National Criticality Experiments Research Center (NCERC) Capabilities

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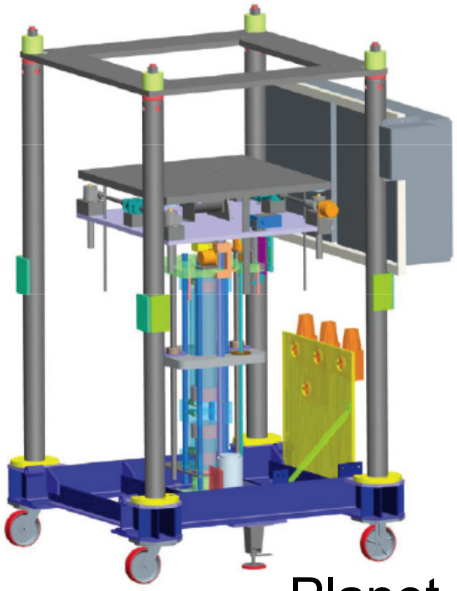
February 20, 2015

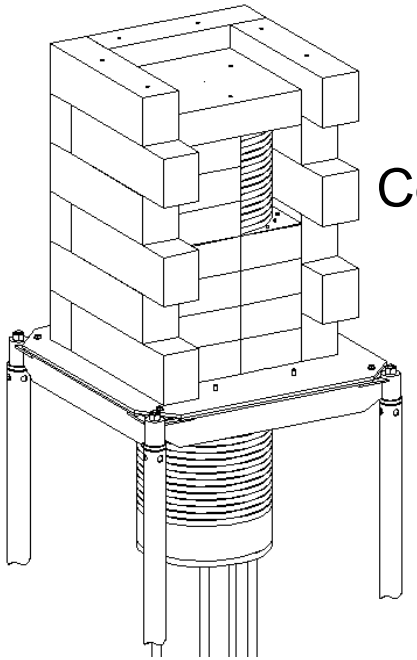
ANS Trinity Section

Nuclear Criticality Experiments Research Center (NCERC) Formerly Criticality Experiments Facility (CEF)

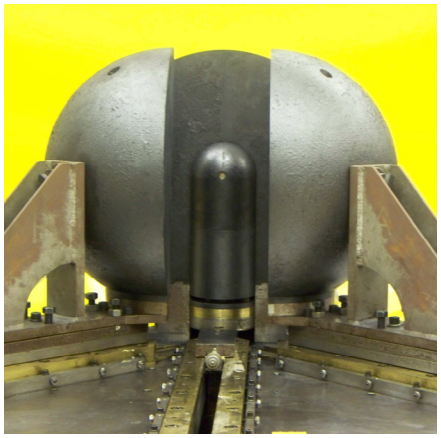
- Four Critical Assemblies
  - Planet
  - Comet
  - Flattop
  - Godiva IV
- Subcritical Measurements
  - Radiation Test Objects
  - Subcritical Benchmarks



Planet

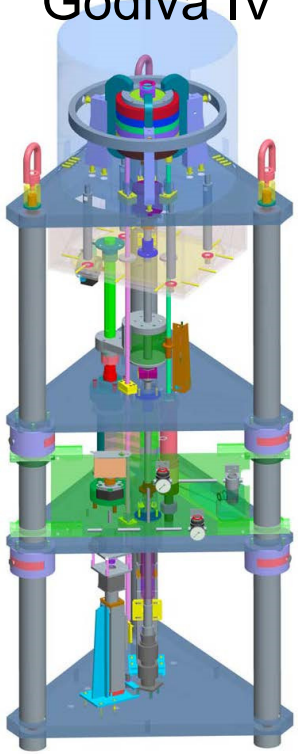


Comet



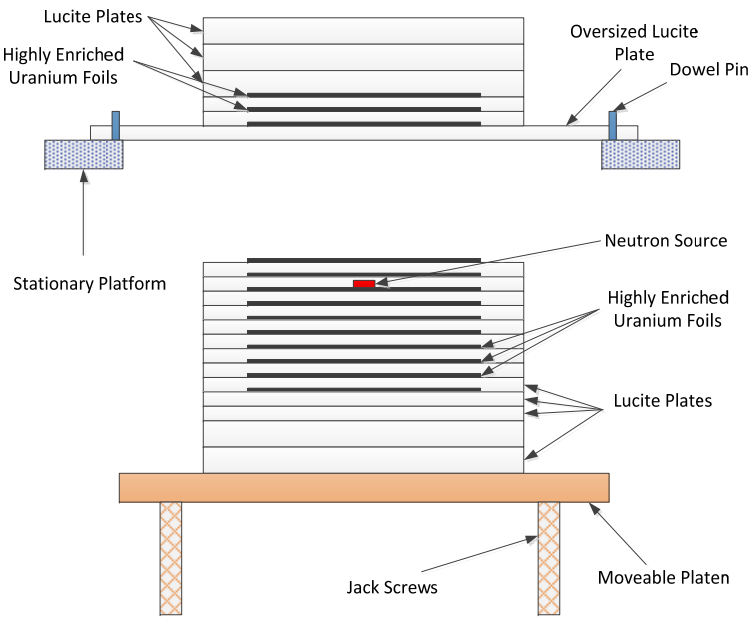
Flattop

Godiva IV



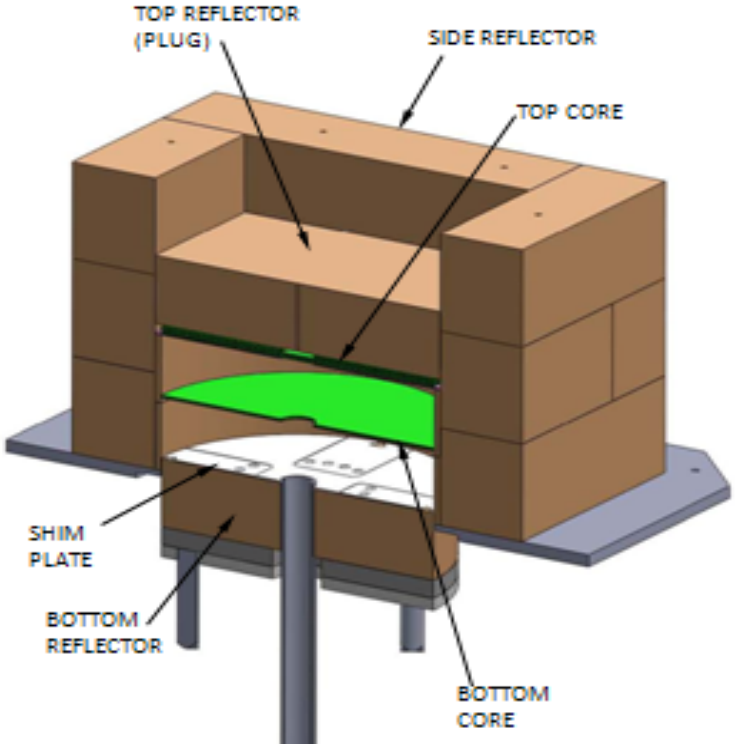
Planet

- Stationary platform
- Moveable platen



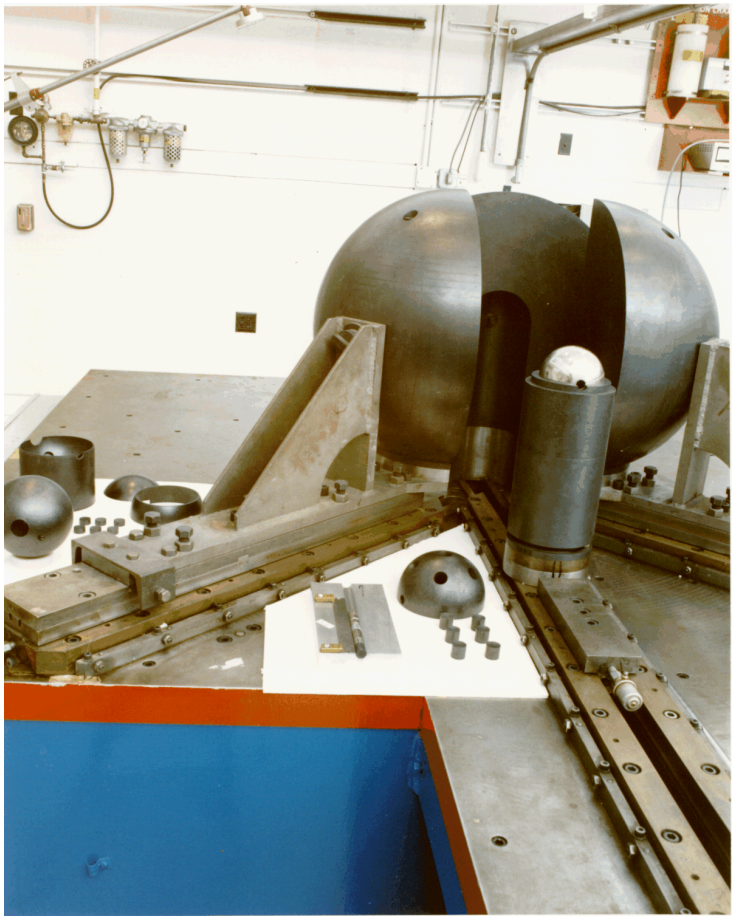
Comet

- Larger lift capacity than Planet
- Zeus series of experiments
  - Vary Graphite/Uranium Ratio
  - Poly, Iron also used
- Foil Irradiations



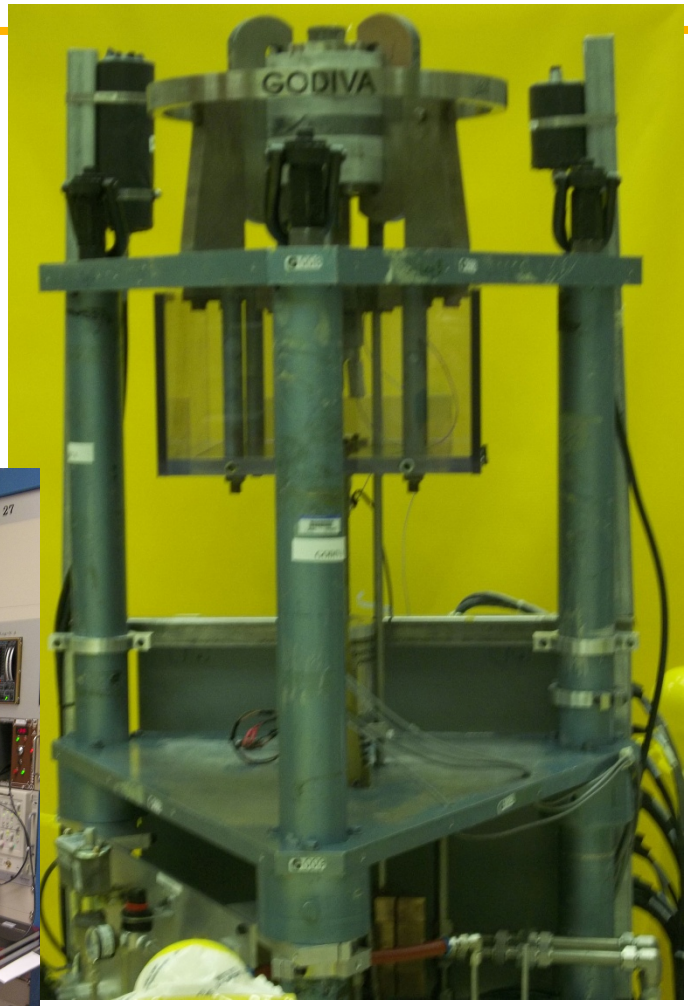
Flattop

- Spherical, reflected fast system
- 1000 kg natural uranium reflector
  - 500 kg hemisphere
  - Two 250 kg quarter-sphere safety blocks
- Glory hole for mass adjustment, samples, activation foils, etc.
- Interchangeable U-235 and Pu-239 cores.

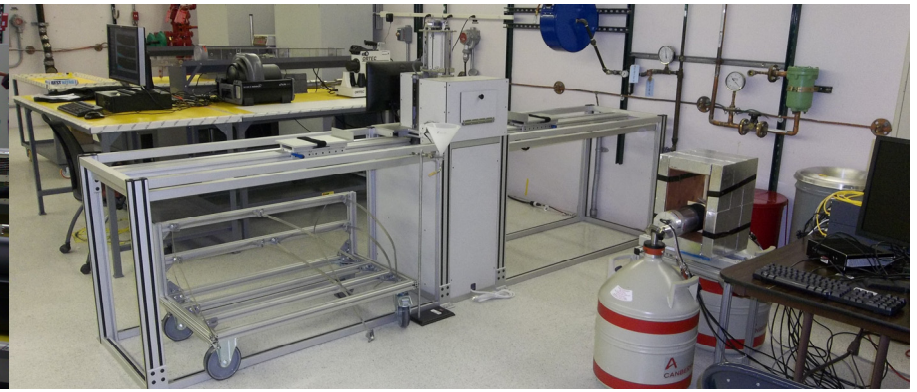


Godiva IV

- Cylindrical uranium metal fast burst assembly
- 65 kg, 93% enriched
- 7-inch diameter (17.8 cm), 6-inch tall (15.2 cm)



NCERC Count Room



- Multiple electrically-cooled HPGe systems
- Alpha spectrometer for U/Pu/Rn determinations
- Autoradiography system
- Automated sample changer
- Room for user systems (e.g., PNNL coincidence counter)

Godiva Startup Timeline

- Godiva IV was built in 1967 and operated at TA-18 until…

- July 2004—Last Prompt Burst
- August 2004—Last Critical Operation

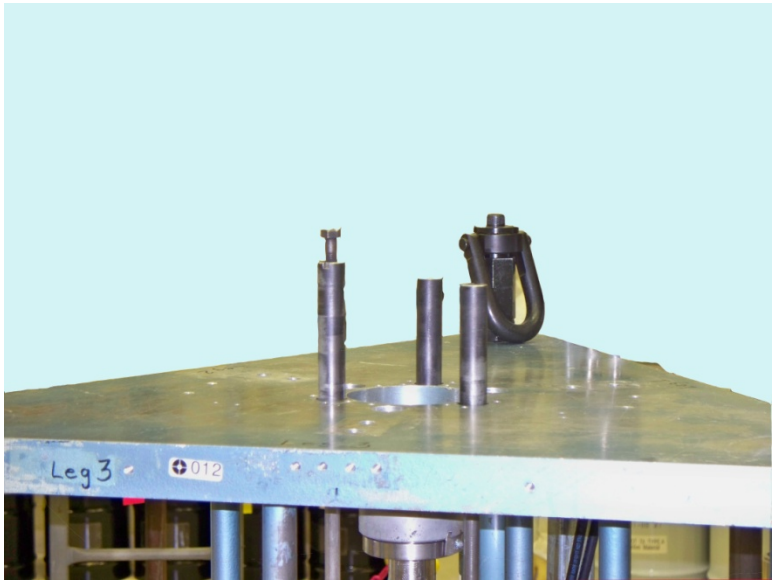
- July 2005—Godiva was disassembled…

- April 2012—Godiva assembled—ANSI/ANS-series 8
- October 2012—First Critical at DAF—ANSI/ANS-1
- September 2013—First Prompt at DAF—ANSI/ANS-14.1

Criticality Safety

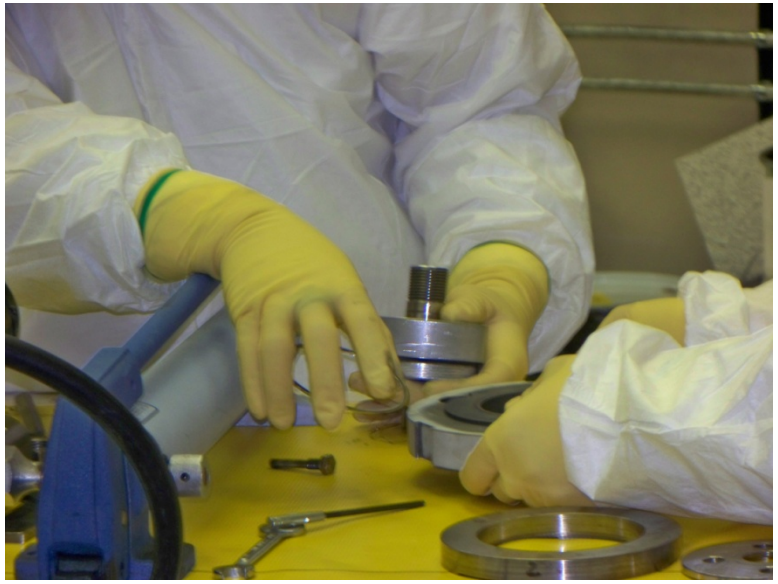
- Fire suppression system shall be disabled during assembly operations.
- Fire suppression efforts or agents of any type are NOT allowed.
- Table positioned ≥ 3 feet from any concrete surface.
- Demarcated 3-inch buffer boundary.
- Full core must be in the hydraulic press or within the buffer boundary.
- Maximum of 2 personnel may be within 2 feet of the full core when the Saturn ring is off.
- Assembly table height ≥ 41 inches

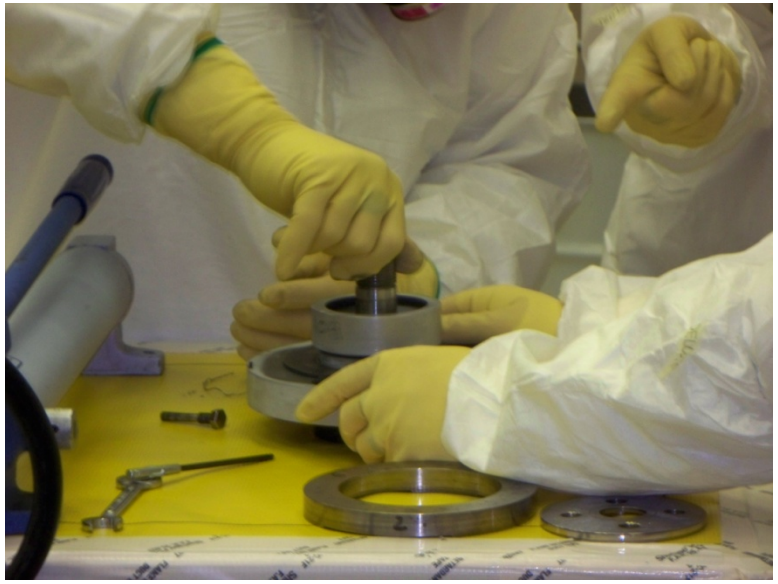
Install Control Rods, Burst Rod, and Safety Block



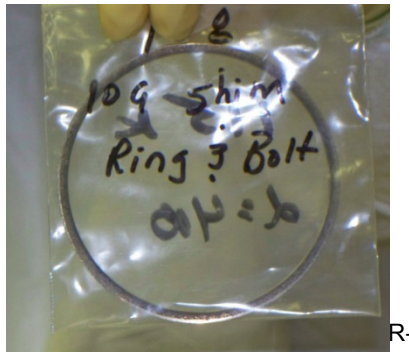
- Measured position of top of control elements relative to top of Godiva stand at both out and in positions.

Upper Fuel Assembly





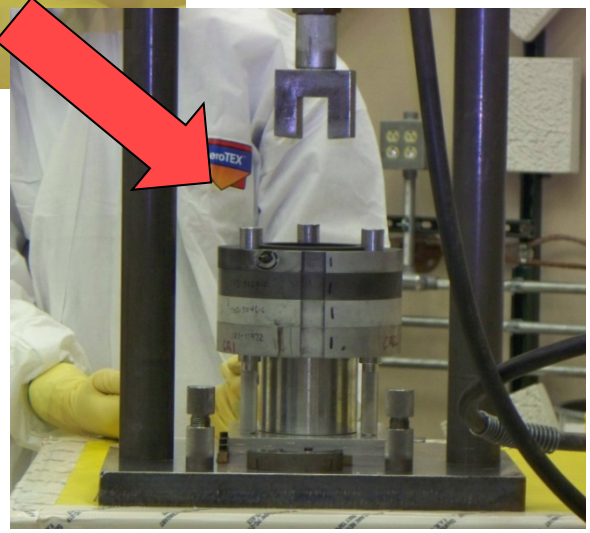
- Thicker shim ring constructed to compensate for fuel lost over time.



Stack the Lower Core

- Alignment of grooves absolutely essential

Place Upper Fuel on Lower Fuel



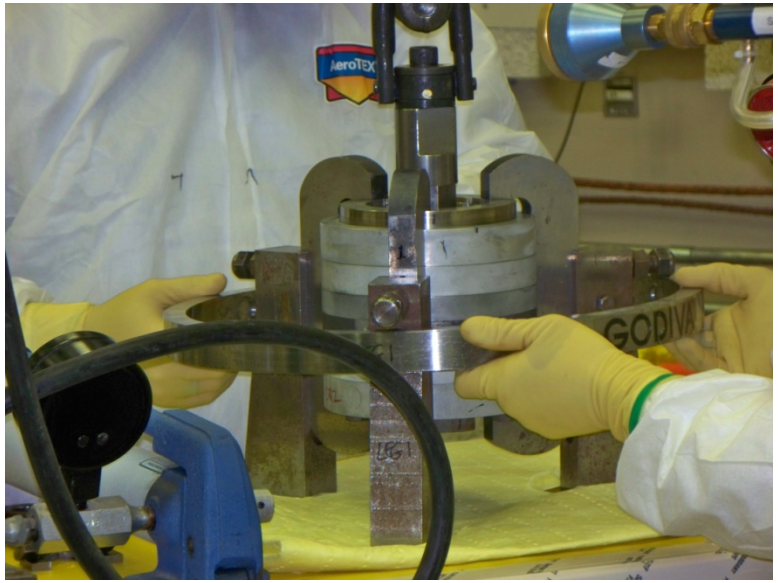
- Upper assembly lifted by crane and lowered onto lower stack.

- Audible indication of increased multiplication as upper assembly is lowered onto stack.

Install the C-Clamps

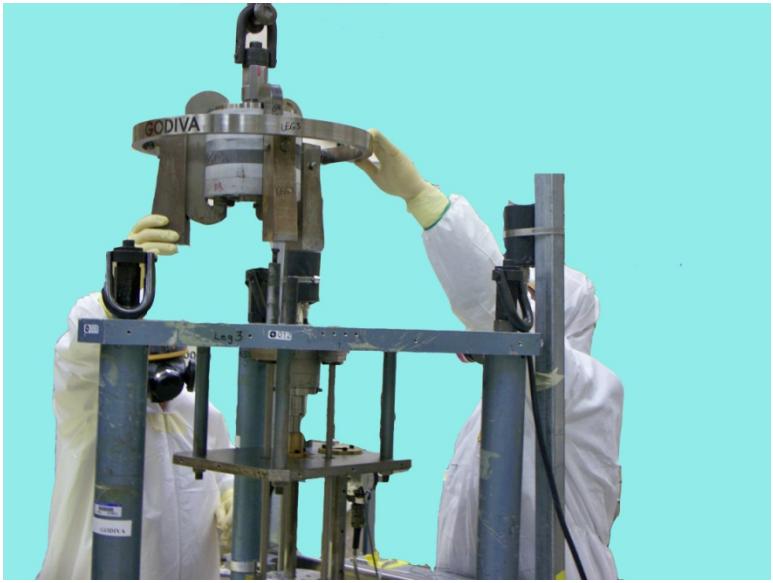
- First clamp is easiest.
- Iterate to get all clamps seated satisfactorily.

Install the Saturn Ring



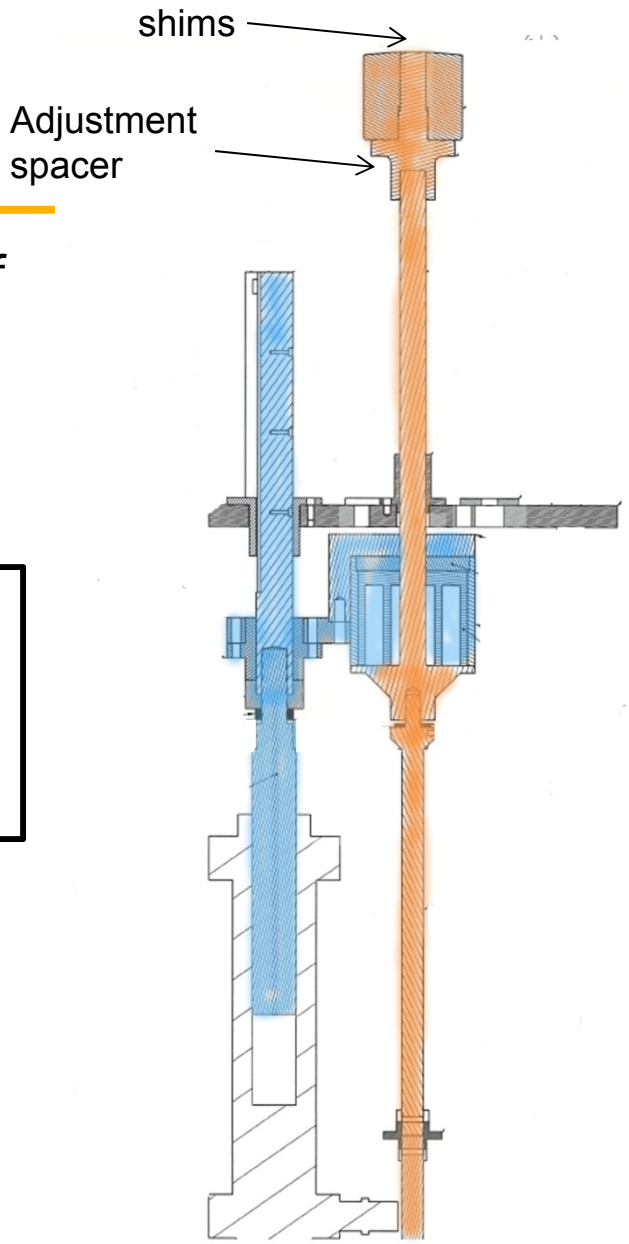
- Bolts are tensioned outward.
- Measuring and adjusting for equal distance to ensure even tension.

Install the Core



- Table is rolled next to stand.
- Core lowered *carefully* over protruding control rods.
- Brackets are bolted on.

Set the Safety Block Gap



- Use combinations of shims placed on top of Safety Block to measure gap distance
- Adjust Safety Block Position with spacer
- Repeat to measure gap distance.

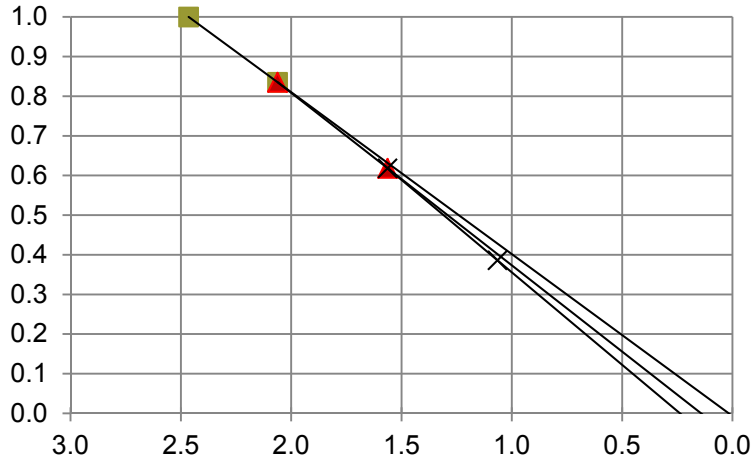
Gap distance is between the thickness of shims where Safety Block will drop out and next smaller amount of shims where Safety Block will not drop out.

- Final gap distance is 0.0145” - 0.0175”

Approach to Critical

- 1/M on Sum of Control Rod positions

Position (in)	Total Counts	1/M	M	Predicted Critical
2.47	52091	1.00	1.00	-
2.06	62355	1.20	0.84	0.02
1.56	84252	1.62	0.62	0.14
1.07	134989	2.59	0.39	0.24



- Excess reactivity $1.07 compared to $1.23 prior to disassembly

Experiment Plan for Godiva Characterization

Fulfilling requirements of ANSI/ANS-14.1

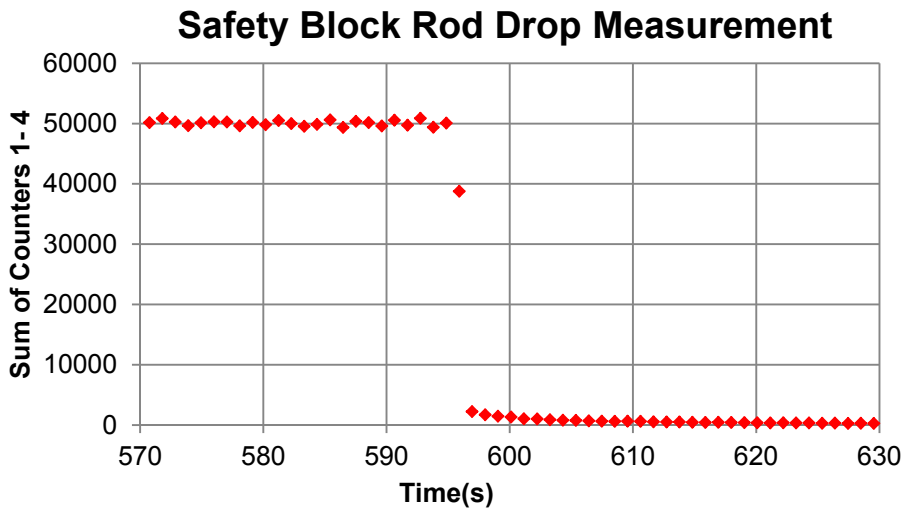
- Remote Approach-to-Critical
- Delayed Critical and Excess Reactivity
- Burst Rod Worth Estimate
- Reproducibility of Control Elements
- Safety Block Rate of Shutdown
- Control Rod Calibration
- Reactivity Quenching (Temp. Coefficient)
- Approach-to-Prompt Critical
- Burst Reproducibility
- Burst Operations

Reproducibility of Control Elements

Control Rod	Safety Block	Burst Rod
▪ Insert CR 1	▪ Establish positive period	▪ Insert BR
▪ Find DC with CR 2	▪ Measure period	▪ Establish positive period
▪ Record CR 2 position	▪ Remove SB	▪ Measure period
▪ Remove CR 2	▪ Insert SB	▪ Remove BR
▪ Repeat	▪ Repeat	▪ Repeat
0.250 ± 0.001 in	45.07 ± 0.59 sec	21.34 ± 0.41 sec
± 0.04 ¢	± 0.15 ¢	± 0.29 ¢

- Comparable to values measured during 1993 restart

Safety Block Rate of Shutdown



$$\rho(\$) = 1 - \frac{n_0}{n_1}$$

$$\rho(\$) = 1 - \frac{50082}{2256}$$

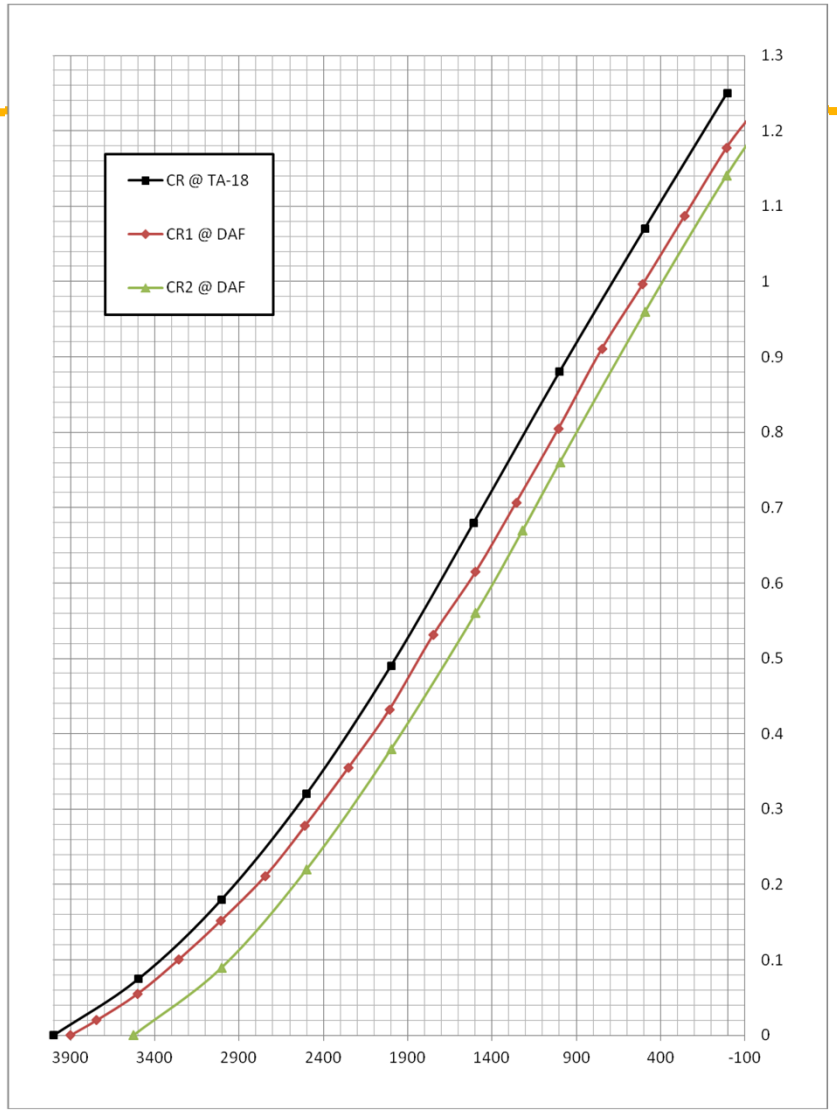
$$\rho(\$) = 1 - 22$$

$$\rho(\$) \approx -\$21$$

$$\Delta t = 2\ s$$

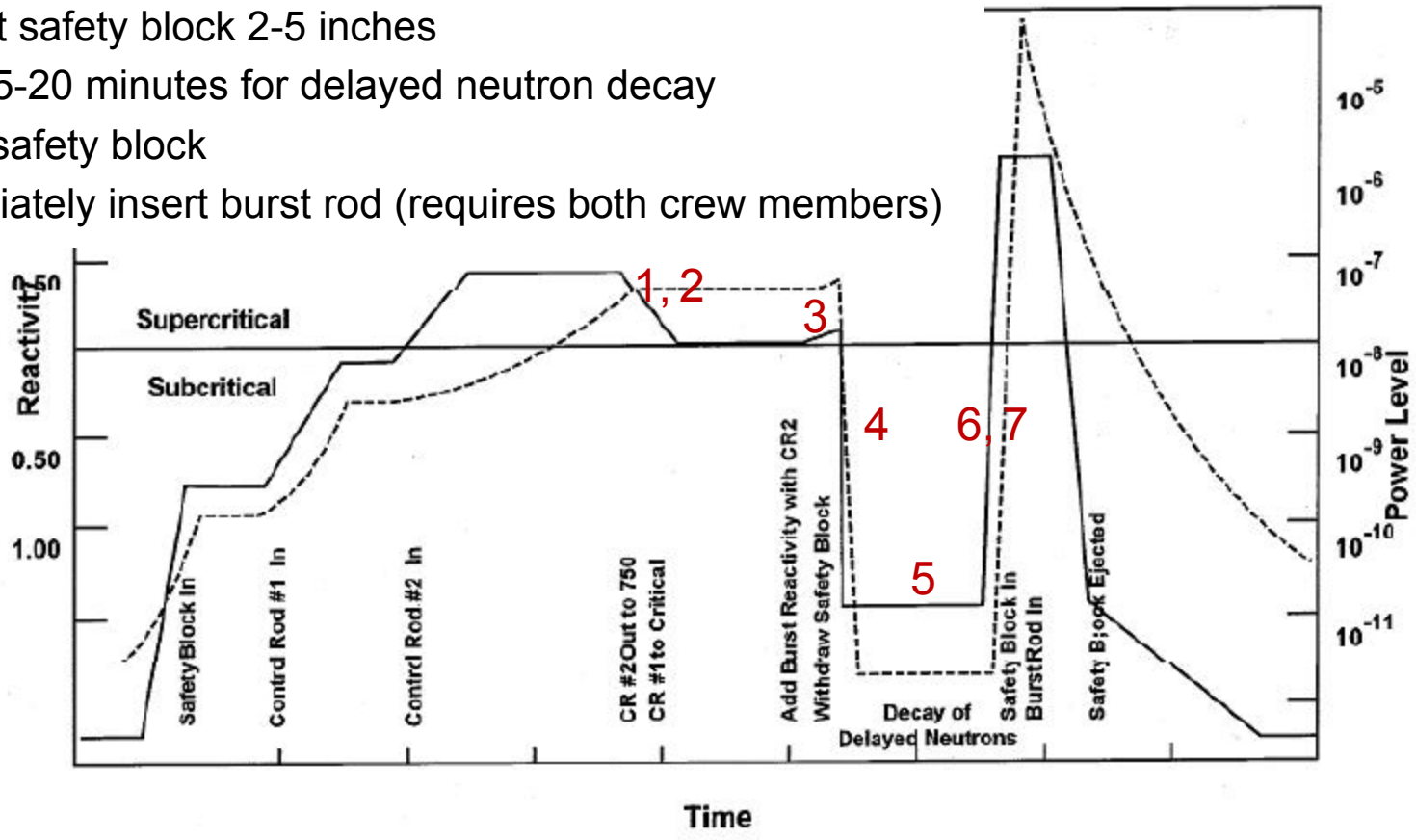
- Shutdown Rate is approx. -$10/s

Control Rod Calibration



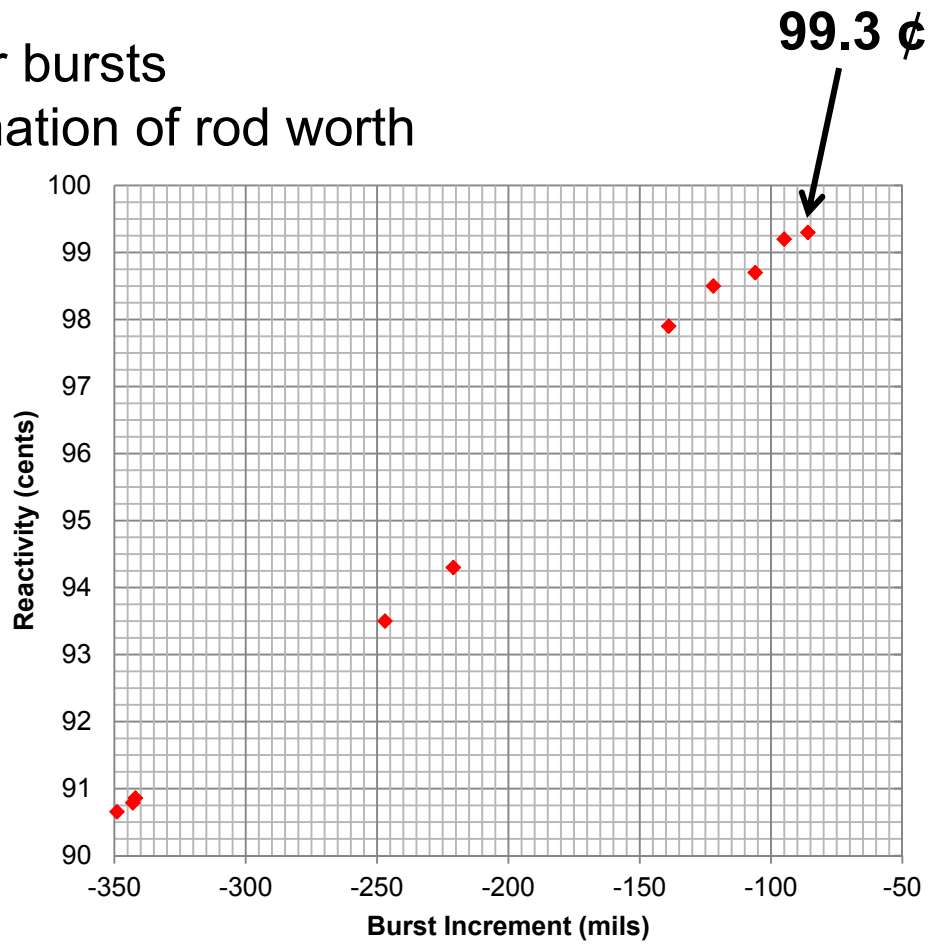
Burst Operation

1. Move Control Rod 2 to 0.250”
2. Find DC with Control Rod 1
3. Insert (or remove) burst increment with Control Rod 2
4. Retract safety block 2-5 inches
5. Wait 15-20 minutes for delayed neutron decay
6. Insert safety block
7. Immediately insert burst rod (requires both crew members)

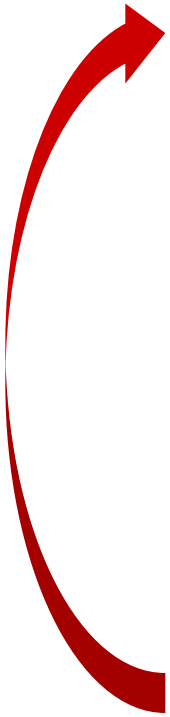


Approach-to-Prompt

- Perform successively larger bursts
  - Most accurate determination of rod worth
  - Demonstrates process



Burst Reproducibility



- Establish DC
- Remove burst increment
- Remove SB
- Wait
- Insert SB
- Insert BR/burst
- BR out
- Repeat

90.69 ± 0.13 ¢

- Establish DC
- Remove burst increment
- Remove SB
- Wait
- Insert SB
- Insert BR/burst
- BR out
- Repeat

90.19 ± 0.03 ¢

First Super-Prompt Burst at DAF, September 2013

On September 10, 2013,
Godiva IV burst for the first time in Nevada.

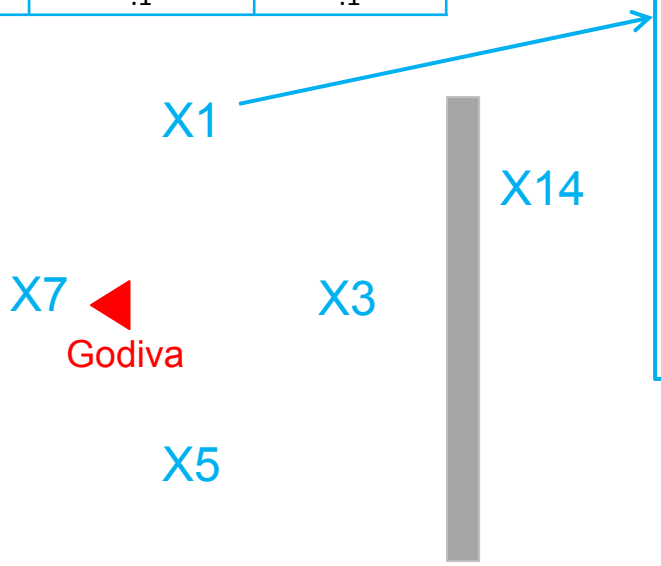
Burst #1963 had a temperature rise of 60º C and a reactivity of $1.03.

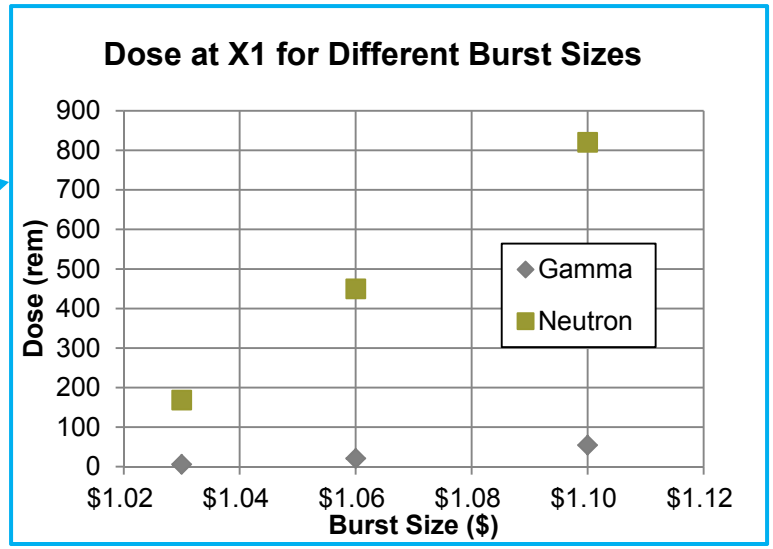
Three more bursts of increasing size followed over the next two days.

Dosimetry

$1.03/60º Burst

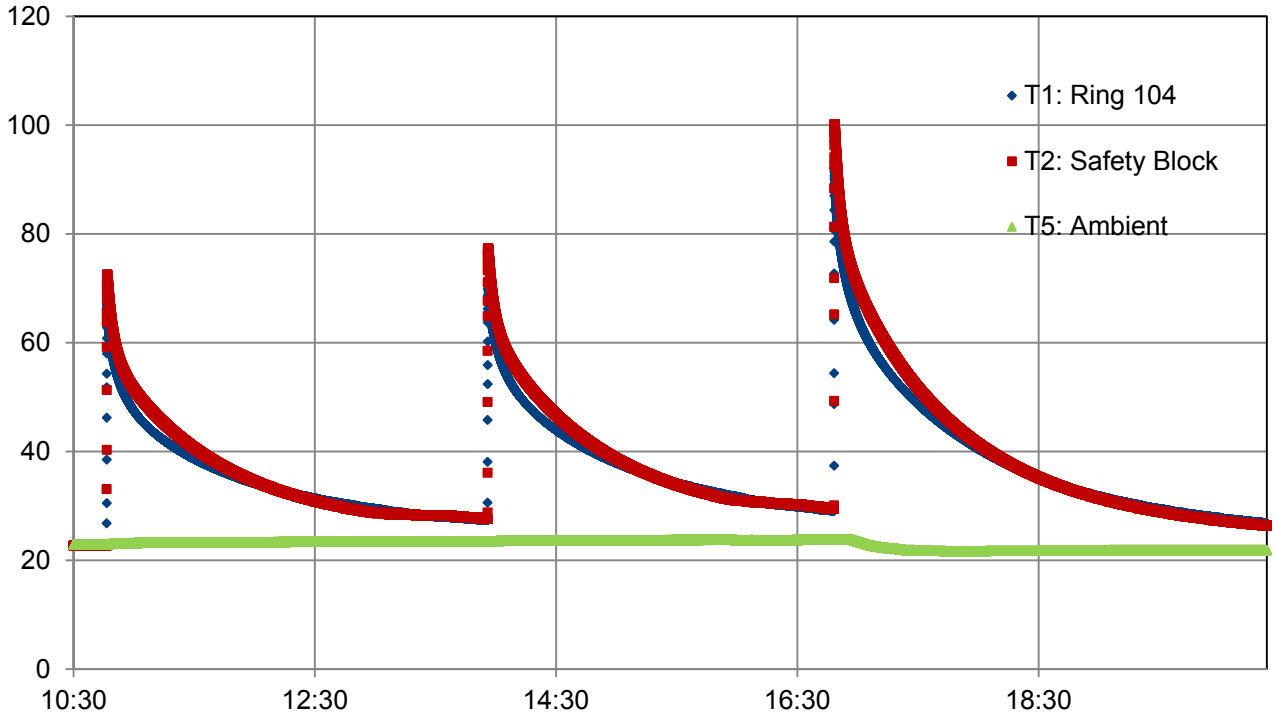
	Gamma Dose (rem)	Neutron Dose (rem)	Total Dose (rem)
X1	6	169	175
X3	7	134	141
X5	13	330	**343**
X7	17	272	288
X14	0	.1	.1





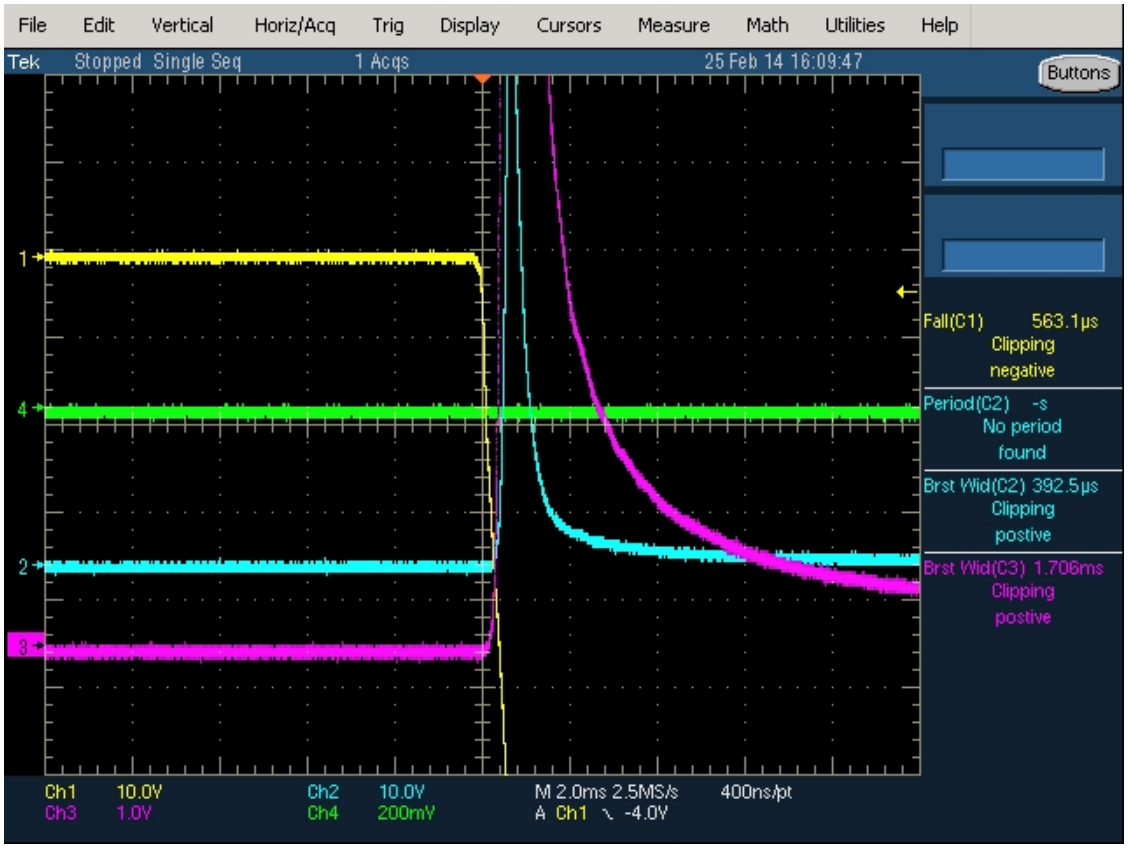
Data – January 14, 2014

- Three bursts in one day



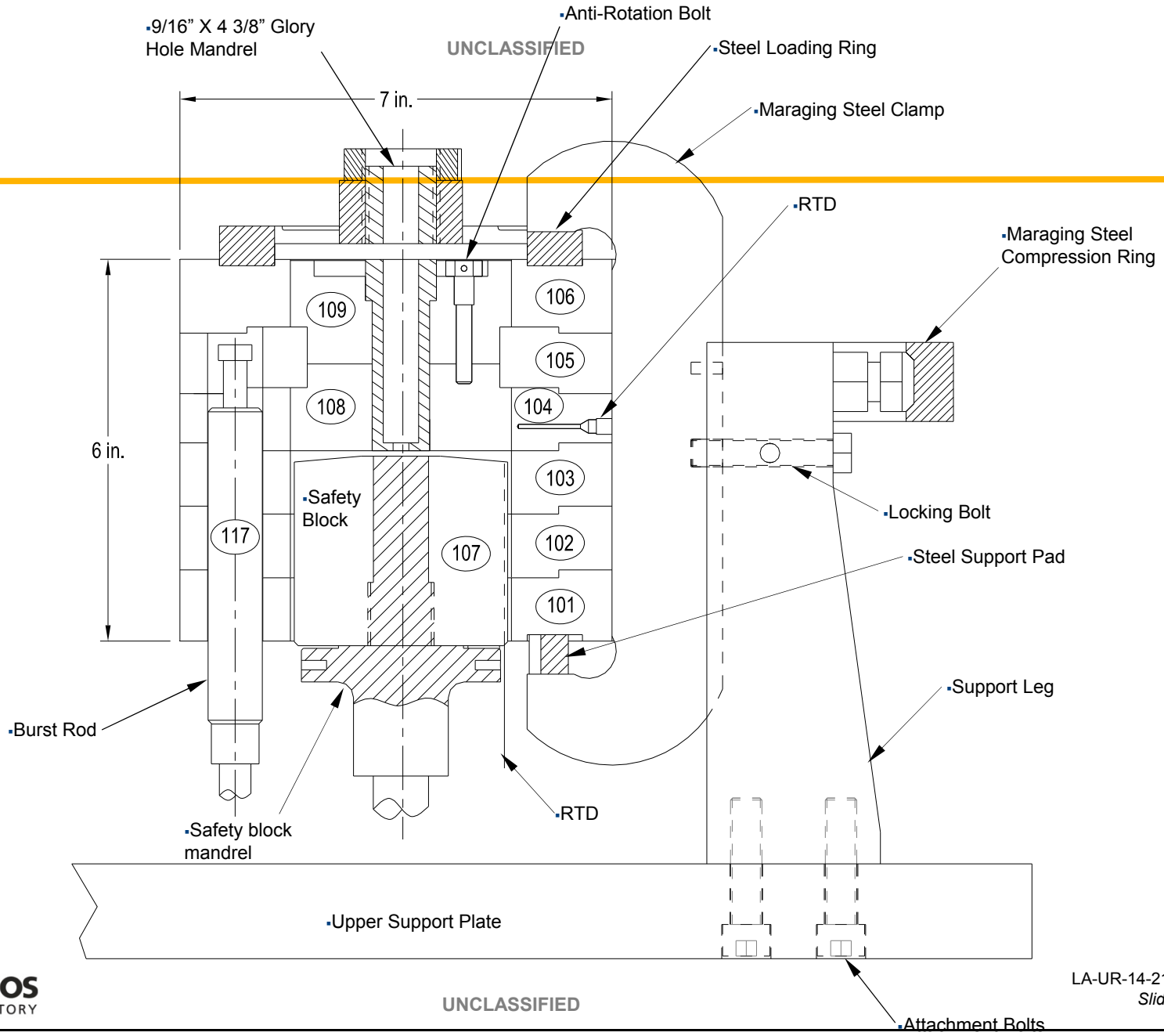
Data – February 25, 2014 – 68º burst

Photomultiplier and photodiode setup and checkout continue



Available Burst Sizes and Specifications

Delta T (C)	Mini-burst	70 degree	150 degree	250 degree
Reactivity	$0.993	$1.04	$1.07	$1.10
Initial Period	15 msec	30 µsec	18 µsec	11 µsec
alpha	66/sec	33000/sec	55000/sec	91000/sec
FWHM	N/A	100 µsec	55 µsec	33 µsec
# fissions		1 E 16	2 E 16	4 E 16


9/16” X 4 3/8” Glory Hole Mandrel
Anti-Rotation Bolt
Steel Loading Ring
Maraging Steel Clamp
7 in.
RTD
Maraging Steel Compression Ring
6 in.
109
106
105
108
104
103
Safety Block
117
107
102
101
Locking Bolt
Steel Support Pad
Support Leg
Burst Rod
Safety block mandrel
RTD
Upper Support Plate
Attachment Bolts

Acknowledgements

This work was supported by the DOE Nuclear Criticality Safety Program, funded and managed by the National Nuclear Security Administration for the Department of Energy.