(Almost) Quantifying the Efficiency of TRIGA Mark I Power Channels

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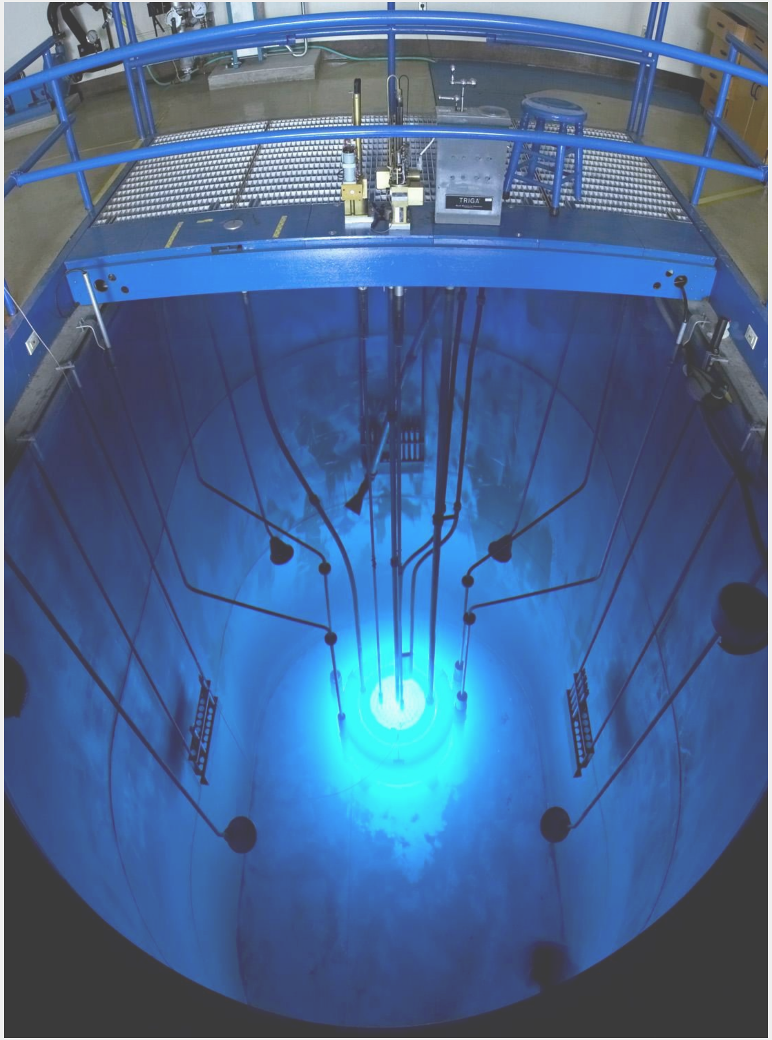
Summary

- ★ Introduction to our power channels
- ★ The experiment and goal
- ★ Method and plan
- ★ Results?
- ★ Interruptions for Maintenance
- ★ What's next?



Reed Research Reactor’s Power Channels

Power Channels

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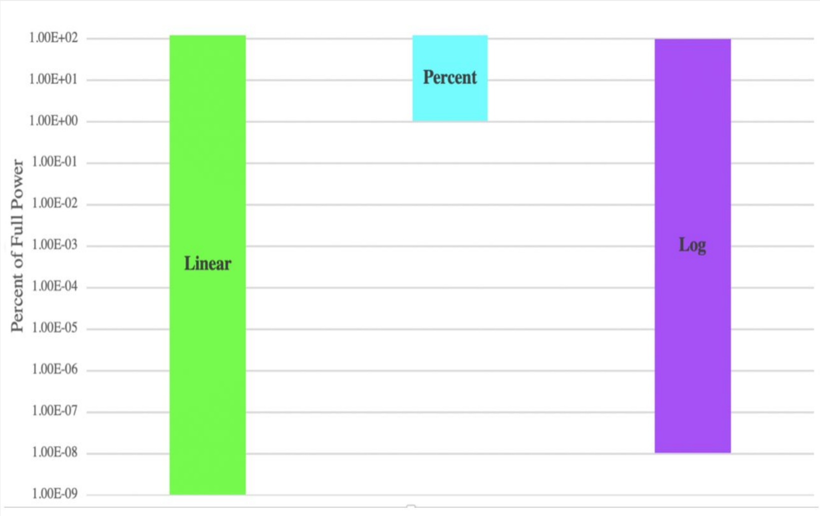
The Reed Research Reactor (RRR) has 3 power measuring channels

Neutron detectors → Power readout in watts

- Fission chamber → Logarithmic channel
  - Operates in pulse mode from 1E-8 - 32% of full power*
  - Switches to Campbelling mode at higher powers
  - Digital readout
- Uncompensated ion chamber → Linear channel
  - Multi-range readout, with percent of selected range displayed
  - Analog readout
- Compensated ion chamber → Percent channel
  - Simple percent of full power* displayed
  - Analog readout

Possible Range of Channel Readout



Power Channels

*full power is 250kW per the RRR's license

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The Experiment and Goal

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Big question: Within the three channels overlapping range, do their readouts deviate from each other or the ‘true’ power?

- Areas of particular interest:
    - Does the accuracy of the log channel change around the 30% mark?
    - Does the percent channel become less accurate at lower powers?
    - If the channels deviate from each other, how much and at what power levels?

Hypothesis: They may end up deviating from the ‘true’ power at lower levels, but will remain within 2% of the true power at higher levels (> 125kW). They should not deviate from each other.

- We calibrate our power measuring channels at 80% of full power once a year.

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Common misconception: range of channels vs efficiency of channels

- Often heard that some power channels are "better than others" at different power levels.
    - Actually referring to range of channels, thus when they can feasibly be used.
    - Led some trainees/staff (including myself) to think one channel was more efficient than another.
- Researched to find which neutron detector (fission chamber, UC/C ion chamber) is 'better' at varying degrees of neutron flux.
    - Unable to find direct tests → motivated this experiment!

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The Method and Plan

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Measure a control power (will be used as ‘true’ power)

- Used a revised nuclear instrumentation calibration procedure:
  - Operate at a constant power
  - Thermocouples through pool measure change in temperature over an operation
  - By relating change of bulk water temperature to heat input of reactor, power can be found
- Gives ‘true’ (or thermal-calculated) power for comparison
- Did not follow the rest of procedure (calibration portion)

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Date		

Time 1		
Time is power is reached		hh:mm
Ch 0		ºC
Ch 1		ºC
Ch 2		ºC
Ch 3		ºC
Ch 4		ºC
Ch 5		ºC
Console		ºC
Average Temp	#DIV/0!	ºC
Pool Height		mm

Time 2		
Time at end of operation		hh:mm
Ch 0		ºC
Ch 1		ºC
Ch 2		ºC
Ch 3		ºC
Ch 4		ºC
Ch 5		ºC
Console		ºC
Average Temp	#DIV/0!	ºC
Pool Height		mm
Linear		kW
Percent		kW
Log: Wide Range		kW
Log: Power Range		kW

Percent Error		
#ERROR!	%	#ERROR!
#ERROR!	%	#ERROR!
#ERROR!	%	#ERROR!
#ERROR!	%	#ERROR!

Constants Used in Calculations		
Core Volume	499220.1016	cm^3
Area of the tank	119380.41	cm^2
ΔHv	2458	Joules/gram
Cp	4.186	Joules/(gram ºC)

Calculating Qin		
Specific volume at Avg Temp 1	#ERROR!	cm^3/g
Specific volume at Avg Temp 2	#ERROR!	cm^3/g
Mass at Time 1	#ERROR!	g
Mass at Time 2	#ERROR!	g
Mass of Evaporation	#ERROR!	g
Qin	#ERROR!	Joules

Wait? What's actually being calculated?

$$Q_{in} = m_T \cdot C_p \cdot \Delta T + m_E(\Delta H_v + C_p \cdot \Delta T)$$

Qin = the heat input of the reactor
mT= the water mass in the tank
Cp = the specific heat of the water
ΔT = the change in bulk water temperature,
mE = the mass of the water that evaporated
ΔHv = the latent heat of vaporization

Calculated Power		
Time at power	0.00	s
Power	#ERROR!	kW

White cells are values that are constant, and the names and units of input parameters. DO NOT EDIT THESE CELLS.

Yellow cells require user input (follow SOP 33)

Blue cells are calculated numbers. Once all of the yellow cells are filled, the blue cells will display numbers. DO NOT EDIT THESE CELLS.

The green cell is the calculated power in kW. DO NOT EDIT THIS CELL.

Method and Plan

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Next step: go critical at different powers, stay at each for three hours

- Record linear, percent, and log channel readouts at the end of the three hours for comparison
- Keep powers > 2% of full power* for accurate percent channel recording

Linear Channel Range	% of Range	Power	% of FULL Power
250 kW	80%	200 kW	80%
250 kW	60%	150 kW	60%
250 kW	40%	100 kW	40%
250 kW	20%	50 kW	20%
25 kW	80%	20 kW	8%
25 kW	60%	15 kW	6%
25 kW	40%	10 kW	4%
25 kW	20%	5 kW	2%

Method and Plan

*full power is 250kW per the RRR's license

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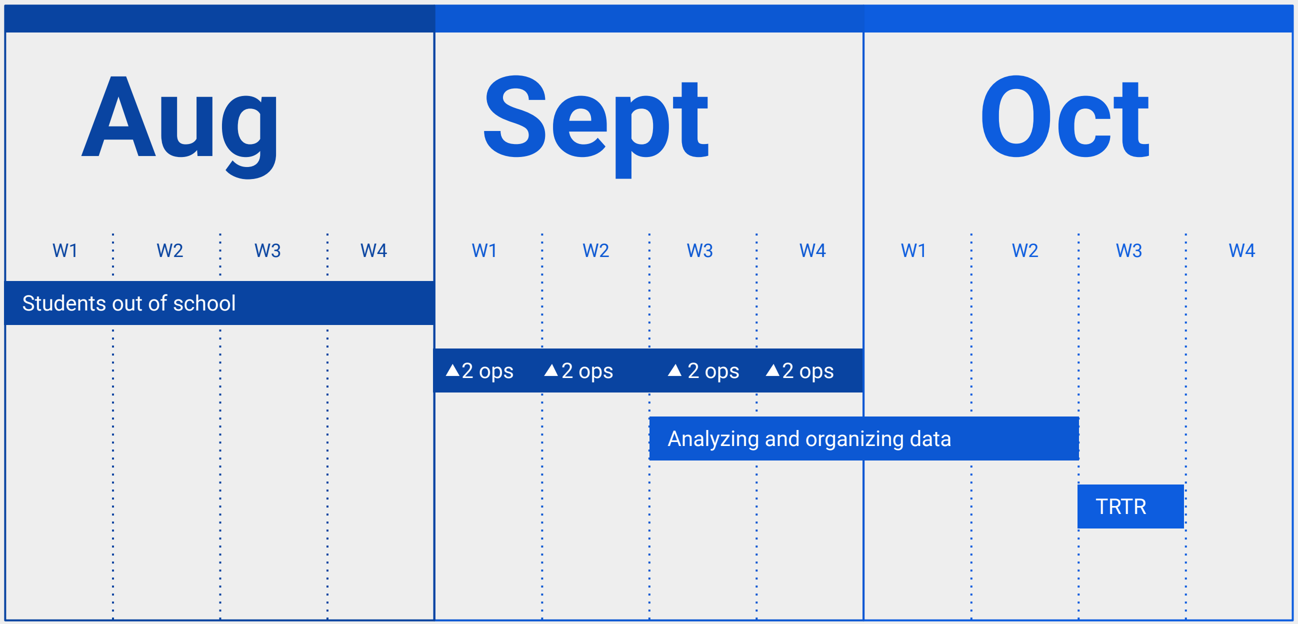
Original plan for operating:

(Limiting factor: operations must be three days apart)



Method and Plan

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Results?

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- No conclusitory data due to maintenance interrupting most operations.
- What was gotten:

Target Power (kW)	True Power (kW)	Linear Channel (kW)	% error	Percent Channel (kW)	% error	Log Channel (kW)	% error
200	202.08	200.0	-1.04	205.0	1.43	203.8	0.82
150	163.12	150.0	-8.74	148.8	-9.62	148.8	-9.62

If accurate, this disproves the first part of my hypothesis.

What maintenance took place?

Maintenance

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Water Pump Failure

- Primary cooling system pump was louder then normal and pressures were reading low.
- Facilities services concluded that the pumps impeller was degraded.
- A new impeller was installed and primary is now operational.

Primary pump's degraded impeller

Ventilation Fan Failure

- Indicators showed there was no airflow into reactor bay.
- Staff concluded that the ventilation fan into the bay was off; all other fans were operating as expected.
- A campus-wide software issue caused the fan to turn off.
- The issue has been resolved, but we're monitoring it to ensure it doesn't happen again.

Maintenance

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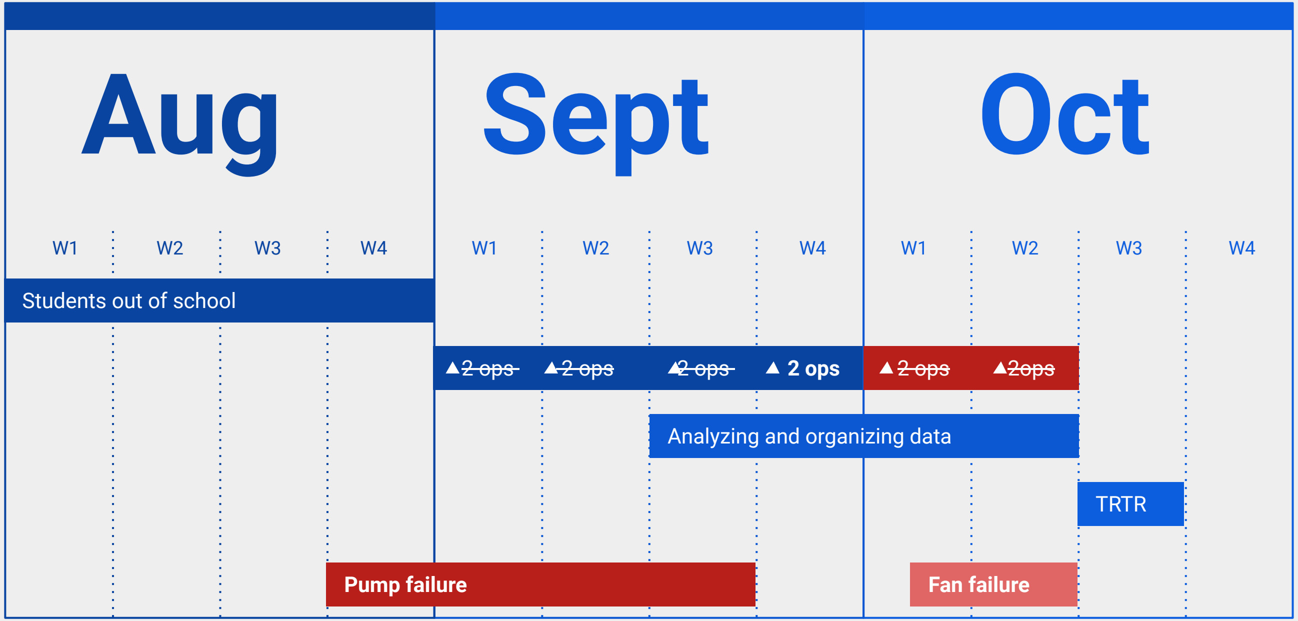
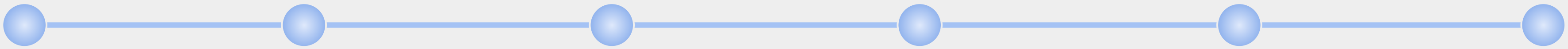
Revised plan for operating:





Maintenance

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Next Steps

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What’s next?

Over the course of the next year I aspire to …

Revise my method of recording channel readouts

Certify the preliminary two data points are accurate

Expand operation plans to do more testing at intermediate powers

Finish the remaining operations, collect remaining data

Evaluate data to quantify the efficiency of each channel

Analyze hypothesis versus results; if any difference, why?

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Thank you!

Power Channels — Experiment & Goal — Method and Plan — Results? — Maintenance — Next Steps