

Sandia Pulsed Reactor Facility Seven Percent Critical Experiment (7uPCX)

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Agenda

- **Seven Percent Critical Experiment (7uPCX)**
 - Purpose
 - Assembly Hardware
 - Dimensions

- **Safety Basis**

- **Operation**

- **Future of 7uPCX**

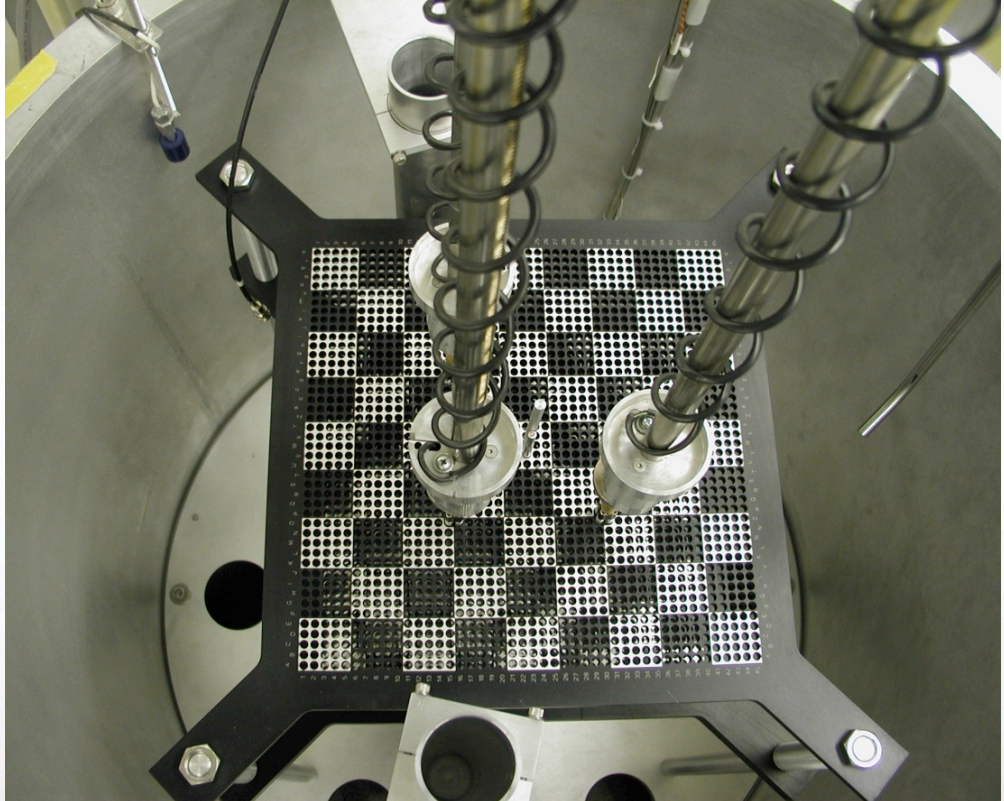
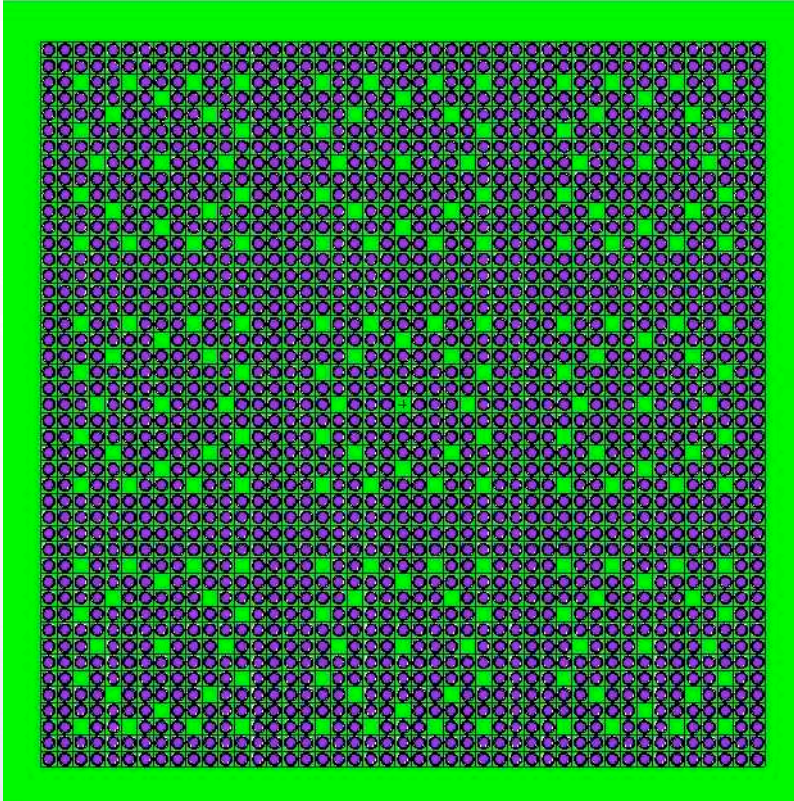


What is 7uPCX

- Seven Percent ^{235}U
- Square Pitch
- Water Moderated
- Was Nuclear Energy Research Initiative (NERI) Funded Project
 - Perform Criticals for 5-10wt. % ^{235}U
- Now Nuclear Criticality Safety Program (NCSP) Funded
- Areva, ORNL, University of Florida and SNL
- Sandia Pulsed Reactor Facility / Critical Experiments (SPRF/CX)
- Reactor Physics Measurements
 - Fully Reflected
 - Square Pitched



7uPCX



Critical Assembly Hardware

- Core Tank
- External Core Tank Hardware
- Fully Reflected Design
 - ◆ 15 cm Water

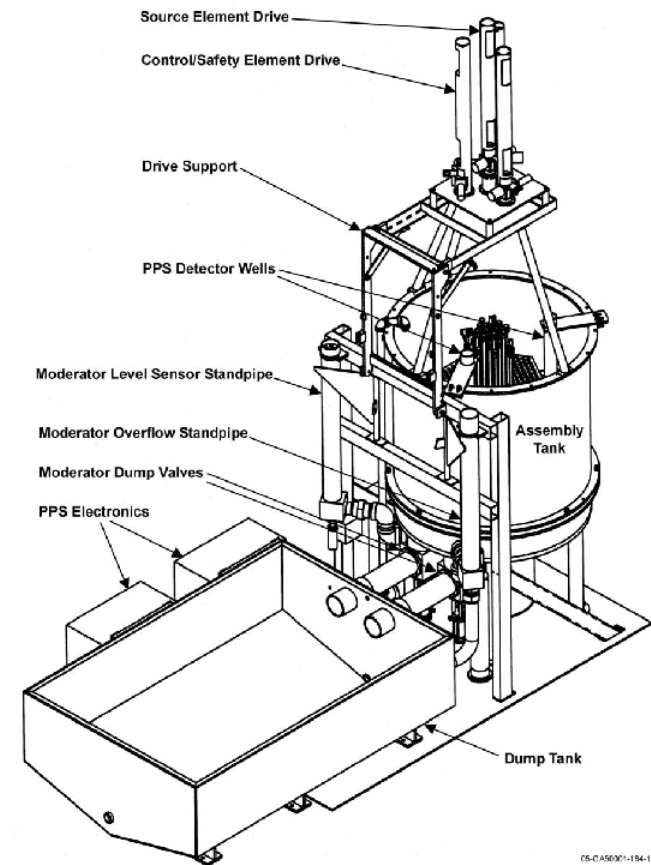
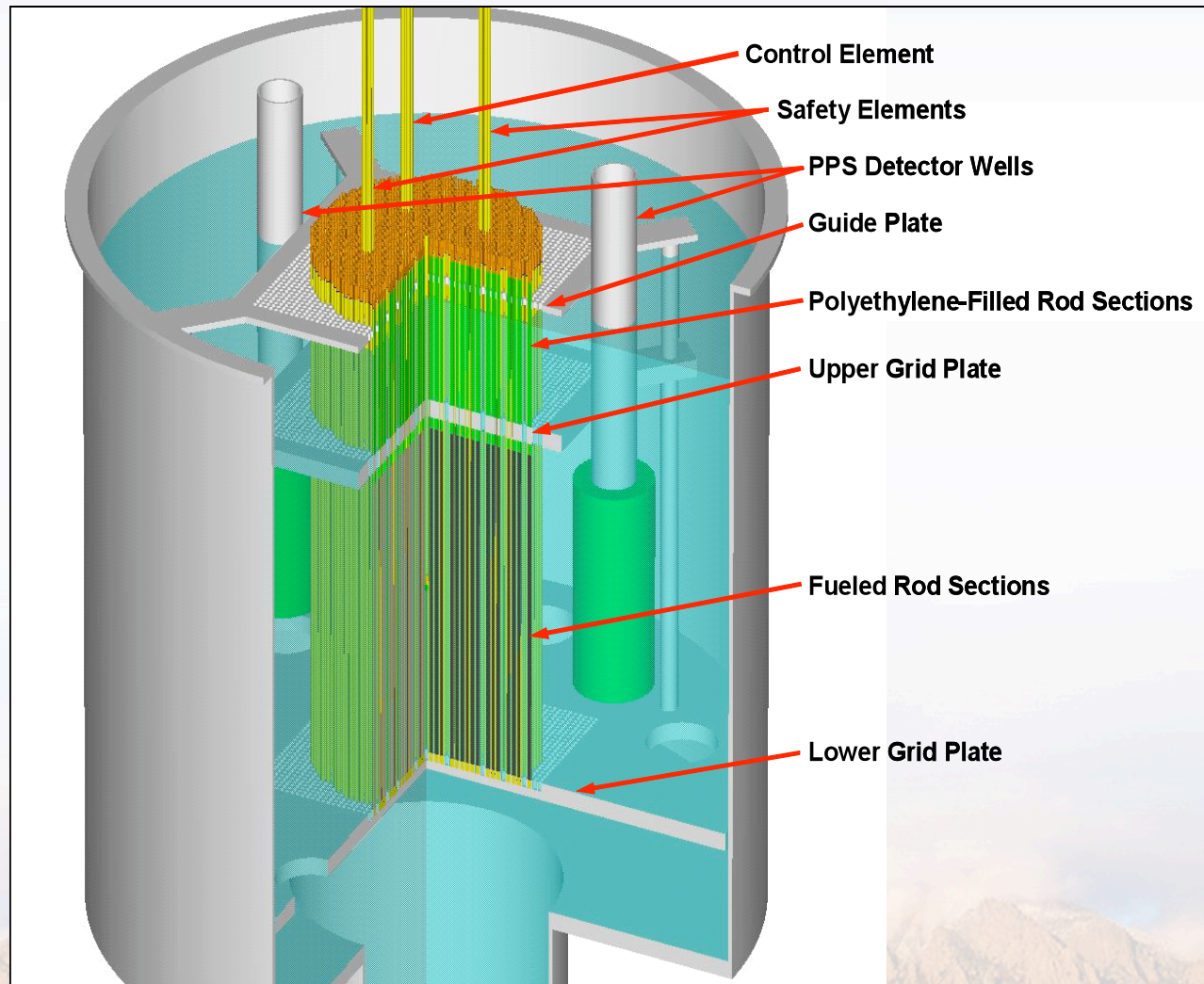


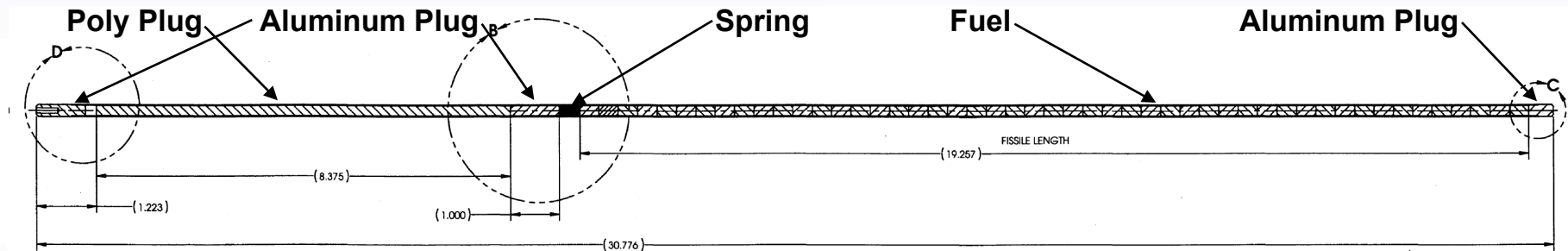
Figure 1. Overall Concept of the Critical Assembly.



Critical Assembly Hardware



The 7uPCX Fuel Rods



- The fuel is 6.90% enriched, 0.207" (0.536 cm) in diameter
- The fuel rods are 0.25" (0.635 cm) in diameter
- The fuel rod cladding and end plugs are aluminum
- The fuel rods extend above the upper grid plate – the upper plug is above the highest level of the moderator
- A polyethylene plug above the upper grid plate replaces the water



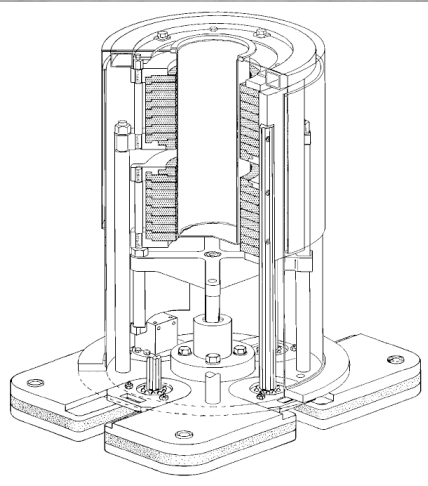


How We Stay Safe

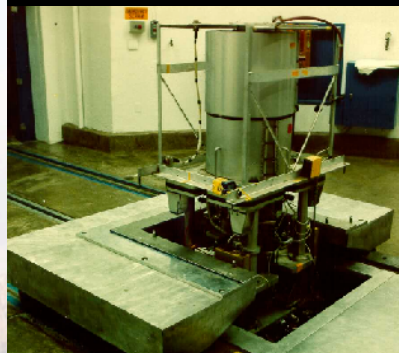
- **Design Basis Accidents**
 - Parking Lot Setup
- **Two Safety Elements and One Control Element**
- **One Safety Significant System**
 - SCRAM button in Reactor Room
- **Fuel, People and Water**
 - Less than 500 kg
 - Water Necessary to go Critical
 - Access Control
- **15 MJ Year Limit**
 - Not significant fission product buildup.



We operate our critical experiments in the Sandia Pulsed Reactor Facility



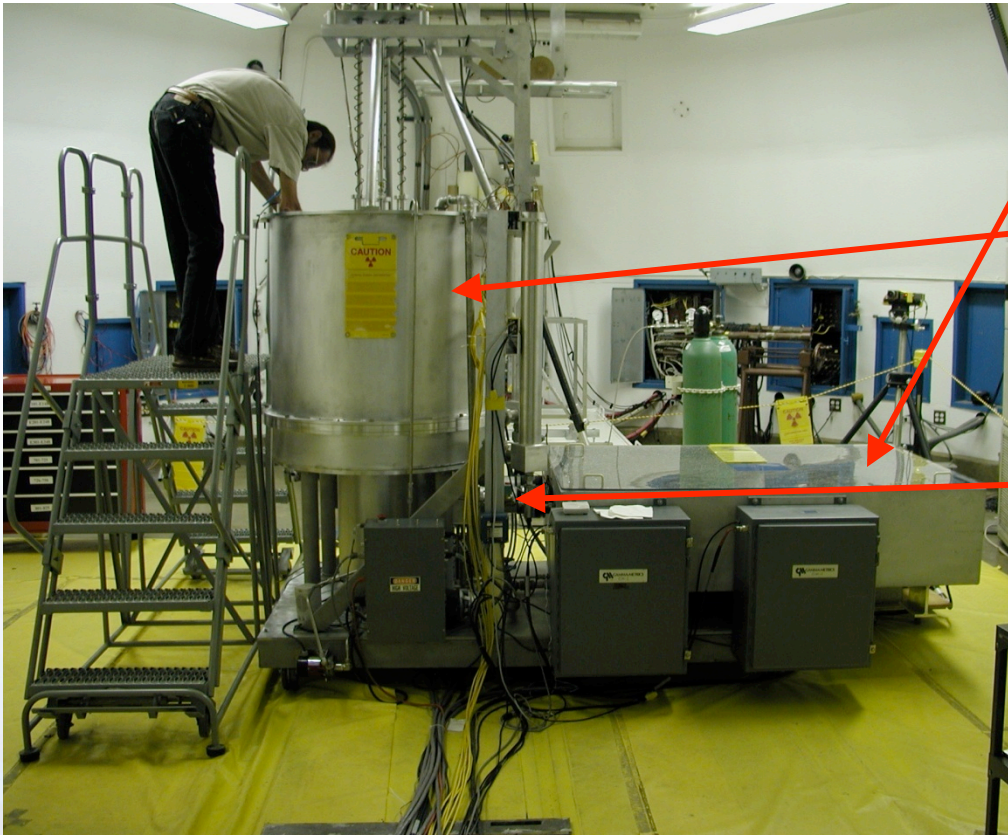
**Sandia Pulsed Reactor
III (SPR-III)**



- The SPRF is an operating Nuclear Facility
- The SPRF has:
 - ✓ a professional operating staff and supporting infrastructure
 - ✓ an existing Authorization Basis (AB)
 - ✓ room in its schedule – the HEU SPR fuel has been removed
- We modify the AB as needed for the critical experiments
- The AB is current
- We restarted our critical experiments capability in May, 2009



The critical assembly safety systems are gravity-driven



- The water moderator is normally stored in the dump tank
- The fuel array is in the elevated core tank
- The core tank is connected to the dump tank by two 4" lines with normally-open remotely-controlled dump valves
- To close the dump valves, a key must be inserted into the console and turned – the key cannot be removed if activated



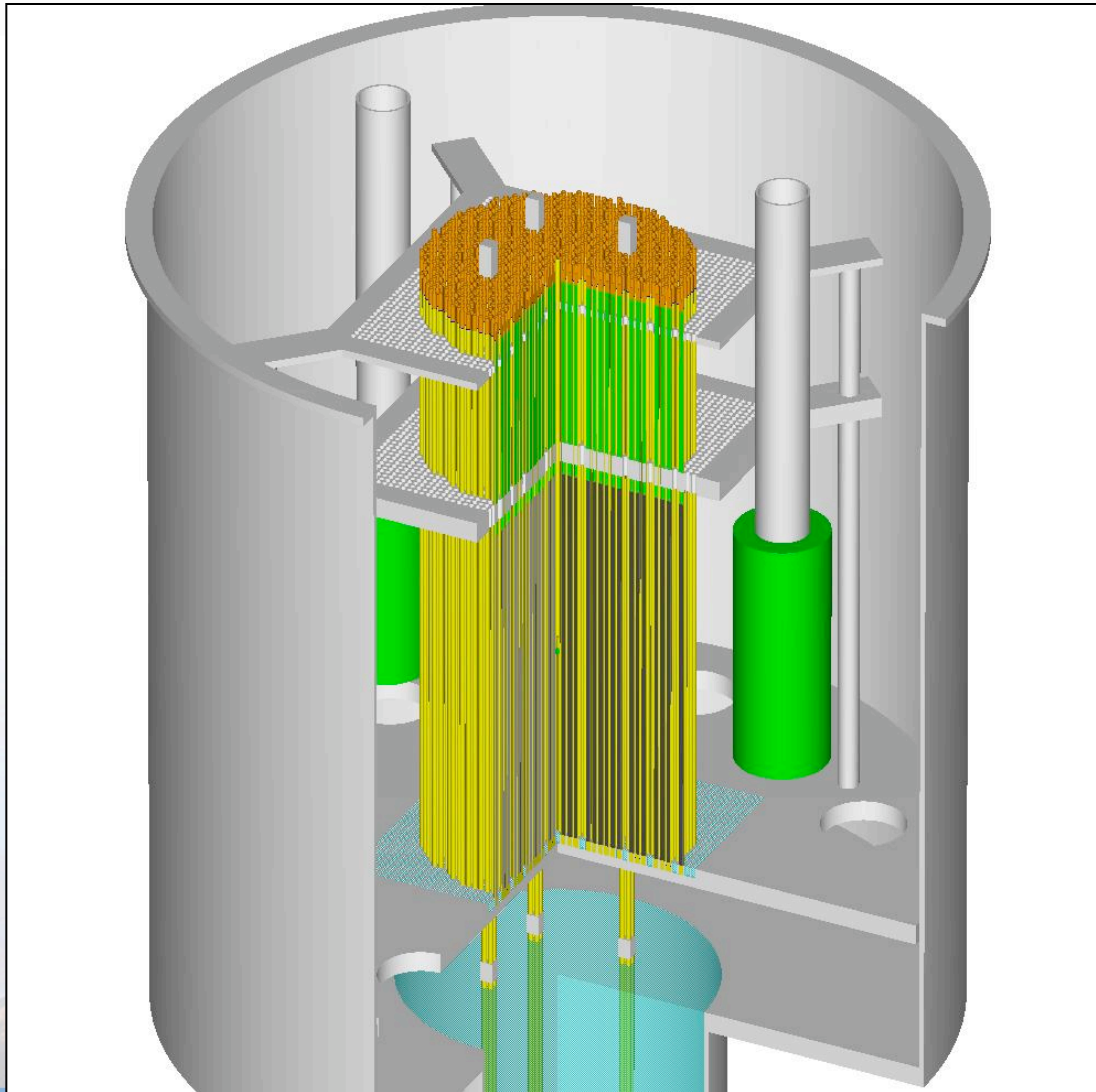


The safety case is simple

- **Low-enriched (<20%) fuel is used**
 - 1000 kg of the fuel is subcritical without water moderator
 - Reactor room is limited to 500 kg of fuel
- **Access controls ensure personnel safety – the key that closes the dump valves and allows water to accumulate in the core tank is tied to the key to the facility door**
 - When people are in the reactor room, the key is out of the console and the dump valves are open (core tank cannot hold water)
 - When the dump valves are closed, the reactor area is locked and people are excluded from the reactor room
 - FUEL – WATER – PEOPLE – pick any TWO
- **The fission product inventory is kept low by limiting the energy deposition in the fuel (15 MJ fission energy per year)**
 - 15 MJ is less than 3 SPR-III pulses
 - Limits accident source term
 - Allows manual handling of fuel during experiments



The shut-down configuration of the assembly



Safety Elements: Down

Control Element: Down

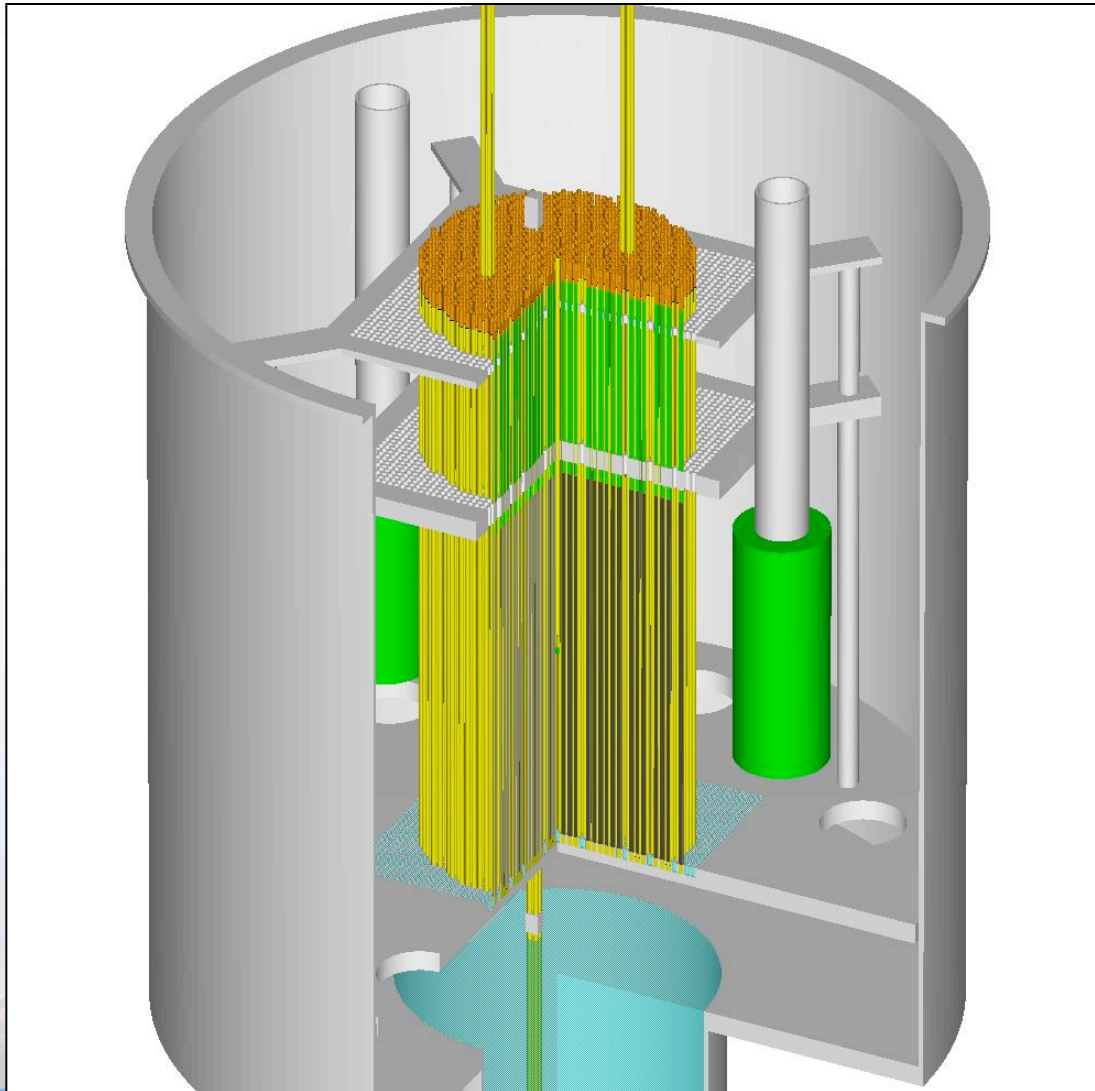
Core Tank: Empty

Personnel: Allowed

In this condition, the assembly is “shut down.” Entry into the reactor room is allowed. The control system need not be manned. Fuel may be removed or added but a “new” configuration may not be built.



Raise the safety elements



Safety Elements: Up

Control Element: Down

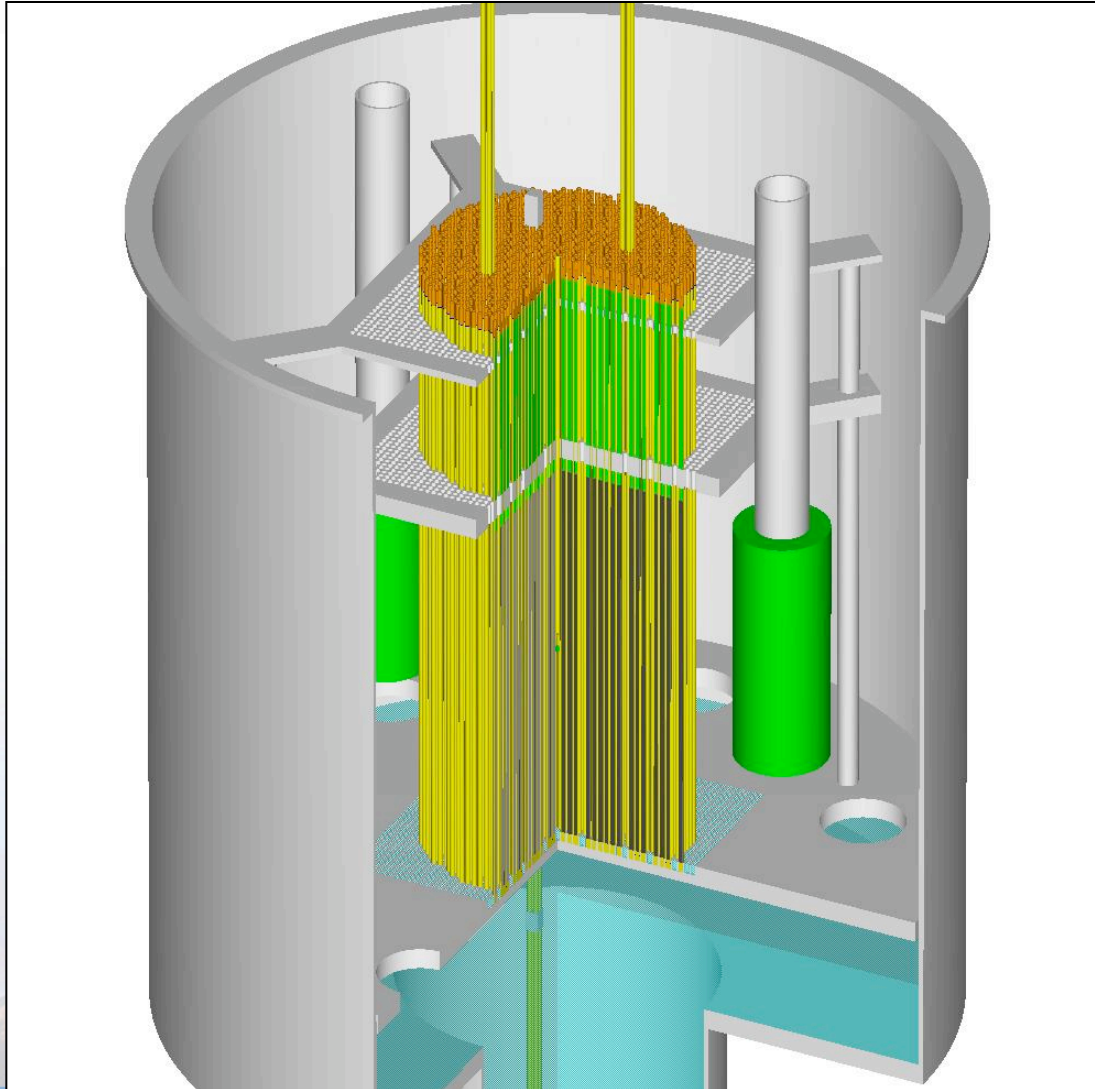
Core Tank: Empty

Personnel: Allowed

In this condition, the assembly is “operating” and a qualified operator must be at the controls at all times. Entry into the reactor room is allowed. Fuel may be added to or removed from the array.



Fill the core tank



Safety Elements: Up

Control Element: Down

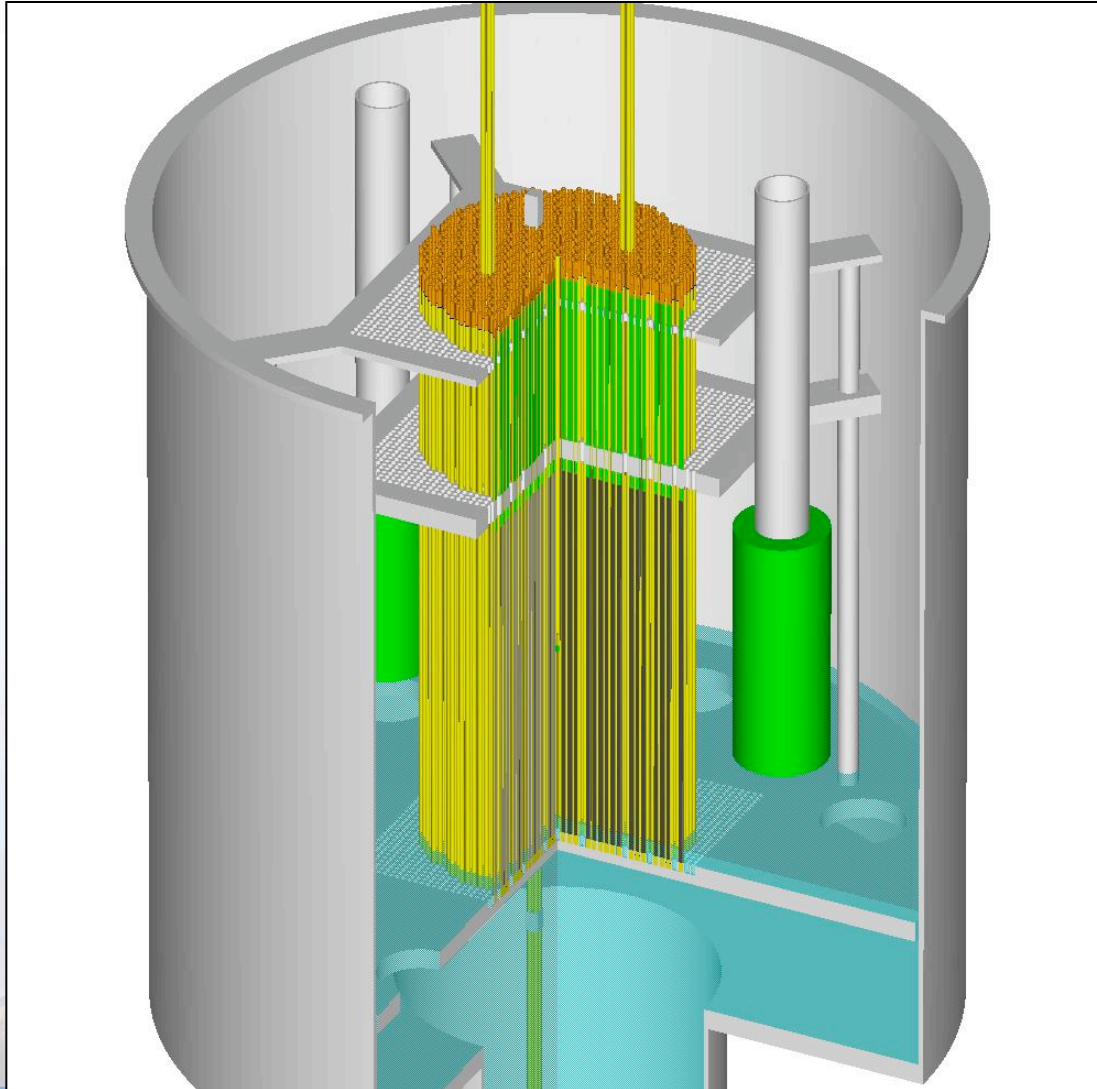
Core Tank: Filling

Personnel: Excluded

Filling the core tank requires about 15 minutes.



Fill the core tank



Safety Elements: Up

Control Element: Down

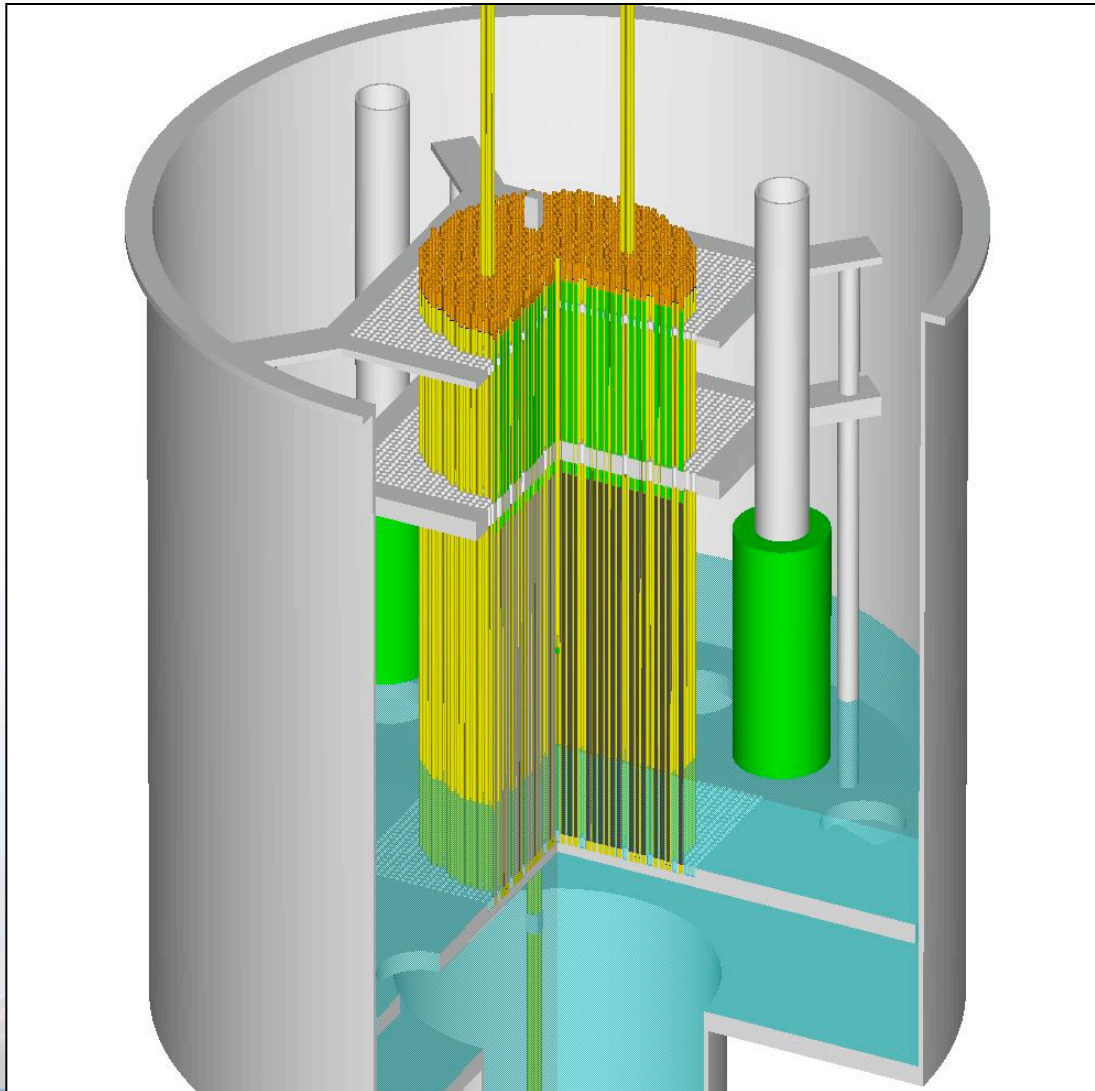
Core Tank: Filling

Personnel: Excluded

Filling the core tank requires about 15 minutes.



Fill the core tank



Safety Elements: Up

Control Element: Down

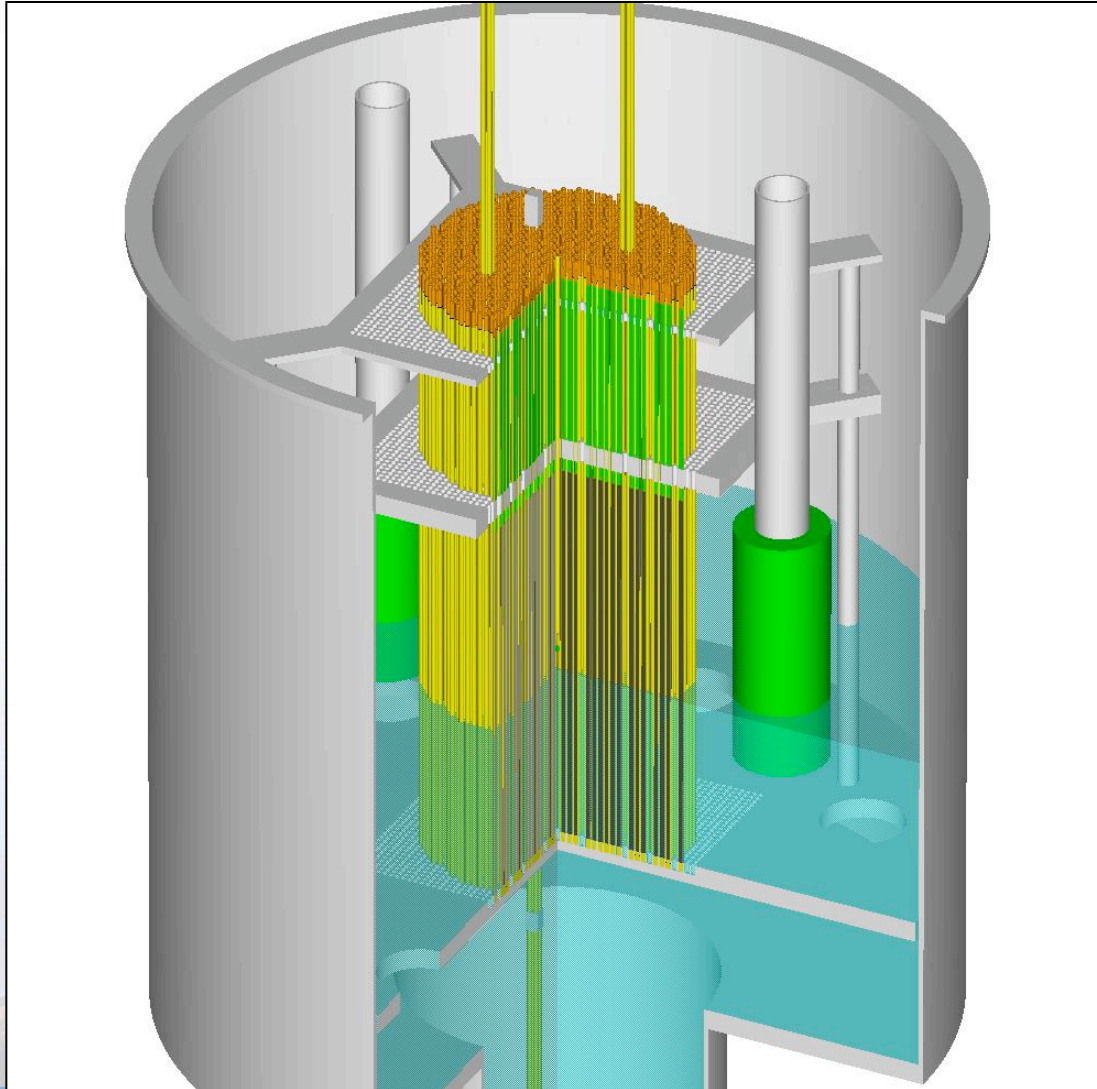
Core Tank: Filling

Personnel: Excluded

Filling the core tank requires
about 15 minutes.



Fill the core tank



Safety Elements: Up

Control Element: Down

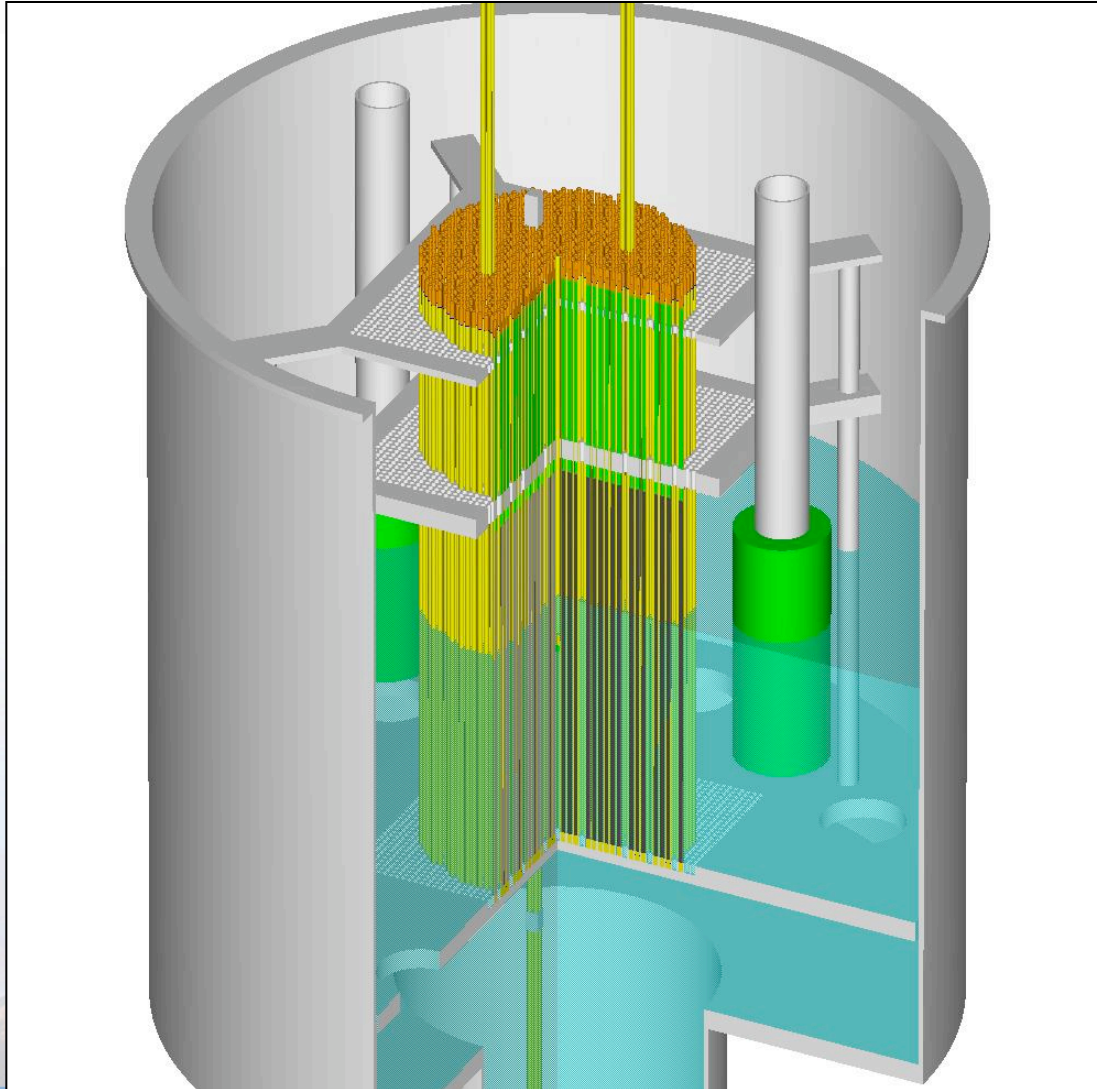
Core Tank: Filling

Personnel: Excluded

**Filling the core tank requires
about 15 minutes.**



Fill the core tank



Safety Elements: Up

Control Element: Down

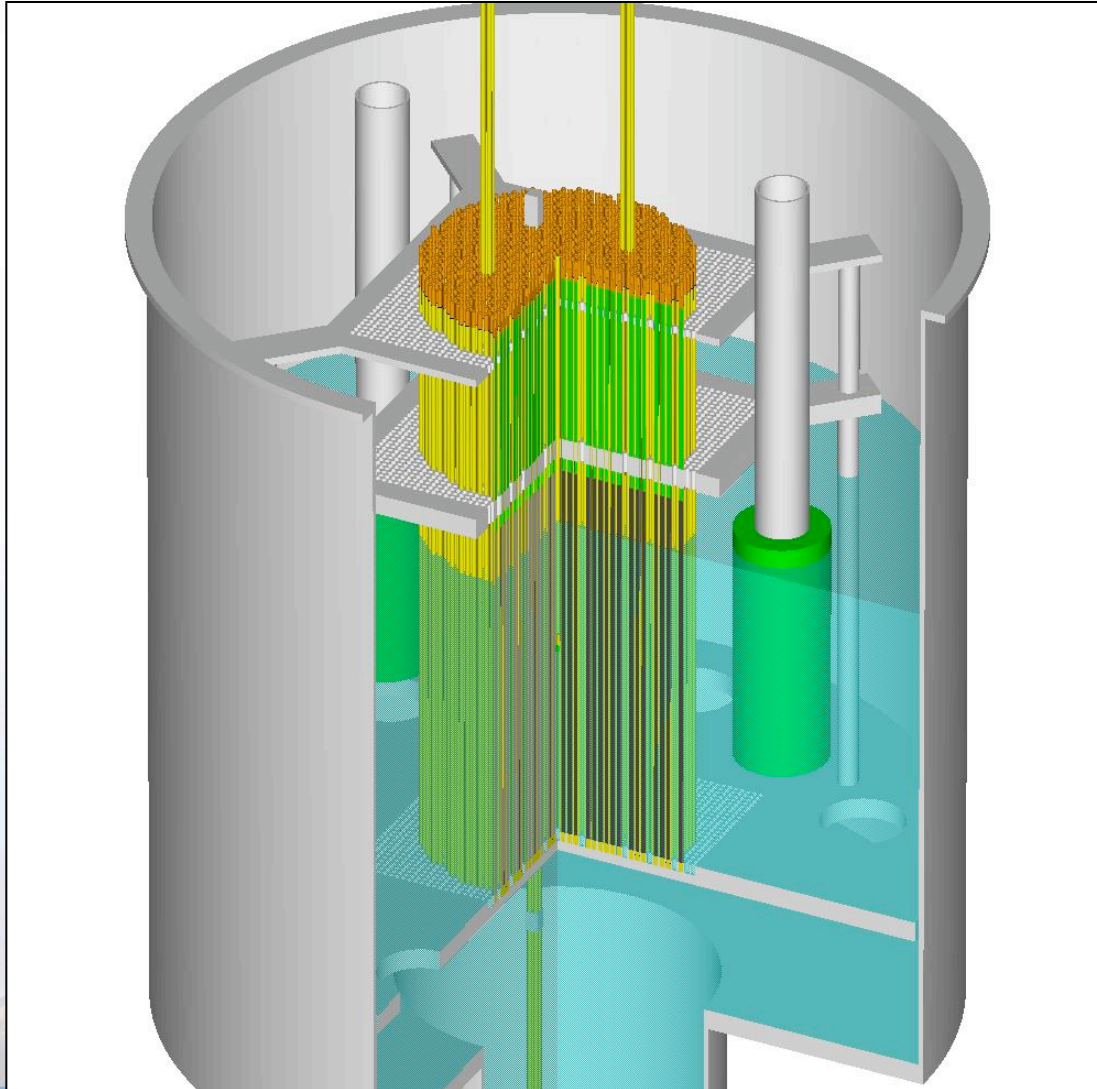
Core Tank: Filling

Personnel: Excluded

Filling the core tank requires
about 15 minutes.



Fill the core tank



Safety Elements: Up

Control Element: Down

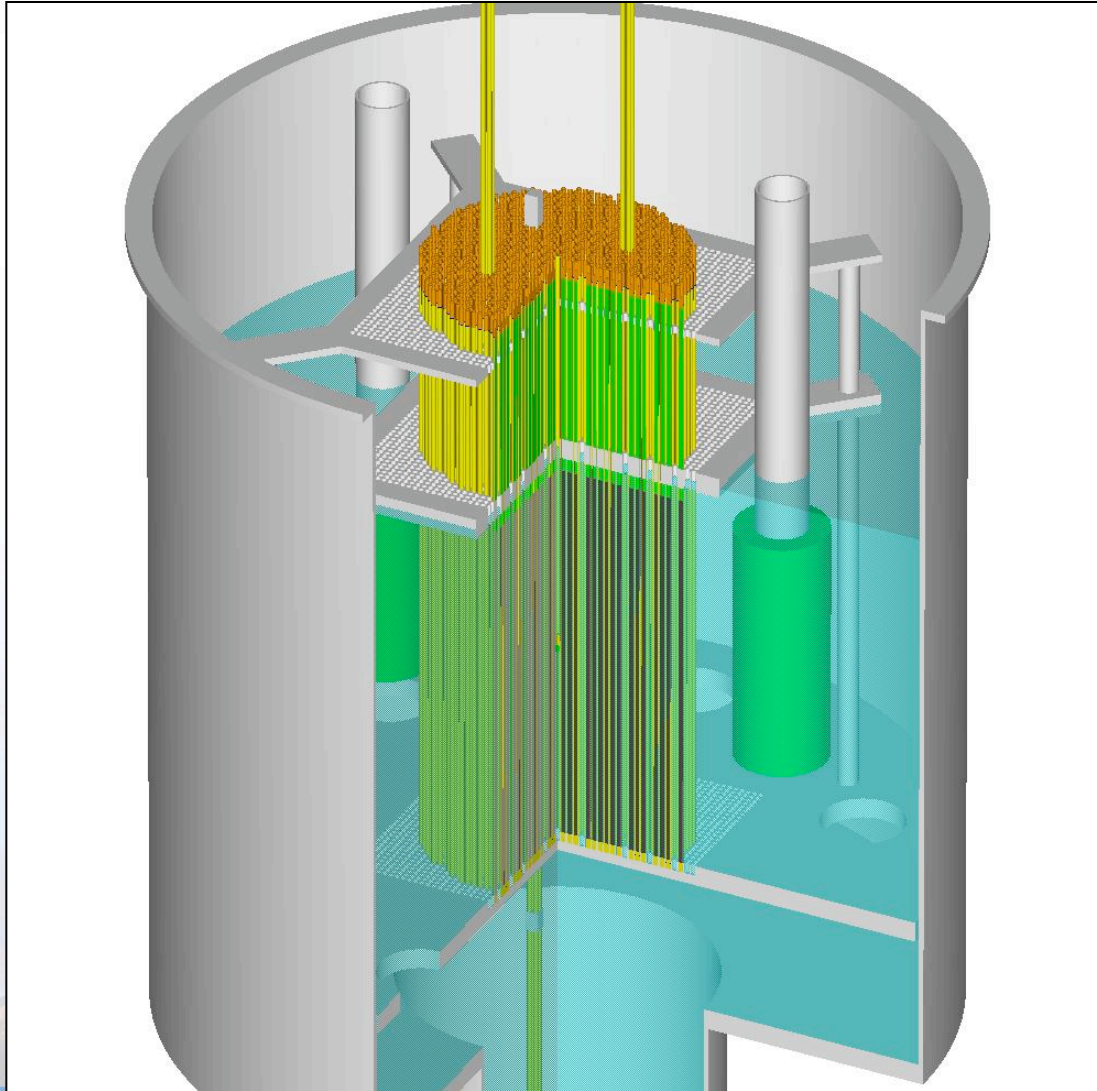
Core Tank: Filling

Personnel: Excluded

Filling the core tank requires about 15 minutes.



Fill the core tank



Safety Elements: Up

Control Element: Down

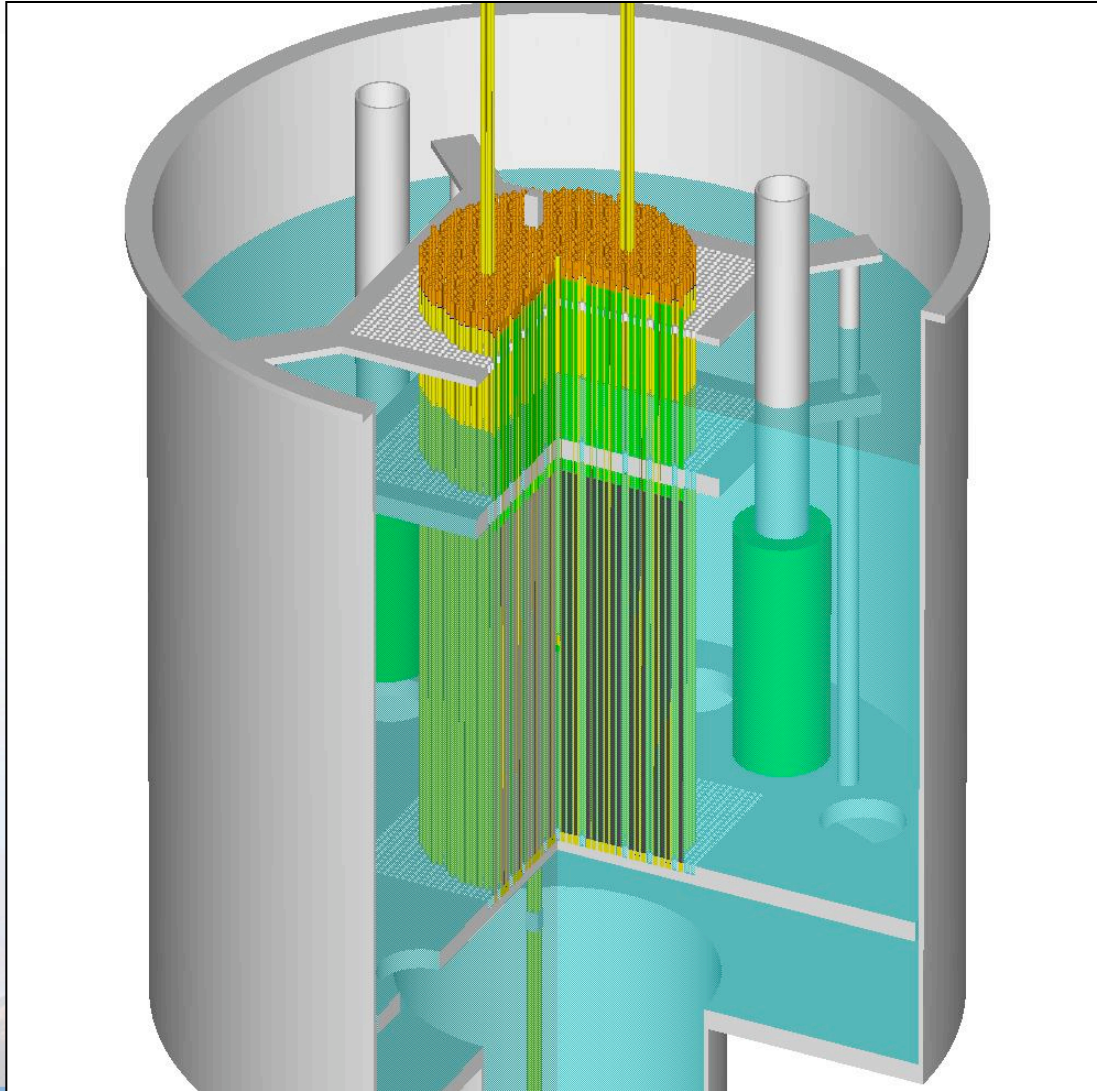
Core Tank: Filling

Personnel: Excluded

**Filling the core tank requires
about 15 minutes.**



Fill the core tank



Safety Elements: Up

Control Element: Down

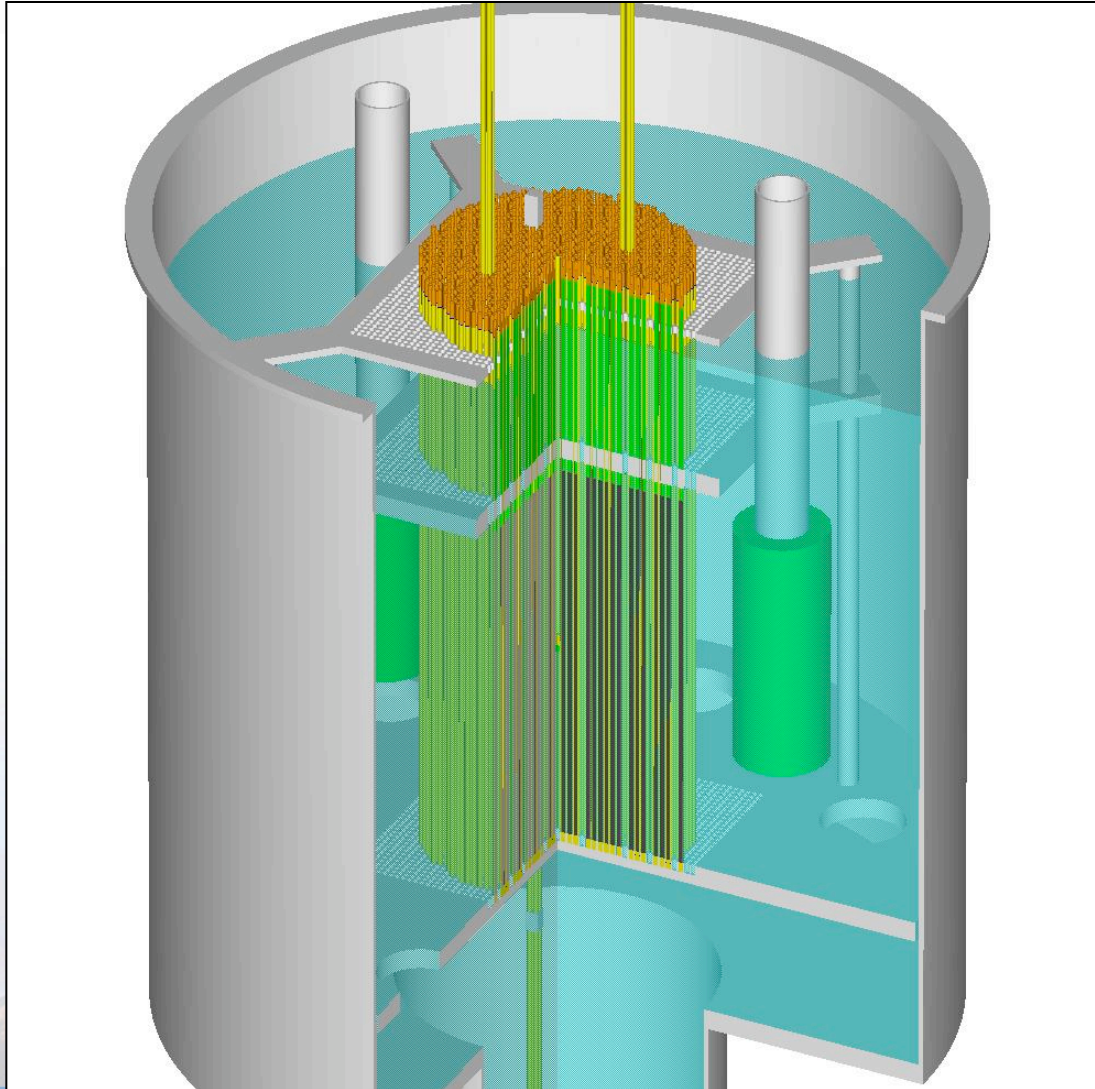
Core Tank: Filling

Personnel: Excluded

**Filling the core tank requires
about 15 minutes.**



Fill the core tank



Safety Elements: Up

Control Element: Down

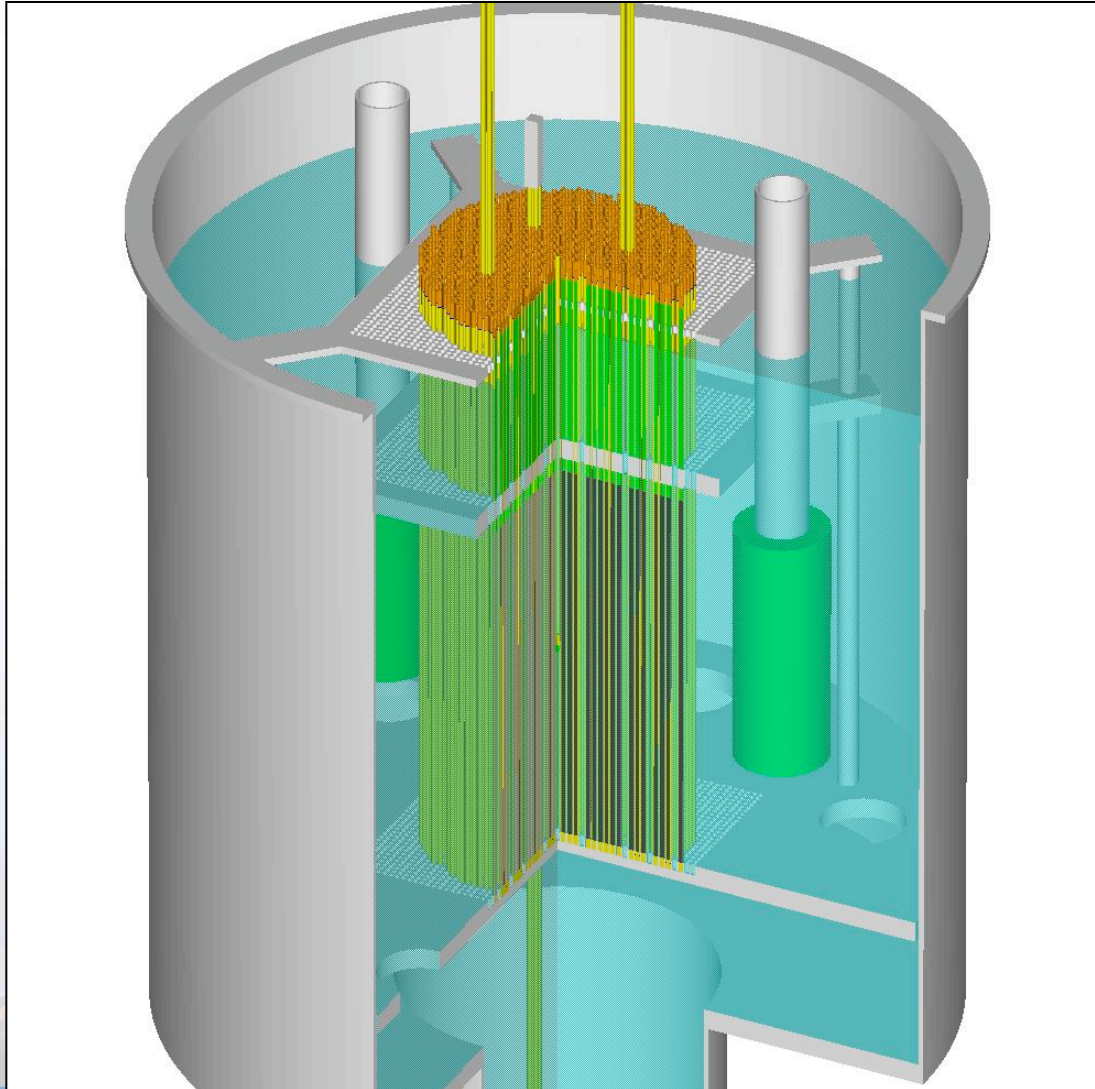
Core Tank: Full

Personnel: Excluded

At this point, the “fast” fill pump is disabled by an interlock and the recirculation pump is turned on. Moderator enters under the water’s surface and drains to the dump tank through a stand pipe.



Raise the control element



Safety Elements: Up

Control Element: Raising

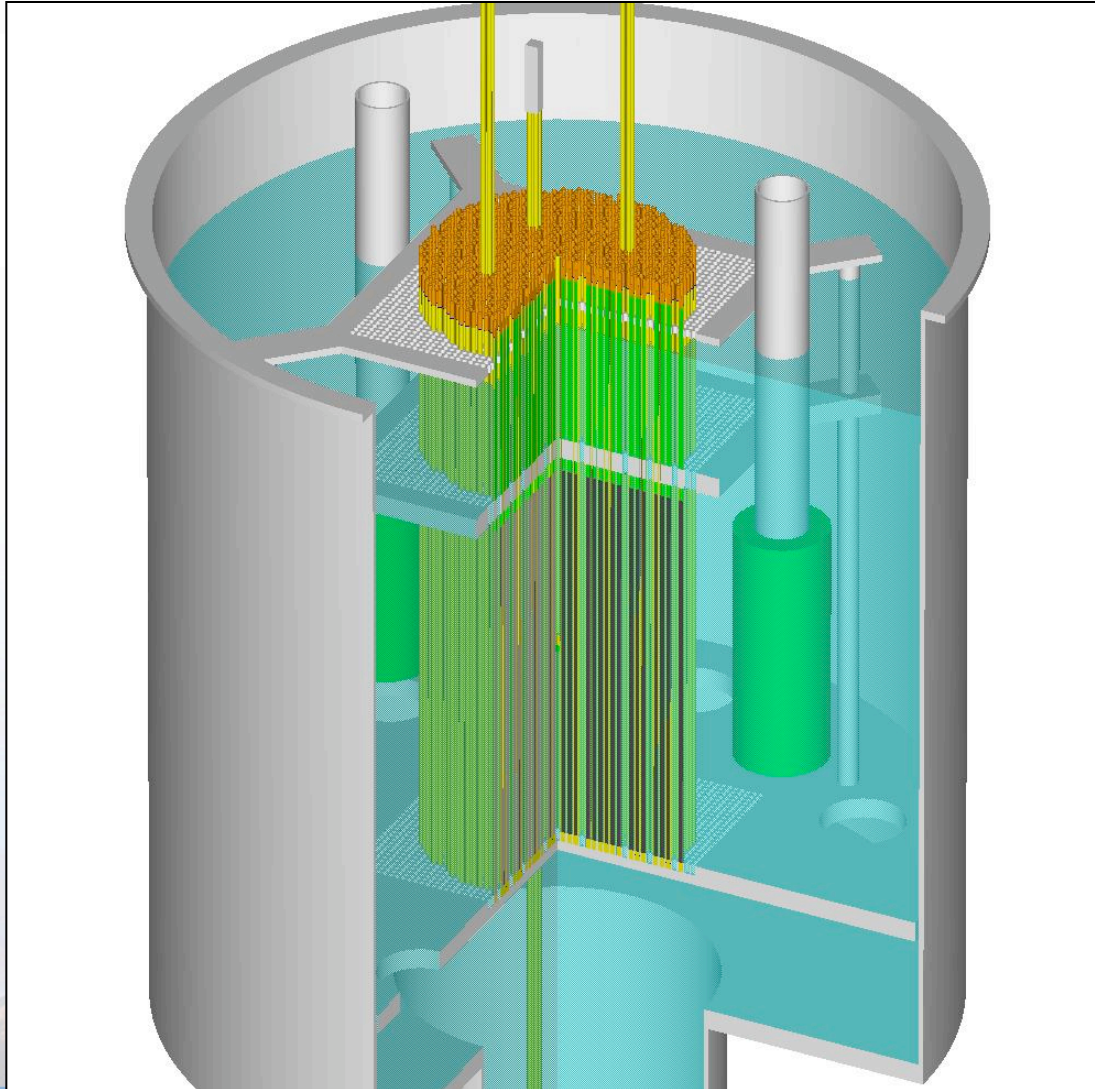
Core Tank: Full

Personnel: Excluded

It takes about 90 seconds to raise the control element.



Raise the control element



Safety Elements: Up

Control Element: Raising

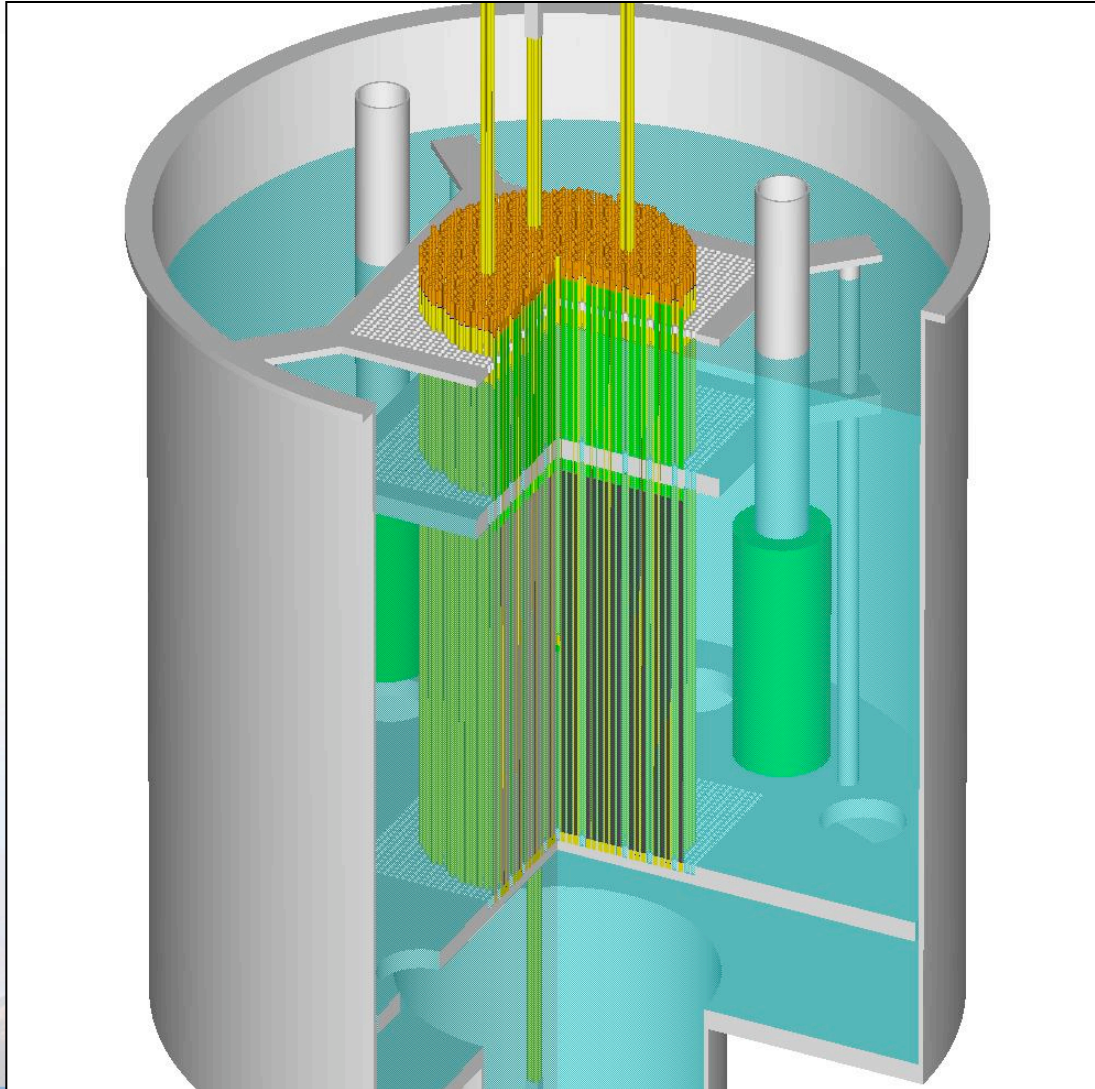
Core Tank: Full

Personnel: Excluded

It takes about 90 seconds to raise the control element.



Raise the control element



Safety Elements: Up

Control Element: Raising

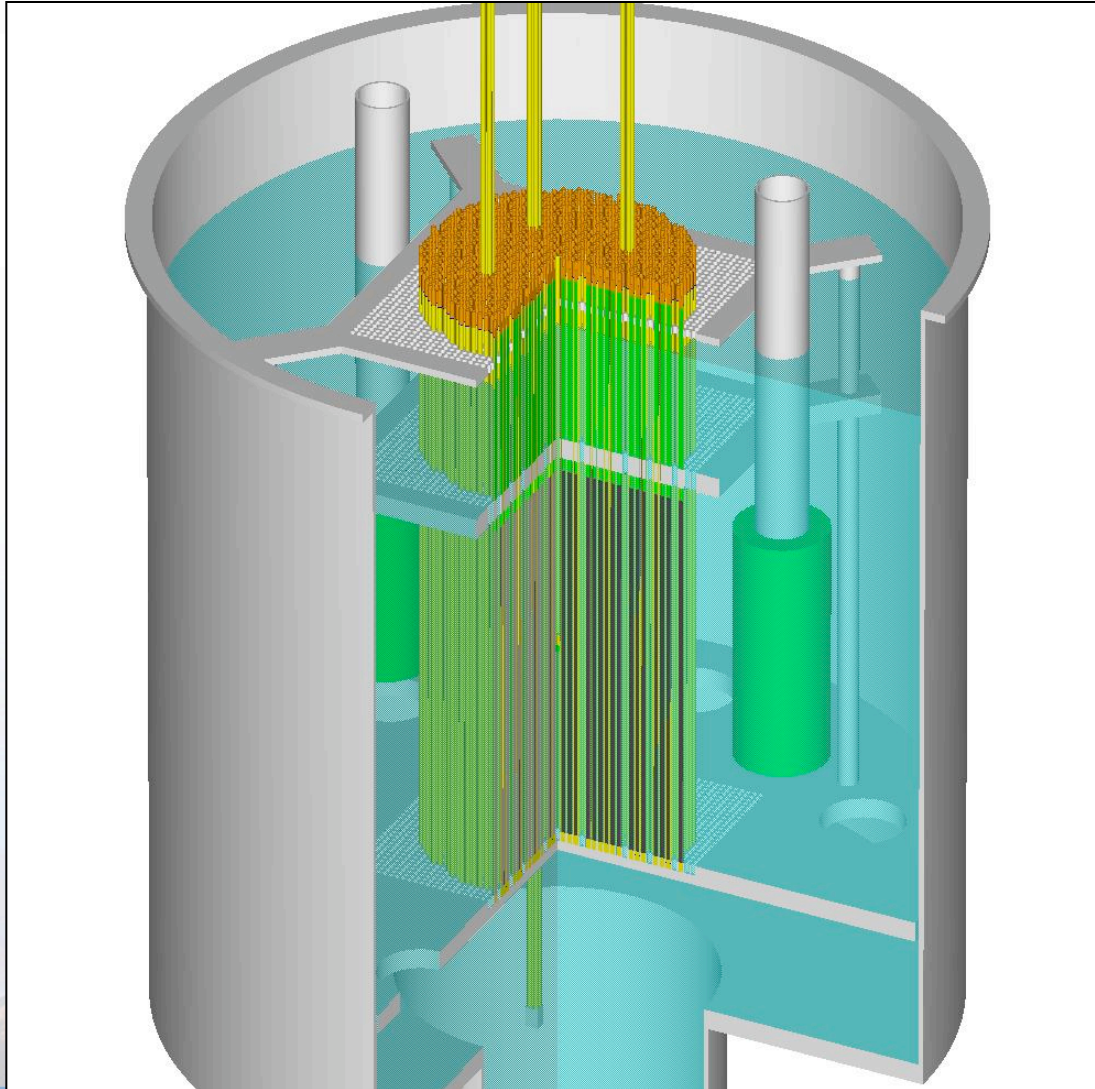
Core Tank: Full

Personnel: Excluded

It takes about 90 seconds to raise the control element.



Raise the control element



Safety Elements: Up

Control Element: Raising

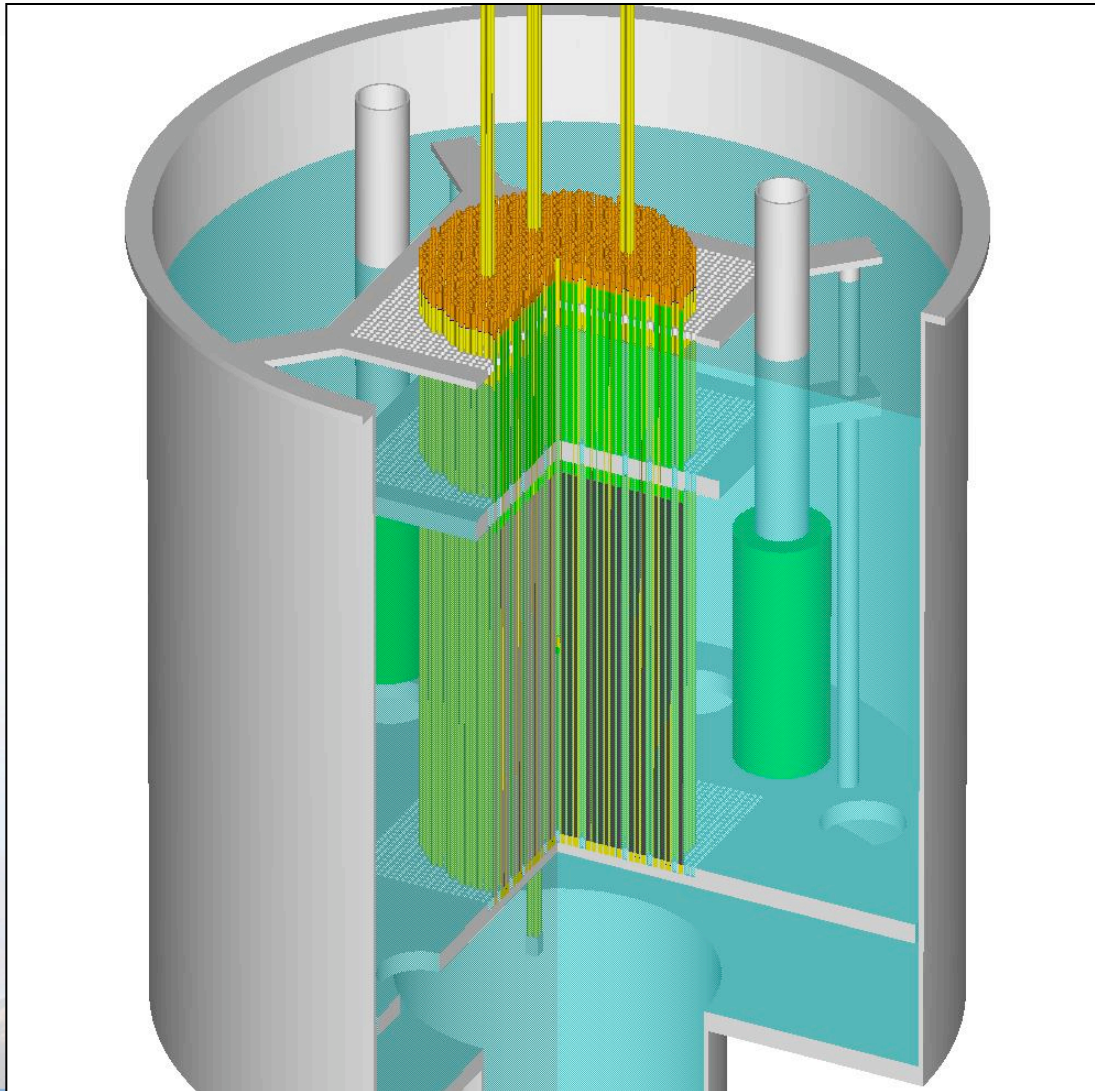
Core Tank: Full

Personnel: Excluded

It takes about 90 seconds to raise the control element.



Raise the control element



Safety Elements: Up

Control Element: Raising

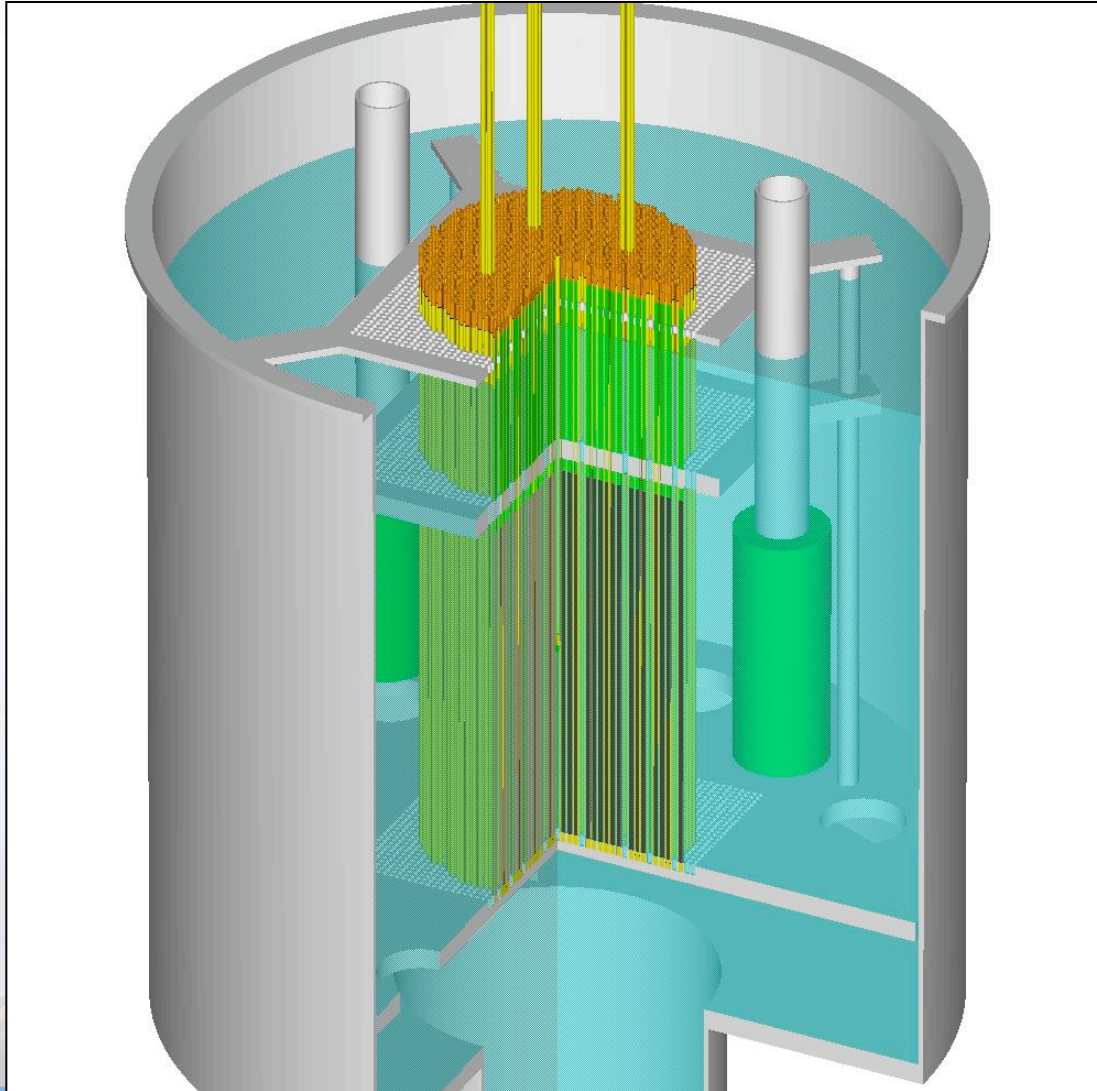
Core Tank: Full

Personnel: Excluded

It takes about 90 seconds to raise the control element.



Raise the control element



Safety Elements: Up

Control Element: Raising

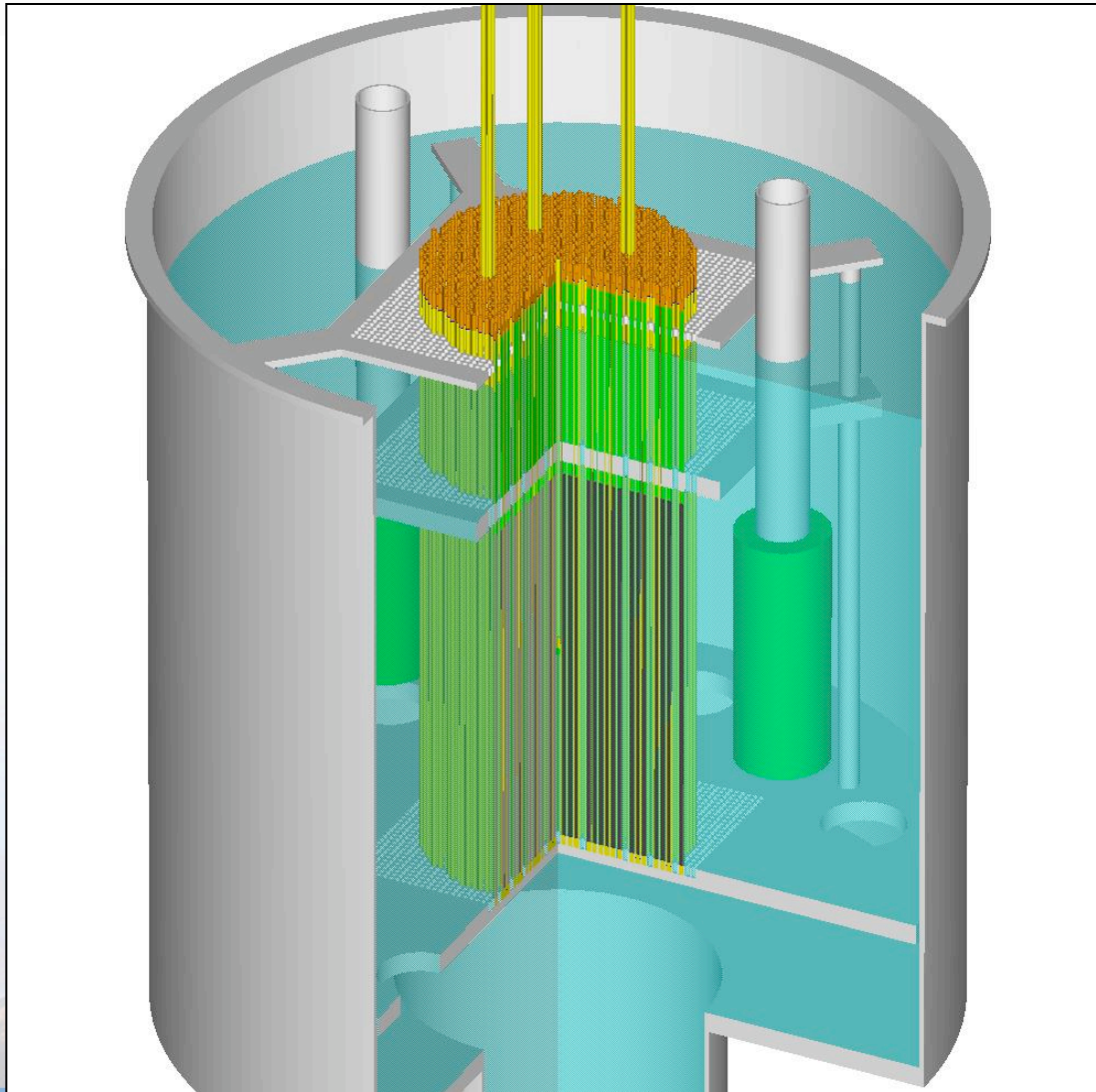
Core Tank: Full

Personnel: Excluded

It takes about 90 seconds to raise the control element.



The assembly reaches its most reactive state



Safety Elements: Up

Control Element: Up

Core Tank: Full

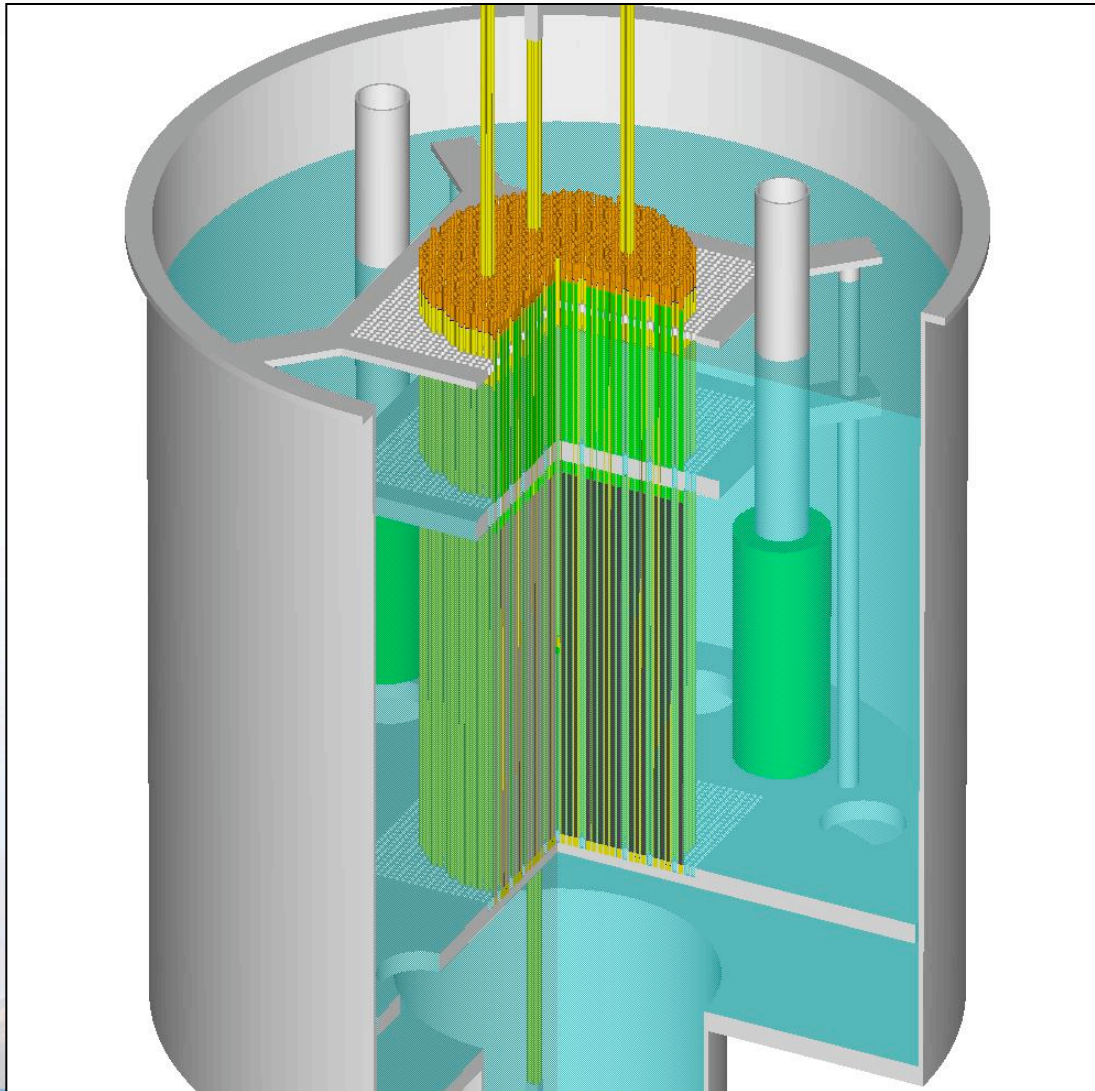
Personnel: Excluded

With all control and safety elements up and full reflection (>6 in. of water on all sides), this is the highest reactivity state of the assembly. Multiplication measurements are made in this configuration.



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Lower the control element



Safety Elements: Up

Control Element: Lowering

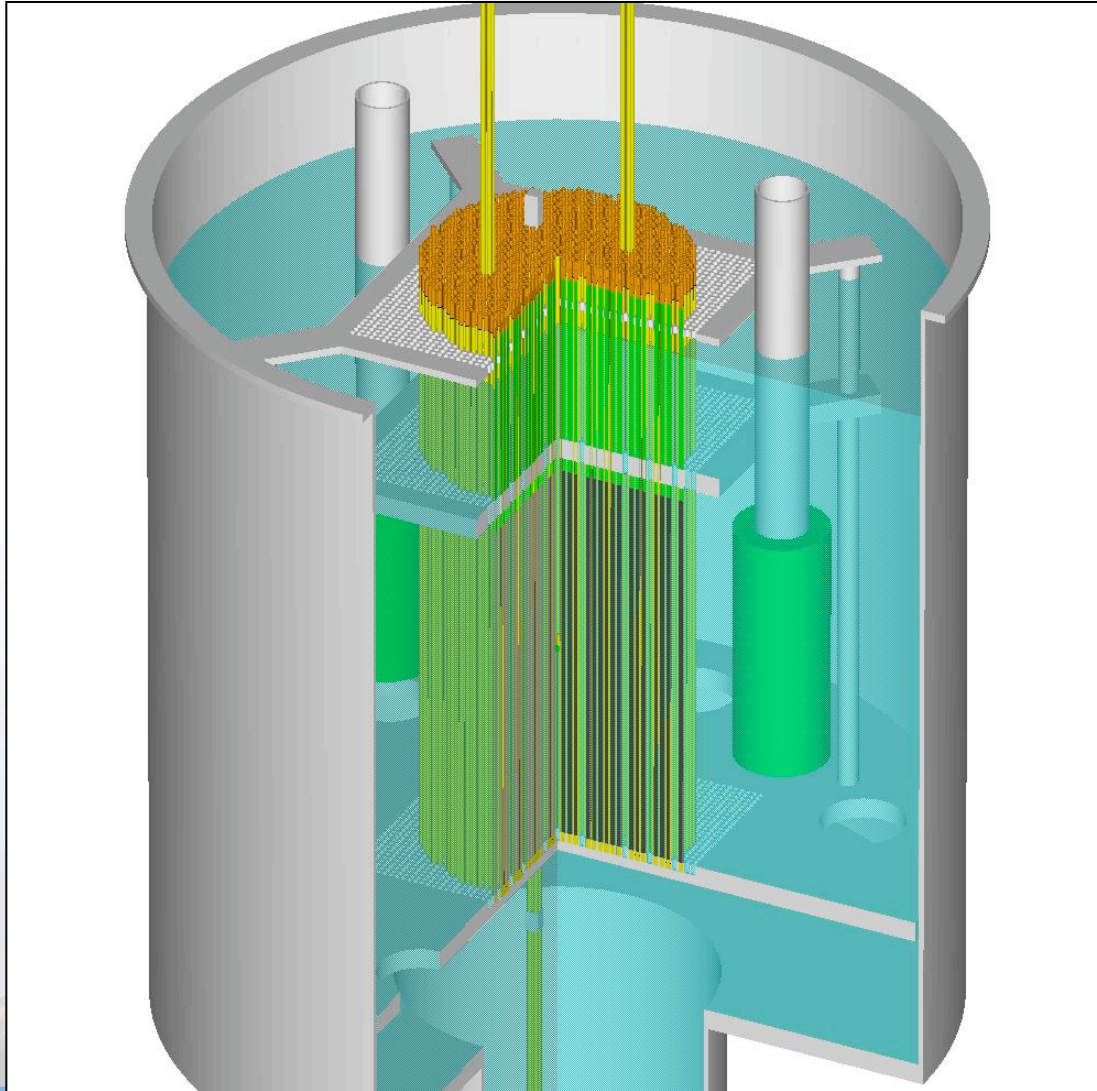
Core Tank: Full

Personnel: Excluded

It takes about 90 seconds to raise the control element.



Lower the control element



Safety Elements: Up

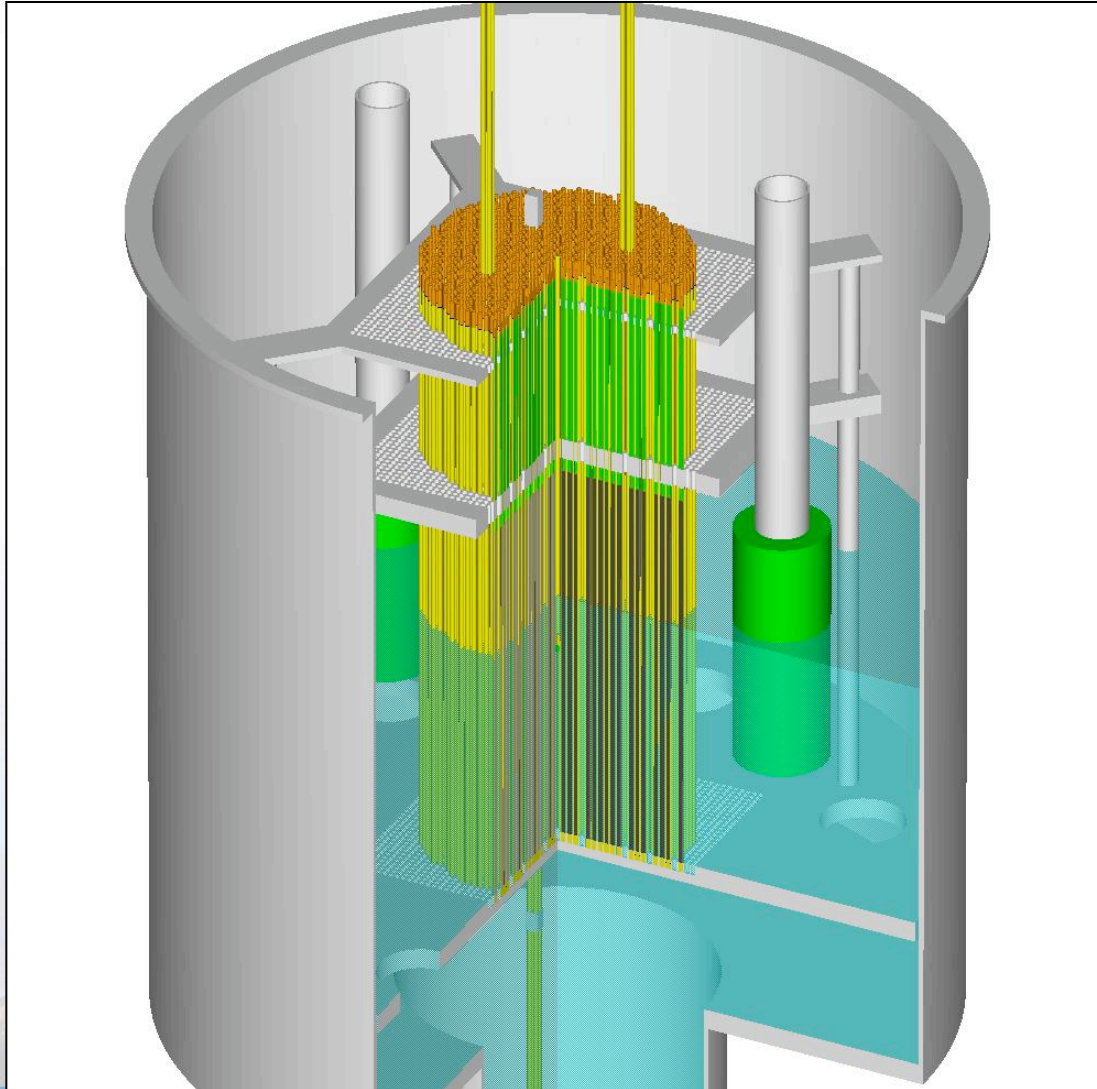
Control Element: Down

Core Tank: Full

Personnel: Excluded



Drain the core tank



Safety Elements: Up

Control Element: Down

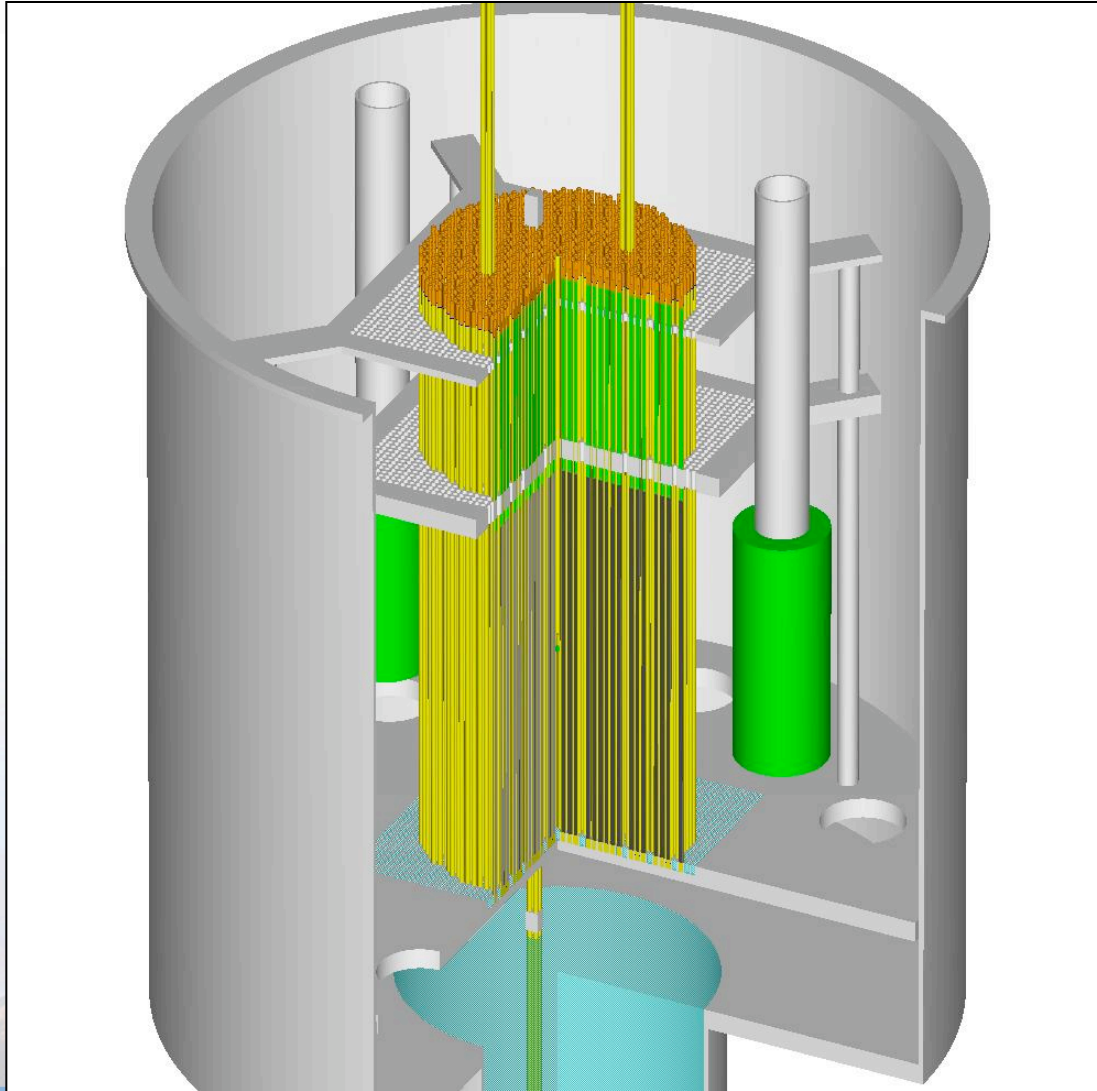
Core Tank: Draining

Personnel: Excluded

Draining the core tank requires only a few seconds.



Drain the core tank



Safety Elements: Up

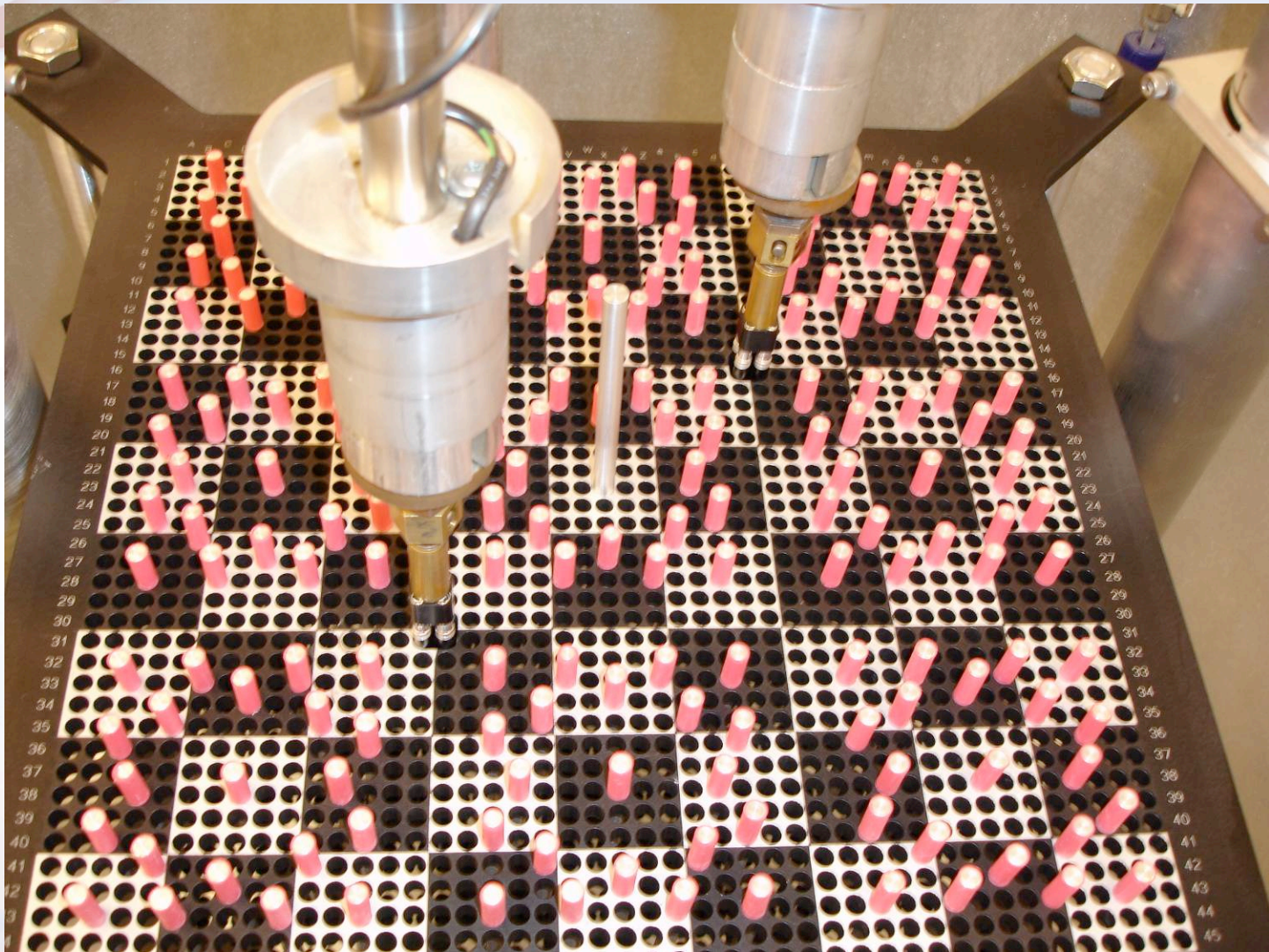
Control Element: Down

Core Tank: Empty

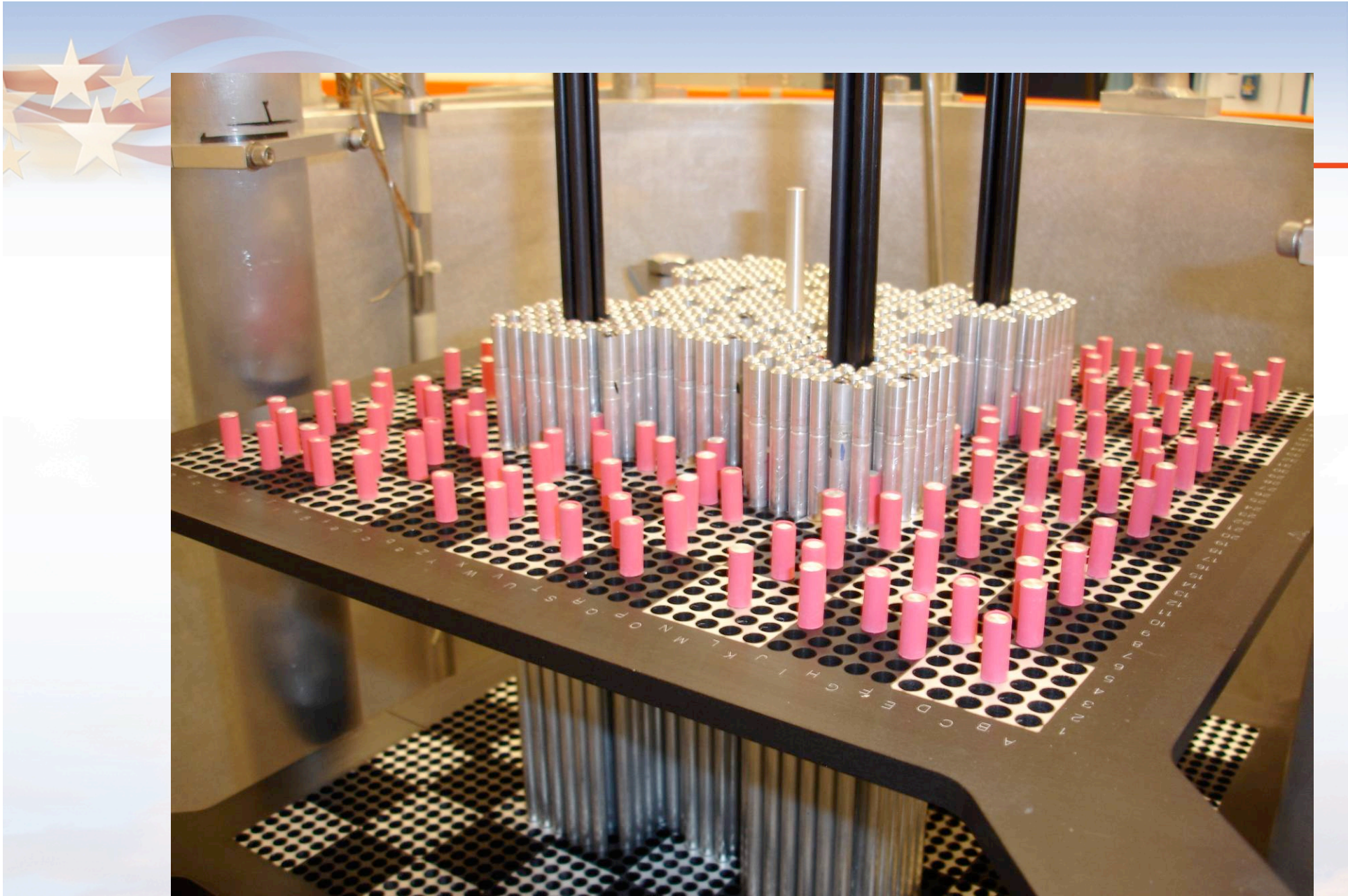
Personnel: Allowed

Now we are back to a condition where fuel may be added to or removed from the array.

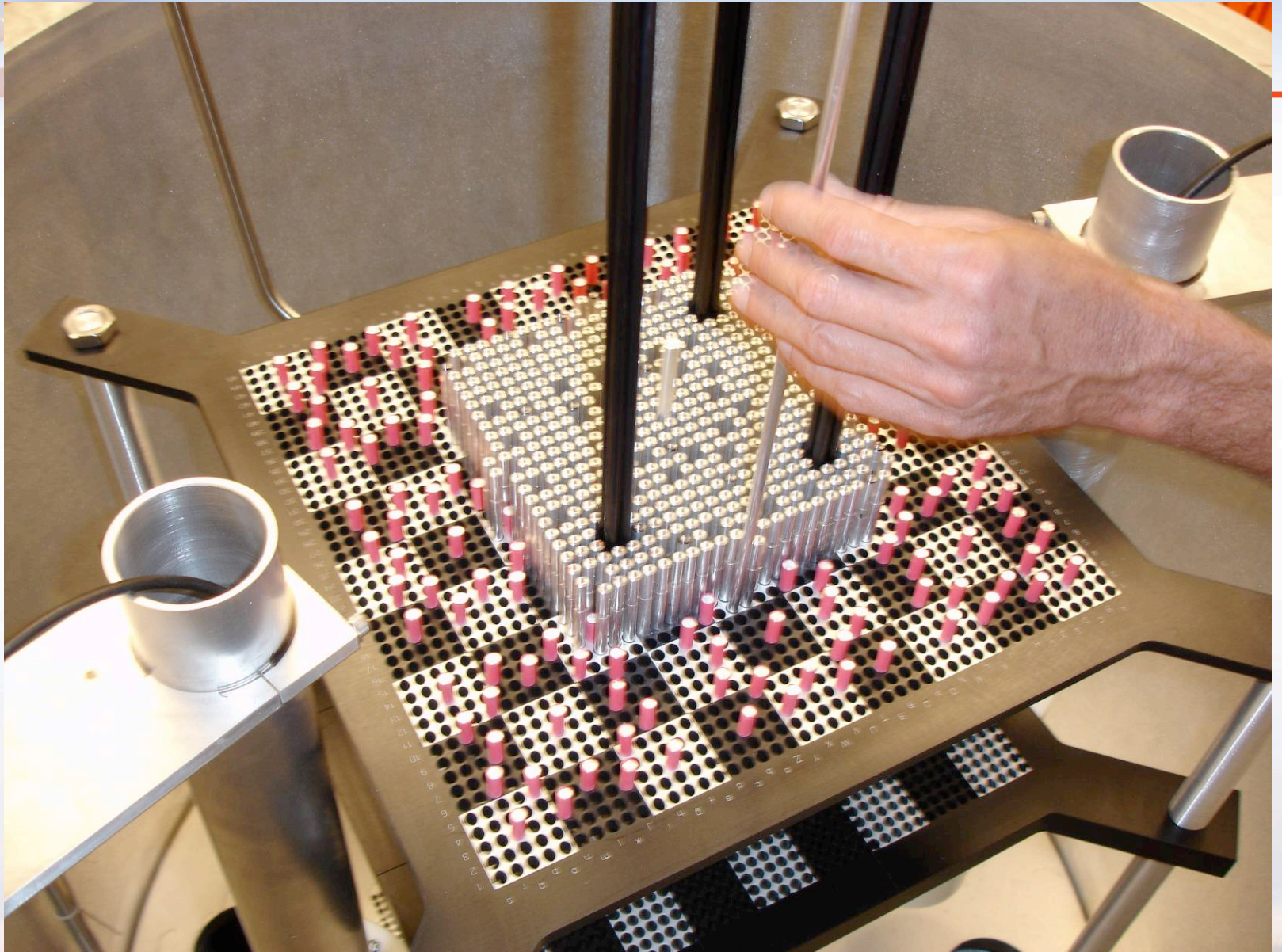
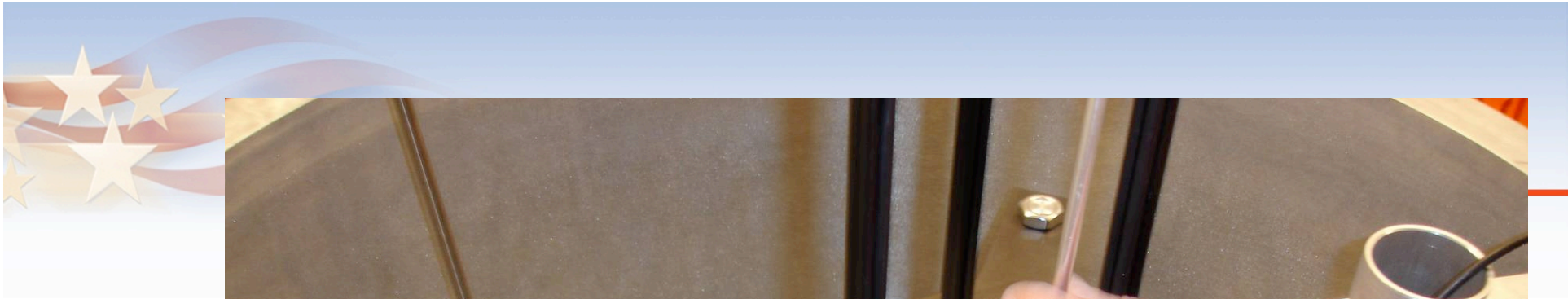


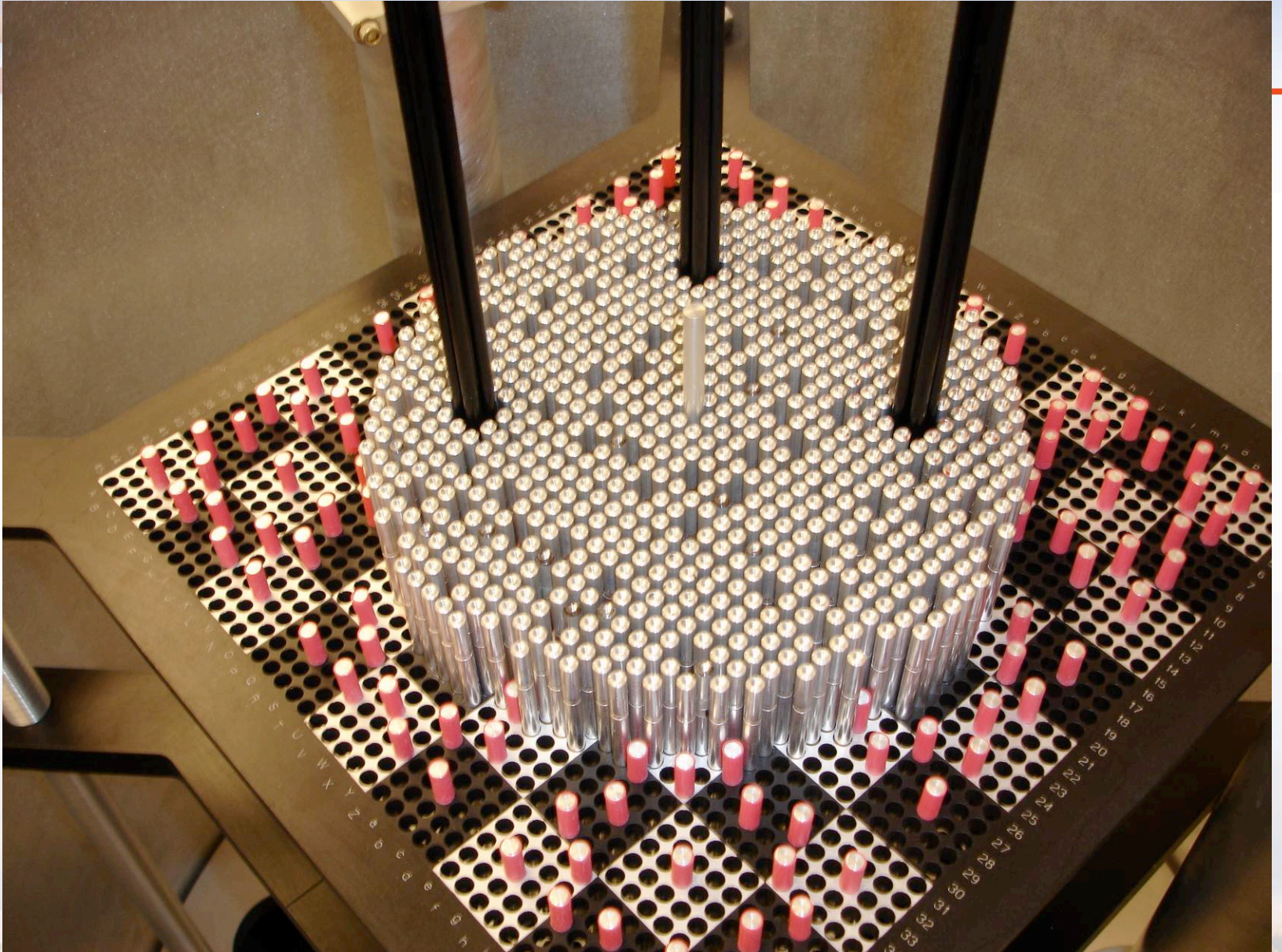


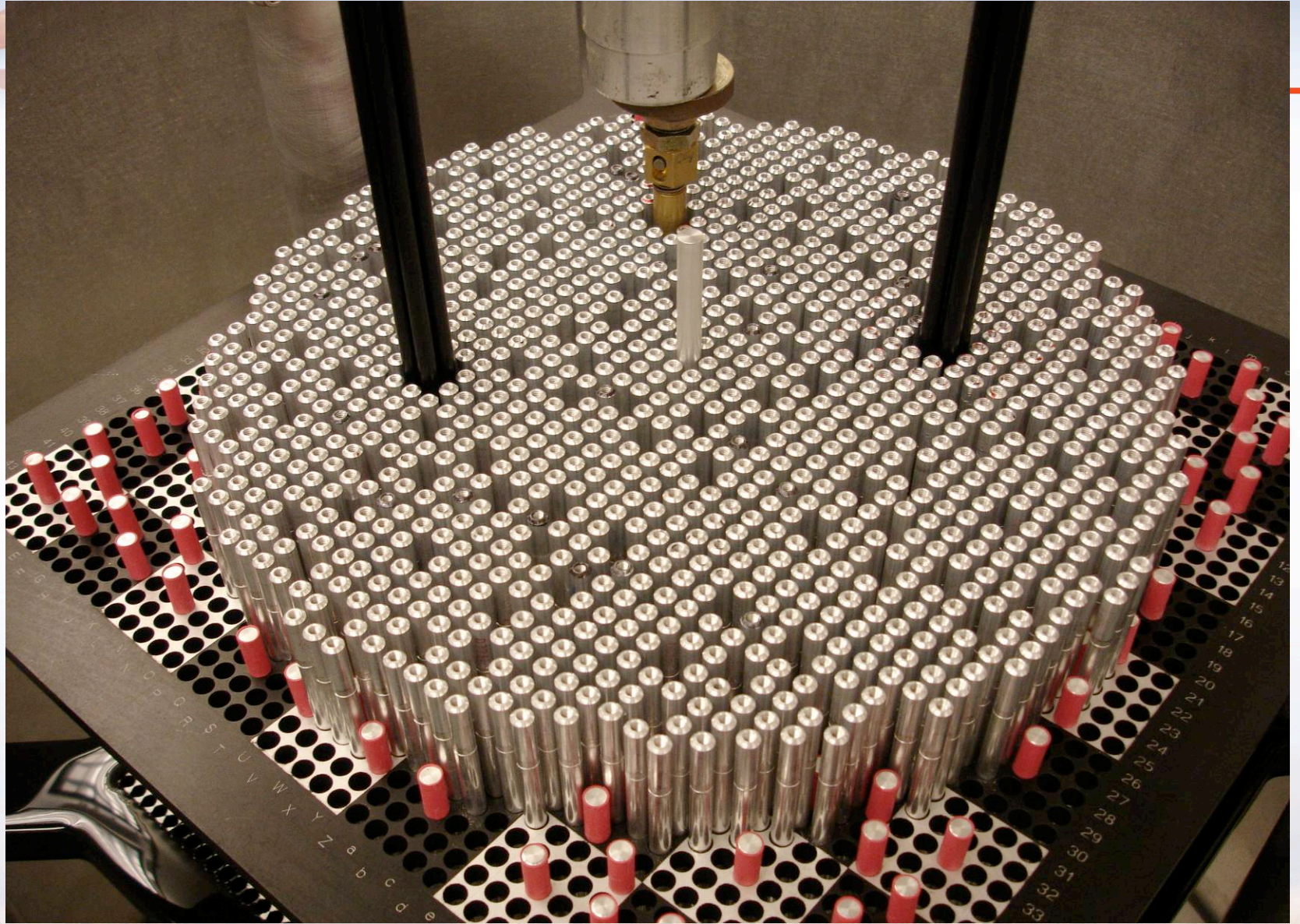




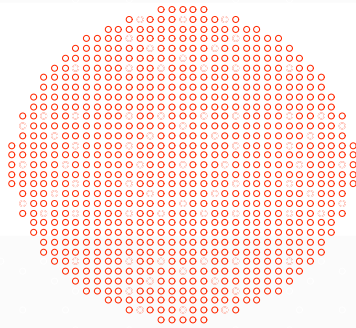








Core configurations during the first approach-to-critical experiment (1)



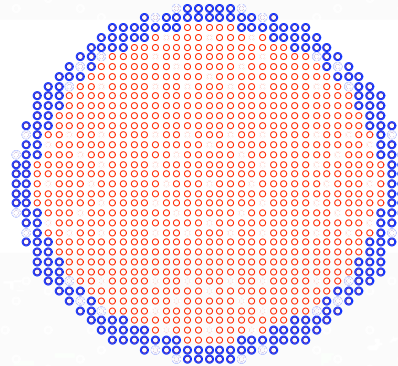
740

Multiplication:

$$M = \frac{1}{1 - k_{eff}}$$

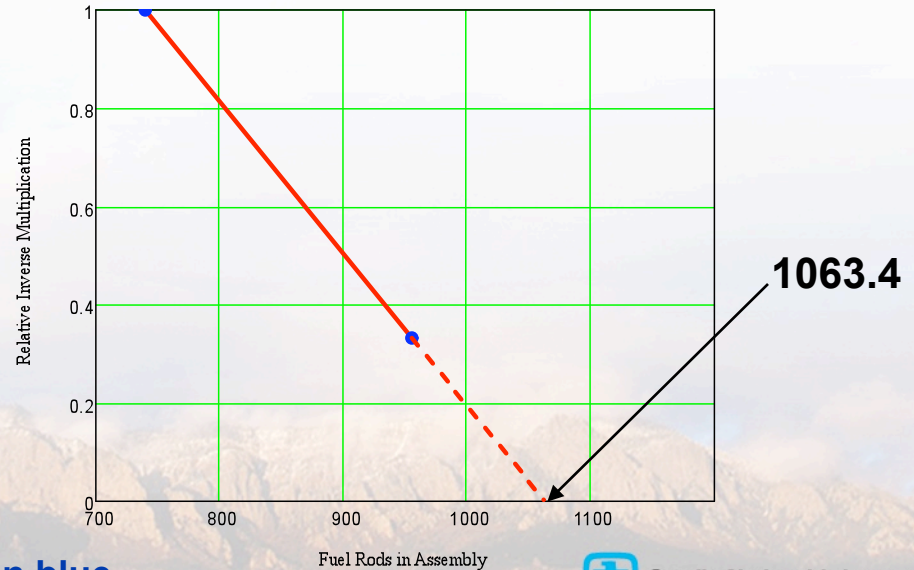
$$\frac{1}{M} = 1 - k_{eff}$$

Project the two inverse multiplication measurements to zero and add half the increment to get the next array – in this case 1009 elements



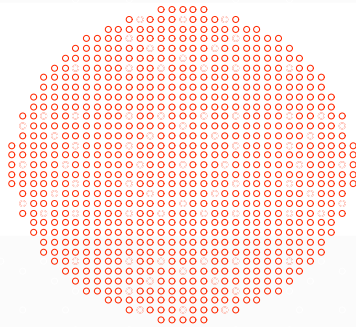
956

The first two arrays have $k_{eff} \sim 0.9$ and $k_{eff} \sim 0.95$ (calculated)

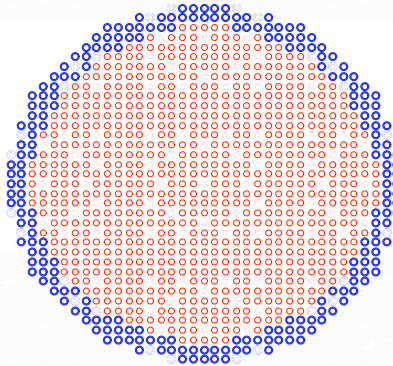


The incremental fuel elements are shown in blue

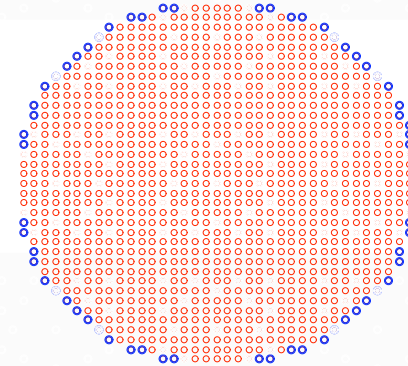
Core configurations during the first approach-to-critical experiment (2)



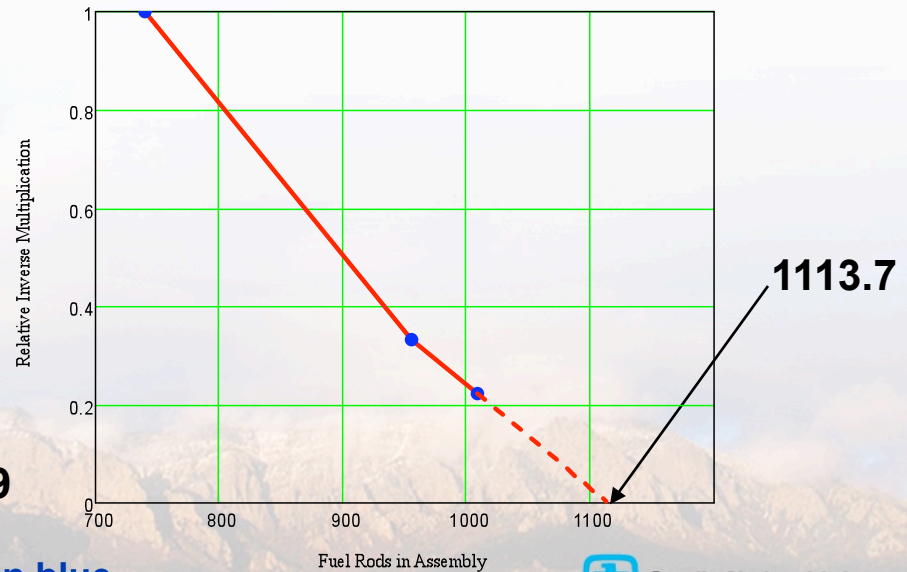
740



956



1009

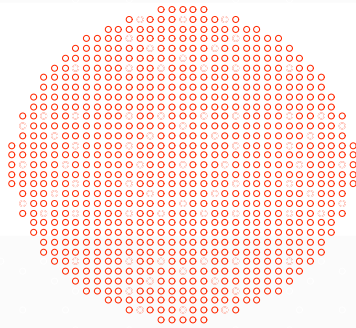


The next array: 1059

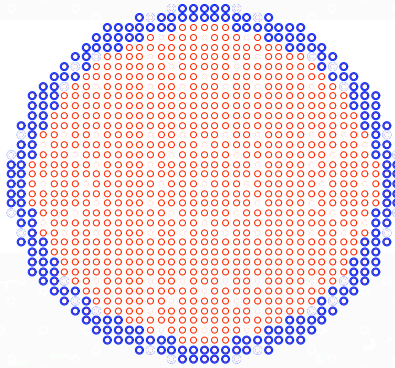
The incremental fuel elements are shown in blue



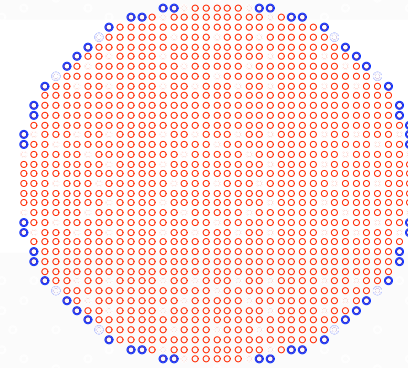
Core configurations during the first approach-to-critical experiment (3)



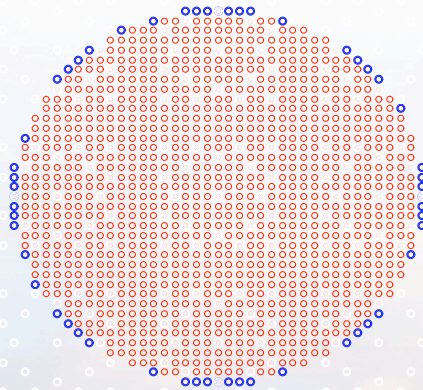
740



956

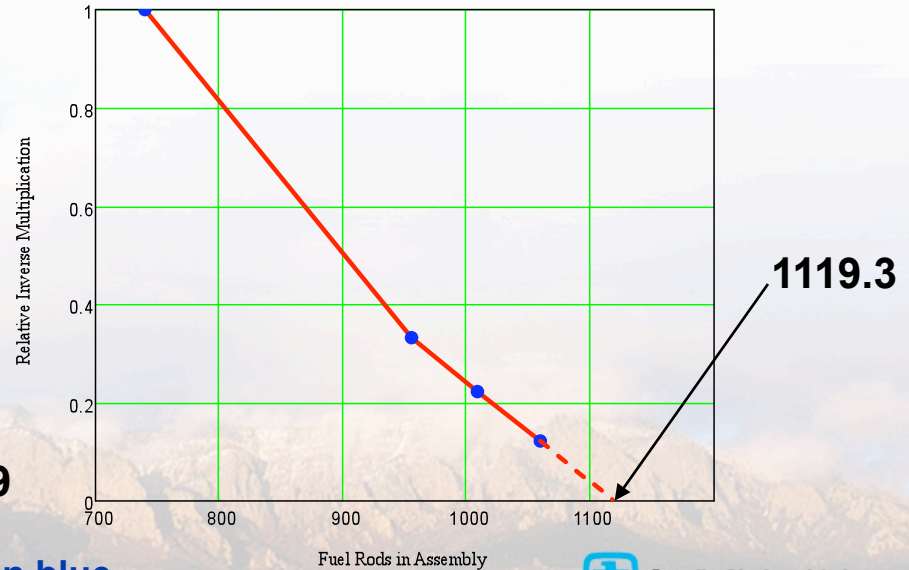


1009



1059

The next array: 1089

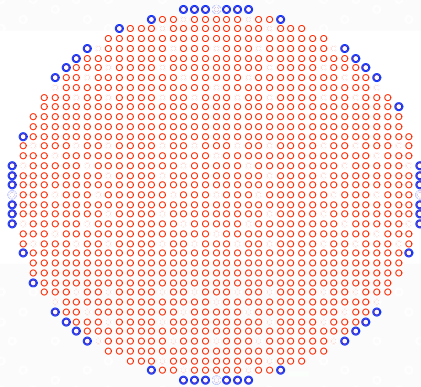


The incremental fuel elements are shown in blue

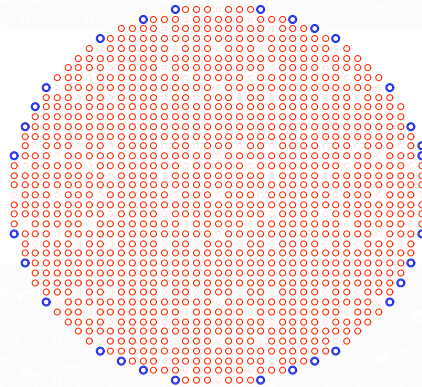


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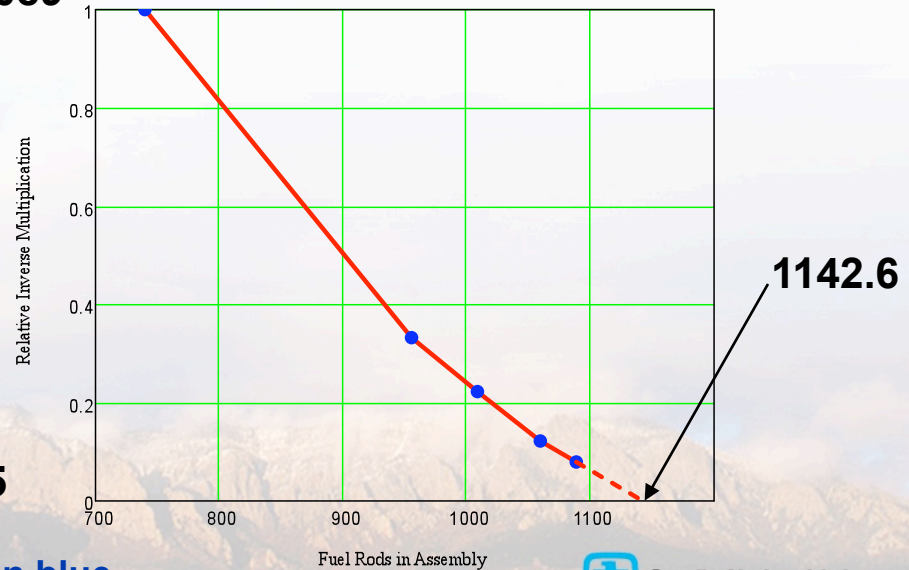
Core configurations during the first approach-to-critical experiment (4)



1059



1089

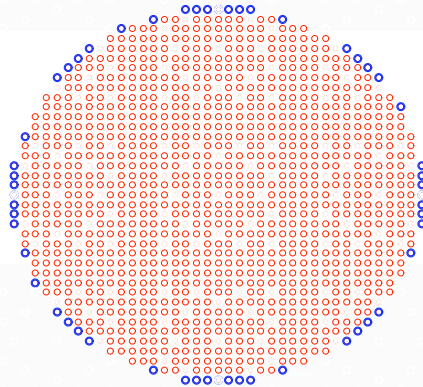


The next array: 1115

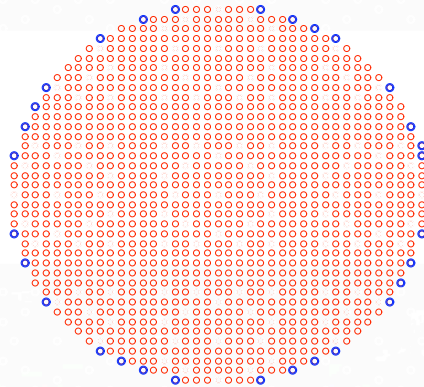
The incremental fuel elements are shown in blue



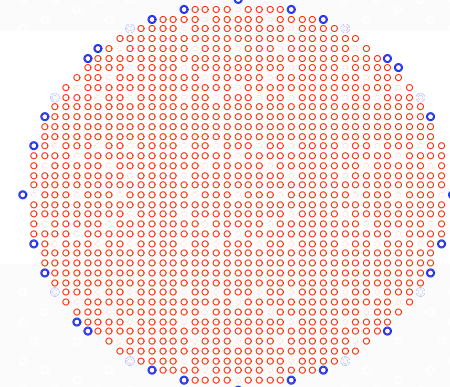
Core configurations during the first approach-to-critical experiment (4)



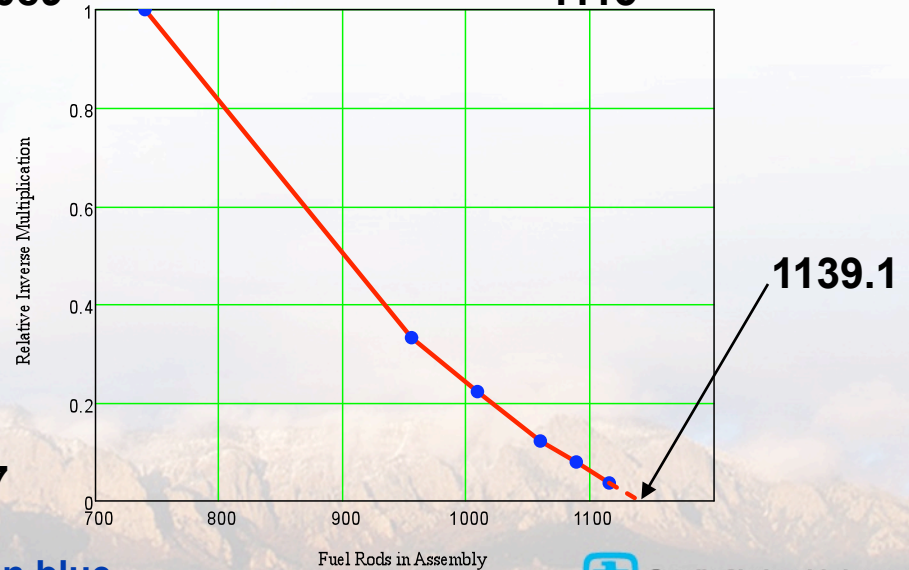
1059



1089



1115

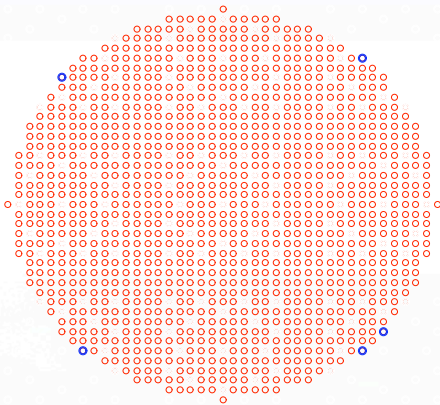


The next array: 1127

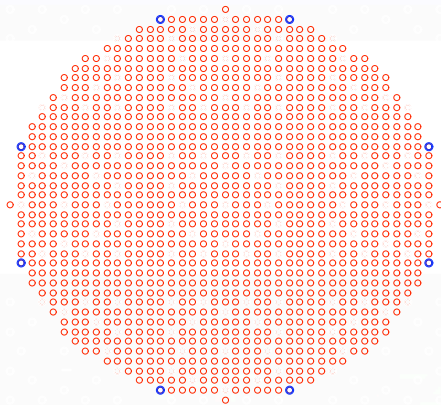
The incremental fuel elements are shown in blue



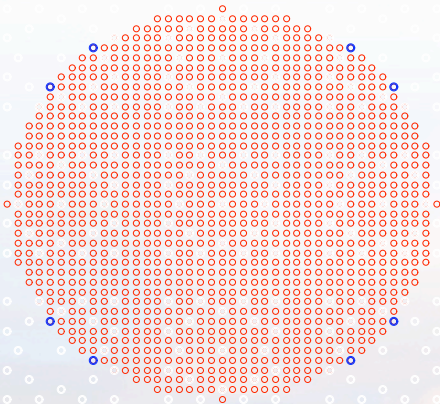
Core configurations during the first approach-to-critical experiment (5)



1120

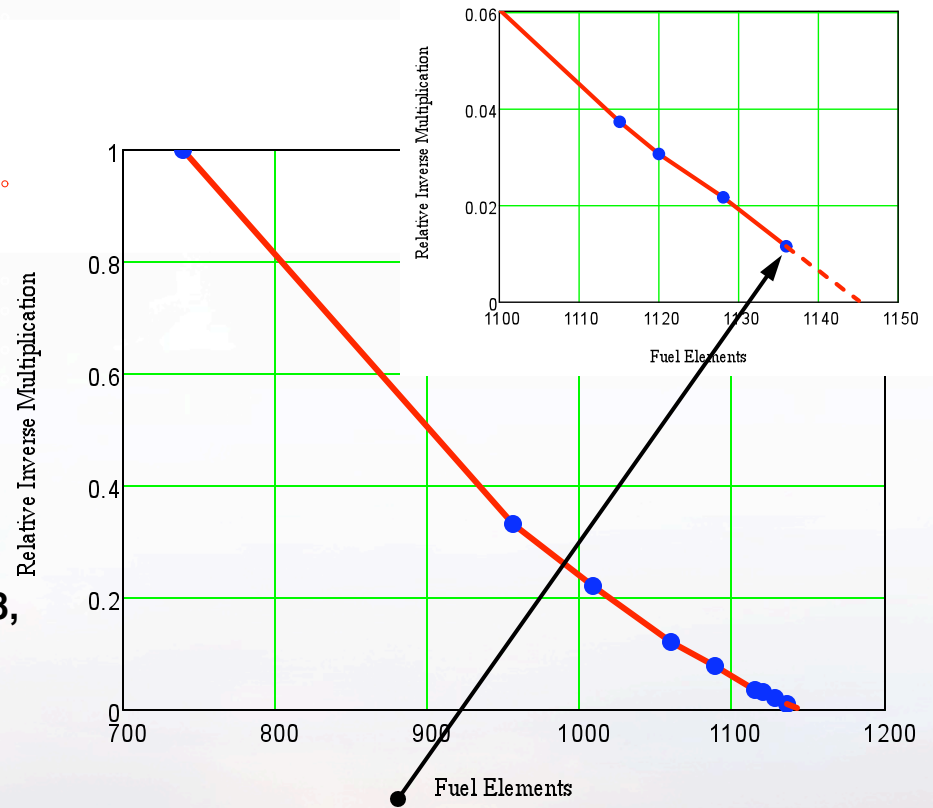


1128



1136

We also made measurements with 1138, 1140, and 1144 elements (all subcritical). A core with 1148 elements was supercritical.



At 1136 fuel elements:

$$N_{crit} = 1145.3$$

$$k_{eff} = 0.9984$$

$$M \sim 610$$



The incremental fuel elements are shown in blue



Future Work

- **Operations with Water Holes**
- **Change Hardware for 0.855 cm Pitch**
- **Criticality Safety Training Course**
 - NCSP Sponsorship/Funding



Critical Experiments at Sandia

