

# 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<sup>1</sup>
  - Report tritium
    - 1500-2500 V, 150-250 torr, > 5 A/cm<sup>2</sup>
- Karabut<sup>2</sup>
  - Report excess heat, nuclear products
    - 100-500 V, 3-10 torr, > 10-100 mA/cm<sup>2</sup>

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<sup>3</sup>

- 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?



## 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

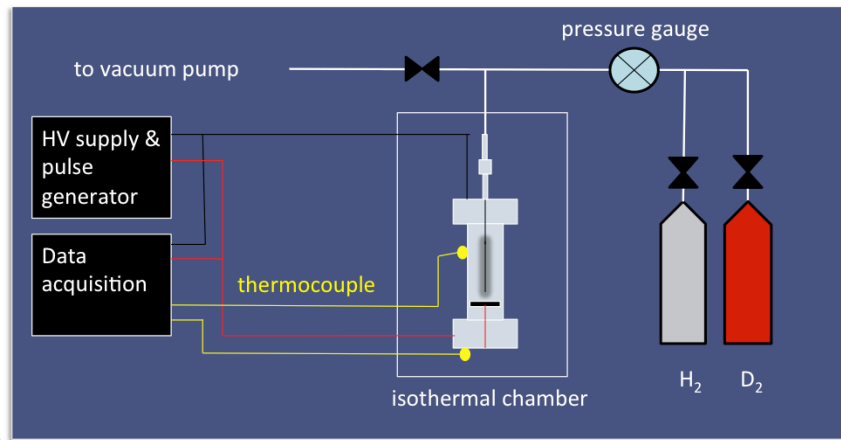


Original work done in uncontrolled environment

Use isothermal and use  $\Delta T$  and  $\Delta P$  as surrogate for power

Compare plasma to resistor with same input waveform

## Block diagram: Operation



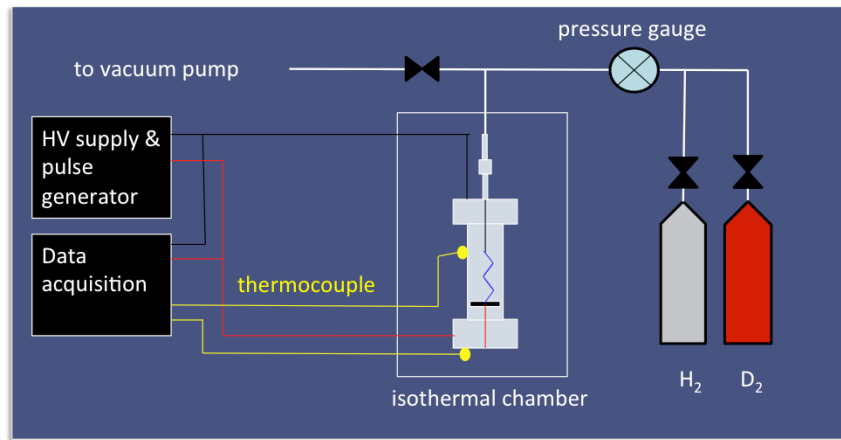
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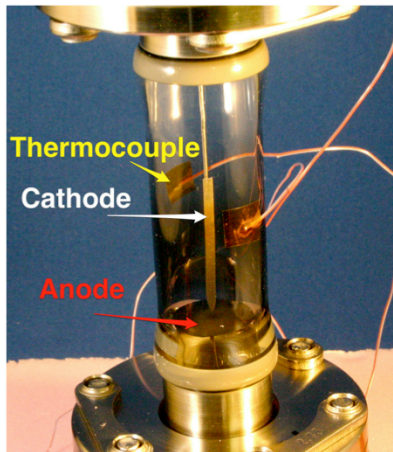
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Calibrate by replacing cathode with resistor

# 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<sup>3</sup> volume
- CF 2.75 flanges
- Thermal time constants
  - 4 min center
  - 40 min flanges



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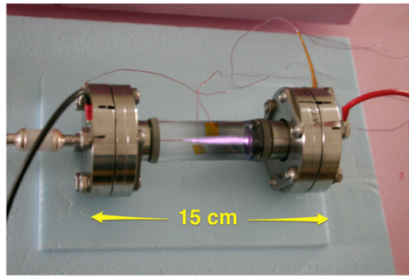
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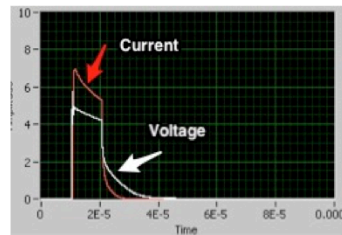
Built from off-the-shelf high vacuum components



# Plasma characteristics



- 150-250 torr
- 900-1300 volts, 5-10 amps
- 5-20  $\mu\text{s}$  pulse @ 50-100 Hz
- Constant power operation
- Sample V & I @ 14-bit, 100 M-sample/sec



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High pressure & current  $\rightarrow$  low duty cycle

Constant power by varying pulse frequency

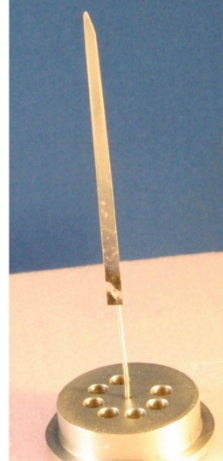
Sharp voltage rise time

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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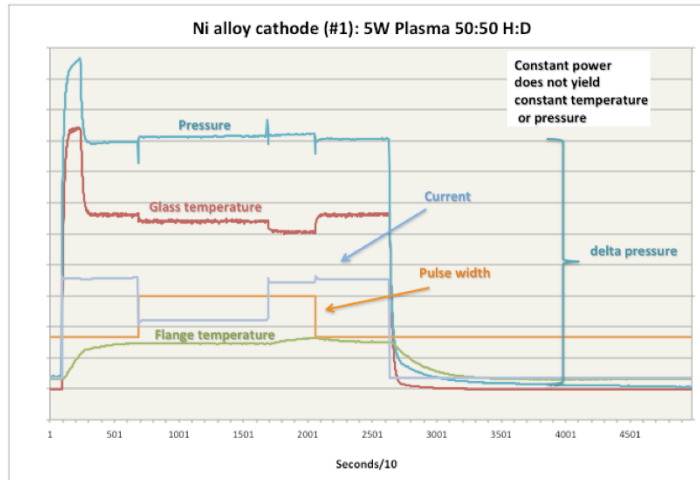
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Ni alloy is commercial mu-metal magnetic shielding

Long skinny cathode

Tested various metals

## Typical run in isothermal chamber



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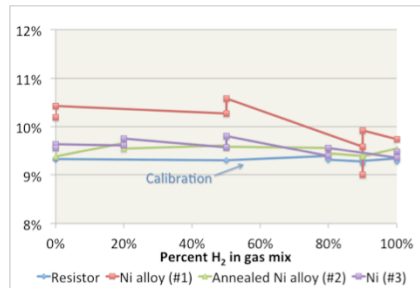


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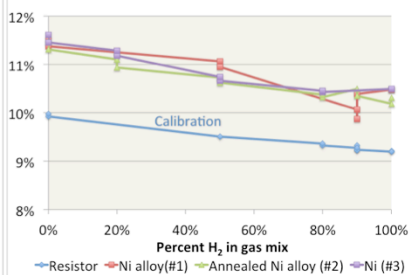
Initial pre-heat then constant power  
Measure T and P after equilibrium  
Note effect of change in pulse width & current

# Thermometry & pressure results

Normalized delta absolute temperature  
 $(T_{5W} - T_{0W})/T_{0W}$



Normalized delta pressure  
 $(P_{5W} - P_{0W})/P_{0W}$



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X axis gas mix, Y is percent increase when heated

Ideal gas law expect  $\Delta P$  and  $\Delta T$  same for same power

$\Delta T$  (weighted average of 4 temps – surface area weights)

$\Delta T$  pretty similar for various cathodes – possible effect with Ni alloy- sputtering??

$\Delta P$  greater in plasma for all gases - ionization

$\Delta P$  greater for heavier gas mix ??

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

## Conclusions from thermometry runs

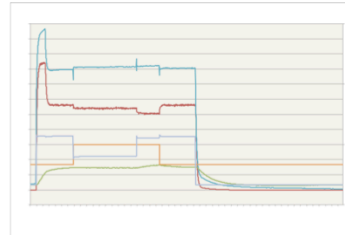
- Excess Heat:
  - Possible 2-5%
- H:D ratio effect:
  - Not observed
- Cathode material effect:
  - Ni alloy may show excess heat



Maybe excess heat – need more precision

## More Conclusions

- Neither  $\Delta P$  nor  $\Delta T$  are adequate proxies for heat output
  - Temperature & pressure sensitivity to plasma condition
  - $\Delta P$  greater for plasma
- **Need a calorimeter!**



Must have calorimeter

## Experiment #2: Goals

- Design calorimeter to look for excess heat
  - Sensitivity  $< 50 \text{ mW}$
  - Long term drift  $< 50 \text{ mW}$
  - Repeatability  $< 50 \text{ mW}$
- $50 \text{ mW} \rightarrow 0.9\%$  at  $5.5\text{W}$  input



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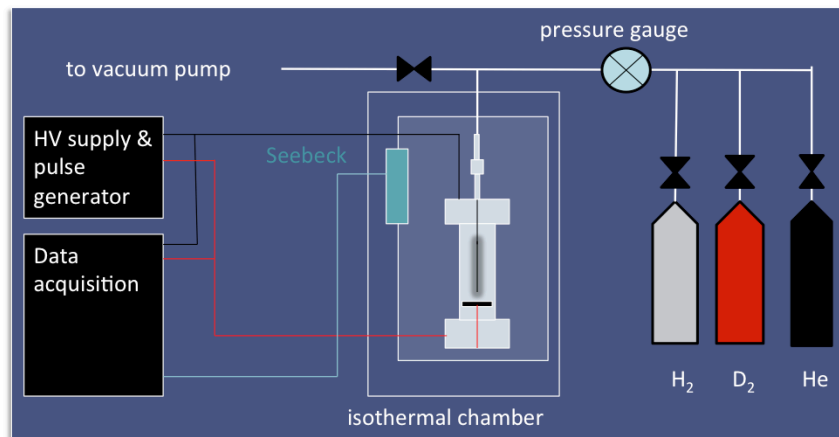
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Build a good calorimeter

Good by this definition should see 1% effect

# Calorimeter: Operation



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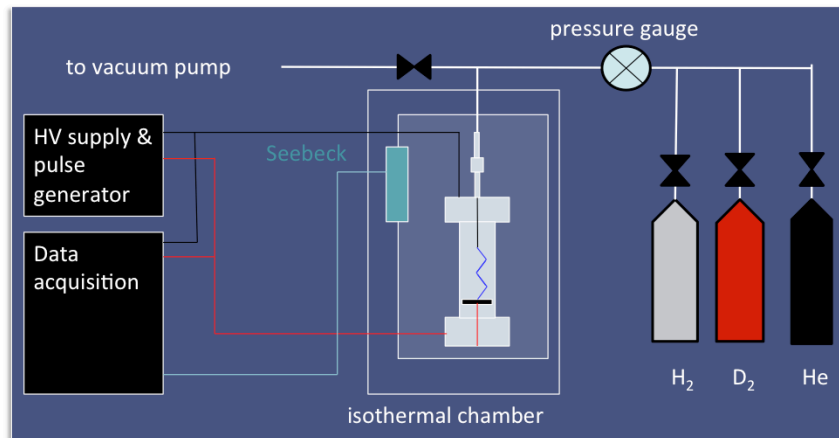
Add seebeck envelope – all heat passes through sensors.

Calibrate with resistor

Means have to take apart to calibrate – worry about reproducibility



# Calorimeter: Calibration



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Calibrate with resistor

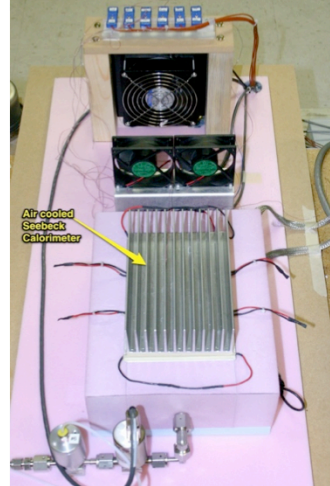
Means have to take apart to calibrate

Challenge of repeatability

# Calorimeter construction

- Air cooled Seebeck<sup>4,5</sup>
  - 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



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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

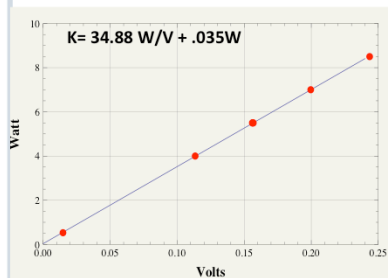
Change gas without opening chamber

Valve & pressure gauge inside isothermal enclosure

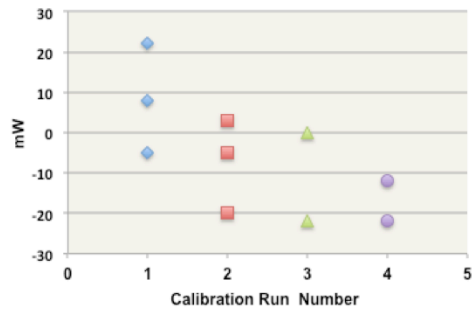
Baratron gauges sensitive to changes in ambient temp

# Calorimeter performance

Input Power vs. Seebeck Voltage



Resistor calibration - residual



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Calibration  $x$ =Volts,  $Y$ =Watts  $\rightarrow$  Very linear

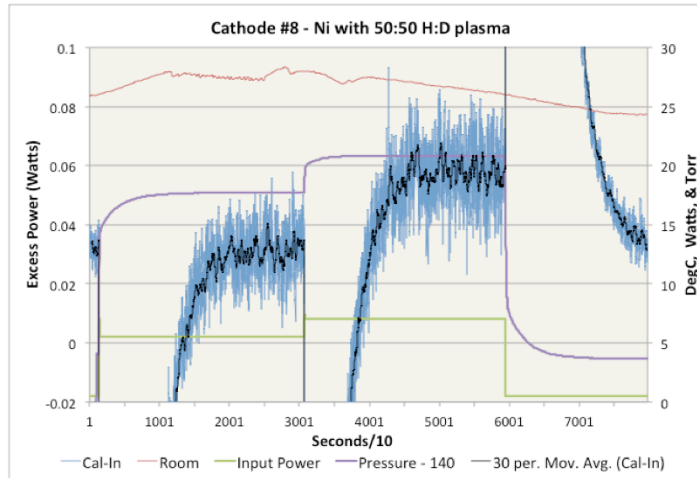
Residual (mW) is calculated – actual

Consistent across assembly/disassembly within  $\pm$  ~30 mW

Only run for month – need more experience

Need to test for heat location sensitivity

## Typical run in calorimeter



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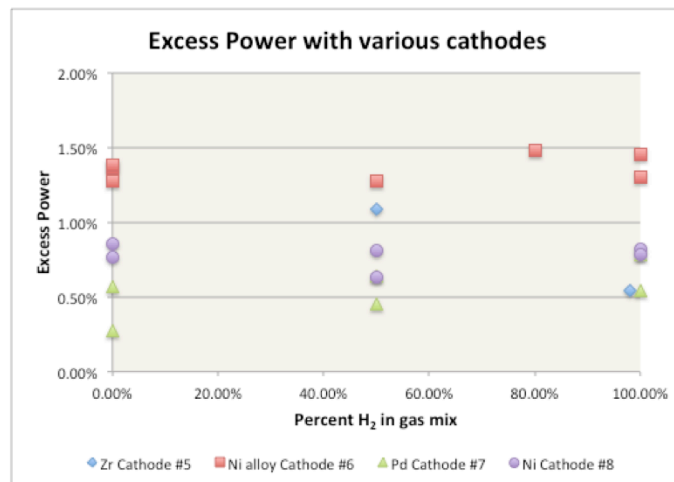
10 second time series

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

# Calorimeter results



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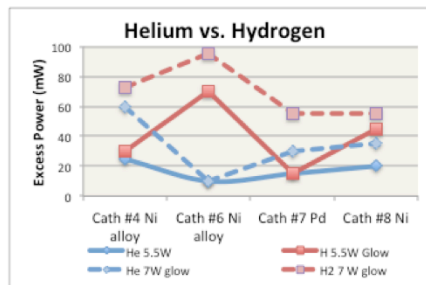
Double values at a given point are low & high input power levels

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

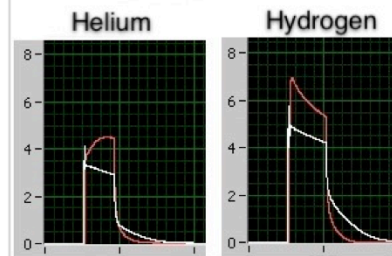
Ni alloy excess power may be real

# Helium as a control?

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



Pulse waveforms



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Note all runs with cathode with undisturbed calorimeter setup

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

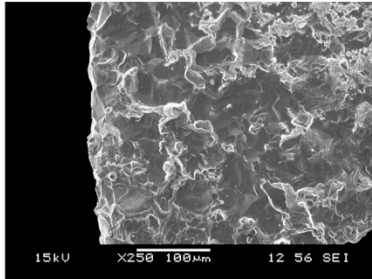
Different plasma propagation as evidenced by waveform

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

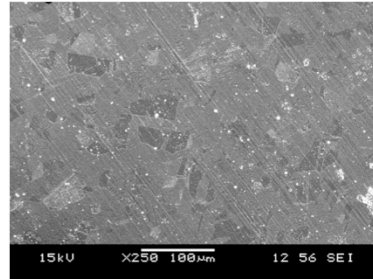
## Cathode environment

- Surface erosion at tip
- Little damage at far end

Cathode tip after ~40 hours plasma



Back-end of cathode



Surface is quickly eroded

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

## Conclusions

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



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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



## 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



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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?