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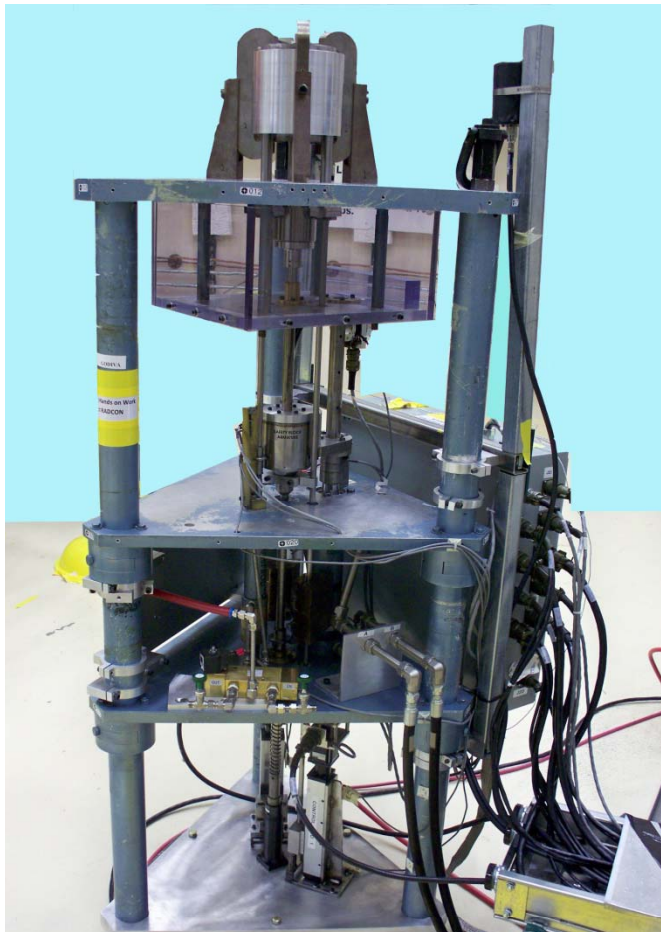
Godiva IV
Reassembly and Startup

Joetta Goda

May 2013

Godiva Assembly Overview



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

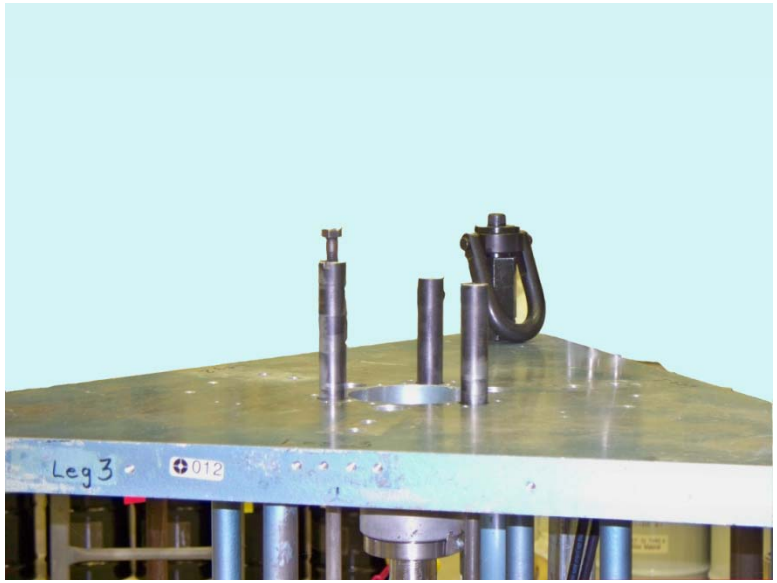
- Core without safety block or control rods
  - Multiplication ~10
  - k_{eff} ~ 0.9

- Assembly/Disassembly activity *rarely* performed
  - 2005
  - 1989

Criticality Safety

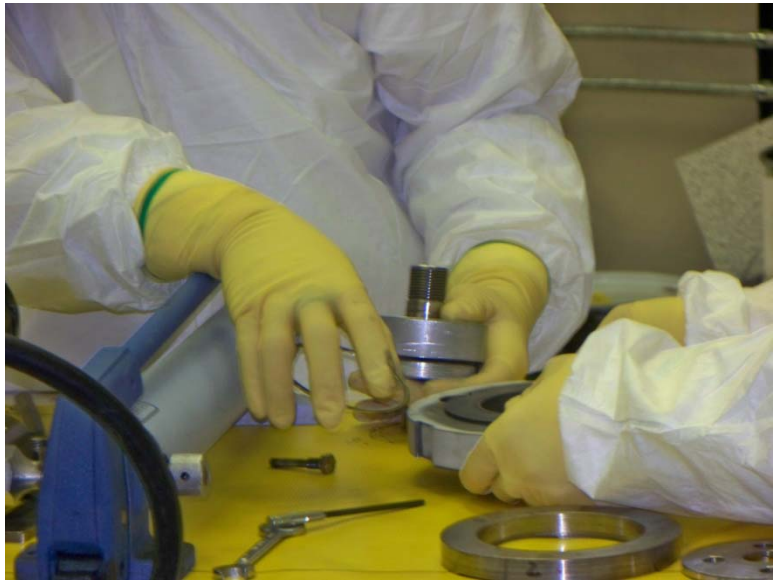
- Fire suppression system shall be disabled during assembly operations.
- Fire suppression efforts or agents of any type are NOT allowed.
- Table positioned ≥ 3 feet from any concrete surface.
- Demarcated 3-inch buffer boundary.
- Full core must be in the hydraulic press or within the buffer boundary.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

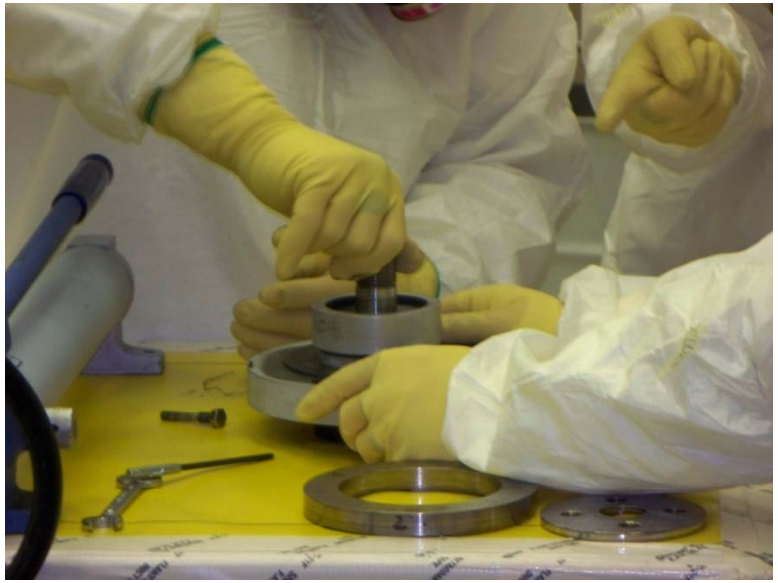
Install Control Rods, Burst Rod, and Safety Block



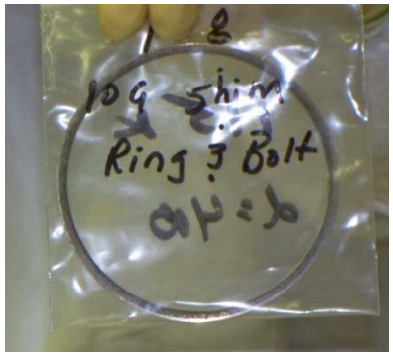
- Measured position of top of control elements relative to top of Godiva stand at both out and in positions.

Upper Fuel Assembly

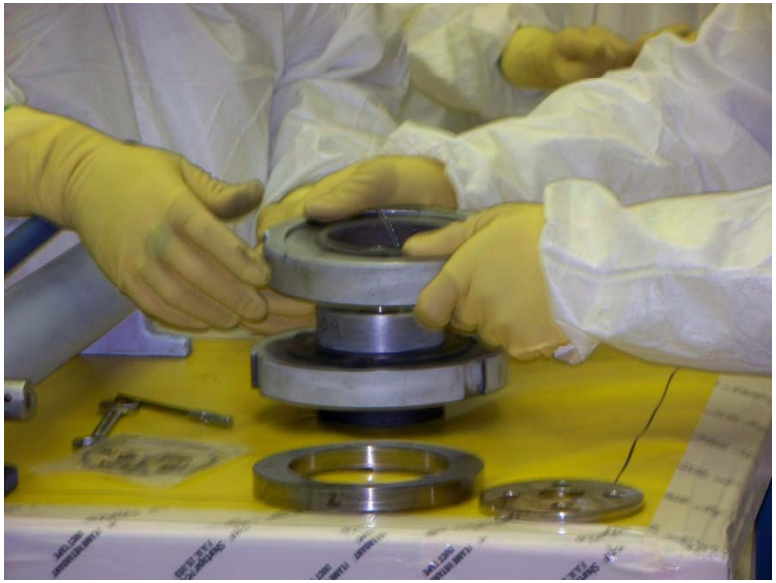


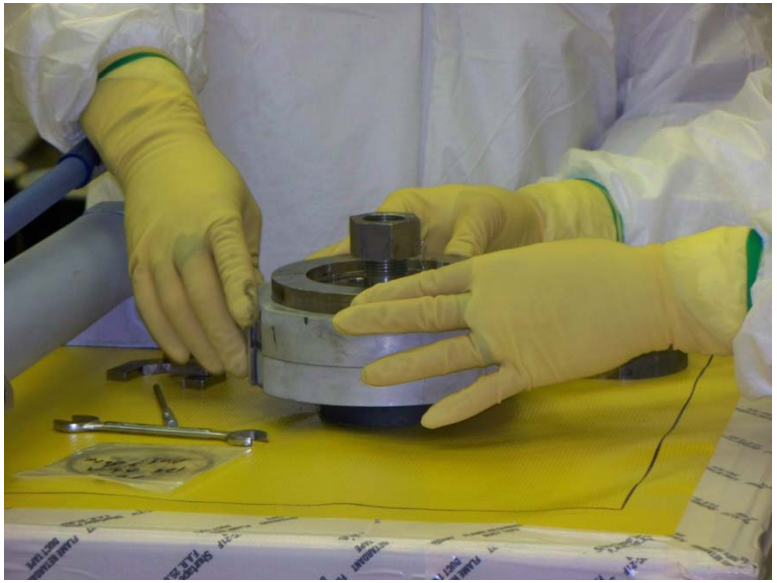


- Thicker shim ring constructed to compensate for fuel lost over time.



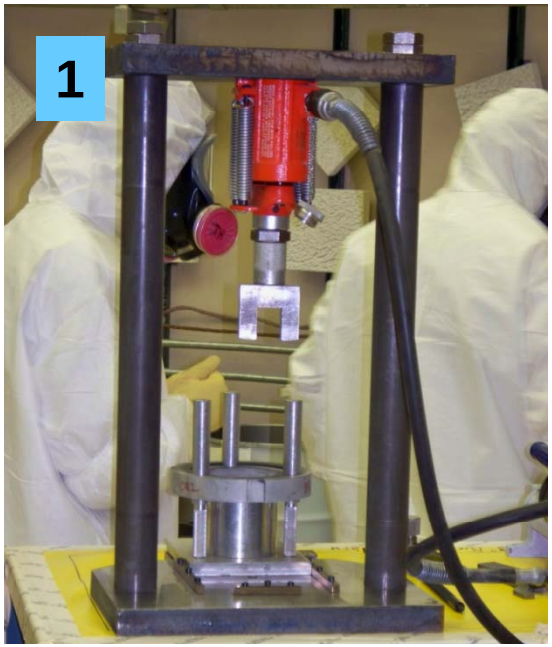
Upper Fuel Assembly (continued)



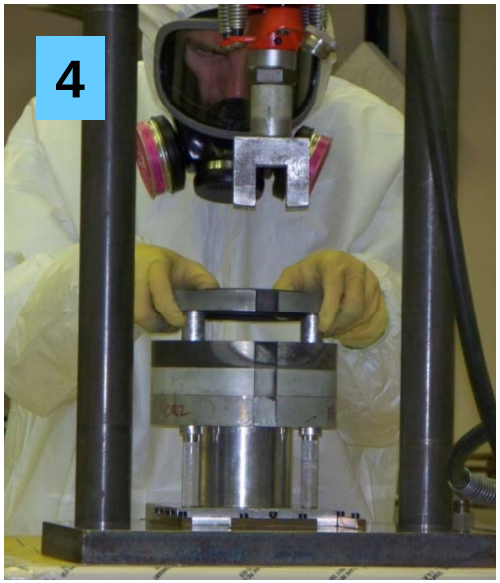


- Load bearing steel ring placed on top of fuel

Stack the Lower Core

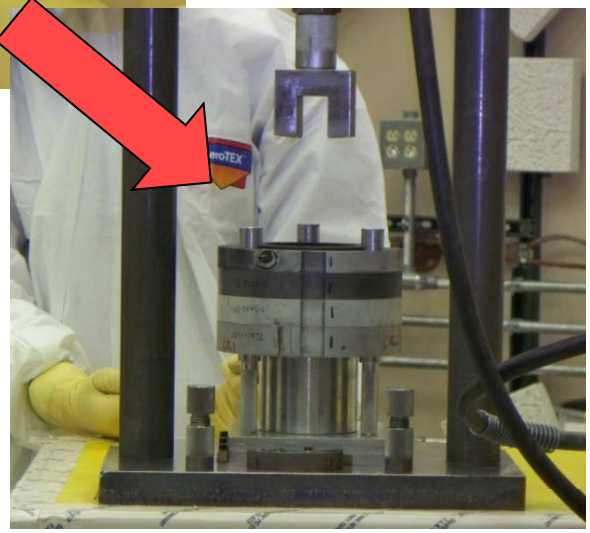


2



- 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.

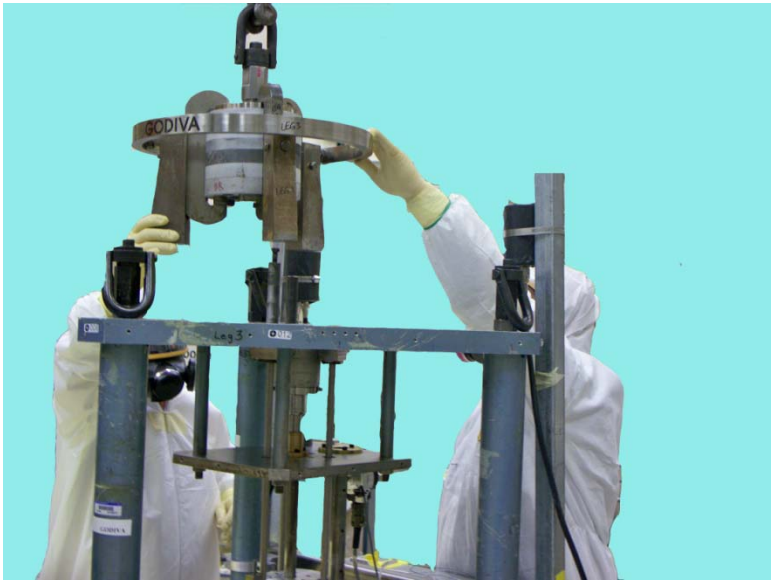
Install the Support Legs

- Core is suspended while legs are attached.

Install the Saturn Ring

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

Install the Core



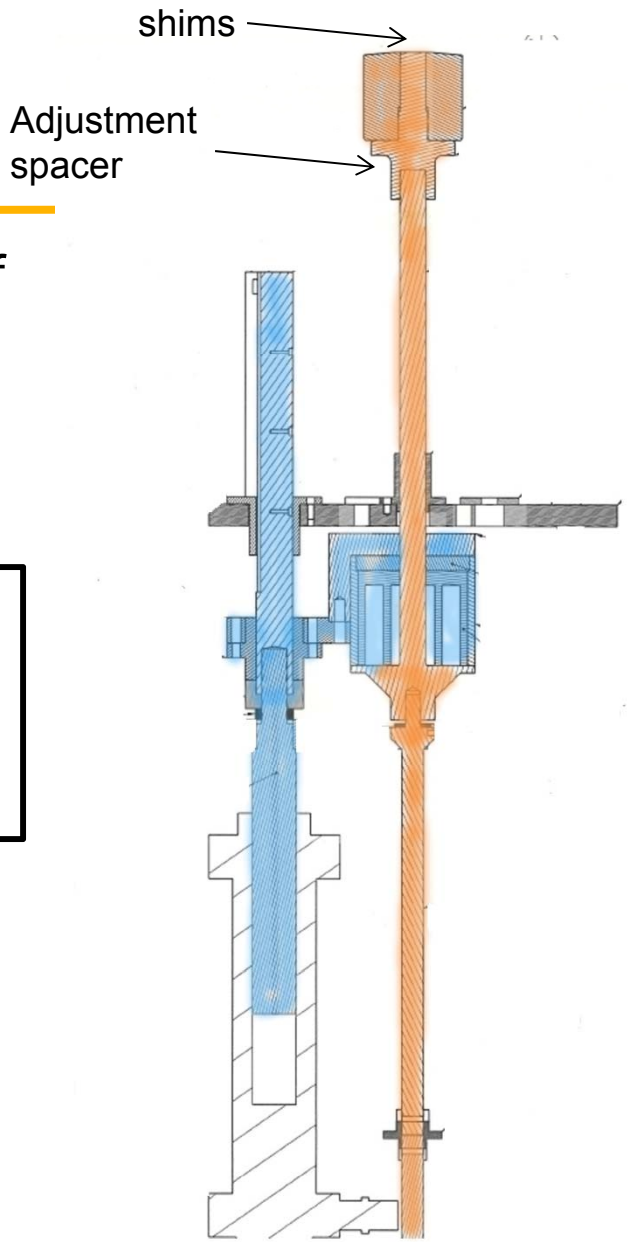
- Table is rolled next to stand.
- Core lowered *carefully* over protruding control rods.
- Brackets are bolted on.

Install the Core (continued)

- Insert source in glory hole.
- Take subcritical neutron multiplication measurements.

- Results consistent with disassembly, multiplication ~8.

Set the Safety Block Gap



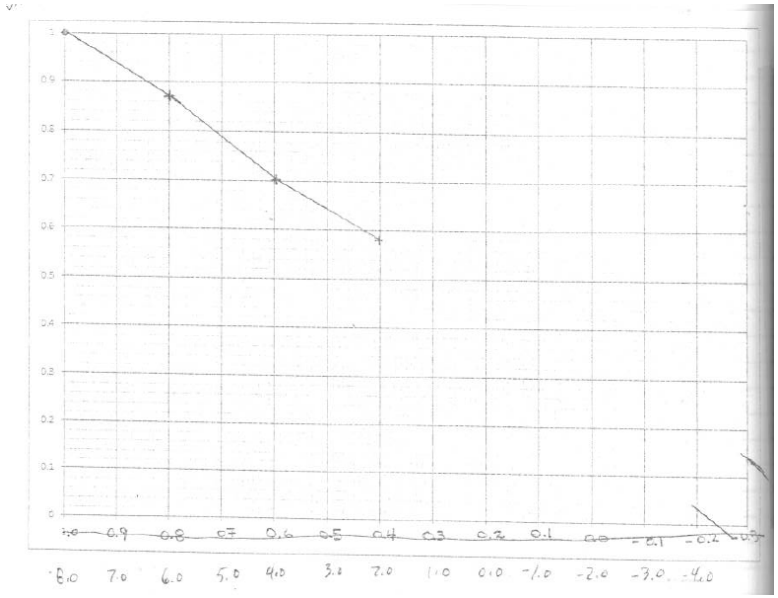
- Use combinations of shims placed on top of Safety Block to measure gap distance
- Adjust Safety Block Position with spacer
- Repeat to measure gap distance.

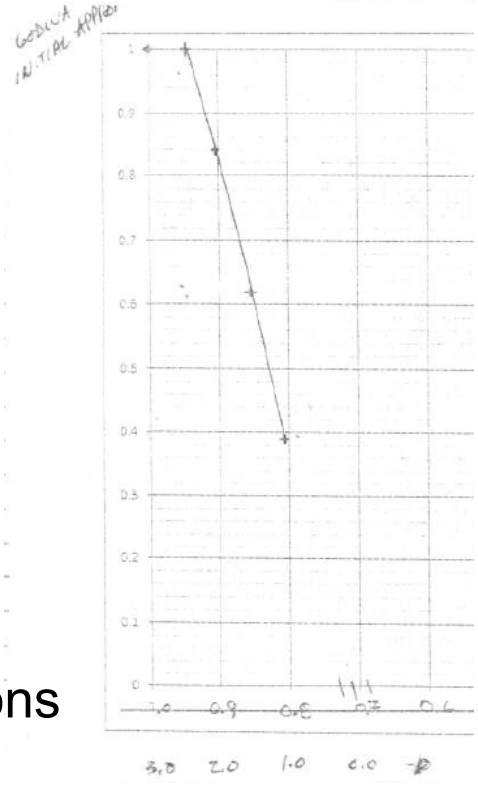
Gap distance is between the thickness of shims where Safety Block will drop out and next smaller amount of shims where Safety Block will not drop out.

- Final gap distance is 0.0145” - 0.0175”

Approach to Critical

- 1/M on Safety Block position

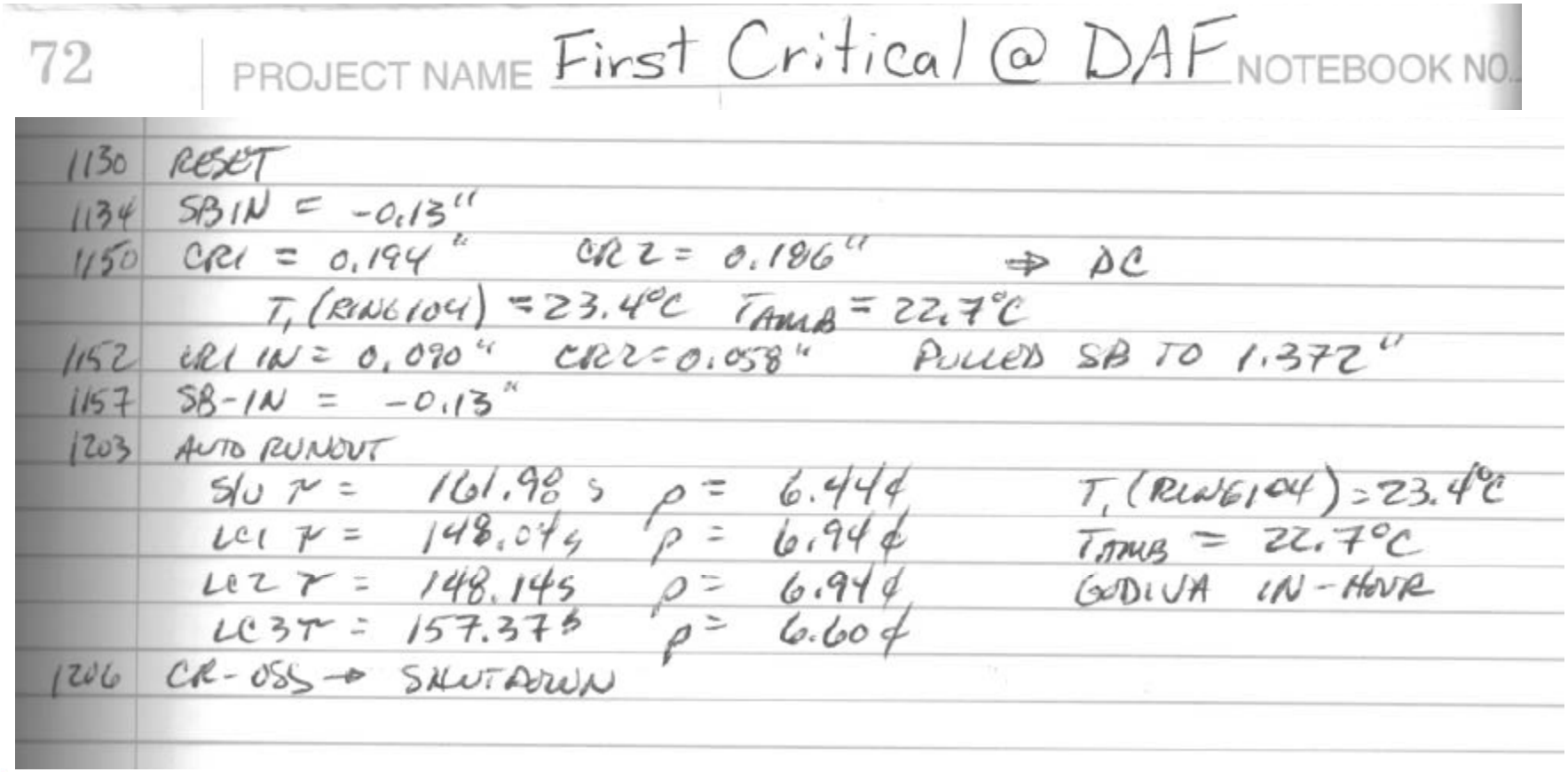




- 1/M on Sum of Control Rod positions

First Critical at DAF

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


72 PROJECT NAME First Critical @ DAF NOTEBOOK NO.

1130 RESET
1134 SB IN = -0.13"
1150 CR1 = 0.194" CR2 = 0.186" ⇒ DC
T, (RNG104) = 23.4°C T AMB = 22.7°C
1152 CR1 IN = 0.090" CR2 = 0.058" PULLED SB TO 1.372"
1157 SB-IN = -0.13"
1203 AUTO RUNOUT
SU T = 161.98 s ρ = 6.44¢ T, (RNG104) = 23.4°C
LC1 T = 148.04 s ρ = 6.94¢ T AMB = 22.7°C
LC2 T = 148.14 s ρ = 6.94¢ GODIVA IN-HOUR
LC3 T = 157.37 s ρ = 6.60¢
1206 CR-OSS → SHUTDOWN

Reproducibility of Control Elements

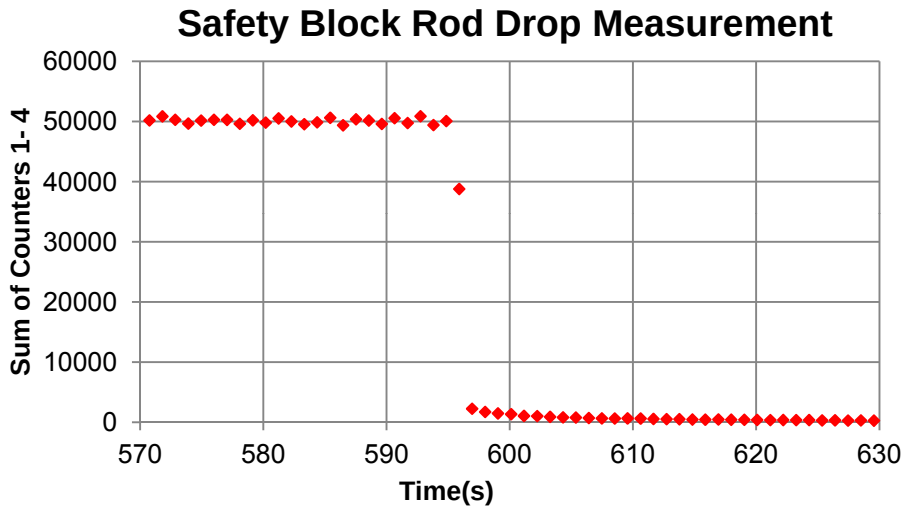
Control Rod	Safety Block	Burst Rod
▪ Insert CR 1	▪ Establish positive period	▪ Insert BR
▪ Find DC with CR 2	▪ Measure period	▪ Establish positive period
▪ Record CR 2 position	▪ Remove SB	▪ Measure period
▪ Remove CR 2	▪ Insert SB	▪ Remove BR
▪ Repeat	▪ Repeat	▪ Repeat
0.250 ± 0.001 in	45.07 ± 0.59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

- Comparable to values measured during 1993 restart

Burst Operation

1. Move Control Rod 2 to 0.500”
2. Find DC with Control Rod 1
3. Insert (or remove) burst increment with Control Rod 2 (nominally 95 mils for 70º burst, 150 mils for 100º burst)
4. Retract safety block 2-5 inches
5. Unlock 3rd burst button, enter BURST OPERATIONS
6. Wait 15-20 minutes for delayed neutron decay
7. Arm instrumentation, Ocilloscope, trigger module
8. Insert safety block
9. Immediately insert burst rod (requires both crew members)

Safety Block Rate of Shutdown



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

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

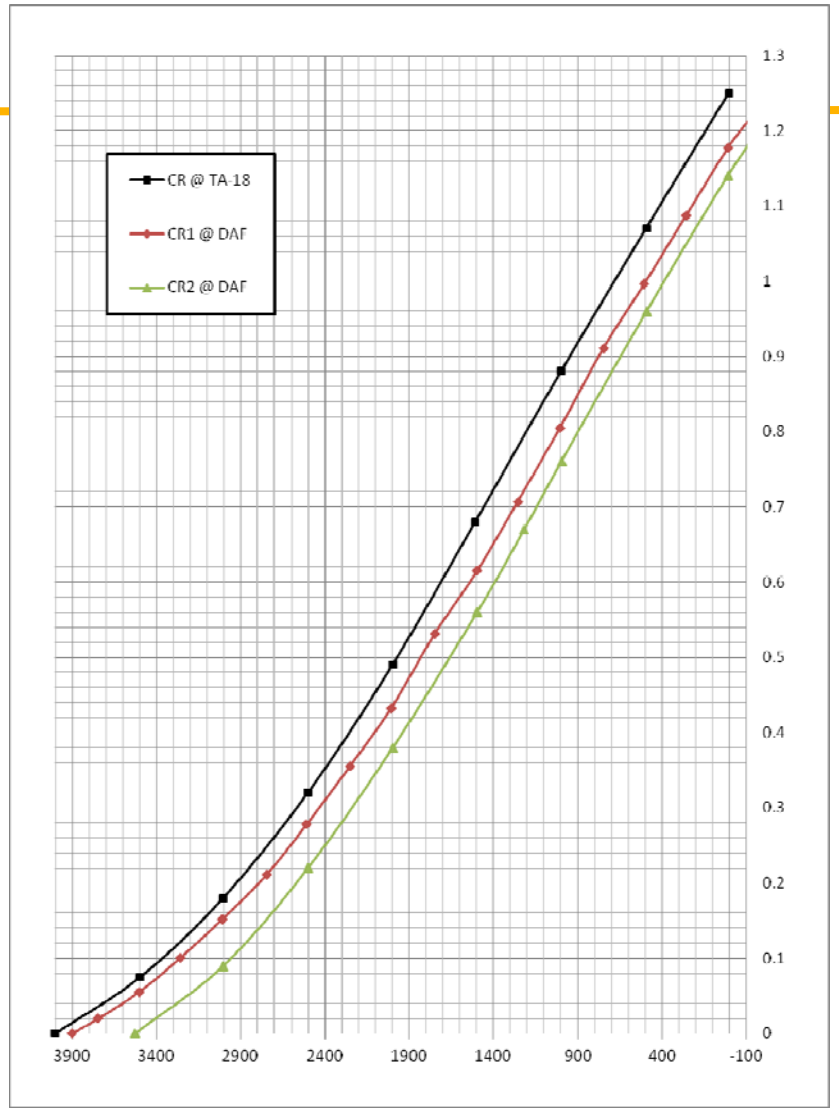
$$\rho(\$) = 1 - 22$$

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

$$\Delta t = 2\ s$$

- Shutdown Rate is approx. -$10/s

Control Rod Calibration



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NNSA

Worth of Burst Rod

Attachment 4
Approach to Prompt Critical Data

	Period (sec)	Desired Reactivity ($)	Reactivity to Remove ($)	CR 2 Position (in.)	Measured Period (sec)	Measured Reactivity ($)	Burst Rod Worth ($)
	15	0.32	0.68	2.050	13.19	$.34	$1.02
	10	0.39	0.61	1.850	8.63	$0.41	$1.02
	5	0.51	0.49	1.500	4.38	$0.54	$1.03
	1	0.78	0.22	0.825	0.85	$0.80	$1.02
*	0.2	~~0.93~~ 0.93	~~0.07~~ 0.09	0.450	0.181	$0.94	$1.01
*	0.1	0.96	~~0.04~~ 0.06	0.246	~~0.0510~~ 0.510	$0.98	$1.02
†	0.05	0.98	~~0.02~~ 0.05	0.279	0.0354	$0.985	$1.01
**	0.012	0.995	0.005	0.261	0.0301	$ 0.987	$ 0.992

Burst Rod Worth
$1.032

Crew Member: DAVID K. HAYES _____ Date: 28 FEB 13
Print Name Signature

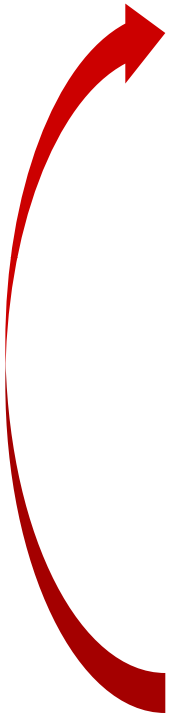
Crew Chief: Joetta Goda _____ Date: 2/28/13
Print Name Signature

* ADJUSTED REACTIVITY INCREMENT TO ACCOUNT FOR $0.02 ON BR.

† $0.03 ADJUSTMENT

** $0.04 Adjustment

Burst Reproducibility



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

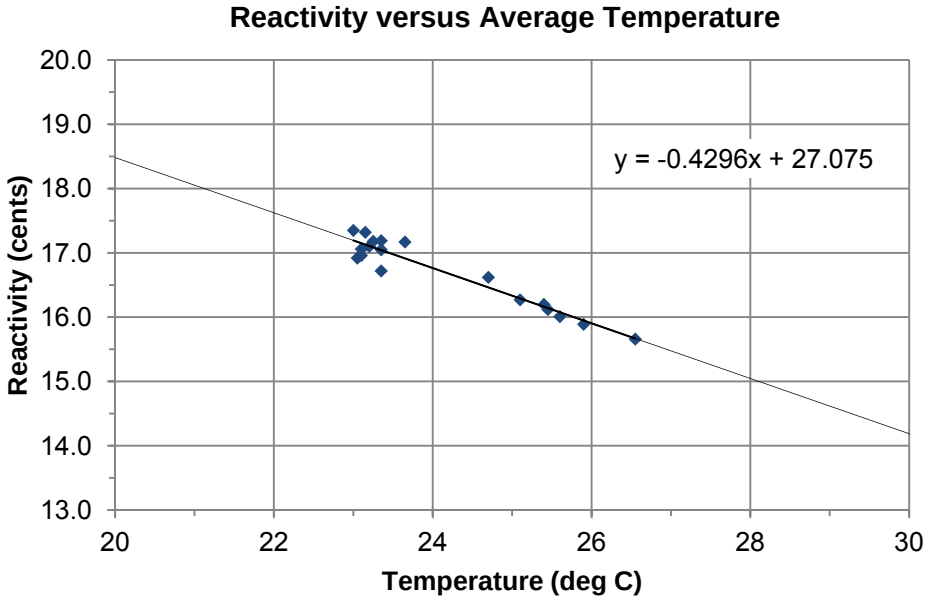
90.69 ± 0.13 ¢

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

90.19 ± 0.03 ¢

Reactivity Quenching (Temperature Coefficient)

- For characterization plan, we started on a positive period and showed that as temperature increased, period decreased.
- A free run would also demonstrate a negative temperature coefficient.
- Enough variation in room temperature over characterization to plot excess reactivity versus temperature.



- 0.4 cents/ºC

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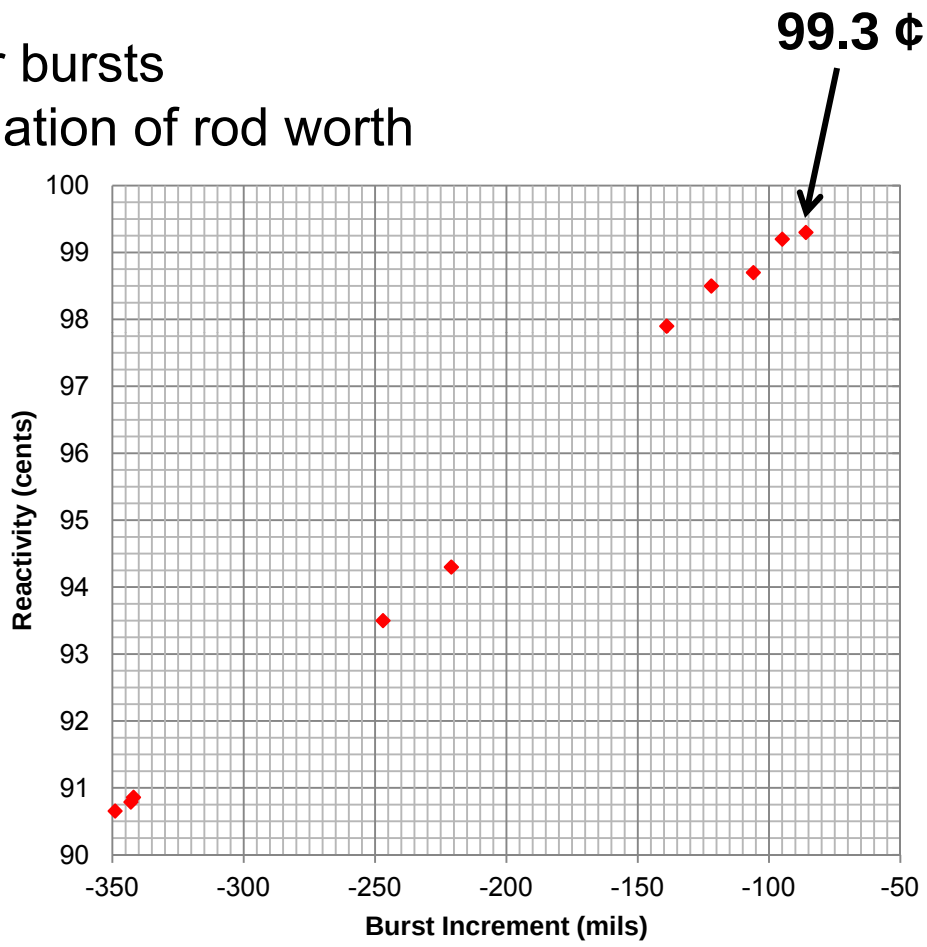
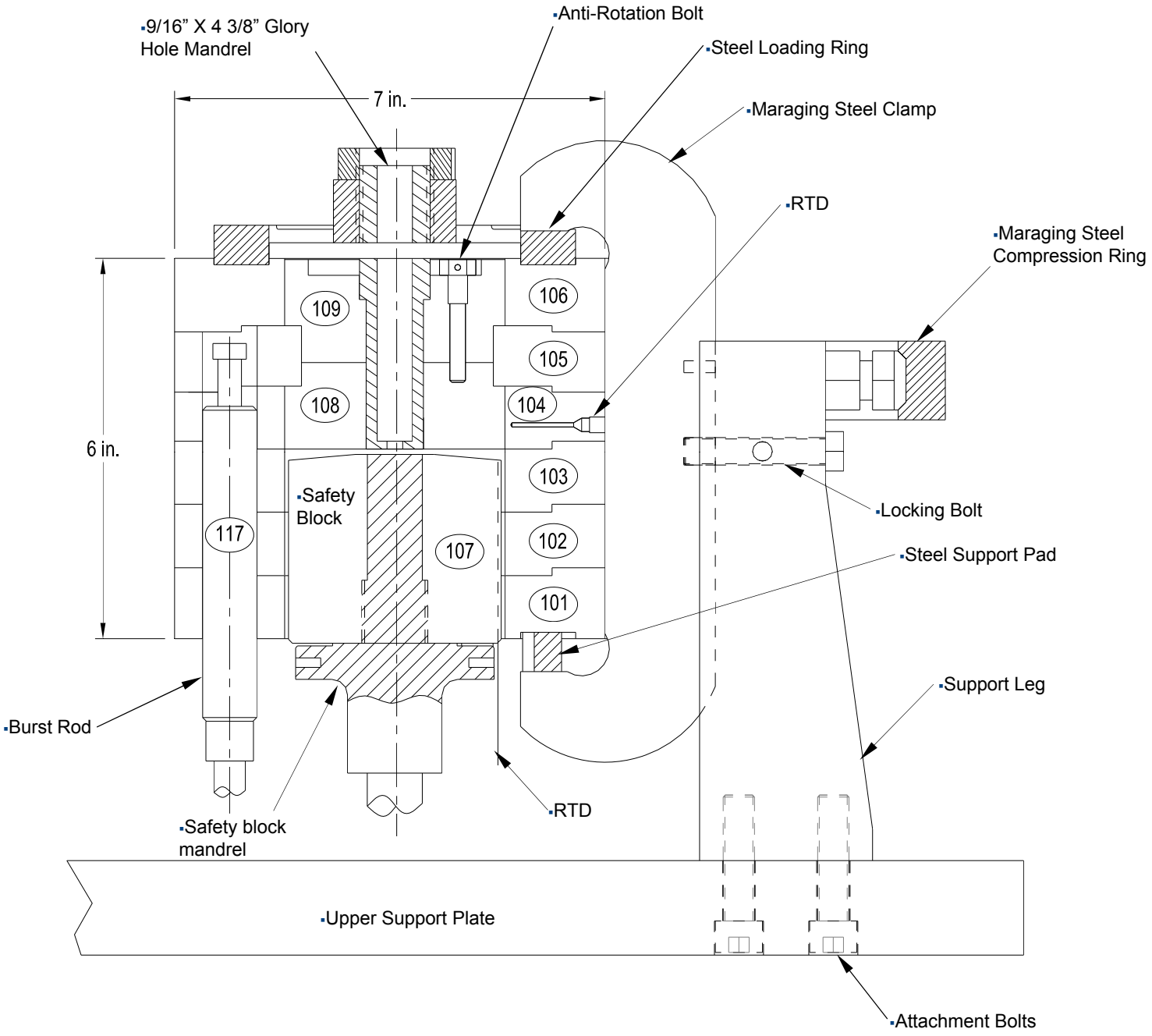
Approach-to-Prompt

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




9/16” X 4 3/8” Glory Hole Mandrel
Anti-Rotation Bolt
Steel Loading Ring
7 in.
Maraging Steel Clamp
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