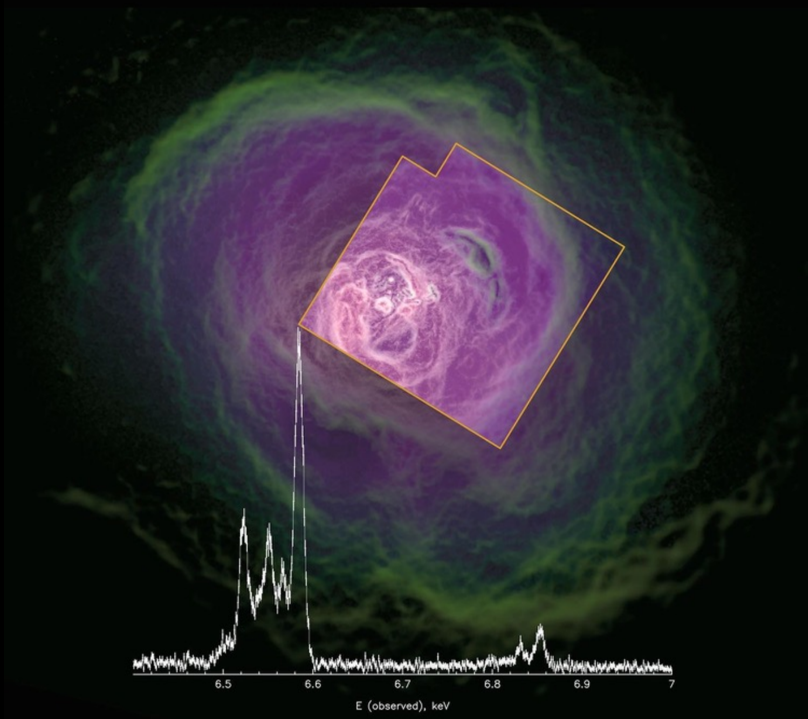
XRISM

X-Ray Imaging and Spectroscopy Mission

Resolve



A Study of the Individual Contributions of Heat Generated by a XRISM/Resolve ADR Stage Magnet and its Magnetic Shielding

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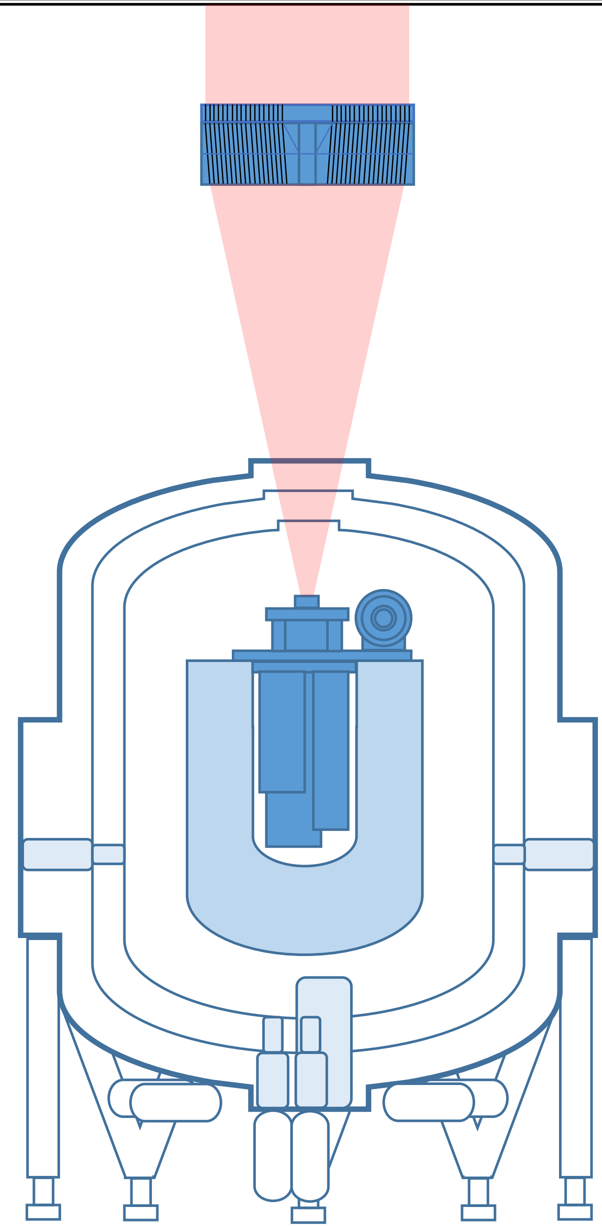
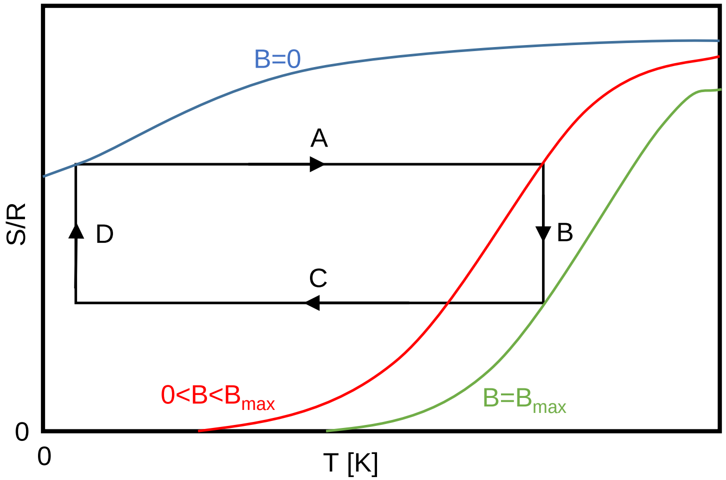
X-Ray Imaging and Spectroscopy Mission (XRISM)

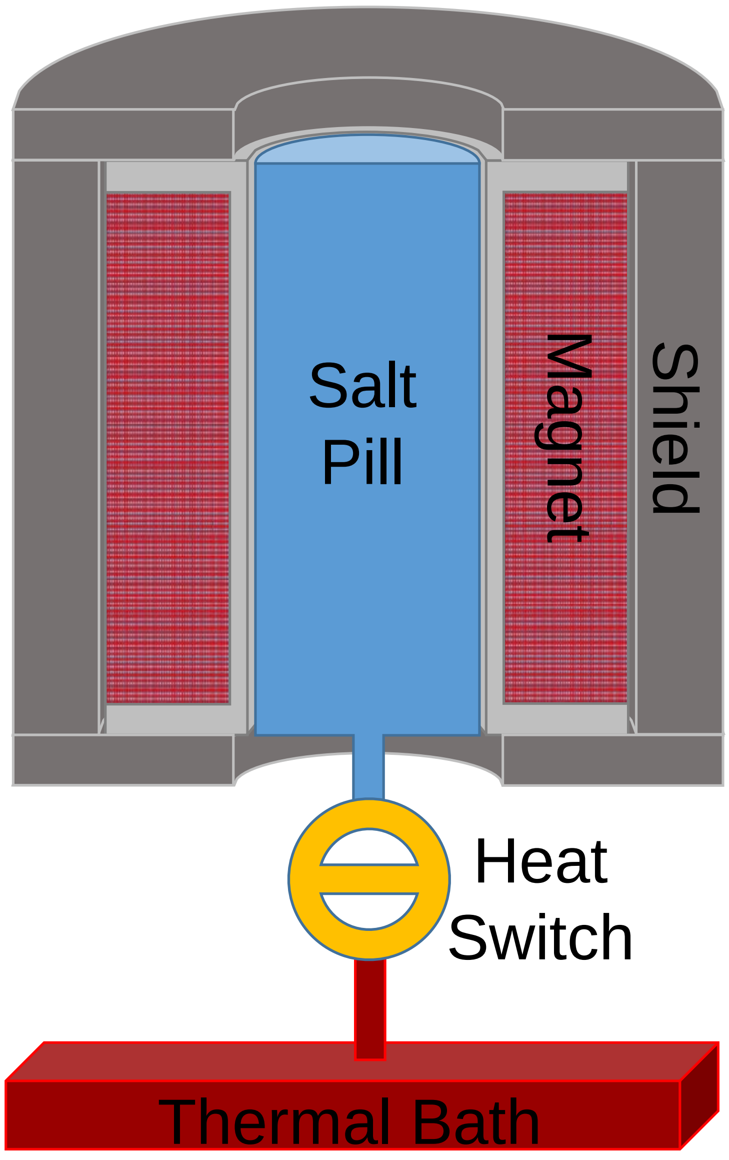
- XRISM
  - A Japanese X-ray astronomy satellite
  - Successor to Hitomi (Astro-H)
- Resolve
  - Is a soft X-ray spectrometer
  - Calorimeter Spectrometer Insert
    - X-ray Detector
    - 3 Stage Adiabatic Demagnetization Refrigerator



Adiabatic Demagnetization Refrigerator (ADR)

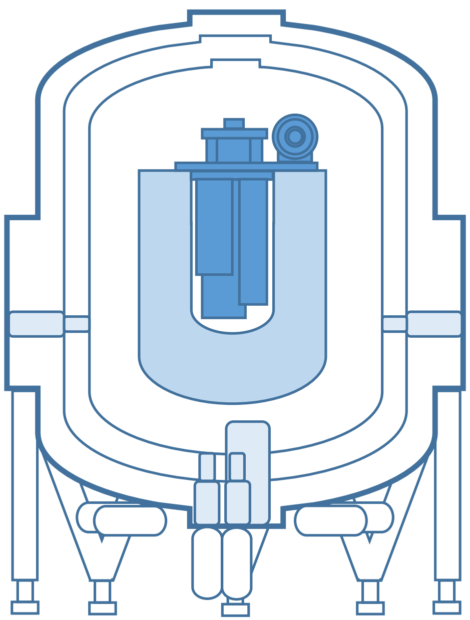
- An ADR absorbs heat by reducing the magnet field on a paramagnetic salt
- When the B=0, the ADR is 'recycled'
  - Ramp B up to increase the temperature
  - Dump the heat to a thermal bath
  - Ramp B down to decrease the temperature
- During the cooling phase, the salt pill/detector is temperature controlled
- A magnetic shield is used
  - Reduce the magnetic field outside the ADR
  - Increase the flux density within the salt pill

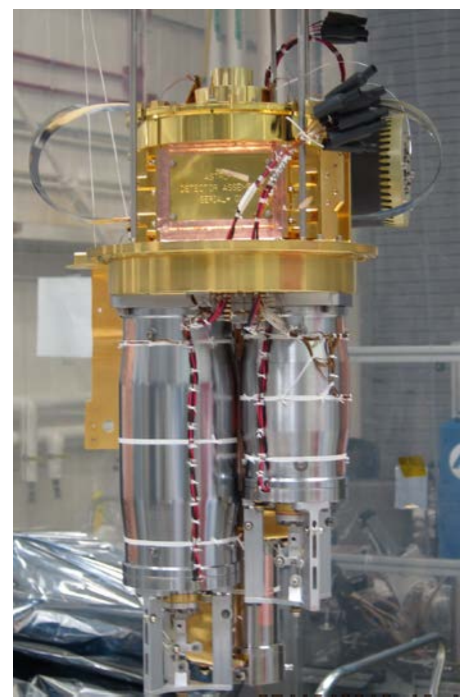




Purpose

- Understand component contributions of the ADR's heat loads (cannot be done on the flight model)
  - Magnet
  - Magnet and shield
- Enhance the thermal model of XRISM's cryogenic system
- Improve design future ADRs



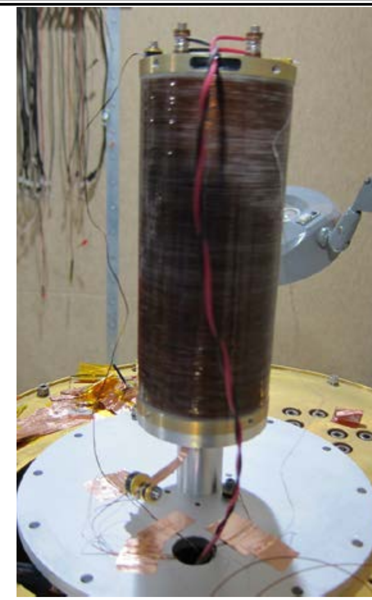


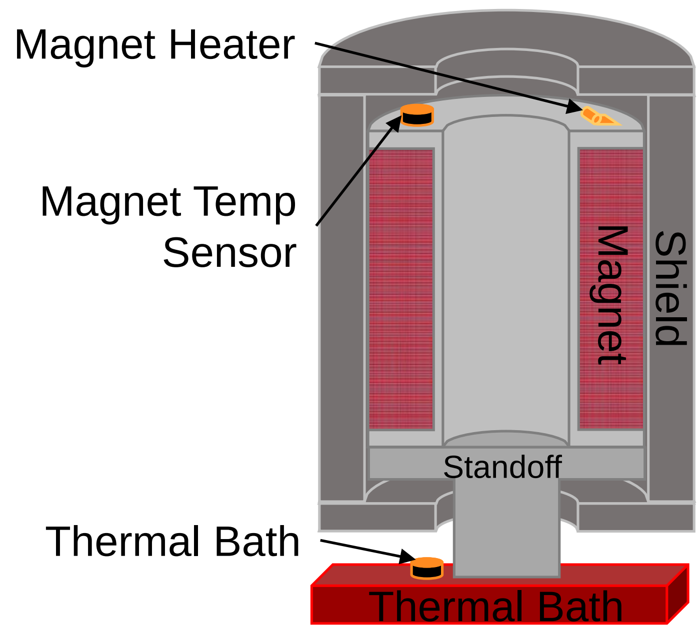
Heat Sources

- Three types of heat generated by changing the magnetic field
  - Joule heating (DC loss)
    - From resistance in the current path
    - $Q_J \propto I$
  - Eddy current heating (AC loss)
    - From Inducted magnetic fields
    - $Q_E \propto \frac{dI}{dt}$
  - Hysteretic heating (AC loss)
    - Trapped flux, magnetic domain alignment, and other path dependencies
    - $Q_H \ is\ path\ dependent$

Experimental Setup

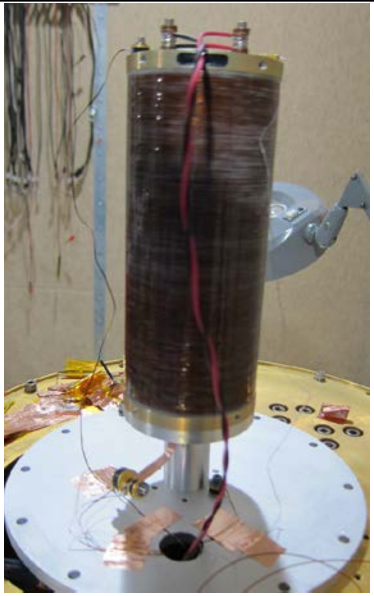
- Magnet attached to the thermal bath via a standoff
- Temperature sensor are attached
  - Top of the magnet
  - Thermal bath
- Heater is attached
  - Top of the magnet
- Two experimental setups done
  - Magnet only
  - Magnet and shield

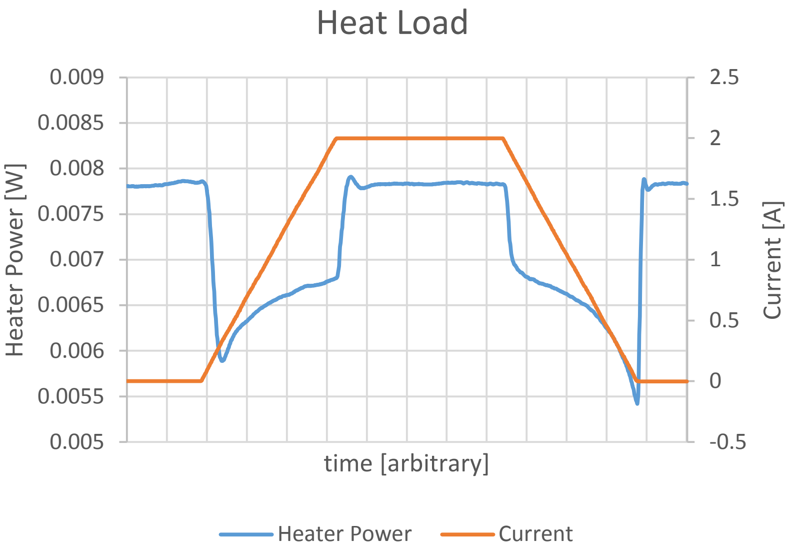




Experimental Setup

- The magnet is temperature controlled via the heater
- As the magnet current is ramps up or down
  - Heater power drops due to the heat generated from the magnet
- As the current remains constant
  - Heater power remains constant but not necessarily at the same value



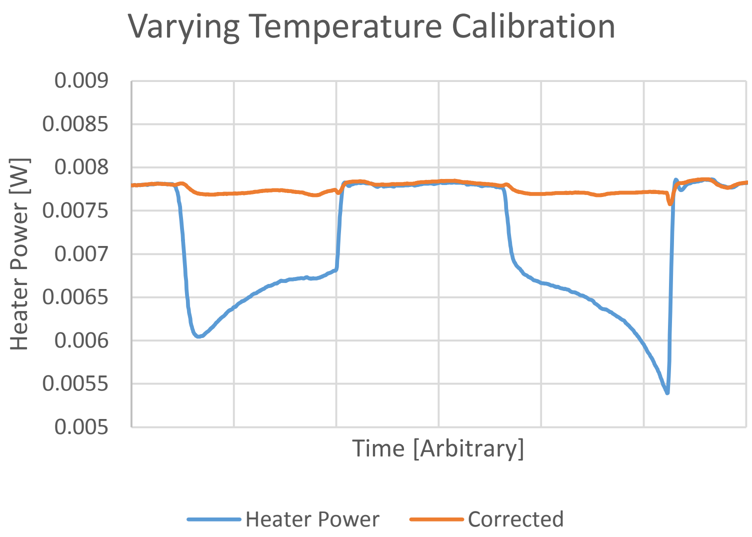


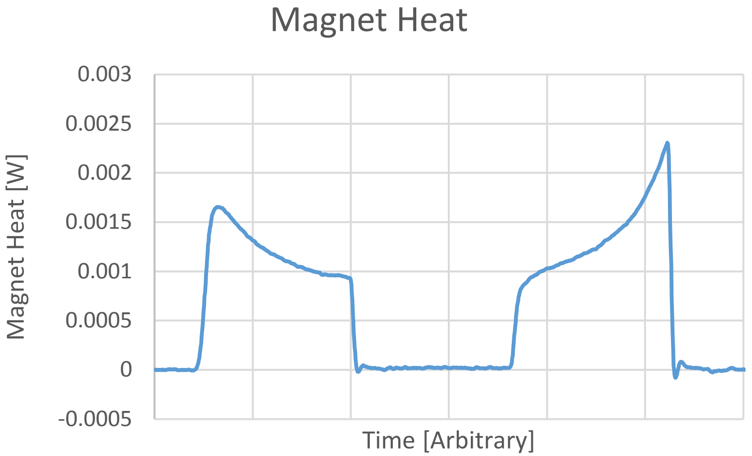
Calibrating for Varying Temperature

- To correct for varying temperatures the thermal conductance is determined from a fit to the data
  - Thermal bath wonders in temperature
  - Magnet's thermal control loop is not instantaneous fast
- Magnet's temperature is manually varied via the heater
- Thermal bath's temperature is monitored for a length of time to measure its temperature variations

$$\mathcal{W} = \frac{\dot{Q}_{heater}}{T_{magnet} - T_{bath}}$$

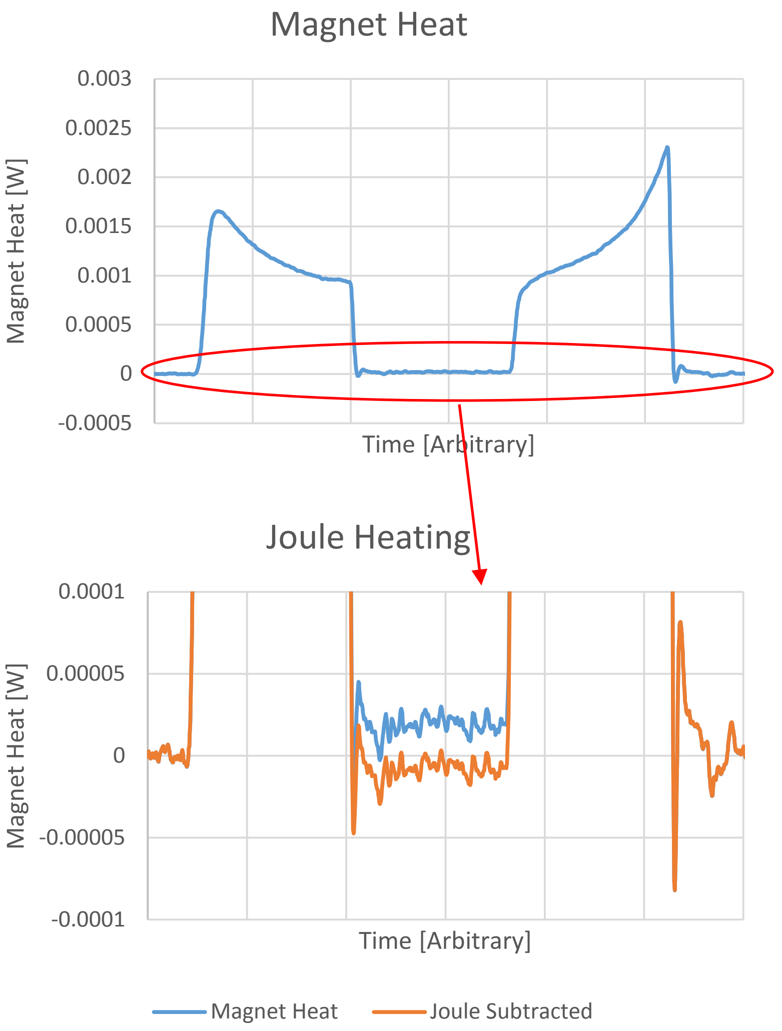
$$\dot{Q}_{corr} = \mathcal{W}(T_{magnet} - T_{bath})$$

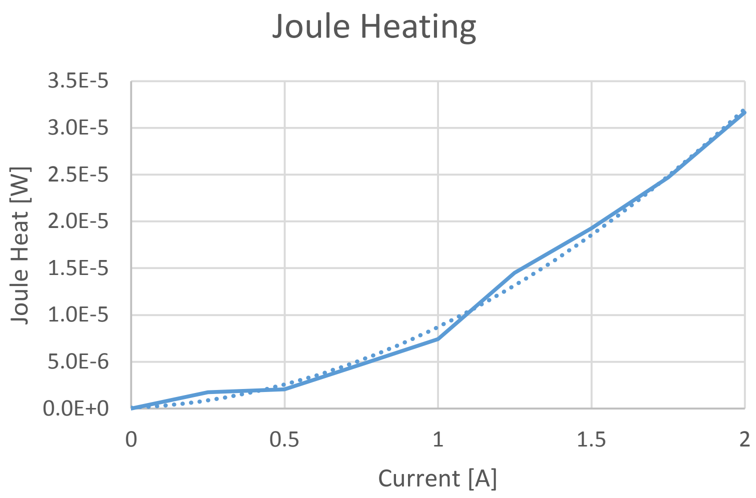




Determining Joule Heating

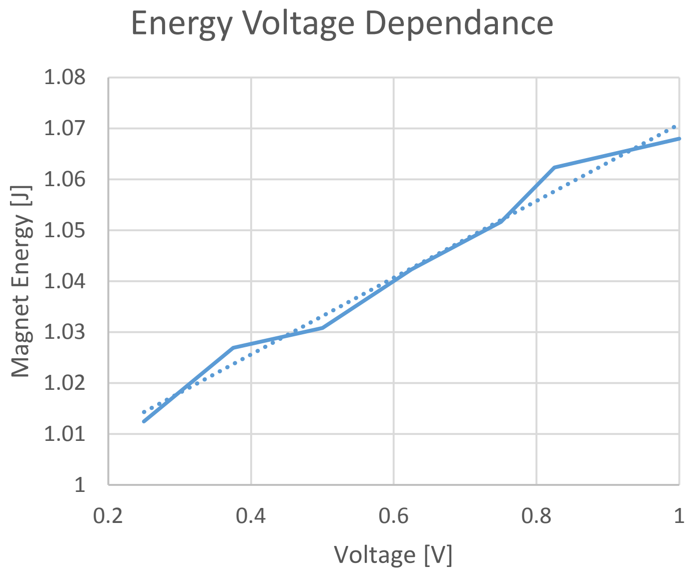
- To determine the joule heating, the current is set to multiple values.
- For each current, the system is allowed to reach a steady state
- The current dependence is fitted, then subtracted from the magnet heat

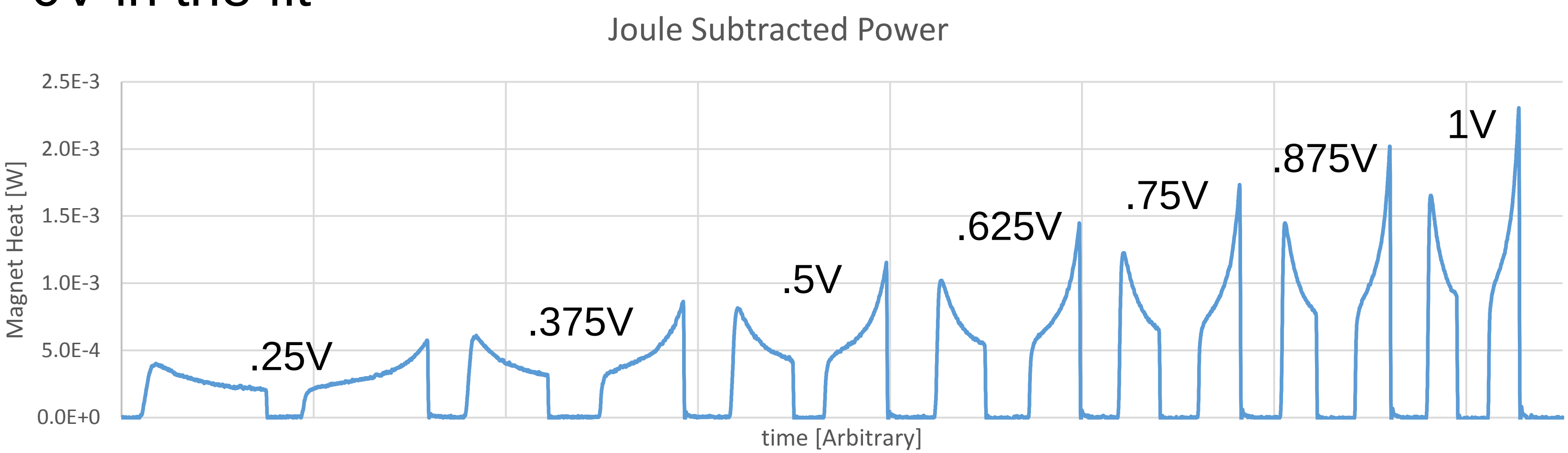




Determining Eddy Current

- Measure the magnet's heat generated across the same current path and vary the voltage
- Integrate and find the voltage dependence
- Total eddy current heating is the voltage dependent energy generated
- Total hysteretic heating is the energy generated as you approach 0V in the fit





Determining Eddy Current

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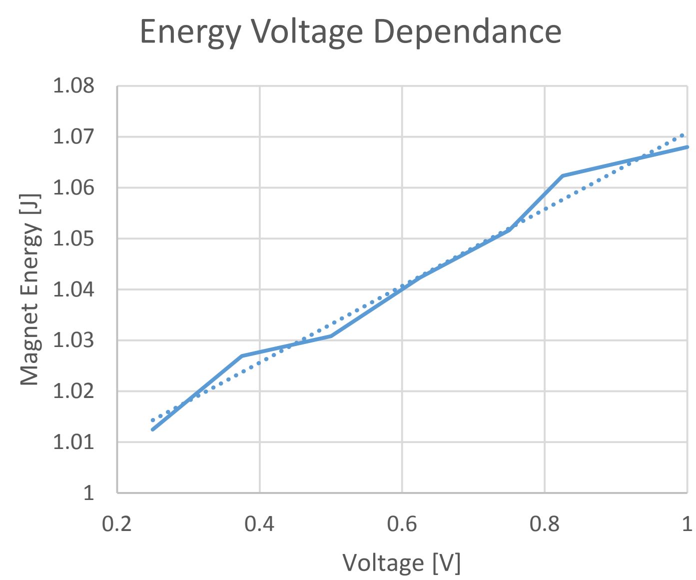
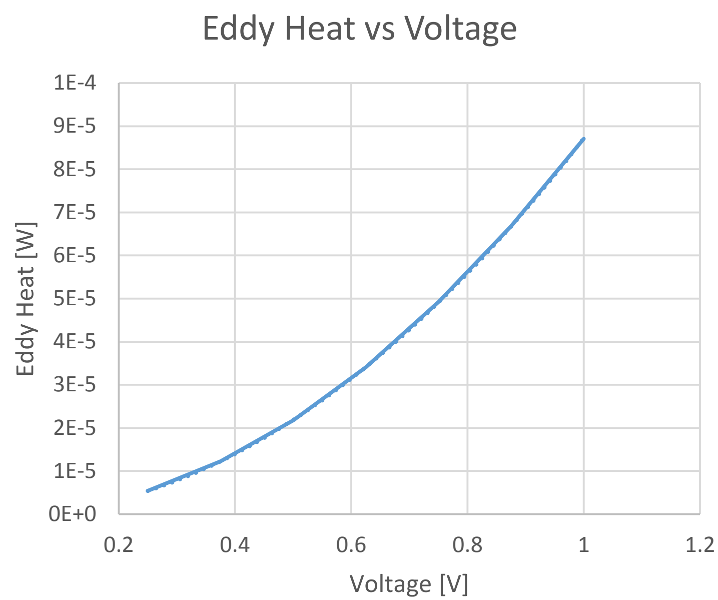
- Integrate and find the voltage dependence.
- Total eddy current heating is the voltage dependent energy generated
- Total hysteretic heating is the energy generated as you approach 0V in the fit
- The average eddy current heating power can be calculated and subtracted out, assuming
  - The voltage was constant during the ramping
  - The ramp rate is slow enough



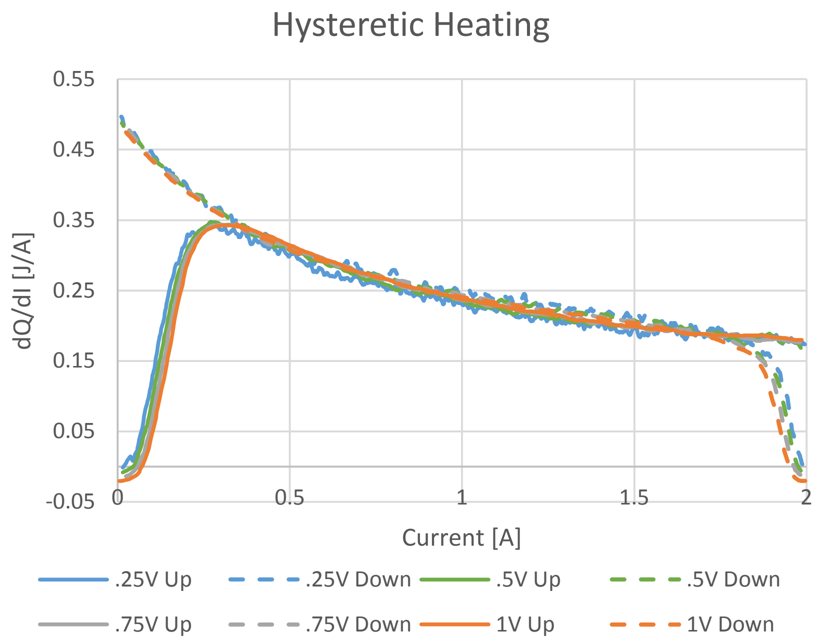


Hysteretic Heating

- What is left is hysteretic heating
- Looking at the heat as a function of current removes the temporal dependence on voltage

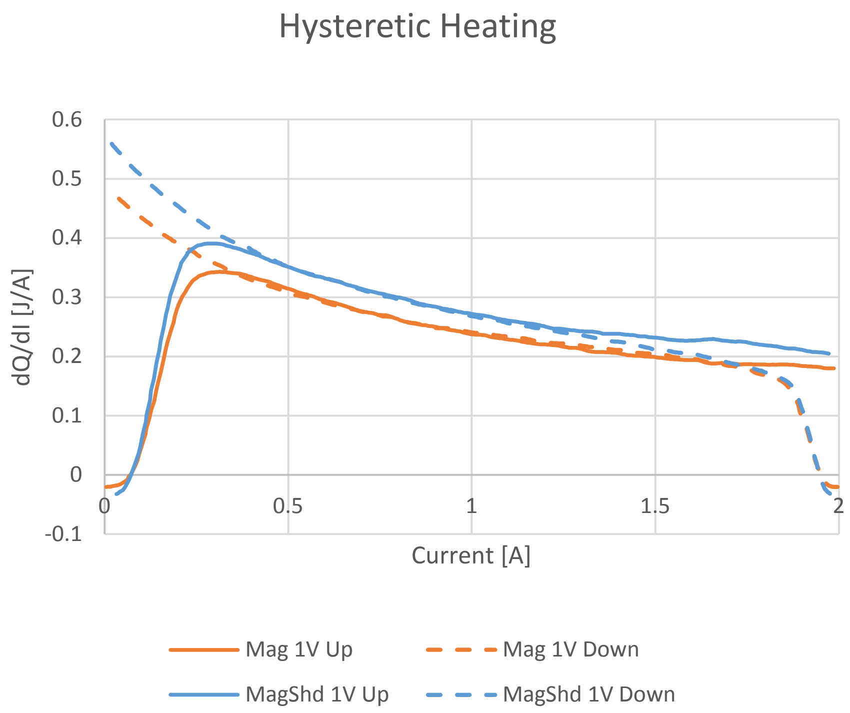
$$\frac{dQ}{dI} = \frac{dQ}{dt} \Big/ \frac{dI}{dt} = \dot{Q}\,\frac{L}{V}$$

- Since all the voltage varying runs took the same current path, they overlap



Comparing Results

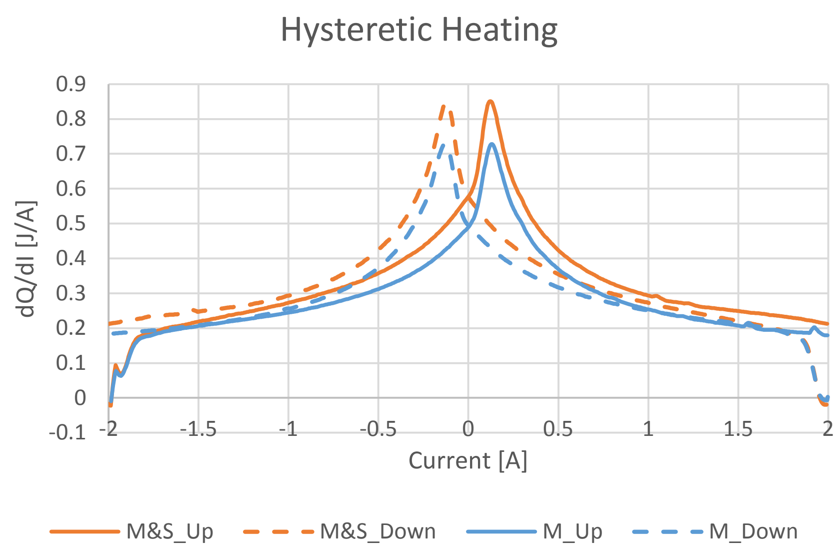
- Current range: 0-2A
- Ramping voltage range: 0.25-1V
- Majority of the heat is from hysteretic heating from the magnet

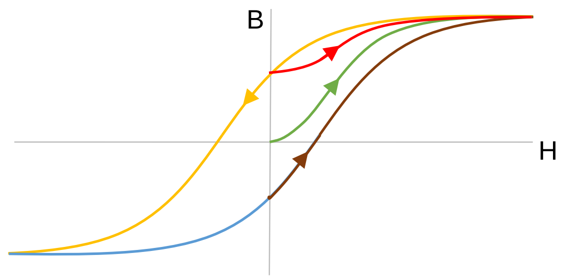


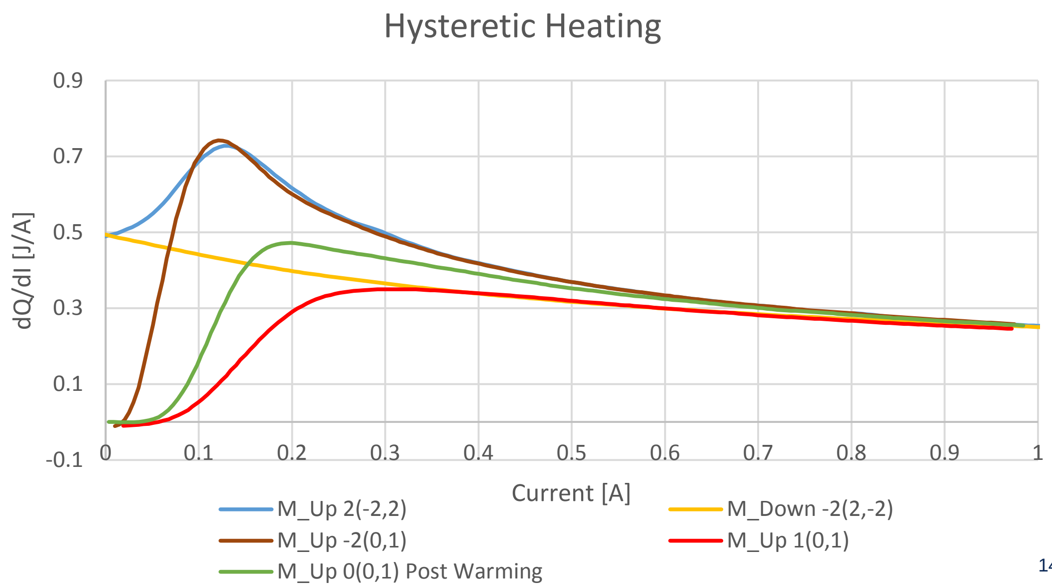
Heating	Magnet Only	Magnet & Shield	Magnet's Contribution
Joule [W]	$7.35 \times 10^{-6}\, I^2$	$2.42 \times 10^{-5}\, I^2$	NA
Eddy [J]	$7.54 \times 10^{-2}\, V$	$1.23 \times 10^{-1}\, V$	61%
Hysteretic [J]	1.00	1.17	85%

Results

- Additionally looked at current range of -2 to 2A
  - Additional heat is produced soon after reversing polarity
- Can see the hysteretic behavior and compare it to the B-H curve
- Going above the T_c of the magnet winding will reset the path behavior







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