# 4. ENERGY PERFORMANCE ASSESSMENT OF HEAT EXCHANGERS

## 4.1 Introduction

Heat exchangers are equipment that transfer heat from one medium to another. The proper design, operation and maintenance of heat exchangers will make the process energy efficient and minimize energy losses. Heat exchanger performance can deteriorate with time, off design operations and other interferences such as fouling, scaling etc. It is necessary to assess periodically the heat exchanger performance in order to maintain them at a high efficiency level. This section comprises certain proven techniques of monitoring the performance of heat exchangers, coolers and condensers from observed operating data of the equipment.

## 4.2 Purpose of the Performance Test

To determine the overall heat transfer coefficient for assessing the performance of the heat exchanger. Any deviation from the design heat transfer coefficient will indicate occurrence of fouling.

## 4.3 Performance Terms and Definitions

**Overall heat transfer coefficient, U**

Heat exchanger performance is normally evaluated by the overall heat transfer coefficient *U that* is defined by the equation

$$\boxed{Q = U \times A \times LMTD}$$

**Where**
**Q** = Heat transferred in **kCal/hr**
**A** = Heat transfer surface area in **m$^2$**
**LMTD** = Log Mean Temperature Difference in $^0$C
**U** = Overall heat transfer Coefficient **kCal/hr/m$^2$/$^0$C**

When the hot and cold stream flows and inlet temperatures are constant, the heat transfer coefficient may be evaluated using the above formula. It may be observed that the heat pick up by the cold fluid starts reducing with time.

**Nomenclature**

A typical heat exchanger is shown in figure 4.1 with nomenclature.

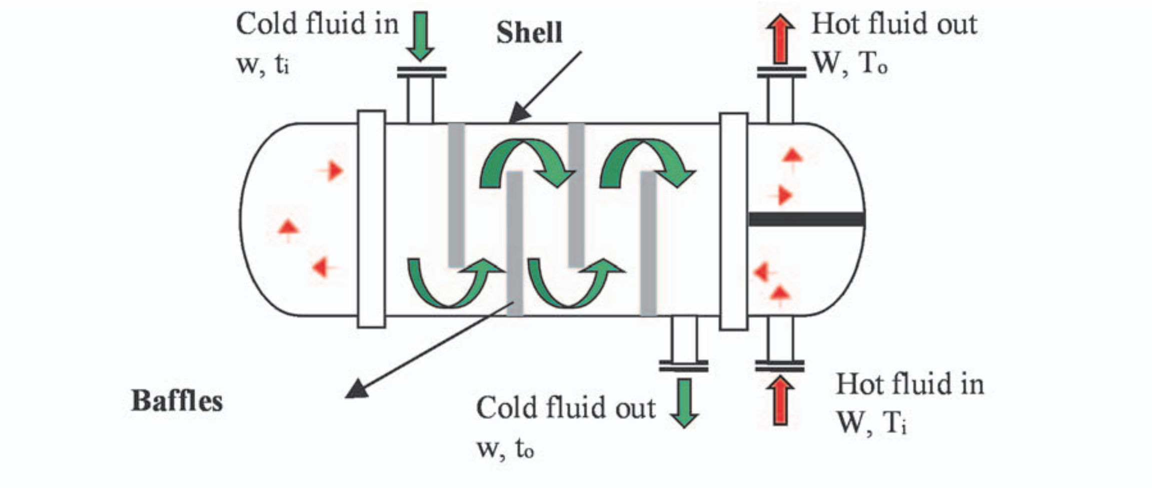


**Figure 4.1 Typical Shell and Tube Heat Exchanger**

Heat duty of the exchanger can be calculated either on the hot side fluid or cold side fluid as given below.

Heat Duty for Hot fluid, $Q_h = W_x C_{ph} \text{ x } (T_i – T_o)$ ..........Eqn–1,

Heat Duty for Cold fluid, $Q_c = wx C_{pc} \text{ x } (t_o – t_i)$ ...........Eqn–2

If the operating heat duty is less than design heat duty, it may be due to heat losses, fouling in tubes, reduced flow rate (hot or cold) etc. Hence, for simple performance monitoring of exchanger, efficiency may be considered as factor of performance irrespective of other parameter. However, in industrial practice, fouling factor method is more predominantly used.

## 4.4 Methodology of Heat Exchanger Performance Assessment

### 4.4.1 Procedure for determination of Overall heat transfer Coefficient, U at field

This is a fairly rigorous method of monitoring the heat exchanger performance by calculating the overall heat transfer coefficient periodically. Technical records are to be maintained for all the exchangers, so that problems associated with reduced efficiency and heat transfer can be identified easily. The record should basically contain historical heat transfer coefficient data versus time / date of observation. A plot of heat transfer coefficient versus time permits rational planning of an exchanger-cleaning program.

The heat transfer coefficient is calculated by the equation

$$U = Q / (A \text{ x } LMTD)$$

Where Q is the heat duty, A is the heat transfer area of the exchanger and LMTD is temperature driving force.

The step by step procedure for determination of Overall heat transfer Coefficient are described below

### Step – A

**Monitoring and reading of steady state parameters of the heat exchanger under evaluation are tabulated as below:**

| Parameters | Units | Inlet | Outlet |
|---|---|---|---|
| Hot fluid flow,W | kg/h | | |
| Cold fluid flow,w | kg/h | | |
| Hot fluid Temp, T | °C | | |
| Cold fluid Temp,t | °C | | |
| Hot fluid Pressure,P | bar g | | |
| Cold fluid Pressure, p | bar g | | |

### Step – B

**With the monitored test data, the physical properties of the stream can be tabulated as required for the evaluation of the thermal data**

| Parameters | Units | Inlet | Outlet |
|---|---|---|---|
| Hot fluid density, $\rho_h$ | kg/m$^3$ | | |
| Cold fluid density, $\rho_c$ | kg/m$^3$ | | |
| Hot fluid Viscosity, $\mu_h$ | MpaS* | | |
| Cold fluid Viscosity, $\mu_c$ | MPaS | | |
| Hot fluid Thermal Conductivity, $k_h$ | kW/(m. K) | | |
| Cold fluid Thermal Conductivity, $k_c$ | kW/(m. K) | | |
| Hot fluid specific heat Capacity, $C_{ph}$ | kJ/(kg. K) | | |
| Cold fluid specific heat Capacity, $C_{pc}$ | kJ/(kg. K) | | |

* MpaS – Mega Pascal Second

Density and viscosity can be determined by analysis of the samples taken from the flow stream at the recorded temperature in the plant laboratory. Thermal conductivity and specific heat capacity if not determined from the samples can be collected from handbooks.

### Step – C

**Calculate the thermal parameters of heat exchanger and compare with the design data**

| Parameters | Units | Test Data | Design Data |
|---|---|---|---|
| Heat Duty, Q | kW | | |
| Hot fluid side pressure drop, $\Delta P_h$ | bar | * | |
| Cold fluid side pressure drop, $\Delta P_c$ | bar | * | |

| | | | |
|---|---|---|---|
| Temperature Range hot fluid , $\Delta T$ | $^{O}C$ | | |
| Temperature Range cold fluid , $\Delta t$ | $^{O}C$ | | |
| Capacity ratio, R | ----- | | |
| Effectiveness, S | ----- | | |
| Corrected LMTD, MTD | $^{O}C$ | | |
| Heat Transfer Coefficient, U | kW/($m^2$. K) | | |

* - The pressure drop for the design flow can be rated with the relation
Pressure drop is proportional to $(\text{Flow})^{1.75}$

**Step – D**

**The following formulae are used for calculating the thermal parameters:**

1. Heat Duty, $Q = q_s + q_l$

Where,
$q_s$ is the sensible heat and $q_l$ is the latent heat

**For Senisble heat**

$q_s =$ W x $C_{ph}$ x$(T_i - T_o)$/1000/3600 in kW

(or)

$q_s =$ w x $C_{pc}$ x $(t_o - t_i)$/1000/3600 in kW

**For Latent heat**

$q_l =$ W x $\lambda_h$ ,

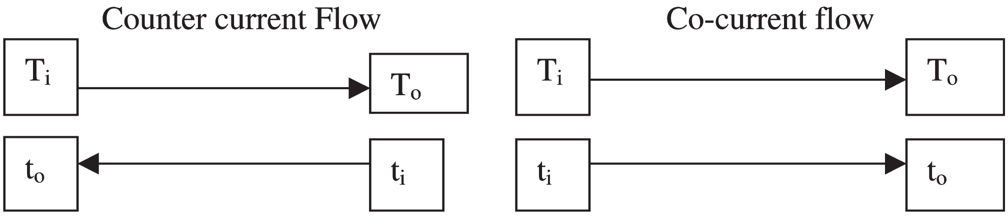
$\lambda_h$ – Latent heat of Condensation of a hot condensing vapor

(or)
$q_l =$ w x $\lambda_c$ , where $\lambda_c$ - Latent heat of Vaporization

2. Hot Fluid Pressure Drop, $\Delta P_h = P_i - P_o$
3. Cold fluid pressure drop, $\Delta P_c = p_i - p_o$
4. Temperature range hot fluid, $\Delta T = T_i - T_o$
5. Temperature range cold fluid, $\Delta t = t_o - t_i$
6. Capacity ratio, R = W x $C_{Ph}$ / w $C_{pc}$ (or) $(T_i - T_o) / (t_o - t_i)$
7. Effectiveness, $S = (t_o - t_i) / (T_i - t_i)$

8. LMTD

a)



LMTD Counter current Flow = $((T_i\text{-}t_o) – (T_o\text{-}t_i)) / \ln ((T_i\text{-}t_o)/(T_o\text{-}t_i))$
LMTD Co current Flow = $((T_i\text{-}t_i) – (T_o\text{-}t_o)) / \ln ((T_i\text{-}t_i)/(T_o\text{-}t_o))$

b) Correction factor for LMTD to account for Cross flow

$$F = \frac{(R + 1)^{1/2} \times \ln ((1- SR)/ (1- S ))}{( 1 – R) \times \ln \left\{ \frac{2- S ( R + 1 – (R +1)^{1/2})}{2- S ( R + 1 + (R +1)^{1/2})} \right\}}$$

9. Corrected LMTD

= F x LMTD

10. Overall Heat Transfer Co-efficient

U = Q / (A x Corrected LMTD)

### 4.4.2 Examples

### a. Liquid - Liquid Exchanger

A shell and tube exchanger of following configuration is considered being used for oil cooler with oil at the shell side and cooling water at the tube side.

**Tube Side**

- 460 Nos x 25.4mmOD x 2.11mm thick x 7211mm long
- Pitch - 31.75mm 30° triangular
- 2 Pass

**Shell Side**

- 787 mm ID
- Baffle space - 787 mm
- 1 Pass

The monitored parameters are as below:

| Parameters | Units | Inlet | Outlet |
|---|---|---|---|
| Hot fluid flow, W | kg/h | 719800 | 719800 |
| Cold fluid flow, w | kg/h | 881150 | 881150 |
| Hot fluid Temp, T | $^{O}$C | 145 | 102 |
| Cold fluid Temp, t | $^{O}$C | 25.5 | 49 |
| Hot fluid Pressure, P | bar g | 4.1 | 2.8 |
| Cold fluid Pressure, p | bar g | 6.2 | 5.1 |

**Calculation of Thermal data:**

Heat Transfer Area = 264.55 $m^2$

1. Heat Duty:

$Q = q_s + q_l$

Hot fluid, Q = 719800 x 2.847 x (145 –102) / 3600 = 24477.4 kW

Cold Fluid, Q = 881150 x 4.187 x (49 – 25.5) / 3600 = 24083.4 kW

2. Hot Fluid Pressure Drop

Pressure Drop = $P_i - P_o$ = 4.1 – 2.8 = 1.3 bar g.

3. Cold Fluid Pressure Drop

Pressure Drop = $p_i - p_o$ = 6.2 – 5.1 = 1.1 bar g.

4. Temperature range hot fluid

Temperature Range $\Delta T = T_i - T_o$ = 145 – 102 = 43 $^{o}$ C.

5. Temperature Range Cold Fluid

Temperature Range $\Delta t = t_o - t_i$ = 49 – 25.5 = 23.5 $^{0}$C.

6. Capacity Ratio

Capacity ratio, R = (Ti-To) / ($t_o$-$t_i$) = 43 / 23.5 = 1.83

7. Effectiveness

Effectiveness, S = $(t_o - t_i) / (T_i - t_i)$ =(49 – 25.5)/(145-25.5) =23.5/119.5 = 0.20.

8. LMTD

a). LMTD, Counter Flow = (96 – 76.5)/ ln (96/76.5) = 85.9 $^{0}$C.

b). Correction Factor to account for Cross flow

$$F = \frac{(R + 1)^{1/2} \text{ x } \ln((1- SR)/(1- S)}{(1 - R) \text{ x } \ln\left\{\frac{2- S(R + 1 - (R \; +1)^{1/2})}{2- S(R + 1 + (R \; +1)^{1/2)}}\right\}}$$

F = 0.977.

9. Corrected LMTD

= F x LMTD = 0.977 x 85.9 = 83.9 °C.

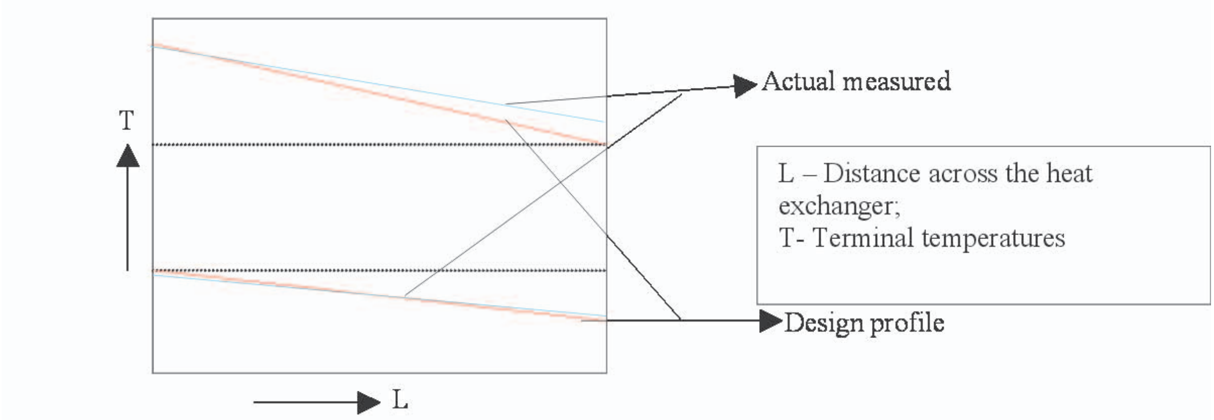
10. Overall Heat Transfer Co-efficient

$U = Q/ A \Delta T = 24477.4/ (264.55 \text{ x } 83.9) = 1.104 \text{ kW/m}^2\text{. K}$

## Comparison of Calculated data with Design Data

| Parameters | Units | Test Data | Design Data |
|---|---|---|---|
| Duty, Q | kW | 24477.4 | 25623 |
| Hot fluid side pressure drop, $\Delta P_h$ | Bar | 1.3 | 1.34 |
| Cold fluid side pressure drop, $\Delta P_c$ | Bar | 1.1 | 0.95 |
| Temperature Range hot fluid, $\Delta T$ | °C | 43 | 45 |
| Temperature Range cold fluid, $\Delta t$ | °C | 23.5 | 25 |
| Capacity ratio, R | ----- | 1.83 | 0.556 |
| Effectiveness, S | ----- | 0.20 | 0.375 |
| Corrected LMTD, MTD | °C | 83.8 | 82.2 |
| **Heat Transfer Coefficient, U** | **kW/(m². K)** | **1.104** | **1.178** |

**Inferences:**



**Heat Duty:** Actual duty differences will be practically negligible as these duty differences could be because of the specific heat capacity deviation with the temperature. Also, there could be some heat loss due to radiation from the hot shell side.

**Pressure drop:** Also, the pressure drop in the shell side of the hot fluid is reported normal (only slightly less than the design figure). This is attributed with the increased average bulk temperature of the hot side due to decreased performance of the exchanger.

**Temperature range:** As seen from the data the deviation in the temperature ranges could be due to the increased fouling in the tubes (cold stream), since a higher pressure drop is noticed.

**Heat Transfer coefficient:** The estimated value has decreased due to increased fouling that has resulted in minimized active area of heat transfer.

**Physical properties:** If available from the data or Lab analysis can be used for verification with the design data sheet as a cross check towards design considerations.

**Troubleshooting:** Fouled exchanger needs cleaning.

### b. Surface Condenser

A shell and tube exchanger of following configuration is considered being used for Condensing turbine exhaust steam with cooling water at the tube side.

Tube Side

20648 Nos x 25.4mmOD x 1.22mm thk x 18300mm long
Pitch - 31.75mm 60° triangular
1 Pass
The monitored parameters are as below:

| **Parameters** | **Units** | **Inlet** | **Outlet** |
|---|---|---|---|
| Hot fluid flow, W | kg/h | 939888 | 939888 |
| Cold fluid flow, w | kg/h | 55584000 | 55584000 |
| Hot fluid Temp, T | °C | No data | 34.9 |
| Cold fluid Temp, t | °C | 18 | 27 |
| Hot fluid Pressure, P | m Bar g | 52.3 mbar | 48.3 |
| Cold fluid Pressure, p | Bar g | 4 | 3.6 |

**Calculation of Thermal data:**

Area = 27871 $m^2$

1. Duty:

   $Q = q_S + q_L$
   Hot fluid, Q = 576990 kW
   Cold Fluid, Q = 581825.5 kW

2. Hot Fluid Pressure Drop
   Pressure Drop = $P_i - P_o$ = 52.3 – 48.3 = 4.0 mbar.
3. Cold Fluid Pressure Drop
   Pressure Drop = $p_i - p_o$ = 4 – 3.6 = 0.4 bar.
4. Temperature range hot fluid
   Temperature Range $\Delta T = T_i - T_o$ = No data
5. Temperature Range Cold Fluid
   Temperature Range $\Delta t = t_i - t_o$ = 27 – 18 = 9 °C.
6. Capacity Ratio
   Capacity ratio, R = Not significant in evaluation here.
7. Effectiveness
   Effectiveness, $S = (t_o - t_i) / (T_i - t_i)$ = Not significant in evaluation here.
8. LMTD

   Calculated considering condensing part only

   a). LMTD, Counter Flow = ((34.9 – 18)–(34.9–27))/ ln ((34.9–18)/(34.9–27))
   = 11.8 deg C.

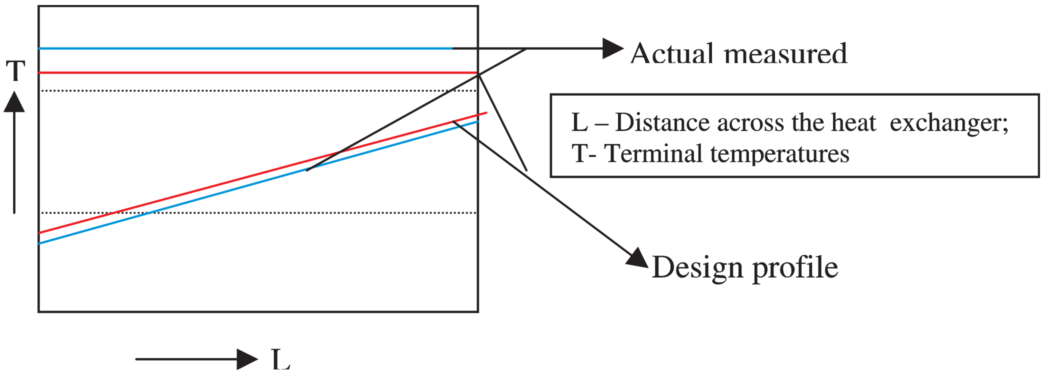
   b). Correction Factor to account for Cross flow

   F = 1.0.

9. Corrected LMTD
   MTD = F x LMTD = 1.0 x 11.8 = 11.8 deg C.
10. Heat Transfer Co-efficient
   Overall HTC, $U = Q / A \Delta T$ = 576990/ (27871 x 11.8) = 1.75 kW/$m^2$. K

**Comparison of Calculated data with Design Data**

| **Parameters** | **Units** | **Test Data** | **Design Data** |
|---|---|---|---|
| Duty, Q | kW | 576990 | 588430 |
| Hot fluid side pressure drop, $\Delta P_h$ | mBar | 4 mbar | 3.7 mbar |
| Cold fluid side pressure drop, $\Delta Pc$ | Bar | 0.4 | |
| Temperature Range hot fluid, $\Delta T$ | °C | | |
| Temperature Range cold fluid, $\Delta t$ | °C | (27–18) = 9 | (28–19) = 9 |
| Capacity ratio, R | ----- | | |
| Effectiveness, S | ----- | | |
| Corrected LMTD, MTD | °C | 11.8 | 8.9 |
| Heat Transfer Coefficient, U | kW/($m^2$. K) | 1.75 | 2.37 |



**Heat Duty:** Actual duty differences will be practically negligible as these duty differences could be because of the specific heat capacity deviation with the temperature. Also, there could be some heat loss due to radiation from the hot shell side.

**Pressure drop:** The condensing side operating pressure raised due to the backpressure caused by the non-condensable. This has resulted in increased pressure drop across the steam side

**Temperature range:** With reference to cooling waterside there is no difference in the range however, the terminal temperature differences has increased indicating lack of proper heat transfer.

**Heat Transfer coefficient:** Heat transfer coefficient has decreased due to increased amount of non-condensable with the steam.

**Trouble shooting:** Operations may be checked for tightness of the circuit and ensure proper venting of the system. The vacuum source might be verified for proper functioning.

## C. Vaporizer

A shell and tube exchanger of following configuration is considered being used for vaporizing chlorine with steam at the shell side.

Tube Side

200 Nos x 25.4mmOD x 1.22mm thick x 6000mm long
Pitch - 31.75mm 30° triangular
2 Pass
Area = 95.7.$m^2$

The monitored parameters are as below:

| Parameters | Units | Inlet | Outlet |
|---|---|---|---|
| Hot fluid flow, W | kg/h | 5015 | 5015 |
| Cold fluid flow, w | kg/h | 43500 | 43500 |
| Hot fluid Temp, T | °C | 108 | 108 |
| Cold fluid Temp, t | °C | 30 | 34 |
| Hot fluid Pressure, P | Bar g | 0.4 | 0.3 |
| Cold fluid Pressure, p | Bar g | 9 | 8.8 |

**Calculation of Thermal data:**

1. Duty:

   $Q = q_S + q_L$

   Hot fluid, Q = 3130 kW

   Cold Fluid, $Q = q_S + q_L$ = 180.3 kW + 2948 kW = 3128.3 kW

2. Hot Fluid Pressure Drop

   Pressure Drop = $P_i - P_o$ = 0.4 – 0.3 = 0.1 bar

3. Cold Fluid Pressure Drop

   Pressure Drop = $p_i - p_o$ = 9 – 8.8 = 0.2 bar.

4. Temperature range hot fluid

   Temperature Range $\Delta T = T_i - T_o = 0$ °C

5. Temperature Range Cold Fluid

   Temperature Range $\Delta t = t_i - t_o$ = 34 – 30 = 4 °C.

6. Capacity Ratio

   Capacity ratio, R = Not significant in evaluation here.

7. Effectiveness

   Effectiveness, $S = (t_o - t_i) / (T_i - t_i)$ = Not significant in evaluation here.

8. LMTD

   Calculated considering condensing part only

   a). LMTD, Counter Flow =((108 – 30)–(108–34))/ ln ((108–30)/(108–34)) = 76 °C.

   b). Correction Factor to account for Cross flow

   F = 1.0.

9. Corrected LMTD

   MTD = F x LMTD = 1.0 x 76 = 76 °C.

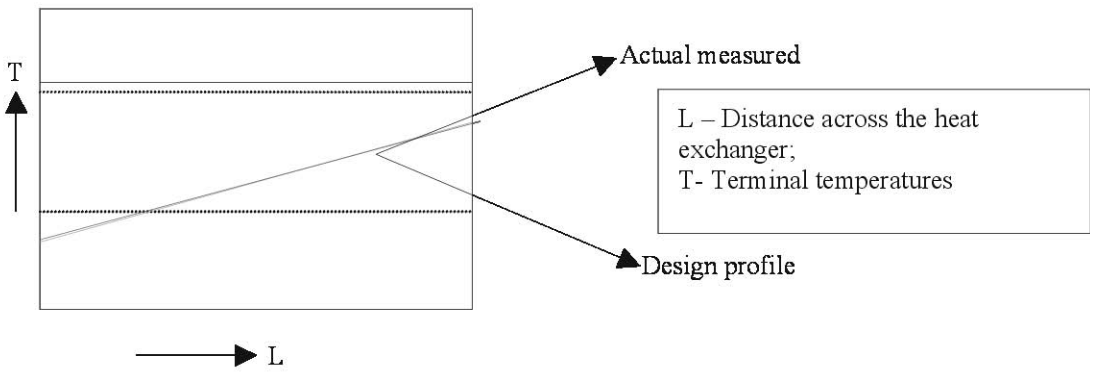
10. Heat Transfer Co-efficient

    Overall HTC, $U = Q/ A \Delta T$ = 3130/ (95.7 x 76) = 0.43 kW/$m^2$. K

## Comparison of Calculated data with Design Data

| Parameters | Units | Test Data | Design Data |
|---|---|---|---|
| Duty, Q | kW | 3130 | 3130 |
| Hot fluid side pressure drop, $\Delta P_h$ | Bar | 0.1 | Neg |
| Cold fluid side pressure drop, $\Delta P_c$ | Bar | 0.2 | |
| Temperature Range hot fluid, $\Delta T$ | °C | | |
| Temperature Range cold fluid, $\Delta t$ | °C | 4 | 4 |
| Capacity ratio, R | ----- | | |
| Effectiveness, S | ----- | | |
| Corrected LMTD, MTD | °C | 76 | |
| Heat Transfer Coefficient, U | kW/(m². K) | 0.42 | 0.44 |

**Inferences:**



**Heat Duty:** There is no difference inferred from the duty as the exchanger is performing as per the requirement

**Pressure drop:** The steam side pressure drop has increased in spite of condensation at the steam side. Indication of non-condensable presence in steam side

**Temperature range:** No deviations

Heat Transfer coefficient: Even at no deviation in the temperature profile at the chlorine side, heat transfer coefficient has decreased with an indication of overpressure at the shell side. This indicates disturbances to the condensation of steam at the shell side. Non-condensable suspected at steam side.

**Trouble shooting:** Operations may be checked for presence of chlorine at the shell side through tube leakages. Observing the steam side vent could do this. Alternately condensate pH could be tested for presence of acidity.

### d. Air heater

A finned tube exchanger of following configuration is considered being used for heating air with steam in the tube side.

The monitored parameters are as below:

| **Parameters** | **Units** | **Inlet** | **Outlet** |
|---|---|---|---|
| Hot fluid flow, W | kg/h | 3000 | 3000 |
| Cold fluid flow, w | kg/h | 92300 | 92300 |
| Hot fluid Temp, T | °C | 150 | 150 |
| Cold fluid Temp, t | °C | 30 | 95 |
| Hot fluid Pressure, P | Bar g | | |
| Cold fluid Pressure, p | mBar g | 200 mbar | 180 mbar |

Calculation of Thermal data:
Bare tube Area = 42.8 $m^2$; Fined tube area = 856 $m^2$

1.Duty:

Hot fluid, Q = 1748 kW

Cold Fluid, Q = 1726 kW

2. Hot Fluid Pressure Drop

Pressure Drop = $P_i – P_o$ = Neg

3. Cold Fluid Pressure Drop

Pressure Drop = $p_i – p_o$ = 200–180 = 20 mbar.

4. Temperature range hot fluid

Temperature Range $\Delta T = T_i – T_o$ = Not required.

5. Temperature Range Cold Fluid

Temperature Range $\Delta t = t_i – t_o$ = 95 – 30 = 65 °C.

6. Capacity Ratio

Capacity ratio, R = Not significant in evaluation here.

7. Effectiveness

Effectiveness, S = $(t_o – t_i) / (T_i – t_i)$ = Not significant in evaluation here.

8. LMTD

Calculated considering condensing part only

a). LMTD, Counter Flow =((150 – 30)–(150–95)/ ln ((150–30)/(150–95)) = 83.3 °C.

b). Correction Factor to account for cross flow

F = 0.95

9. Corrected LMTD

MTD = F x LMTD = 0.95 x 83.3 = 79 °C.

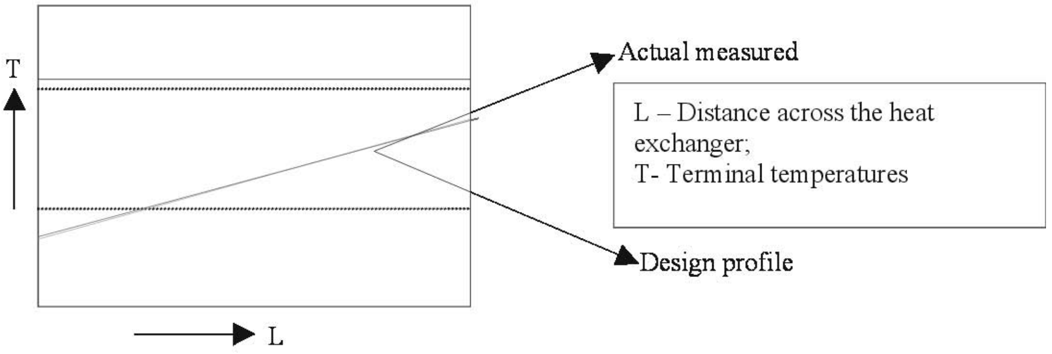
10. Overall Heat Transfer Co-efficient (HTC)

U = Q/ A $\Delta T$ = 1748/ (856 x 79) = 0.026 kW/$m^2$. K

## Comparison of Calculated data with Design Data

| Parameters | Units | Test Data | Design Data |
|---|---|---|---|
| Duty, Q | kW | 1748 | 1800 |
| Hot fluid side pressure drop, $\Delta P_h$ | Bar | Neg | Neg |
| Cold fluid side pressure drop, $\Delta P_c$ | Bar | 20 | 15 |
| Temperature Range hot fluid, $\Delta T$ | °C |  |  |
| Temperature Range cold fluid, $\Delta t$ | °C | 65 | 65 |
| Capacity ratio, R | ----- |  |  |
| Effectiveness, S | ----- |  |  |
| Corrected LMTD, MTD | °C | 79 | 79 |
| Heat Transfer Coefficient, U | kW/($m^2$. K) | 0.026 | 0.03 |

**Inferences:**



**<u>Heat Duty</u>:** The difference inferred from the duty as the exchanger is under performing than required

**<u>Pressure drop</u>:** The airside pressure drop has increased in spite of condensation at the steam side. Indication of choking and dirt blocking at the airside.

**<u>Temperature range</u>:** No deviations

**<u>Heat Transfer coefficient</u>:** Decreased because of decreased fin efficiency due to choking on air side.

**<u>Trouble shooting</u>:** Operations may be checked to perform pulsejet cleaning with steam / blow air jet on air side if the facility is available. Mechanical cleaning may have to be planned during any down time in the immediate future.

## 4.4.3 Instruments for monitoring:

The test and evaluation of the performance of the heat exchanger equipment is carried out by measurement of operating parameters upstream and downstream of the exchanger. Due care needs to be taken to ensure the accuracy and correctness of the measured parameter. The instruments used for measurements require calibration and verification prior to measurement.

| Parameters | Units | Instruments used |
|---|---|---|
| Fluid flow | kg/h | Flow can be measured with instruments like Orifice flow meter, Vortex flow meter, Venturi meters, Coriollis flow meters, Magnetic flow meter<br>as applicable to the fluid service and flow ranges |
| Temperature | °C | Thermo gauge for low ranges, RTD, etc. |
| Pressure | Bar g | Liquid manometers, Draft gauge, Pressure gauges Bourdon and diaphragm type, Absolute pressure transmitters, etc. |
| Density | $kg/m^3$ | Measured in the Laboratory as per ASTM standards, hydrometer, etc |
| Viscosity | MpaS | Measured in the Laboratory as per ASTM standards, viscometer, etc. |
| Specific heat capacity | J/(kg.K) | Measured in the Laboratory as per ASTM standards |
| Thermal conductivity | W/(m.K) | Measured in the Laboratory as per ASTM standards |
| Composition+ | %wt (or) % Vol | Measured in the Laboratory as per ASTM standards using Chemical analysis, HPLC, GC, Spectrophotometer, etc. |

### 4.4.4 Terminology used in Heat Exchangers

| Terminology | Definition | Unit |
|---|---|---|
| Capacity ratio | Ratio of the products of mass flow rate and specific heat capacity of the cold fluid to that of the hot fluid.<br>Also computed by the ratio of temperature range of the hot fluid to that of the cold fluid.<br>Higher the ratio greater will be size of the exchanger | |
| Co current flow exchanger | An exchanger wherein the fluid flow direction of the cold and hot fluids are same | |
| Counter flow exchanger | Exchangers wherein the fluid flow direction of the cold and hot fluids are opposite. Normally preferred | |
| Cross flow | An exchanger wherein the fluid flow direction of the cold and hot fluids are in cross | |

| | | |
|---|---|---|
| Density | It is the mass per unit volume of a material | $kg/m^3$ |
| Effectiveness | Ratio of the cold fluid temperature range to that of the inlet temperature difference of the hot and cold fluid. Higher the ratio lesser will be requirement of heat transfer surface | |
| Fouling | The phenomenon of formation and development of scales and deposits over the heat transfer surface diminishing the heat flux. The process of fouling will get indicated by the increase in pressure drop | |
| Fouling Factor | The reciprocal of heat transfer coefficient of the dirt formed in the heat exchange process. Higher the factor lesser will be the overall heat transfer coefficient. | $(m^2.K)/W$ |
| Heat Duty | The capacity of the heat exchanger equipment expressed in terms of heat transfer rate, viz. magnitude of energy or heat transferred per time. It means the exchanger is capable of performing at this capacity in the given system | W |
| Heat exchanger | Refers to the nomenclature of equipment designed and constructed to transmit heat content (enthalpy or energy) of a comparatively high temperature hot fluid to a lower temperature cold fluid wherein the temperature of the hot fluid decreases (or remain constant in case of losing latent heat of condensation) and the temperature of the cold fluid increases (or remain constant in case of gaining latent heat of vaporisation). A heat exchanger will normally provide indirect contact heating. E.g. A cooling tower cannot be called a heat exchanger where water is cooled by direct contact with air | |
| Heat Flux | The rate of heat transfer per unit surface of a heat exchanger | $W/ m^2$ |
| Heat transfer | The process of transport of heat energy from a hot source to the comparatively cold surrounding | |
| Heat transfer surface or heat Transfer area | Refers to the surface area of the heat exchanger that provides the indirect contact between the hot and cold fluid in effecting the heat transfer. Thus the heat transfer area is defined as the surface having both sides wetted with one side by the hot fluid and the other side by the cold fluid providing indirect contact for heat transfer | $m^2$ |
| Individual Heat transfer Coefficient | The heat flux per unit temperature difference across boundary layer of the hot / cold fluid film formed at the heat transfer surface. The magnitude of heat transfer coefficient indicates the ability of heat conductivity of the given fluid. It increases with increase in density, velocity, specific heat, geometry of the film forming surface | $W/( m^2.K)$ |

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| LMTD Correction factor | Calculated considering the Capacity and effectiveness of a heat exchanging process. When multiplied with LMTD gives the corrected LMTD thus accounting for the temperature driving force for the cross flow pattern as applicable inside the exchanger | |
| Logarithmic Mean Temperature difference, LMTD | The logarithmic average of the terminal temperature approaches across a heat exchanger | °C |
| Overall Heat transfer Coefficient | The ratio of heat flux per unit difference in approach across a heat exchange equipment considering the individual coefficient and heat exchanger metal surface conductivity. The magnitude indicates the ability of heat transfer for a given surface. Higher the coefficient lesser will be the heat transfer surface requirement | W/(m$^2$.K) |
| Pressure drop | The difference in pressure between the inlet and outlet of a heat exchanger | Bar |
| Specific heat capacity | The heat content per unit weight of any material per degree raise/fall in temperature | J/(kg.K) |
| Temperature Approach | The difference in the temperature between the hot and cold fluids at the inlet / outlet of the heat exchanger. The greater the difference greater will be heat transfer flux | °C |
| Temperature Range | The difference in the temperature between the inlet and outlet of a hot/cold fluid in a heat exchanger | °C |
| Terminal temperature | The temperatures at the inlet / outlet of the hot / cold fluid steams across a heat exchanger | °C |
| Thermal Conductivity | The rate of heat transfer by conduction though any substance across a distance per unit temperature difference | W/(m$^2$.K) |
| Viscosity | The force on unit volume of any material that will cause per velocity | Pa |

## QUESTIONS

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|---|---|
| 1. | What is meant by LMTD ? |
| 2. | Distinguish between heat exchanger efficiency and effectiveness. |
| 3. | Explain the terms heat duty and capacity ratio. |
| 4. | What is meant by fouling? |
| 5. | List five heat exchangers used in industrial practice. |
| 6. | What are the parameters, which are to be monitored for the performance assessment of heat exchangers? |
| 7. | In a heat exchanger the hot stream enters at 70°C and leaves at 55°C. On the other side the cold stream enters at 30°C and leaves at 55°C. Find out the LMTD of the heat exchanger. |
| 8. | In a condenser what type of heats are considered in estimating the heat duty?<br>a) Latent Heat b) Sensible heat c) Specific heat d) Latent heat and sensible heat |
| 9. | What is the need for performance assessment of a heat exchanger? |
| 10. | The unit of overall coefficient of heat transfer is<br>a) kCal/hr/$m^2$ °C b) kCal/kg °C c) kCal/$m^2$ hr d) kCal/hg $m^2$ |

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