Calculation and Discussion

4-1 Calculation

To produce chilled water for cooling inlet air at General Electric(GE)gas turbine frame 6 at Garri power plant to get design condition (Appendix (2)) 145kg/s of chilled water must be cooled from maximum temperature at Khartoum 43°C to Design Condition 15 °C .and then calculate the following :-

- Quantity of heat must be removed from air and absorbed by chilled water.
- Quantity of chilled water.
- Heat exchanger area.
- Number of tubes needed to install intake air filter house the exits dimensions is 7*7 meter.
- The Chiller System Selection.

Assumptions:

- Steady operating conditions exist.
- Changes in the kinetic and potential energies of fluid streams are negligible.
- Fluid properties are constant.
- The material of heat exchanger is pure copper.
- LMTD method is used to analyze the heat exchanger (Temperatures are known)

4-1-1 Quantity of heat to be removed from air

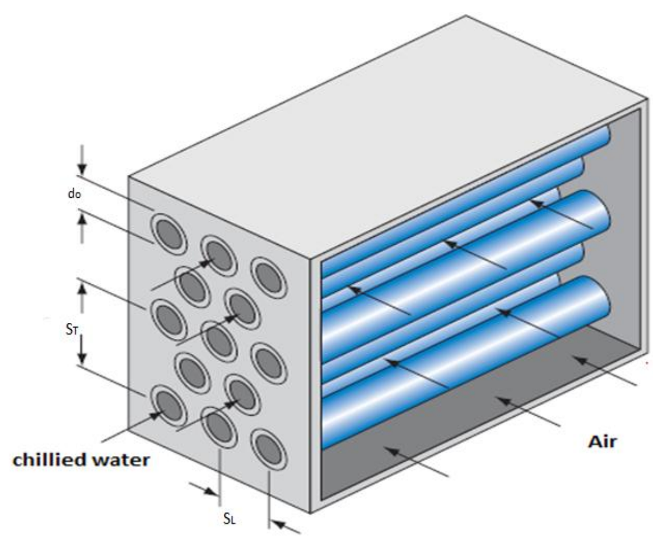


Figure 4-1 Cross flow heat exchanger (Chilled water & Air).

Table 4.1 The Thermodynamics specifications of fluids

$\dot{m}_a$ (kg/s)	T_{chi} (°C)	T_{cho} (°C)	T_{ai} (°C)	T_{ao} (°C)
145	7	12	43	15

- From Thermo physical Properties of Air at atmospheric pressure at film temperature (T_f)A (4).

$$T_f = \frac{Tao + Tai}{2} = \frac{15+43}{2} = 29\ °C$$

$\rho_f = 1.1694\ kg/m^3.\ cp_f = 1.007\ kJ/kg\ K, \nu_f = 1.5942 * 10^{-5} m^2/s$, $K_f = 0.026352\ w/m^2K$, $Pr_f = 0.7122$, $Pr_s = 0.71$

-From Thermo physical Properties of water at Average temperature (T_{avg})A (5).

$$T_{avg} = \frac{T_{chi} + T_{cho}}{2} = \frac{7+12}{2} = 9.5\ °C$$

$\rho_{cw} = 999.7 kg/m^3$.,$pr_{cw} = 9.62 m^2/s, \nu_{cw} = 13.37 * 10^{-7} m^2/s$, $K_{cw} = 0.57\ W/m^2k$,$cp_{cw} = 4.197 kJ/kg\ K$.

Heat lost by air = Heat gained by chilled water

$Q = m_{ch.} * cp_{ch} * (T_{cho} - T_{chi}) = m_a * cp_a * (T_{ai} - T_{ao})$.

$Q_a = m_a * cp_a * (T_{ai} - T_{ao})$.

$Q_a = 145 * 1.007 * (43 - 15) = 4088.42\ kw$.

A10% factor of safety is assumed for better design.

$$Q_{design} = (1 + 0.10) * Q_{calc}$$

$$Q_{design} = Q_a = Q_{ch} = (1 + .10) * 4088.42 = 4497.262\ kw \simeq 5\ MW.$$

There for heat to be removed is 4497.262 kW.

4-1-2 Quantity of chilled water

Referring to first law of thermodynamics the heat removed from the air absorbed by the chilled water when neglecting loses at surrounding so the quantity absorbed by chilled water is 4497.262 kW.

$$\dot{m}_{ch} = \frac{Q_{ch}}{cp_{ch} * (T_{cho} - T_{chi})} = \frac{4497.262}{4.197 * (12 - 7)} = 214.308 \text{ kg/s}$$

$$V_{ch} = \frac{\dot{m}_{ch}}{\rho_{ch}} = \frac{214.308}{999.7} = 0.2144 \frac{m^3}{s} = 771.89 \frac{m^3}{hr}.$$

4-1-3 Number of tubes need to install inside the intake air filter house

To calculate the number of heat exchanger tubes first calculate the heat exchanger area need to occur heat transfer, at filter house cross section area is 7*7 m, and7 m long Appendix(9).

$$Q = U * A_o * LMTD * F$$

$$LMTD = \frac{\Delta T_1 - \Delta T_2}{\ln(\frac{\Delta T_1}{\Delta T_2})}$$

$$\Delta T_1 = T_{ao} - T_{chi} = 15 - 7 = 8 \text{ °C}$$

$$\Delta T_2 = T_{ai} - T_{cho} = 43 - 12 = 31 \text{ °C}$$

$$LMTD = \frac{\Delta T_1 - \Delta T_2}{\ln(\frac{\Delta T_1}{\Delta T_2})} = \frac{8-31}{\ln(\frac{8}{31})} = 16.979 \text{ °C or K.}$$

$$P = \frac{t_2 - t_1}{T_1 - t_1} = \frac{12-7}{43-7} = 0.13889.$$

$$R = \frac{T_1 - T_2}{t_2 - t_1} = \frac{43 - 15}{12 - 7} = 5.6$$

From curve At P=0.13889, R=5.6 . Appendix (3).

F=0.7844.

$$Q = U * A_o * LMTD * F$$

Table 4.2 Heat Exchanger parameters

D_o(mm)	D_i(mm)	d_o(mm)	d_i(mm)	L(m)	$\dot{m}_{ch}$ $(\frac{kg}{s})$
107.6	101.6	10	8	7	214.308

4-1-3-1 Volume flow rate of chilled water through the large pipe

$$m^{\cdot}_{cw} = \rho_{cw} * A_{cw} * V_{cw}$$

$$V_{cw} = \frac{m^{\cdot}_{cw}}{\rho_{cw} * A_{cw}}$$

$$A_{cw} = \frac{\pi * {D_i}^2}{4} = \frac{\pi * 0.1016^2}{4} = 0.008107 \text{ m}^2.$$

$$V_{cw} = \frac{214.308}{999.7 * 0.008107} = 26.4428 \text{ m/ s}.$$

$$q_{supply} = A_{cw} * V_{cw} = 0.008107 * 26.4428 = 0.2143 \text{ m}^3/\text{s}$$

4-1-3-2 Number of rows

To find the number of rows divide the heat exchange length (7m) to the pipe diameter plus space between the pipe assume that the pipe diameter is 0.01m space equal to the pipe diameter (0.02m) from above

The number of pipes at single row:

$d_{(both\ sides)}$=0.02 m

$space_{(both\ sides)}$= 0.02 m

$$\text{Number of rows} = \frac{L}{d_{(both\ sides)} + space_{(both\ sides)}} = \frac{7}{0.04} = 175 \text{ rows}$$

$$N_{row} = 175 \text{ rows}.$$

4-1-3-3 Volume flow rate of chilled water through the small pipe

$$q_{tube} = \frac{q_{supply}}{N_{row}} = \frac{0.2143}{175} = 0.0012249 \text{ m}^3/\text{s}.$$

$$A_{tube} = \frac{\pi * {d_i}^2}{4} = \frac{\pi * 0.008^2}{4} = 5.026 * 10^{-5} \text{ m}^2.$$

$$v_{tube} = \frac{q_{tube}}{A_{tube}} = \frac{0.0012249}{5.026 * 10^{-5}} = 24.373 \text{ m/s}$$

4-1-3-4 Overall heat transfer coefficient

$$R_T = \frac{1}{h_i * A_i} + R_{wall} + \frac{1}{h_o * A_o} + \frac{R_{f,i}}{A_i} + \frac{R_{f,o}}{A_o}$$

- For wall

$$R_{wall} = \frac{\ln(\frac{d_o}{d_i})}{2 * \pi * k * l}$$

L=7m, $k = 401 \, ^{W}/_{m\,k}$. Appendix (6).

$$R_{wall} = \frac{\ln(\frac{d_o}{d_i})}{2*\pi*k*l} = \frac{\ln(\frac{10}{8})}{2*\pi*401*7} = 1.2652 * 10^{-5} \text{ K/W (neglected very small value).}$$

- For inside tube (chilled water)

$$Re_{cw} = \frac{V_{cw} * d_i}{\nu_{cw}} = \frac{24.373 * .008}{13.37 * 10^{-7}} = 145836.6$$

145837> 4000

The flow of chilled water is turbulent.

$$Nu_{cw} = 0.023Re^{0.8} * pr^{0.4} \text{ A(11)}$$

$$Nu_{cw} = 0.023 * Re_{cw}^{0.8} * Pr_{cw}^{0.4} = 0.023 * (145837)^{0.8} * (9.62)^{0.4} = 613.44$$

$$Nu_{cw} = \frac{h_{cw} * d_i}{K_{cw}}$$

$$h_{cw} = \frac{Nu_{cw} * K_{cw}}{d_i} = \frac{613.44 * 0.57875}{0.008} = 44378.7193 \text{ W/m}^2\text{k}$$

Fouling factor of chilled water

$R_{f,cw}$ =0.0001.From table. Appendix (10)

- For outside tube (air)

$m^{\cdot}_a = \rho_a * A_a * V_a$

$A_a = 7 * 7 = 49\ m^2.$

$V_a = \frac{m^{\cdot}_a}{\rho_a * A_a} = \frac{145}{1.1694*49}$=2.5305 m/s.

$A_{min} = (S_T - 2 * D) * L * N_{row}$, [14]

$A_{min} = (0.04 - 2 * 0.01) * 7 * 175 = 24.5\ m^2.$

$U_{max} = \frac{S_T/_2}{\sqrt{(S_T{}^2 + (S_T/_2)^2)} - d_o} *$ free flow velocity [14]

$U_{max} = \frac{0.04/_2}{\sqrt{(0.04)^2 + (0.04/_2)^2)} - 0.01} * 2.5305 = 1.457\ m/s.$

$Re_a = \frac{U_{max} * d_o}{\nu_f} = \frac{1.457 * 0.01}{1.5942 * 10^{-5}} = 914$

50<914<1000

This is in the laminar regime

Since $S_T / S_L = 40/40 = 1 < 2$

For staggered bank with $S_T / S_L < 2$

$Nu_a = 0.9 * Re_a{}^{0.4} * Pr^{0.36} * (\frac{pr}{pr_s})^{0.25}$ Appendix (7).

$Nu_D = 0.9 * (908.29)^{0.4} * (0.7122)^{0.36} * (\frac{0.7122}{0.71})^{0.25} = 12.18$

$h_a = \frac{Nu_D * k_a}{d_o} = \frac{12.18*0.026352}{0.010} = 32.11\ w/m^2k$.

Fouling factor of air

$R_{f,a}$ =0.0004. From table Appendix (10)

$a_i = \pi * d_i * L = \pi * 0.008 * 7 = 0.1759\ m^2$

$a_o = \pi * d_o * L = \pi * 0.010 * 7 = 0.2199\ m^2$.

$$R_T = \frac{1}{h_i * a_i} + R_{wall} + \frac{1}{h_o * a_o}$$

$$\frac{1}{U_o * a_o} = \frac{1}{h_i * a_i} + R_{wall} + \frac{1}{h_o * a_o} + \frac{R_{f,i}}{a_i} + \frac{R_{f,o}}{a_o}$$

$$= \frac{1}{44378.7193 * 0.1759} + 0 + \frac{1}{32.034 * 0.2199} + \frac{0.0001}{0.1759} + \frac{0.0004}{0.2199}$$

$U_o = 241.94\ W/m^2k$.

$$A_o = \frac{Q}{U_o * LMTD * F} = \frac{4497.262 * 1000}{241.94 * 16.979 * 0.7844} = 1395.65\ m^2$$

$A_o = N_{tubes} * \pi * d_o * l$

$N_{tubes} = \frac{A_o}{\pi * d_o * l} = \frac{1395.65}{\pi * 0.010 * 7} = 6346.4 \approx 6347$ tubes.

4-1-3-5 The Number of cooling stages

$$Nst = \frac{N_{tubes}}{N_{row}} = \frac{6347}{175} = 36.27 \text{ stages} \approx 37 \text{ stages.}$$

4-1-4 Heat Exchanger Area

$A_o = 1395.65\ m^2$.

4-1-5 the Chiller System Selection

From performance Tables Appendix (8)

At LWT= 44 °F(6.67°C), T.CAP = Q (kW)/3.5=4497.262/3.5=1283 Ton.

The chilled water flow rate (WFR) $= 771.89\,\frac{m^3}{hr} = 2829.86\,\frac{gallon}{min}$.

Make two selection first selections based on nominal temperature, second selection based on actual temperature.

Table 4.3 chiller system Model PSC 460

Ambient Temperature (°F)	T.CAP$_s$ (Ton)	WFR (GPM)	PI (kW)	WPD (psi)
95 (35°C)	427.9	1022.9	477.9	7.4
115 (45°C)	371.4	887.9	564.8	5.7

$$\text{Number of Chillers} = {}^{T.CAP}/_{T.CAP_s} = {}^{1283}/_{427.9} = 2.998\text{chillers} \approx 3 \text{ chillers.}$$

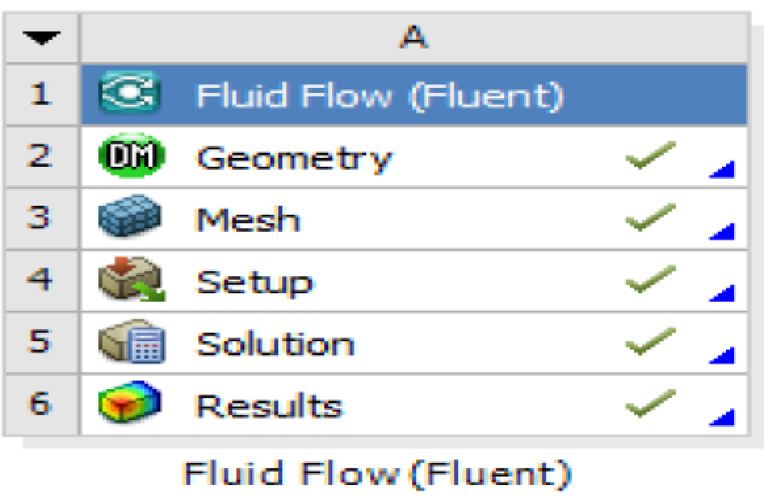
Power input = 3*564.8=1694.4 KW.

4-2 Simulation:

4-2-1 Introduction

Ansys is American computer-aided engineering software, Ansys publishes engineering across arrange of disciplines including finite element analysis, structural analysis, computational fluid dynamics, explicit and implicit method and heat transfer.

There are main five steps in Ansys :



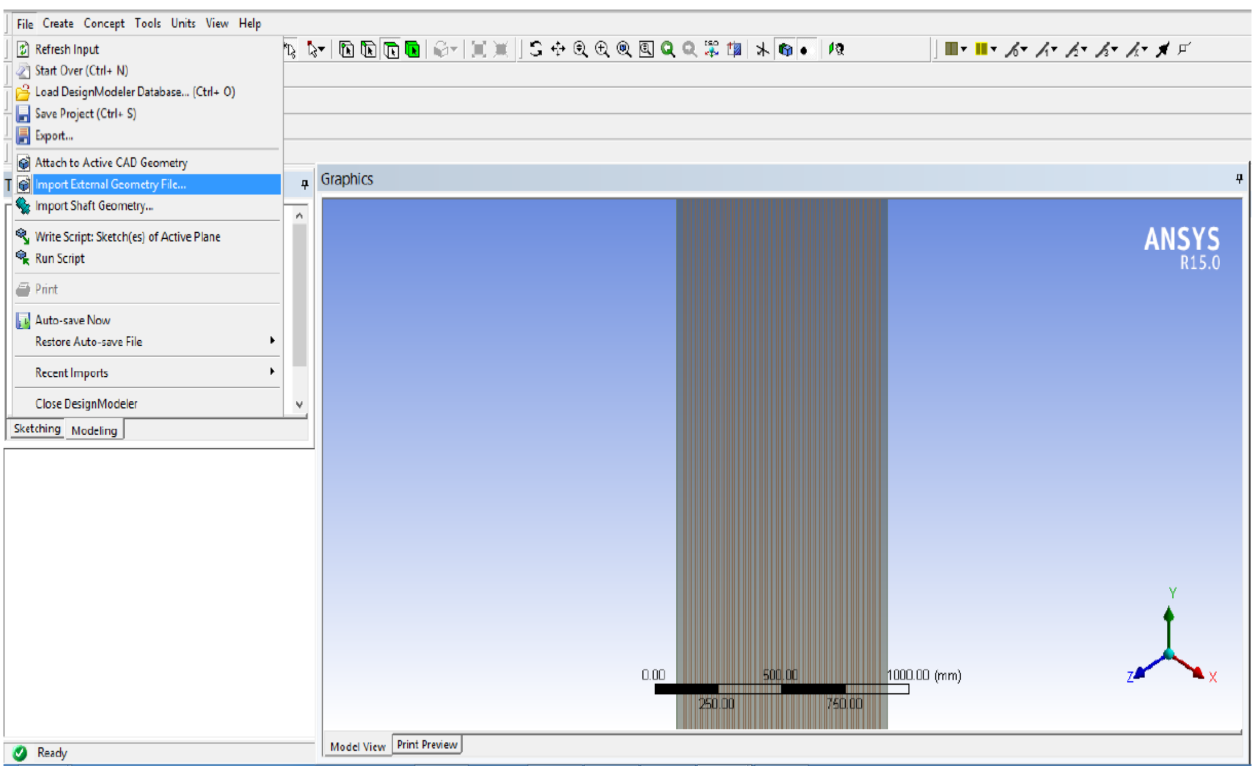
4-2 -2Geometry

Heat exchange drawn by using solid work software .the following table contains the data used in the drawing heat exchange

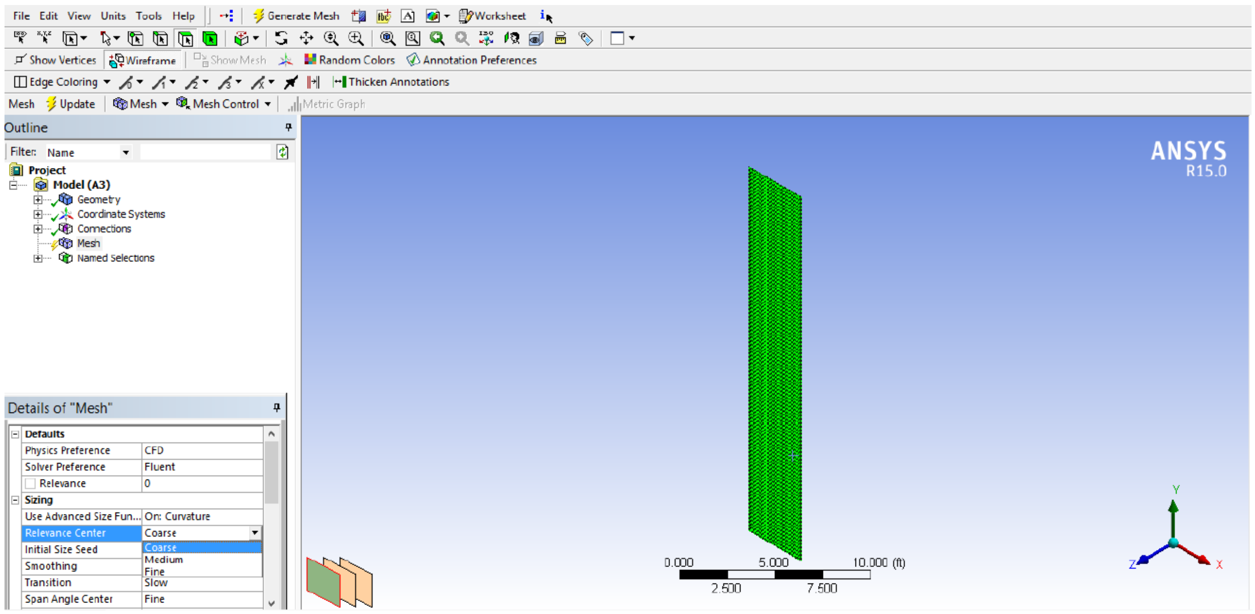
Table 4.4 Dimensions of single tube of heat exchange

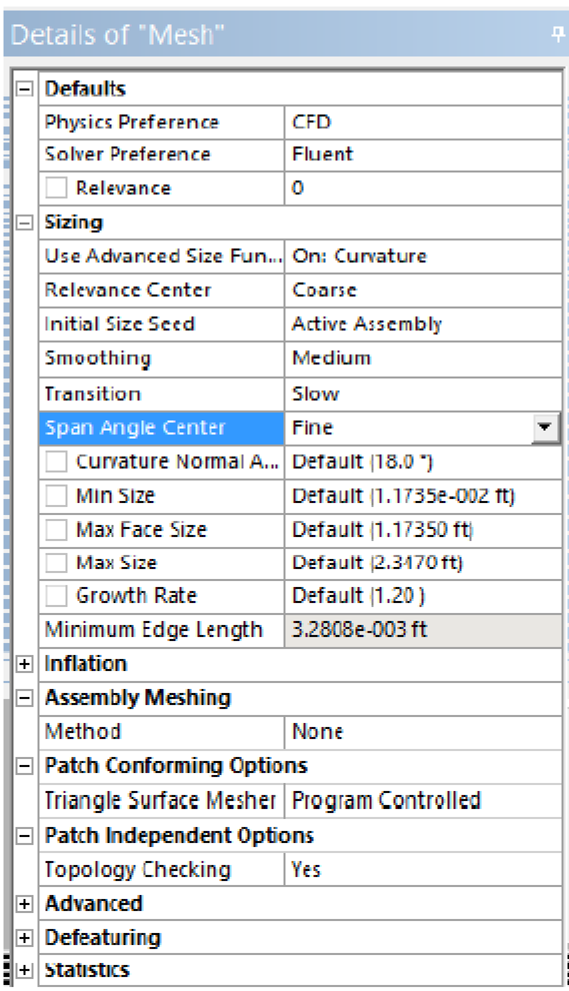
Dimensions	The value
d_i(mm)	8
$d_o(mm)$	10
L(m)	7
$N_{st}(stages)$	37

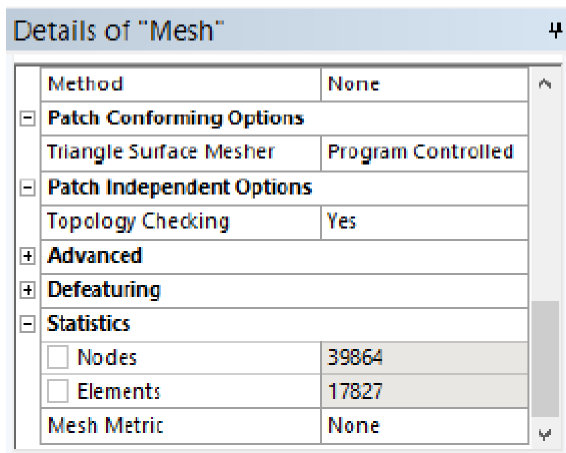
Import external geometry file from solid work software to the Ansys software.



4-2-3 Mesh


File Edit View Units Tools Help
Generate Mesh
Worksheet
Show Vertices
Wireframe
Show Mesh
Random Colors
Annotation Preferences
Edge Coloring
Thicken Annotations
Mesh
Update
Mesh
Mesh Control
Metric Graph
Outline
Filter: Name
Project
Model (A3)
Geometry
Coordinate Systems
Connections
Mesh
Named Selections
Details of "Mesh"
ANSYS
R15.0
0.000
5.000
10.000 (ft)
2.500
7.500


Details of "Mesh"
Defaults
Physics Preference CFD
Solver Preference Fluent
Relevance 0
Sizing
Use Advanced Size Fun... On: Curvature
Relevance Center Coarse
Initial Size Seed Active Assembly
Smoothing Medium
Transition Slow
Span Angle Center Fine
Curvature Normal A... Default (18.0 °)
Min Size Default (1.1735e-002 ft)
Max Face Size Default (1.17350 ft)
Max Size Default (2.3470 ft)
Growth Rate Default (1.20)
Minimum Edge Length 3.2808e-003 ft
Inflation
Assembly Meshing
Method None
Patch Conforming Options
Triangle Surface Mesher Program Controlled
Patch Independent Options
Topology Checking Yes
Advanced
Defeaturing
Statistics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Patch Conforming Options
Triangle Surface Mesher Program Controlled
Patch Independent Options
Topology Checking Yes
Advanced
Defeaturing
Statistics
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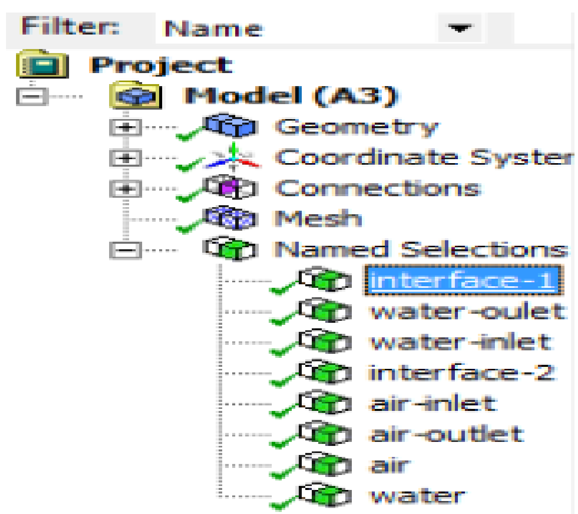
Elements 17827
Mesh Metric None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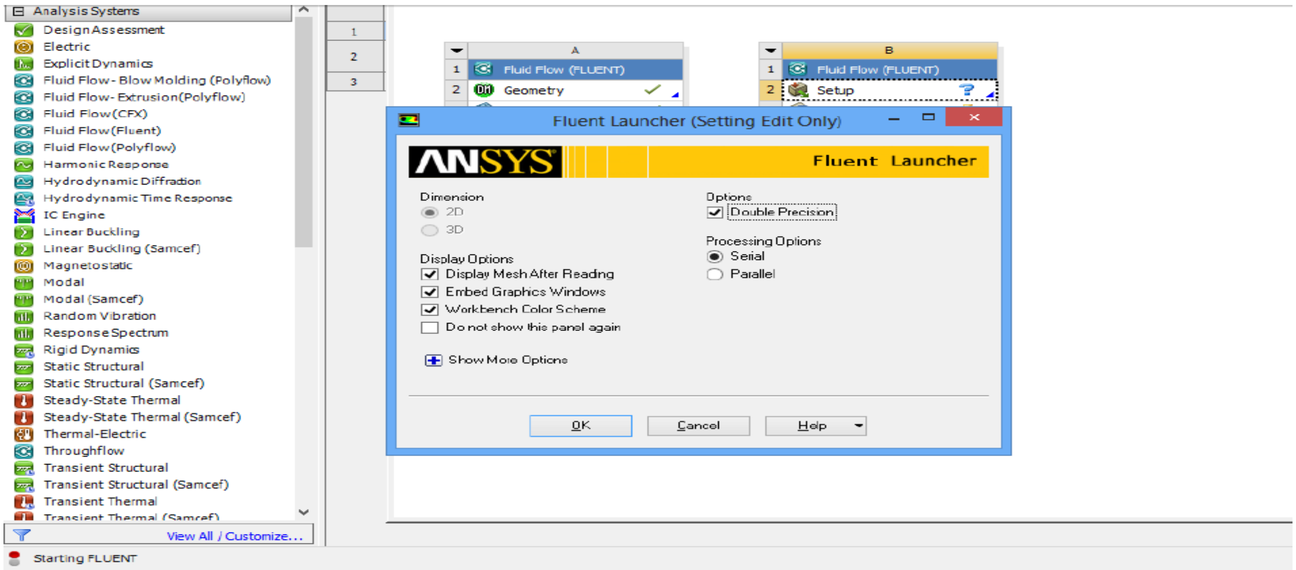
Model (A3)
Geometry
Connections
Mesh
Named Selections
interface-1
water-oulet
water-inlet
interface-2
air-inlet
air-outlet
air
water

4-2-4 Setup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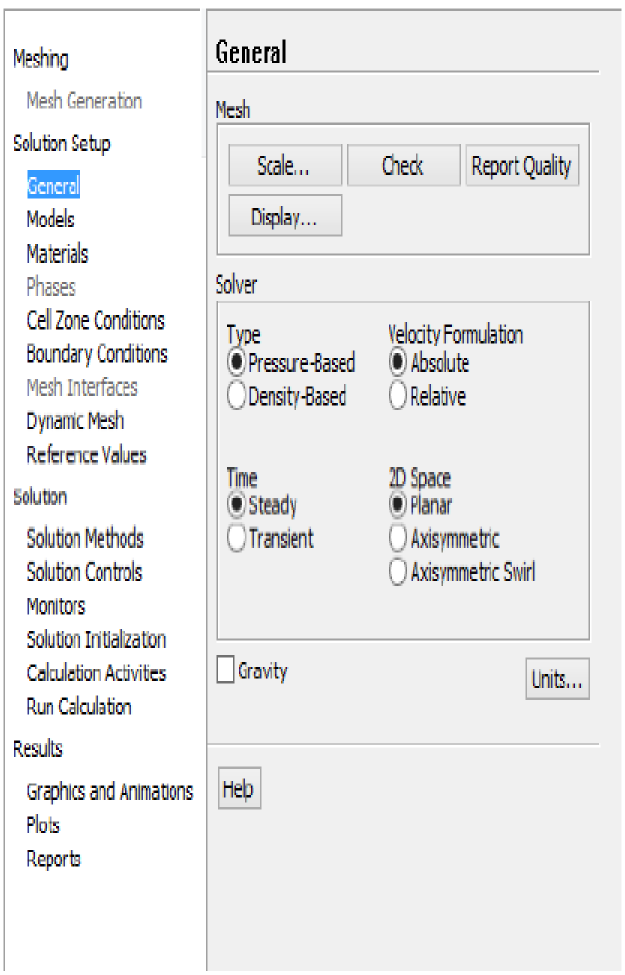
Design Assessment
Electric
Explicit Dynamics
Fluid Flow - Blow Molding (Polyflow)
Fluid Flow - Extrusion(Polyflow)
Fluid Flow(CFX)
Fluid Flow(Fluent)
Fluid Flow(Polyflow)
Harmonic Response
Hydrodynamic Diffraction
Hydrodynamic Time Response
IC Engine
Linear Buckling
Linear Buckling (Samcef)
Magnetostatic
Modal
Modal (Samcef)
Random Vibration
Response Spectrum
Rigid Dynamics
Static Structural
Static Structural (Samcef)
Steady-State Thermal
Steady-State Thermal (Samcef)
Thermal-Electric
Throughflow
Transient Structural
Transient Structural (Samcef)
Transient Thermal
View All / Customize...
Starting FLUENT
Fluid Flow (FLUENT)
Geometry
Setup
Fluent Launcher (Setting Edit Only)
ANSYS
Fluent Launcher
Dimension
2D
3D
Options
Double Precision
Processing Options
Serial
Parallel
Display Options
Display Mesh After Reading
Embed Graphics Windows
Workbench Color Scheme
Do not show this panel again
Show More Options
OK
Cancel
Help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Solution Setup
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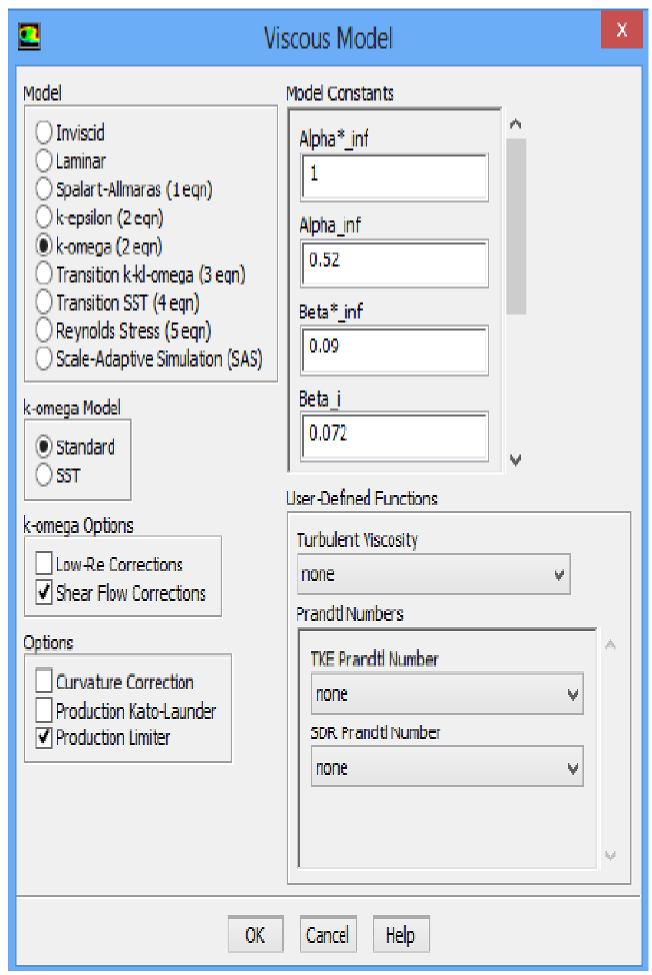
Materials
Phases
Cell Zone Conditions
Boundary Conditions
Mesh Interfaces
Dynamic Mesh
Reference Values
Solution
Solution Methods
Solution Controls
Monitors
Solution Initialization
Calculation Activities
Run Calculation
Results
Graphics and Animations
Plots
Reports
General
Mesh
Scale...
Check
Report Quality
Display...
Solver
Type
Pressure-Based
Density-Based
Velocity Formulation
Absolute
Relative
Time
Steady
Transient
2D Space
Planar
Axisymmetric
Axisymmetric Swirl
Gravity
Units...
Help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Model
Inviscid
Laminar
Spalart-Allmaras (1 eqn)
k-epsilon (2 eqn)
k-omega (2 eqn)
Transition k-kl-omega (3 eqn)
Transition SST (4 eqn)
Reynolds Stress (5 eqn)
Scale-Adaptive Simulation (SAS)
k-omega Model
Standard
SST
k-omega Options
Low-Re Corrections
Shear Flow Corrections
Options
Curvature Correction
Production Kato-Launder
Production Limiter
Model Constants
Alpha*_inf
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Alpha_inf
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Beta*_inf
0.09
Beta_i
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Turbulent Viscosity
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Prandtl Numbers
TKE Prandtl Number
none
SDR Prandtl Number
none
OK
Cancel
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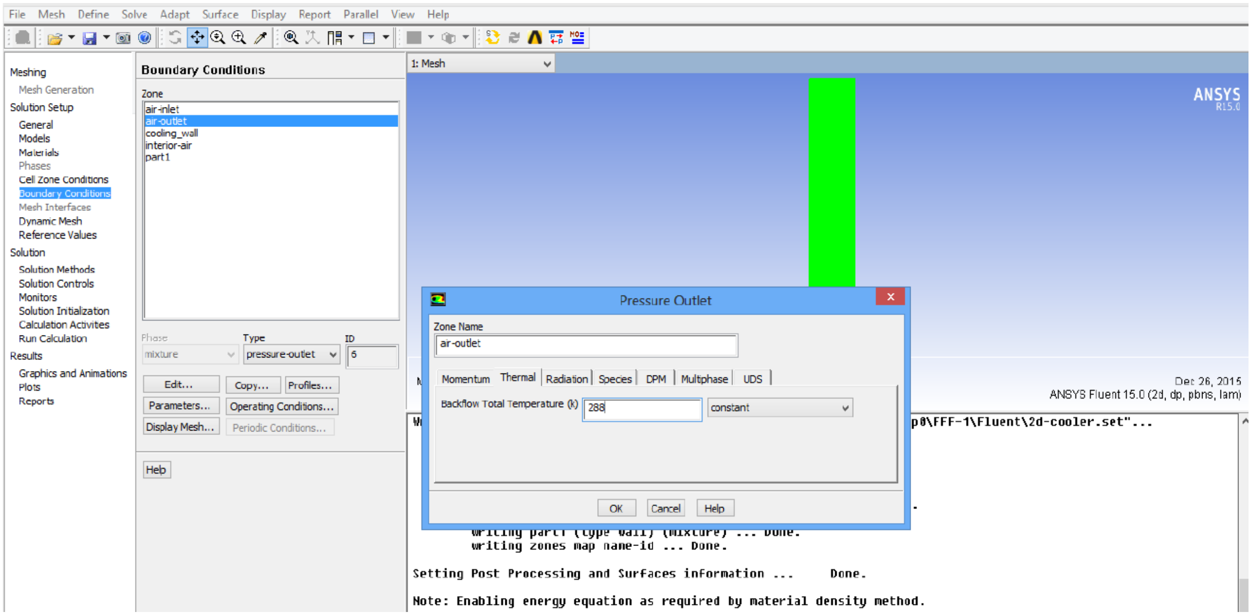
File Mesh Define Solve Adapt Surface Display Report Parallel View Help
Meshing
Mesh Generation
Solution Setup
General
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Materials
Phases
Cell Zone Conditions
Boundary Conditions
Mesh Interfaces
Dynamic Mesh
Reference Values
Solution
Solution Methods
Solution Controls
Monitors
Solution Initialization
Calculation Activities
Run Calculation
Results
Graphics and Animations
Plots
Reports
Boundary Conditions
Zone
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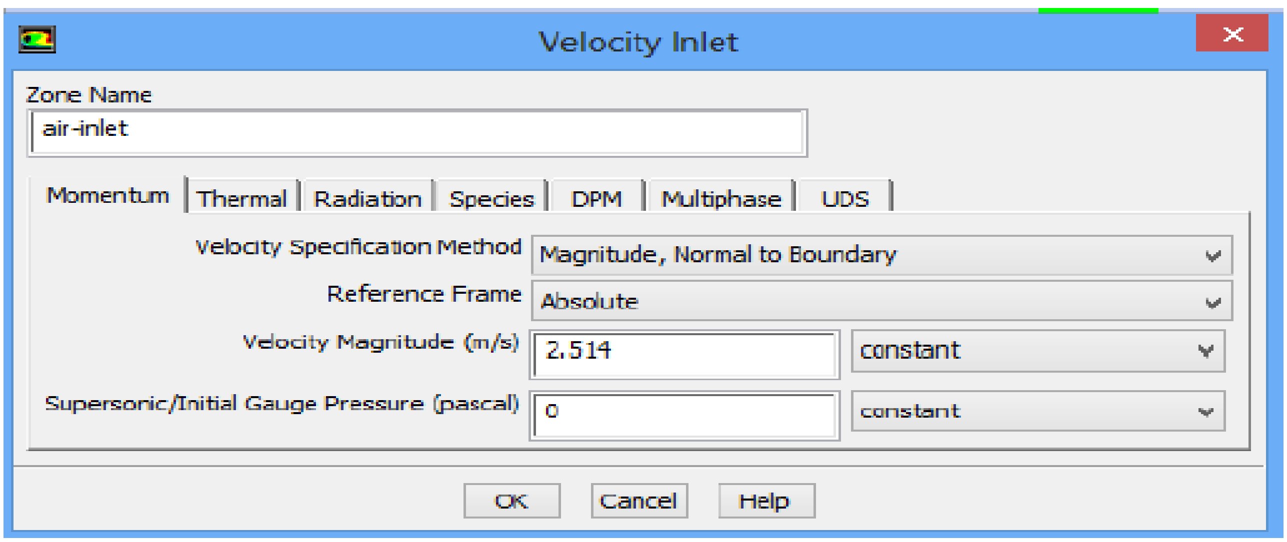
air-outlet
cooling_wall
interior-air
part1
Phase
Type
ID
mixture
pressure-outlet
6
Edit...
Copy...
Profiles...
Parameters...
Operating Conditions...
Display Mesh...
Periodic Conditions...
Help
1: Mesh
ANSYS
R15.0
Pressure Outlet
Zone Name
air-outlet
Momentum
Thermal
Radiation
Species
DPM
Multiphase
UDS
Backflow Total Temperature (k)
288
constant
OK
Cancel
Help
Dec 26, 2015
ANSYS Fluent 15.0 (2d, dp, pbns, lam)
p0\FFF-1\Fluent\2d-cooler.set"...
writing zones map name-id ... Done.
Setting Post Processing and Surfaces information ... Done.
Note: Enabling energy equation as required by material density method.


Velocity Inlet
Zone Name
air-inlet
Momentum
Thermal
Radiation
Species
DPM
Multiphase
UDS
Velocity Specification Method
Magnitude, Normal to Boundary
Reference Frame
Absolute
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Supersonic/Initial Gauge Pressure (pascal)
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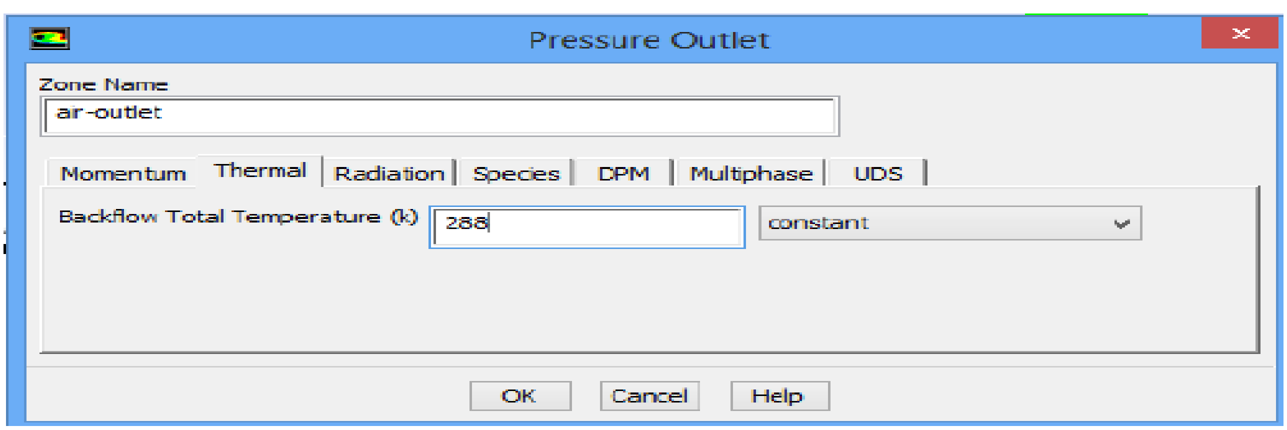
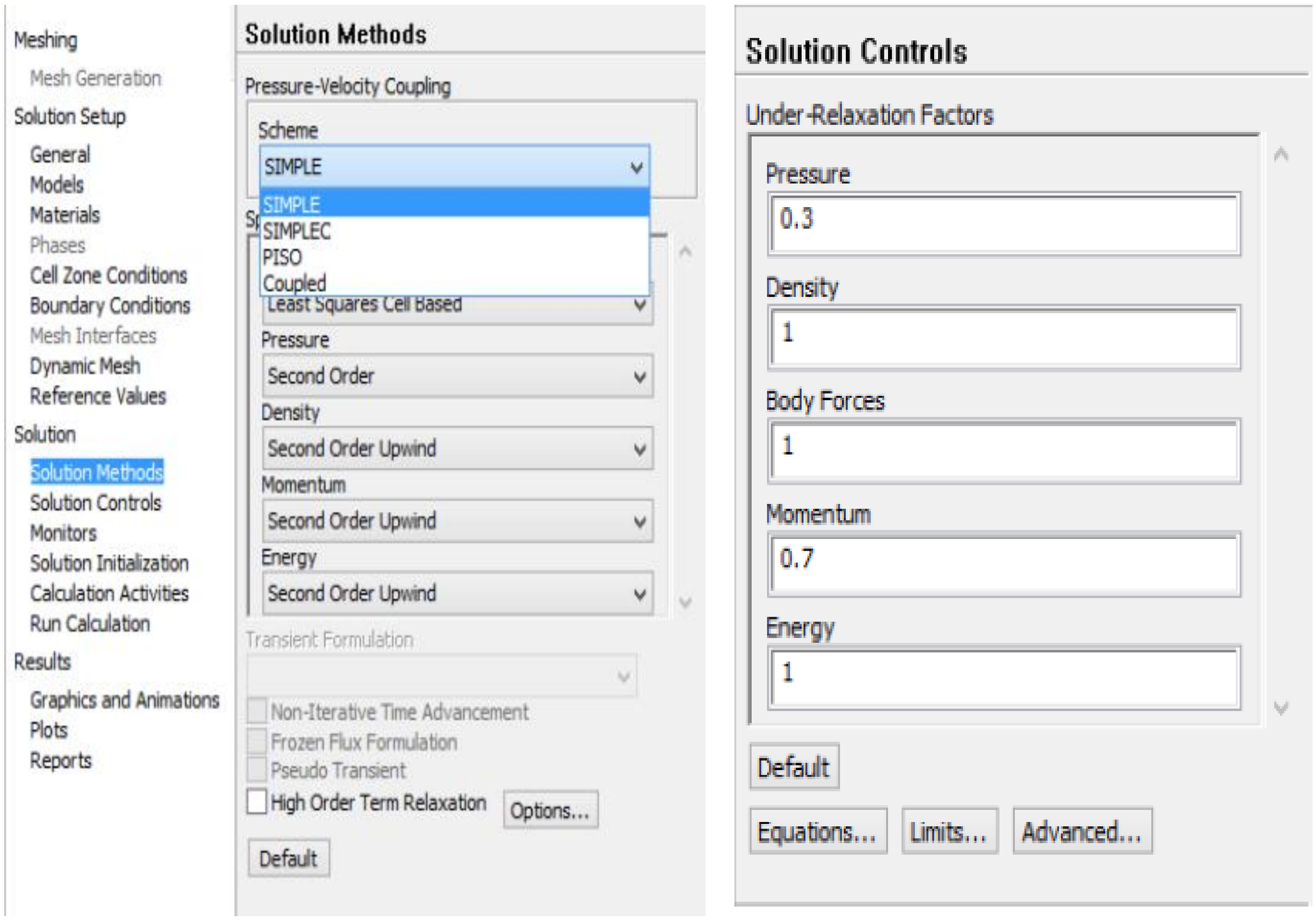
constant
OK
Cancel
Help


Pressure Outlet
Zone Name
air-outlet
Momentum
Thermal
Radiation
Species
DPM
Multiphase
UDS
Backflow Total Temperature (k)
288
constant
OK
Cancel
Help

4-2-5 Solution



4-2-6 Result

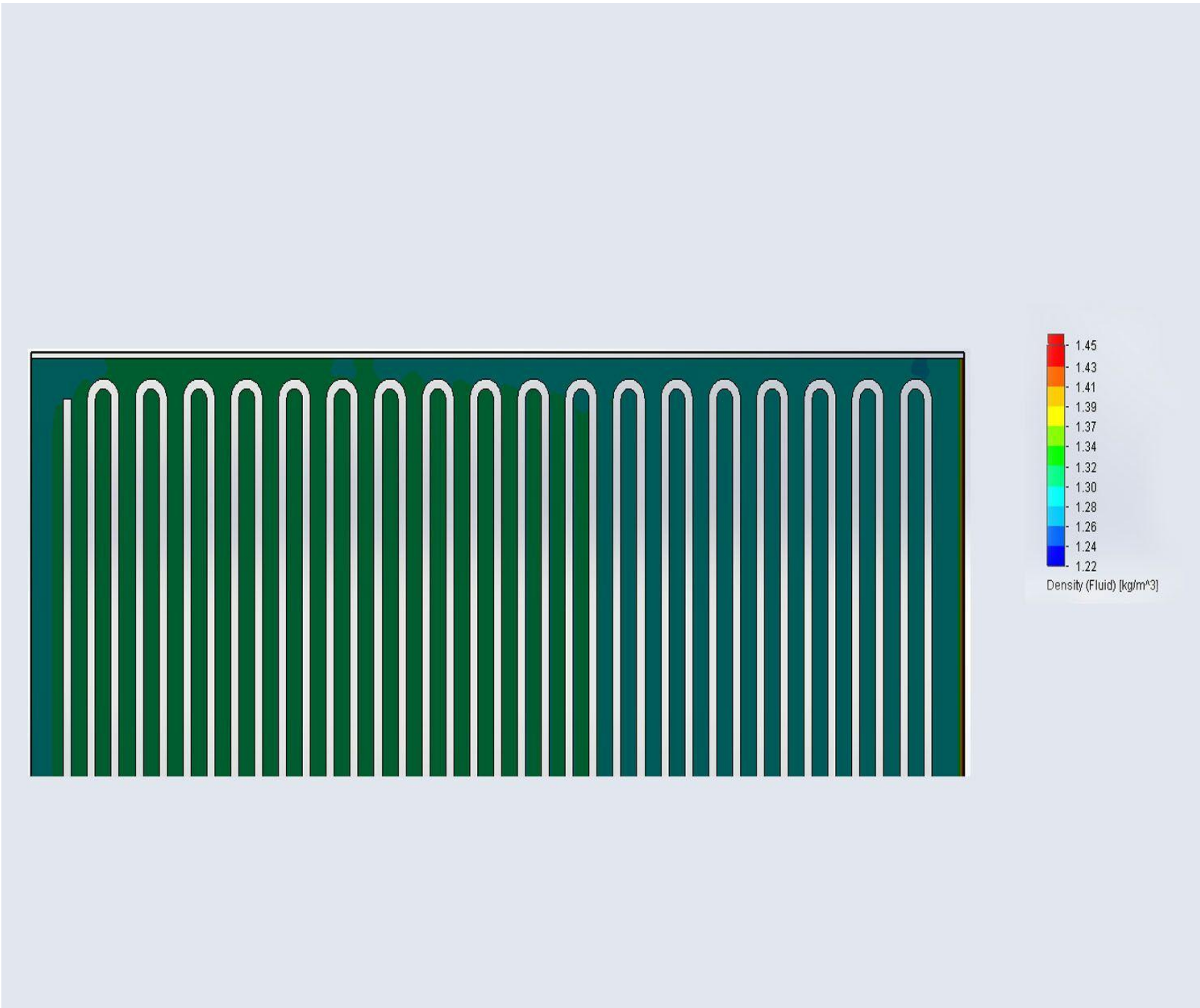


Figure 4-2 Air density distributions in heat exchanger.

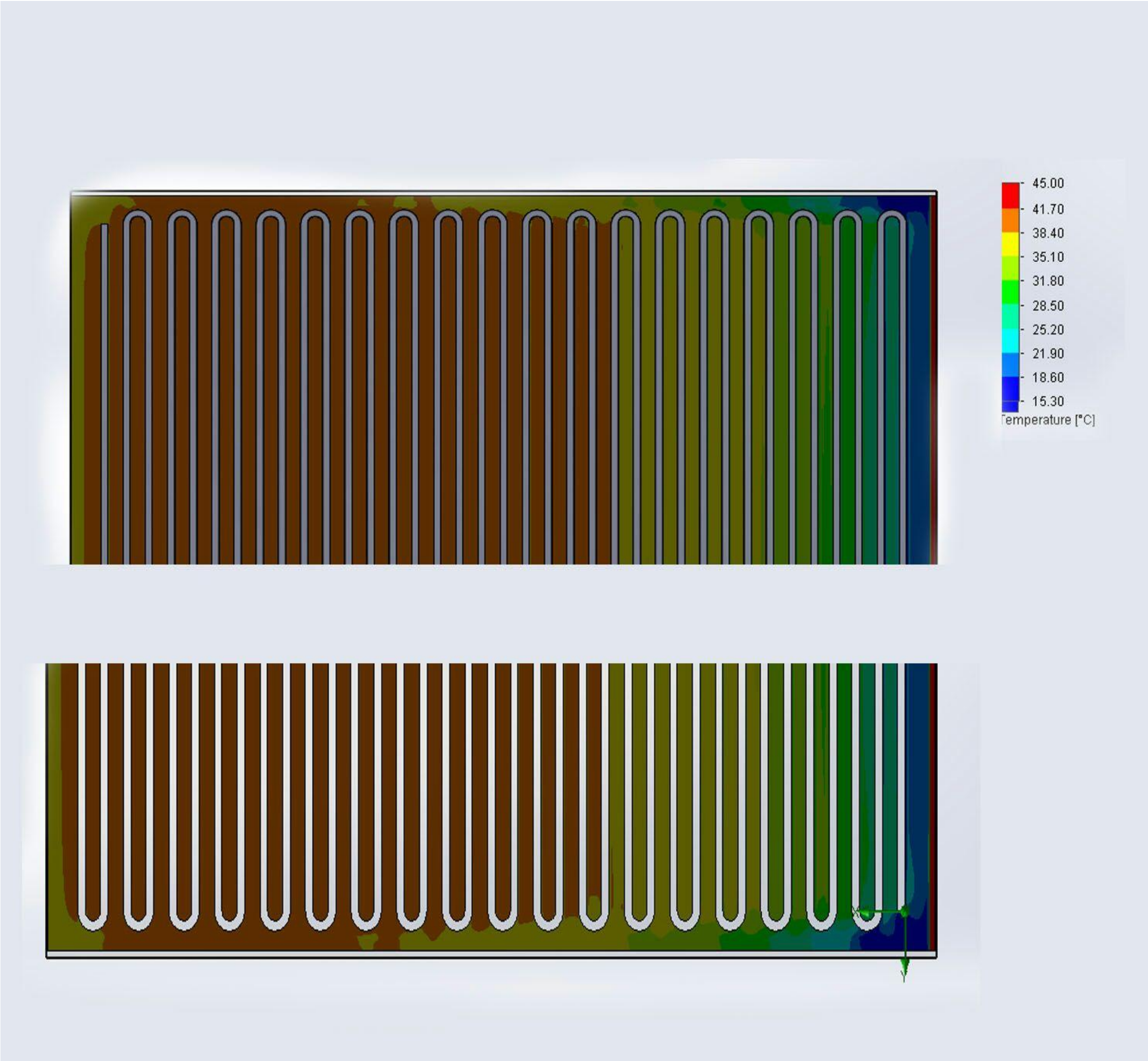


Figure 4-3 Distribution of air Temperature in heat exchanger.

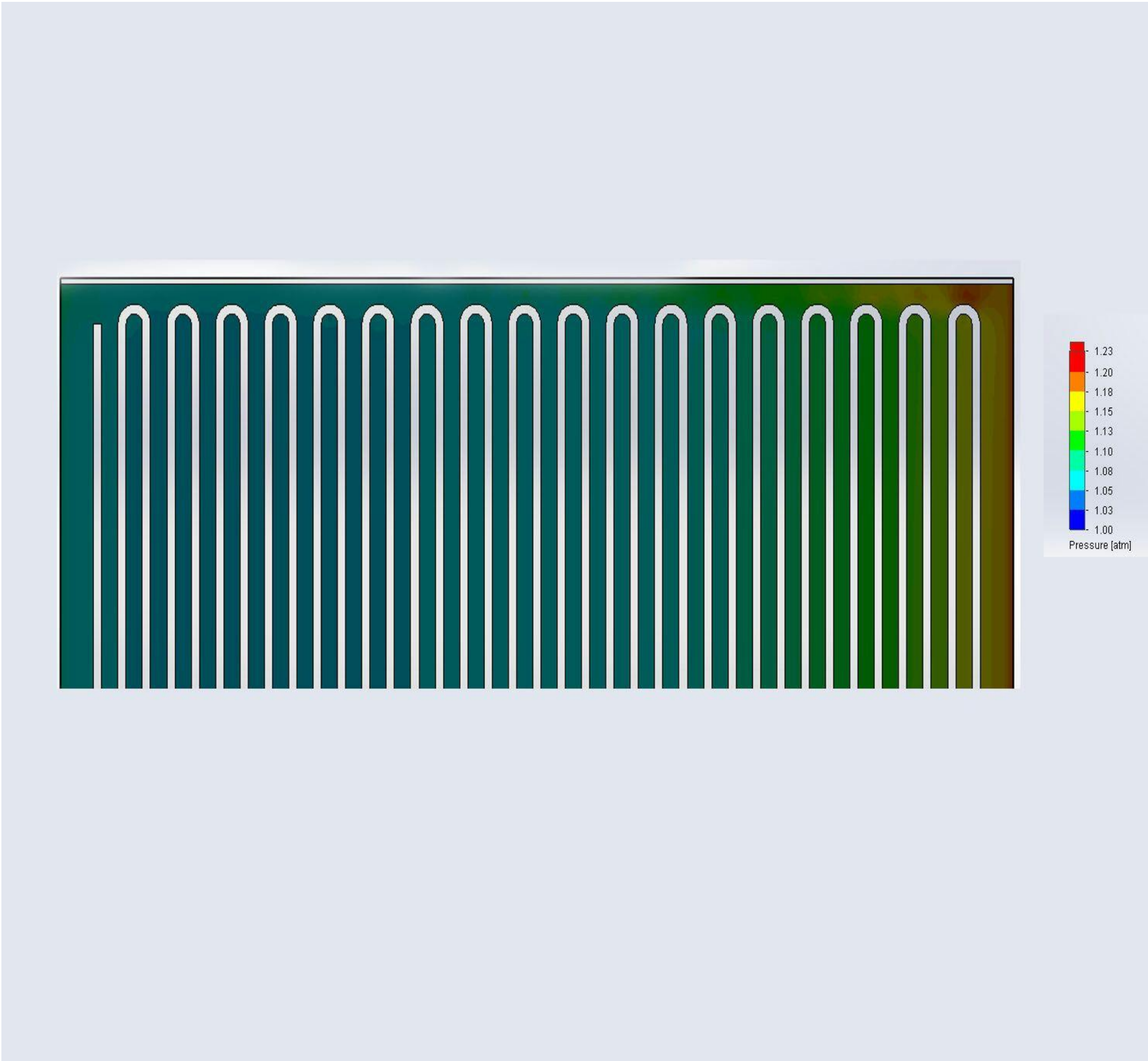


Figure 4-4 Air pressure distributions in heat exchanger.

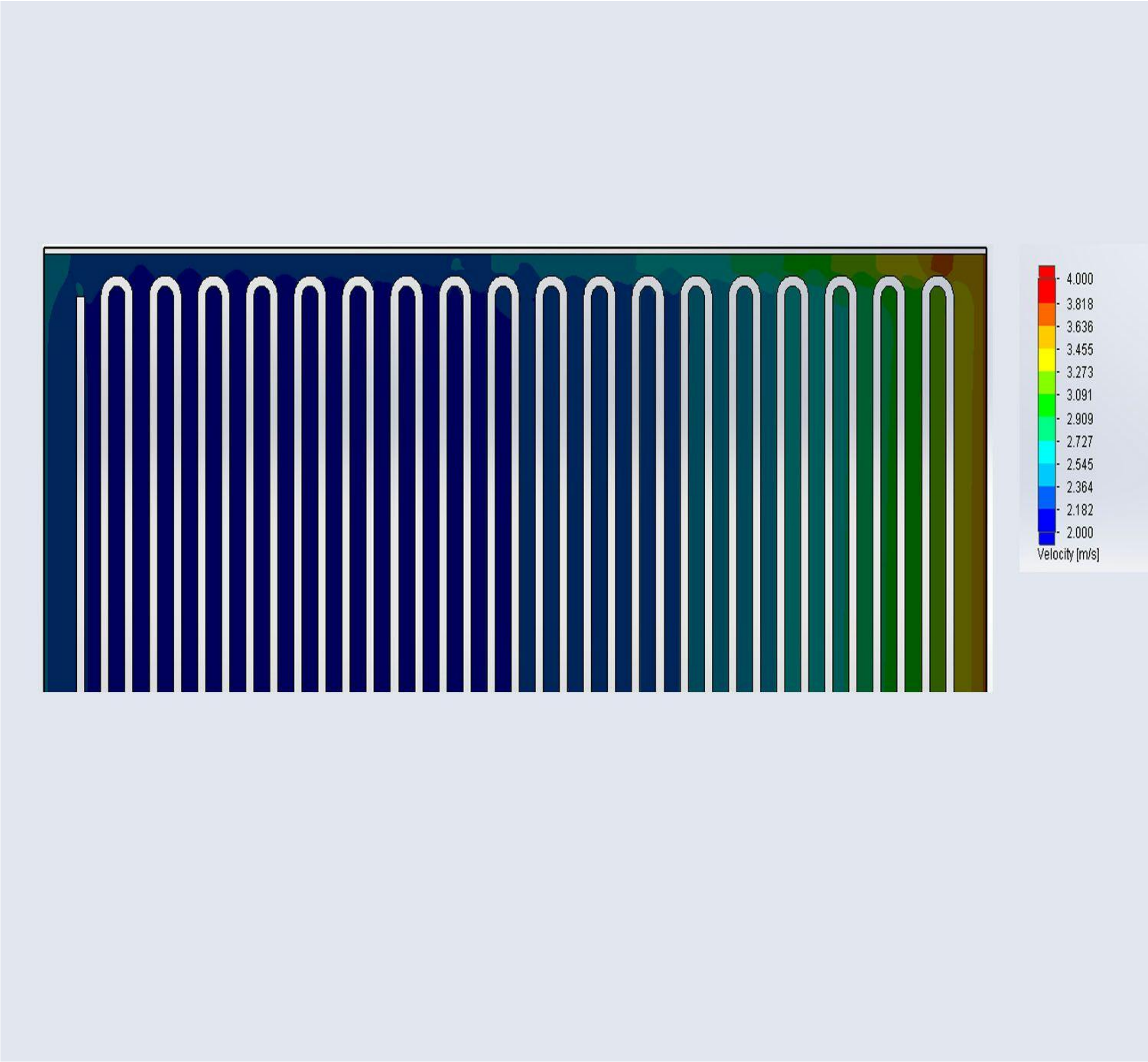


Figure 4-5 Distribution of air velocity in heat exchanger.

4-3 Discussion

The result compared before and after using chilling system, the comparison at power generated, Efficiency and heat rate. table 4.5 and table 4.6 show the effect on the gas turbine, power generated, efficiency and heat rate Before installing the system and after installing chilling cooler as expected result to the unit design .Appendix(1).

Table 4.5 Power generated, efficiency and heat rate at gas turbine before and after install evaporator Unit.

Before installing Evaporator system				**After install Evaporator system**				**Saved Heat rate** kJ/kWh
Unit	Power generated at 5 July 2008	Efficiency %	heat rate kJ/kWh	Unit	Power generated at 5 May 2010	Efficiency %	heat rate kJ/kWh	
Unit 1	30	30	11909.0	Unit 1	34	31	11463.0	446
Unit 2	30	29.8	12048.7	Unit 2	34	31	11463.3	585.4
Unit 3	29	30	11886.7	Unit 3	32.5	31	11422.3	464.4
Unit 4	27.5	29	12353.7	Unit 4	31	31	11562.2	791.5
Unit 5	28	28	12772.1	Unit 5	31	29.4	12244.0	528.1
Unit 6	28	27	13287.0	Unit 6	31.5	28.5	12636.4	650.6
Unit 7	28	28.5	12630.8	Unit 7	31	29	12412.4	218.4
Unit 8	31	28	12767.0	Unit 8	35	29	12388.5	378.5
Average								507.8

Table 4.6 Power generated, efficiency and heat rate at gas turbine before and after install chilling Unit.

Before installing chilling system				**After install chilling system**				**Saved Heat rate** kJ/kWh
Unit	power generated at 5 July 2008	Efficiency %	heat rate kJ/kWh	Unit	Power designed	Efficiency %	heat rate kJ/kWh	
Unit 1	30	30	11909.0	Unit 1	42	32	11225.7	683.3
Unit 2	30	29.8	12048.7	Unit 2	42	32	11225.7	823
Unit 3	29	30	11886.7	Unit 3	42	32	11225.7	661
Unit 4	27.5	29	12353.7	Unit 4	42	32	11225.7	1128
Unit 5	28	28	12772.1	Unit 5	42	32	11225.7	1546.4
Unit 6	28	27	13287.0	Unit 6	42	32	11225.7	2061.3
Unit 7	28	28.5	12630.8	Unit 7	42	32	11225.7	1405.1
Unit 8	31	28	12767.0	Unit 8	42	32	11225.7	1541.3
Average								1231.17

From above table 4.5After install evaporator system the average heat rate saved is 507.8kJ/kWh, therefore the fuel energy can be saved is 507.8 kJ per each kWh of power generation, table 4.6After install chilling system the average heat rate saved is 1231.17 kJ/kWh therefore the fuel energy can be saved is 1231.17kJ per each kWh of power generation.

The amount of fuel saved is equal to heat rate per KW divided by the Lower Heat Value of diesel (42612 kJ/kg) :

Fuel saved after install evaporator system $= \frac{507.8625 \text{ kJ/kWh}}{42612 \text{ kJ/kg}}$ = 0.011918 kg/kWh.

Fuel saved after install chilling system = $\frac{1231.175 \text{ kJ/kWh}}{42612 \text{ kJ/kg}}$ = 0.0288926 kg/kWh.

For example unit 6 at 14 august2015 generated 715000 kWh

Fuel saved from unit6 after Install Evaporator System =715000 kWh ×0.011918 kg/kWh =8.521 ton.

Fuel saved from unit6 after Install chilling System =715000 kWh ×0.0288926 kg/kWh =20.65 ton.

The fuel saved in chilling System is more than fuel saved in evaporator system by 58%

The amount of fuel saved after using chiller system make the project attractive to do additional researches for installation and study the environment impact to area.

Additionally using cooling system at the inlet air of gas turbine increase the exhaust mass flow rate to the heat recovery steam generation (HRSG) Which increase the amount of steam generated and increase the power generated from steam turbine in combined cycle, expected increase is 2 MW of steam turbine .

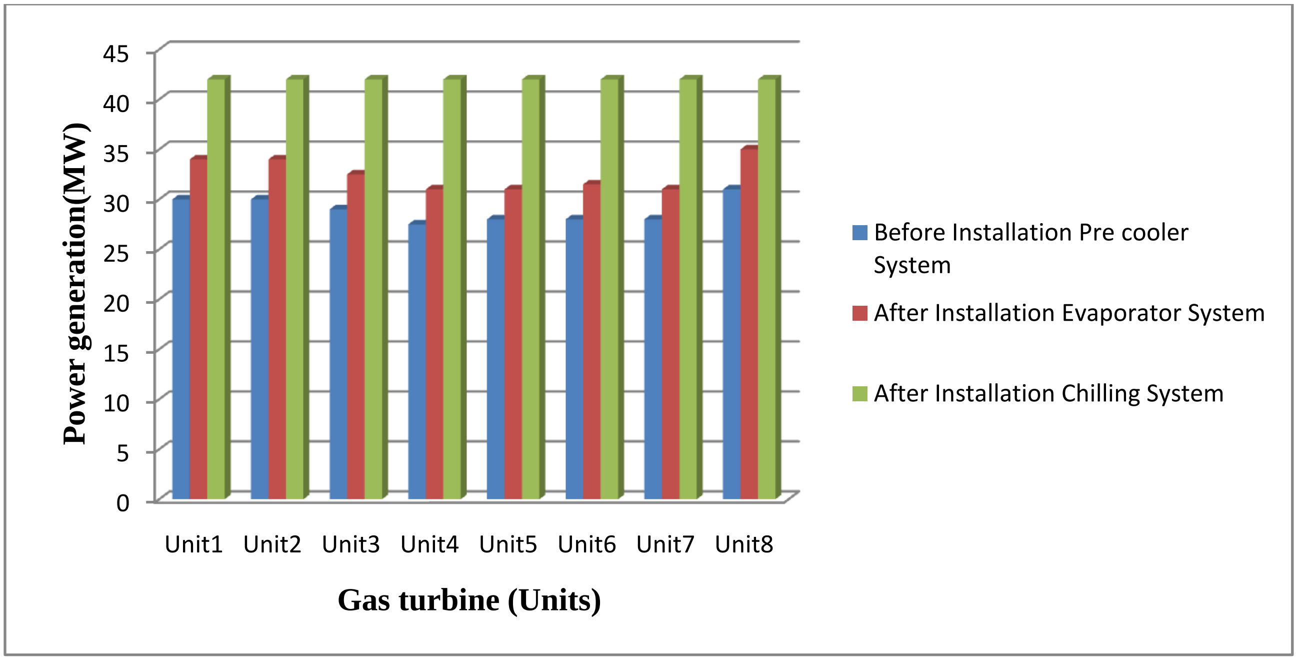


Figure 4-6 the effect of Evaporator cooler and chilling cooler of the gas turbine in power generated

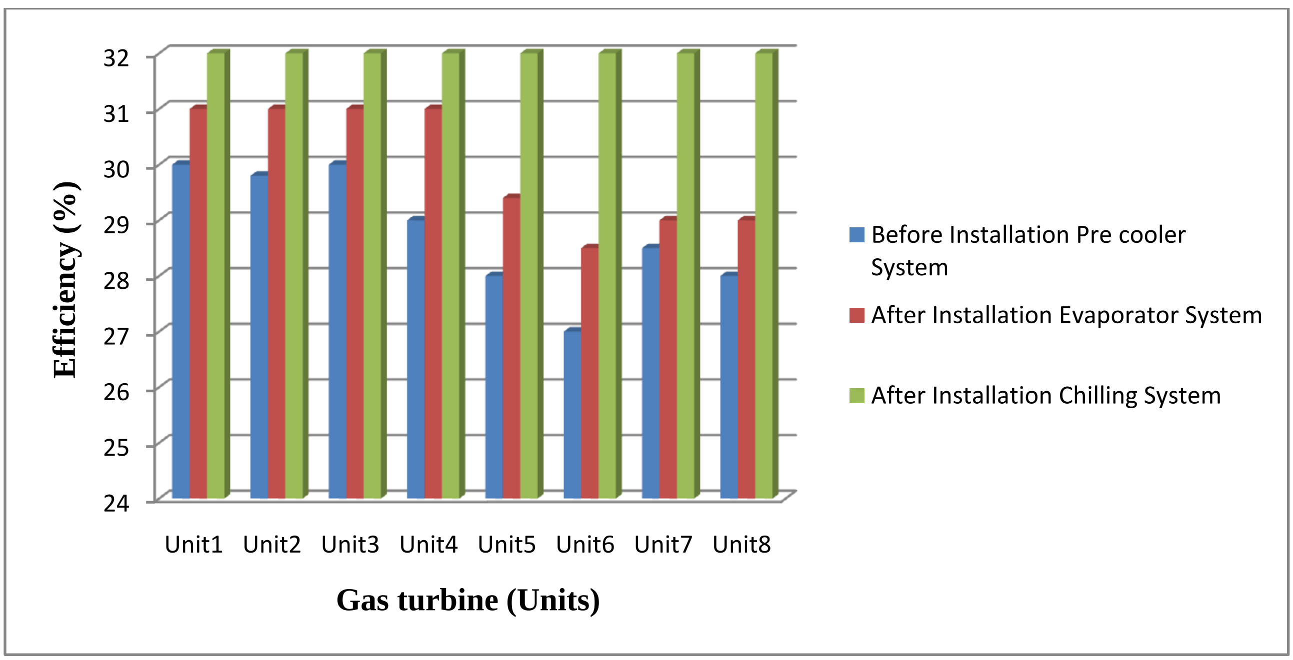


Figure 4-7 the effect of Evaporator cooler and chilling cooler of the Efficiency gas turbine.

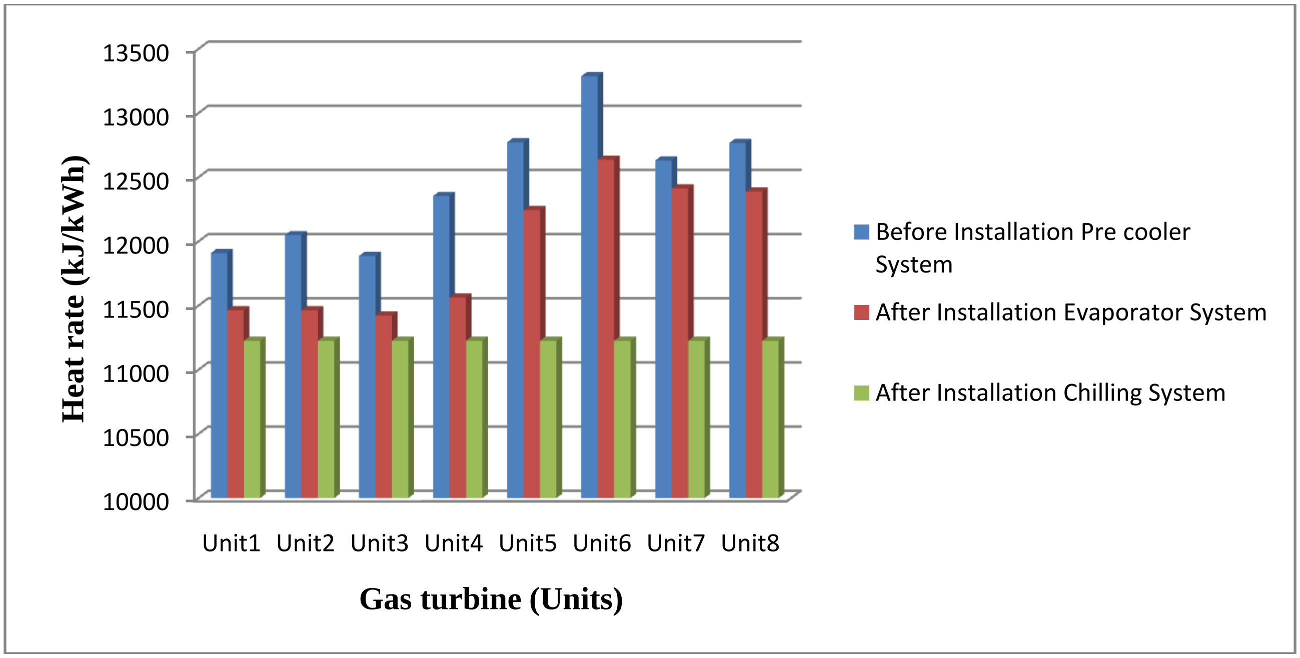


Figure 4-8The effect of using evaporator cooler and chilling cooler in heat rate of the gas turbine

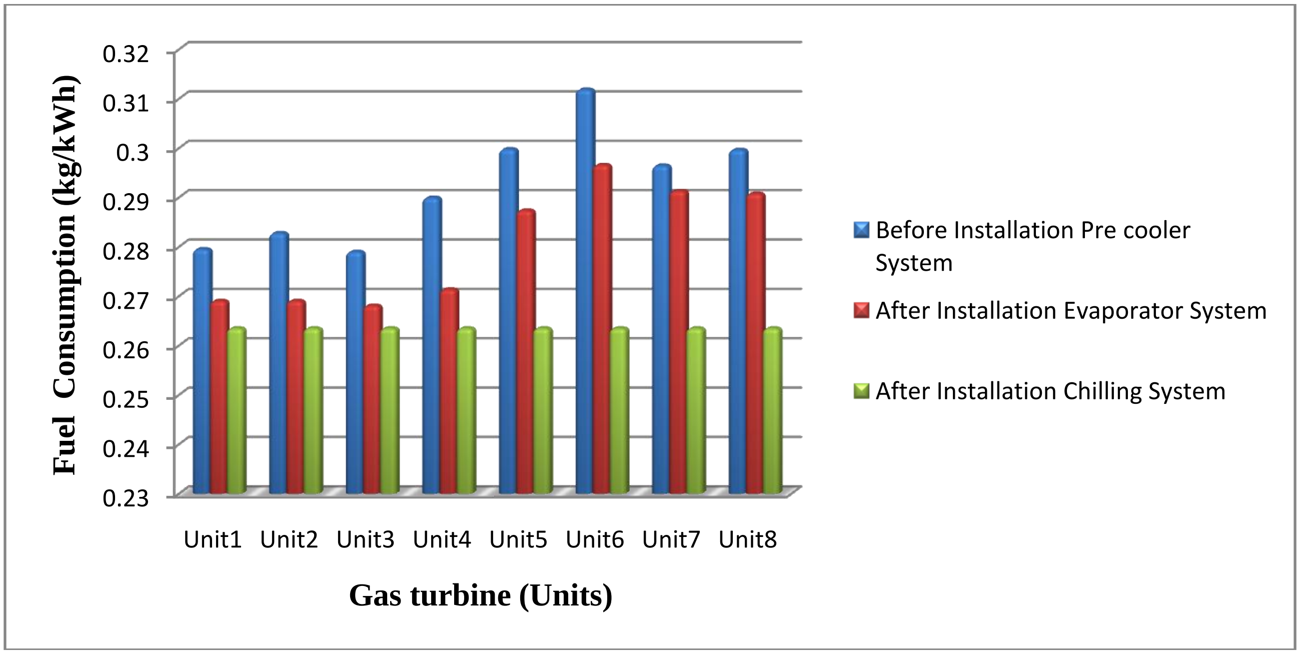


Figure 4-9 Fuel consumption of the gas turbine with Evaporator cooler and chilling cooler.

4-4 Payback period

4-4-1 Evaporator cooler

The system gave a total power increase of 32.5 MW. NEC sells electricity at a rate of 0.1 SG/kWh for residential consumers and at a rate of 0.26 SG/kWh for industry. Assuming full capacity operation at an average rate of 0.23 SG/kWh (0.072 Euro/kWh), the additional megawatts give NEC 7475 SG (2336 Euro) per hour of operation. From this revenue alone, the system could pay back its initial cost of 1,310,000 Euro in 561 hours, or 24 days of full-capacity operation.

The initial cost of one unit is163, 750 Euro (524000SDG) [12]El-Hassan et al.

4-4-2 Chiller cooler

The cost of purchasing and installation single chiller = 2000000 SDG.

The cost of purchasing and installation three chillers=3*2000000=6000000SDG.

The cost of purchasing and installation Heat Exchanger = 2750000 SDG.

Total cost of chiller system =6000000+2750000=8750000SDG.

KWh price =0.17 SDG/ KWh.

The increase in output power after pre cooler per hour=8 MWh.

The price of the increased power output per day=8*1000*24*0.17 =32640SDG/day.

$$\text{The payback period} = \frac{\text{Total cost for chiller system}}{\text{The price of the increased power output per day}}$$

= 8750000/32640 =268.0759 days ≈ 268 days, 1.82 hours.