Chemical Engineering 612

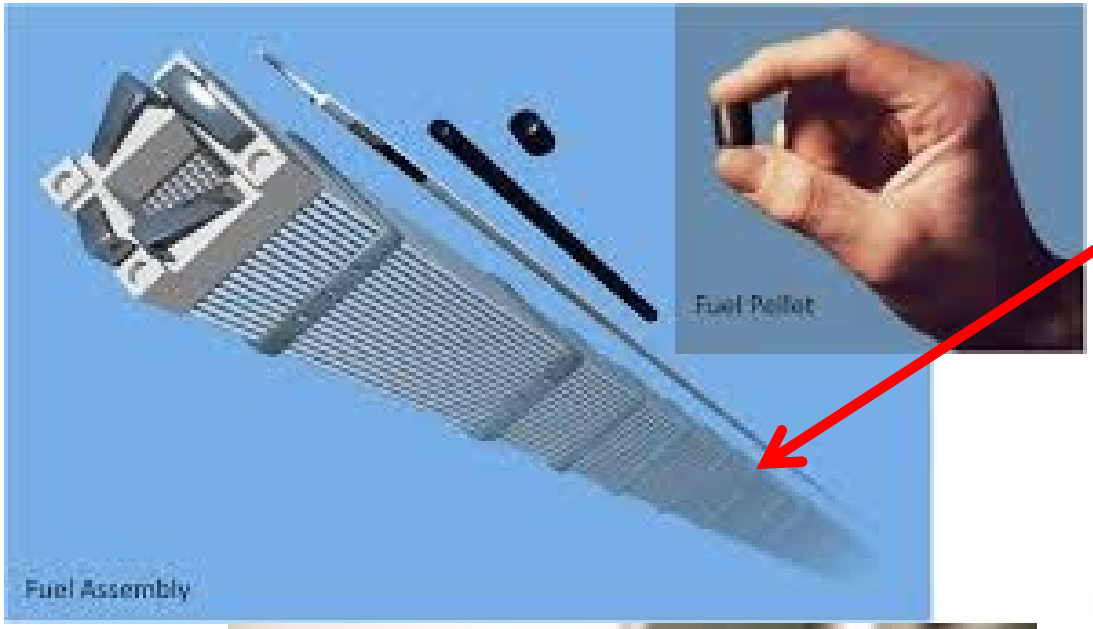
Introductory Nuclear Engineering

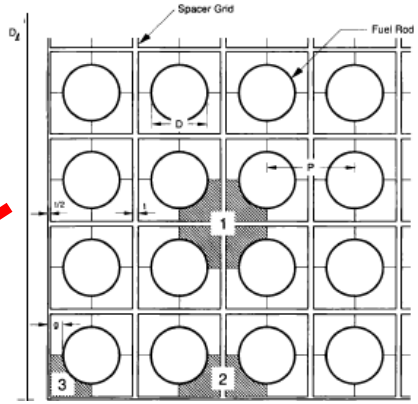
Lecture 11

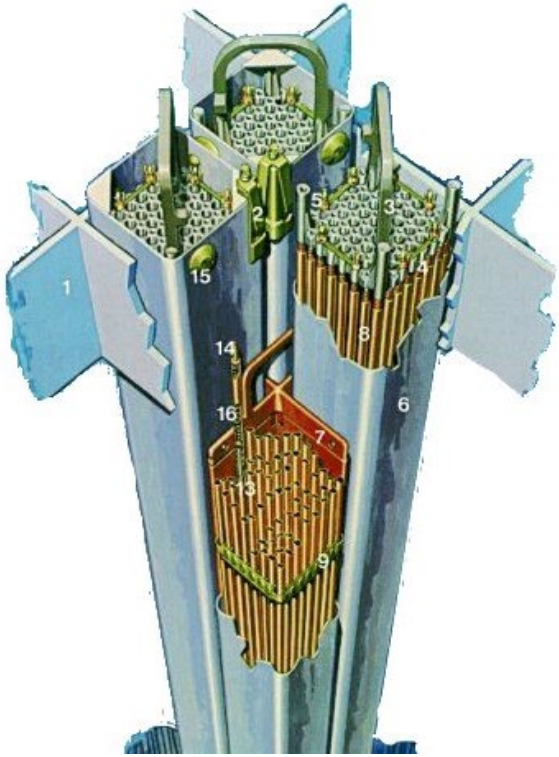
Core Thermal Analysis

Spiritual Thought

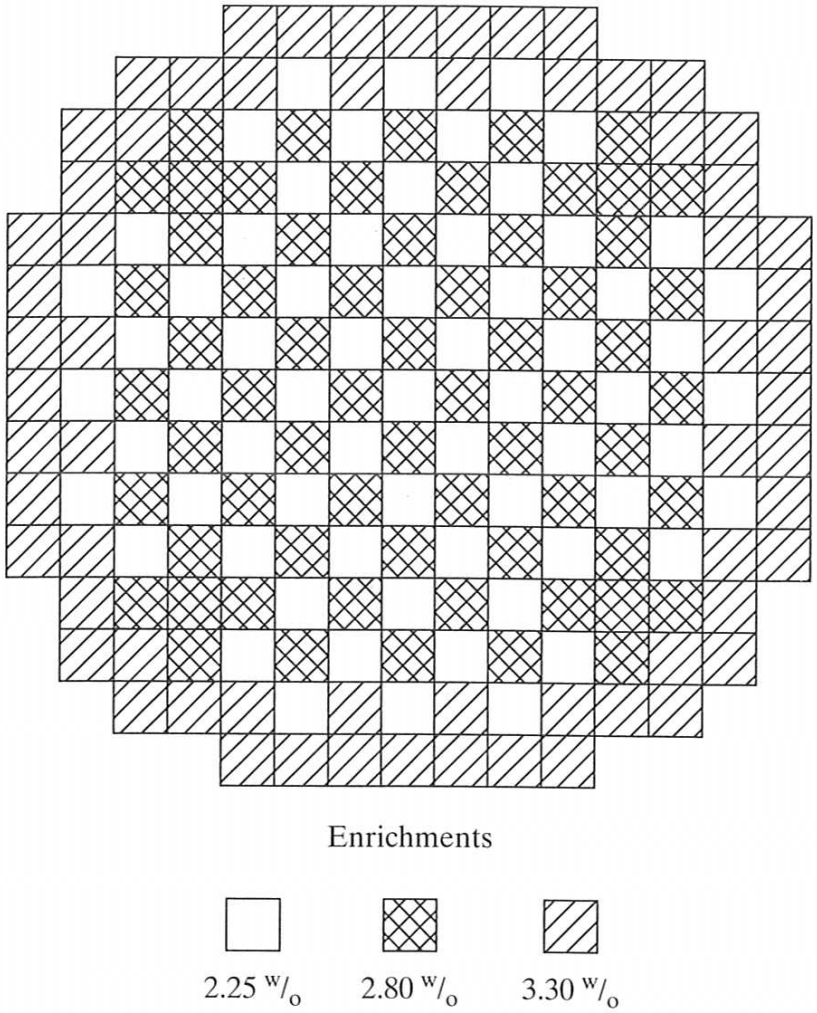
Core Design

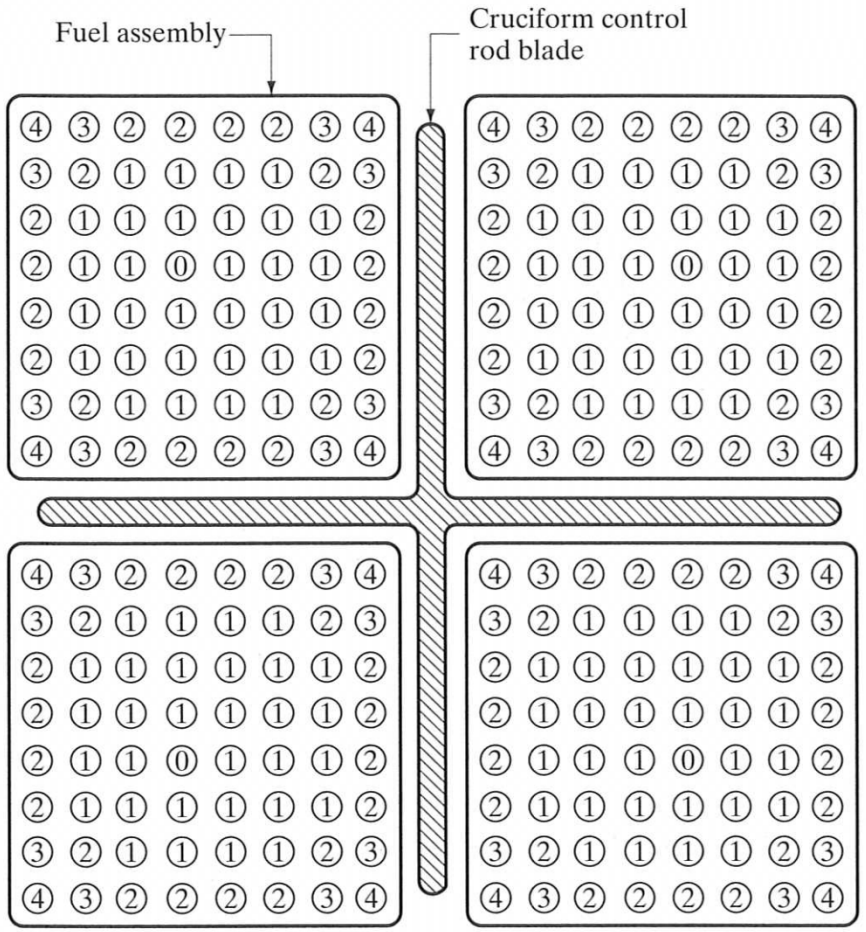




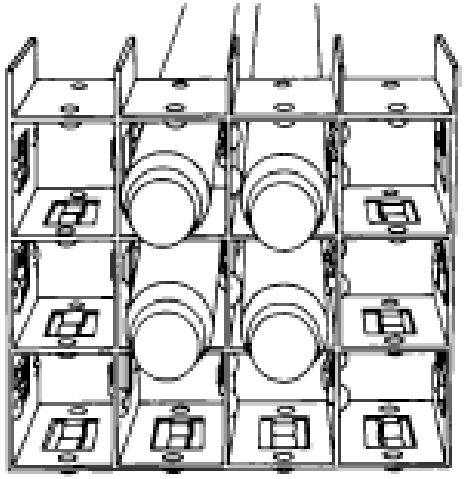


Fuel Loading Patterns





Subchannel Configuration



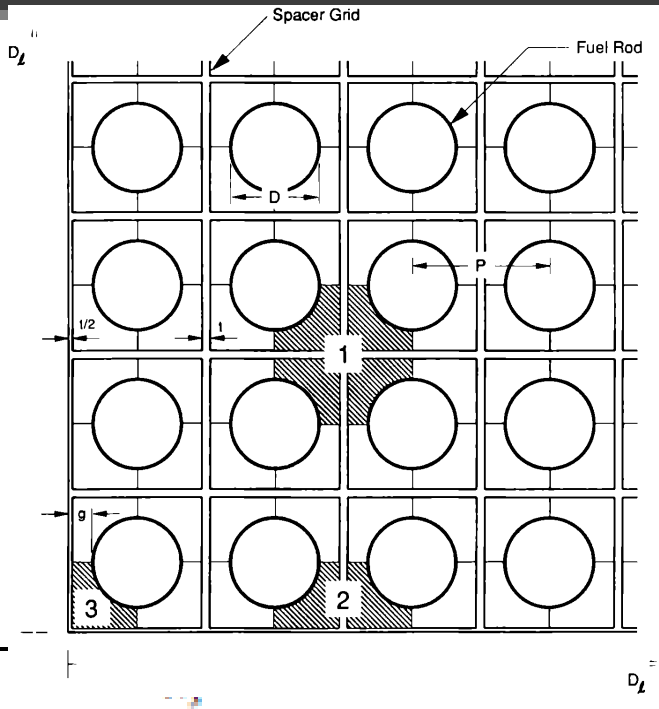
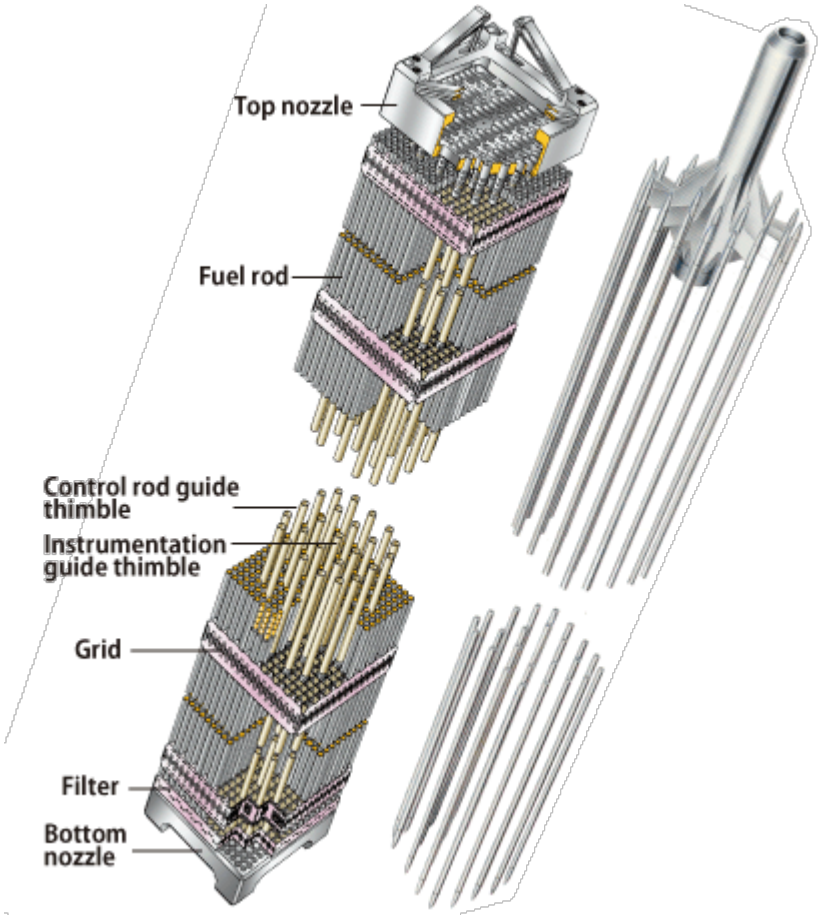


Table 1-4 Subchannels for square arrays

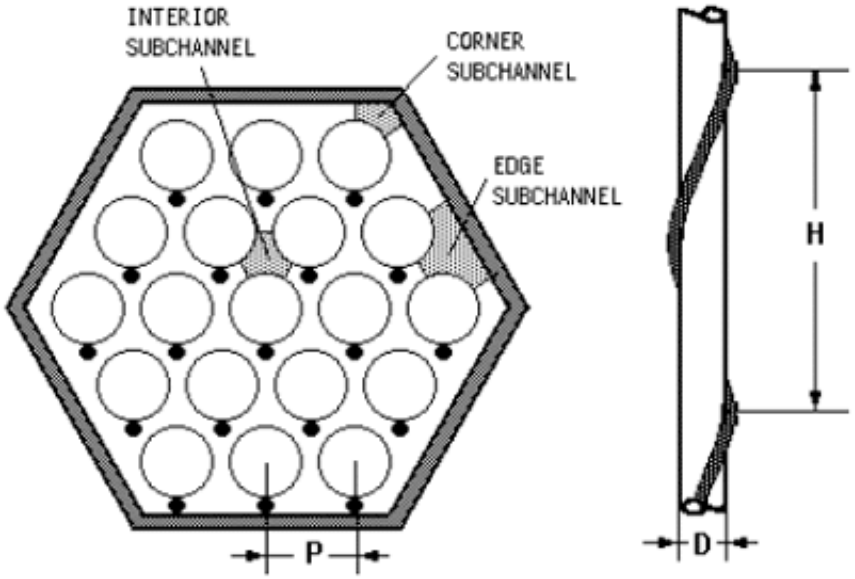
Rows of rods	N_p Total no. of rods	N_1 No. of interior subchannels	N_2 No. of edge subchannels	No. of corner subchannels
1	1	0	0	4
2	4	1	4	4
3	9	4	8	4
4	16	9	12	4
5	25	16	16	4
6	36	25	20	4
7	49	36	24	4
8	64	49	28	4
N_{rows}	N_{rows}^2	$(N_{rows} - 1)^2$	$4(N_{rows} - 1)$	4

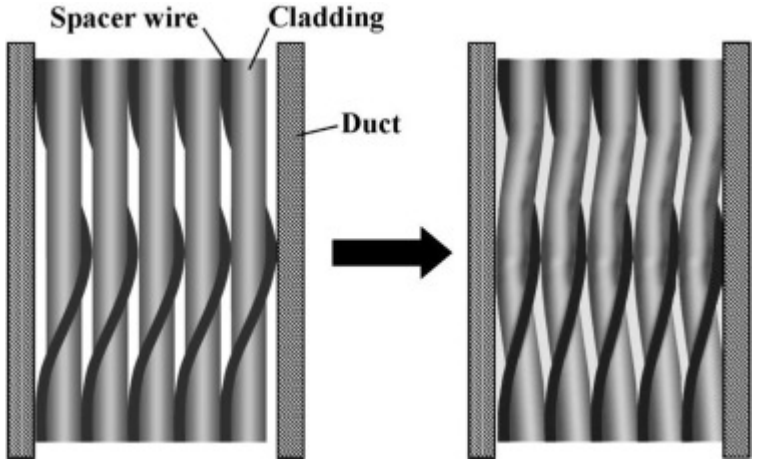
Cluster Control Rods



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

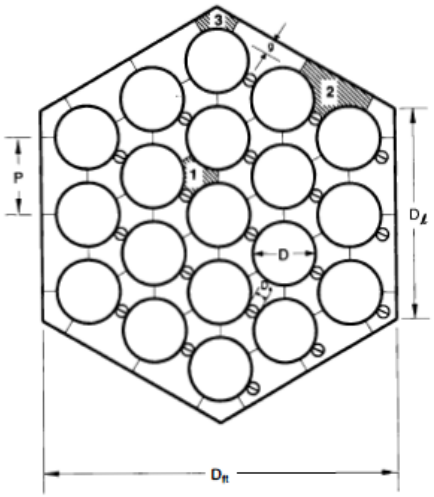
Additional useful relations between N_p, N_{pS}, and N_1 are as follows.

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

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

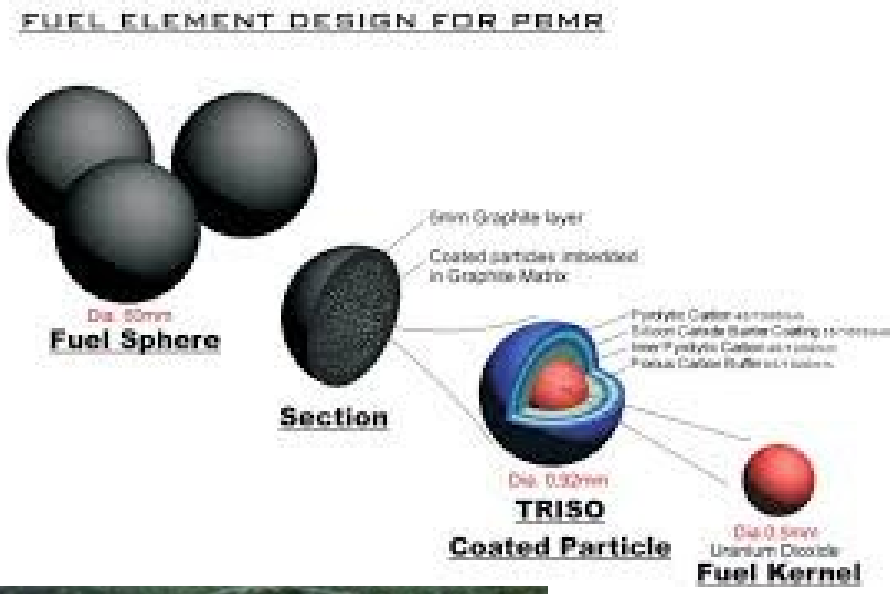
$$N_1 = 6(N_{pS} - 1)^2$$

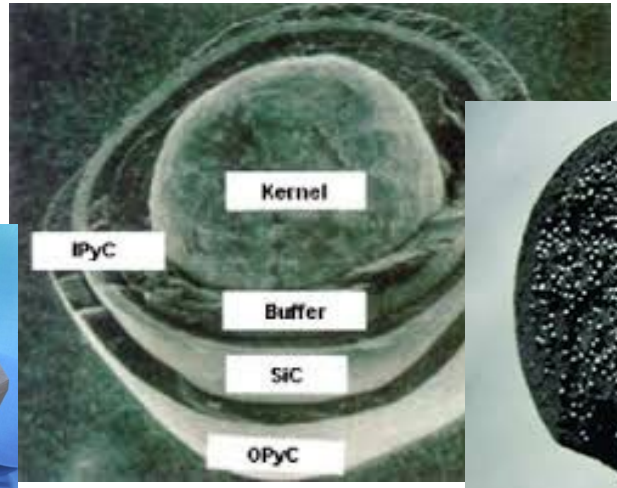
$$N_2 = 6(N_{pS} - 1)$$

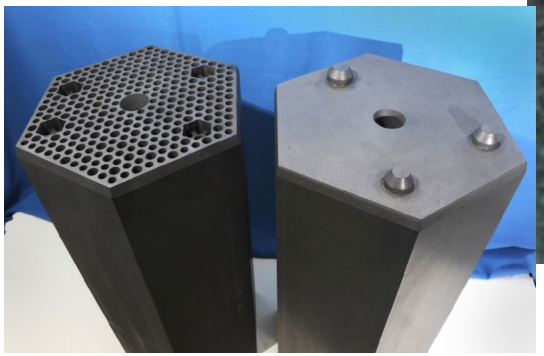


VHTR Fuel (USNC)

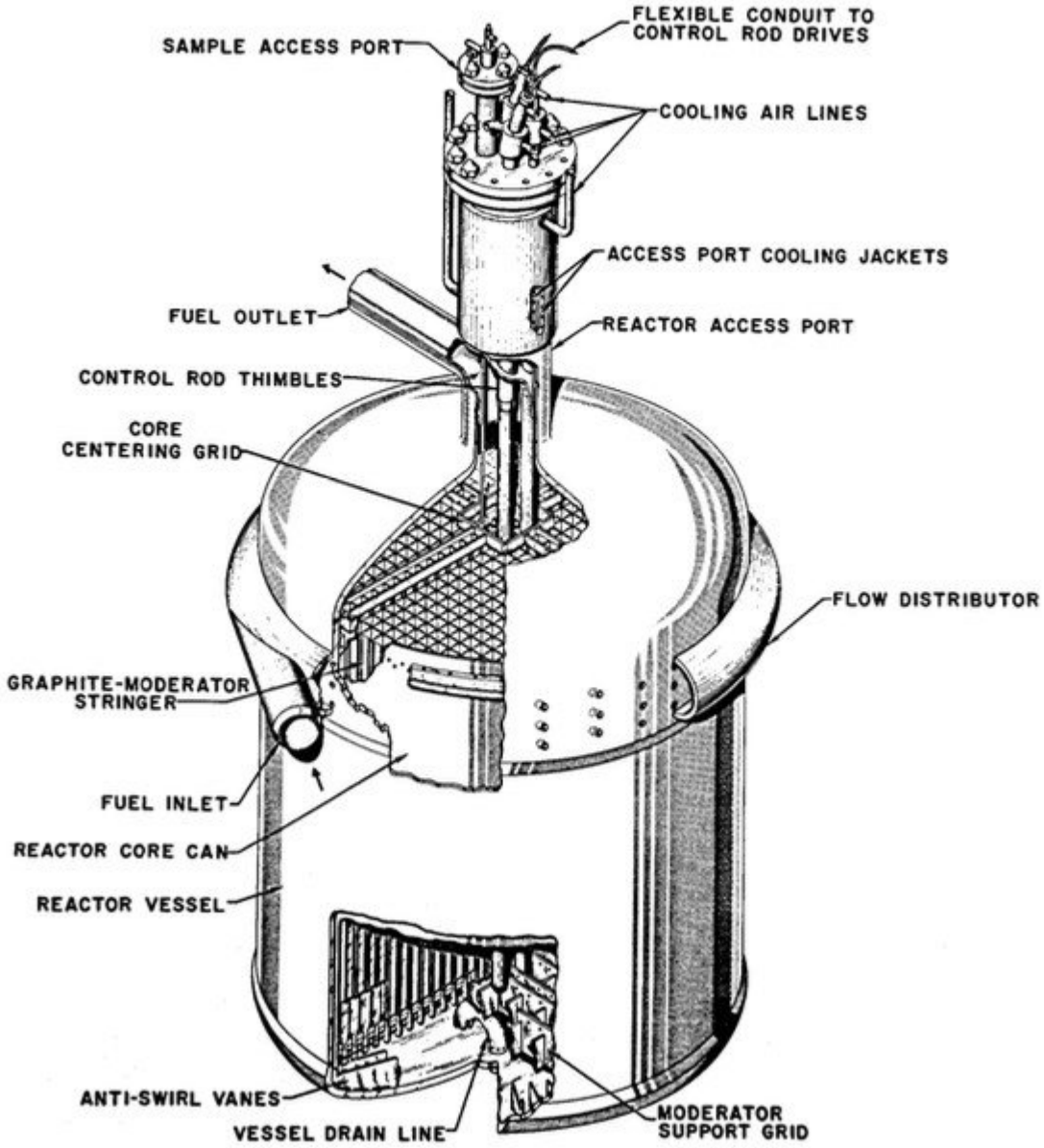
- TRISO fuel
  - Man tiny pellets into graphite matrix sphere
  - Melt-down proof
  - Failure specs?
- Susceptible to air-ingress accidents (fire)
- Also used in FHR



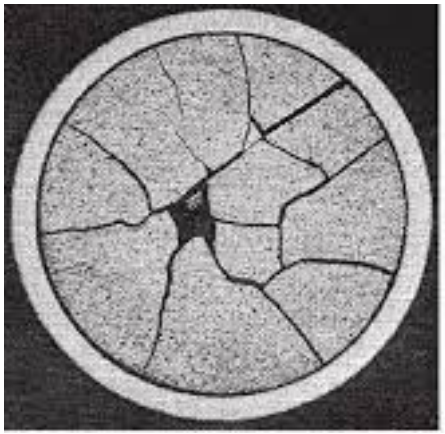




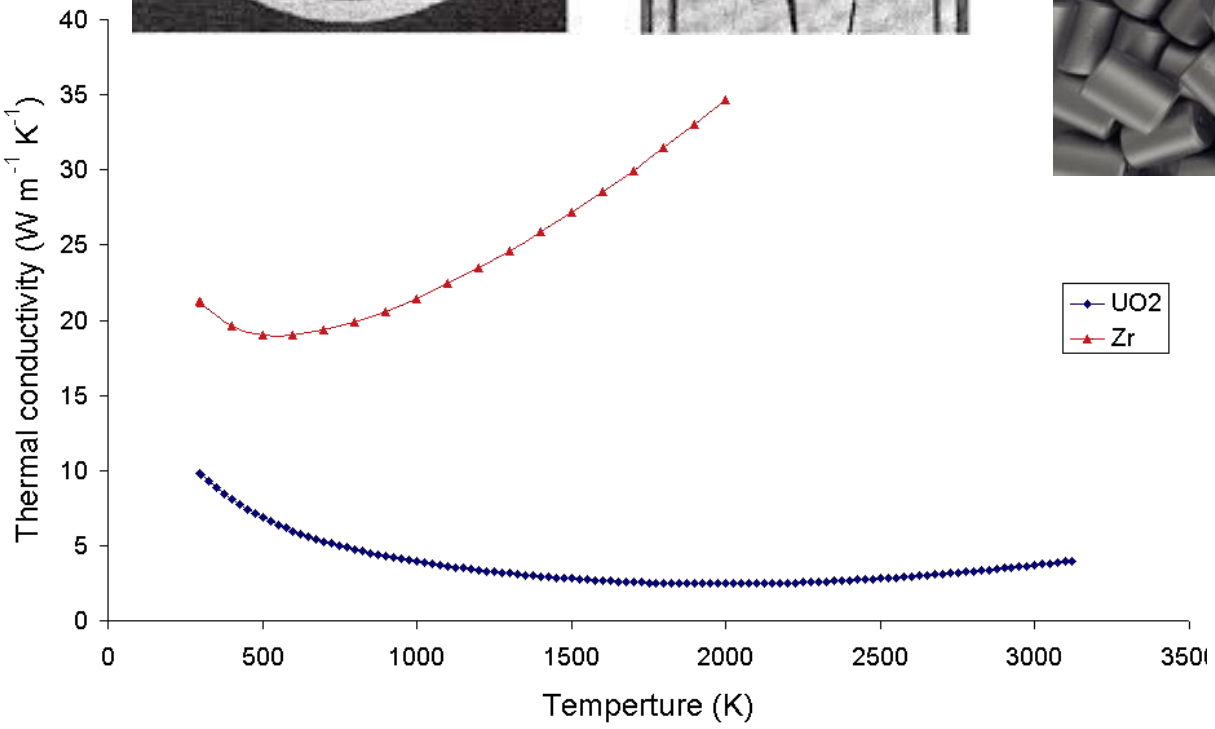
MSR Core

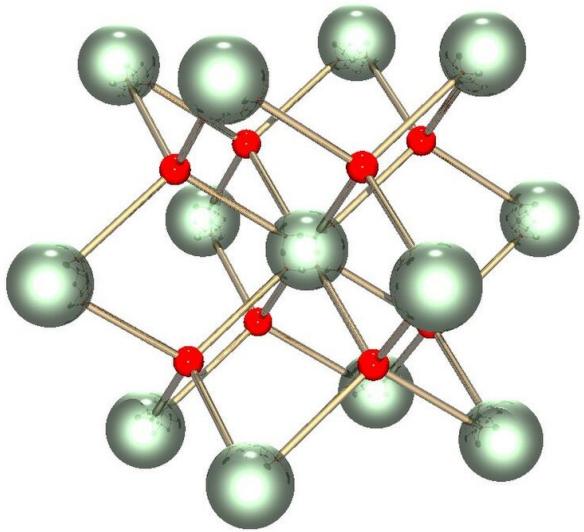


Uranium Oxide Fuel



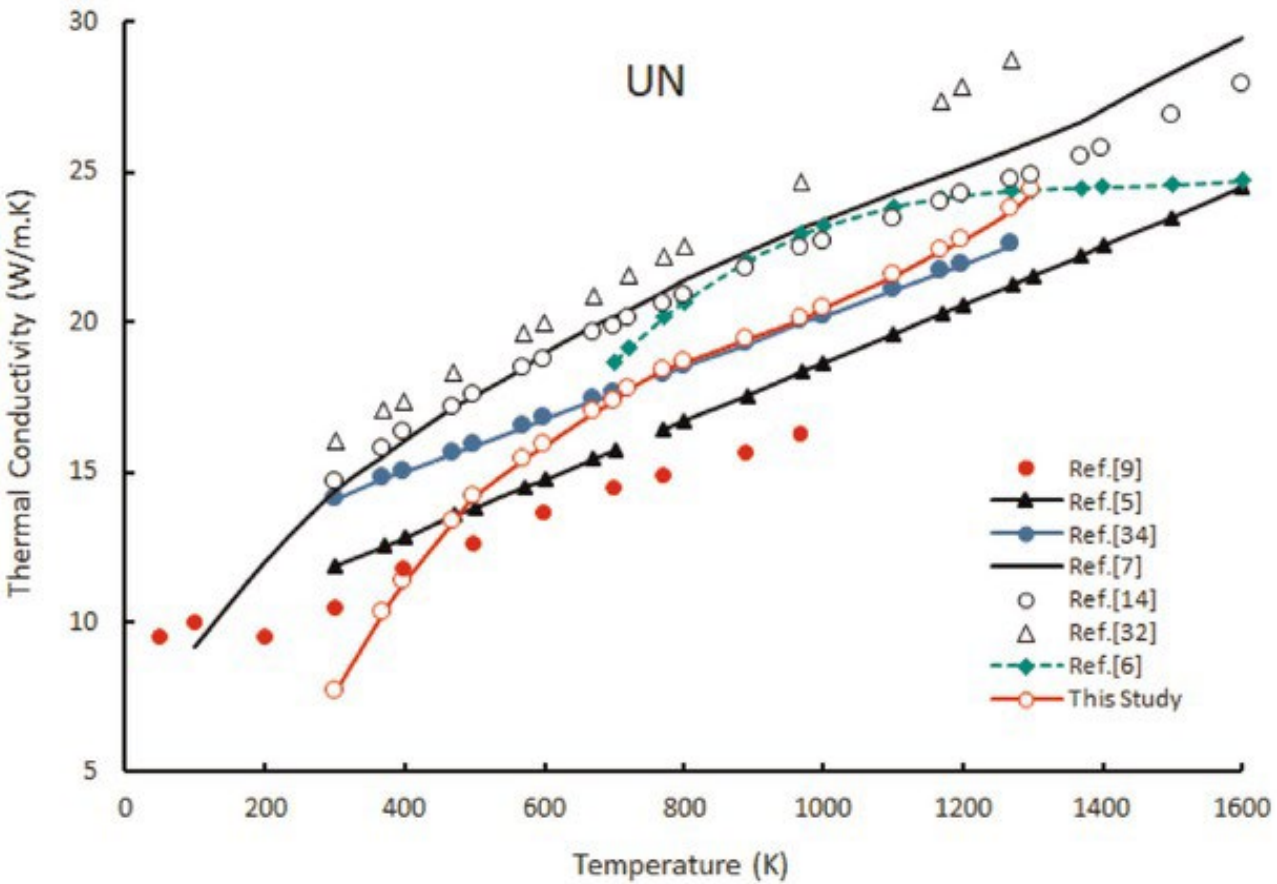
T_m = 2865 °C

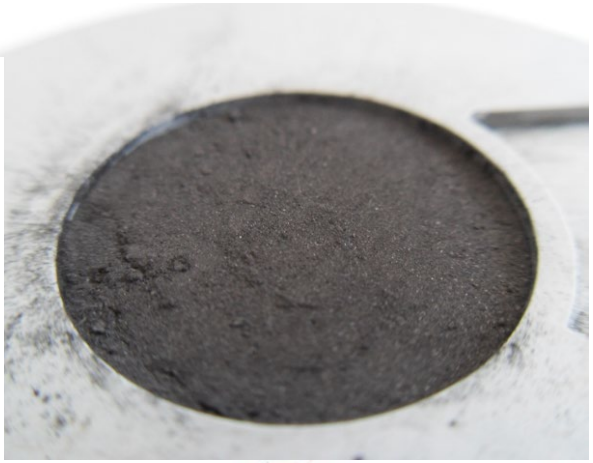


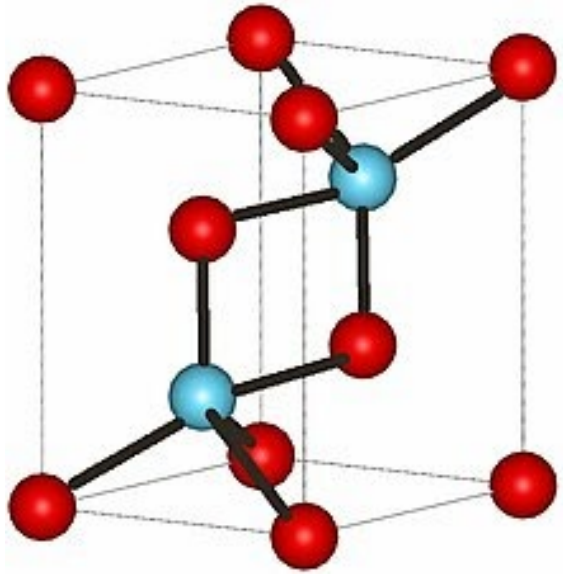


Uranium Nitride Fuel

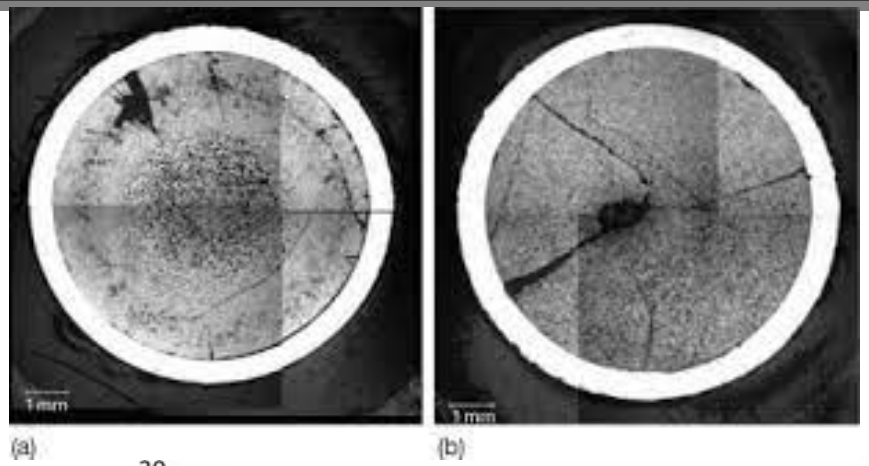
T_m = 900 °C

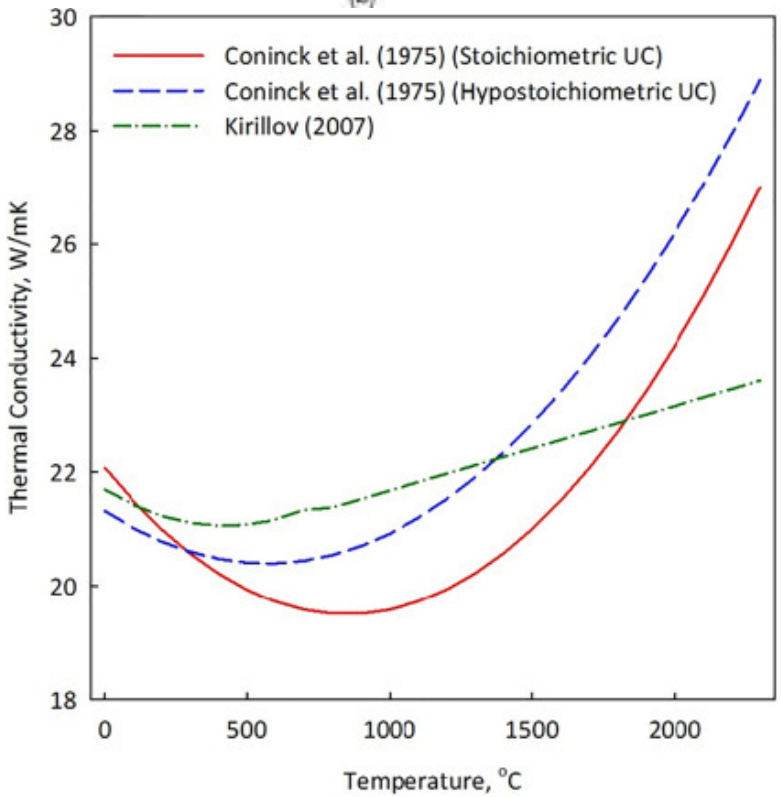




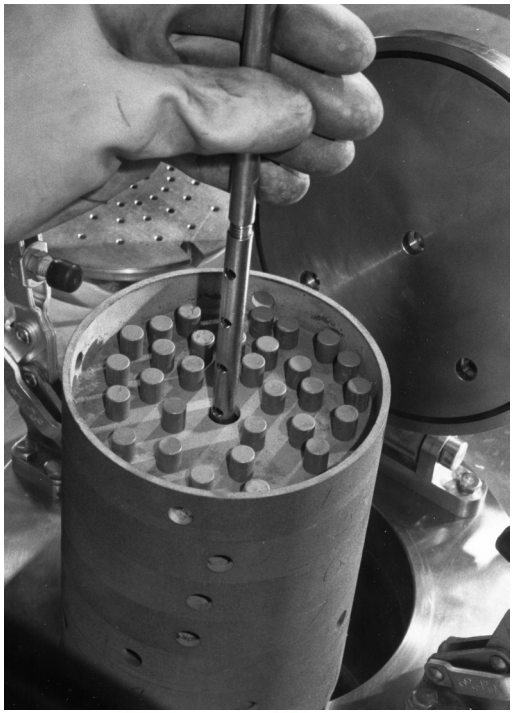


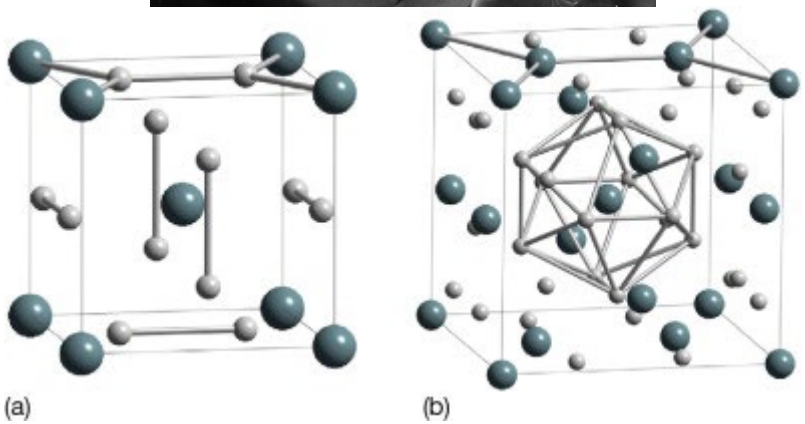
Uranium Carbide Fuel





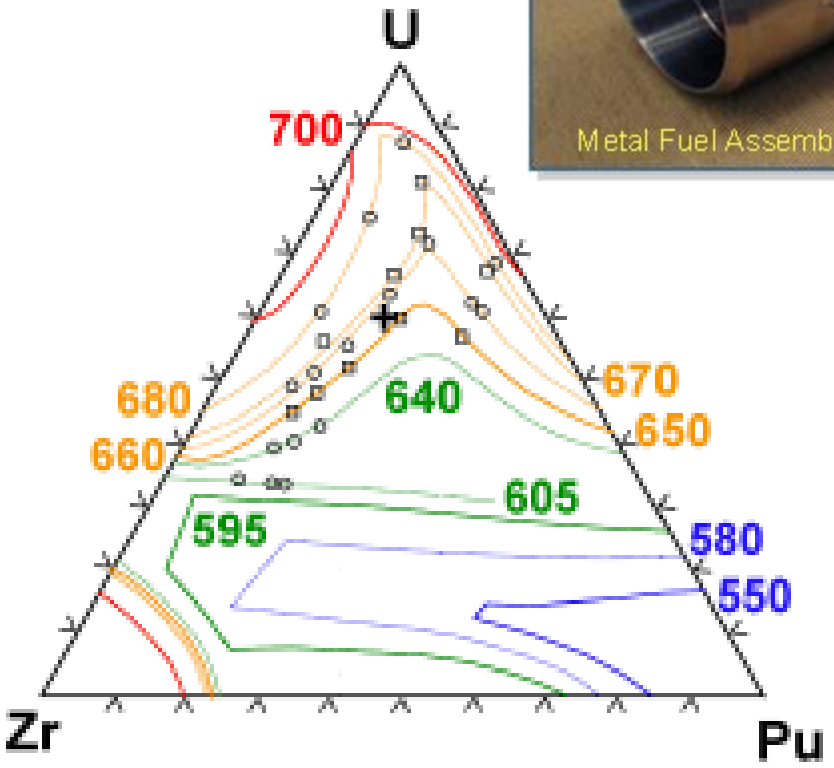
T_m = 2350 °C

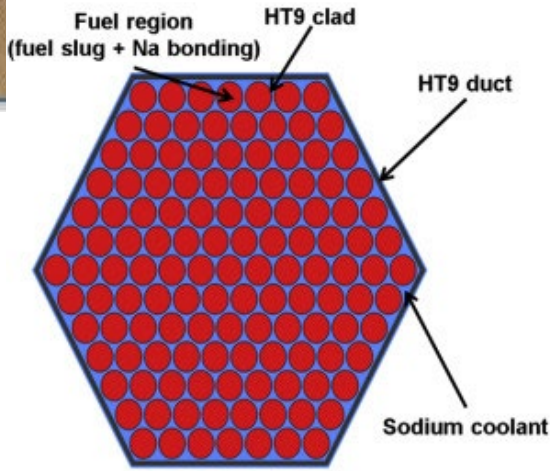


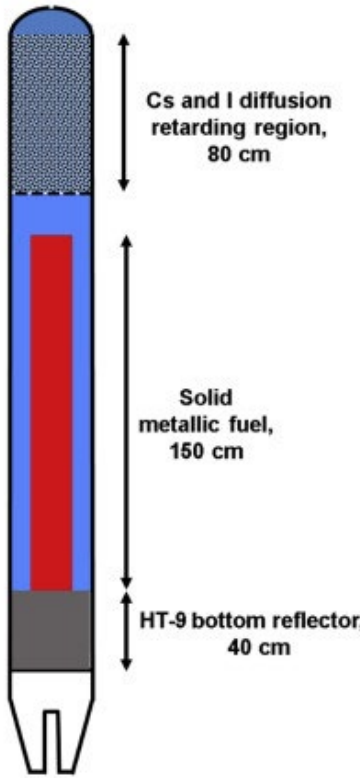


Metallic Fuel – U-20Pu-10Zr

k_f ~ 8.4 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
    - $Q = \dot{m} C_p \Delta T$