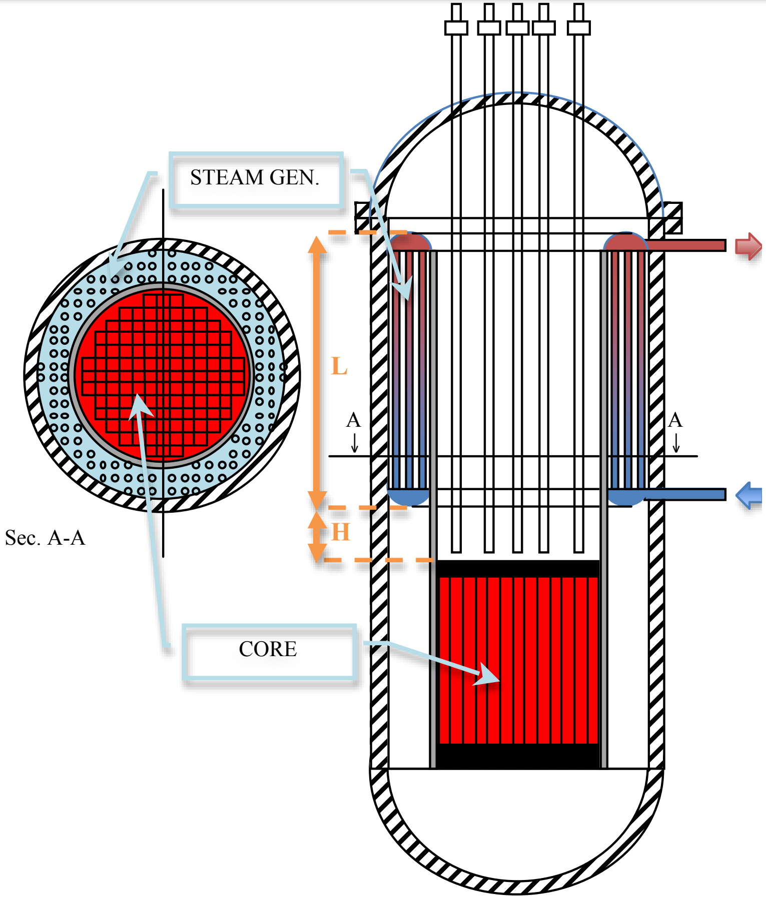
- Project Work #1 -
Small Modular Reactor, Natural Circulation mode



Natural Circulation SMR		
Reactor Thermal Power	300 MWth	W
Tcore in	292 degC	Tin
enthalpy-in	1300 kJ/kg	hin
density-in	727.6 kg/m³	ρin
Tcore out	329 degC	Tout
enthalpy-out	1520 kJ/kg	hout
density-out	643.5 kg/m³	ρout
Primary pressure	155 bar	Pc
# Fuel assemblies	121	Nfa
Fuel assembly (fuel rods)	(17 x 17)	
Fuel rod diam.	9.5 mm	Dfr
Fuel rod pitch	12.67 mm	Pfr
Fuel rod length	3 m	Lfr
Once-Through Steam Generator		
SG Tube outer diam.	10 mm	OD
SG Tube inner diam.	8.5 mm	ID
SG Tube pitch	15 mm	Psg
SG pressure	65 bar	Ps
Tsat (@65 bar)	280.82 degC	Tsg
Tube thermal conductivity	30 W/m K	Ksg
RPV inner diam.	3.75 m	
Barrel outer diam.	2.75 m	
Global heat transfer coeff.	5100 W/m² K	α
Form pressure loss coeff.		
Core support plate	4	K1
Core upper plate	4	K2
SG area - inlet	3.5	K3
SG area - outlet	3.5	K4
Fuel rod, SG tube roughness	4×10^{-6} m	e
Fluid viscosity	8.284×10^{-5} kg/m s	μ

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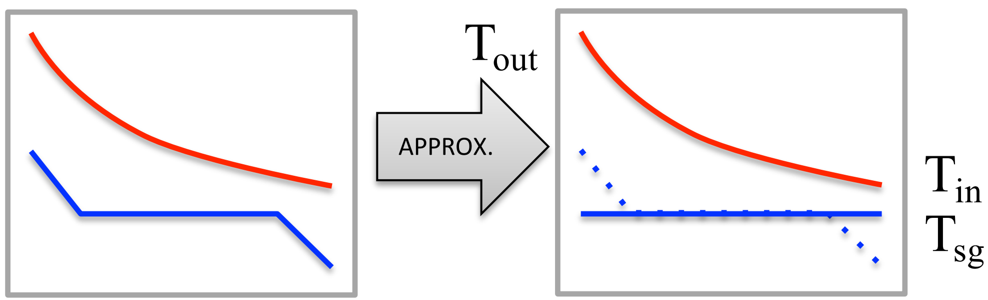
Thermal power transferred to SG: $W_{SG} = \alpha \; S \; \Delta T$

Number of SG tubes Nt (approx.): Nt = 80% x Annular area / SG tube lattice area
(SG tube lattice area = Pitch^2)

SG heat transfer surface S: $S = L \; \pi \; D \; Nt$



Primary-Secondary Temp. jump ΔT:
(logaritmic average)

$$\Delta T = \frac{(T_{out} - T_{sg}) - (T_{in} - T_{sg})}{\ln \left[(T_{out} - T_{sg}) / (T_{in} - T_{sg}) \right]}$$

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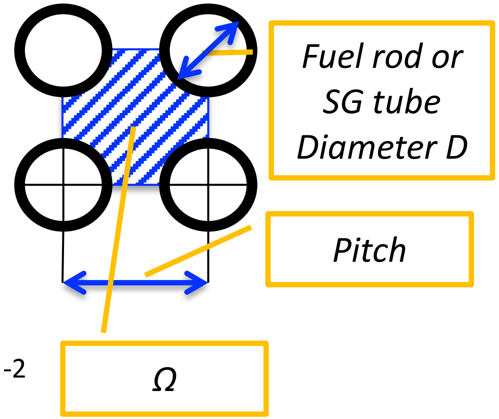
Square lattice for Fuel rods and SG Tube bundle



Reactor core flow rate Γ: $W = \Gamma\ (h_{out} - h_{in})$

Fluid velocity v: $\Gamma = \rho\ v\ \Omega_{total}$

Local pressure drops: $\Delta Pc = K\ \rho\ v^2/2$

Distributed pressure drops: $\Delta Pf = L\ 2\ f\ \Gamma^2 / (\rho\ D_{eq}\ \Omega^2)$

Friction factor: $f = [\ 3.8\ \log_{10}(10/Re + 0.2\ e/D_{eq})\ ]^{-2}$

Reynolds number: $Re = \rho\ v\ D_{eq} / \mu$

Equivalent hydraulic diameter: $D_{eq} = 4\ \Omega / \Pi$

Fluid cross section area Ω (see figure), Wetted perimeter $\Pi = \pi\ D$

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- **First goal**: code a steady-state model for the Small Modular Reactor, to dimensioning:
  - the tube-bundle average length of the Steam Generator modules
  - the clearance between the Core and the Steam Generators, to sustain the Natural Circulation mode

- **Second goal**: code a model able to perform parametric analysis of the SMR configuration, by changing:
  - core thermal power
  - secondary pressure
  - steam generator tube pitch or tube outer diameter

- **Third goal**: design (and - if possible - start coding) a dynamic model for the SMR, able to simulate operational transients for the Steam Generators (Feedwater Temperature and Feedwater Flowrate stepwise variations, assuming constant core power – no neutronic feedbacks)

SUGGESTION: IDENTIFY APPROPRIATE QUESTIONS

1. What is the final **goal**?
2. What are the **requirements**?
3. What are the most important physical (thermal-hydraulics) **phenomena**?
4. What are the **boundary conditions**?
5. What are the appropriate **assumptions**?
6. What is a suitable **modelling** strategy?
7. What are the **tools** / the **data** we need?
8. What is a suitable **solving system** / solving **procedure**?
9. What are suitable **tests** to prove we are progressing in the right way?