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Kilopower Reactor Using Stirling Technology (KRUSTY) Update

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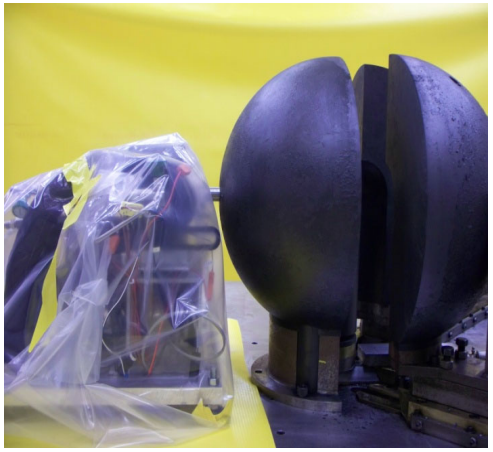
Outline

- Background
- Objectives of the KRUSTY experiment
  - KRUSTY test phases
- Comparison of measured data vs Simulations
  - Results of warm criticals
  - Results of 28 hr high temperature run
- Conclusions

Background (Timeline)



- 2012 NCERC and NASA conducted a small scale demonstration experiment called DUFF (Demonstration Using Flat-Top Fissions)
- 2014 Planning of the next demonstration experiment is examined
- 2015 Kilopower (KRUSTY) project gets started
- 2017 KRUSTY experiment begins (November)

Objectives

- The main objective of the KRUSTY experiment is to evaluate the operational performance of a compact reactor that closely resembles the flight unit NASA will use for deep space exploration missions
- Test the dynamic behavior (transients) of the reactor
- Test the integrity of the fuel

KRUSTY test phases

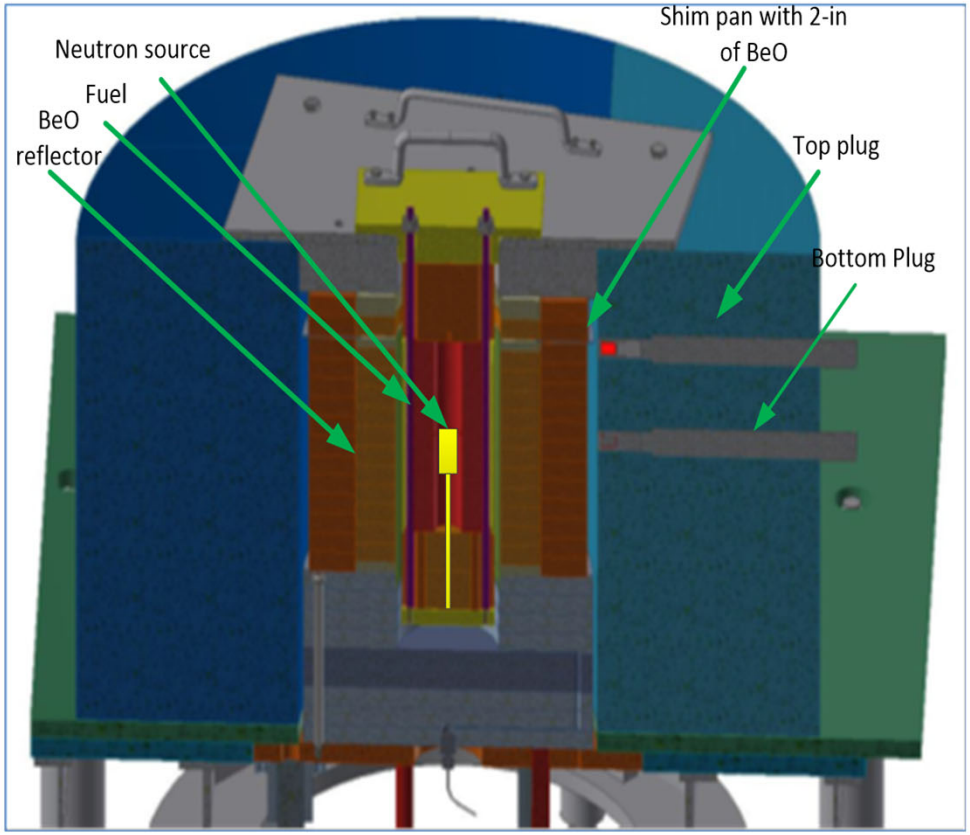
Phase 1: Component Critical Measurements
- Critical configuration is determined
- BeO reflector worth measured
- B_4C control rod worth measurements
- Room temperature

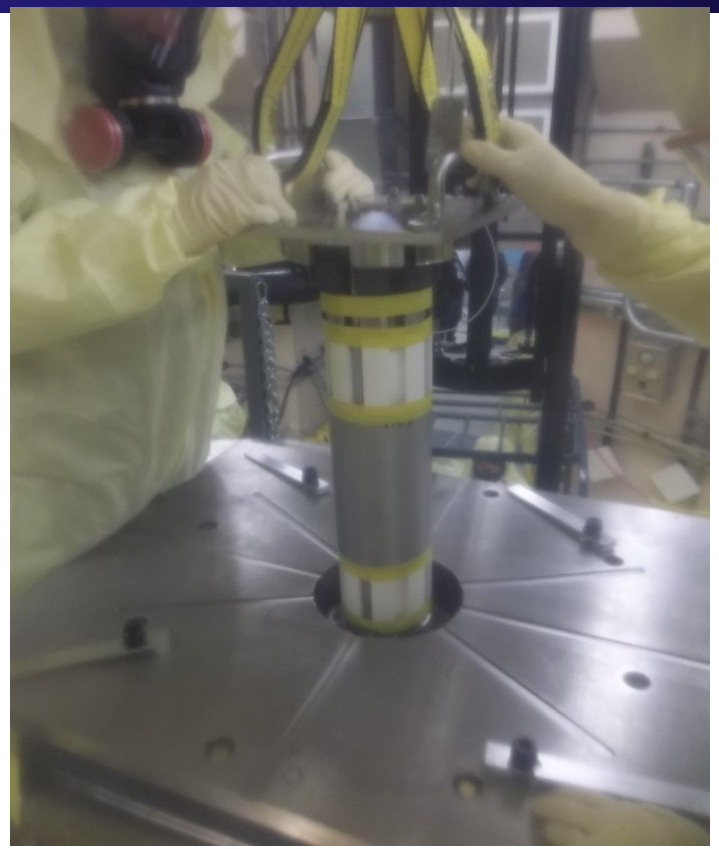
Phase 2: Cold Critical Measurements
- Heat pipes installed
- Stirling engines installed
- Above items in a vacuum chamber
- Critical configuration found
- B_4C control rod worth measurements
- Room temperature

Phase 3: Warm criticals
- 15 cent free run, 30 cent run, 60 cent run
- Moderate temperature rise (<450°C)

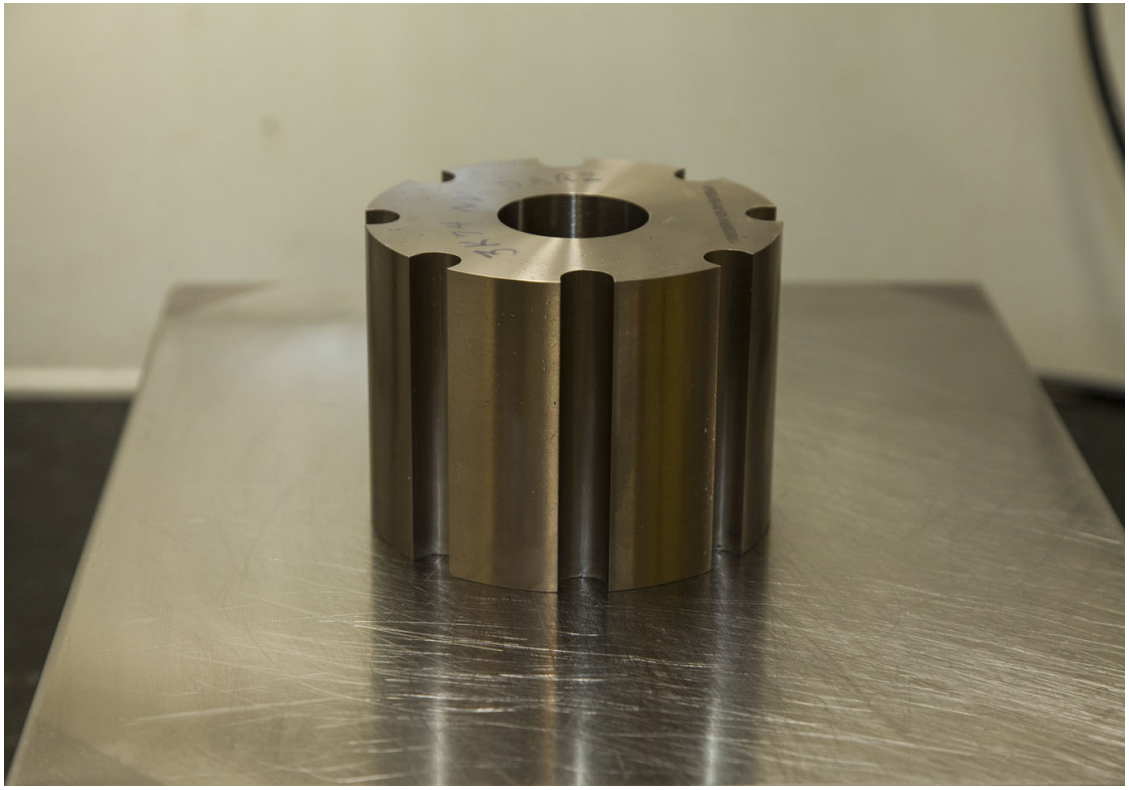
Phase 4: High Temperature Operations
- Mission power profile is executed
- Significant temperature rise (800°C)

KRUSTY Experiment (Phase 1)



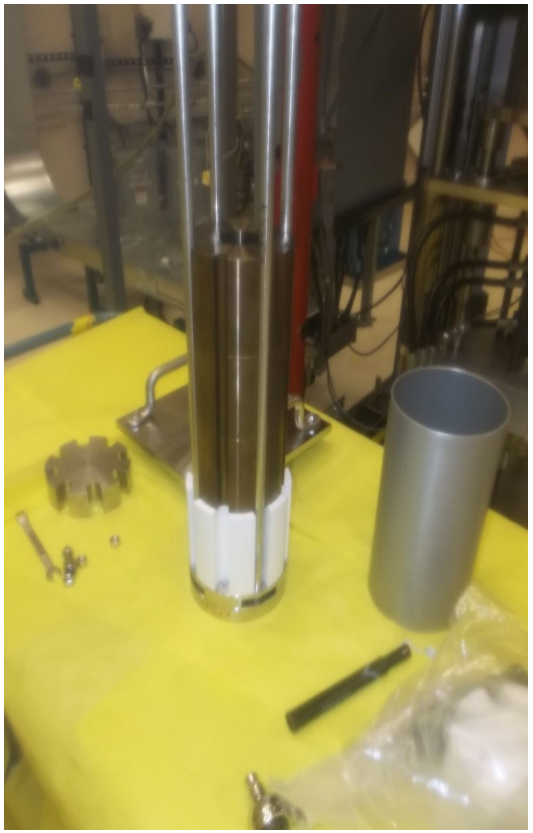


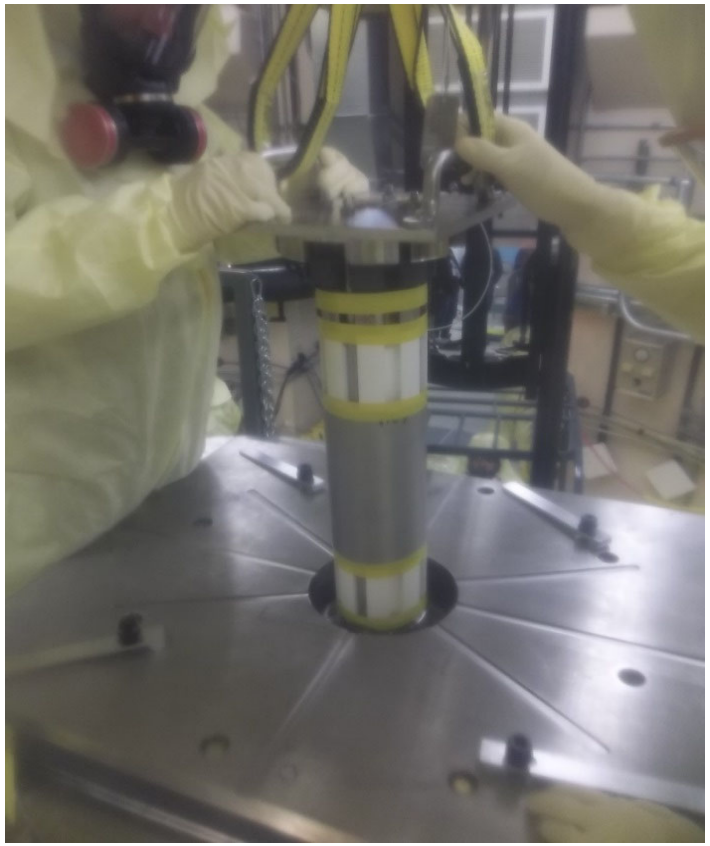
Core for the KRUSTY Experiment



- **Weight ~ 11 kg**
- **Density** ~ 17.4 g/cc
- **Uranium alloy (~7.65 wt% Mo)**
- **The uranium is isotopically enriched to ~ 93 wt% ^{235}U**

Phase 1: Component Criticals

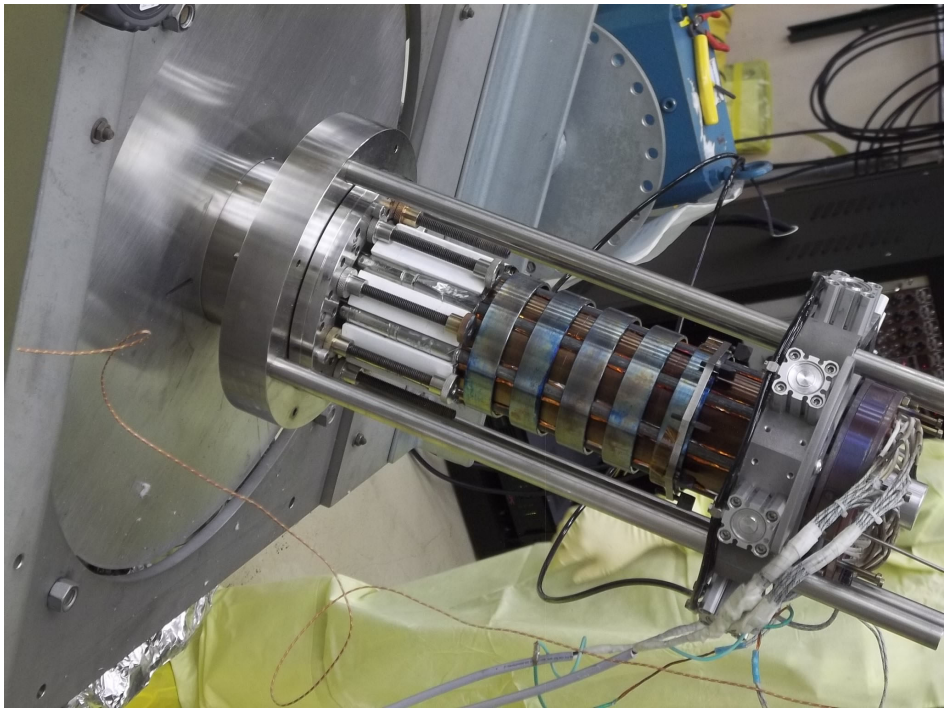


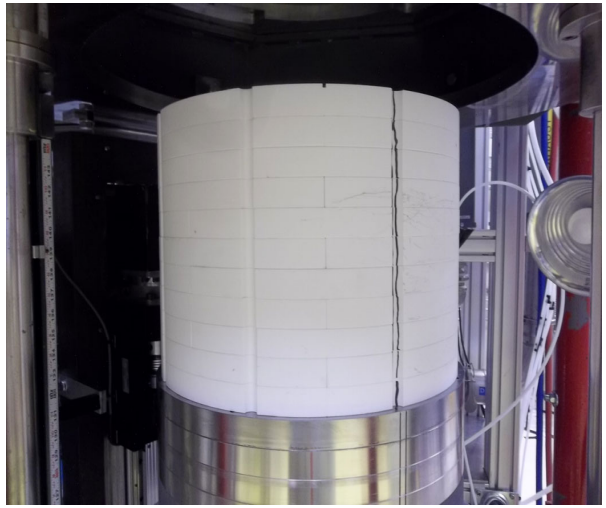


Results(Component Criticals)

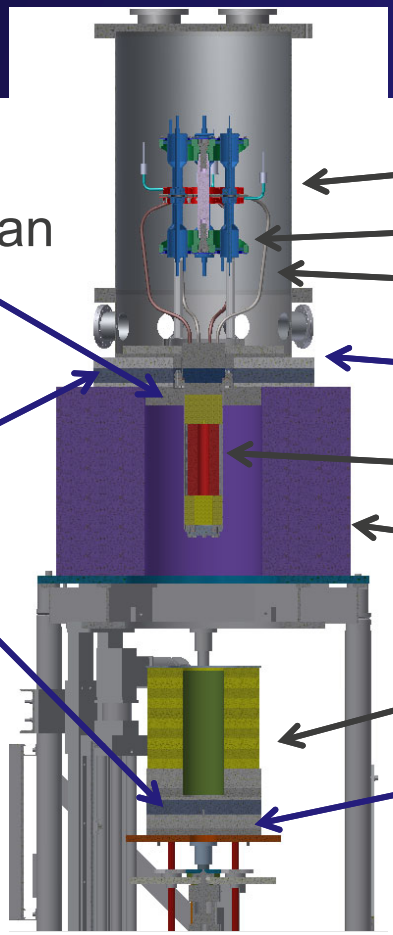
Sequential Operations Configuration	BeO Height (in)	Shim BeO (in)	B_4C Height (in)	Source Holder	Source Holder installed	Reactivity Measured (cents)	Reactivity Calculated (cents)
Baseline initial critical	11.250	0	0	Al	x	9.50	10.6
Unload and reload 4" of BeO	11.250	0	0	Al	x	6.90	10.6
No change	11.250	0	0	Al	x	6.90	10.6
Only top source plug removed	11.250	0	0	Al	x	6.80	10.6
Only bottom source plug removed	11.250	0	0	Al	x	7.00	10.6
Both source plugs removed	11.250	0	0	Al	x	6.90	10.6
Plug replaced (baseline)	11.250	0	0	Al	x	8.50	10.6
Add 1/8" BeO	11.375	0	0	Al	x	51.60	52.4
No change	11.375	0	0	Al	x	50.00	52.4
Remove 1/8" BeO (baseline)	11.250	0	0	Al	x	9.20	10.6
Remove source and holder	11.250	0	0			2.30	1.6
No Change	11.250	0	0			2.30	1.6
Add 1/8" BeO	11.375	0	0			45.20	43.4
Add Al source holder	11.375	0	0	Al		46.80	46.2
No change	11.375	0	0	Al		48.20	46.2
Remove 1/8" BeO	11.250	0	0	Al	x	5.01	4.4

Phase 2: Cold Criticals

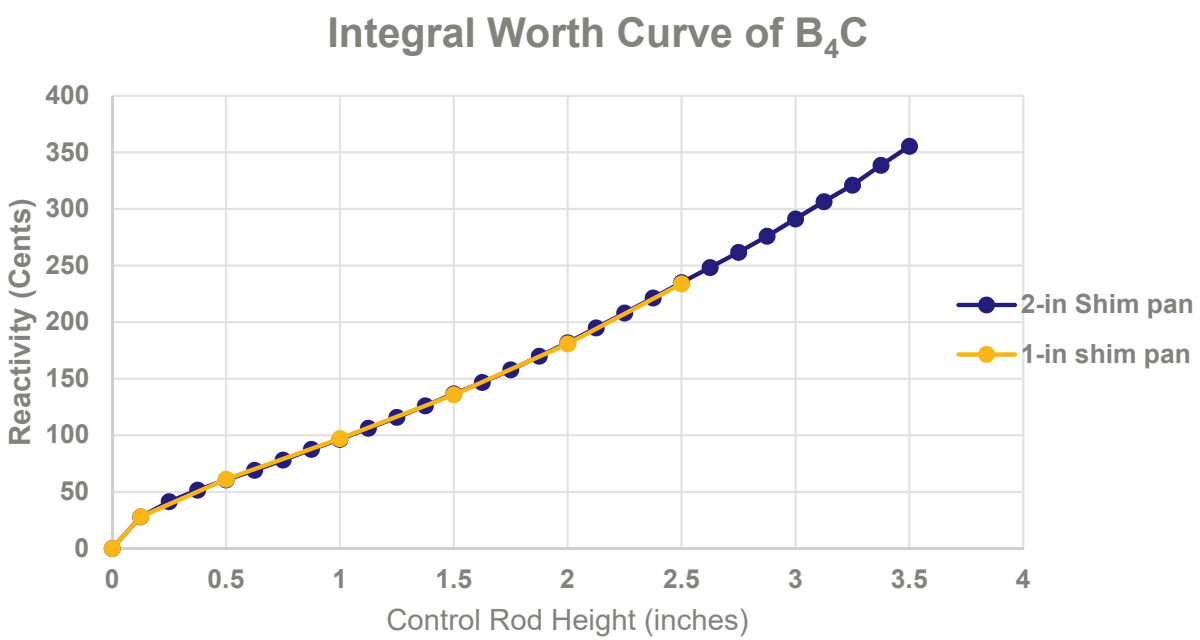




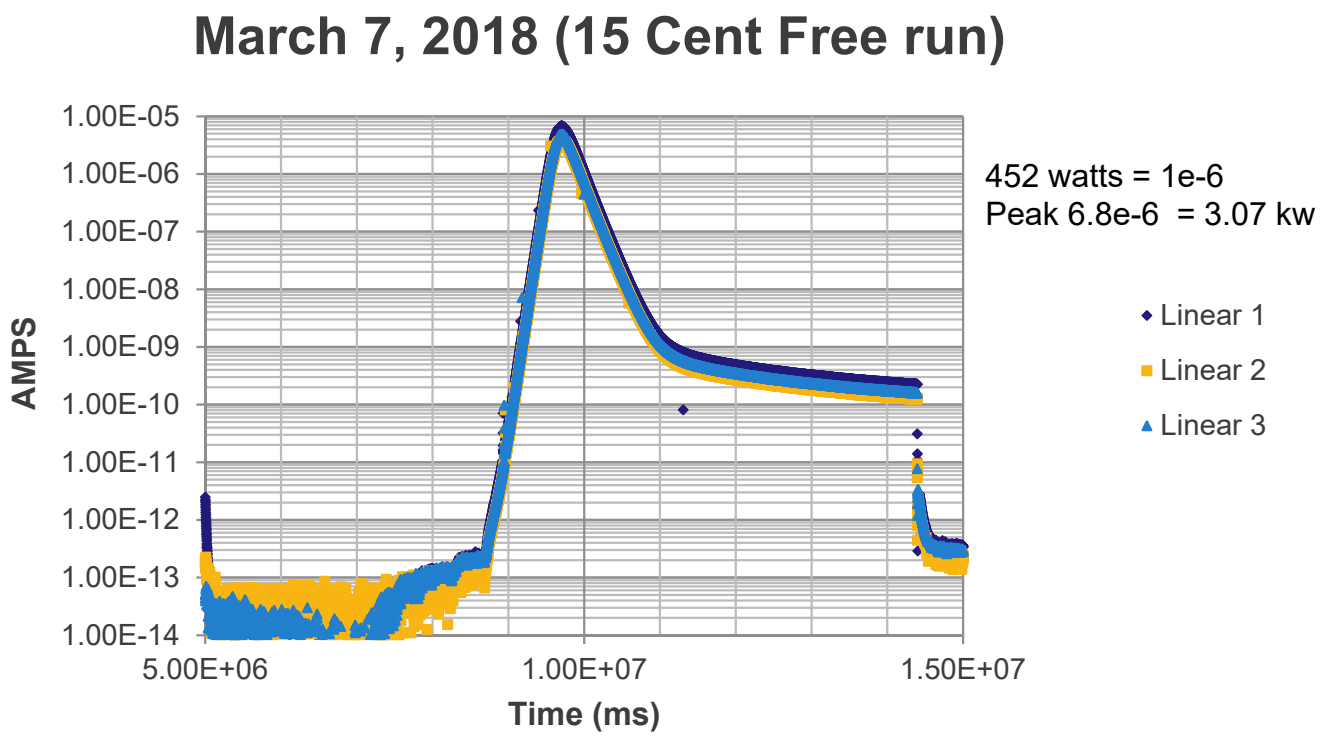
KRUSTY Experiment (Phases 2, 3, and 4)



Control rod worth measurement (Phase 2: cold criticals)

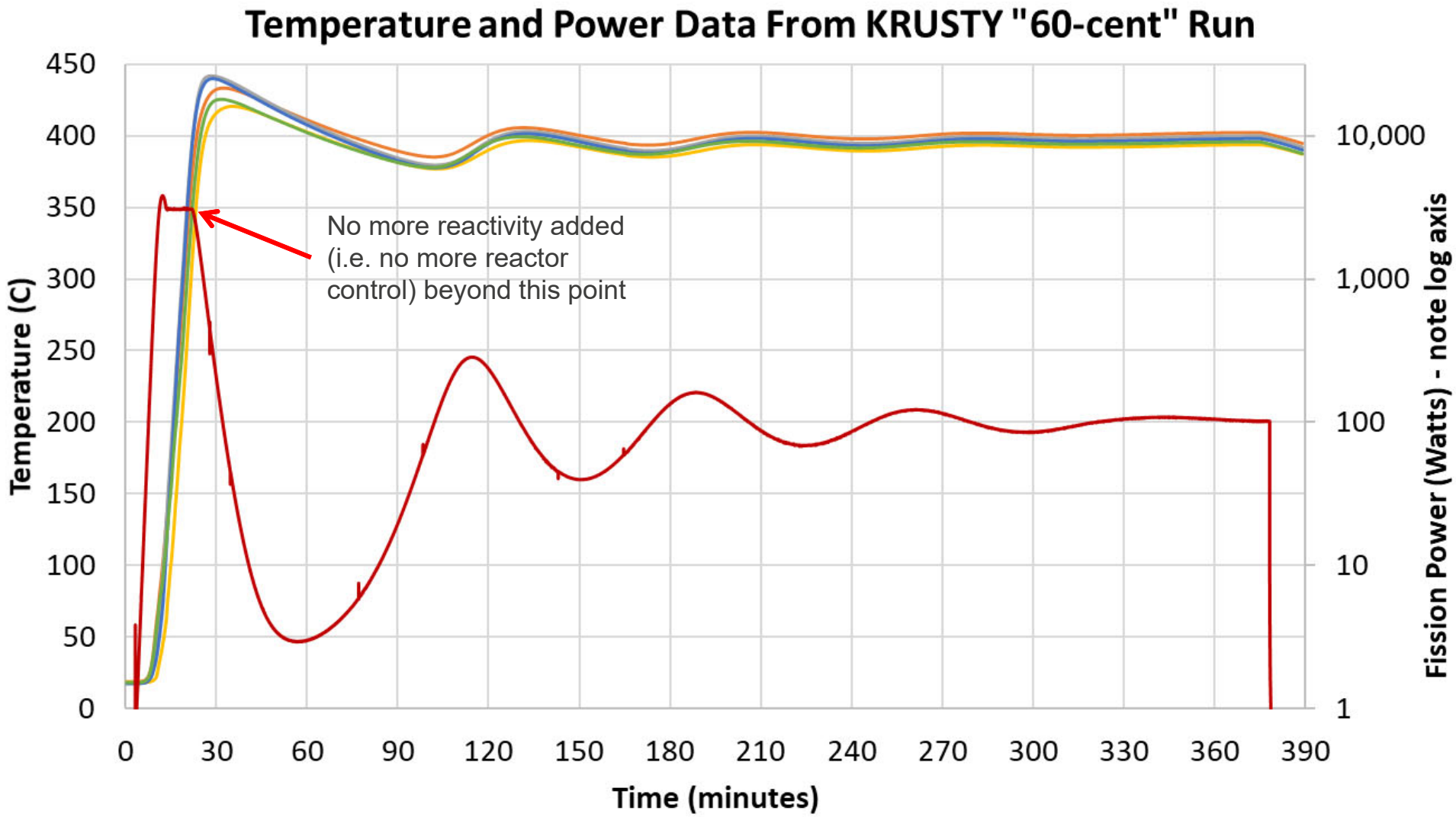


Phase 3: Warm Criticals



Maximum Temperature
218 °C

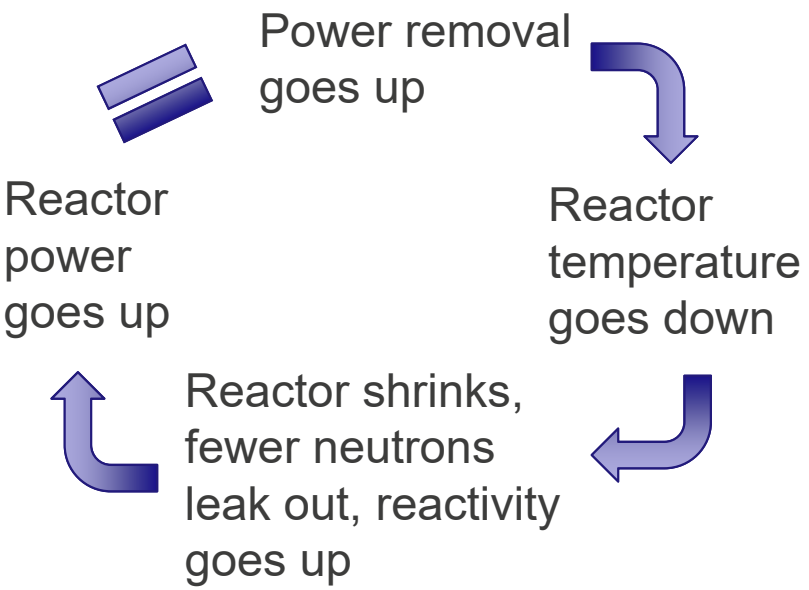
Warm Critical



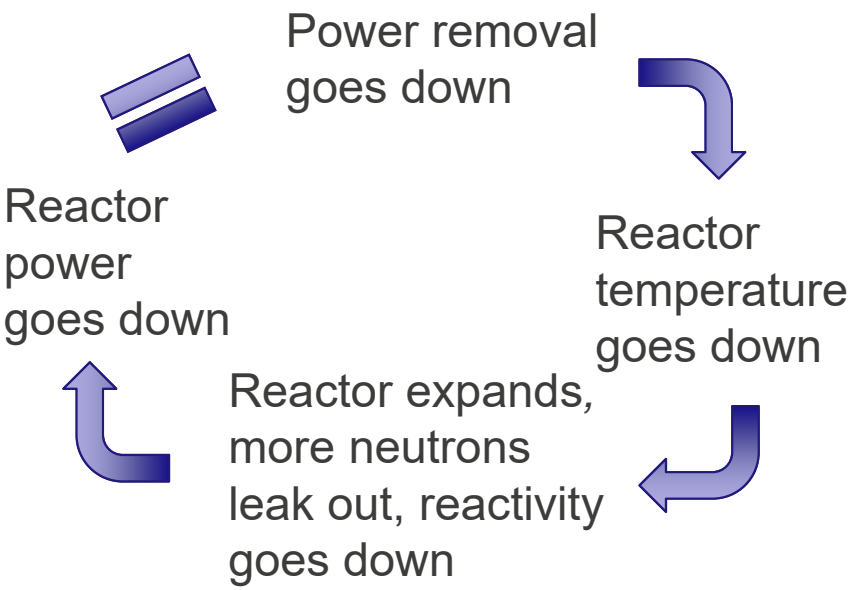
Kilopower Reactors are Self-Regulating (Phase 4)

KRUSTY, and all Kilopower reactors are designed to passively accommodate all possible states of the power conversion system, including worst-case failures.

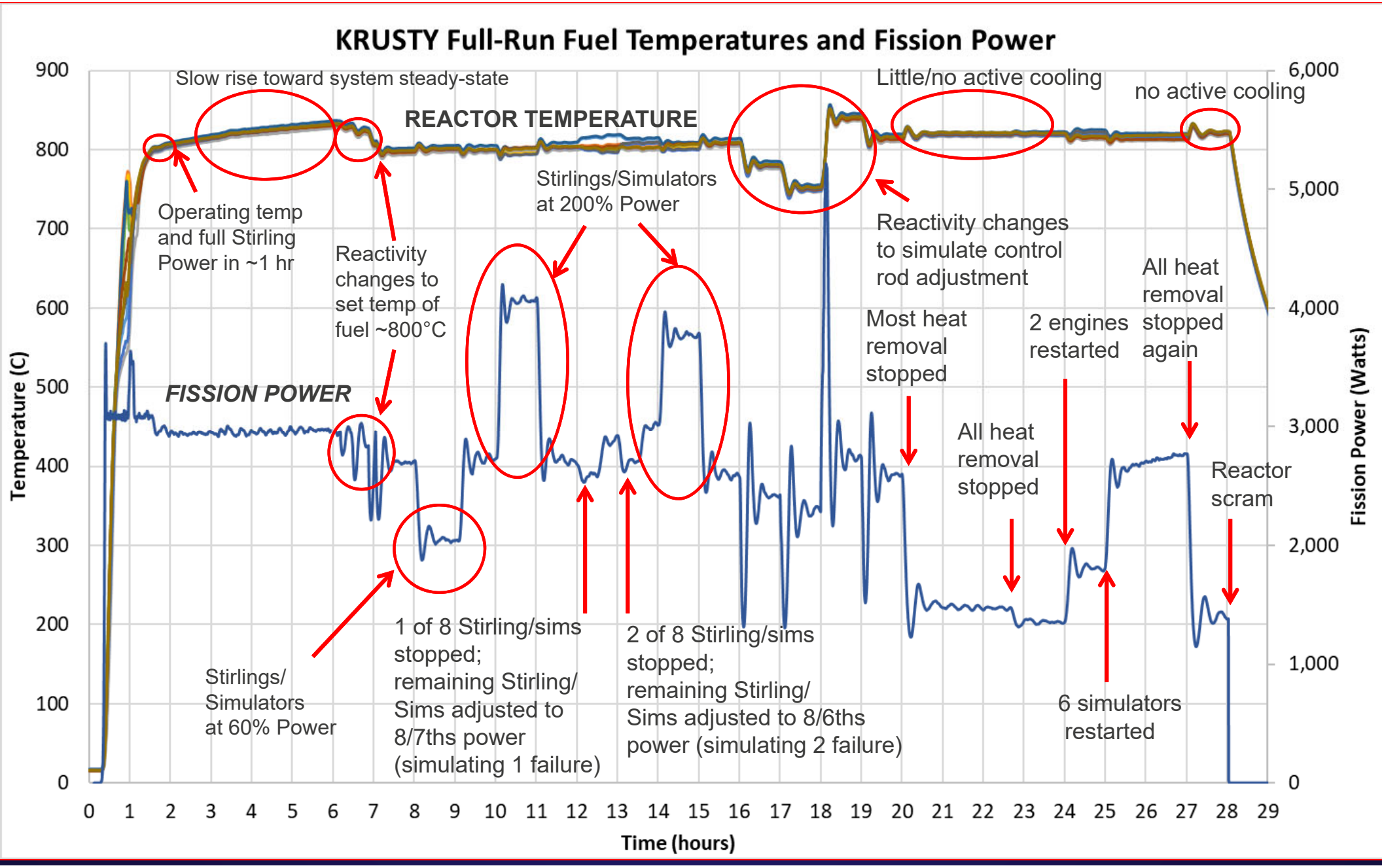
Stirling Engines Draw more Power



Stirling Engines Draw less Power



Note: the above occurs via a few dampened oscillations, similar to any classical underdamped stable system.


KRUSTY Full-Run Fuel Temperatures and Fission Power
Temperature (C)
Fission Power (Watts)
Time (hours)
REACTOR TEMPERATURE
FISSION POWER
Slow rise toward system steady-state
Operating temp and full Stirling Power in ~1 hr
Reactivity changes to set temp of fuel ~800°C
Stirlings/ Simulators at 60% Power
1 of 8 Stirling/sims stopped; remaining Stirling/ Sims adjusted to 8/7ths power (simulating 1 failure)
Stirlings/Simulators at 200% Power
2 of 8 Stirling/sims stopped; remaining Stirling/ Sims adjusted to 8/6ths power (simulating 2 failure)
Little/no active cooling
Reactivity changes to simulate control rod adjustment
Most heat removal stopped
All heat removal stopped
2 engines restarted
6 simulators restarted
no active cooling
All heat removal stopped again
Reactor scram

Conclusions

- A lot of progress was made in the past year to accomplish the goals for this experiment
- Experimental and computational results compared quite well
- Several benchmarks will be developed and published in the ICSBEP or IRPhEP handbooks.
- Planning for the next series of experiments started

Future Work

- Moon mission

Thank you

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