Security and Emergency Planning

July 24, 2019

NRC Headquarters

Introduction to Oklo

- Founded in 2013
- Awards
- Funded in 2015, additional funding in 2018
- Growing team
- Designing compact fast reactor – microreactor

Need for small-scale nuclear

- Many remote areas currently employ diesel generators for electricity production, which are expensive, unreliable, and dirty
- In Alaska, over 200 microgrids bring power to rural residents
  - Alaskan residential electricity rates average more than 50 cents/kWh
  - 400 million kWh from diesel in Alaska statewide in 2013, costing $200M/yr
- Other isolated areas (e.g. islands) also spend significantly on electricity generation
  - US Virgin Islands spend about $240M/yr
- NRC stated priority for applications for high cost markets (CFR 50.43(b))

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Oklo solution – passive compact fast reactor

- MW-scale fast reactor meets the needs of these communities
- Can generate electricity and process heat
- Well-understood fuel and materials
- No moving parts in primary cooling system
- Reduced maintenance profile
- No offsite power dependence
- No carbon emissions

Design

Metal fuel

- Keeps fission products within the metal up to a certain burnup
- Resistant to cracking or chipping - does not pulverize
- Relative ease of manufacture, insensitivity to manufacture method
- High thermal conductivity and low specific heat
  - Lower peak fuel temperature and stored energy
  - Easier to dissipate heat from the fuel
- Large negative temperature reactivity coefficient
  - Metal fuel expands due to temperature increases
- Designed to have very low power density

EBR-II

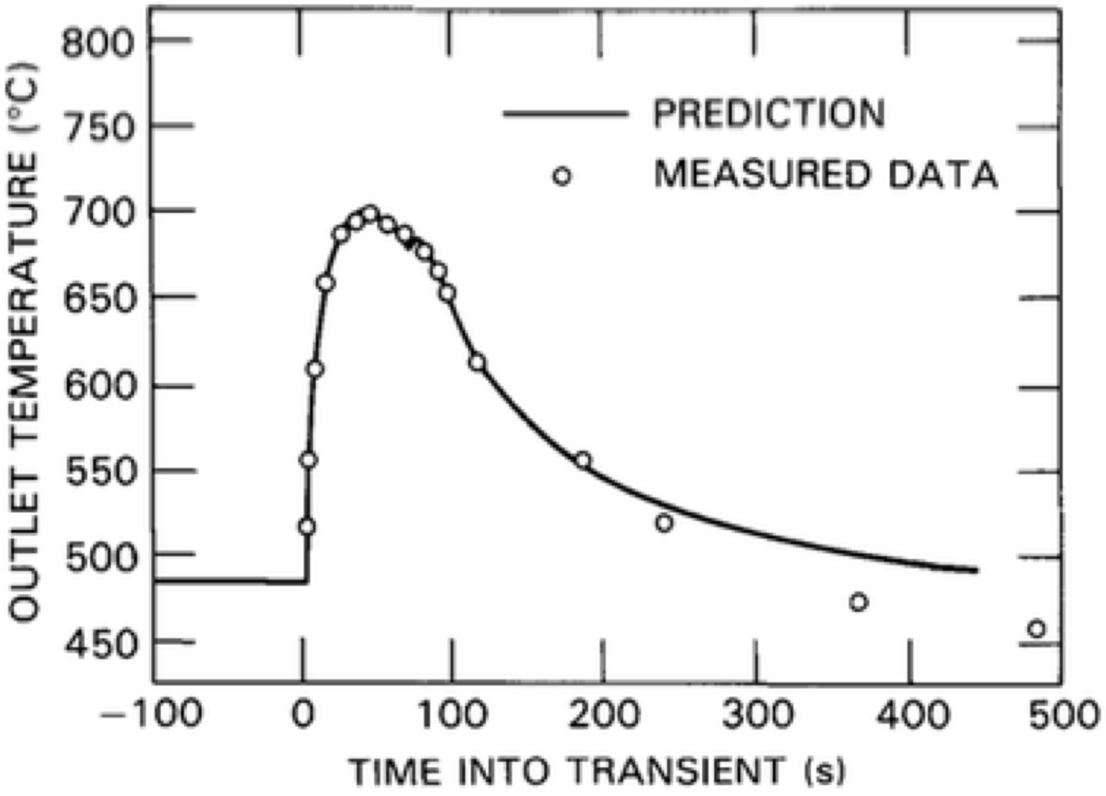
- EBR-II was a 62.5MWth, 19 MWe sodium-cooled fast reactor with metallic fuel
- EBR-II:
  - operated for 30 years
  - sold power to the grid
  - had higher capacity factor than fleet at the time
- Years of quality assured testing done with the EBR-II reactor

EBR-II Shutdown Heat Removal Tests (SHRT)

- Performed on the same day (April 3rd, 1986)
- Two types of unprotected loss-of-cooling accidents
  - Loss of Flow Without Scram
  - Loss of Heat Sink Without Scram
- Performed on the actual, operating reactor at full power
- Started back up after both tests without damage

EBR-II Loss of flow without scram

- Loss of Flow Without Scram (LOFWS): Primary coolant pumps turned off while operating at full power
- Reactor shut down due to fuel thermal expansion feedbacks
- No damage to fuel or otherwise



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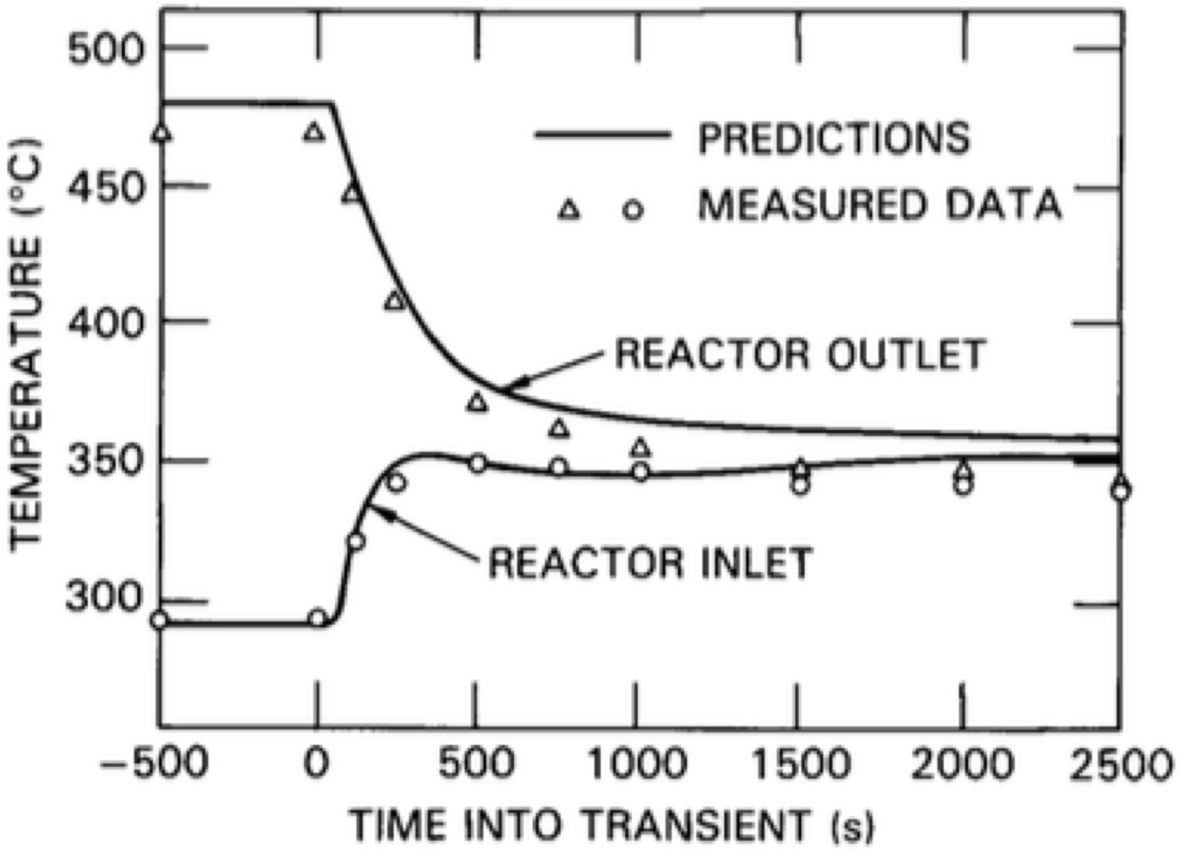
EBR-II Loss of heat sink without scram

- Loss of Heat Sink Without Scram (LOHSWS): Intermediate coolant pumps turned off while operating at full power
- Again, reactor shuts down without scram due to thermal expansion feedbacks
- No damage to fuel or otherwise



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EBR-II Safety test takeaways

"These are sensational results. Two of the most severe accidents that can threaten nuclear power systems have been shown to be of no consequence to safety or even operation of EBR-II. The reactor was inherently protected without requiring emergency power, safety systems, or operator intervention."

-J.I. Sackett

"OPERATING AND TEST EXPERIENCE WITH EBR-II, THE IFR PROTOTYPE", Progress in Nuclear Energy 31, 1-2, pp. 111-129, 1997.

Simple structures, systems, and components

- No pumps, valves, etc. in core or primary heat transport from core
- Passive and very efficient heat transport from core – heat pipes function as thermal superconductors
- Hundreds of independent paths for passive heat transport from core
- No chemistry control required
- No pressure control required
- Minimal safety-related SSCs expected

Other design features

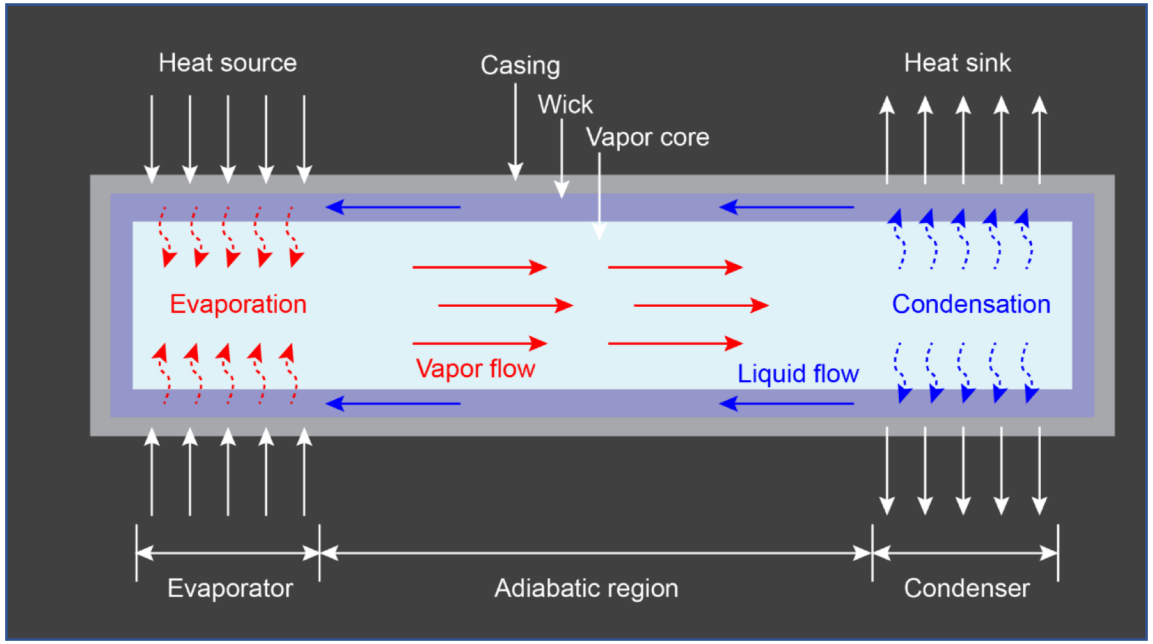
- Below-grade emplacement of the entire system offers simplicity, safety, and security benefits, such as:
  - Seismic
  - Aircraft impact
  - Tornado/high wind
  - Terrorist threat analysis
- Primary heat transport operates at sub-atmospheric pressure

  No significant driving forces for release
- No periodic refueling intervals
  - Little to no fuel movement
  - Likely no heavy machinery onsite – no way of removing fuel

No offsite power dependence

- Driven by market needs – may be the only source of power
- Thus, designed without reliance on AC power
  - LOOP and SBO not a concern
- Very little decay heat – no active systems required
  - 1000x less than LWR
  - On the scale of a lawn mower engine
- Backup sources of power still being evaluated, not needed for safety

Heat pipe operation



- No chemistry control
- No filtering
- No makeup inventory required
- No pressure maintenance required, operates at sub-atmospheric pressure
- No possibility for flow or temperature instabilities as in complex flow loops
- Self annealing in case of exposure to air (extremely low likelihood event)
- Long life data
- Irradiation data from EBR-II

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Safety Case and Impacts on Security and EP

Oklo DG-1353 pilot application overview

- NRC has been developing guidance to support a risk-informed structure (DG-1353) and called for non-LWR developers to pilot the guidance
- DG-1353 references NEI 18-04, "Risk-Informed Performance-Based Guidance for Non-Light Water Reactors Licensing Basis Development"
- Oklo piloted the DG-1353 guidance holistically in an application structure (ML18282A002)

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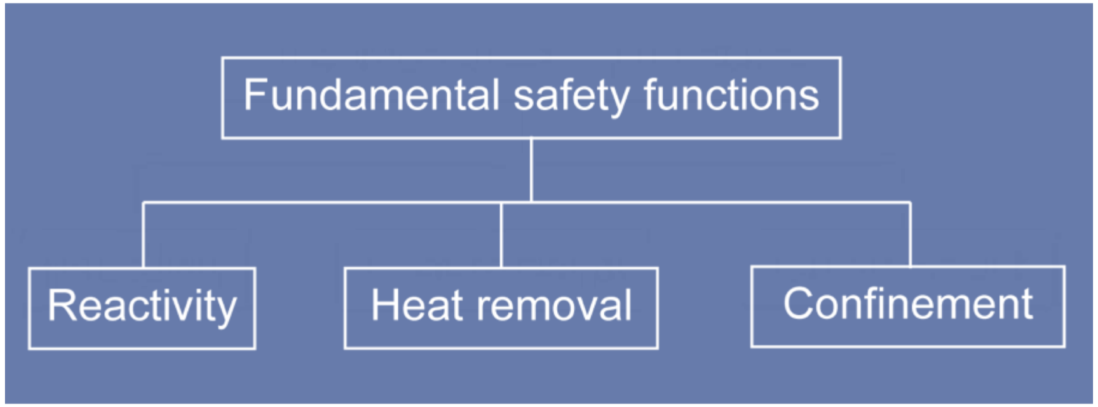
Core concept of safety case

- Small reactor
- Small source term
- Small risk to public health and safety and the environment
- Regulatory limits can be met by inherent, physical characteristics as opposed to active or passive systems

Fundamental safety functions



- Typically referenced from IAEA Specific Safety Requirements SSR-2/1, "Safety of Nuclear Power Plants: Design"
- Also included in NRC non-LWR Roadmap (ML17312B567)

1. Control of reactivity
2. Removal of heat from the reactor and fuel store
3. Confinement of radioactive material

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Oklo DG-1353 pilot application results

- Scope of pilot was to internal, at-power events
  - However, aircraft impact analysis was included
  - Included security plan as well as environmental report, among other sections
- All risk-informed licensing basis events resulted in no dose to the public
- Only one deterministic design basis accident resulted in dose, which was well below the 50.34 limits at 100m from the reactor

Oklo DG-1353 pilot application structure based on regulatory requirements

10 CFR 52.77, 52.79, and 52.80 specify application requirements for a COLA. These can be grouped into the following 5 sections:

I. Company Information and Financial Requirements (52.77)

II. FSAR (52.79)

III. Proposed ITAAC – not piloted (52.80)

IV. Environmental Report (52.80)

V. Addressing Loss of Large Area of Plant Due to Explosions or Fire – not piloted (52.80)

The final application is expected to have seven (7) sections. Two (2) other high-level parts are expected to be added to this structure or separated out from the FSAR requirements section to mimic past application structures:

VI. Technical Specifications, and

VII. Departures/Exemptions.

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Oklo DG-1353 pilot application contents – Part II – FSAR

1. Siting Information
2. Description and Analysis of Structures, Systems, and Components
3. Radioactive Materials to Be Produced in Operation
4. Probabilistic Risk Assessment
5. Design and Performance of Structures, Systems, and Components
6. Design of Facility
7. Fire Protection
8. Station Blackout
9. Electrical Equipment Important to Safety
10. Programs Related to ASME Codes
11. Reactor Vessel Maintenance Program
12. Maintenance Rule
13. Earthquake Criteria
14. Unresolved and Generic Safety Issues
15. Emergency Plans
16. Emergency Planning with State and Local Governments
17. Prototype Operational Conditions
18. Design and Construction Quality Assurance Program Description
19. Organization Structure for Operations
20. Operational Elements of the Quality Assurance Program Description
21. Preoperational Testing and Initial Operations
22. Operational Plans
23. Technical Specifications
24. Technical Qualifications of the Applicant
25. Operator Training Program
26. Training Program
27. Operator Requalification
28. Physical Security
29. Safeguards
30. Incorporation of Operational Insights
31. Radiation Protection
32. Fire Protection Program
33. Risk Reduction from Anticipated Transients Without Scram
34. Criticality Accidents
35. Fitness for Duty Program
36. Minimization of Contamination
37. Aircraft Impact Assessment

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FSAR 15 & 16 – Pilot sections related to emergency preparedness

- FSAR 15, “Emergency Plans,” as required by 52.79(a)(21) was piloted and included a largely complete emergency plan
- FSAR 16, “Emergency Planning with State and Local Governments,” as required by 52.79(a)(22) was not piloted

FSAR 15 – Emergency plans

- Oklo's unique market demands relatively small power source
- Reactor more on scale with nonpower reactors
  - Nonpower reactors vary in power level from 0.000005-20 MWth
  - 40% of licensed nonpower reactors are at or below 10 MWth
- Oklo informed its emergency plan in the pilot by the endorsed standard for nonpower reactors
  - ANSI/ANS 15.16-2015, "Emergency Planning for Research Reactors"
  - Endorsed by Regulatory Guide 2.6, "Emergency Planning for Research and Test Reactors and Other Non-power Production and Utilization Facilities," Revision 2

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FSAR 15 – Emergency plan pilot objectives

- Provide a basis for action
- Identifies:
  - Personnel who need to take action,
  - Materials available, and
  - Onsite and offsite support organizations that should be contacted
- Designates areas of responsibility for coping with emergencies onsite
- EP plan submitted in the pilot very similar to what is currently approved and used by the nonpower reactor community

FSAR 28 – Physical security

- General physical security approach described in pilot since physical security plans contain SGI
- Focus in pilot was on normal operations only – SNM secured
  - Other modes not considered
  - Cases with moving of fuel not piloted since all fuel remains in the core
- Physical security approach informed by:
  - Power reactor regulations in 73.55
  - Nonpower reactor regulations in 73.60 and 73.67

FSAR 28 – Physical security of SNM

- Much less fuel than a large LWR
  - Less appealing target
- Fast spectrum fuel that is self-protecting
  - Fuel not moderated – adversary would need unrealistic amount of shielding
- No fresh or spent fuel stored on site
  - No refueling over core life
  - No spent fuel or dry cask containers
- Difficulty of access to fuel
  - Cannot be removed quickly from reactor
  - Many physical barriers to the reactor core
  - Heavy and specialized machinery necessary
- Reactor located below grade

FSAR 28 – Physical security through detection and procedures

- Redundancy for earliness detection described in the pilot through:
  - Onsite monitors
  - Tamper-indicating, alerting physical barriers
  - Video cameras:
    - Interior
    - Exterior: pan, tilt, zoom, thermal
- Intrusion alarms onsite
- Access controls through preauthorization, badging, locks, personnel entry control systems, etc.

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