**6. HEAT EXCHANGER**

**HEAT EXCHANGER:** Tt is a device which is used to exchange thermal energy from one fluid to another fluid either direct or indirect contact. E.g. Boiler, Condenser, Evaporator, Etc…

|  |  |
| --- | --- |
| **AREA DENSITY ():** | For Car Radiator,  For Ceramic Glass Turbine,  For Generator of Stirling engine, |

If , HE is called Compact Type HE.

**PARALLEL FLOW:** Both the Fluids moving in same direction.

**COUNTER FLOW:** Both the Fluids moving in opposite direction.

**OVERALL HEAT TRANSFER COEFFICIENT (OHTC) ():**

It’s Experimentally determined Quantity.

|  |  |
| --- | --- |
|  |  |
| Fouling Resistance () |  |
| Fouling Factor | If |

Here, Q remains the along the direction of heat transfer.

|  |  |  |
| --- | --- | --- |
| **HOLLOW CYLINDER** | **HOLLOW SPHERE** | **PLANE WALL** |
|  |  |  |

**GENERALISED RATE OF THERMAL ENERGY BALANCE:**

|  |  |
| --- | --- |
| From SFEE,  For Both the Fluid of HE, | Mass Flow rate of hot fluid and cold fluid ()  Specific heat of hot fluid and cold fluid ()  Inlet and outlet temperature of hot fluid,  Inlet and outlet temperature of cold fluid |

**HEAT CAPACITY RATE ():**

* It denotes at given time how much energy required to change a temperature by or .
* Fluid undergoes large temperature variation at a given time for a **fluid having minimum heat capacity rate**.

|  |  |
| --- | --- |
|  |  |

**HEAT CAPACITY RATIO ():**

* If , Temperature change in hot fluid and cold fluid will be same.
* In Phase change (Boiling, Evaporation, Condensation),

**ANALYSIS OF HEAT EXCHANGER:**

1. **LMTD METHOD:**

**Assumptions:**

1. 1D Heat Flow (Radial Flow)
2. Steady State
3. No internal heat generation
4. Neglect KE & PE changes
5. All thermophysical properties of fluid are constant.
6. Overall heat transfer coefficient value is constant.
7. Outer surface of heat exchanger is well insulated.
8. Radiation heat loss is neglected.
9. No Partial phase changes.

**CASE-I: DOUBLE PIPE PARALLEL FLOW HEAT EXCHANGER**

|  |  |  |
| --- | --- | --- |
|  |  | |
| |  |  | | --- | --- | |  |  |   By integration, | | By integration & Eq. (1), |
| From Equation (2) & (3), | |  |

**CASE-II: DOUBLE PIPE COUNTER FLOW HEAT EXCHANGER**

|  |  |  |
| --- | --- | --- |
|  |  | |
| |  |  | | --- | --- | |  |  |   By integration, | | By integration & Eq. (1), |
| From Equation (2) & (3), | |  |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | | |  | |
|  |  |  | |  |

|  |  |  |
| --- | --- | --- |
| **LMTD** | **AMTD** | By series expansion of ln term in LMTD, |
|  |  |
| If (Linear Profile), Else | |

**SPECIAL CASES:**

**CASE-I:** When Both fluids have equal heat capacity rate in counter flow heat exchanger.

|  |  |  |  |
| --- | --- | --- | --- |
|  |  |  |  |

In counter flow when , temperature profile is linear & parallel.

**CASE-II: Phase Change Devices ()**

**Boiler/ Evaporator:**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| For Parallel Flow and Counter Flow are same for Boiling & evaporation process.  For Evaporator,  For Condenser,   |  |  | | --- | --- | |  |  | |  | | |  |  |

**COMPARISON OF PARALLEL FLOW & COUNTER FLOW:**

|  |  |
| --- | --- |
| In parallel Flow, cannot be less than . | In Counter Flow, can be less than . |

So, Possibility in Counter Flow,

|  |  |  |
| --- | --- | --- |
|  |  | Where, |
| It may possible that, | It may possible that, |
|  |  |

* is calculated for a fluid having minimum heat capacity rate by assuming counter flow HE of infinite length.
* When is constant,

|  |  |  |
| --- | --- | --- |
|  |  |  |

* In HE, Counter Flow HE is considered as reference.

Depends on Geometry & Flow Direction.

* For counter flow or Phase change devices

**NOTE:** Parallel Flow HE is used when Oil because with increasing temperature Viscosity decreases and pump power decreases. Hence, Selection is purely depending on the Requirement.

LMTD Method is used to find surface area of HE when outlet Temp. of fluid is known ().

1. **EFFECTIVENESS () NTU METHOD:**

|  |  |
| --- | --- |
| **HOT FLUID WITH** | **COLD FLUID WITH** |
|  |  |
|  |  |
| From & | From & |

|  |  |
| --- | --- |
| **EFFECTIVENESS OF PARALLEL FLOW** | **EFFECTIVENESS OF COUNTER FLOW** |
| **HOT FLUID WITH** | **HOT FLUID WITH** |
|  |  |
|  |  |
| **CASE-I:** For Boiling or Condensation (Phase Change),  For ,  **CASE-II:** Both the fluids have equal heat capacity rate,  For ,  **CASE-III**: For ,  **NOTE:** For more effectiveness | **CASE-I:** For Boiling or Condensation (Phase Change),  For ,  **CASE-II:** Both the fluids have equal heat capacity rate,  For , |
| **Parallel Flow:****Counter Flow**Online course and simulator for engineering thermodynamics | **NTU Method Important Points:**  Here,   |  |  | | --- | --- | |  |  |  |  | | --- | |  |   NTU Measures Size of HE & It’s also called as dimensionless area. For Good Thermal & Economical Design NTU is limited up to 1.5. NTU increase rapidly from 0 to 1.5. Beyond 3 NTU is almost Constant.  For phase Change,  As NTU increases the Size of HE increases (Bulky).  = No. of Heat Transfer Unit  is representation of Stanton Number in terms of (Overall heat Transfer Coefficient.) |
| **Same results can be obtained for cold fluid with** | |

|  |  |
| --- | --- |
| **LMTD Method** | **NTU Method** |
| It’s used when Temperature is given and Area required to find for the Heat Exchanger. | It’s used when Area is given and Temperature required to find for the Heat Exchanger. |