Heat Exchangers

Heat Exchangers Function

1-H. Ex. Function is to transfer heat energy from a fluid to another fluid

2-Double action can be applied in the same time,

a- Cooling a fluid is required as a terminal product.

b- Heating another fluid is required as a heat recovery.

Heat Transfer modes

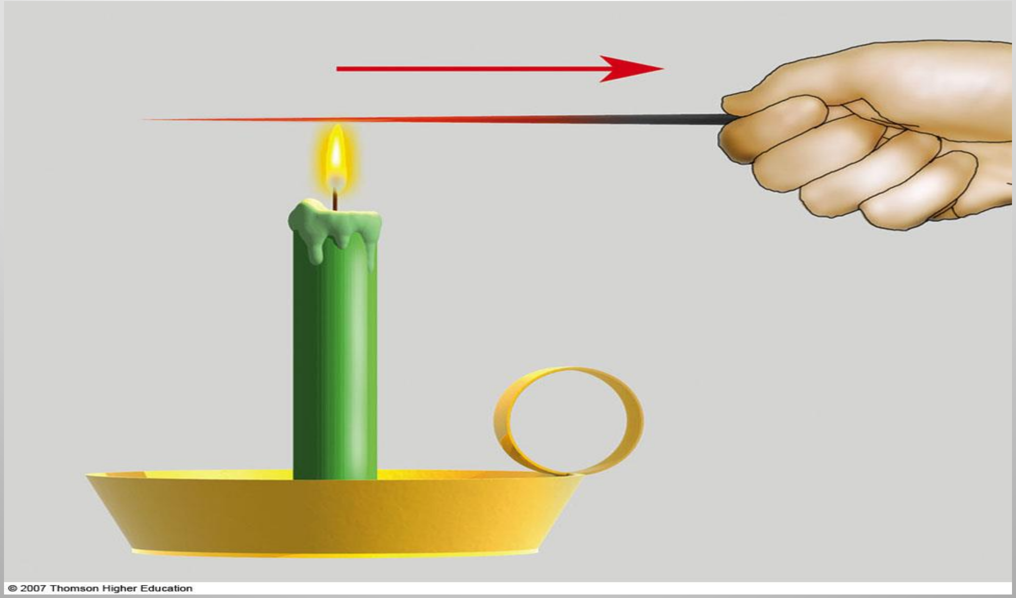
Conduction

Convection

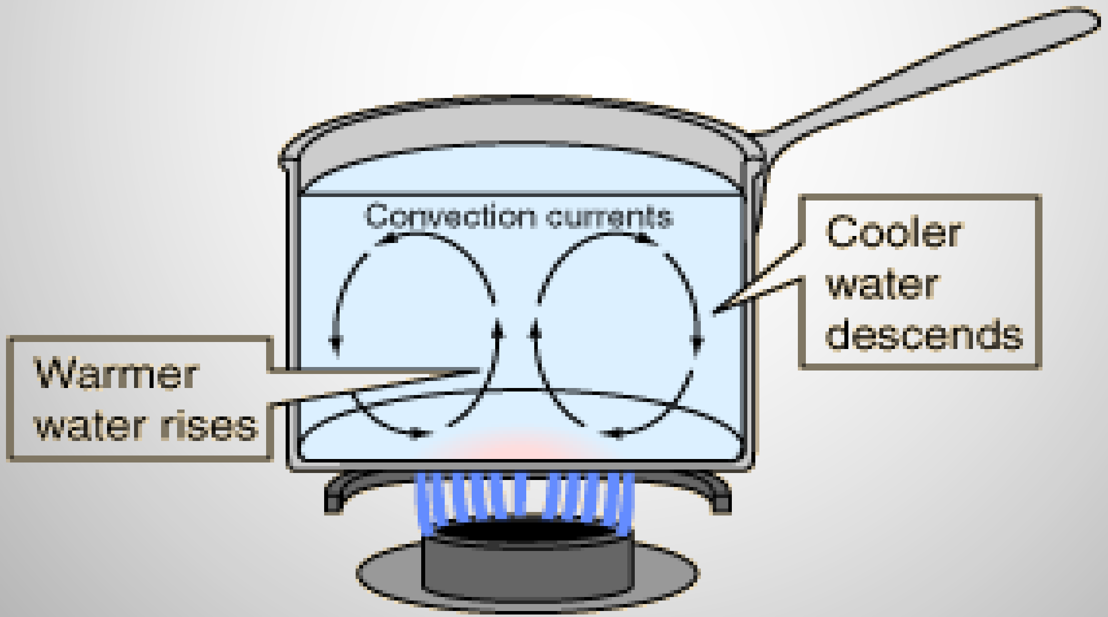
Radiation

Heat transfer methods

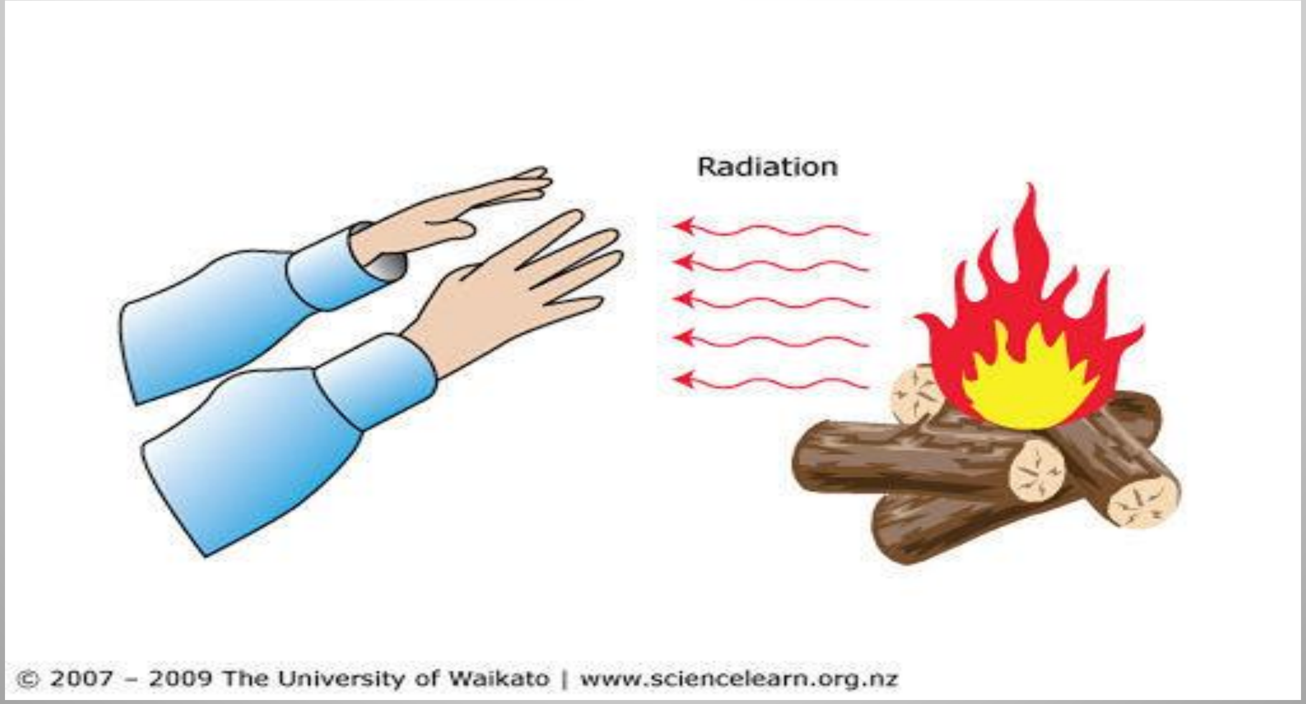
- **Conduction**; Heat energy is transferred through solid objects such as tubes, heads, baffles, plates, fins, and shell, by conduction. This process occurs when the molecules that make up the solid matrix begin to absorb heat energy from a hotter source. Since the molecules are in a fixed matrix and cannot move, they begin to vibrate and, in so doing, transfer the energy from the hot side to the cooler side.
  Conduction is the fastest and most efficient way of transferring heat between two solid objects.



- **Convection**: is heat transfer by mass motion of a fluid such as air or water when the heated fluid is caused to move away from the source of heat, carrying energy with it. Convection above a hot surface occurs because hot air expands, becomes less dense, and rises.



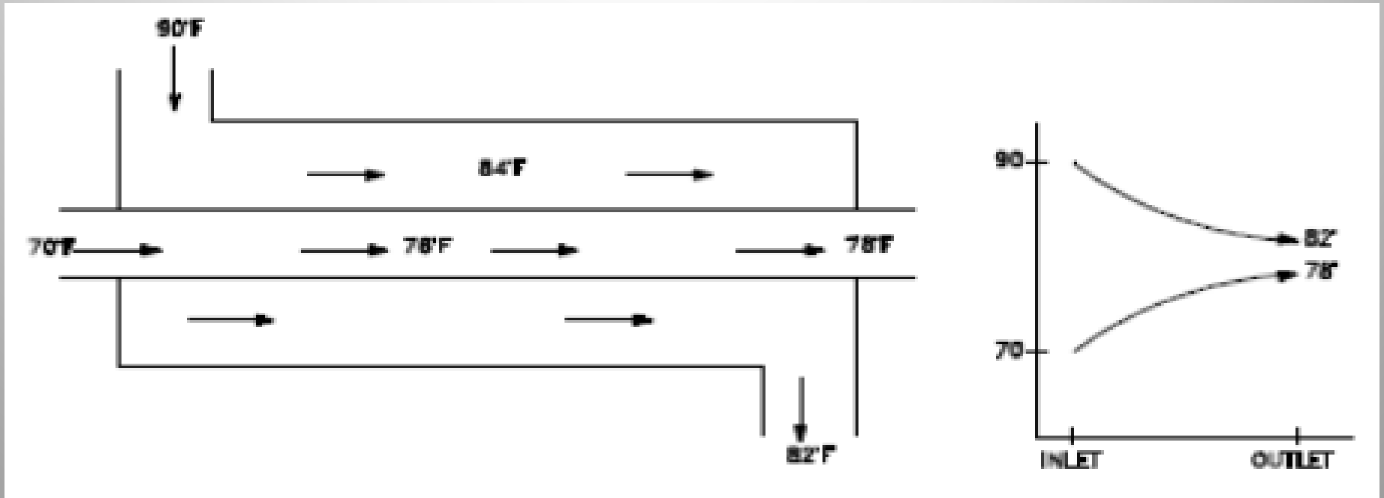
- **Radiation:** Radiation is a method of heat transfer that does not rely upon any contact between the heat source and the heated object as is the case with conduction and convection. Heat can be transmitted through empty space by thermal radiation often called infrared radiation. This is a type electromagnetic radiation . No mass is exchanged and no medium is required in the process of radiation. Examples of radiation is the heat from the sun



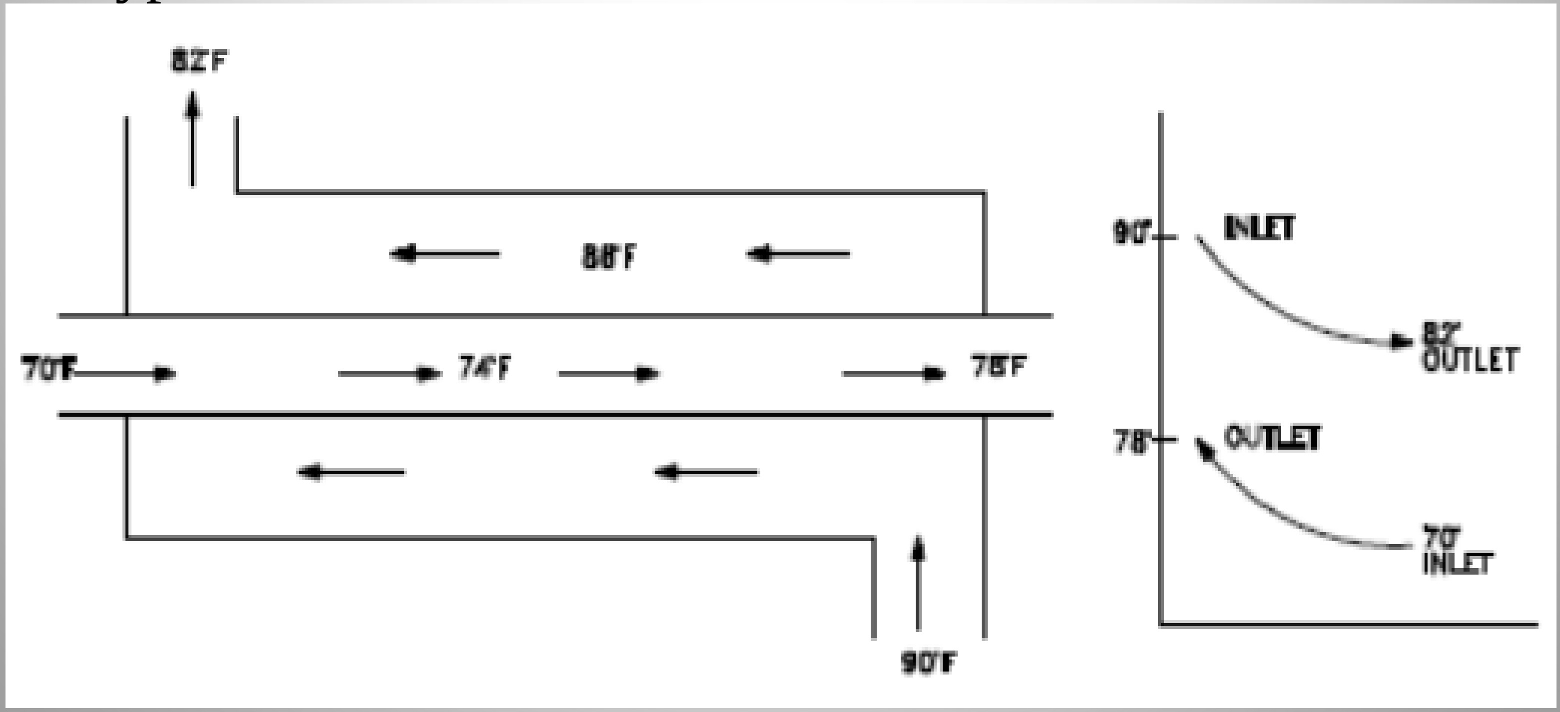
Types of Heat Exchangers

Heat Exchangers can be classified according to the direction of flowing of the two fluids to each other.

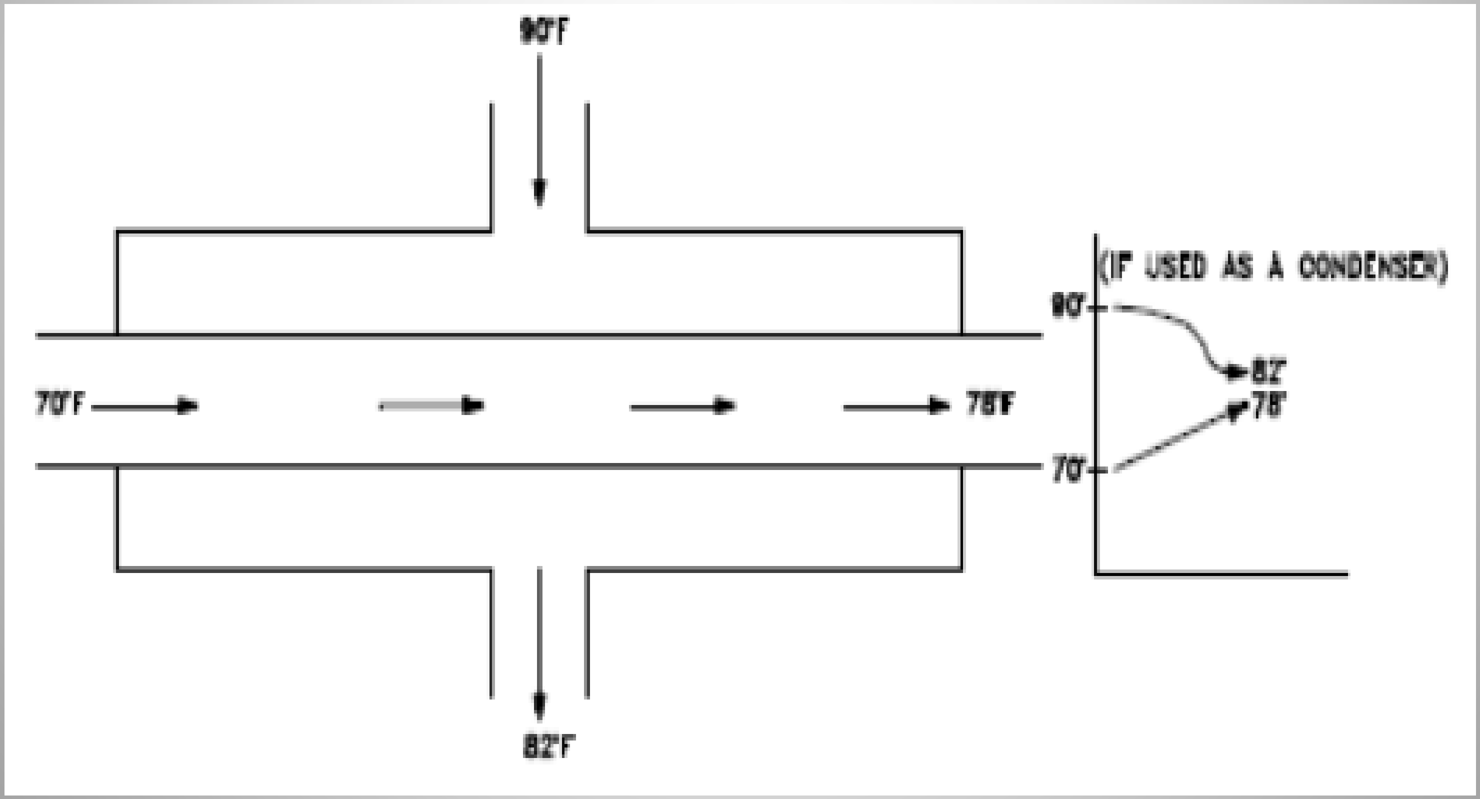
- **Co-current (parallel) flow**: Exists when both the tube side fluid and the shell side fluid flow in the same direction. In this case, the two fluids enter the heat exchanger from the same end with a large temperature difference. As the fluids transfer heat, hotter to cooler, the temperatures of the two fluids approach each other. Note that the hottest cold-fluid temperature is always less than the coldest hot-fluid temperature.



- **Counter current flow**: Exists when the two fluids flow in opposite directions. Each of the fluids enters the heat exchanger at opposite ends. Because the cooler fluid exits the counter flow heat exchanger at the end where the hot fluid enters the heat exchanger, the cooler fluid will approach the inlet temperature of the hot fluid.
  Counter flow heat exchangers are the most efficient of the three types.



- **Cross flow:** exists when one fluid flows perpendicular to the second fluid; that is, one fluid flows through tubes and the second fluid passes around the tubes at 90° angle. Cross flow heat exchangers are usually found in applications where one of the fluids changes state (2-phase flow).



Factors Affect Heat Transfer in Heat Exchangers

Tubes metal
Mass flow Rate
Temperature difference
Fouling
Time of Exposure
Flow regime

Type of Flow

Laminar Flow

Laminar Flow is usually exist at low flow rate

Turbulent Flow

Turbulent Flow is usually exist at high flow rate, allows molecules to mix and absorb heat more readily than does laminar flow.

Turbulent Flow decrease thickness of static film, increasing the rate of heat transfer.

Can be classified also according to service .

- Heat Exchanger

  Both sides single phase and process stream

- Cooler

  One stream process fluid and the other cooling water or air

- Heater

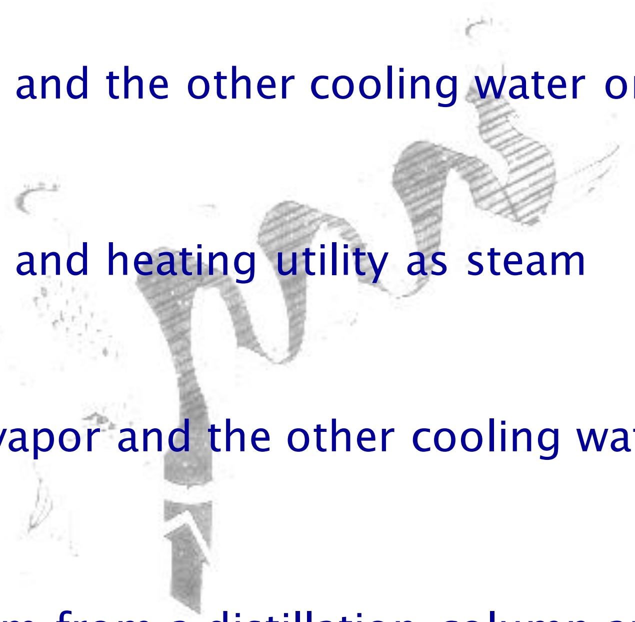
  One stream process fluid and heating utility as steam

- Condenser

  One stream condensing vapor and the other cooling water or air

- Reboiler

  One stream bottom stream from a distillation column and the other a hot utility.



Classifications; according to Geometry

Heat Exchangers

- Pipe coil
- Double Pipe
- Hairpin
- Shell and Tube
- Reboilers
- Plate and Frame
- Plate Fins
- Air Cooled
- Spiral

Classifications

- Heat Exchangers
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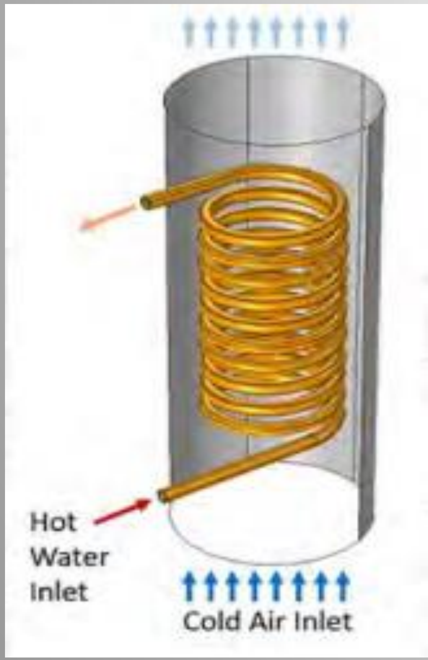

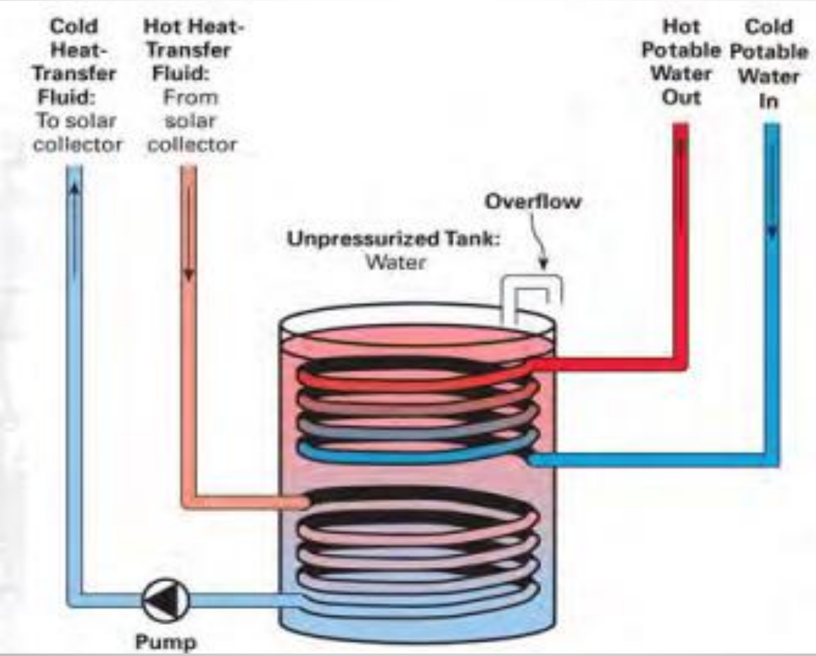

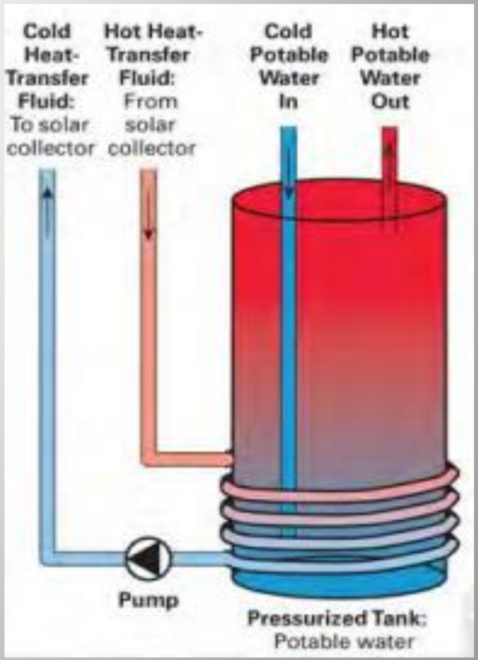

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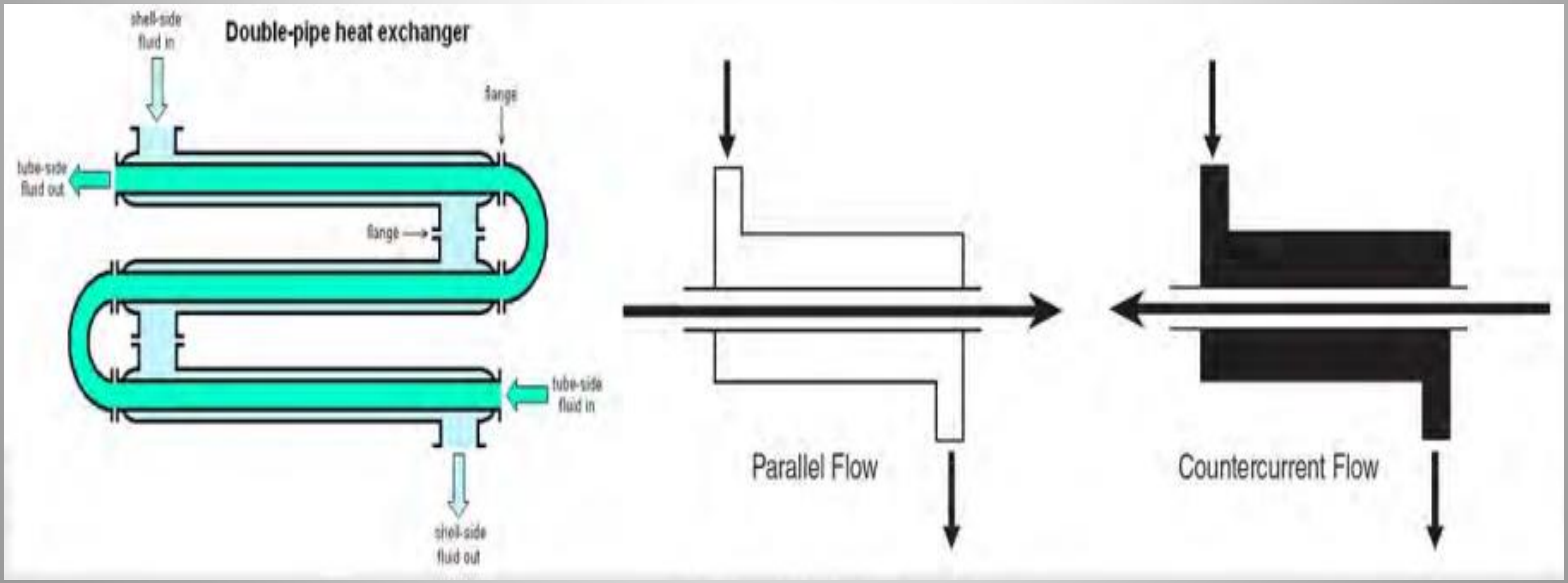

- A double-pipe exchanger has a pipe inside a pipe, The outside pipe provides the shell, and the inner pipe provides the tube.

- The double pipe heat exchanger does not provide large heat transfer surface areas and is commonly used for low heat duties with smaller surface area requirements. When larger heat exchange duty is required a number of these units can connected in series or in parallel to fit into the space available.

- The double pipe heat exchanger is compact and the components and fittings are small in dimension, which makes them a natural choice for high-pressure services.

- Fins can be added to the internal tube’s external wall to increase heat transfer.

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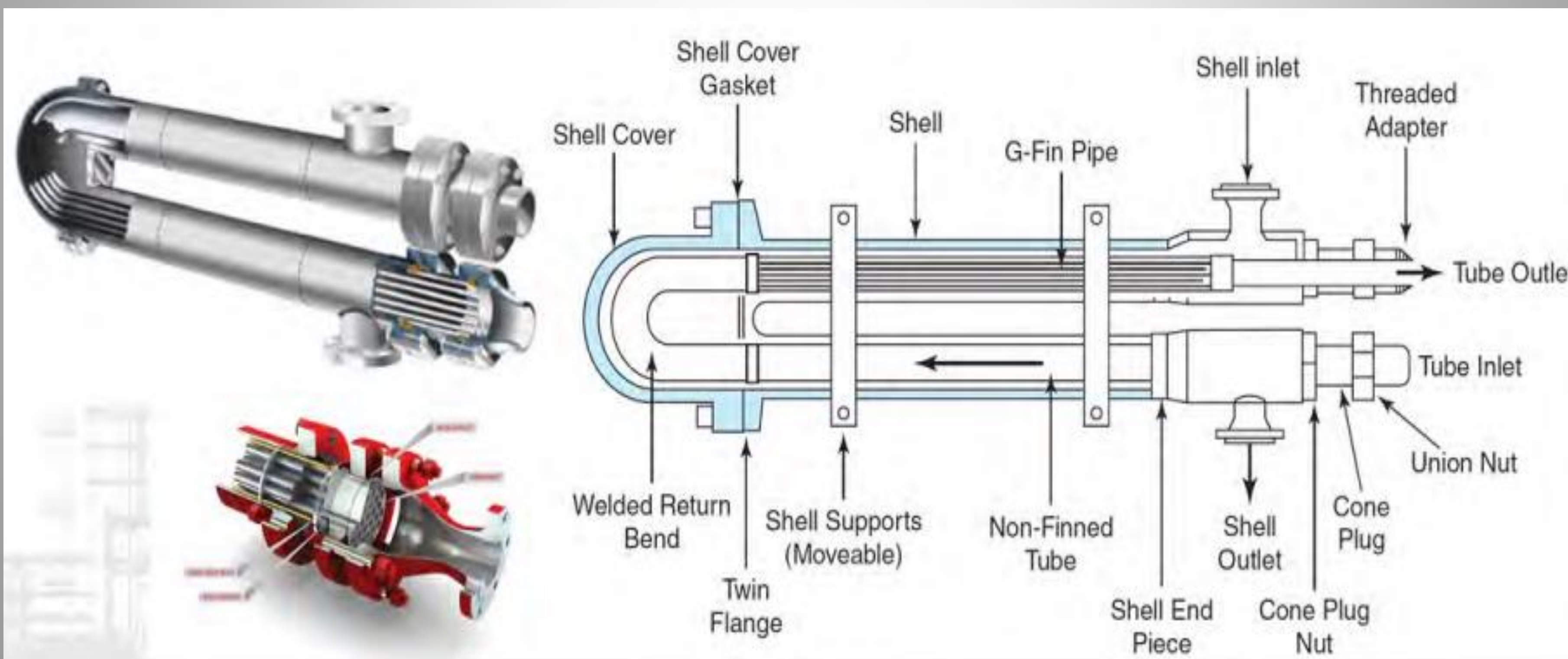

- The hairpin (Multi-pipe) resembles a typical shell-and-tube heat exchanger, stretched and bent into a hairpin.
- excellent capacity for thermal expansion because of its U-tube type shape.
- its finned design, which works well with fluids that have a low heat transfer coefficient.
- its high pressure on the tube side.
- it is easy to install and clean; its modular design makes it easy to add new sections.

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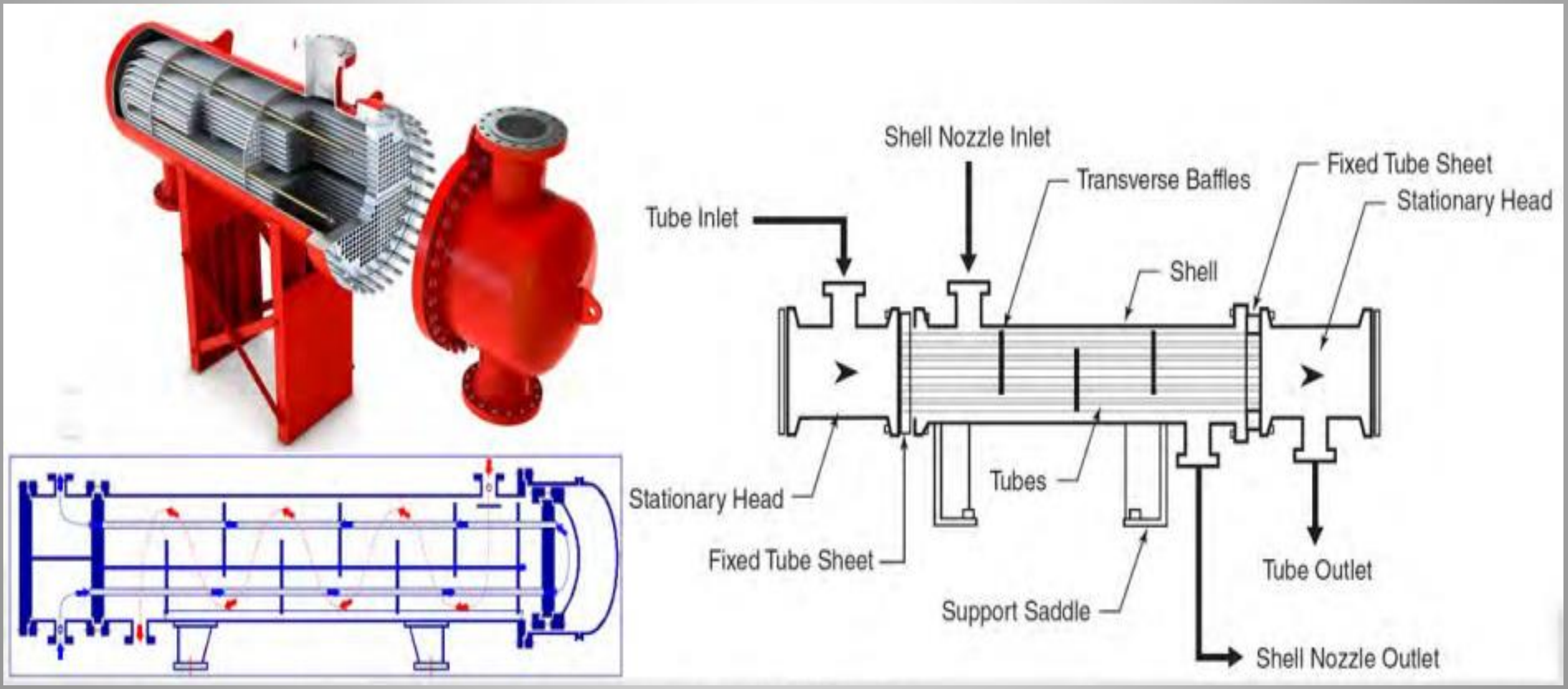

- The most common type of heat exchanger in industrial applications.
- They contain a large number of tubes (sometimes several hundred) packed in a shell with their axes parallel to that of the shell. Heat transfer takes place as one fluid flows inside the tubes while the other fluid flows outside the tubes through the shell.
- ideal for large scale applications.
- Shell-and-tube heat exchangers are further classified according to the number of shell and tube passes involved.

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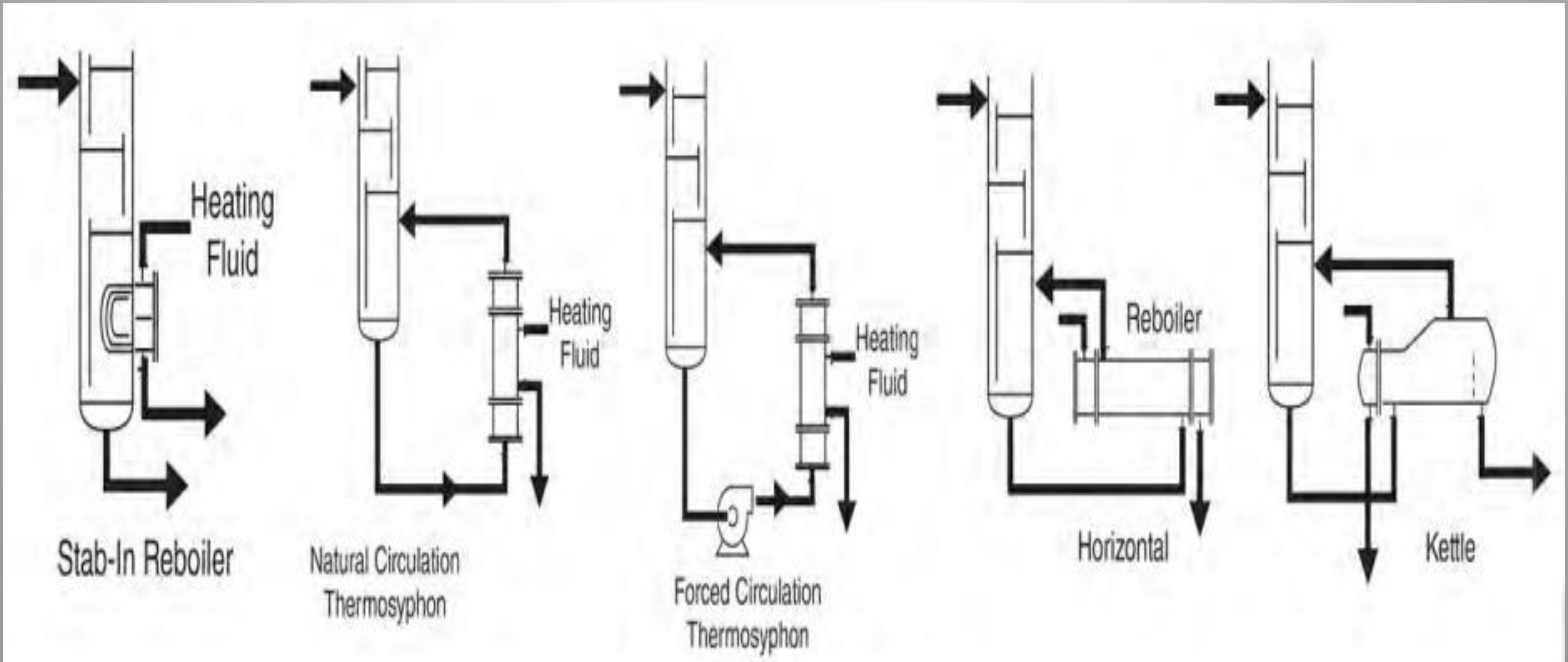

- A heating fluid like steam or hot oil flows through the tubes, the shell side fluid is a liquid which partially vaporizes.

Kettle Type Reboiler

A large vapor cavity above the heated process medium allows vapors to concentrate. Liquid that does not vaporize flows over a weir and into the liquid outlet.

Thermosyphon Reboiler

is designed with no vapor space above the tubes, hence liquid and vapor returned back to tower.

The critical design factor is providing sufficient liquid head in the column to support vapor or liquid flow-back to the column.

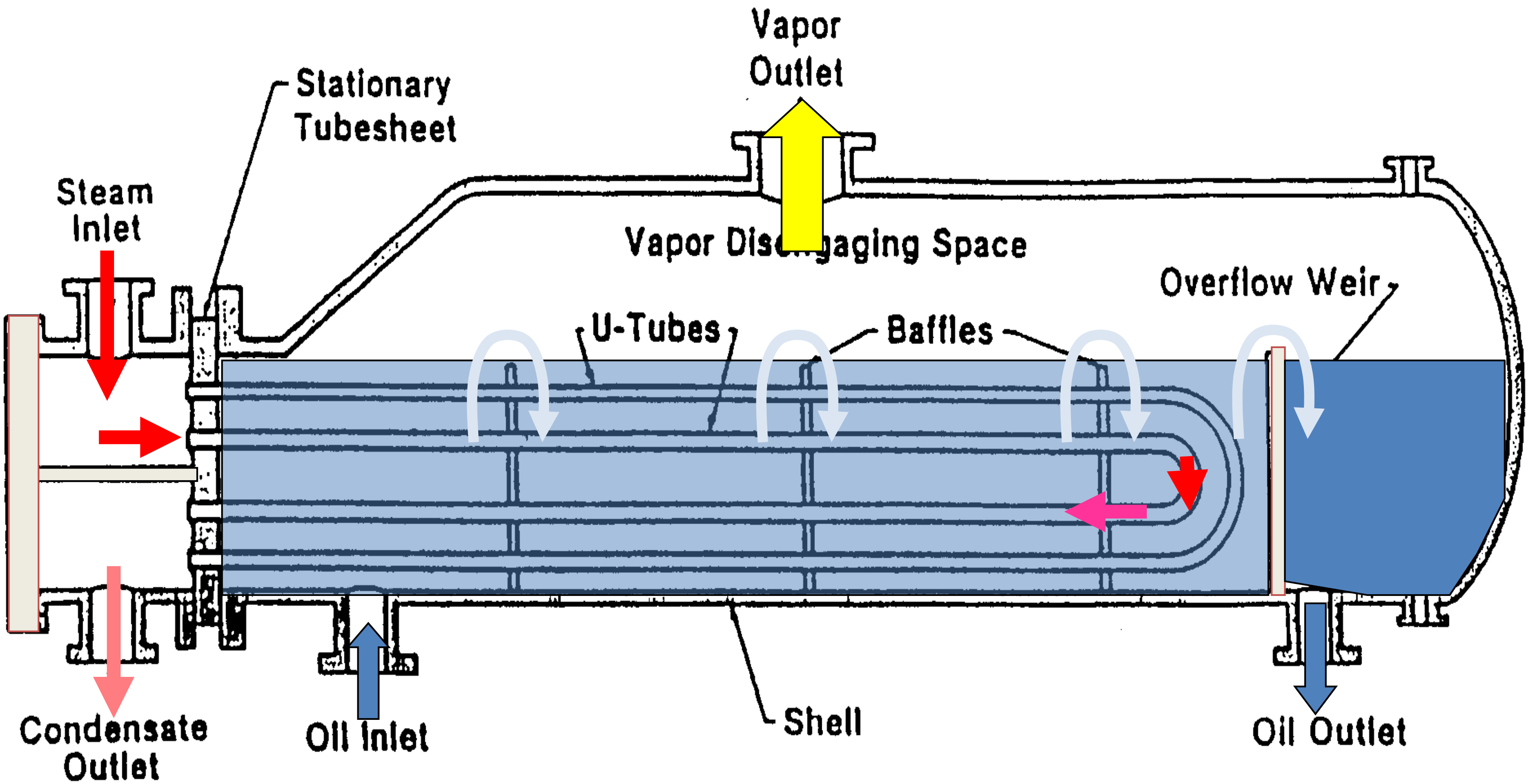

Fig.11 U-tube kettle type reboiler.

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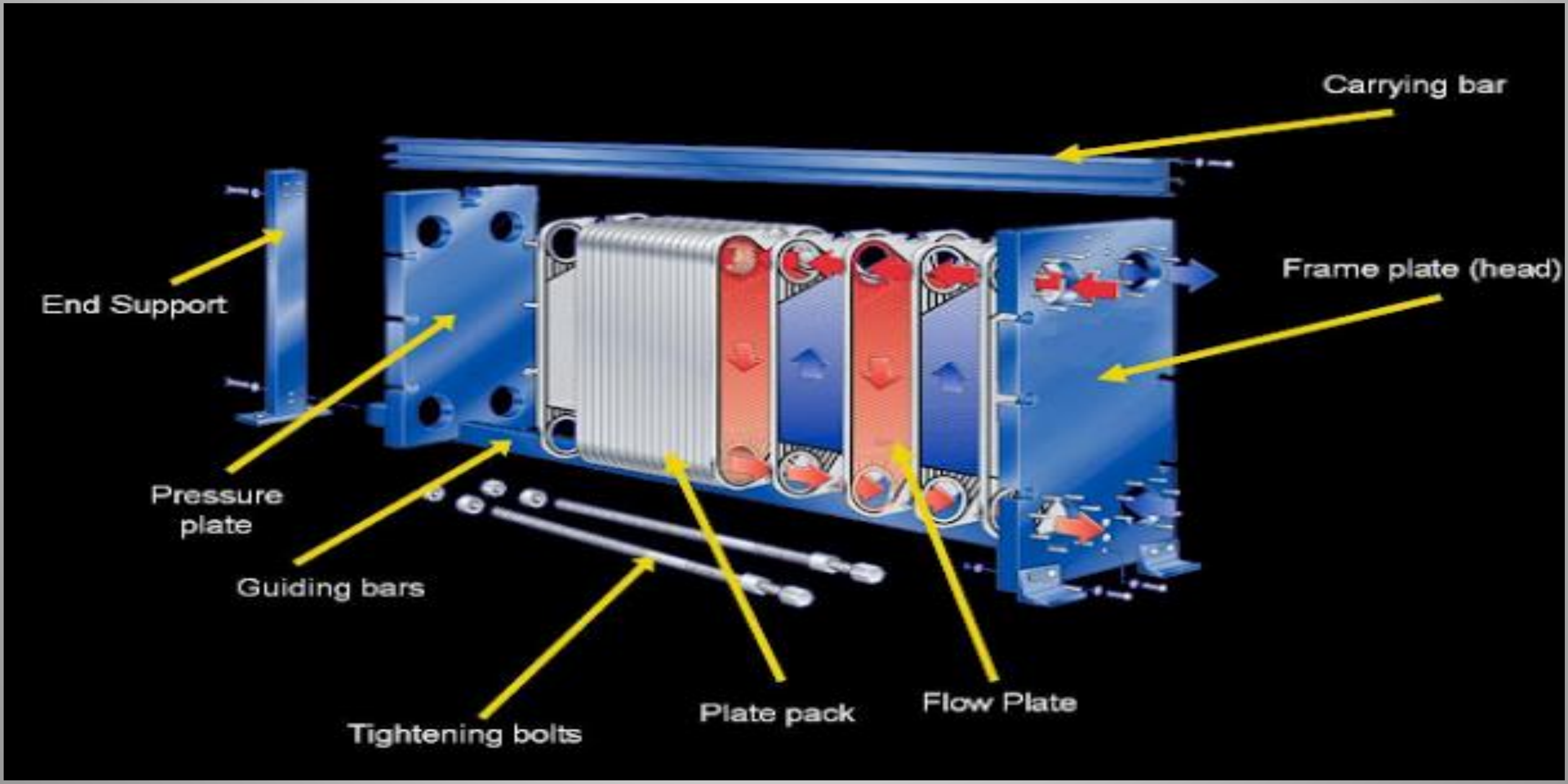

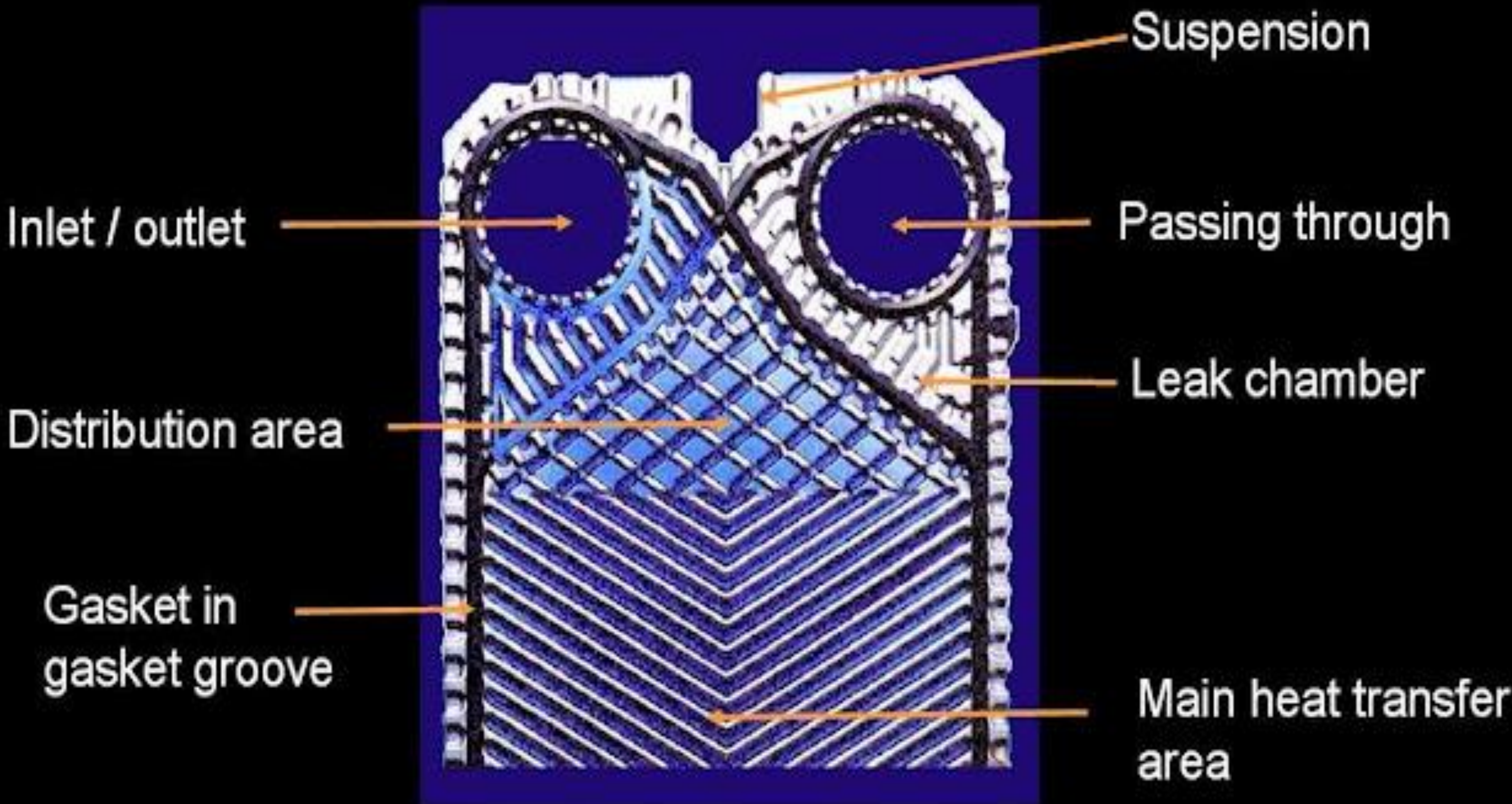

Main Components of plate

Thin sheet design, cold formed in single step hydraulic pressing (up to 40000 tons)

- Plate heat exchangers (PHE) have a number of pressed metal plates, aligned on a frame clamped together with gaskets between the plates.
- Each pressed plate is corrugated, having a alternating ridges and grooves.
- The fluids flow between alternating plates. The flow distribution depends upon the opening of the circumferential gasket (gasket running around the outside of the plates) to an inlet or outlet port. Circumferential gaskets surround the inlet and outlet ports. These gaskets prevent mixing of the exchanger fluids.
- The corrugated plates create turbulence, which also promotes high heat transfer rates, by continuously altering the flow direction and velocity of the fluids.

Plate frame heat exchanger

- **Easy to Remove and Clean**

Plate Heat Exchangers are easy to clean by remove the tie bolts and slide back the movable frame part. Then the plate pack can be inspected, pressure cleaned, or removed for refurbishment if required.

- **Expandable**

A very significant feature of the plate Heat Exchanger is that it is expandable. Increasing the Heat Transfer requirements means simply adding plates instead of buying a new Heat Exchanger, saving time and money.

- **High Efficiency**

Because of the pressed patterns in the plates and the relative narrow gaps, very high turbulence is achieved at relative low fluid velocity. This combined with counter directional flow results in very high Heat Transfer coefficients.

Classifications

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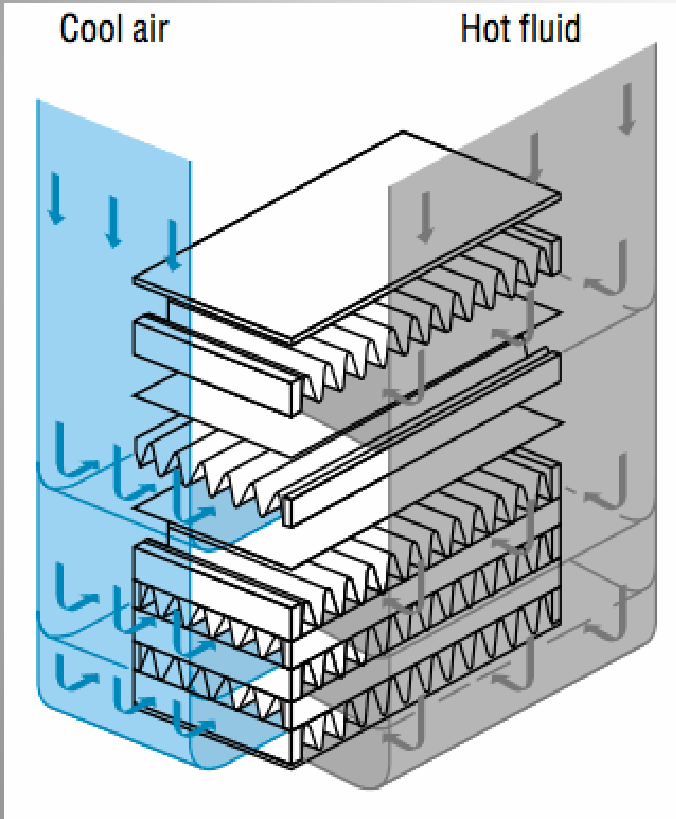

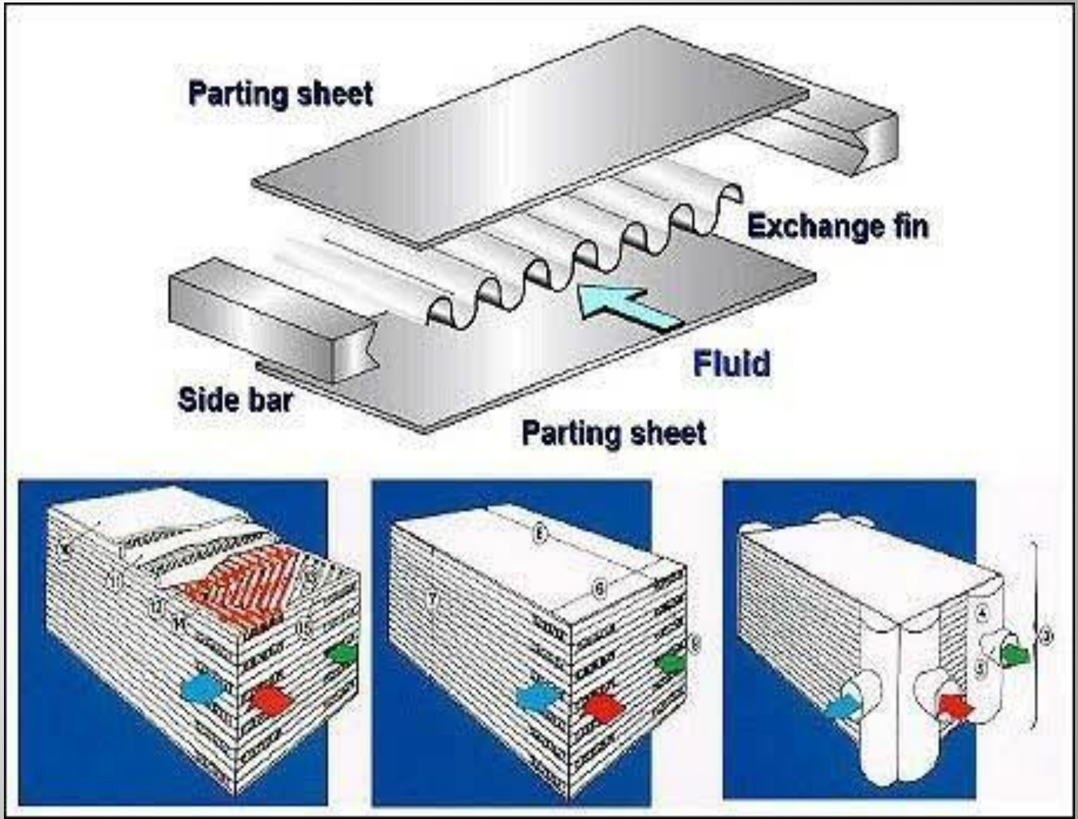

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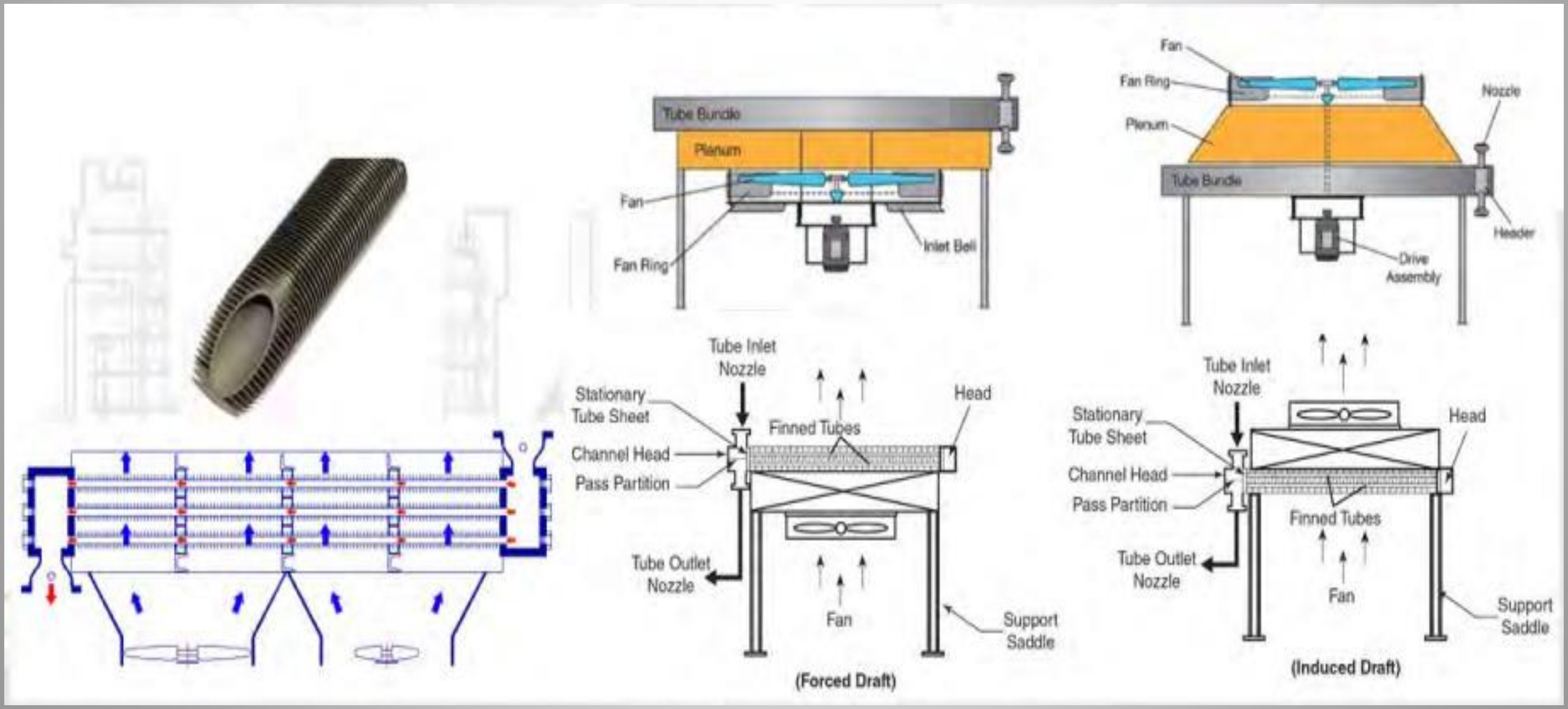
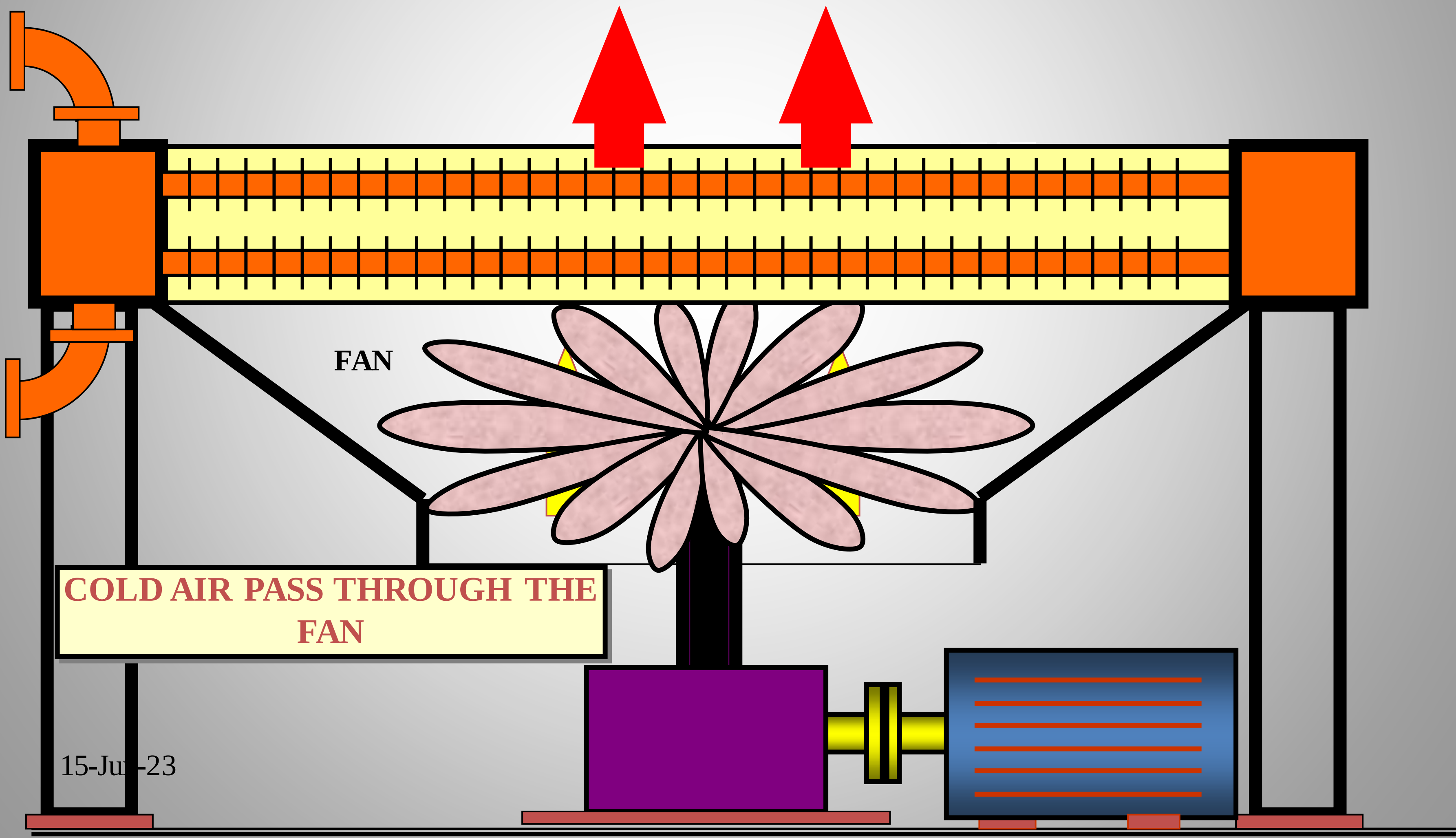
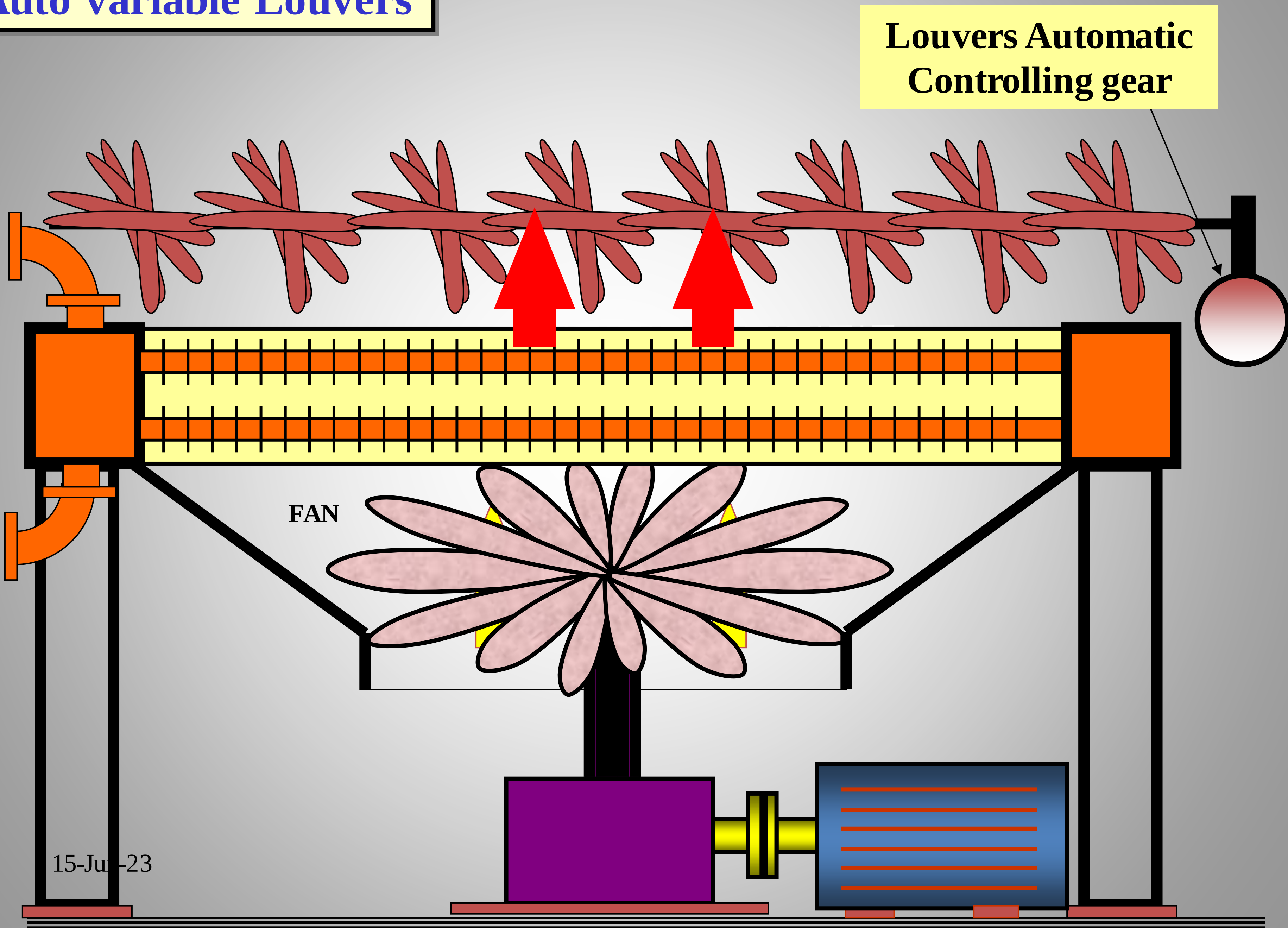


- Air is used as the outside medium to transfer heat away from the tubes.
- Fans can be mounted above or below the tubes in forced-draft or induced-draft arrangements.
- Air-cooled heat exchangers can be found in service on air compressors, in recirculation systems, and in condensing operations.
- The aerial cooler is preferred for processes where the temperature of fluids to be cooled is at least 55°C. They are also used where fouling of the tubes on the cooling waterside of a water-cooled exchanger is a concern. If a fluid stream at a high temperature requires cooling below the ambient temperature, a combination of aerial cooling followed by water-cooling will often prove to be efficient and economical since a large portion of the heat load is removed before the water is used.

2- FORCED-DRAFT



Auto variable Louvers



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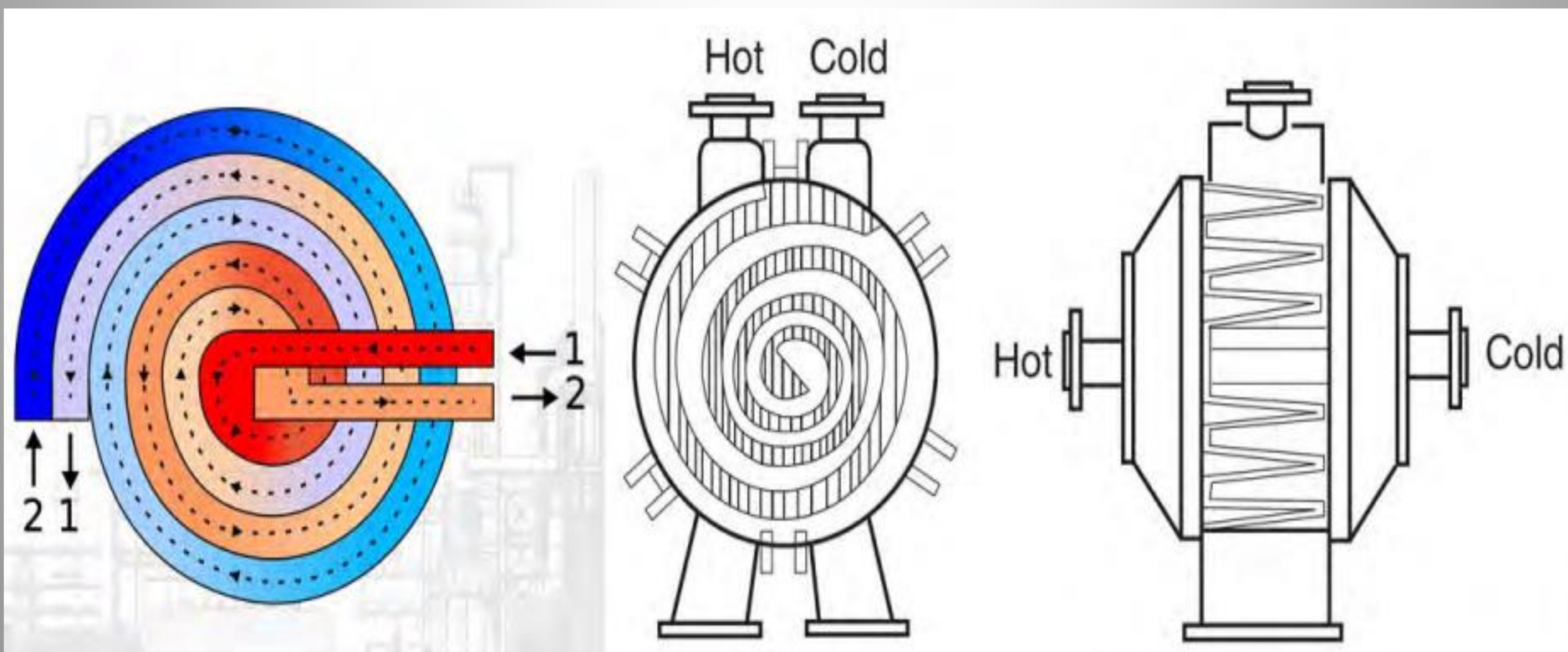
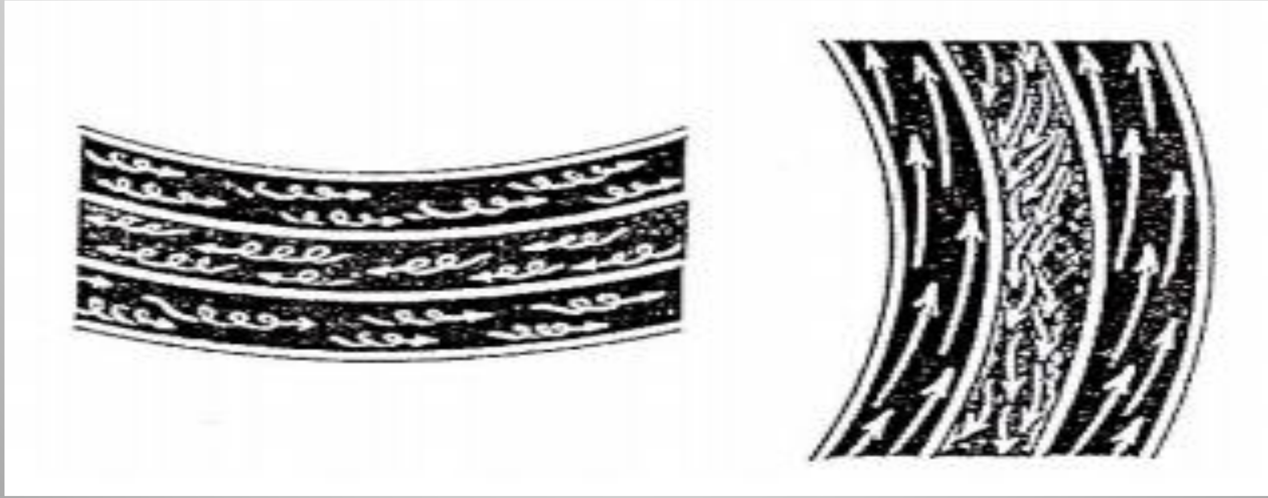


- The hot fluid enters near the center of the exchanger and flows from the inside outward. The cold fluid enters at the outside and flows in the opposite direction toward the center. In this way, true counter-flow is achieved.
- The continually curving passage creates high turbulence.
- The scrubbing effect of the fluids in each path minimizes fouling significantly compared to tube style heat exchangers, so spiral exchanger an excellent choice for fluids that tend to deposit sludge or contain solids in suspension.



Heat Exchangers are classified according to their function:

Recuperative:

two fluids separated by a solid wall (this is the most common type)

Evaporative:

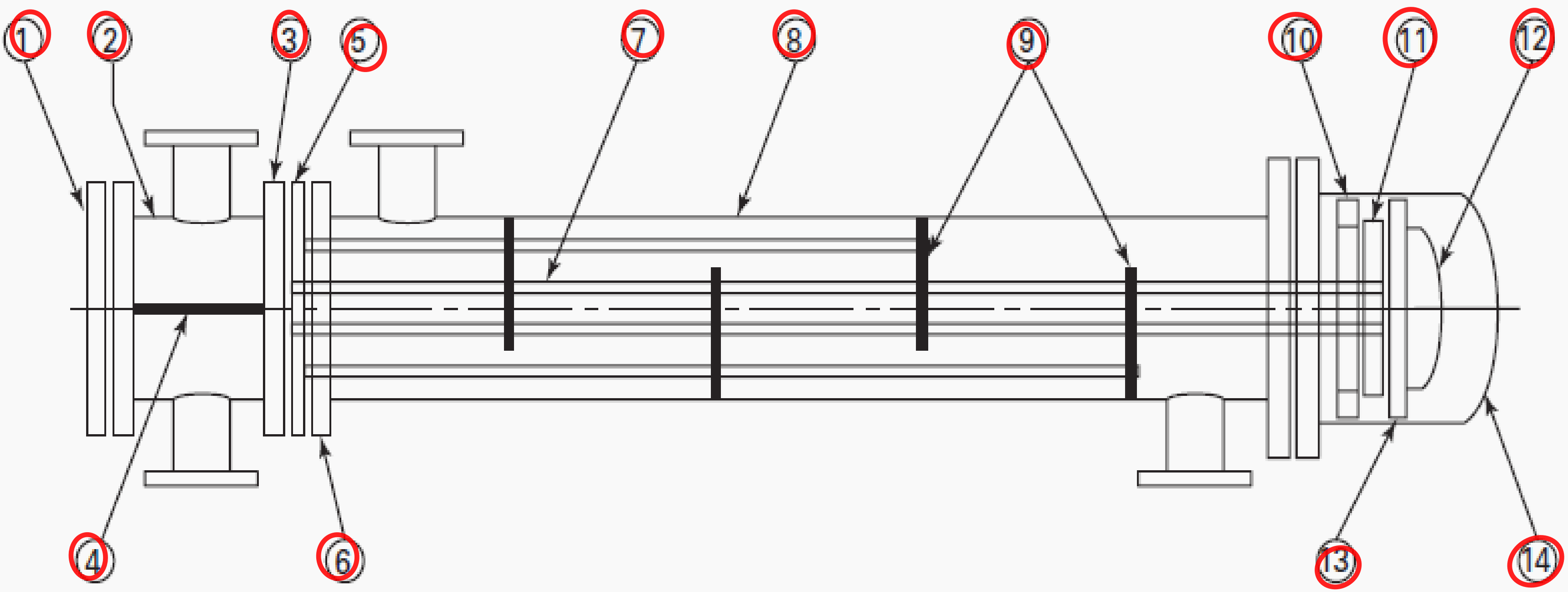
Enthalpy of evaporation of one fluid is used to heat or cool the other fluid (condensers/evaporators and boilers)

Regenerative:

use a third material which stores/releases heat

Shell and Tube Heat Exchanger

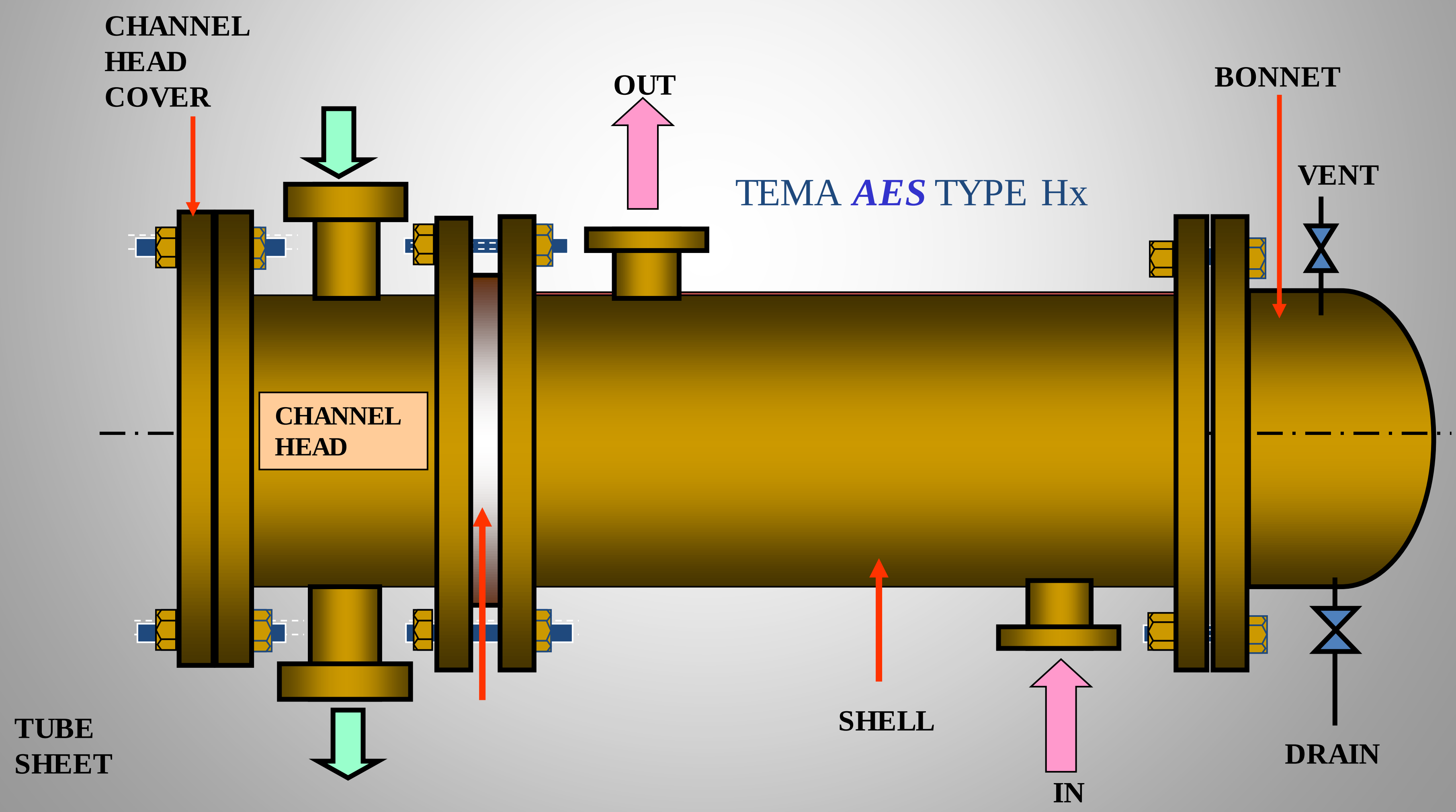
Main Components



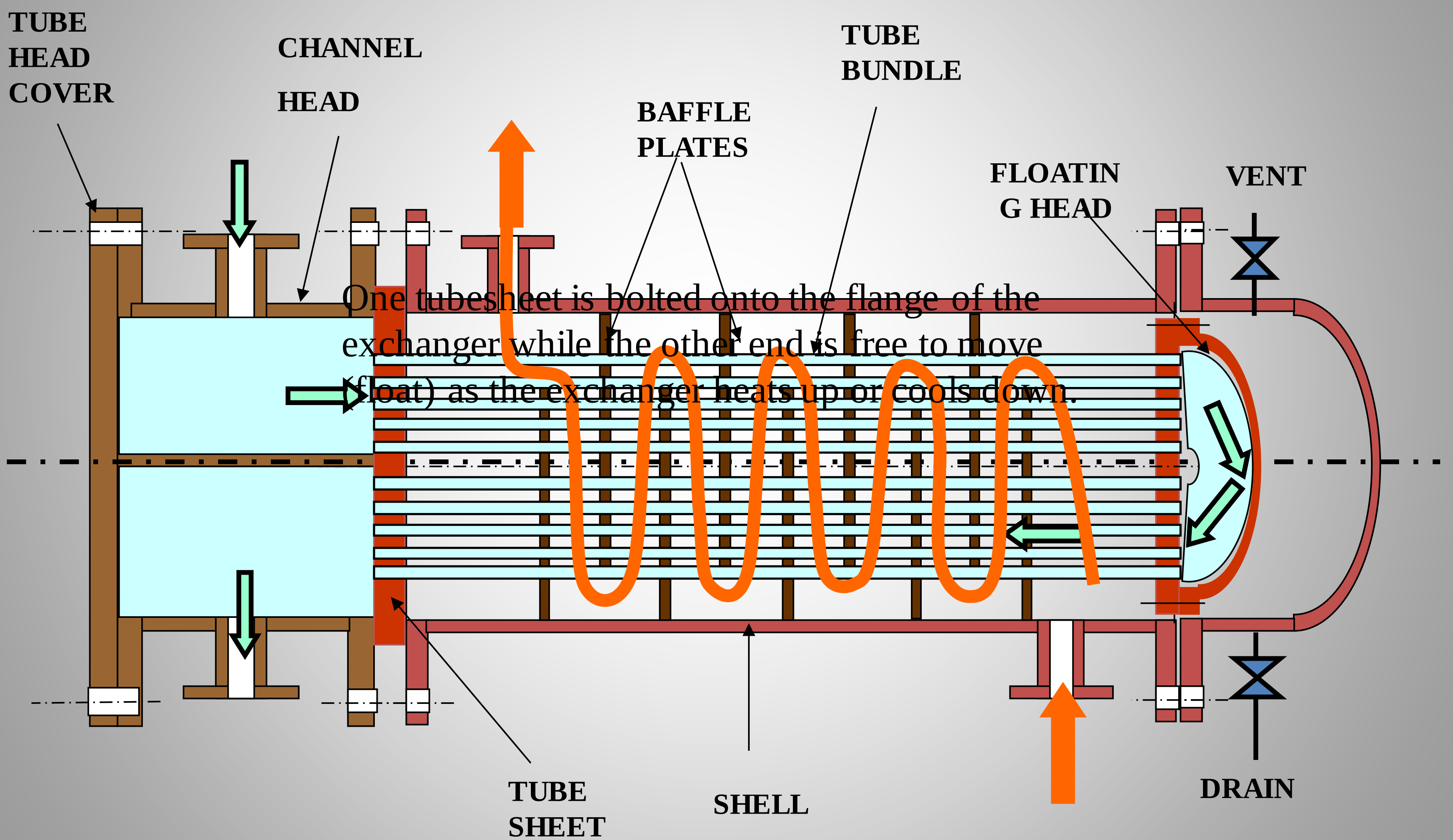
1- Channel Cover
2- Channel
3- Channel Flange
4- Pass Partition
5- Stationary Tubesheet
6- Shell Flange
7- Tube
8- Shell
9- Baffles
10- Floating Head backing Device
11- Floating Tubesheet
12- Floating Head
13- Floating Head Flange
14 -Shell Cover

Heat Exchanger Construction

1-Floating Head Heat Exchanger

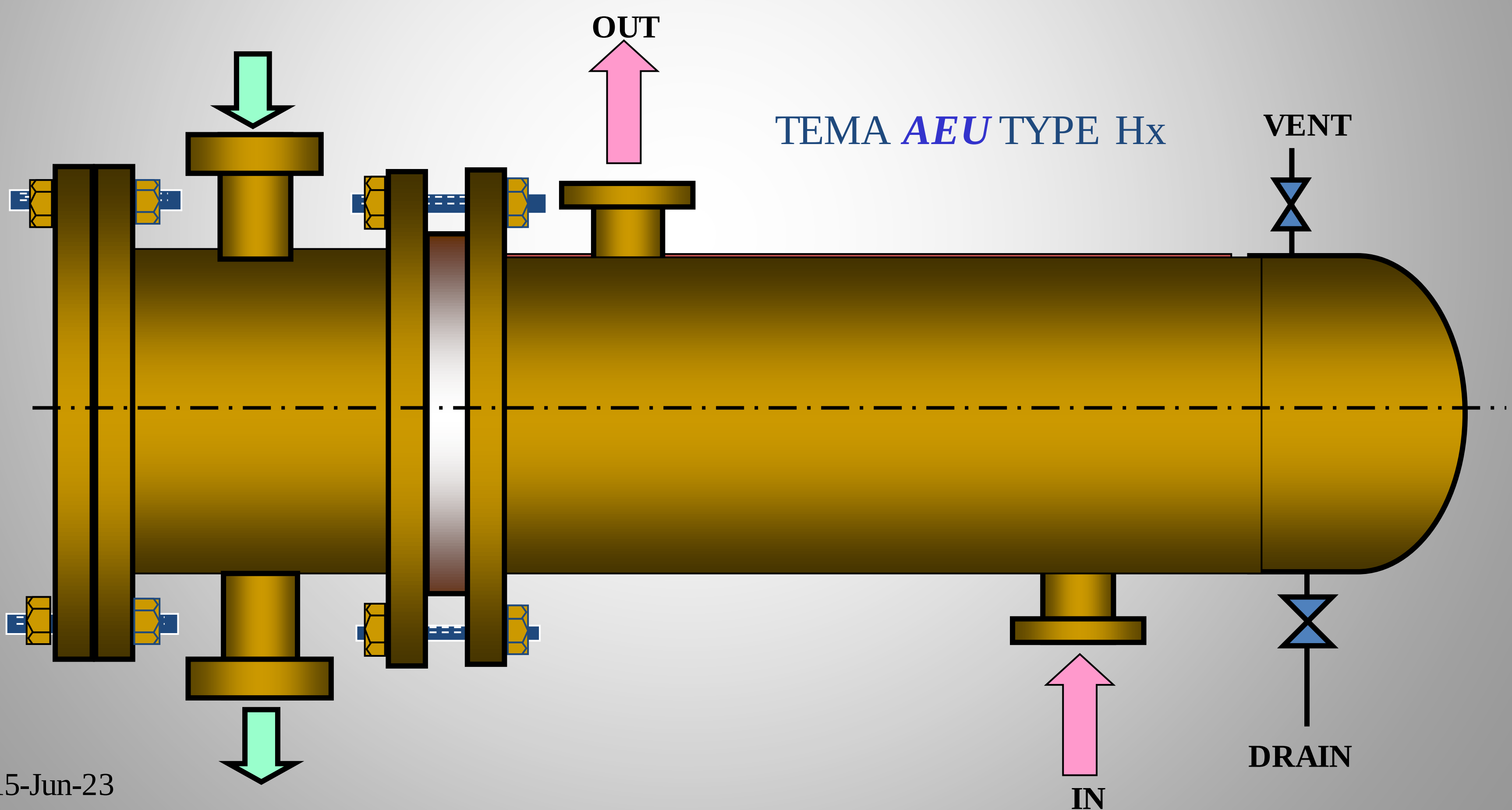


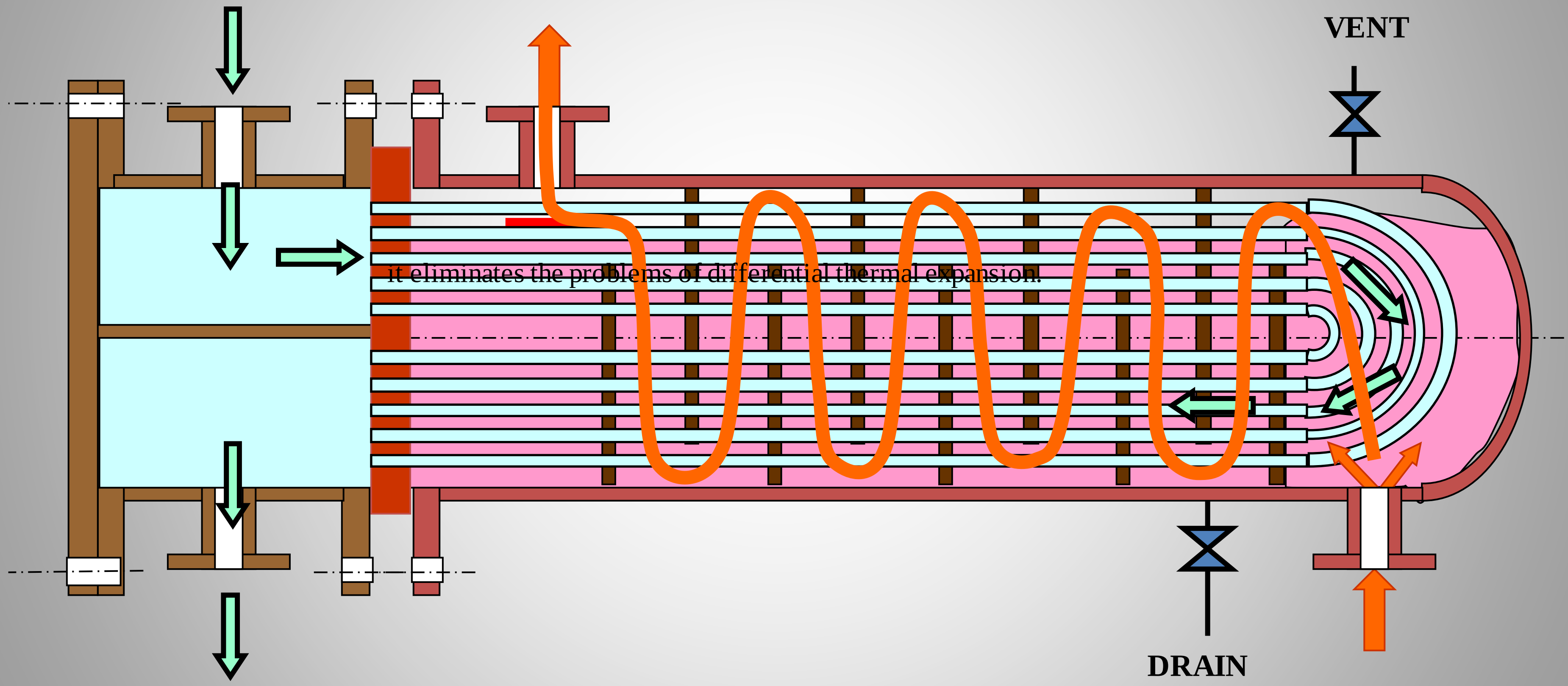
One tubesheet is bolted onto the flange of the exchanger while the other end is free to move (float) as the exchanger heats up or cools down.



One tubesheet is bolted onto the flange of the exchanger while the other end is free to move (float) as the exchanger heats up or cools down.

2- “U” Tube Heat Exchanger




VENT
it eliminates the problems of differential thermal expansion.
DRAIN

it eliminates the problems of differential thermal expansion.

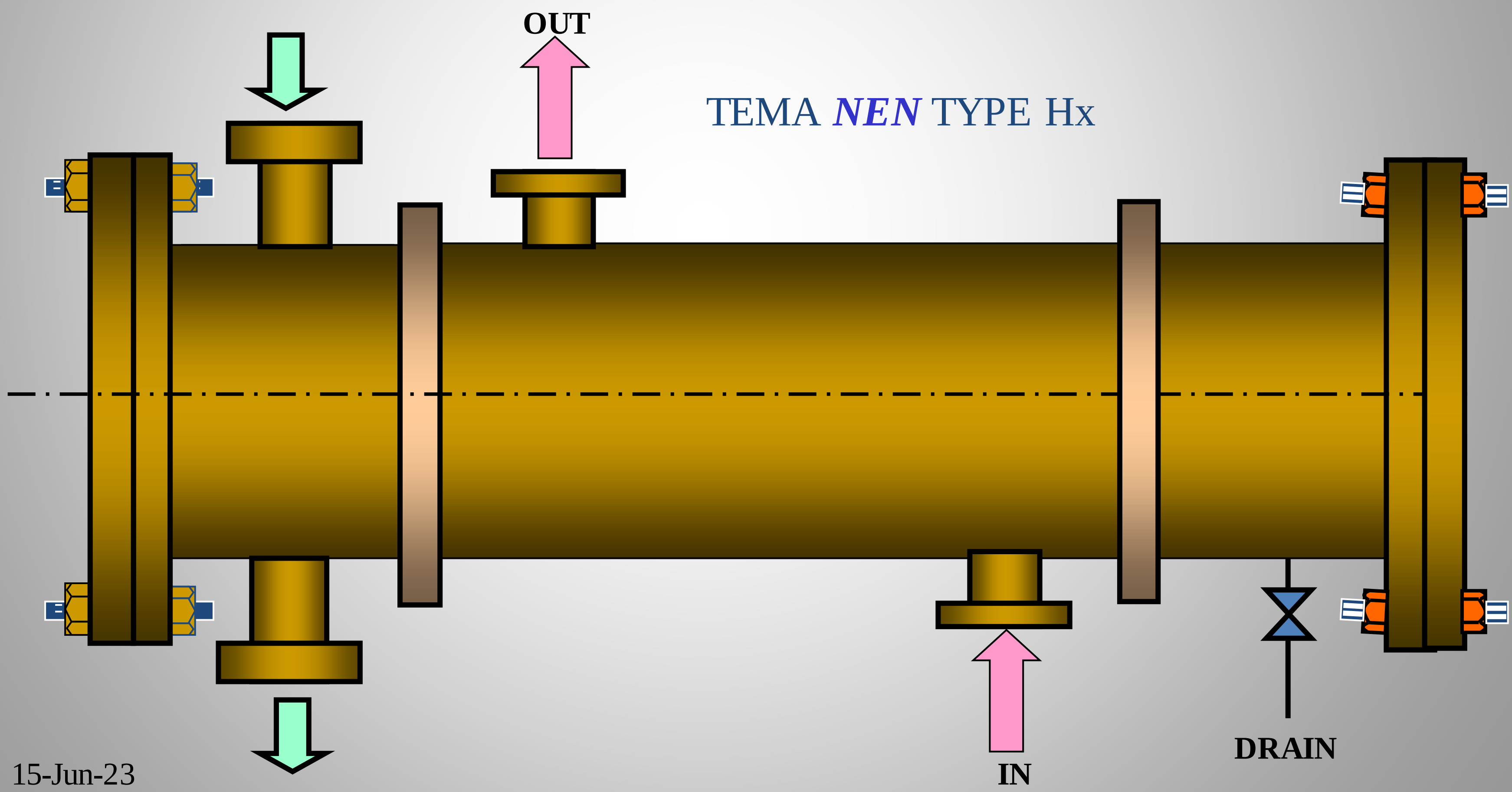
The tubesheet is bolted onto one flange at one end of the exchanger, but the tubes are free to expand and contract as necessary inside the shell.

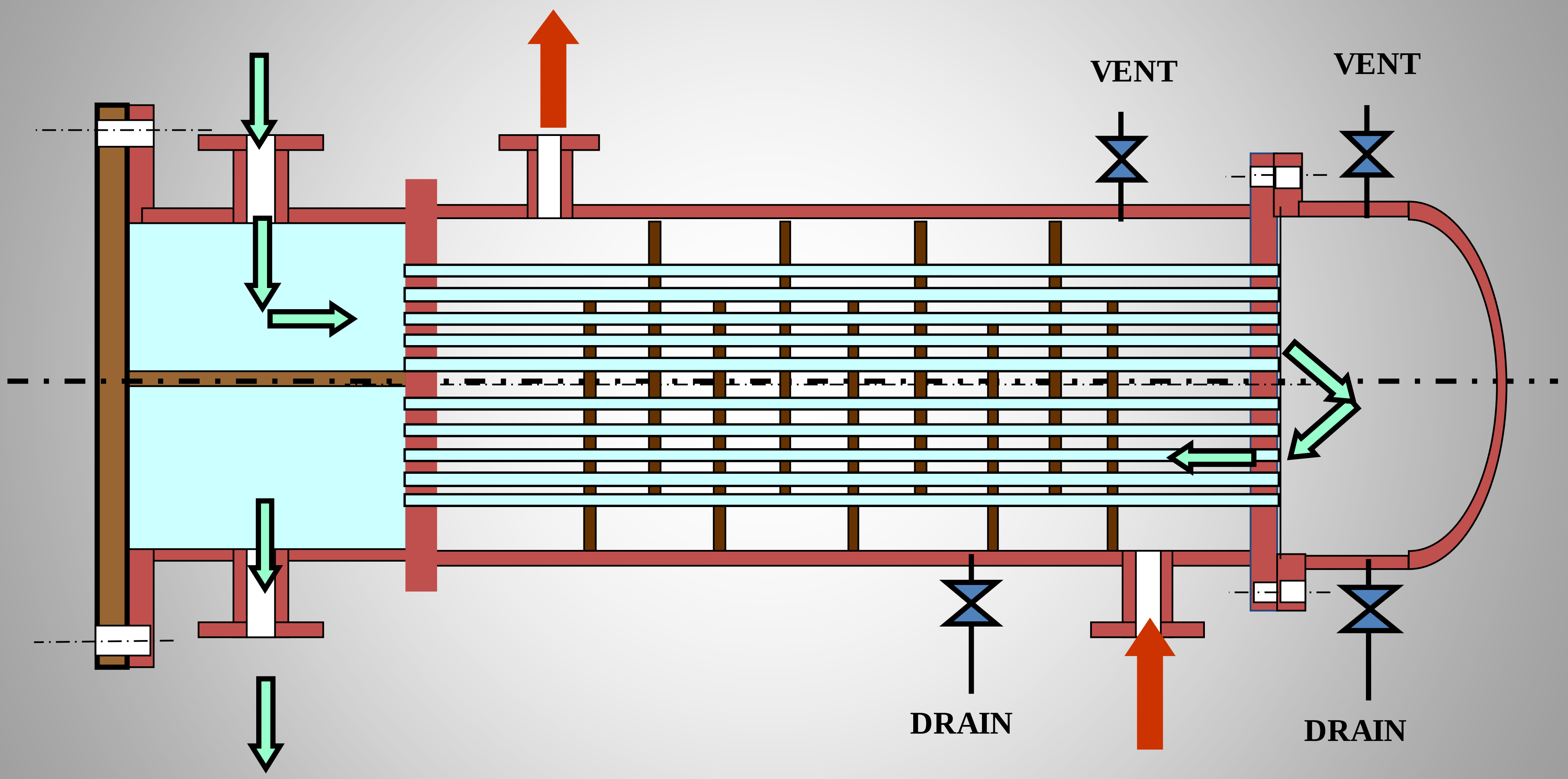
The U-tube bundle can be easily removed for cleaning and maintenance.

3-Fixed Tubes Heat Exchanger

Tube Bundle is completely welded

TEMA ***NEN*** TYPE Hx

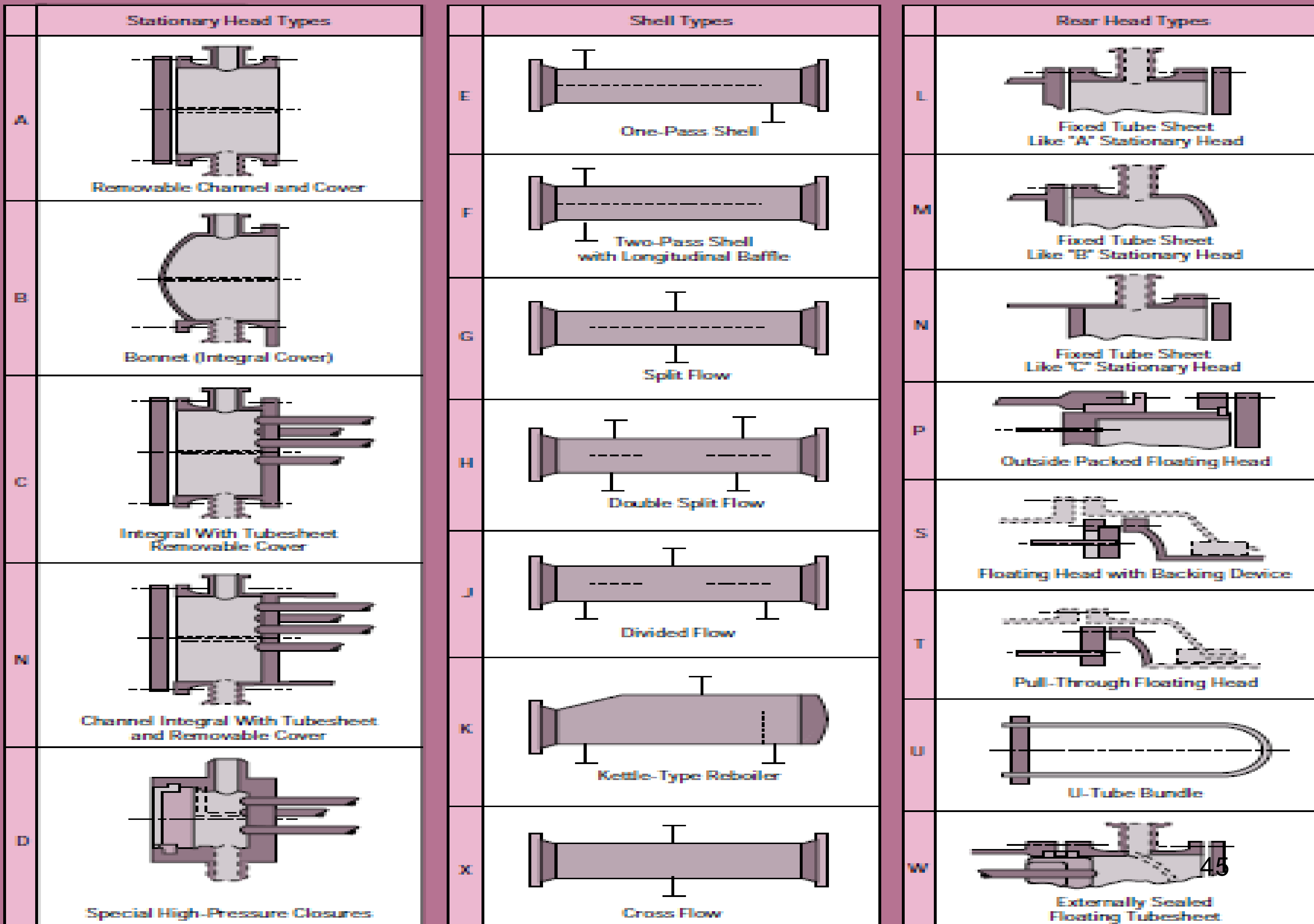



VENT
VENT
DRAIN
DRAIN

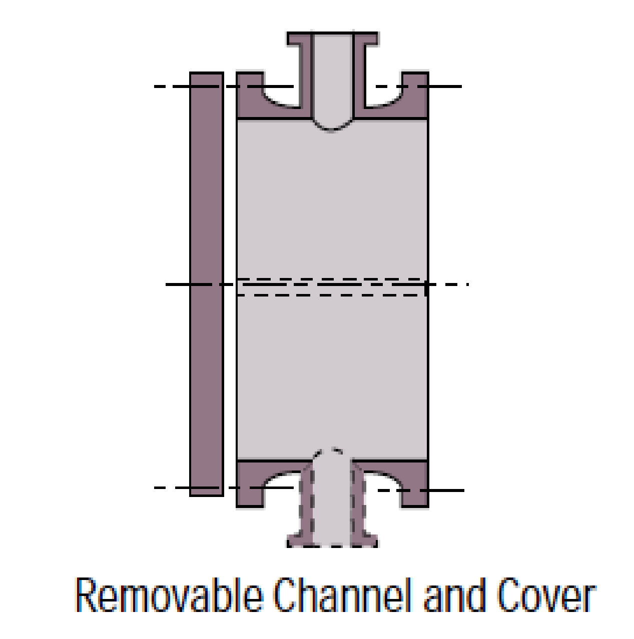
The fixed tubesheet shell and tube heat exchanger is simple in design: and easy to fabricate, resulting in a lower initial capital cost. Individual tubes can be easily repaired or plugged.

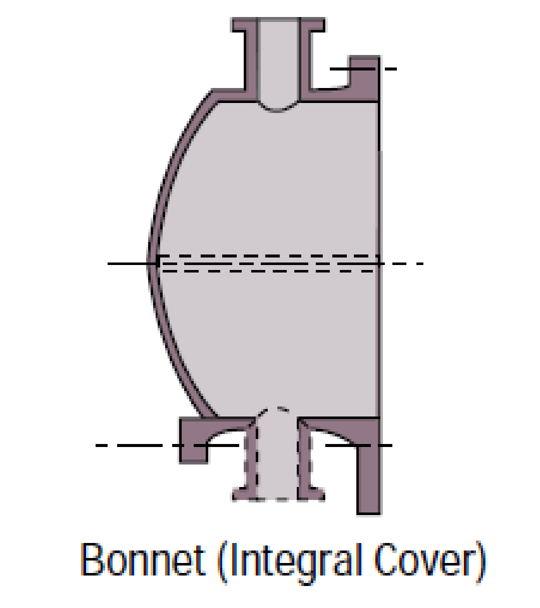
The main disadvantage is that the tube bundle cannot be removed for cleaning, maintenance or inspection. Because of this, the fixed tubesheet exchanger is best suited for service where the shell side fluids are clean The inside of the tubes can be accessed for cleaning and should be the side carrying the dirtier fluid. Chemical cleaning is the only method of cleaning the outside of the tubes.

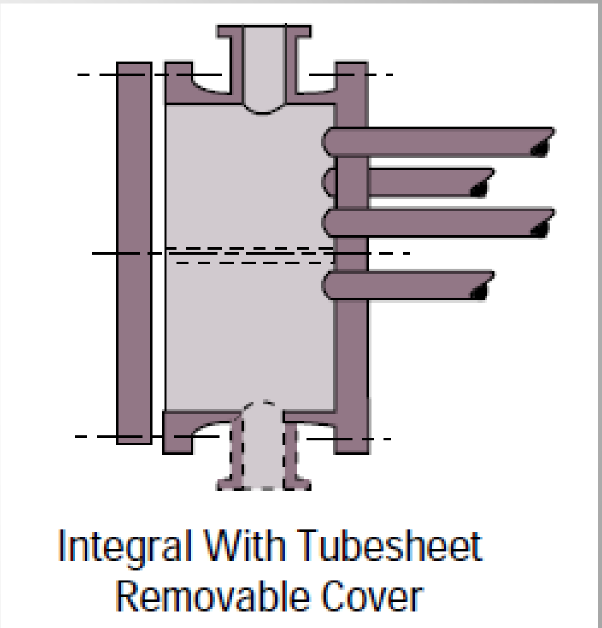
TEMA; Tubular Exchanger Manufacturers Association



Front Head Type





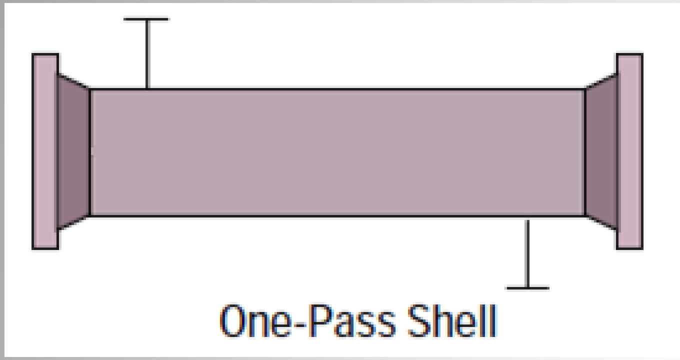


A – Type

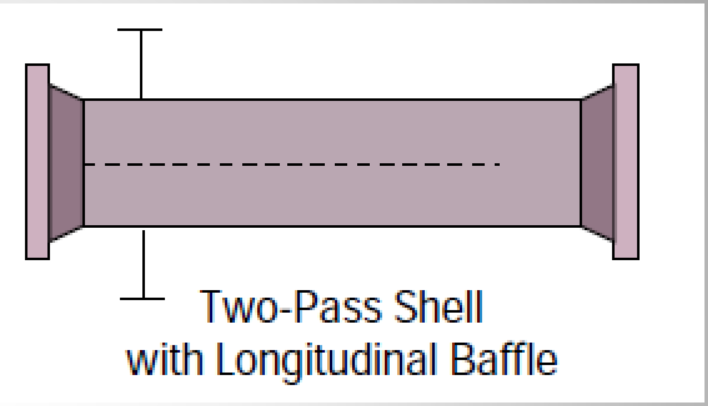
B – Type

C – Type

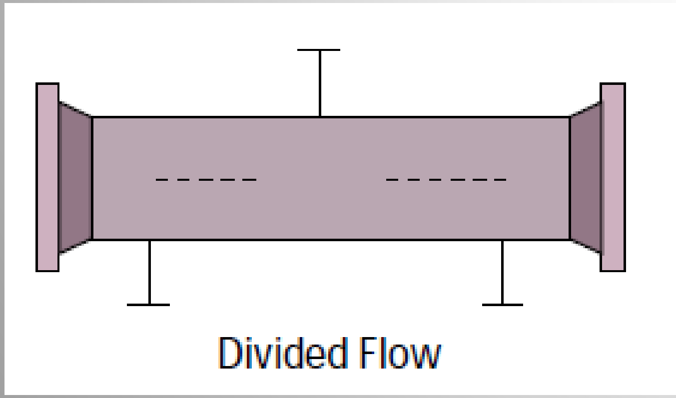
Shell Type



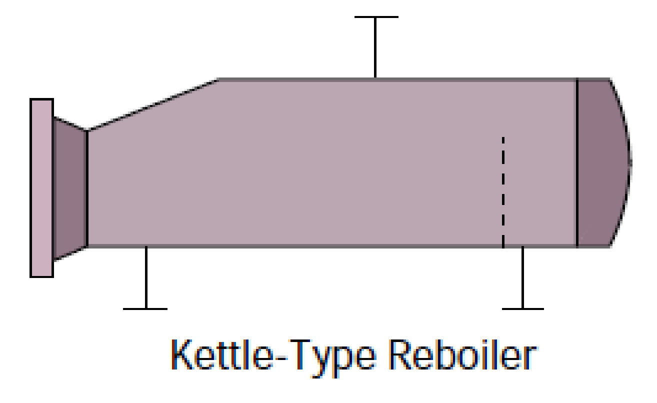
E – Type



F – Type

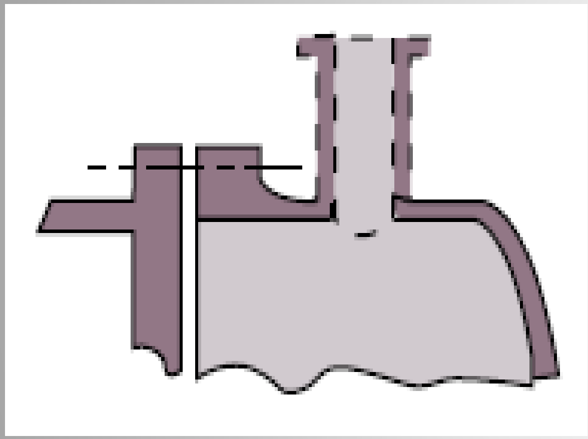


J – Type



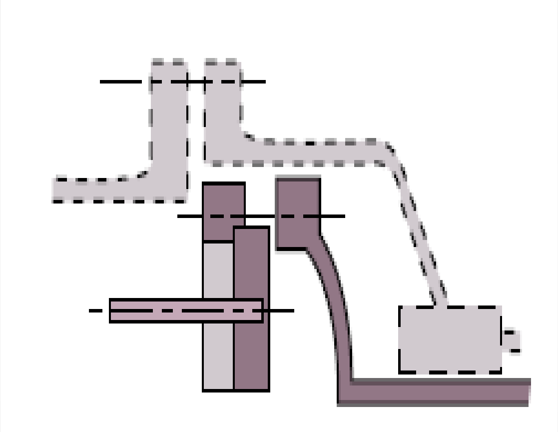
K – Type

Rear End Head Types



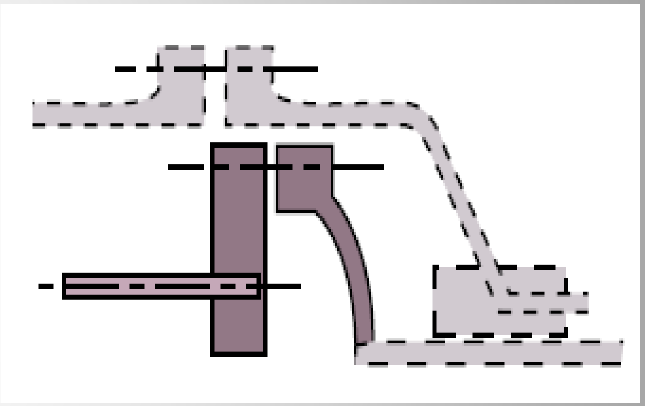
M – Type

Fixed Tubesheet



S – Type

Floating Head



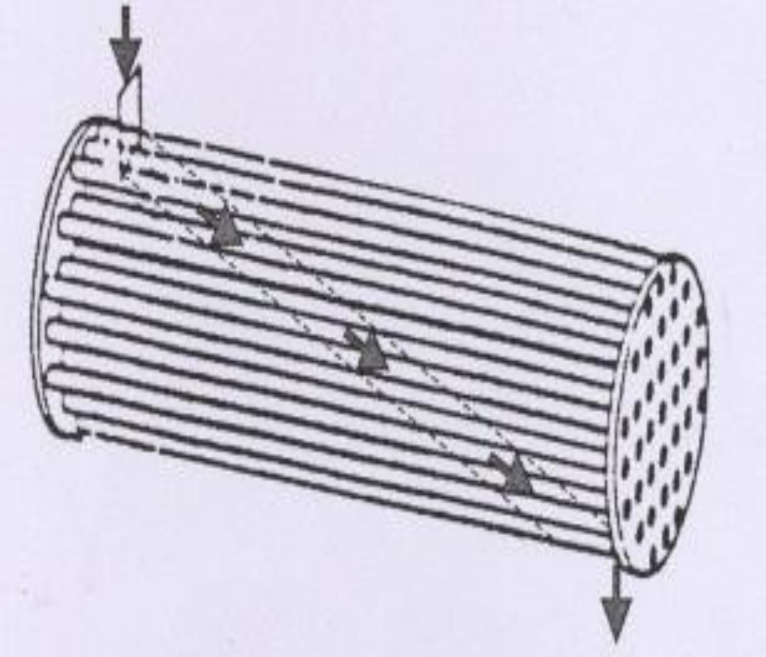
T – Type

Pull-Through Floating Head

Baffle plates

Baffles are transverse or longitudinal plates installed on the shell side of heat exchangers to force the shell side fluid to flow across the tubes in a specific pattern, and to support and secure the tubes and prevent vibration.

The modified flow improves heat transfer between the shell side and tube side fluids.



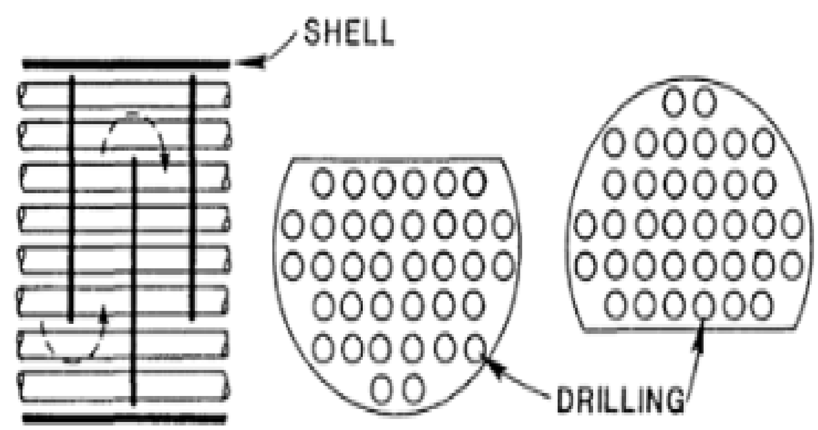
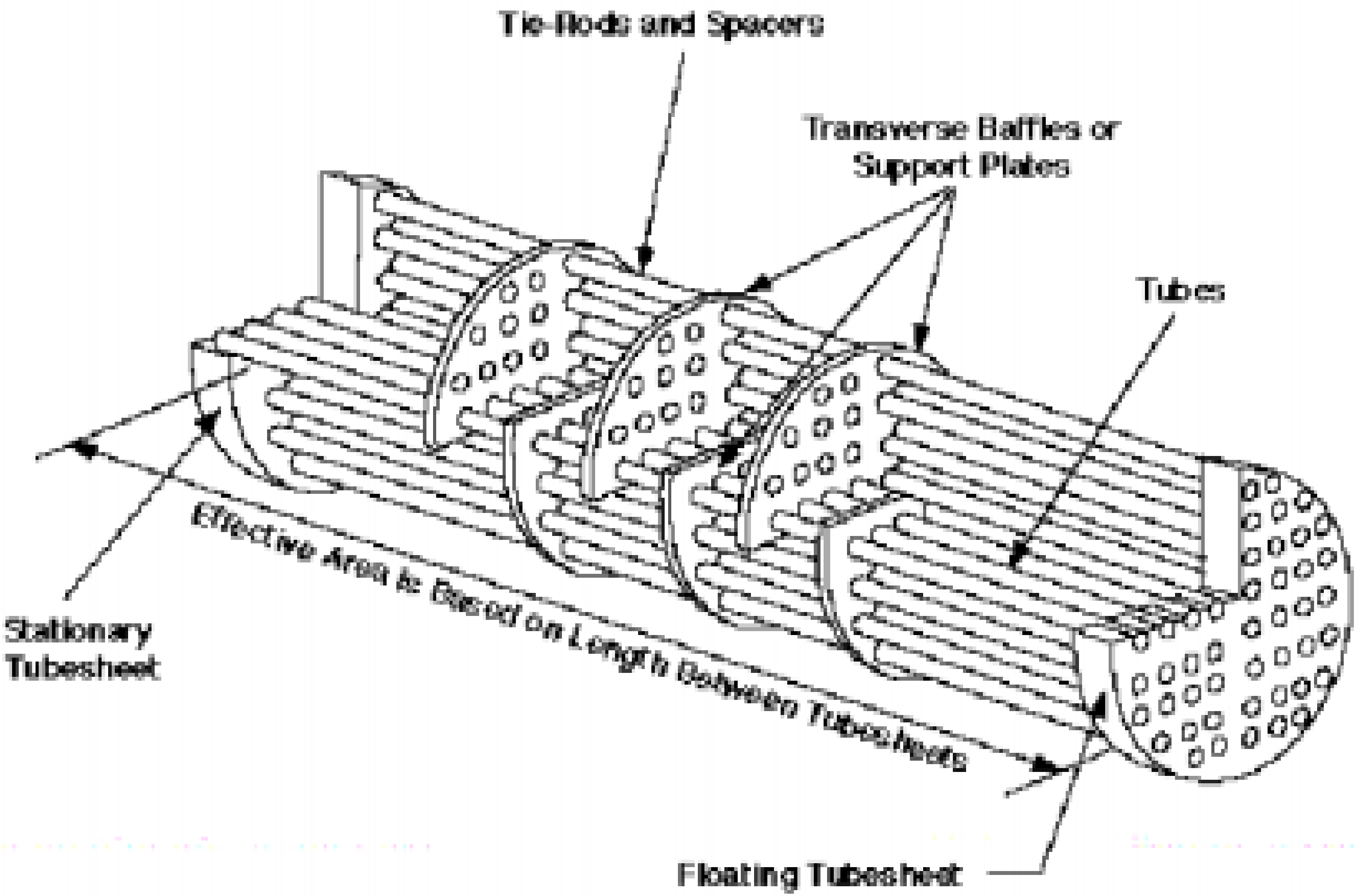


Figure 3-3. Transverse baffle detail.



Tie-Rods and Spacers
Transverse Baffles or
Support Plates
Tubes
Stationary
Tubesheet
Effective Area is Based on Length Between Tubesheets
Floating Tubesheet

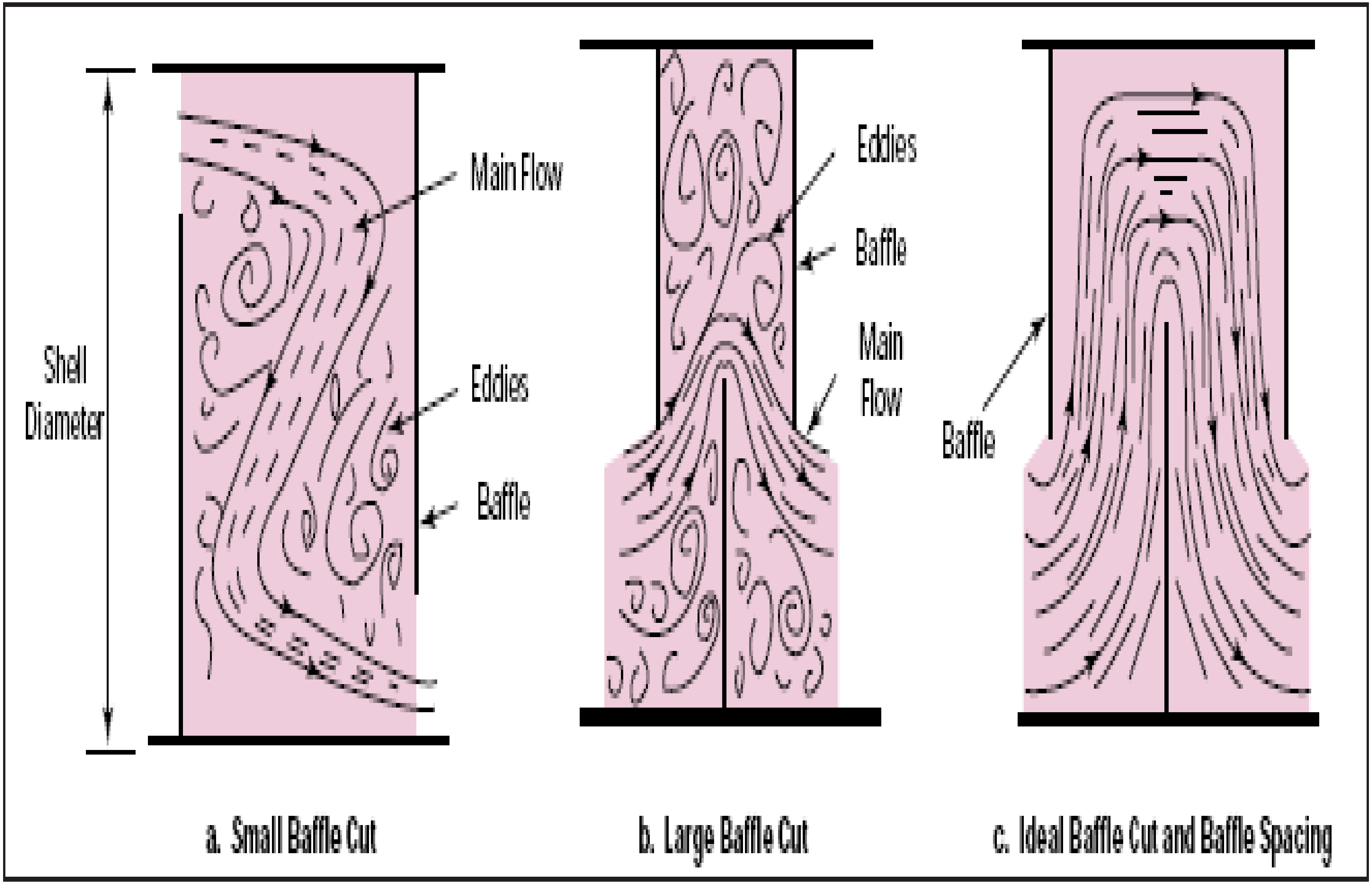
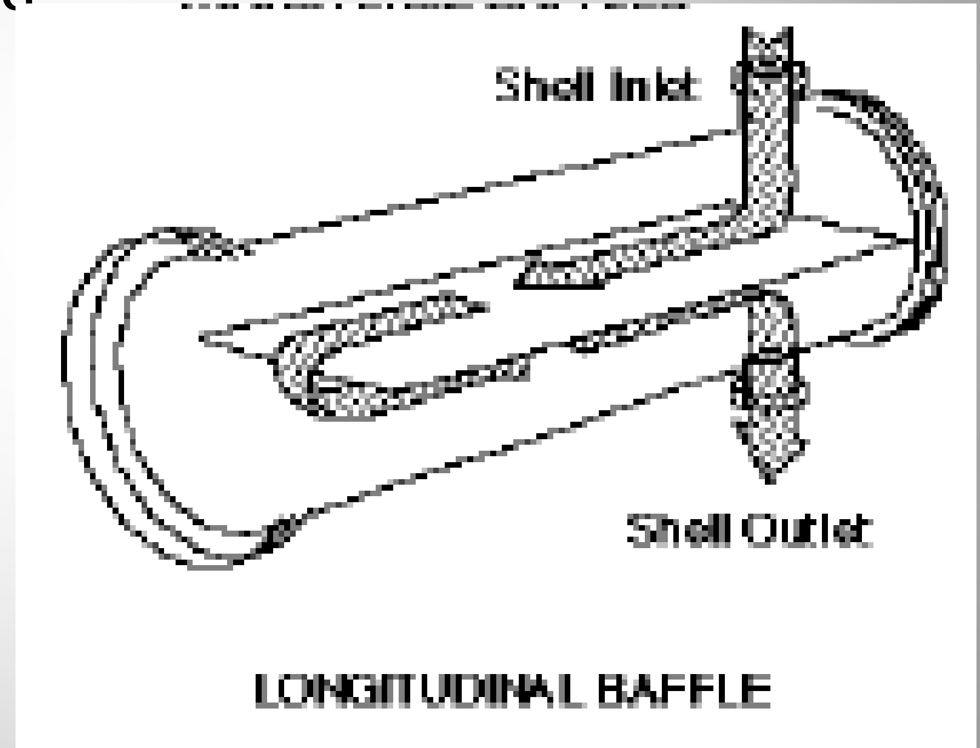


Figure 9. Effect of small and large baffle cuts.

Longitudinal Baffles

- divide tube bundle and shell Into two parts. This done to achieve multi-pass shell.

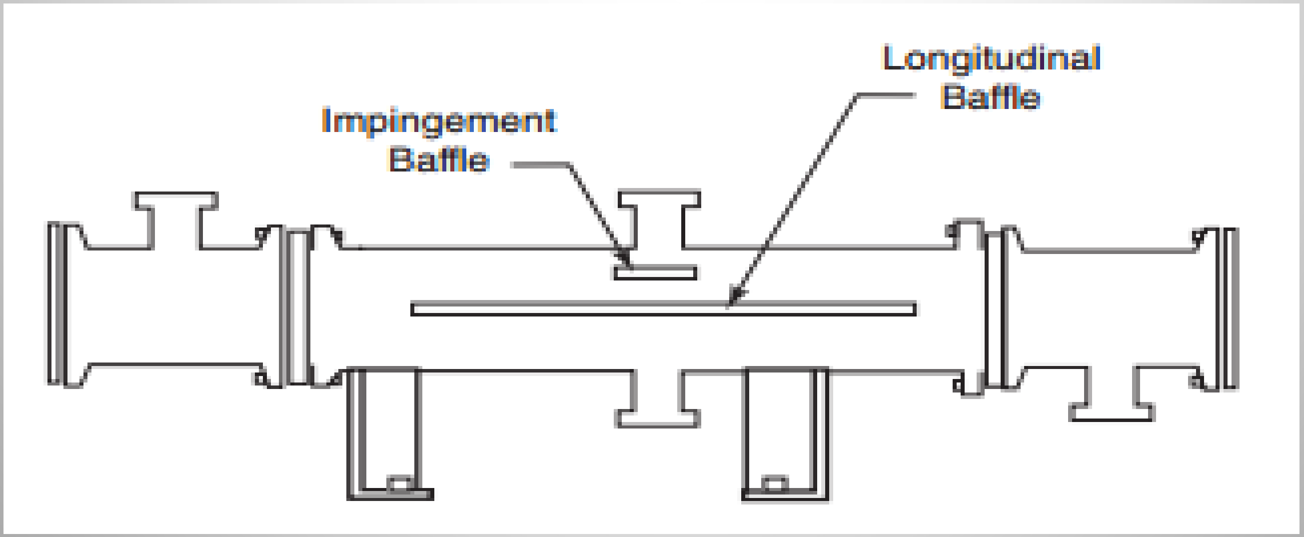


IMPINGEMENT BAFFLE PLATES

Impingement Baffle are plates positioned under the inlet nozzle of the shell to improve fluid Distribution.

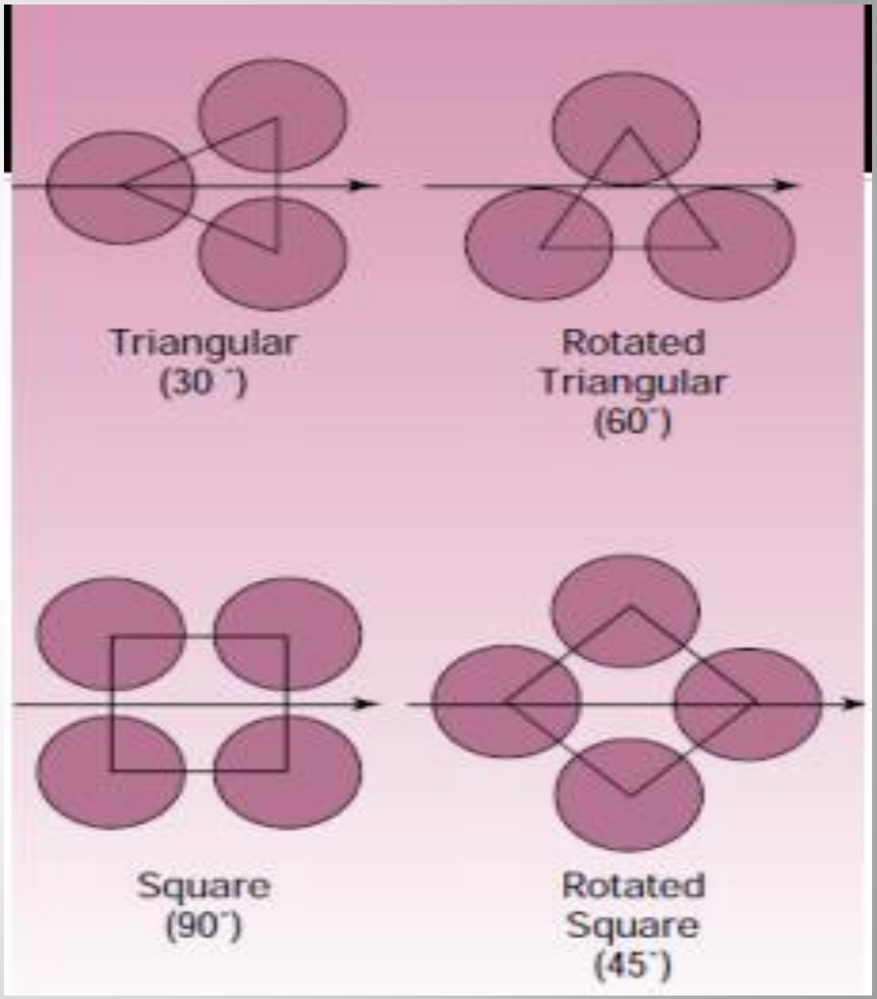
protect tubing from direct fluid impact, preventing cutting, pitting, and erosion problems in the tubes.

Impingement Baffle are used with gases and vapors Condensers.

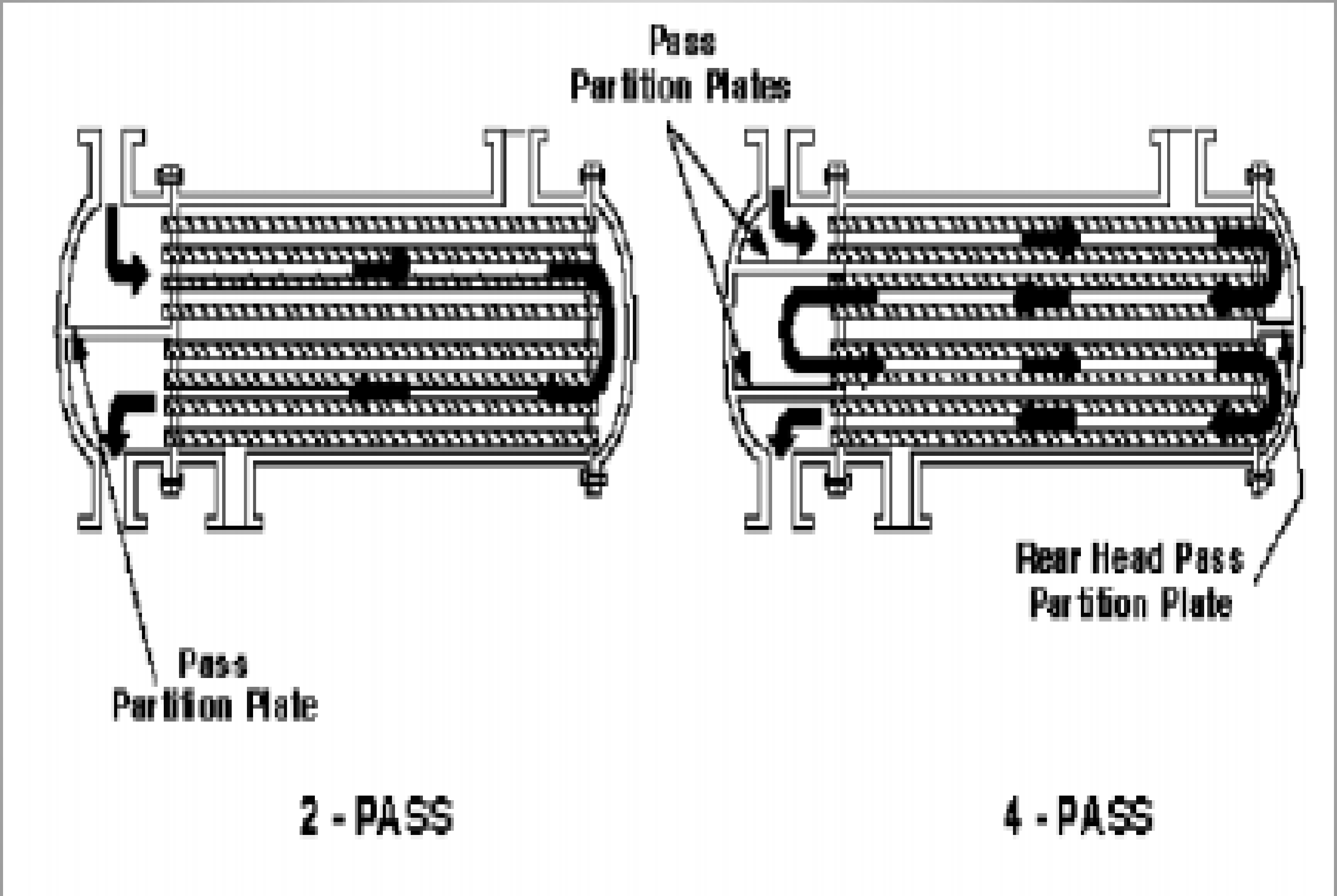


Tube lay out Patterns

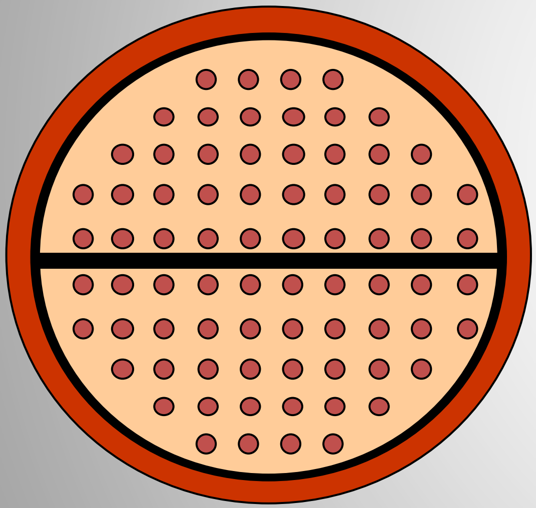
Tube holes cannot be drilled very close together, since this may structurally weaken the tube sheet. The shortest distance between two adjacent tube holes is called the “clearance.” Tubes are laid out in either square or triangular patterns.



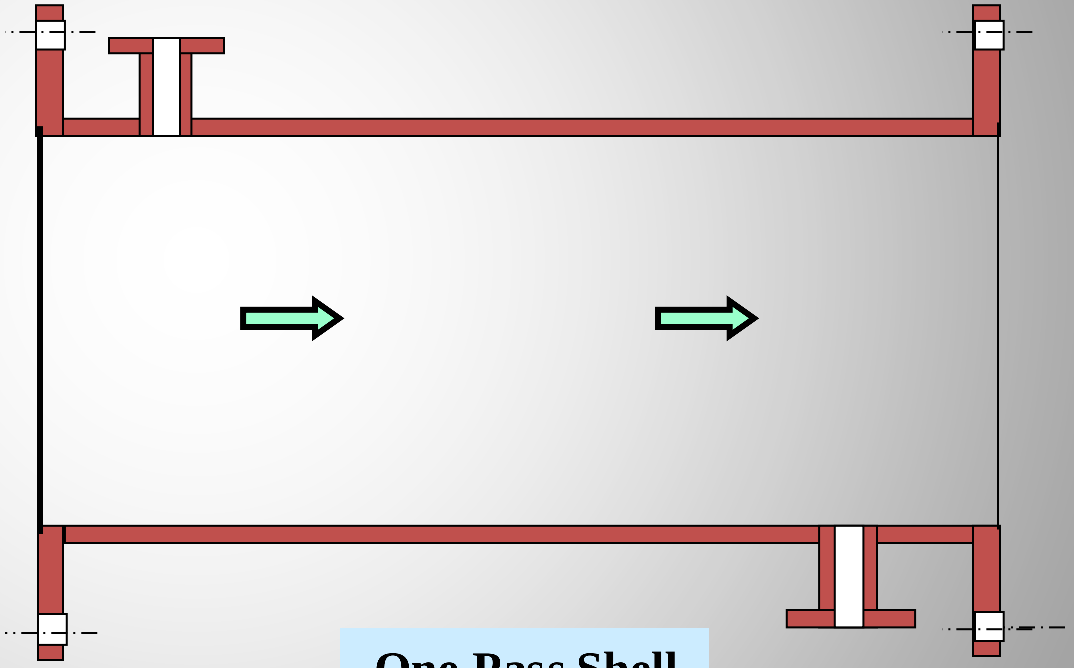
Tube side passes



Two Pass Tube Bundle H.Ex. **And** One Pass Shell H.Ex.

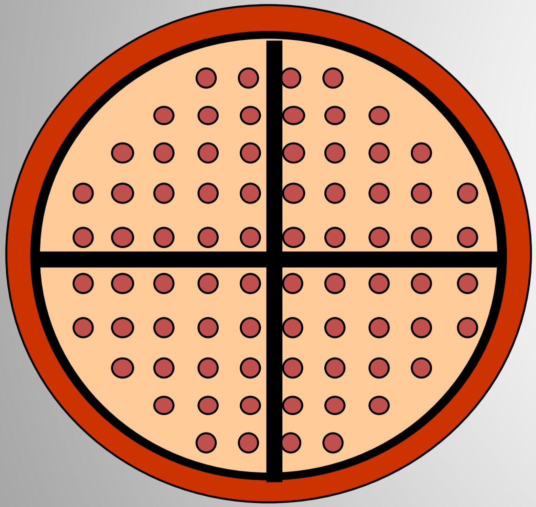


Two Pass Tube Bundle H.Ex.

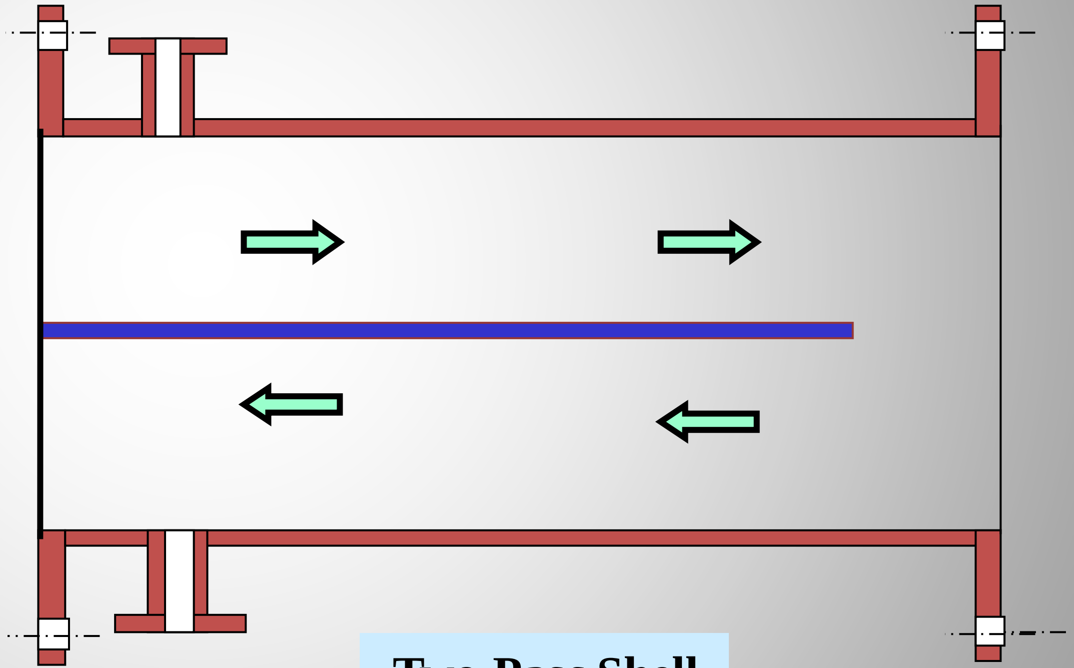


One Pass Shell H.Ex.

Four Pass Tube Bundle H.Ex. **And** Two Pass Shell H.Ex.

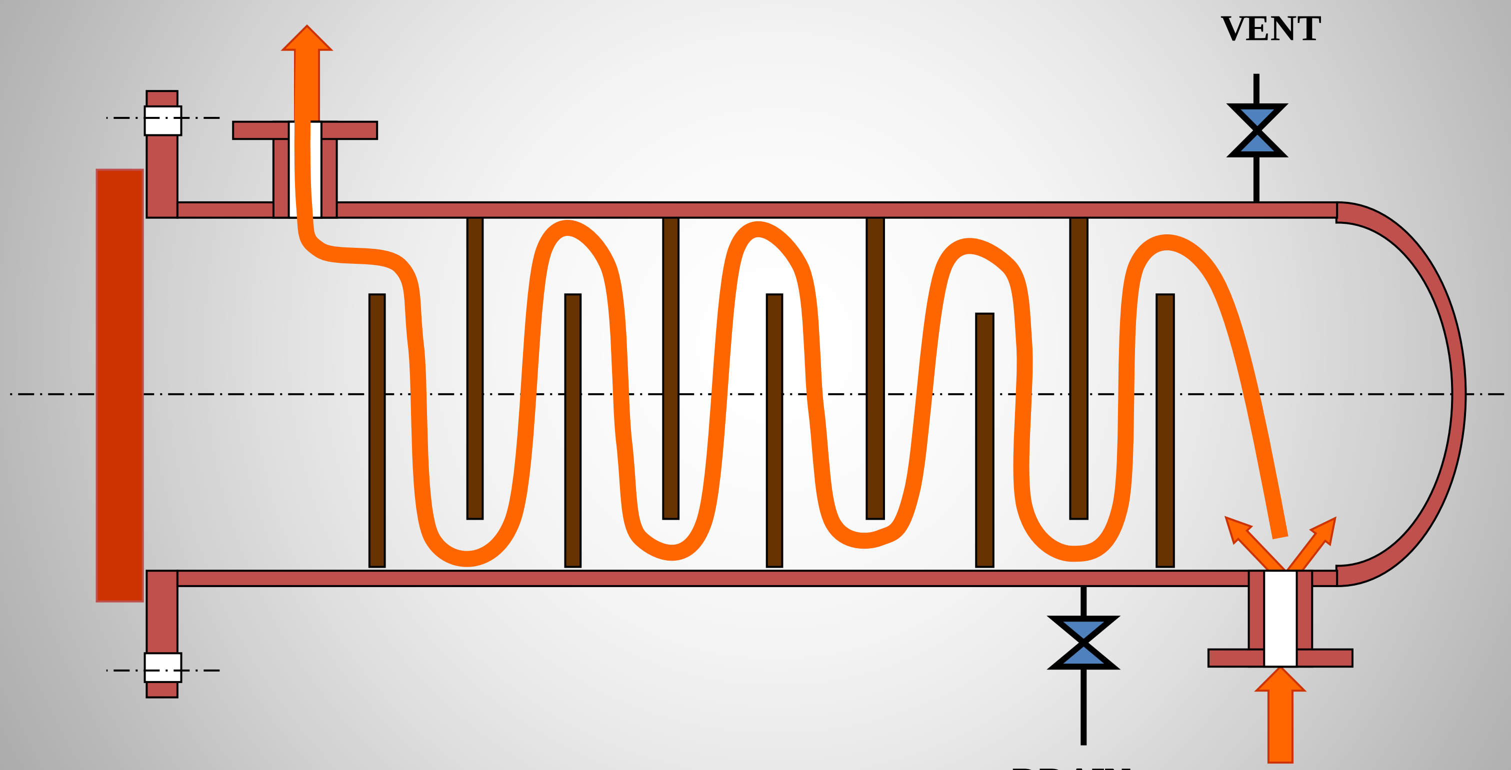


Four Pass Tube Bundle H.Ex.

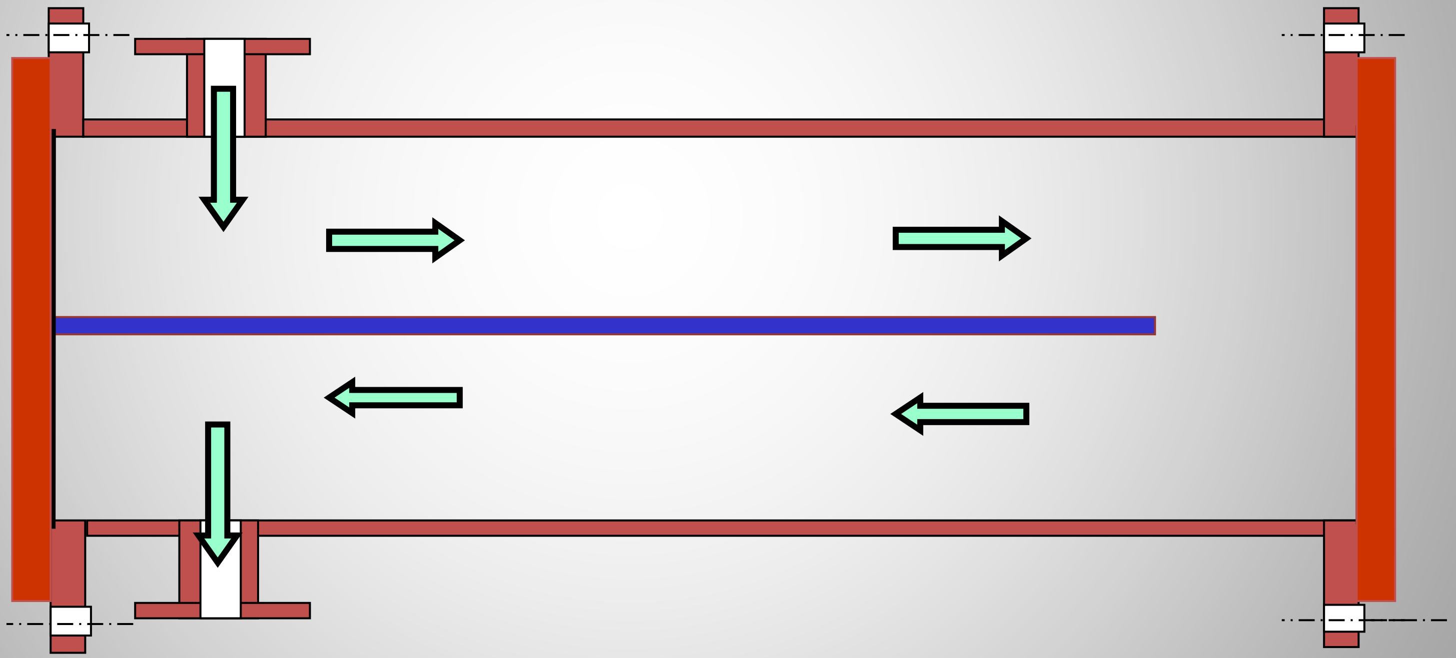


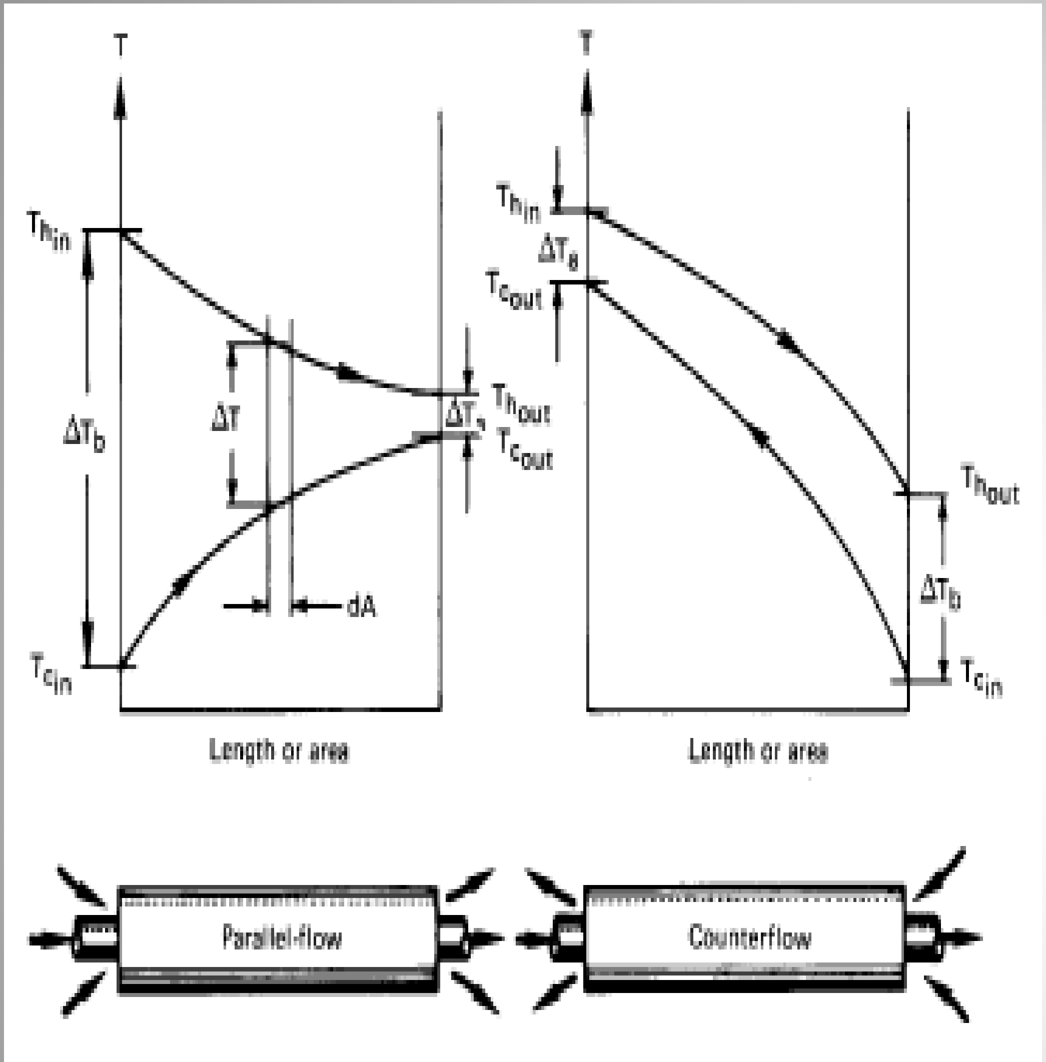
Two Pass Shell H.Ex.

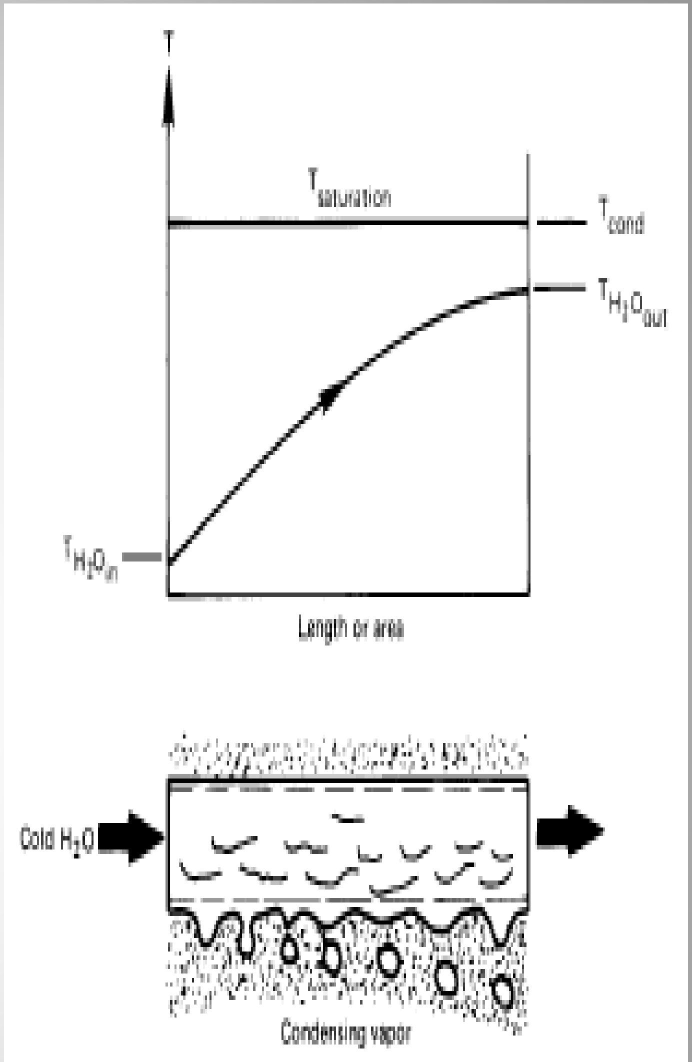
One Pass Shell H.Ex.



Two Pass Shell H.Ex.







Changing in Temp.
Ex. Car Radiator

Changing in Phase
Ex. Reboiler

A Methodology for Heat Exchanger Design Calculations
- The Log Mean Temperature Difference (LMTD) Method -

A form of Newton's Law of Cooling may be applied to heat exchangers by using a log-mean value of the temperature difference between the two fluids:

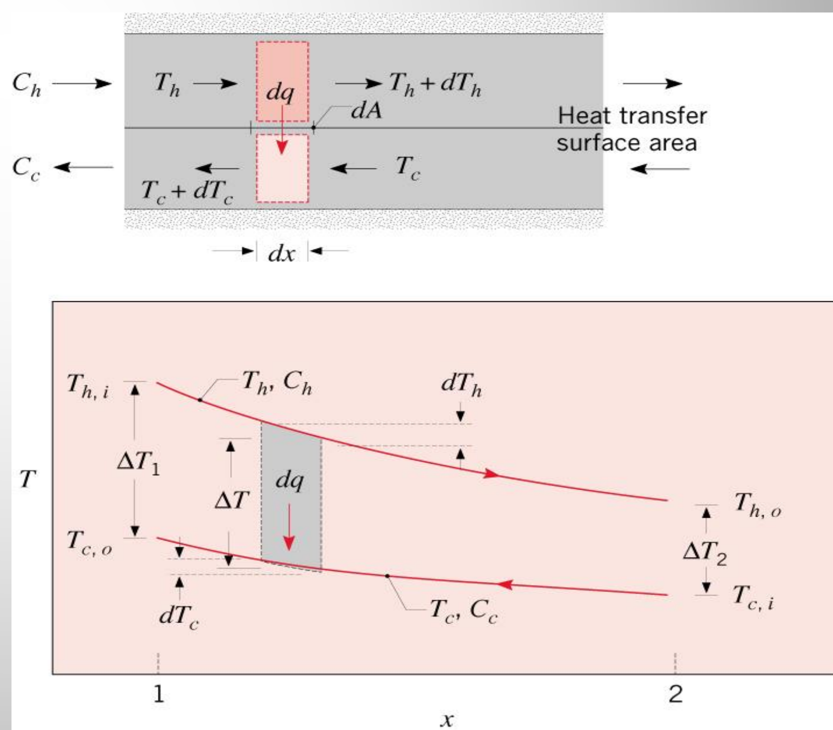
$$q = U A \Delta T_{1m} \qquad \Delta T_{1m} = \frac{\Delta T_1 - \Delta T_2}{1n(\Delta T_1 / \Delta T_2)}$$

Evaluation of ΔT_1 and ΔT_2 depends on the heat exchanger type.

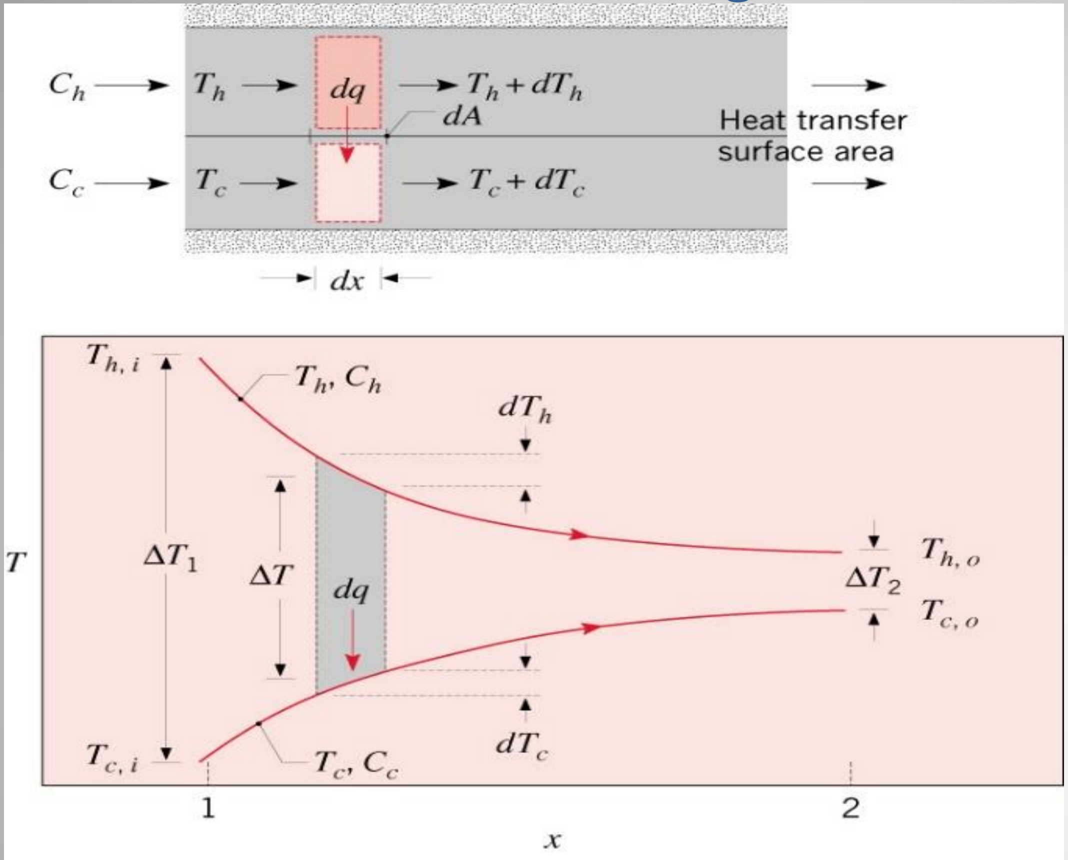
- Counter-Flow Heat Exchanger:

$$\begin{aligned} \Delta T_1 &\equiv T_{h,1} - T_{c,1} \\ &= T_{h,i} - T_{c,o} \end{aligned}$$

$$\begin{aligned} \Delta T_2 &\equiv T_{h,2} - T_{c,2} \\ &= T_{h,o} - T_{c,i} \end{aligned}$$



- Parallel-Flow Heat Exchanger:



$$\Delta T_1 \equiv T_{h,1} - T_{c,1} = T_{h,i} - T_{c,i}$$

$$\Delta T_2 \equiv T_{h,2} - T_{c,2} = T_{h,o} - T_{c,o}$$

- Note that $T_{c,o}$ can not exceed $T_{h,o}$ for a PF HX.
- For equivalent values of UA and inlet temperatures,

$$\Delta T_{1m,CF} > \Delta T_{1m,PF}$$

Heat Transfer in H. E.

Heat transfer in a heat exchanger is by conduction and convection. The rate of heat transfer, "Q", in a heat exchanger is calculated using the following equation:

$$\mathbf{Q = Uo\ Ao\ \Delta\ T_{Lm}}$$

Q = Heat transfer rate (BTU/hr)
Uo = Overall heat transfer coefficient (BTU/hr-ft2-oF
Ao = Cross sectional heat transfer area (ft2)
$\Delta\ T_{lm}$ = Log mean temperature difference (o F)

Example

A heat exchanger is operated under the following conditions as a counter flow and a co-current flow:

T1 =represents the hot fluid temperature

T1 in = 200 oF T1 out = 145 oF

Uo = 70 BTU/hr-ft2-oF Ao =75 ft2

T2 = represents the cold fluid temperature

T2 in = 80 oF T2 out = 120 oF

Solution

$$\text{Counter flow } \Delta T_{lm} = \frac{(200-120)-(145-80)}{\ln\frac{(200-120)}{(145-80)}} = 72^\circ F$$

$$\text{Co-current flow } \Delta T_{lm} = \frac{(200-80)-(145-120)}{\ln\frac{(200-80)}{(145-120)}} = 61^\circ F$$

$$Q = U_o A_o \Delta T_{lm}$$

Heat Transfer for the counter flow conditions:

$$Q = \frac{(70\ BTU)}{hr - ft^2 - {}^oF}(75\ ft^2)(72\ {}^oF)$$

$Q = 3.8 * 10^5$ BTU / hr

Heat Transfer for the co-current flow conditions:

$$Q = \frac{(70\ BTU)}{hr - ft^2 - {}^oF}(75\ ft^2)(61\ {}^oF)$$

$Q = 3.2 * 10^5$ BTU / hr

The results demonstrate that given the same operating conditions, operating the same heat exchanger in a counter flow manner will result in a greater heat transfer rate than operating in parallel flow.

Fluid Placement

- **A. Shell-Side**
  1. Fluid having the lowest flow rate
  2. Condensing or boiling fluid

- **B. Tube-Side**
  1. Toxic fluids to minimize leakage
  2. Corrosive fluids; (special alloy tubes can be used to resist internal corrosion, which is much less expensive than building the entire shell and tubes from special alloys).
  3. Fouling fluids; since it is easier to clean, especially when mechanical cleaning is needed.
  4. High temperature fluids requiring alloy materials
  5. High pressure fluid normally flows through the tubes since tubes can collapse from overpressure forces from the outside.

Start Up And Shutdown

On initial start up and shutdown the heat exchanger can be subjected to damage Such as thermal chock, over pressure or hydraulic hammer
This can lead to leaky tube to tube sheet joints because of excessive thermal expansion of tubes or the shell.

New H.Ex. Start Up Procedure

1. Check H.Ex. Parts no loose bolts,
2. All valves in the shut position.
3. Start cold fluid, then gradually start hot fluid.
4. When fluid stream is liquid, check that there is no pocket gas via vent valve.
5. Check H.Ex Leaks
6. Temperature changes should be slowly, and flow rate gradually increased

H.Ex. Shutdown Procedure

Stop the hot fluid first

H.Ex. Valves should not be closed while it is full of liquids.

How to detect Operational Problem

Decline of heat transfer efficiency

High pressure drop

Internal gasket leaks

Internal Tubes leaks

External leaks

Laboratory Sample results

Types Of H.Ex. Failure

1- Tubes Leaking

2- Tube Sheet Leaking

3- Tubes Plugging

4- Shell Plugging

H.Ex. Leak Test

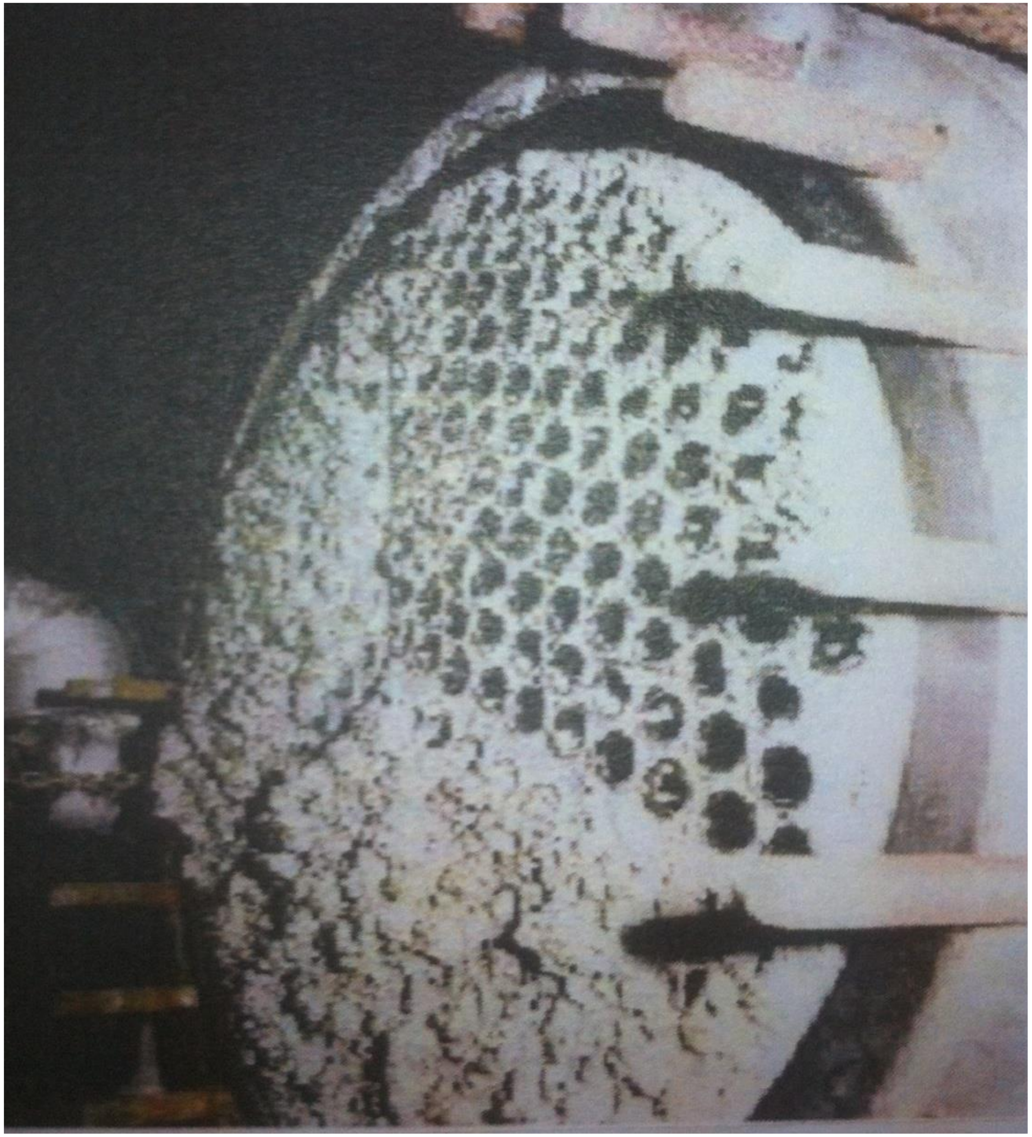
Visual Leak Test

Hydrostatic Test

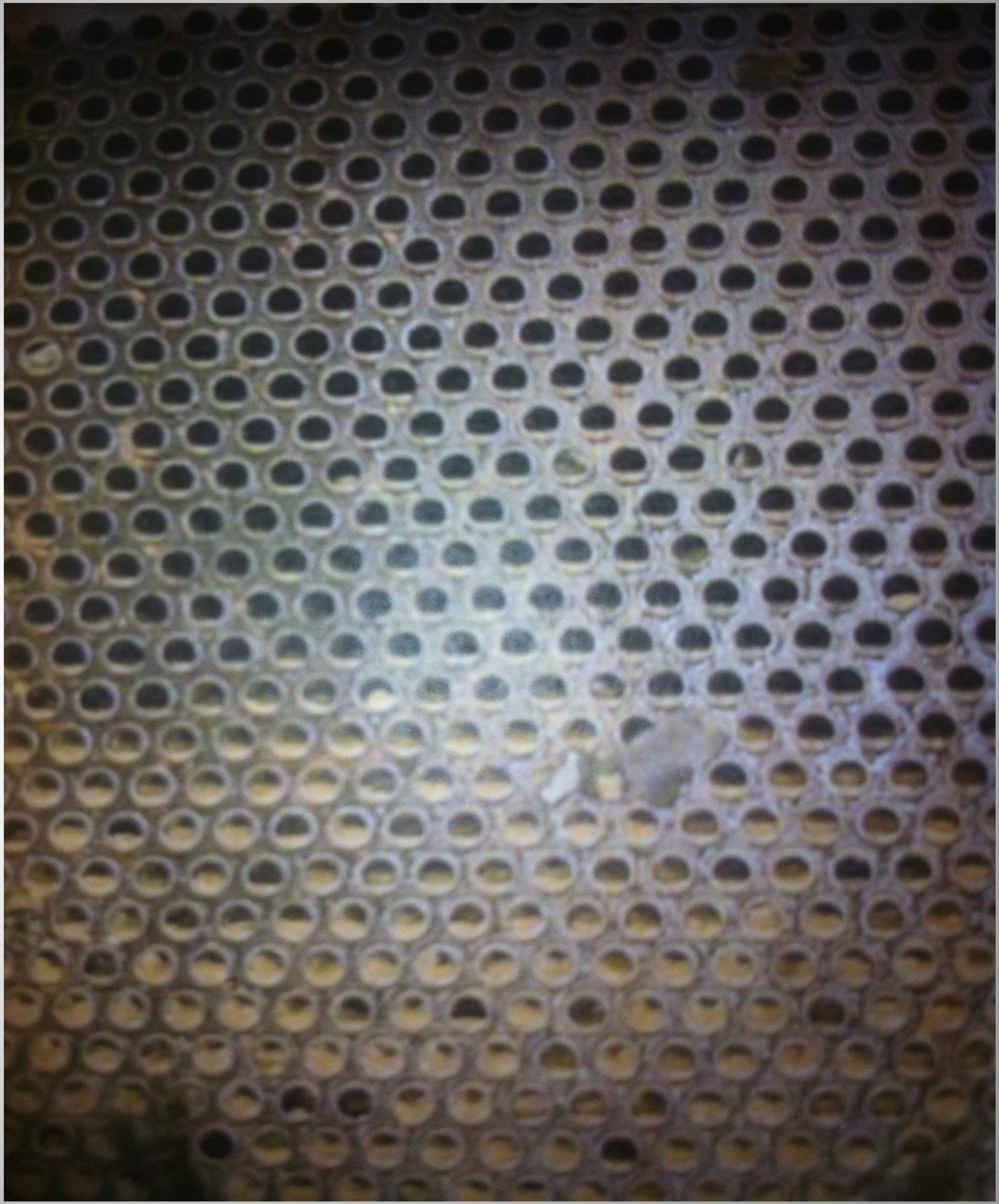
Sample Lab. Test

External Fouling

Tubes Plugging



Tubes Fouling



Heat Ex. Fouling

Fouling definition

Fouling is a trim used to describe undesirable deposits on a heat exchanger surface. These deposits result in an increase of resistance to both fluid flow and heat transfer. A slight sludge or scale buildup on either side of the tube greatly reduces effectiveness. An increase in pressure drop through the exchanger or a drop in heat exchange efficiency usually indicates that cleaning is needed.

Types of Fouling

Mineral scales,

- Sedimentation (dirt or clay in the cooling water supply),
- Coking (hot surfaces and carbon deposits),
- Corrosion

How to handle the problem of Fouling

- Mineral scales can be combated with chemical treatments while the process is running.
- Sedimentation is prevented or lessened through the proper use of a filtering system.
- Corrosion is prevented through the proper selection of exchanger materials as well as through use of corrosion inhibitor.
- Coking is common in hydrocarbon processing and is not always possible to eliminate.
- Hydro blasting cleaning (high pressure water jet pump) 10,000 psi

  For out side tube fouling and Shell cleaning

  Turbine cleaning for inside tube heavy fouling and Shell cleaning

Hydrostatic Test

Hydrostatic test will supervised and responsibility of Inspection department

Test blinds (capable to withstand the test pressure),
to be installed at inlet and outlet nozzles of shell and tube sides.

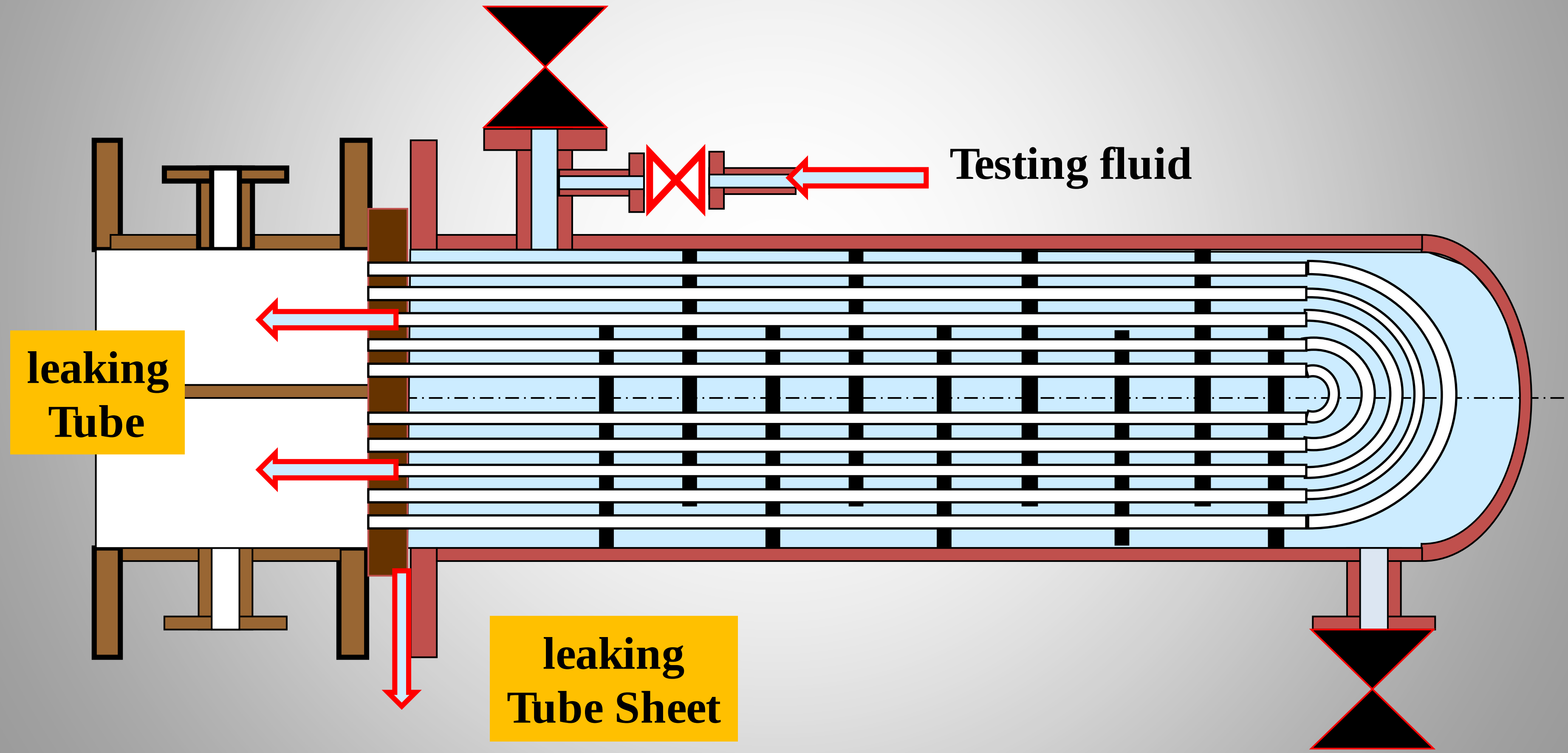
Apply pressure in shell side, check tubes leaking (outside or inside)

Drain the tube water

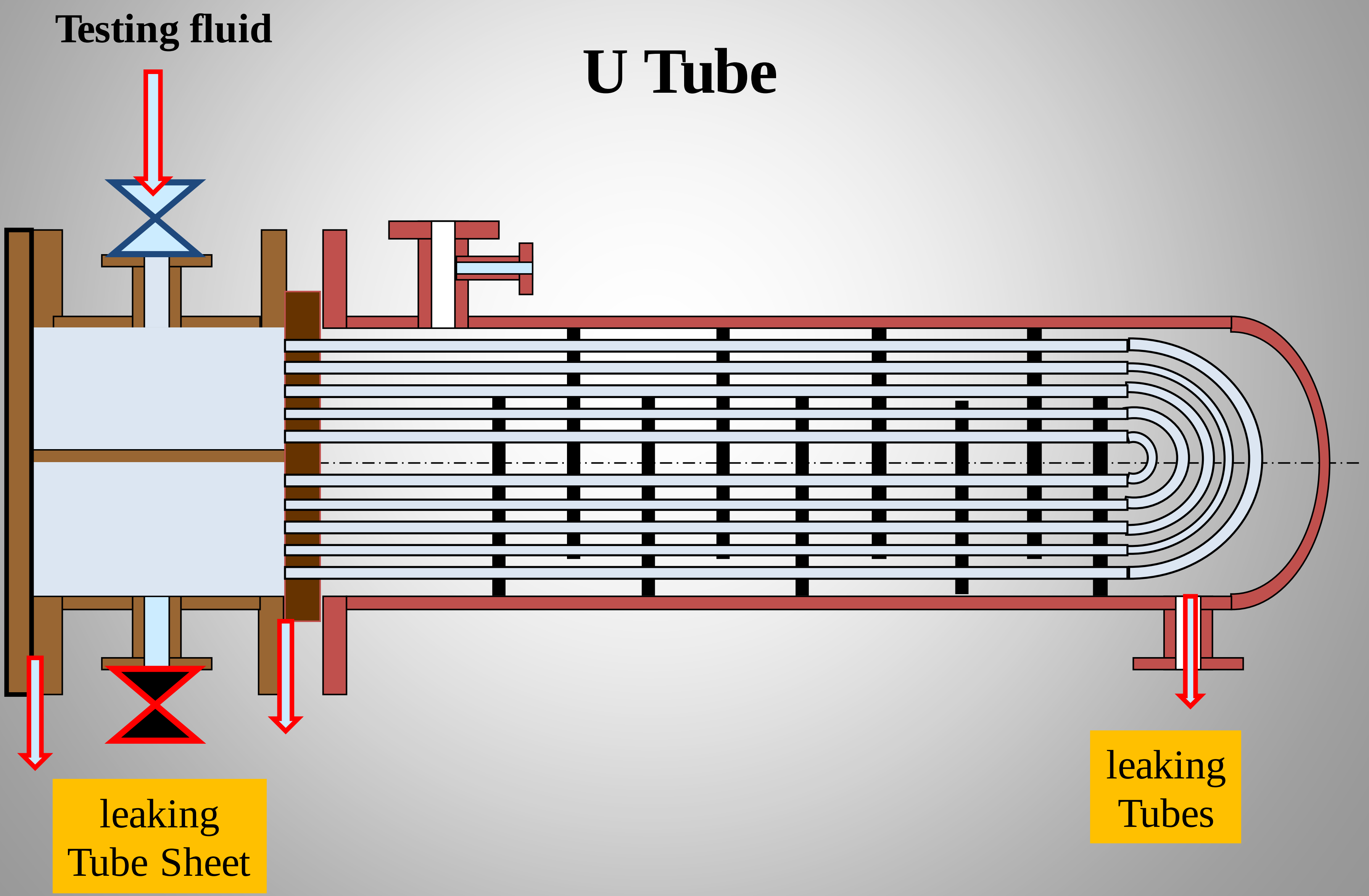
Apply pressure in tube side, check tubes leaking, tube sheet leaking

HYDRAULIC TESTING

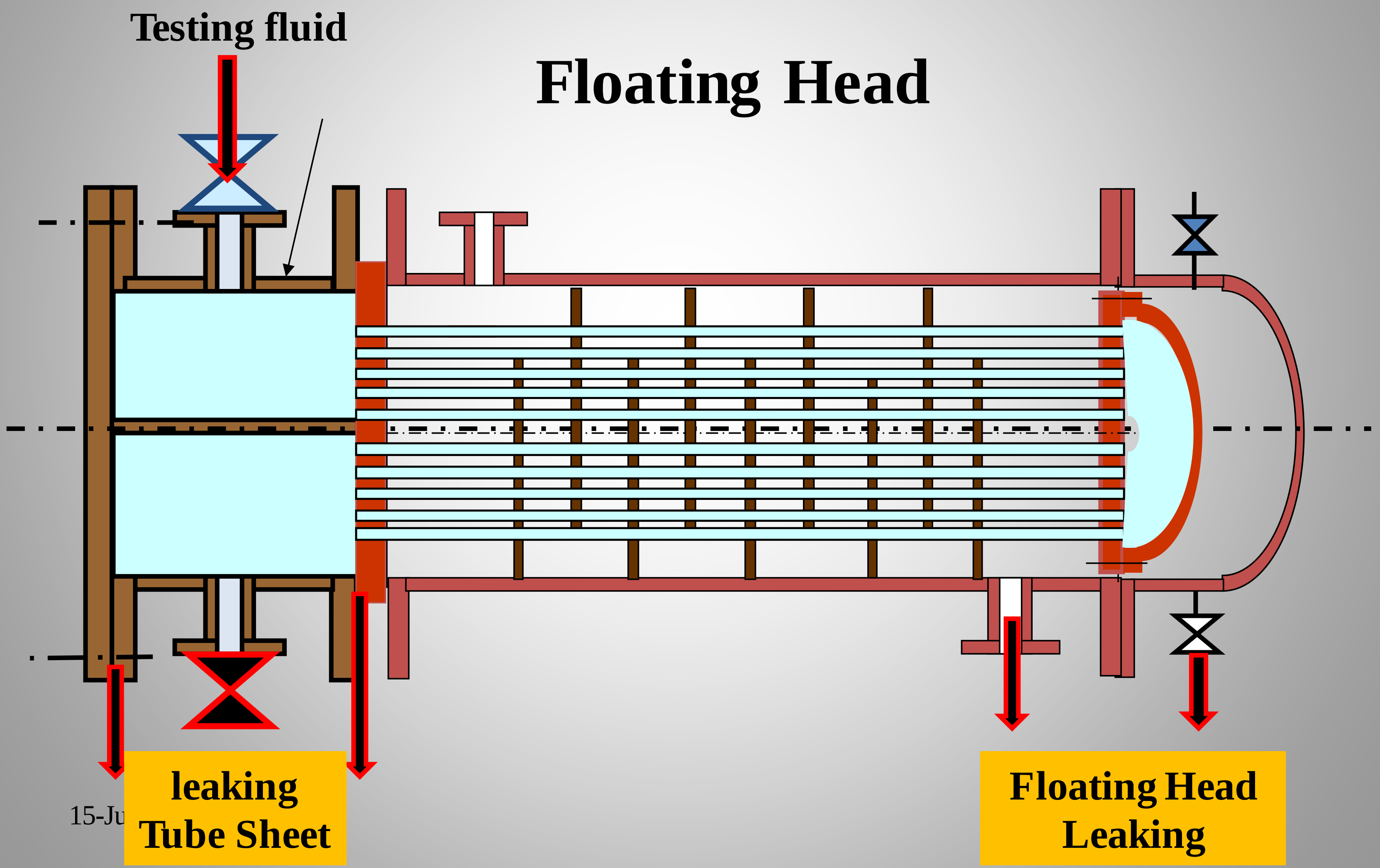
Shell Side Test

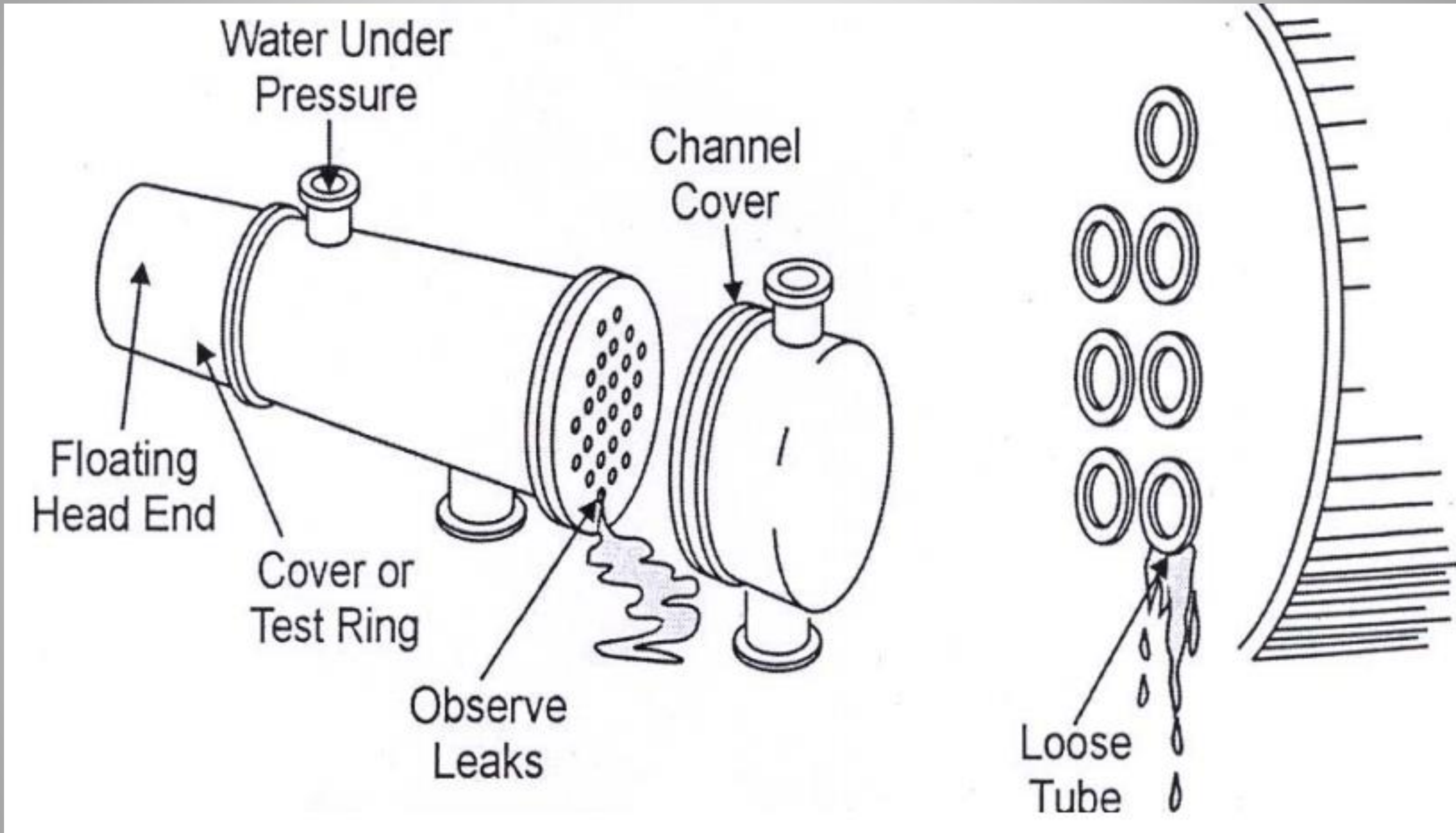


Tube Side Test



Tube Side Test




Water Under
Pressure
Channel
Cover
Floating
Head End
Cover or
Test Ring
Observe
Leaks
Loose
Tube

Heat Exchanger Maintenance

MAXIMUM PLUGGED TUBES 20% TO 25% OF PASS TUBES NO.