ELSMOR

Towards European Licensing of Small Modular Reactors

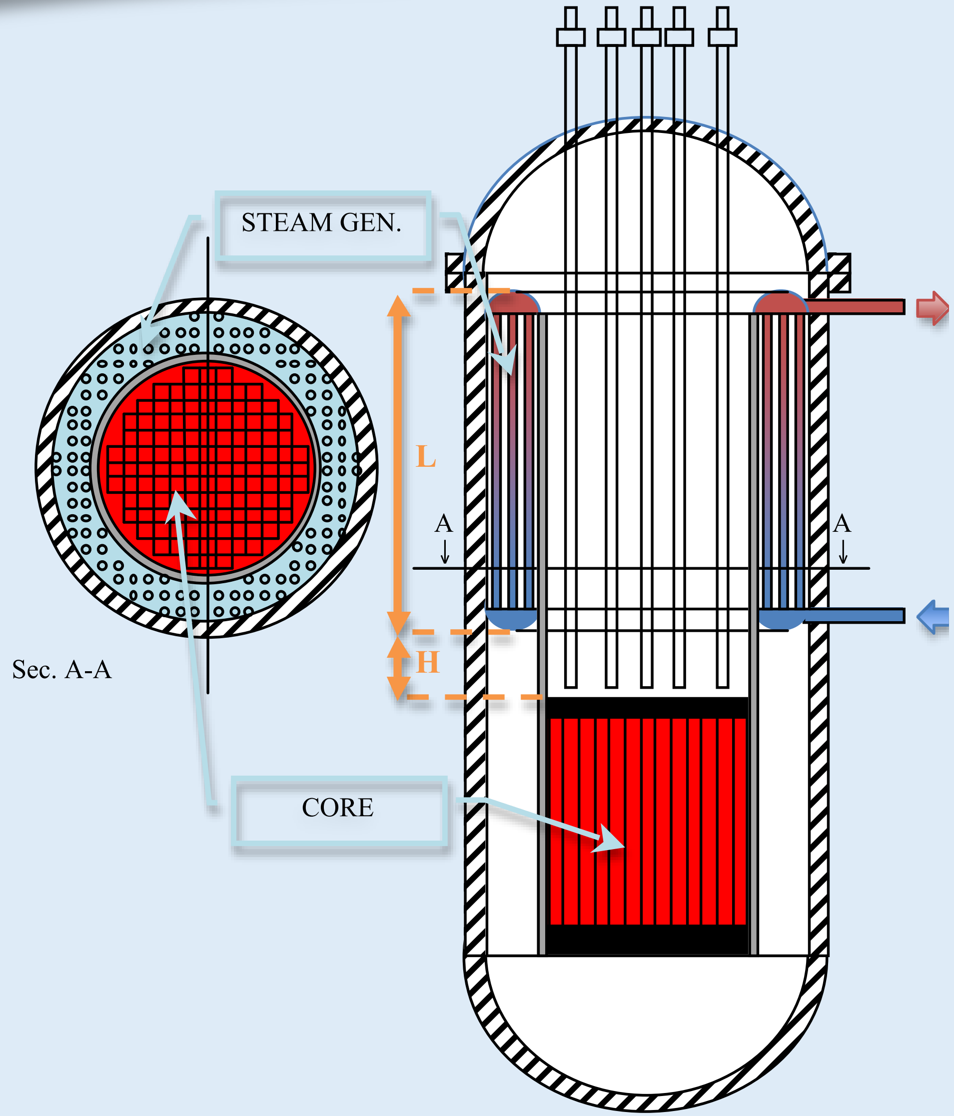
International Summer School on

Early-deployable Small Modular Reactors

2022

July, Tue 5 - Fri 8

Working Groups – SMR exercise 2: natural circulation calc.



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/m^3	ρin
Tcore out	329 degC	Tout
enthalpy-out	1520 kJ/kg	hout
density-out	643.5 kg/m^3	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/m^2 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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SMR: Integral PWR type
Full natural circulation

Calculate:

1. The length L of the Steam Generator tube bundle
2. The gap/clearance H from core top to SG bottom, to sustain the natural circulation

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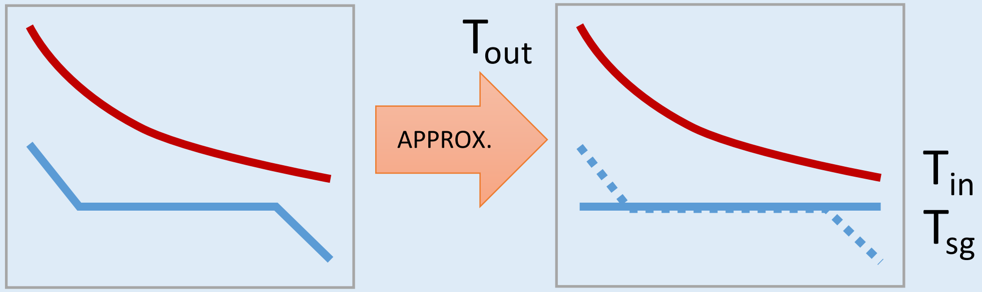
Thermal power transferred to SG: $W_{SG} = \alpha\ S\ \Delta T$

Number of SG tubes Nt (approx.): $Nt = 80\% \times \text{Annular area} / \text{SG tube lattice area}$

(SG tube lattice area = Pitch²)

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



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

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

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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Square lattice for Fuel rods and SG Tube bundle