ENERGY & EXERGY ANALYSIS OF THERMAL POWER PLANT

AT WANAKBORI THERMAL POWER STATION

Guide – Dep. Er. N. B. Raolji (Industrial)
Dr. N. K. Shah (Internal)

Presented By – URVISH CHAUHAN
18MMET02

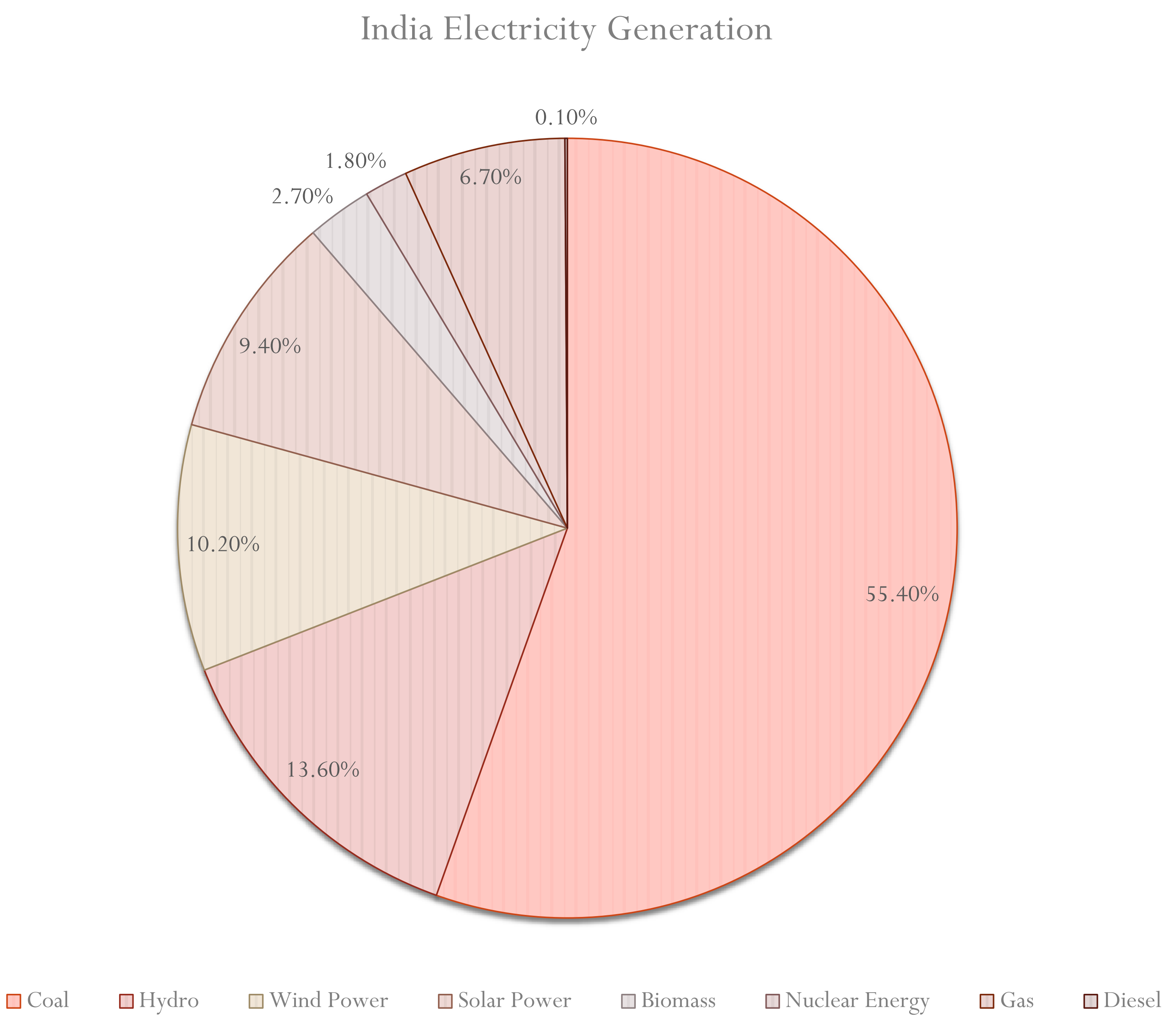
Contents

Introduction

- Energy sector plays very important role developing country's economic development.
- Energy consumption shows the development stages of country and living standards of communities.
- India is third largest energy consumer in world as per energy information administration of India.
- Objective of energy conservation is to reduce energy generation cost.
- Electricity generation capacity 1,362 MW in 1947 to 3,56,100 MW in year 2020.
- Thermal power plant generation capacity 854 MW in 1947 to 2,26,279 in year 2020.

Electricity Installed Capacity of India

- **Coal - 2,05,134.5 MW**
- Hydro - 50,382.38 MW
- Wind - 37,693.75 MW
- Solar - 34,627.82 MW
- Biomass – 10,022.95 MW
- Nuclear – 6,780 MW
- Gas - 24,955.36 MW
- Diesel - 509.71 MW



Motivation

- The rate of power demand increases is extremely high compared with the rate of generation capacity increase.
- To establish new power plant required few years. However, improving performance of present power plant certain demand can be fulfilled with less time period.
- To improve capacity of the plant one needs to determine performance of various components.
- Fore that purpose component wise energy and exergy analysis will help to identify the performance of the power plant.

Energy

- Energy is define as the capacity of a physical system to perform work.

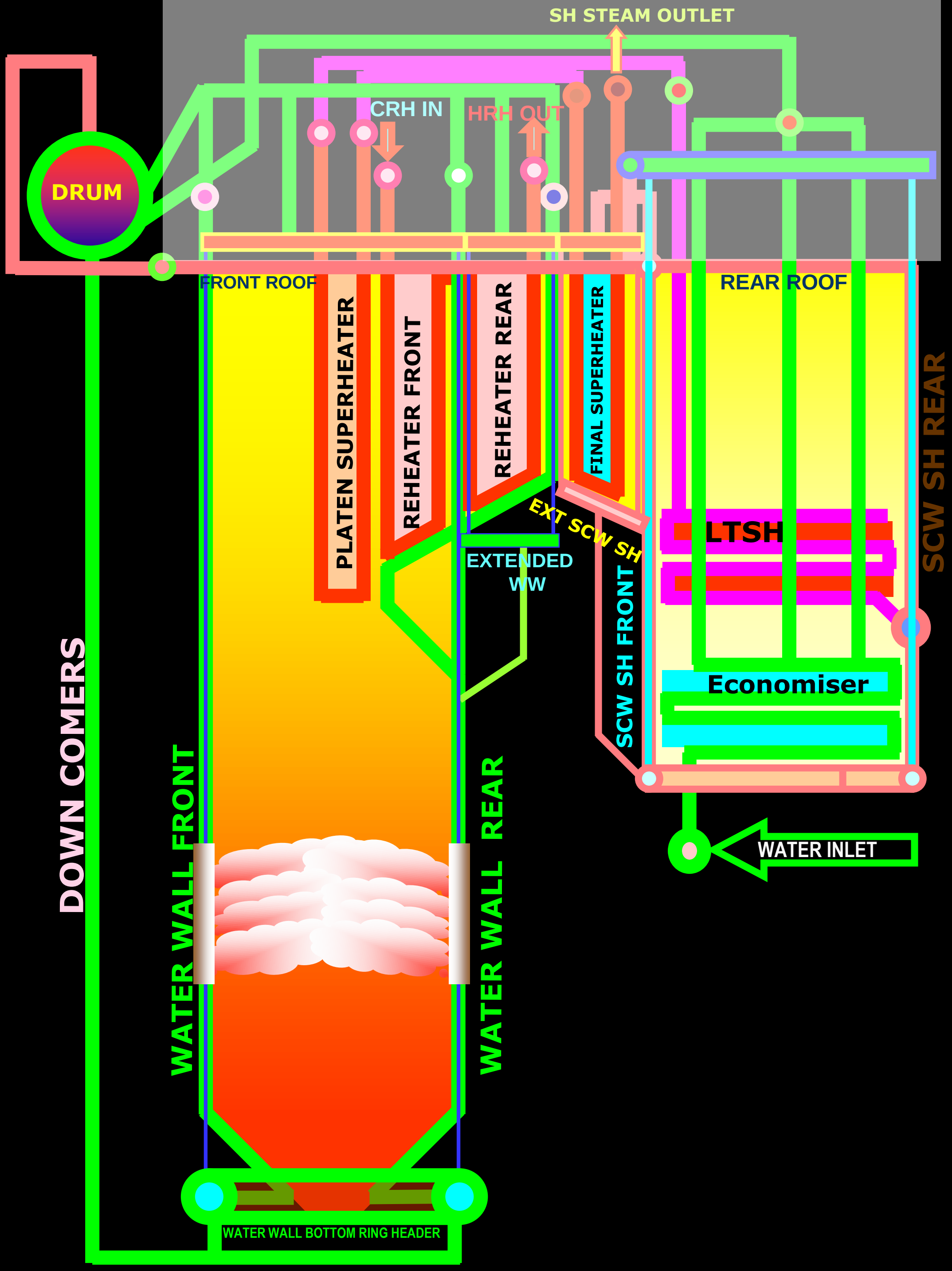
Classification of energy:

1. Primary and Secondary energy
2. Commercial and Non-commercial energy
3. Renewable and Non-Renewable energy

Exergy

- Exergy is define as the maximum useful work possible during a process.
- After system and surroundings reach equilibrium, the exergy is zero.

Classification of exergy : Physical and Chemical



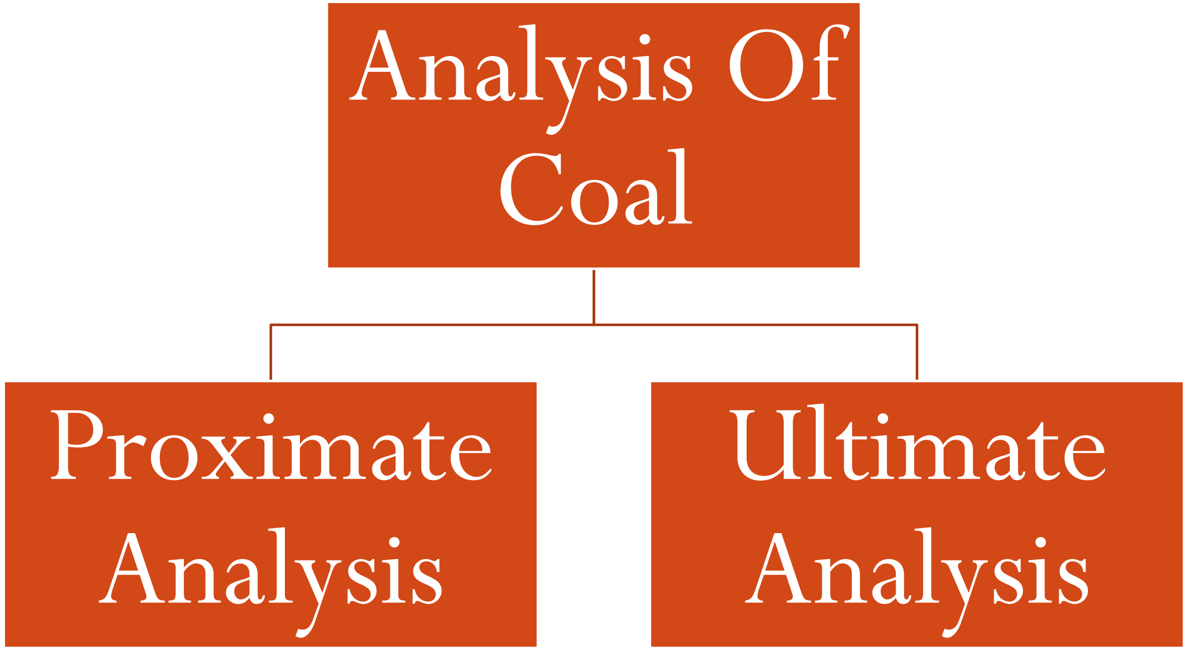
SH STEAM OUTLET
DRUM
CRH IN
HRH OUT
FRONT ROOF
REAR ROOF
PLATEN SUPERHEATER
REHEATER FRONT
REHEATER REAR
FINAL SUPERHEATER
SCW SH REAR
EXT SCW SH
LTSH
EXTENDED
WW
SCW SH FRONT
Economiser
WATER INLET
DOWN COMERS
WATER WALL FRONT
WATER WALL REAR
WATER WALL BOTTOM RING HEADER

Coal use in Wanakbori Thermal Power Plant

- In Wanakbori Thermal Power Plant we use mainly 3 types of coal is used.
  - Indian coal
  - Wash coal
  - Imported coal
- Indian coal: - Bituminous type Indian coal is use at GSECL Wanakbori thermal power plan. Its calorific value is nearby 3200 kCal/kg. some of Indian coal is very good equality Thames calorific value is also around 4700 kCal/kg.
- Wash coal: - Coal comes from mine is a complex of materials. By washing quality of coal is improved. Impurities as Sulfur, Ash and Rock are removed from coal so transport charges are reduced. Its calorific value is around 4000 kCal/kg.
- Imported coal: - It is very good quality of coal. Its calorific value is around 5500 kCal/kg and sometime more than 6000 kCal/kg.

Analysis of coal

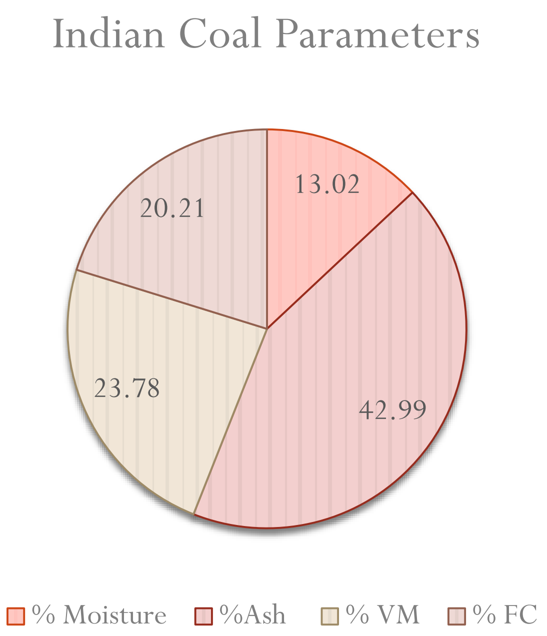
- The composition of the coal varies from mine to mine. Here it is necessary to analysis for commercial purpose and price fixing.

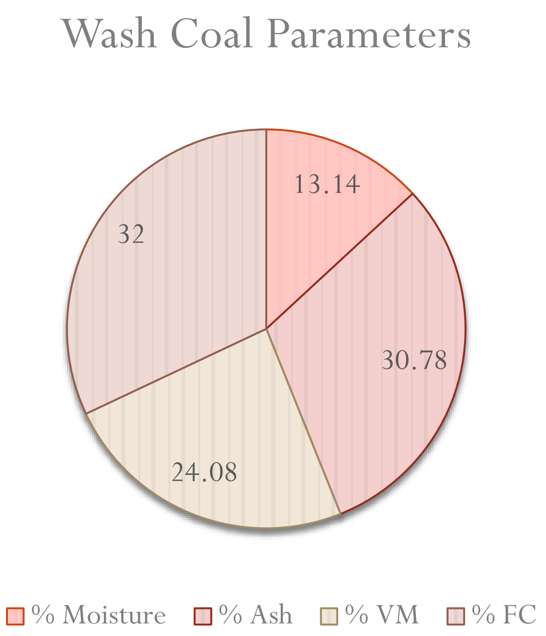


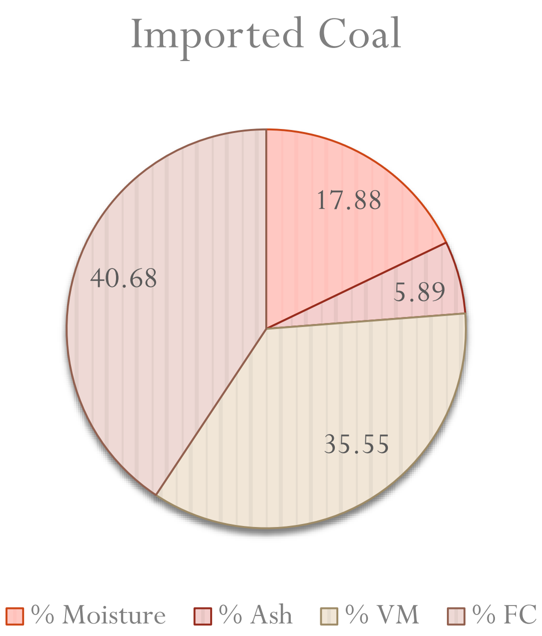
Proximate analysis and its methodology

Content	With/without Lid	Apparatus	Temperature	Time
Percentage of moisture (M)	Without Lid	Oven	110 °C	One Hour
Percentage of volatile matter (VM)	With Lid	Muffle Furnace	925 °C	Seven Minutes
Percentage of ash (A)	Without lid	Muffle Furnace	700 °C	Half an Hour
Percentage of carbon (C)	C=100 – M – VM - A	----	----	----

Proximate Analysis Results







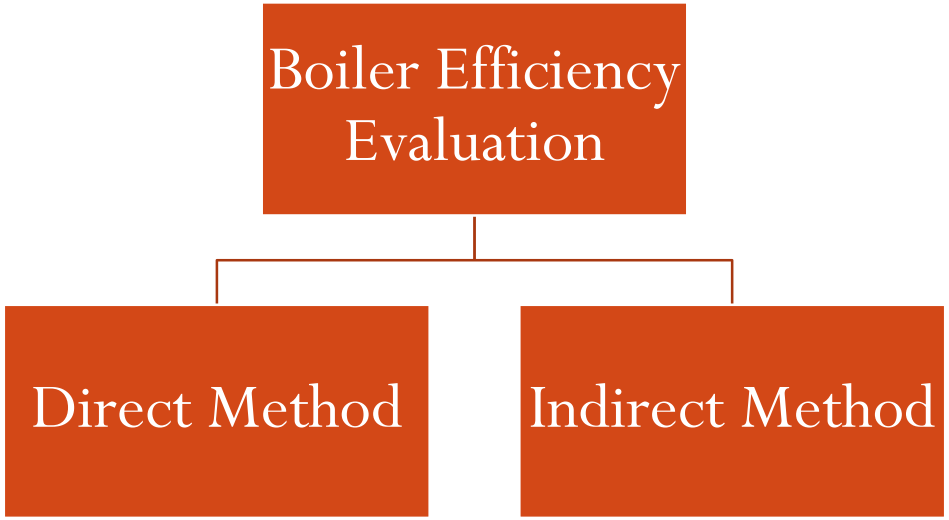
CV 3030.15 kCal/kg.

CV 4078.90 kCal/kg

CV 5482.80 kCal/kg.

Calculation of Boiler efficiency

- Thermal efficiency of boiler is defined as the percentage of heat input that is effectively utilized to generation steam. There are two methods of assessing boiler efficiency.
- It is not always true that a boiler will work at its rated efficiency. Almost all the times, it has been found that the boilers operate at much lower than the rated efficiencies if proper efficiency monitoring is not done.



Direct Method

- This is also known an 'input output method' due to the fact that it need only the useful output (steam) and the heat input (Fuel) for evaluating the efficiency. This efficiency can be evaluated using the formula.

$$\textbf{Boiler Efficiency} = \frac{\text{Steam Generation} * (\text{Steam Enthalpy} - \text{Feed Water Enthalpy})}{\text{FuelConsumption} * \text{CalorificValue}}$$

- Quickly find the efficiency of boilers
- Few parameters required
- Few instrument required for monitoring

- Does not give clues to the operator as to why efficiency of system is lower
- Does not calculate various losses accountable for various efficiency levels

Input data for Direct Method

Steam generation	656	Ton/h
Enthalpy of super-heated steam (P= T=	3420.32	kJ/kg
Enthalpy of feed water (T=)	1014.72	kJ/kg
Gross Calorific Value of Fuel	16430.05	kJ/kg
Coal consumption	115	Ton/h

Efficiency = 83.52 %

Indirect method

- Indirect method is also called as heat loss method
- The efficiency can be arrived by subtracting the heat loss fractions from 100

The principal loss occur in a boiler are

- Loss of heat due to dry flue gas
- Loss of heat due to Combustible loss
- Loss of heat due to Sensible heat loss
- Loss of heat due to radiation
- Loss of heat due to moisture
- Loss of heat due to mill rejection
- Loss of heat due to carbon monoxide
- Loss of heat due to moisture in air
- Loss of heat due to unburnt

Result of Indirect method

Sr No	Results	Value
1	Dry gas loss	5.708 %
2	Combustible loss	0.634 %
3	Sensible heat loss	0.426 %
4	Radiation loss	0.214 %
5	Moisture loss	6.501 %
6	Loss due to mill rejection	0.019 %
7	Loss due to carbon monoxide (CO)	0.151 %
8	Loss due to moisture in air	0.101 %
9	Unaccounted loss	1 %
10	Total boiler losses	14.754 %
11	Boiler efficiency	**85.246 %**

Energy Analysis

- Mass balance equation for control volume under steady flow

$$\dot{m}_{in} = \dot{m}_{out}$$

- Energy balance equation for control volume under steady flow

$$\dot{m}_{in}\left(h + \frac{v^2}{2} + gz\right)_{in} + Q = \dot{m}_{out}\left(h + \frac{v^2}{2} + gz\right)_{out} + W$$

- Assumption : Change in K.E. and P.E. is neglected

- First low efficiency or Energy efficiency

$$Energy\ Efficiency = \frac{Energy\ Out}{Energy\ Input} = 1 - \frac{Energy\ Loss}{Energy\ Input}$$

Exergy Analysis

- Exergy balance equation for control volume under steady flow

$$Exergy\ In = Exergy\ Utilized + Exergy\ Loss + Exergy\ Distruction$$

$$(ma)_{in} = (ma)_{out} + Q_L\left(1 - \frac{T_0}{T_S}\right) + I$$

$$a = h + \frac{v^2}{2} + gz - T_0 S$$

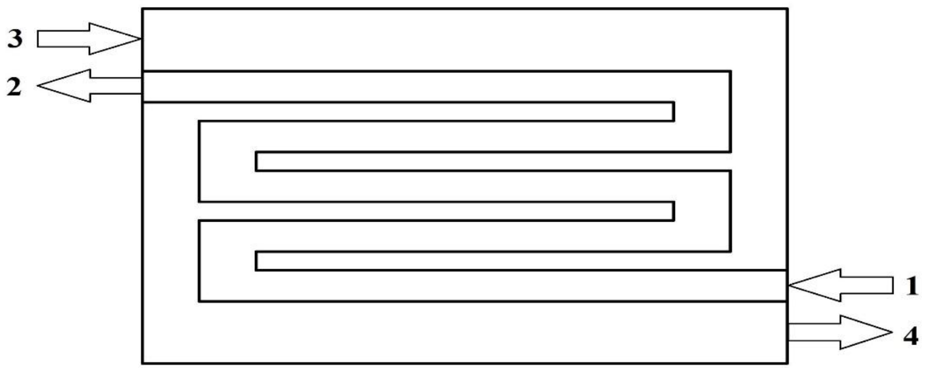
Assumption : Exergy due change in KE and PE is neglected.

- Second low efficiency or Energy efficiency

$$Exergy\ Efficiency = \frac{Exergy\ Out}{Exergy\ Input} = 1 - \frac{Exergy\ Distruction + Exergy\ Loss}{Energy\ Input}$$

Economizer

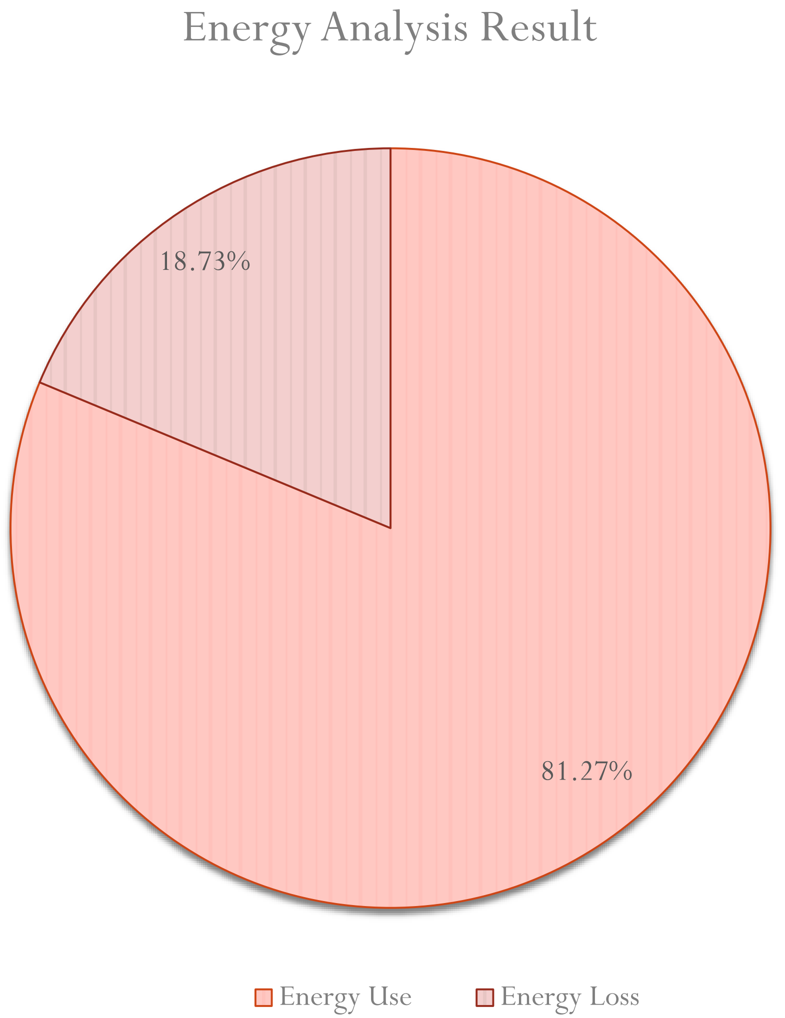
Mass flow rate of economizer water	m1,m2	182.22 kg/s
Temperature of economizer water in	T1	514.6 K
Temperature of economizer water out	T2	552 K
Mass flow rate of flue gas at economizer	m3,m4	258.94 kg/
Temperature of flue gas in at economizer	T3	743 K
Temperature of flue gas out at economizer	T4	630 K

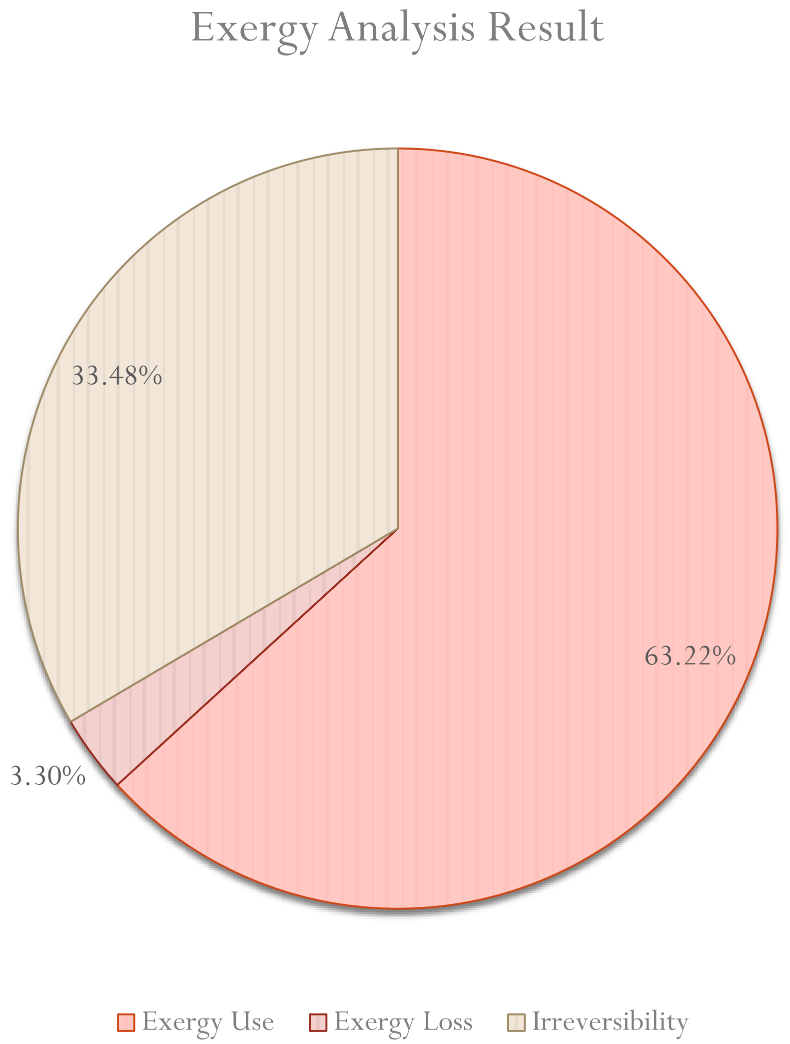


Energy in kJ/kg	Energy out kJ/kg	Energy loss kJ/kg	Efficiency (η_I) %
35112.81	28534.87	6577.94	81.27 %

Exergy in kJ/s	Exergy out kJ/s	Exergy loss kJ/s	Irreversibility kJ/s	Efficiency(η_{II}) %
19733.75	12476.42	651.87	6605.46	63.22 %

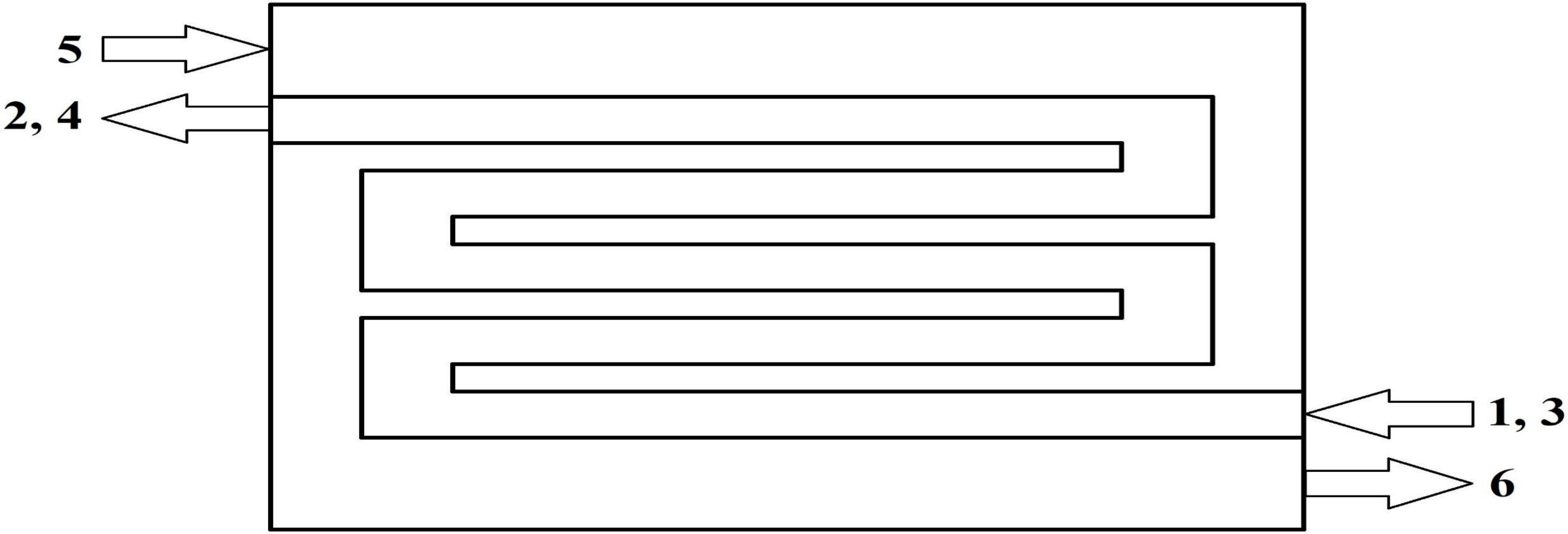
Economizer Analysis Result





Air Pre-Heater

Figure shows that primary and secondary air enters from section 1 and leaves from section 2. Flue gas enters from 3 and leaves from section 4. In between primary and secondary air gets heat from flue gas and flue gas loss heat energy.



Air Pre-Heater Required Data

Mass flow rate of Primary Air	m1, m2	28.22 kg/s
Temperature of primary air in	T1	308 K
Temperature of primary air out	T2	609 K
Mass flow rate of secondary air	m3, m4	157.94 kg/s
Temperature of secondary air in	T3	308 K
Temperature of secondary air out	T4	604 K
Mass flow rate of flue gas at Air Pre-heater	m5, m6	258.94 kg/s
Temperature of flue gas in at Air Pre-heater	T5	630 K
Temperature of flue gas out at Air Pre-heater	T6	423 K

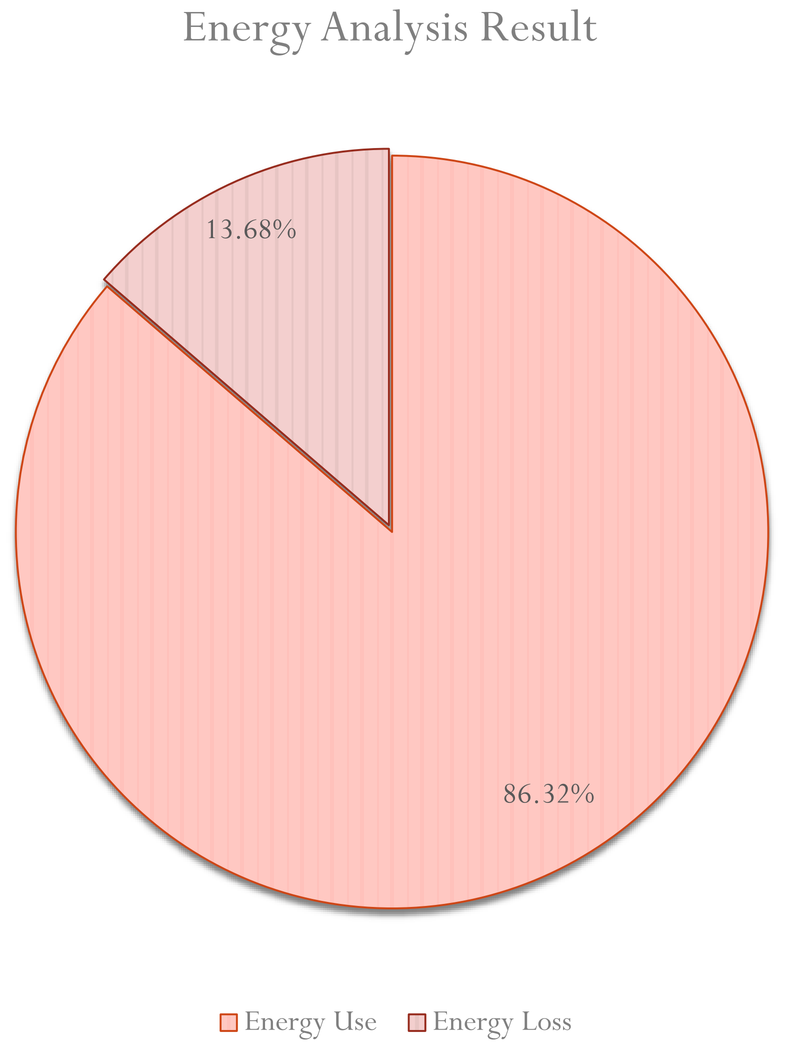
Energy Analysis of Air Pre-Heatere

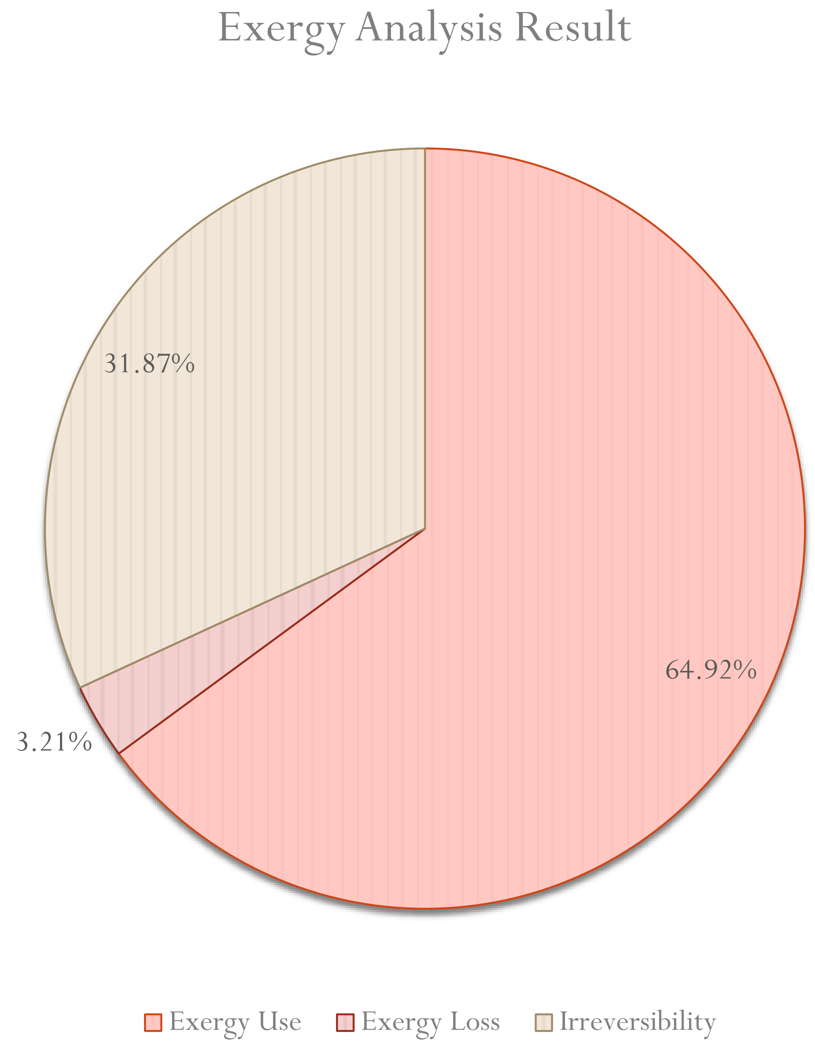
Energy in	Energy out	Energy loss (Q_L)	Efficiency (η_I)
64321.69 kJ/s	55522.68 kJ/s	8799.01 kJ/s	86.32%

Exergy Analysis of Air-Pre Heater

Exergy in	Exergy out	Exergy loss	Irreversibility	Efficiency(η_{II})
27187.79 kJ/s	17650.91 kJ/s	871.97 kJ/s	8664.90 kJ/s	64.92%

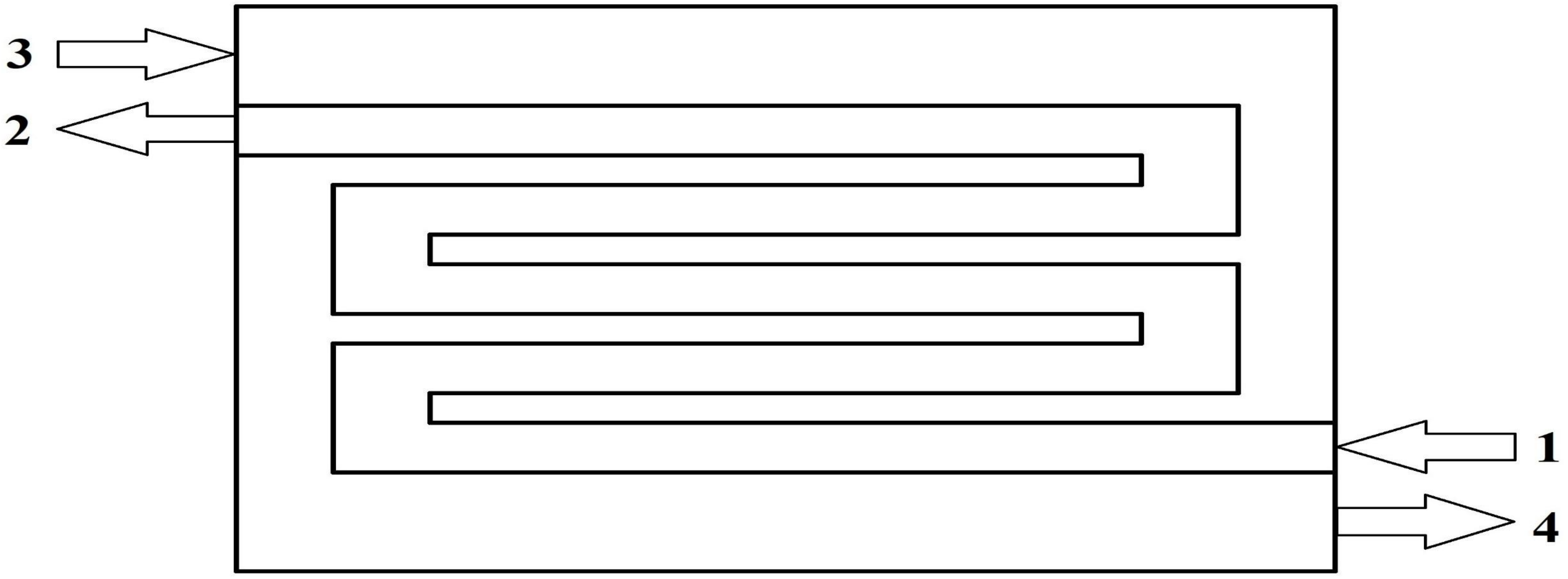
Air Pre-heater Analysis Result





Super Heater

Figure shows that steam enters from section 1 and leaves from section 2. Flue gas enters from section 3 and leaves from section 4. In between steam get sensible heat from flue gas become dry and flue gas loss heat energy.



Super Heater Required Data

Mass flow rate of super heater steam	m1, m2	182.22 kg/s
Temperature of super heater steam in	T1	622 K
Enthalpy of super heater steam in	h1	1658.68 kJ/kg
Entropy of super heater steam in	S1	3.76 kJ/kg K
Temperature of super heater steam out	T2	813 K
Enthalpy of super heater steam out	h2	3417.72 kJ/kg
Entropy of super heater steam out	S2	6.47 kJ/kg K
Mass flow rate of flue gas at super heater	m3, m4	258.94 kg/s
Temperature of flue gas in at super heater	T3	1436 K
Temperature of flue gas out at super heater	T4	964 K

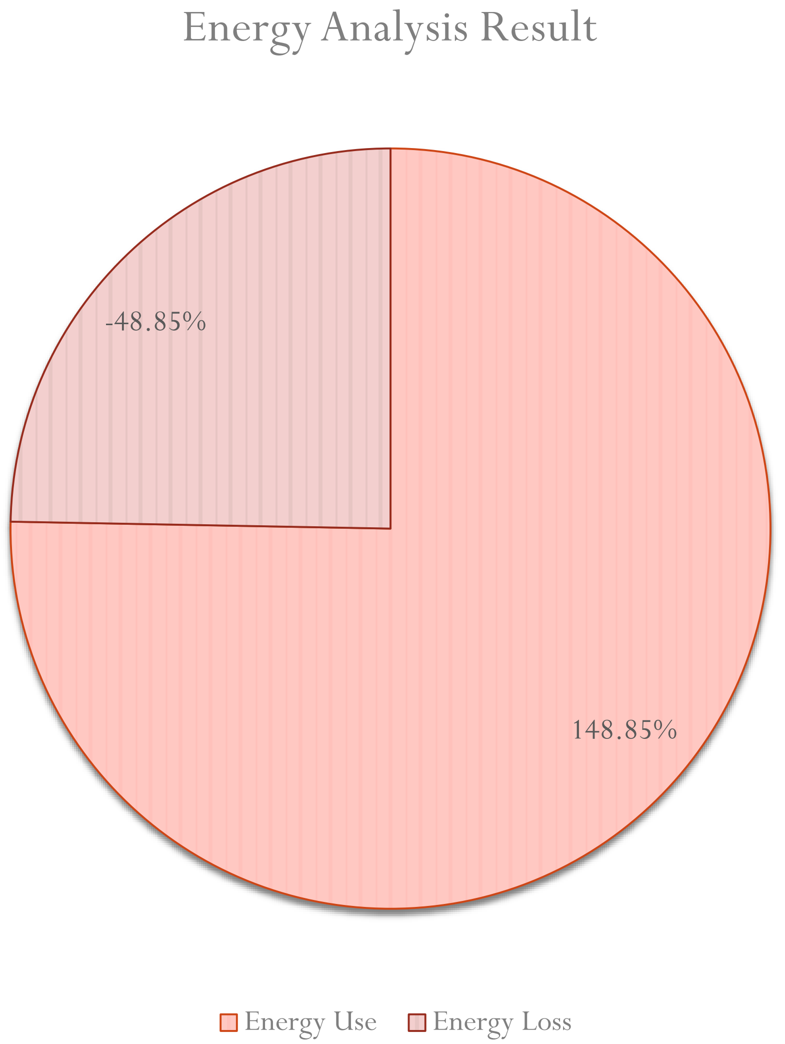
Energy Analysis of Super Heater

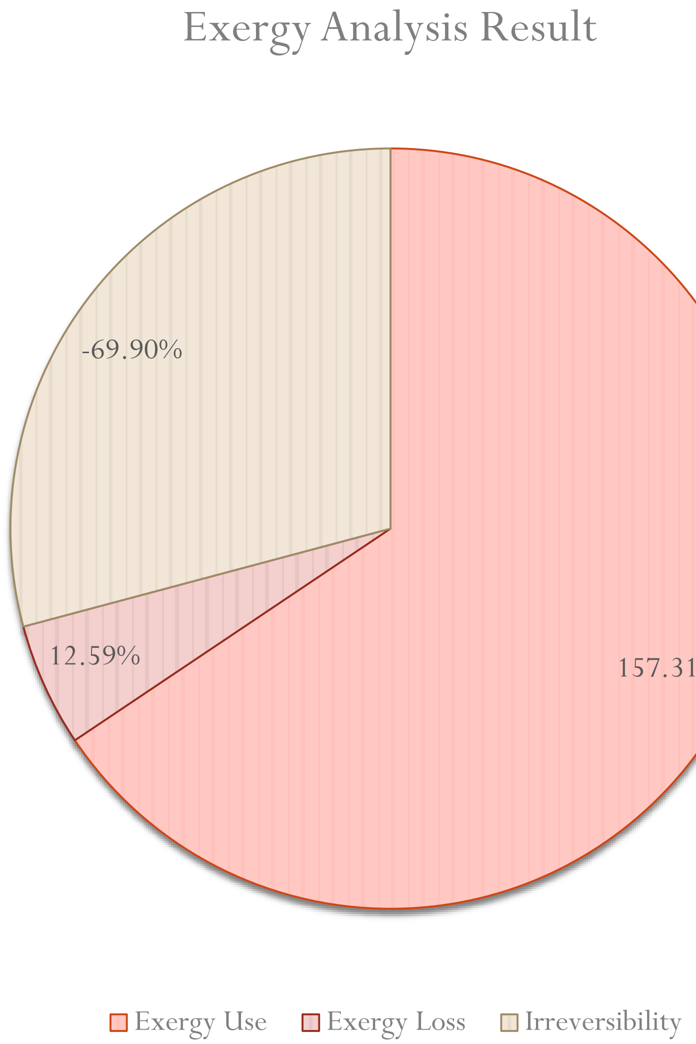
Energy in	Energy out	Energy loss (Q_L)	Efficiency (η_I)
215337.83 kJ/s	320536.36 kJ/s	-105198.53 kJ/s	148.85%

Exergy Analysis of Super Heater

Exergy in	Exergy out	Exergy loss	Irreversibility	Efficiency(η_{II})
109515.40 kJ/s	**172280.15 kJ/s**	**13785.45 kJ/s**	**-76550.19 kJ/s**	**157.31%**

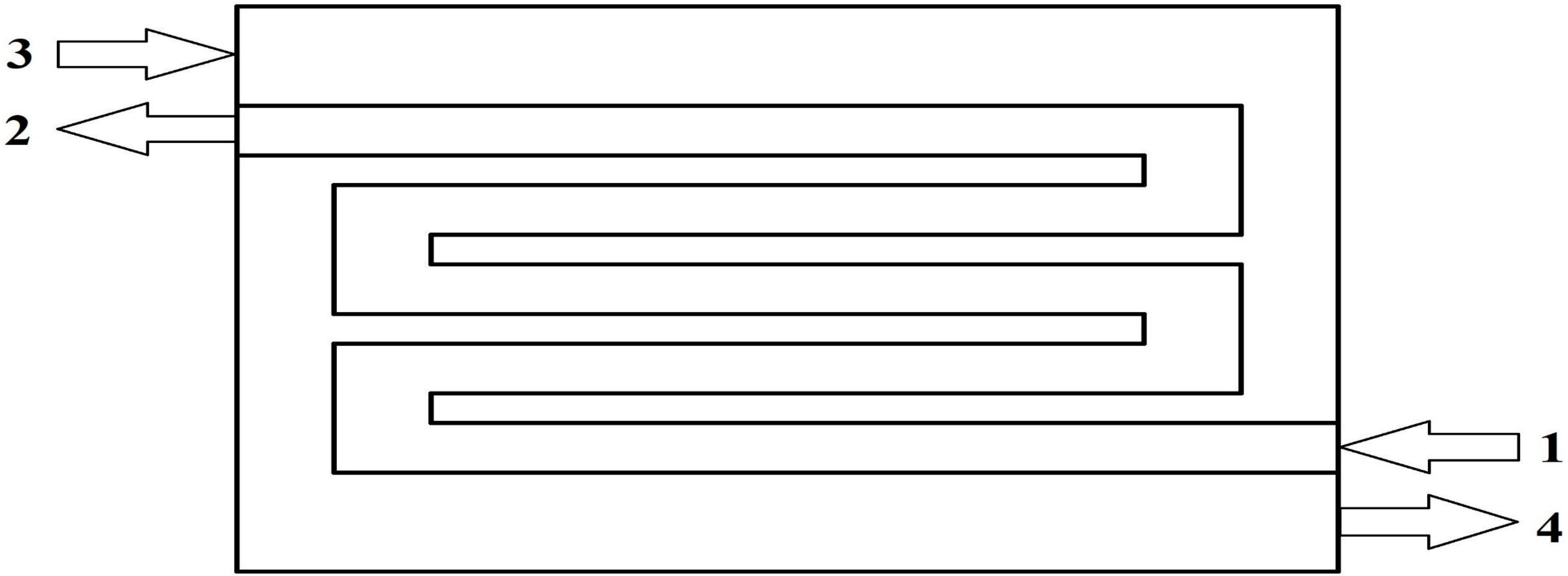
Super Heater Analysis Result





Re-heater

Figure shows that steam enters from section 1 and leaves from section 2. Flue gas enters from section 3 and leaves from section 4. In between steam get sensible heat from flue gas and flue gas loss heat energy.



Re-heater Heater Required Data

Mass flow rate of re-heater steam	m1, m2	157.17 kg/s
Temperature of re-heater steam in	T1	609.6 K
Enthalpy of re-heater steam in	h1	3065.30 kJ/kg
Entropy of re-heater steam in	S1	6.57 kJ/kg K
Temperature of re-heater steam out	T2	813 K
Enthalpy of re-heater steam out	h2	3540.76 kJ/kg
Entropy of re-heater steam out	S2	7.26 kJ/kg K
Mass flow rate of flue gas at re-heater	m3, m4	258.94 kg/s
Temperature of flue gas in at re-heater	T3	1286 K
Temperature of flue gas out at re-heater	T4	1022 K

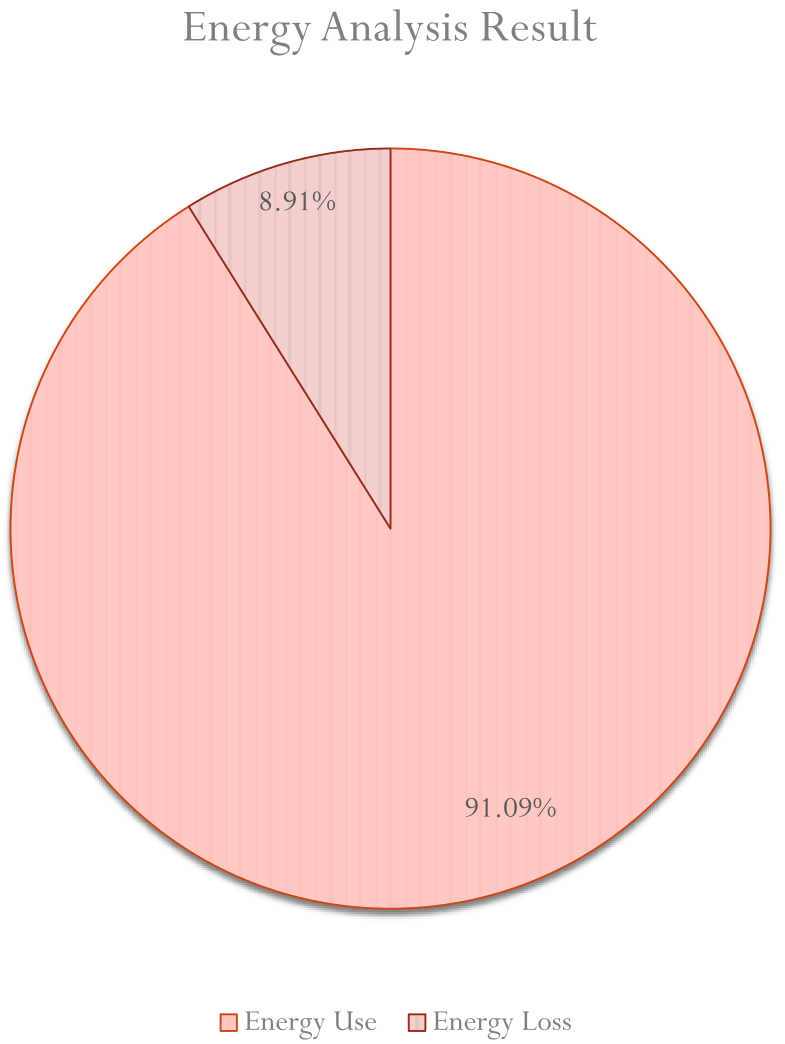
Energy Analysis of Re-heater

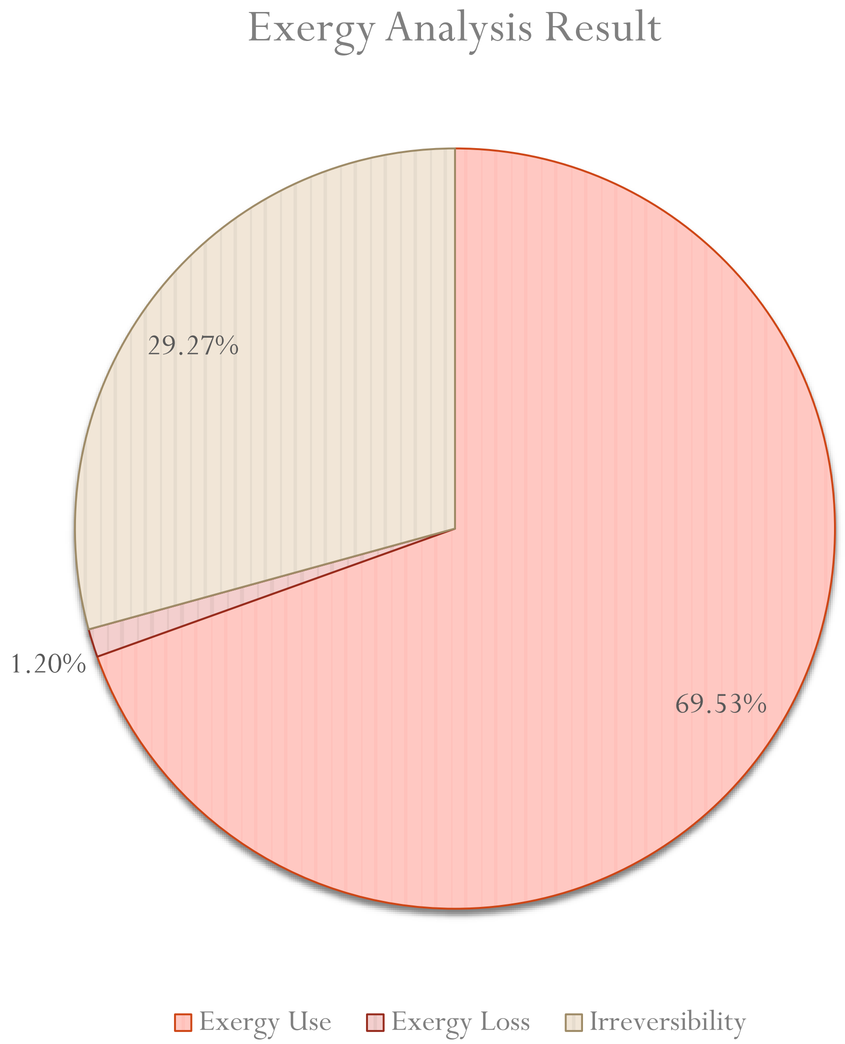
Energy in	Energy out	Energy loss (Q_L)	Efficiency (η_I)
82033.46 kJ/s	7472.99 kJ/s	7307.47 kJ/s	91.09%

Exergy Analysis of Super Heater

Exergy in	Exergy out	Exergy loss	Irreversibility	Efficiency(η_{II})
60613.86 kJ/s	42145.34 kJ/s	724.12 kJ/s	17744.40 kJ/s	69.53%

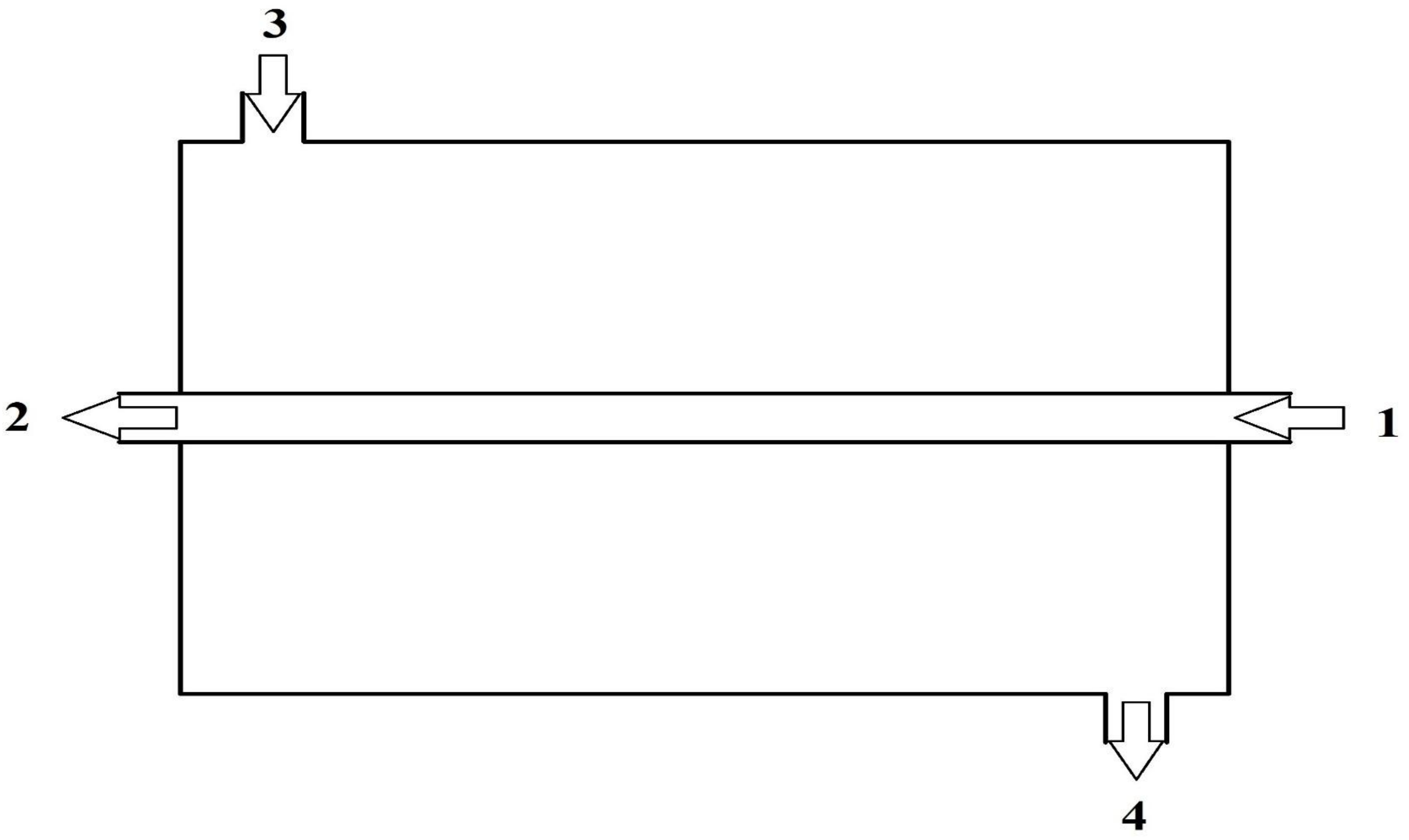
Re-heater Analysis Result





LPH 1

Figure shows that feed water enters from section 1 and leaves from section 2. Steam enters from section 3 and leaves from section 4. In between water get sensible heat from steam.



LPH 1 Required Data

Mass flow rate of LPH 1 feed water in	m1	125.25 kg/s
Temperature of LPH 1 feed water in	T1	322.4 K
Enthalpy of LPH 1 feed water in	h1	208.46 kJ/kg
Entropy of LPH 1 feed water in	S1	0.69 kJ/kg K
Mass flow rate of LPH 1 feed water out	m2	125.25 kg/s
Temperature of LPH 1 feed water out	T2	346.2 K
Enthalpy of LPH 1 feed water out	h2	307.67 kJ/kg
Entropy of LPH 1 feed water out	S2	0.99 kJ/kg K
Mass flow rate of LPH 1 steam in	m3	5.36 kg/s
Temperature of LPH 1 steam in	T3	357.6 K
Enthalpy of LPH 1 steam in	h3	2652.25 kJ/kg
Entropy of LPH 1 steam in	S3	7.66 kJ/kg K
Mass flow rate of LPH 1 water out	m4	5.36 kg/s
Temperature of LPH 1 water out	T4	319.9 K
Enthalpy of LPH 1 water out	h4	327.35 kJ/kg
Entropy of LPH 1 water out	S4	1.04 kJ/kg K

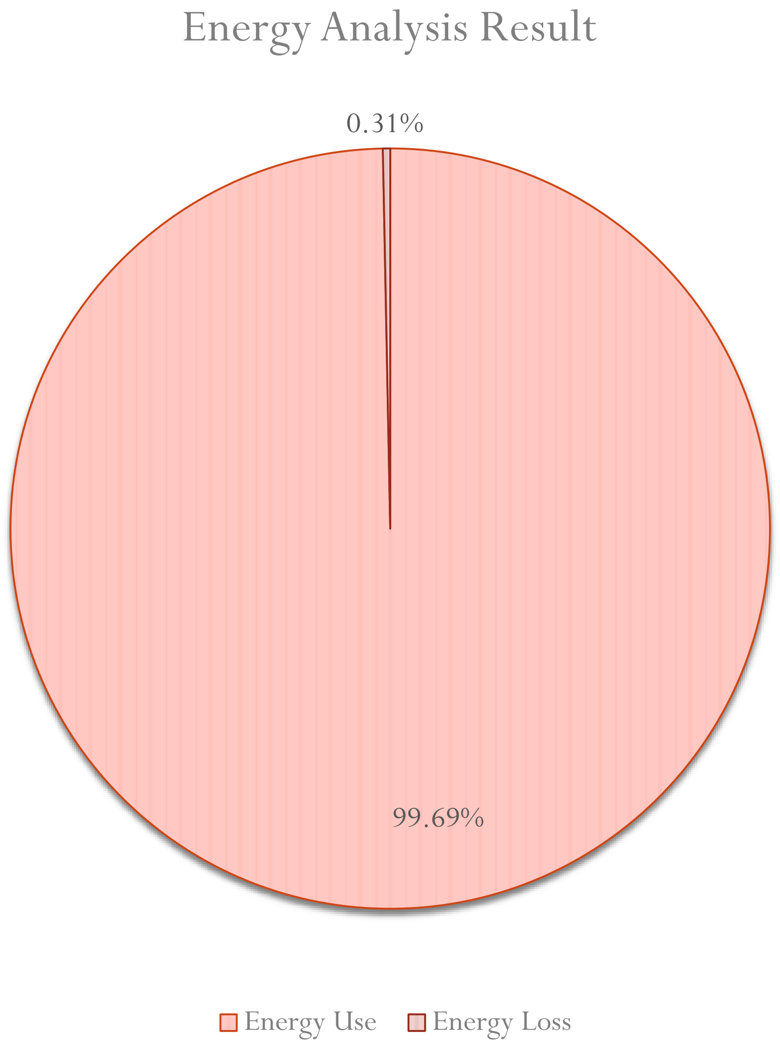
Energy Analysis of LPH 1

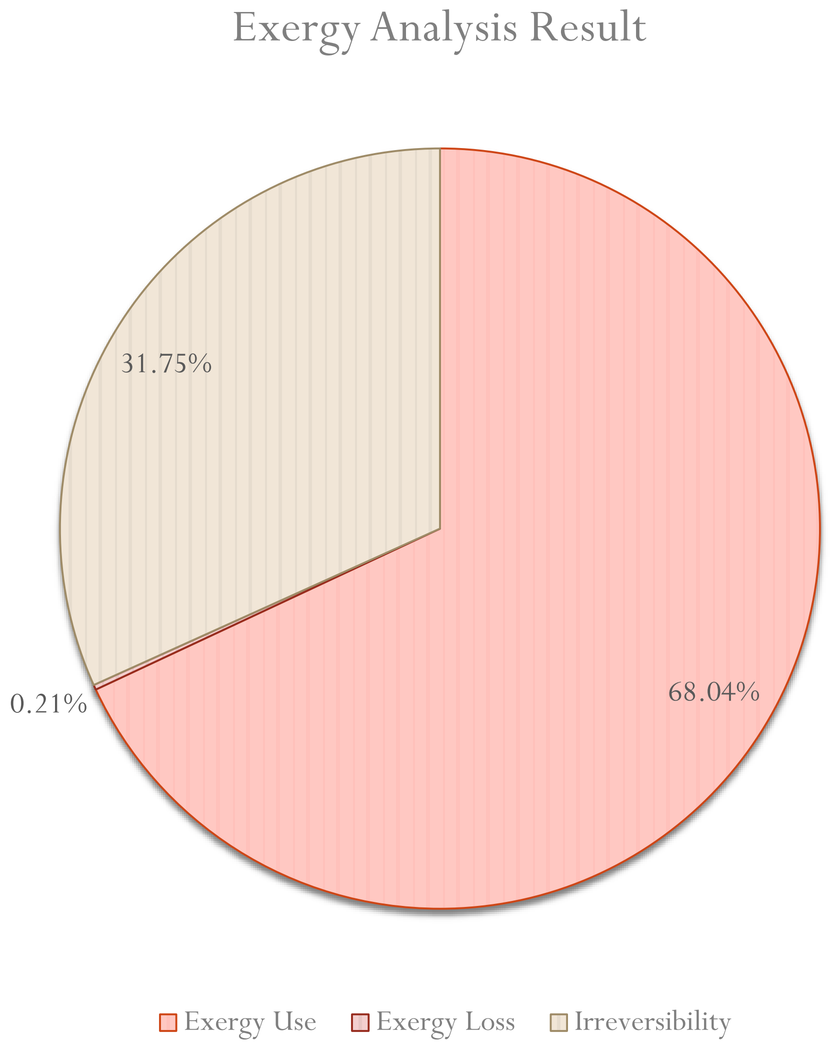
Energy in	Energy out	Energy loss (Q_L)	Efficiency (η_I)
12464.07 kJ/s	12425.83 kJ/s	38.24 kJ/s	99.69%

Exergy Analysis of LPH 1

Exergy in	Exergy out	Exergy loss	Irreversibility	Efficiency(η_{II})
1805.65 kJ/s	**1228.48 kJ/s**	**3.79 kJ/s**	**573.38 kJ/s**	**68.04%**

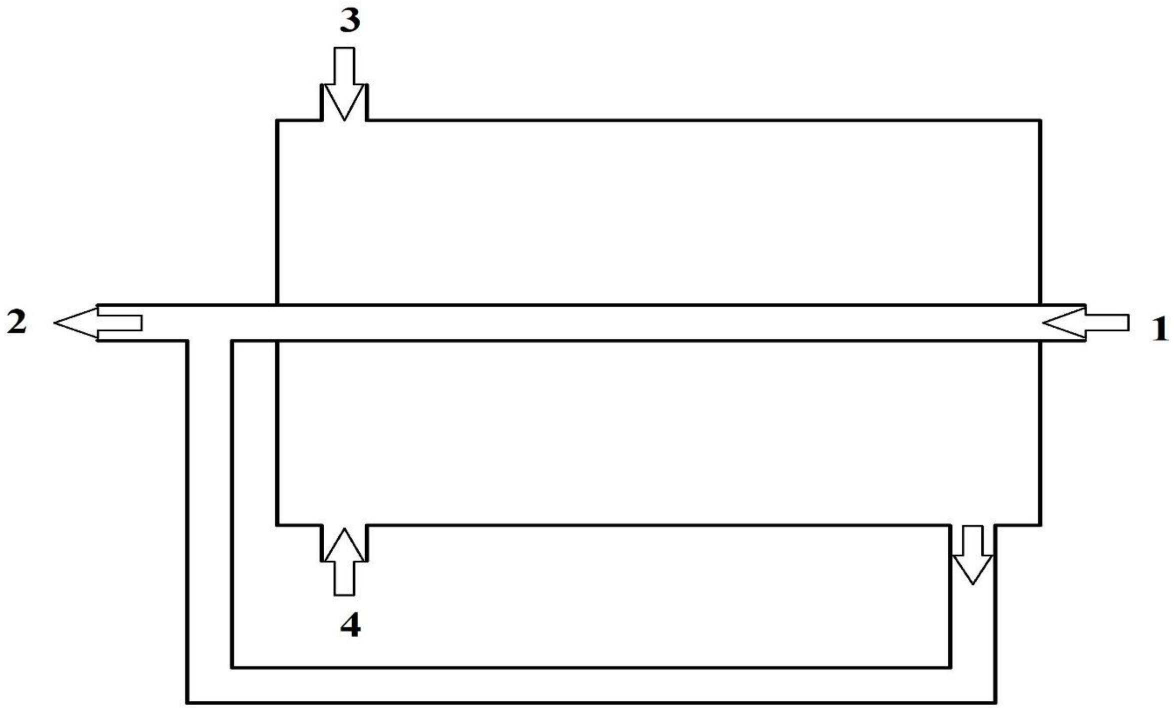
LPH 1 Analysis Result





LPH 2

Figure shows that feed water enters from section 1. Steam enters from section 3. hot water enters from section 4. Section 3 and 4 steam and water mix it gives heat to feed water then both become water it will pump in feed water which comes out from section 2. In between feed water get sensible heat from steam and hot water.



LPH 2 Required Data

Mass flow rate of LPH 2 feed water in	m1	125.25 kg/s
Temperature of LPH 2 feed water in	T1	346.2 K
Enthalpy of LPH 2 feed water in	h1	307.67 kJ/kg
Entropy of LPH 2 feed water in	S1	0.99 kJ/kg K
Mass flow rate of LPH 2 feed water out	m2	143.44 kg/s
Temperature of LPH 2 feed water out	T2	373.8 K
Enthalpy of LPH 2 feed water out	h2	423.62 kJ/kg
Entropy of LPH 2 feed water out	S2	1.31 kJ/kg K
Mass flow rate of LPH 2 steam in	m3	5.03 kg/s
Temperature of LPH 2 steam in	T3	515.8 K
Enthalpy of LPH 2 steam in	h3	2959.08 kJ/kg
Entropy of LPH 2 steam in	S3	7.91 kJ/kg K
Mass flow rate of LPH 2 hot water in	m4	13.17 kg/s
Temperature of LPH 2 hot water in	T4	378.2 K
Enthalpy of LPH 2 hot water in	h4	558.83 kJ/kg
Entropy of LPH 2 hot water in	S4	1.66 kJ/kg K

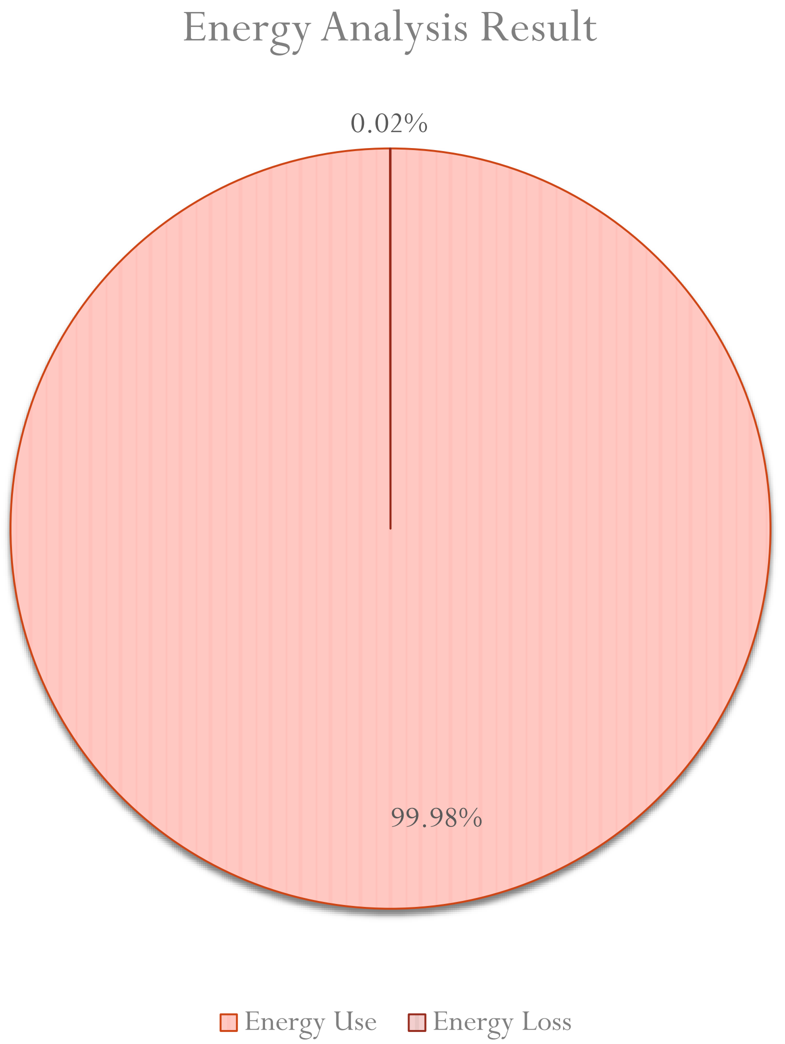
Energy Analysis of LPH 2

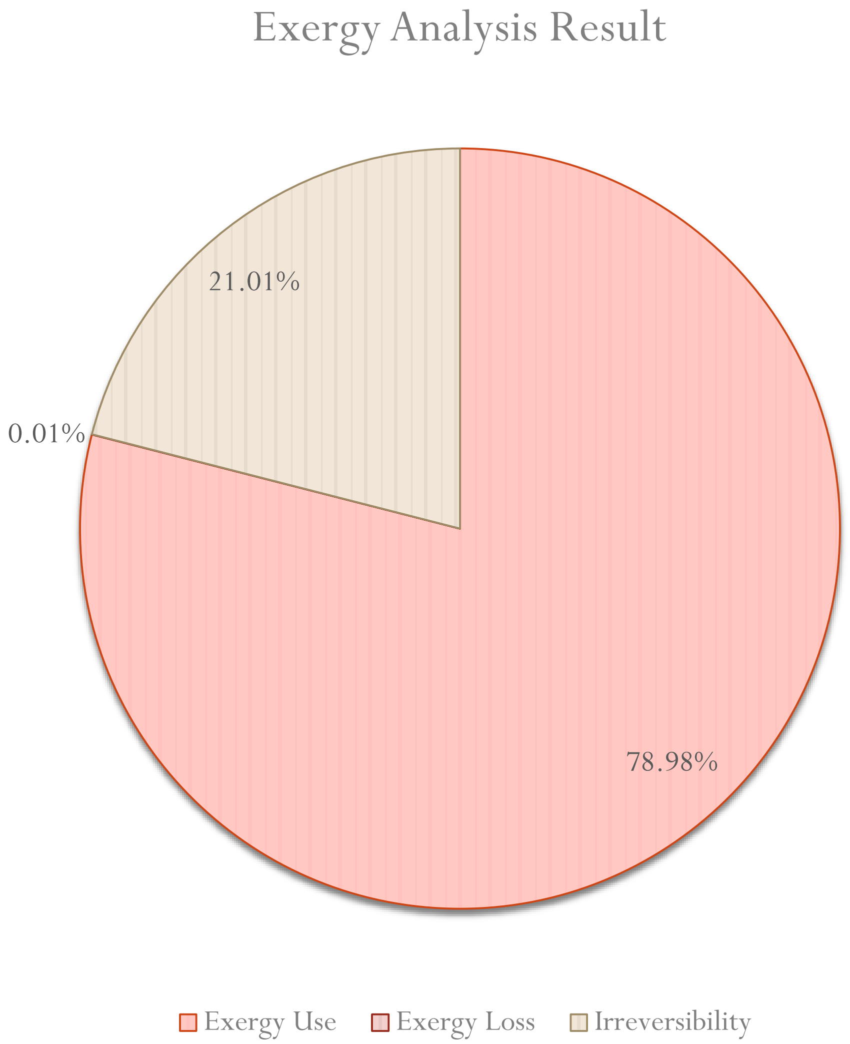
Energy in	Energy out	Energy loss (Q_L)	Efficiency (η_I)
22235.56 kJ/s	22230.60 kJ/s	4.95 kJ/s	99.98%

Exergy Analysis of LPH 2

Exergy in	Exergy out	Exergy loss	Irreversibility	Efficiency(η_{II})
3753.67 kJ/s	2964.66 kJ/s	0.49 kJ/s	788.52 kJ/s	78.98%

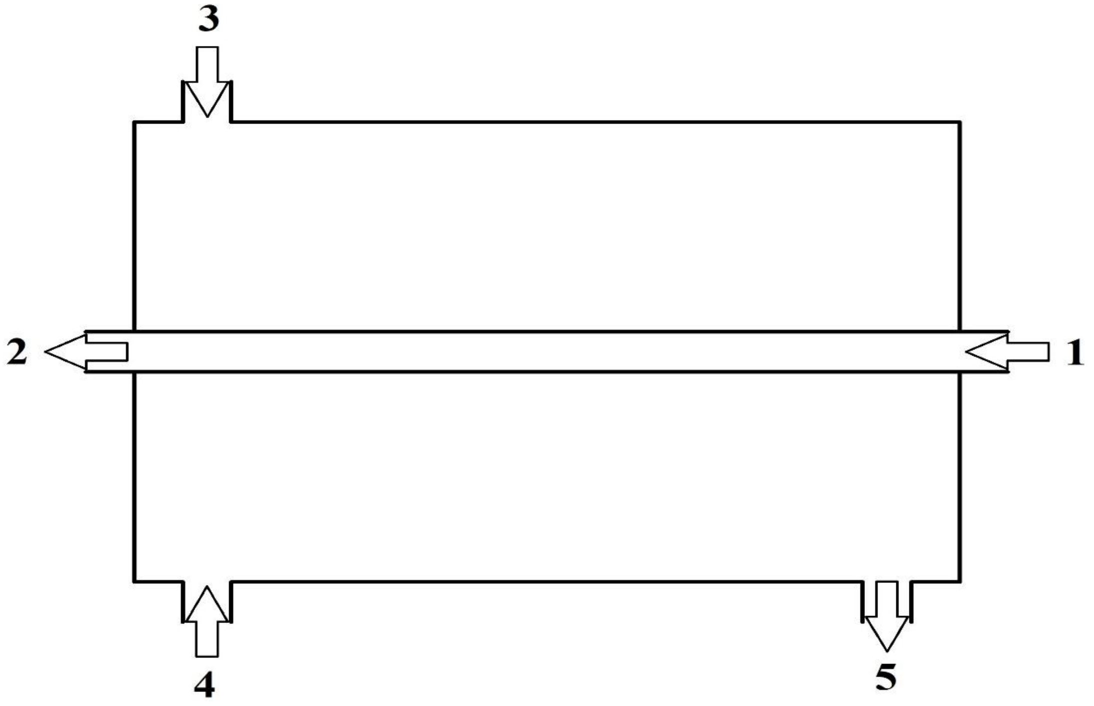
LPH 2 Analysis Result





LPH 3

Figure shows that feed water enters from section 1 and leaves from section 2. Steam enters from section 3. hot water enters from section 4. Section 3 and 4 steam and water mix it gives heat to feed water then both become water. It leaves from section 5. In between feed water get sensible heat from steam and hot water.



LPH 3 Required Data

Mass flow rate of LPH 3 feed water in	m1	143.44 kg/s
Temperature of LPH 3 feed water in	T1	373.8 K
Enthalpy of LPH 3 feed water in	h1	423.62 kJ/kg
Entropy of LPH 3 feed water in	S1	1.31 kJ/kg K
Mass flow rate of LPH 3 feed water out	m2	143.44 kg/s
Temperature of LPH 3 feed water out	T2	400.9 K
Enthalpy of LPH 3 feed water out	h2	538.74 kJ/kg
Entropy of LPH 3 feed water out	S2	1.61 kJ/kg K
Mass flow rate of LPH 3 steam in	m3	6.47 kg/s
Temperature of LPH 3 steam in	T3	531.1 K
Enthalpy of LPH 3 steam in	h3	2992.99 kJ/kg
Entropy of LPH 3 steam in	S3	7.55 kJ/kg

LPH 3 Required Data

Mass flow rate of LPH 3 hot water in	m4	6.69 kg/s
Temperature of LPH 3 hot water in	T4	405.9 K
Enthalpy of LPH 3 hot water in	h4	675.62 kJ/kg
Entropy of LPH 3 hot water in	S4	1.93 kJ/kg K
Mass flow rate of LPH 3 water out	m5	13.17 kg/s
Temperature of LPH 3 water out	T5	378.2 K
Enthalpy of LPH 3 water out	h5	558.83 kJ/kg
Entropy of LPH 3 water out	S5	1.66 kJ/kg K

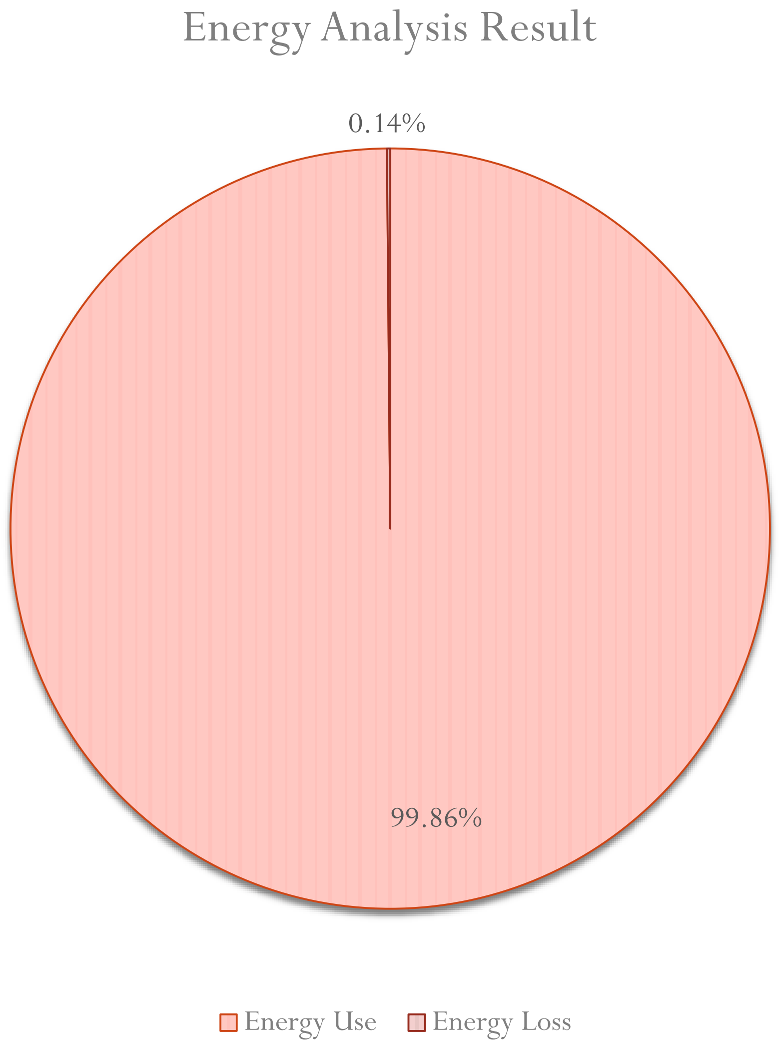
Energy Analysis of LPH 3

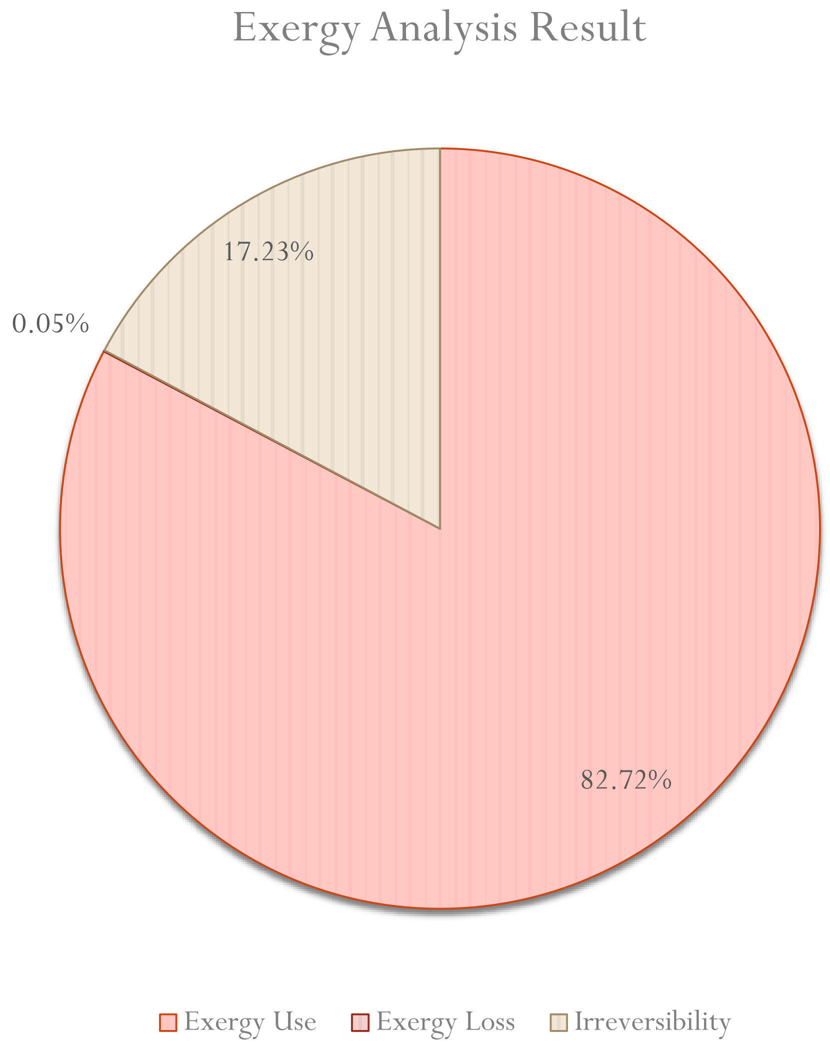
Energy in	Energy out	Energy loss (Q_L)	Efficiency (η_I)
16536.26 kJ/s	16512.61 kJ/s	23.65 kJ/s	99.86%

Exergy Analysis of LPH 3

Exergy in	Exergy out	Exergy loss	Irreversibility	Efficiency(η_{II})
4563.42 kJ/s	**3774.74 kJ/s**	**2.34 kJ/s**	**786.33 kJ/s**	**82.72%**

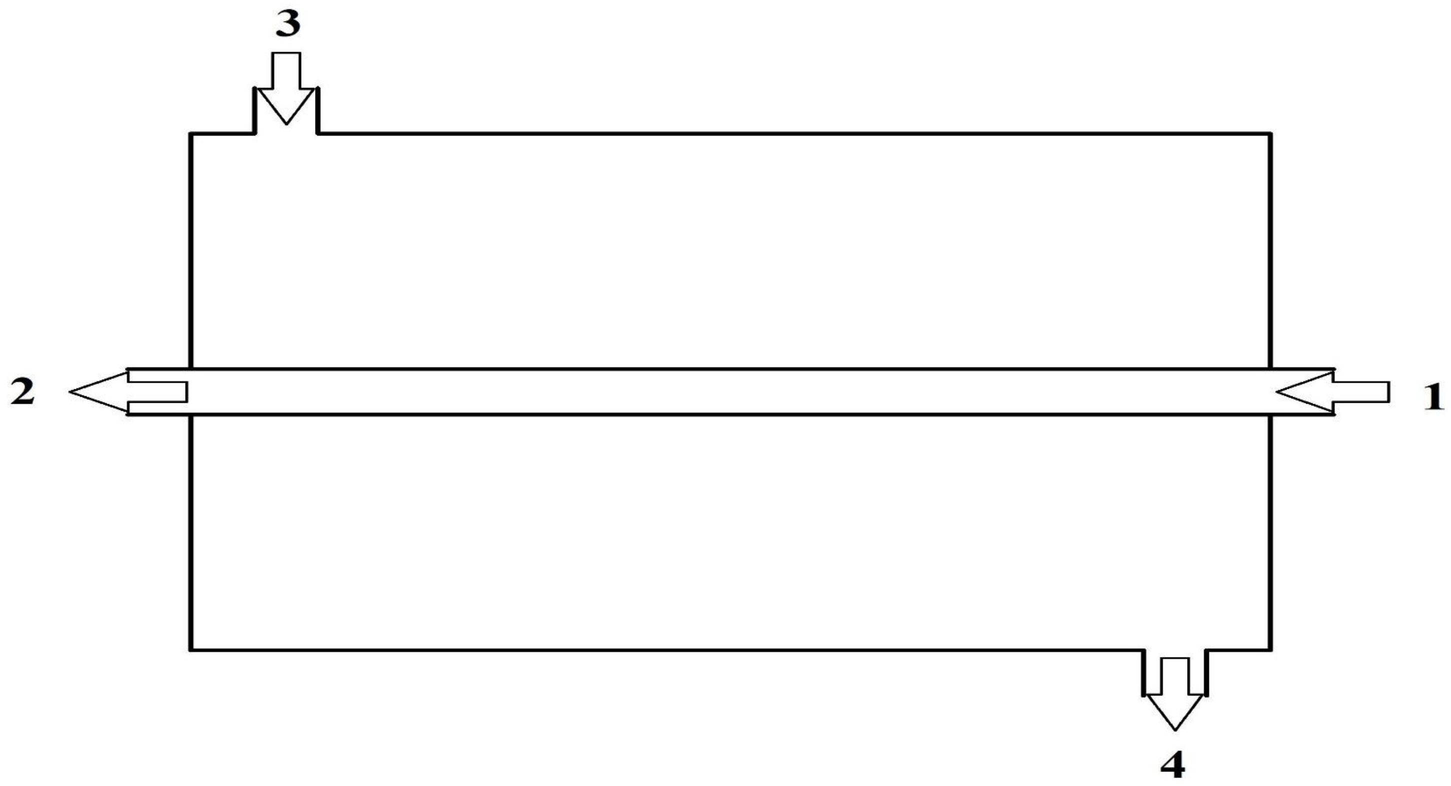
LPH 3 Analysis Result





LPH 4

Figure shows that feed water enters from section 1 and leaves from section 2. Steam enters from section 3. Section 3 steam gives heat to feed water then become water. It leaves from section 4. In between feed water get sensible heat from steam.



LPH 4 Required Data

Mass flow rate of LPH 4 feed water in	m1	143.44 kg/s
Temperature of LPH 4 feed water in	T1	400.9 K
Enthalpy of LPH 4 feed water in	h1	538.74 kJ/kg
Entropy of LPH 4 feed water in	S1	1.61 kJ/kg K
Mass flow rate of LPH 4 feed water out	m2	143.44 kg/s
Temperature of LPH 4 feed water out	T2	428 K
Enthalpy of LPH 4 feed water out	h2	654.69 kJ/kg
Entropy of LPH 4 feed water out	S2	1.89 kJ/kg K
Mass flow rate of LPH 4 steam in	m3	6.69 kg/s
Temperature of LPH 4 steam in	T3	622.9 K
Enthalpy of LPH 4 steam in	h3	3165.03 kJ/kg
Entropy of LPH 4 steam in	S3	7.52 kJ/kg K
Mass flow rate of LPH 4 water out	m4	6.69 kg/s
Temperature of LPH 4 water out	T4	405.9 K
Enthalpy of LPH 4 water out	h4	675.62 kJ/kg
Entropy of LPH 4 water out	S4	1.93 kJ/kg K

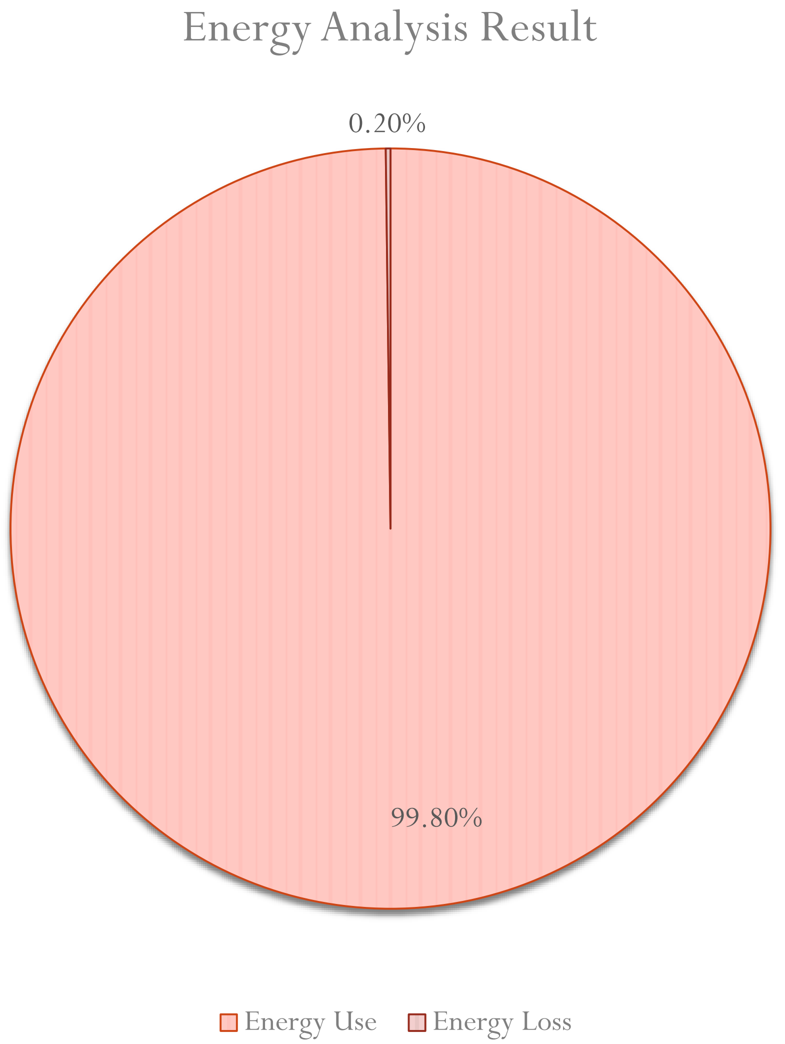
Energy Analysis of LPH 4

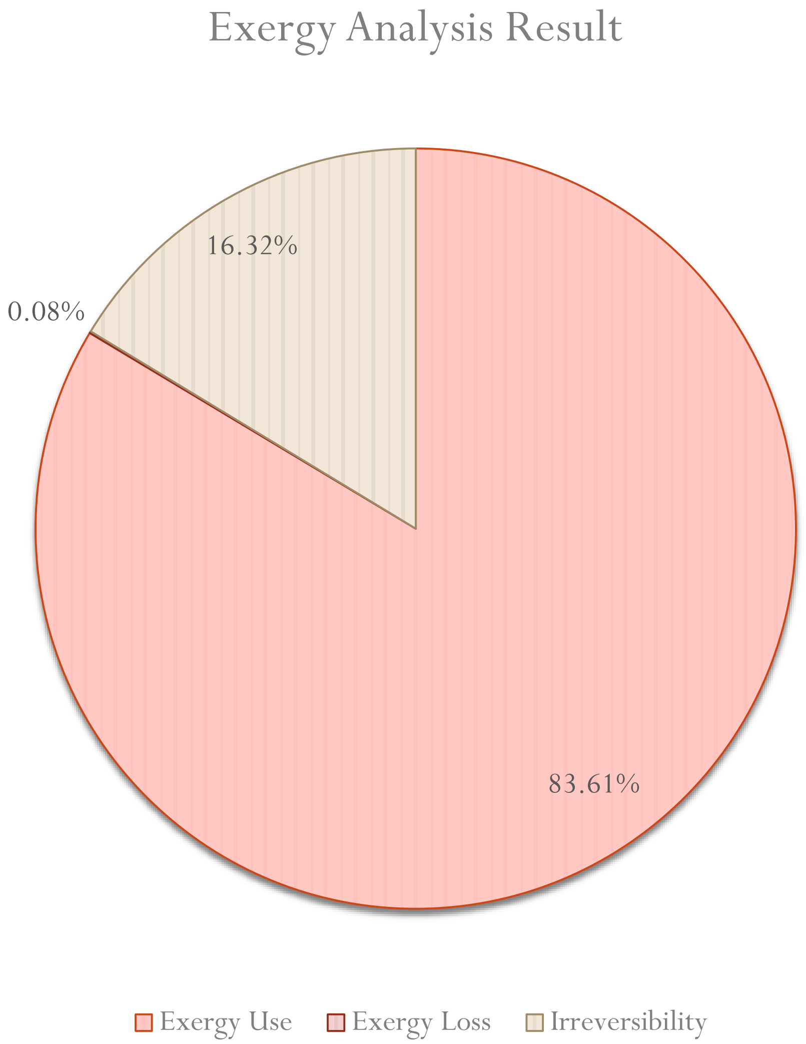
Energy in	Energy out	Energy loss (Q_L)	Efficiency (η_I)
14332.27 kJ/s	14304.28 kJ/s	27.99 kJ/s	99.80%

Exergy Analysis of LPH 4

Exergy in	Exergy out	Exergy loss	Irreversibility	Efficiency(η_{II})
5430.63 kJ/s	**4540.33 kJ/s**	**4.20 kJ/s**	**886.09 kJ/s**	**83.61%**

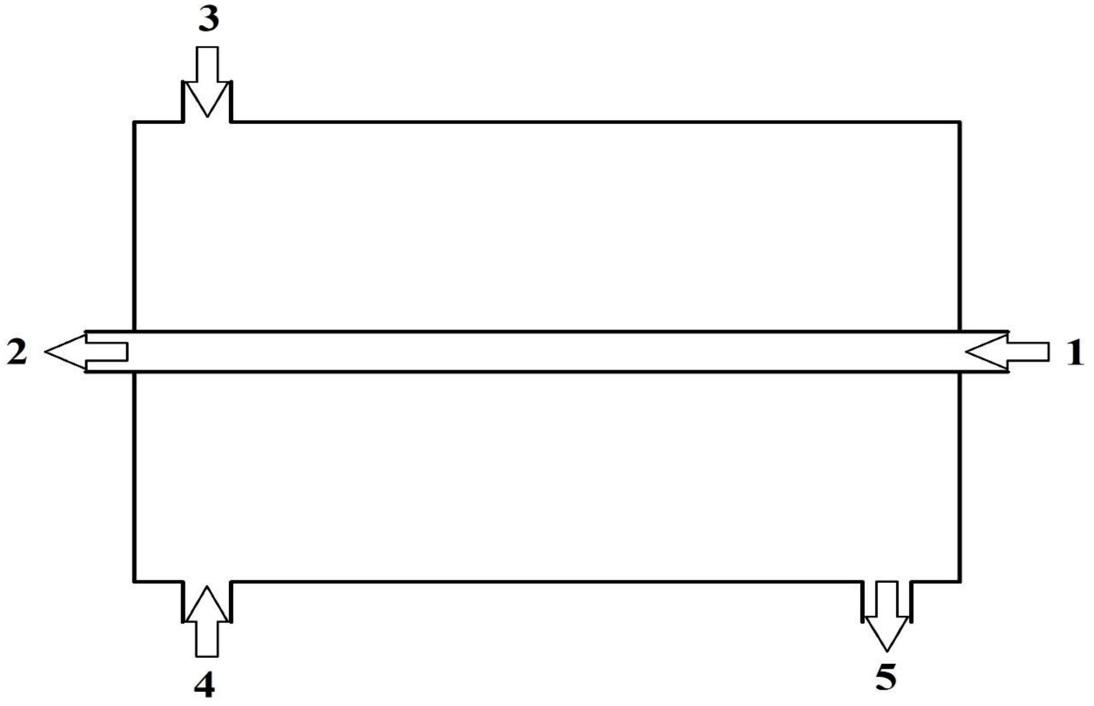
LPH 4 Analysis Result





HPH 1

Figure shows that feed water enters from section 1 and leaves from section 2. Steam enters from section 3. hot water enters from section 4. Section 3 and 4 steam and water mix it gives heat to feed water then both become water. It leaves from section 5. In between feed water get sensible heat from steam and hot water.



HPH 1 Required Data

Mass flow rate of HPH 1 feed water in	m1	169.72 kg/s
Temperature of HPH 1 feed water in	T1	443.4 K
Enthalpy of HPH 1 feed water in	h1	730.04 kJ/kg
Entropy of HPH 1 feed water in	S1	2.02 kJ/kg K
Mass flow rate of HPH 1 feed water out	m2	169.72 kg/s
Temperature of HPH 1 feed water out	T2	458.4 K
Enthalpy of HPH 1 feed water out	h2	795.34 kJ/kg
Entropy of HPH 1 feed water out	S2	2.17 kJ/kg K
Mass flow rate of HPH 1 steam in	m3	5.06 kg/s
Temperature of HPH 1 steam in	T3	710.1 K
Enthalpy of HPH 1 steam in	h3	3340.43 kJ/kg
Entropy of HPH 1 steam in	S3	7.49 kJ/kg

HPH 1 Required Data

Mass flow rate of HPH 1 hot water in	m4	21.17 kg/s
Temperature of HPH 1 hot water in	T4	460.4 K
Enthalpy of HPH 1 hot water in	h4	832.18 kJ/kg
Entropy of HPH 1 hot water in	S4	2.30 kJ/kg K
Mass flow rate of HPH 1 water out	m5	25.19 kg/s
Temperature of HPH 1 water out	T5	437.2 K
Enthalpy of HPH 1 water out	h5	795.34 kJ/kg
Entropy of HPH 1 water out	S5	2.22 kJ/kg K

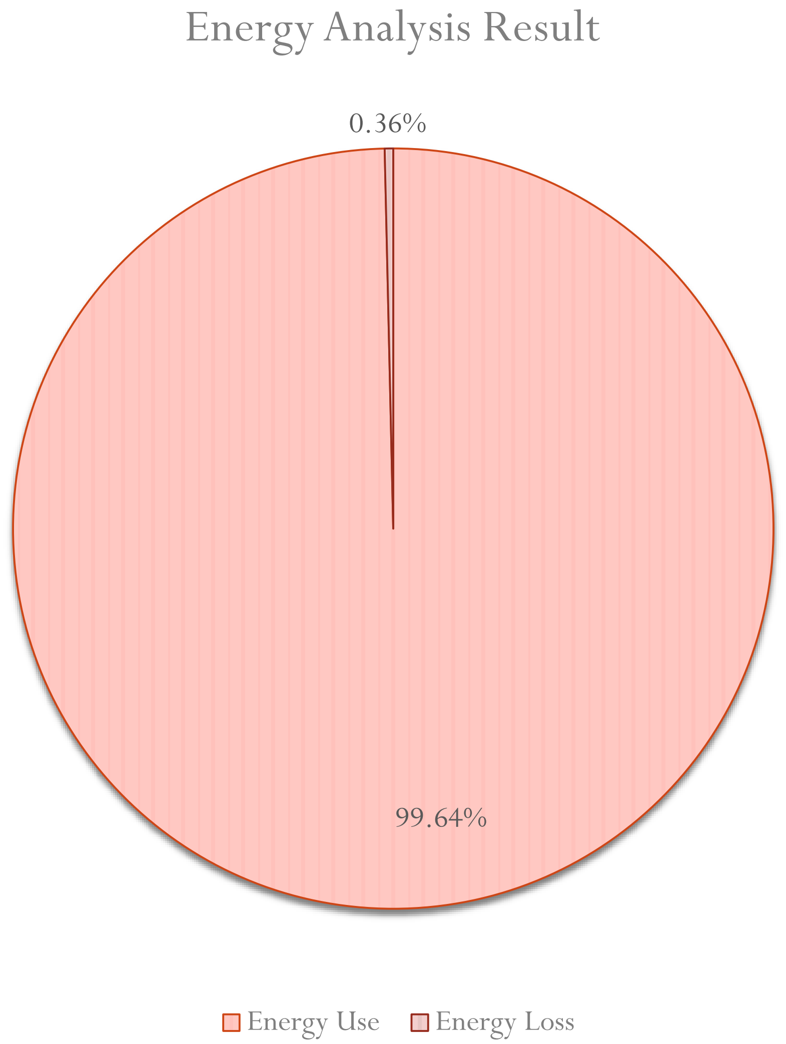
Energy Analysis of HPH 1

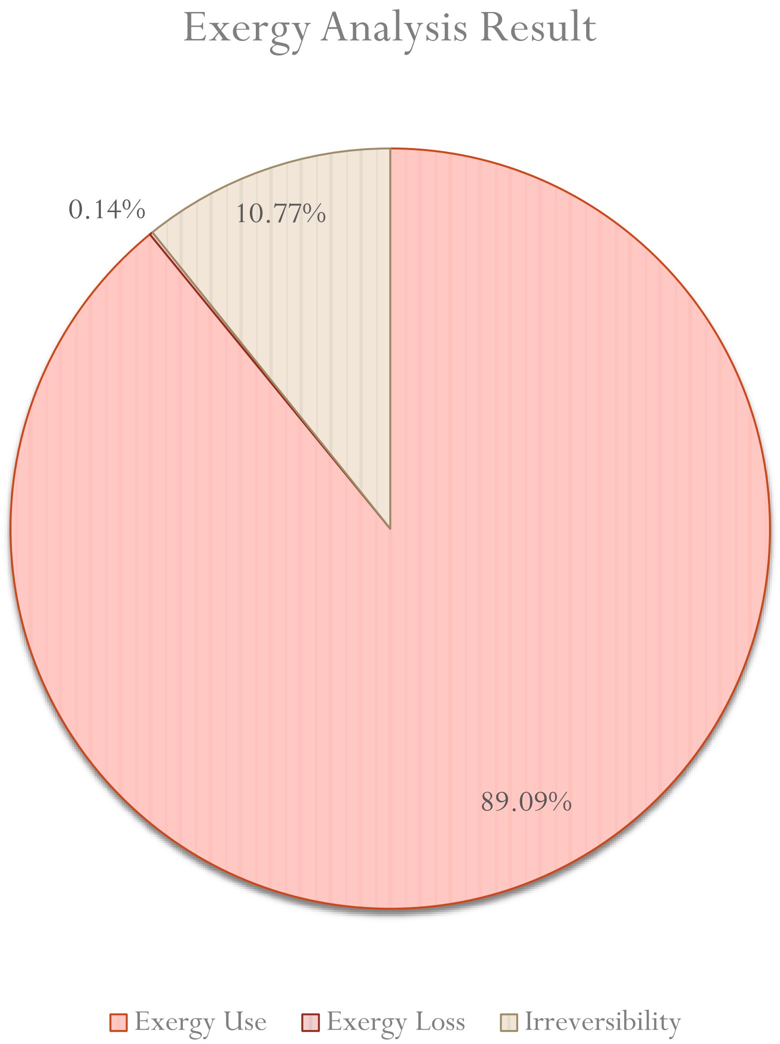
Energy in	Energy out	Energy loss (Q_L)	Efficiency (η_I)
11123.55 kJ/s	11083.13 kJ/s	40.42 kJ/s	99.64%

Exergy Analysis of HPH 1

Exergy in	Exergy out	Exergy loss	Irreversibility	Efficiency(η_{II})
4210.62 kJ/s	3751.13 kJ/s	6.07 kJ/s	453.42 kJ/s	89.09%

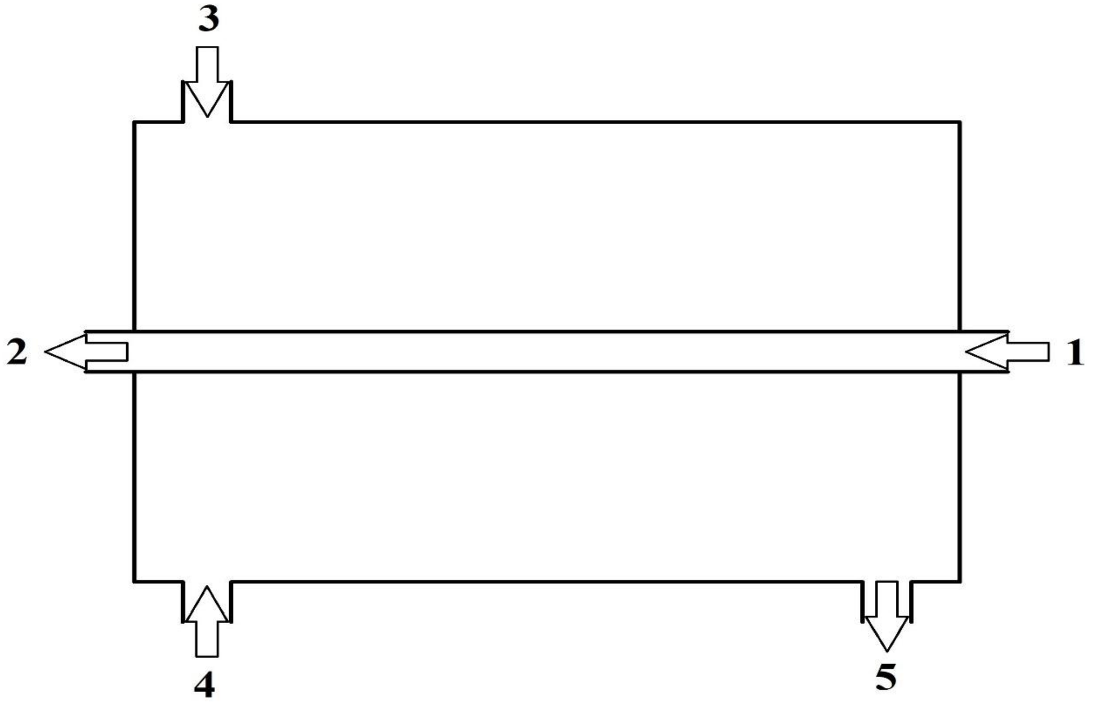
HPH 1 Analysis Result





HPH 2

Figure shows that feed water enters from section 1 and leaves from section 2. Steam enters from section 3. hot water enters from section 4. Section 3 and 4 steam and water mix it gives heat to feed water then both become water. It leaves from section 5. In between feed water get sensible heat from steam and hot water.



HPH 2 Required Data

Mass flow rate of HPH 2 feed water in	m1	169.72 kg/s
Temperature of HPH 2 feed water in	T1	458.4 K
Enthalpy of HPH 2 feed water in	h1	795.34 kJ/kg
Entropy of HPH 2 feed water in	S1	2.17 kJ/kg K
Mass flow rate of HPH 2 feed water out	m2	169.72 kg/s
Temperature of HPH 2 feed water out	T2	495.2 K
Enthalpy of HPH 2 feed water out	h2	958.18 kJ/kg
Entropy of HPH 2 feed water out	S2	2.51 kJ/kg K
Mass flow rate of HPH 2 steam in	m3	11.86 kg/s
Temperature of HPH 2 steam in	T3	582.2 K
Enthalpy of HPH 2 steam in	h3	3.34.85 kJ/kg
Entropy of HPH 2 steam in	S3	6.65 kJ/kg

HPH 2 Required Data

Mass flow rate of HPH 2 hot water in	$m4$	9.28 kg/s
Temperature of HPH 2 hot water in	$T4$	499.7 K
Enthalpy of HPH 2 hot water in	$h4$	1000.45 kJ/kg
Entropy of HPH 2 hot water in	$S4$	2.62 kJ/kg K
Mass flow rate of HPH 2 water out	$m5$	21.14 kg/s
Temperature of HPH 2 water out	$T5$	460.4 K
Enthalpy of HPH 2 water out	$h5$	832.18 kJ/kg
Entropy of HPH 2 water out	$S5$	2.30 kJ/kg K

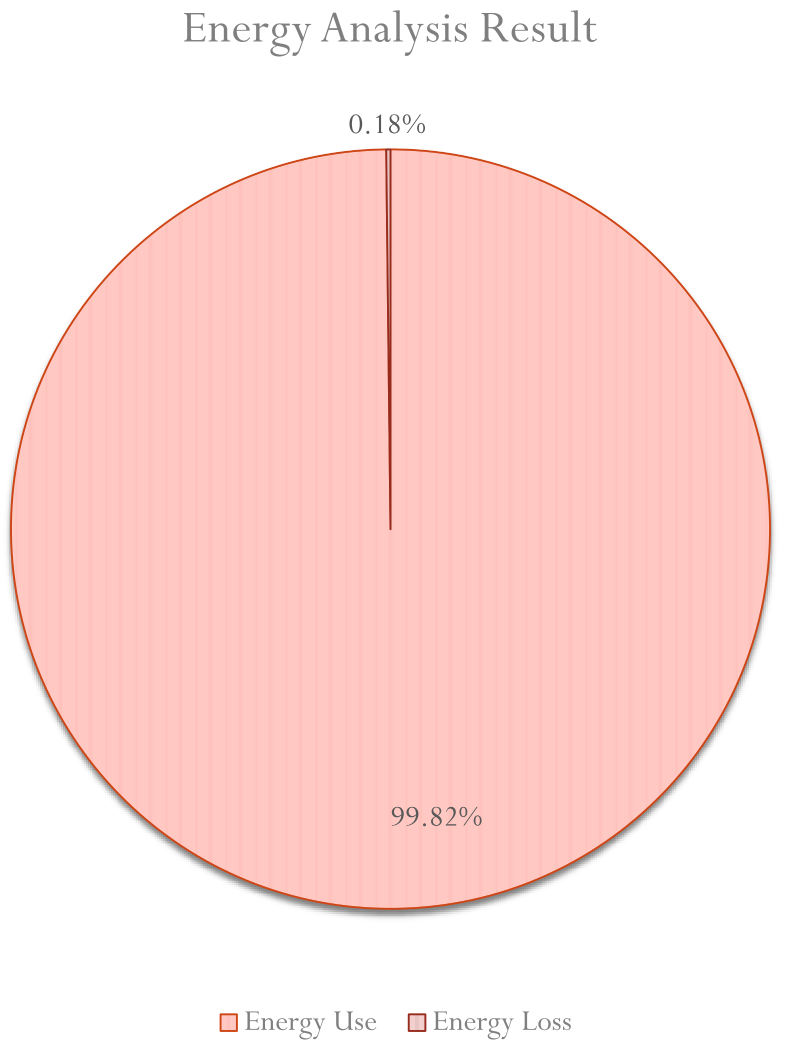
Energy Analysis of HPH 2

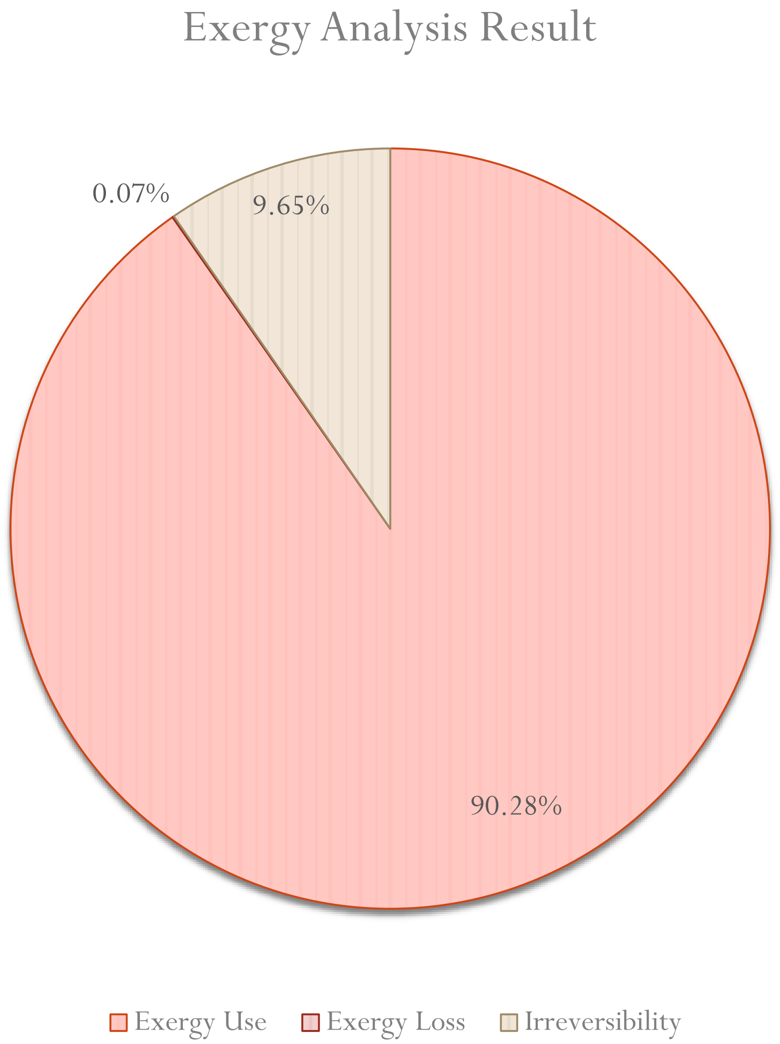
Energy in	Energy out	Energy loss (Q_L)	Efficiency (η_I)
27687.39 kJ/s	27636.79 kJ/s	50.60 kJ/s	99.82%

Exergy Analysis of HPH 2

Exergy in	Exergy out	Exergy loss	Irreversibility	Efficiency(η_{II})
11324.32 kJ/s	10223.29 kJ/s	7.60 kJ/s	1093.43 kJ/s	90.28%

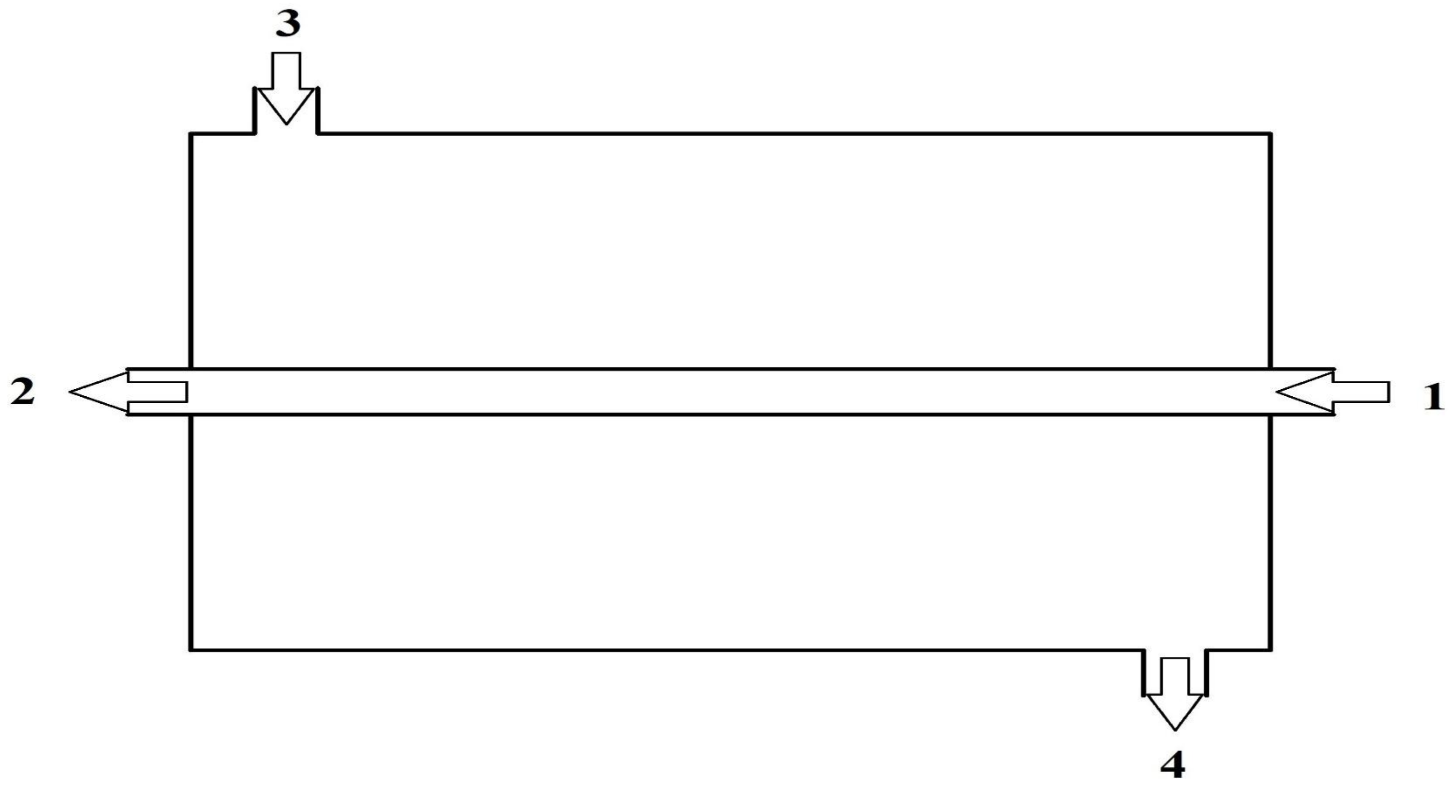
HPH 2 Analysis Result





HPH 3

Figure shows that feed water enters from section 1 and leaves from section 2. Steam enters from section 3. Section 3 steam gives heat to feed water then become water. It leaves from section 4. In between feed water get sensible heat from steam.



HPH 3 Required Data

Mass flow rate of HPH 3 feed water in	m1	169.72 kg/s
Temperature of HPH 3 feed water in	T1	495.2 K
Enthalpy of HPH 3 feed water in	h1	958.18 kJ/kg
Entropy of HPH 3 feed water in	S1	2.51 kJ/kg K
Mass flow rate of HPH 3 feed water out	m2	169.72 kg/s
Temperature of HPH 3 feed water out	T2	520.4 K
Enthalpy of HPH 3 feed water out	h2	1074.13 kJ/kg
Entropy of HPH 3 feed water out	S2	2.74 kJ/kg K
Mass flow rate of HPH 3 steam in	m3	9.28 kg/s
Temperature of HPH 3 steam in	T3	633.4 K
Enthalpy of HPH 3 steam in	h3	3122.76 kJ/kg
Entropy of HPH 3 steam in	S3	6.62 kJ/kg K
Mass flow rate of HPH 3 water out	m4	9.28 kg/s
Temperature of HPH 3 water out	T4	499.7 K
Enthalpy of HPH 3 water out	h4	1000.45 kJ/kg
Entropy of HPH 3 water out	S4	2.62 kJ/kg K

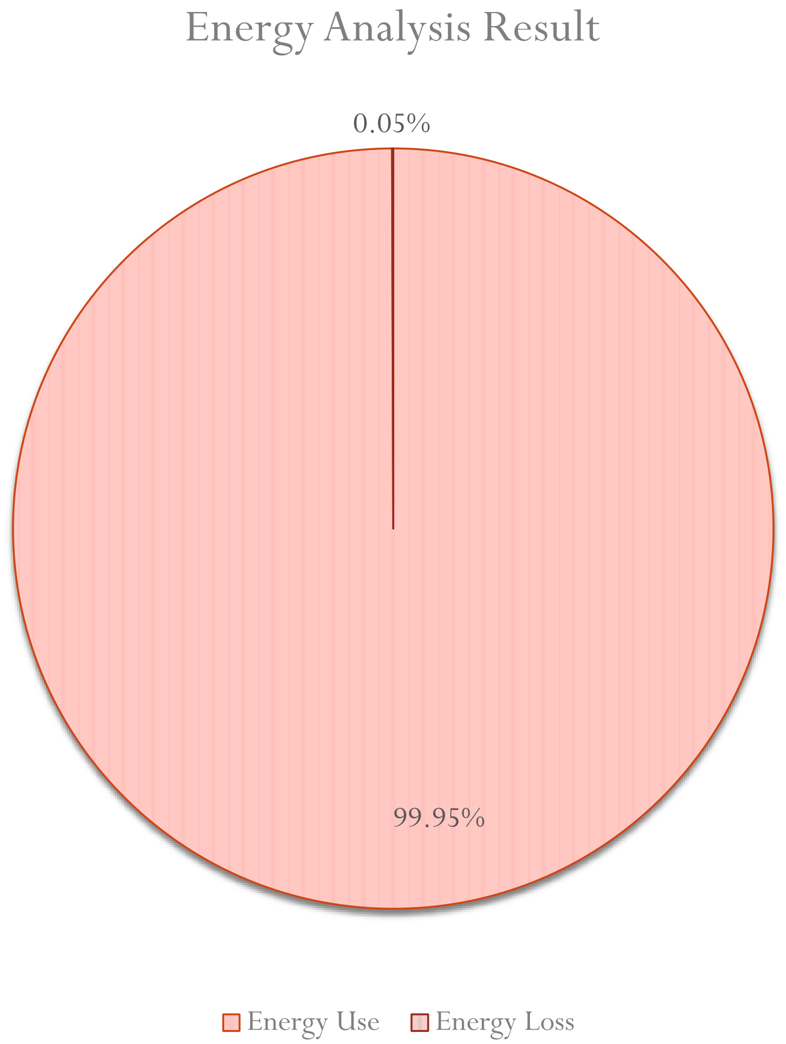
Energy Analysis of HPH 3

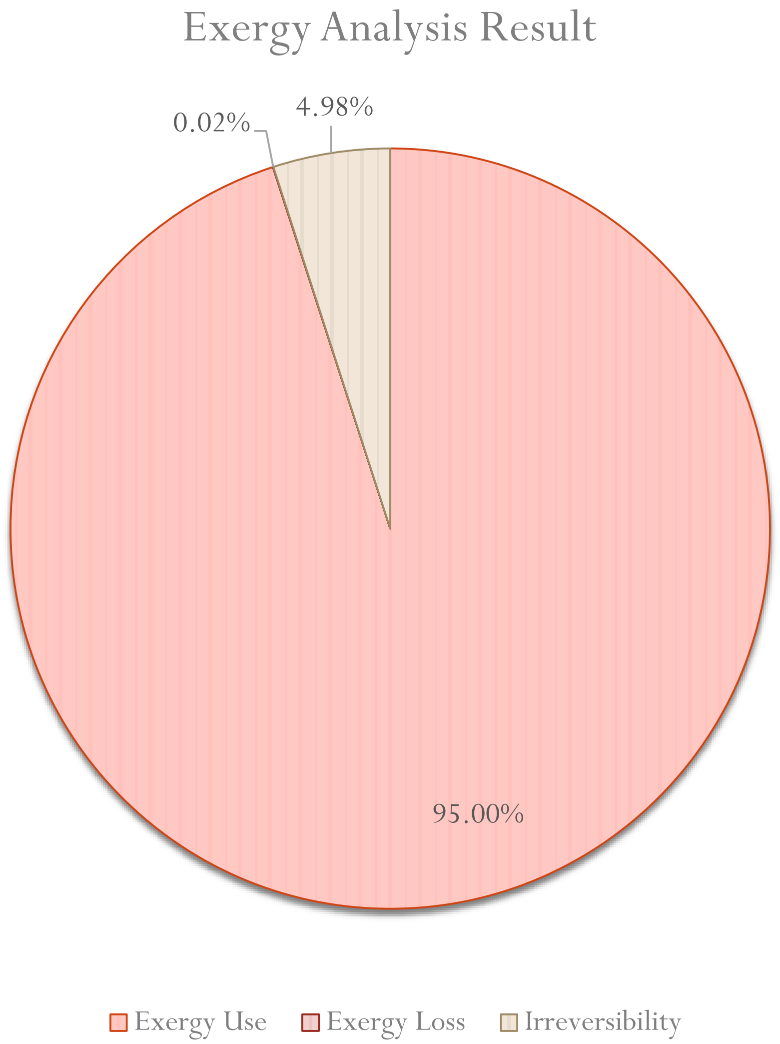
Energy in	Energy out	Energy loss (Q_L)	Efficiency (η_I)
19690.25 kJ/s	19679.67 kJ/s	10.58 kJ/s	99.95%

Exergy Analysis of HPH 3

Exergy in	Exergy out	Exergy loss	Irreversibility	Efficiency(η_{II})
8548.56 kJ/s	8121.58 kJ/s	1.59 kJ/s	425.39 kJ/s	95.01%

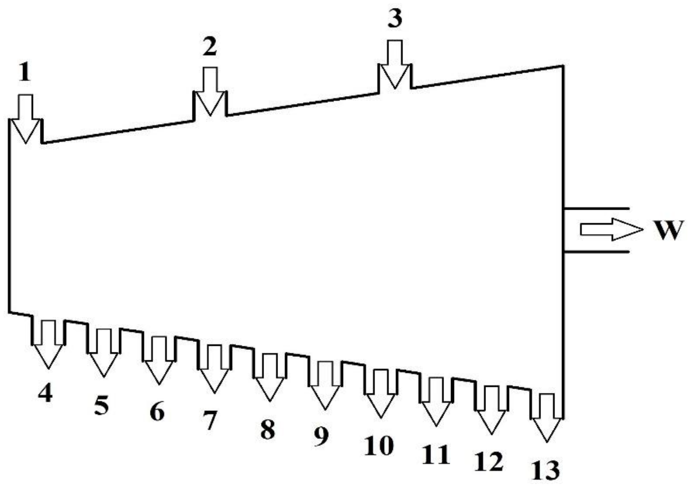
HPH 3 Analysis Result





Turbine

Figure shows that super-heated steam in HP turbine enters from section 1, reheated steam in IP turbine enters from section 2, Steam in LP turbine enters from section 3. Steam leaves by extraction in HP turbine from section 4 and section 5. Steam leaves in HP turbine from section 6. Steam leaves by extraction in IP turbine from section 7, section 8, section 9 and section 10. Steam leaves in IP turbine from section 11. Steam leaves by extraction in LP turbine by section 12. Steam leaves in IP turbine from section 13. In between thermal energy are converted to mechanical work.



Turbine Required Data

Mass flow rate of HP turbine steam in	m1	169.72 kg/s
Temperature of HP turbine steam in	T1	808 K
Enthalpy of HP turbine steam in	h1	3433.78 kJ/kg
Entropy of HP turbine steam in	S1	6.56 kJ/kg K
Mass flow rate of IP turbine steam in	m2	147.22 kg/s
Temperature of IP turbine steam in	T2	808 K
Enthalpy of IP turbine steam in	h2	3541.36 kJ/kg
Entropy of IP turbine steam in	S2	7.44 kJ/kg K
Mass flow rate of LP turbine steam in	m3	124.53 kg/s
Temperature of LP turbine steam in	T3	438.4 K
Enthalpy of LP turbine steam in	h3	2804.62 kJ/kg
Entropy of LP turbine steam in	S3	7.55 kJ/kg K

Turbine Required Data

Mass flow rate of HP turbine steam extraction 1	m4	9.28 kg/s
Temperature of HP turbine steam extraction 1	T4	634.1 K
Enthalpy of HP turbine steam extraction 1	h4	3118.99 kJ/kg
Entropy of HP turbine steam extraction 1	S4	6. 06 kJ/kg K
Mass flow rate of HP turbine steam extraction 2	m5	13.22 kg/s
Temperature of HP turbine steam extraction 2	T5	582.2 K
Enthalpy of HP turbine steam extraction 2	h5	3027.73 kJ/kg
Entropy of HP turbine steam extraction 2	S5	6.65 kJ/kg K
Mass flow rate of HP turbine steam out	m6	147.22 kg/s
Temperature of HP turbine steam out	T6	583 K
Enthalpy of HP turbine steam out	h6	3027.73 kJ/kg
Entropy of HP turbine steam out	S6	6.63 kJ/kg K

Turbine Required Data

Mass flow rate of IP turbine steam extraction 1	m7	4.50 kg/s
Temperature of IP turbine steam extraction 1	T7	710.4 K
Enthalpy of IP turbine steam extraction 1	h7	3340.43 kJ/kg
Entropy of IP turbine steam extraction 1	S7	7.49 kJ/kg K
Mass flow rate of IP turbine steam extraction 2	m8	6.69 kg/s
Temperature of IP turbine steam extraction 2	T8	623.3 K
Enthalpy of IP turbine steam extraction 2	h8	3165.03 kJ/kg
Entropy of IP turbine steam extraction 2	S8	7.50 kJ/kg K
Mass flow rate of IP turbine steam extraction 3	m9	6.47 kg/s
Temperature of IP turbine steam extraction 3	T9	531.4 K
Enthalpy of IP turbine steam extraction 3	h9	2983.78 kJ/kg
Entropy of IP turbine steam extraction 3	S9	7.52 kJ/kg K

Turbine Required Data

Mass flow rate of IP turbine steam extraction 4	m10	5.03 kg/s
Temperature of IP turbine steam extraction 4	T10	516 K
Enthalpy of IP turbine steam extraction 4	h10	2959.08 kJ/kg
Entropy of IP turbine steam extraction 4	S10	7.88 kJ/kg K
Mass flow rate of IP turbine steam out	m11	124.53 kg/s
Temperature of IP turbine steam out	T11	438.4 K
Enthalpy of IP turbine steam out	h11	2804.62 kJ/kg
Entropy of IP turbine steam out	S11	7.55 kJ/kg K
Mass flow rate of LP turbine steam extraction 1	m12	5.36 kg/s
Temperature of LP turbine steam extraction 1	T12	357.9 K
Enthalpy of LP turbine steam extraction 1	h12	2652.25 kJ/kg
Entropy of LP turbine steam extraction 1	S12	7.62 kJ/kg K
Mass flow rate of LP turbine steam out	m13	119177 kg/s
Temperature of LP turbine steam out	T13	319.9 K
Enthalpy of LP turbine steam out	h13	2437.09 kJ/kg
Entropy of LP turbine steam out	s13	7.609 kJ/kg K

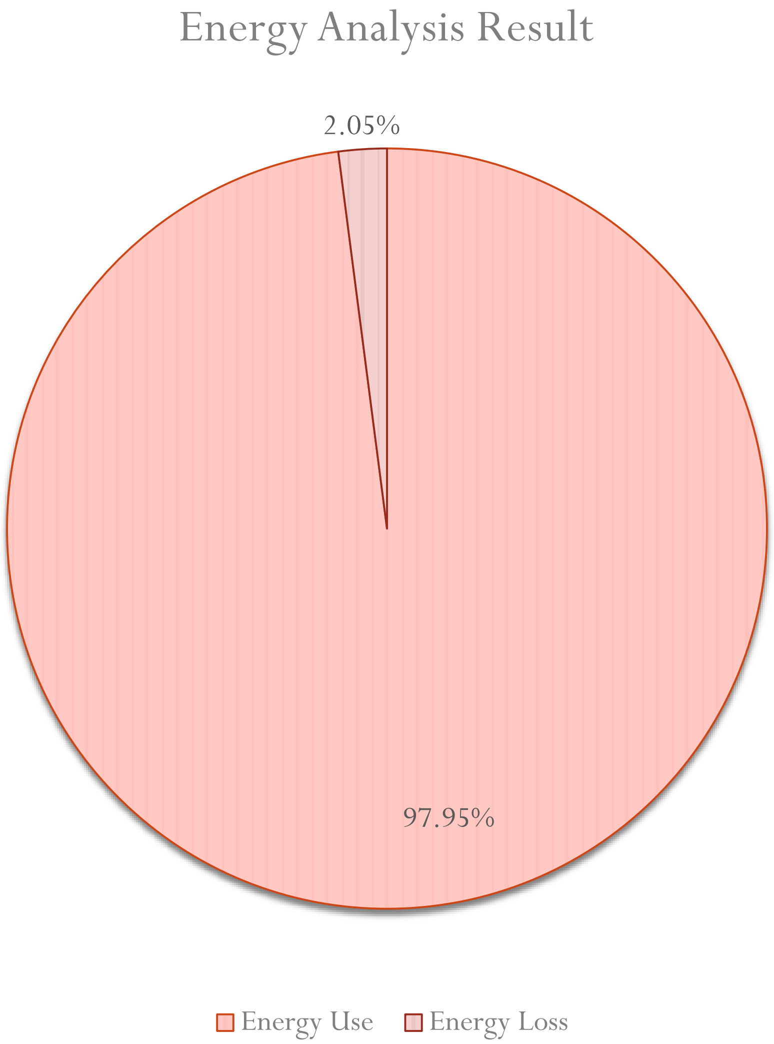
Energy Analysis of Turbine

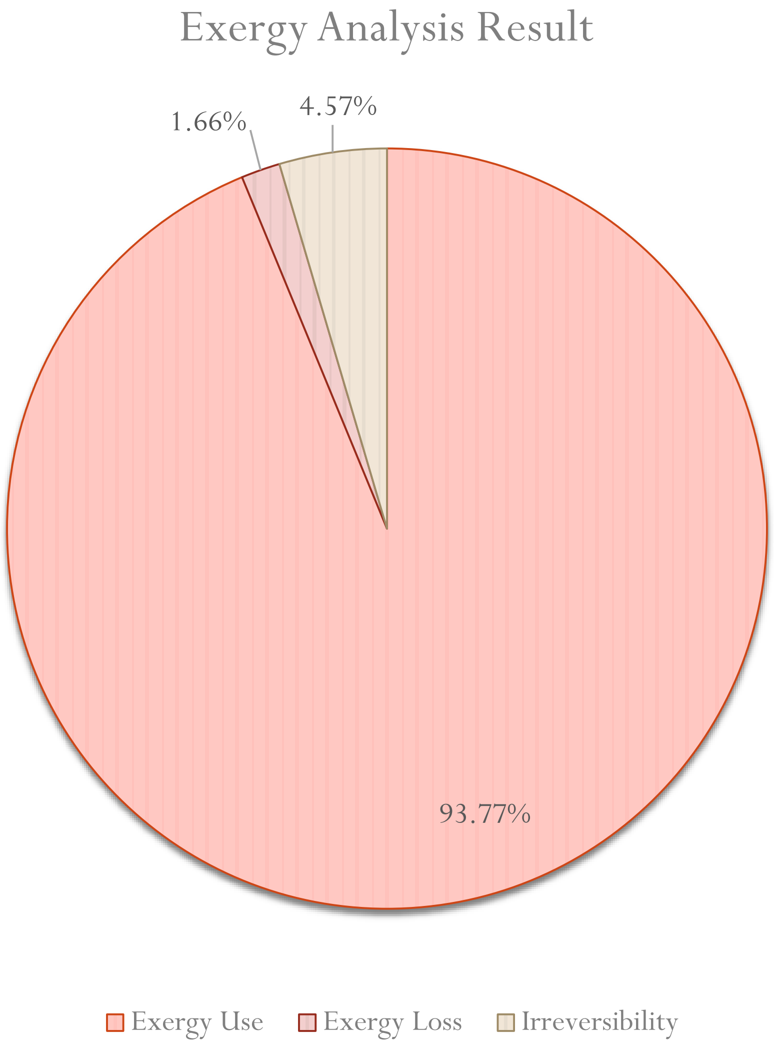
Energy in	Energy out	Energy loss (Q_L)	Efficiency (η_I)
21435.83 kJ/s	210000 kJ/s	4385.83 kJ/s	97.95%

Exergy Analysis of Turbine

Exergy in	Exergy out	Exergy loss	Irreversibility	Efficiency(η_{II})
223962.12 kJ/s	210000 kJ/s	3727.33 kJ/s	10234.79 kJ/s	93.77%

Turbine Analysis Result





Conclusion

- Coal Analysis result gives good quality coal generate less ash and its calorific value is high. Best quality coal which is use in Wanakbori Thermal Power Plant is imported coal.
- Boiler performance evaluated using direct and indirect method. Both methods gives similar efficiency.
- Based on indirect method it is found that loss due to flue gas and moisture is higher.
- Energy efficiency of component is in most of cases is more than Exergy efficiency of the component of Thermal Power Plant.
- By Finding Energy Efficiency and Exergy Efficiency component wise we get component performance.
- It is found that all component performance is good.

Future work

- To do component wise exergy and energy analysis of remaining components of boiler.
- To find exergy and energy analysis at various load of Thermal Power Plant.

References

- Erdem, H. H., Akkaya, A. V., Cetin, B., Dagdas, A., Sevilgen, S. H., Sahin, B., … Atas, S. (2009). Comparative energetic and exergetic performance analyses for coal-fired thermal power plants in Turkey. *International Journal of Thermal Sciences*, *48*(11), 2179–2186.
- Aljundi, I. H. (2009). Energy and exergy analysis of a steam power plant in Jordan. *Applied Thermal Engineering*, *29*(2–3), 324–328.
- Regulagadda, P., Dincer, I., & Naterer, G. F. (2010). Exergy analysis of a thermal power plant with measured boiler and turbine losses. *Applied Thermal Engineering*, *30*(8–9), 970–976.
- Ganapathy, T., Alagumurthi, N., Gakkhar, R. P., & Murugesan, K. (2009). Exergy analysis of operating lignite fired thermal power plant. *Journal of Engineering Science and Technology Review*, *2*(1), 123–130.
- P. K. Nag (2005). Engineering Thermodynamics *third edition Tata McGraw-Hill Education.*

THANK YOU