

Chemical Engineering 612

Introductory Nuclear Engineering

Lecture 11

Core Thermal Analysis

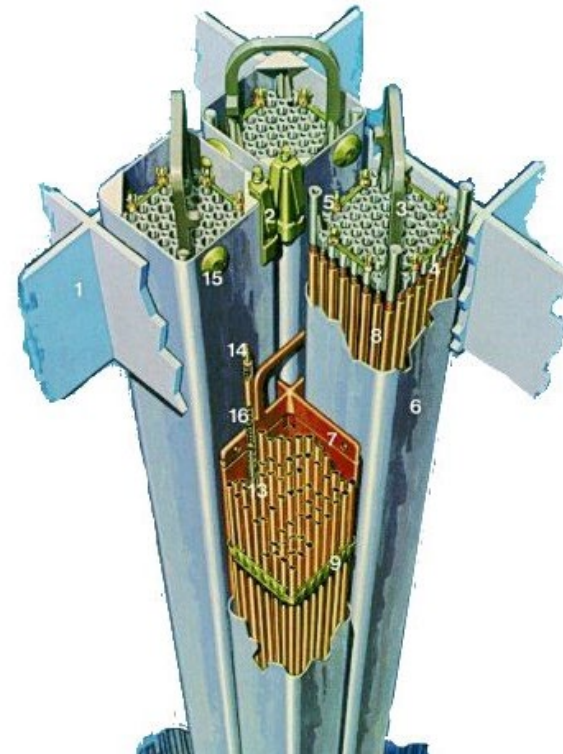
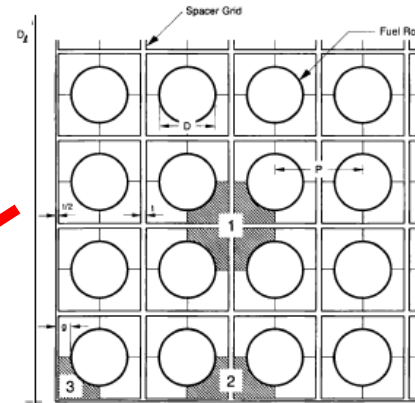
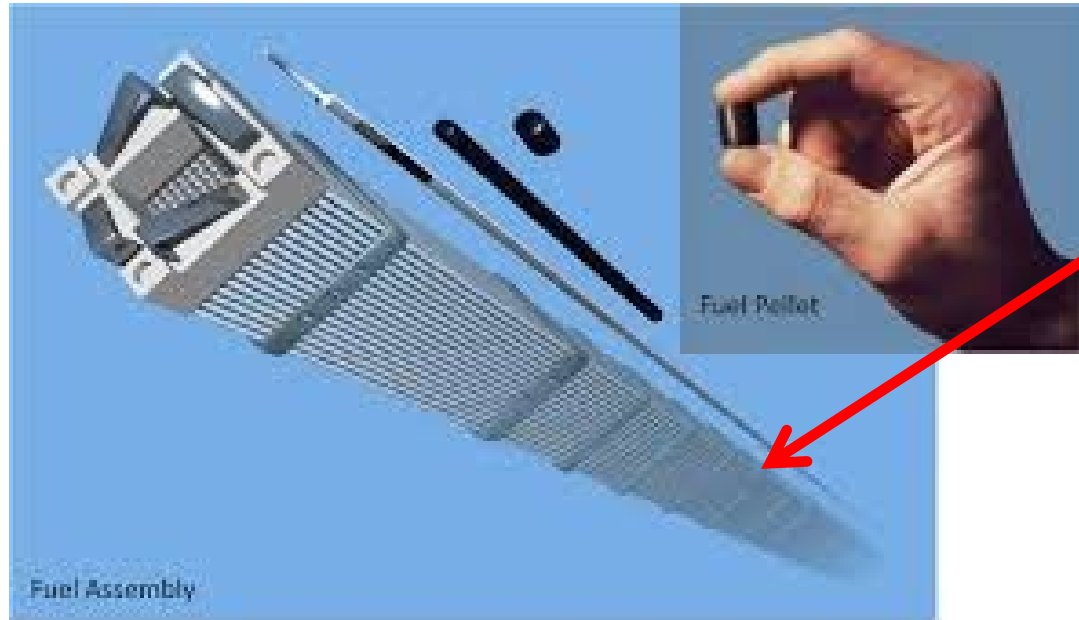


Spiritual Thought

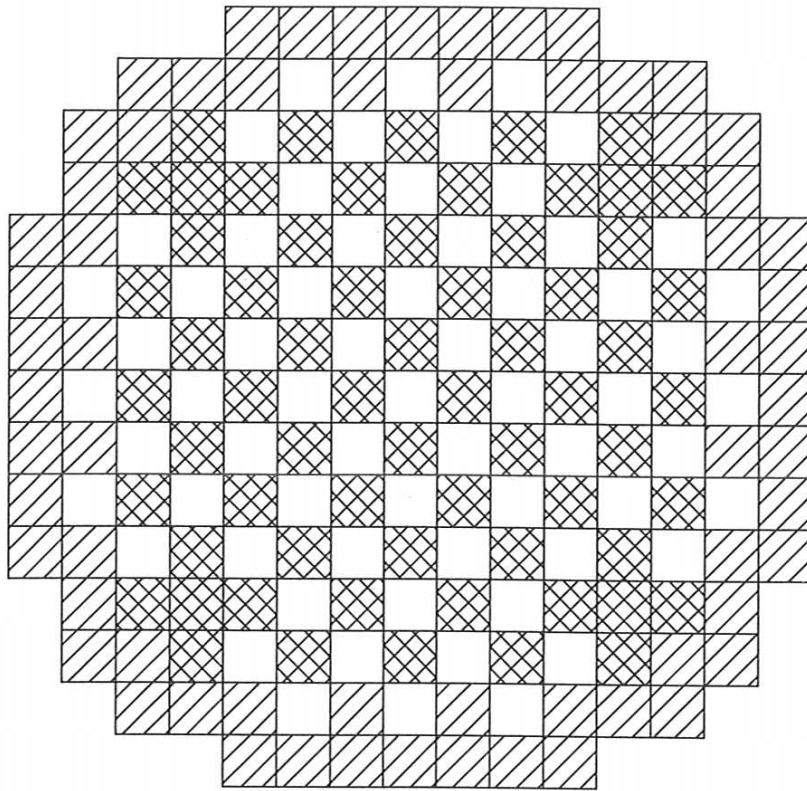


PRINCE
of **PEACE**

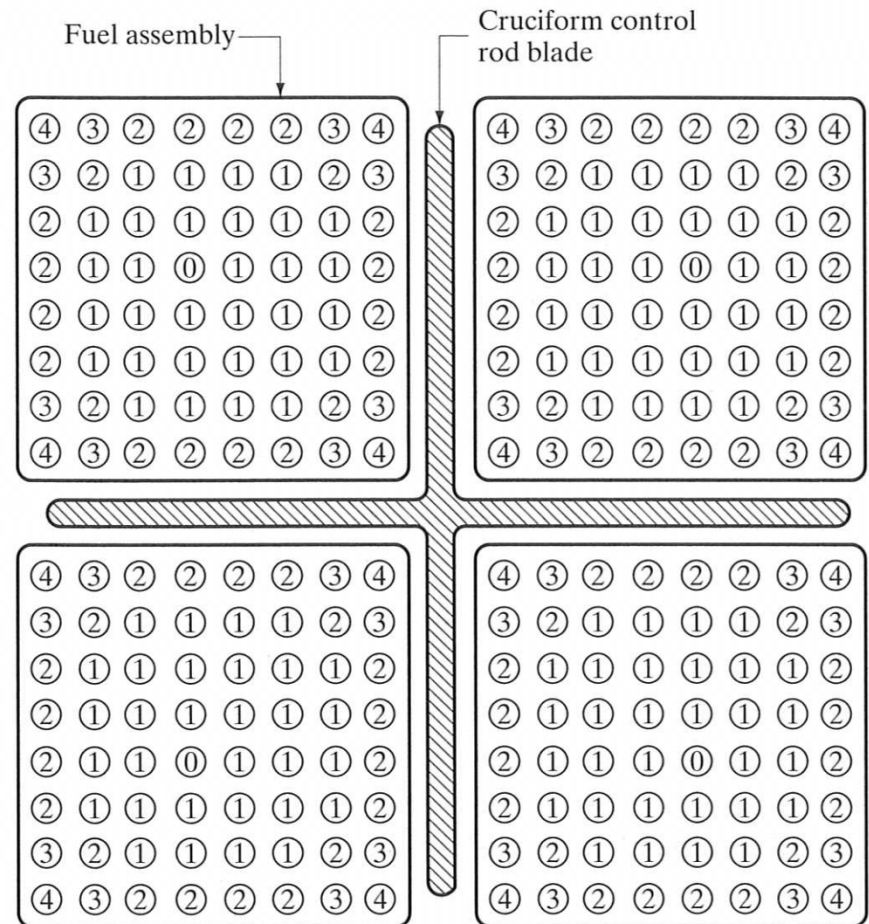
Core Design



Fuel Loading Patterns



Enrichments



Subchannel Configuration

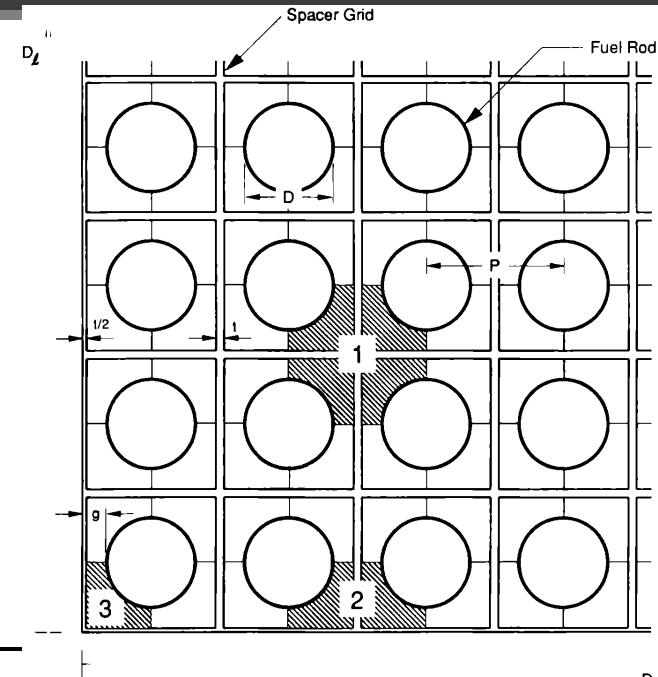
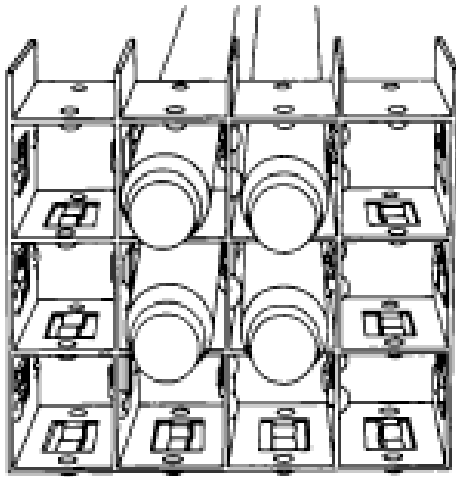
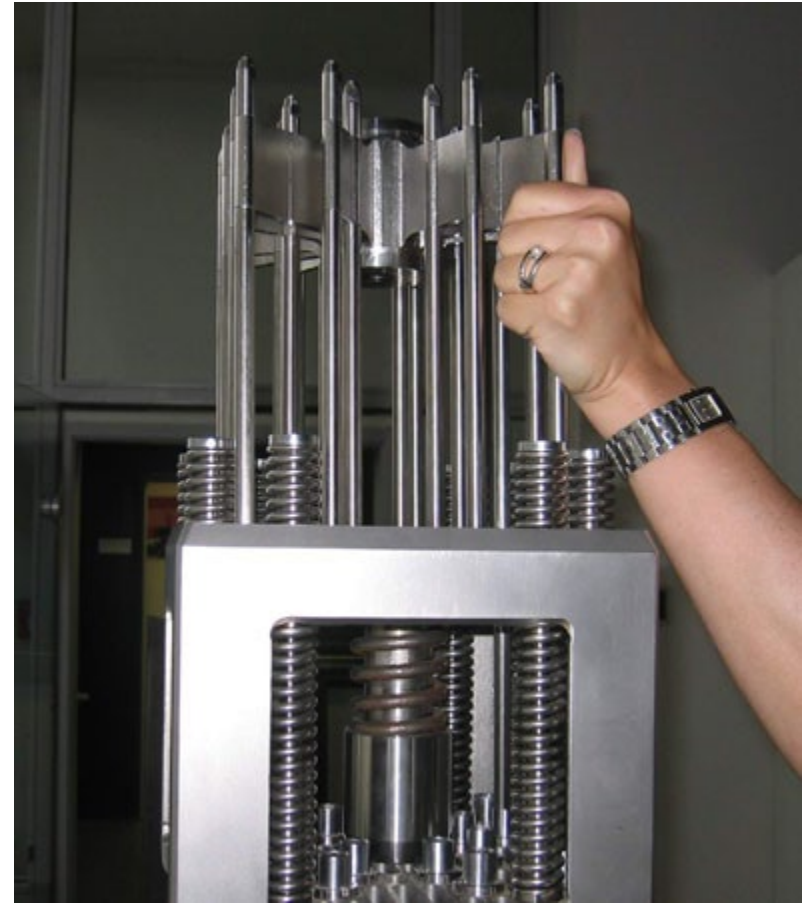
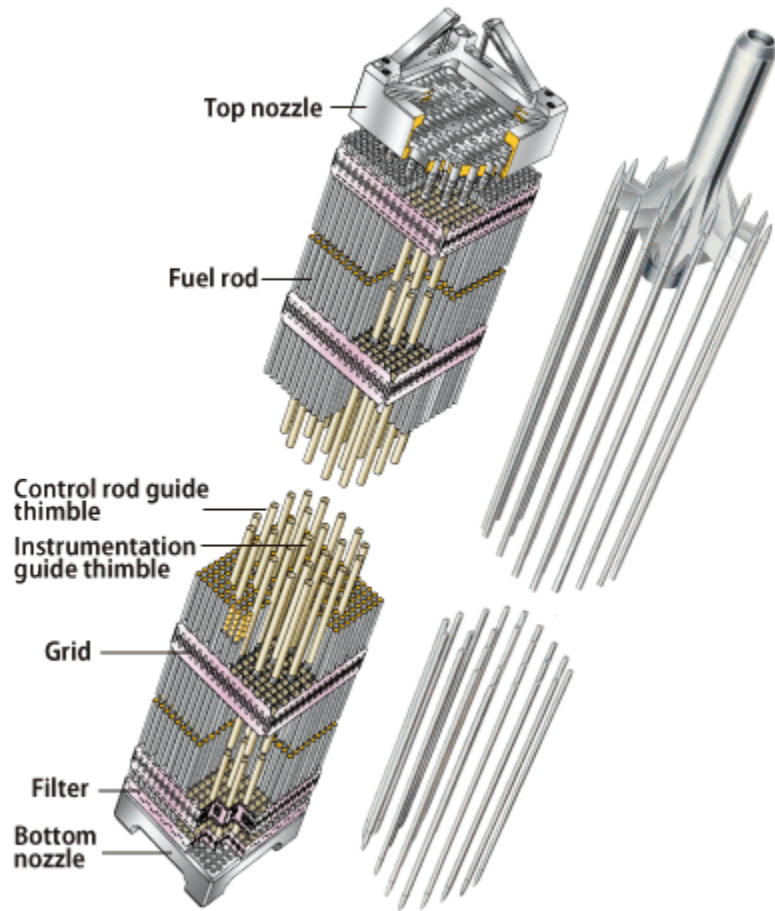


Table 1-4 Subchannels for square arrays

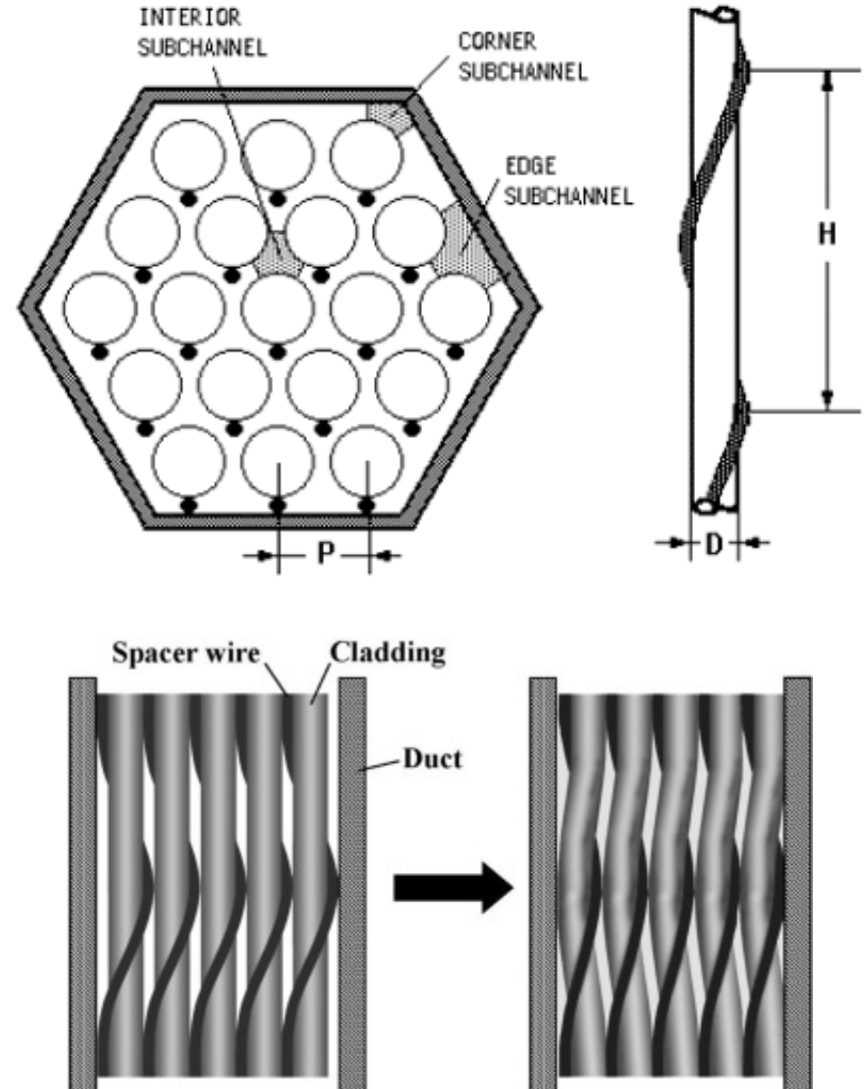
Rows of rods	N_p Total no. of rods	N_i No. of interior subchannels	N_2 No. of edge subchannels	N_3 No. of corner subchannels
1	1	0	0	4
2	4	1	4	4
3	9	4	8	4
4	16	9	12	4
5	25	16	16	4
6	36	25	20	4
7	49	36	24	4
8	64	49	28	4
N_{rows}	N_{rows}^2	$(N_{\text{rows}} - 1)^2$	$4(N_{\text{rows}} - 1)$	4

Cluster Control Rods



Metal Fast Reactor Assemblies

- Cylindrical Fuel Rods
 - Metallic Fuel
 - U-Zr-Pu Matrix
 - Solid or Annular
- Wire Wrapped Spacers
 - Small Pitch
 - Prevent Touching
 - Induce Mixing
- Closed Assemblies
 - Wall – “duct”



Rings of rods	N_p Total no. of rods	N_{ps} No. of rods along a side	N_1 No. of interior subchannels	N_2 No. of edge subchannels	N_3 No. of corner subchannels
1	7	2	6	6	6
2	19	3	24	12	6
3	37	4	54	18	6
4	61	5	96	24	6
5	91	6	150	30	6
6	127	7	216	36	6
7	169	8	294	42	6
8	217	9	384	48	6
9	271	10	486	54	6
N_{rings}	$\sum_{n=1}^{N_{rings}} 6n$	$N_{rings} + 1$	$6N_{rings}^2$	$6N_{rings}$	6

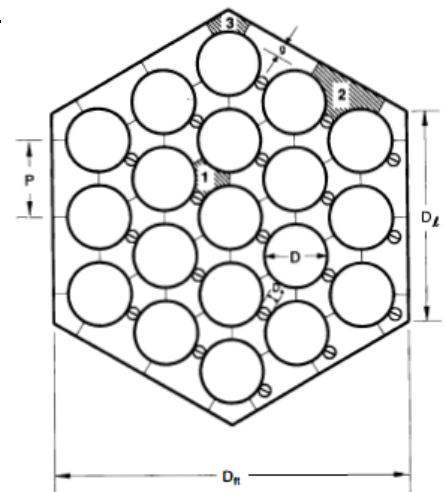
Additional useful relations between N_p , N_{ps} , and N_1 are as follows.

$$N_{ps} = \left[1 + \sqrt{1 + \frac{4}{3}(N_p - 1)} \right] / 2$$

$$N_p = 3N_{ps}(N_{ps} - 1) + 1$$

$$N_1 = 6(N_{ps} - 1)^2$$

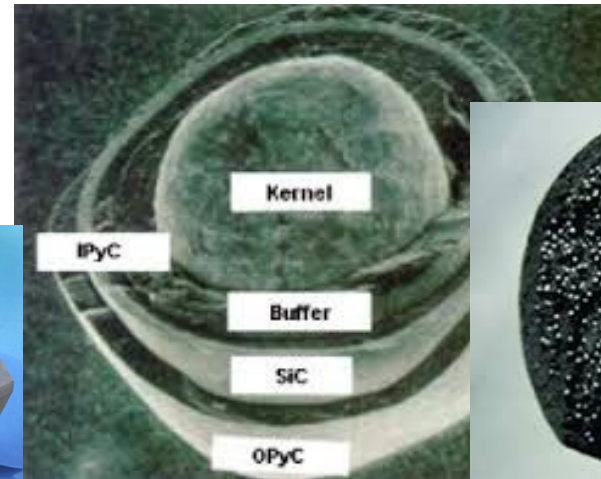
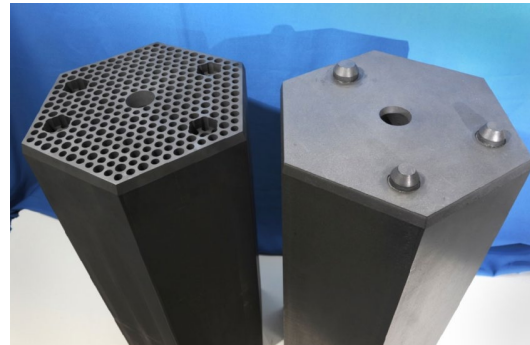
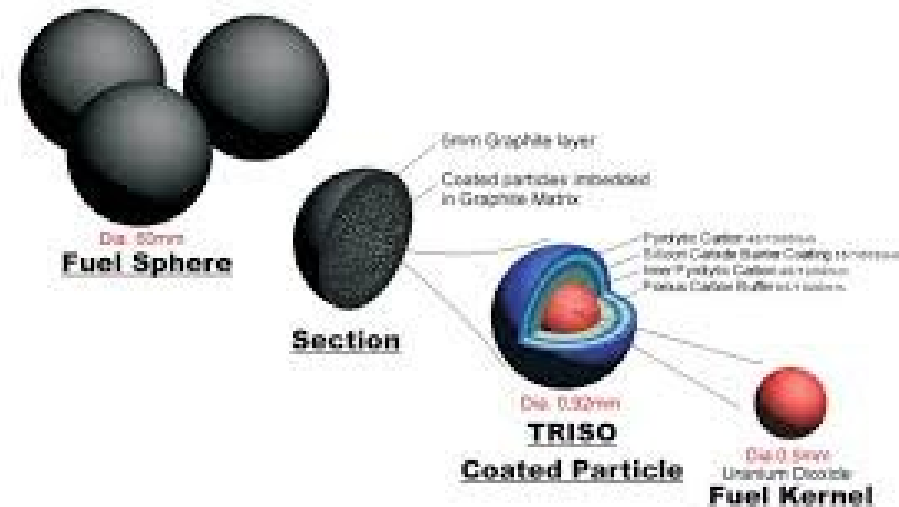
$$N_2 = 6(N_{ps} - 1)$$



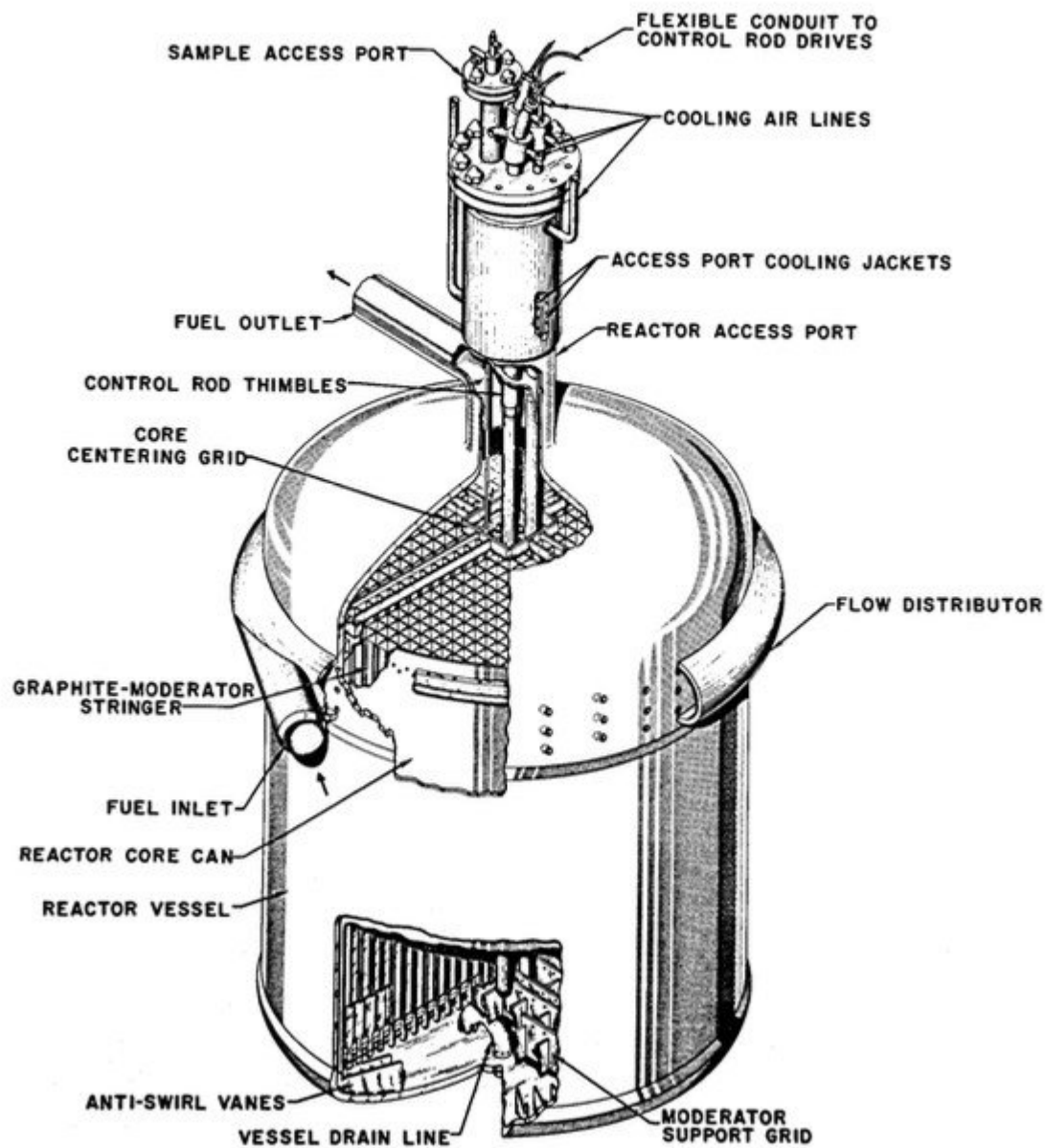
VHTR Fuel (USNC)

- TRISO fuel
 - Many tiny pellets into graphite matrix sphere
 - Melt-down proof
 - Failure specs?
- Susceptible to air-ingress accidents (fire)
- Also used in FHR

FUEL ELEMENT DESIGN FOR PBMR

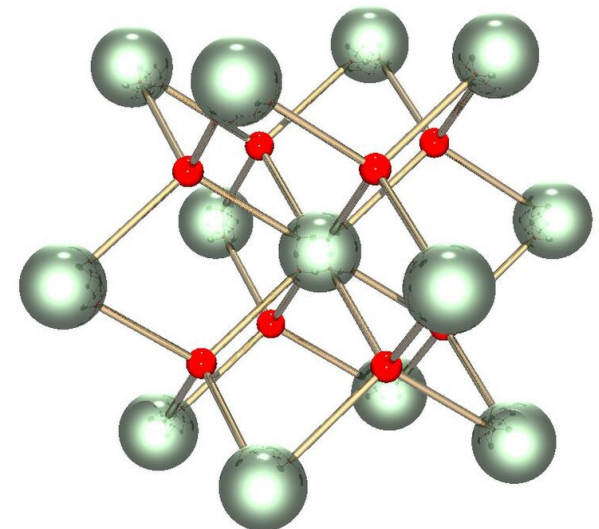
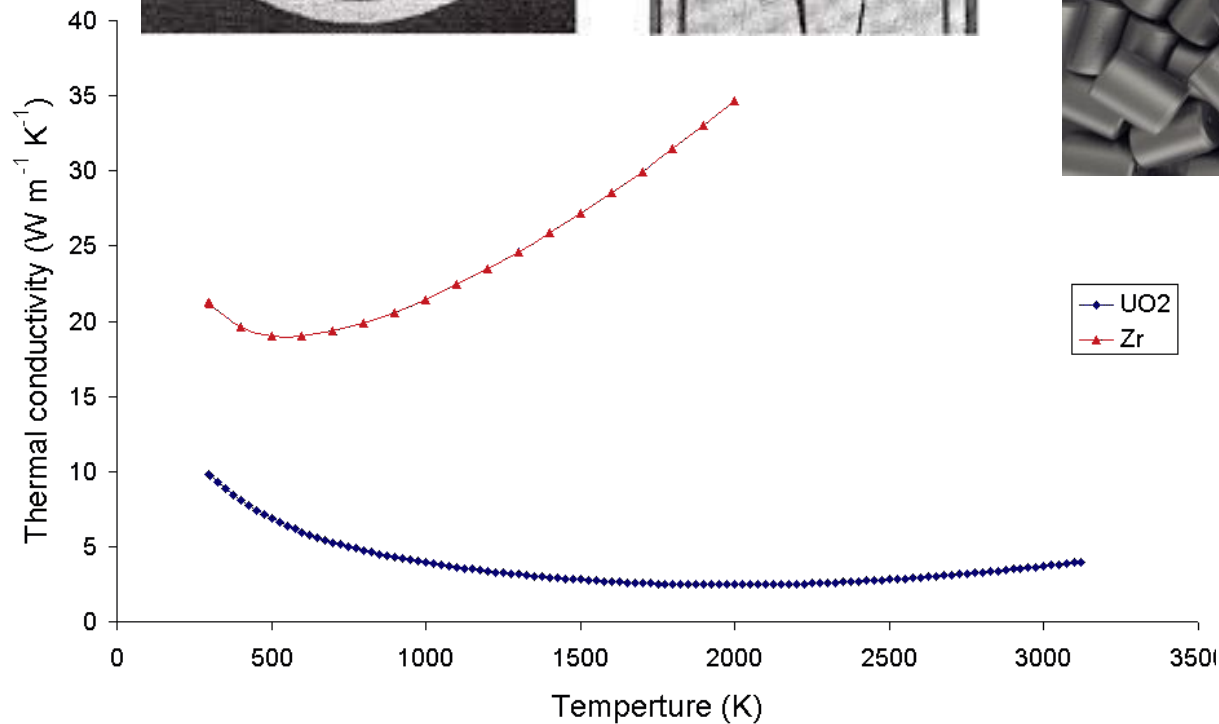
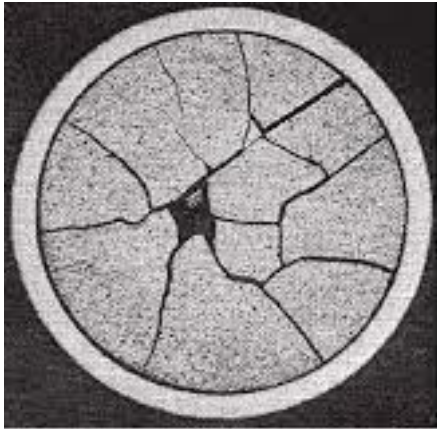


MSR Core



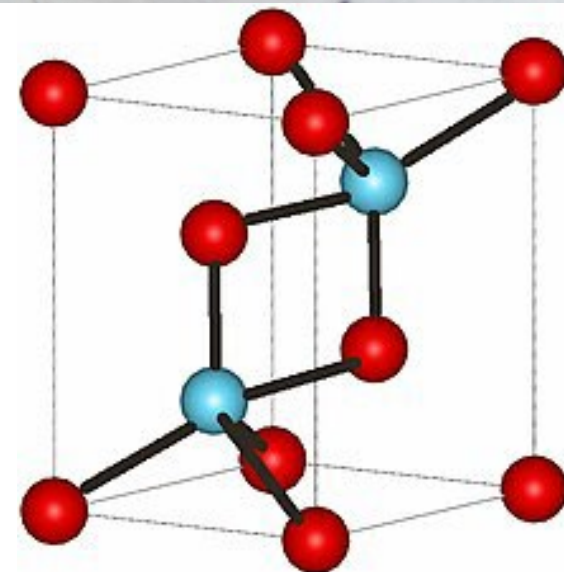
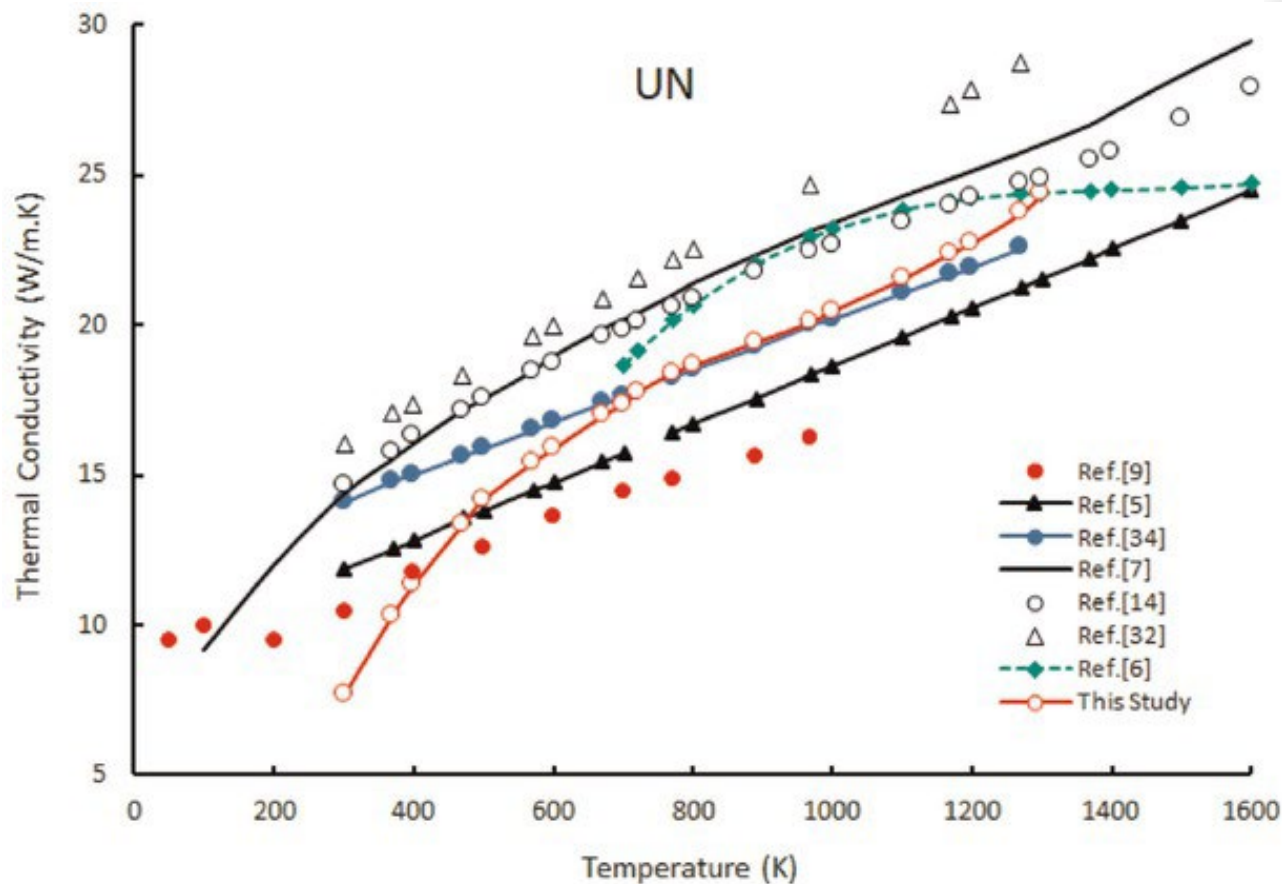
Uranium Oxide Fuel

$$T_m = 2865\text{ }^{\circ}\text{C}$$

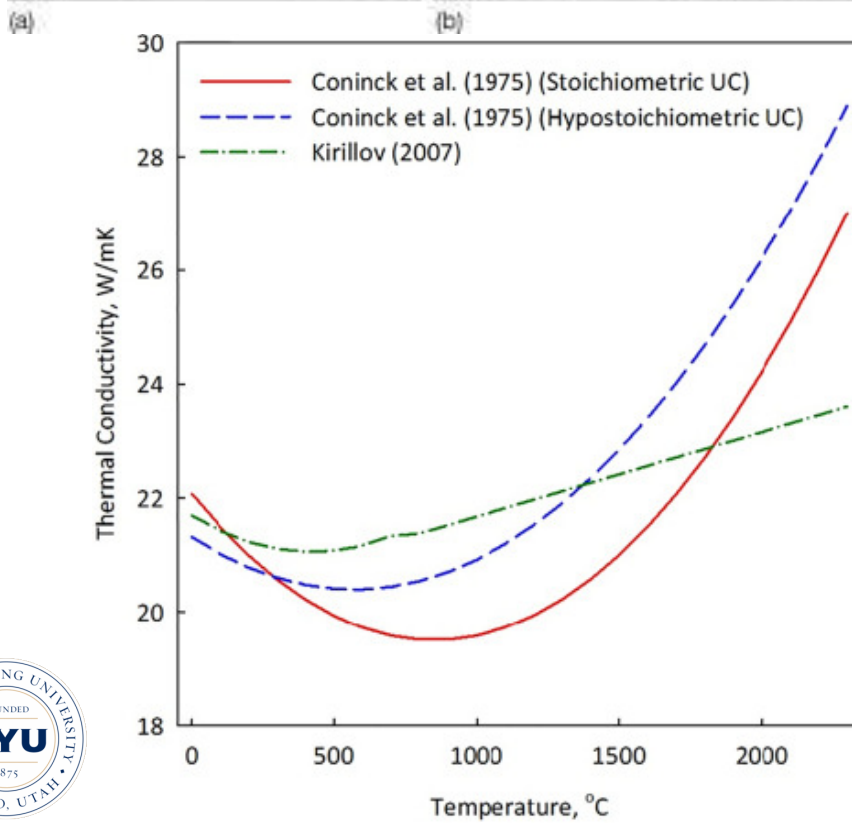
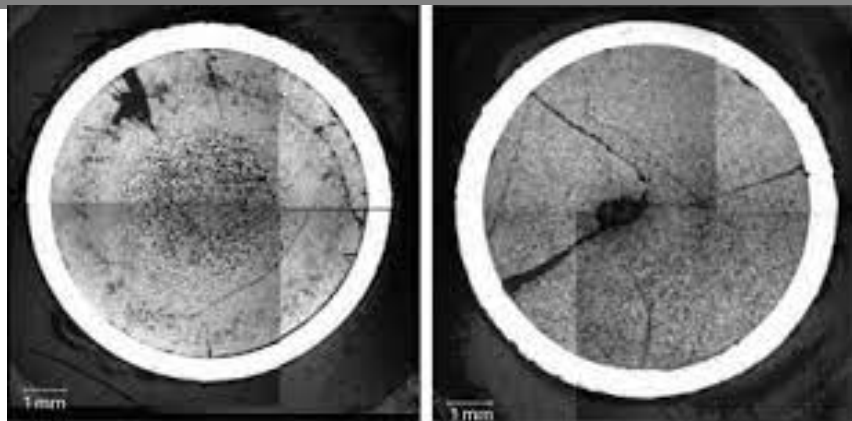


Uranium Nitride Fuel

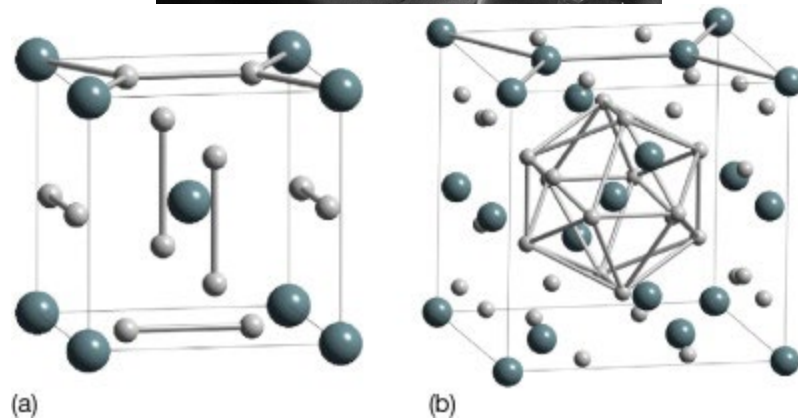
$$T_m = 900\text{ }^{\circ}\text{C}$$



Uranium Carbide Fuel

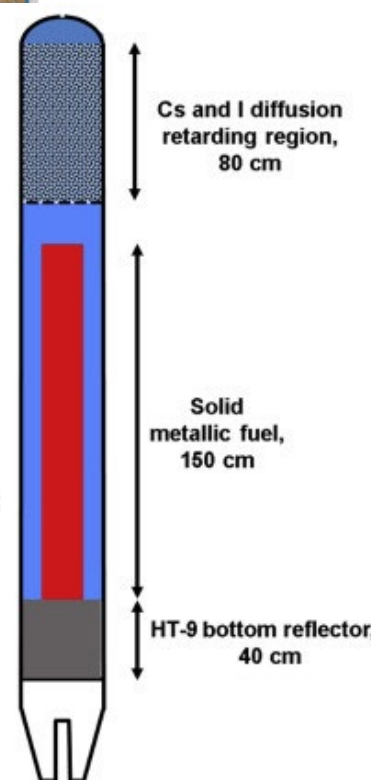
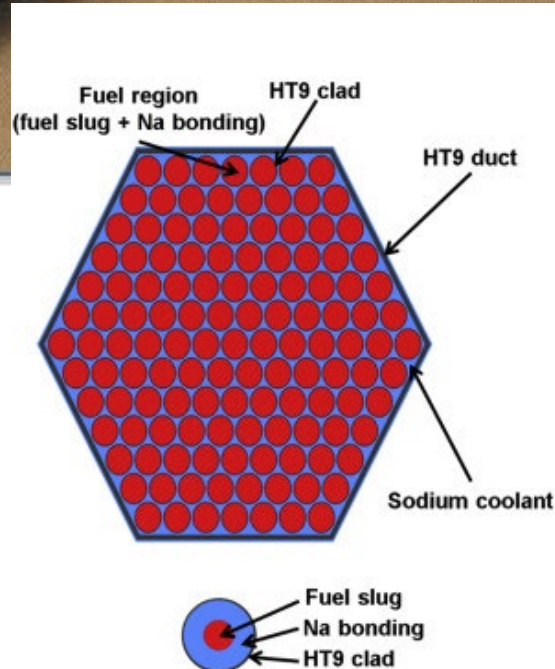
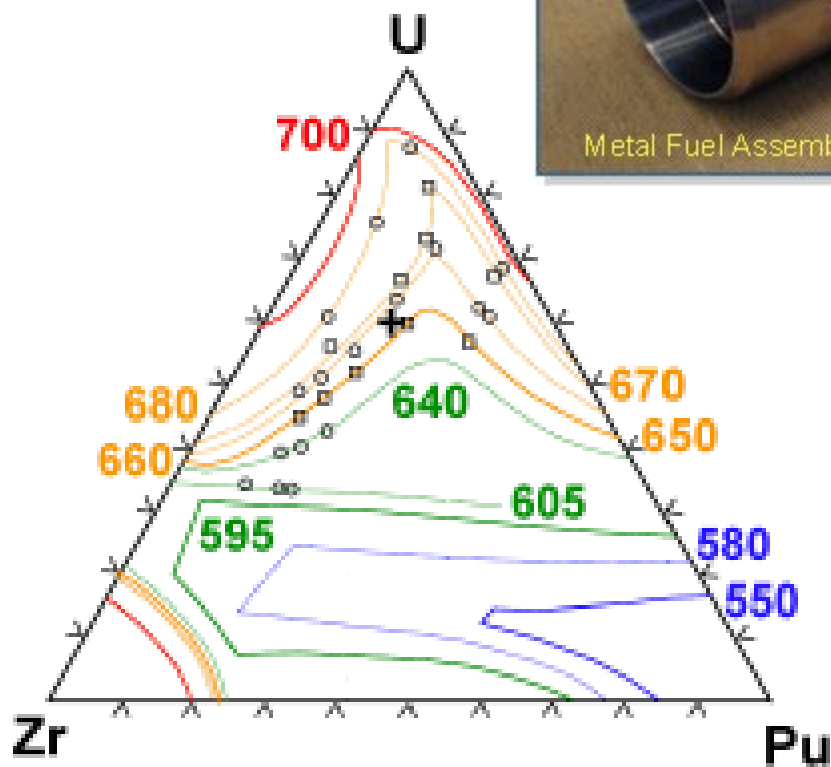


$$T_m = 2350\text{ }^{\circ}\text{C}$$



Metallic Fuel – U-20Pu-10Zr

$$k_f \sim 8.4 \text{ W/m-K}$$



Thermal Parameters

- Thermal Evaluation of Core:
 - Heat generation
 - Neutron Flux – DIFFICULT!
 - Fuel – Type, Number Density
 - Poisons, shim – Directly affects flux
 - $q''' = N\sigma_f\Phi_{avg}E_f = \sum_f N\Phi_{avg}E_f = \frac{W}{cm^3}$
 - pump power requirements
 - $P = \Delta P\dot{V} = \Delta P \frac{\dot{m}}{\rho}$
 - heat removal
 - $Q = \dot{m}C_p\Delta T$

