# Tutorial 10: Natural Circulation in an open loop

# Problem Description:

Three pipes are connected to form an open loop in the shape of 'U'. The pipes have a diameter of 0.1 m and a length of 0.2 m. The loop is filled with water, and its ends are open to the atmosphere (ambient temperature = 15 °C, pressure = 1 bar). The horizontal pipe at the bottom is uniformly heated with a power of 20 kW. Assume the friction factor in the pipes as 0.05. It is required to estimate the loop flow rate and temperature difference.

# Steps:

(Note the input file for this tutorial problem is already saved in /deck/example18.py)

1. Draw the layout and label the components for the problem as shown below:

A picture containing chart

Description automatically generated

1. Create a new circuit with the following commands:

circuit1 **=** comp**.**Circuit**(**"circuit1"**,**solveSS**=True)**

circuit1**.**assign\_fluid**(**"Water"**,**"CoolProp"**,**incomp**=True)**

1. Add nodes to the circuit with the following commands:

node1 **=** circuit1**.**add\_node**(**"node1"**,**elevation**=**0.2**)**

node2 **=** circuit1**.**add\_node**(**"node2"**,**elevation**=**0.**)**

node3 **=** circuit1**.**add\_node**(**"node3"**,**elevation**=**0.**)**

node4 **=** circuit1**.**add\_node**(**"node4"**,**elevation**=**0.2**,**ttemp\_old**=**289.**)**

Note that a guess value slightly higher than the initial temperature is specified in node 4 to have an initial temperature gradient in the circuit to initiate natural circulation in the first iteration

1. Add pipes to the circuit with the following commands:

pipe1**=**circuit1**.**add\_pipe**(**identifier**=**"pipe1"**,**diameter**=**0.1**,**length**=**0.2**,**unode**=**"node1"**,**dnode**=**"node2"**,**fricopt**=**0.05**,**roughness**=**30.E-6**,**ncell**=**10**)**

pipe2**=**circuit1**.**add\_pipe**(**identifier**=**"pipe2"**,**diameter**=**0.1**,**length**=**0.2**,**unode**=**"node2"**,**dnode**=**"node3"**,**fricopt**=**0.05**,**roughness**=**30.E-6**,**ncell**=**10**,**heat\_input**=**2.E4**)**

pipe3**=**circuit1**.**add\_pipe**(**identifier**=**"pipe3"**,**diameter**=**0.1**,**length**=**0.2**,**unode**=**"node3"**,**dnode**=**"node4"**,**fricopt**=**0.05**,**roughness**=**30.E-6**,**ncell**=**10**)**

Note that the pipes are incremented (say, 10 nos.) to have more accurate results since cell average densities are used to calculate the driving head for natural circulation

1. Attach boundary conditions to the nodes

bc1 **=** comp**.**BC**(**"bc1"**,**"node1"**,**'P'**,**1.E5**)**

bc2 **=** comp**.**BC**(**"bc2"**,**"node1"**,**'T'**,**288.**)**

bc3 **=** comp**.**BC**(**"bc3"**,**"node4"**,**'P'**,**1.E5**)**

Note that these values correspond to the ambient conditions specified in the problem

1. Modify convergence criteria

**import** solver\_settings

solver\_settings**.**conv\_crit\_temp\_SS **=** 1.E-7

solver\_settings**.**conv\_crit\_flow **=** 1.E-7

Note that for natural circulation, since it is difficult to get convergence with default convergence criteria (residue ~10-10), higher residue values (~10-7) are used in the convergence criteria. However, the results obtained are in general accurate enough for practical purposes.

1. Verify the mass flow rate (volume flow rate x density) (in any pipe) is equal to 0.8834 kg/s from the output file. The temperature difference between the hot and cold leg should be 5.409 °C.