Heat Exchangers

Heat Exchangers

- A device whose primary purpose is the transfer of energy between two fluids is named a Heat Exchanger.

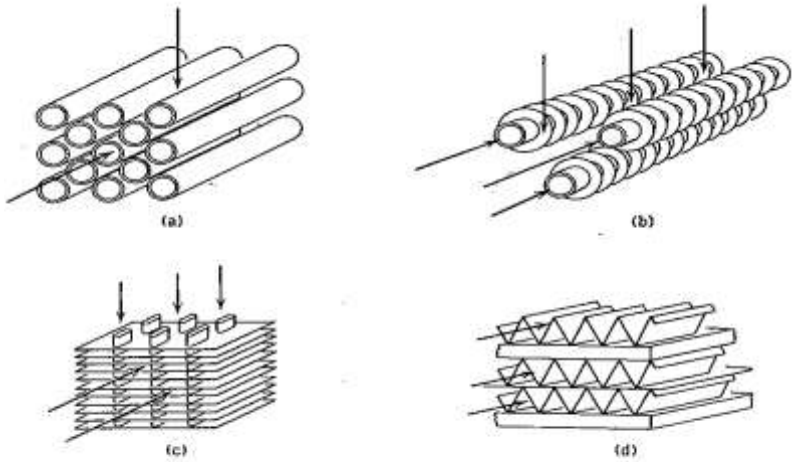
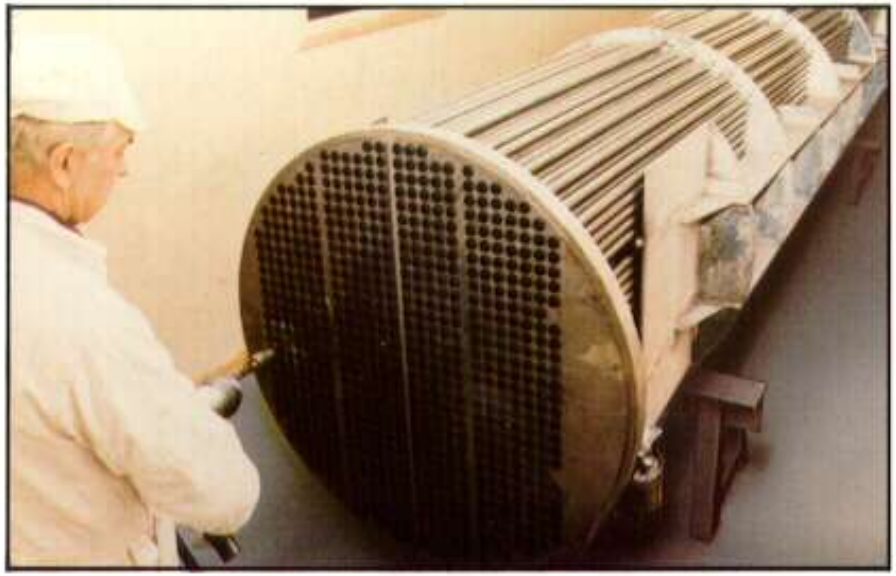


Figure 22.4 Compact heat-exchanger configurations.

Contents

Why shell-and-tube?
Scope of shell-and-tube
Construction
TEMA standards
Choice of TEMA type
Fluid allocation
Design problems
Enhancement
Improved designs



How is the heat transfer?

- Heat can transfer between the surface of a solid conductor and the surrounding medium whenever temperature gradient exists.

  Conduction

  Convection

    Natural convection

    Forced Convection

Natural and forced Convection

Natural convection occurs whenever heat flows between a solid and fluid, or between fluid layers.

As a result of heat exchange

Change in density of effective fluid layers taken place, which causes upward flow of heated fluid.

If this motion is associated with heat transfer mechanism only, then it is called Natural Convection

Forced Convection

If this motion is associated by mechanical means such as pumps, gravity or fans, the movement of the fluid is enforced.

And in this case, we then speak of Forced convection.

Why shell-and-tube?

CEC survey: S&T accounted for 85% of new exchangers supplied to oil-refining, chemical, petrochemical and power companies in leading European countries. Why?

- Can be designed for almost any duty with a very wide range of temperatures and pressures
- Can be built in many materials
- Many suppliers
- Repair can be by non-specialists
- Design methods and mechanical codes have been established from many years of experience

Scope of shell-and-tube

Maximum pressure

- **Shell 300 bar (4500 psia)**
- **Tube 1400 bar (20000 psia)**

Temperature range

- **Maximum 600°C (1100°F) or even 650°C**
- **Minimum -100°C (-150°F)**

Fluids

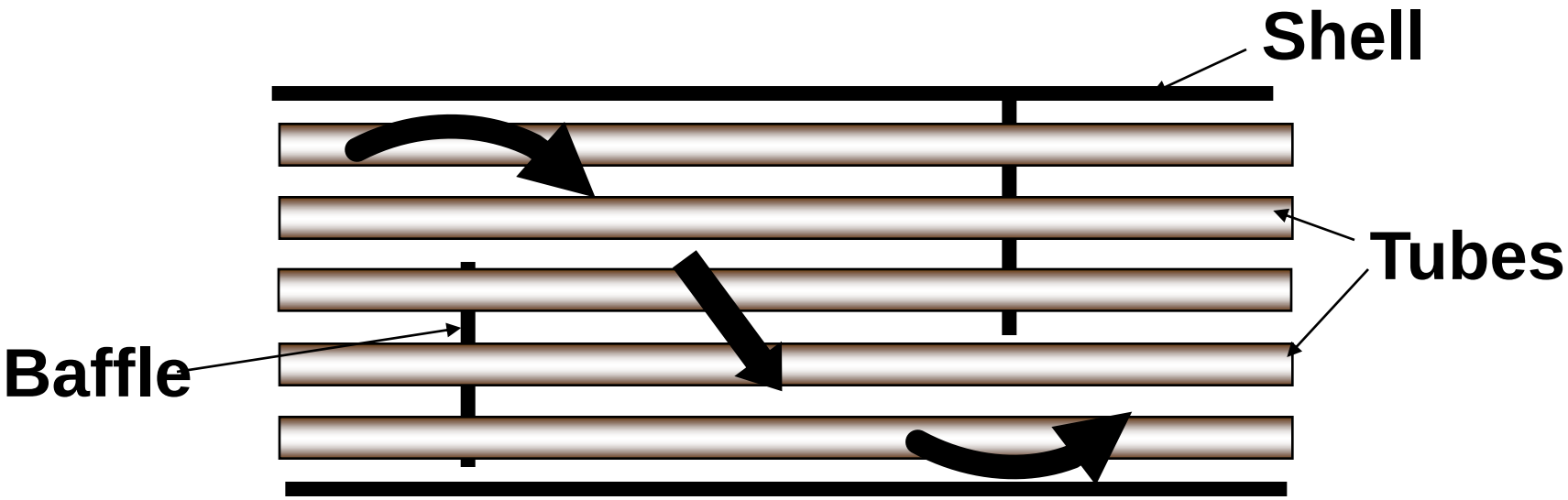
- **Subject to materials**
- **Available in a wide range of materials**

Size per unit 100 - 10000 ft^2 (10 - 1000 m^2)

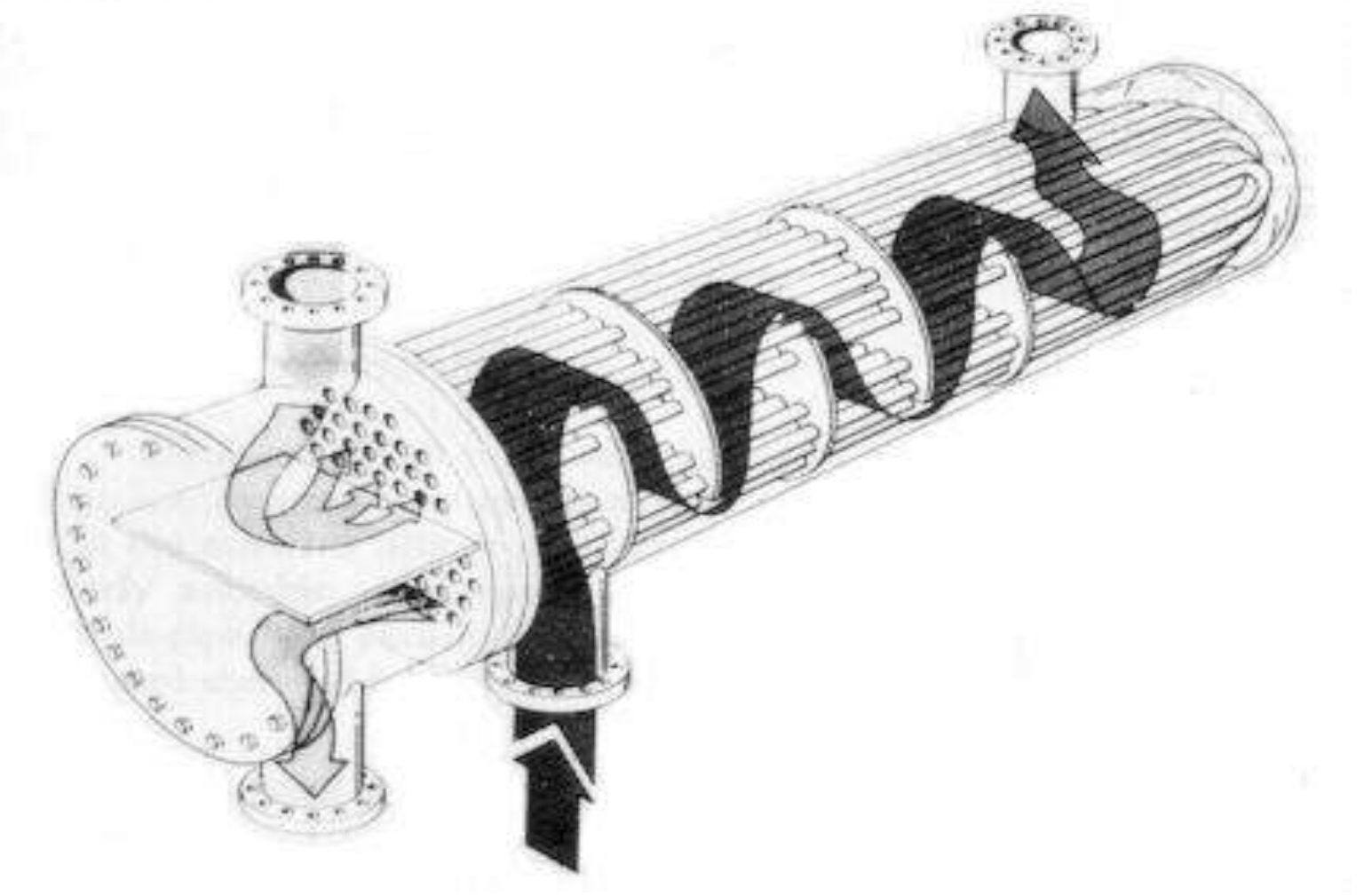
Can be extended with special designs/materials

Construction

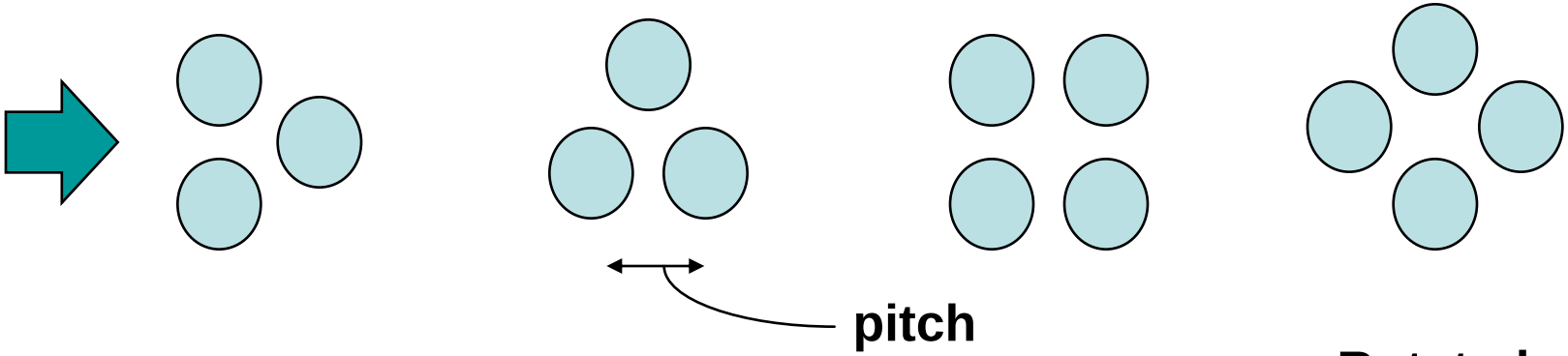
- Bundle of tubes in large cylindrical shell
- Baffles used both to support the tubes and to direct into multiple cross flow
- Gaps or clearances must be left between the baffle and the shell and between the tubes and the baffle to enable assembly



Shell-side flow



Tube layouts



Triangular 30°

Rotated triangular 60°

Square 90°

Rotated square 45°

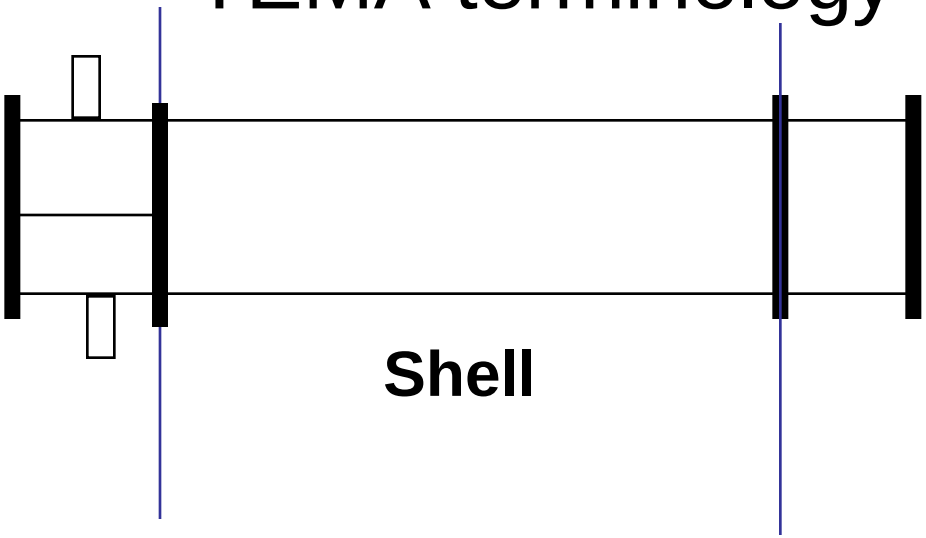
- Typically, 1 in tubes on a 1.25 in pitch or 0.75 in tubes on a 1 in pitch
- Triangular layouts give more tubes in a given shell
- Square layouts give cleaning lanes with close pitch

TEMA standards

Tubular Exchanger Manufacturers Association

- The design and construction is usually based on TEMA 8th Edition 1998
- Supplements pressure vessel codes like ASME and BS 5500
- Sets out constructional details, recommended tube sizes, allowable clearances, terminology etc.
- Provides basis for contracts
- Tends to be followed rigidly even when not strictly necessary
- Many users have their own additions to the standard which suppliers must follow

TEMA terminology



Front end stationary head type

Shell

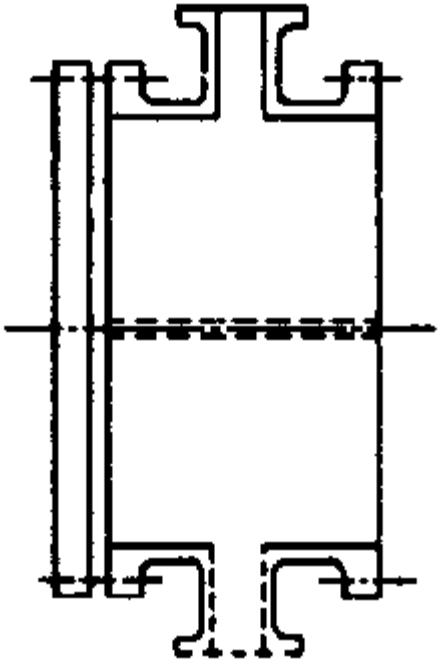
Rear end head type

- Letters given for the front end, shell and rear end types
- Exchanger given three letter designation
- Above is AEL

Front head type

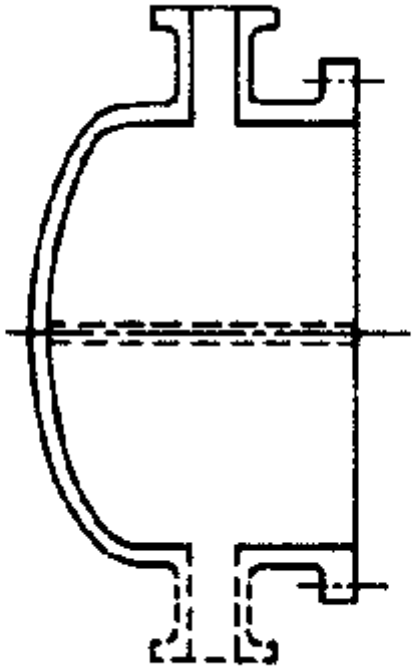
- A-type is standard for dirty tube side
- B-type for clean tube side duties. Use if possible since cheap and simple.

A



Channel and removable cover

B

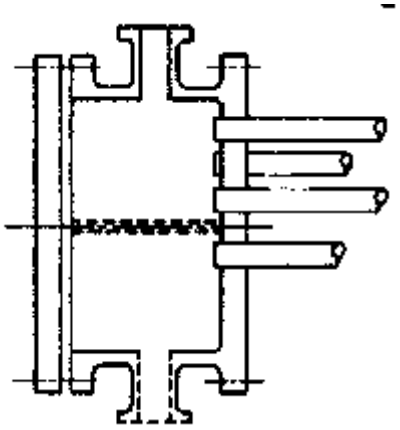


Bonnet (integral cover)

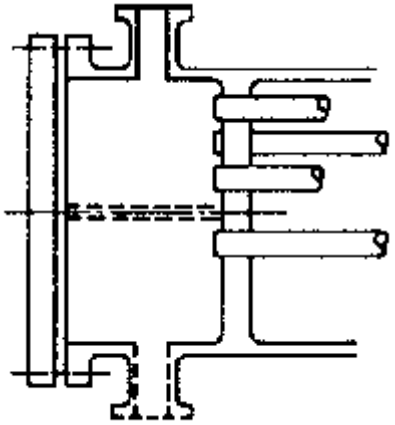
More front-end head types

- C-type with removable shell for hazardous tube-side fluids, heavy bundles or services that need frequent shell-side cleaning
- N-type for fixed for hazardous fluids on shell side
- D-type or welded to tube sheet bonnet for high pressure (over 150 bar)

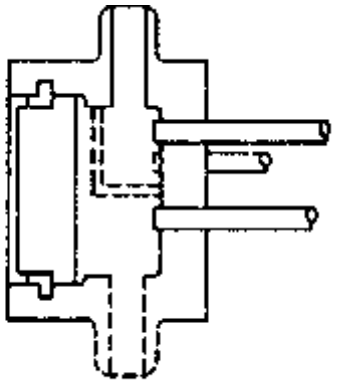
B



N



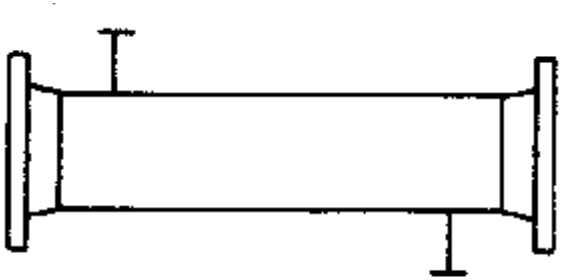
D



Shell type

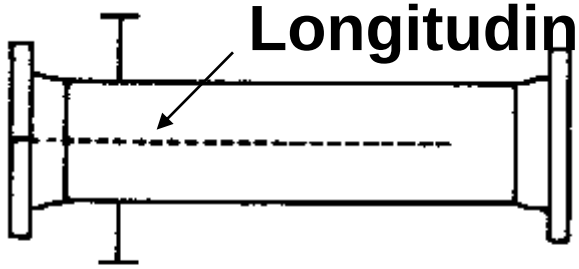
- E-type shell should be used if possible but
- F shell gives pure counter-current flow with two tube passes (avoids very long exchangers)

E



One-pass shell

F



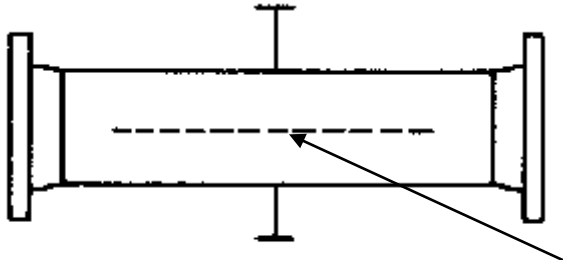
Two-pass shell

Note, longitudinal baffles are difficult to seal with the shell especially when reinserting the shell after maintenance

More shell types

- G and H shells normally only used for horizontal thermosyphon reboilers
- J and X shells if allowable pressure drop can not be achieved in an E shell

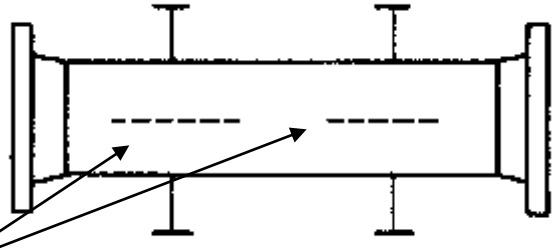
G



Split flow

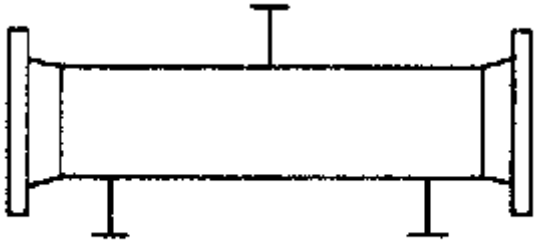
Longitudinal baffles

H



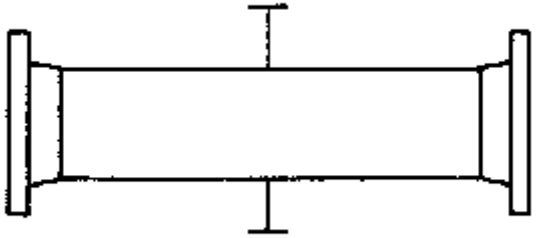
Double split flow

J



Divided flow

X



Cross flow

Rear head type

These fall into three general types

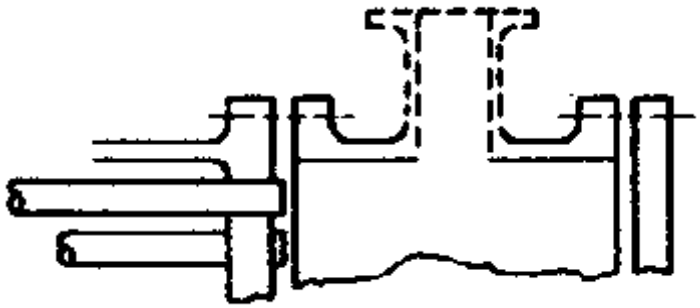
- fixed tube sheet (L, M, N)
- U-tube
- floating head (P, S, T, W)

Use fixed tube sheet if ΔT below 50^{o}C, otherwise use other types to allow for differential thermal expansion

You can use bellows in shell to allow for expansion but these are special items which have pressure limitations (max. 35 bar)

Fixed rear head types

L



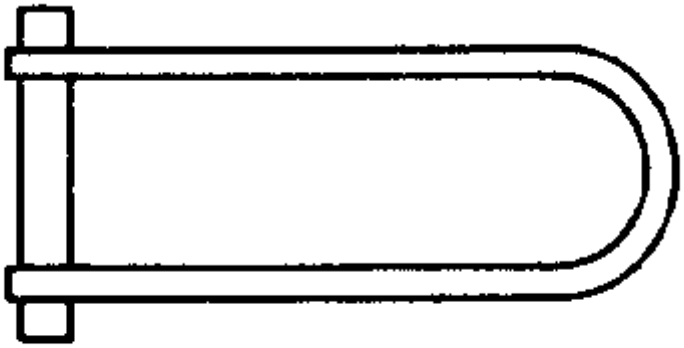
Fixed tube sheet

- L is a mirror of the A front end head
- M is a mirror of the bonnet (B) front end
- N is the mirror of the N front end

Floating heads and U tube

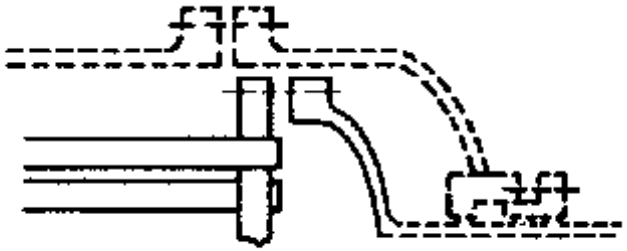
Allow bundle removal and mechanical cleaning on the shell side

- U tube is simple design but it is difficult to clean the tube side round the bend



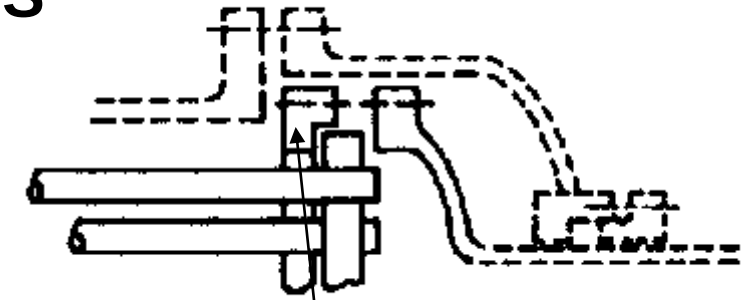
Floating heads

T

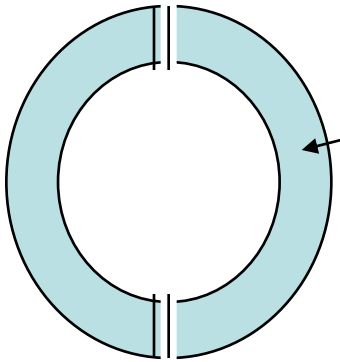


Pull through floating head
Note large shell/bundle gap

S



Similar to T but with smaller shell/bundle gap

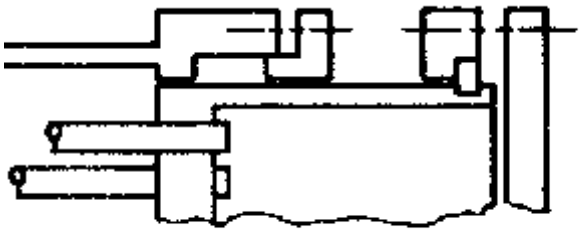


Split backing ring

Other floating heads

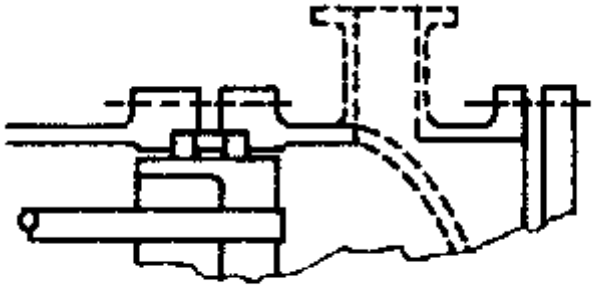
- Not used often and then with small exchangers

P



Outside packing to give smaller shell/bundle gap

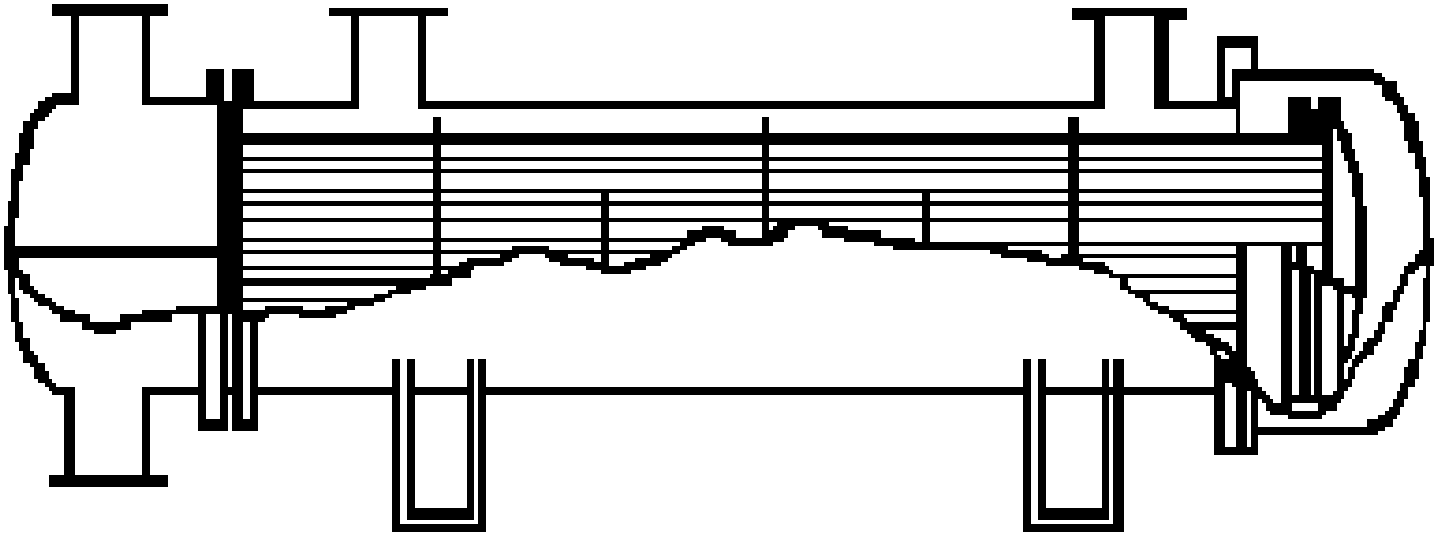
W



Externally sealed floating tube sheet
maximum of 2 tube passes

Example

- BES
- Bonnet front end, single shell pass and split backing ring floating head



Allocation of fluids

- Put dirty stream on the tube side - easier to clean inside the tubes
- Put high pressure stream in the tubes to avoid thick, expensive shell
- When special materials required for one stream, put that one in the tubes to avoid expensive shell
- Cross flow gives higher coefficients than in plane tubes, hence put fluid with lowest coefficient on the shell side
- If no obvious benefit, try streams both ways and see which gives best design

Typical maximum exchanger sizes

	Floating Head	Fixed head & U tube
Diameter	60 in (1524 mm)	80 in (2000 mm)
Length	30 ft (9 m)	40 ft (12 m)
Area	13 650 ft^2 (1270 m^2)	46 400 ft^2 (4310 m^2)

Note that, to remove bundle, you need to allow at least as much length as the length of the bundle

Fouling

Shell and tubes can handle fouling but it can be reduced by

- keeping velocities sufficiently high to avoid deposits
- avoiding stagnant regions where dirt will collect
- avoiding hot spots where coking or scaling might occur
- avoiding cold spots where liquids might freeze or where corrosive products may condense for gases

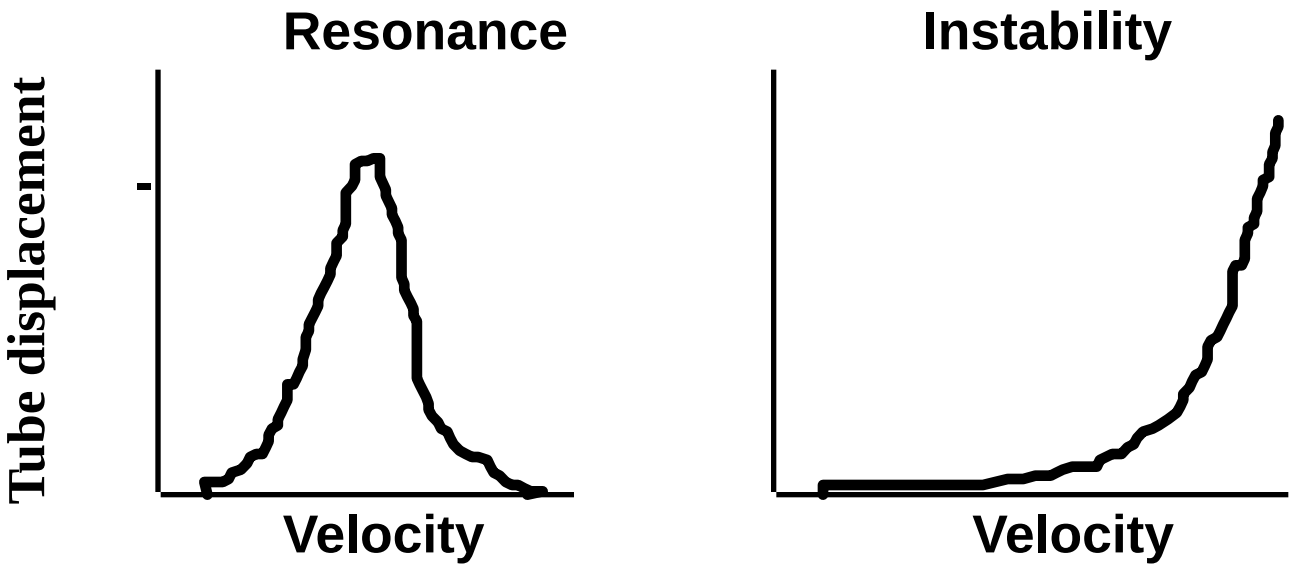
High fouling resistances are a self-fulfilling prophecy

Flow-induced vibration

Two types - RESONANCE and INSTABILITY

- Resonance occurs when the natural frequency coincides with a resonant frequency
- Fluid elastic instability

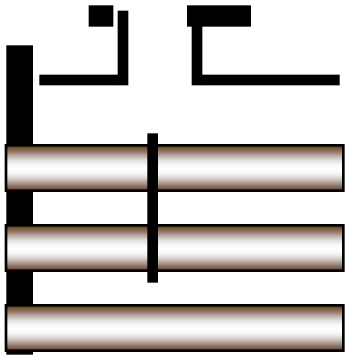
Both depend on span length and velocity



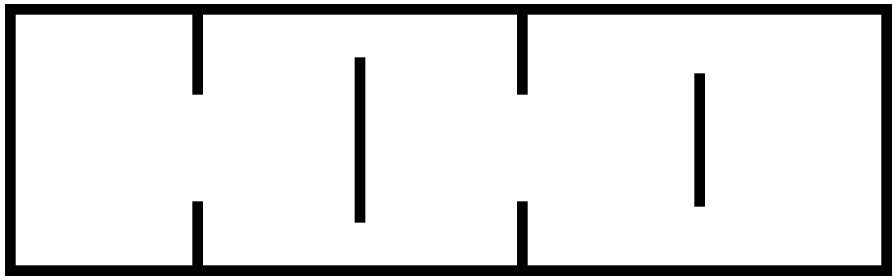
Avoiding vibration

- Inlet support baffles - partial baffles in first few tube rows under the nozzles
- Double segmental baffles - approximately halve cross flow velocity but also reduce heat transfer coefficients
- Patent tube-support devices
- No tubes in the window (with intermediate support baffles)
- J-Shell - velocity is halved for same baffle spacing as an E shell but decreased heat transfer coefficients

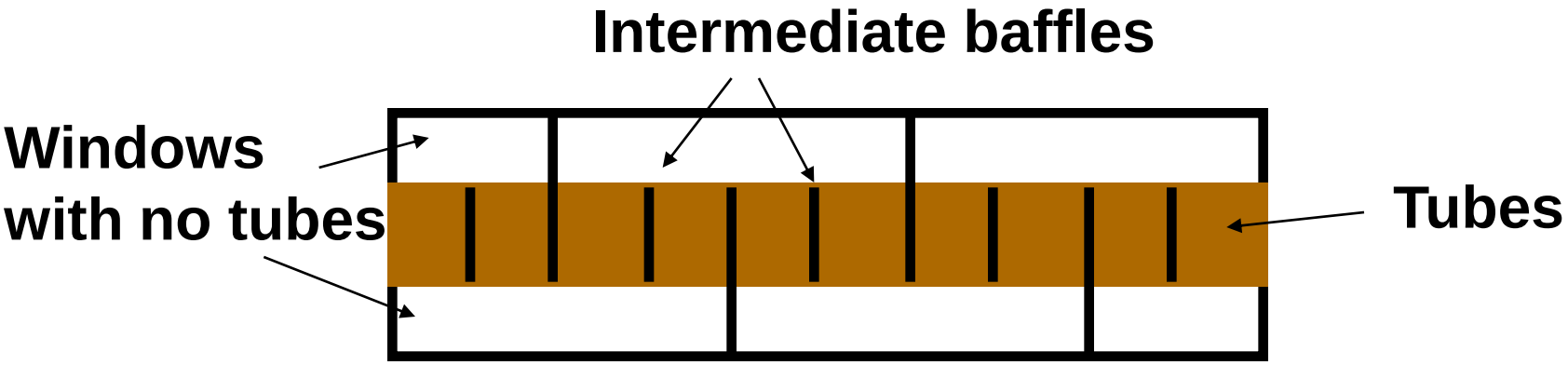
Avoiding vibration (cont.)



Inlet support baffles



Double-segmental baffles



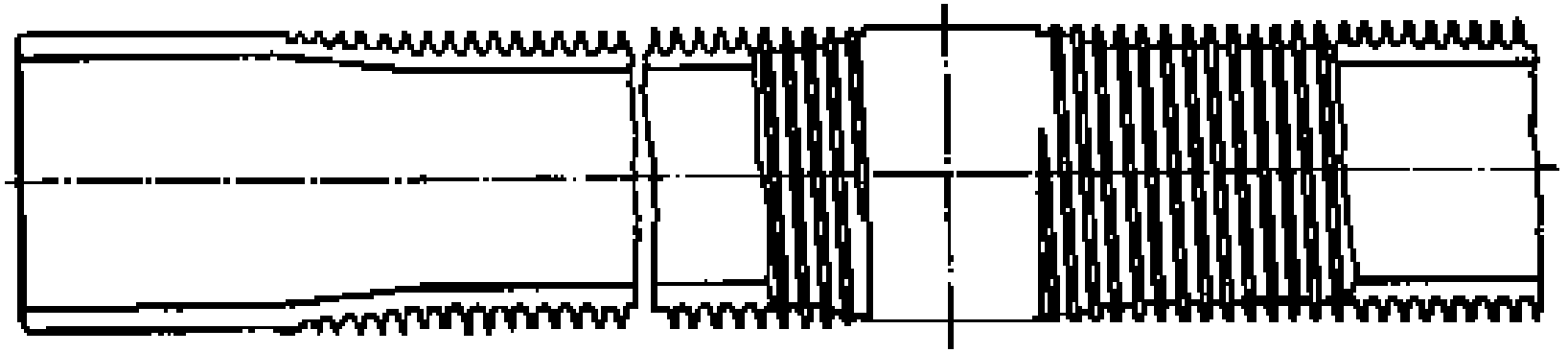
No tubes in the window - with intermediate support baffles

Shell-side enhancement

- Usually done with integral, low-fin tubes
  - 11 to 40 fpi (fins per inch). High end for condensation
  - fin heights 0.8 to 1.5 mm
- Designed with o.d. (over the fin) to fit into the a standard shell-and-tube
- The enhancement for single phase arises from the extra surface area (50 to 250% extra area)
- Special surfaces have been developed for boiling and condensation

Low-finned Tubes

- Flat end to go into tube sheet and intermediate flat portions for baffle locations



- Available in variety of metals including stainless steel, titanium and inconels

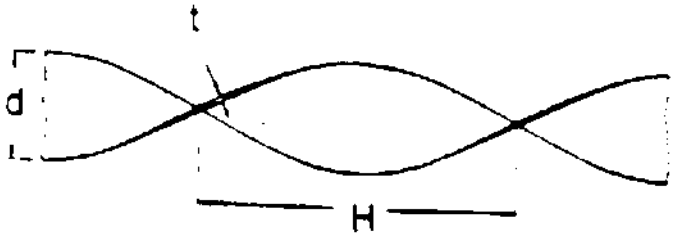
Tube Lamina Flow Performance

As liquids pass through the tube side of the exchanger there can be less efficient heat exchange because of lamina flow. If the flow pattern can be disrupted in to a more turbulent pattern then the exchanger efficiency will be improved

Tube-side enhancement using inserts

Spiral wound wire and twisted tape

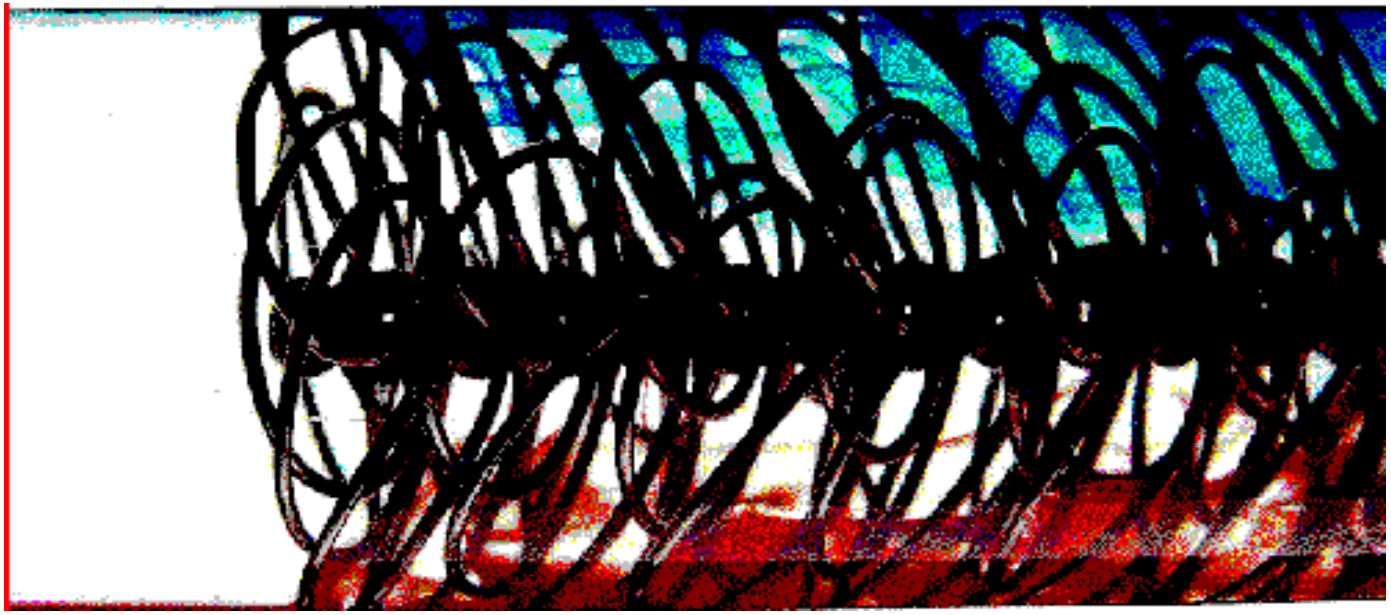
- Increase tube side heat transfer coefficient but at the cost of larger pressure drop (although exchanger can be reconfigured to allow for higher pressure drop)
- In some circumstances, they can significantly reduce fouling. In others they may make things worse
- Can be retrofitted



Twisted tape

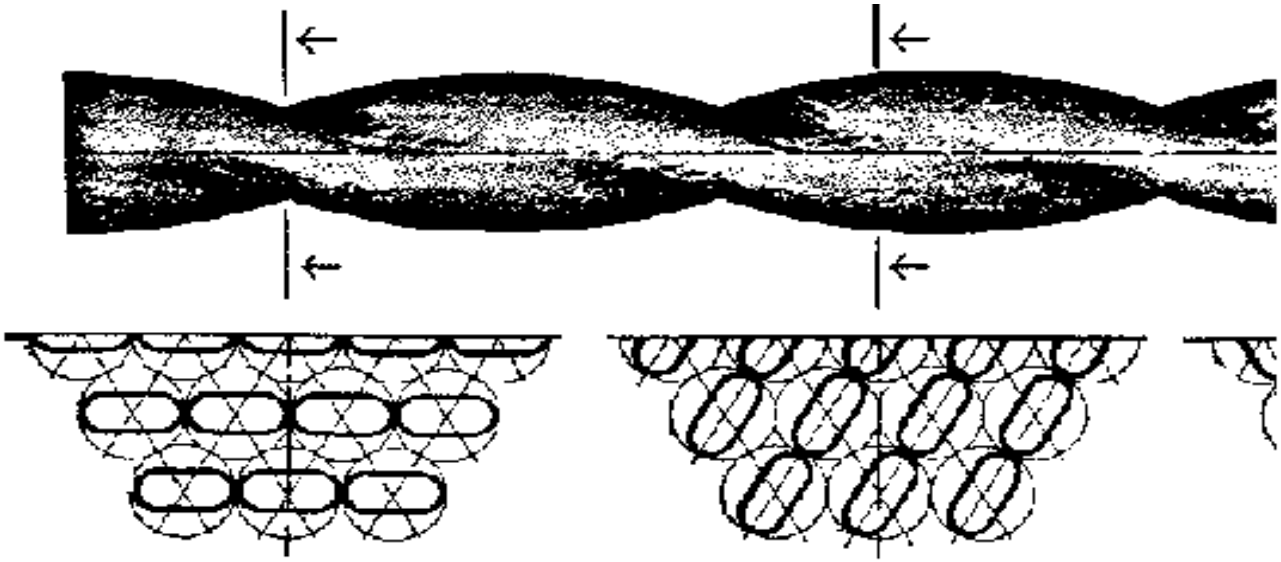
Wire-wound inserts (HiTRAN)

- Both mixes the core (radial mixing) and breaks up the boundary layer
- Available in range of wire densities for different duties



Twisted tube (Brown Fintube)

- Tubes support each other
- Used for single phase and condensing duties in the power, chemical and pulp and paper industries

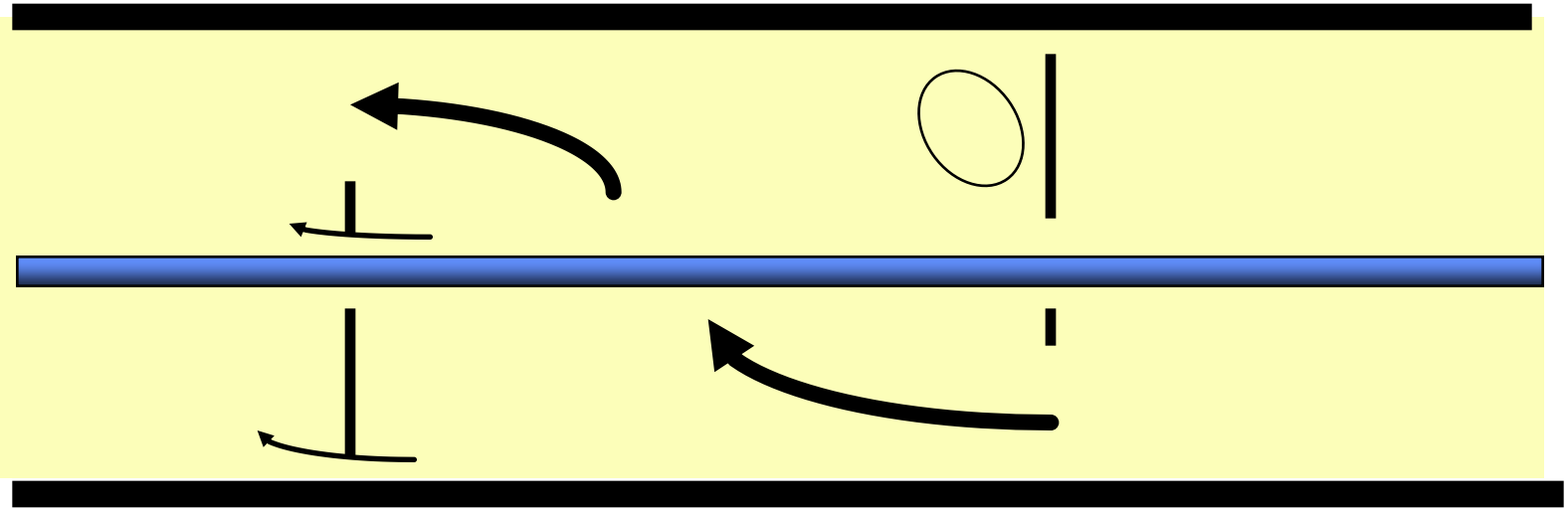


Problems of Conventional S & T

Zigzag path on shell side leads to

- Poor use of shell-side pressure drop
- Possible vibration from cross flow
- Dead spots
  - Poor heat transfer
  - Allows fouling
- Recirculation zones
  - Poor thermal effectiveness, ε

Conventional Shell-side Flow



Shell-side axial flow

Some problems can be overcome by having axial flow

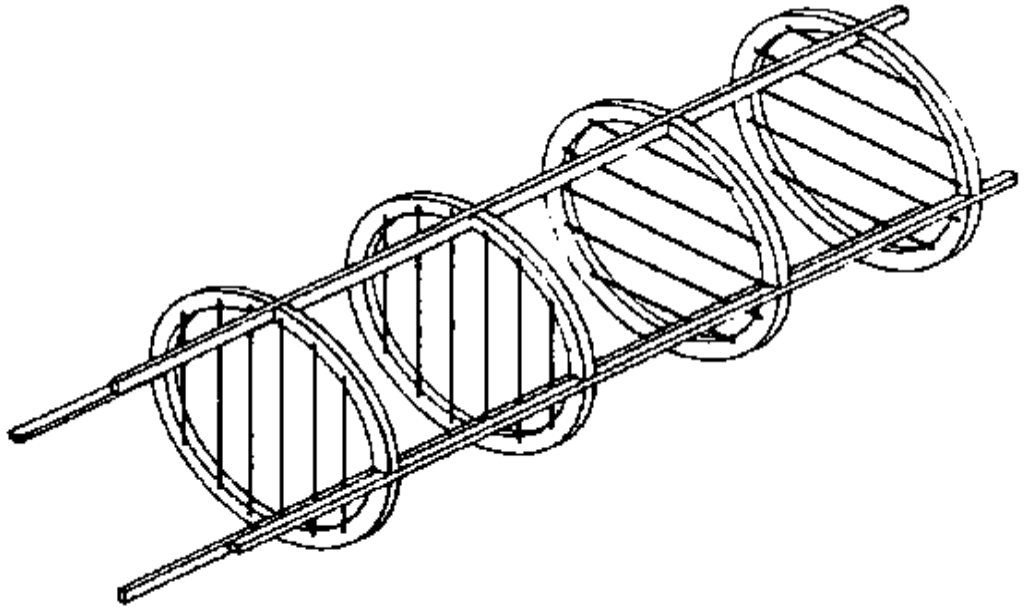
- Good heat transfer per unit pressure drop but
  - for a given duty may get very long thin units
  - problems in supporting the tube

RODbaffles (Phillips petroleum)

- introduced to avoid vibrations by providing additional support for the tubes
- also found other advantages
  - low pressure drop
  - low fouling and easy to clean
  - high thermal effectiveness

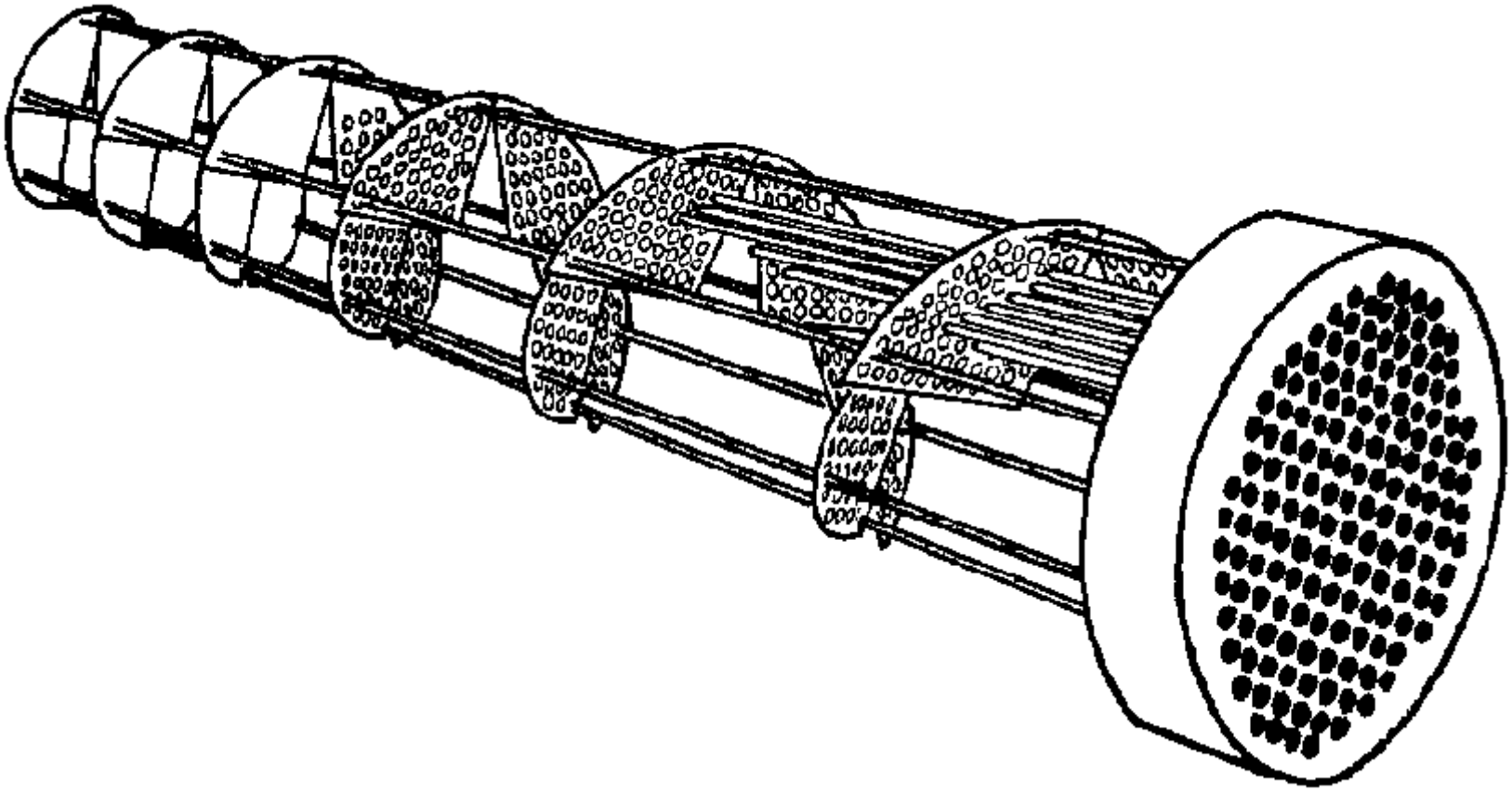
RODbaffles

Tend to be about 10% more expensive for the same shell diameter

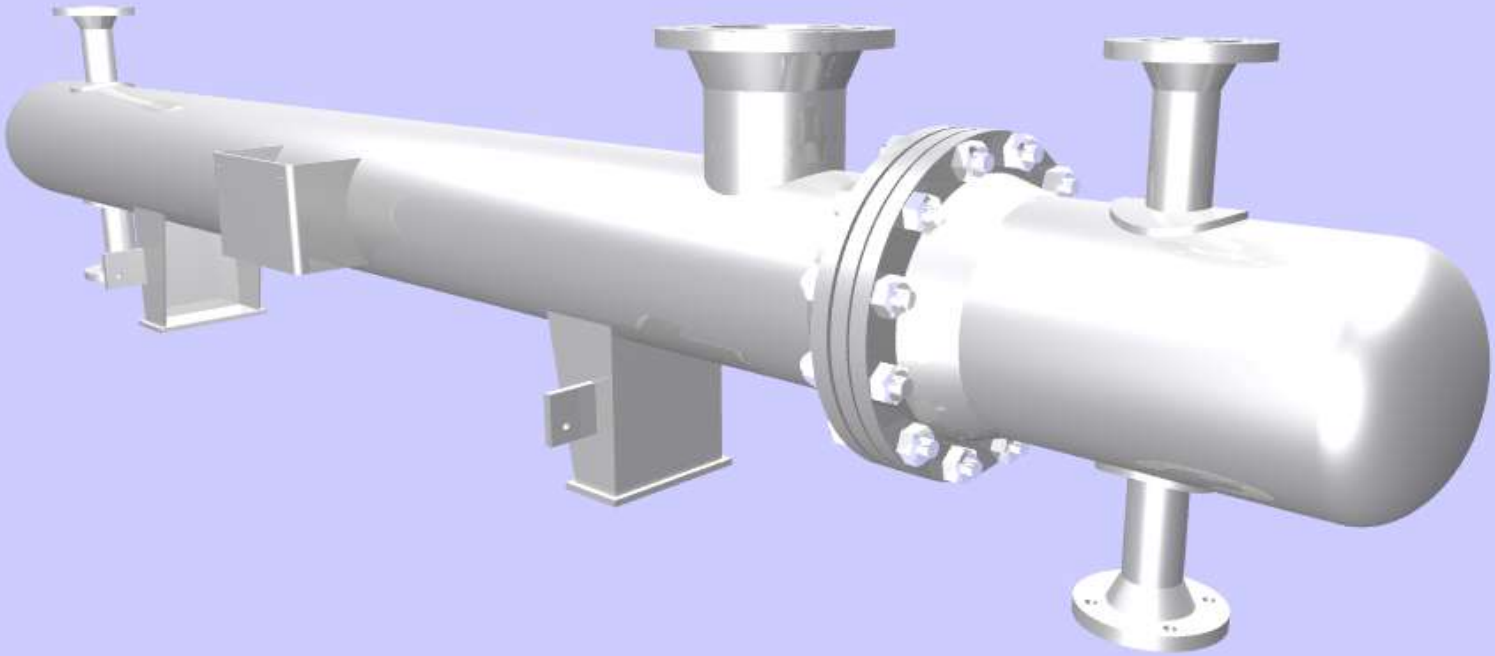


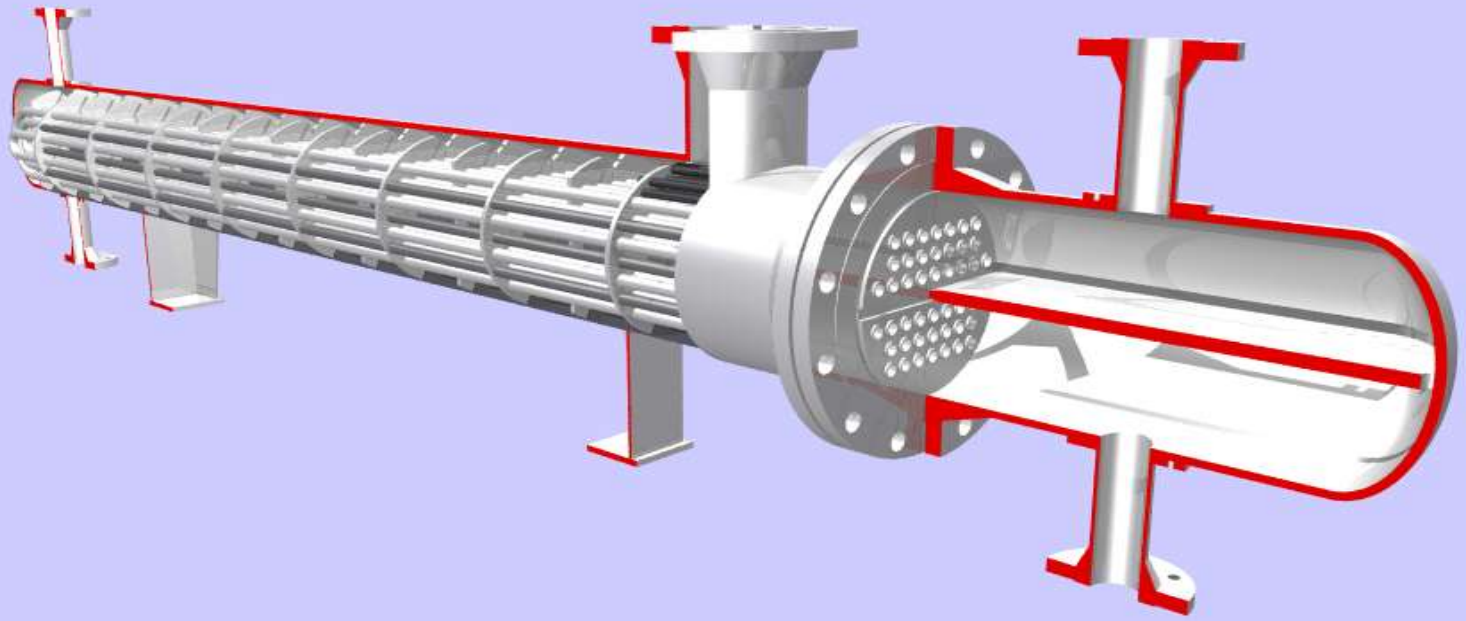
Shell-side helical flow (ABB Lummus)

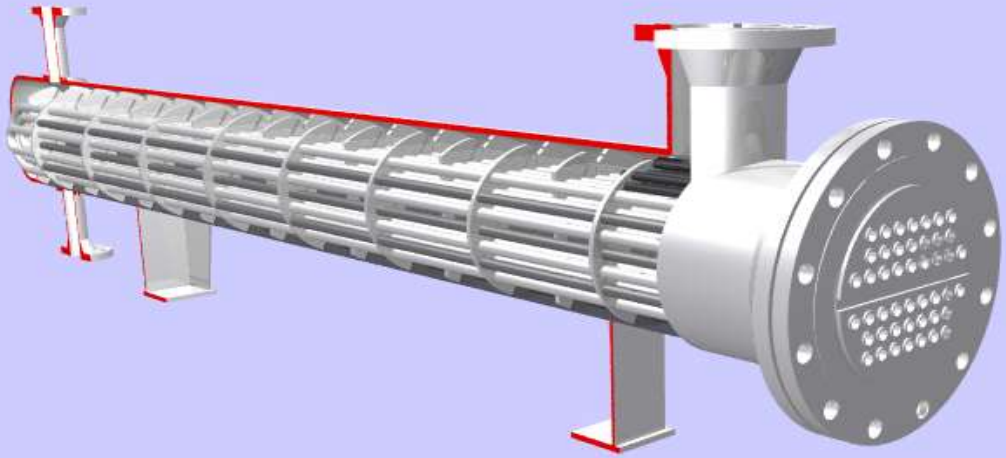
Independently developed by two groups in Norway and Czech Republic

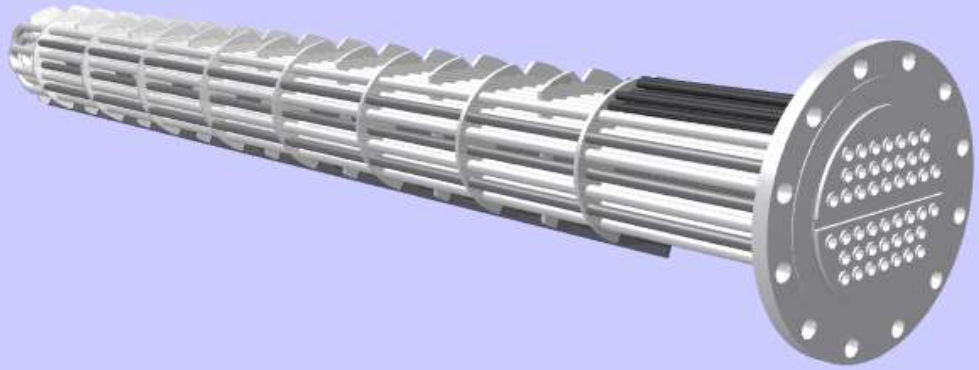


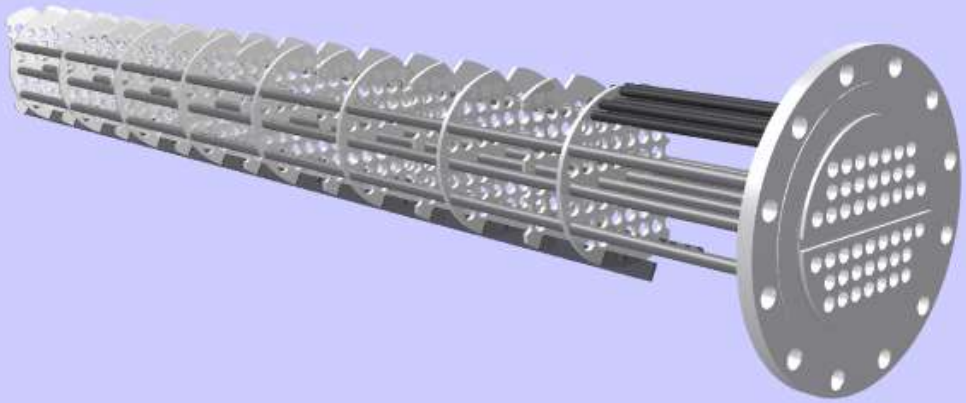
Typical Shell &Tube Exchanger

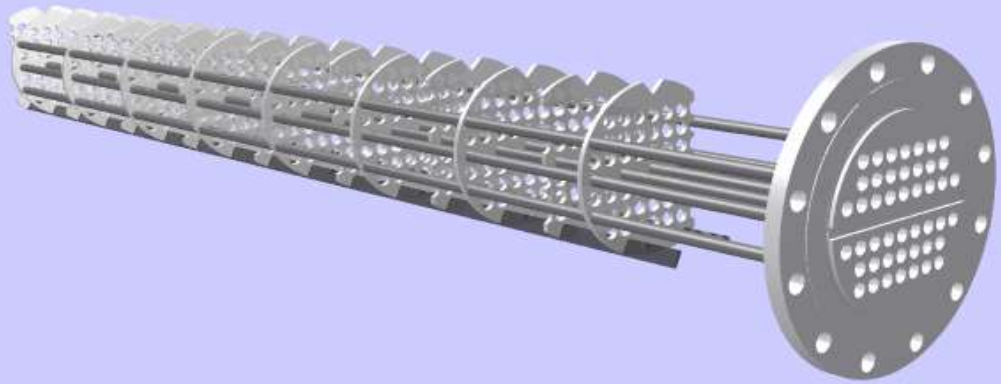


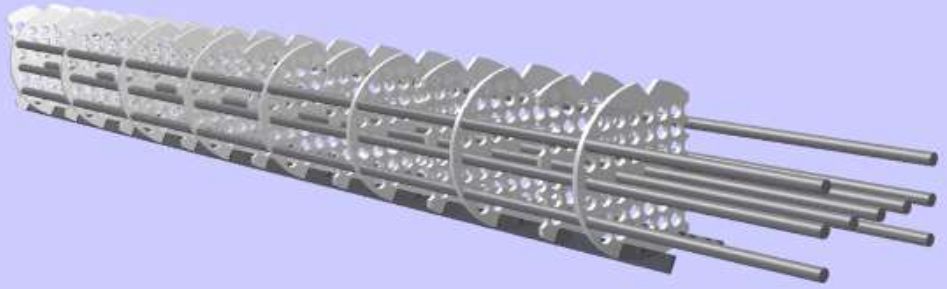


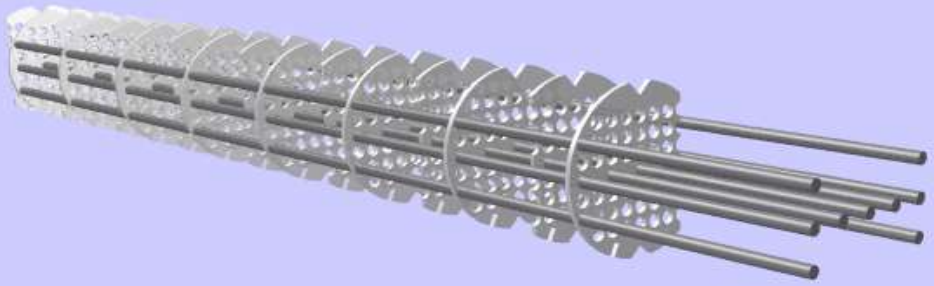


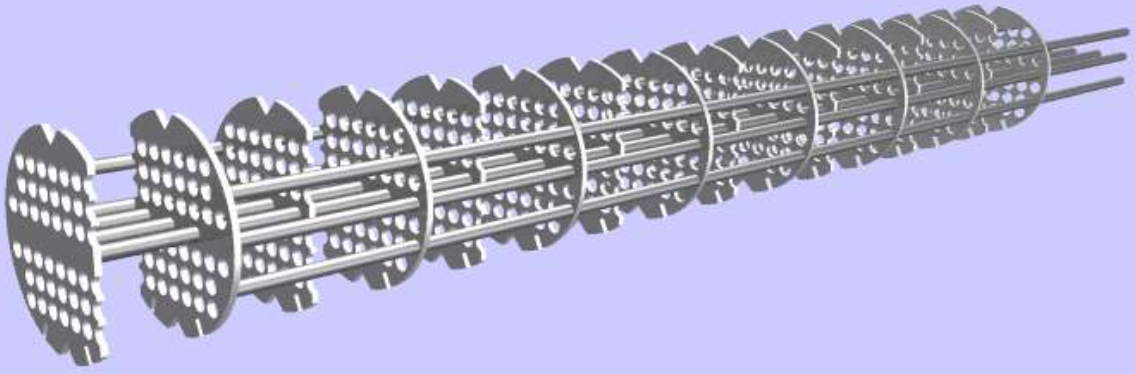


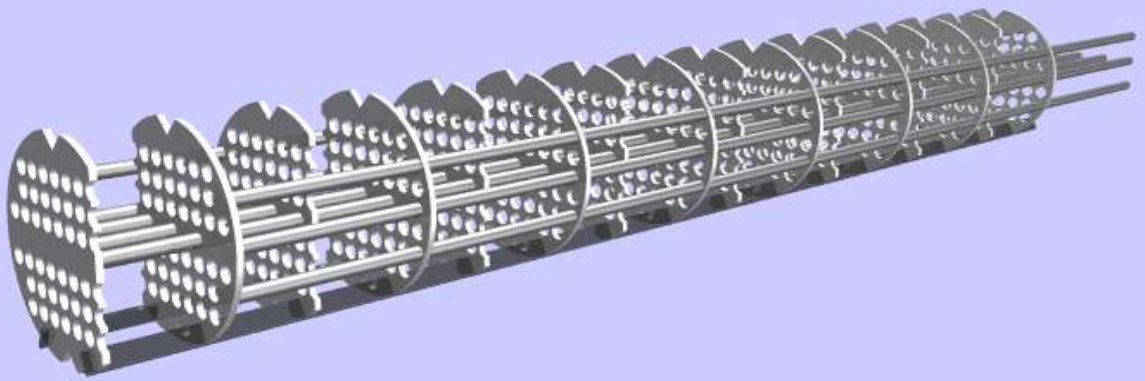


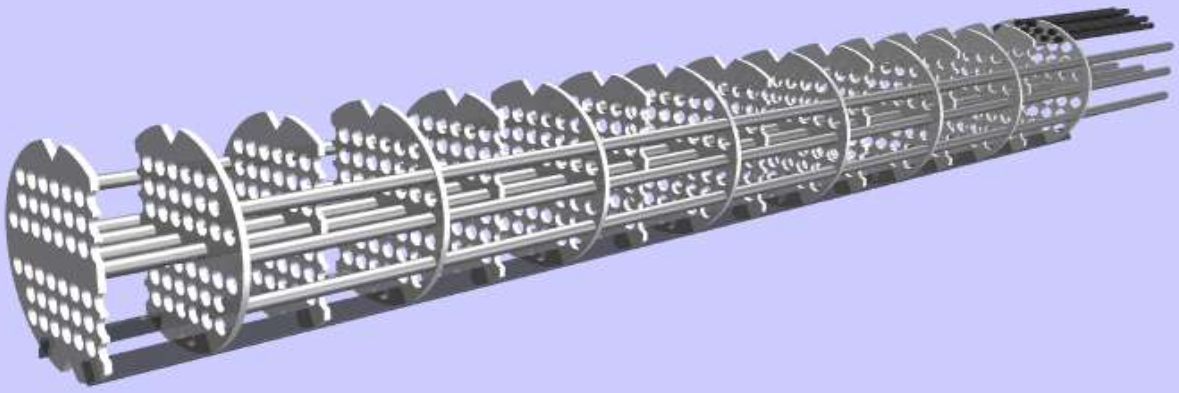


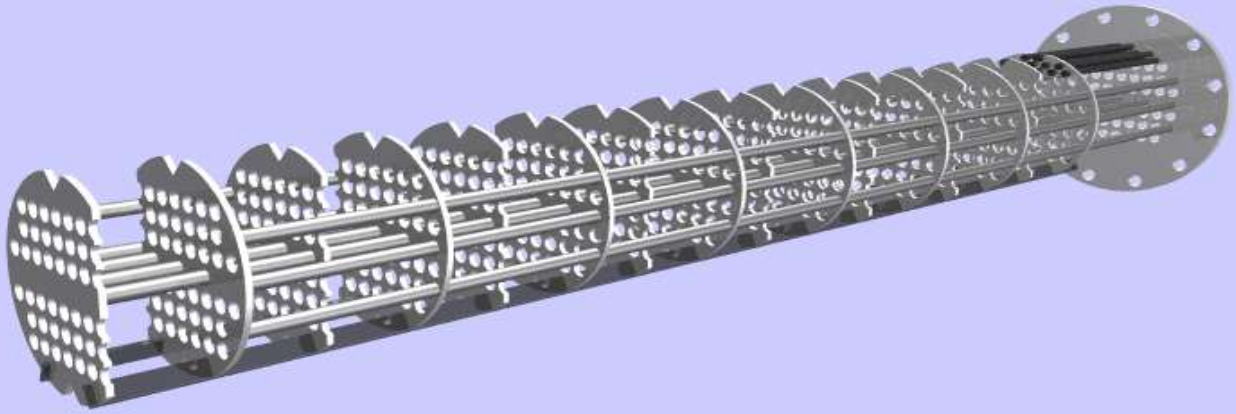


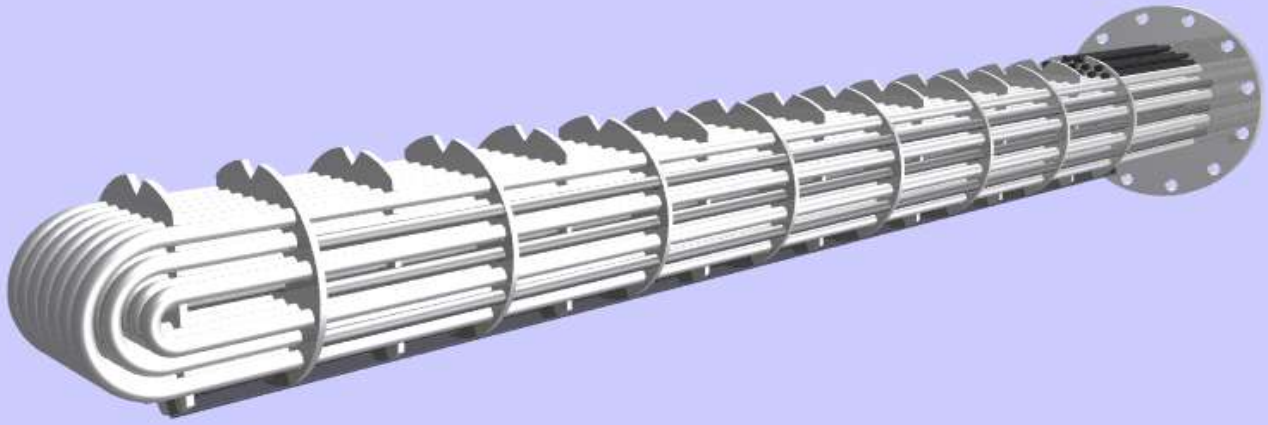


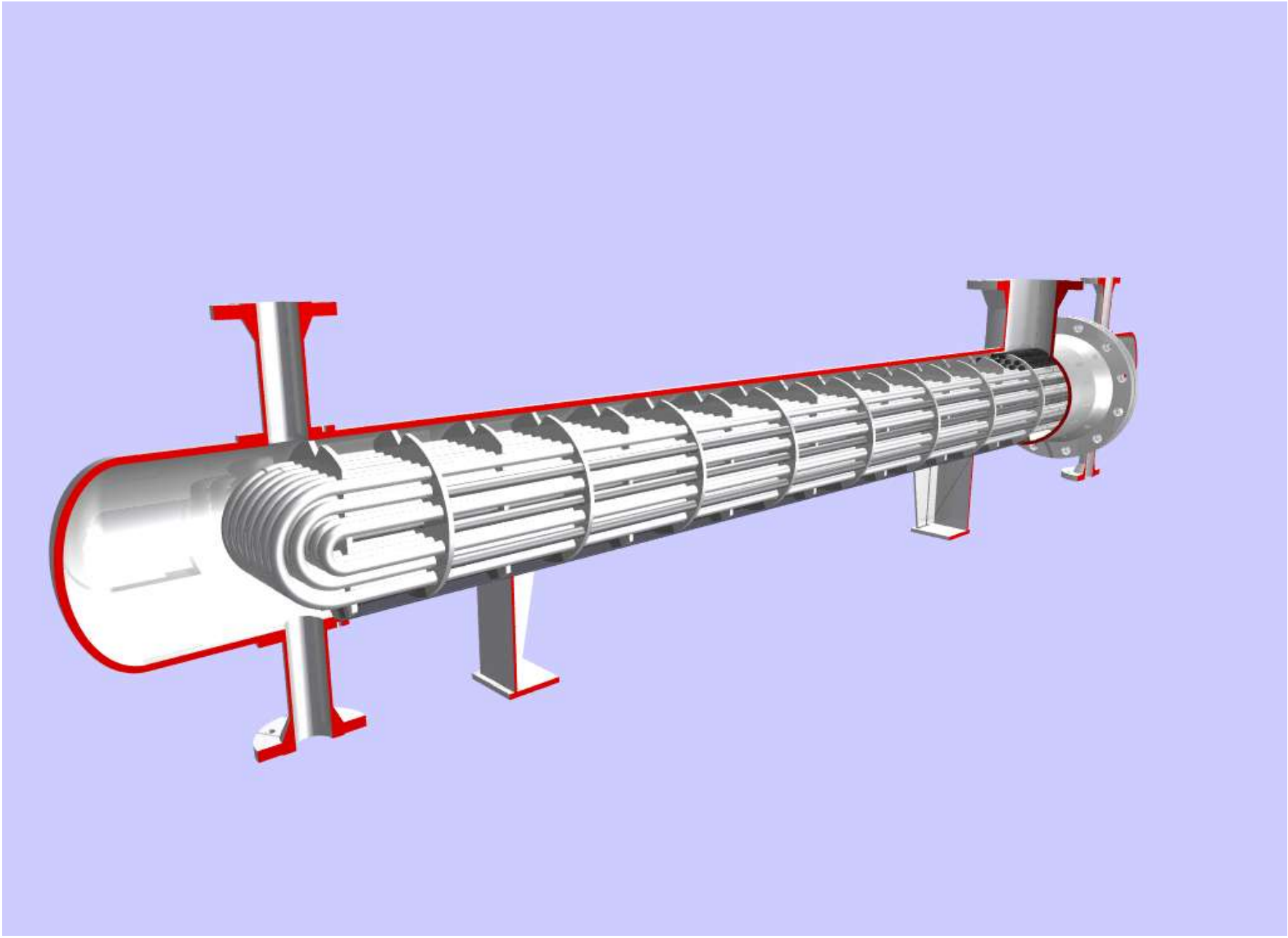


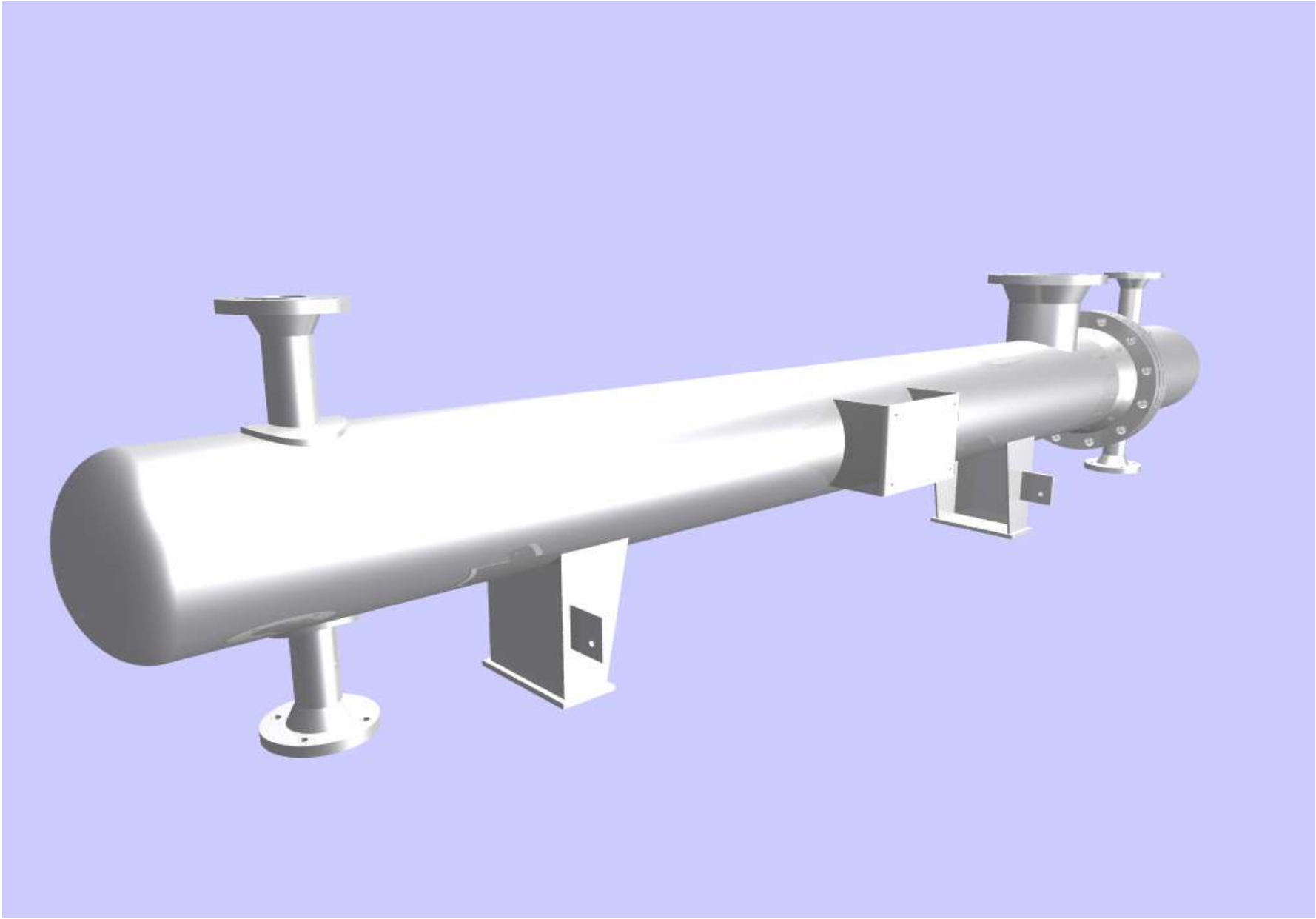




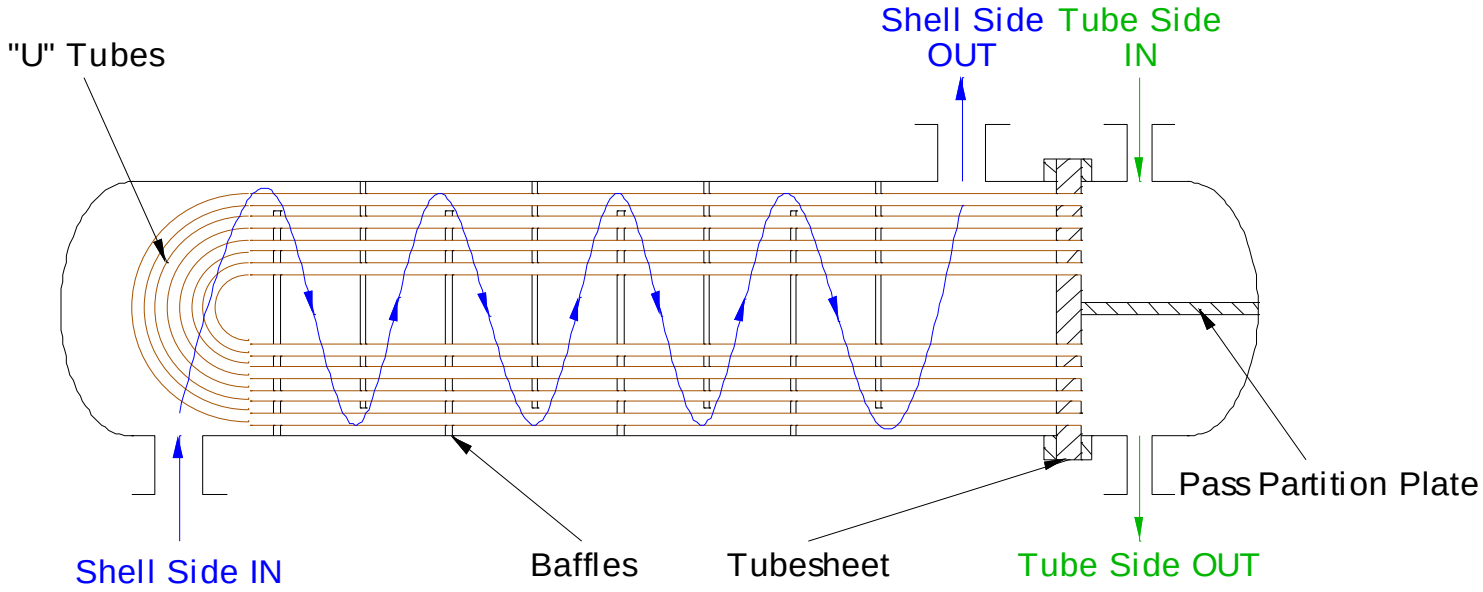




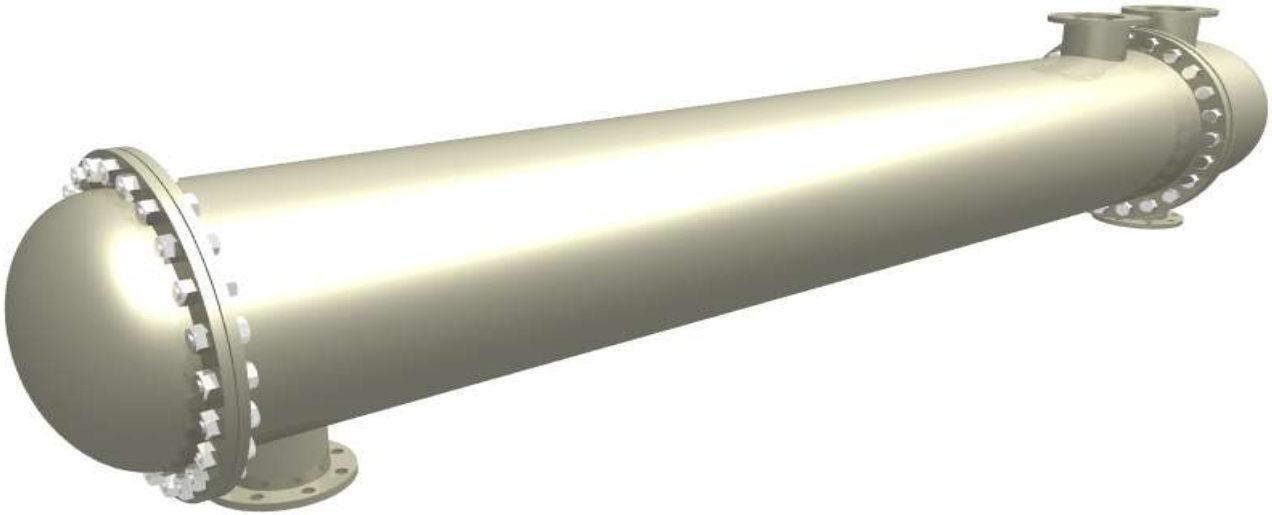


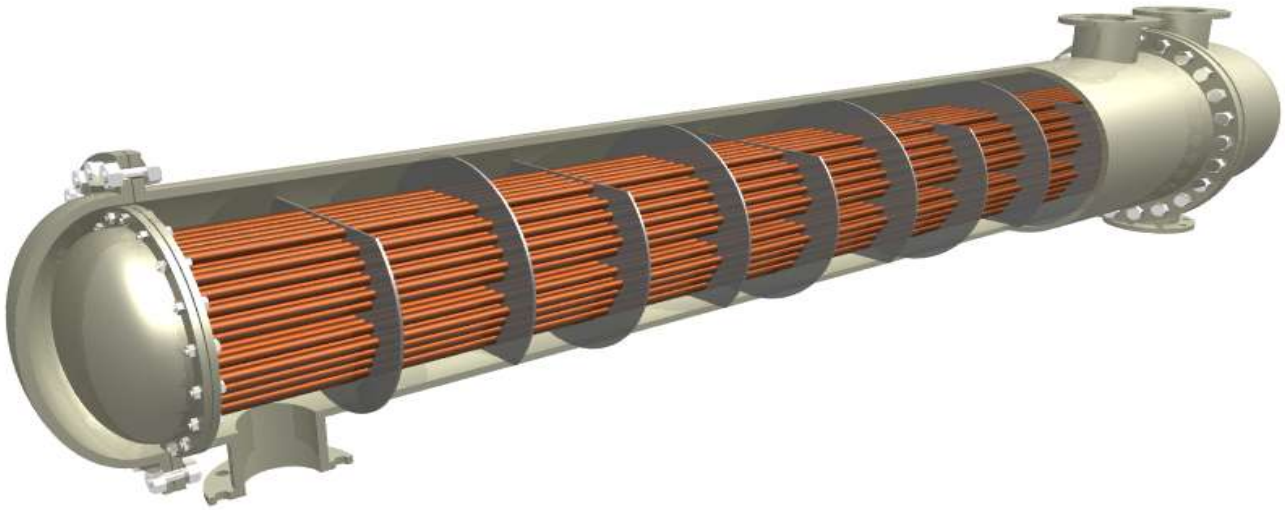


U Tube Heat Exchanger

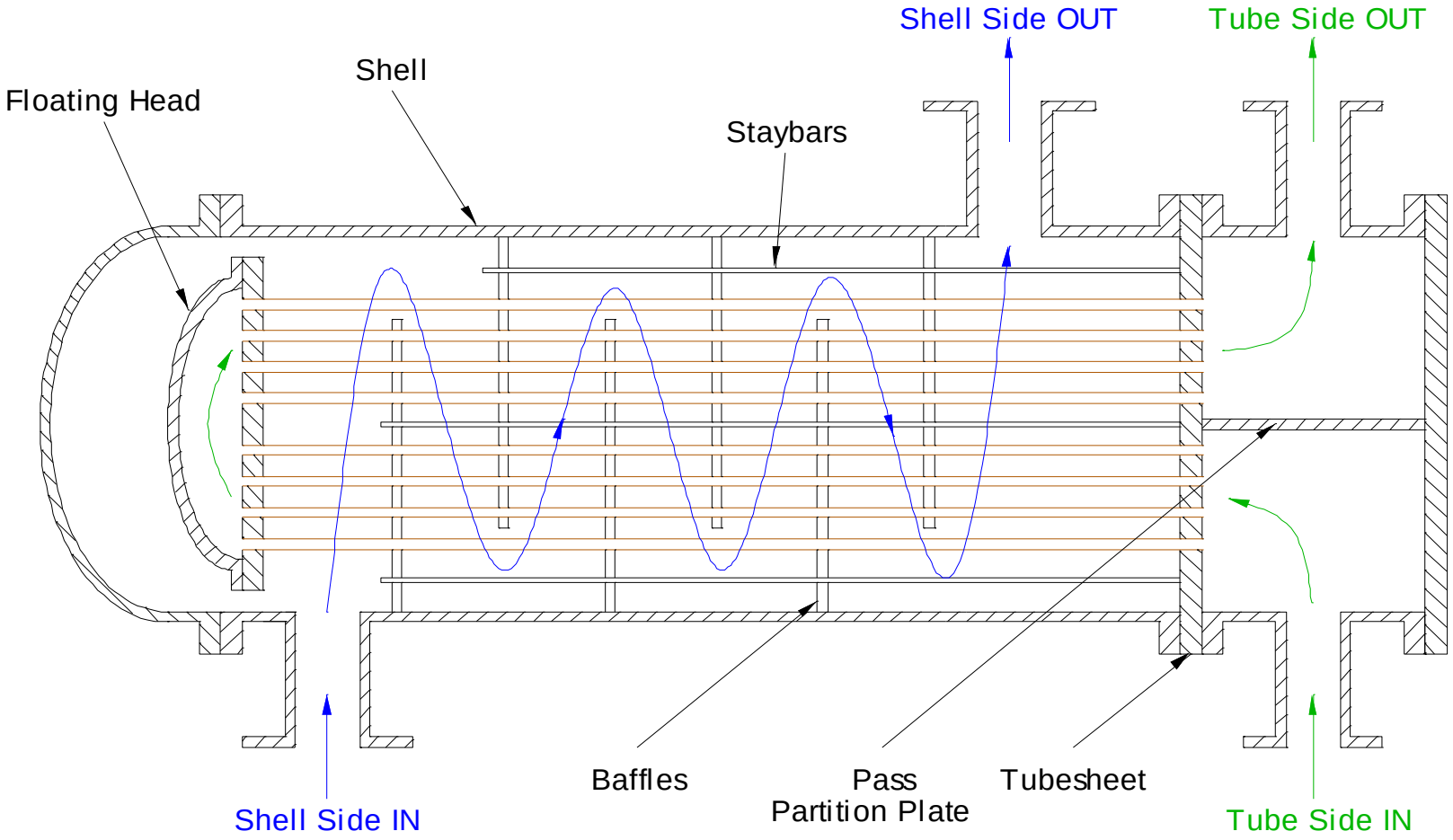


Floating head heat exchanger



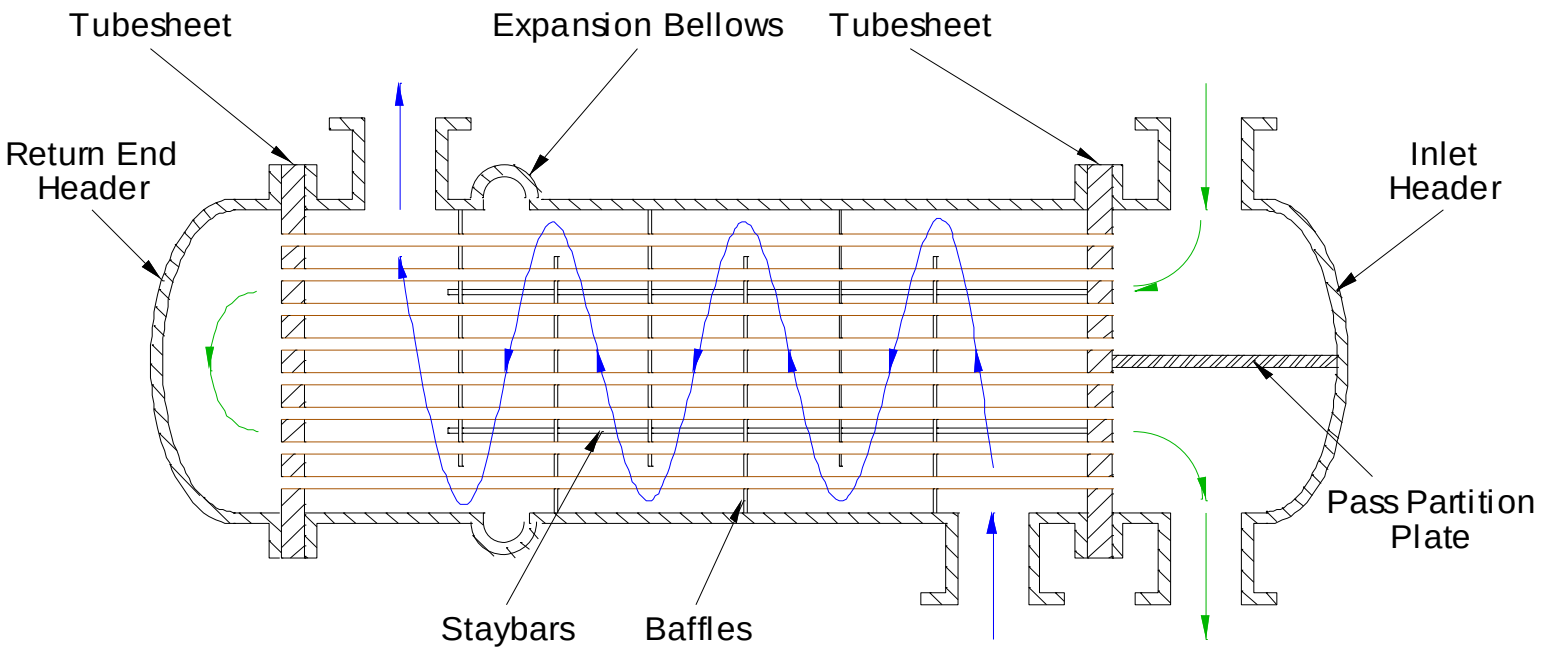


Floating Head Heat Exchanger



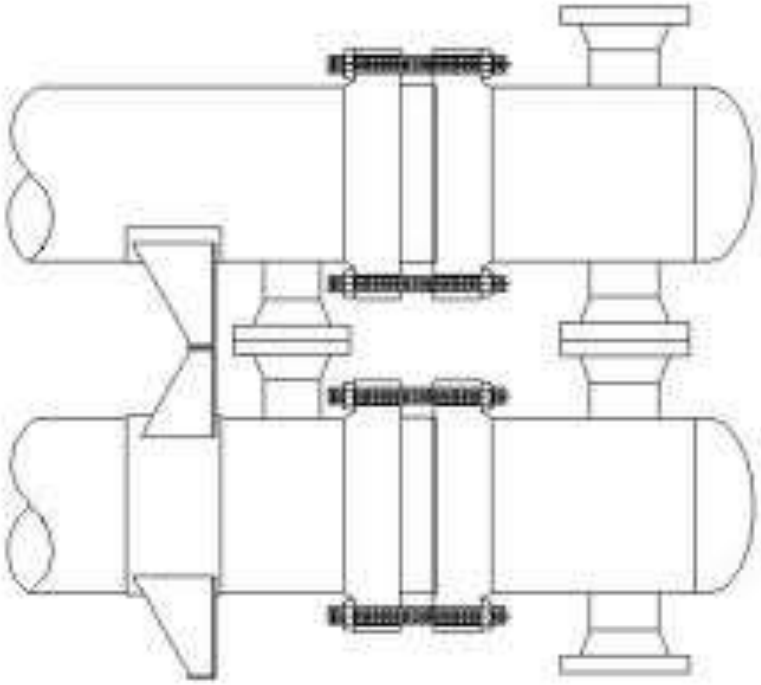
Fixed head exchanger

Fixed Head Heat Exchanger



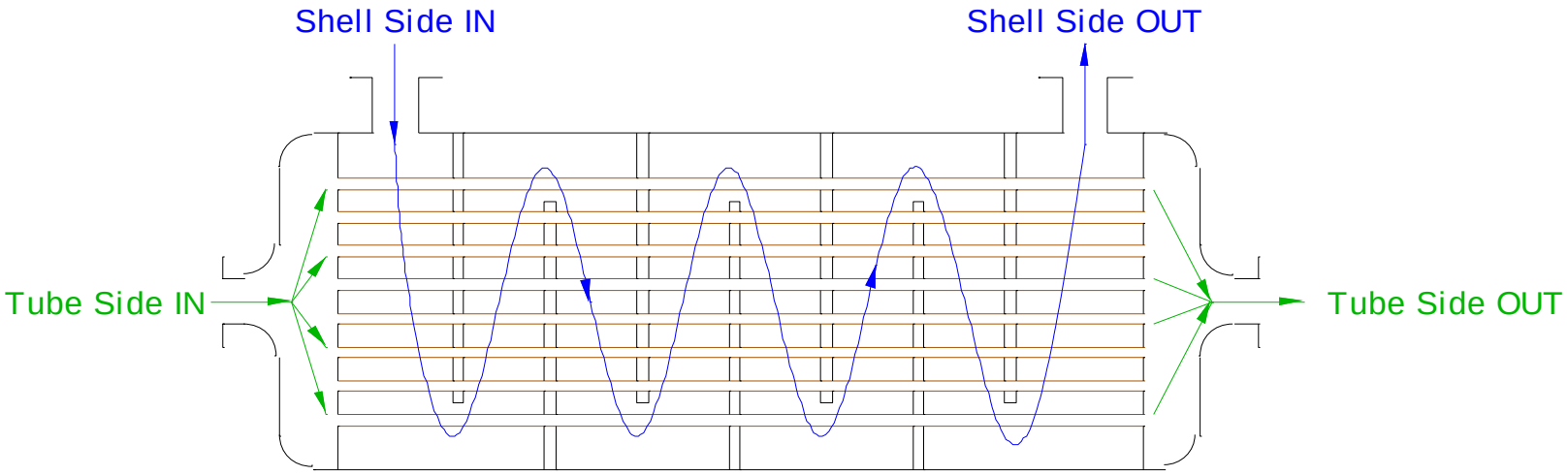
Expansion Bellows

Bellows constraints (gags)

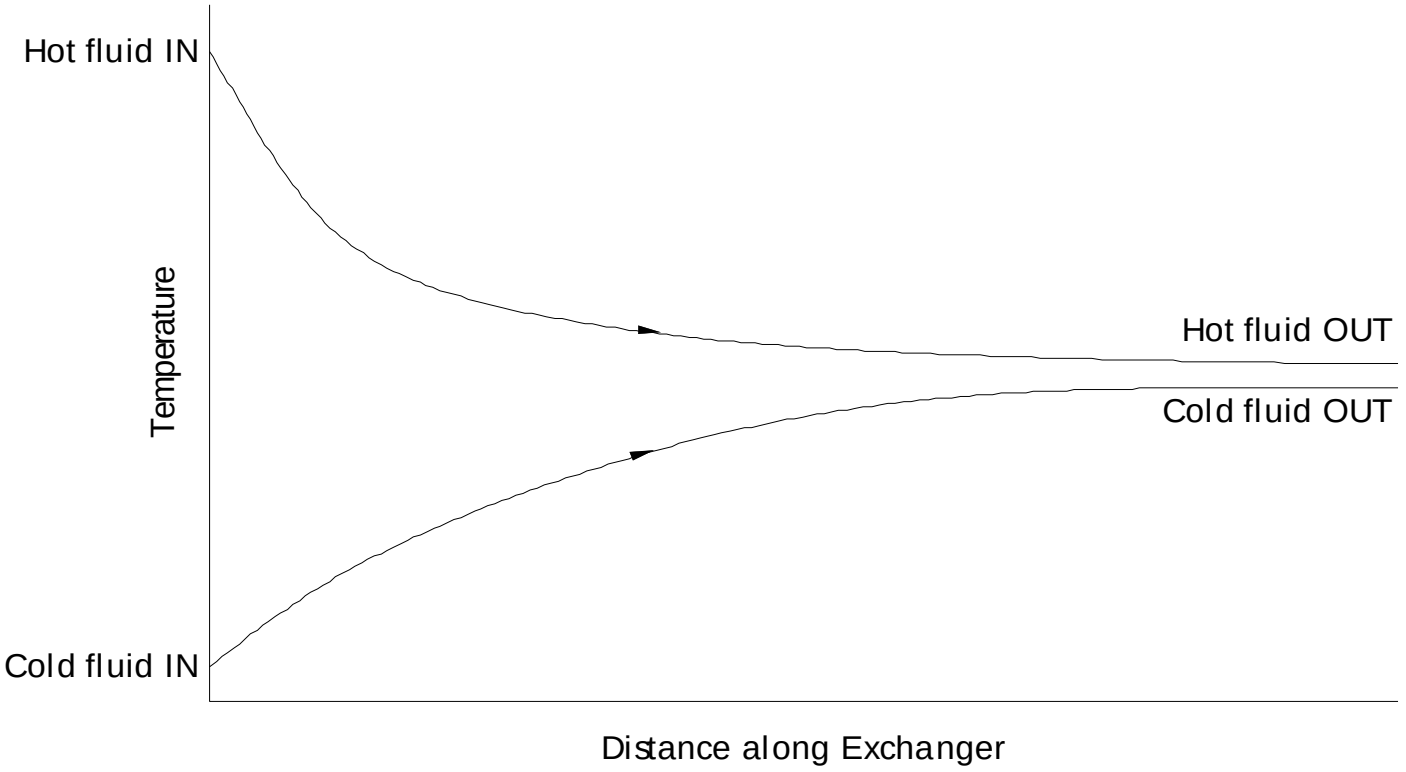


Flow patterns

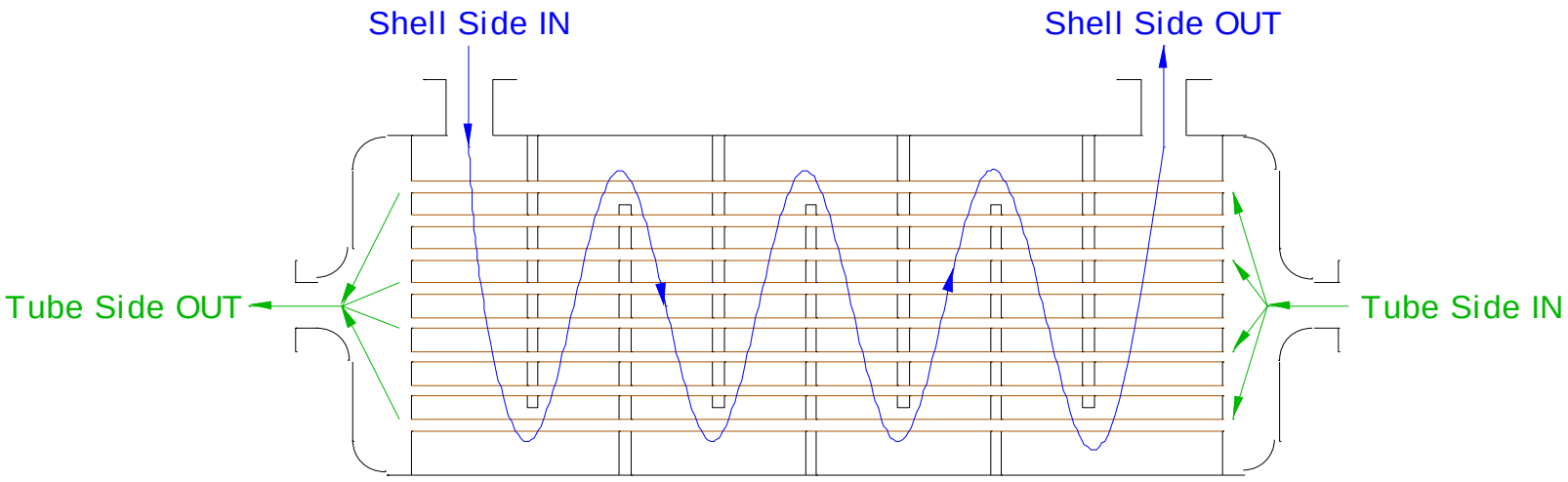
Co - Current Flow



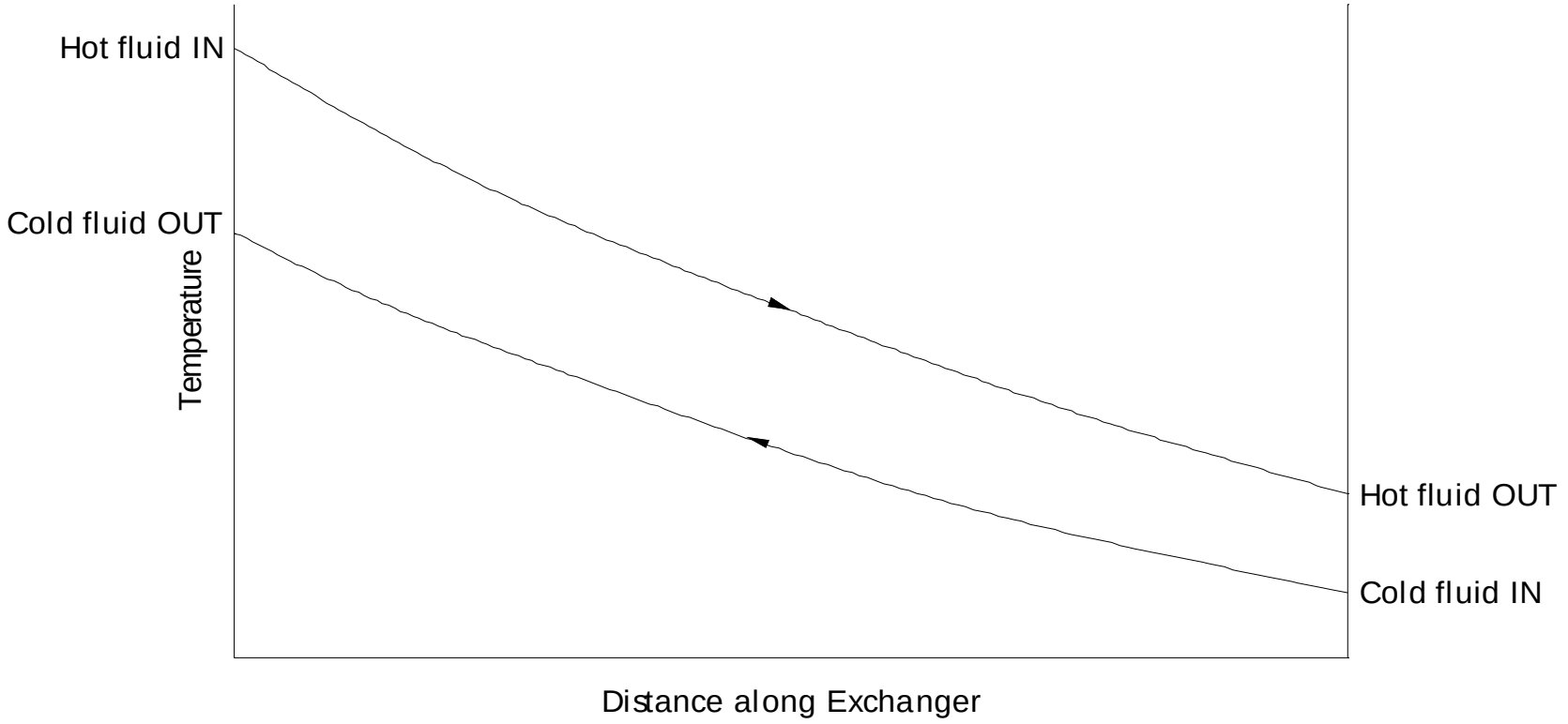
Co - Current Flow



Countercurrent Flow

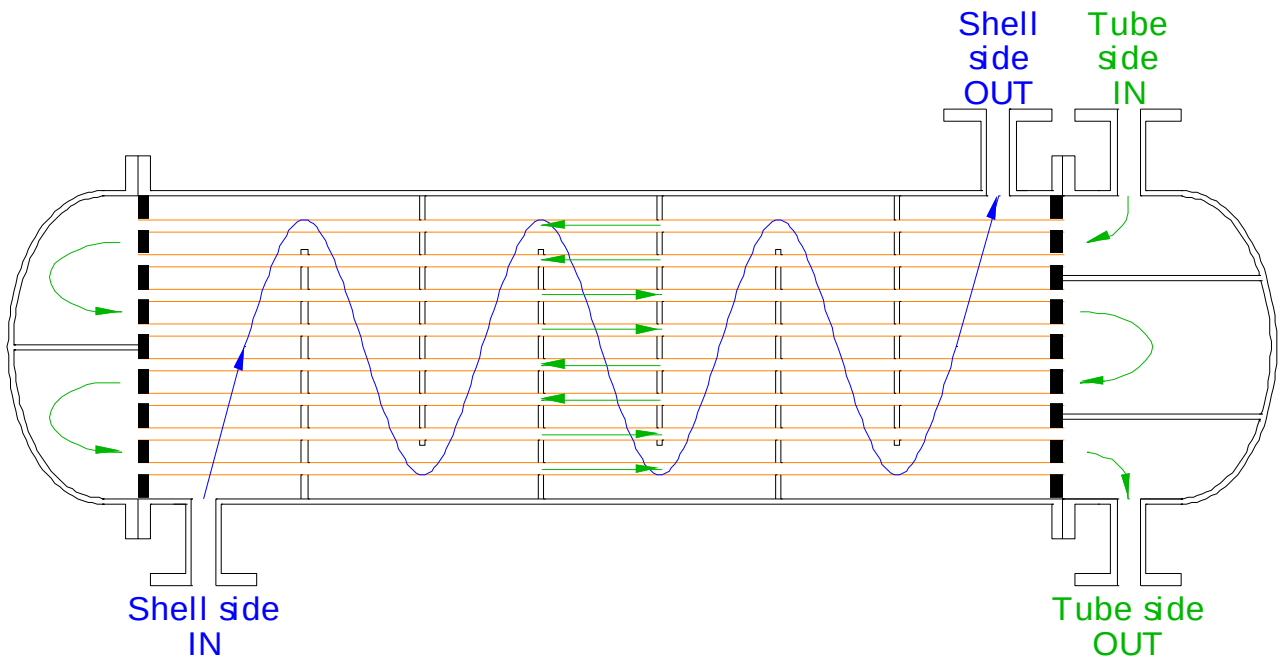


Countercurrent Flow



Design of heat exchangers

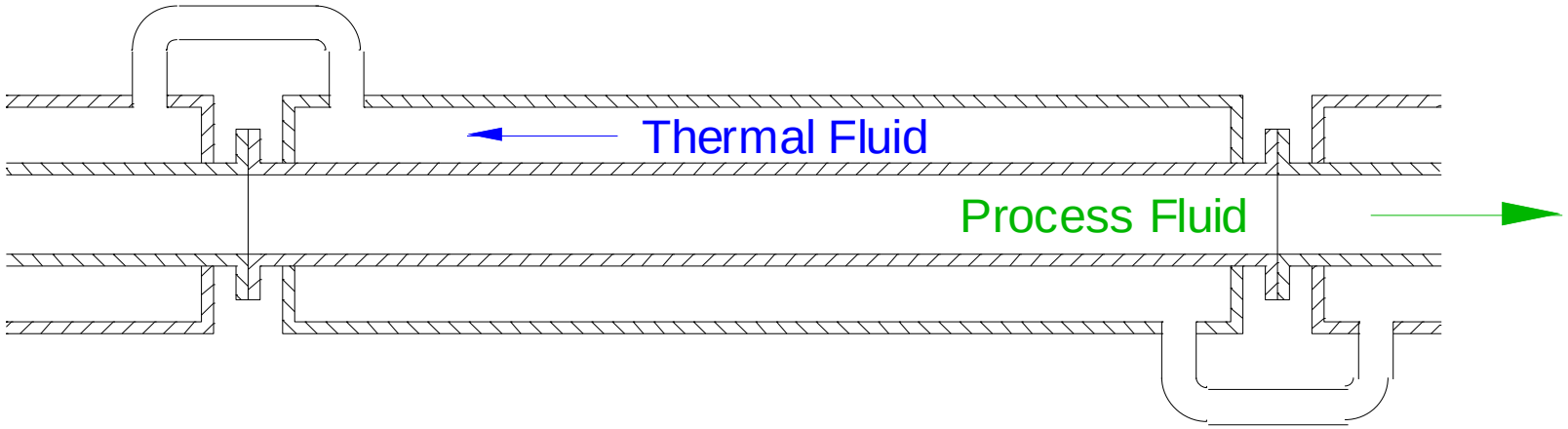
Four pass Exchanger



Cleaning

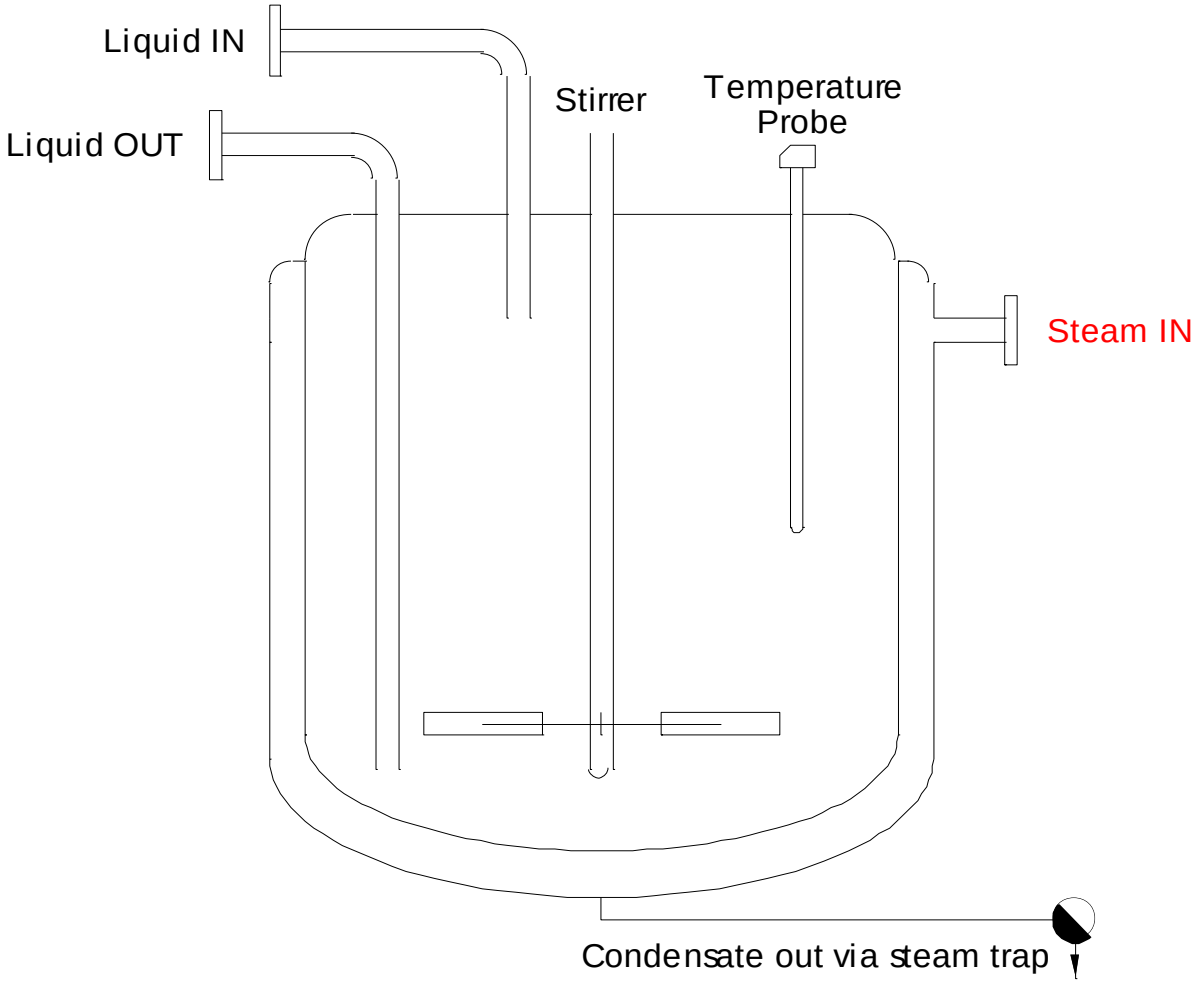
Jacketed pipelines

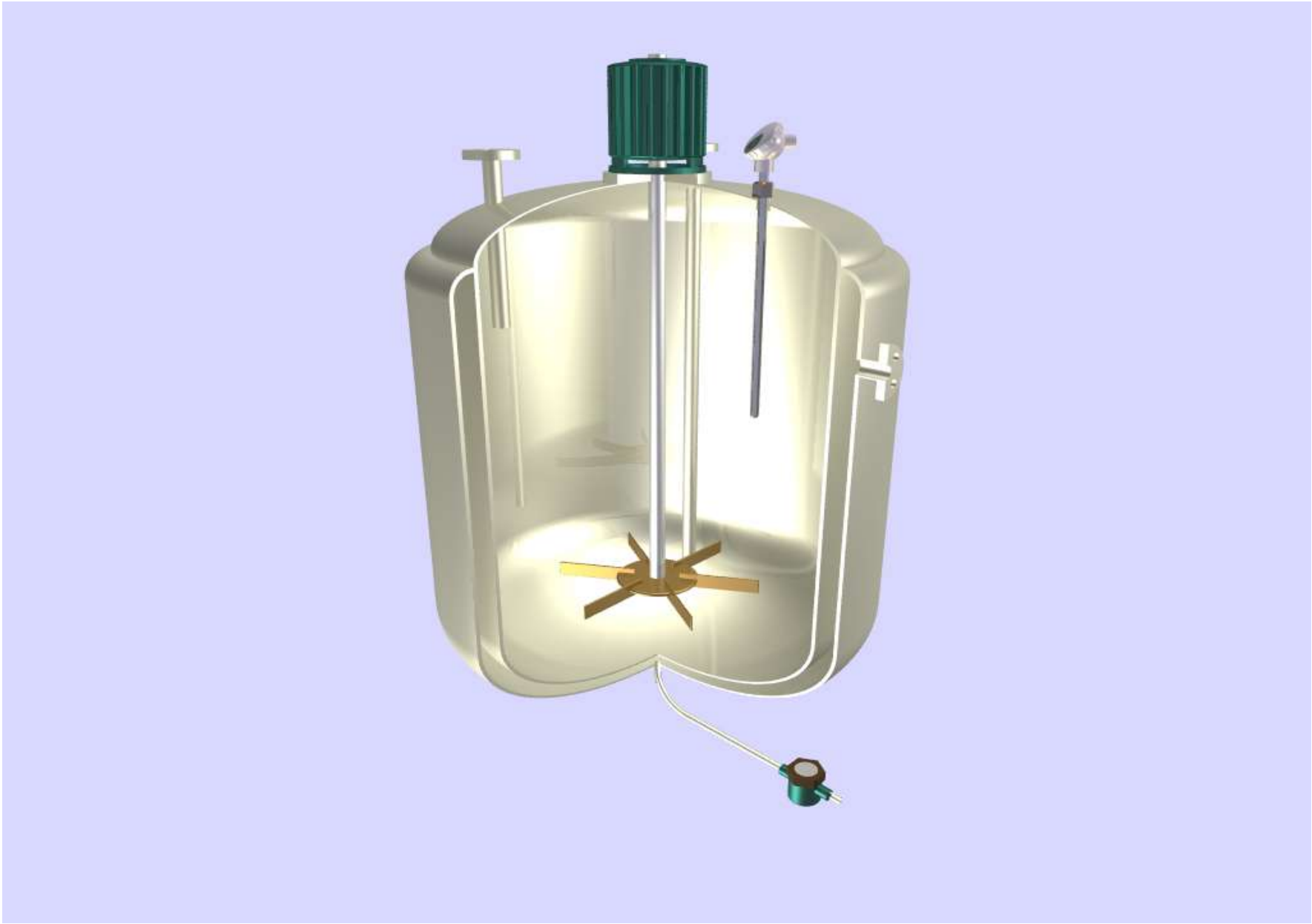
Jacketed Pipeline



Jacketed Vessels

Jacketed Vessel



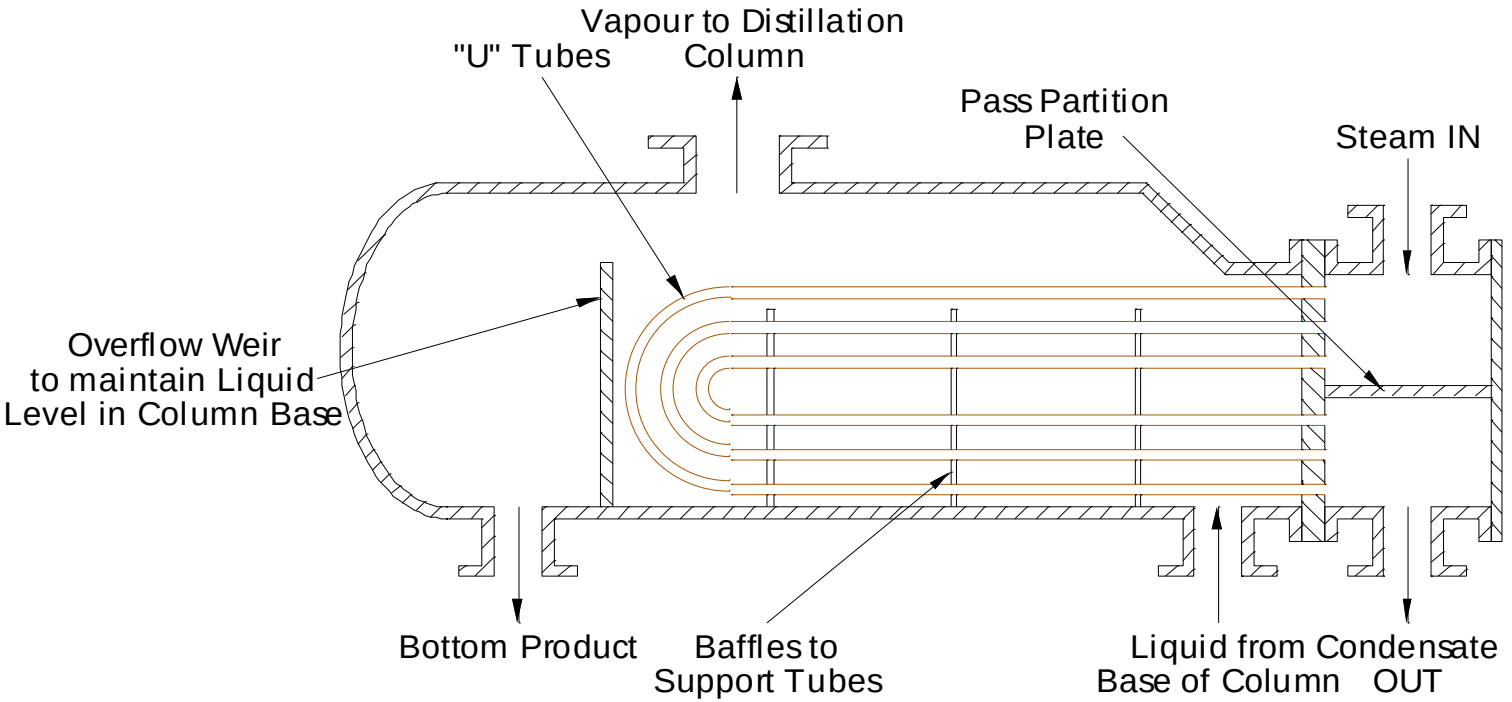


Further types of exchanger

- Kettle reboiler
- Double pipe exchanger
- Carbon Block
- Plate heat exchanger
- Spiral heat exchanger
- Air cooled exchanger

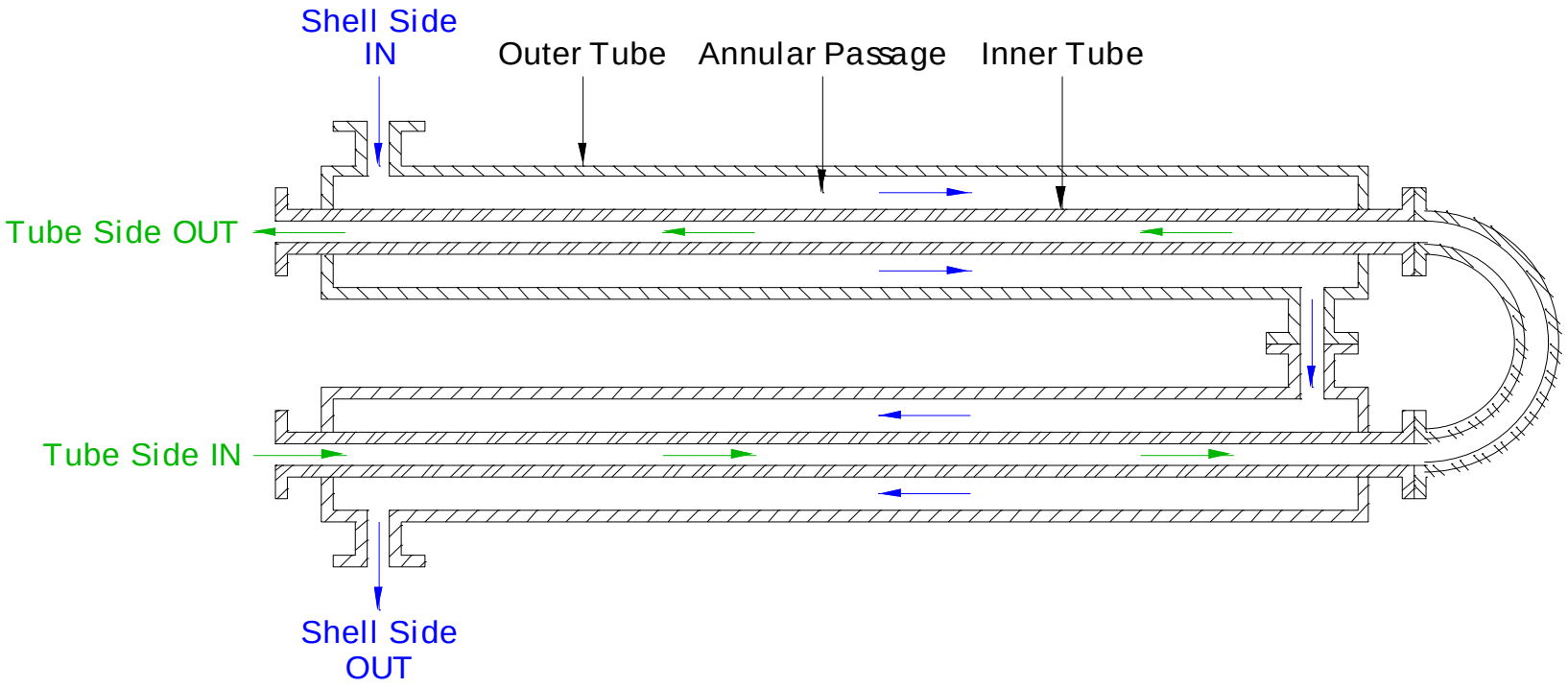
Kettle Reboiler

Kettle Type "U" Tube Reboiler



Double pipe Exchanger

Double Pipe Heat Exchanger



Carbon Block

Plate Heat Exchanger

Plate Heat Exchanger

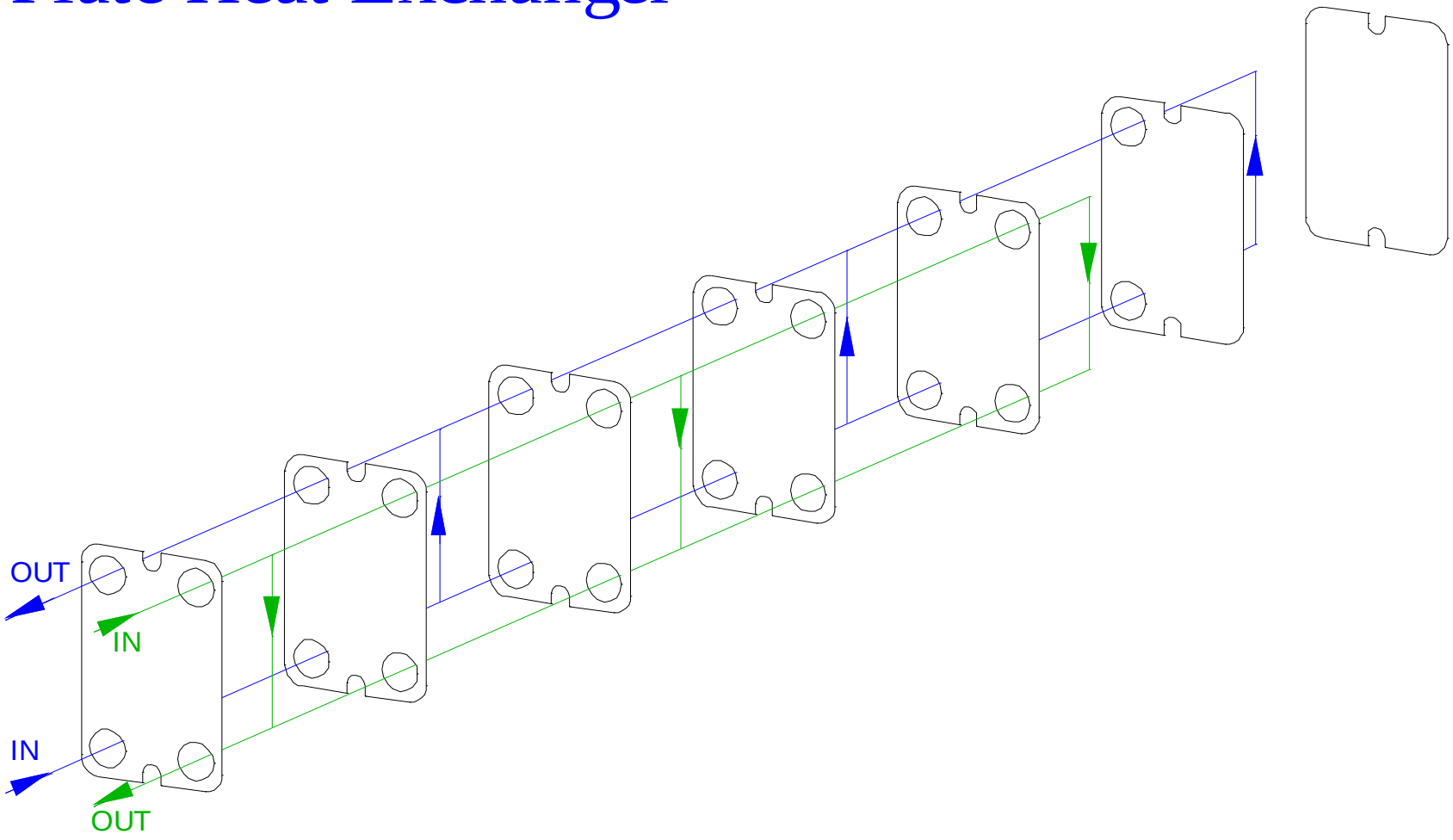
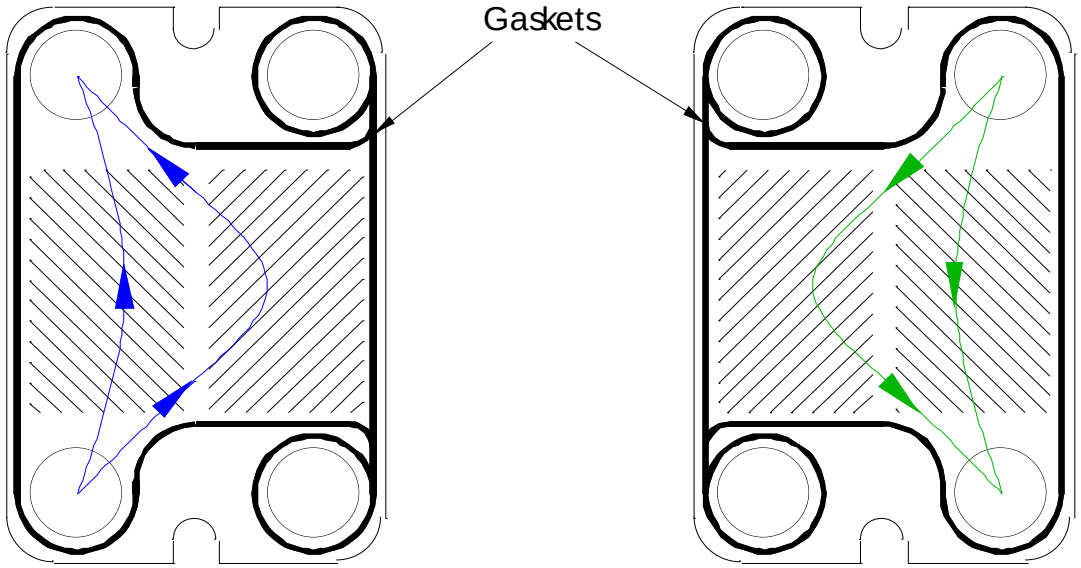
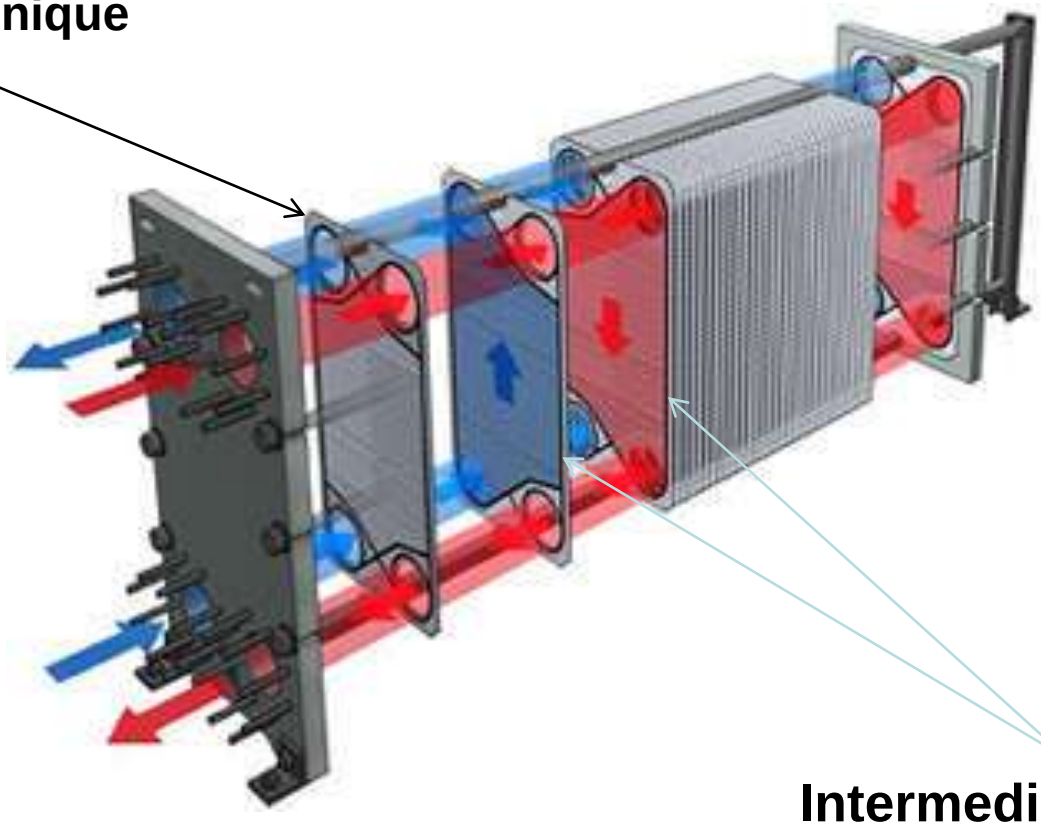


Plate Heat Exchanger



End Gasket Unique



Intermediate Gaskets
Alternate

Spiral Heat Exchanger

Air Cooled Exchangers

Surface Air Fan Exchanger

Surface Air Fan Exchanger

A fan is used to drive air through a bank of finned tubes

The End

Any Questions?