Transient Reactor Test (TREAT) Facility Restart Effort

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2018 TRTR Meeting

www.inl.gov

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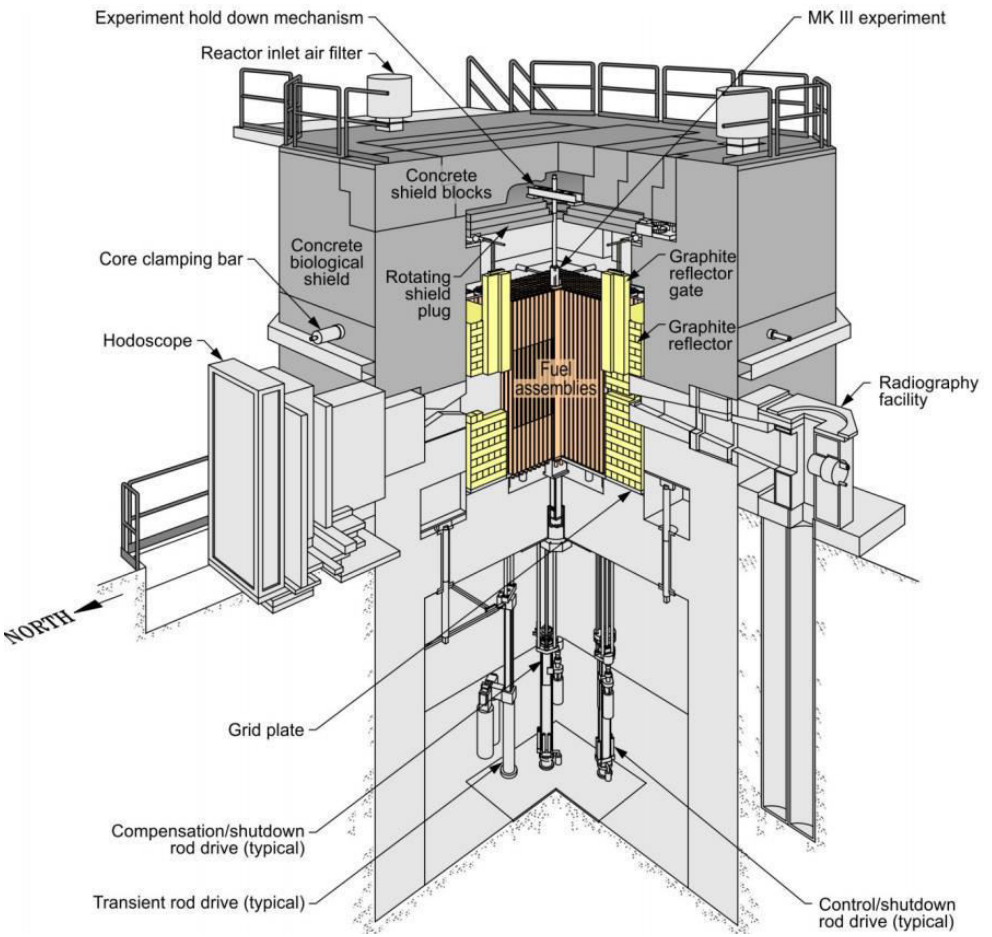
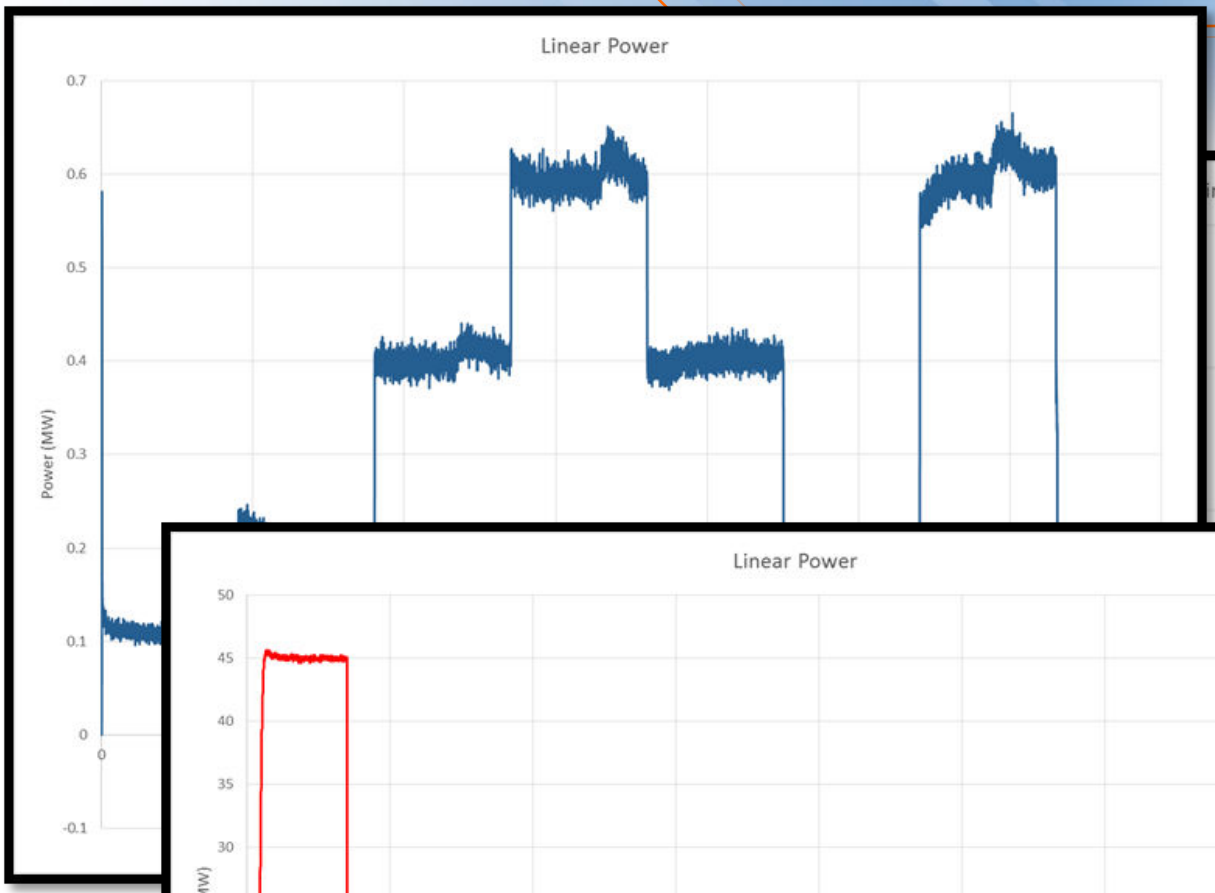
Background of the TREAT

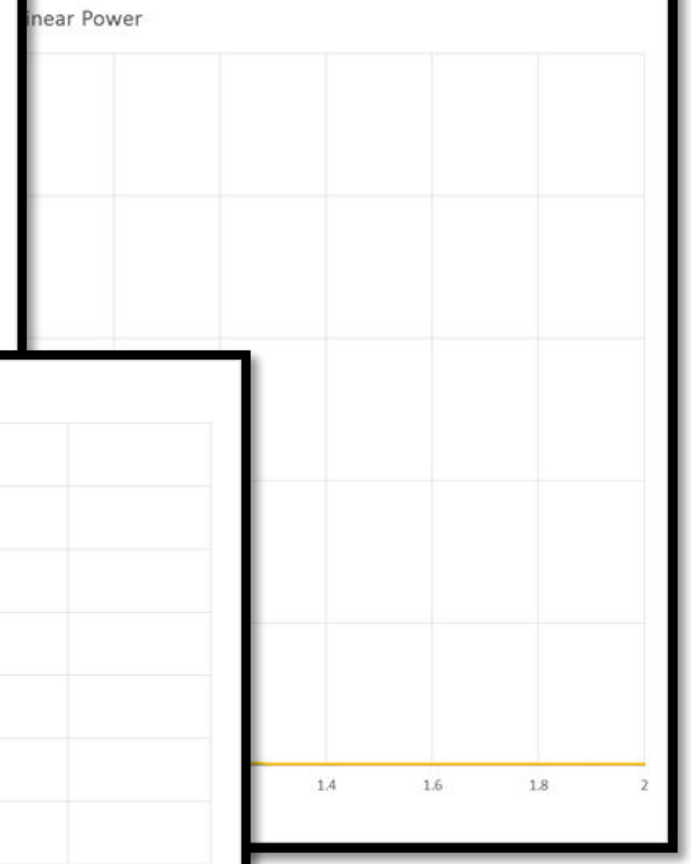
- Located at Idaho National Laboratory (INL)
- Construction began 1958 and concluded in 1959
  - $1.46 million in1959 do
    $12.5 million 2018
- Operated 1959 – 1994
  - Performed nearly 3,000
    transients
  - Primarily supported test
    Integral Fast Reactor fuels
  - Analogous to car crash testing but with nuclear fuel
  - Placed in standby in 1994 with fuel in core

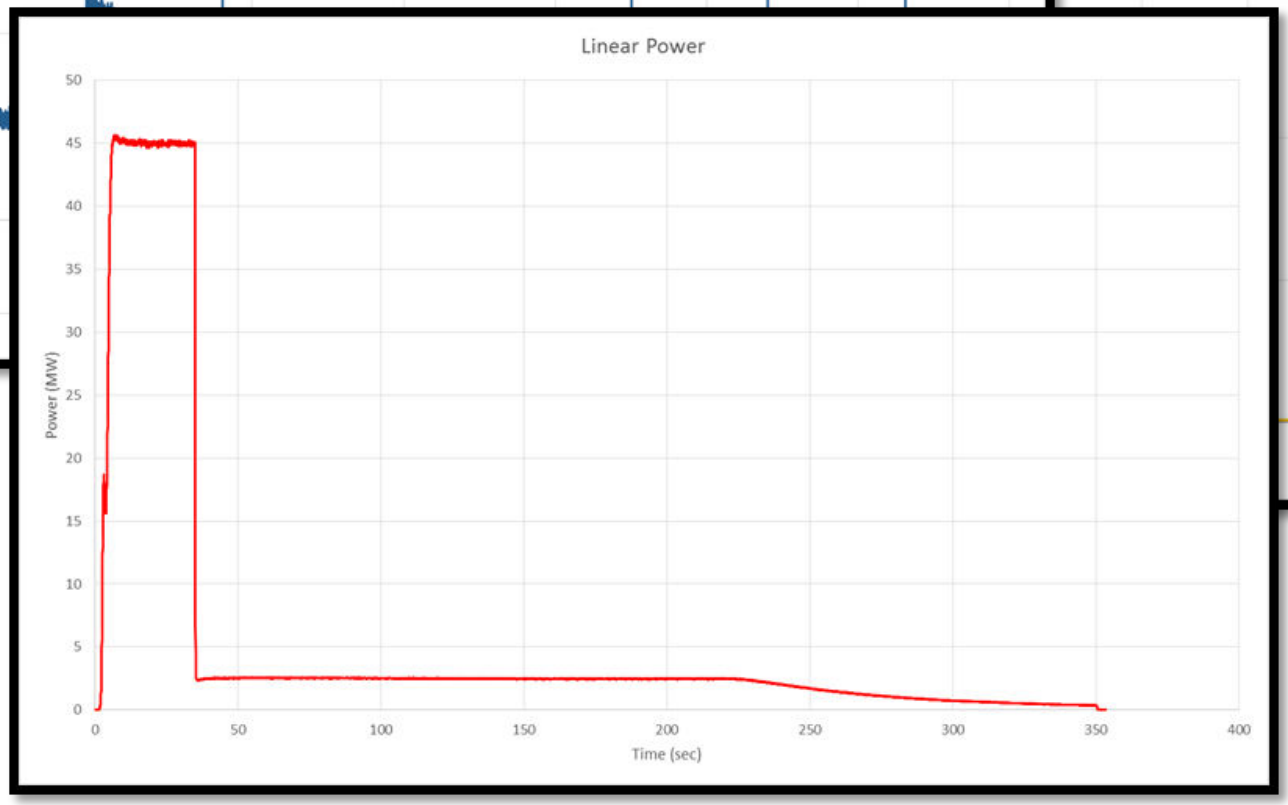
Background of the TREAT

- 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 2,900 MJ
- Temperature Limited, clipped, or shaped (examples on next slide)



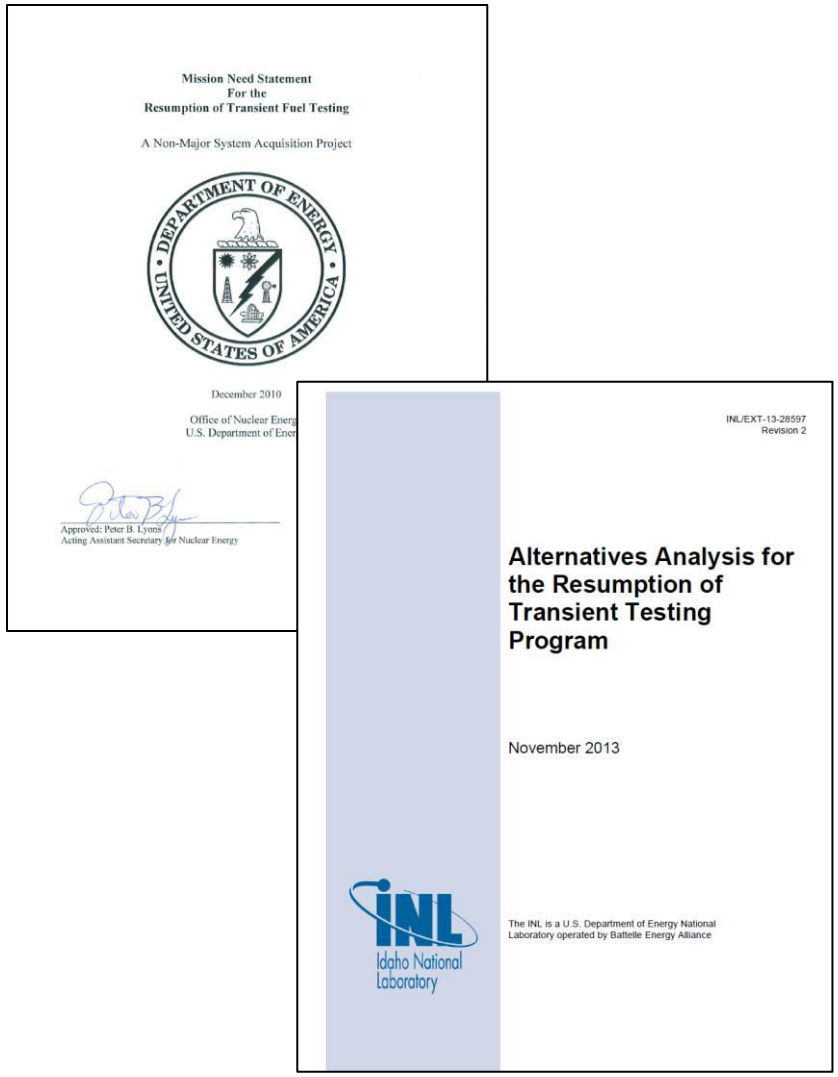

Linear Power
Power (MW)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
0


near Power
1.4
1.6
1.8
2


Linear Power
Power (MW)
50
45
40
35
30
25
20
15
10
5
0
0
50
100
150
200
250
300
350
400
Time (sec)

Resumption of Transient Testing Program

- In December 2010 the U.S. Department of Energy (DOE) established a mission need to resume transient testing in the United States
- Development of more accident tolerant and resistant fuels
- Goal to resume testing by 2018
- Three alternatives considered
  - Do nothing
  - Restart TREAT
  - Annual Core Research Reactor
- DOE makes decision to restart TREAT in Feb 2014.



Where to restart

- Create goals and milestones
- Re-establish staff and begin building knowledge base
- Acquire every record that can be found
- Work in close coordination with regulator (DOE) to establish the philosophy that this is a recovery from an extended reactor outage and updating the safety basis.
- Focus on time-related factors
  - Age-related degradation for equipment
  - Changes in operational and engineering standards, codes, regulations
- Think out of the box

Snake found near the hodoscope pit

Goals and milestones

- Informs progress towards mission accomplishment.
- Tracked through standard earned value and project management tools.
- Examples include:
  - Re-establish preventative maintenance
  - Implementation of a documented safety analysis
  - Perform functional testing of systems and components
- In all the Resumption of Transient Testing Program had 41 milestones spanning from December 2014 to August 2017.
  - 32 milestones completed ahead of schedule
  - 7 milestones completed on time
  - 2 milestone late

Staffing

- While a few former TREAT employees still worked at INL, the majority had retired or were otherwise unavailable
- Those who were available were contracted back to provide invaluable insights, knowledge transfer, and training.
  - They also help identify what to keep and what to throw away (paper, parts, equipment)
  - A few retirees still remain to answer the mysterious questions.
- Staff were steadily hired on and today there are about 50 staff that support TREAT full time.

Searching for records

- The challenge
  - Time
    - Fifty-five years since startup and nearly 20 since shutdown.
    - Unknown number of records
  - Multiple locations
    - Records between INL and Argonne National Lab
  - Changes in methodology
    - File tracking and numbering schemes (prefixes, suffixes, etc.)
  - Changes in technology
    - Hardcopy in boxes, microfilm, desk drawer, filling cabinets, take home vs scanned into a document repository

Searching for records (cont)

- The solution
  - Scan every can-be-found-document.
    - 264 boxes found in storage in Idaho
    - Several found in US government repositories
  - Heavy reliance on legacy personnel to sort it all out.
  - Several records still in thin air
  - Bring documents up to current standards
    - Literally redrawing several unreadable or poorly scanned drawings (which to the very real challenge of reestablishing configuration management and the relationship between CAD modeling and engineering modeling)
    - Creating new procedures
    - Rewriting old procedures
      - Knowledge based vs procedural based

Recovering from an extended outage

- A lot of discussion goes into convincing all parties that 19 years is an outage
- When TREAT was shutdown the fuel was left in the core or in storage and several experiments were left in storage.
  - Turn the lights off and lock the door so to speak
- Usable space is always in high demand.
  - While TREAT was not operated after 1994 other organizations continued to use the facility
- Aims to avoid the schedule and cost it takes to apply capital asset project management.
- Large scale refurbishment for system readiness.
  - Returning to service where reasonable
  - Like for like replacement
  - Bringing up to standard

Focus on time-related factors

Reactor Control System

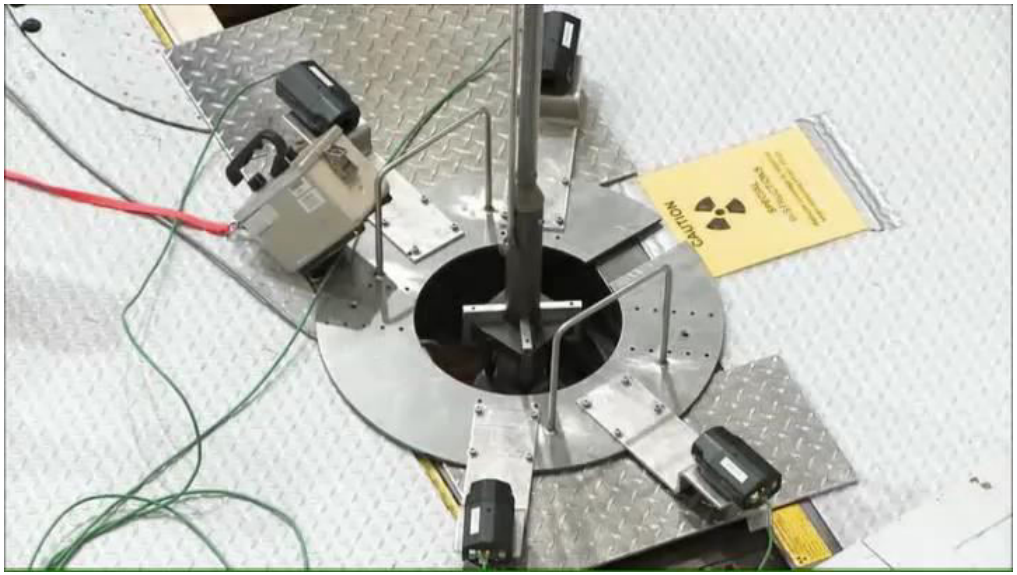
- Between 1959 and 1994 TREAT underwent several upgrades.
- Building upgrades in1963, 1972, 1979, 1982
- Major upgrade in 1989
  - New 60 ton crane, upgrades to reactor control and plant protection systems, modification to filtration and cooling systems, structural modifications
- In terms of the current commercial fleet, 1989 technology is fairly new.
- Age related degradation for other equipment
  - Physical aging
  - Obsolescence
- System readiness
  - Functions as designed
  - Configuration management in place

Reestablish the Safety Analysis Report (SAR)

- Communicate with the regulator early and often
  - Submitted the SAR to DOE chapter by chapter
  - Don't submit the next chapter until DOE approves the strategy in the current chapter
  - Reduced rewrite, established expectations, gave confidence in the process
- Bring TREAT's SAR up to current standards
  - SAR was last updated in 1989 with minor revision in 1992
  - DOE standards of safety are always evolving in the direction of conservatism.
  - TREAT is inherently safe
    - 1 safety limit is established on fuel temperature of 820℃
      - Control limit of 600℃ to minimize cladding oxidation

Think outside the box

- Fuel inspection
- Use statistical analysis to determine the number of fuel elements to be fully inspected to obtain confidence that the entire usable inventory is okay.
- Borescope all coolant channels in core.
- Saved about 4 months of time
- Limits probability of fuel damage which has the greatest likelihood of being damaged during handling.
- Trained on non-fueled assemblies to validate the process

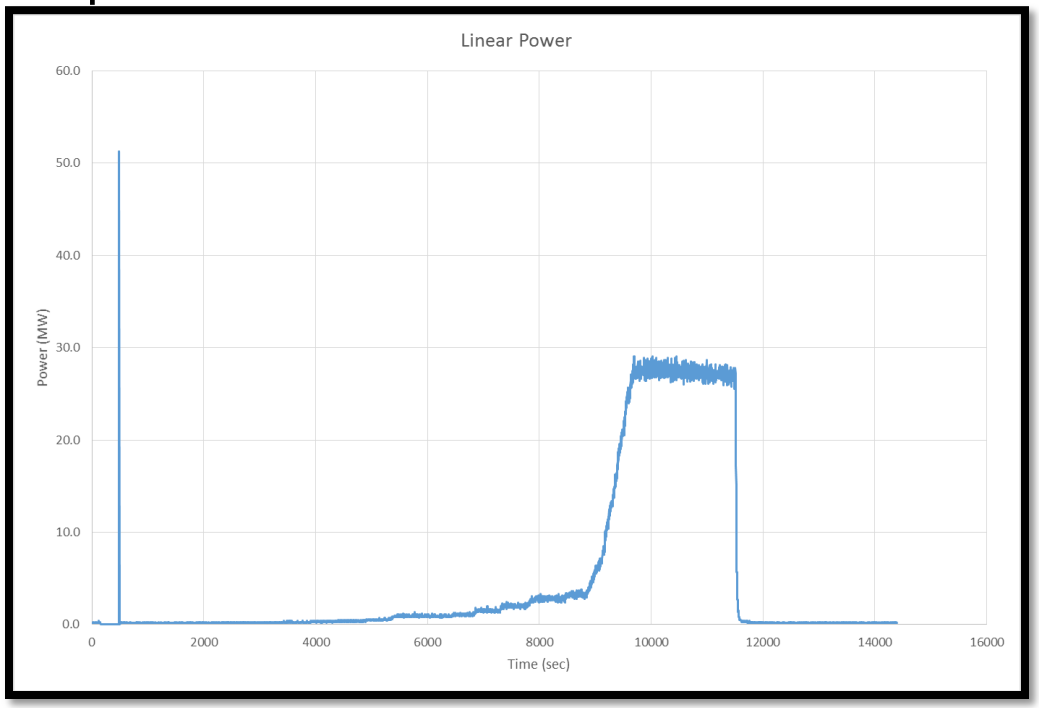


Think outside the box (cont)

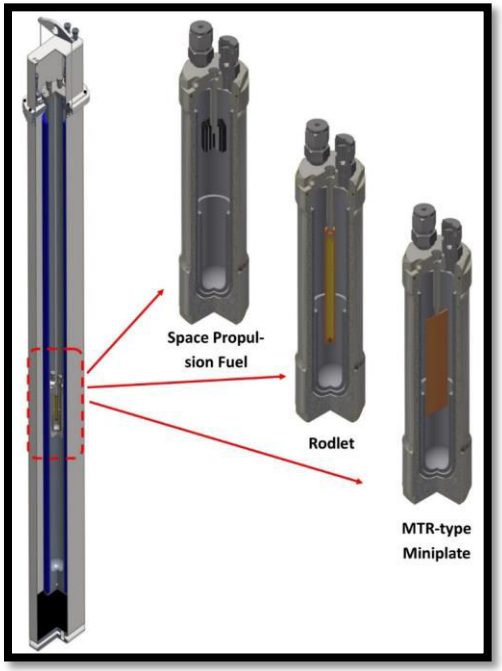
- How to train operators when they can't operate the reactor?
  - Turn reactor into simulator
  - TREAT has computer simulator
  - Poison the core so the control/transient rods can be operated.

Restart

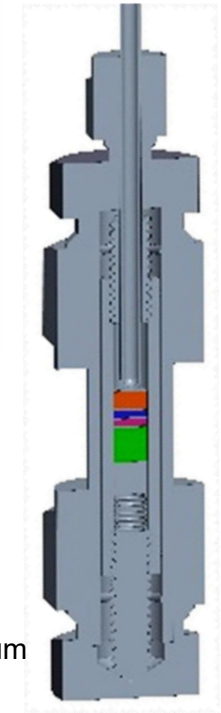
- TREAT was restarted on November 14, 2017. This was 13 months ahead of original goals and saved $20 million from the total $75 million budget.
- Effort took about 3 ½ years
- Before start up all operators were provisionally qualified so initial efforts during restart were to fully qualify operators.
- To date ~33 transients have been performed
  - Transient prescriptions
    - RIA
    - Minimum pulse width
  - MIT tests
  - Concurrent testing
  - Fast clip
  - LOCA
  - ATF-SETH



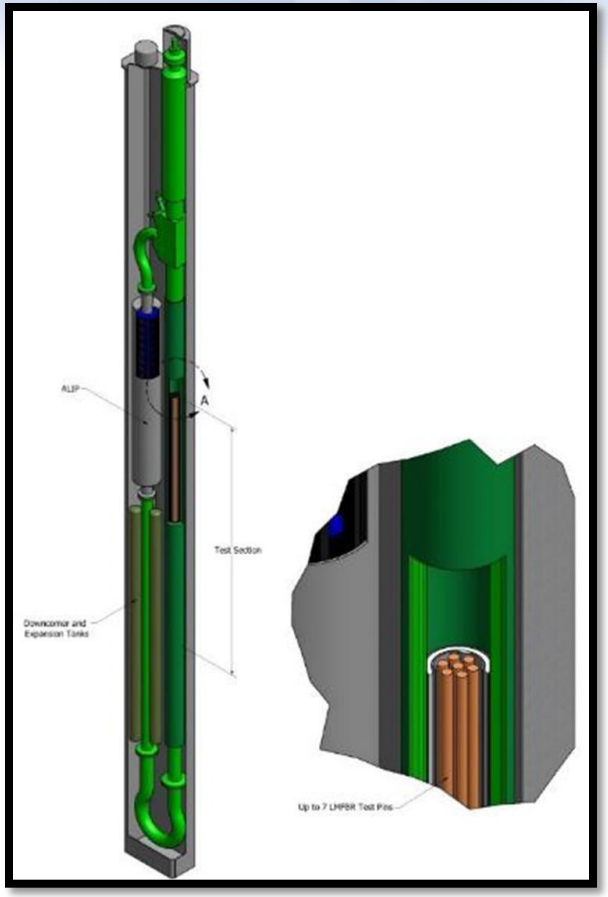
What's next



Dry Capsule Separate Effects Testing (On Going)



Research on Plutonium (Early 19)



Sodium Separate Effects Testing (FY 20)

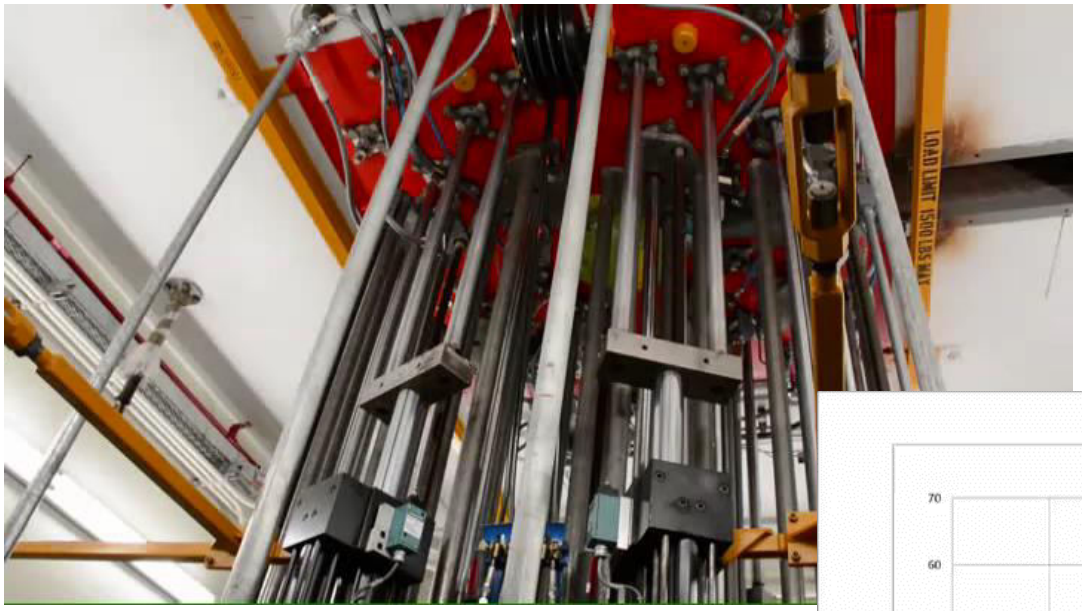
Others: AQUASETH, DRIFT, MIMIC, NASA

Optical Viewing Tests (Future….)

Summary

- Transient testing has been reestablished in the United States.
- The RTTP began in early 2014 and concluded in late 2017. The program completed 13 months ahead of schedule and ~$20 million under budget.
- Several factors contributed to success.
  - Extended reactor outage approach
  - Focus on time-related factors
  - Assistance from legacy personnel
  - Implementation of goals and milestones into schedule
  - Facility operational readiness assessments
  - Unique approaches to training and system readiness
  - Close and frequent communication between INL and DOE on strategy, progress, and SAR update.
  - Others – it is difficult to summarize all the small, but significant successes of RTTP to 15 minutes.

Questions?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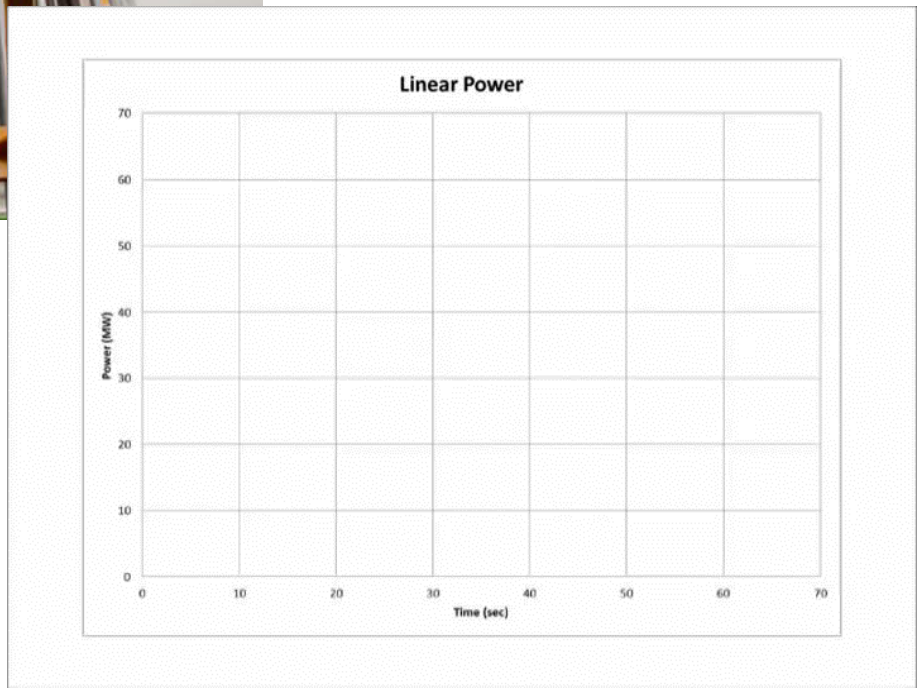
Linear Power
Power (MW)
Time (sec)
0
10
20
30
40
50
60
70