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Group Activity-I

Basics of SFR Core Thermal-Hydraulic Modeling

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1 INTRODUCTION

Phenix is a sodium cooled pool-type fast reactor of 563 MW(th) (250MW(e)). It started it's operation in 1973 and it was stopped in 2009. From 1993, it was operated at a reduced power of 350 MW(th) (140 MW(e)).

The Reactor characteristic described in the exercise represent Phenix reactor, the parameters given are for Phenix Reactor during it's early years of operation and the data was taken from IAEA-TECDOC-1703 and IAEA-TECDOC-1742

The main objectives of the exercise are:

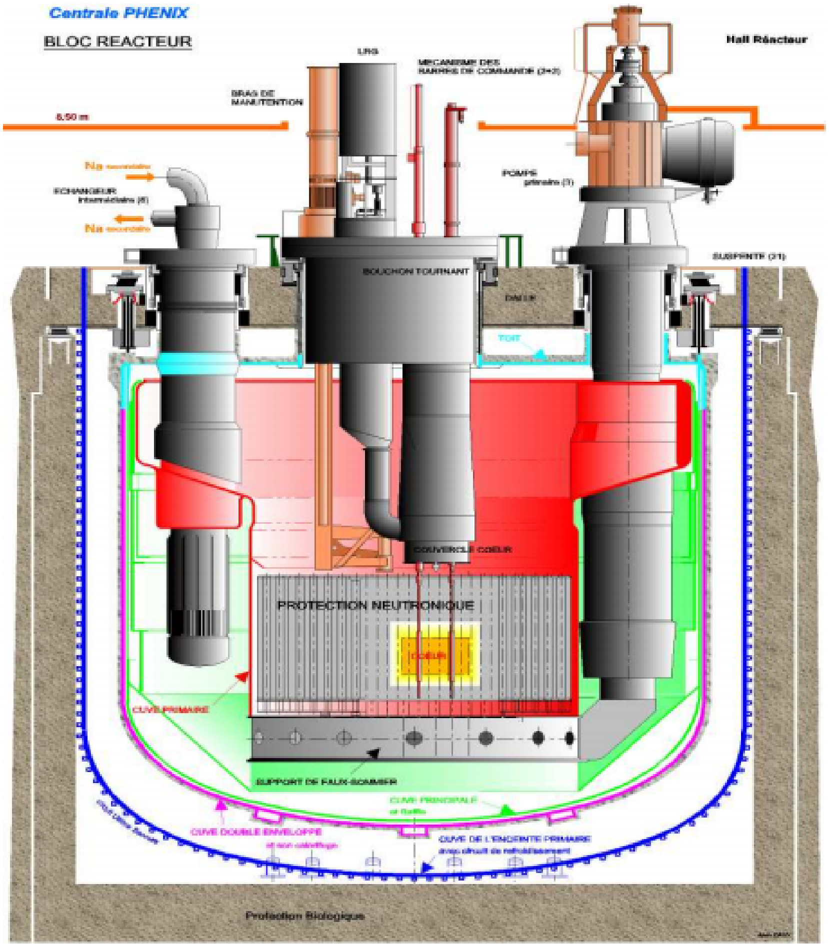

Figure 1.1: Phenix Reactor Block

- To understand the basic thermal hydraulic characteristics of a sodium cooled fast reactor
- To calculate the power profile, temperature profile etc. to understand the reactor behaviour

2 Reactor Information

2.1 Core Configuration

Number of fuel SA in the inner core:	54
Number of fuel SA in the outer core:	56
Number of fertile SA:	86
Number of control rod SA:	6
Number of safety rod SA:	1
Number of steel reflector SA:	212
Number of B4C shielding SA:	765
Number of steel shielding SA:	297

For the purpose of exercise, consider only the fuel Sub Assemblies

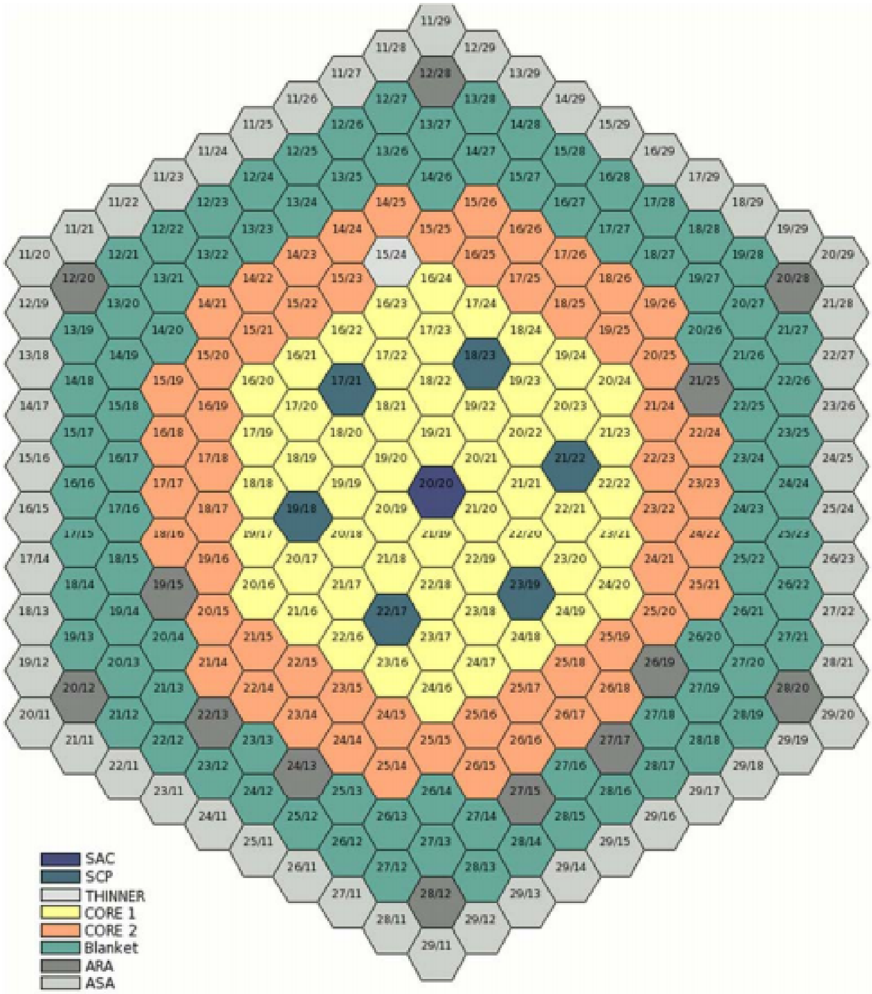

Figure 2.1: Core Configuration

2.2 Geometrical Data for the Fuel Subassembly

Number of pins in SA:	217
Pitch of pins (P):	7,773 mm
Inner diameter of fuel clad:	5,65 mm
Outer diameter of fuel clad (D):	6,55 mm
Diameter of fuel pellet:	5,42 mm
Width across flat of SA:	116,9 mm
SA length:	4300 mm
Active core portion length:	850 mm

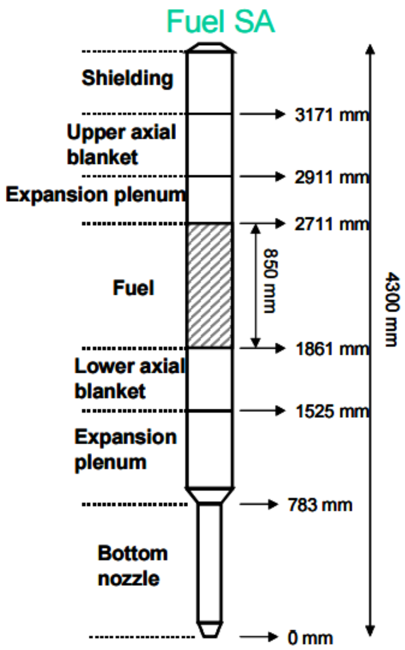

Figure 2.2: Fuel Sub Assembly

2.3 Reactor Parameters

Parameter	**563 MW regime (1974-1993)**	**350 MW regime (1993-2009)**
Thermal power (MW)	563	345
Gross electrical power (MW)	250	142
Net electrical power (MW)	233	129
Neutron flux at core centerline (n/cm2.s)	7×10^{15}	4.5×10^{15}
Primary sodium core outlet temperature (°C)	560	530
Primary sodium core inlet temperature (°C)	400	385
Secondary sodium SG inlet temperature (°C)	550	525
Superheated steam temperature (°C)	512	490

$PeakingFactor K = K_z \times K_r = 1.62$
where, K_z is the axial peaking factor and K_r is the radial peaking factor

Consider the 563 MW regime for the exercise

2.4 Most Powerful Subassembly

Thermal Power (MW)	6.037971
Mass Flow $\dot{m}$(kg/s)	25.1147
Inlet Temperature T_{in} (°C)	400

2.5 Sodium Properties

Specific Heat Capacity C_p (J/Kg.K)	1268
Thermal Conductivity λ_{Na} (W/m.K)	66
Viscosity η (Pa.s)	2.410^{-4}
Density ρ_{Na}	$830 kgm^{-3}$

2.6 Other Material Properties

Thermal Conductivity Clad- λ_{cl} (W/m.K)	22
Thermal Conductivity Gap- $\lambda_g (W/m.K)$	0.5
Thermal Conductivity Fuel- $\lambda_f (W/m.K)$	3.2

2.7 Useful Equations and Correlations

Fourier Law:

$$q''(r) = -\lambda(r, T)\nabla T \tag{2.1}$$

where, q'' is the heat flux $[W/m^2]$

Heat conduction equation:

$$\rho C_p \frac{dT}{dt} = -div q'' + q''' \tag{2.2}$$

Assume a cosine distribution of power profile

$$q'(z) = q'_{max} cos \frac{\pi z}{h_{eff}} \tag{2.3}$$

where q' is linear heat generation rate$[W/m]$ and h_{eff} is the effective height of the active core.

Nusselt Number:

$$Nu = 0.58[1.1(P/D)^2 - 1]^{0.55} Pe^{0.45} \tag{2.4}$$

$$Nu = \frac{h_{Na} \times D_e}{\lambda} \tag{2.5}$$

Peclet Number:

$$Pe = \frac{\rho v D_e C_p}{\lambda} \tag{2.6}$$

3 Exercise Description

Calculate the following

1. The total mass flow($\dot{m}_{total}$) of the reactor
2. The axial (K_z) and radial (K_r) peaking factors
3. The effective height of the active core :h_{eff}
   Hint: You would need an iterative process to calculate it
4. Axial linear power distribution across the most powerful subassembly (plot z vs q')
   Hint: Divide the assembly into 20 or more nodes and then calculate at each point

5. Axial temperature distribution profile across the most powerful subassembly (plot z vs T)

6. Axial temperature distribution of clad outer surface (T_{co}), clad inner surface (T_{ci}), fuel pellet outer surface (T_{fo}) and fuel pellet centerline (T_{fi})

Optional

1. Check the velocity through most powerful subassembly and adjust it to $9 m/s$, then start increasing the reactor thermal power, comment upon the maximum power it could reach taking into consideration the fuel centerline limiting condition to be 2700 °C, or cladding limit of 700 °C.

Note: Use Excel or any programming language that you prefer