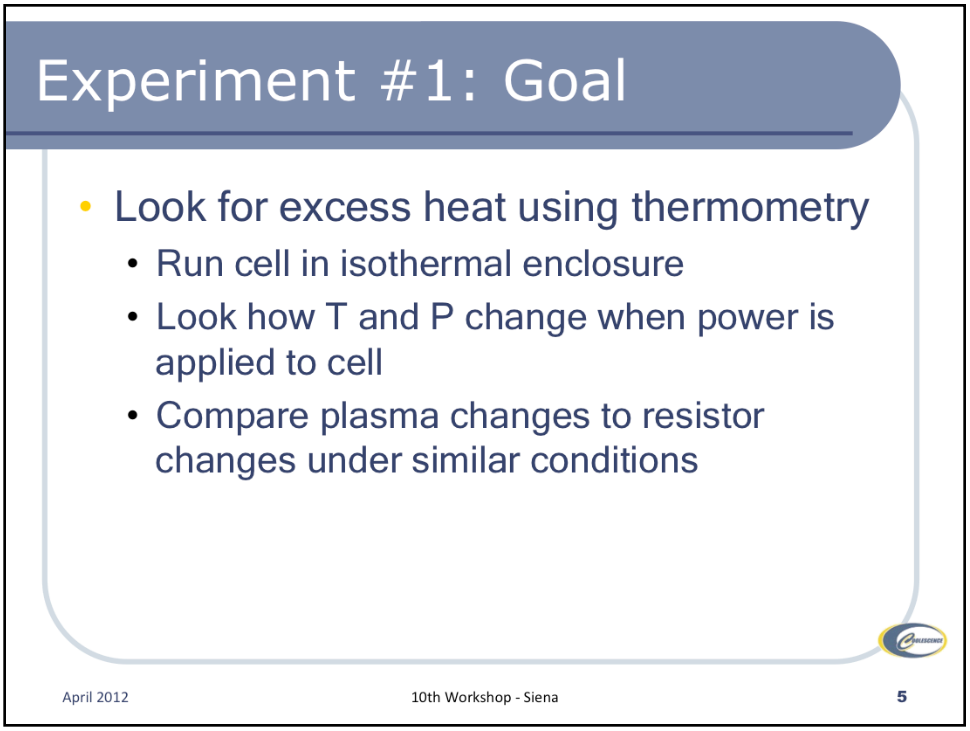
3. Claytor, Private conversation, September 2011

Cells that produced tritium also seem to make excess heat

This work undertaken to validate these simple experiments

Research Objective

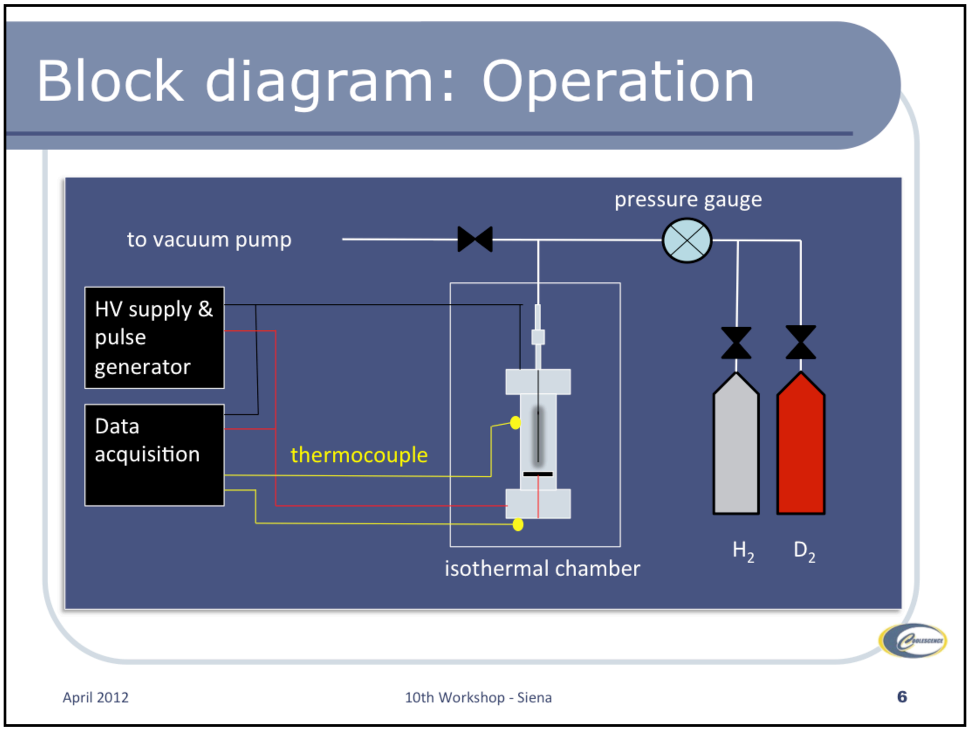
- Do we see excess heat in H/D plasma?
- Does excess heat depend on H:D ratio?
- Does excess heat depend on cathode material?



Original work done in uncontrolled environment

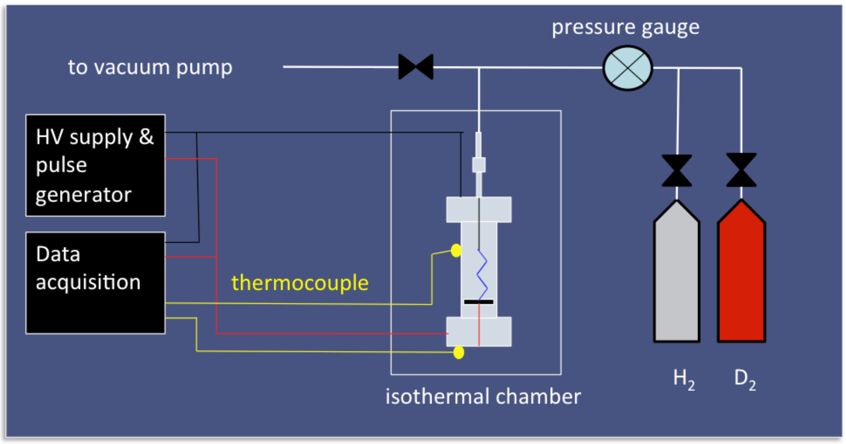
Use isothermal and use ΔT and ΔP as surrogate for power

Compare plasma to resistor with same input waveform

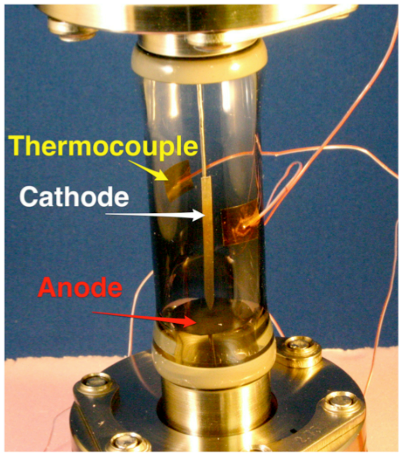


Calibrate by replacing cathode with resistor

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

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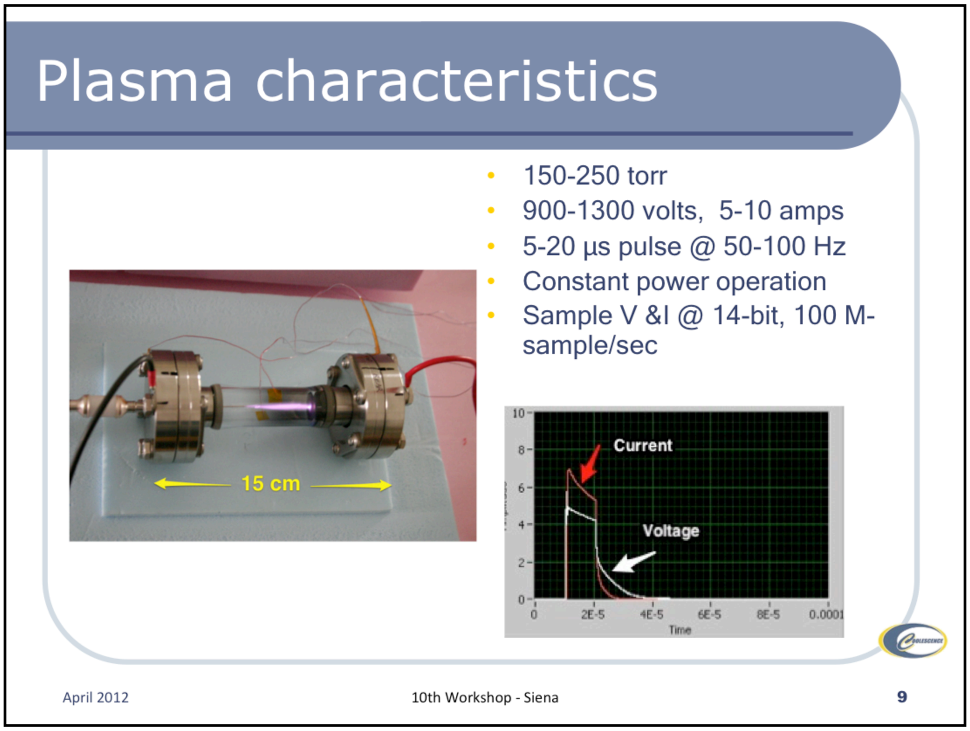
Built from off-the-shelf high vacuum components



High pressure & current → low duty cycle

Constant power by varying pulse frequency

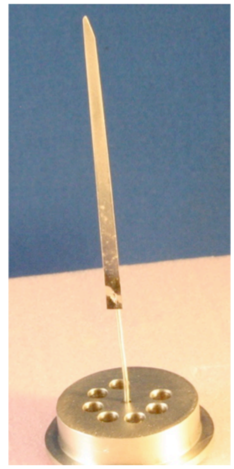
Sharp voltage rise time

Custom built pulse generator – IGBT discharges capacitor bank – HV DC supplied by commercial supply

100 M samples/sec data acquisition. Analyze every pulse to compute input power

Cathode Materials

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



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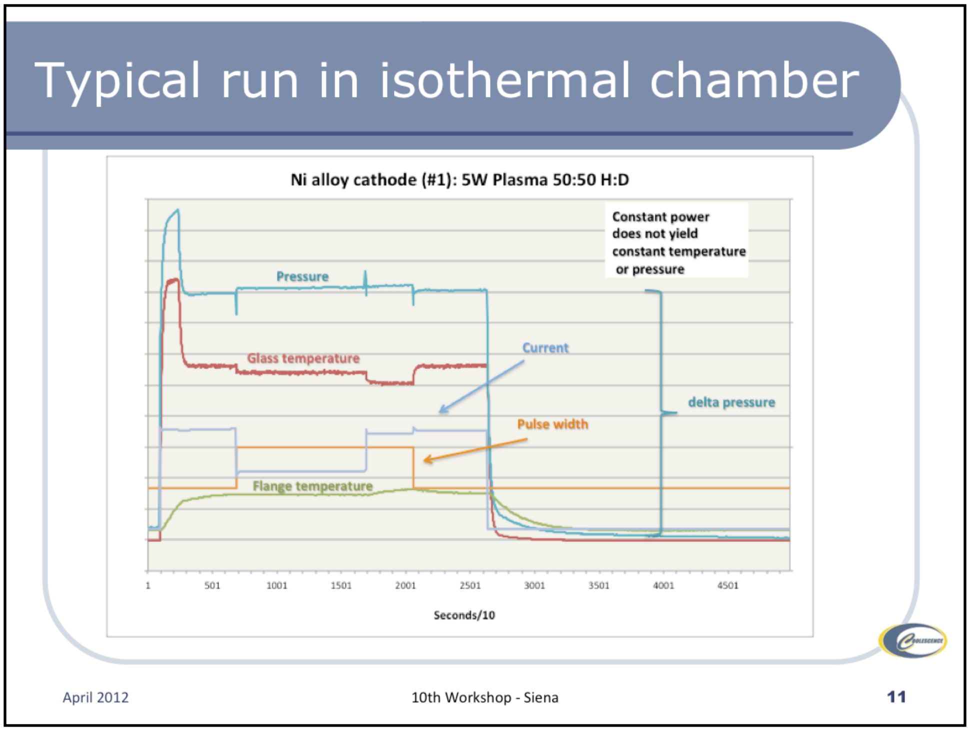
Ni alloy is commercial mu-metal magnetic shielding

Long skinny cathode

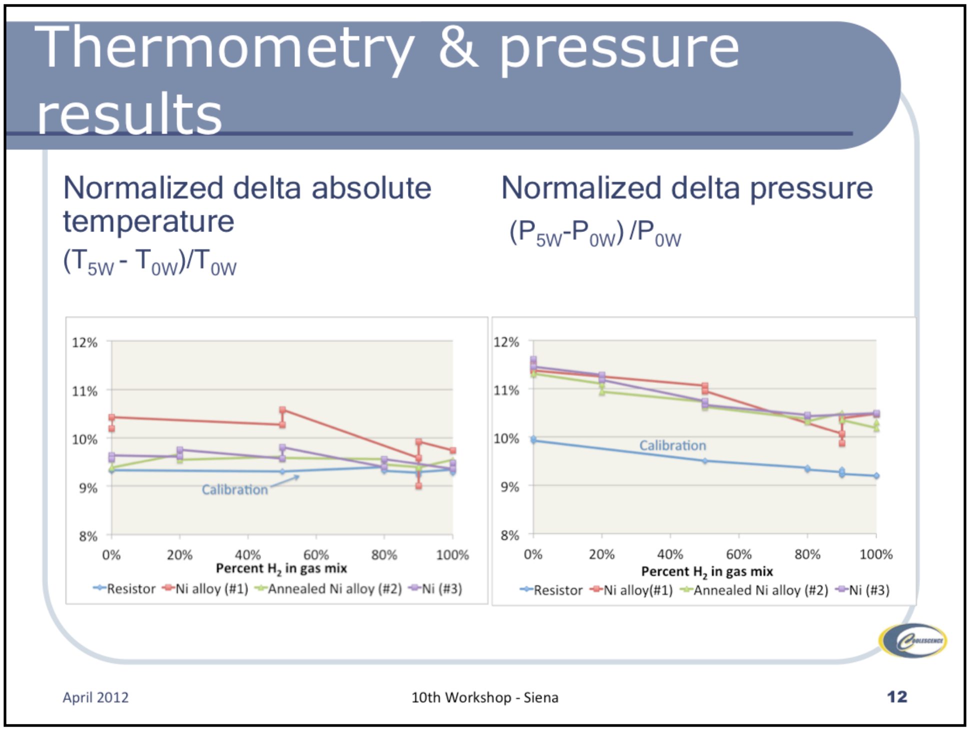
Tested various metals



Initial pre-heat then constant power

Measure T and P after equilibrium

Note effect of change in pulse width & current



X axis gas mix, Y is percent increase when heated

Ideal gas law expect ΔP and ΔT same for same power

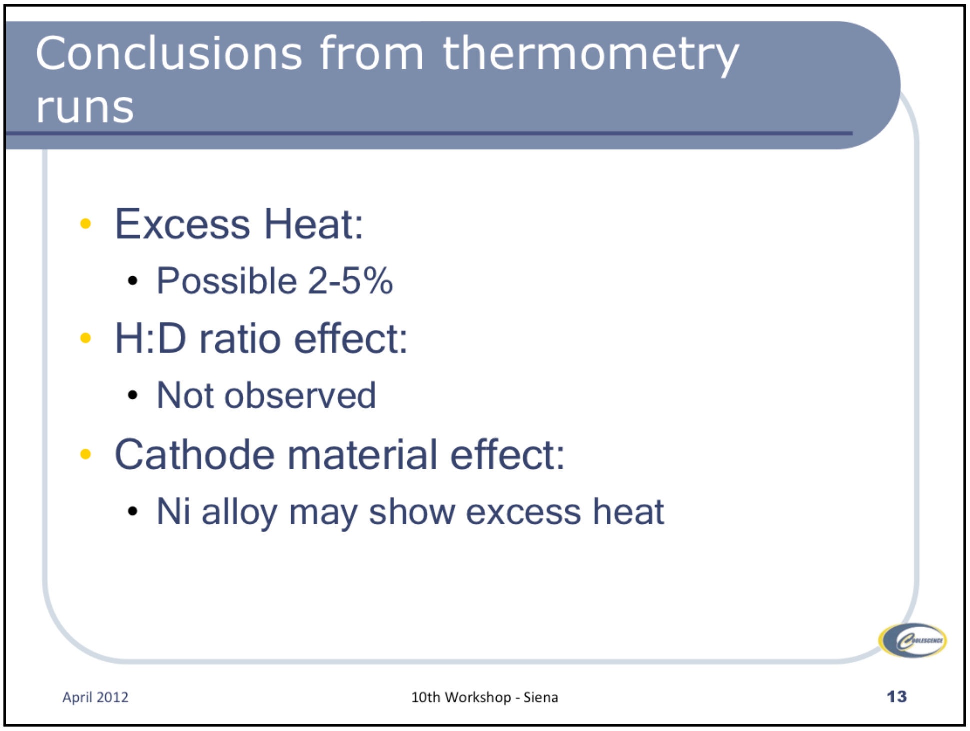
ΔT (weighted average of 4 temps – surface area weights)

ΔT pretty similar for various cathodes – possible effect with Ni alloy- sputtering??

ΔP greater in plasma for all gases - ionization

ΔP greater for heavier gas mix ??

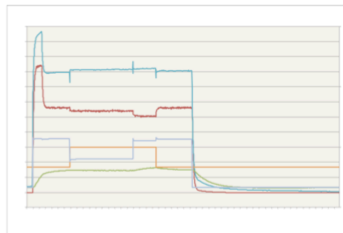
Cathode #1 may have lost heat due to darkening of glass due to sputtering



Maybe excess heat – need more precision

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!**



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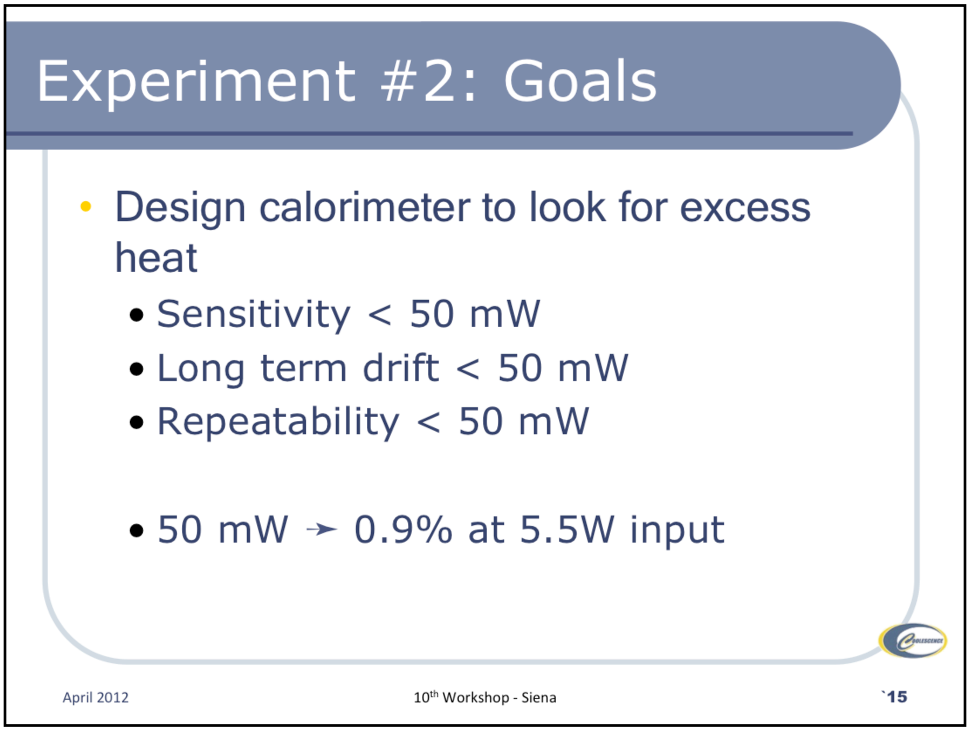
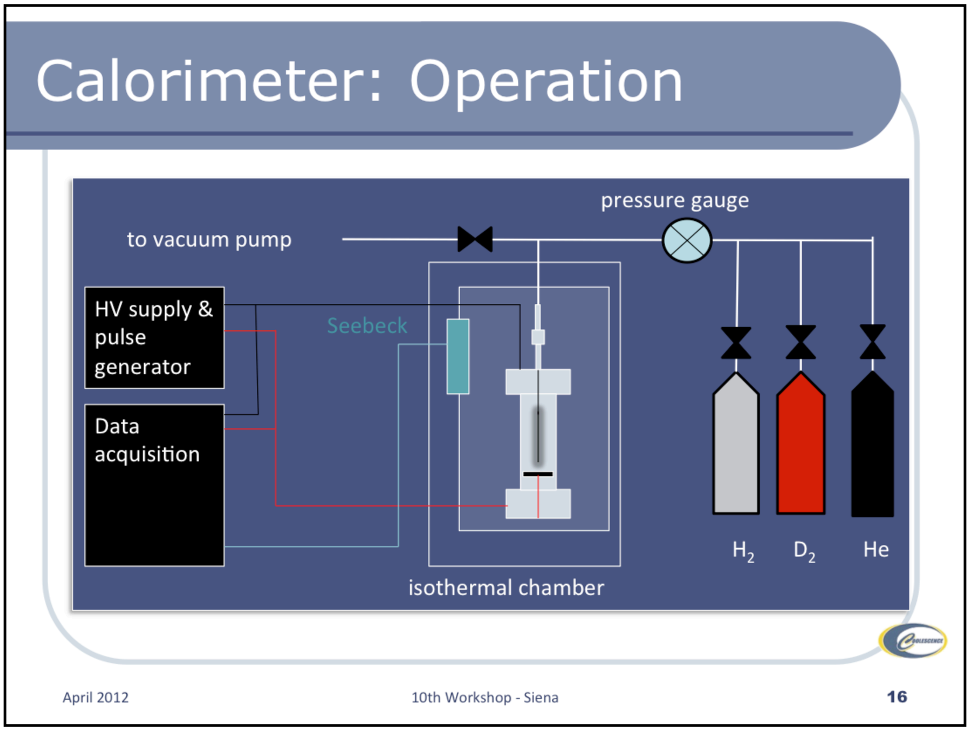
Must have calorimeter



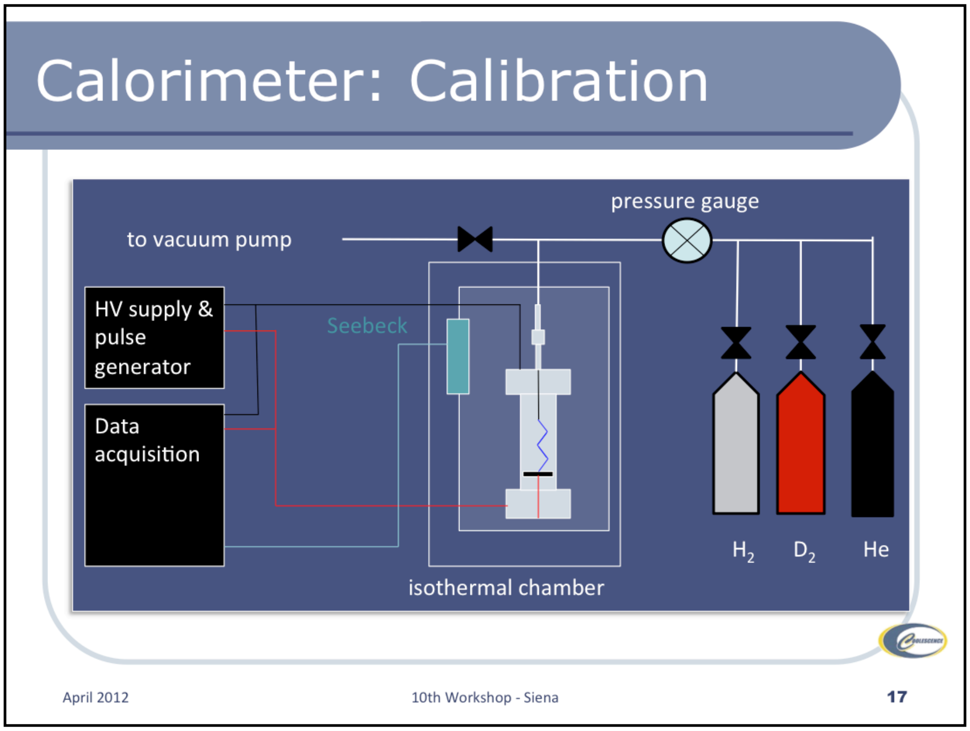
Build a good calorimete
Good by this definition should see 1% effect



Add seebeck envelope – all heat passes through sensors.

Calibrate with resistor

Means have to take apart to calibrate – worry about reproducability



Calibrate with resistor

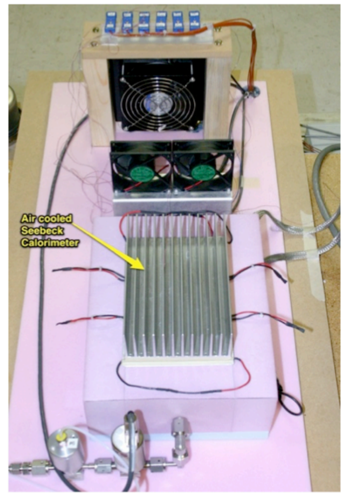
Means have to take apart to calibrate

Challenge of repeatability

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



I call air cooled Seebeck – Storms water cooled, later NRL and Letts air cooled designs

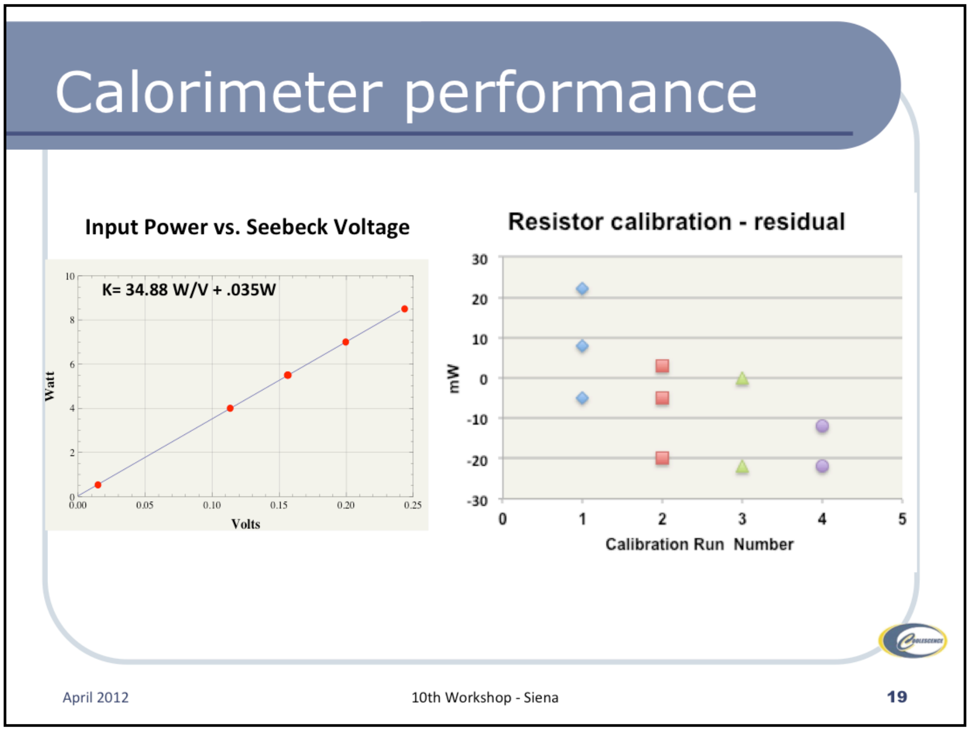
All heat passes through Seebeck junctions (TEC)

Output is sum all Seebeck junction voltages

EPF – expanded polystyrene foam

Change gas without opening chamber

Valve & pressure gauge inside isothermal enclosure
Baratron gauges sensitive to changes in ambient temp



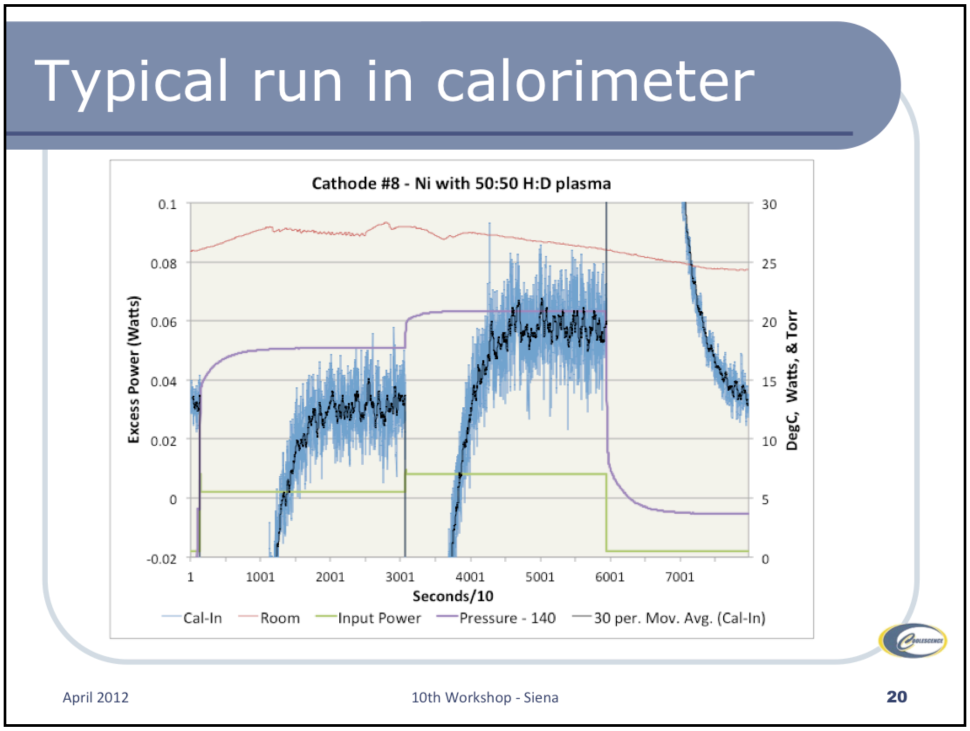
Calibration x=Volts, Y=Watts -> Very linear

Residual (mW) is calculated – actual

Consistent across assembly/disassembly within +/- ~30 mW

Only run for month – need more experience

Need to test for heat location sensitivity

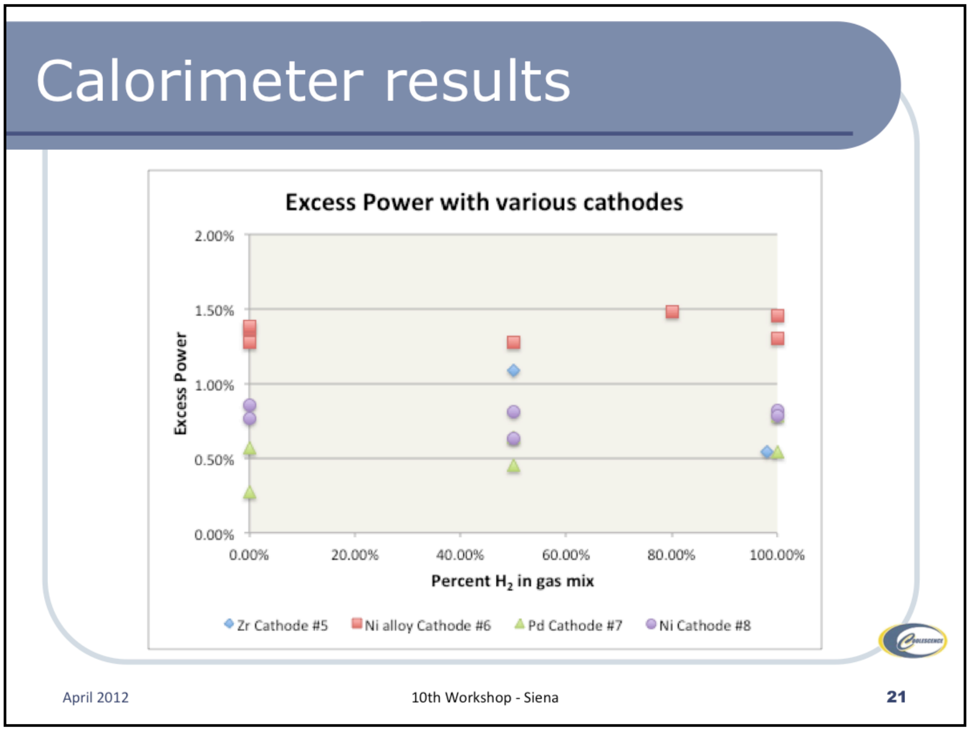


10 second time series

Very little room coupling

Most runs at two power levels (5W and 6.5W glow – fan is 0.5W so total power is 5.5 or 7W)

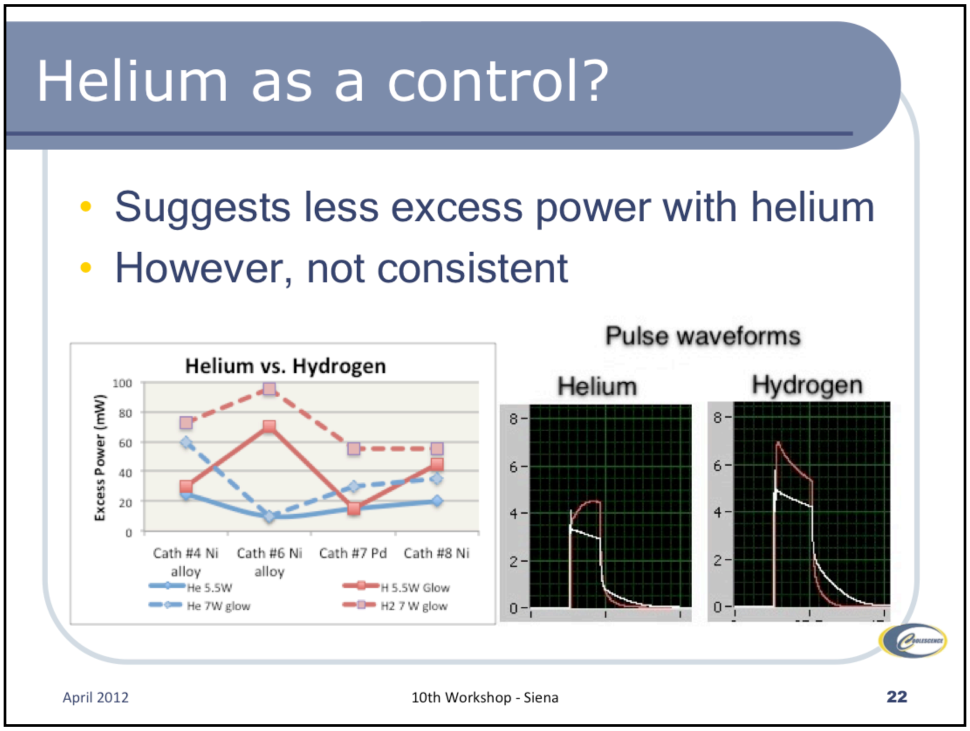
Noise is both Seebeck voltage & input power variation



Double values at a given point are low & high input power levels

Suggests dependence on cathode material -> Ni alloy is best we've tested so far

Ni alloy excess power may be real

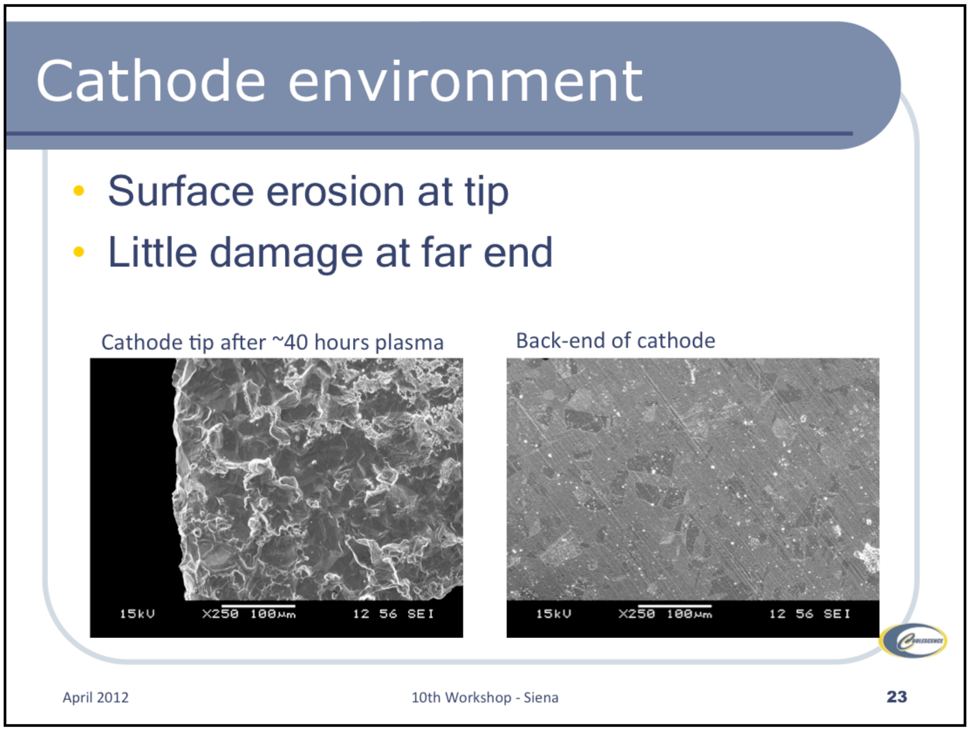


Note all runs with cathode with undisturbed calorimeter setup

Not sure helium it is valid control – may be variations in plasma conditons

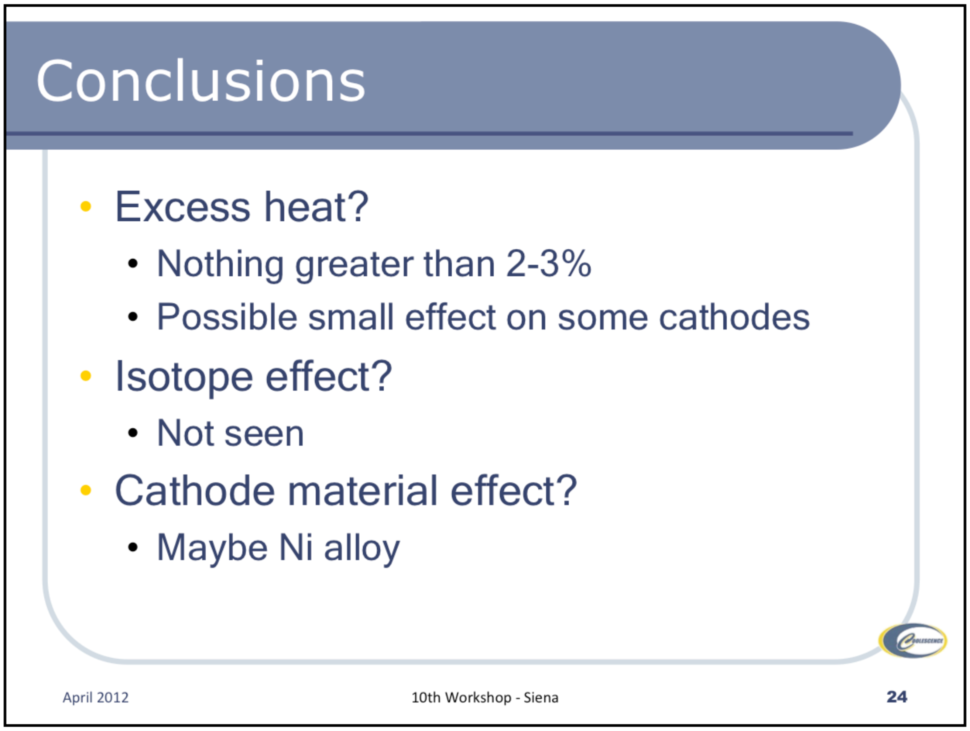
Different plasma propagation as evidenced by waveform

None-the-less this suggests hydrogen makes more excess heat



Surface is quickly eroded

If LENR has implications about on – NAE can't take long to build



Excess Heat:

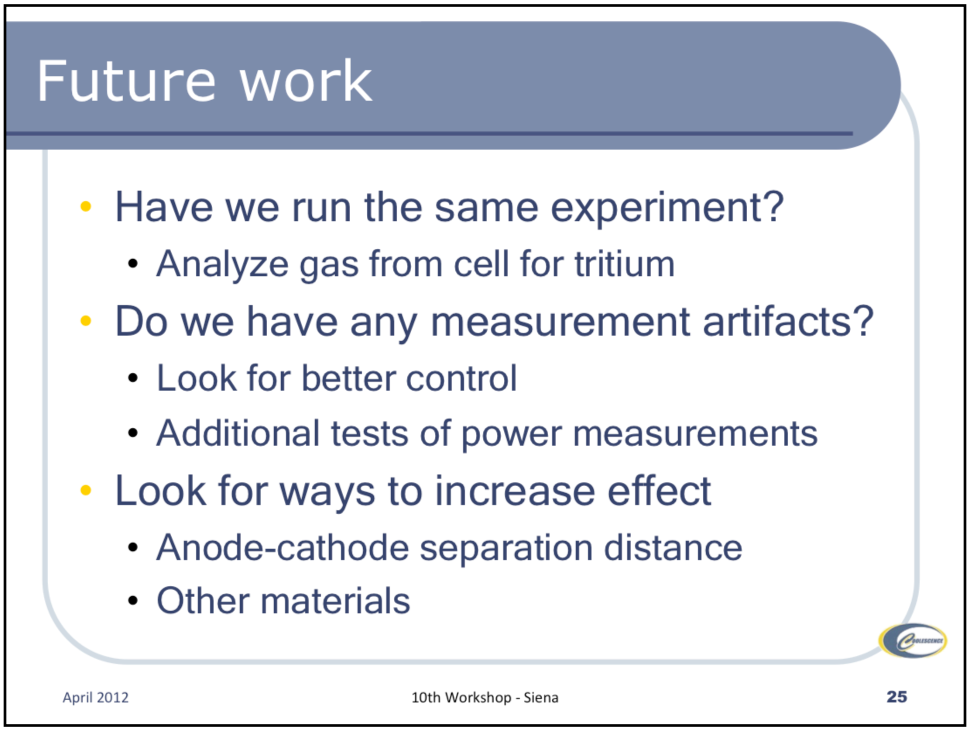
Confident: xP < 2-3%

Tentative: Maybe some xP – close to calorimeter limits

Isotope Effect: - not seen

Cathode material - not sure

Good calorimetry is a must



Results are sufficiently interesting to keep going

Make sure we're running same experiment

Make sure no artifacts causing results

Better characterize calorimeter

What is an adequate control?