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Design Engineer

A Study of a Helium-3 Injection System at TREAT

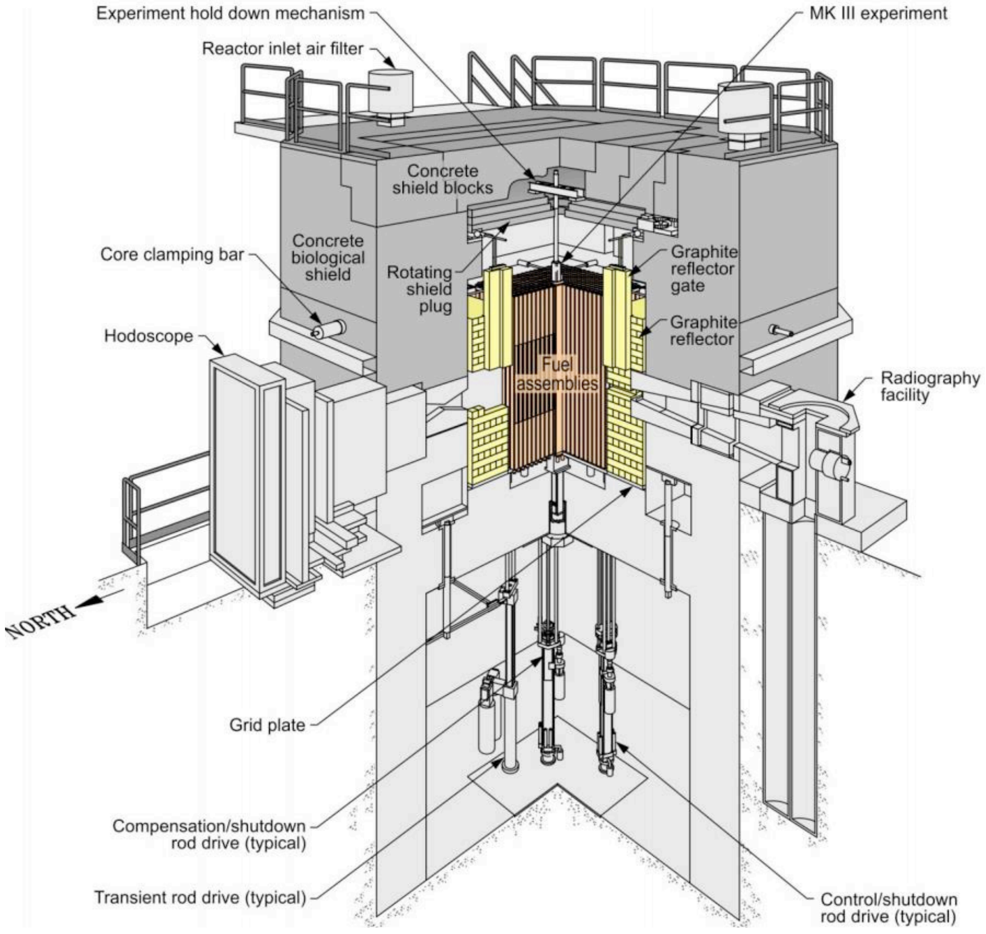
Update and Design

Outline

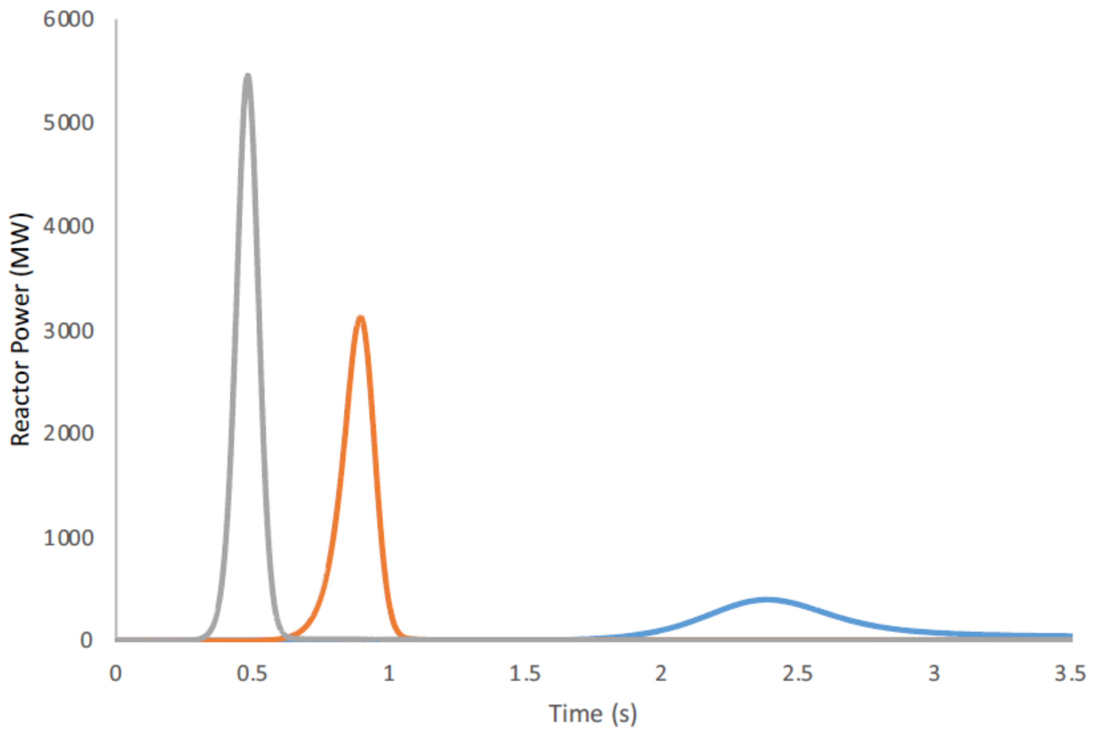
- What is the Transient Reactor Test Facility (TREAT)
  - Summary
  - Capabilities
  - Reactor Control
- Reactivity Initiated Accidents (RIAs)
- TREAT capabilities for RIA testing
  - 2019 Study of how to meet RIA fuel testing needs
- Current design of the Helium-3 Negative Reactivity Injection (HENRI) system
  - In core modules
  - Recovery system
  - Operation
  - Analyzed capability added to TREAT

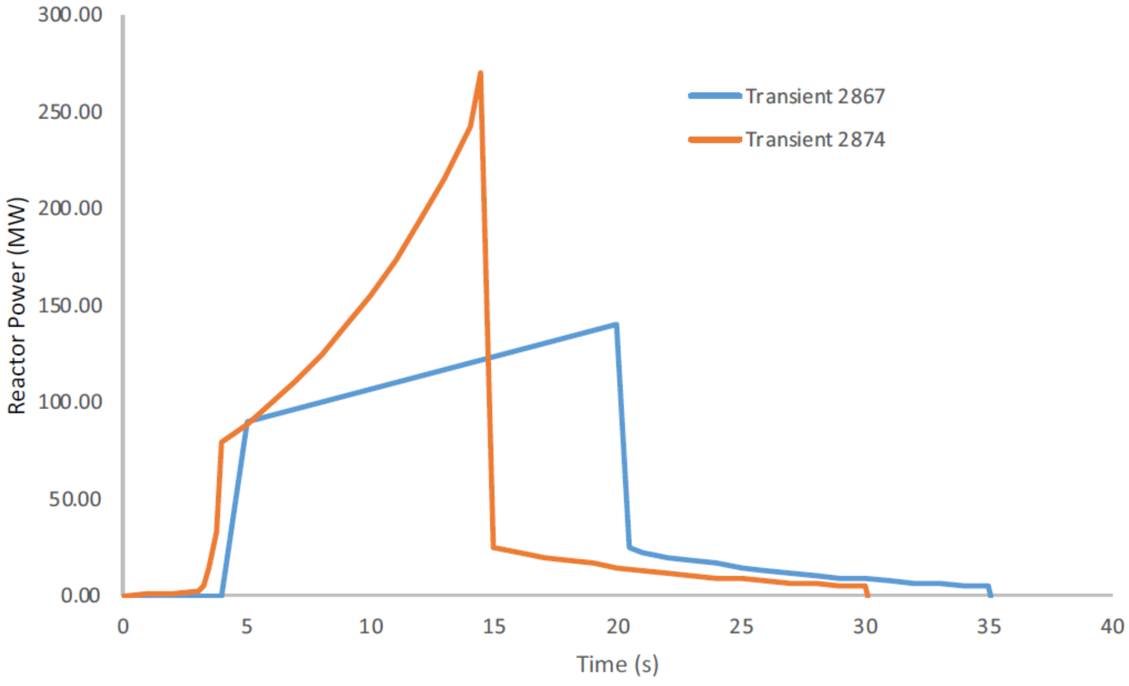
Transient Reactor Test Facility (TREAT) Overview

- Air-cooled, graphite moderated reactor
- 10,000:1 atoms C to atoms U
- Steady state of 120 kW
- Minimum Period of 0.023 s
- Peak Power of 18,000 MW
- Peak Energy of 2,100 MJ
- Performs transients:
  - Temperature Limited
  - Clipped
  - Shaped
- Tests nuclear fuels in extreme transient environments (crash testing of nuclear fuels)



TREAT Overview





TREAT Control Overview

Type	Nominal Reactivity Worth (Core 1469) [3]	Effective Length [2]	Velocity	
			Reactivity Insertion [3]	Reactivity Removal (Clip/Scram) [3]
Control/Shutdown Rods	0.088 Δk/k	58 in.	20 in./min.	300 in./sec.
Compensation/Shutdown Rods	0.069 Δk/k	58 in.	20 in./min.	300 in./sec.
Transient Rods	0.085 Δk/k	40 in.	Adjustable (0-140 in./sec.)	140 in./sec

- 20 Control Rods
  - 8 control/shutdown rods
  - 4 compensation shutdown rods
  - 8 transient rods

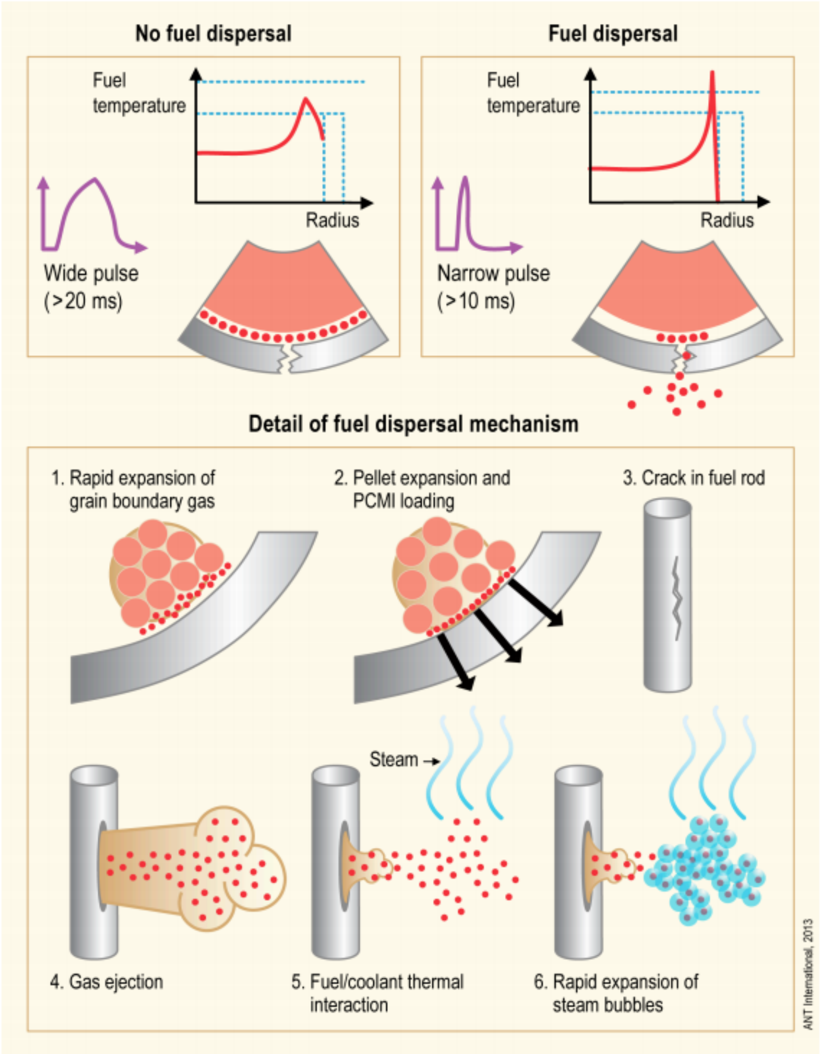
- Control/shutdown rods bring the TREAT core critical and maintain it at power.
- Transient rods are positioned based on desired power profile.
- Compensation/shutdown rods are typically removed from the core during reactor operation

Reactivity Initiated Accidents (RIA)

- Reactivity events for Light Water Reactors (LWRs) are considered design basis accidents for the current nuclear fleet.
  - Loss of long-term cooling ability within the core
  - Damage to the pressure boundary or core of the reactor through the propagation of pressure waves.

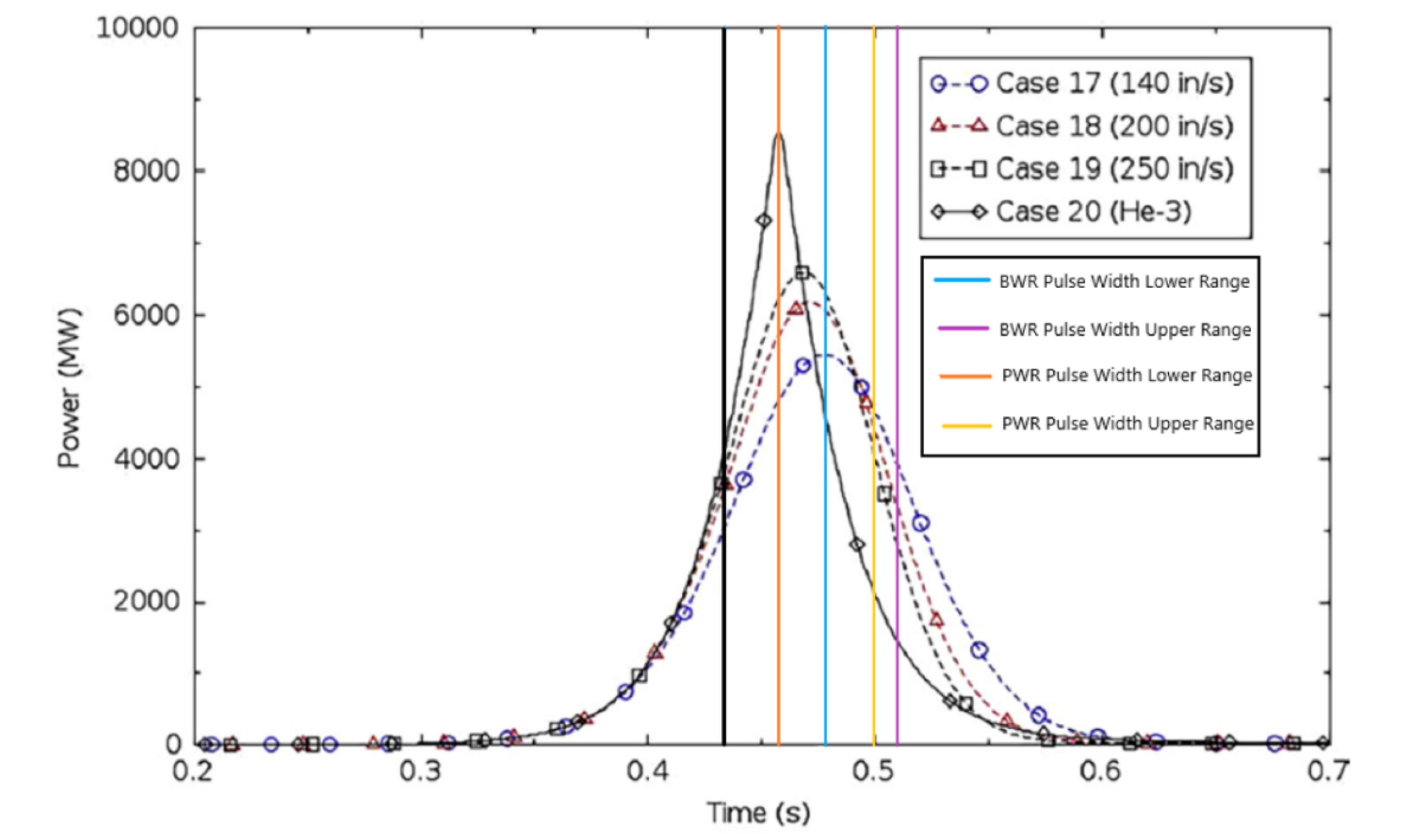
- Fuel failure does not imply a loss of cool-ability or the creation of pressure waves, however, it is typically studied because it is a prerequisite which leads to such events.

- Desired fuel failure damage mechanisms are:
  - Cladding ballooning and burst
  - Embrittlement and failure by high temperature oxidation
  - Melting of fuel pellets and/or cladding



TREAT Current RIA Capabilities

- 3-dim hat would lead t
  - Fc nds
  - Fc nds
- Testin imately 90 +/- 3 r
- Due t for RIA testin
  - Ex ay to re be a c which

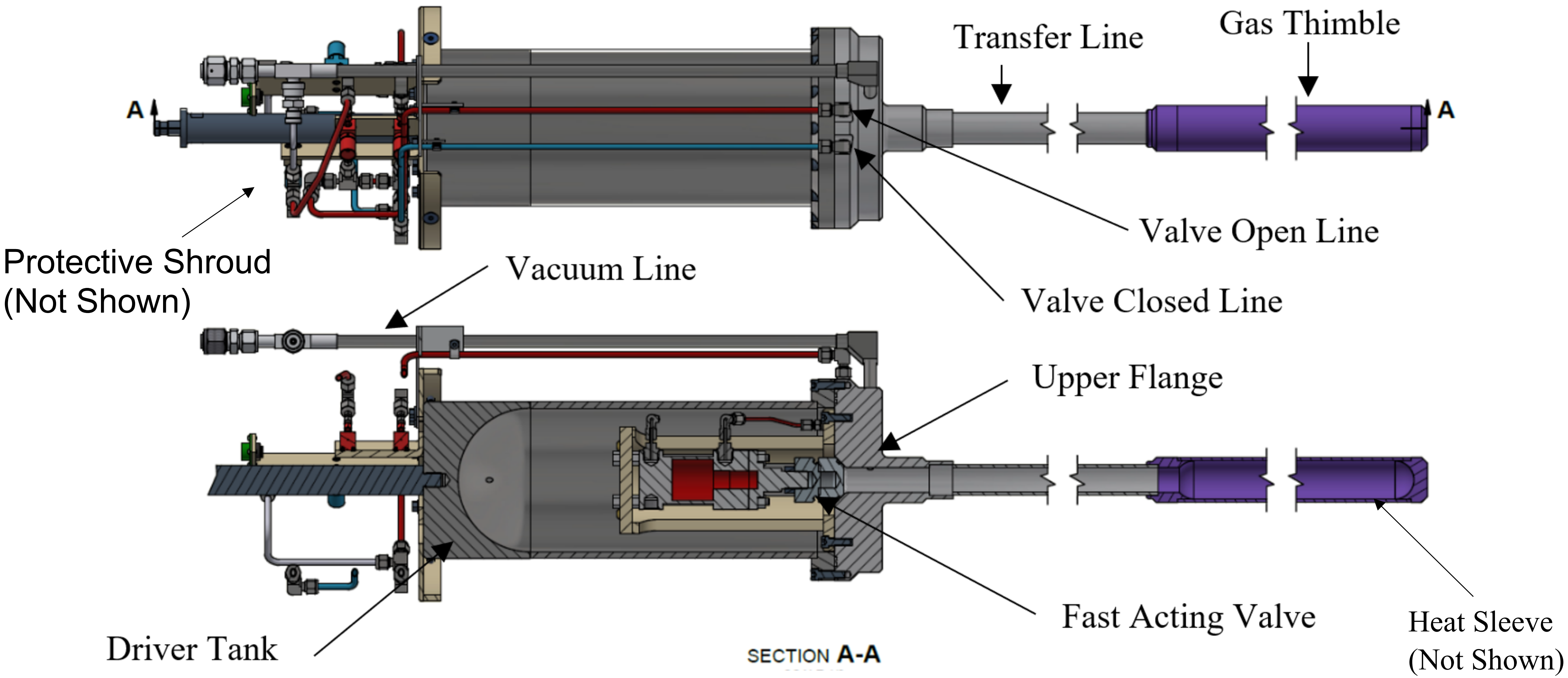


- Gaseous helium-3 – Winner, Winner!

Helium-3 Negative Reactivity Insertion (HENRI) Needs

- Needs to add -5% Δk/k reactivity
  - Max pulse is approximately 4.5% Δk/k
- Reactivity needed to be inserted in 5 ms or less
- Modular design
  - Add excess reactivity to the core by removing modules
- Symmetrical in the core
  - Maintain a symmetric flux

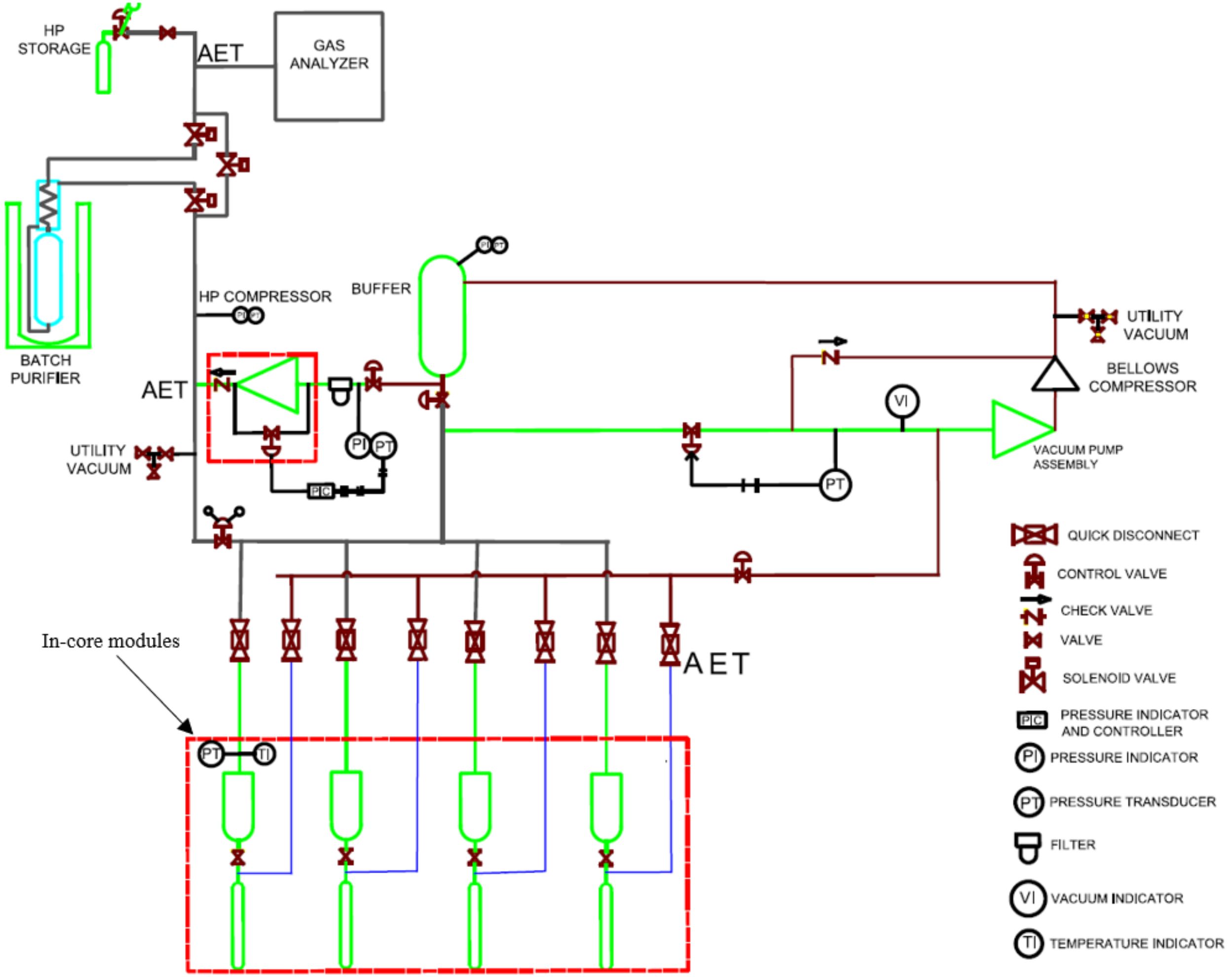
HENRI Module Design



HENRI Module Design

- Driver Tank – 6 liter storage of ~250 psig He-3 prior to transient.
- Transfer Line – Nominal 1” schd 40 line between active core region and Driver Tank. Also contains the interface flange for the Driver Tank.
- Gas Thimble – Nominal 1.5” schd 40 active region capsule.
- Valve Lines – Used for the opening and closing of the Fast Acting Valve.
- Fast Acting Valve – Triggered during transient to allow He-3 into the Gas Thimble through the Transfer Line.
- Heat Sleeve – Tight tolerance pipe to be put inside the Gas Thimble to absorb heat and reduce structural bending on the pressure boundary.
- Protective Shroud – Shroud to cover all solenoid valves at the top of the Driver Tank to reduce likelihood of damage during operations.

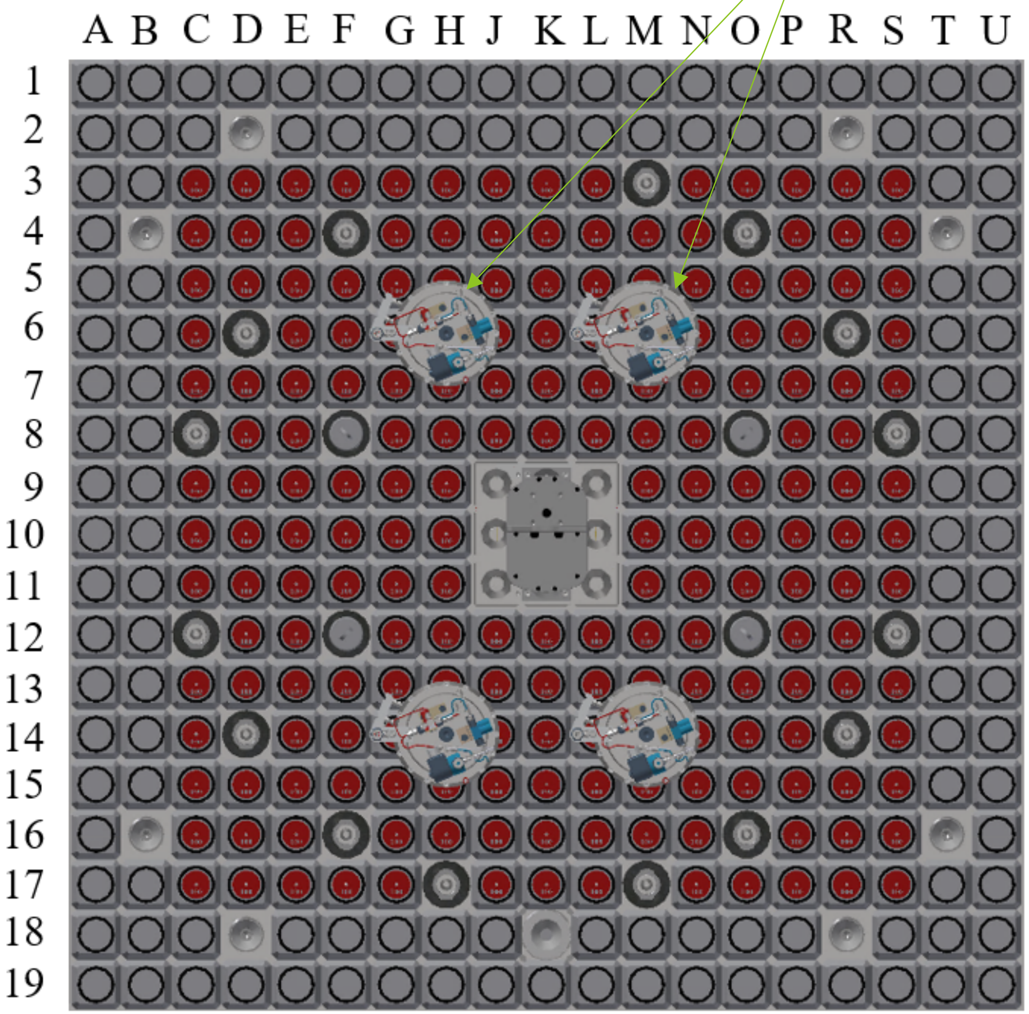
Recovery System

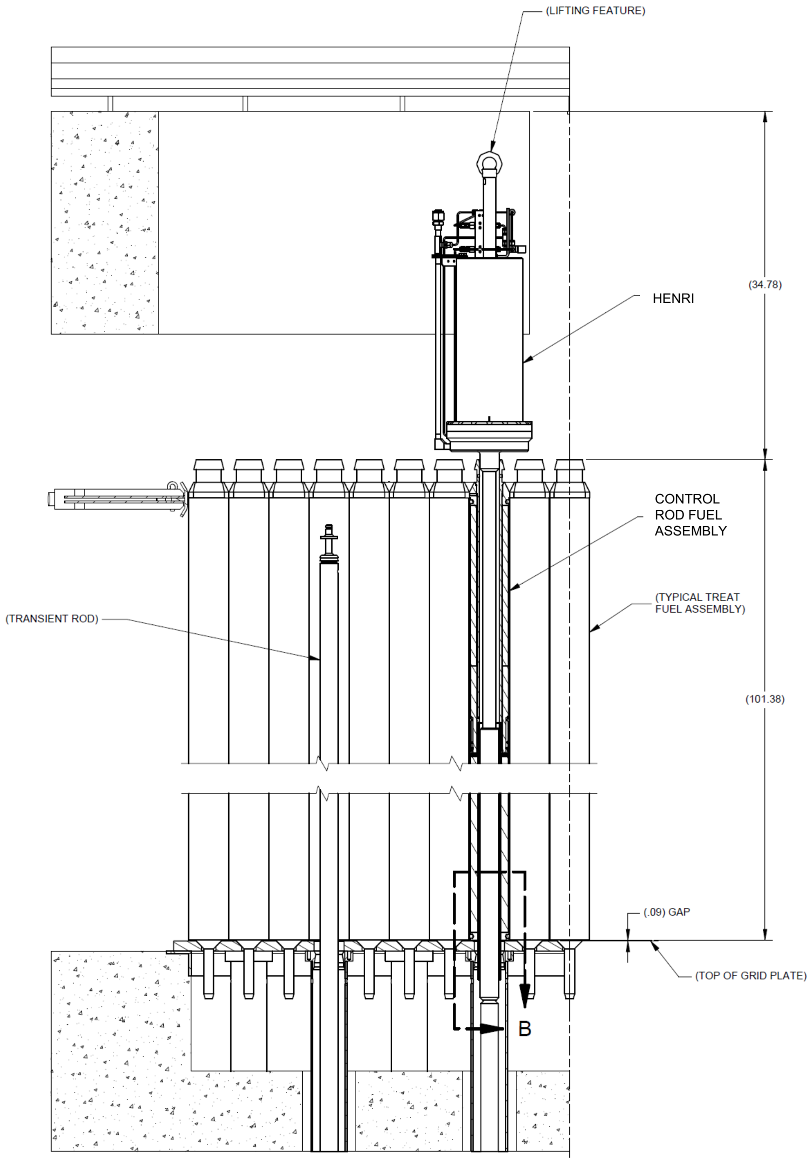


- Function:
  - Evacuate the Gas Thimbles pre- and post transient.
  - Provide low pressure storage when not in use, reduced leakage.
  - Ability to purify the He from potential contaminants.
  - Repressurize gas to high pressure as needed.

HENRI Configuration

HENRI Modules

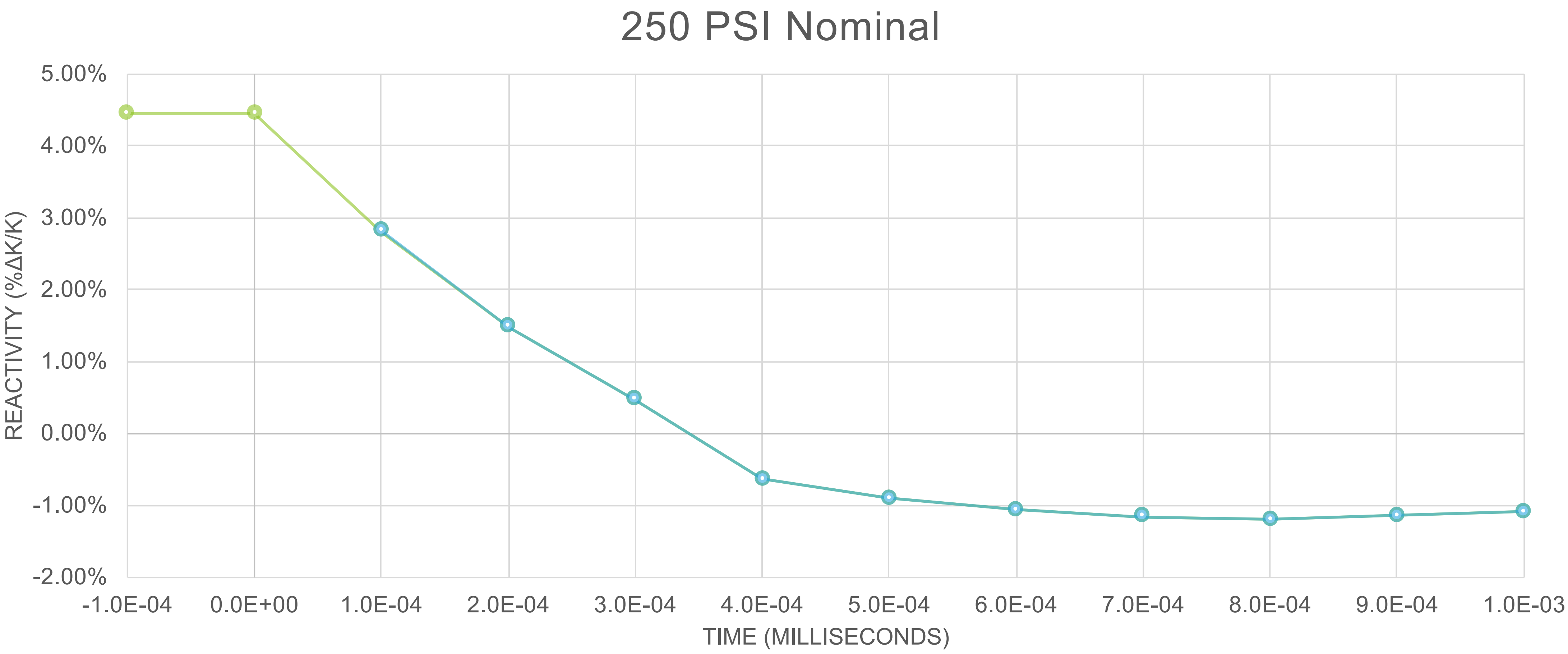




HENRI Operation

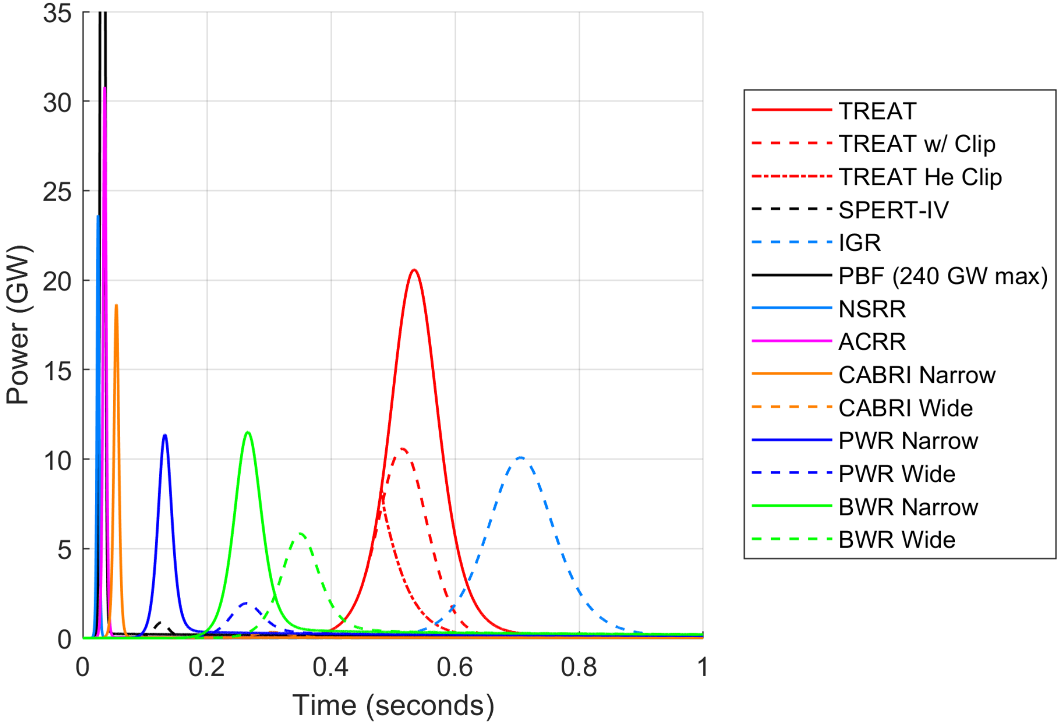
1. Pretransient
    a. Pressurize gas to high pressure as needed (Recovery System)
    b. Evacuate Gas Thimble (Recovery System)
    c. Ensure Fast Acting Valve is closed (HENRI Module)
    d. Fill Driver Tank to approximately 250 psig (Recovery System)
2. Transient
    a. Open Fast Acting Valve (HENRI Module)
3. Post Transient
    a. Remove gas from HENRI module (Recovery System)
    b. Purify the helium gas (Recovery System)

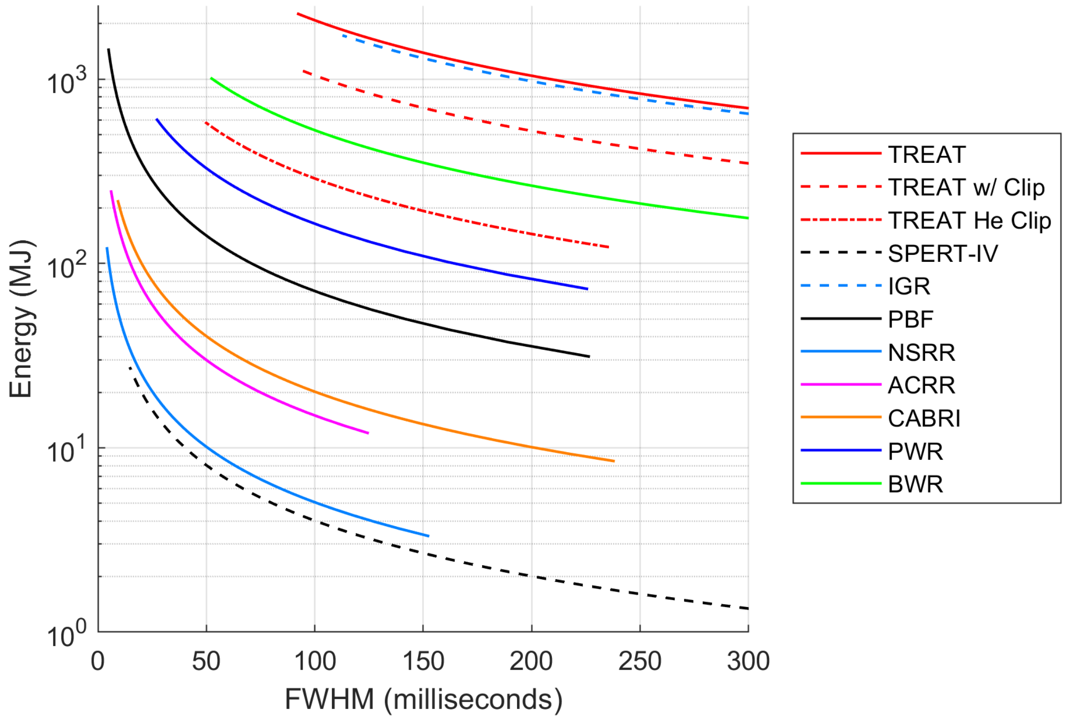
Analyzed Capability of HENRI



- @ 250 psig TREAT can achieve a clip in less than 4 ms from maximum pulse.

Analyzed Capability of HENRI





Comparison plots of TREAT with He-3 capabilities and LWR desired pulses along with other capabilities in the world.

References

[1] C. Race, “Narrowing Pulse Widths Using Helium-3 at the Transient Reactor Test Facility (TREAT) – An Evaluation of the Helium-3 Negative Reactivity Injection (HENRI) System,” 2022

[2] Argonne National Laboratory, "TREAT Baseline Description Document," 1992.

[3] Idaho National Laboratory, "Transient Reactor Test (TREAT) Facility FSAR. SAR-420," 2022.

[4] J. D. Bess, N. E. Woolstenhulme, C. B. Davis, L. M. Dusanter, C. D. Folsom, J. R. Parry, T. H. Shorthill and H. Zhao, "Narrowing transient testing pulse widths to enhance LWR RIA experiment design in the TREAT facility," Annals of Nuclear Energy, vol. 124, pp. 548-571, 2019.

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