AMOGH M GADAGI #PROJECT 1

Task 1. Deliverables for task 1

Case A: Z1 = 0.8 m, Z2 = 0.2 m

Case B: Z1 = 0.2 m, Z2 = 0.8 m (i.e., swapping the vertical positions of inlet and outlet from Case A)

1. The values of outlet temperature, $T_{out,}$ from the simulations of the two cases

   The outlet temperature is obtained by $T_{out} = \frac{\int\int v\, n\, T\, d\, A}{\int\int v\, n\, d\, A}$ ______________________(1)

```
                Integral
                     num
---------------------- ---------------------
           outlet_small        0.0097255855

                Integral
      Velocity Magnitude             (m/s)(m2)
---------------------- ---------------------
           outlet_small        3.1205441e-05
```

Figure 1. Case A

```
                Integral
                     num
---------------------- ---------------------
           outlet_small        0.0096529759

                Integral
      Velocity Magnitude             (m/s)(m2)
---------------------- ---------------------
           outlet_small        3.1067713e-05

 Area-Weighted Average
      Static Temperature                  (k)
---------------------- ---------------------
           outlet_small           310.70757
```

Figure 2. Case B

By using the outlet temperature equation (1) we obtain the T_{out}

Case A – Outlet temperature = $\frac{0.0097255855}{3.1205441e{-}05}$ = 311.663132721

Case B – Outlet temperature = $\frac{0.0096529759}{3.1067713e{-}05}$ = 310.707643656

Another method to confirm the answers, the surface integral of area weighted average is taken and the outlet temperature is calculated by fluent. Figure 3 and 4 explain the same concept for case A and Case B respectively. This method directly calculates the temperature at the outlet

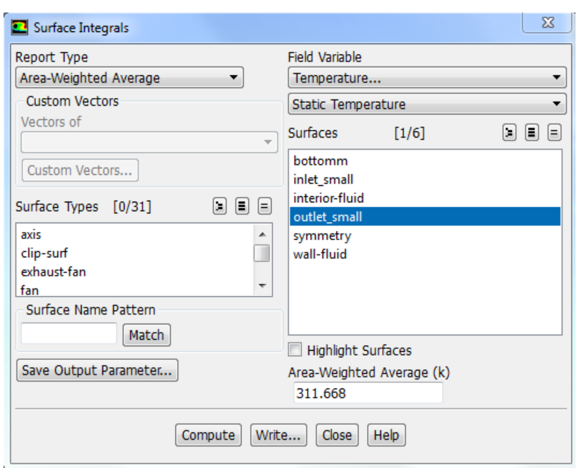

Figure 3. Case A

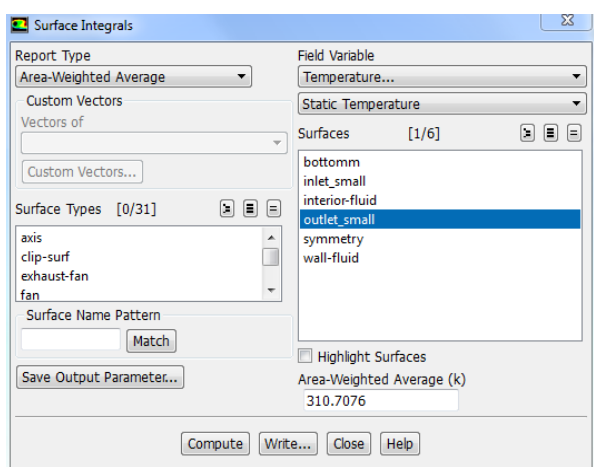

Figure 4. Case B

The outlet temperature obtained by using the equation (1) and the temperature obtained by area weighted average are same. Thus the outlet temperatures in case A is 311.663132 and case B is 310.70764

2. The Contour plots of temperature on the plane of symmetry for the two cases

   The contour plots are obtained on the plane of the symmetry for two different cases. Figures 5 and 6 are the contour plots for case A and case B respectively

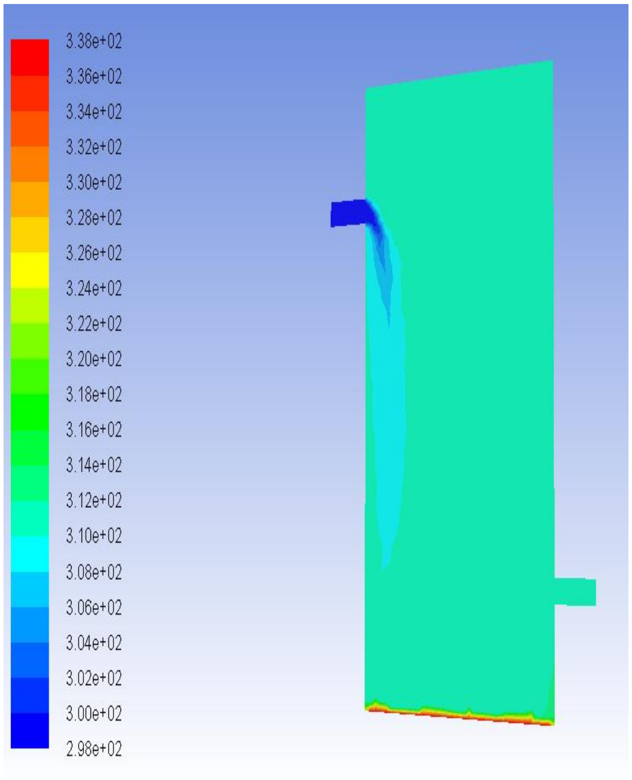

Figure 5. Case A

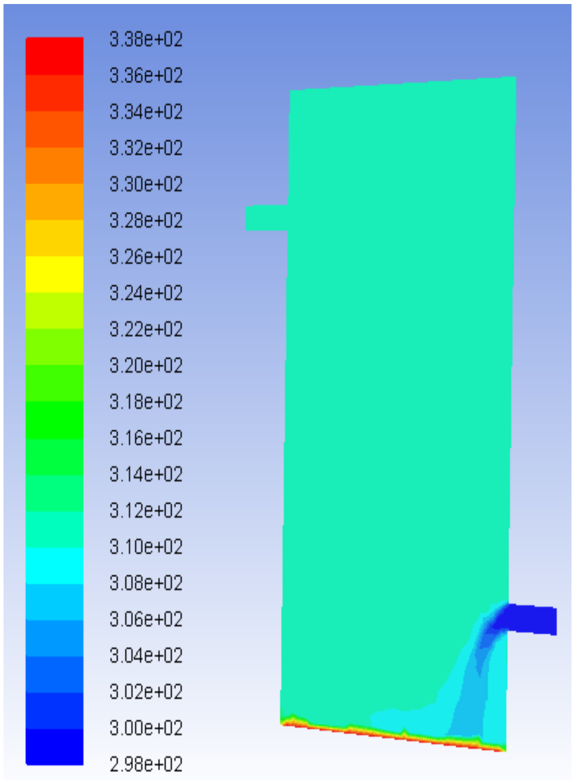

Figure 6. Case B

The inlet has a temperature of 298 K and the bottom of the tank is heated to 338 K. The outlet temperature is calculated as shown in deliverable 1. In case A, as soon as the fluid enters the tank at 298 K, it flows to the bottom of the tank and gets heated again as the bottom of the tank is at 338 K. Thus the liquid at the bottom of the tank has less density and it circulates to the top of the tank. Eventually the heated liquid exits from the pressure outlet. Case B is different as the bottom one is the inlet. As soon as the fluid enters the tank it gets heated up. The heated fluid which has less density circulates to the top of the tank.

3. Plots of stream lines for the two cases

   The streamlines are obtained from the CFD post processing and are as shown in figures 7 and 8. The figure 7 depicts front view of the streamlines for case A whereas figure 8 gives the isometric view of the streamlines for case A.

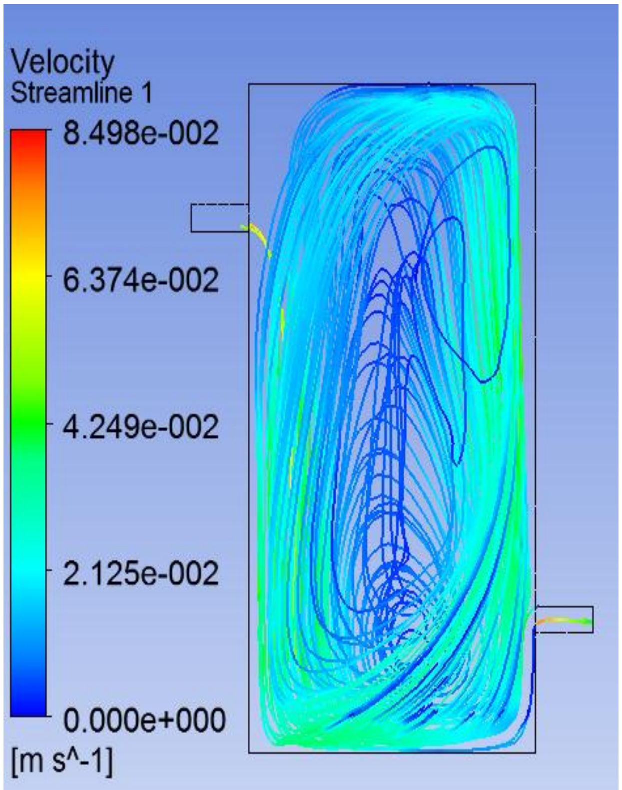

Figure 7. Front view, case A

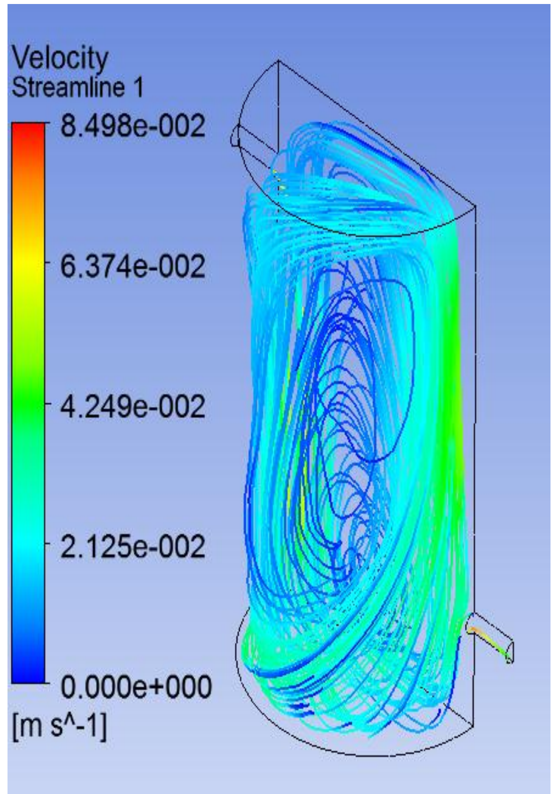

Figure 8. Isometric view, case A

Figure 9 and figure 10 represents the front and isometric view of the streamlines for case B.

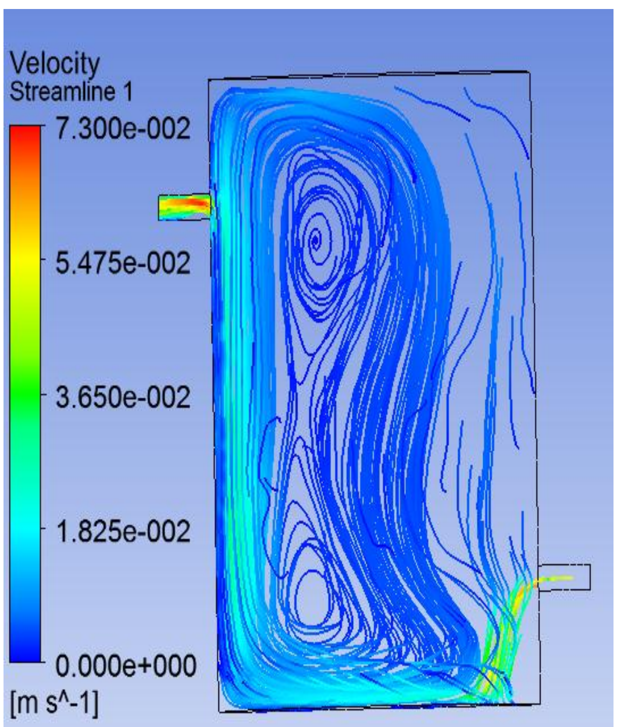

Figure 9. Front view, case B

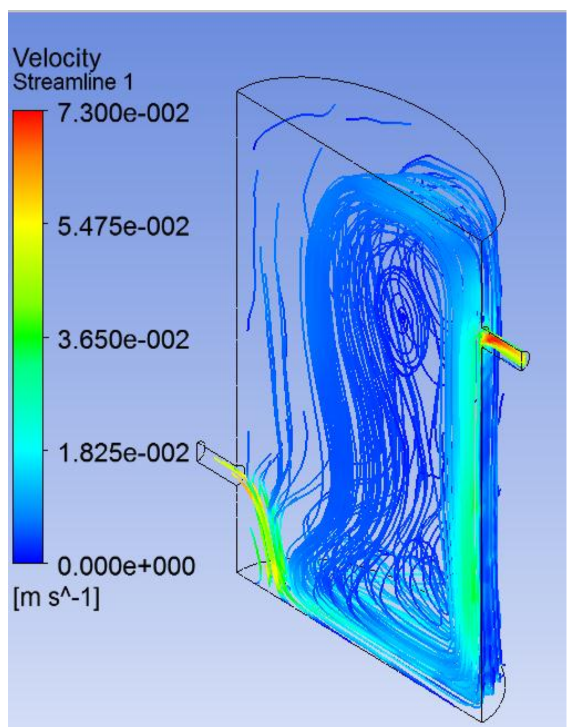

Figure 10. Isometric view, case B

4. A discussion of the possible reasons for the differences in Tout between the two cases based on the information obtained from the numerical simulations.

   ANS - The temperature at the outlet is greater in case A than in case B. This may be because in case B, the outlet is far from the bottom plate and thus the liquid when gets in contact with the bottom plate gets heated up and this liquid is then circulated to the top as the density will be lesser. Thus there is heat dissipation. This dissipation is given out to the surrounding liquid and thus temperature is lost by the liquid before exiting from outlet. Also in case A bottom plate is situated near the outlet and thus the major heat is carried away by the liquid from the bottom plate and exits from the outlet. Hence the outlet temperature in case A is greater than in case B

Task 2

This task will assess the dependence of Tout on the geometry of the main water tank by considering two additional designs

Case C: D1 = 0.625 m, D2 = 0.4 m. The inlet and outlet are aligned with the major axis of the ellipse.

Case D: D1 = 0.4 m, D2 = 0.625 m. The inlet and outlet are aligned with the minor axis of the ellipse.

Task 2. Deliverables for task 2

1. The values of outlet temperature, T_{out}, from the simulations of the two cases

   The outlet temperature is obtained by $T_{out} = \frac{\int\int v\ n\ T\ d\ A}{\int\int v\ n\ d\ A}$ ______________________________(1)

```
                 Integral
        custom-function-0
---------------------- --------------------
             outlet_small        0.0096871364

                 Integral
       Velocity Magnitude           (m/s)(m2)
---------------------- --------------------
             outlet_small       3.1170442e-05

                 Integral
       Static Temperature             (k)(m2)
---------------------- --------------------
             outlet_small          0.19207191

   Area-Weighted Average
       Static Temperature                 (k)
---------------------- --------------------
             outlet_small           310.78013
```

Figure 11. Case C

```
                 Integral
        custom-function-0
---------------------- --------------------
             outlet_small        0.0096563153

                 Integral
       Velocity Magnitude           (m/s)(m2)
---------------------- --------------------
             outlet_small       3.1082465e-05

   Area-Weighted Average
       Static Temperature                 (k)
---------------------- --------------------
             outlet_small           310.66782
```

Figure 12. Case D

By using the outlet temperature equation (1) we obtain the T_{out}

Case C – Outlet temperature = $\frac{0.0096871364}{3.1170442e{-05}}$ = 310.77956482

Case D – Outlet temperature = $\frac{0.0096563153}{3.1082465e{-05}}$ = 310.667615969

Another method to confirm the answers, the surface integral of area weighted average is taken and the outlet temperature is calculated by fluent. Figure 13 and 14 explain the same concept for case A and Case B respectively. This method directly calculates the temperature at the outlet

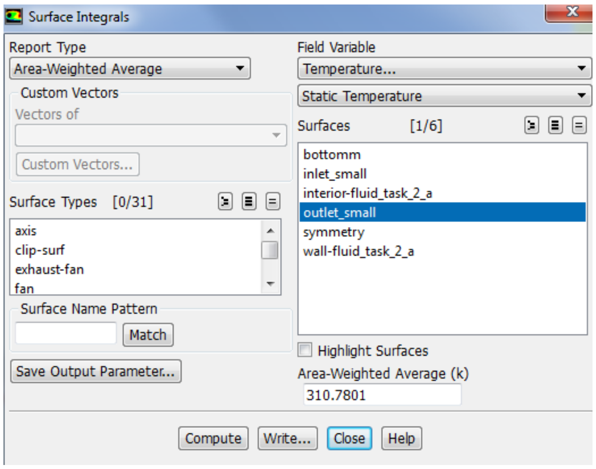

Figure 13. Case C

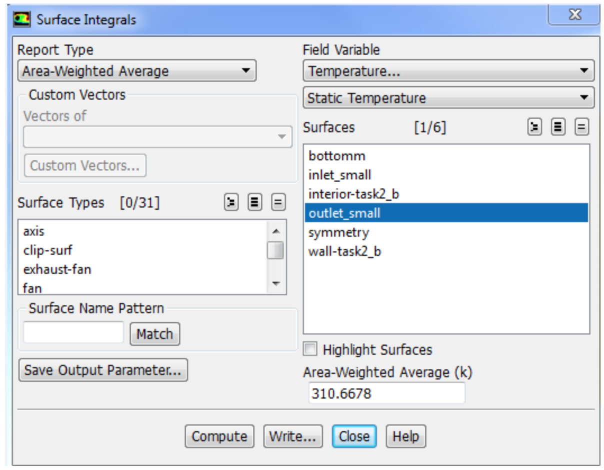

Figure 14. Case D

The outlet temperature obtained by using the equation (1) and the temperature obtained by area weighted average are same. Thus the outlet temperatures in case A is 310.77956482and case B is 310.667615969

2. The Contour plots of temperature on the plane of symmetry for the two cases
   The contour plots are obtained on the plane of the symmetry for two different cases. Figures 13 and 14 are the contour plots for case A and case B respectively

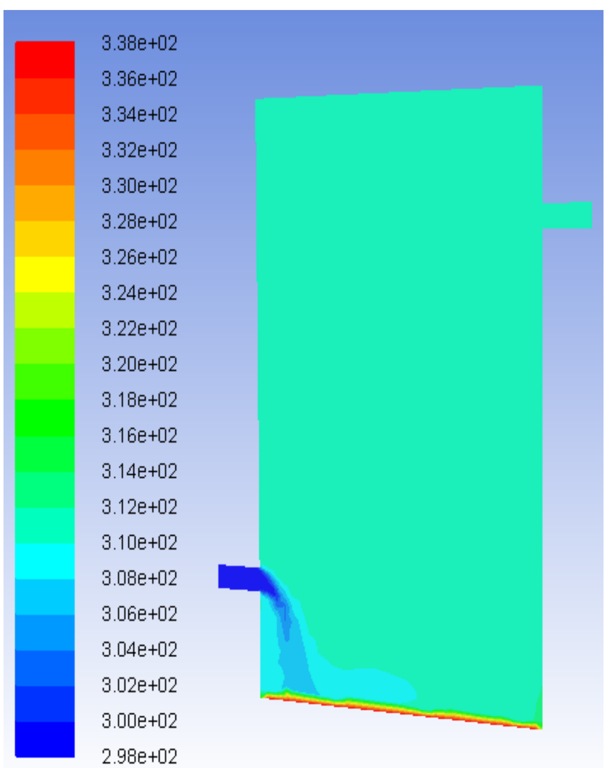

Figure 15. Case C

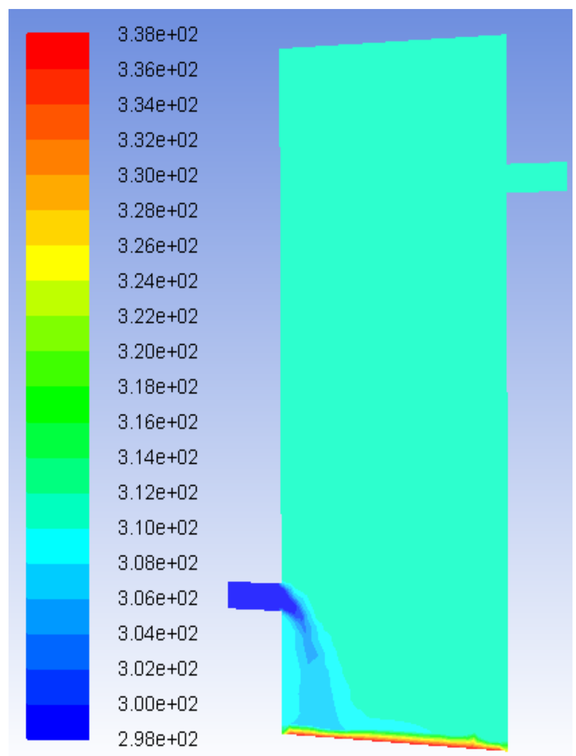

Figure 16. Case D

The inlet is closer to the bottom of the tank and thus the temperature is high in both of them. Due to the geometry of the tanks in case C and case D, the contour plots vary. The value of the temperature along the tank in both the cases are almost same but the pattern in spreading of the liquid as it approaches the bottom of the tank differs. Thus the contour plots.

3. Plots of stream lines for the two cases

Figure 17 depicts front view of the streamlines for case C whereas figure 18 gives the isometric view of the streamlines for case C.

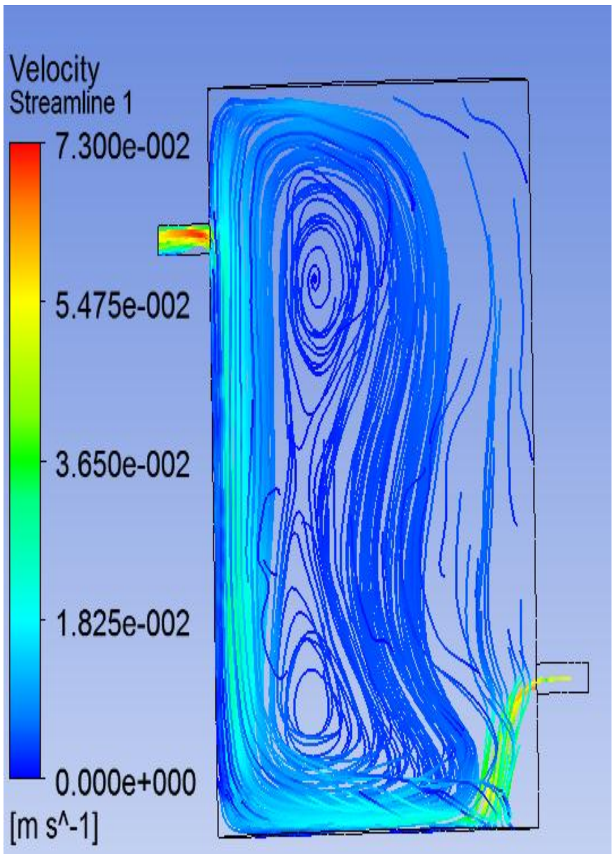

Figure 17. Front view, case C

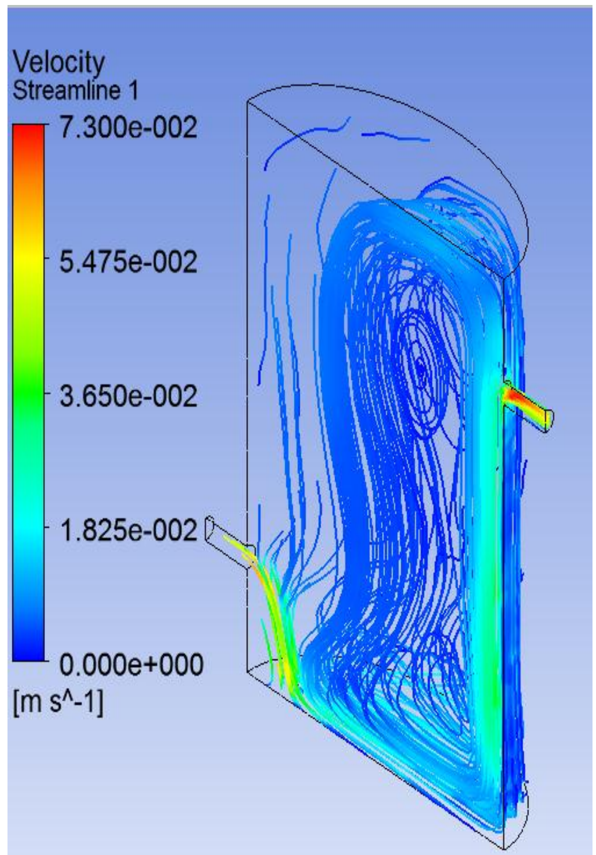

Figure 18. Isometric view, case C

Figure 19 and figure 20 represent the front and isometric view of the streamlines for case D

The streamlines are obtained from the CFD post processing and are as shown in figures 17 and 18. Thus streamlines depicts the flow of the liquid in the tank and the pattern of how it gets heated up as it goes through the tank. The streamlines are very helpful in determining the path of the liquid and the changes in its properties.

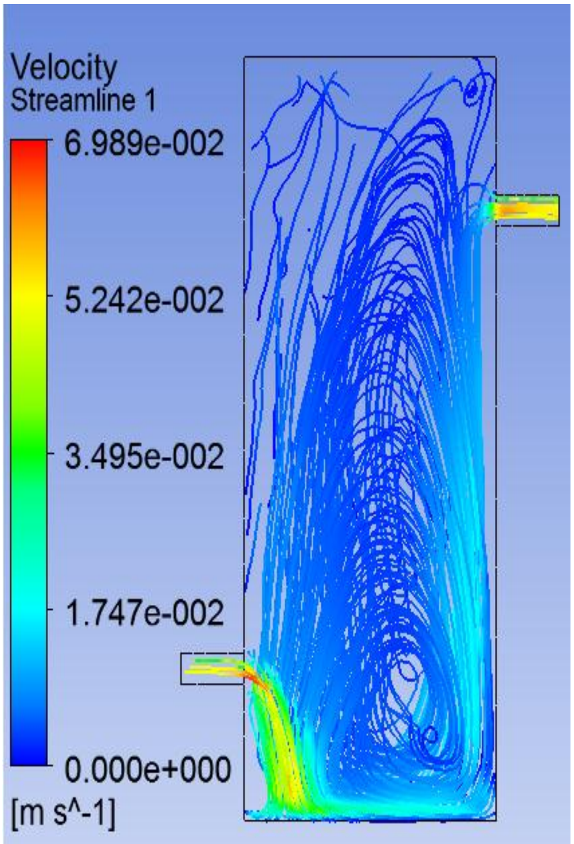

Figure 19. Front view, case D

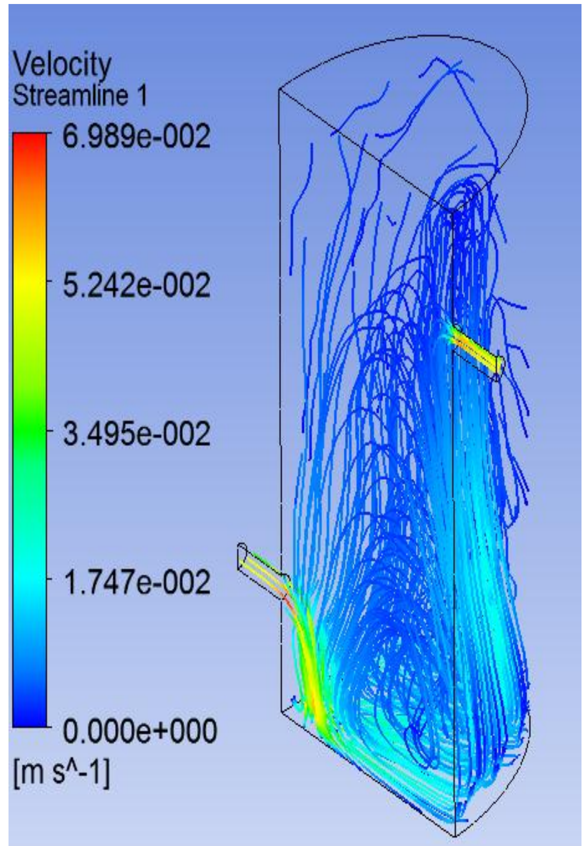

Figure 20. Isometric view, case D

4. A discussion of the possible reasons for the differences in Tout between the two cases based on the information obtained from the numerical simulations

   ANS – The shape of the ellipse is defined by the major and minor axis. In case C the major axis is larger than that of case D. Thus the tank is narrower in case of case C as compared to case D. Thus the fluid molecules collide with the wall of the tank and gain some energy, which can be heat energy, this will thus increase the temperature of the liquid molecules in the tank and thus result in increase in outlet temperature. In case of case D, the tank is wider as the major is axis smaller. Thus the liquid gets enough room to circulate and when it hits the wall, the liquid doesn't gain much energy as compared to the narrower tank.

5. Comparing the efficiency of the elliptical design with the circular one in Task 1
   The temperature is higher in elliptical case compared to that of the spherical case and hence the efficiency might be greater for elliptical design.

Task 3. Deliverables for task 3.

Density is set constant and gravity is turned off

1. The values of outlet temperature, $T_{out,}$ from the simulations of the two cases

   The outlet temperature is obtained by $T_{out} = \frac{\int\int v\, n\, T\, d\, A}{\int\int v\, n\, d\, A}$ ______________________(1)

```
                 Integral
         custom-function-0
------------------------ --------------------
             outlet_small         0.0093381415

                 Integral
        Velocity Magnitude              (m/s)(m2)
------------------------ --------------------
             outlet_small         3.083576e-05

     Area-Weighted Average
        Static Temperature                  (k)
------------------------ --------------------
             outlet_small            302.83321
```

Figure 21. Task 3

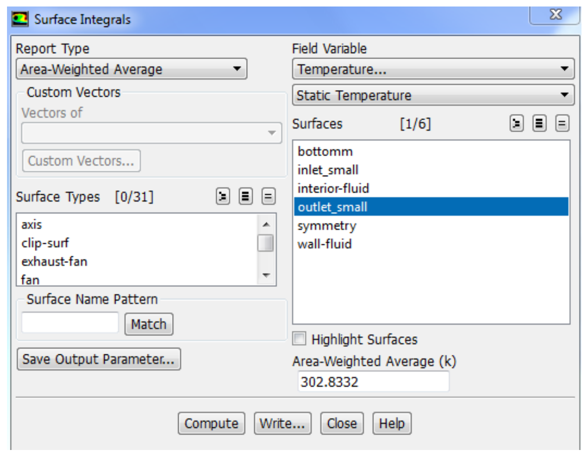

Figure 22. Task 3

By using the outlet temperature equation (1) we obtain the T_{out}

Task 3 – Outlet temperature = $\frac{0.0093381415}{3.083576e{-}05}$ = 302.834809325

Another method to confirm the answers, the surface integral of area weighted average is taken and the outlet temperature is calculated by fluent. Figure 3 and 4 explain the same concept for case A and Case B respectively. This method directly calculates the temperature at the outlet. Figure 22 gives the table through which the area weighted average is calculated and hence temperature. Figure 21 gives the value of the numerator and denominator which are used in equation (1) to get the outlet temperature.

2. The Contour plots of temperature on the plane of symmetry for the two cases

   The contour plots are obtained on the plane of the symmetry for two different cases. Figure 23 is the contour plots for task 3.

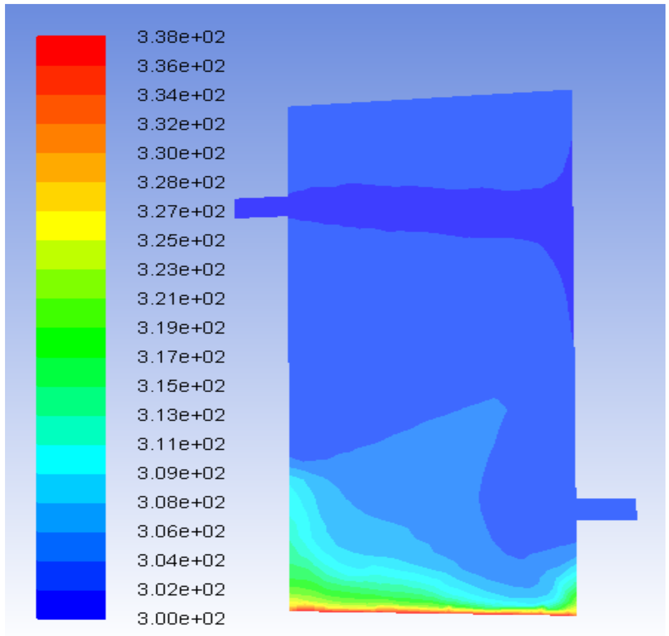

Figure 23. Contour plot of task 3

3. Plots of stream lines

Figure 24 depicts front view of the streamlines for case C whereas figure 25 gives the isometric view of the streamlines for case C.

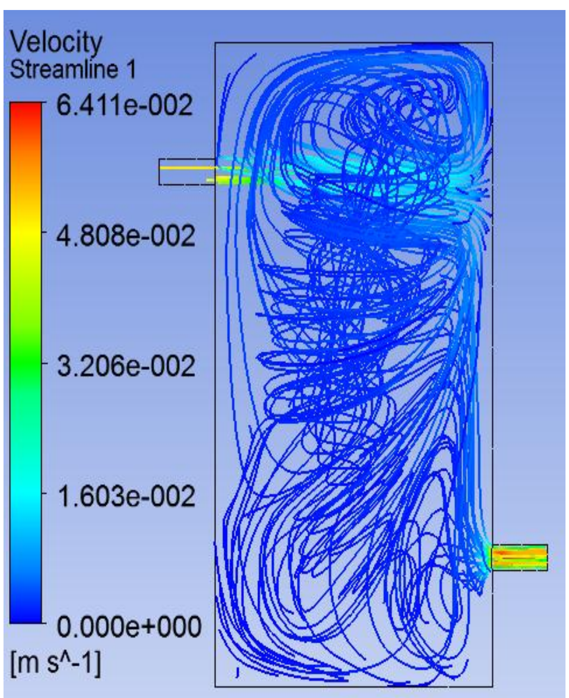

Figure 24. Front view, task 3

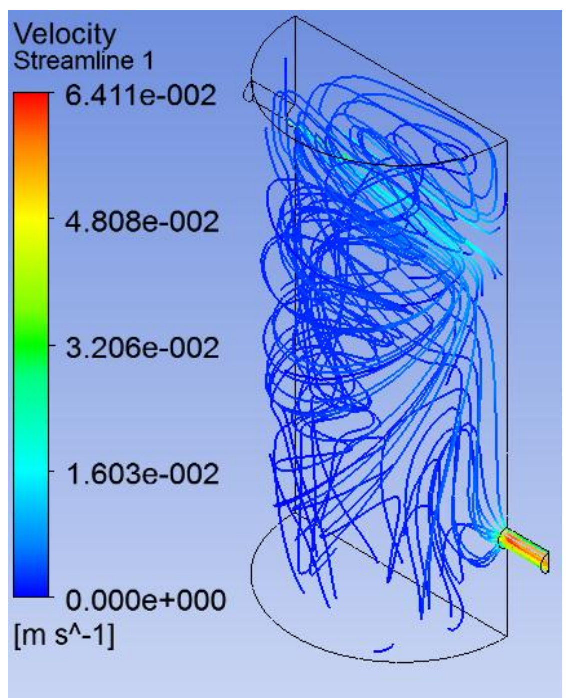

Figure 25. Isometric view, task 3

4. Gravity is turned off and the density is set constant. There is no effect of gravity for the liquid, hence the liquid tends to just get in the tank and not try to get to the bottom of the tank as the gravity is neglected. If you turn off gravity, then the pressure within a fluid will not vary with depth. Thus the pressure almost remains constant and hence no buoyancy (because gravity is set off), which causes less outlet temperature. Due to the constant density the T_{out} is less.

   When density is set constant,

   - Gravity is set off and hence gravity neglected.
   - Boussinesq equation is set off i.e no buoyance-driven thermal convection and hence absence of operating density, operating temperature and thermal expansion coefficient.

   Thus due to these missing parameters the t_{out} is less.

Task 4. Deliverables for task 4

1. Total heat flow rate from the bottom plate of the tank

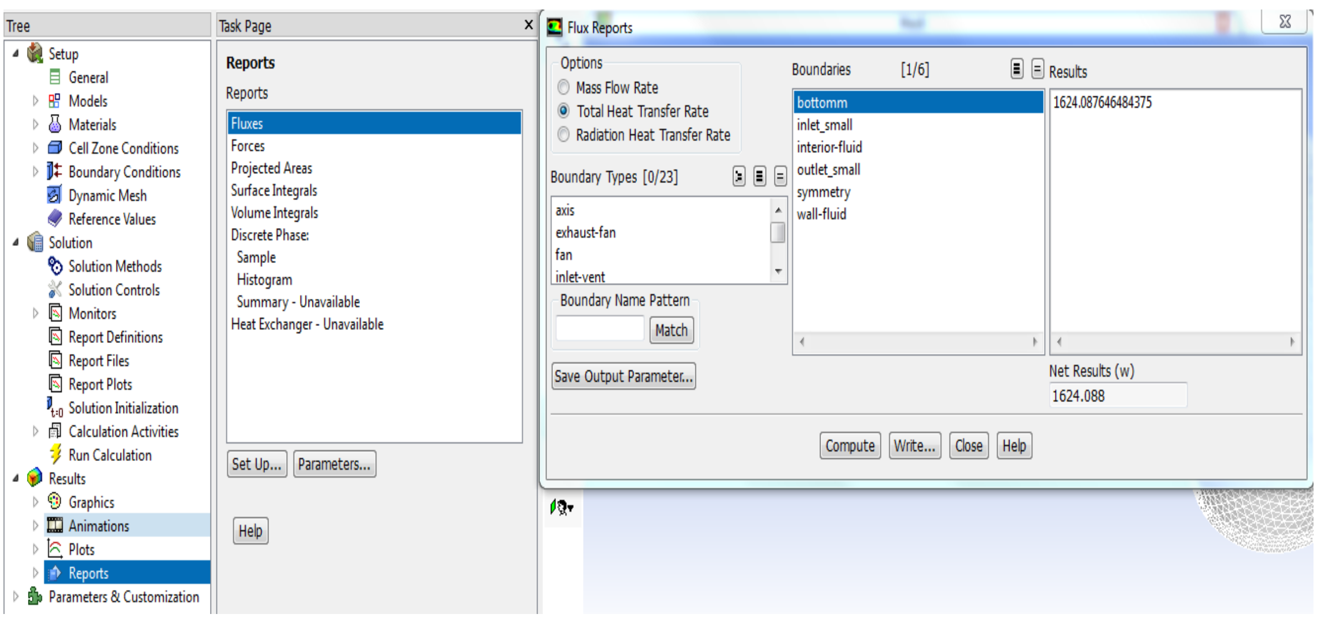

Figure 26. Fluent steps for calculating the heat transfer rate

2. Total heat flow rate from the tank = 2*1624.088 W = 3248.176 W

   Average heat flux at bottom plate = $\frac{Total\ heat\ flow\ rate}{Area\ of\ the\ bottom\ plate}$

   Average heat flux = $\frac{3248.176}{\left(\frac{\pi}{4}\right)*0.5*0.5}$ = 16542.8245258 W/m^2

3. Change the bottom boundary condition and insert heat flux instead of temperature and run the simulation

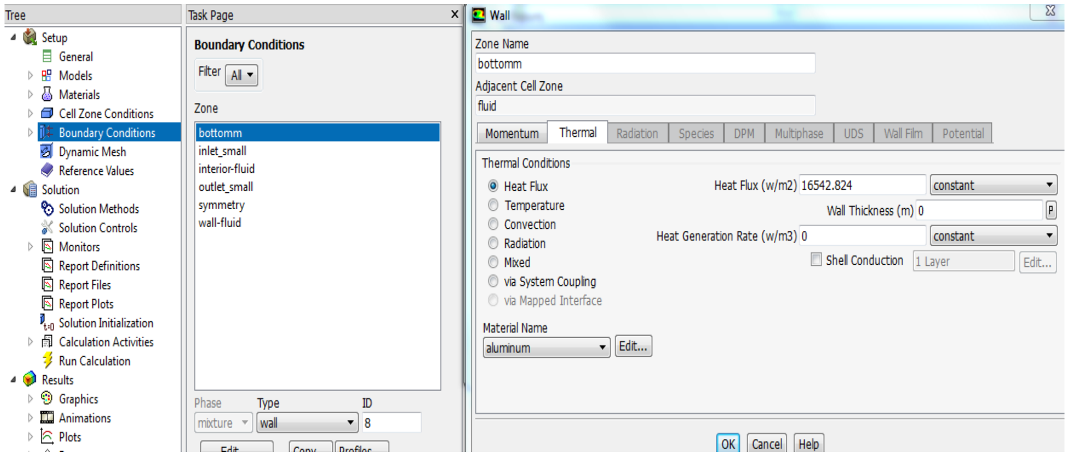

Figure 27. Setting up the bottom boundary condition

4. Calculating the outlet temperature

```
                 Integral
         custom-function-0
------------------------- --------------------
              outlet_small         0.0096565684

                 Integral
        Velocity Magnitude            (m/s)(m2)
------------------------- --------------------
              outlet_small         3.1080315e-05

     Area-Weighted Average
        Static Temperature                  (k)
------------------------- --------------------
              outlet_small             310.6972
```

Figure 28. Task 4

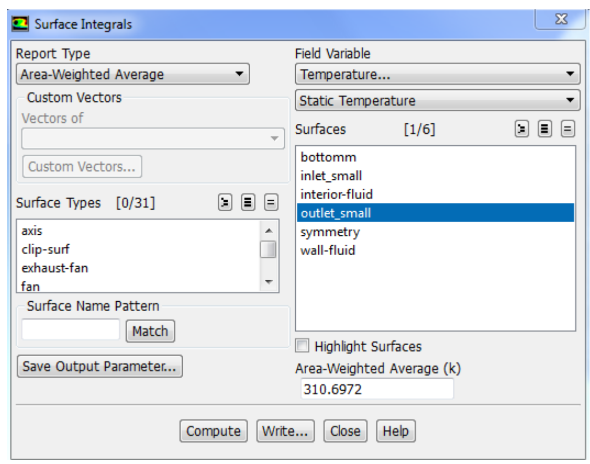

Figure 29. Task 4

By using the outlet temperature equation (1) we obtain the Tout

Task 4 – Outlet temperature = $\frac{0.0096565684}{3.1080315e{-05}}$ = 310.697250012.

5. Explanation – It provides almost the same T outlet as that of case B task 1. Instead of setting the bottom plate at 338 K we replaced it by providing a heat flux of 16542.8245258 W/m^2 which almost produces/heats up the bottom plate if it was maintained at 338 K. Thus the heat flux provision nullifies the temperature constant thing and thus we obtain almost the same outlet temperature.