SAND2014-16340PE

Conceptual Design of a Low-Enriched Horizontal Split-Table Critical Assembly

Nuclear Criticality Safety Program
Preliminary Horizontal Split-Table Experiment Design Meeting

Las Vegas, NV

July 31, 2014

Gary A. Harms
Sandia National Laboratories

SAND2014-XXXXP

Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

What is Ahead

- We were asked to provide a cost estimate for a large horizontal split-table critical assembly
- We initiated a conceptual design for such an assembly
- What follows is a description of the conceptual design

Our charge

Explore the possibility of:

A large, 6´x 6´ or greater, horizontal split table at SNL working under the current security cat environment.

J. N. McKamy

July 12, 2012

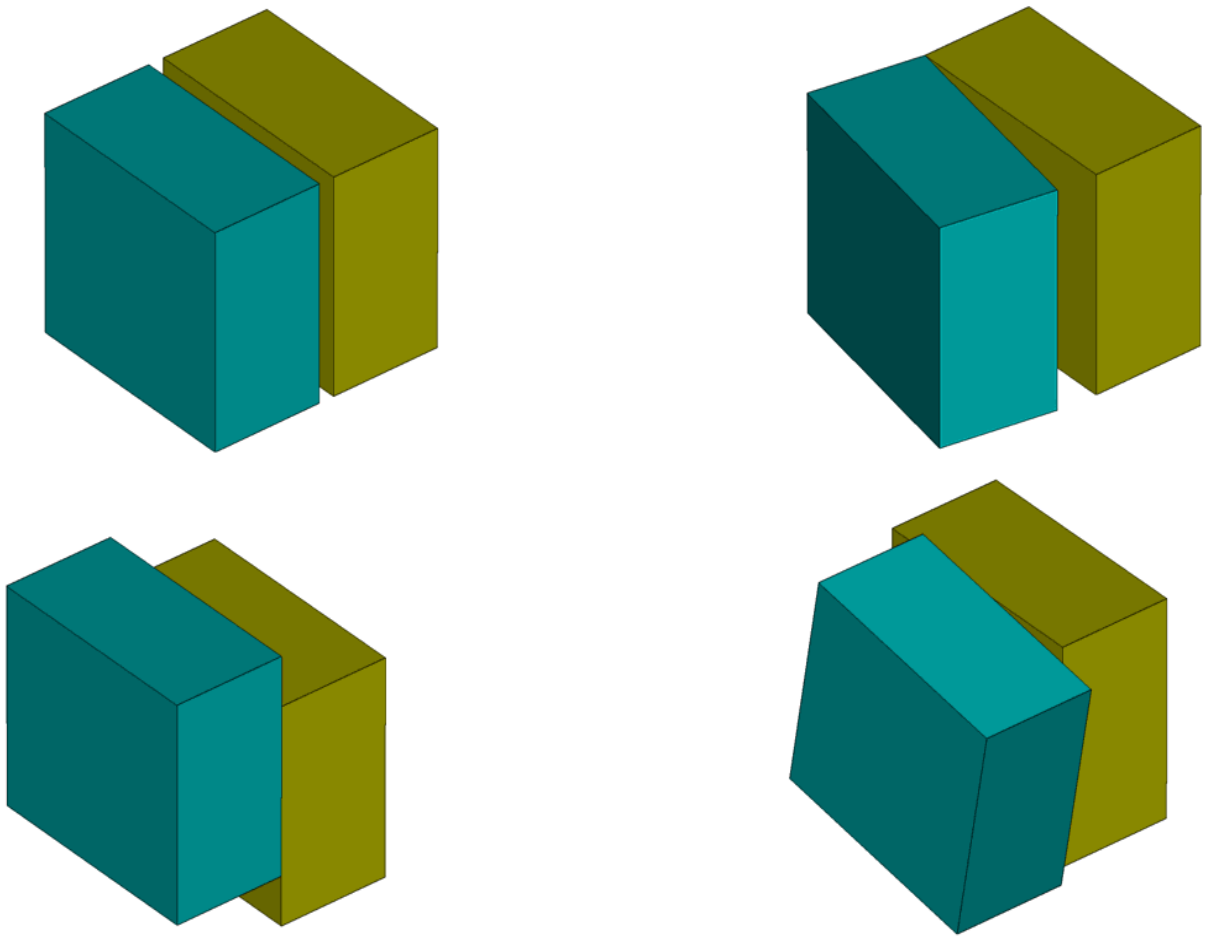
Low-Enriched General-Purpose Split-Table Critical Assembly – IER-226

- C_EdT:
  - Allison Miller (SNL)
  - Mike Dunn (ORNL)
  - Thomas Miller (ORNL)
  - Dave Heinrichs (LLNL)
  - Gary Harms (SNL)
- CED-1 Conceptual Design is complete
- CED-2 Final Design has been initiated

- Note that this IER is for the design of the Critical Assembly, not for a specific experiment

Split-Table Sensitivities

- Possible Geometric Inaccuracies



We Needed Some Notional Critical Experiments to Explore the Uncertainties

- U-10Mo Cube
- U-10Mo with SiO_2
- U-10Mo with Beryllium
- UO_2 mixed with and reflected by graphite

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Table 2-2. Characteristics of Four Critical Assemblies Used in Study

	U-10Mo Cube	U-10Mo with SiO_2	U-10Mo with Be	UO_2 with Graphite
Fuel	U-10Mo	U-10Mo	U-10Mo	UO_2
Fuel Intrinsic Density (g/cm^3)	16.86	16.86	16.86	10.97
Diluent	None	SiO_2	Beryllium Metal	Graphite
Diluent Intrinsic Density	-	2.648	1.848	1.70
Diluent Volume Fraction (%)[1]	-	64	87	99.816
Void Fraction in the Core (%)	0	10	10	10
Fueled Volume Side Length (cm)	43.78	100	100	100
Fuel Mass (kg)	1,415	5,463	1,973	18.2
Reflector	None	None	None	Graphite
Reflector Thickness (cm)	-	-	-	50

1. Fraction of the non-void core volume that is occupied by the diluent.

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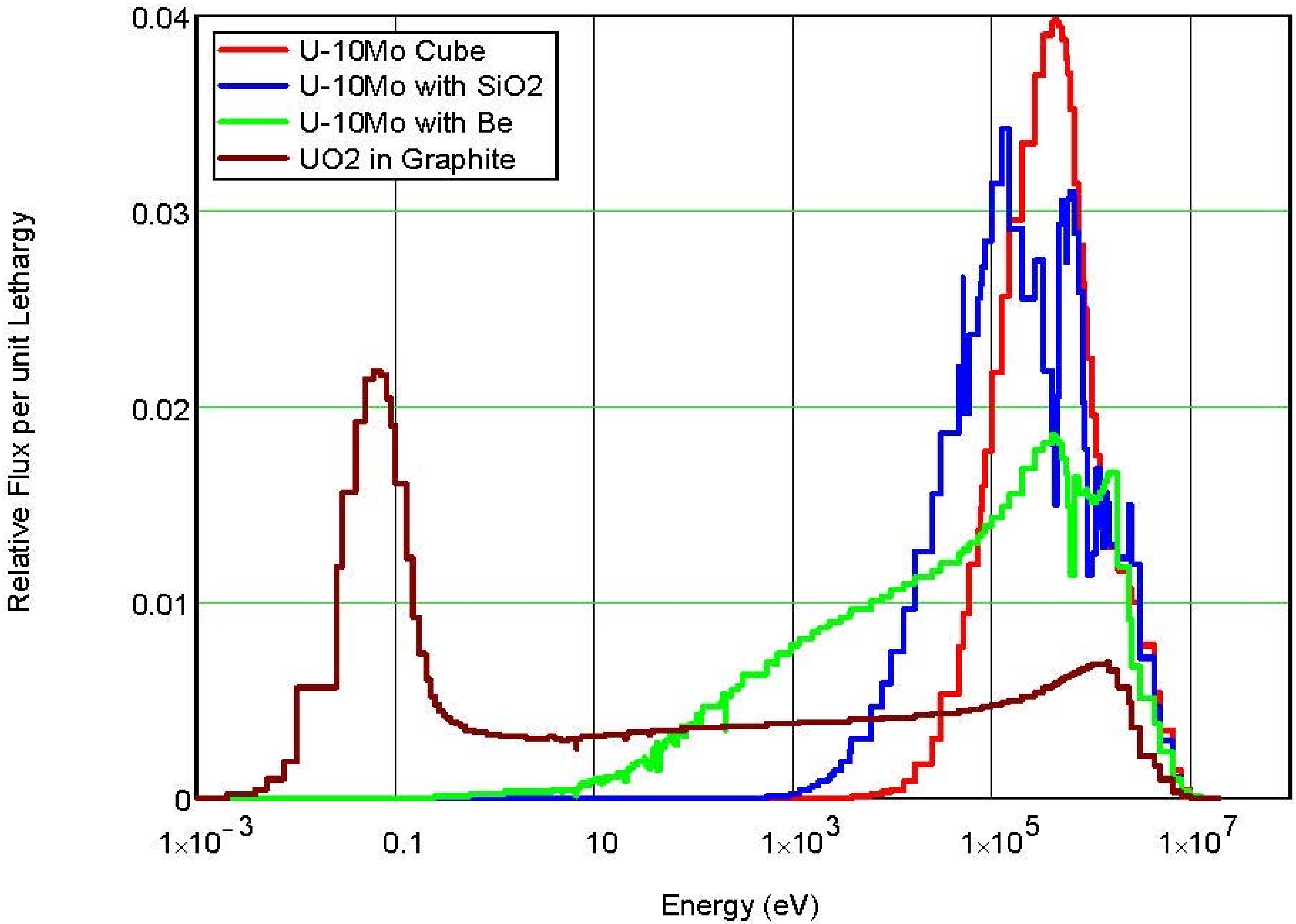
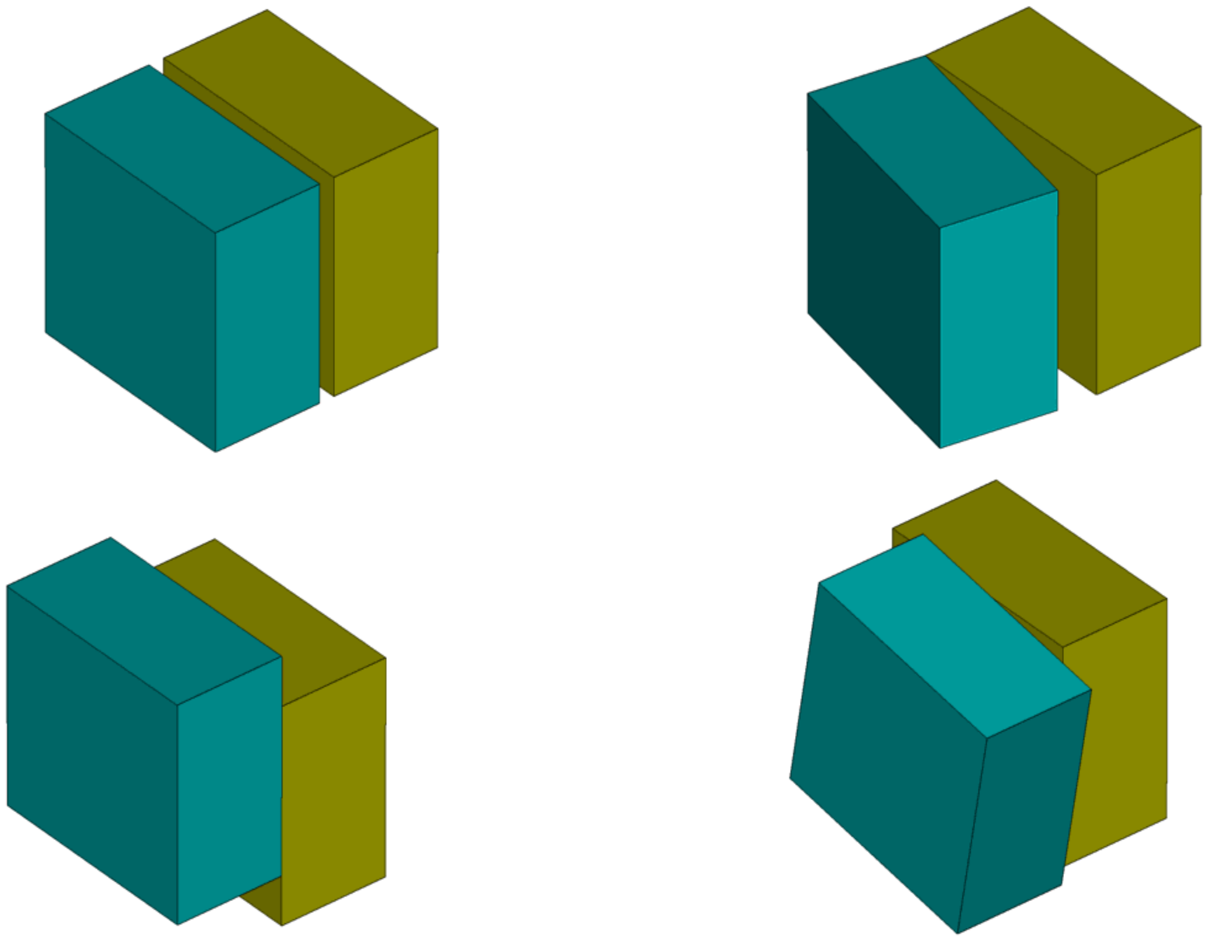
Neutron Spectra of the Four Notional Critical Assemblies

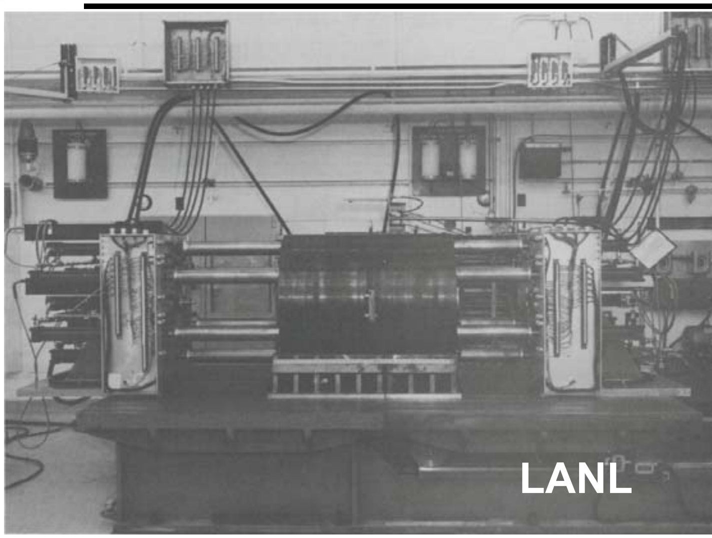


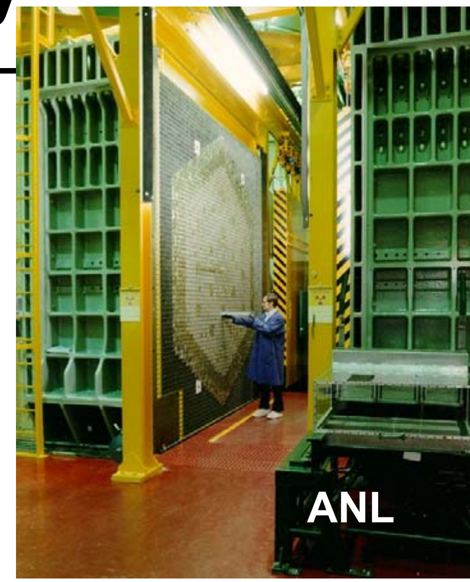
Split-Table Sensitivities

- **Possible Geometric Inaccuracies**

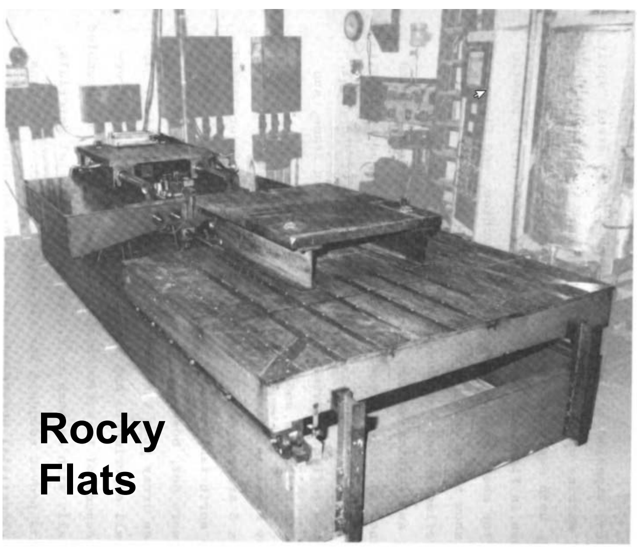


Split Table History





- We did a literature survey of past split tables in the US



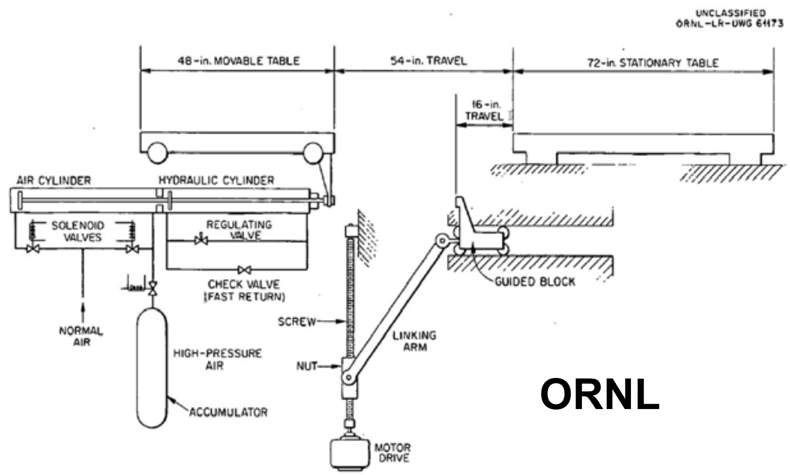


Fig. 3.6.3. Schematic of Drive Arrangement for Split-Table Machine.

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Common Features

- Two major core-supporting structures
  - Horizontal motion
- Very large in dimensions and mass
- A system for precise location of the two “halves”
- A fast-acting fail-safe safety system
- A control system for fine reactivity adjustment
  - Design dependent on the experiment
- A plant-protection system to back the operators up in unplanned events

Design Options

- All past systems we surveyed were constructed from purpose-built components
- OPTION 1 – do the same thing here
  - All components designed and built from scratch
- OPTION 2 – use commercial "off-the-shelf" (COTS) components where possible
  - In particular, the movable table shares many characteristics with existing large boring/milling machines
  - Can one of these machines be the basis for the critical assembly?

Critical Assembly Design Goals

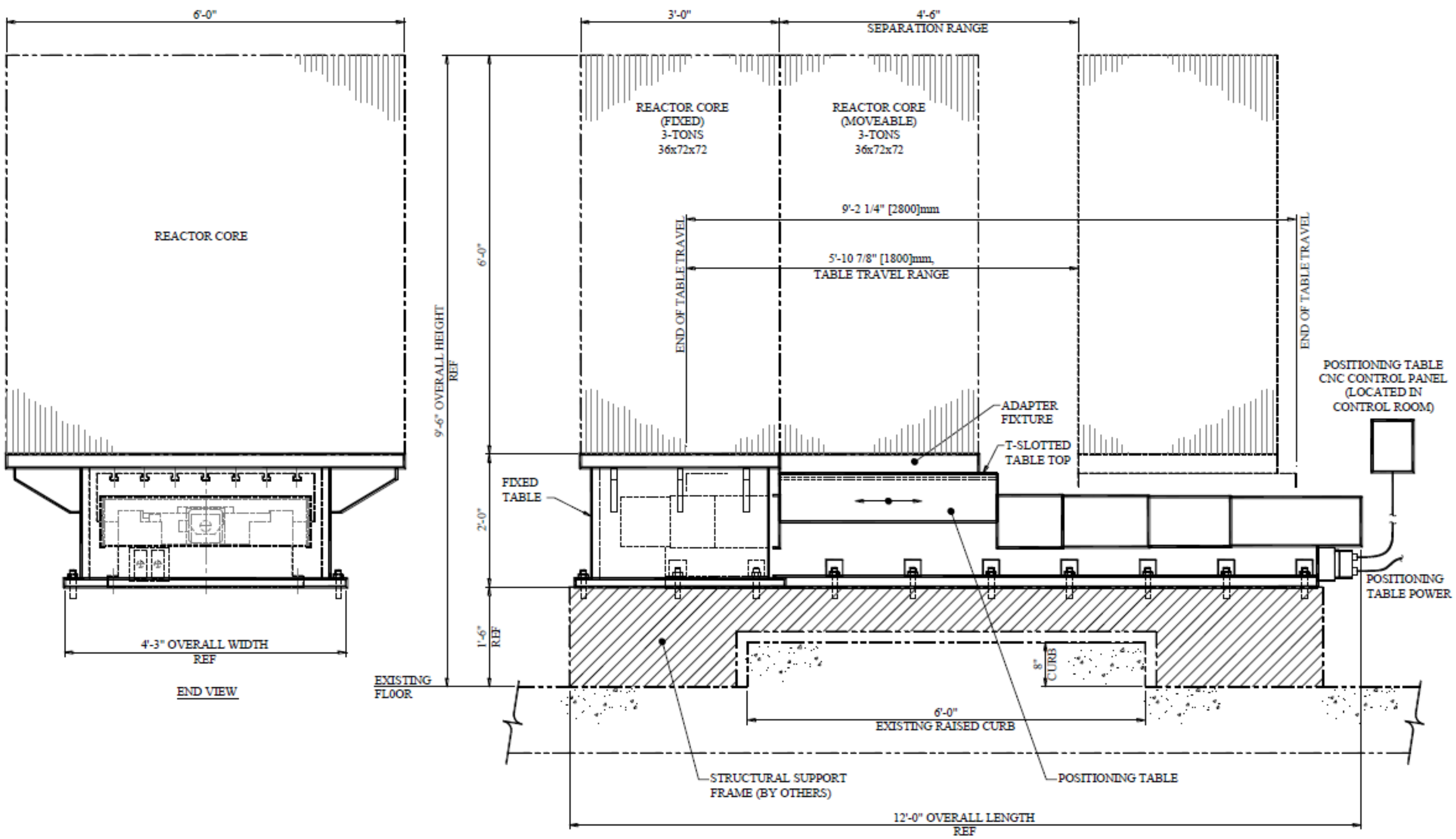
Experiment:

- 6 ft x 6 ft x 6 ft experiment
- 6,000 kg total, 3,000 kg on the movable platform
- Platform position(s) must be known to within approximately 0.0005-inch or better.
- Platforms are to be flat and parallel.
- Metal platform to be structurally sound to control and maintain relative position throughout all ranges of motion up to maximum payload.
- Fixed table and movable table must come together and touch.
- Fixed and movable tables must separate by at least 3 ft.
- Position reporting on three axes is preferred.

Control:

- Platform separates using a simple remote command/control approach.
- Provision for monitoring and reporting travel speed, direction, and position.
- Safety interlocks required to control unintended system response.
- Translation axis must move and be controlled, however, there is no speed requirement.
- The split-table control system and the reactor control system are separate.
- Capability to control the split-table locally as well as from a remote control room.

Option 2 Using a COTS Movable Table Appears to be the Most Cost-Effective Approach



The assembly would consist of a modified commercial boring/milling machine and a purpose-built fixed table

Critical Experiment Feasibility

- Systems Using Fuel Currently Available at the SCX
  - 7uPCX and BUCCX Fuel with Polyethylene
  - 7uPCX Fuel with Graphite Moderator
  - Harder Neutron Spectra with Existing Fuel (?)
    - Quantities and enrichment limit options for hard spectra
- Systems with New Fuel
  - Uranium Metal with 10 Weight Percent Molybdenum (U-10Mo)
  - Homogeneous Systems with U-10Mo Fuel
  - System with U-10Mo Plates Interleaved with Graphite

Shutdown Mechanisms

- Experiment Dependent
- Separation of Two Halves
  - Primary or Secondary Shutdown
  - SCRAM Initiated
- Insertion of Absorber Rods
  - Most Appropriate for Thermal Systems
- Reflector Control
  - Most Appropriate for Hard-Spectrum Experiments
- In-Core Control Mechanisms

Critical Experiments at Sandia

- The primary purpose of the reactor facilities at Sandia is to support our nuclear weapons mission
- The facilities and staff necessary to enable that work are exactly what are needed to support critical experiments.
- We are operating a water-moderated pin-fueled critical assembly

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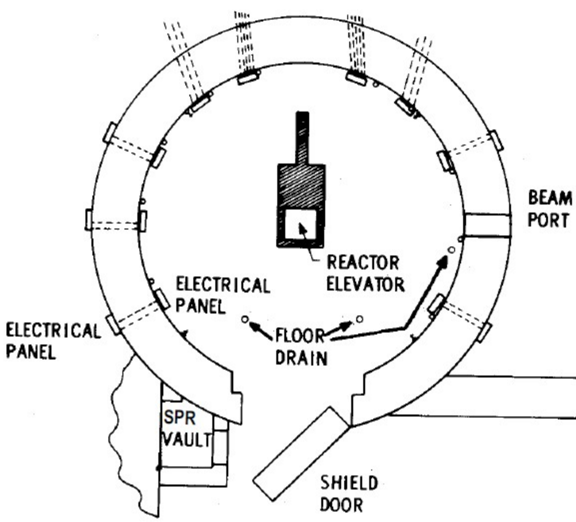
We operate our critical experiments in the Sandia Pulsed Reactor Facility

- 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
- The reactor building is a 30-ft inside diameter concrete cylindrical shell capped by a hemispherical shell
- The dropped reactor room ceiling is 12 ft above the borated concrete floor
- The walls and ceiling are 4-in gypsum, 4-in borated gypsum from inside to outside



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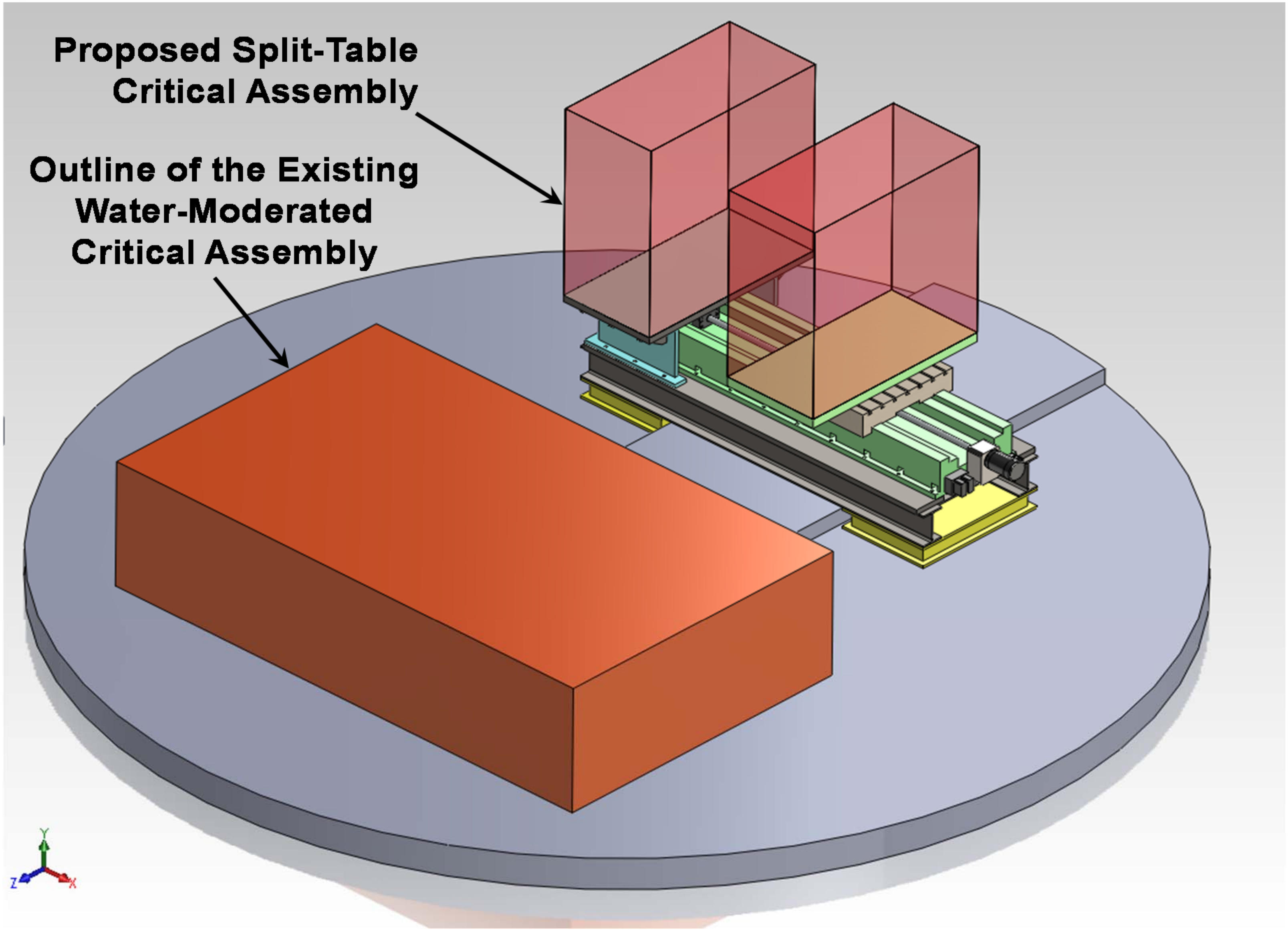
Possible Layout in the Reactor Room



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Current Limitations on Our Water-Moderated Experiments

- **Design Features**
  - All CA cores are designed so that criticality cannot be obtained without liquid moderator in the core tank.
  - ASSEMBLY fuel type SHALL be UO2.
  - ASSEMBLY core UO_2 mass SHALL be no less than 50 kg.
  - ASSEMBLY fuel enrichment (weight % ^{235}U) SHALL be no more than 20%.

- **Specific Administrative Controls**
  - The total amount of UO_2 (≤ 20% enrichment) associated with active critical experiments SHALL be no greater than 500 kg.
  - The accumulated energy production for the ASSEMBLY SHALL be no more than 15 MJ over a ONE YEAR PERIOD.

The Current Limitations Will Need To Change

- Design Features
  - ~~All CA cores are designed so that criticality cannot be obtained without liquid moderator in the core tank.~~
  - ~~ASSEMBLY fuel type SHALL be UO2.~~
  - ~~ASSEMBLY core UO_2 mass SHALL be no less than 50 kg.~~
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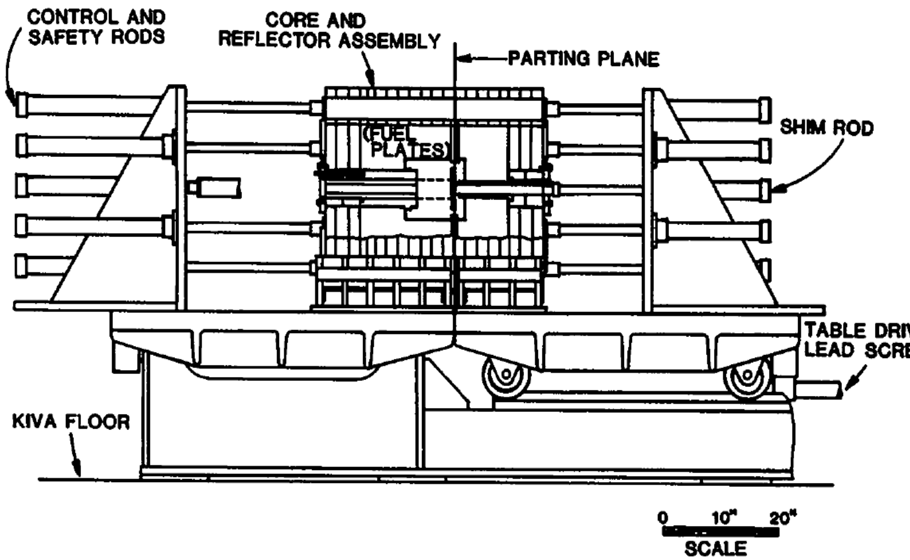
- Specific Administrative Controls
  - ~~The total amount of UO_2 (≤ 20% enrichment) associated with active critical experiments SHALL be no greater than 500 kg.~~
  - The accumulated energy production for the ASSEMBLY SHALL be no more than 15 MJ over a ONE YEAR PERIOD.

Concluding Remarks

- We were asked to provide a cost estimate for a large horizontal split-table critical assembly
- We initiated a conceptual design for such an assembly
- We arrived at a design that was based on a commercially-available movable component with the remainder purpose-built components
- The conceptual design is for the Critical Assembly
- Experiment design to follow

Critical Experiments at Sandia

Survey of Past Split-Table Machines



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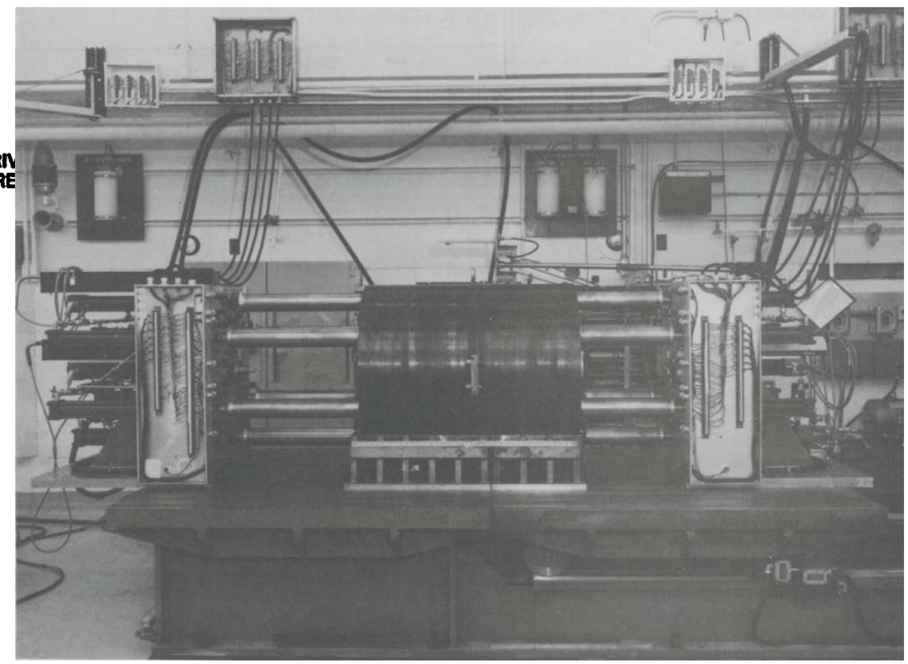
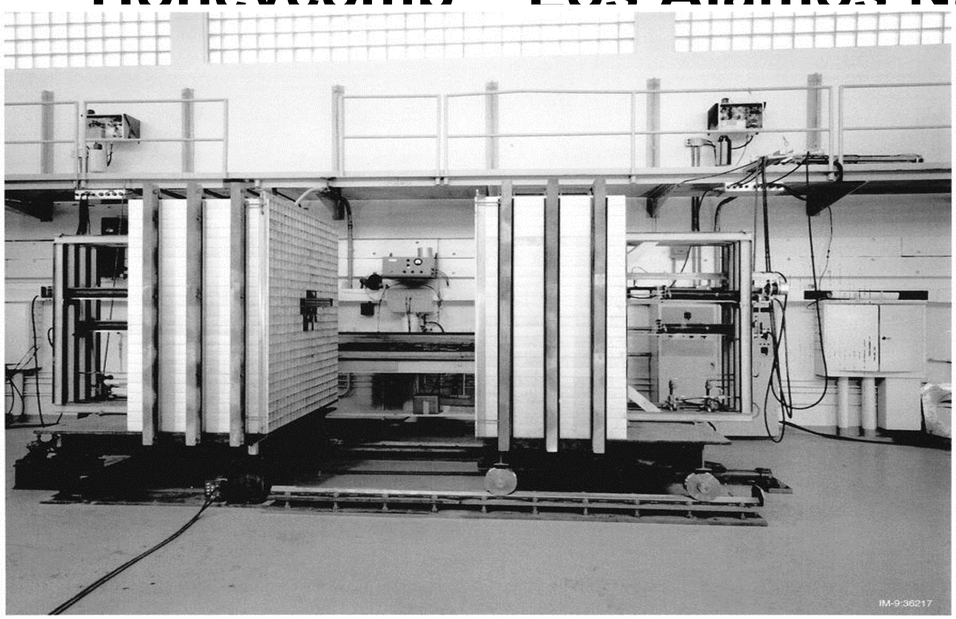


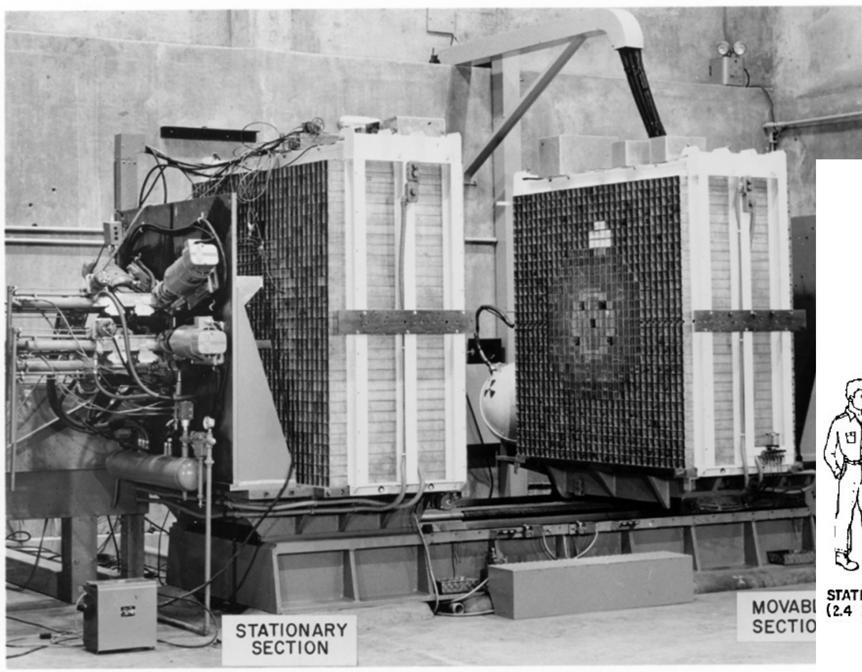
Survey of Past Split-Table Machines

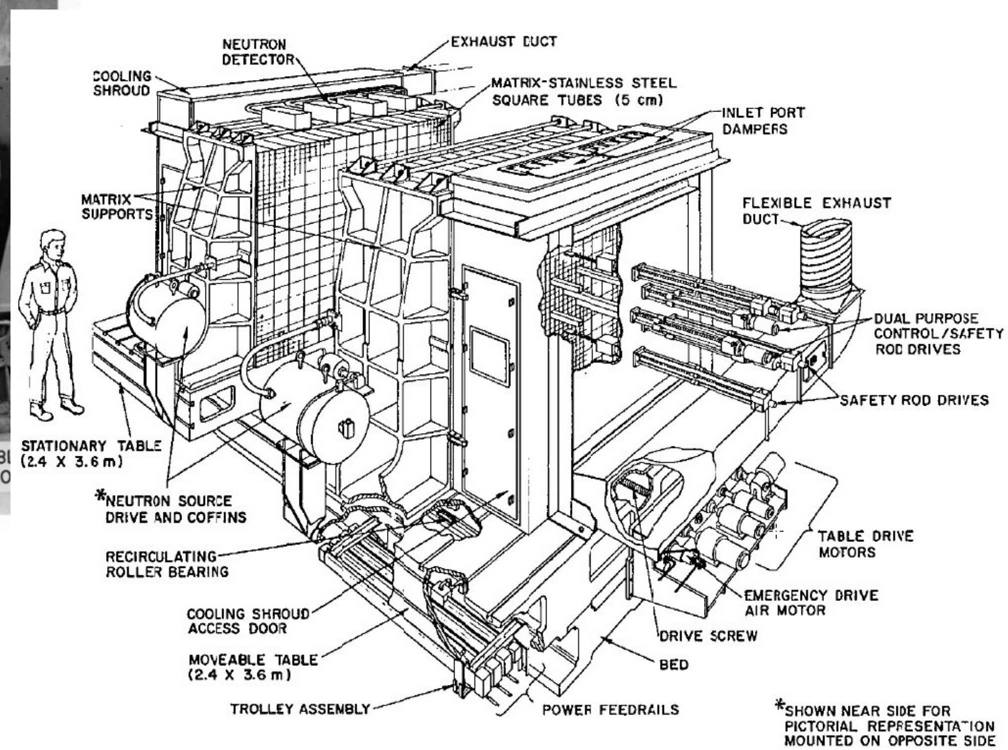
- Honeycomb – Los Alamos National Laboratory

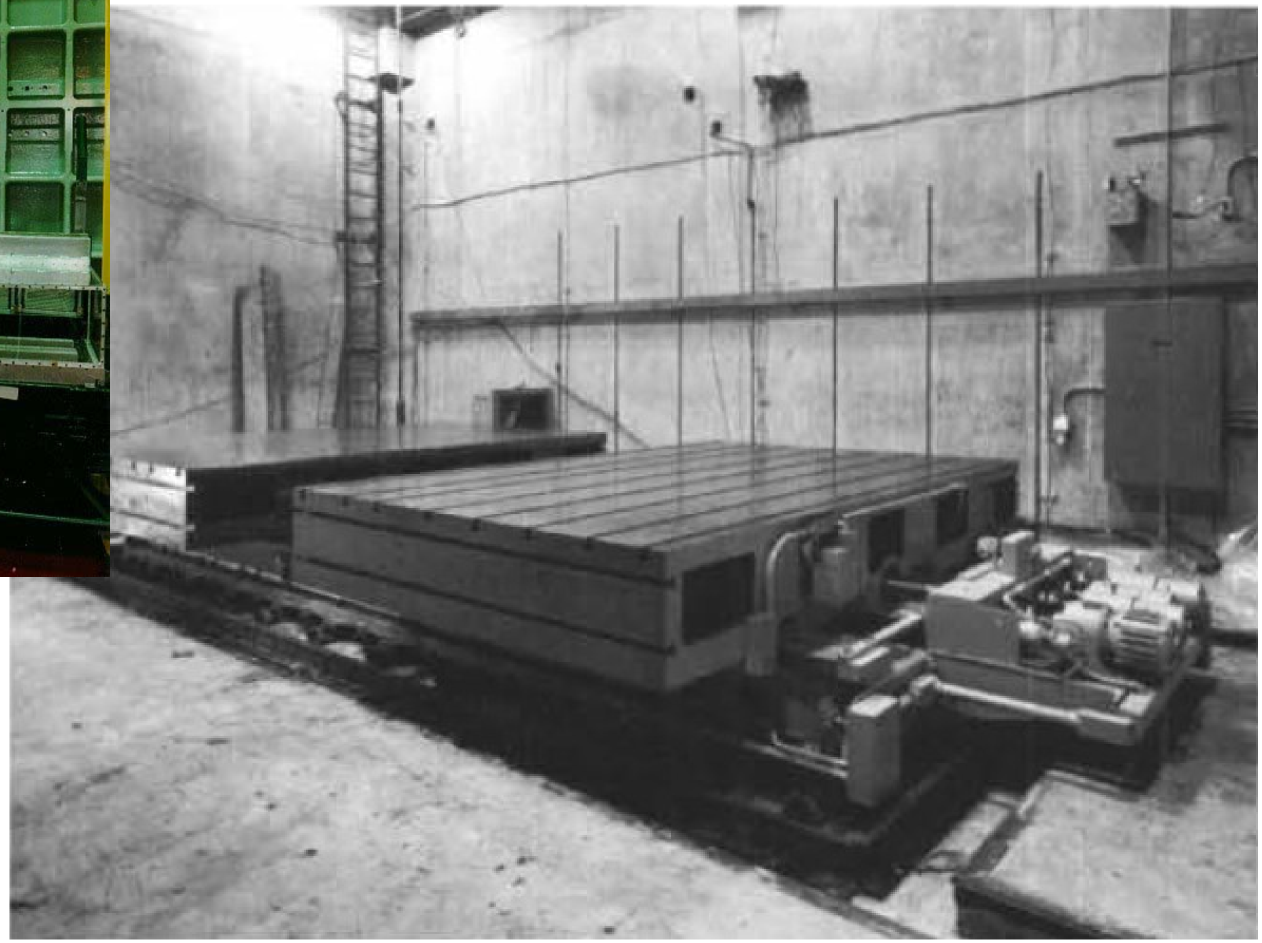


Survey of Past Split-Table Machines

National Laboratory







Survey of Past Split-Table Machines

- Horizo - Oak
  Ridge

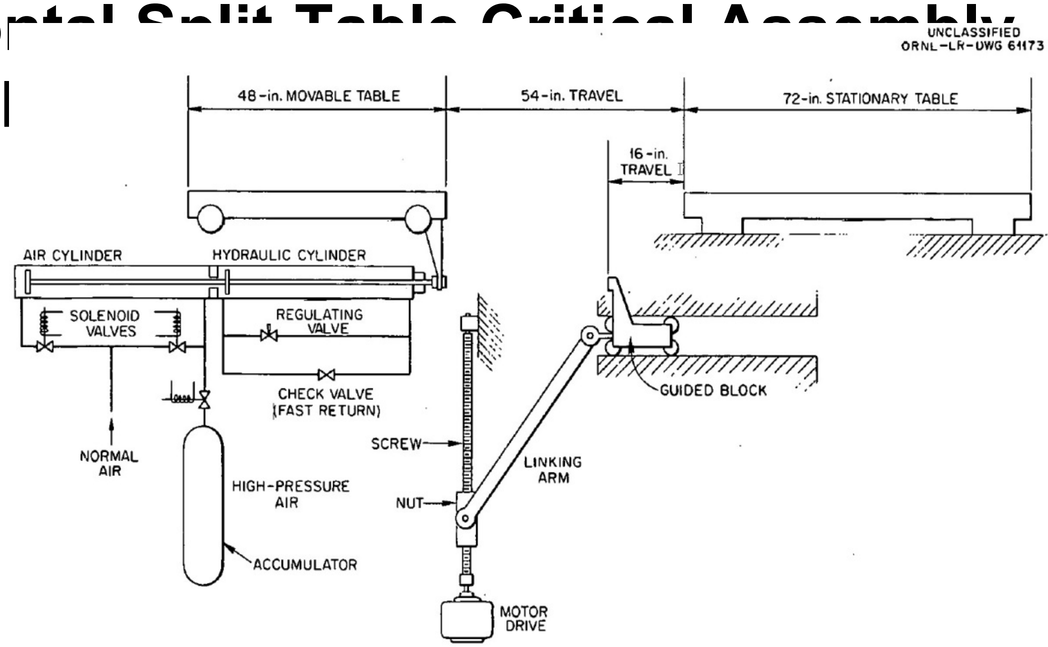
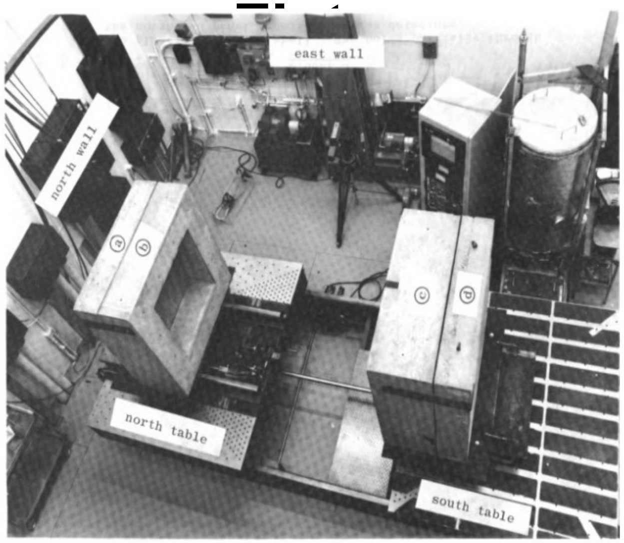
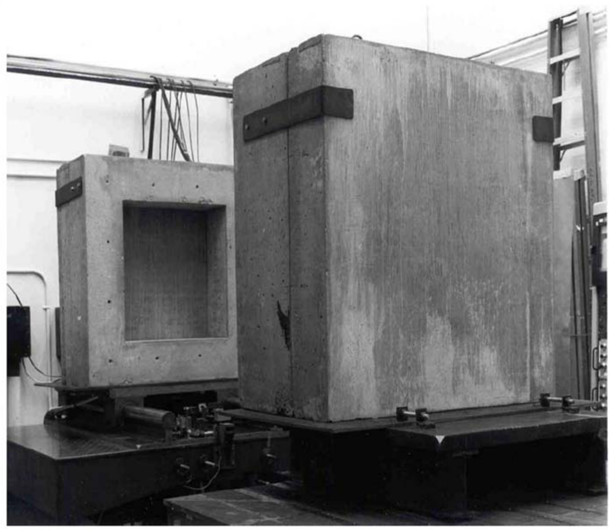


Fig. 3.6.3. Schematic of Drive Arrangement for Split-Table Machine.

Survey of Past Split-Table Machines

- Horizontal Split-Table Critical Assembly – Rocky





Neutron Spectra in the Notional Assemblies

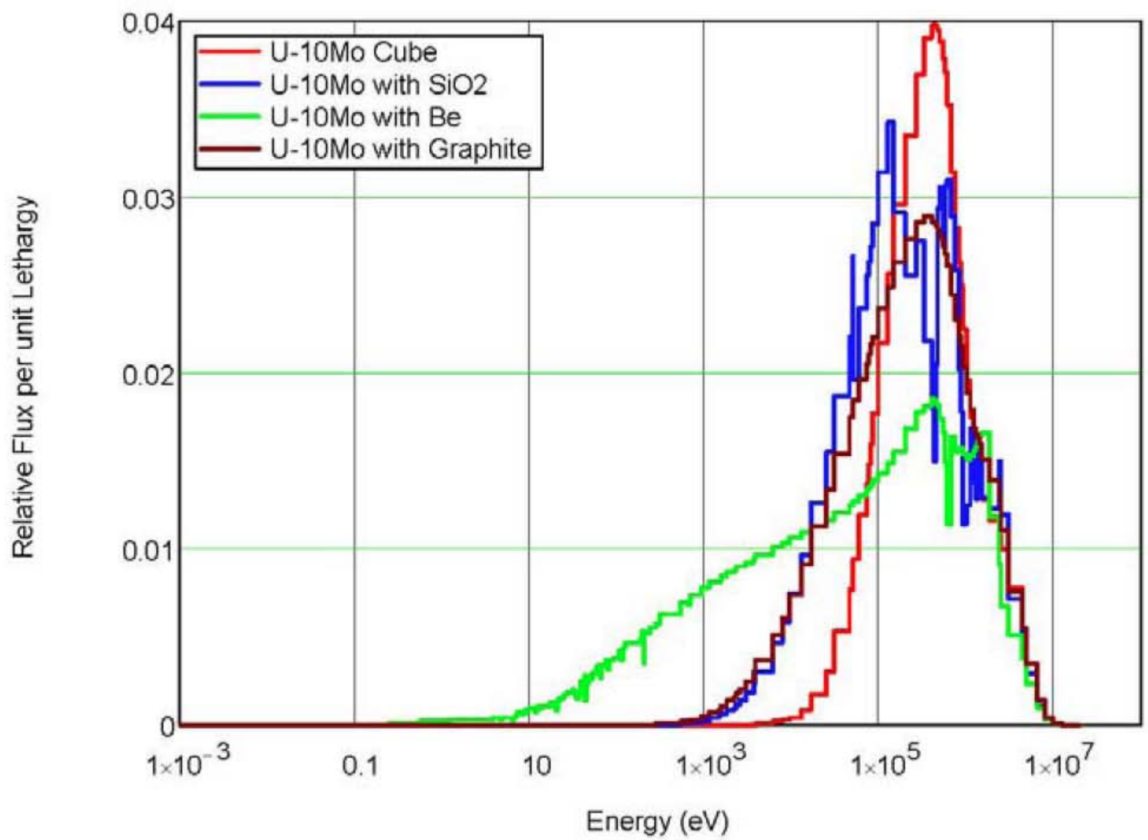


Figure 5-4 Comparison of Neutron Spectra in Four U-10Mo Fueled Systems

Assembly Design Requirements

Experiment:

- 6 ft x 6 ft experiment
- 6,000 kg
- Platform position(s) must be established, maintained, and controlled along a 3-axis reference datum to within approximately 0.0005-inch or better (intent to report in the 4th decimal).
- Platforms are to be flat and parallel (intent to establish these tolerances in the 4th decimal).
- Metal platform, structurally sound to control and maintain position relative to datum tolerances throughout all ranges of motion up to maximum payload.
- Fixed table and movable table must come together and touch.
- Position reporting in three (3) axis is preferred.

Control:

- Platform separates using a simple remote command/control approach with the capability to start, stop, and change direction at the desire of the operator.
- Provision for monitoring and reporting system response will be required for travel speed, direction, and position.
- Safety interlocks will be required to control unintended or inadvertent system response.
- Translation axis must move and be controlled, however, there is no rate of motion (movable table speed) requirements.
- No interface between the split-table control system and the reactor control system (i.e., any SCRAM feature would be performed by the reactor control system).
- Capability to control the split-table locally as well as from a remote control room shall be provided.