Water and Mercury Pipe Flow Simulation in FLUENT

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Outline

- Straight Pipe flow
- Curved pipe flow

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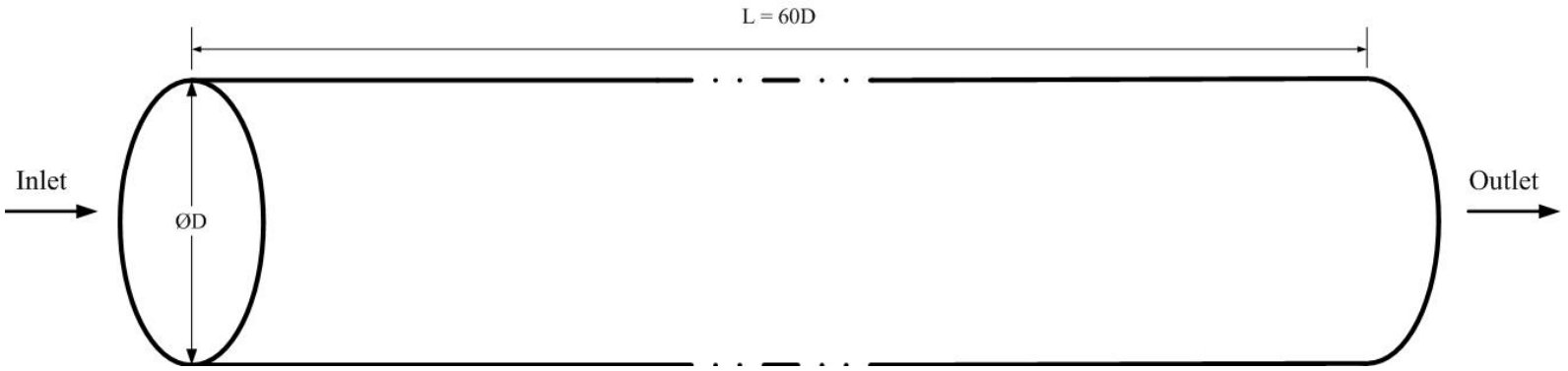
- Straight Pipe flow
- Curved pipe flow

Straight Pipe flow
— Physical problem

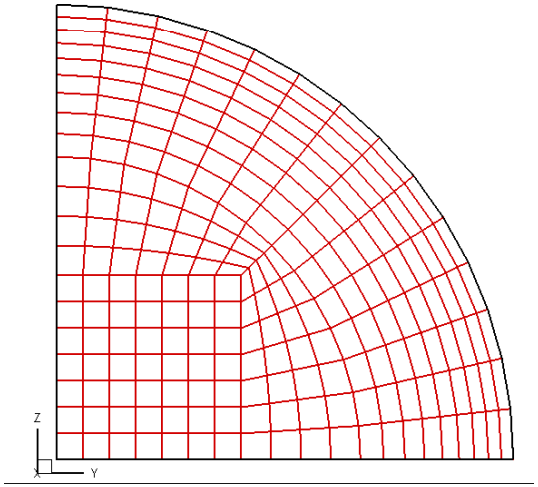
Isothermal mercury/ water flow through a 60D straight pipe into the air environment

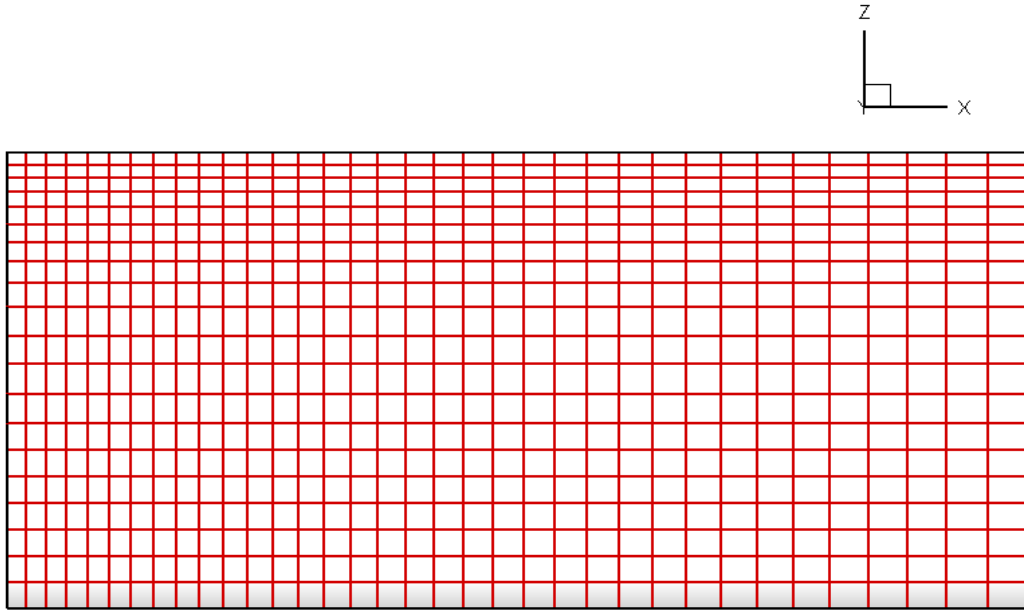


Medium	Reynolds Number	Inner Diameter	Inlet Velocity	Inlet Pressure	Outlet Pressure*
Mercury	1500	41.844 μm	4.04 m/s	18.5 bar	15.67 bar
Water	1500	331.404 μm	4.04 m/s	18.5 bar	18.291bar

*$u_{ave} = 0.5\ u_{max} = (P_1\text{-}P_2)D^2/(32\mu L)$

Straight Pipe flow in FLUENT
— Mesh





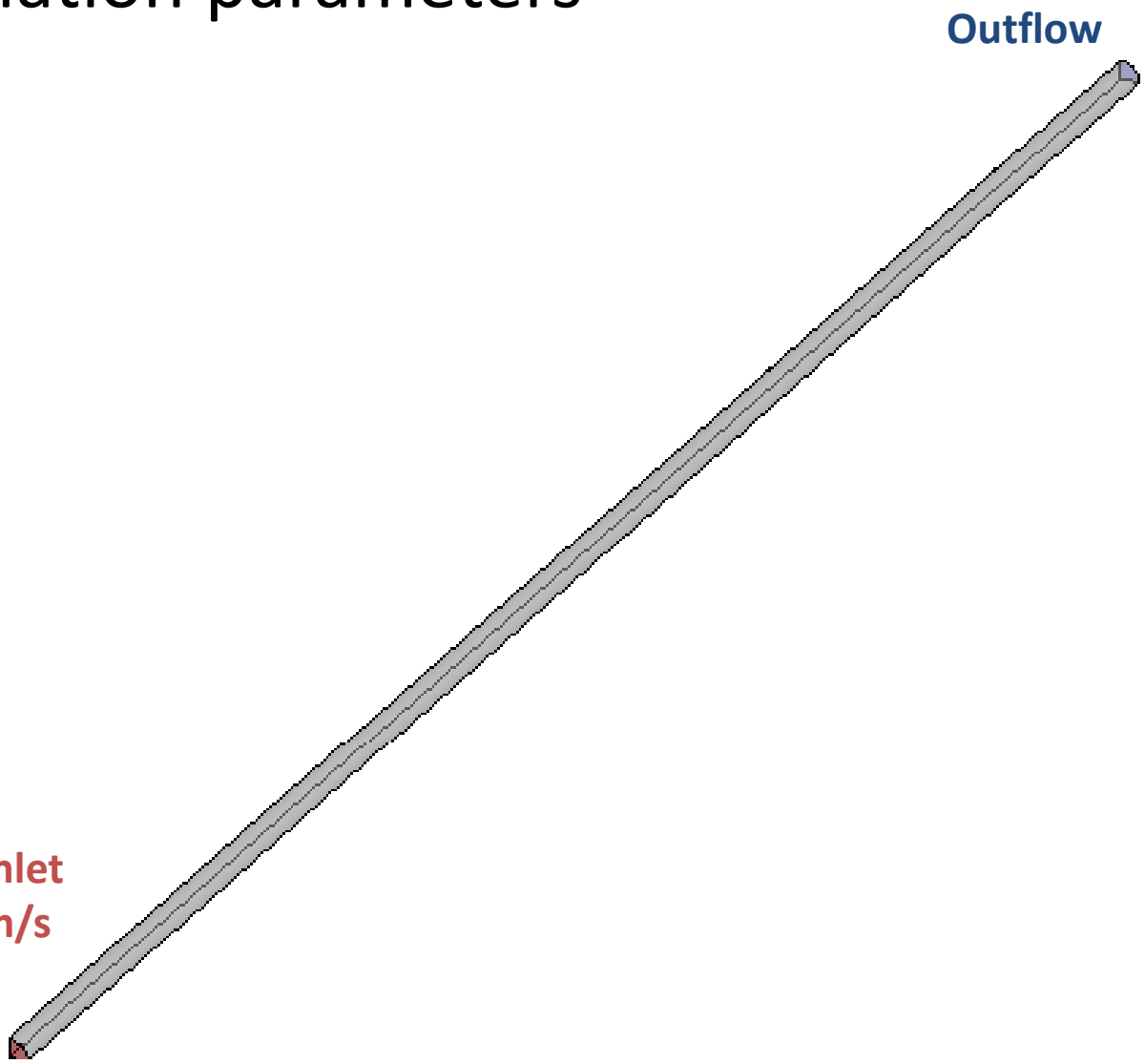
$n_x \times n_r \times n_\theta = 190 \times 20 \times 14$

$\Delta x_{min} = 0.02D$

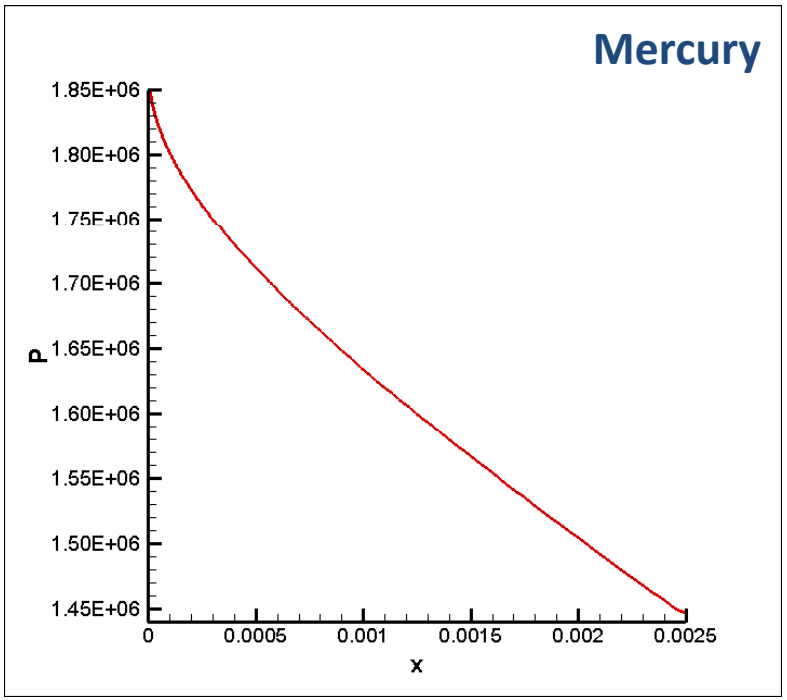
$\Delta r_{min} = 0.0013D$

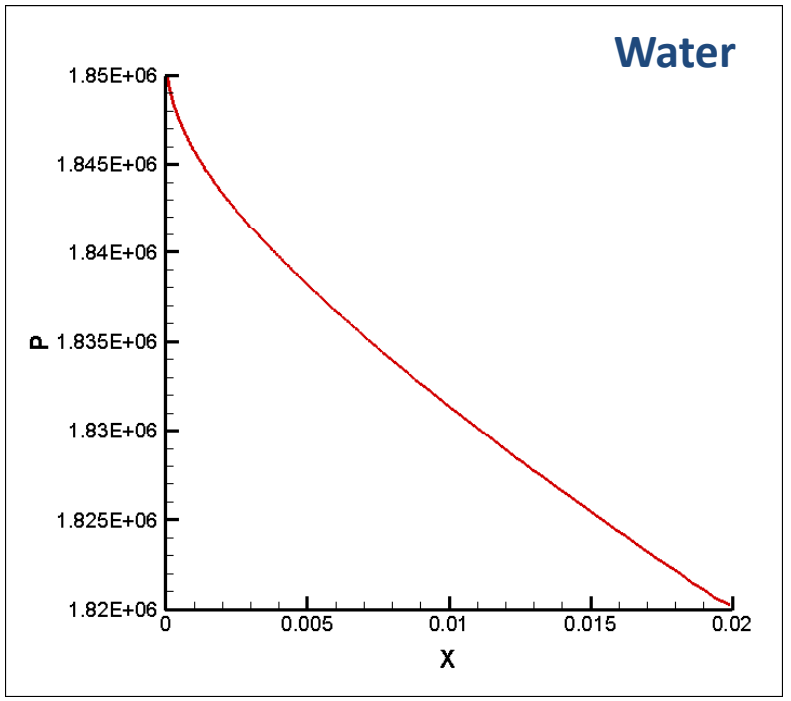
n is the cell No.

Straight Pipe flow in FLUENT
— Simulation parameters



Straight Pipe flow in FLUENT
— Central line plot(1)

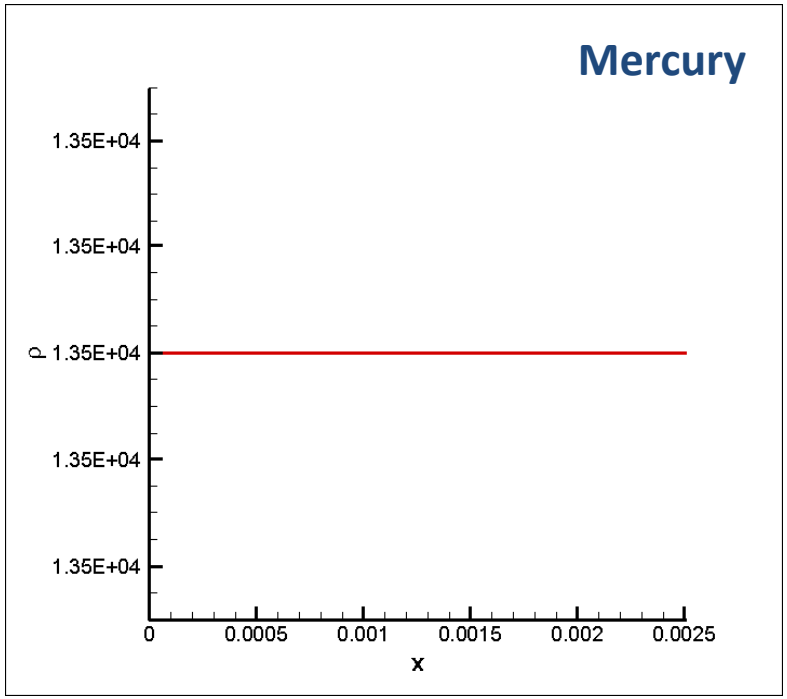


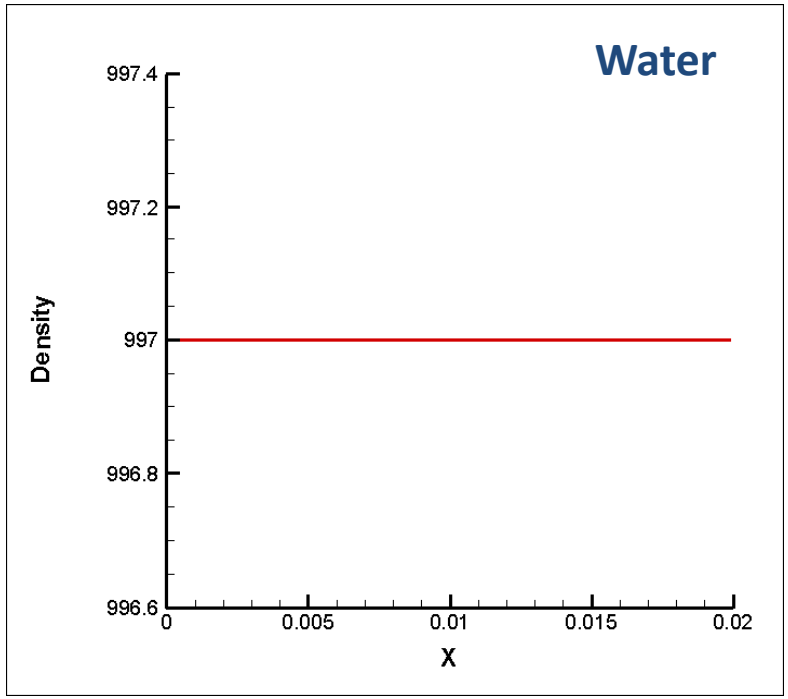


Units:

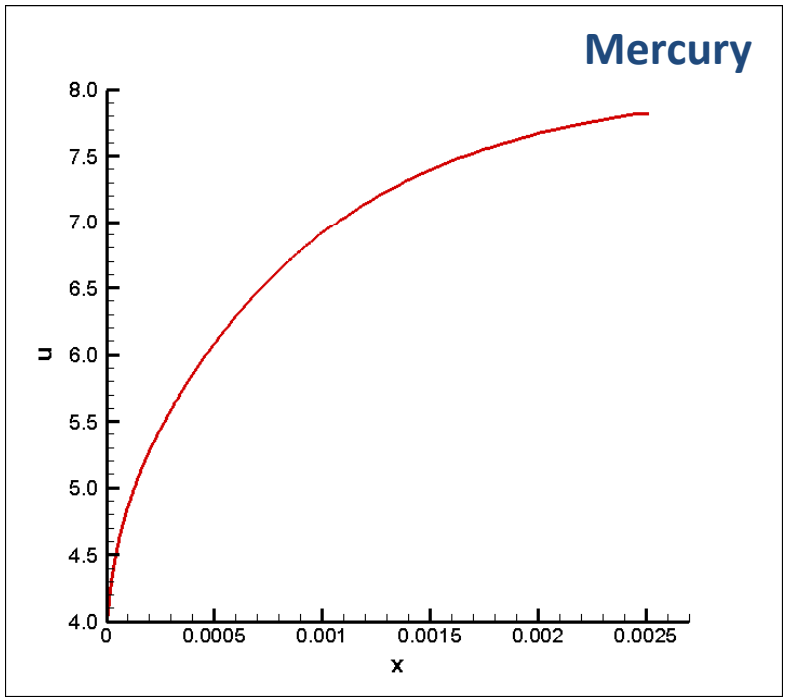
r (m); u (m/s); ρ (kg/m³); P (Pa)

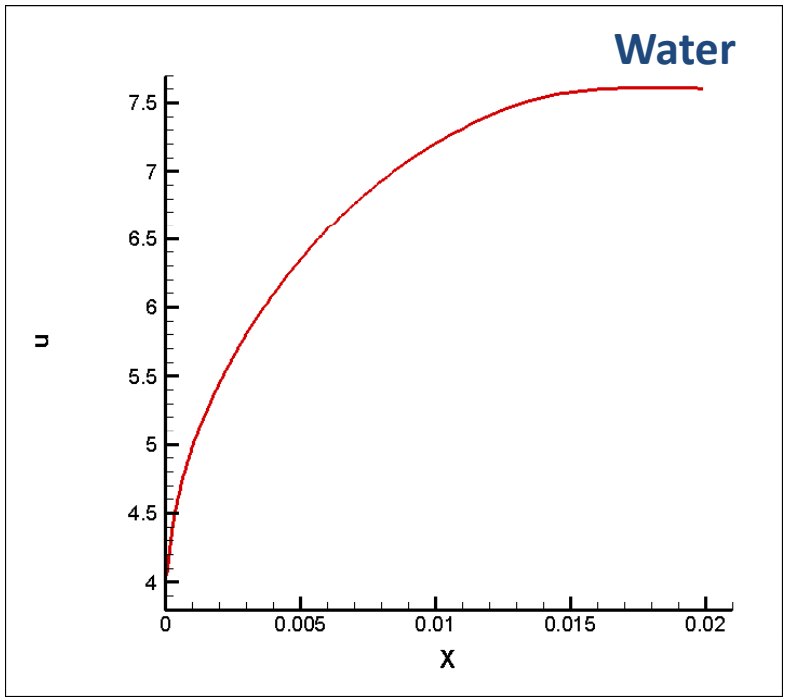
Straight Pipe flow in FLUENT
— Central line plot(2)



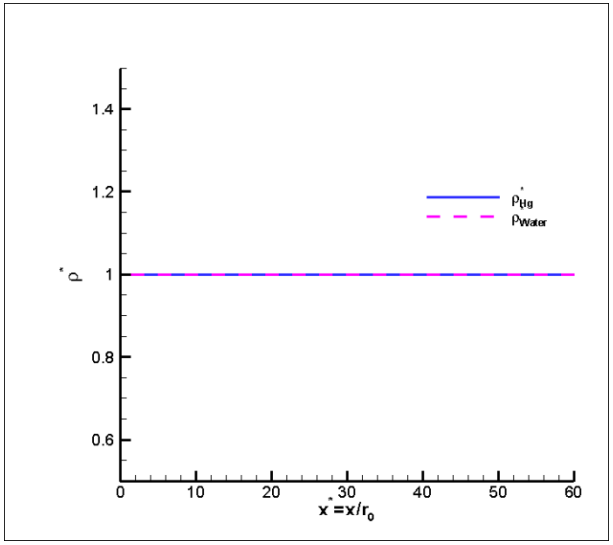


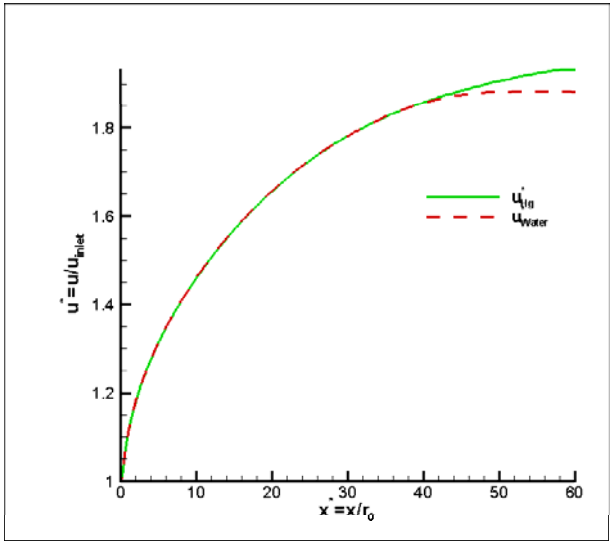
Straight Pipe flow in FLUENT
— Central line plot(3)

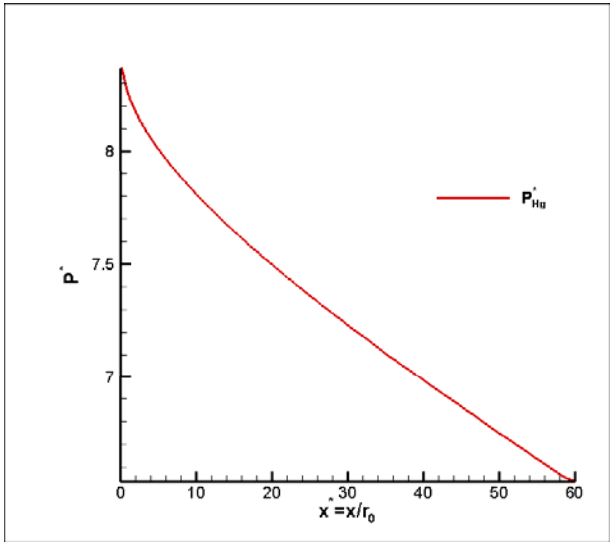


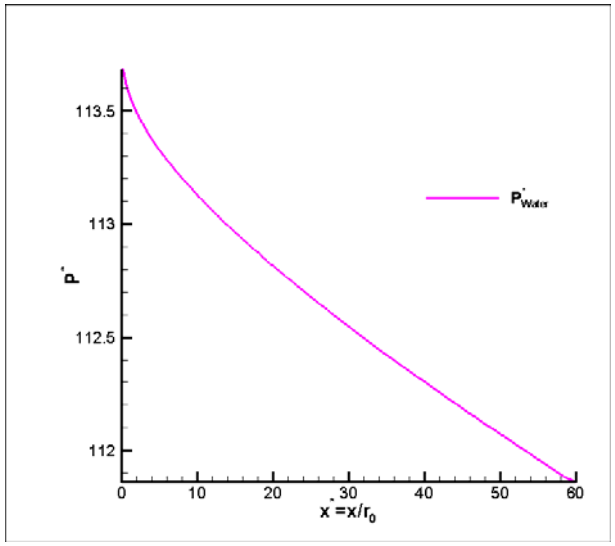


Straight Pipe flow in FLUENT
— Central line plot(4)

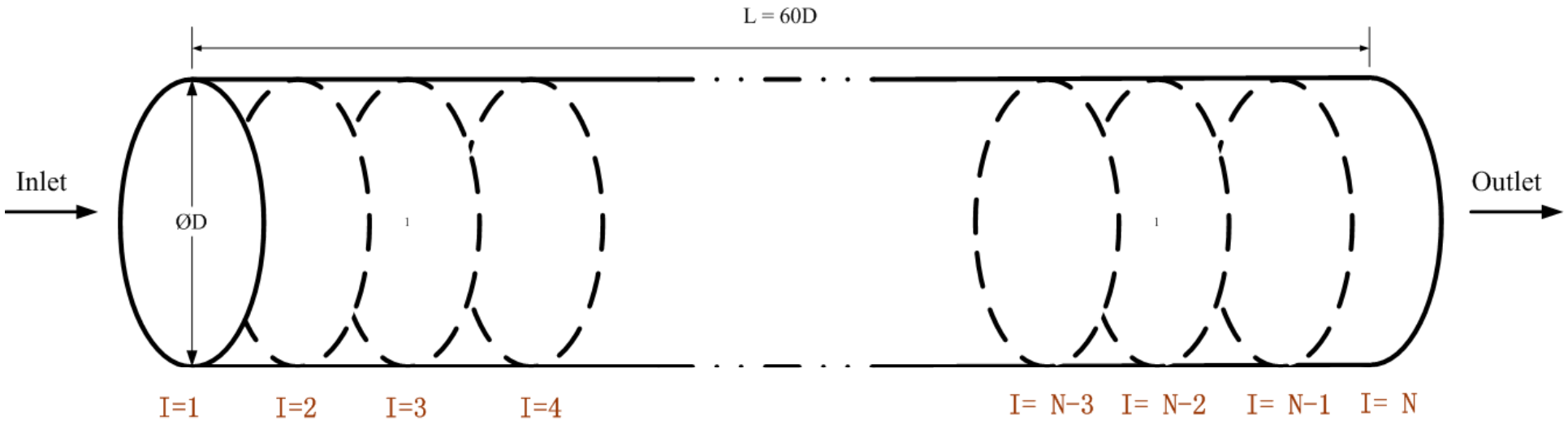








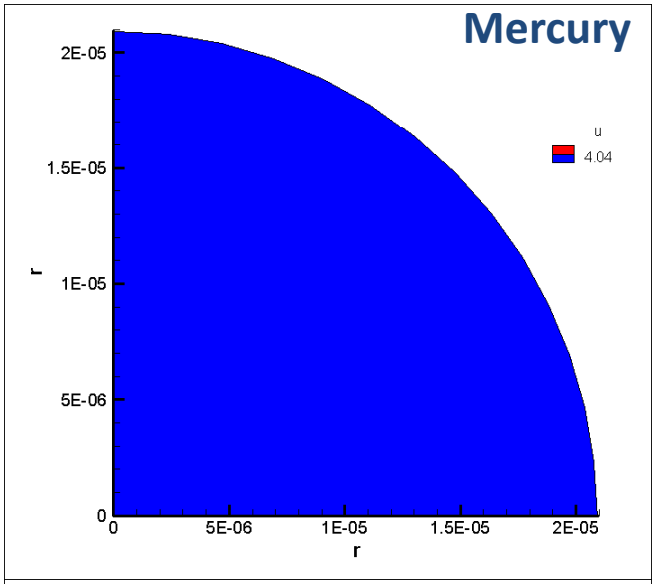
Straight Pipe flow in FLUENT
— Radial distribution of axial velocity (1)

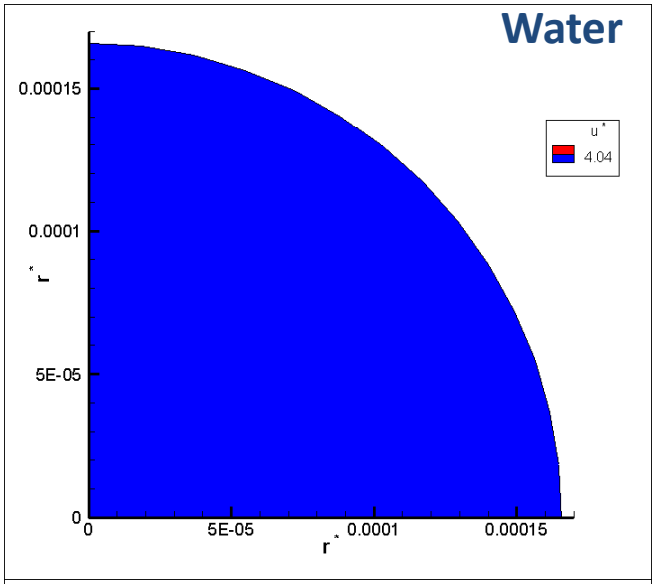


Slices are chosen for each 10 pipe diameter

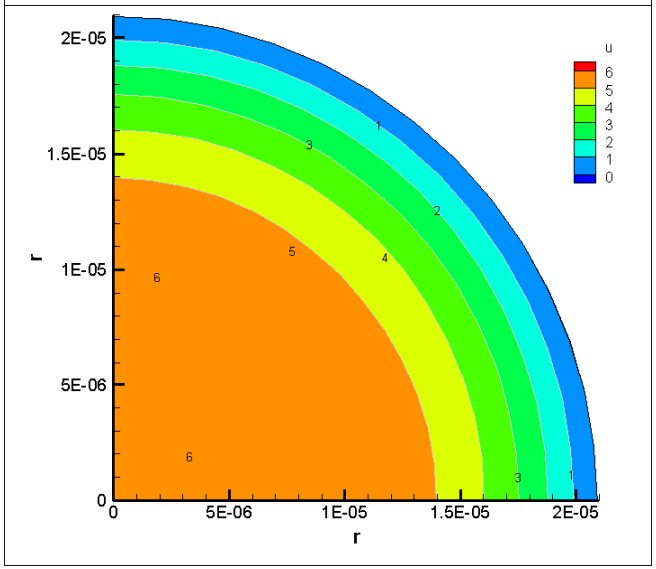
Straight Pipe flow in FLUENT
— Radial distribution of axial velocity (2)

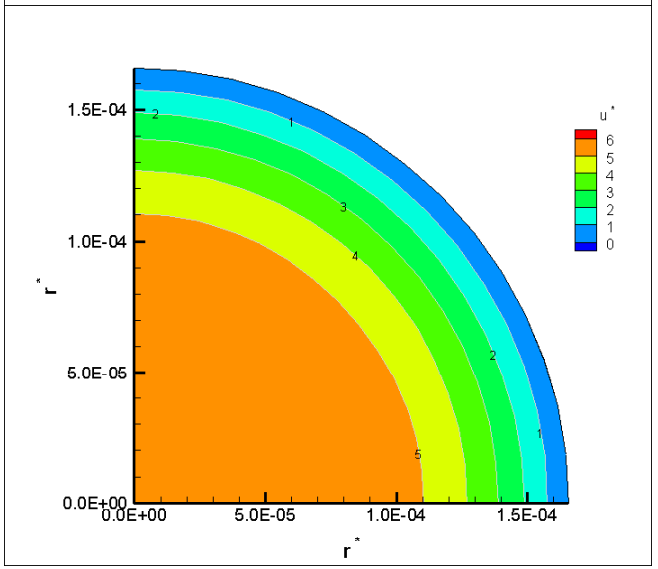
I=0





I=10D

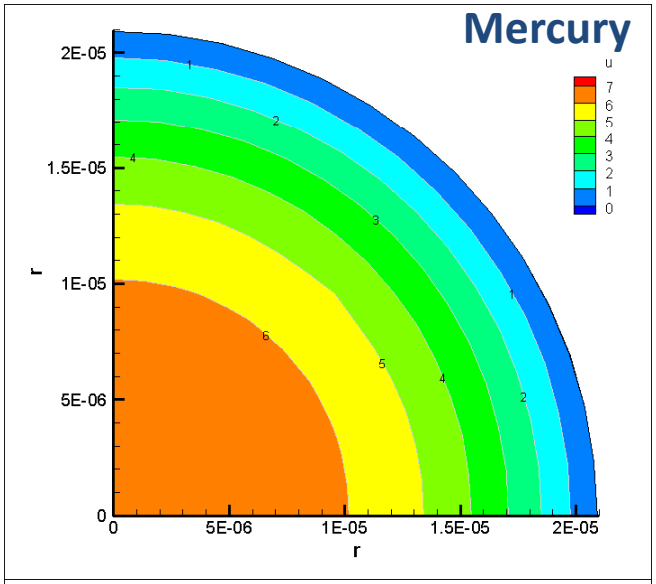


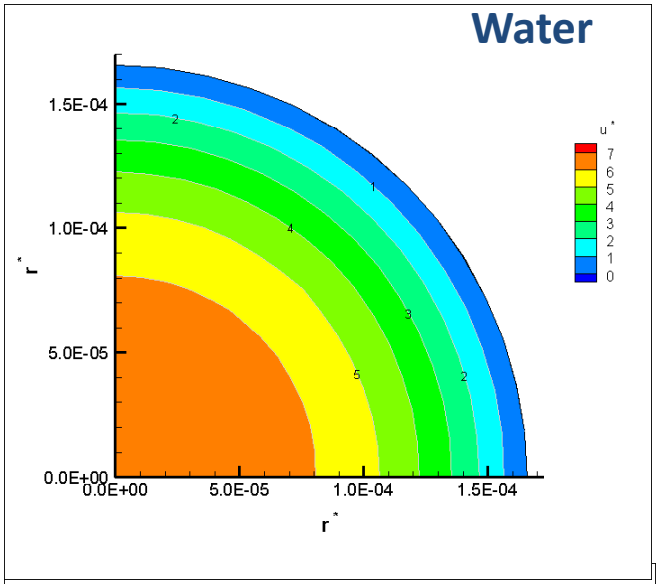


Straight Pipe flow in FLUENT

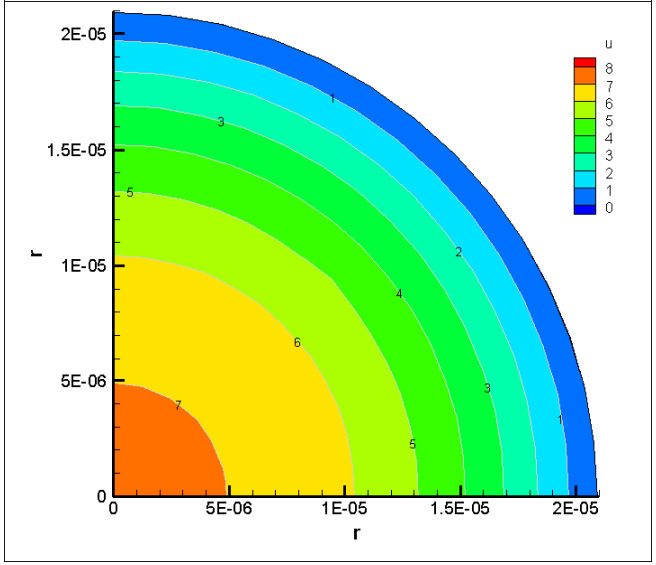
— Radial distribution of axial velocity (3)

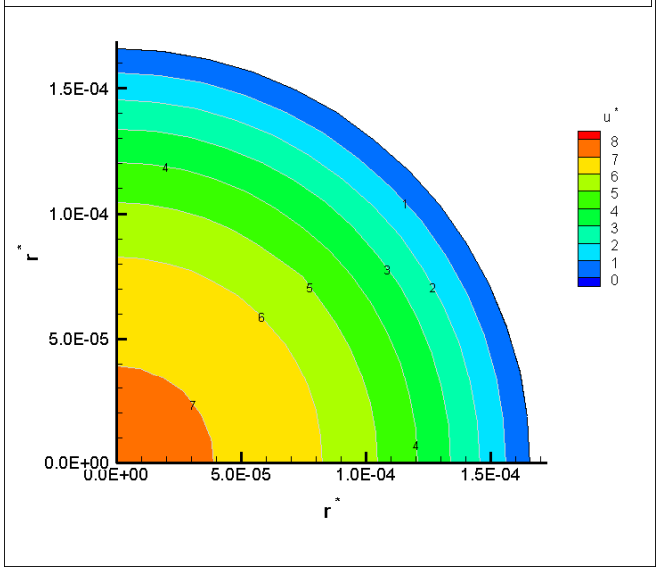
l=20D





l=30D

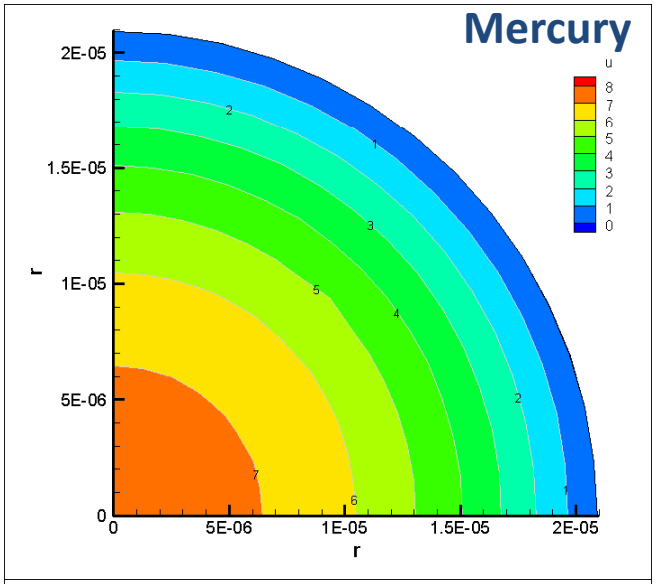


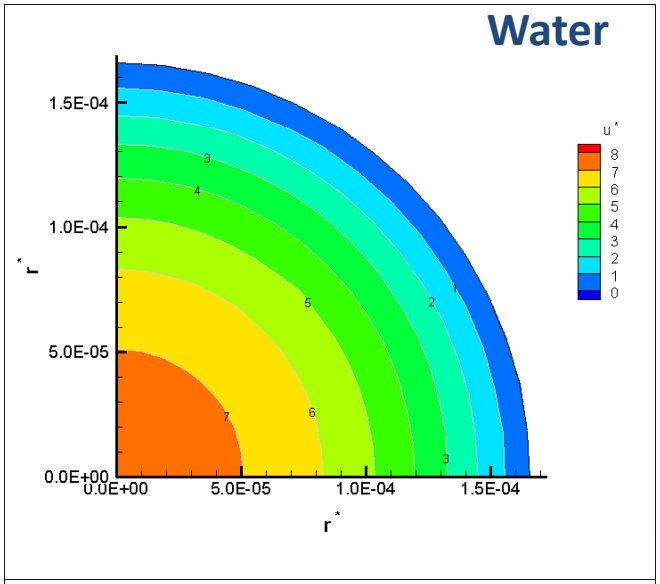


Straight Pipe flow in FLUENT

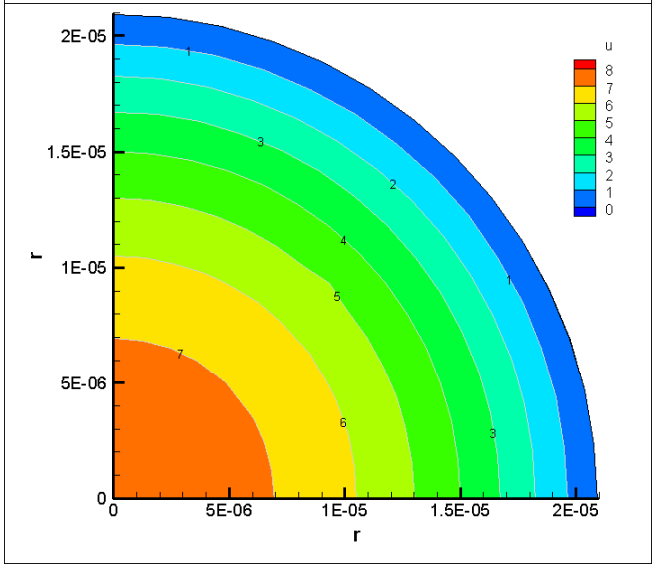
— Radial distribution of axial velocity (4)

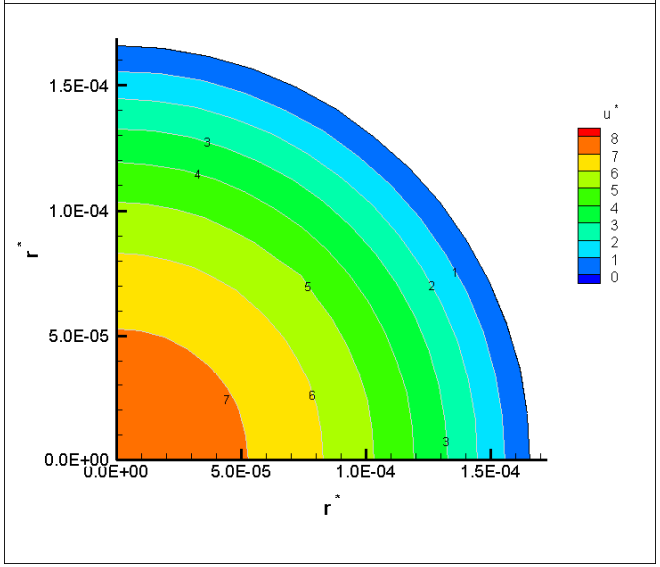
l=40D





l=50D



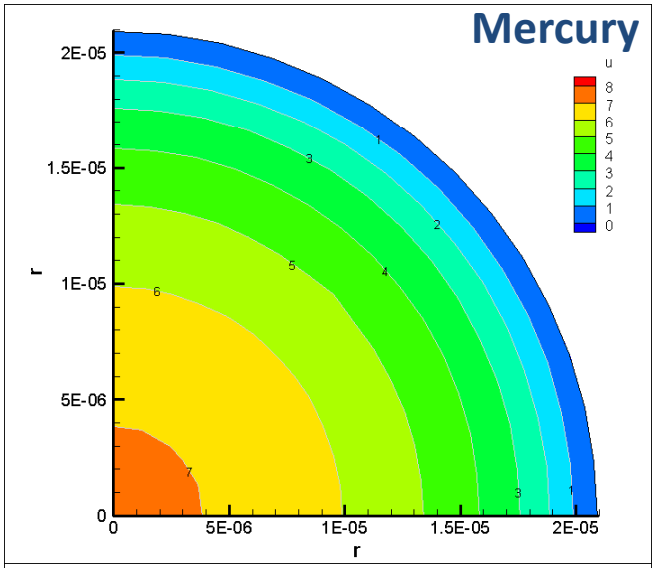


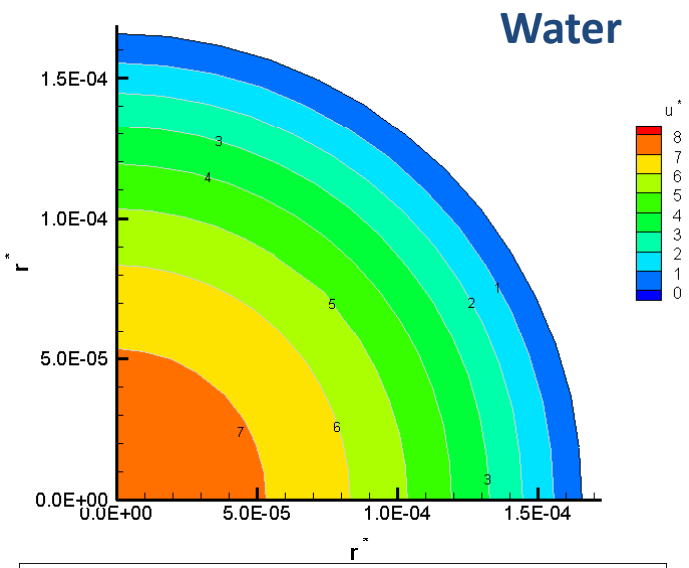
Straight Pipe flow in FLUENT

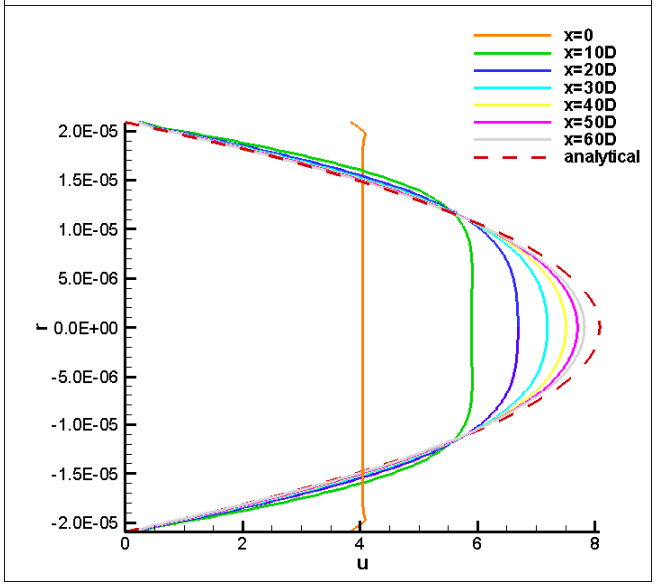
— Radial distribution of axial velocity (5)

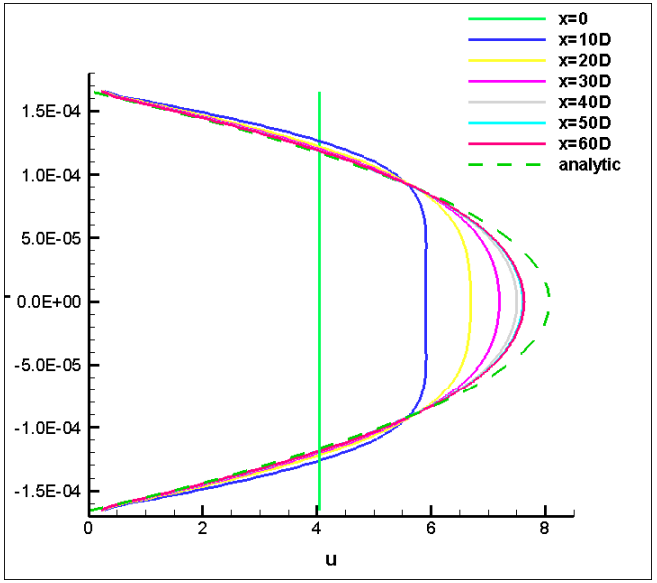
I=60D

Axial Velocity Profile

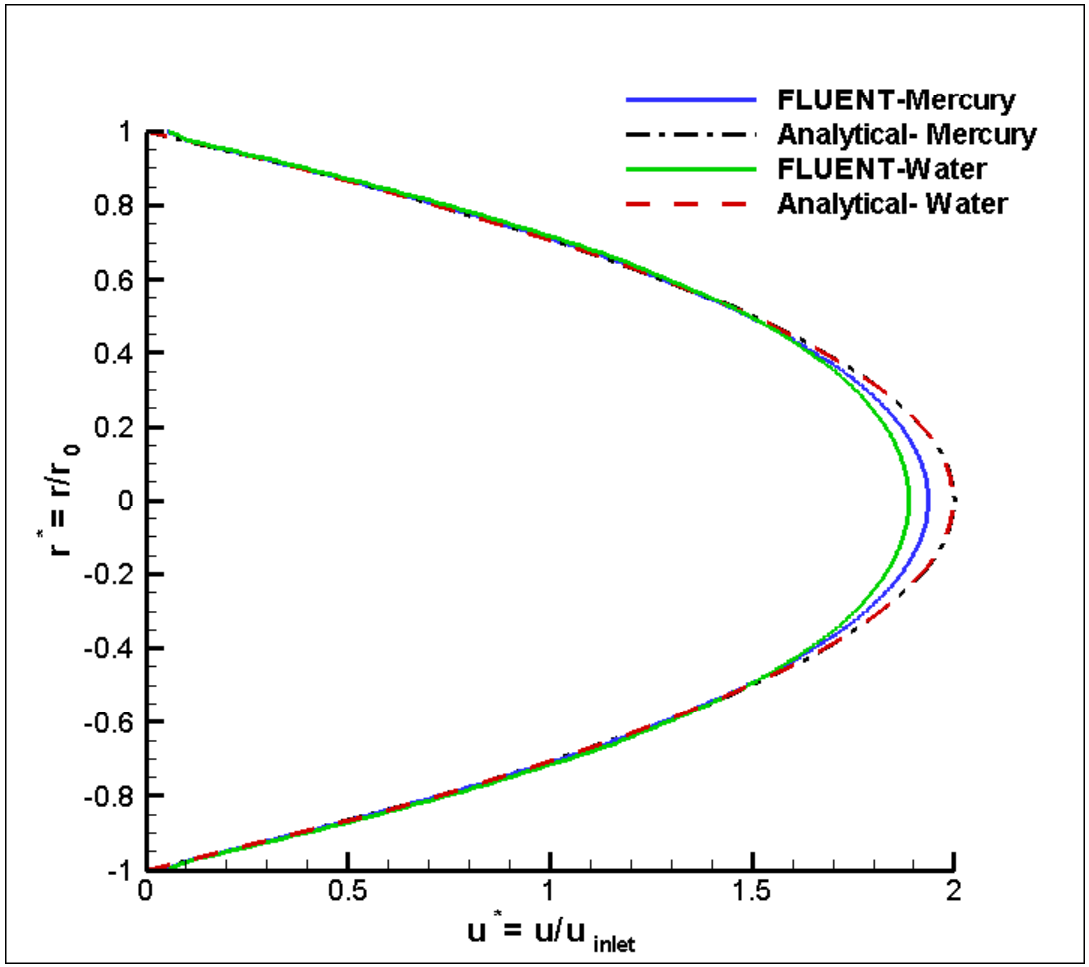








Straight Pipe flow in FLUENT
— Radial distribution of axial velocity (6)



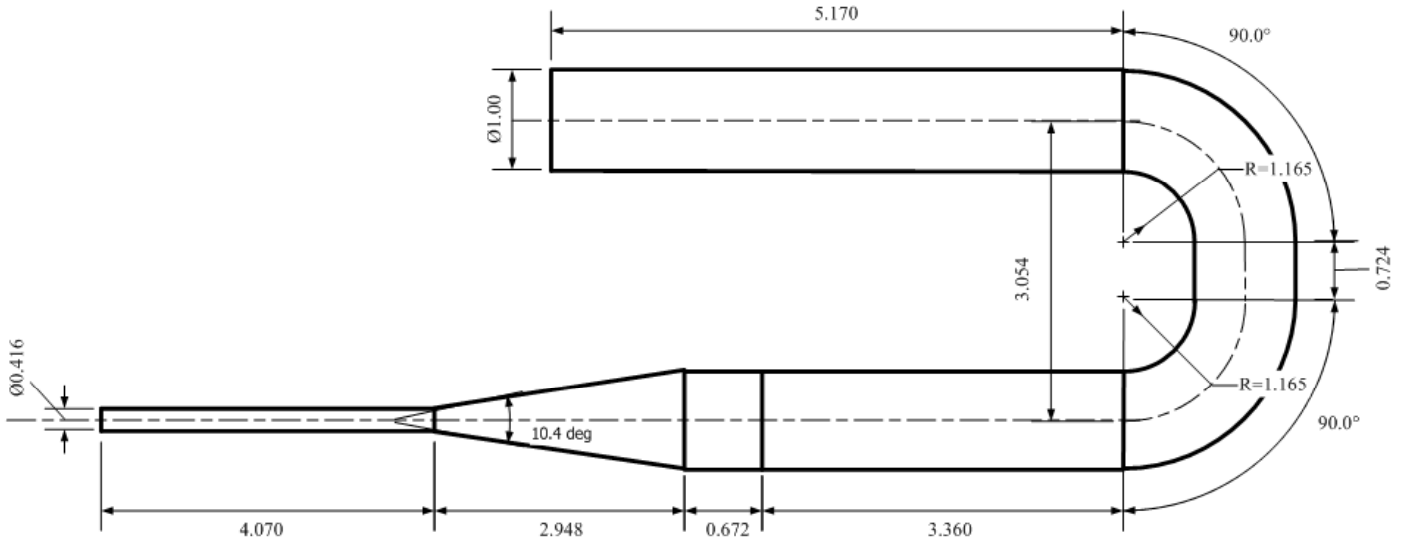
Non-dimensional axial velocity profile comparison at I=60D

Outline

- Straight Pipe flow
- Curved pipe flow

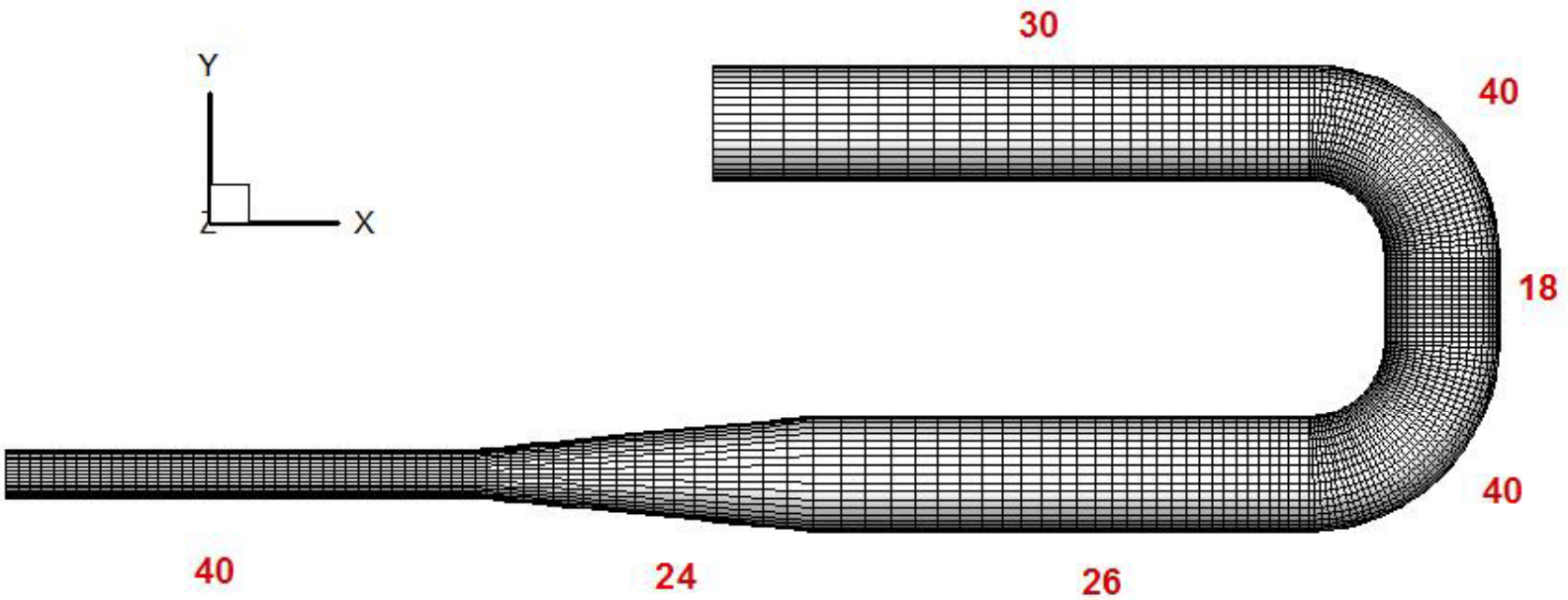
Curved Pipe flow
— Physical problem

Isothermal mercury/ water flow through a bend pipe into the air environment

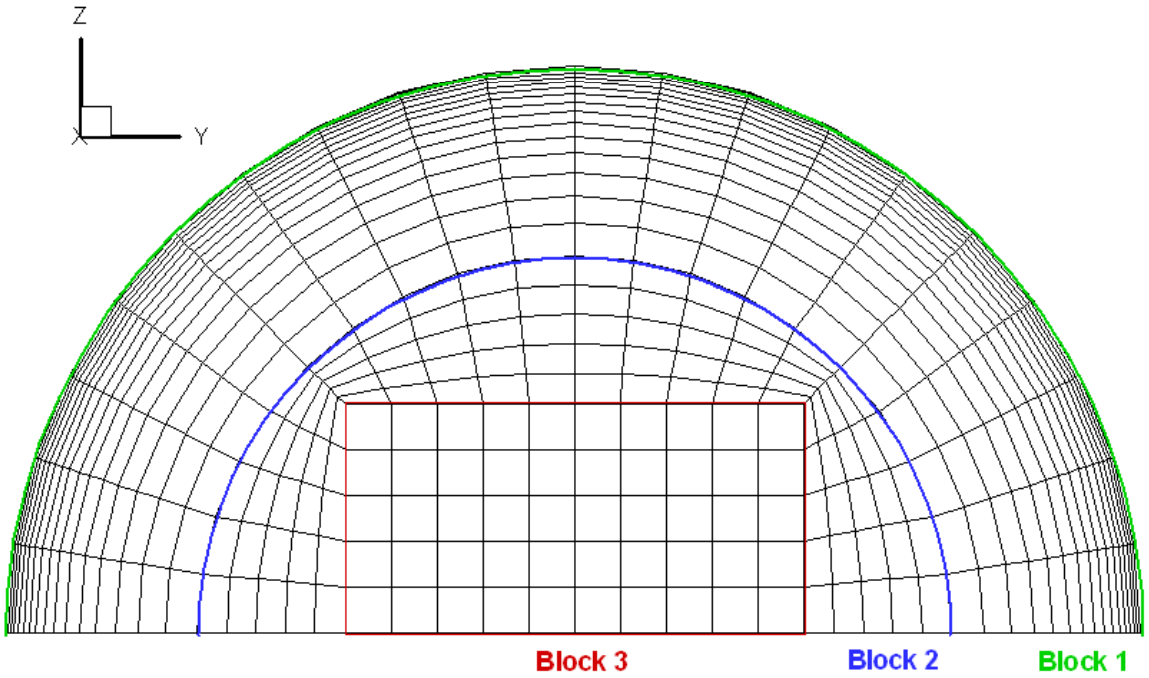


Medium	Reynolds Number	Inner Diameter	Inlet Velocity	Inlet Pressure	Ma	Y values (y^+=1)
Mercury	8.05×10^5	0.884”	4.04 m/s	18.5 bar	2.878×10^{-3}	0.72 µm
Water	8.05×10^5	7”	4.04 m/s	18.5 bar	2.751×10^{-3}	5.74 µm

Curved pipe flow in FLUENT
— Mesh (1)

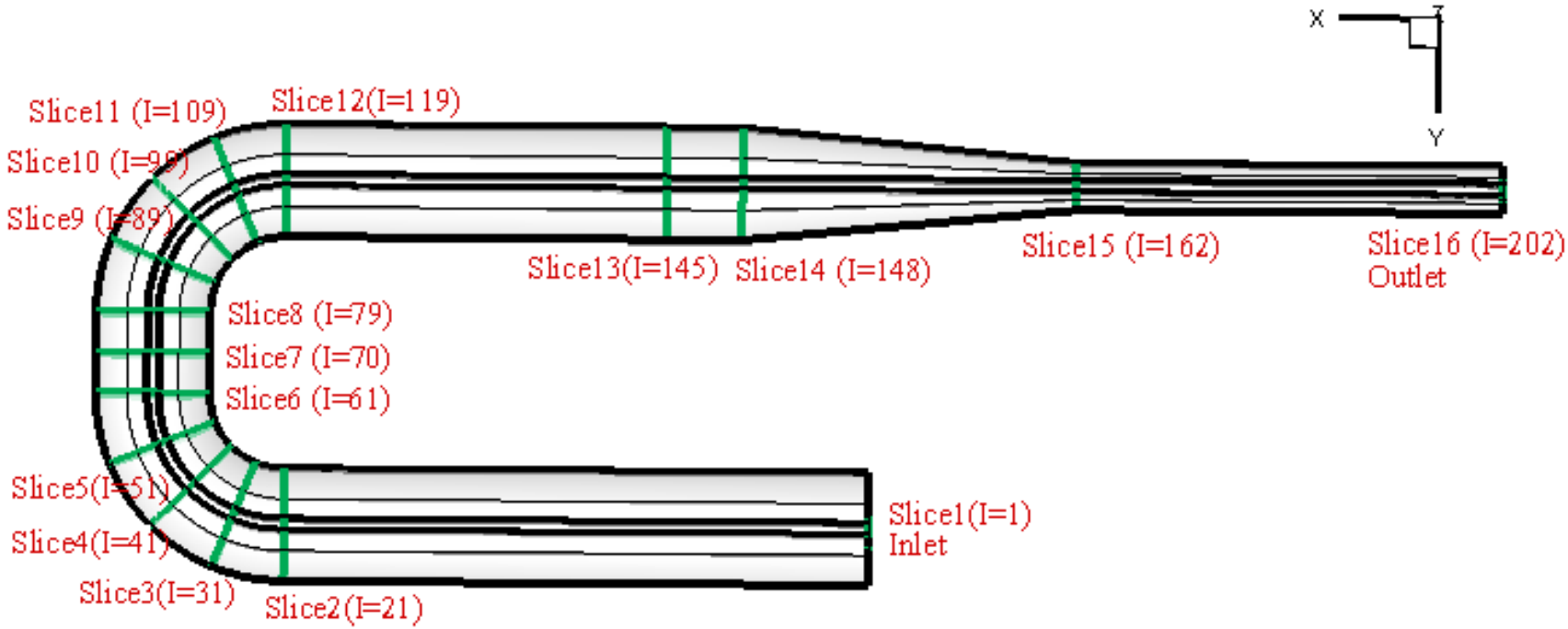


Curved pipe flow in FLUENT
— Mesh (2)



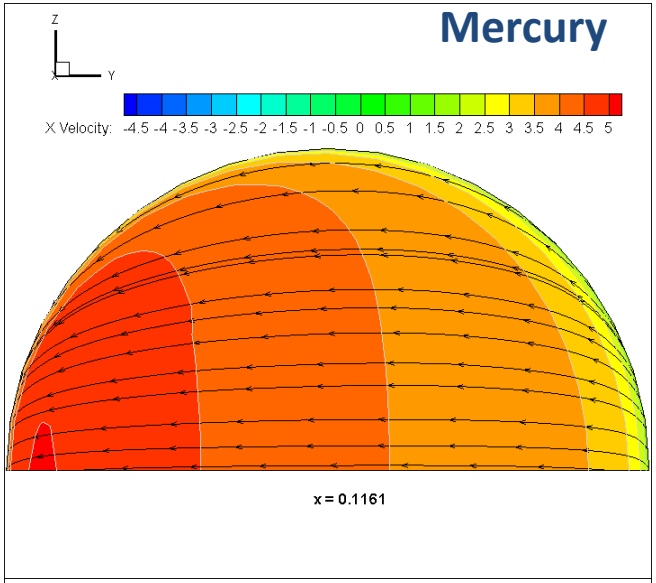
Materials	Diameter (m)	Height (μm) (cell near-wall, y^+=40)		Block 1 Size (m)	Block 3 Size	Mesh ($N_x \times N_r \times N_\theta$)
Mercury	0.0224536	Upstream	57.916	OD_{in}=0.0224536; ID_{in}=0.01494	L_{in}=0.00908	218×15×20(B1)
		Downstream	24.093	OD_{out}=0.00934; ID_{out}=0.006215	L_{out}=0.00378	218×5×20(B2)
Water	0.1778	Upstream	458.972	OD_{in}=0.1778; ID_{in}=0.1183	L_{in}=0.0719	218×10×5(B3)
		Downstream	190.933	OD_{out}=0.073965; ID_{out}=0.04922	L_{out}=0.0299	

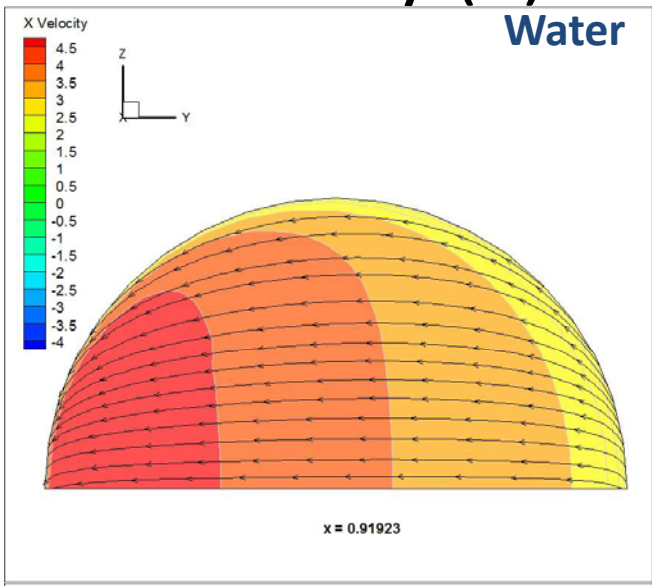
Curved pipe flow in FLUENT
— Slices positions

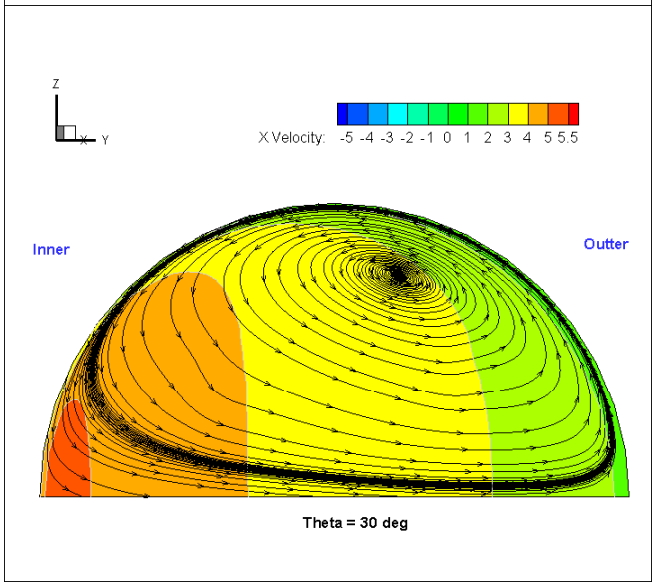


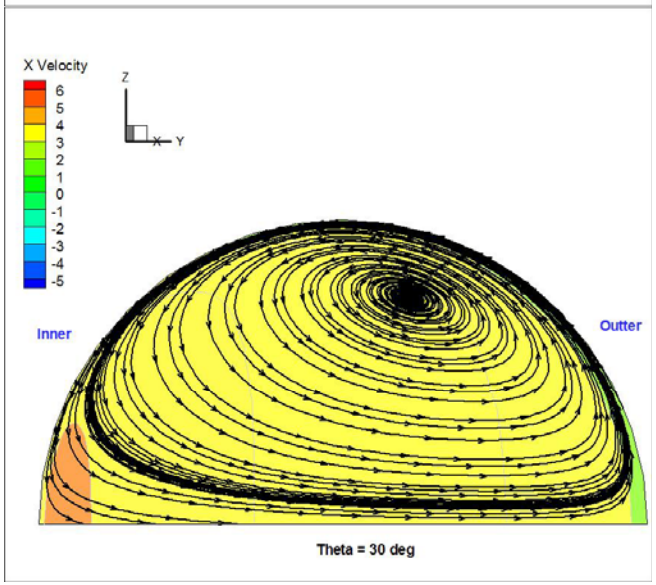
Curved pipe flow in FLUENT

— Radial distribution of axial velocity (1)



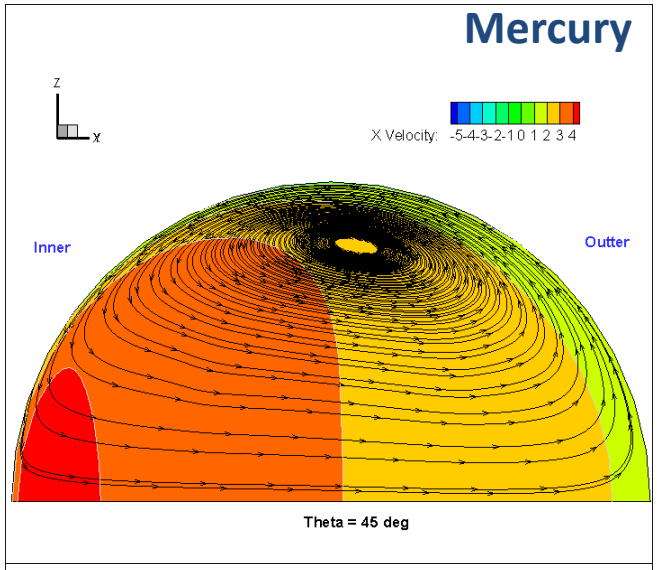


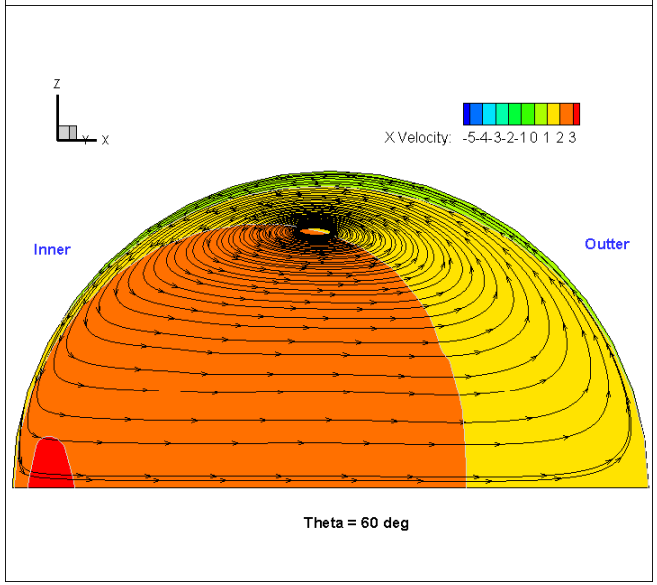


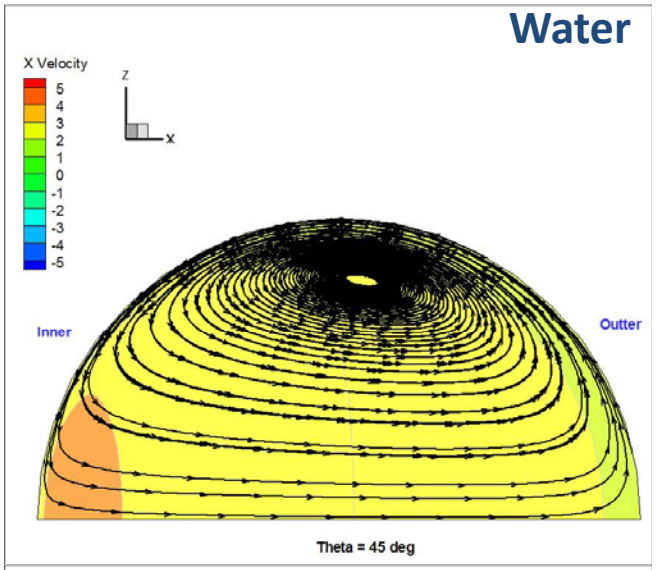


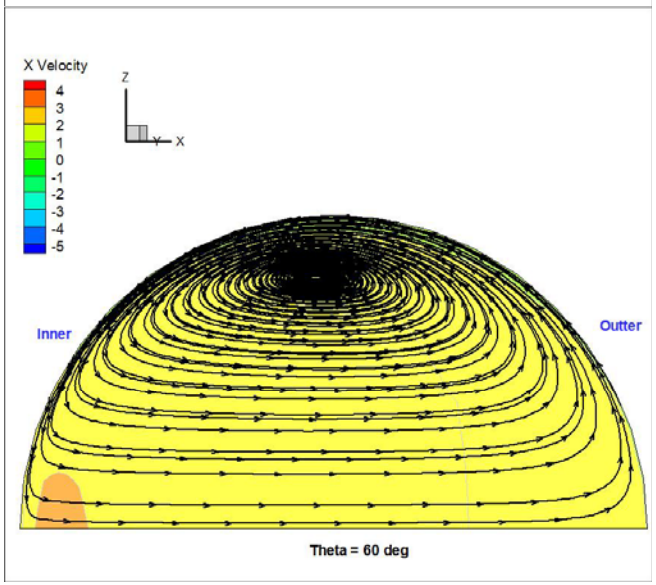
Curved pipe flow in FLUENT

— Radial distribution of axial velocity (2)



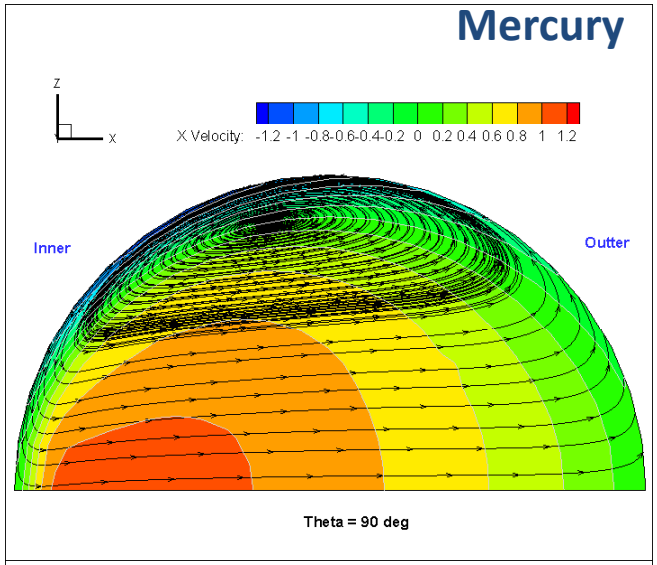


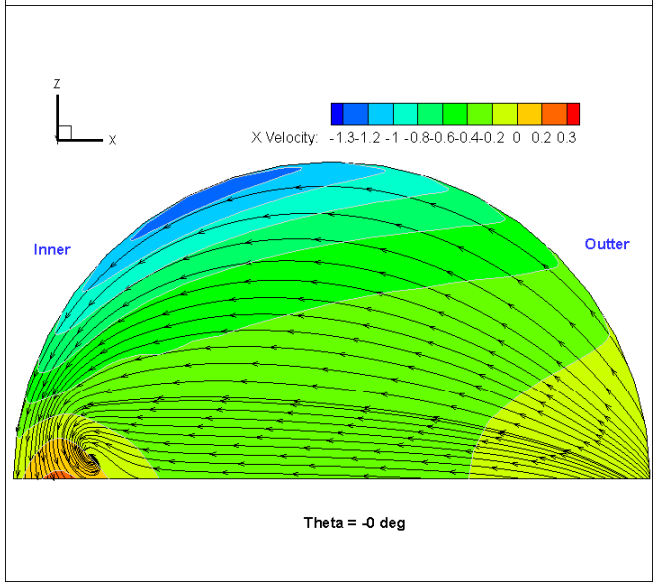


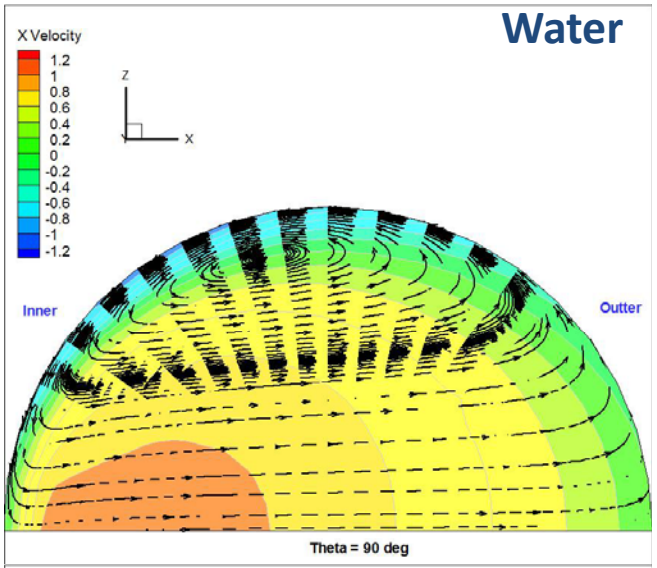


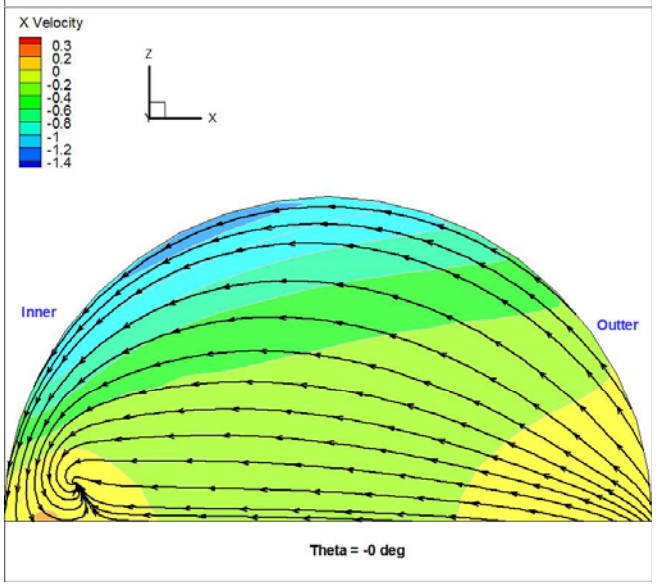
Curved pipe flow in FLUENT

— Radial distribution of axial velocity (3)



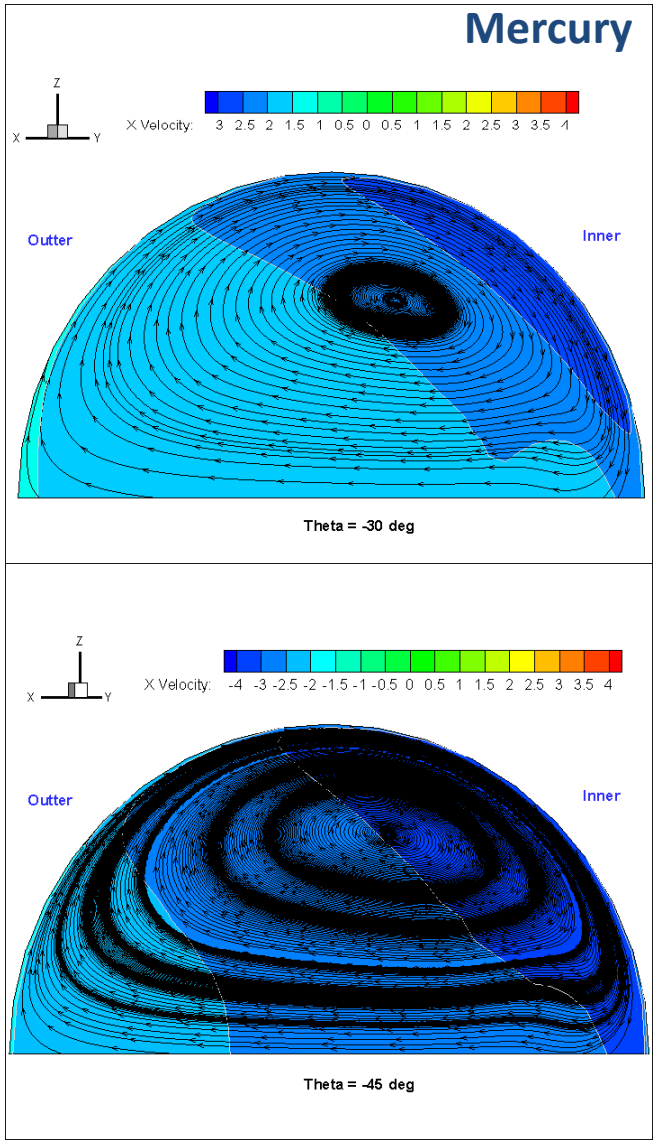


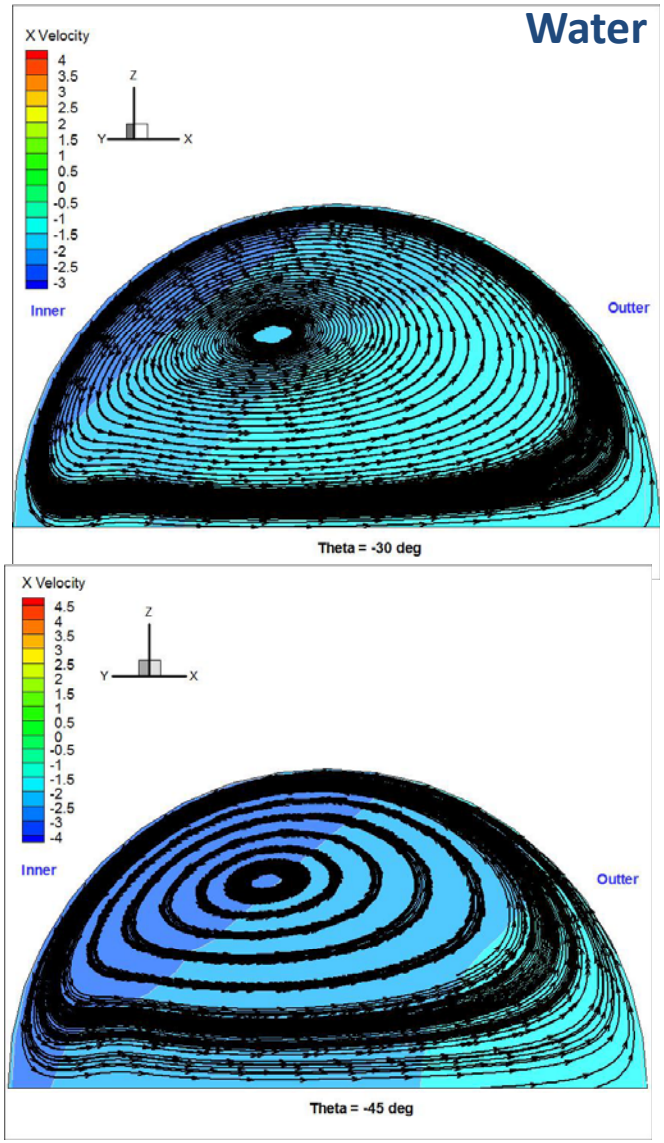




Curved pipe flow in FLUENT

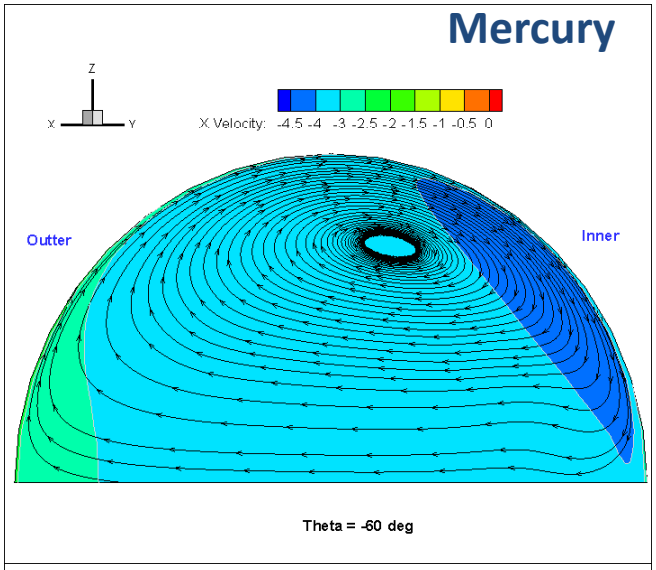
— Radial distribution of axial velocity (4)

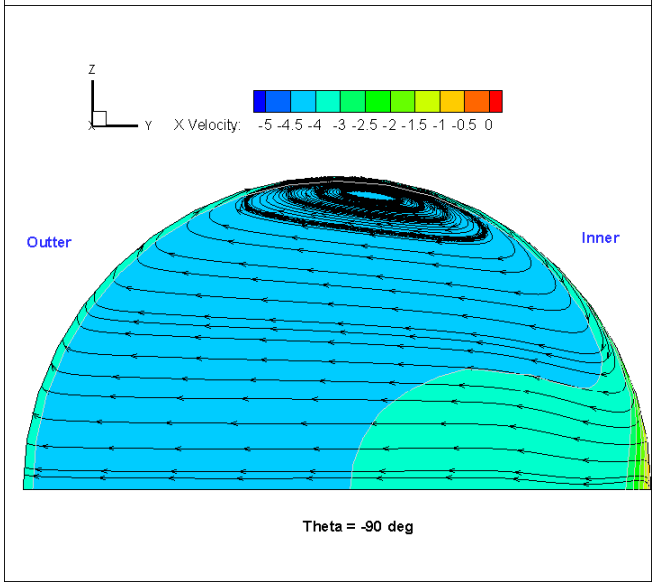


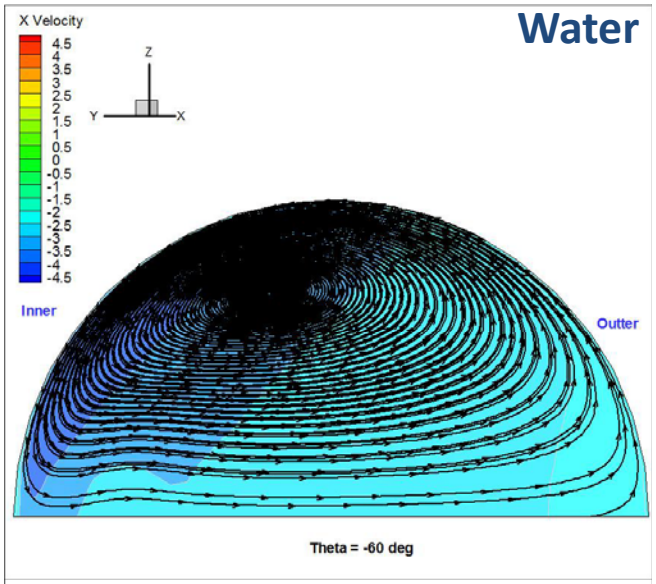


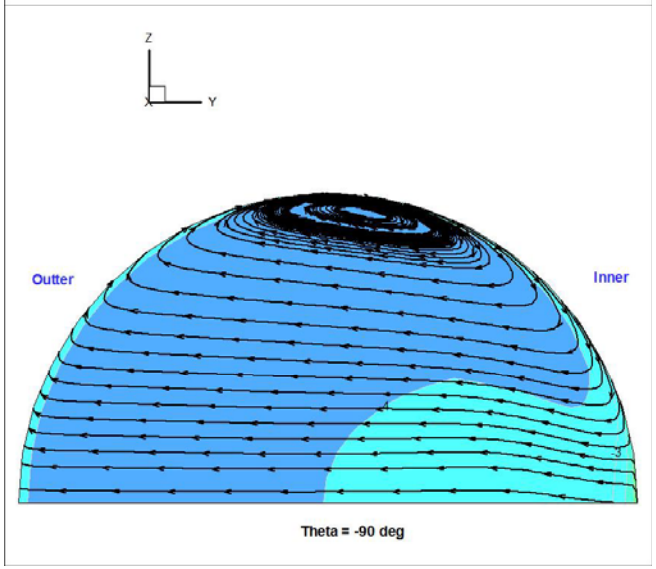
Curved pipe flow in FLUENT

— Radial distribution of axial velocity (5)



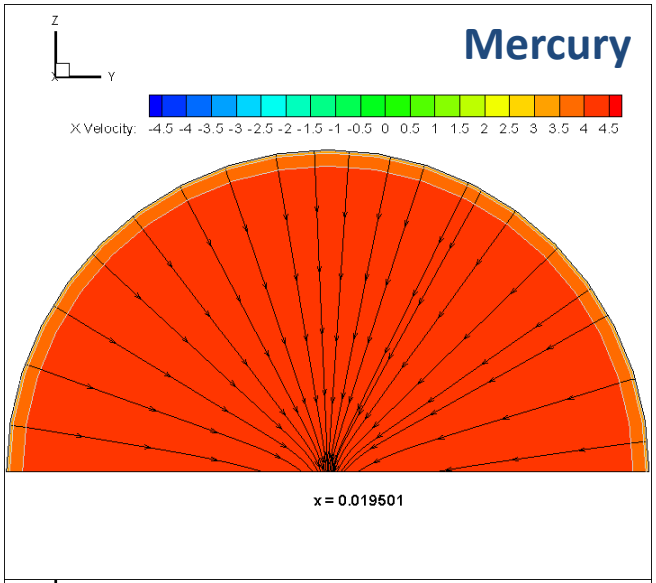


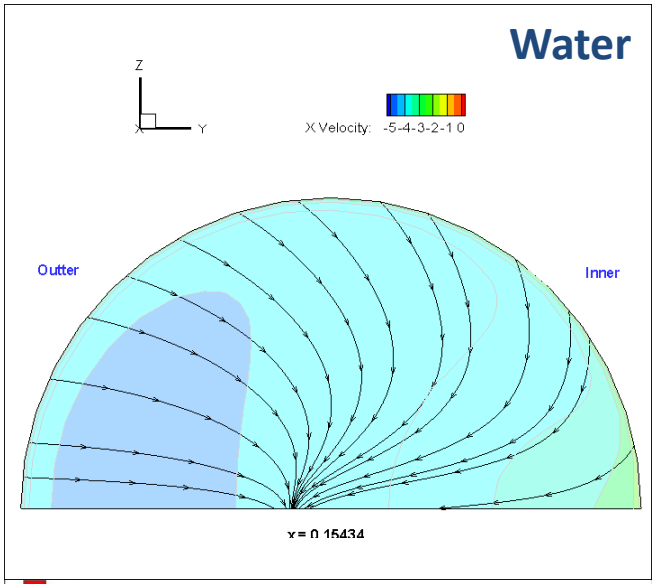


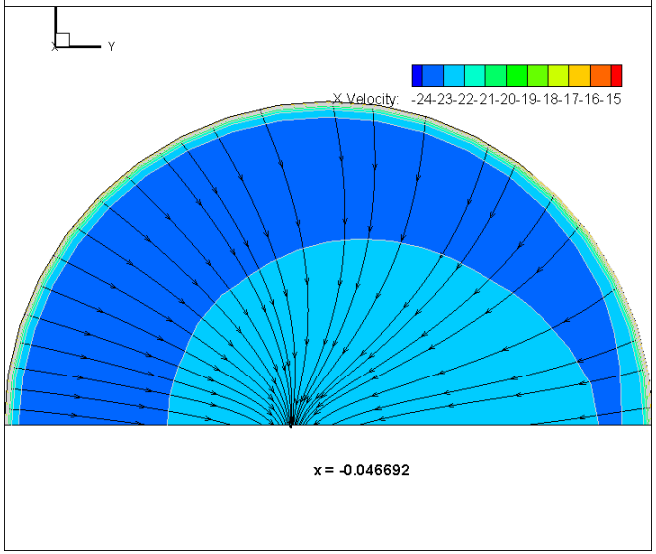


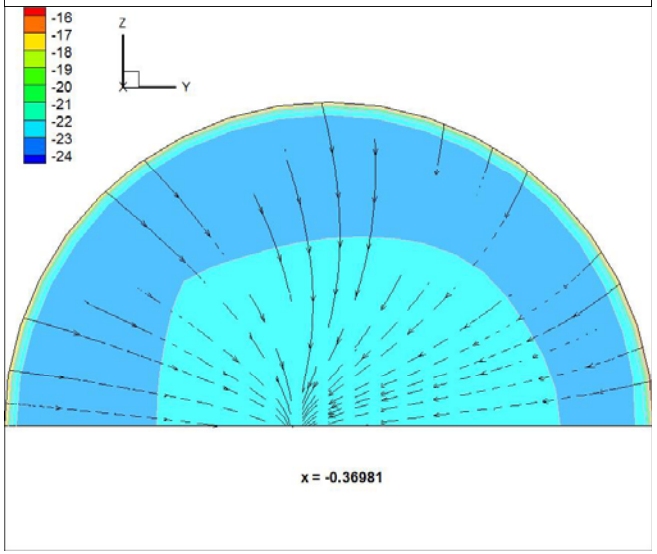
Curved pipe flow in FLUENT

— Radial distribution of axial velocity (6)

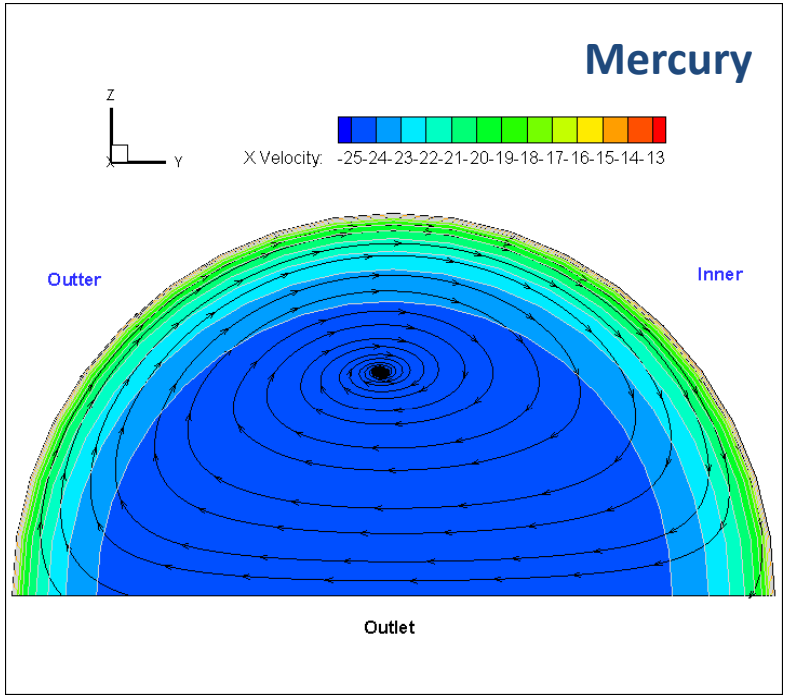


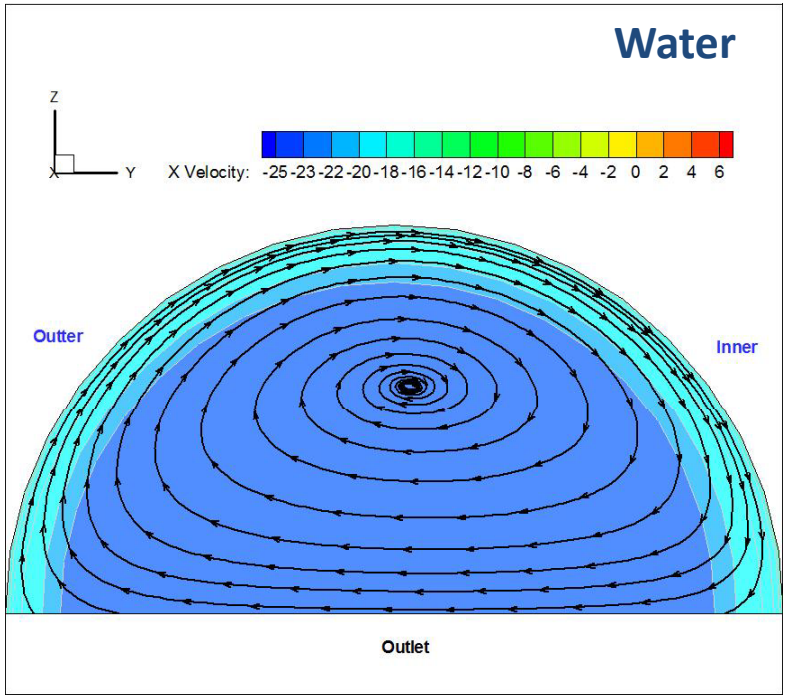




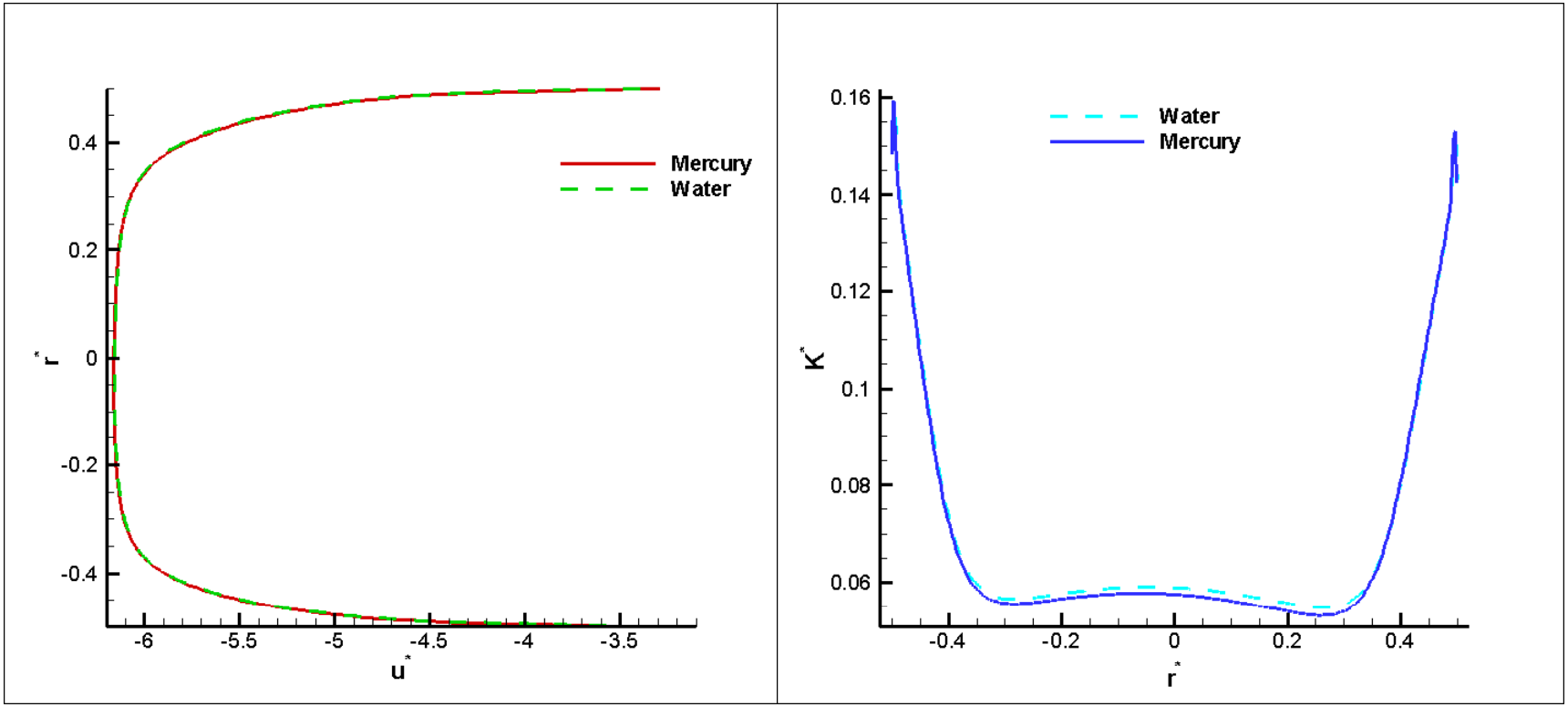


Curved pipe flow in FLUENT
— Radial distribution of axial velocity (7)



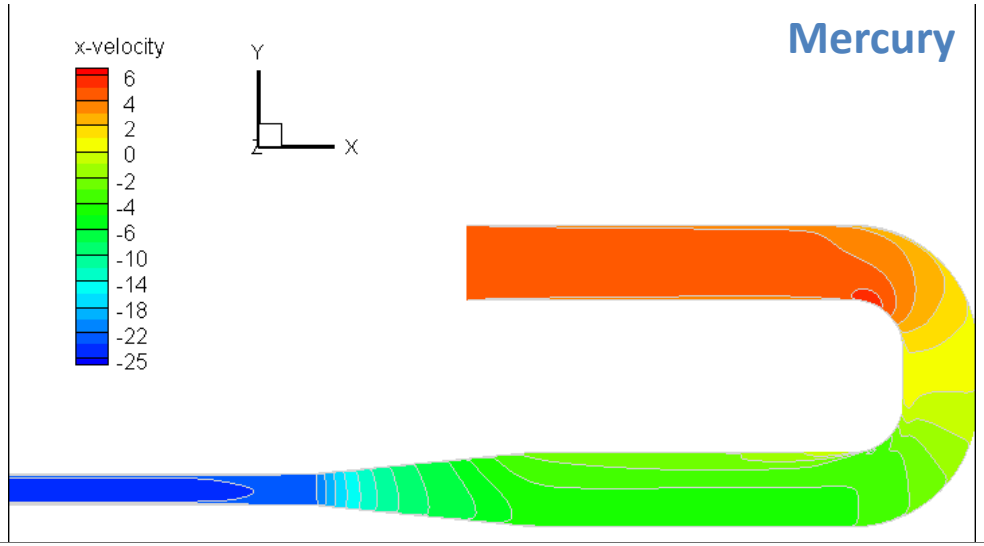


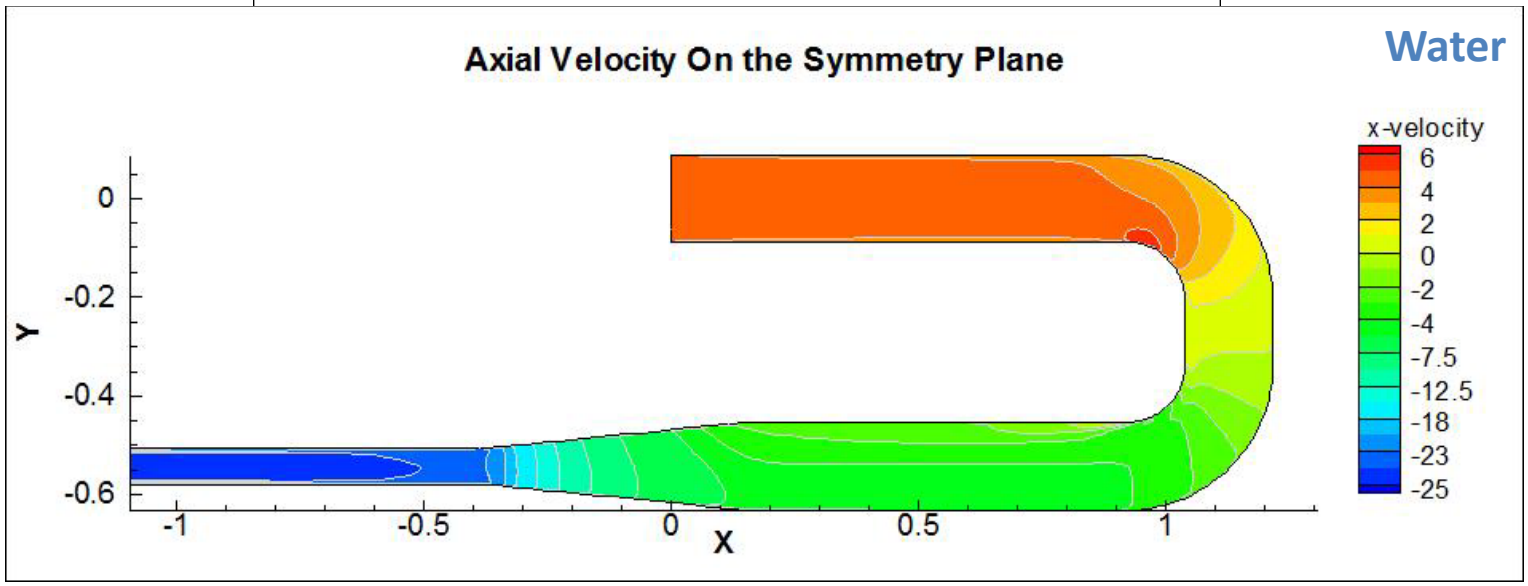
Curved pipe flow in FLUENT
— Parameters at the outlet



Curved pipe flow in FLUENT

— Axial distribution of axial velocity





Appendix A

Analytical solution

$$u(r) = (P_1 - P_2)(R^2 - r^2)/ (4\mu L)$$

Water

$u_{water}(r) = (1.85-1.8291)(R_{water}^2 - r^2)/ (480\times0.893\times10^{-3}\times R_{water})$

$=7.225617-2.942564\ r^2$

Where $0 \le r \le 165.702$

Mercury

$u_{mercury}(r) = (1.85-1.567)(R_{mercury}^2 - r^2)/ (480\times1.526\times10^{-3}\times R_{mercury})$

$= 8.083395 - 0.0184666\ r^2$

Where $0 \le r \le 20.922$