NSE
Nuclear Science & Engineering at MIT
science : systems : society

PROBLEM SET #3

Due date 4/6 9.30AM

22.315 - Applied Computational Fluid Dynamics and Heat Transfer
SPRING 2023

Introduction

Solution Methods:

- This homework targets the application of what we have learned in class about solution methods, their strengths, weaknesses and how to accelerate their convergence, or deal with stability issues.

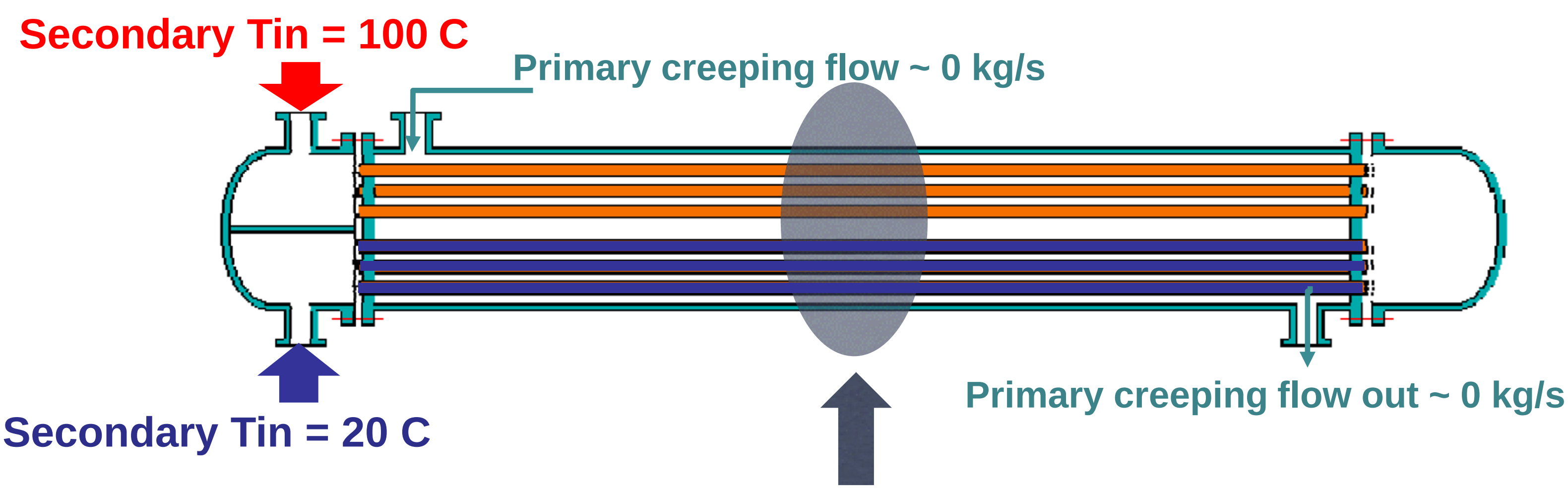
- **We will mainly concentrate on obtaining a steady state solution** but the student is welcome to extend his analysis to the applicability of a transient solution.

- **The student should review the flow case before starting running calculations** to get a good "feel" of the challenges, evaluate the well-posedness implementation of the boundary conditions and the optimal initial condition settings to accelerate convergence.

- **The student MUST discuss the reasoning that leads to the choices** in solver, and initial conditions settings as well as post processing and evaluation of solver convergence.

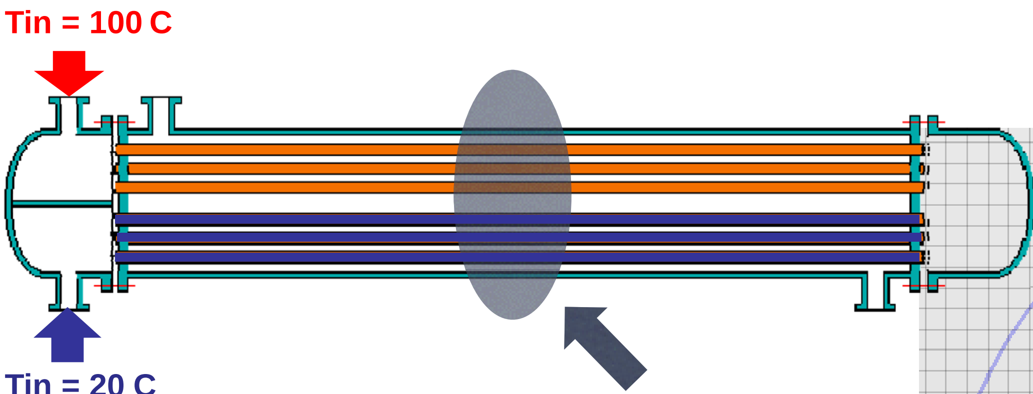
Case Description – I *(not important for homework)*

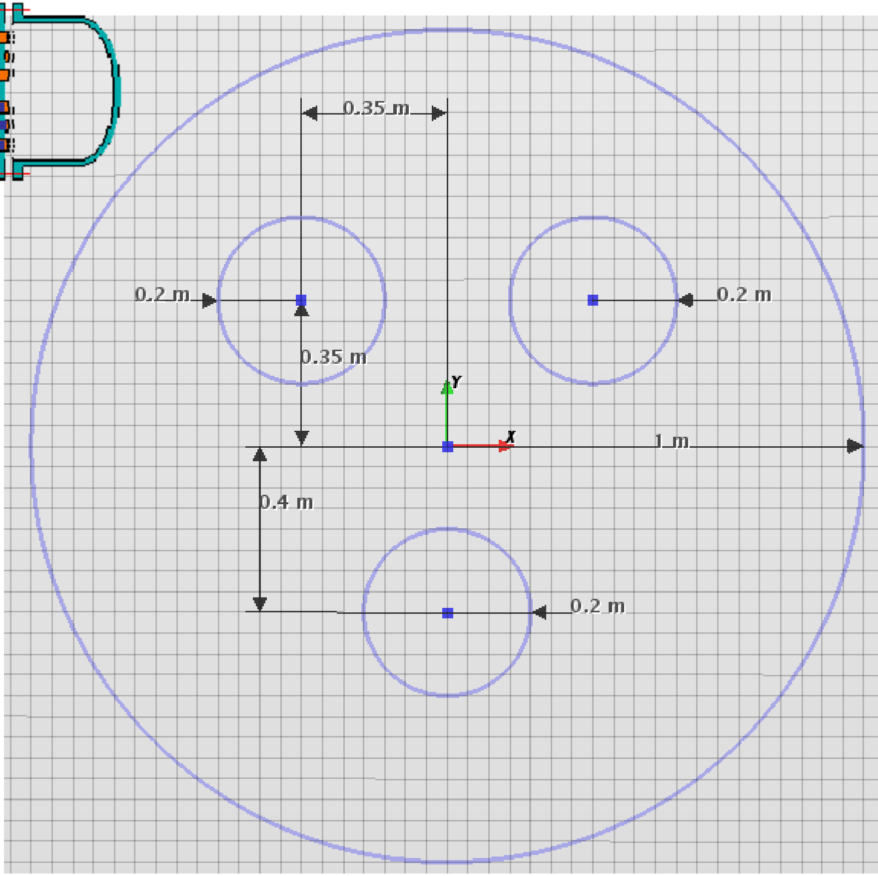
- We want to evaluate the temperature distribution in a peculiar chemical reactor, where secondary side temperature is controlled to produce a specific temperature distribution in the primary side.
- We can simplify the problem to concentrate on the simulation of flow and temperature distribution in a 2D section, assuming constant water properties for the fluid.
- *A representative configuration is shown below:*



- We will use an extremely simplified, 2-dimensional representative setup of the problem

Case Description - II





Geometry

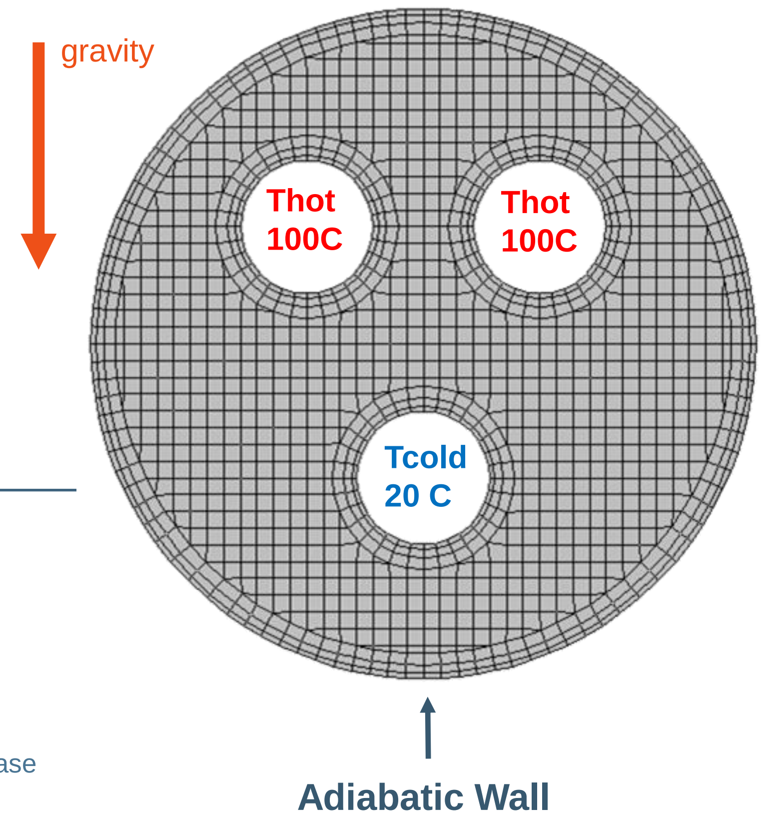
- Reactor radius = 1 m
- Hot/Cold Pipes radius = 20 cm

Case Description - III

Mesh

- ***<u>It is sufficient for this homework to model a 2D domain as represented in the picture.</u>***
- You are free to optimize the mesh, minimum recommended values are:

Base Size	Value	20 cm
			Number of Prism Layers	Number of Prism Layers	3
			Prism Layer Stretching	Prism Layer Stretching	1.5
Prism Layer Thickness		Absolute
				Absolute Size	Value	7.5 cm
Surface Size	Relative/Absolute	Relative to base
				Relative Minimum Size	Percentage of Base	100.0
	Absolute Size	5 cm
				Relative Target Size	Percentage of Base	100.0
	Absolute Size	5 cm



Case Description - IV

Fluid properties (Liquid)

Liquid Properties		
| || +-1 Density	Method	Constant
| || | `-1 Constant	Value	1000 kg/m^3
| || +-2 Dynamic Viscosity	Method	Constant
| || | `-1 Constant	Value	8.88E-5 Pa-s
| || +-3 Specific Heat	Method	Constant
| || | `-1 Constant	Value	4200.0 J/kg-K
| || +-4 Thermal Conductivity	Method	Constant
| || | `-1 Constant	Value	0.62 W/m-K
| || +-5 Thermal Expansion Coefficient	Method	Constant
| || | `-1 Constant	Value	4E-4 / K

- As we are using constant fluid properties you can rely on the **Boussinesq model** for buoyancy with the indicated thermal expansion coefficient.
- **Turbulence –** the recommended procedure is to use the very basic turbulence model to represent the expected turbulence, but be aware that this is an unconfirmed assumption (you will not be graded on this aspect) **-** ***Realizable K-Epsilon Two-Layer All-yplus***

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- Setup and solve a steady state simulations for the 2D(3D is acceptable) problem representing the chemical reactor.
- **<u>Your work shall include the following points:</u>**
  - ✓ Problem setup including initial conditions.
  - ✓ **Discussion of solution method(s) tested, with particular attention to the expected performance of the solution method.**
  - ✓ **Demonstration and discussion of the numerical and physical convergence of the solution.**
  - ✓ **Analysis of the results, particularly temperature distribution inside the reactor.**
  - ✓ Qualitative: Based on the approach and analysis of the problem, what is your level of confidence in the results (for example a simple estimate of the maximum error on the local temperature, is your error 1C, 5C, 20C ?)

Suggestion: make sure to identify potential approaches from what you have learned in class rather than trial and error which can become costly for this homework

Note: ideas to accelerate the solution are always rewarded