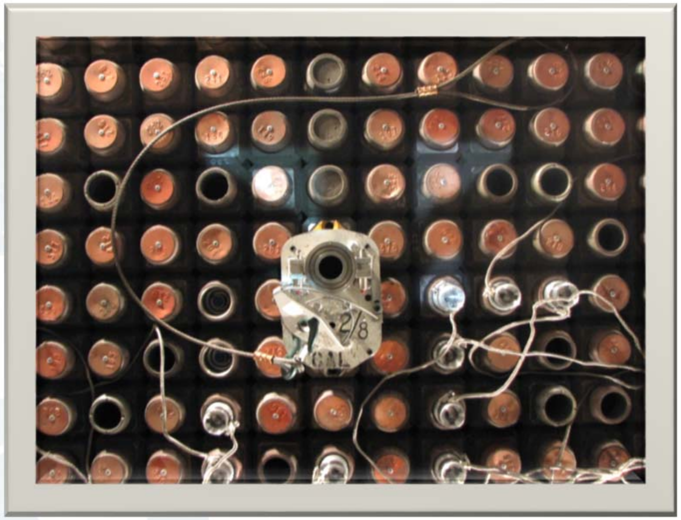
IRPhEP Benchmark Development Guidance for TREAT-IRP Activities

John D. Bess
Idaho National Laboratory



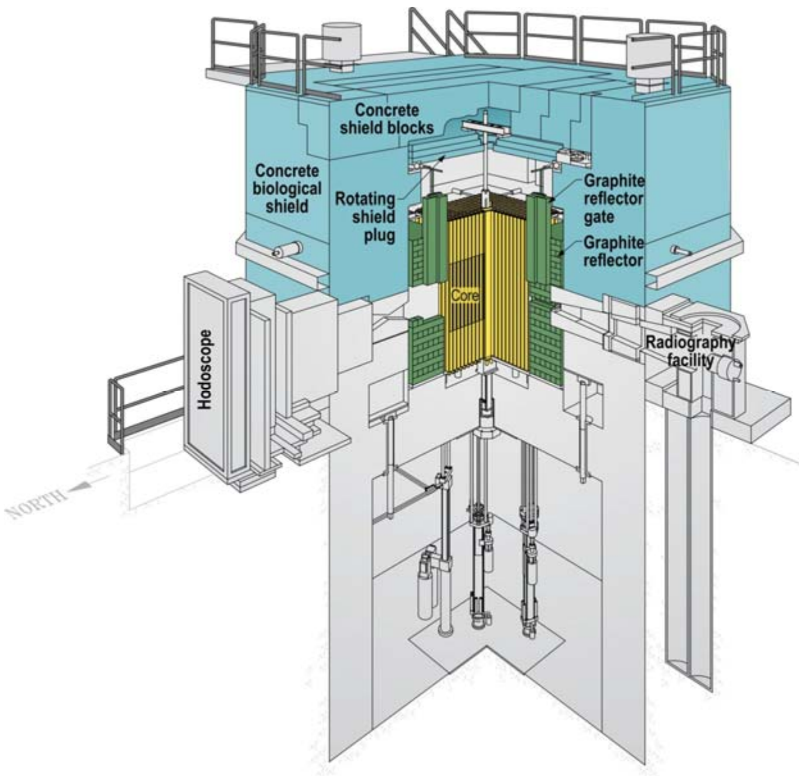
TREAT-IRP Kickoff Meeting
Idaho Falls, ID
November 19-20, 2015

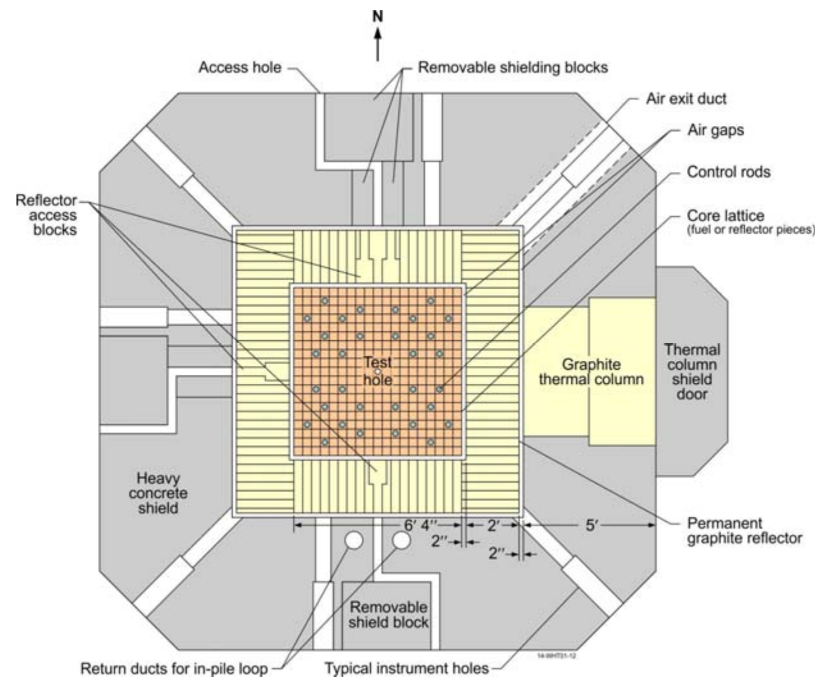
Outline

- TREAT, What's (Neutronically) Important
- MOOSE Crossing
- IRPhEP Recommendations
- Optimally Picking the Low-Hanging Fruit

TREAT, What's (Neutronically) Important

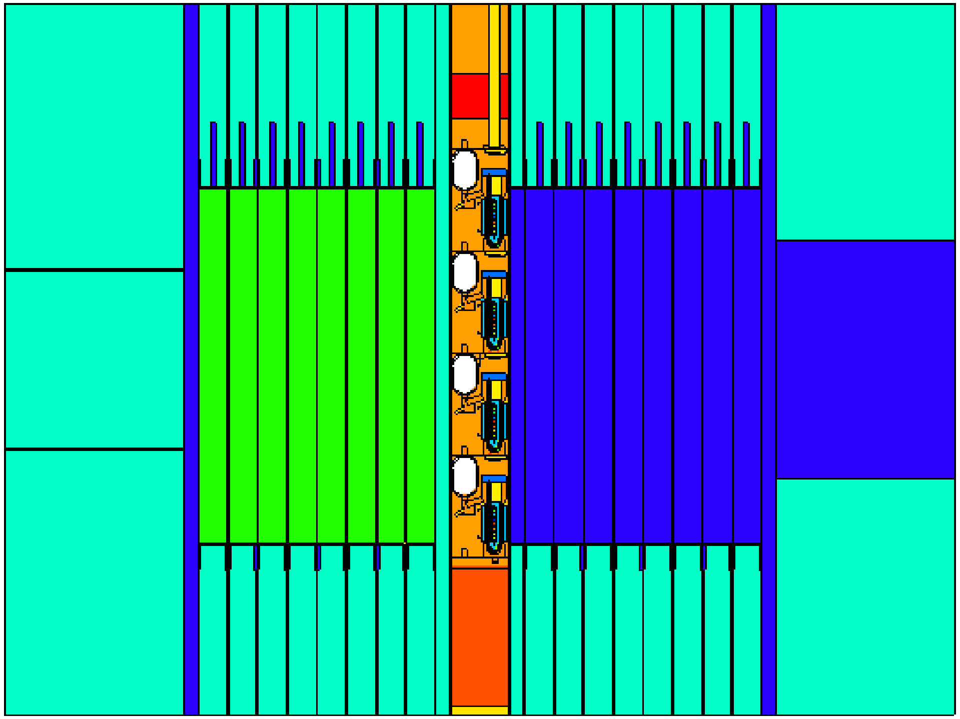
Brief Overview of TREAT

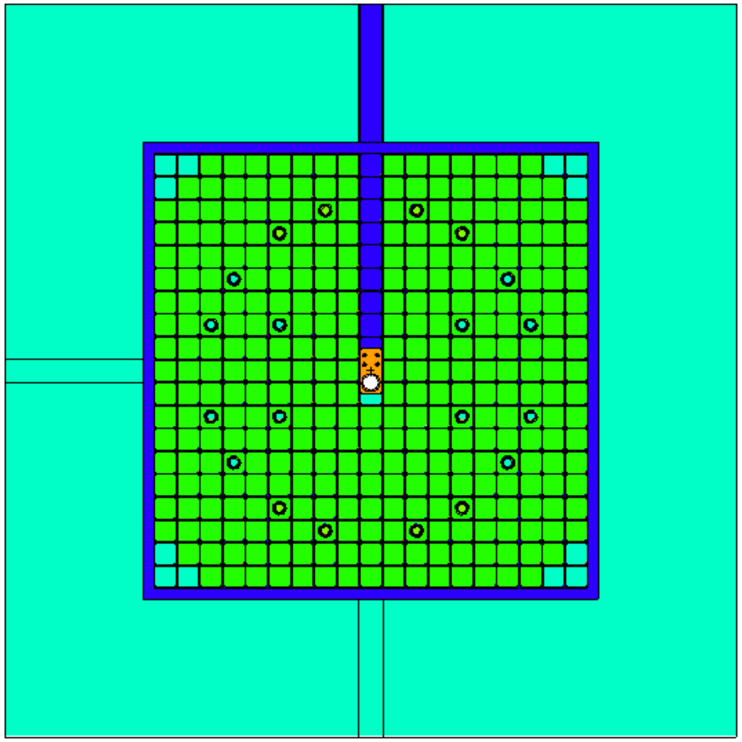




Detectors in Biological Shielding

Overview of Basic Core-Only MCNP Model





Incomplete but Used for Basic Scoping Studies

Peak-to-Average Power per TREAT Assembly

	A	B	C	D	E	F	G	H	J	K	L	M	N	O	P	R	S	T	U
1	Z	Z	F	F	F	F	F	F	F	X	F	F	F	F	F	F	F	Z	Z
2	Z	F	F	F	F	F	F	F	F	X	F	F	F	F	F	F	F	F	Z
3	F	F	F	F	F	F	F	CS	F	X	F	CS	F	F	F	F	F	F	F
4	F	F	F	F	F	CS	F	F	F	X	F	F	F	CS	F	F	F	F	F
5	F	F	F	F	F	F	F	F	F	X	F	F	F	F	F	F	F	F	F
6	F	F	F	CT	F	F	F	F	F	X	F	F	F	F	F	CT	F	F	F
7	F	F	F	F	F	F	F	F	F	X	F	F	F	F	F	F	F	F	F
8	F	F	CT	F	F	CC	F	F	F	X	F	F	F	CC	F	F	CT	F	F
9	F	F	F	F	F	F	F	F	F	X2	F	F	F	F	F	F	F	F	F
10	F	F	F	F	F	F	F	F	F	mS	F	F	F	F	F	F	F	F	F
11	F	F	F	F	F	F	F	F	F	Z2	F	F	F	F	F	F	F	F	F
12	F	F	CT	F	F	CC	F	F	F	F	F	F	F	CC	F	F	CT	F	F
13	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F
14	F	F	F	CT	F	F	F	F	F	F	F	F	F	F	F	CT	F	F	F
15	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F
16	F	F	F	F	F	CS	F	F	F	F	F	F	F	CS	F	F	F	F	F
17	F	F	F	F	F	F	F	CS	F	F	F	CS	F	F	F	F	F	F	F
18	Z	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	Z
19	Z	Z	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	Z	Z

	A	B	C	D	E	F	G	H	J	K	L	M	N	O	P	R	S	T	U
1	0.014	0.023	0.699	0.701	0.707	0.708	0.703	0.697	0.698	0.007	0.697	0.694	0.697	0.696	0.689	0.681	0.689	0.023	0.014
2	0.024	0.724	0.718	0.725	0.724	0.713	0.691	0.671	0.701	0.009	0.700	0.670	0.688	0.708	0.719	0.721	0.720	0.736	0.024
3	0.759	0.755	0.778	0.792	0.774	0.734	0.713	0.540	0.736	0.011	0.737	0.540	0.713	0.735	0.776	0.798	0.788	0.776	0.793
4	0.800	0.817	0.859	0.884	0.850	0.620	0.815	0.828	0.841	0.012	0.843	0.832	0.819	0.624	0.858	0.896	0.878	0.846	0.847
5	0.868	0.896	0.952	0.993	0.997	0.976	0.993	0.992	0.955	0.013	0.957	0.997	1.000	0.986	1.009	1.009	0.974	0.927	0.916
6	0.944	0.975	1.043	0.818	1.142	1.158	1.153	1.120	1.044	0.014	1.045	1.124	1.162	1.170	1.157	0.832	1.066	1.006	0.984
7	1.009	1.047	1.125	1.201	1.259	1.282	1.268	1.210	1.098	0.016	1.101	1.216	1.277	1.296	1.276	1.222	1.148	1.075	1.045
8	1.063	1.106	0.886	1.285	1.351	1.015	1.349	1.268	1.109	0.018	1.112	1.274	1.359	1.025	1.368	1.306	0.904	1.134	1.096
9	1.104	1.153	1.249	1.350	1.420	1.443	1.413	1.302	1.067	0.012	1.070	1.309	1.424	1.459	1.439	1.373	1.274	1.179	1.132
10	1.127	1.181	1.284	1.389	1.465	1.494	1.465	1.347	1.066	mS	1.068	1.354	1.477	1.511	1.485	1.413	1.309	1.206	1.154
11	1.130	1.184	1.285	1.395	1.477	1.513	1.503	1.421	1.218	0.059	1.221	1.428	1.515	1.530	1.496	1.417	1.310	1.207	1.156
12	1.115	1.163	0.937	1.369	1.455	1.111	1.518	1.489	1.416	1.368	1.421	1.497	1.530	1.122	1.473	1.390	0.953	1.187	1.140
13	1.084	1.129	1.220	1.316	1.400	1.457	1.492	1.503	1.493	1.487	1.499	1.512	1.506	1.474	1.419	1.337	1.242	1.153	1.110
14	1.039	1.077	1.157	0.917	1.303	1.358	1.406	1.443	1.463	1.472	1.468	1.451	1.419	1.375	1.322	0.934	1.180	1.101	1.064
15	0.983	1.009	1.077	1.136	1.161	1.171	1.242	1.308	1.352	1.371	1.356	1.317	1.254	1.188	1.181	1.159	1.102	1.035	1.008
16	0.923	0.936	0.987	1.027	1.005	0.755	1.036	1.104	1.181	1.220	1.186	1.112	1.048	0.767	1.027	1.052	1.012	0.961	0.948
17	0.876	0.871	0.900	0.927	0.924	0.902	0.907	0.712	1.009	1.068	1.014	0.718	0.920	0.921	0.949	0.956	0.928	0.899	0.903
18	0.027	0.835	0.832	0.848	0.864	0.874	0.873	0.877	0.932	0.966	0.939	0.887	0.890	0.898	0.896	0.883	0.866	0.868	0.028
19	0.016	0.026	0.804	0.808	0.834	0.860	0.880	0.900	0.922	0.934	0.928	0.913	0.903	0.893	0.879	0.860	0.850	0.027	0.017

CC	Compensation Rod Fuel Assembly
CS	Control/Shutdown Rod Fuel Assembly
CT	Transient Rod Fuel Assembly
F	Standard Fuel Assembly
mS	multiSERTTA Test Vehicle
X	48" Access Hole Dummy Assembly
X2	48" Access Hole Dummy Half-Assembly
Z	Zr-Clad Dummy Assembly
Z2	Zr-Clad Dummy Half-Assembly

Power Distribution

98% Reactor

1% Perm. Reflector

1% Lost

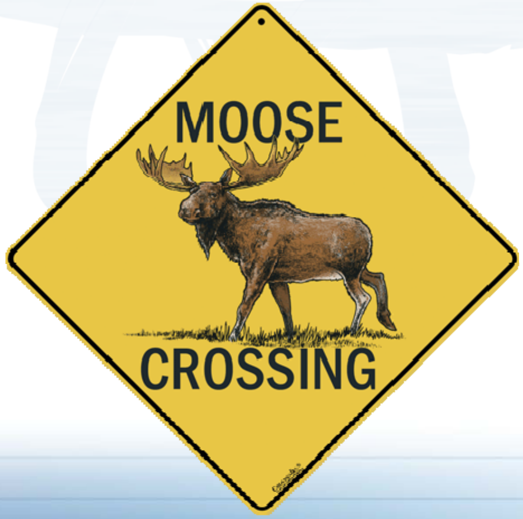
0	Minimum
0.153	10%
0.306	20%
0.459	30%
0.612	40%
0.765	50%
0.918	60%
1.071	70%
1.224	80%
1.377	90%
1.530	Maximum

Detectors in Biological Shielding

Idaho National Laboratory

* Courtesy Mark DeHart (INL)

MOOSE Crossing



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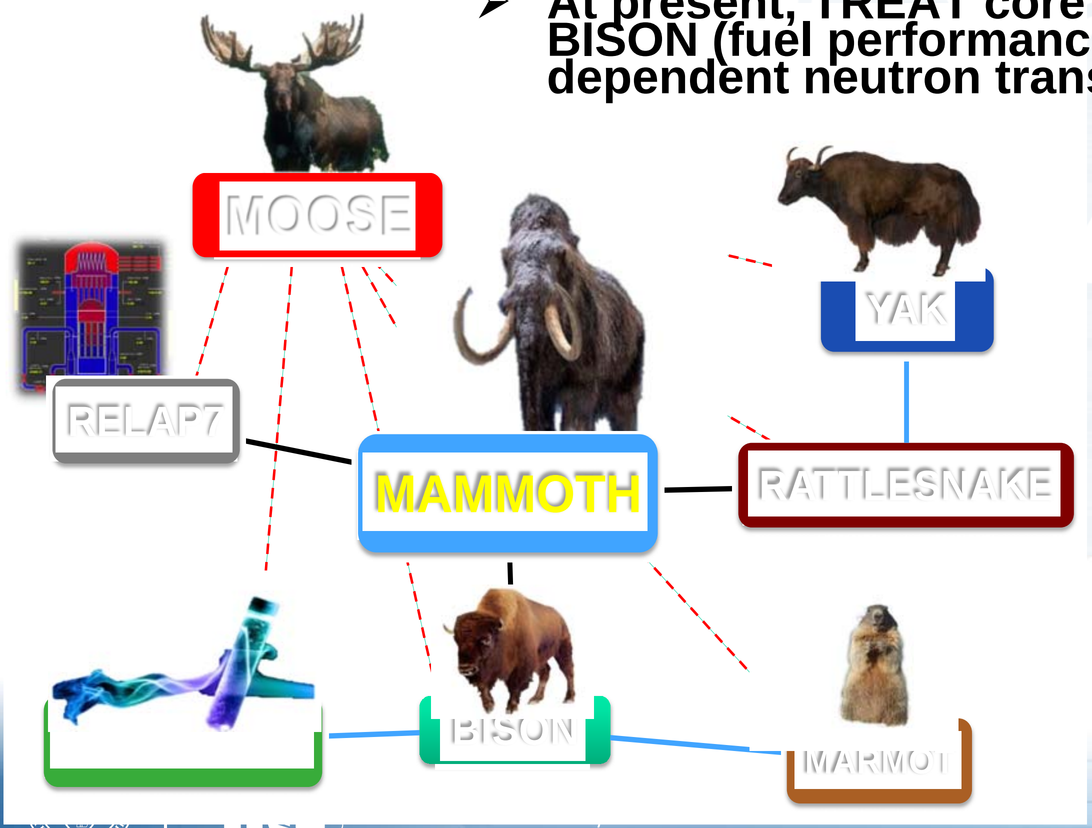
Modeling TREAT with MAMMOTH

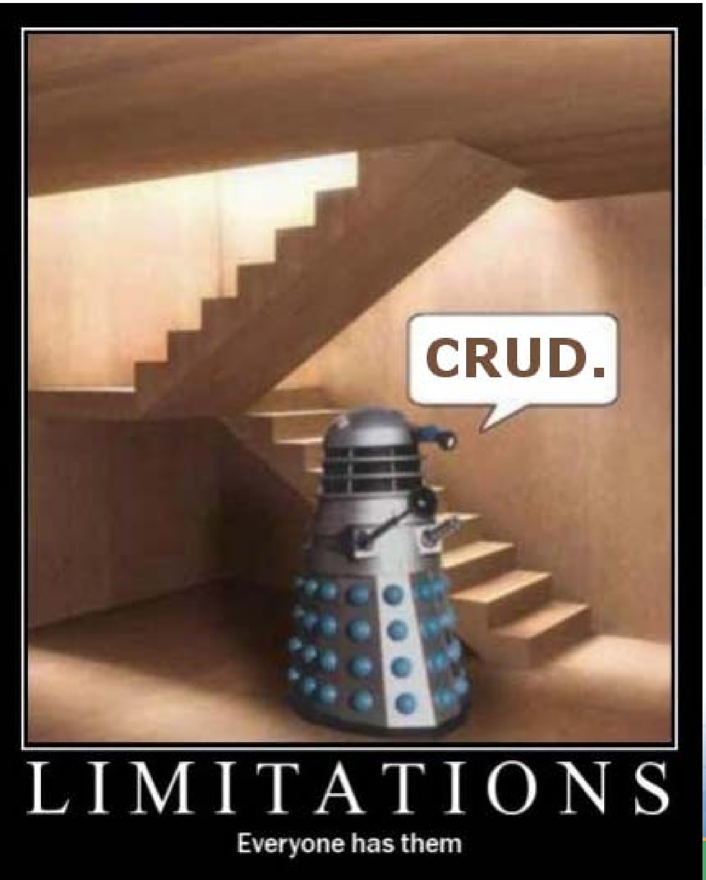
- MAMMOTH built via MOOSE framework (Multi-physics Object Oriented Simulation Environment)
- MOOSE allows implicit coupling of MOOSE animals
- MAMMOTH is the MOOSE-based multi-physics reactor analysis tool.
  - At present, TREAT core simulation efforts rely on BISON (fuel performance), Rattlesnake (time-dependent neutron transport) and MAMMOTH.



- LWR-type pin experiments are being evaluated using RELAP-7 as well.
- Note that MAMMOTH is a single executable code with multiple personalities all co-existing.
- All codes are based on FEM – MOOSE routines perform all solutions.
- All data from all codes is available to the solver(s) used.

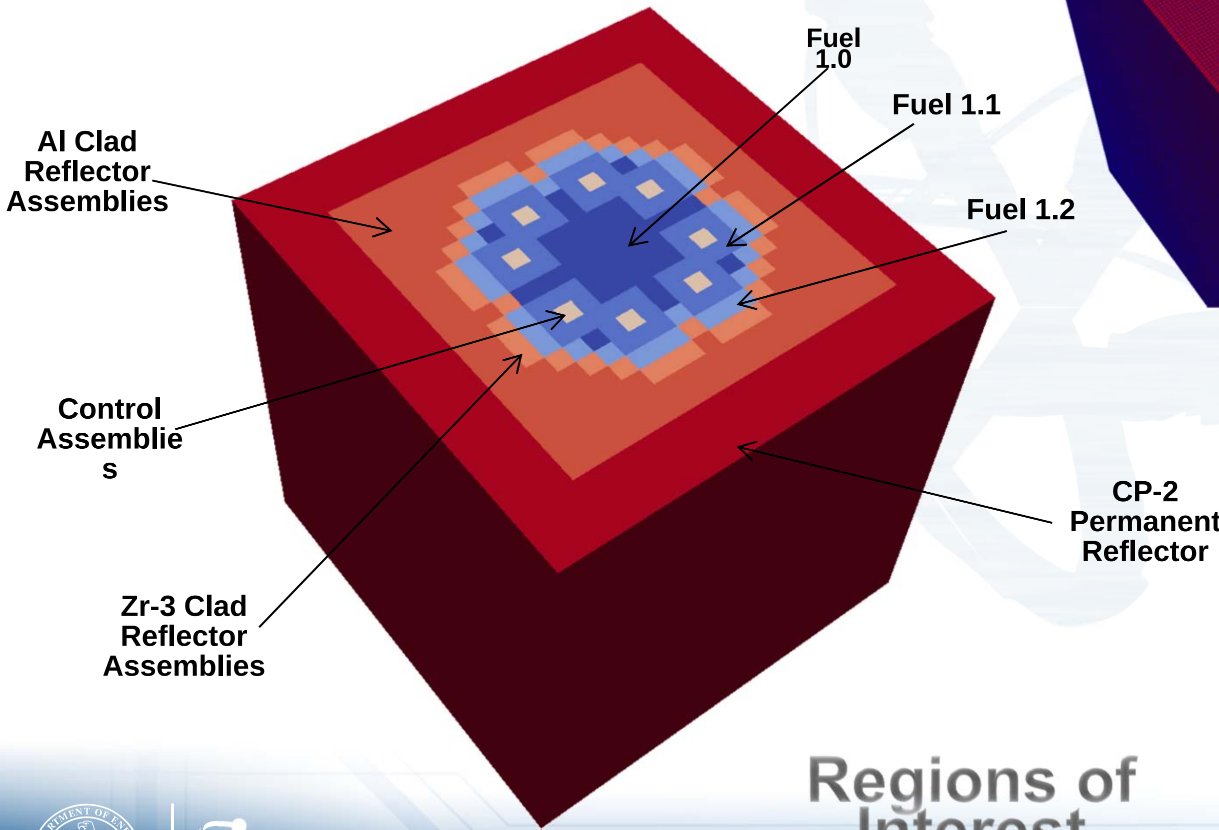
TREAT Modeling and Simulation (M&S)

- Unfortunately, advanced modeling and simulation isn't.
- Based on an advanced concept, the process to adapt that concept to a complex real-world problem requires time in terms of effort and testing.

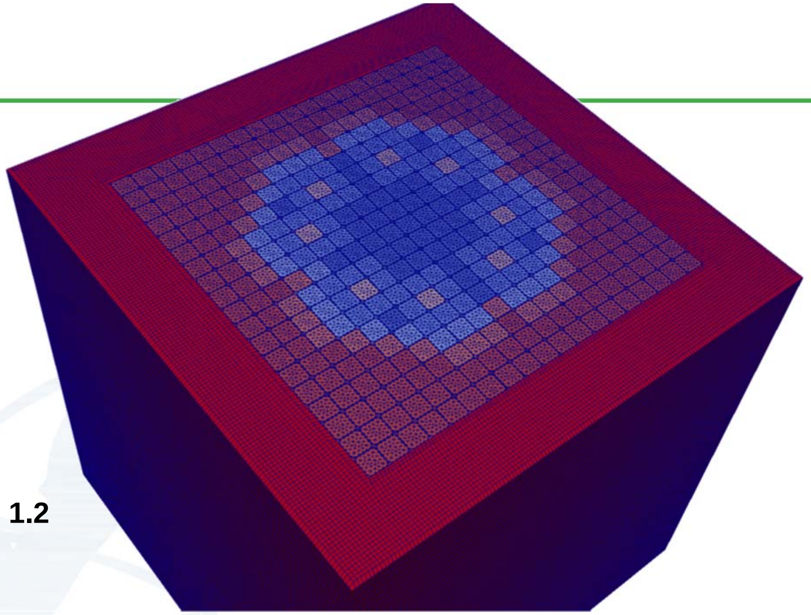


- The desired outcome of MAMMOTH M&S will be to simulate the complex interactions occurring in a TREAT experiment, driven by the coupled physics of a temperature-limited or controlled transient.
- The first phase of this approach has been to develop the core transient simulation capability that couples RATTLESNAKE, BISON, and cross section generation.
- A parallel, independent effort studied burnup of fuel pins during a reactor cycle, followed by a rapid transient.

Minimum Critical Core

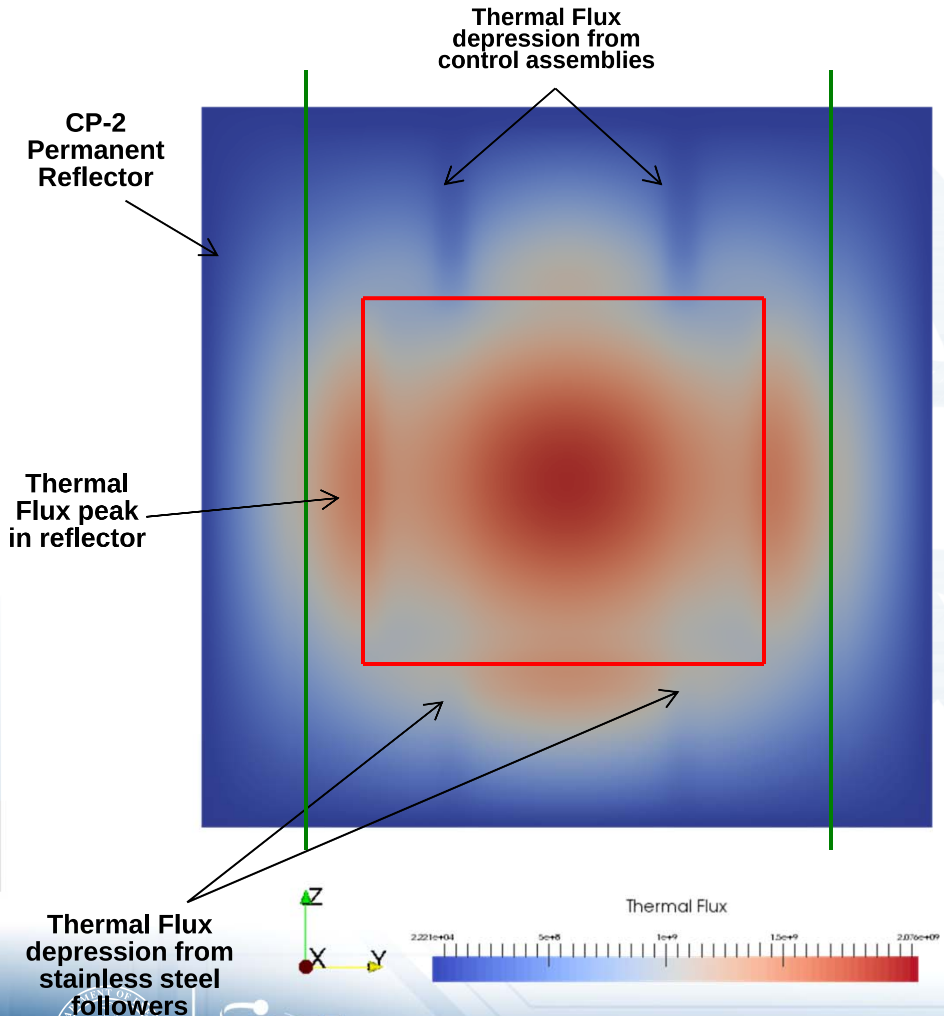


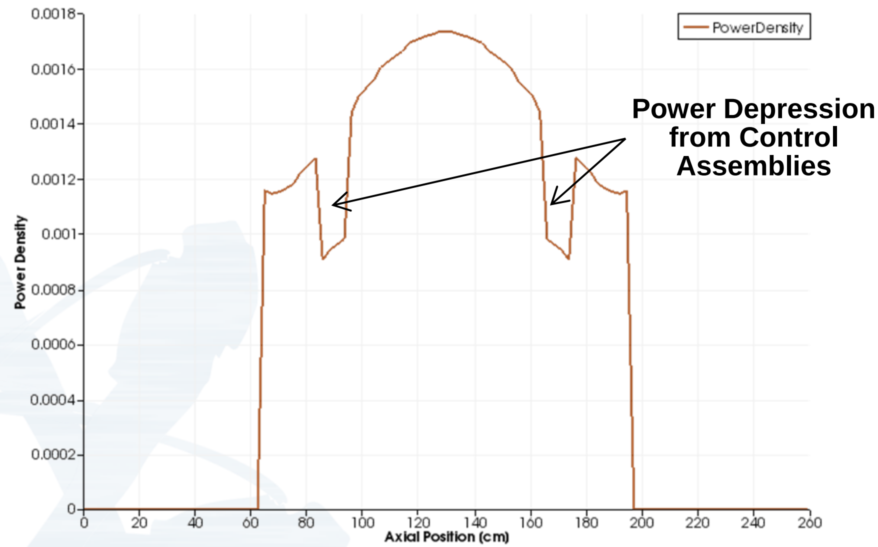
Regions of Interest

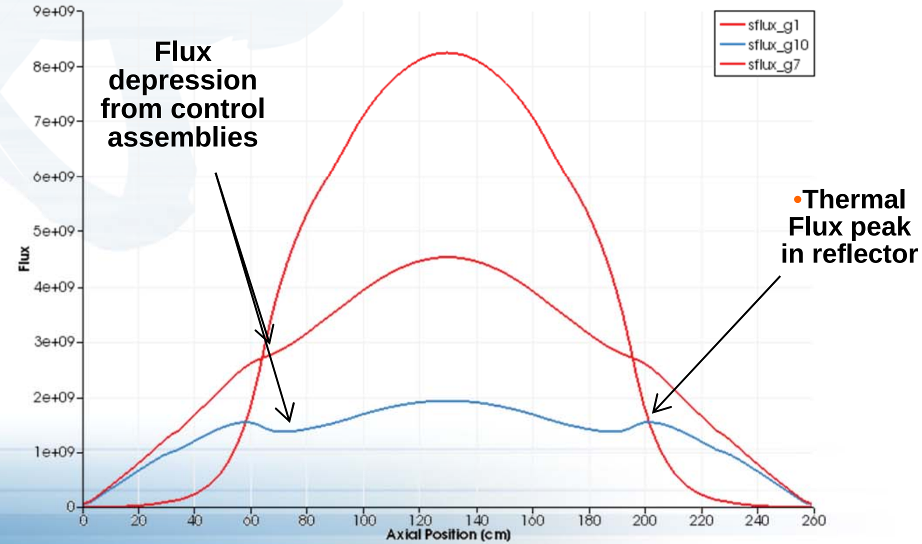


Meshing

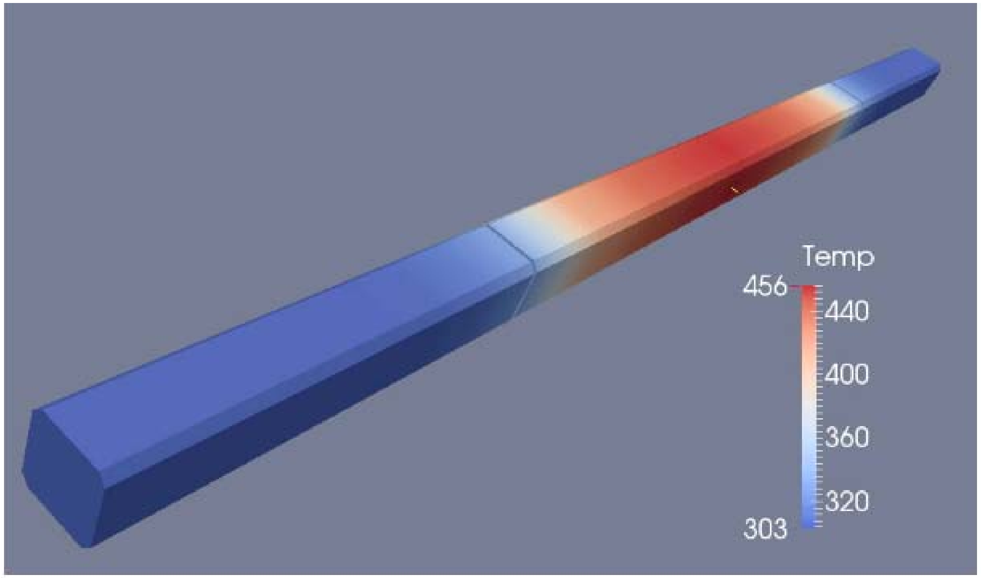
Minimum Critical Core

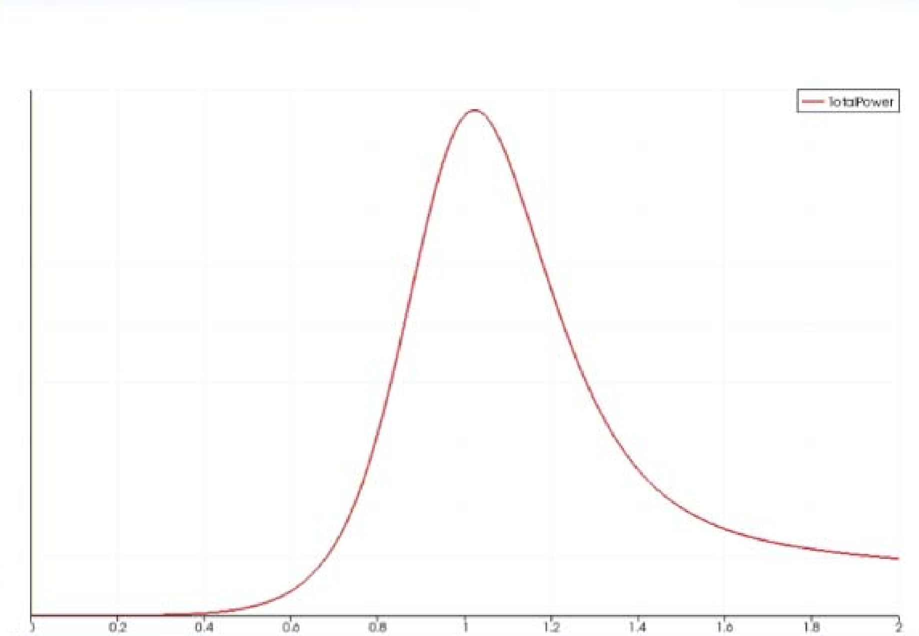






Coupled Physics in MAMMOTH

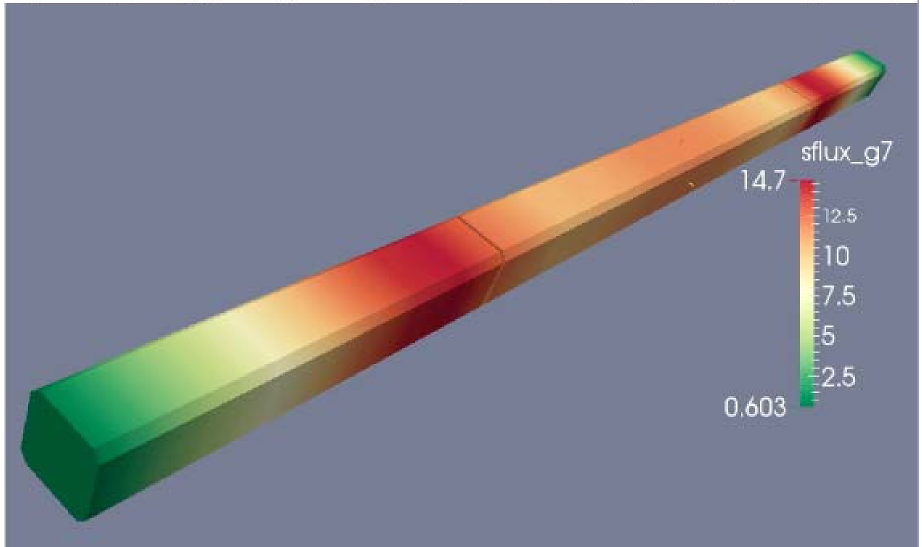




Temperature (K) ↑

- Reactivity increase (boron removal) between 0.01 and 0.1s
- Reactivity decrease is due to temperature feedback

Thermal Flux →

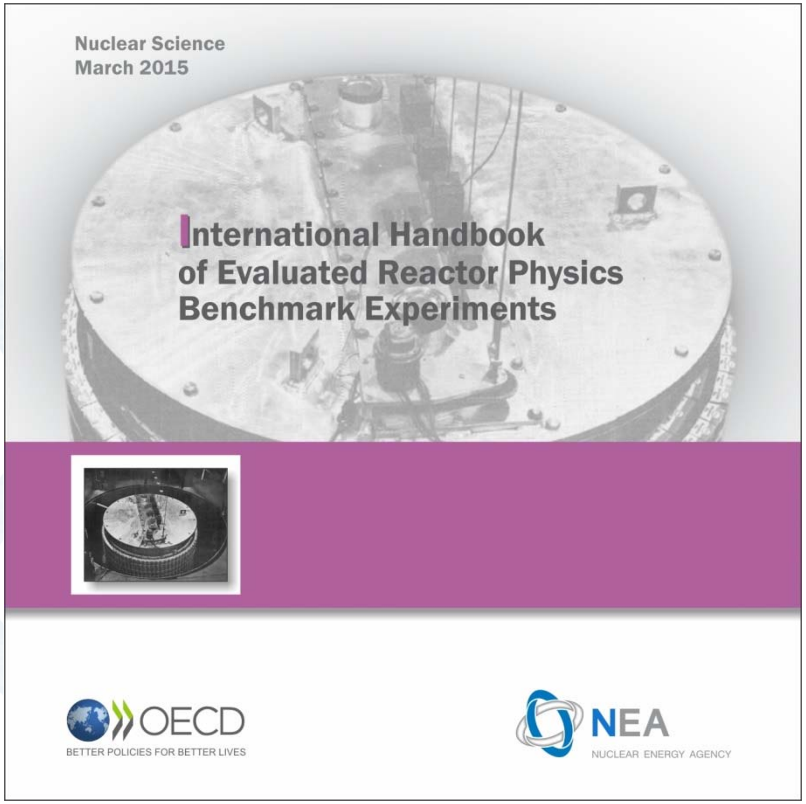


IRPhEP Recommendations

International Handbook of Evaluated Reactor Physics Benchmark Experiments

March 2015 Edition

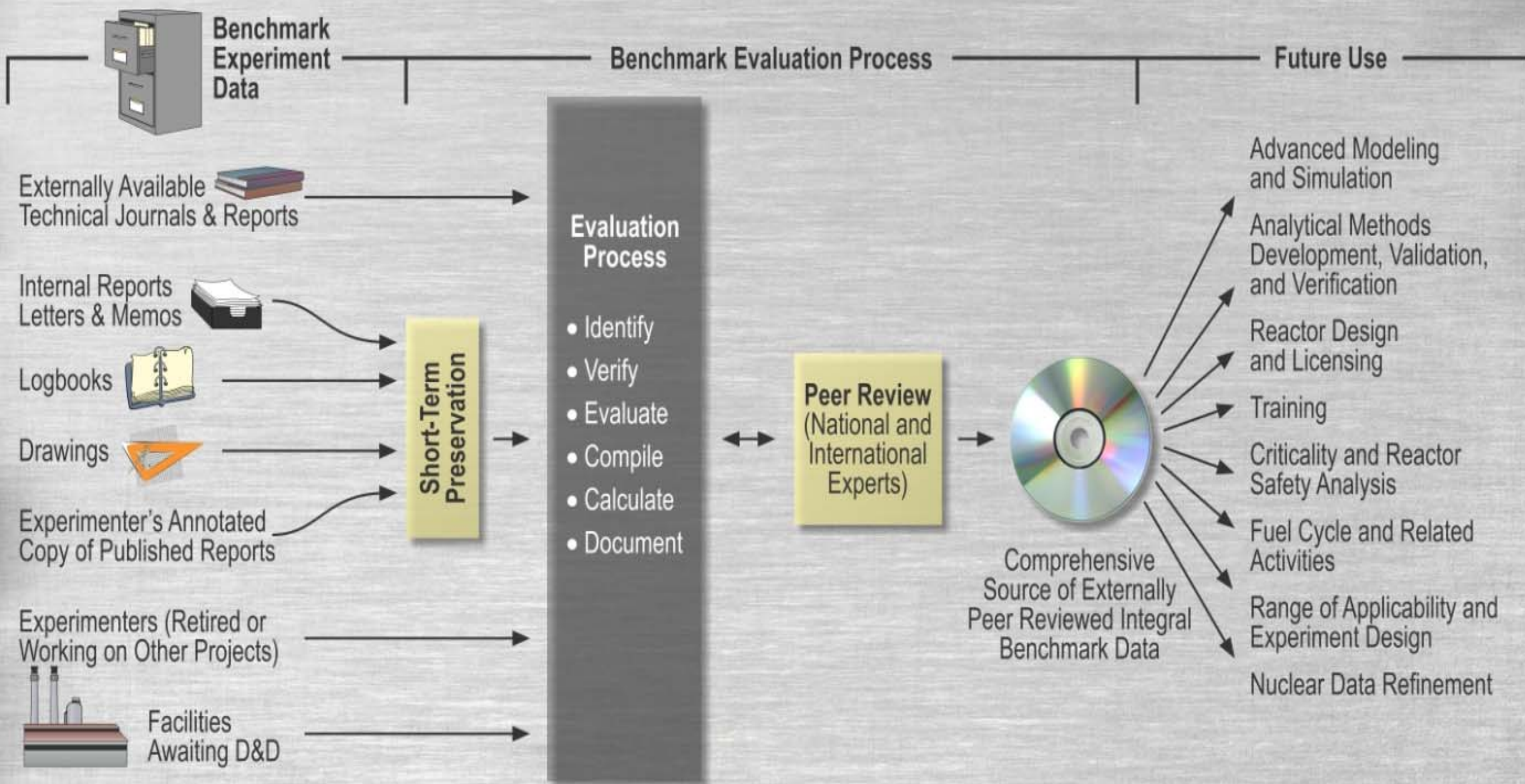
- 20 Contributing Countries
- Data from 143 Experimental Series performed at 50 Reactor Facilities
- Data from 139 are published as approved benchmarks
- Data from 4 are published in DRAFT form
- Handbook available to OECD member countries, all contributing countries, and to others on a case-by-case basis



http://irphep.inl.gov/

http://www.oecd-nea.org/science/wprs/irphe/

INTERNATIONAL BENCHMARK PROGRAMS



Baseline Assessment of TREAT for Modeling and Analysis Needs

- **INL/EXT-15-35372**
- **October 2015**
- **One-Stop-Shop**
  - **Drawings**
  - **Materials**
- **Modeling and simulation**
- **NOT A BENCHMARK**
  - **But still very useful**
    - **For doing a benchmark**

Steps in Benchmark Completion

- Generate detailed TREAT MCNP models
- Perform model simplifications
  - Develop benchmark models
  - Compute biases and bias uncertainties
- Evaluate experimental uncertainties
- Prepare draft benchmark report
- Internal review
- Independent review (IRPhEP)
- IRPhEP Technical Review Meeting
  - April
- Publish IRPhEP Handbook
  - September/October

Typical Measurement Types for IRPhEP

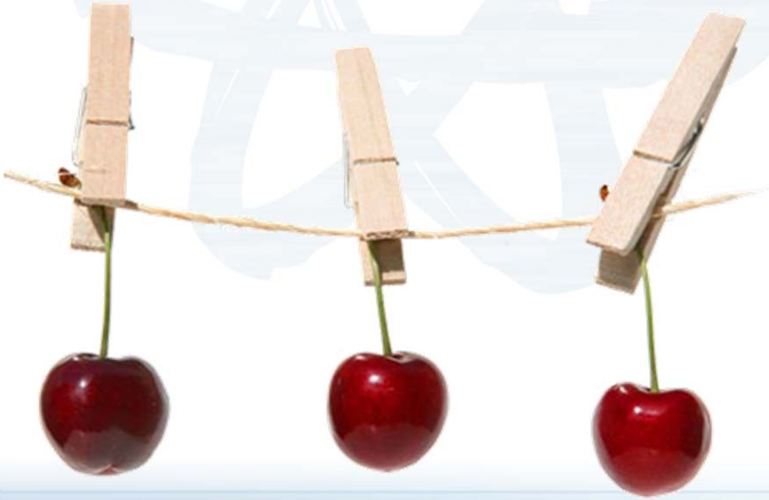
- Critical/ Subcritical
- Buckling/ Extrapolation Length
- Spectral Characteristics
- Reactivity Effects
- Reactivity Coefficient Data
- Kinetics Measurements Data
- Reaction-Rate Distributions
- Power Distribution Data
- Isotopic Measurements
- Miscellaneous

If it was worth measuring, then it is worth evaluating.

Key Items of Interest (i.e. Lessons Learned)

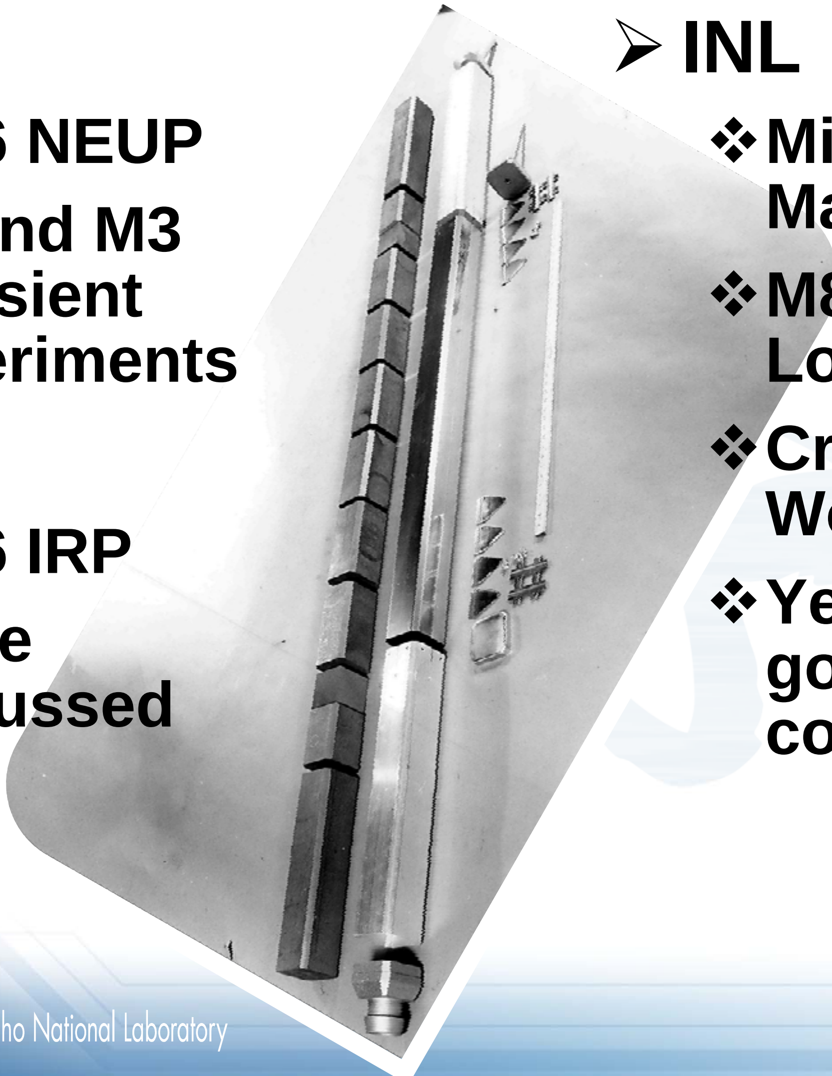
- **Can submit evaluation by parts**
  - Criticality 1st year
  - Additional measurements 2nd-3rd years
  - This allows for feedback earlier in a multiyear process
- **Reduce statistical uncertainty or evaluated results will be worthless**
- **Split up major core configurations into separate reports**
  - TREAT-FUND-RESR-001
  - -002, -003, -004, etc.

Optimally Picking the Low-Hanging Fruit



Current Known Benchmarking Efforts

- **NCSU**
  - **FY16 NEUP**
  - **M2 and M3 Transient Experiments**
- **OSU**
  - **FY16 IRP**
  - **To Be Discussed**



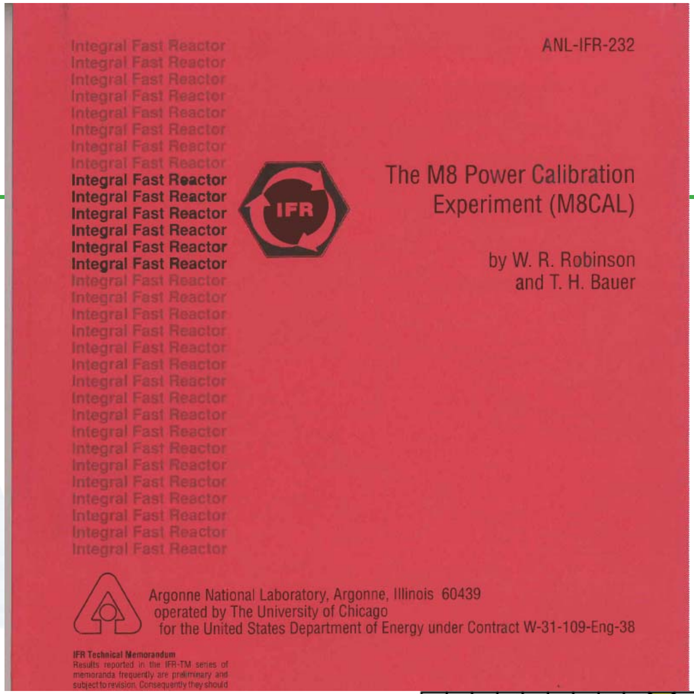
- **INL**
  - **Minimum Critical Mass Core Loading**
  - **M8CAL Core Loading**
  - **Criticality and Rod Worths**
  - **Yet to identify a good intermediate core loading**

What is Most Relevant Today

- Numerous experimental series performed in TREAT during its years of operation
  - Physics testing
  - LWR fuel
  - Graphite fuel
  - LMFR fuel
  - 6604 reactor startups
  - 1469 core loadings
  - 2885 transient runs
- Core configuration and control rods positions adjustable
- Only experimental campaigns with upgraded core
  - M8CAL
  - AN-CAL
- These experiments also have most available documented data

M8CAL

- Current core loading
- High fissile pins but low fissile monitor wires
- Low-Level Steady-State (LLSS) runs and transients
- With and without neutron filters


ANL-IFR-232

Integral Fast Reactor

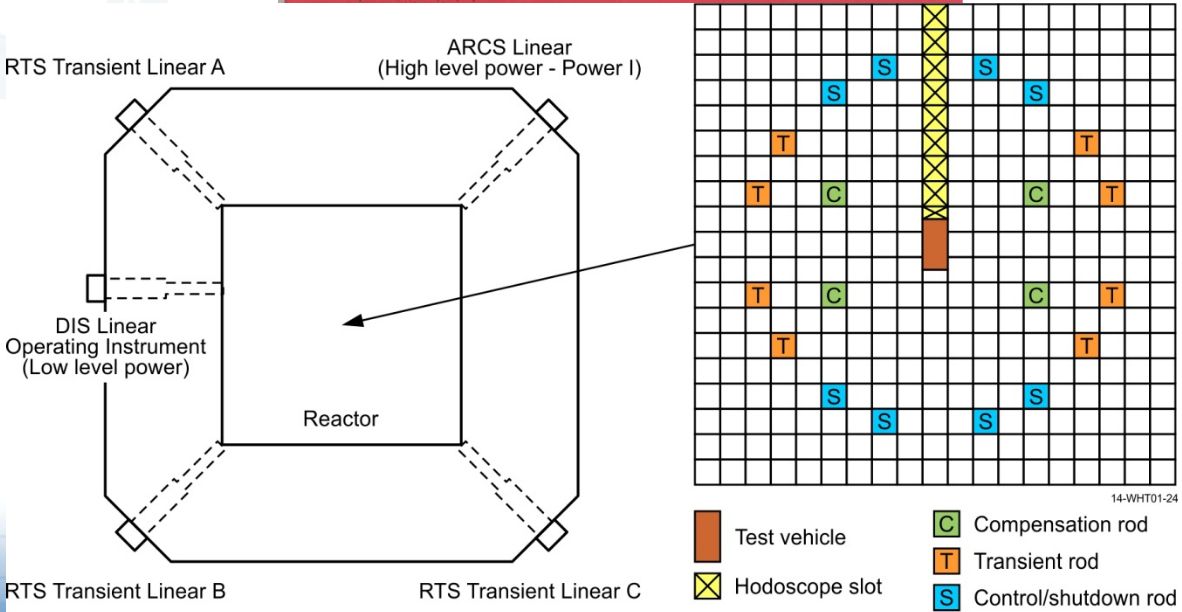
IFR

The M8 Power Calibration Experiment (M8CAL)

by W. R. Robinson and T. H. Bauer

Argonne National Laboratory, Argonne, Illinois 60439
operated by The University of Chicago
for the United States Department of Energy under Contract W-31-109-Eng-38

IFR Technical Memorandum
Results reported in the IFR-TM series of memoranda frequently are preliminary and subject to revision. Consequently they should



Summary of M8CAL TREAT Operations

Core Configuration	TREAT Transient Number	Date of TREAT Operation	Control Rod Configuration	Wire Number	Test Train	Identification	Wire Holder	TREAT Energy, MJ	Hodoscope Operation?
Full-slotted	---	10/16/90 10/17/90	B		Fueled	Low-level, steady-state (LLSS) irradiation providing background signal for the hodoscope (NO FUEL)	---	437	Yes
Full-slotted	---	10/19/90	B	L91-8-10	Unfueled	LLSS	LO3	667	Yes
Full-slotted	2811	10/25/90	B	L91-8-11	Unfueled	Full Heat Balance Transient	LO3	655.4	No
Full-slotted	2812	10/26/90	B	L91-8-12	Unfueled	Heat Balance Transient (Partial)	LO3	404.7	No
Full-slotted	2815	11/14/90	D	L91-8-13	Unfueled	8-s Period Transient	LO3	996.0	Yes
Full-slotted	2816	11/15/90	D	L91-8-14	Unfueled	8-s Period Transient (Partial)	LO3	661.8	No
Half-slotted	---	8/24/92	A	L91-60-1	Unfueled	LLSS	LO3	576	No
Half-slotted	---	8/26/92	A	---	Fueled	LLSS for hodoscope background signal measurement (NO FUEL)	---	---	Yes
Half-slotted	2858	8/31/92	C	L91-8-2	Unfueled	Heat Balance Transient (Partial)	LO3	423.1	No
Half-slotted	2862	9/23/92	C	L91-8-3	Unfueled	Full Heat Balance Transient	LO3	655.0	Yes
Half-slotted	2864	10/14/92	D	L91-8-4	Unfueled	8-s Period Transient	LO3	1868.4	Yes
Half-slotted	2867	10/27/92	D	L91-8-7	Unfueled	30-s Period Transient	LO3	1956.7	Yes
Half-slotted	2868	10/29/92	C	L91-8-8	Unfueled	30-s Period Transient (Partial)	LO3	1198.6	No
Half-slotted	2869	10/30/92	C	L91-8-9	Unfueled	30-s Period Transient (Partial)	LO3	602.1	No
Half-slotted	2871	11/10/92	D	L91-8-15	Unfueled	30-s Period Transient (with power roll-over)	LO3	1999.8	No
Half-slotted	2873	11/19/92	D	L91-8-5	Unfueled	80-s Period Transient	LO3	1797.8	Yes
Half-slotted	---	11/20/92	A	L91-8-1	Unfueled	LLSS	LO3	576	Yes
Half-slotted	---	1/29/93	A	T-433 T-462	Fueled	LLSS	---	480	Yes
Half-slotted	---	2/8/93	A	L91-8-6	Unfueled	LLSS	LO3	480	Yes
Half-slotted	---	2/12/93	A	H91-8-1	Unfueled	LLSS	M2CAL	576	No
Half-slotted	2874	2/17/93	D	H91-8-2	Unfueled	8-s Period Transient	M2CAL	1807.1	No
Half-slotted	---	3/2/93	B	L91-8-16	Unfueled	LLSS	LO3	576	Yes
Half-slotted	---	3/5/93	A	H-316 H-307	Fueled	LLSS	---	480	Yes

AN-CAL

- Similar to future loadings with current core
- Various core characterization packages
- Detailed temperature-limited transients for reactivity limits

ANL/NPR-92/11

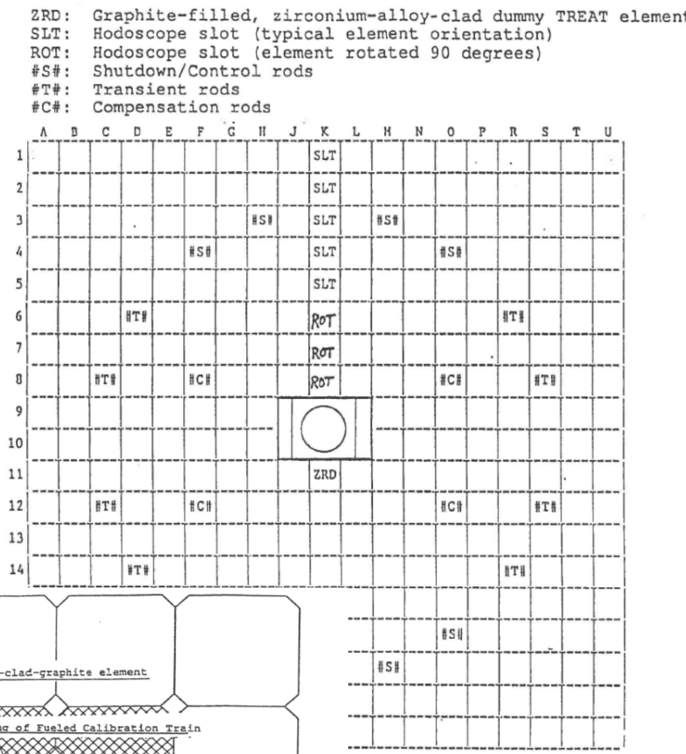
TREAT NPR CALIBRATION EXPERIMENT
AN-CAL

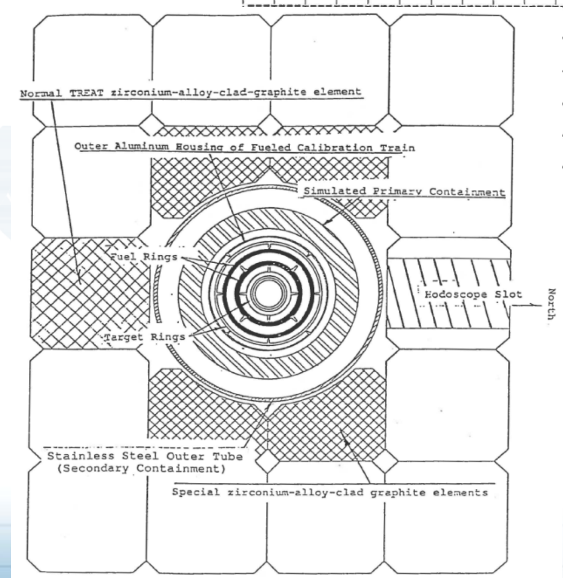
by

W. R. Robinson, R. J. Page, and A. E. Wright

Reactor Engineering Division
Argonne National Laboratory
Argonne, Illinois 60439

September 1992





Summary of AN-CAL TREAT Operations

Date of TREAT Operation	Simulated Primary Container	Test Train	Identification	TREAT Energy, MJ	Monitor Wire Number	Location of Wire in Unfueled Calibration Train	Hodoscope Requirement
2/5/91	Stainless Steel (SST)	UCT	LLSS (Wire)	722.4	AN-48-1 AN-3x2-1 AN-3x2-2 AN-3x2-3	North East South West	Horizontal Scan
5/21	SST	UCT	Heat Balance (HB) (full)	219.2	AN-48-3 AN-3x2-15 AN-3x2-16 AN-3x2-17	North East South West	
5/23	SST	UCT	HB (partial)	144.5	AN-3x2-18	North	
5/24	SST	UCT	HB (partial)	74.91	AN-3x2-19	North	
5/28	SST	UCT	SBLOCA (1) (full)	1001(*)	AN-3x2-12	North	
5/29	SST	UCT	SBLOCA (1) (partial)	631.7	AN-3x2-13	North	
5/30	SST	UCT	SBLOCA (1) (partial)	311.2	AN-3x2-14	North	
6/11	SST	UCT	SBLOCA (2) (full)	894.2	AN-48-2 AN-3x2-4 AN-3x2-5 AN-3x2-6	North East South West	Operational
6/27	SST	UCT	SBLOCA (2) (partial)	568.0	AN-3x2-7	North	
6/28	SST	UCT	SBLOCA (2) (partial)	279.1	AN-3x2-8	North	
7/31	SST	UCT	SBLOCA (3) (full)	847.5	AN-3x2-26	North	
8/ 8	SST	UCT	LOPA (full)	976.1(*)	AN-3x2-23	North	
8/ 9	SST	UCT	LOPA (partial)	597.8	AN-3x2-24	North	
8/12	SST	UCT	LOPA (partial)	304.8	AN-3x2-25	North	
8/14	SST	UCT	HB (partial)	144.5	AN-3x2-27	North	
8/15	SST	UCT	TOP (full)	959.0(*)	AN-3x2-9	North	Operational
8/16	SST	UCT	TOP (partial)	580.3	AN-3x2-10	North	
8/20	SST	UCT	TOP (partial)	314.8	AN-3x2-11	North	
8/21	SST	UCT	LLSS (Wire)	720.0	AN-48-5	North	Vertical Scan
9/25	SST	FCT	LLSS (Fuel)	480.0			Horizontal Scan
3/31/92	Aluminum	UCT	LLSS (Wire)	720.0	AN-48-4 AN-3x2-20 AN-3x2-21 AN-3x2-22	North East South West	Horizontal Scan
4/24/92	Aluminum	FCT	LLSS (Fuel)	299.7			Horizontal Scan

(*) Clipped transient with power tail.

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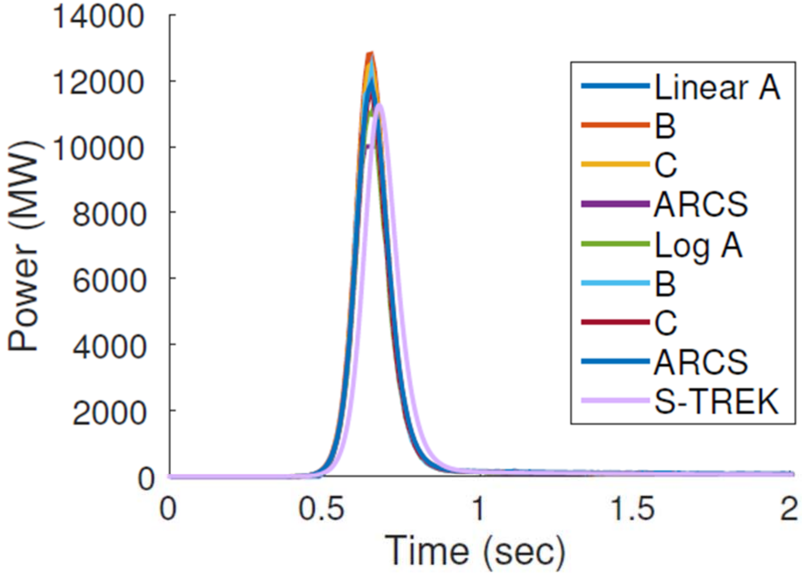
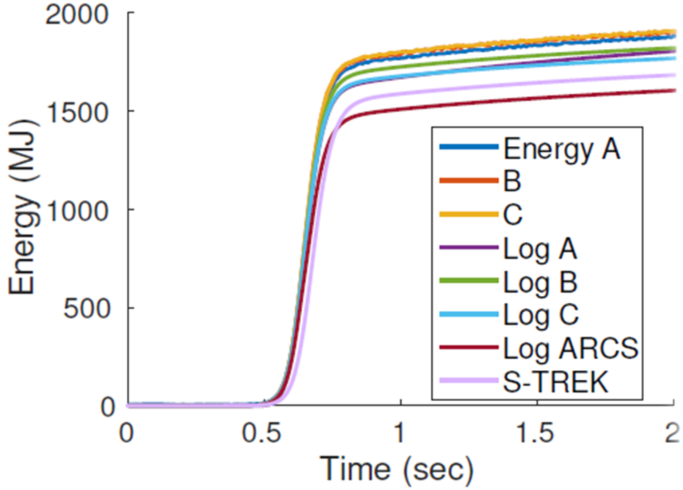
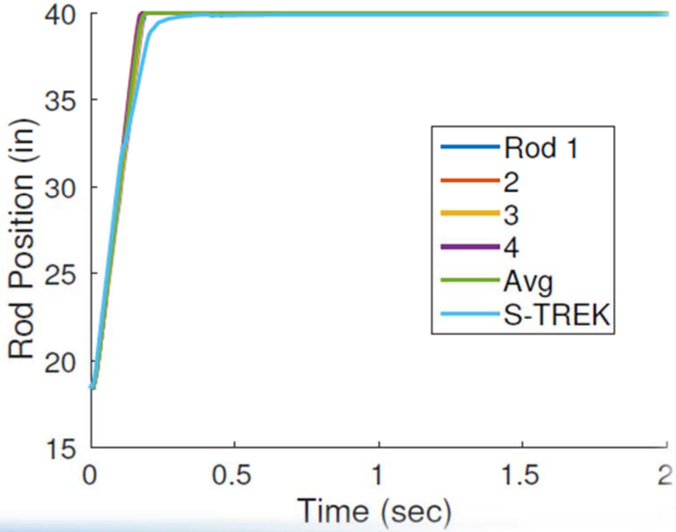
* Courtesy Vishal Patel (CSNR)

Transient 2857 (Natural, Unshaped)

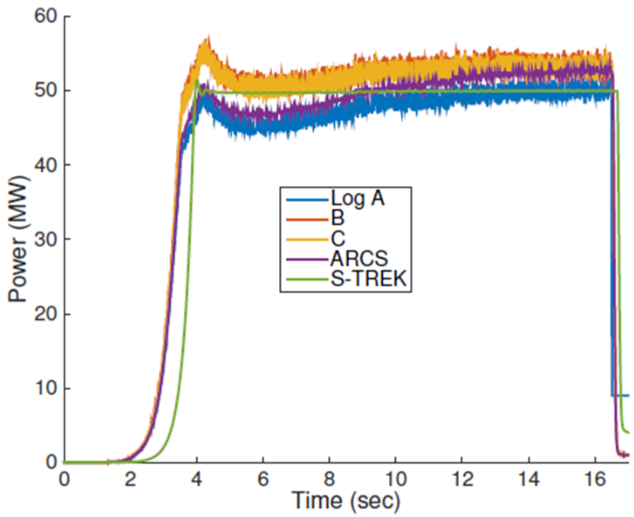


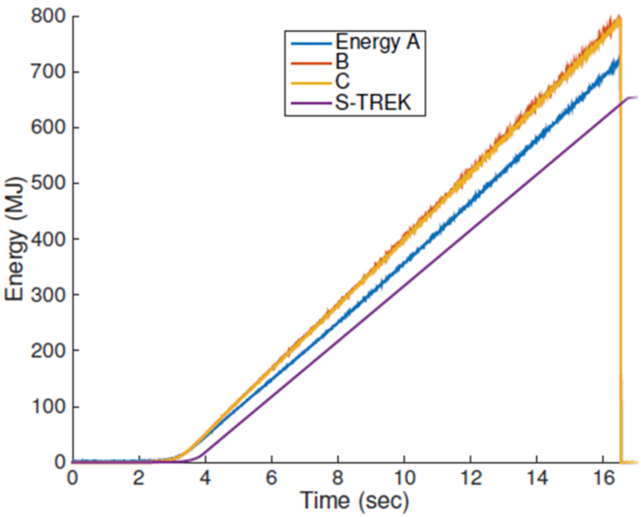


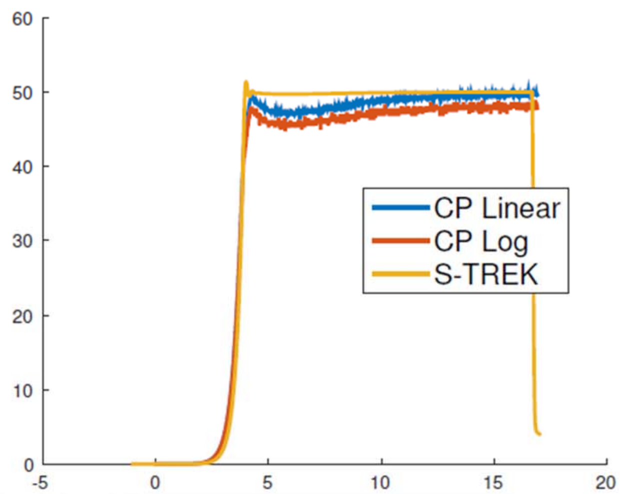


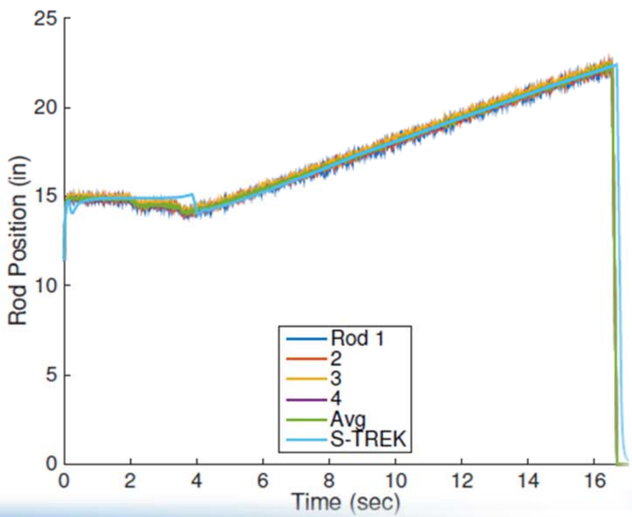
* Courtesy Vishal Patel (CSNR)

Transient 2860 (Shaped)









TREAT-IRP
Best Path Forward

- **Goal:**
  - ❖ 2 steady-state and 2 transient tests
- **Steady-state cores**
  - ❖ M8CAL and AN-CAL (pick a loading from each)
  - ❖ IRPhEP benchmark evaluations
- **Transient tests**
  - ❖ Pick transient test that corresponds with selected steady-state core loadings
  - ❖ Natural and a shaped transient for diversity
  - ❖ Expand existing IRPhEP evaluation work
- **Stretch Goal:**
  - ❖ Can use knowledge and expertise to further evaluate M8CAL and AN-CAL experiment suites

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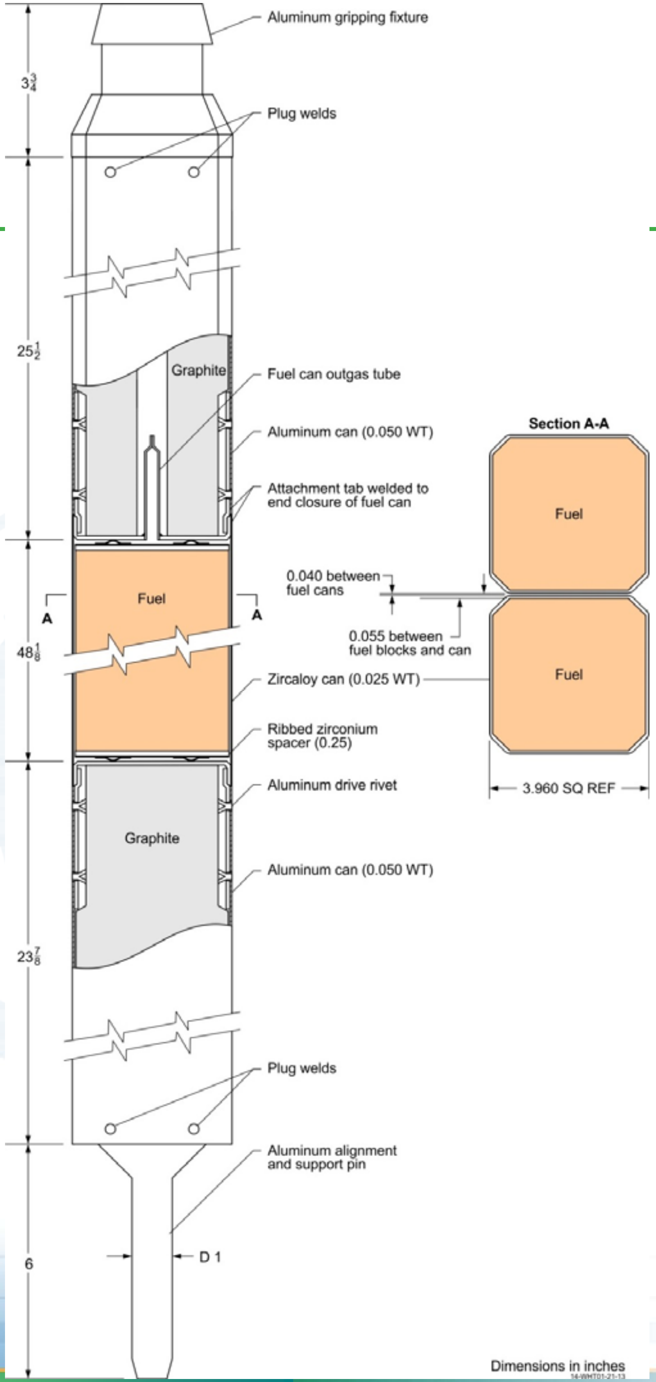
Conclusions

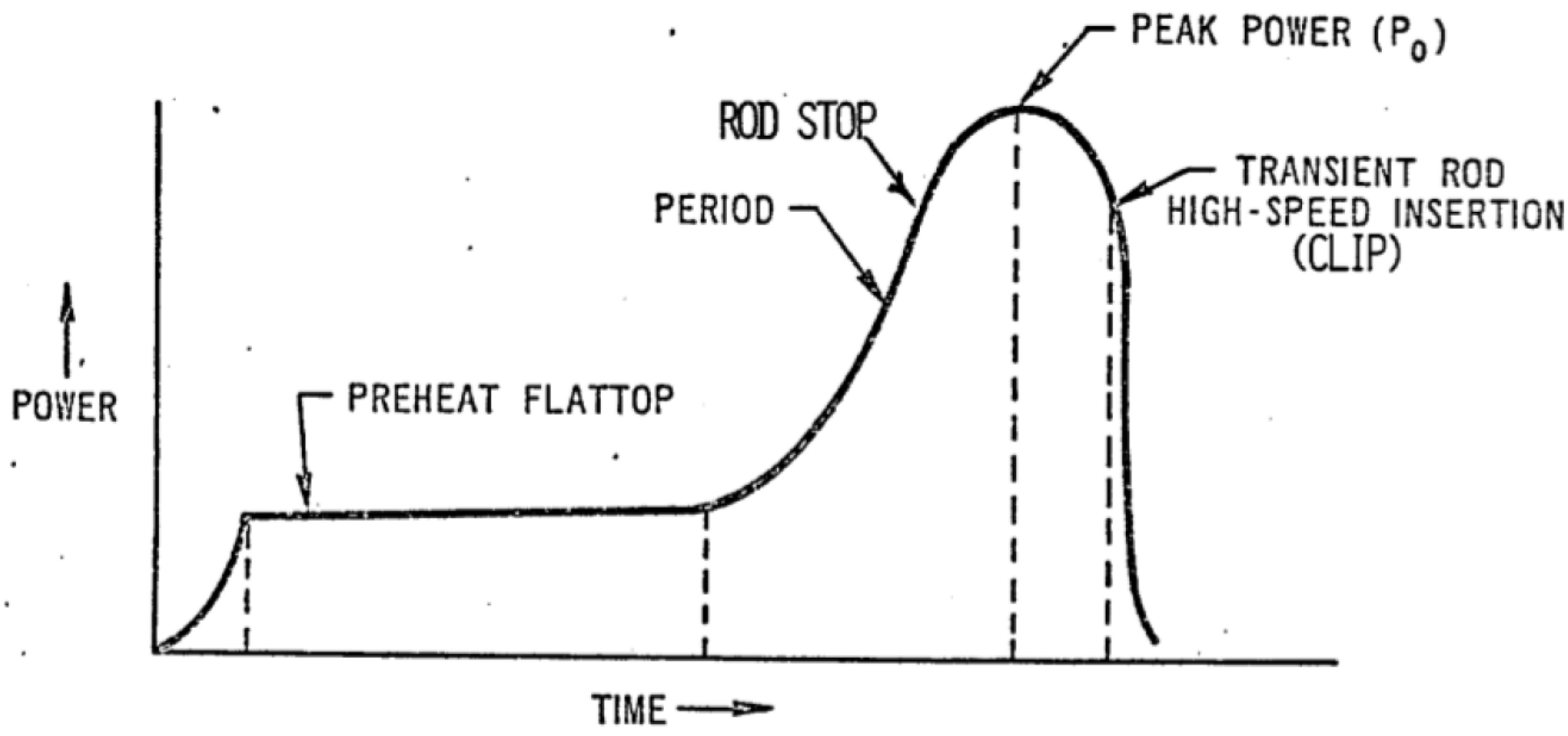
- Determine what is neutronically important per measurement type
- Ongoing progress in MOOSE modeling and simulation
- Established IRPhEP format for neutronics benchmark development
- M8CAL and AN-CAL experiments easiest option for most impactful benchmark development

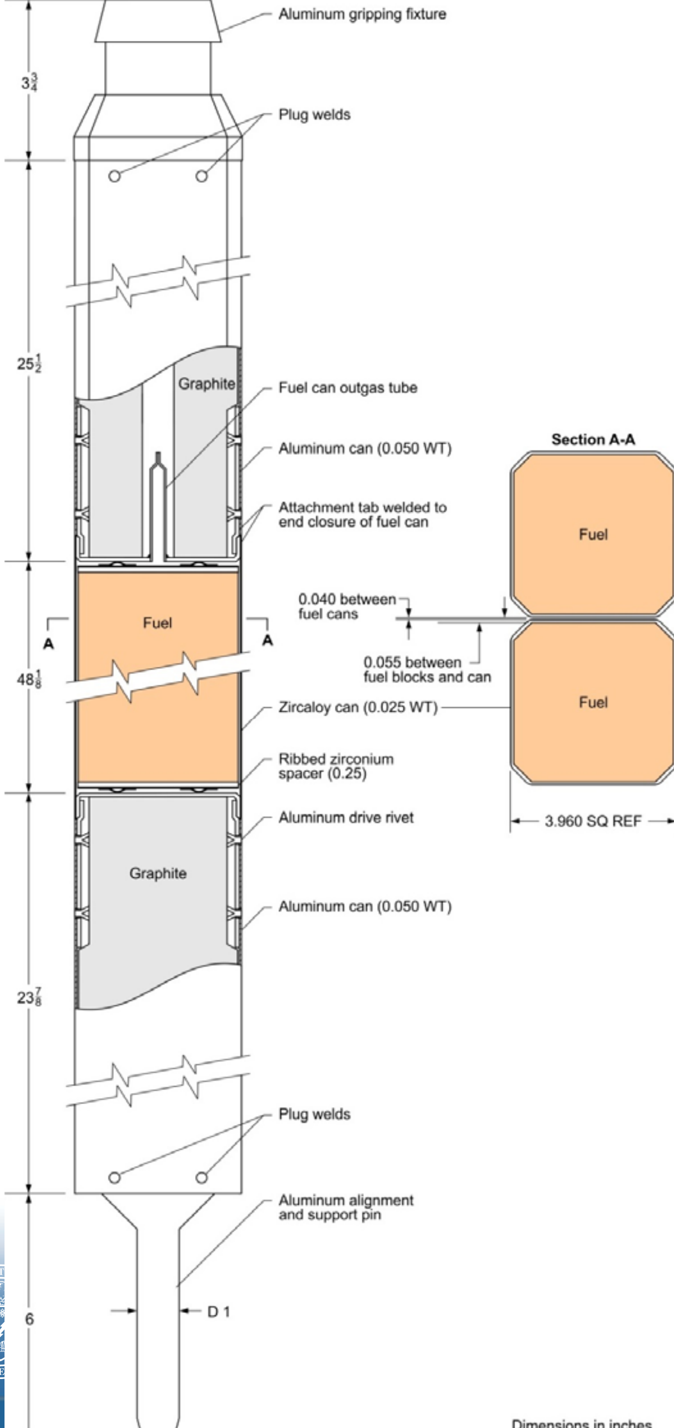
¿Questions?


Aluminum gripping fixture
Plug welds
Graphite
Fuel can outgas tube
Aluminum can (0.050 WT)
Attachment tab welded to end closure of fuel can
Section A-A
Fuel
Fuel
0.040 between fuel cans
0.055 between fuel blocks and can
Fuel
A
A
Zircaloy can (0.025 WT)
Ribbed zirconium spacer (0.25)
Aluminum drive rivet
3.960 SQ REF
Graphite
Aluminum can (0.050 WT)
Plug welds
Aluminum alignment and support pin
D 1
Dimensions in inches

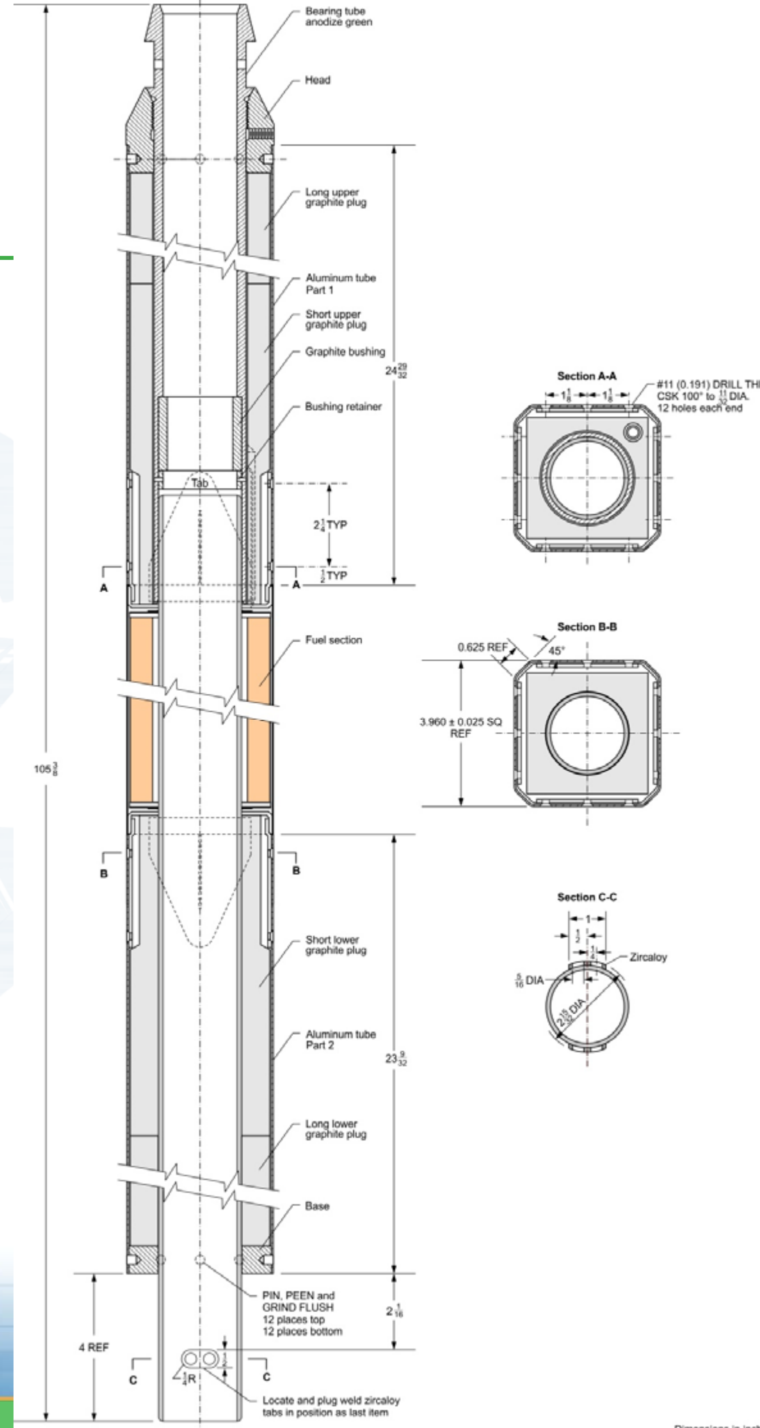
Extra Slides

Transient Example

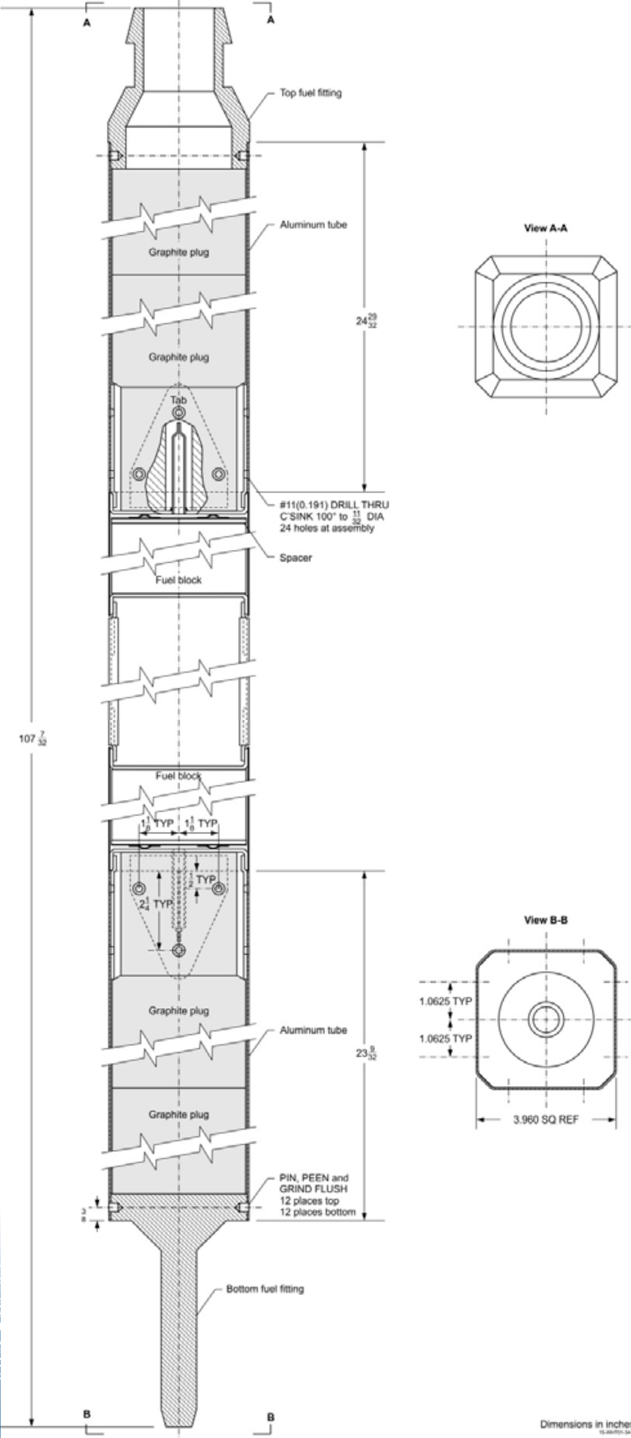


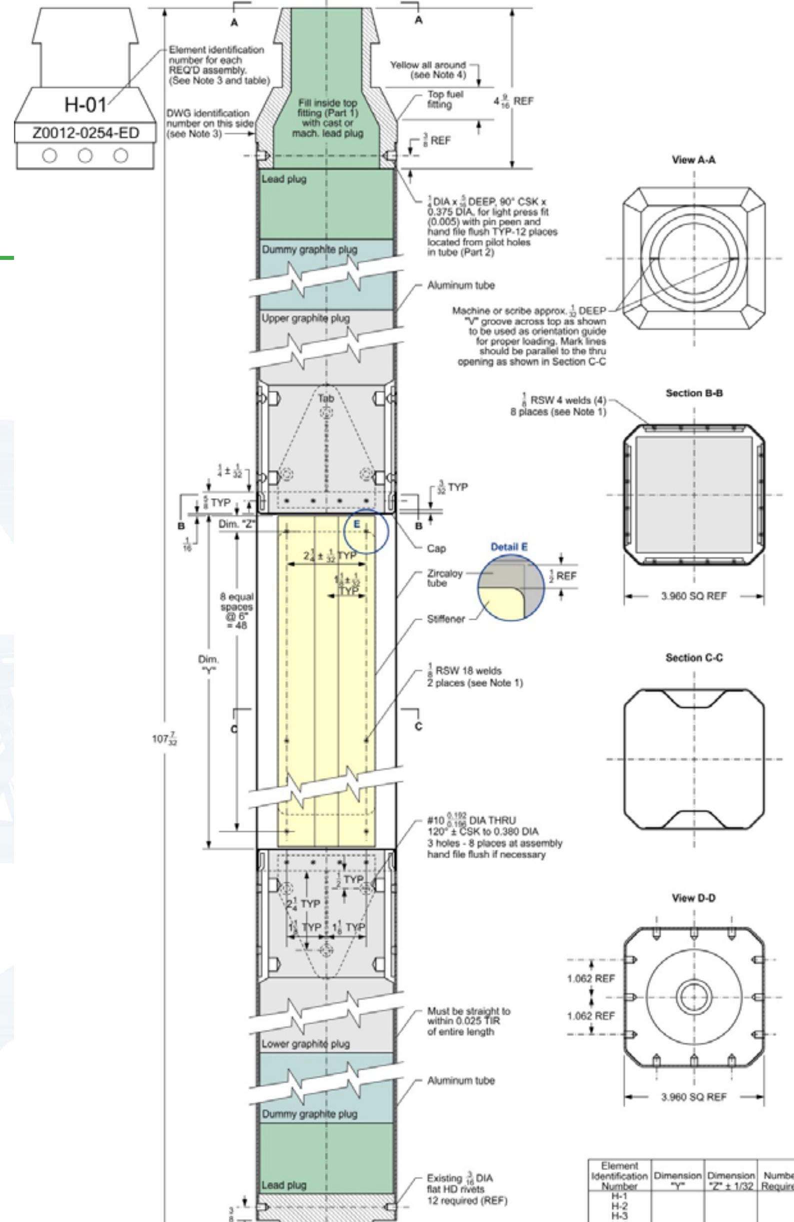


Aluminum gripping fixture
Plug welds
Graphite
Fuel can outgas tube
Aluminum can (0.050 WT)
Attachment tab welded to end closure of fuel can
Fuel
A
A
0.040 between fuel cans
0.055 between fuel blocks and can
Zircaloy can (0.025 WT)
Ribbed zirconium spacer (0.25)
Aluminum drive rivet
Graphite
Aluminum can (0.050 WT)
Plug welds
Aluminum alignment and support pin
D 1
Section A-A
Fuel
Fuel
3.960 SQ REF
Dimensions in inches



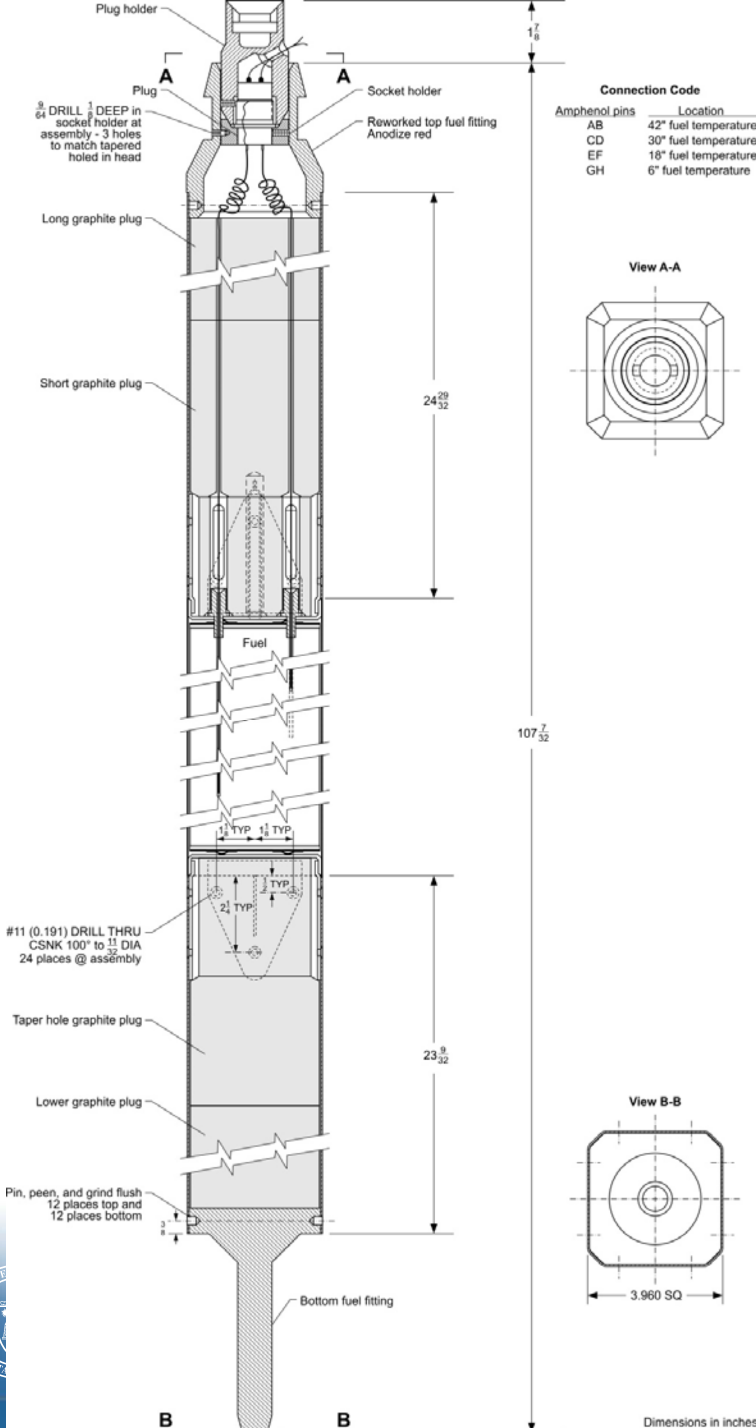
Bearing tube anodize green
Head
Long upper graphite plug
Aluminum tube Part 1
Short upper graphite plug
Graphite bushing
Bushing retainer
Tab
TYP
TYP
A
A
Fuel section
B
B
Short lower graphite plug
Aluminum tube Part 2
Long lower graphite plug
Base
PIN, PEEN and GRIND FLUSH 12 places top 12 places bottom
4 REF
C
C
Locate and plug weld zircaloy tabs in position as last item
Section A-A
#11 (0.191) DRILL THRU CSK 100° to DIA. 12 holes each end
Section B-B
0.625 REF
45°
3.960 ± 0.025 SQ REF
Section C-C
Zircaloy
DIA
Dimensions in inches



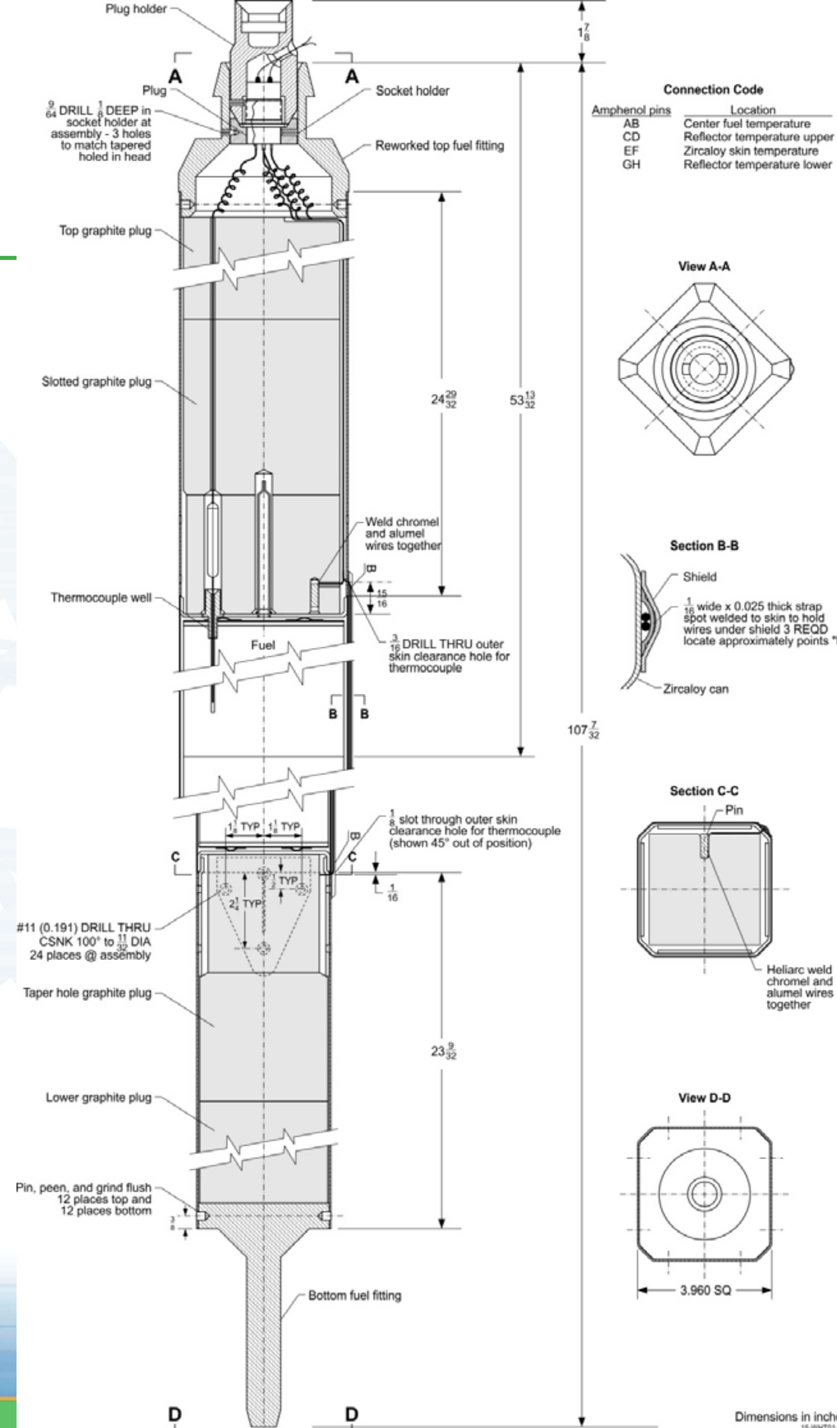


NOTES:
1. Spot weld and rivet assemble per SPEC R0501-1031-SF-00
2. For additional information see SPEC R0501-1031-SF-00
3. Engrave identification number as shown ($\frac{1}{4}$" high characters)
4. Anodize top fuel fitting (Part 1) surfaces to colors specified
5. Estimated weight 90 lbs
6. a Calculated MAX permissible tensile load on assembly 538 lbs
   b Calculated MAX permissible compressive load on assembly 210 lbs
7. Elements H-9, H-10, H-19B and H-20B have been modified per DWG Z0012-0265-ED

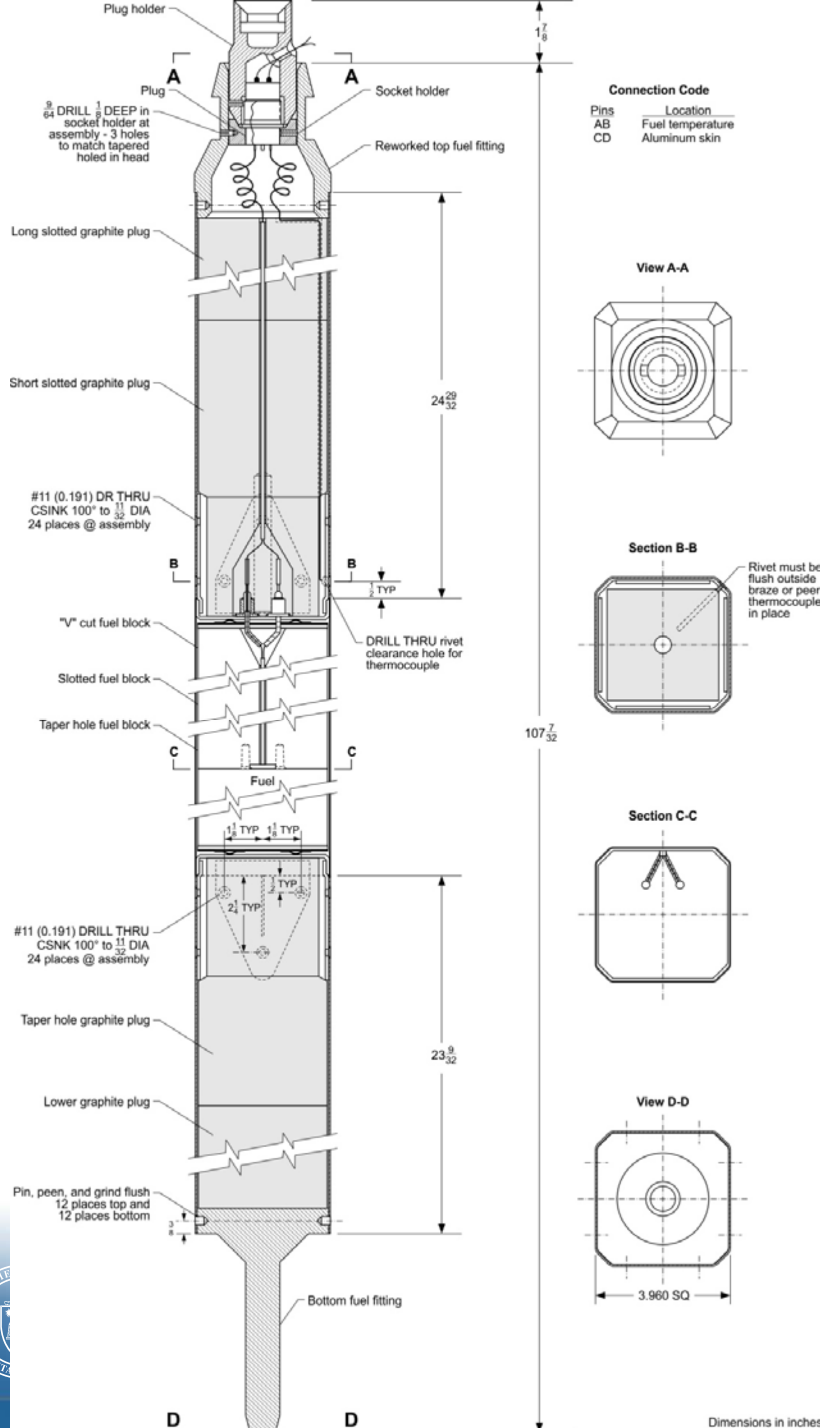
Element Identification Number	Dimension "Y"	Dimension "Z" ± 1/32	Number Required
H-1 H-2 H-3 H-4 H-5 H-6 H-7 H-8 H-9[7] H-10[7] H-11 H-12 H-13 H-14 H-15 H-16 H-17 H-18	49	7/16	1
H-19b[7]	50	5/16	
H-20b[7]	50	5/16	



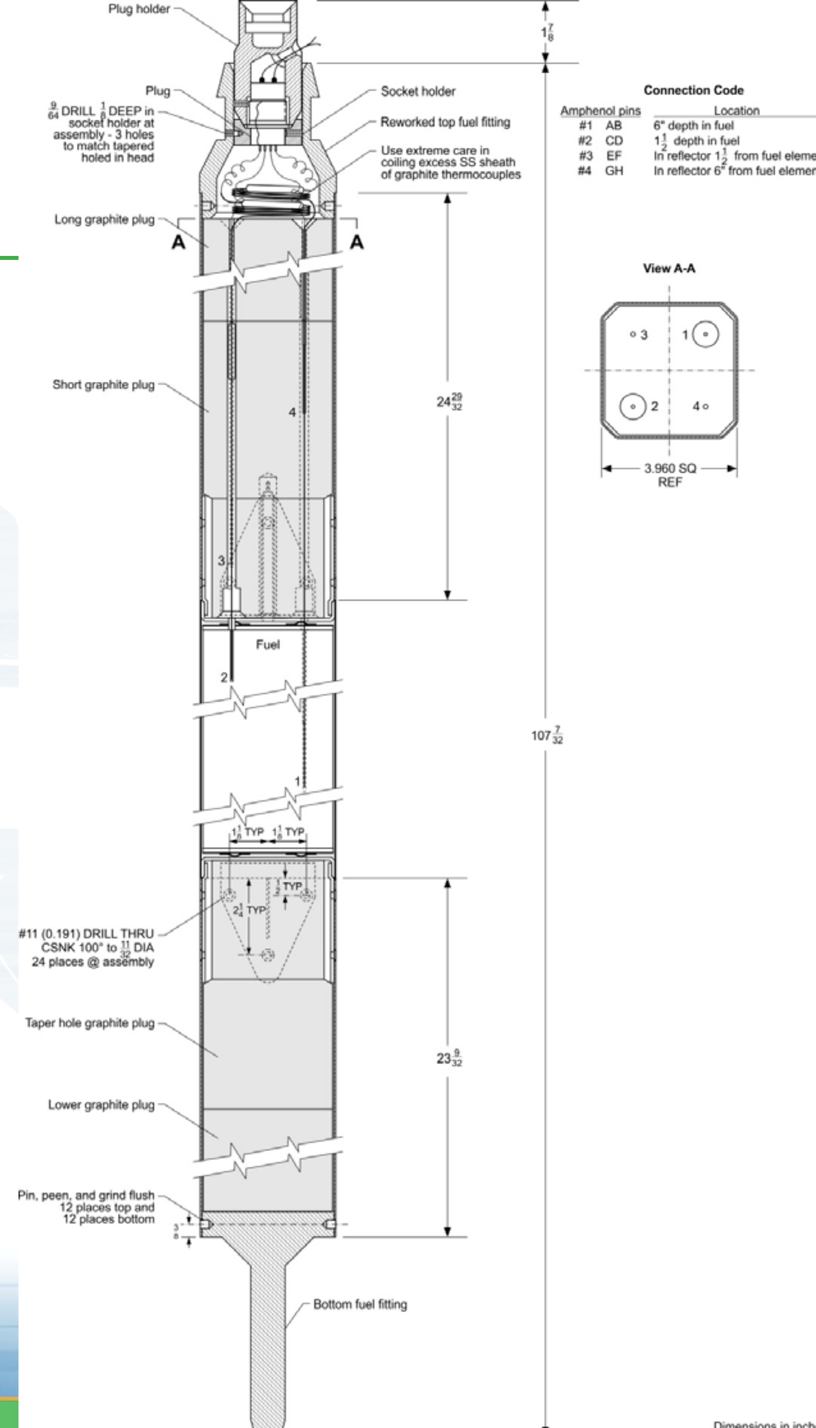
Plug holder
Plug
Socket holder
$\frac{9}{64}$ DRILL $\frac{1}{8}$ DEEP in socket holder at assembly - 3 holes to match tapered holed in head
Reworked top fuel fitting Anodize red
A
A
$1\frac{7}{8}$
Connection Code
Amphenol pins
Location
AB
42" fuel temperature
CD
30" fuel temperature
EF
18" fuel temperature
GH
6" fuel temperature
Long graphite plug
View A-A
Short graphite plug
$24\frac{29}{32}$
Fuel
$107\frac{7}{32}$
$1\frac{1}{8}$ TYP
$1\frac{1}{8}$ TYP
TYP
$2\frac{1}{4}$ TYP
#11 (0.191) DRILL THRU CSNK 100° to $\frac{11}{32}$ DIA 24 places @ assembly
Taper hole graphite plug
$23\frac{9}{32}$
View B-B
Lower graphite plug
Pin, peen, and grind flush 12 places top and 12 places bottom
$\frac{3}{8}$
3.960 SQ
Bottom fuel fitting
B
B
Dimensions in inches



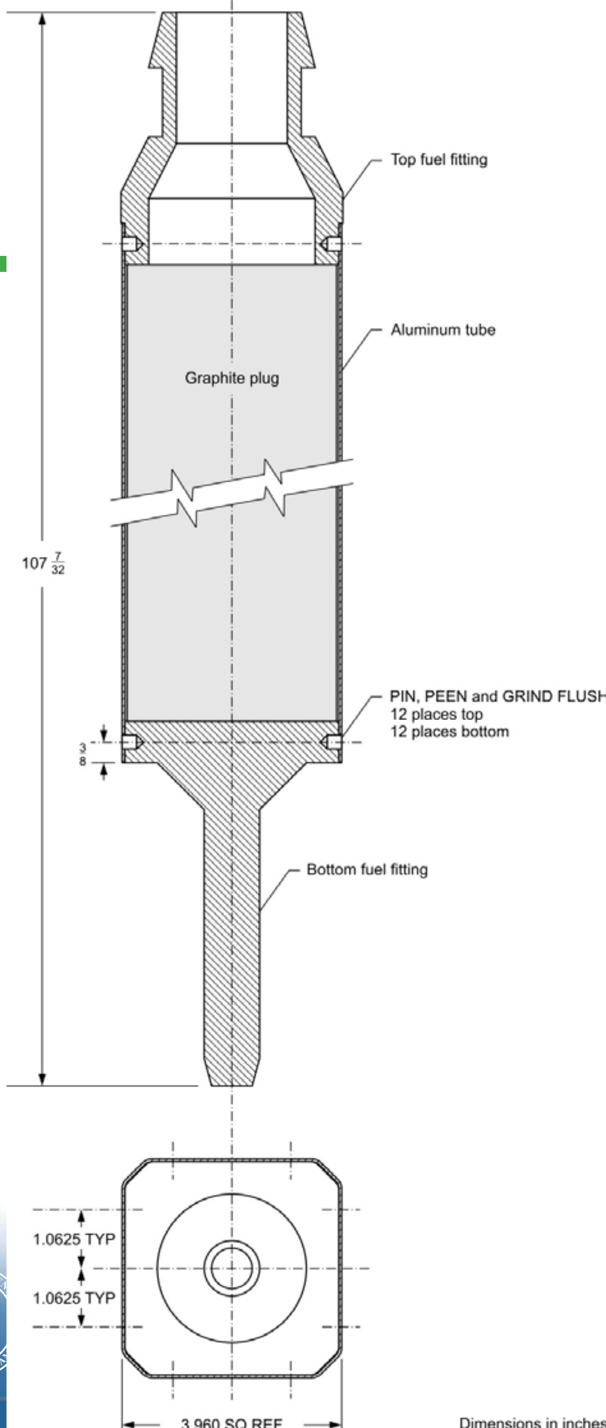
Plug holder
Plug
Socket holder
$\frac{9}{64}$ DRILL $\frac{1}{8}$ DEEP in socket holder at assembly - 3 holes to match tapered holed in head
Reworked top fuel fitting
A
A
$1\frac{7}{8}$
Connection Code
Amphenol pins
Location
AB
Center fuel temperature
CD
Reflector temperature upper
EF
Zircaloy skin temperature
GH
Reflector temperature lower
Top graphite plug
View A-A
Slotted graphite plug
$24\frac{29}{32}$
$53\frac{13}{32}$
Weld chromel and alumel wires together
Section B-B
Shield
$\frac{1}{16}$ wide x 0.025 thick strap spot welded to skin to hold wires under shield 3 REQD locate approximately points "B"
Thermocouple well
$\frac{15}{16}$
$\frac{3}{16}$ DRILL THRU outer skin clearance hole for thermocouple
Fuel
Zircaloy can
B
B
$107\frac{7}{32}$
Section C-C
Pin
$\frac{1}{8}$ slot through outer skin clearance hole for thermocouple (shown 45° out of position)
$1\frac{1}{8}$ TYP
$1\frac{1}{8}$ TYP
C
C
TYP
$2\frac{1}{4}$ TYP
$\frac{1}{16}$
#11 (0.191) DRILL THRU CSNK 100° to $\frac{11}{32}$ DIA 24 places @ assembly
Heliarc weld chromel and alumel wires together
Taper hole graphite plug
$23\frac{9}{32}$
Lower graphite plug
View D-D
Pin, peen, and grind flush 12 places top and 12 places bottom
$\frac{3}{8}$
3.960 SQ
Bottom fuel fitting
D
D
Dimensions in inches



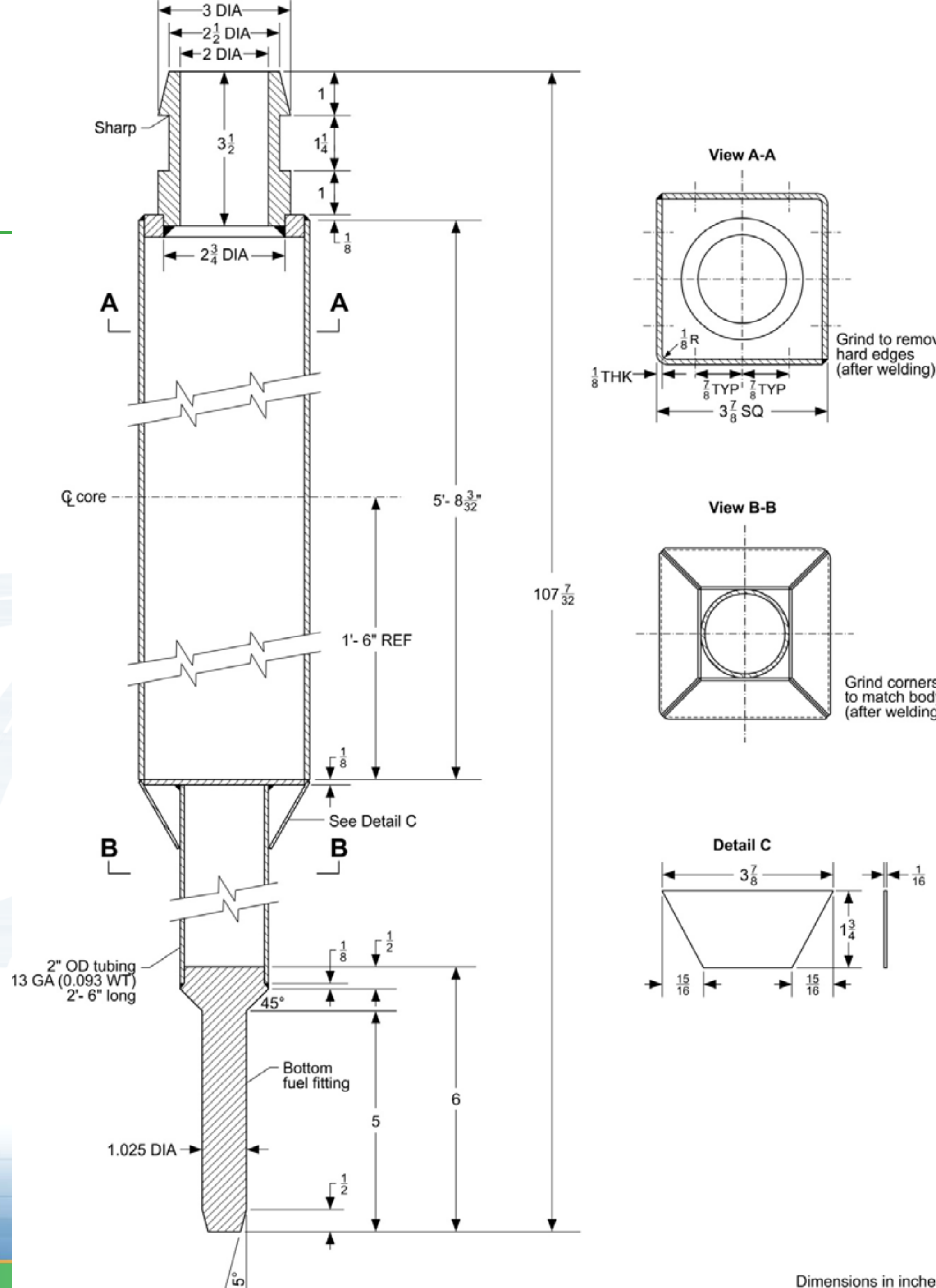
Plug holder
Plug
9/64 DRILL 1/8 DEEP in socket holder at assembly - 3 holes to match tapered holed in head
Socket holder
Reworked top fuel fitting
Connection Code
Pins Location
AB Fuel temperature
CD Aluminum skin
Long slotted graphite plug
Short slotted graphite plug
View A-A
#11 (0.191) DR THRU CSINK 100° to 11/32 DIA 24 places @ assembly
Section B-B
Rivet must be flush outside braze or peen thermocouple in place
1/2 TYP
"V" cut fuel block
DRILL THRU rivet clearance hole for thermocouple
Slotted fuel block
Taper hole fuel block
Fuel
Section C-C
1 1/8 TYP 1 1/8 TYP
#11 (0.191) DRILL THRU CSNK 100° to 11/32 DIA 24 places @ assembly
Taper hole graphite plug
Lower graphite plug
View D-D
Pin, peen, and grind flush 12 places top and 12 places bottom
Bottom fuel fitting
3.960 SQ
1 7/8
24 29/32
107 7/32
23 9/32
Dimensions in inches



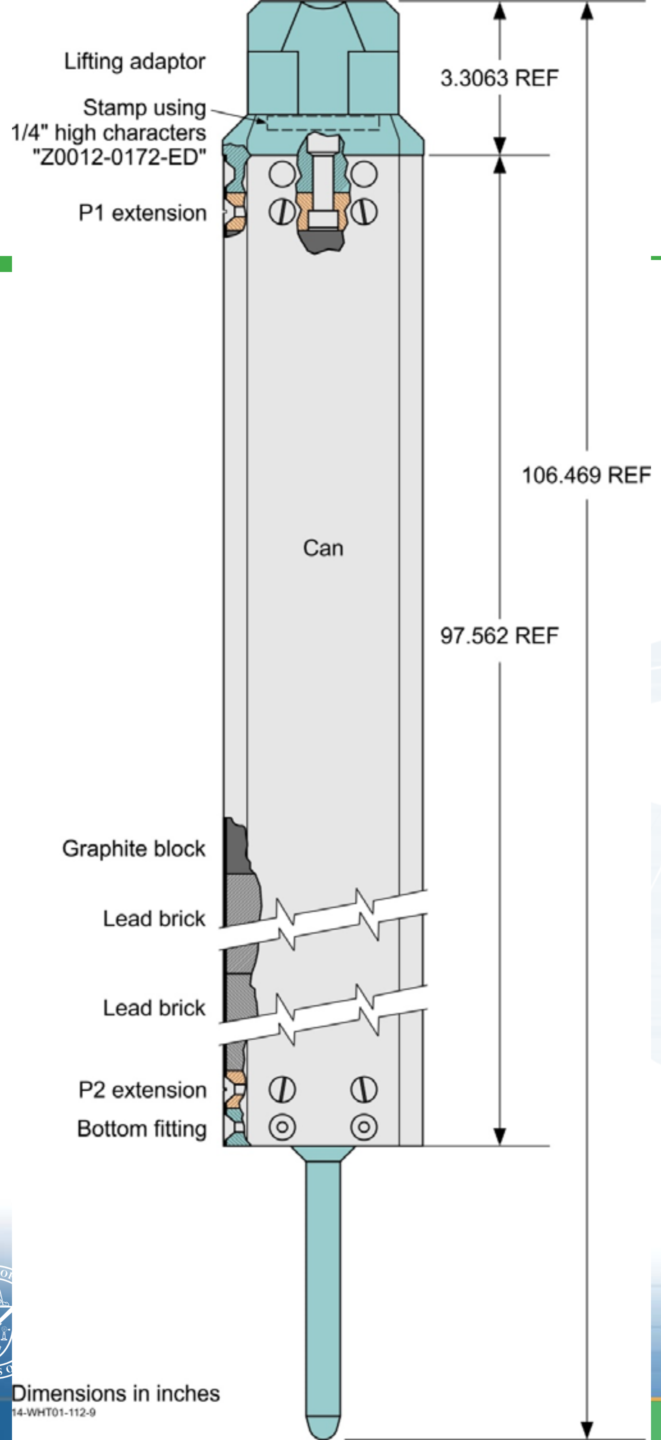
Plug holder
Plug
9/64 DRILL 1/8 DEEP in socket holder at assembly - 3 holes to match tapered holed in head
Socket holder
Reworked top fuel fitting
Use extreme care in coiling excess SS sheath of graphite thermocouples
Connection Code
Amphenol pins Location
#1 AB 6" depth in fuel
#2 CD 1 1/2 depth in fuel
#3 EF In reflector 1 1/2 from fuel element
#4 GH In reflector 6" from fuel element
Long graphite plug
View A-A
Short graphite plug
3.960 SQ REF
Fuel
#11 (0.191) DRILL THRU CSNK 100° to 11/32 DIA 24 places @ assembly
Taper hole graphite plug
Lower graphite plug
Pin, peen, and grind flush 12 places top and 12 places bottom
Bottom fuel fitting
1 7/8
24 29/32
107 7/32
23 9/32
Dimensions in inches



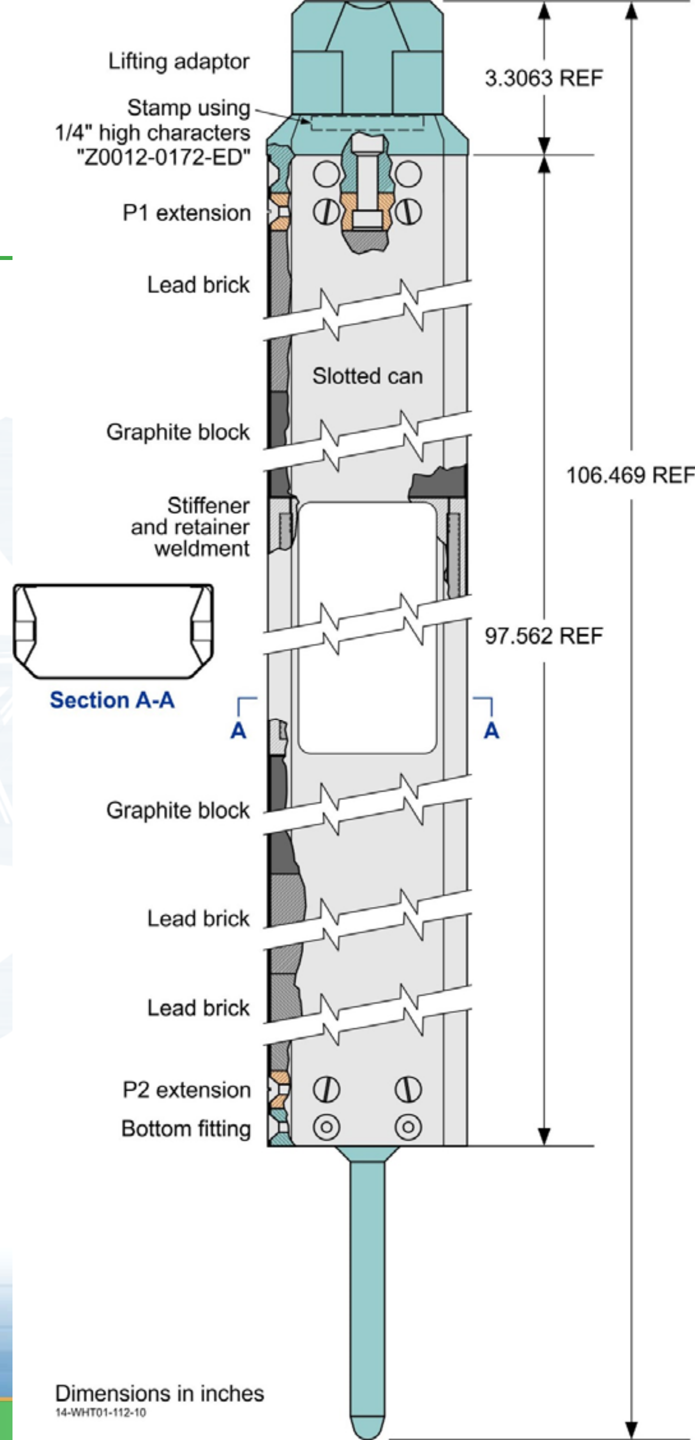
Top fuel fitting
Aluminum tube
Graphite plug
107 7/32
PIN, PEEN and GRIND FLUSH
12 places top
12 places bottom
3/8
Bottom fuel fitting
1.0625 TYP
1.0625 TYP
3.960 SQ REF
Dimensions in inches



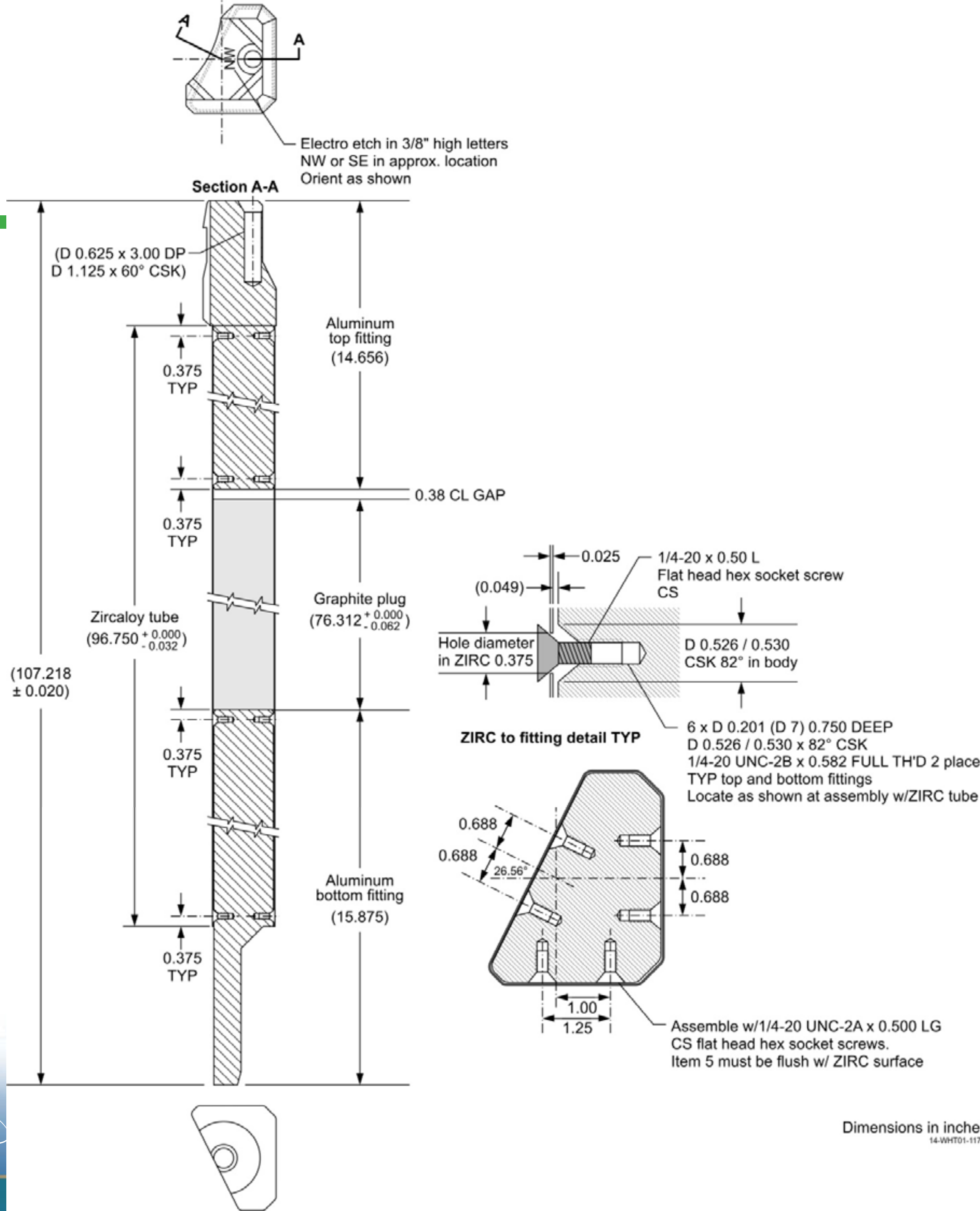
3 DIA
2 1/2 DIA
2 DIA
Sharp
3 1/2
1
1 1/4
1
1/8
2 3/4 DIA
A
A
℄ core
5'- 8 3/32"
107 7/32
1'- 6" REF
1/8
See Detail C
B
B
2" OD tubing
13 GA (0.093 WT)
2'- 6" long
1/8
1/2
45°
Bottom
fuel fitting
6
5
1.025 DIA
1/2
15°
View A-A
1/8 R
Grind to remove
hard edges
(after welding)
1/8 THK
7/8 TYP
7/8 TYP
3 7/8 SQ
View B-B
Grind corners
to match body
(after welding)
Detail C
3 7/8
1/16
1 3/4
15/16
15/16
Dimensions in inches

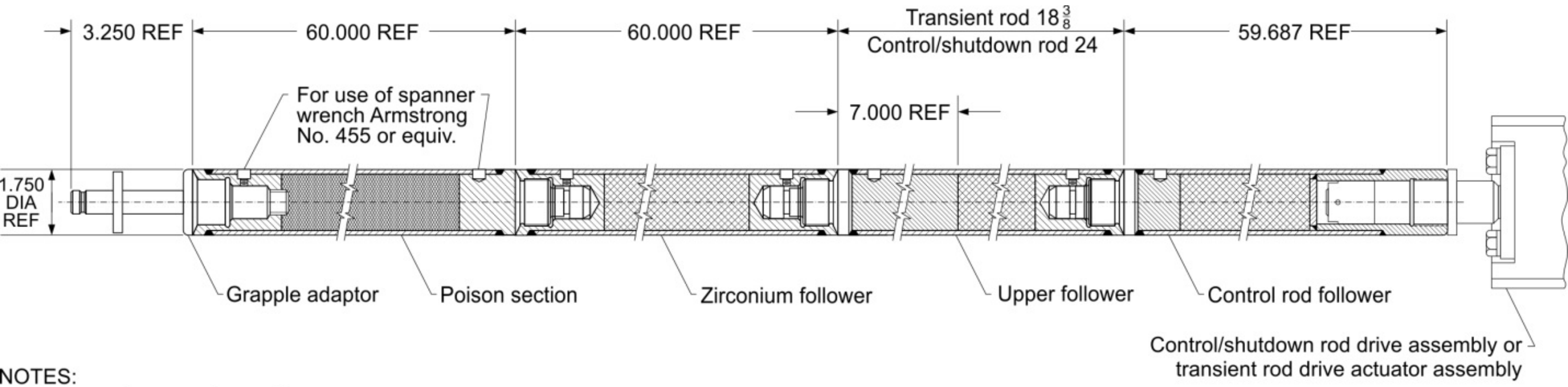


Lifting adaptor
Stamp using
1/4" high characters
"Z0012-0172-ED"
P1 extension
3.3063 REF
106.469 REF
97.562 REF
Can
Graphite block
Lead brick
Lead brick
P2 extension
Bottom fitting
Dimensions in inches
14-WHT01-112-9



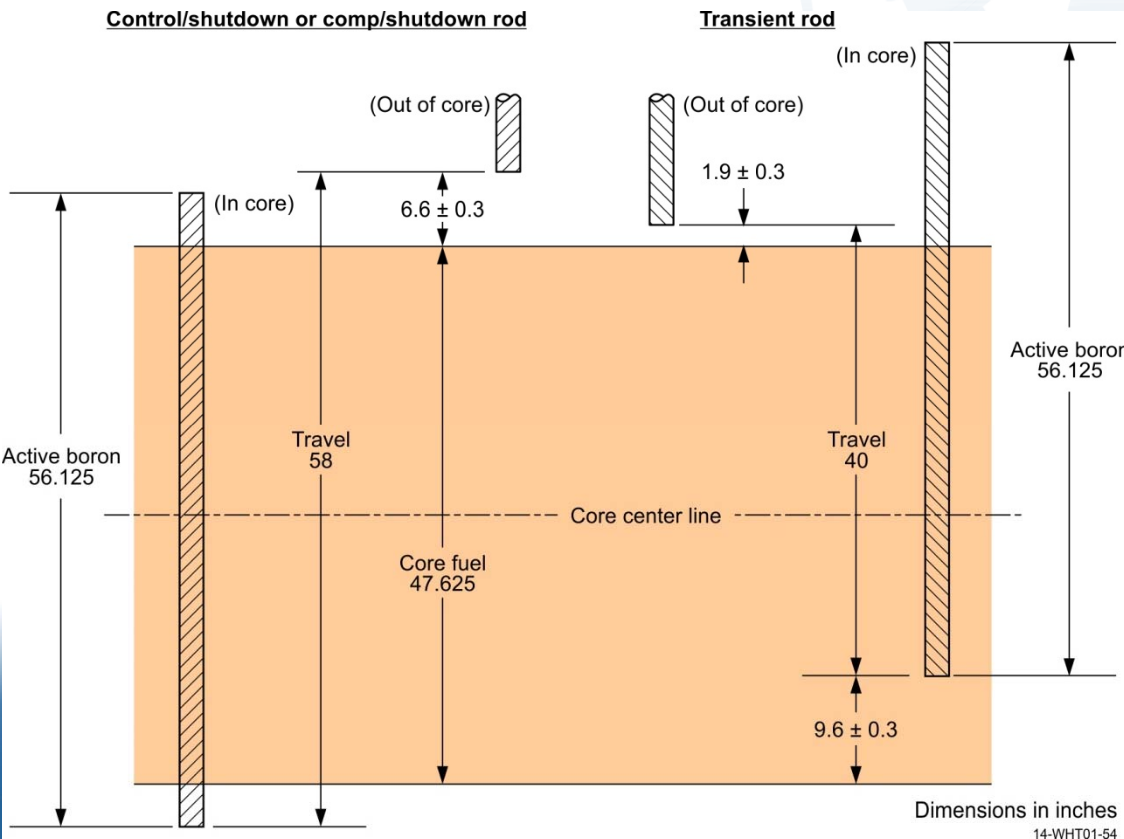
Lifting adaptor
Stamp using
1/4" high characters
"Z0012-0172-ED"
P1 extension
Lead brick
Slotted can
Graphite block
Stiffener
and retainer
weldment
Section A-A
A
A
3.3063 REF
106.469 REF
97.562 REF
Graphite block
Lead brick
Lead brick
P2 extension
Bottom fitting
Dimensions in inches
14-WHT01-112-10

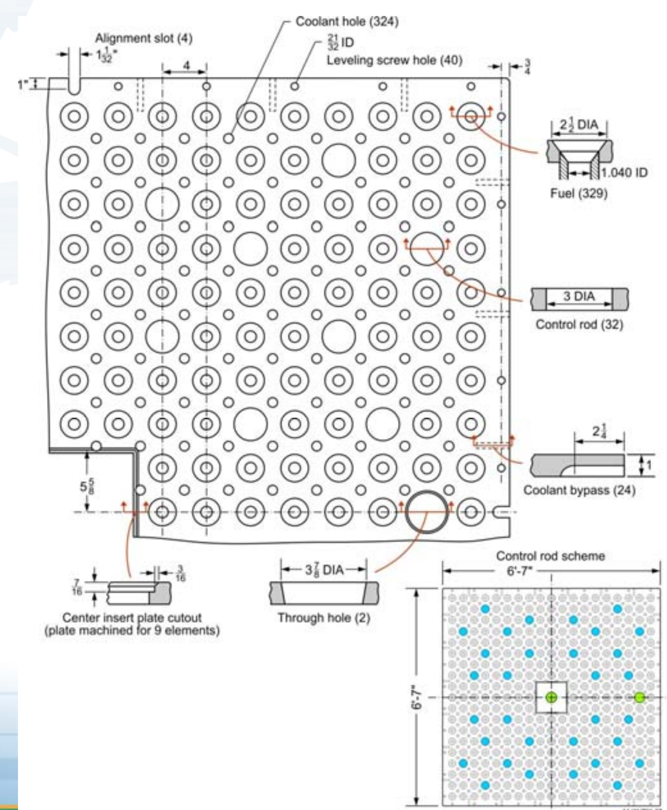

A
A
NW
Electro etch in 3/8" high letters
NW or SE in approx. location
Orient as shown
Section A-A
(D 0.625 x 3.00 DP
D 1.125 x 60° CSK)
Aluminum
top fitting
(14.656)
0.375
TYP
0.38 CL GAP
0.375
TYP
Graphite plug
(76.312 +0.000 -0.062)
Zircaloy tube
(96.750 +0.000 -0.032)
(107.218
± 0.020)
0.375
TYP
Aluminum
bottom fitting
(15.875)
0.375
TYP
0.025
1/4-20 x 0.50 L
Flat head hex socket screw
CS
(0.049)
Hole diameter
in ZIRC 0.375
D 0.526 / 0.530
CSK 82° in body
ZIRC to fitting detail TYP
6 x D 0.201 (D 7) 0.750 DEEP
D 0.526 / 0.530 x 82° CSK
1/4-20 UNC-2B x 0.582 FULL TH'D 2 places
TYP top and bottom fittings
Locate as shown at assembly w/ZIRC tube
0.688
0.688
26.56°
0.688
0.688
1.00
1.25
Assemble w/1/4-20 UNC-2A x 0.500 LG
CS flat head hex socket screws.
Item 5 must be flush w/ ZIRC surface
Dimensions in inches
14-WHT01-117-7

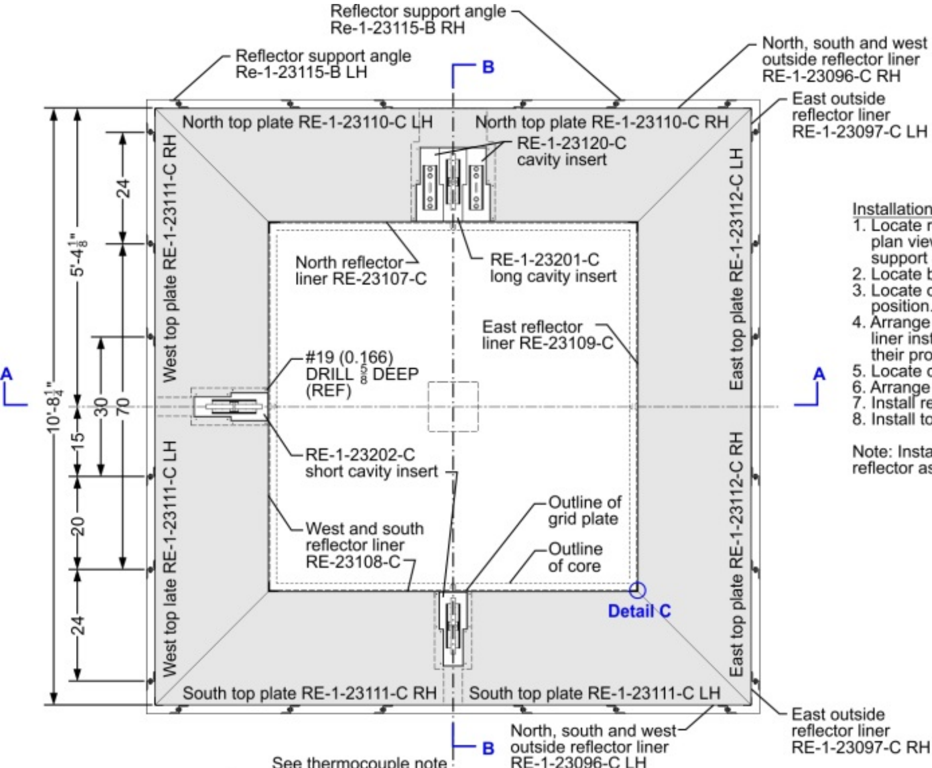


NOTES:
Joints must have no sharp offset
Moly solid lubricant or Mobil SHC 460 synthetic grease used in assembly of all joints

Dimensions in inches
15-WHT01-31

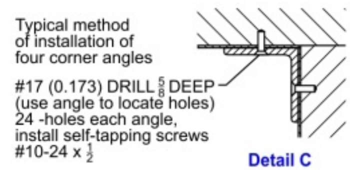




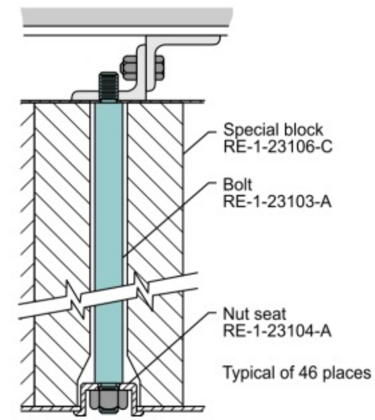


Installation Procedure
1. Locate reflector support angles as shown in auxiliary plan view and weld clip angles to shielding. Adjust support angles to given dimensions.
2. Locate bottom plates and fasten using Item #1.
3. Locate outside steel reflector liners and tack weld in position.
4. Arrange graphite blocks in position against outside steel liner installing special graphite blocks and long bolts in their propr location.
5. Locate cavity liners and inserts.
6. Arrange remaining graphite, tier by tier as shown.
7. Install reflector liners and hold in place (Detail C)
8. Install top plates and corner angles (Detail C)

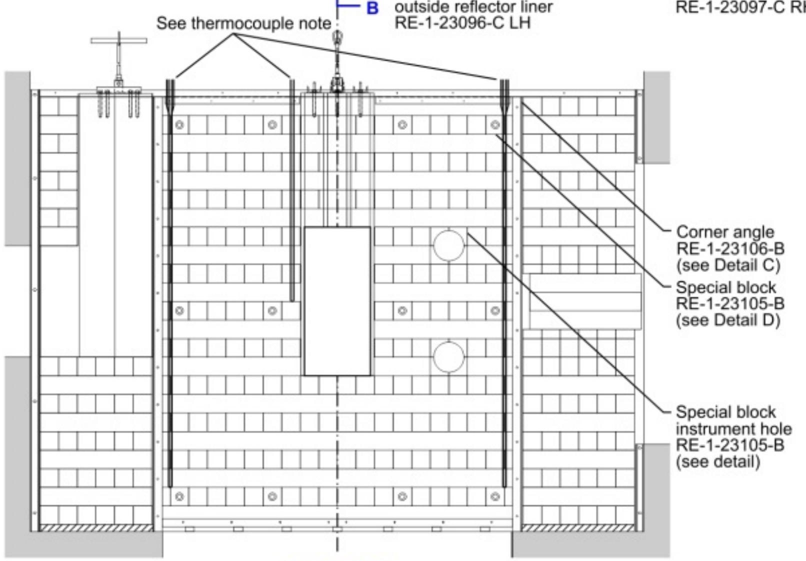
Note: Install B thermocouples each face between liner and reflector as shown in Section A-A - total 20 thermocouples.



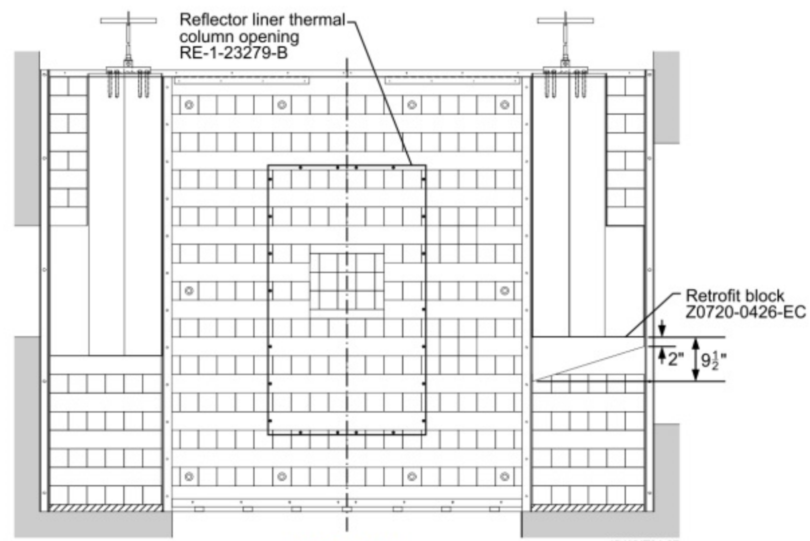
Detail C



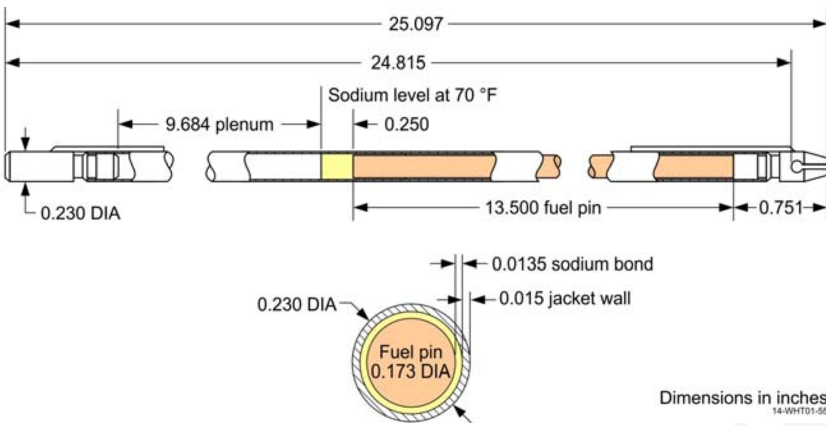
Detail D



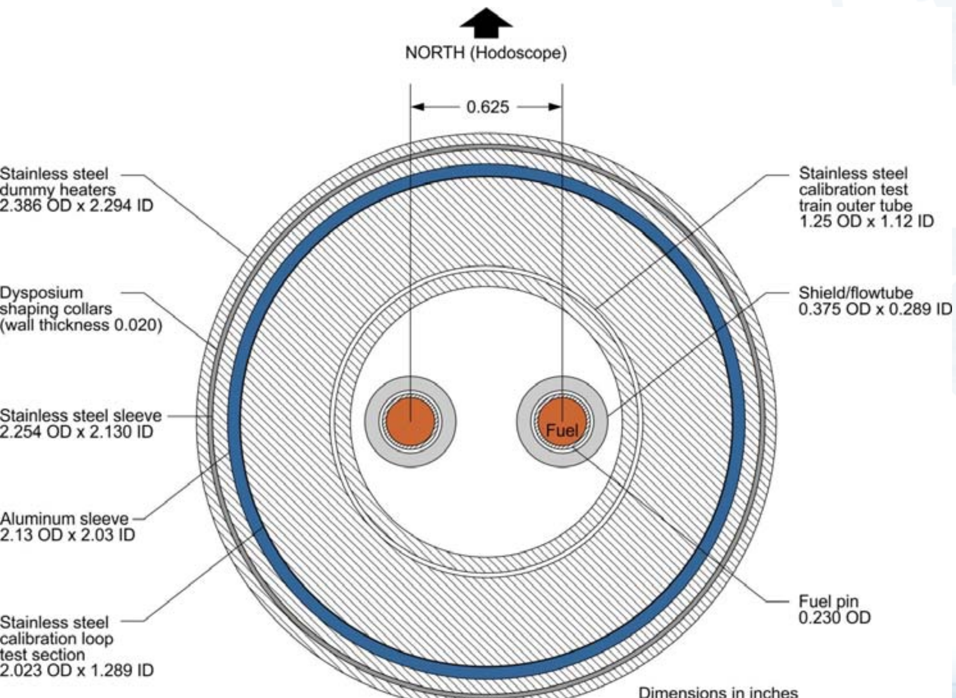
Section A-A



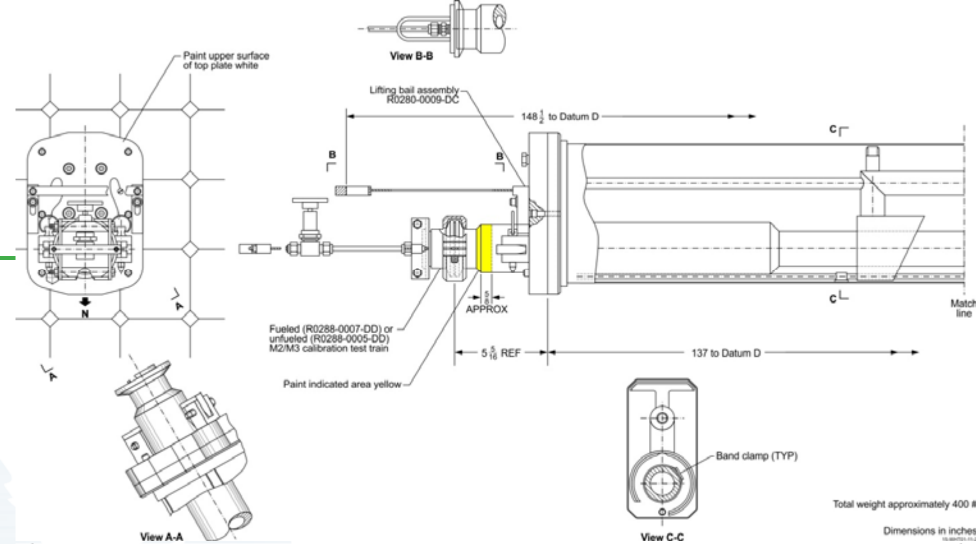
Section B-B



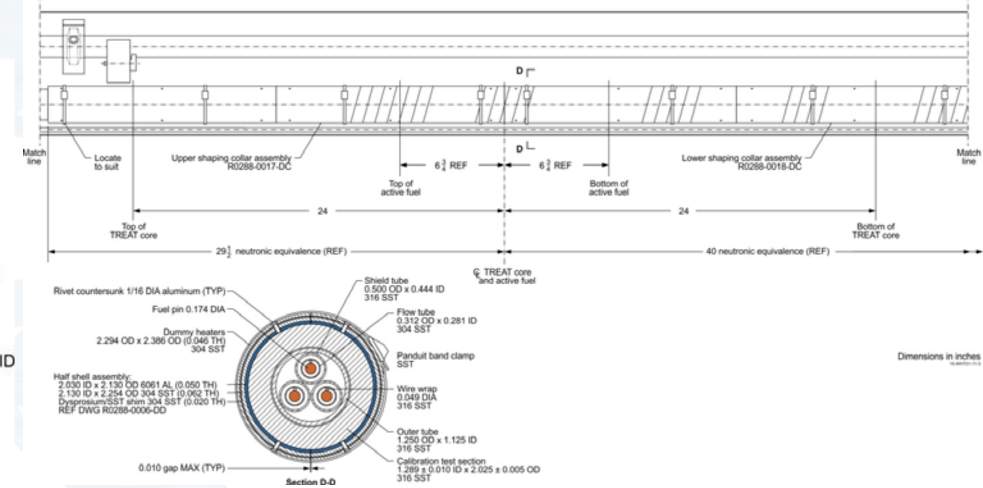
25.097
24.815
Sodium level at 70 °F
9.684 plenum
0.250
0.230 DIA
13.500 fuel pin
0.751
0.0135 sodium bond
0.015 jacket wall
0.230 DIA
Fuel pin
0.173 DIA
Dimensions in inches
14-WHT01-55



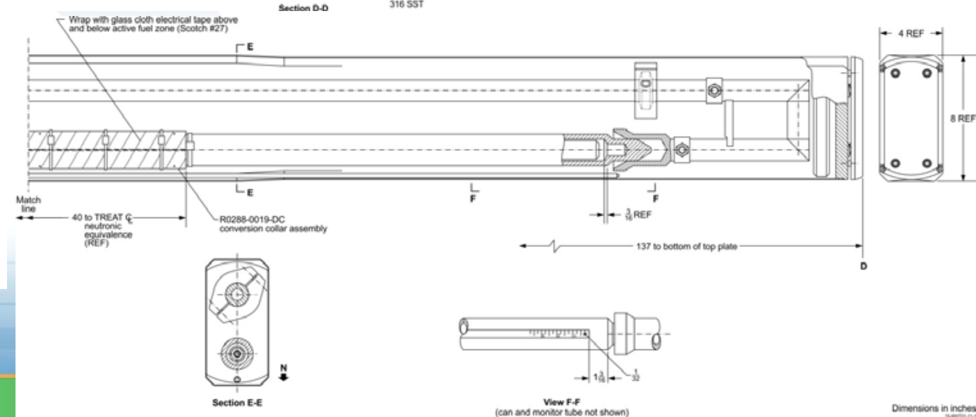
NORTH (Hodoscope)
0.625
Stainless steel dummy heaters 2.386 OD x 2.294 ID
Dysposium shaping collars (wall thickness 0.020)
Stainless steel sleeve 2.254 OD x 2.130 ID
Aluminum sleeve 2.13 OD x 2.03 ID
Stainless steel calibration loop test section 2.023 OD x 1.289 ID
Stainless steel calibration test train outer tube 1.25 OD x 1.12 ID
Shield/flowtube 0.375 OD x 0.289 ID
Fuel
Fuel pin 0.230 OD
Dimensions in inches
14-WHT01-23-1



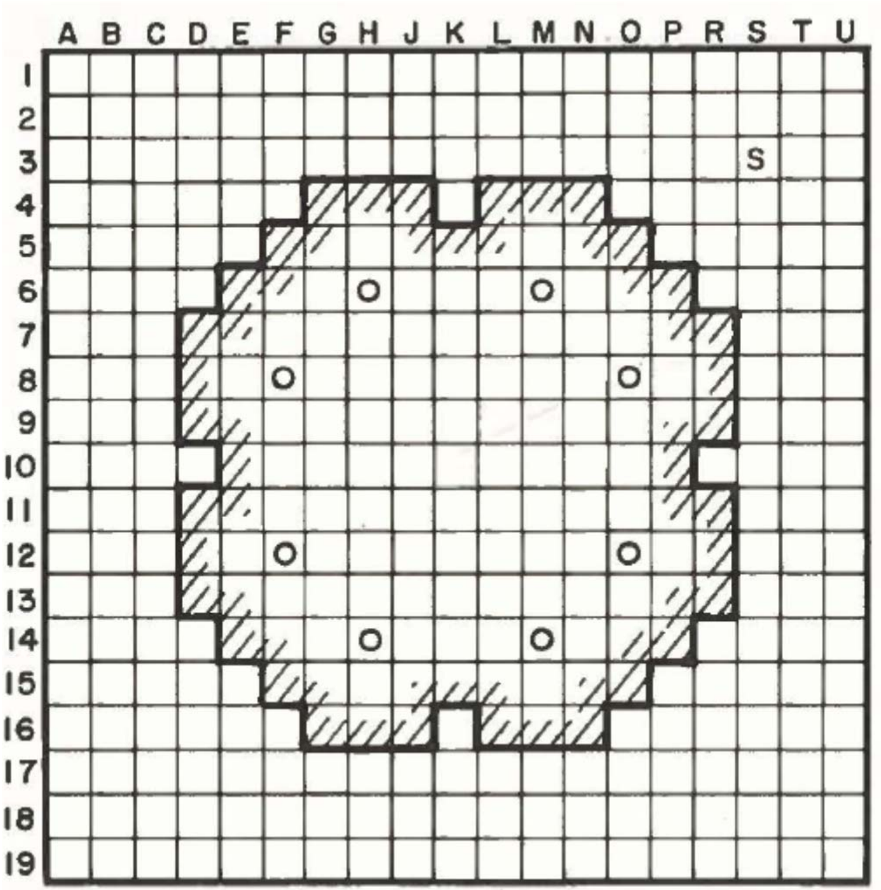
View B-B
Paint upper surface of top plate white
Lifting bail assembly R0280-0009-DC
148 1/2 to Datum D
APPROX
Fueled (R0288-0007-DD) or unfueled (R0288-0005-DD) M2/M3 calibration test train
Paint indicated area yellow
5 5/16 REF
137 to Datum D
Band clamp (TYP)
Total weight approximately 400 #
View A-A
View C-C
Dimensions in inches

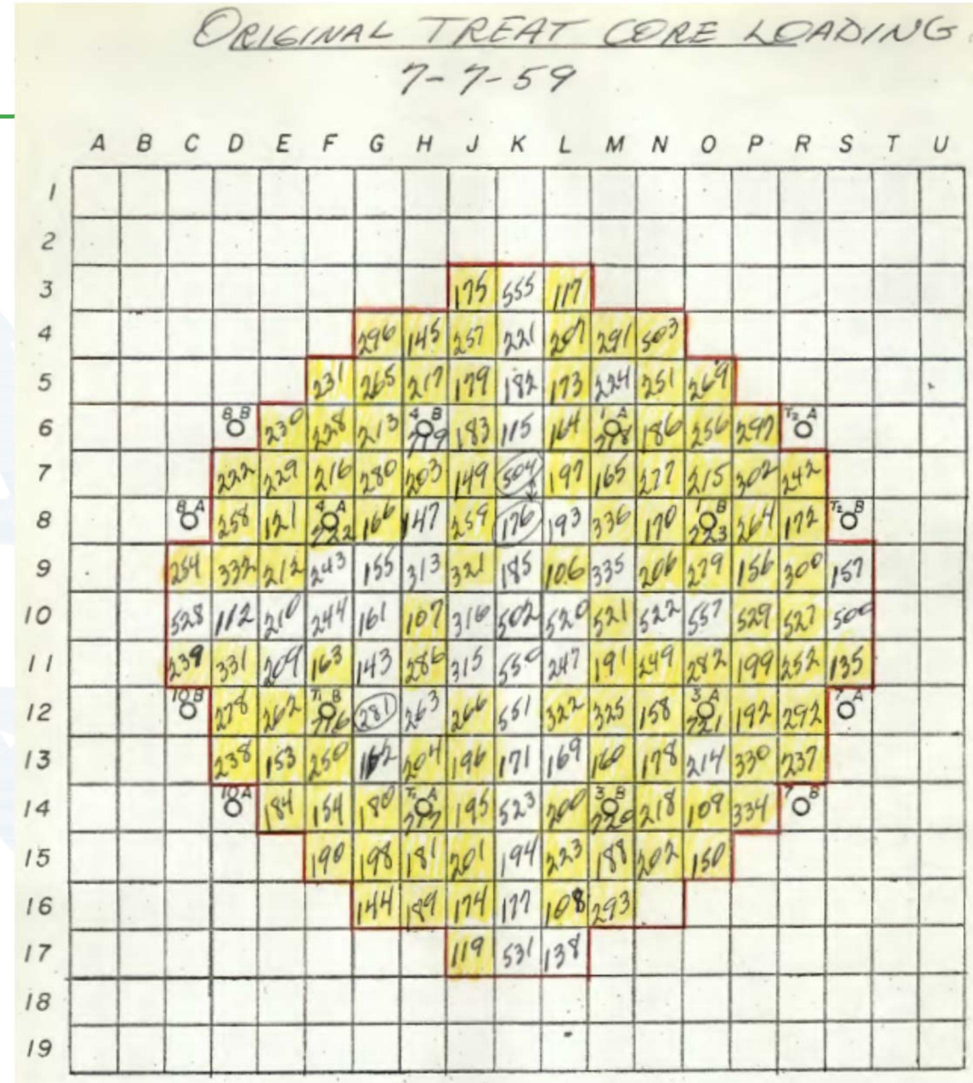


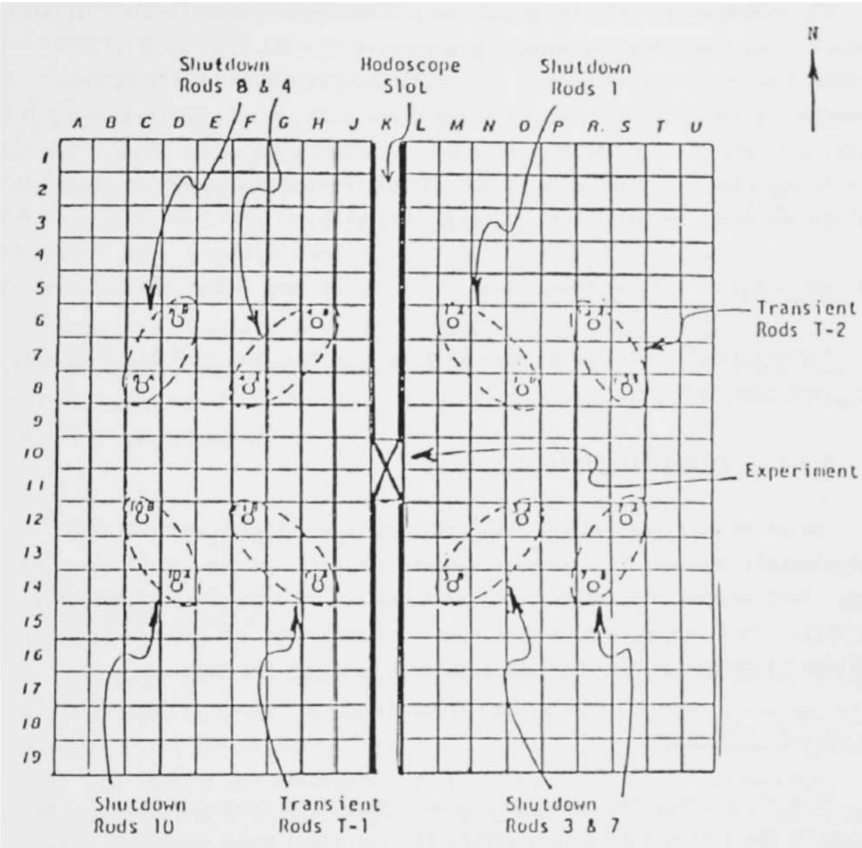
Match line
Locate to suit
Upper shaping collar assembly R0288-0017-DC
Top of active fuel
Bottom of active fuel
Lower shaping collar assembly R0288-0018-DC
Top of TREAT core
Bottom of TREAT core
29 3/4 neutronic equivalence (REF)
40 neutronic equivalence (REF)
℄ TREAT core and active fuel
Rivet countersunk 1/16 DIA aluminum (TYP)
Fuel pin 0.174 DIA
Dummy heaters 2.294 OD x 2.386 OD (0.046 TH) 304 SST
Half shell assembly: 2.030 ID x 2.130 OD 6061 AL (0.050 TH) 2.130 ID x 2.254 OD 304 SST (0.062 TH) Dysprosium/SST shim 304 SST (0.020 TH) REF DWG R0288-0006-DD
0.010 gap MAX (TYP)
Shield tube 0.500 OD x 0.444 ID 316 SST
Flow tube 0.312 OD x 0.281 ID 304 SST
Panduit band clamp SST
Wire wrap 0.049 DIA 316 SST
Outer tube 1.250 OD x 1.125 ID 316 SST
Calibration test section 1.289 ± 0.010 ID x 2.025 ± 0.005 OD 316 SST
Section D-D
Dimensions in inches

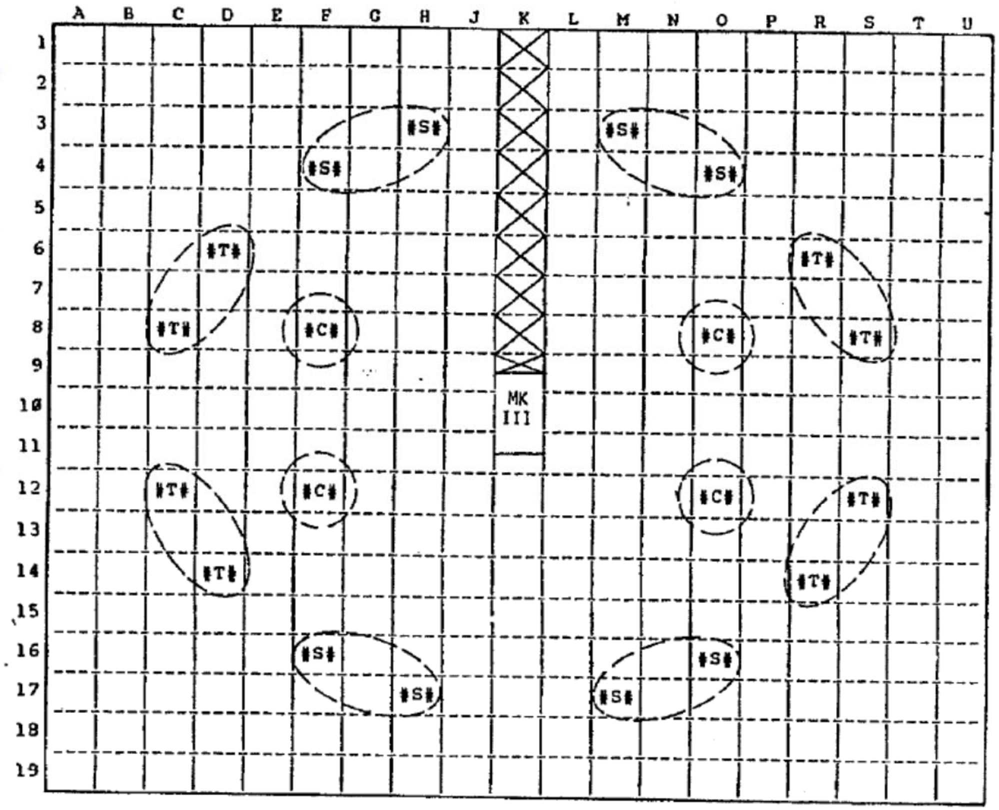


Wrap with glass cloth electrical tape above and below active fuel zone (Scotch #27)
4 REF
8 REF
Match line
40 to TREAT ℄ neutronic equivalence (REF)
R0288-0019-DC conversion collar assembly
137 to bottom of top plate
Section E-E
View F-F (can and monitor tube not shown)
Dimensions in inches




ORIGINAL TREAT CORE LOADING
7-7-59





Slotted Hodoscope Assembly

#C# Compensation/Shutdown Rod Assembly

#T# Transient Rod Pair

#S# Shutdown Rod Pair