HEAT EXCHANGERS

PURPOSE

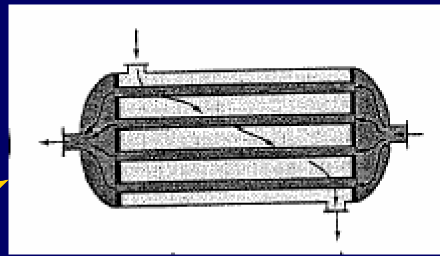
- A heat exchanger is an apparatus performing heat exchange between two or several fluids. It can carry out this task by:
  - Segregating the fluids and making them exchange heat through a wall
  - Mixing them finely. This is direct heat exchange as in cooling towers
  - Using principally radiations as heating medium (furnaces)
  - Using an intermediary fluid

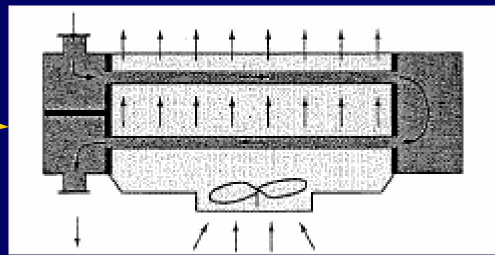
- Heat exchangers are everywhere in our industry:
  - Shell and tube heat exhangers to heat up or cool down a feed or a product
  - Fired heaters
  - Air coolers
  - Cooling towers
  - Rotating machines anciliaries include heat exchangers to cool down lubrication oil
  - Pipe tracing
  - Even insulated pipes may be considered as heat exchangers (except one wants to limit heat transfer)

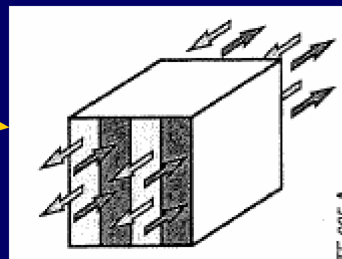
JUST BECAUSE PROCESS CONSIST IN EXCHANGING MASS AND ENERGY

HEAT EXCHANGER OVERVIEW

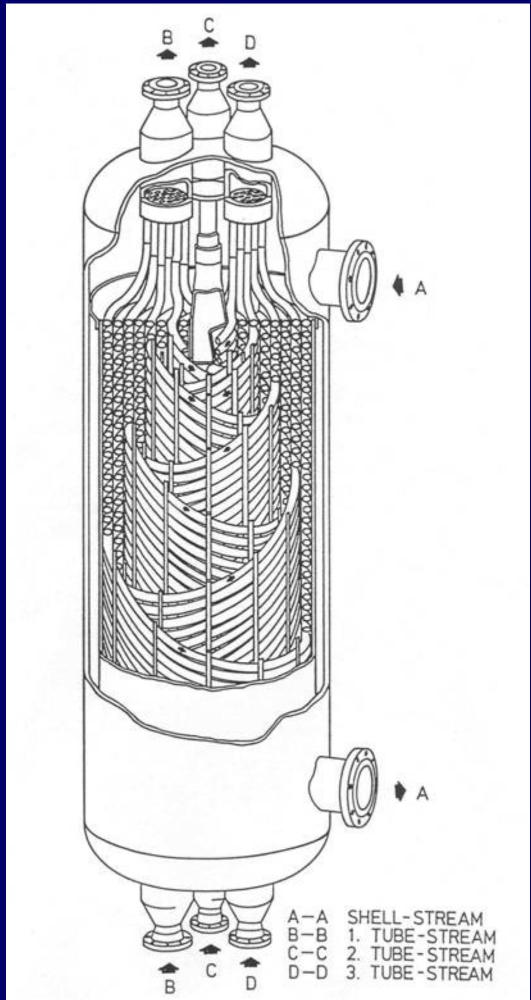
- Heat exchangers can be sorted in four big families:
  - Shell and Tube type – more than 90% of all the application
  - Air coolers
  - Fired heaters
  - Special heat exchangers such as:
    - Plate and frame heat exchangers
    - Brazed or welded plate fin heat exchangers
    - Coil wound heat exchanger







COIL WOUND HEAT EXCHANGER



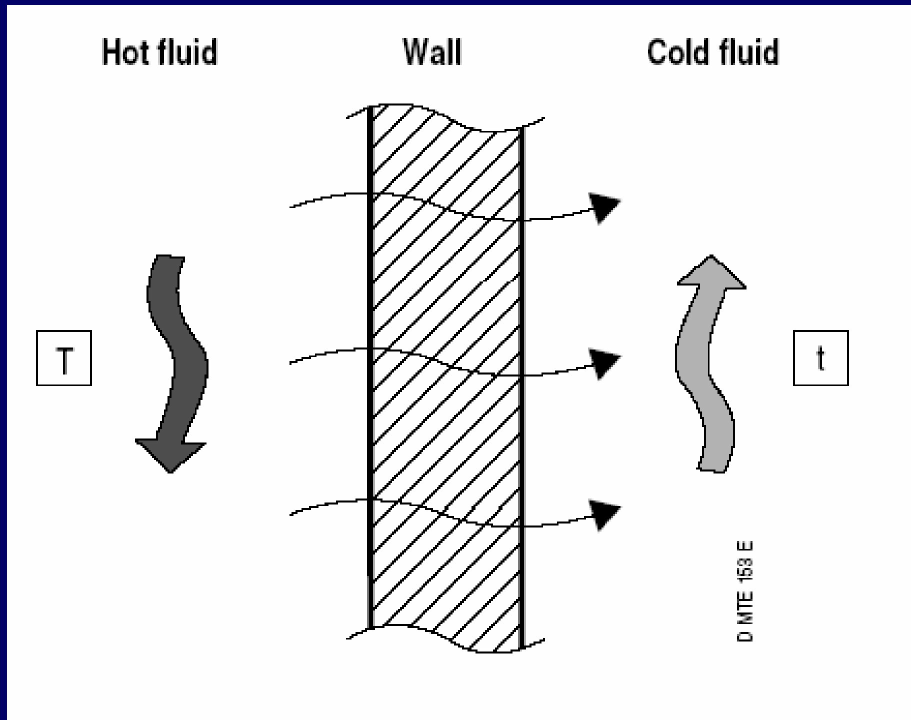
CONVENTIONS IN HEAT TRANSFER

- Upper case terms refer generally to the hot side (the side which cools down)
- Lower case terms refer generally to the cold side (the side which heats up)
- Cold stream is generally colored in blue
- Hot stream is generally colored in red
  - C or c is the thermal capacity (kJ/kg or kcal/kg)
  - M or m the mass flow rate (kg/h)
  - A the heat exchange area (m^2)
  - U the overall transfer coefficient ($W/m^2.°C$ or $kcal/h.m^2.°C$)
    - U can be clean or dirty
- F is the correction factor taking into account the HX technology

PHYSICS

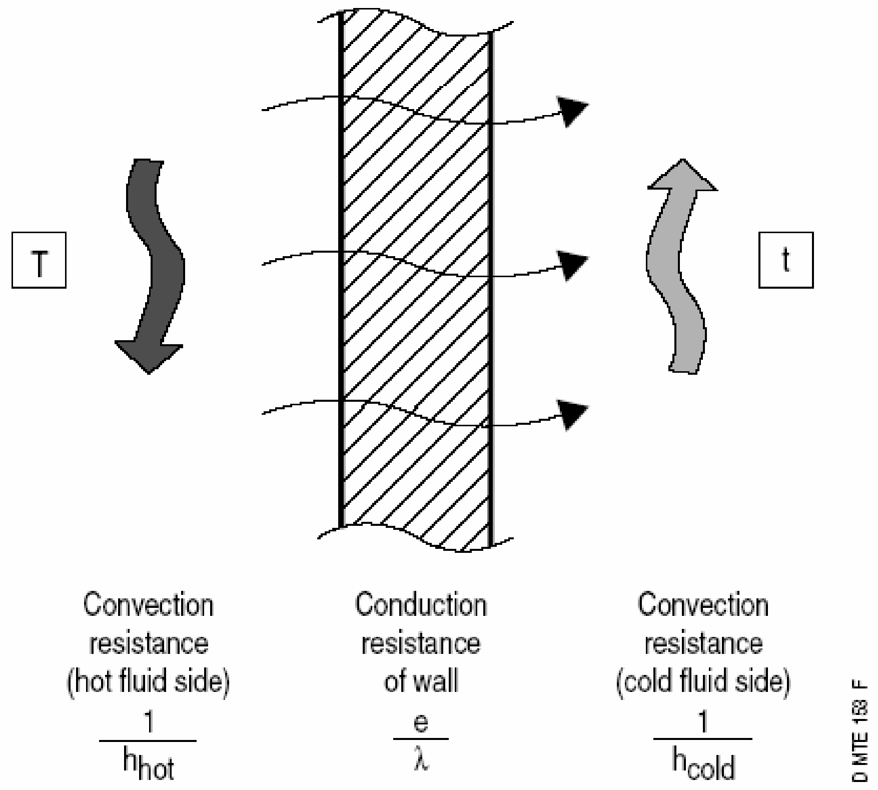
- Heat transfer depends on:
  - The thermal gradient T-t
  - The transfer coefficients hot fluid side and cold fluid side (film coefficients)
  - The wall material conductivity

- Film coefficients are themselves dependant on:
  - Fluid turbulence (Reynolds number)
  - Thermal physical properties (Prandtl number)



Local heat transfer law: $\text{Ø} = \frac{T-t}{R}$

PHYSICS



Total resistance = Σ resistances in series

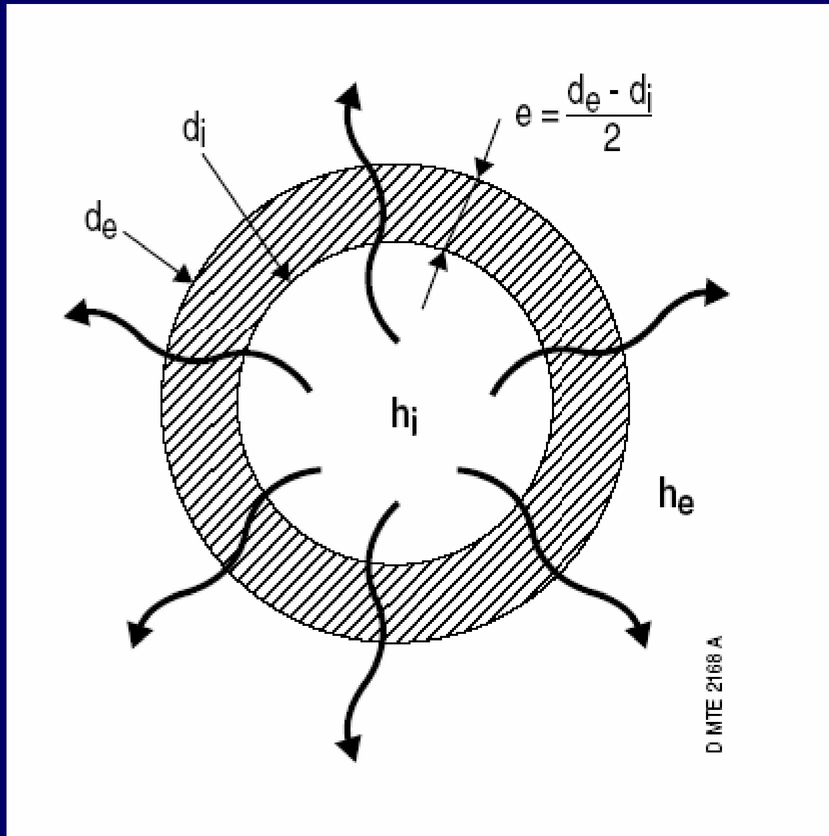
$$R = \frac{1}{h_{hot}} + \frac{e}{\lambda} + \frac{1}{h_{cold}}$$

PHYSICS

- In case of cylindrical wall

$$R_{ext} = \left(\frac{1}{h_i} \cdot \frac{d_e}{d_i}\right) + \left(\frac{d_e}{2\lambda} \cdot Ln \frac{d_e}{d_i}\right) + \frac{1}{h_e}$$

R_{ext}: total resistance versus **external surface** ($h.m^2.°C/kcal$)



ANALYSIS OF FACTORS INFLUENCING HEAT TRANSFER COEFFICIENTS

$$R = \frac{1}{h_{hot}} + \frac{e}{\lambda_{paroi}} + \frac{1}{h_{cold}}$$

- e/λwall is very small
- h coeff depends on
  - Physical properties of fluid
  - Flow turbulence
  - Physical phenomena along with the heat transfer (change of state)

GENERAL LAW

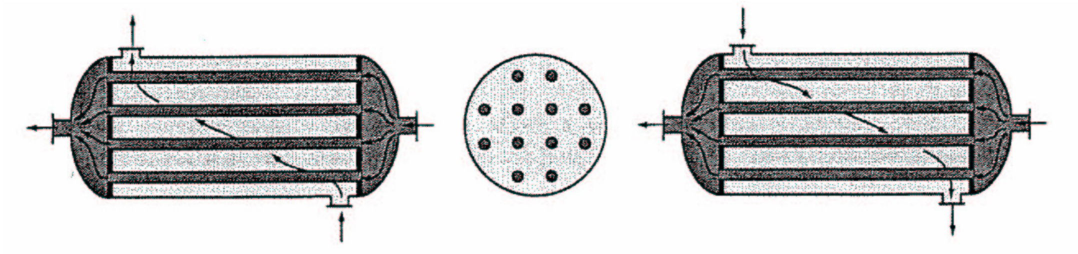
- For a <u>counter-current</u> or <u>co-current</u> heat exchange:
  - $Q = U\ A\ LMTD$ where
    - Q is the total exchanged heat
    - U is the transfer coefficient
    - A is the heat transfer area
    - LMTD is the Logarithmic Mean Temperature Difference
- For other types (1-n, cross flow), the formula becomes:
  - $Q = F\ U\ A\ LMTD_{CC}$

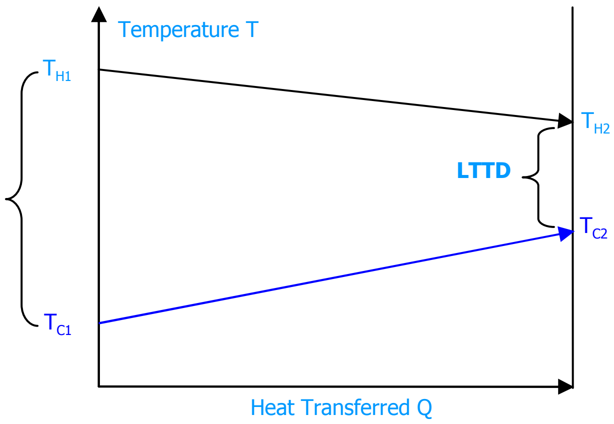
Q – TOTAL EXCHANGED HEAT

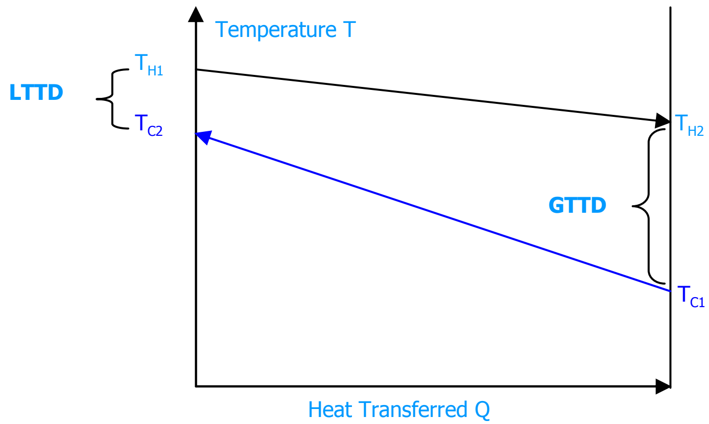
- Q is the enthalpy difference between outlet and inlet for each side multiplied by the mass flow rate
- Q is the same for cold side and hot side (basically one does not take into account the heat losses, which are negligible)
- In case of only sensible heat exchange
  - $Q=MC\Delta T$ or $Q=mc\Delta t$
- In case of latent heat exchange
  - $Q=m\Delta H$vap or cond
- Beware in case of a mixture phase change relations are more complex and thermodynamic simulator must be used

LMTD

Co-current Flow | **Countercurrent Flow**







$$LMTD = \frac{(GTTD)-(LTTD)}{Ln\left(\frac{GTTD}{LTTD}\right)}$$

LMTD

- For non linear curves (condensation, vaporisation), calculating the LMTD with four points may cause a severe error
- In this case, one should calculate the LMTD with several points
  - For a pure body in phase change 2 points are sufficient
  - For a mixture in phase change more points are needed

$$LMTD = \frac{Q_{Total}}{\sum_n \left[Q_n / (LMTD)_n \right]}$$

LMTD

- Beware taking LMTD with four points may lead to consequent errors:

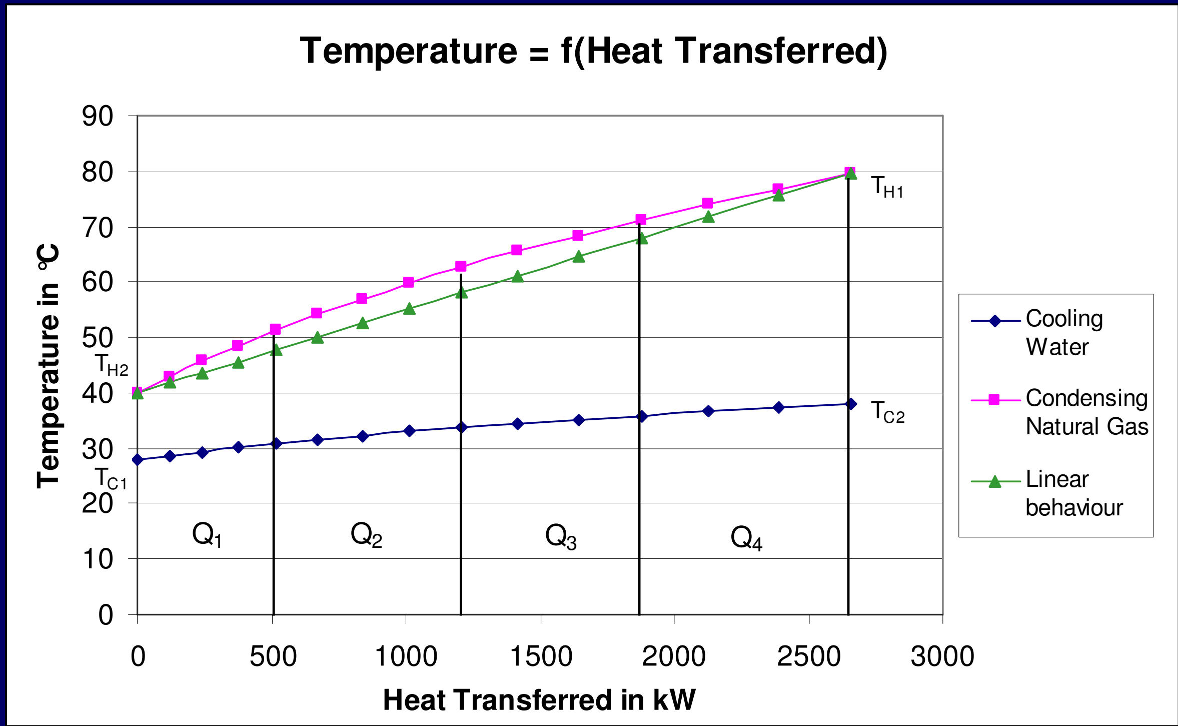
Example:

- Considering a countercurrent natural gas / cooling water cooler and condenser with the following operating conditions:

$$Q_{Total} = 2660\ kW$$
$$T_{C1} = 28°C \qquad T_{C2} = 38°C$$
$$T_{H1} = 80°C \qquad T_{H2} = 40°C$$

- As the natural gas is condensing in the heat exchanger, the temperature versus duty curve is not linear as shown below:

LMTD



Calculation Method	LMTD in °C	Absolute Error in °C	Relative Error in %
End points calculation (Linear behaviour)	23.8	0	0
Weighed calculation with n = 4	26.0	2.2	9.2
Weighed calculation with n = 14	26.2	2.4	10.1

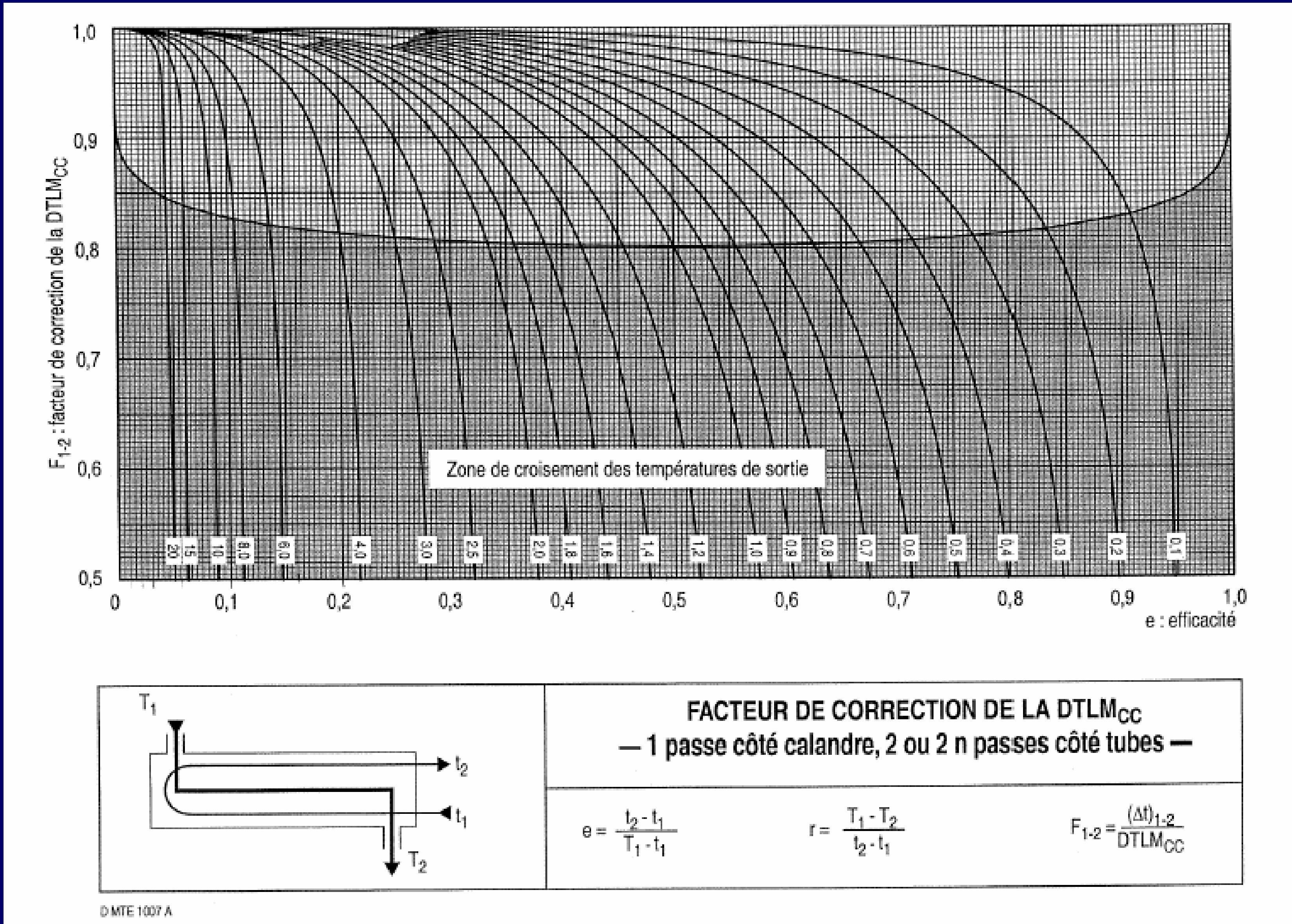
LMTD

- Note that Process Simulators (Hysys, Pro II) do calculate an integrated LMTD point by point

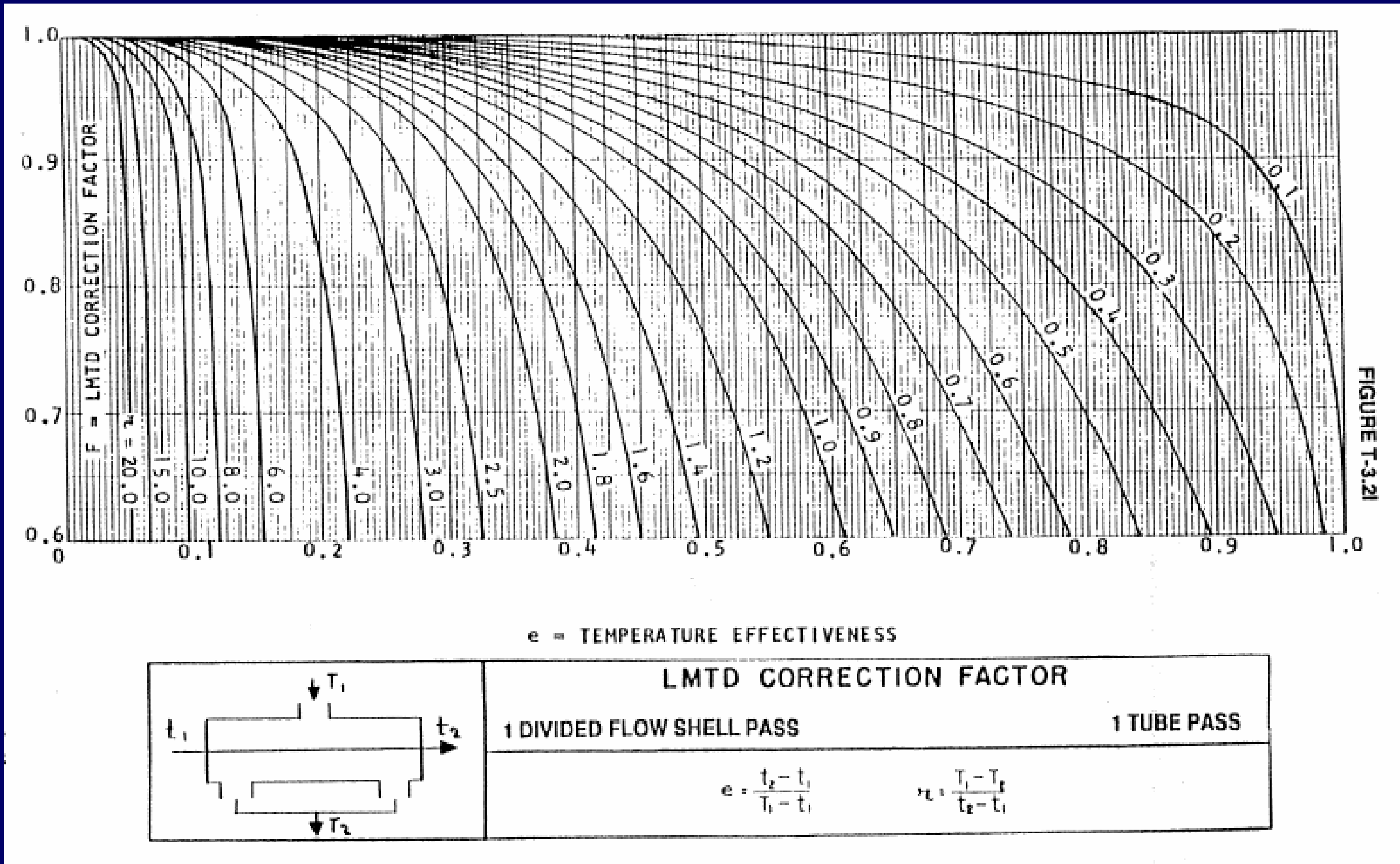
F FACTOR

- F factor depends on the technology of heat exchanger used
  - F=1 for pure counter-current or pure co-current heat exchangers
  - For other types F is function of:
    - The thermal efficiency e or E = heat exchanged / heat exchanged if the heat transfer area was infinite
    - The thermal capacity ratio r or R = mc/MC

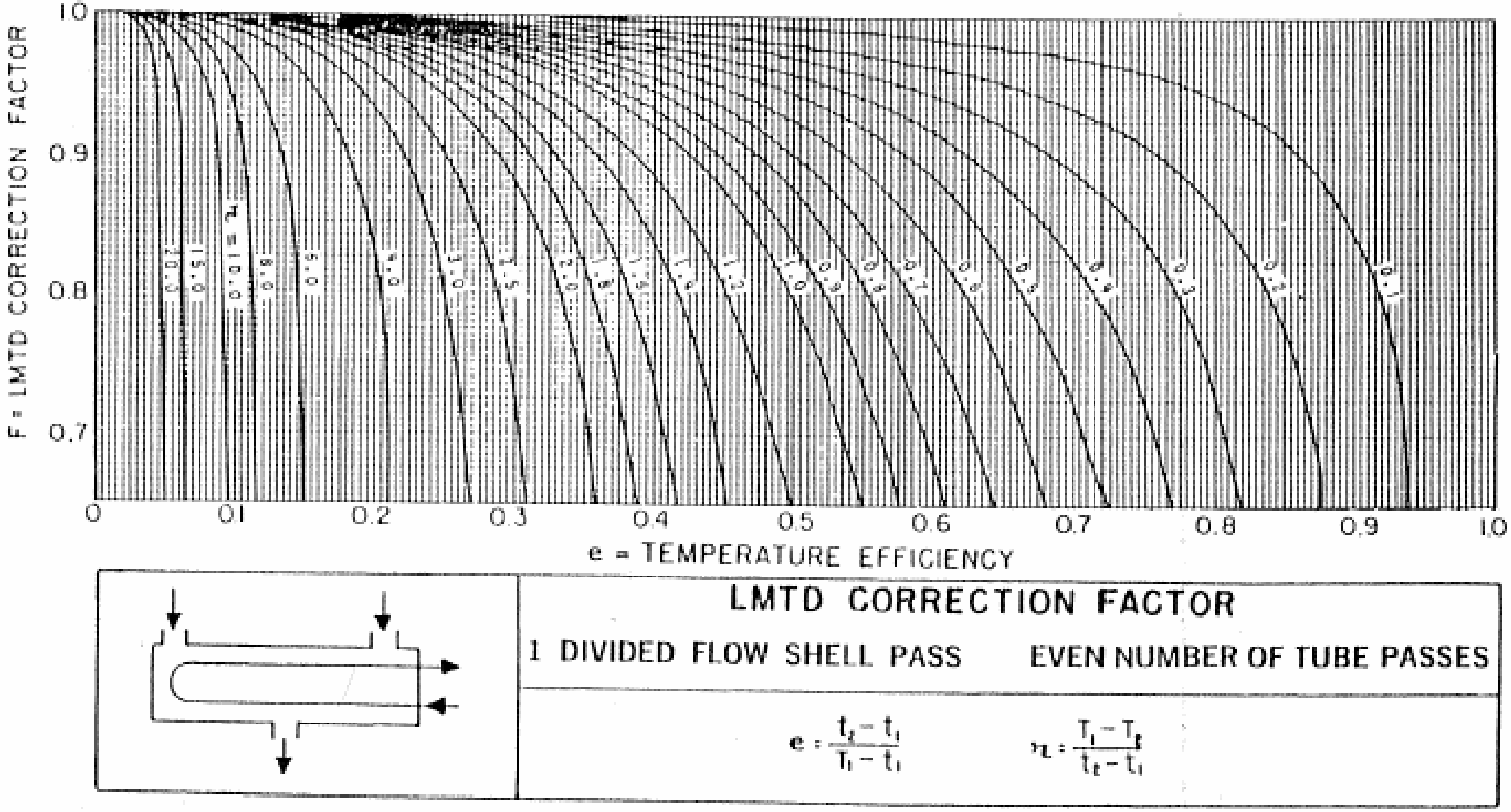
1-2n HEAT EXCHANGER



DIVIDED FLOW HX

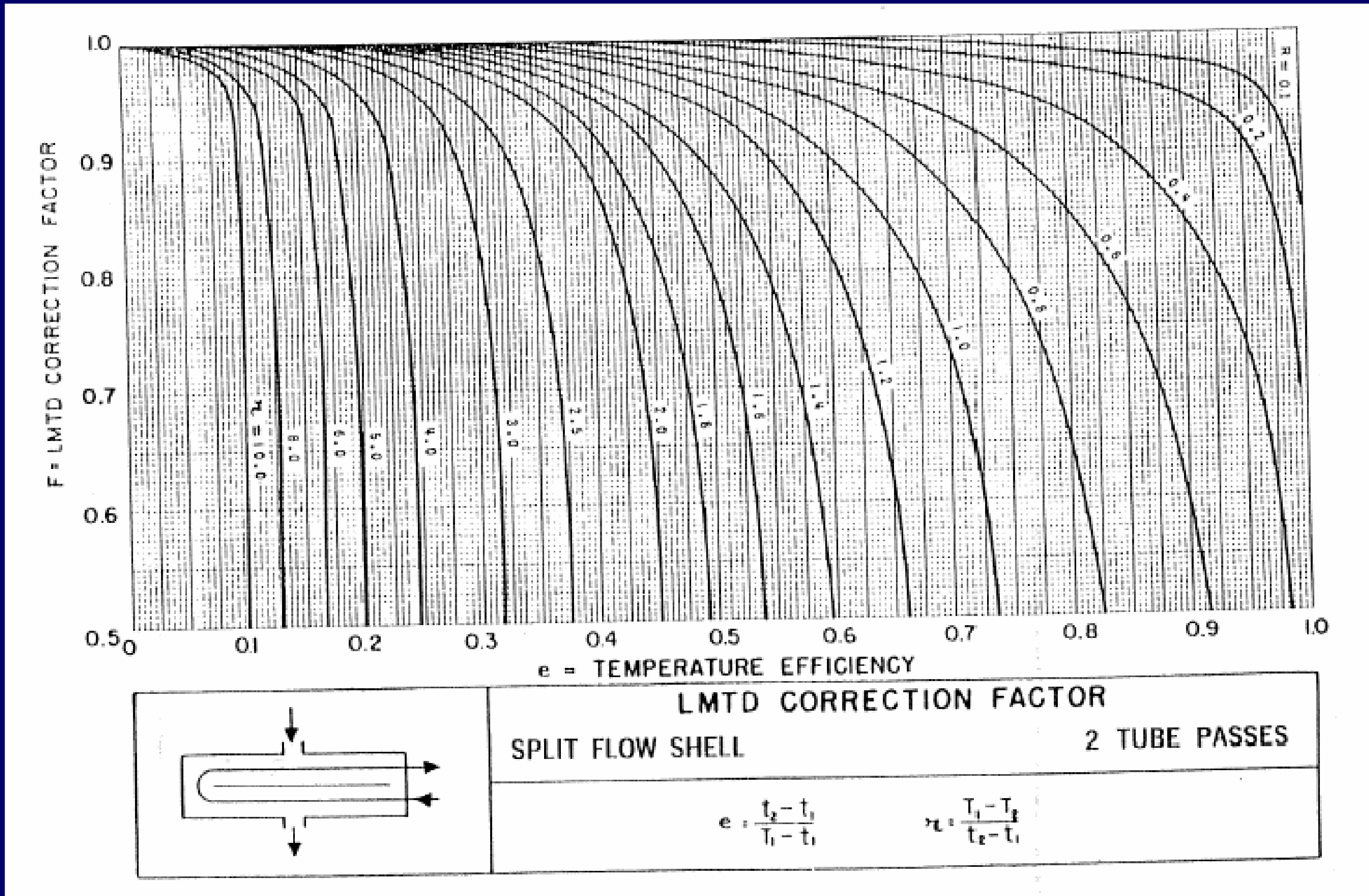


DIVIDED FLOW HX

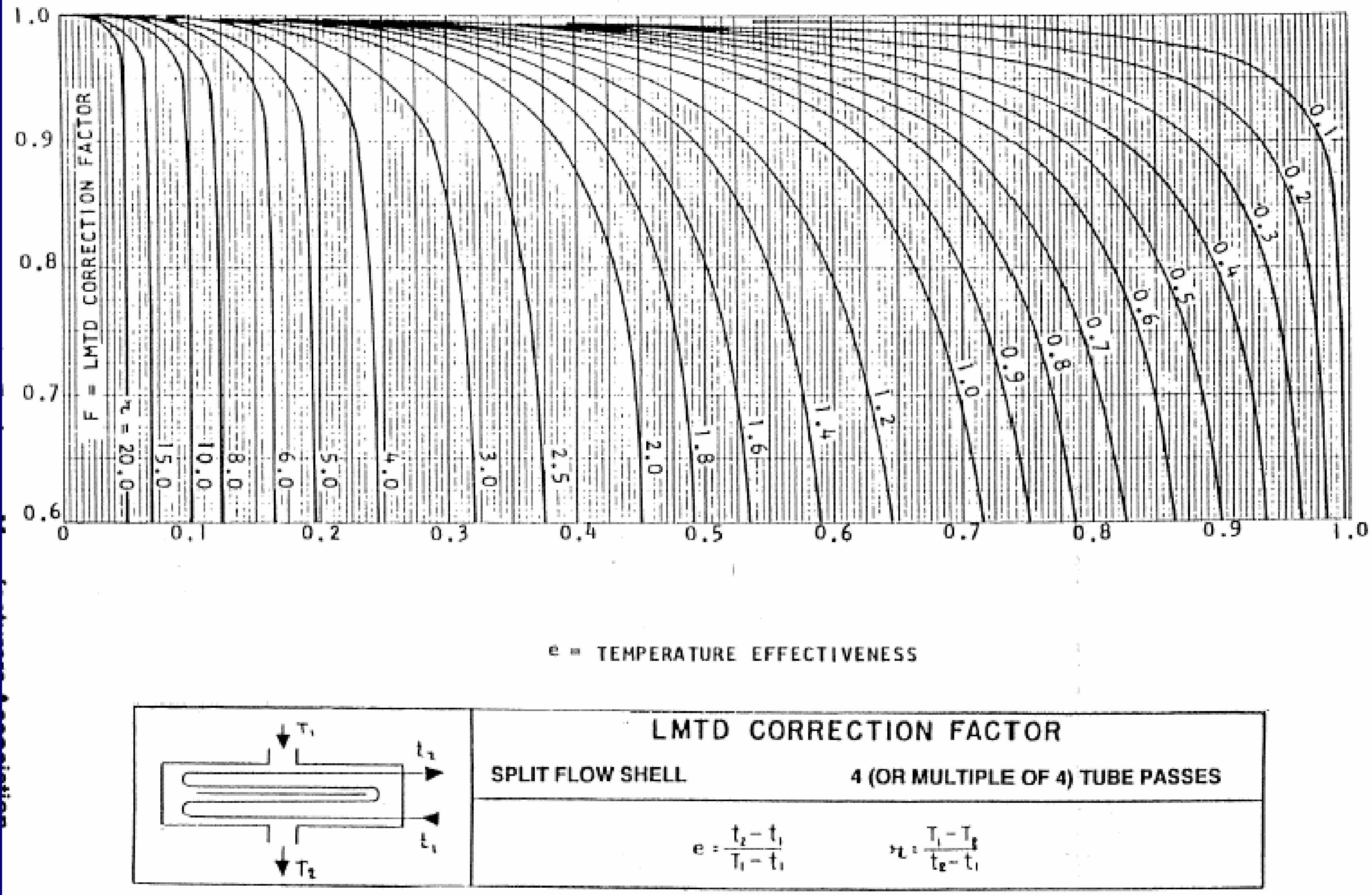


$$e = \frac{t_2 - t_1}{T_1 - t_1} \qquad \eta = \frac{T_1 - T_2}{t_2 - t_1}$$

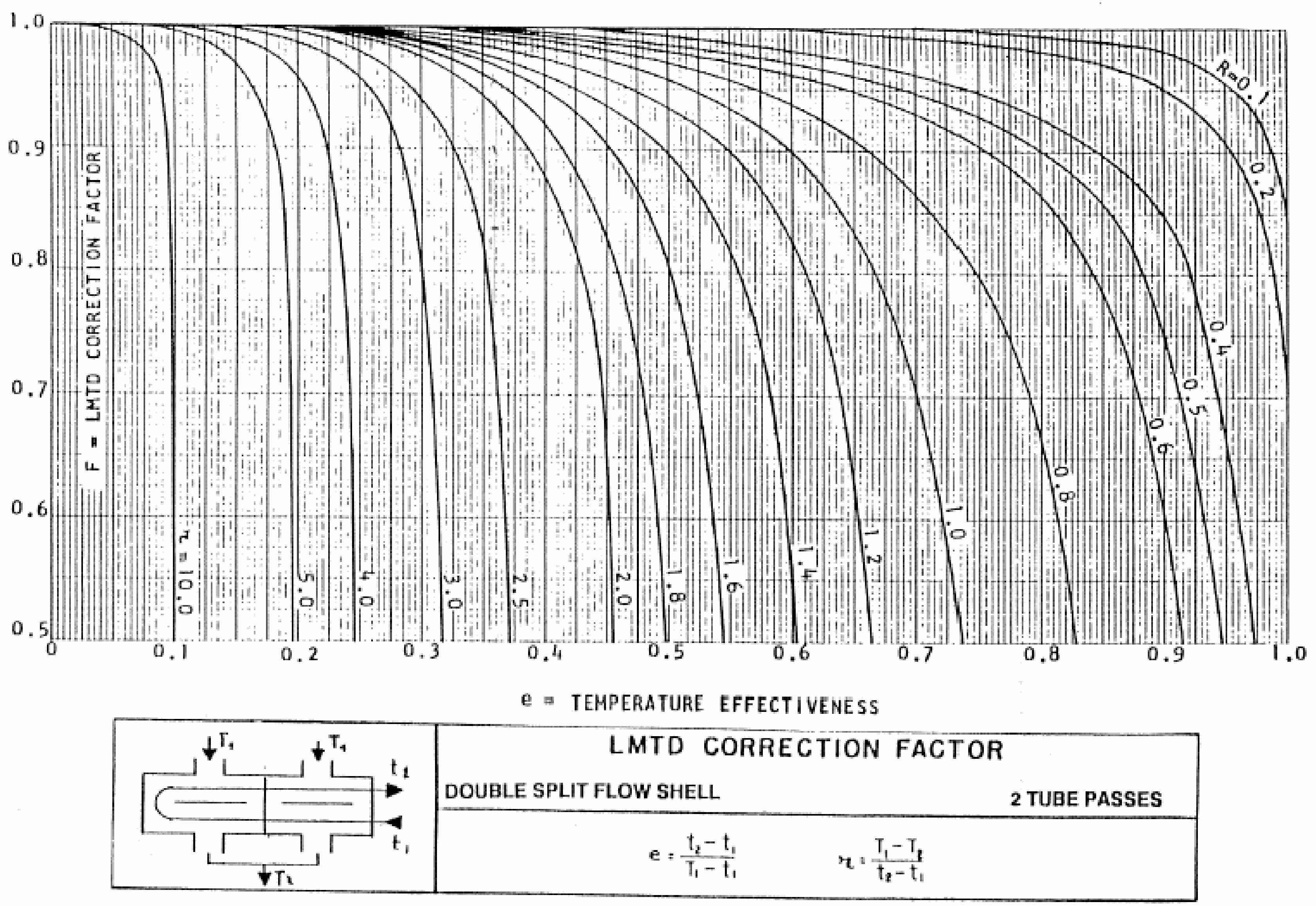
SPLIT FLOW HX



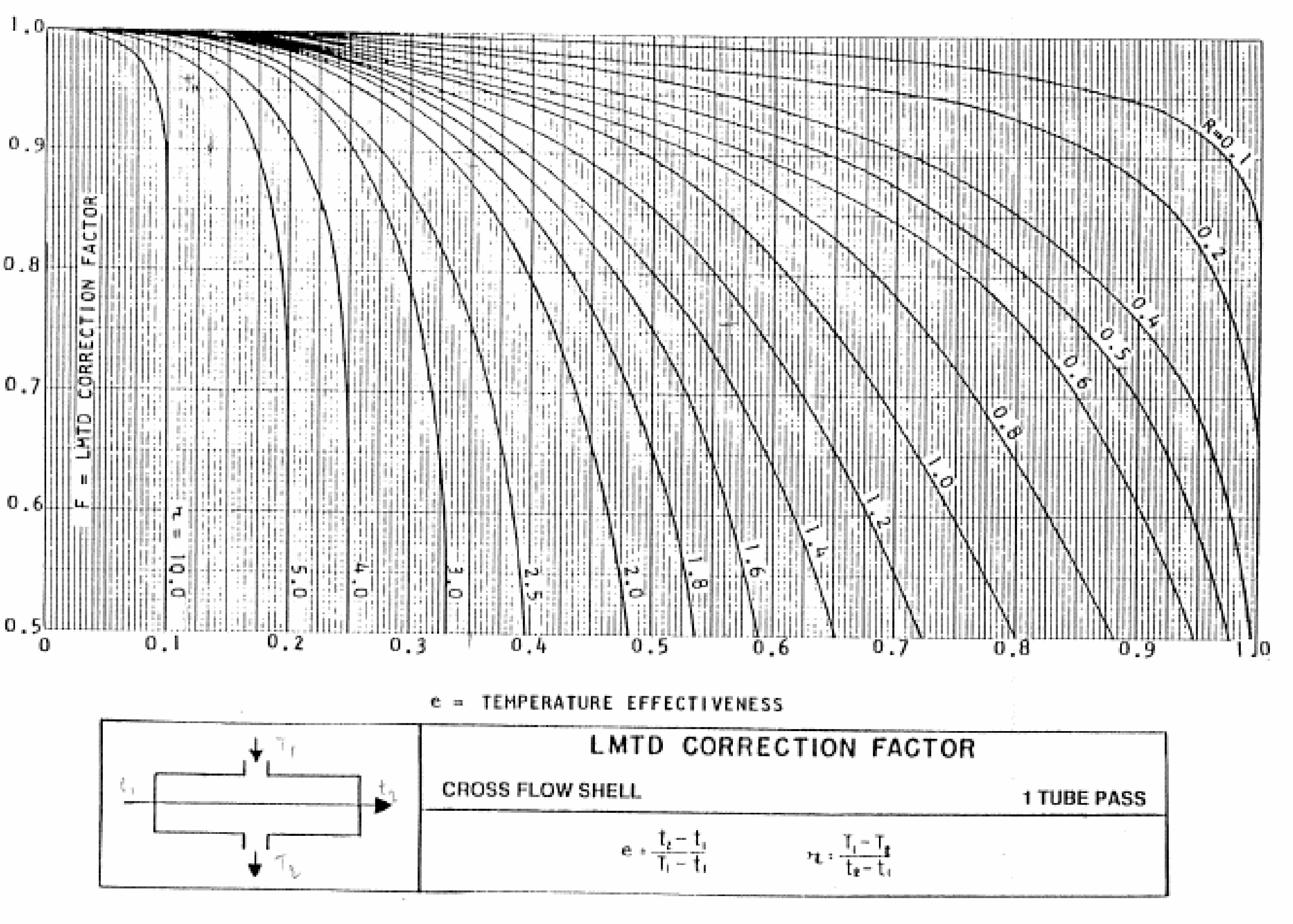
SPLIT FLOW HX



DOUBLE SPLIT FLOW HX



CROSS FLOW HX



U COEFFICIENT

TABLE 11-3 Typical Overall Heat-Transfer Coefficients in Tubular Heat Exchangers

U = Btu/(°F · ft² · h)

Shell side	Tube side	Design U	Includes total dirt
Liquid-liquid media			
Aroclor 1248	Jet fuels	100–150	0.0015
Cutback asphalt	Water	10–20	.01
Demineralized water	Water	300–500	.001
Ethanol amine (MEA or DEA) 10–25% solutions	Water or DEA, or MEA solutions	140–200	.003
Fuel oil	Water	15–25	.007
Fuel oil	Oil	10–15	.008
Gasoline	Water	60–100	.003
Heavy oils	Heavy oils	10–40	.004
Heavy oils	Water	15–50	.005
Hydrogen-rich reformer stream	Hydrogen-rich reformer stream	90–120	.002
Kerosene or gas oil	Water	25–50	.005
Kerosene or gas oil	Oil	20–35	.005
Kerosene or jet fuels	Trichlorethylene	40–50	.0015
Jacket water	Water	230–300	.002
Lube oil (low viscosity)	Water	25–50	.002
Lube oil (high viscosity)	Water	40–80	.003
Lube oil	Oil	11–20	.006
Naphtha	Water	50–70	.005
Naphtha	Oil	25–35	.005
Organic solvents	Water	50–150	.003
Organic solvents	Brine	35–90	.003
Organic solvents	Organic solvents	20–60	.002
Tall oil derivatives, vegetable oil, etc.	Water	20–50	.004
Water	Caustic soda solutions (10–30%)	100–250	.003
Water	Water	200–250	.003
Wax distillate	Water	15–25	.005
Wax distillate	Oil	13–23	.005
Condensing vapor-liquid media			
Alcohol vapor	Water	100–200	.002
Asphalt (450°F.)	Dowtherm vapor	40–60	.006
Dowtherm vapor	Tall oil and derivatives	60–80	.004
Dowtherm vapor	Dowtherm liquid	80–120	.0015
Gas-plant tar	Steam	40–50	.0055
High-boiling hydrocarbons V	Water	20–50	.003
Low-boiling hydrocarbons A	Water	80–200	.003
Hydrocarbon vapors (partial condenser)	Oil	25–40	.004
Organic solvents A	Water	100–200	.003
Organic solvents high NC, A	Water or brine	20–60	.003
Organic solvents low NC, V	Water or brine	50–120	.003
Kerosene	Water	30–65	.004
Kerosene	Oil	20–30	.005
Naphtha	Water	50–75	.005
Naphtha	Oil	20–30	.005
Stabilizer reflux vapors	Water	80–120	.003
Steam	Feed water	400–1000	.0005
Steam	No. 6 fuel oil	15–25	.0055
Steam	No. 2 fuel oil	60–90	.0025
Sulfur dioxide	Water	150–200	.003
Tall-oil derivatives, vegetable oils (vapor)	Water	20–50	.004
Water	Aromatic vapor-stream azeotrope	40–80	.005
Gas-liquid media			
Air, N_2, etc. (compressed)	Water or brine	40–80	.005
Air, N_2, etc., A	Water or brine	10–50	.005
Water or brine	Air, N_2 (compressed)	20–40	.005
Water or brine	Air, N_2, etc., A	5–20	.005
Water	Hydrogen containing natural-gas mixtures	80–125	.003
Vaporizers			
Anhydrous ammonia	Steam condensing	150–300	.0015
Chlorine	Steam condensing	150–300	.0015
Chlorine	Light heat-transfer oil	40–60	.0015
Propane, butane, etc.	Steam condensing	200–300	.0015
Water	Steam condensing	250–400	.0015

NC = noncondensable gas present.
V = vacuum.
A = atmospheric pressure.
Dirt (or fouling factor) units are (h · ft² · °F)/Btu.
To convert British thermal units per hour-square foot-degrees Fahrenheit to joules per square meter-second-kelvins, multiply by 5.6783; to convert hours per square foot-degree Fahrenheit-British thermal units to square meters per second-kelvin-joules, multiply by 0.1761.

Perry chemical handbook

U COEFFICIENT

Typical Overall Heat Transfer Coefficients-U

SHELL AND TUBE EXCHANGERS		
	Coefficient	
Service	Btu/hr·ft^2·°F	kJ/h·m^2·°C
Water Coolers		
Gas 1-35 bars	35-50	715-1020
Gas 35-70 bars	50-80	1020-1635
Gas over 70 bars	80-100	1635-2045
Natural Gasoline, LPG	70-90	1430-1840
MEA	130-150	2655-3065
Air	15-25	305-510
Water	170-200	3475-4085
Water Condensers		
Amine regenerator	100-110	2045-2250
Fractionator overhead	70-80	1430-1635
Light hydrocarbons	85-135	1735-2760
Reboilers		
Steam	140-160	2860-3270
Hot oil	90-120	1840-2450
Glycol	10-20	205-410
Amine	100-120	2045-2450
General		
Oil-oil	80-100	1635-2045
Propane-propane	100-130	2045-2655
Rich MEA-lean MEA	120-130	2450-2655
Gas-gas (<35 bars)	50-70	1020-1430
Gas-gas (about 70 bars)	55-75	1125-1530
Gas-propane chiller	60-90	1225-1840
AERIAL COOLERS		
Condensers		
Light hydrocarbons	75-90	1530-1840
MEA	70-90	1430-1840
Freon	70-90	1430-1840
Coolers		
Light hydrocarbon liquids	70-90	1430-1840
Water	100-120	2045-2450
Lube oil	10-20	205-410
Gas	50-70	1020-1430

FOULING

- One has previously seen that

$$R = \frac{1}{h_{hot}} + \frac{e}{\lambda_{paroi}} + \frac{1}{h_{cold}}$$

- U, the overall transfer coeff. is
  $U = 1/R$

- R as written beside does not take into account any dirt that could accumulate on the wall (on both sides) and which could modify the transfer coefficient

- This R leads to the U clean

- Fouling is the results of different phenomenon such as precipitation, sedimentation, chemical reactions, corrosion or biological growth. Fouling is complex, dynamic, and in times degrades the performance of the heat exchanger. Consequently, fouling resistances shall be determined depending on the fluid and then specified in the process datasheet to provide overdesign. Indeed, the heat exchanger is generally oversized for clean operation and barely adequate for conditions just before it should be cleaned.

FOLLING

- Fouling coefficients must then be added to the overall resistance

- Typical values are:

PROCESS FLUIDS	Fouling factors	
	m² °C / W	h ft² / Btu
Heavy oil	0.00050	0.0028
Oil	0.00040	0.0023
Heavy Gas Oil	0.00035	0.0020
Light Gas Oil	0.00030	0.0017
Gasoline	0.00020	0.0011
LPG (liquid)	0.00020	0.0011
Natural gas	0.00015	0.0009
Regeneration gas (dryers)	0.00017	0.0010
Amine solution	0.00040	0.0023
Glycol	0.00040	0.0023
Refrigerant (propane or mixed refrigerant)	0.00010	0.0006
Oily water	0.00030	0.0017
UTILITY FLUIDS	**Fouling factors**	
	m² °C / W	**h ft² / Btu**
Sea cooling water	0.00030	0.0017
River cooling water	0.00040	0.0023
Fresh (desalinated) cooling water in closed loop	0.00020	0.0011
Well water	0.00040	0.0023
Atmospheric air	0.00035	0.0020
Fuel gas	0.00017	0.0010
Hot oil	0.00020	0.0009
Super heated steam	0.00010	0.0006
Saturated steam / steam condensate	0.00017	0.0010
Boiler feed water	0.00017	0.0010
Instrument air, Nitrogen	0.00017	0.0010

FOULING

- One should add to the clean heat transfer resistance the following term:

$$R_s = R_{si}\frac{d_e}{d_i} + R_{se}$$

  - Where Rs is the fouling resistance
  - Rsi the tube internal fouling resistance
  - Rse the tube external resistance

Ratio de/di (external tube diameter / internal tube diameter) to refer to the external surface

HEAT TRANSFER COEFFICIENT

- To calculate U, one needs to evaluate h tube side and shell side
- h coefficients are very complex to calculate, especially for the shell side, it depends on:
  - The physical properties of the fluid
  - The flow regime (turbulence)
  - Physical phenomena simultaneous to heat transfer
  - Heat leaks (for the shell side)
- For the tube side in turbulent flow (Re>10000) and sensible heat exchange:

$$Nu = \frac{h_i d_i}{\lambda} = 0{,}023 \; Re^{0{,}8} \; Pr^{1/3} \left(\frac{\mu}{\mu_p}\right)^{0{,}14}$$

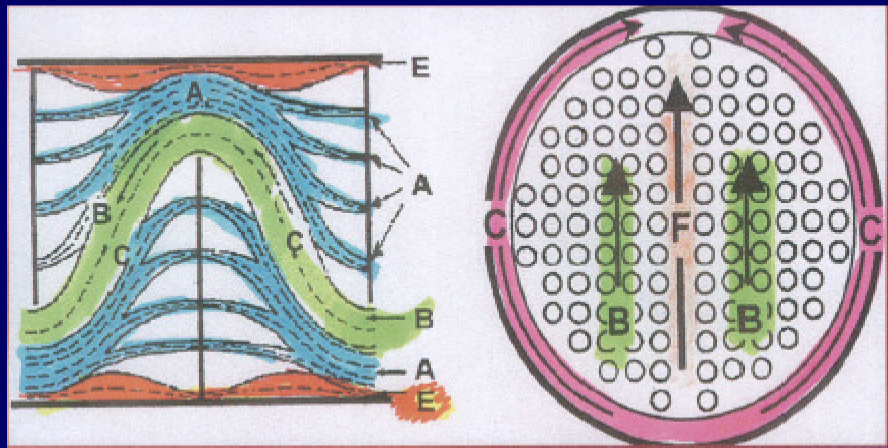
$$Pr = C\mu/\lambda$$

HEAT TRANSFER COEFFICIENT SHELL SIDE

- Transfert coefficient for a mono-phasic stream flowing transversaly a bundle of tubes is:
  $Nu = a\ Re^{1/3}\ Pr^{-1/3}(\mu/\mu_p)^{0.14}$

  Nu gives h_e

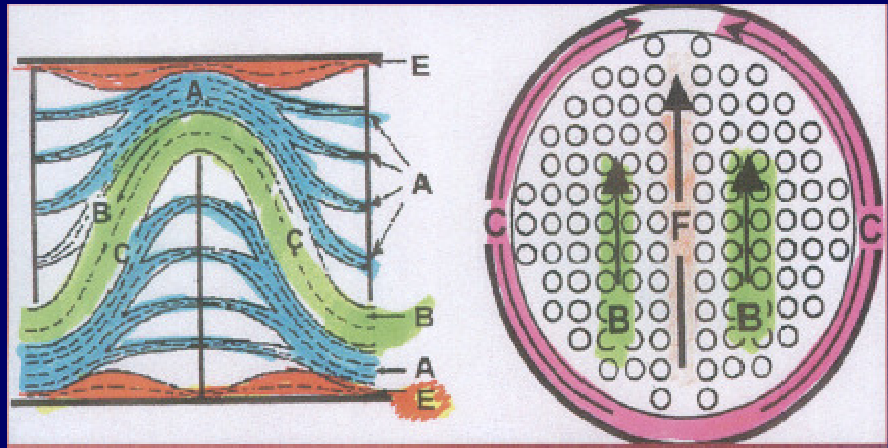
- Heat transfer coefficient for shell side is:
  $h_c = h_e . k_{CH} . k_{BP} . k_{Re}$ (method Bell)

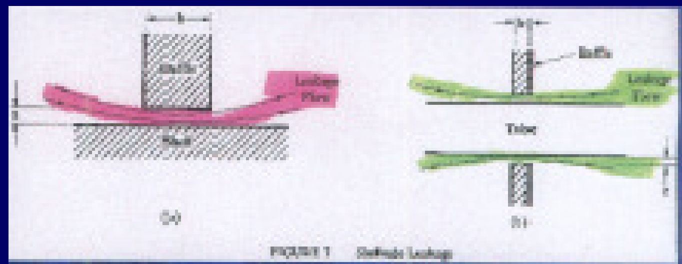


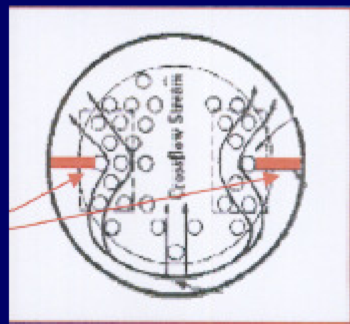
HEAT TRANSFER COEFFICIENT
SHELL SIDE

- Current A is partly useful but less efficient than current A
- Current B is useful
- Current C is completely useless
- Current E is completely useless
- Current F is completely useless but present only on types E, J, K and X

- To reduce current A: reduce baffle tube clearance
- To reduce current C: implement sealing strips
- To reduce current E: reduce baffle shell clearance
- To reduce current F only ways are to change shell type (F, G, H)



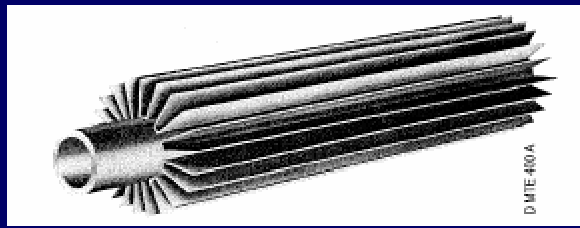


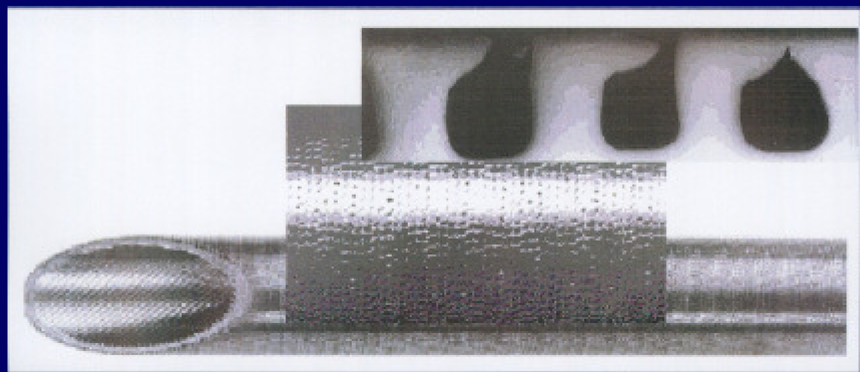


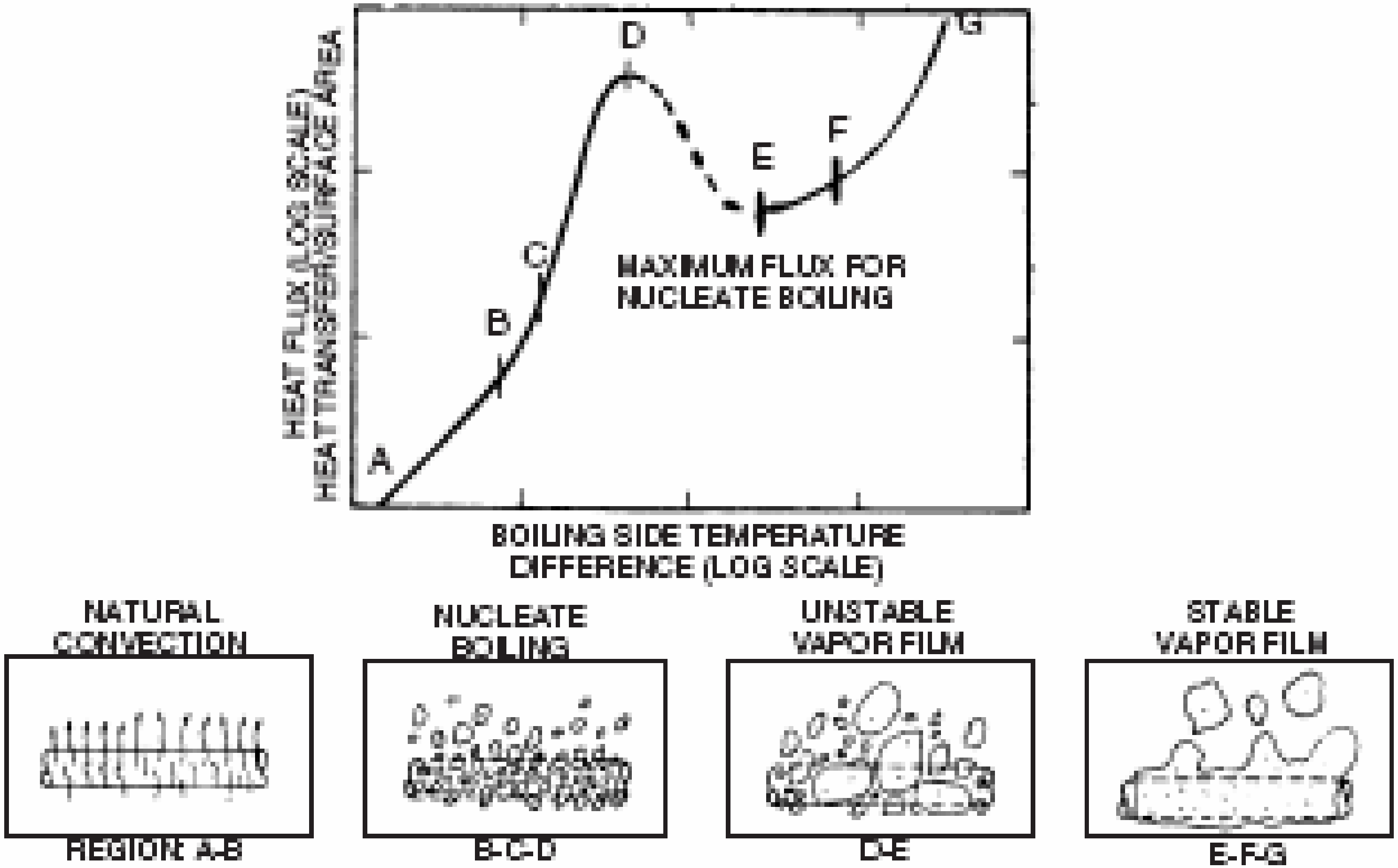
HEAT TRANSFER AREA

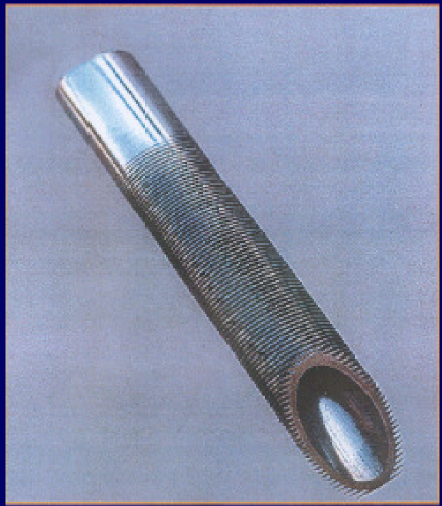
- A is the total heat transfer area
- $A = \pi d_e L$ (external diameter since U is expressed with regards to external surface) if the tubes are bare

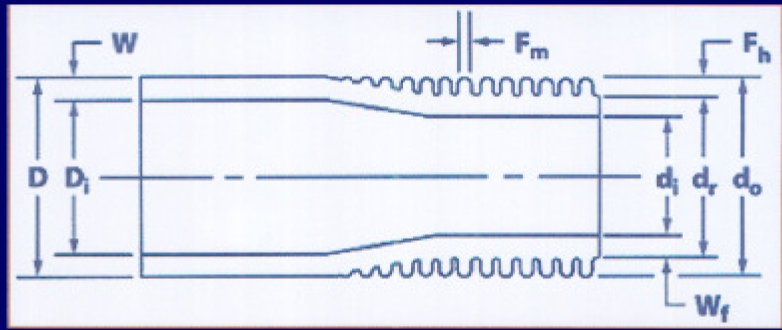
- One can increase the surface with special tube design (more expensive)
  - Low fin tubes (area increase factor up to 10)
- One can create nucleation sites to maximise ebullition heat transfer coefficient (Wielland tubes)

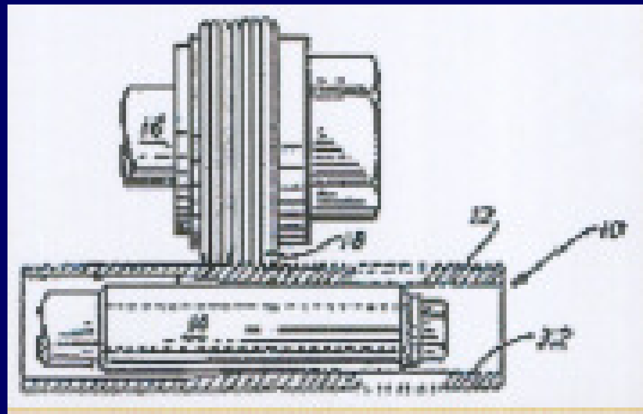





HEAT FLUX (LOG SCALE)
HEAT TRANSFER/SURFACE AREA
A
B
C
D
E
F
G
MAXIMUM FLUX FOR
NUCLEATE BOILING
BOILING SIDE TEMPERATURE
DIFFERENCE (LOG SCALE)
NATURAL
CONVECTION
REGION: A-B
NUCLEATE
BOILING
B-C-D
UNSTABLE
VAPOR FILM
D-E
STABLE
VAPOR FILM
E-F-G




W
F_m
F_h
D
D_i
d_i
d_r
d_o
W_f

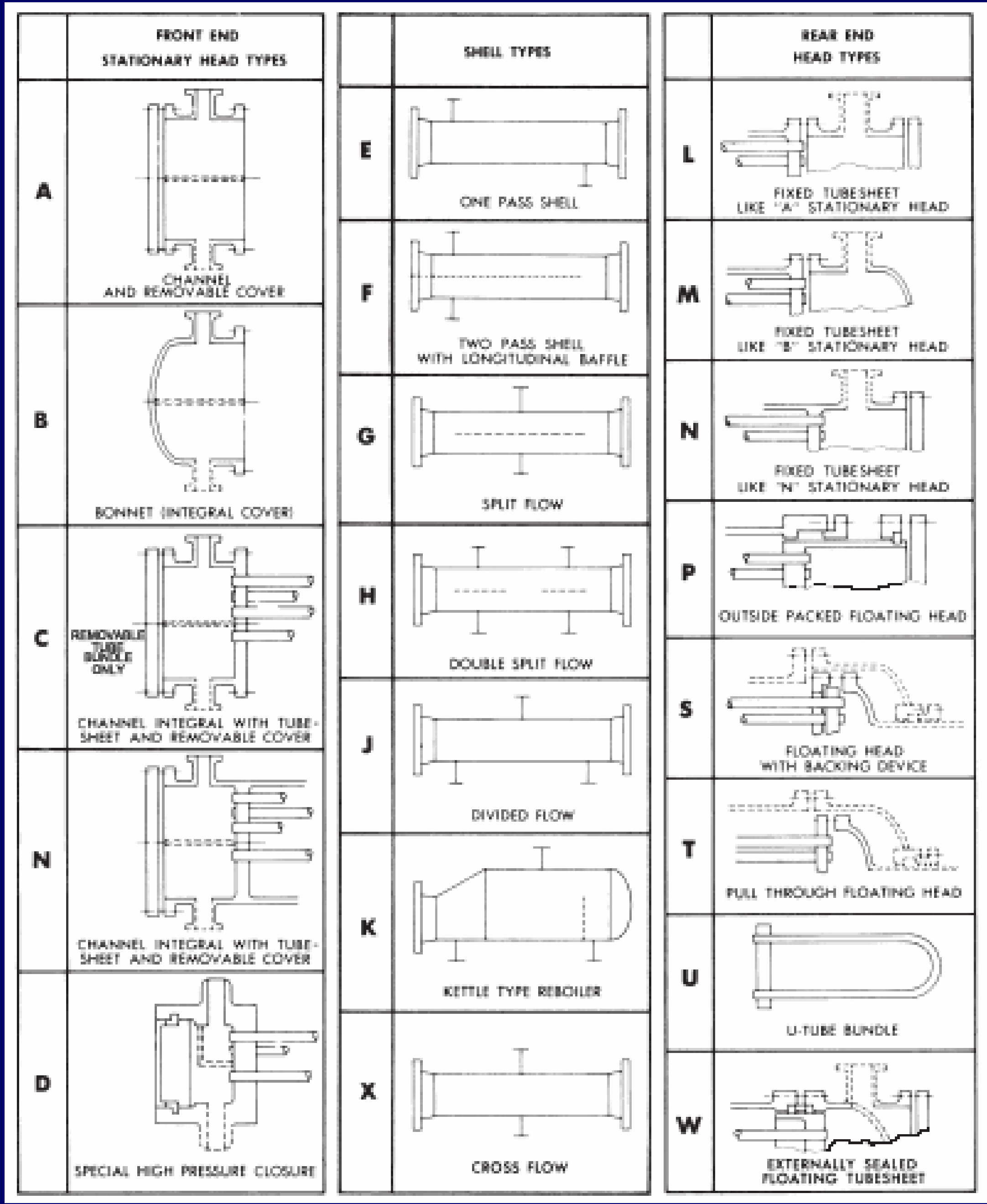


SHELL AND TUBE TECHNOLOGY

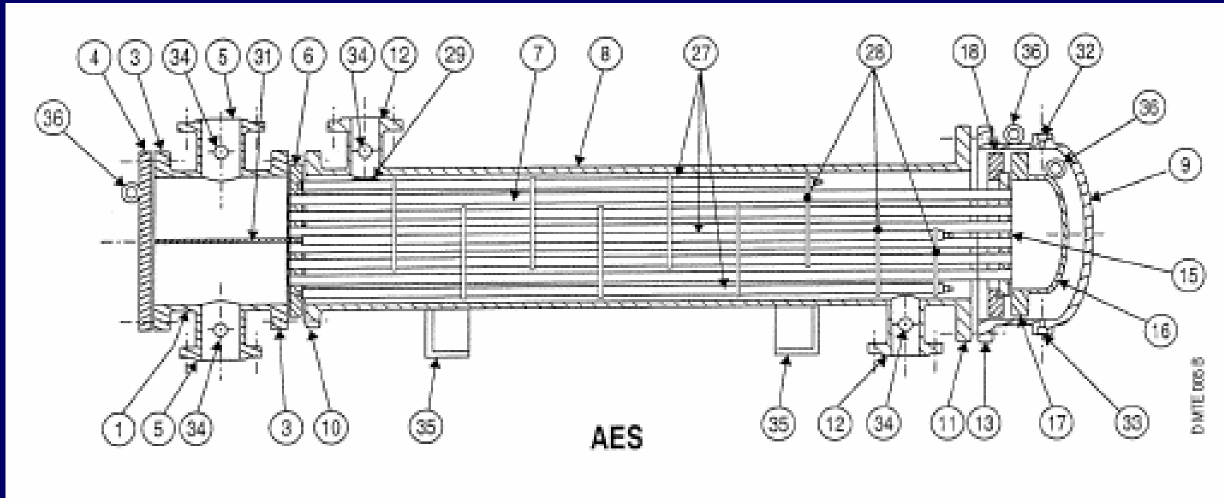
- Shell and tube HX is the labour horse of chemical engineering
- Very robust
- Common rudimentary design
- Can be applied for all services
- Can be cleaned (if designed so as to)
- There is a lot of manufacturers
- Completely defined by the TEMA code

TEMA HEAT EXCHANGER

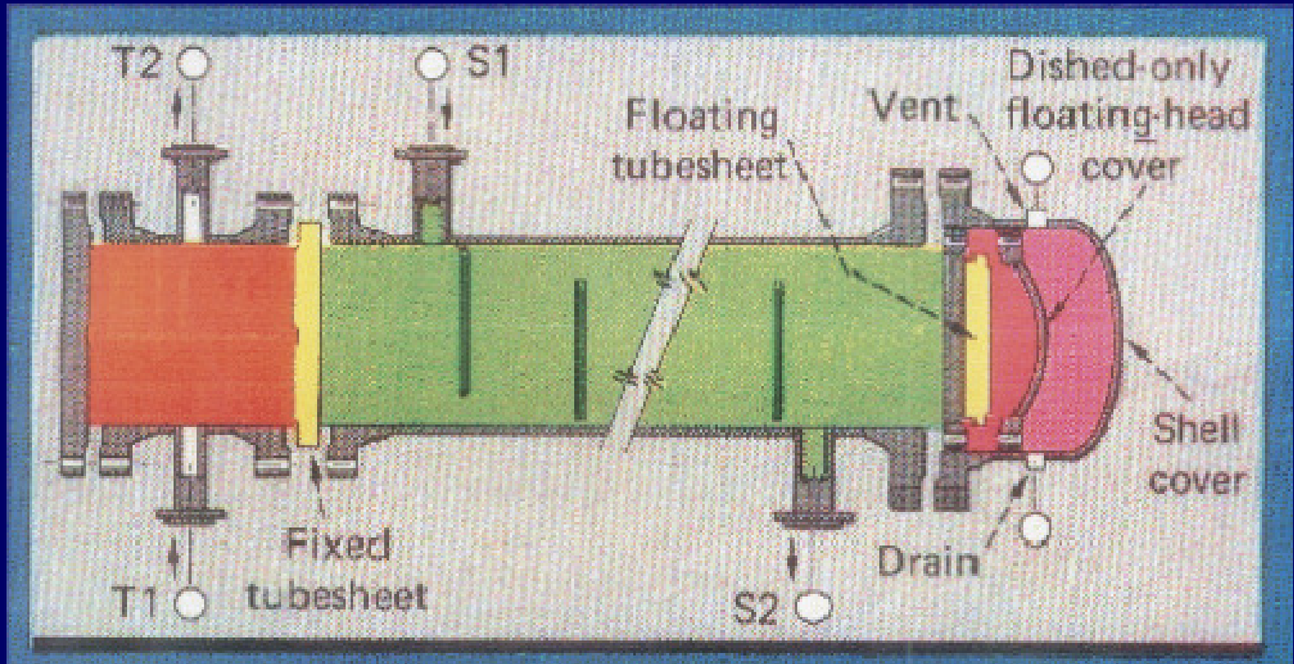
- TEMA (Tubular Exchanger Manufacturer Association) defines shell and tube heat exchanger by a code of three letters (e.g. BEU)
  - First letter is for the front end type
  - Second letter is for the shell type
  - Third letter is for the rear end type


FRONT END
STATIONARY HEAD TYPES
A
CHANNEL
AND REMOVABLE COVER
B
BONNET (INTEGRAL COVER)
C
REMOVABLE
TUBE
BUNDLE
ONLY
CHANNEL INTEGRAL WITH TUBE-SHEET AND REMOVABLE COVER
N
CHANNEL INTEGRAL WITH TUBE-SHEET AND REMOVABLE COVER
D
SPECIAL HIGH PRESSURE CLOSURE
SHELL TYPES
E
ONE PASS SHELL
F
TWO PASS SHELL
WITH LONGITUDINAL BAFFLE
G
SPLIT FLOW
H
DOUBLE SPLIT FLOW
J
DIVIDED FLOW
K
KETTLE TYPE REBOILER
X
CROSS FLOW
REAR END
HEAD TYPES
L
FIXED TUBESHEET
LIKE "A" STATIONARY HEAD
M
FIXED TUBESHEET
LIKE "B" STATIONARY HEAD
N
FIXED TUBESHEET
LIKE "N" STATIONARY HEAD
P
OUTSIDE PACKED FLOATING HEAD
S
FLOATING HEAD
WITH BACKING DEVICE
T
PULL THROUGH FLOATING HEAD
U
U-TUBE BUNDLE
W
EXTERNALLY SEALED
FLOATING TUBESHEET

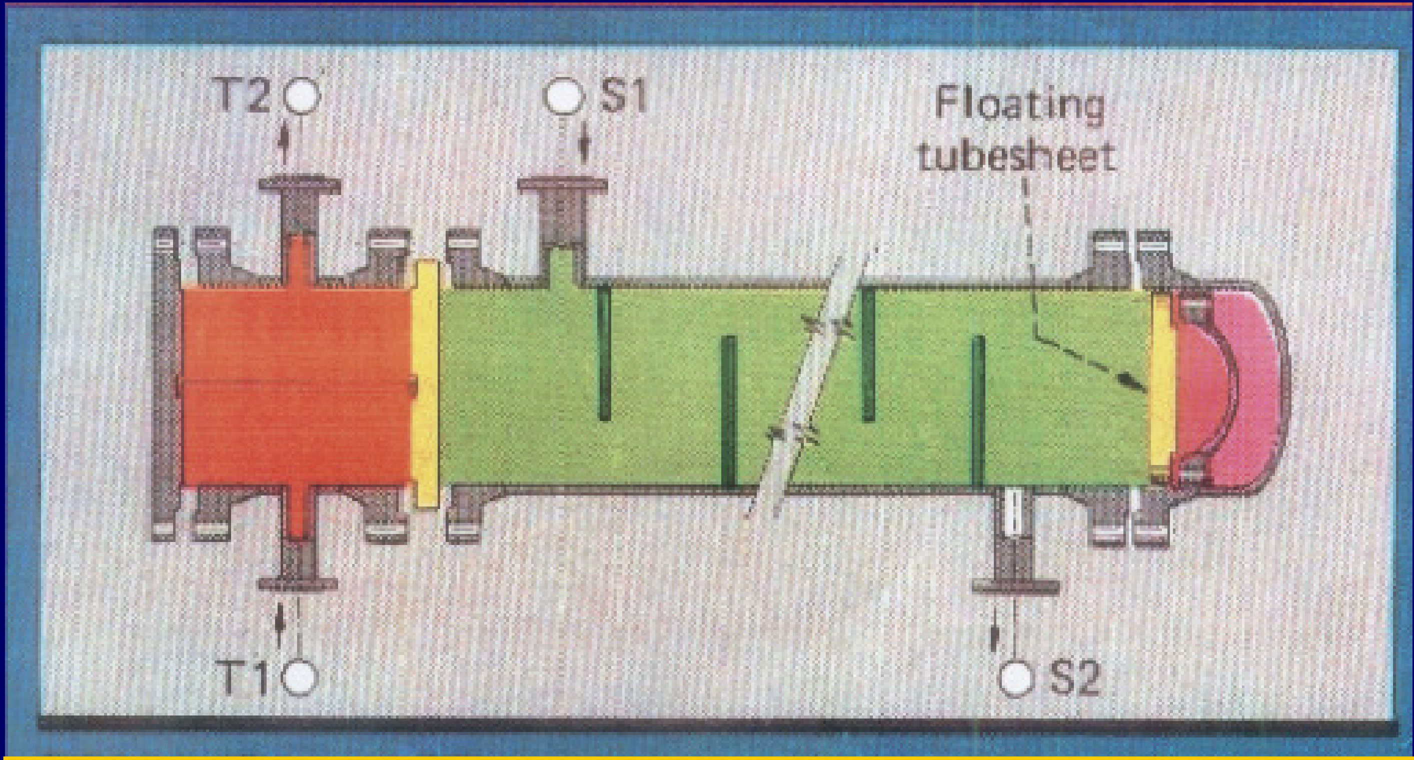
1. Stationary Head-Channel
2. Stationary Head-Bonnet
3. Stationary Head Flange-Channel or Bonnet
4. Channel cover
5. Stationary Head Nozzle
6. Stationary Tubesheet
7. Tubes
8. Shell
9. Shell Cover
10. Shell Flange-Stationary Head End
11. Shell Flange-Rear Head End
12. Shell Nozzle
13. Shell Cover Flange
14. Expansion Joint
15. Floating Tubesheet
16. Floating Head Cover
17. Floating Head Cover Flange
18. Floating Head Backing Device
19. Split Shear Ring
20. Slip-on Backing Flange
21. Floating Head Cover-External
22. Floating Tubesheet Skirt
23. Packing Box
24. Packing
25. Packing Gland
26. Lantern Ring
27. Tierods and Spacers
28. Transverse Baffles or Support Plates
29. Impingement Plate
30. Longitudinal Baffle
31. Pass Partition
32. Vent Connection
33. Drain Connection
34. Instrument Connection
35. Support Saddle
36. Lifting Lug
37. Support Bracket
38. Weir
39. Liquid Level Connection



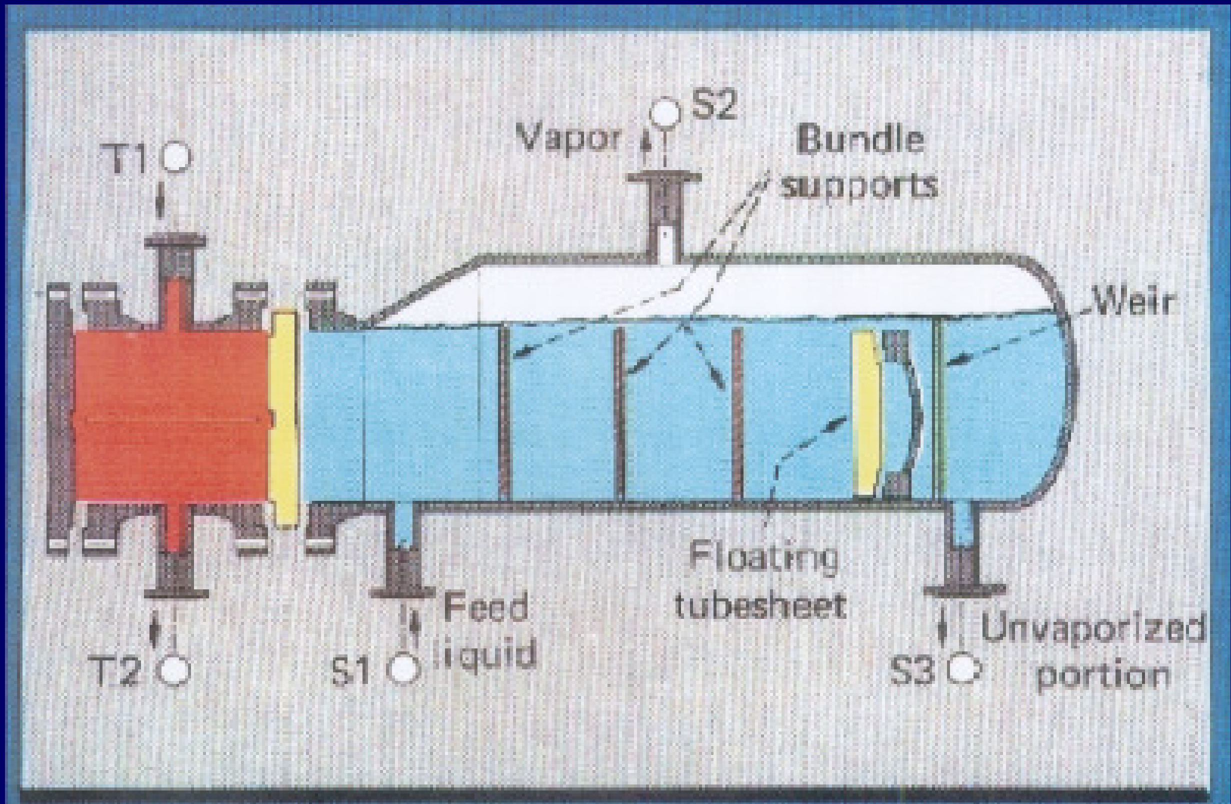
TEMA SHELL AND TUBES



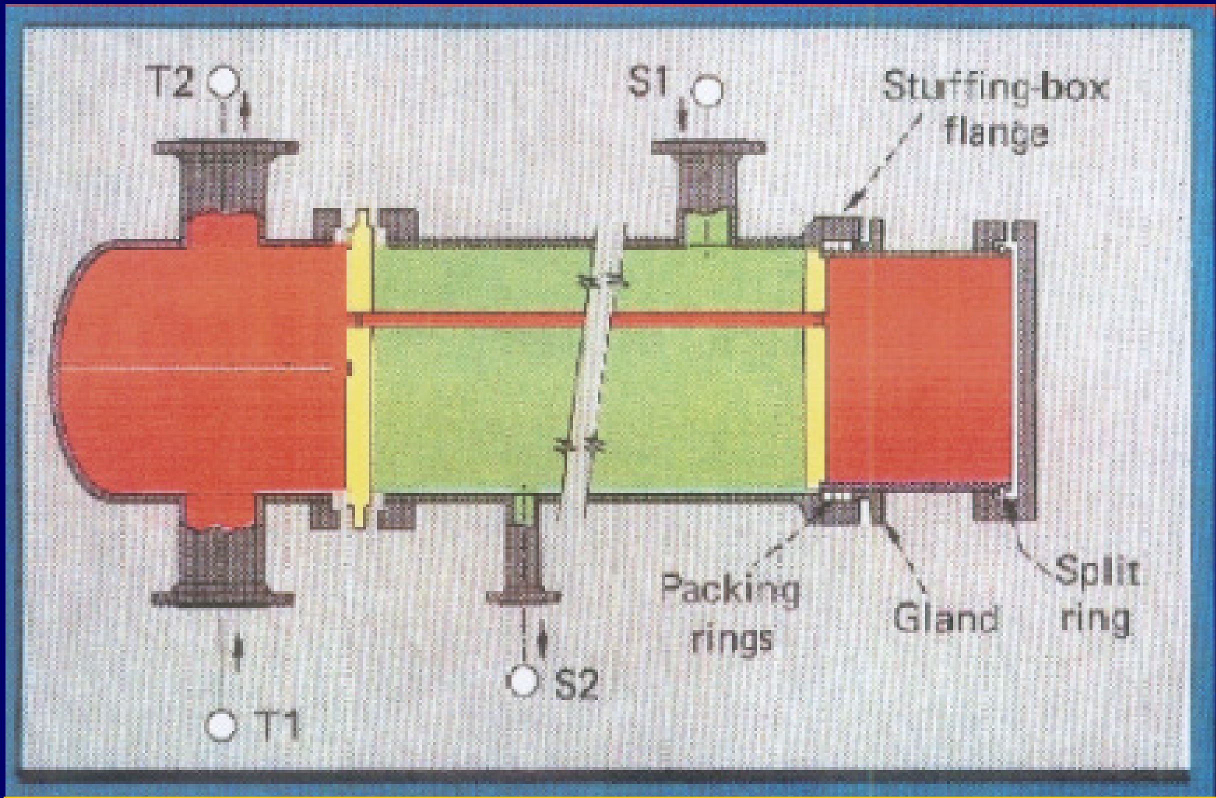
TEMA SHELL AND TUBES



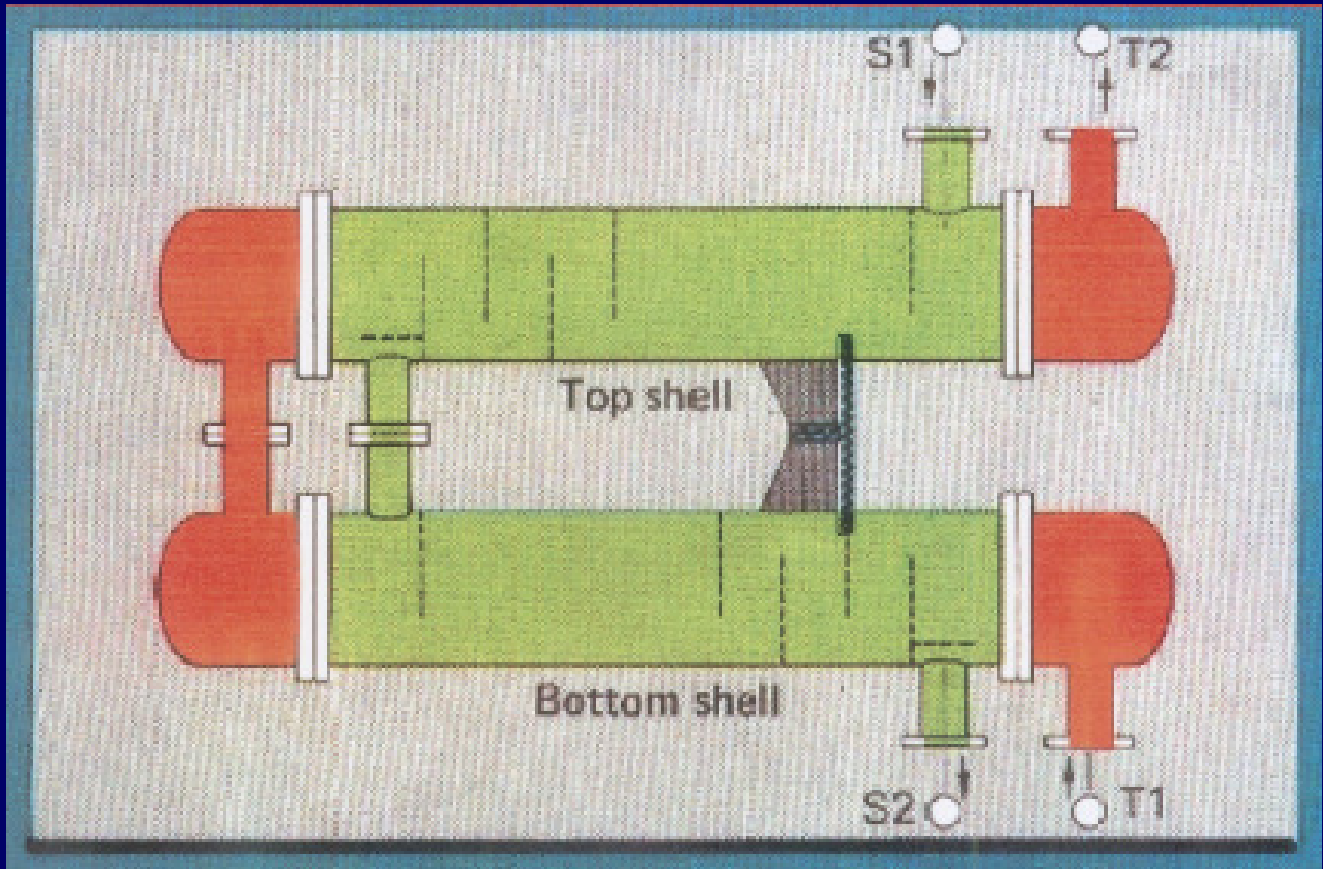
TEMA SHELL AND TUBES



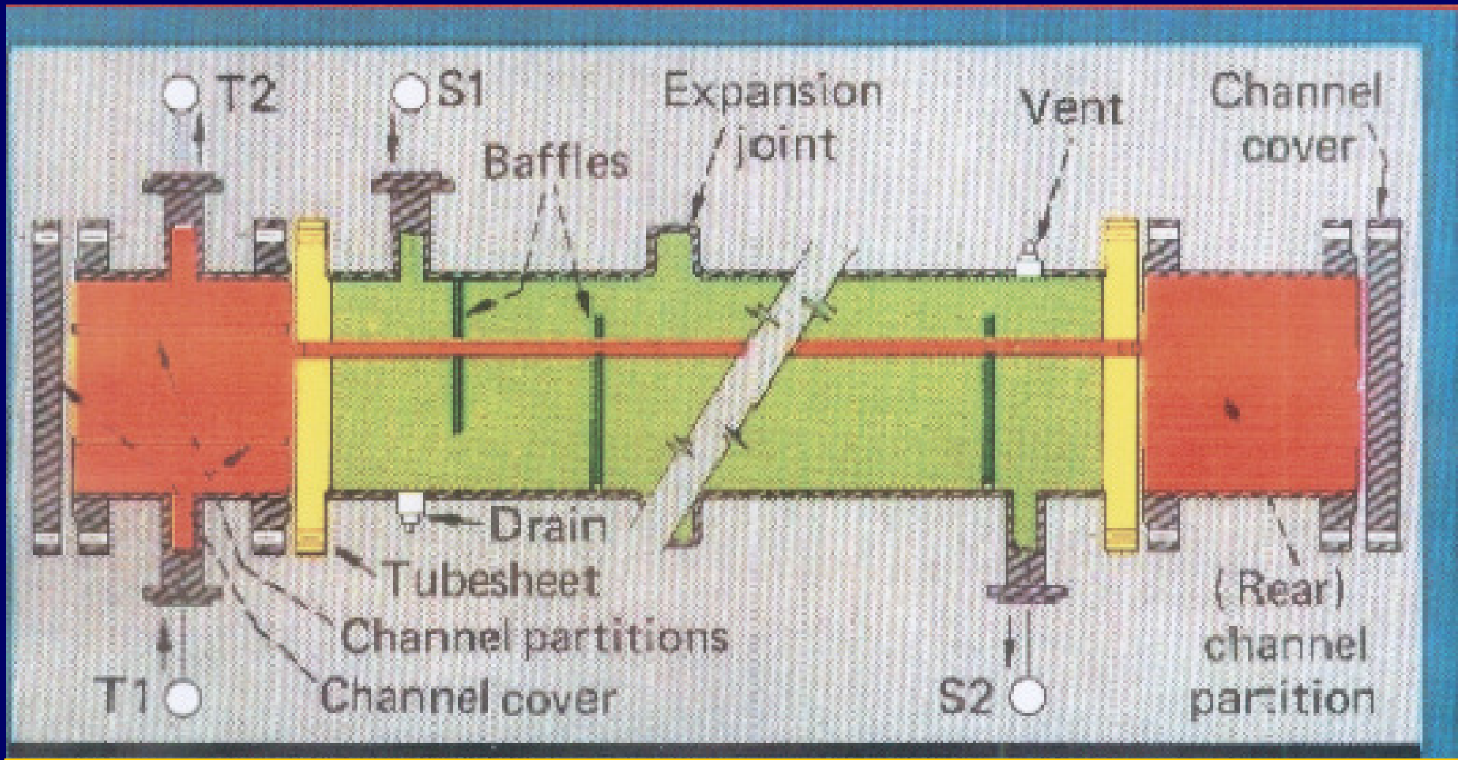
TEMA SHELL AND TUBES



TEMA SHELL AND TUBES



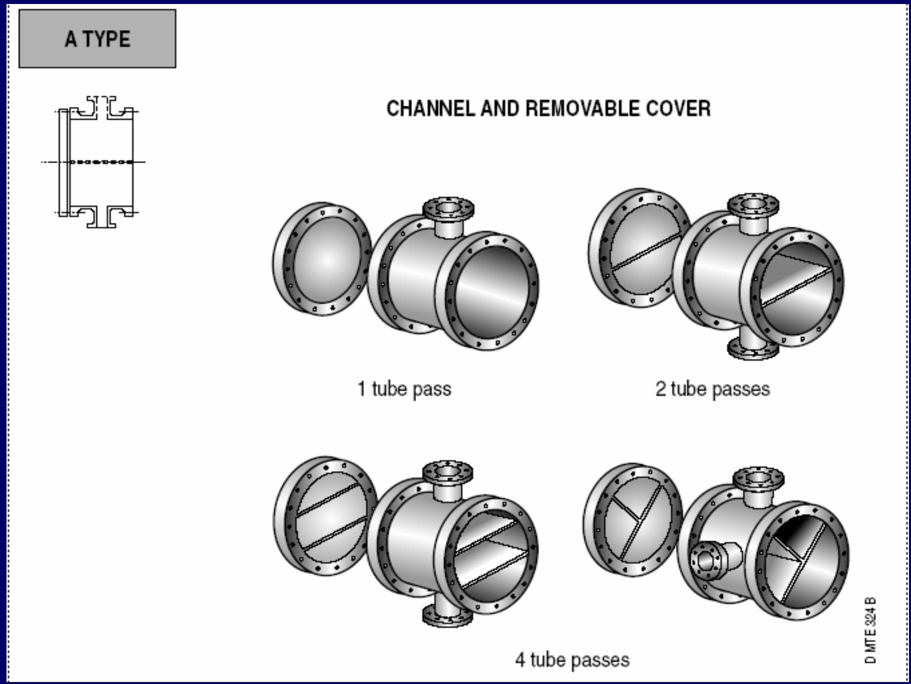
TEMA SHELL AND TUBES



TEMA TYPE CHOICE

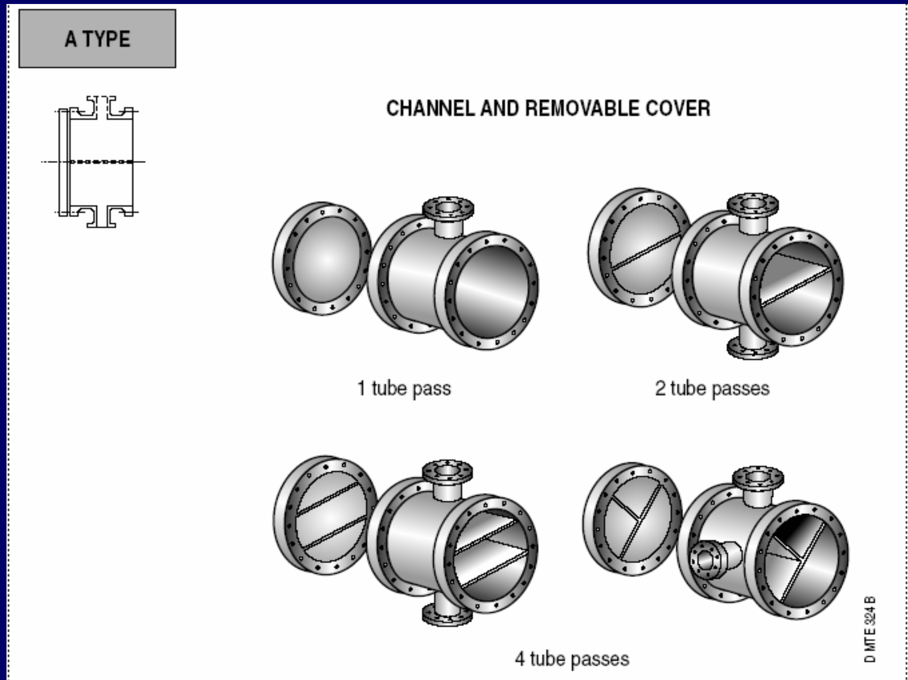
- ADVANTAGES:
  - Easy demantling allows cleaning and inspection without unfastening the tube nozzles

- DRAWBACKS:
  - Two gaskets are required to ensure tightness
  - Poor resistance to pressure
  - Cost factor higher than B type



TEMA TYPE CHOICE

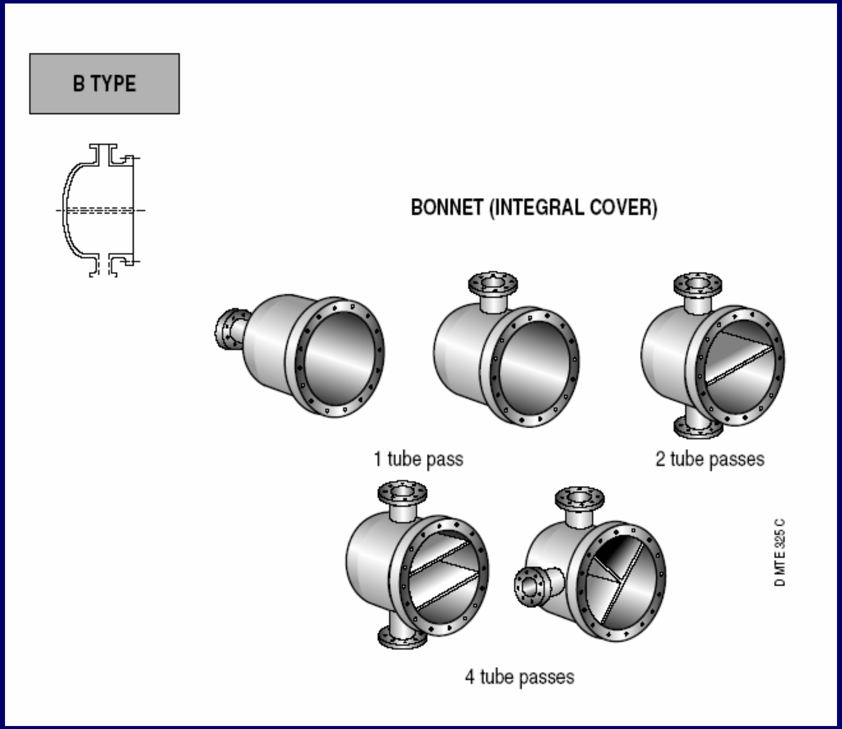
- ADVANTAGES:
  - Easy demantling allows cleaning and inspection without unfastening the tube nozzles



- DRAWBACKS:
  - Two gaskets are required to ensure tightness
  - Poor resistance to pressure
  - Cost factor higher than B type
- APPLICATION:
  - Dirty services with low pressure

TEMA TYPE CHOICE

- ADVANTAGES:
  - Cheap
  - Resistance to high pressure due to elliptical design
  - Only one gasket is needed



- DRAWBACKS:
  - Access to tube can only be given after complete nozzle dismantling

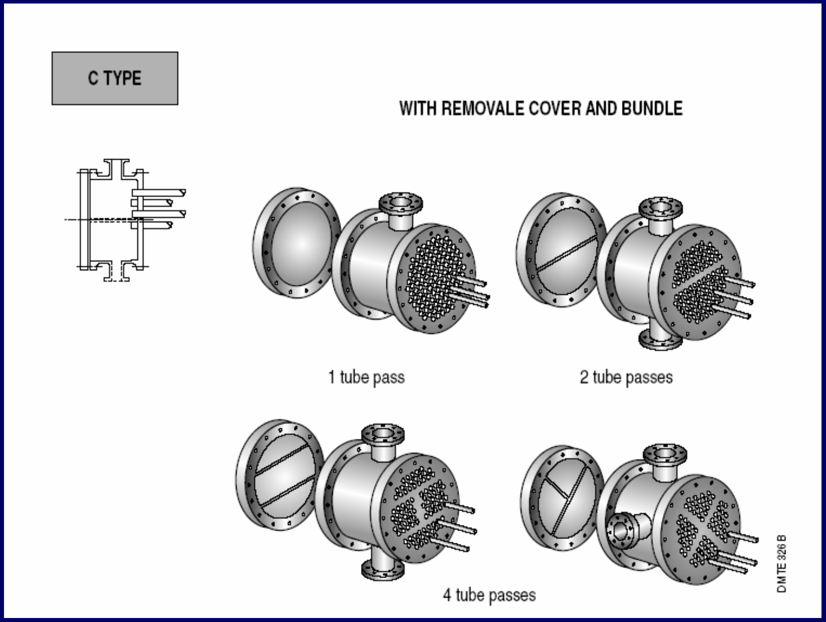
- APPLICATION:
  - Clean products, which do not need frequent cleaning
  - Commonly used with U tubes type

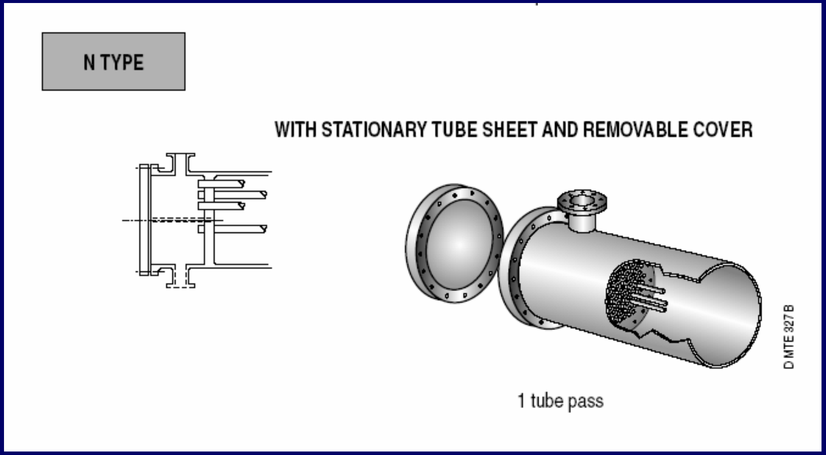
TEMA TYPE CHOICE

- ADVANTAGES:
  - No more gasket between the tube sheet and the distribution box

- DRAWBACKS:
  - Less pressure resistant than bonnet type

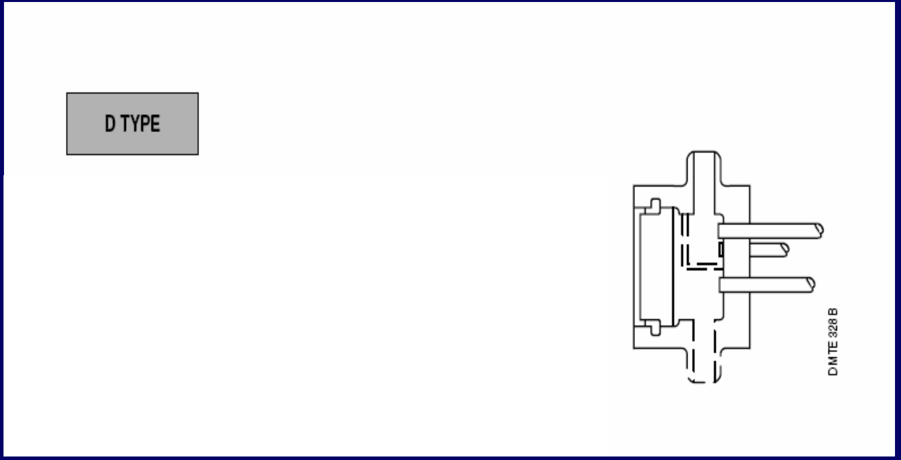
- APPLICATION:
  - Not really used in oil and gas industry





TEMA TYPE CHOICE

- Channel has been made by solid forged work or have been completely welded
- Can be used as rear end

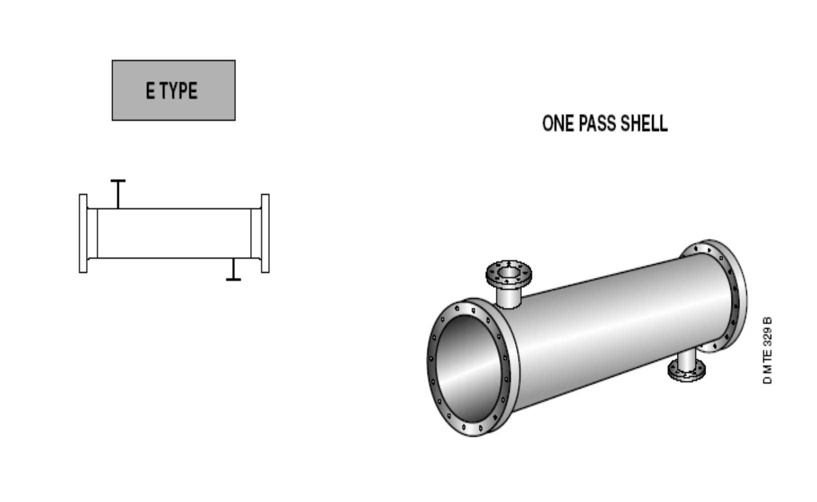


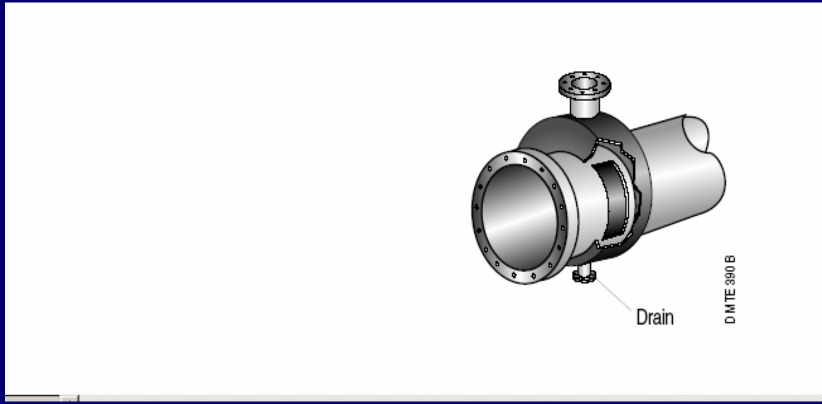
- ADVANTAGES:
  - For special closing system
  - Sustains very high pressure

- DRAWBACKS:
  - Expensive

TEMA TYPE CHOICE

- ADVANTAGES:
  - Cheap
- DRAWBACKS:
  - Bad distribution
    - Nozzle diameter may be increased
    - Vapour bell may be reuired in case of very high vapour flow rate



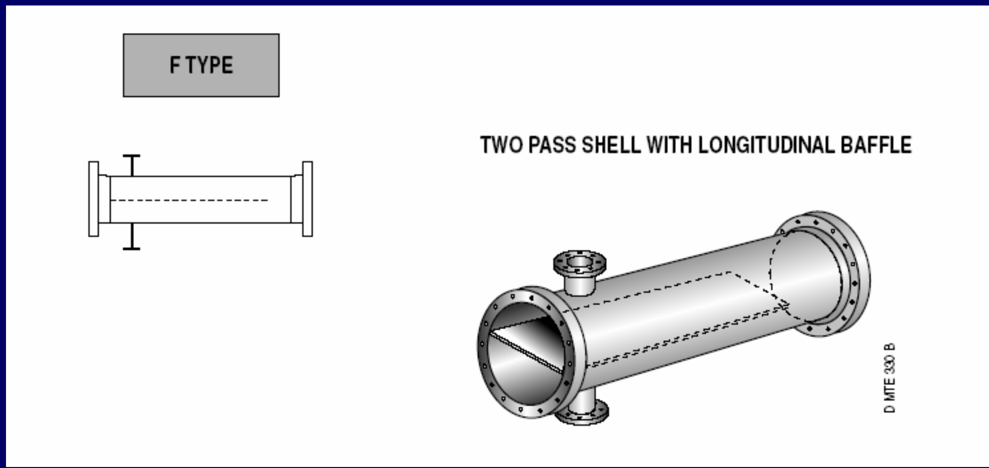


TEMA TYPE CHOICE

- ADVANTAGES:
  - No longer F current

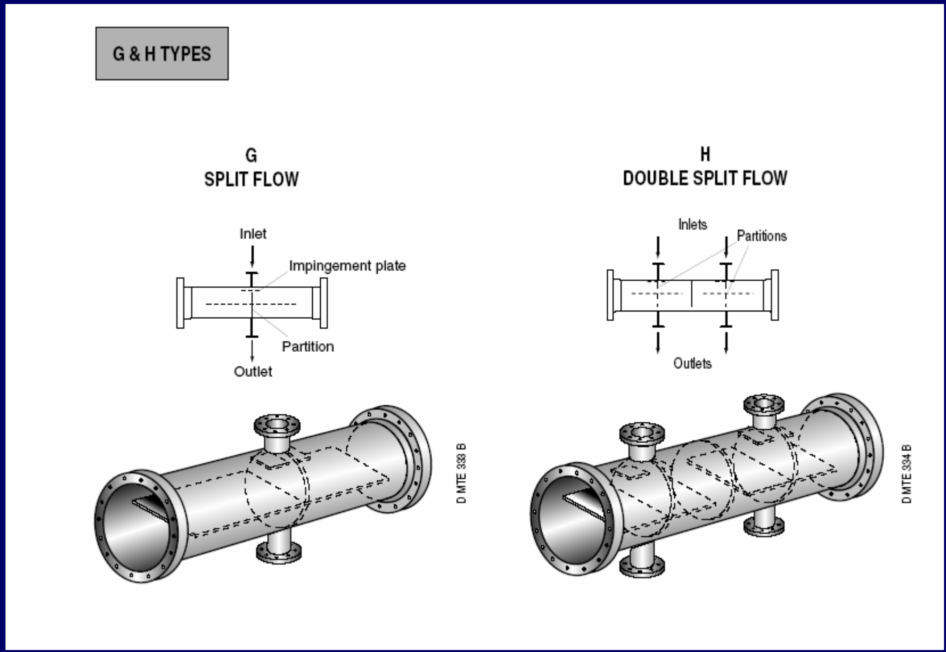
- DRAWBACKS:
  - Limited to low pressure drops
  - Leak do exist between the

Longitudinal baffle and the shell



TEMA TYPE CHOICE

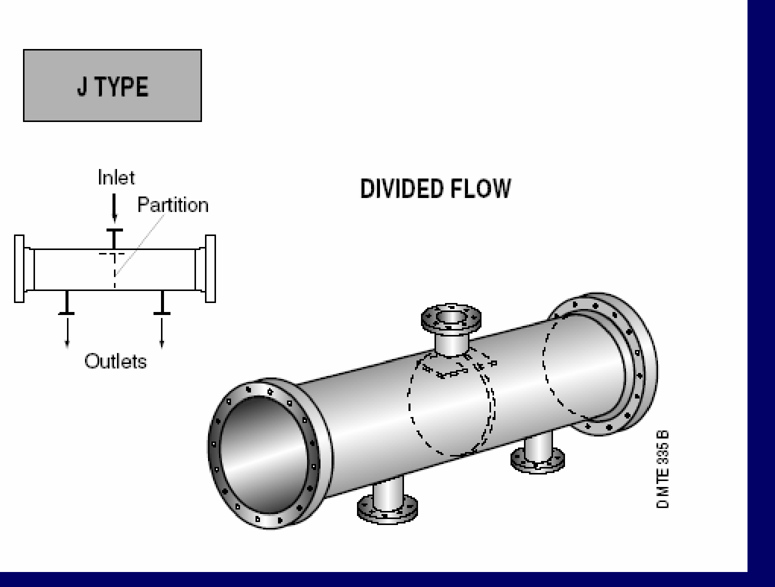
- ADVANTAGES:
  - Low shell pressure drop as no baffle
  - Efficiency higher than for 1-n apparatus



- DRAWBACKS:
  - Tube length limit due to lack of support (in transversal baffle design, baffles support tubes)
  - Hard to avoid poor distribution

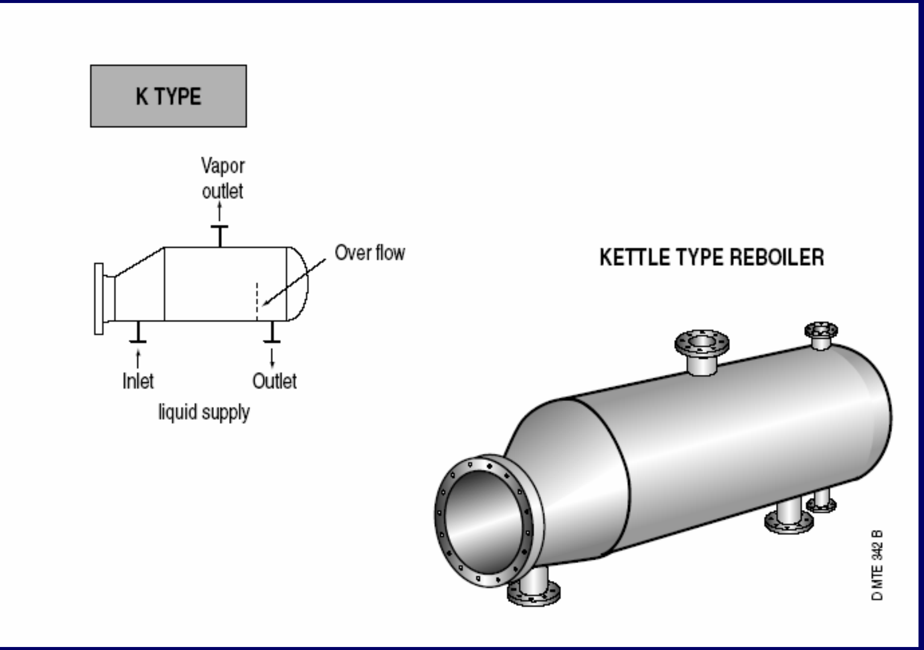
TEMA TYPE CHOICE

- ADVANTAGES:
  - Low pressure drop
- DRAWBACKS:
  - Piping more complex
- APPLICATION:
  - Used when considerable actual flow change occurs



TEMA TYPE CHOICE

- ADVANTAGES:
  - Provide a liquid vapor equilibrium
  - High vaporization rate (30 to 40%)

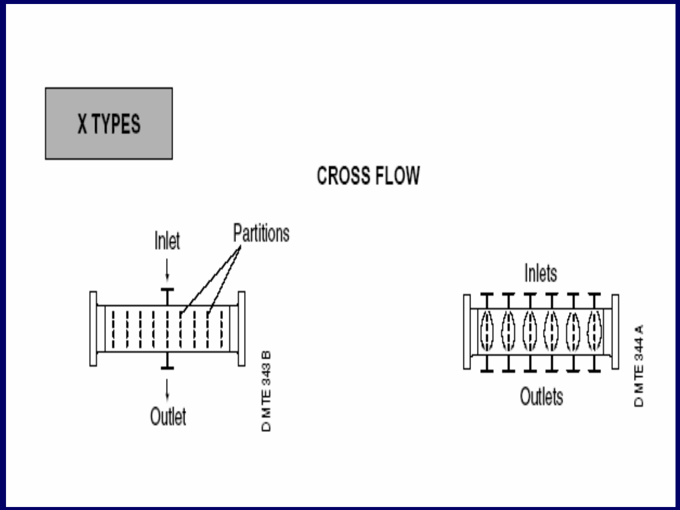


- DRAWBACKS:
  - Bulky and costly

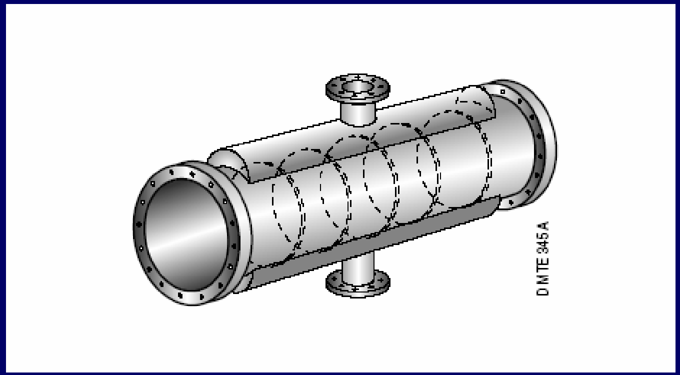
- APPLICATION:
  - Column reboiler

TEMA TYPE CHOICE

- ADVANTAGES:
  - Low pressure drop and provides good tube support, which avoids vibrations
  - Efficiency close to that of the counter current

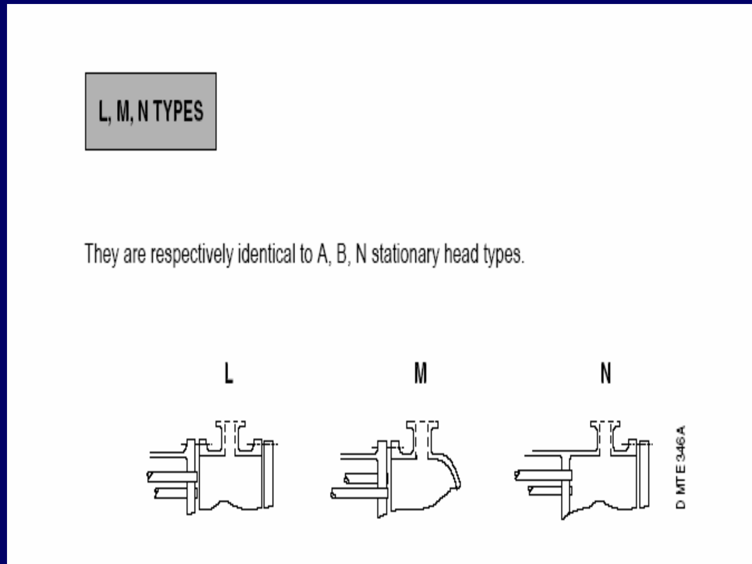


- DRAWBACKS:
  - Costly distribution device

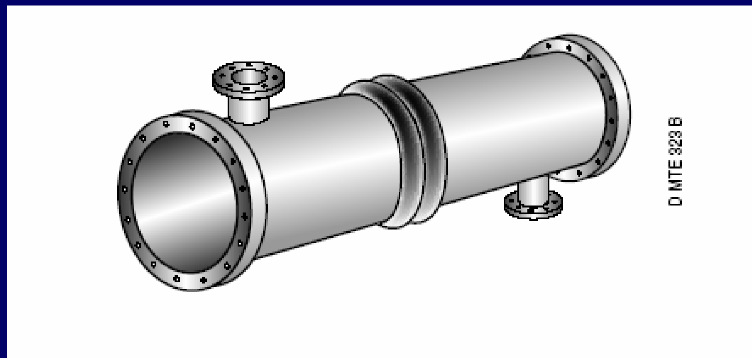


TEMA TYPE CHOICE

- ADVANTAGES:
  - Good use of the volume in the shell
  - They allow use of double tube sheet
  - They ease the cleaning as far as L and N types are concerned for the front end
  - Less expensive than floating head

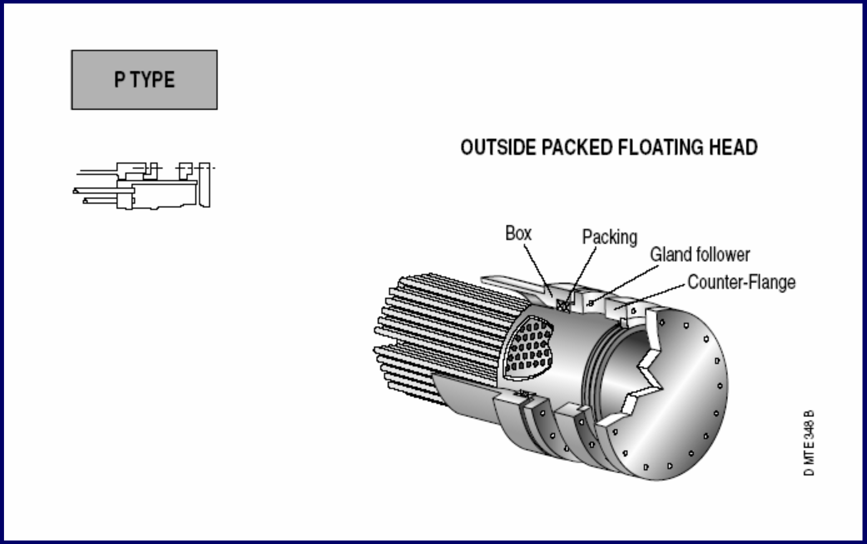


- DRAWBACKS:
  - Can not be used if big temperature difference during the life of the HX
  - Bundle can not be dismantled
  - Shell can not be accessed



TEMA TYPE CHOICE

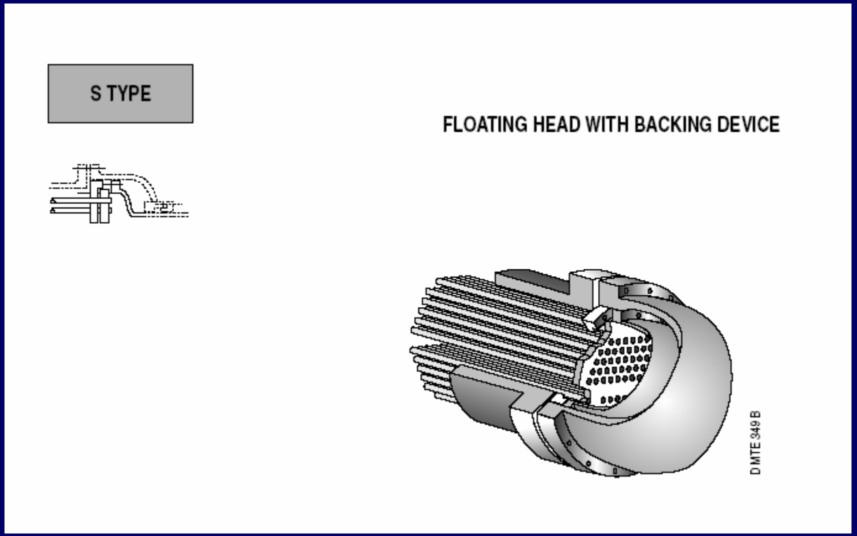
- ADVANTAGES:
  - Differential expansion are not a problem



- DRAWBACKS:
  - Bad tightness = safety problem

TEMA TYPE CHOICE

- ADVANTAGES:
  - Sustain big differential expansion
  - Bundle can be dismantled

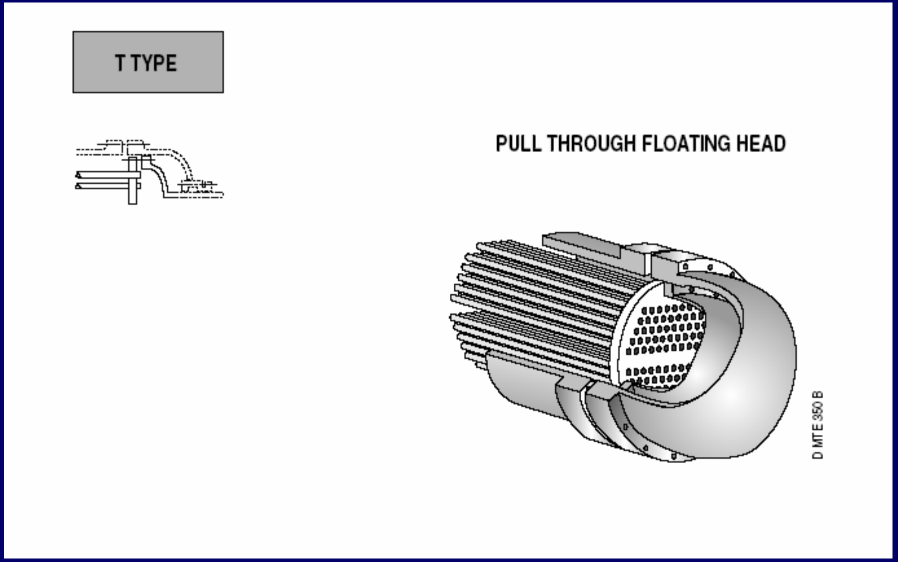


- DRAWBACKS:
  - If one pass tube, packing is needed implying risk of leakage
  - It is expensive
  - Leakage is not visble
  - Bundle not really easy to dismantle

TEMA TYPE CHOICE

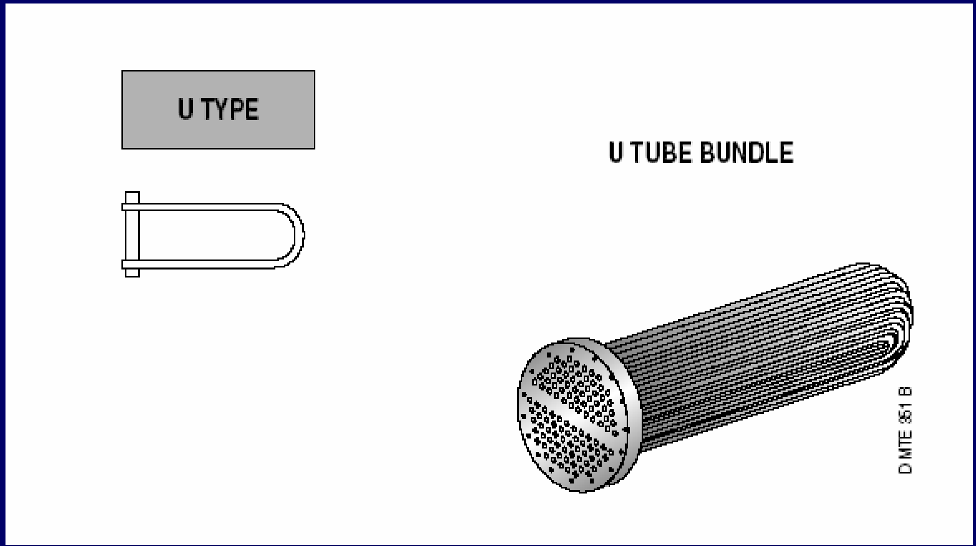
- ADVANTAGES:
  - With regards to S type, bundle removal is easier

- DRAWBACKS:
  - Not os many tubes than for tube S

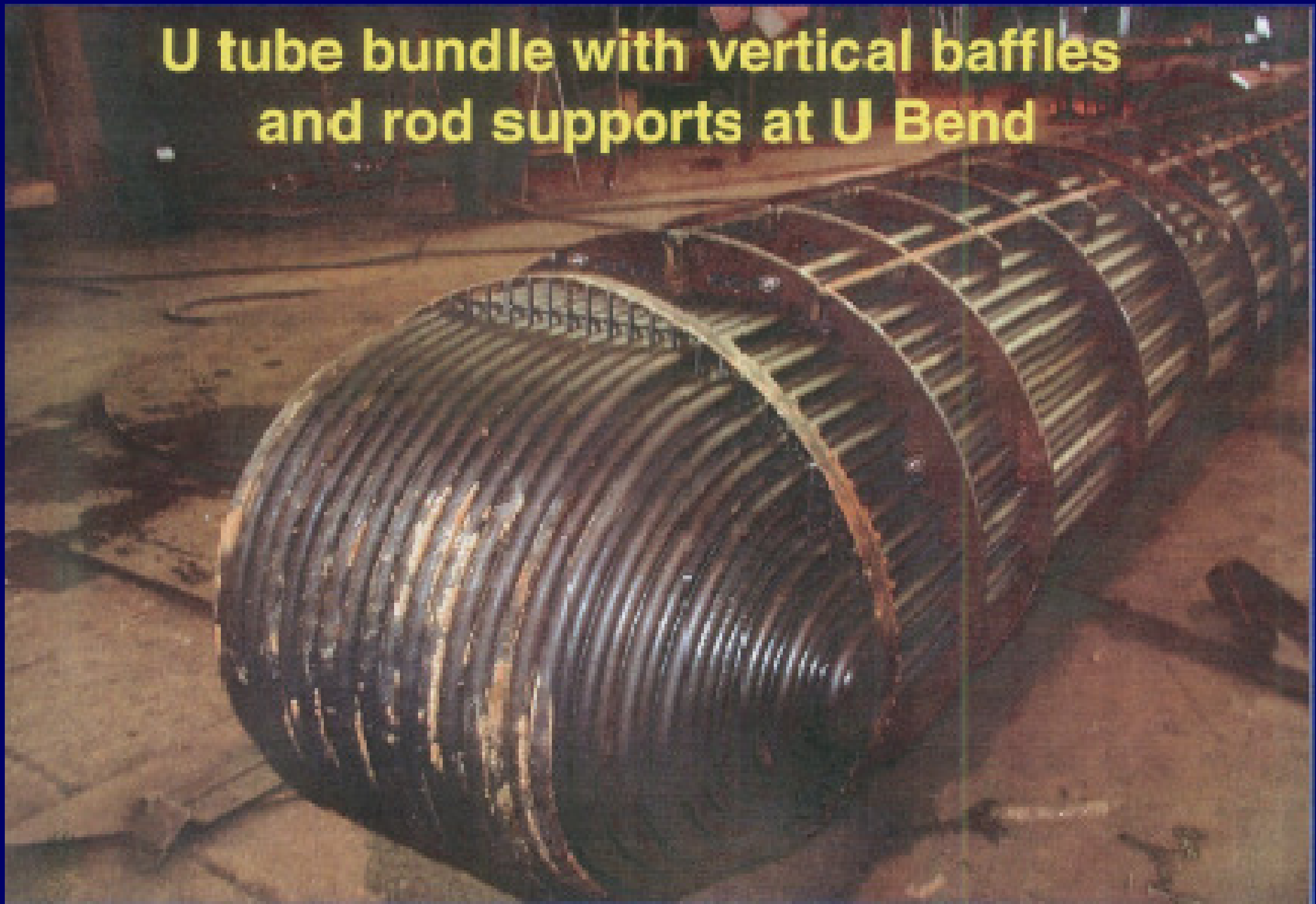


TEMA TYPE CHOICE

- ADVANTAGES:
  - Low price
  - Easy dismantling
  - No gasket
  - Allows high temperature difference



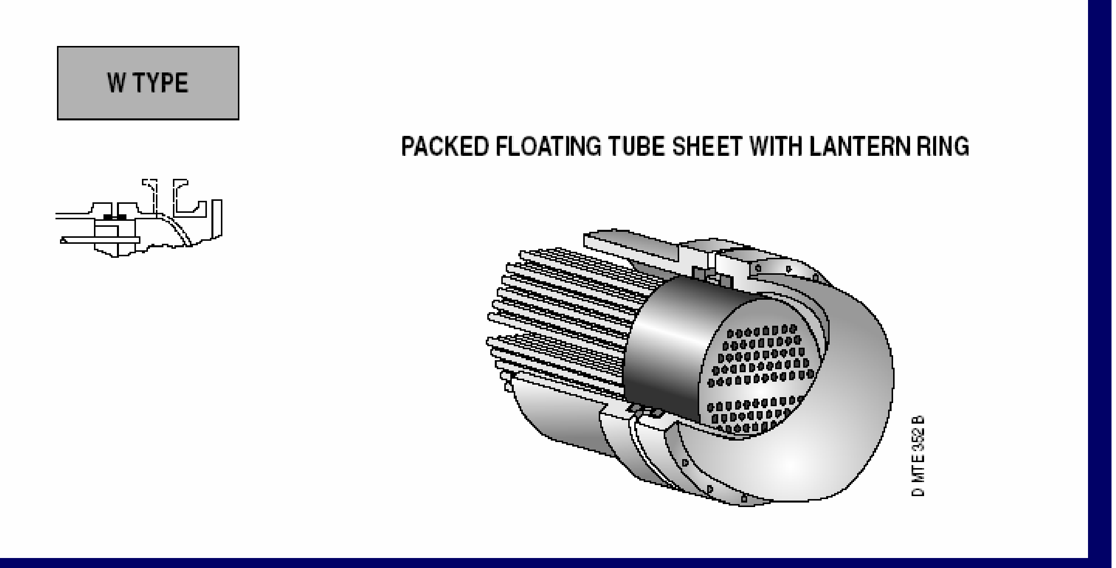
- DRAWBACKS:
  - Reserved to rather clean products
  - High speed in the coils may produce erosion


U tube bundle with vertical baffles
and rod supports at U Bend

TEMA TYPE CHOICE

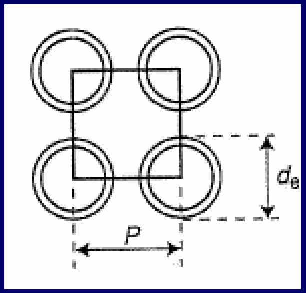
- ADVANTAGES:
  - Leak can be detected

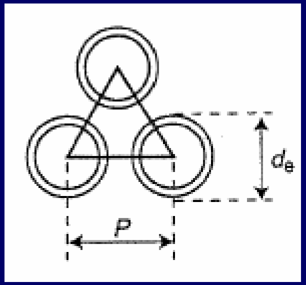
- DRAWBACKS:
  - Tightness is not perfect



PITCH

- Triangular pitch:
  - More tubes per section
  - Outside wall is hard to clean
- Square pitch
  - Easily cleanable





WHICH FLUID FOR WHICH SIDE

- Rule of the thumb for the selection:
  - Dirtier fluid rather in tube side
  - If dirty fluid in the shell side, foresee square pitched
  - As much as possible balance the heat transfer coefficient between shell side and tube side
  - Viscous liquid should be placed shell side
  - High pressure fluid should be placed tube side
  - Erosive product should be placed tube side

BUNDLE CLEANING

COMPACT HEAT EXCHANGER

- More exchange area per cubic meter. They are:
  - Plate fin heat exchanger
  - Core in kettle
  - Coil wound heat exchanger
  - Plate and frame heat exchanger
  - Spiral heat exchanger

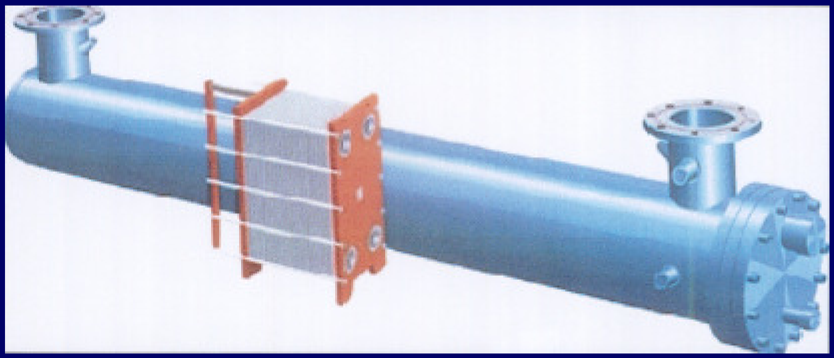
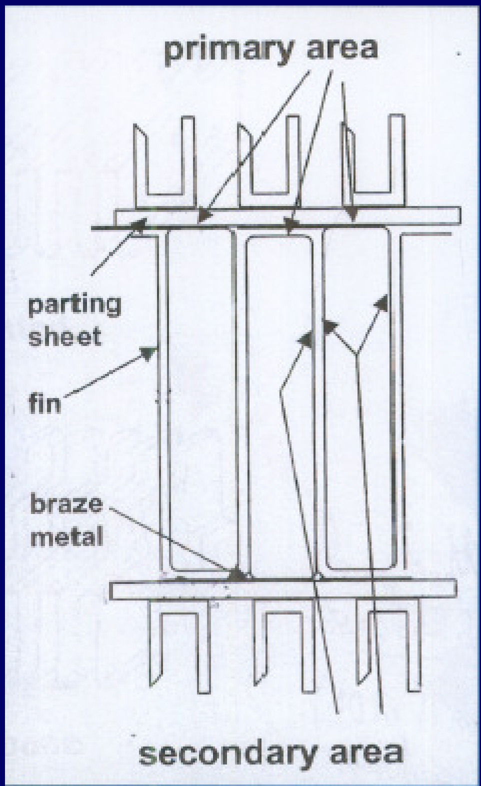
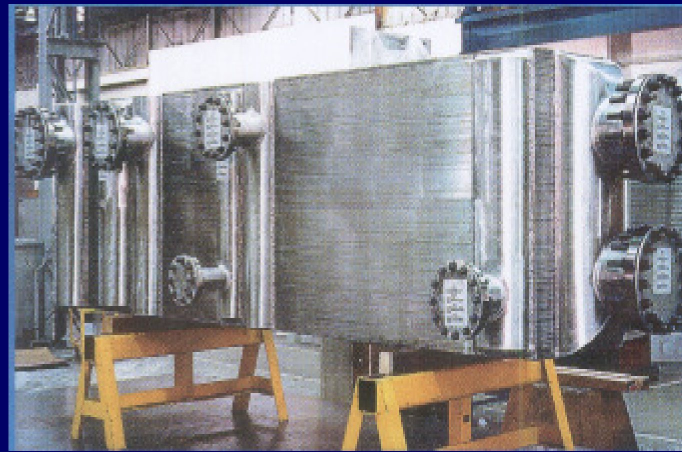
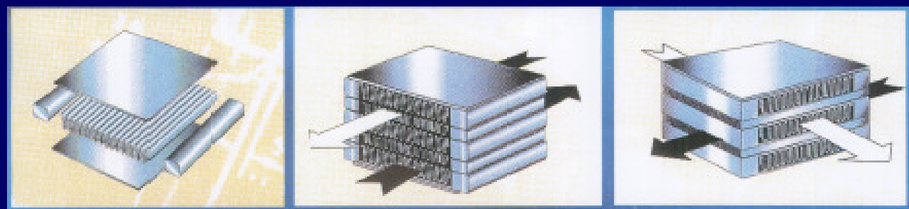


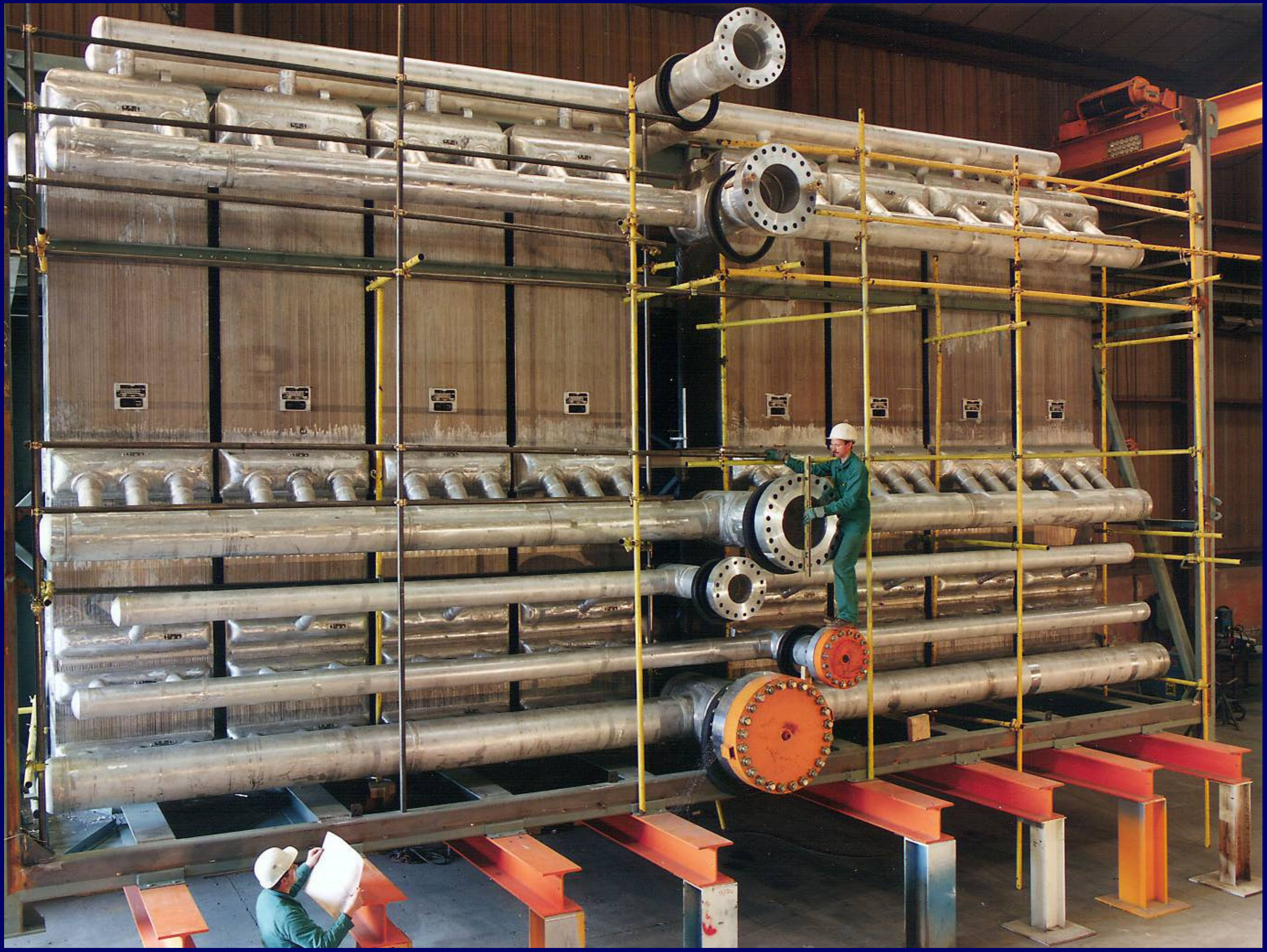
PLATE FIN HEAT EXCHANGER

- Aluminium brazed
- Reserved for very clean services (not dismantable)

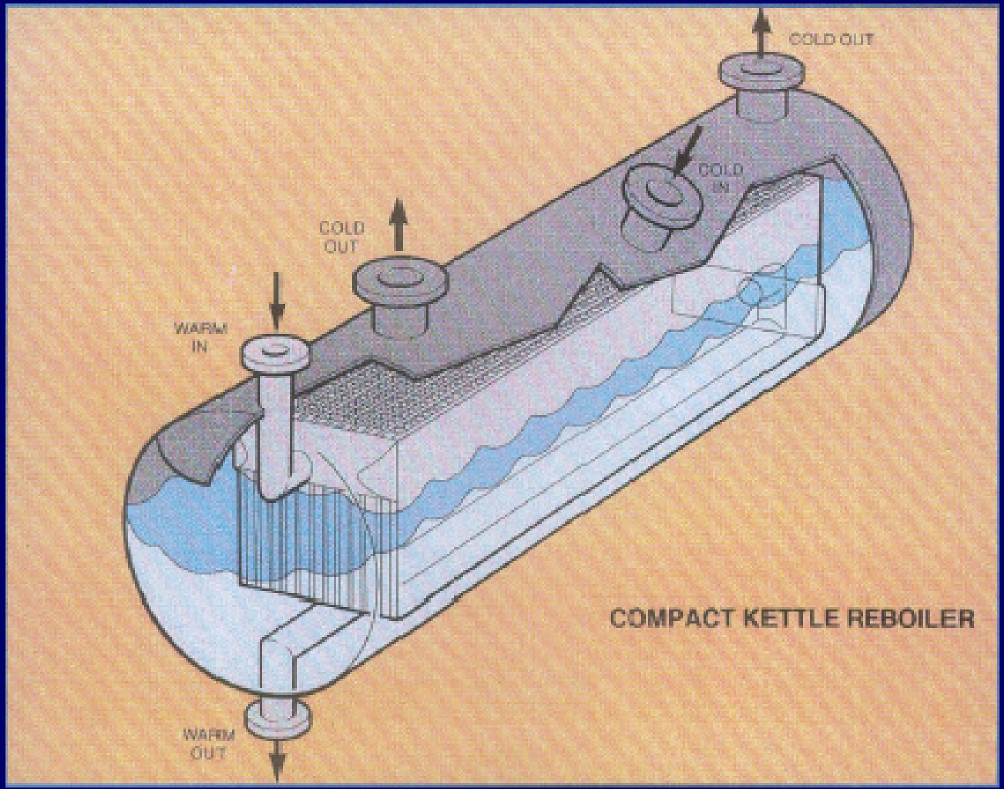








CORE IN KETTLE



COIL WOUND HEAT EXCHANGER

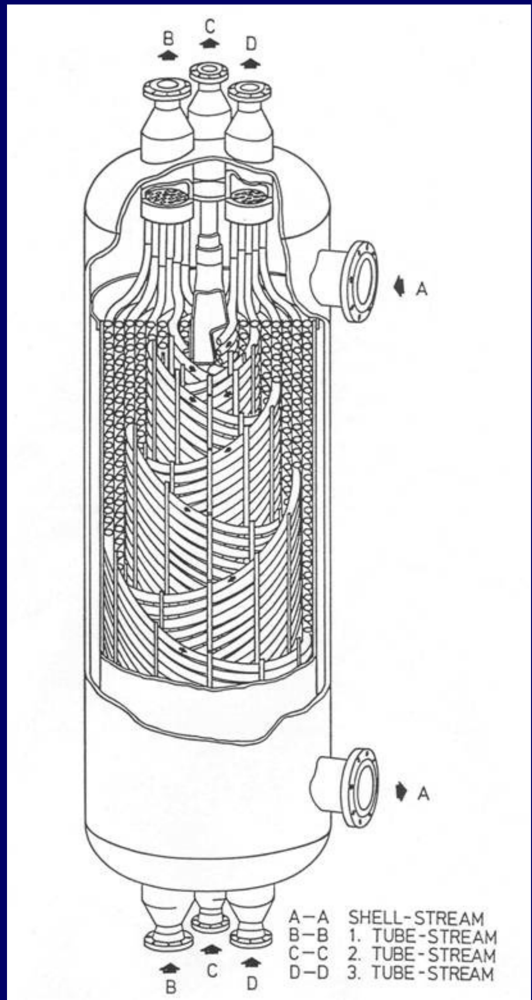
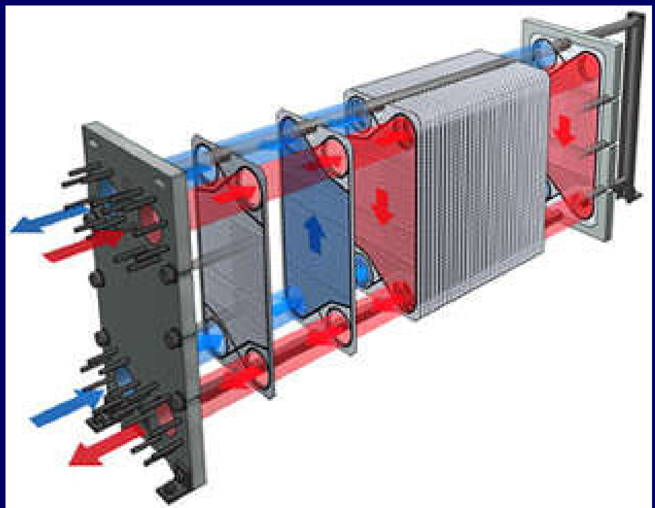


PLATE AND FRAME HEAT EXCHANGER

- Commonly used for CW / SW heat exchanger
- Cleanable
- Beware of the shear stress: put off line one cell rather reducing flow rate in each cell



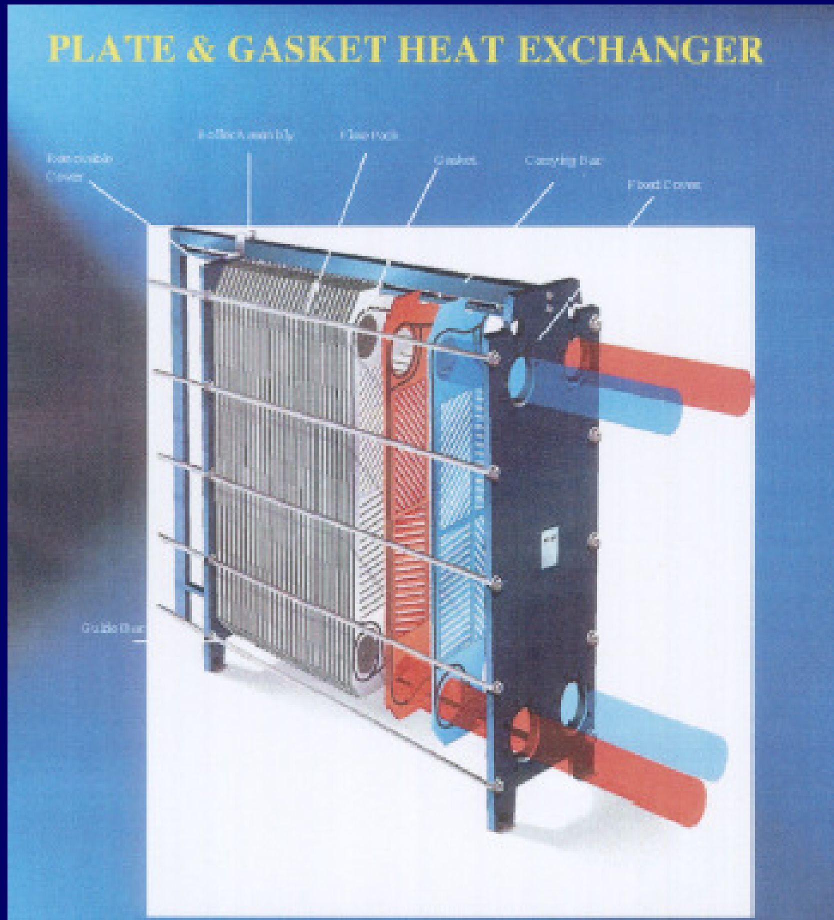
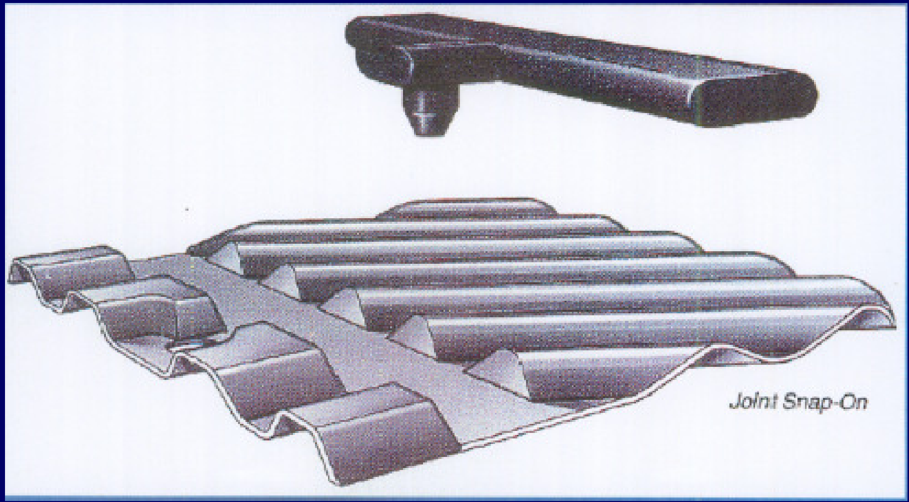


PLATE AND FRAME HEAT EXCHANGER

PLATE AND FRAME HEAT EXCHANGER



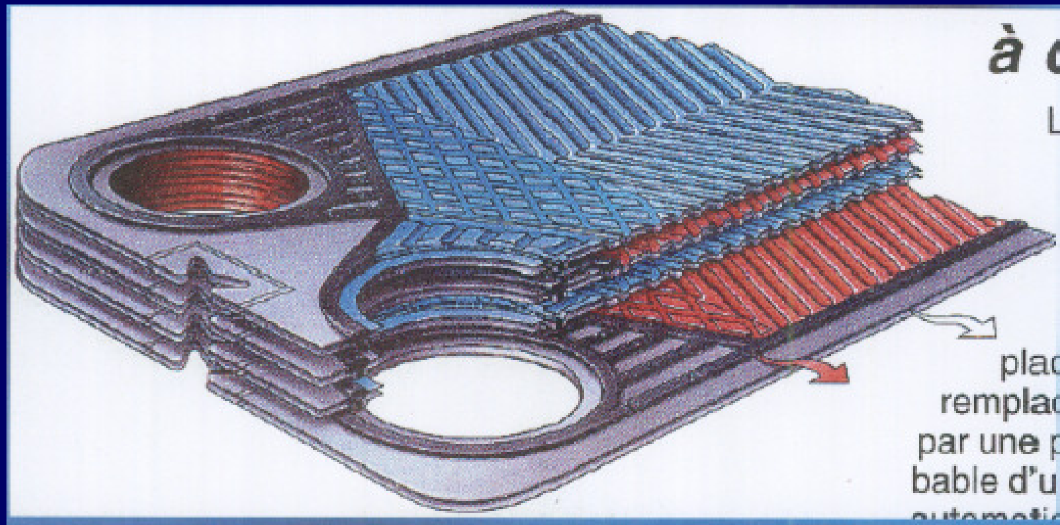
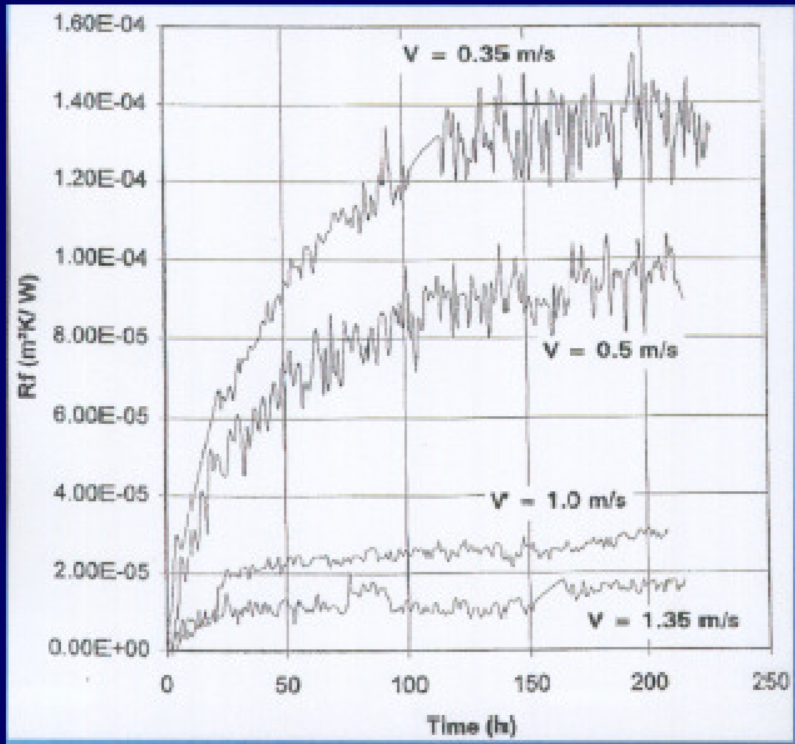


PLATE AND FRAME HEAT EXCHANGER



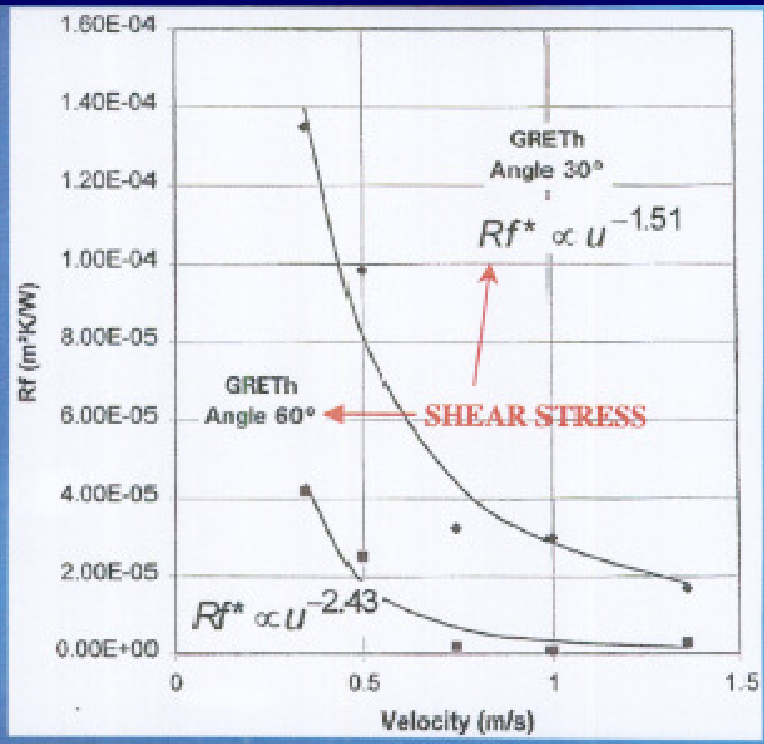
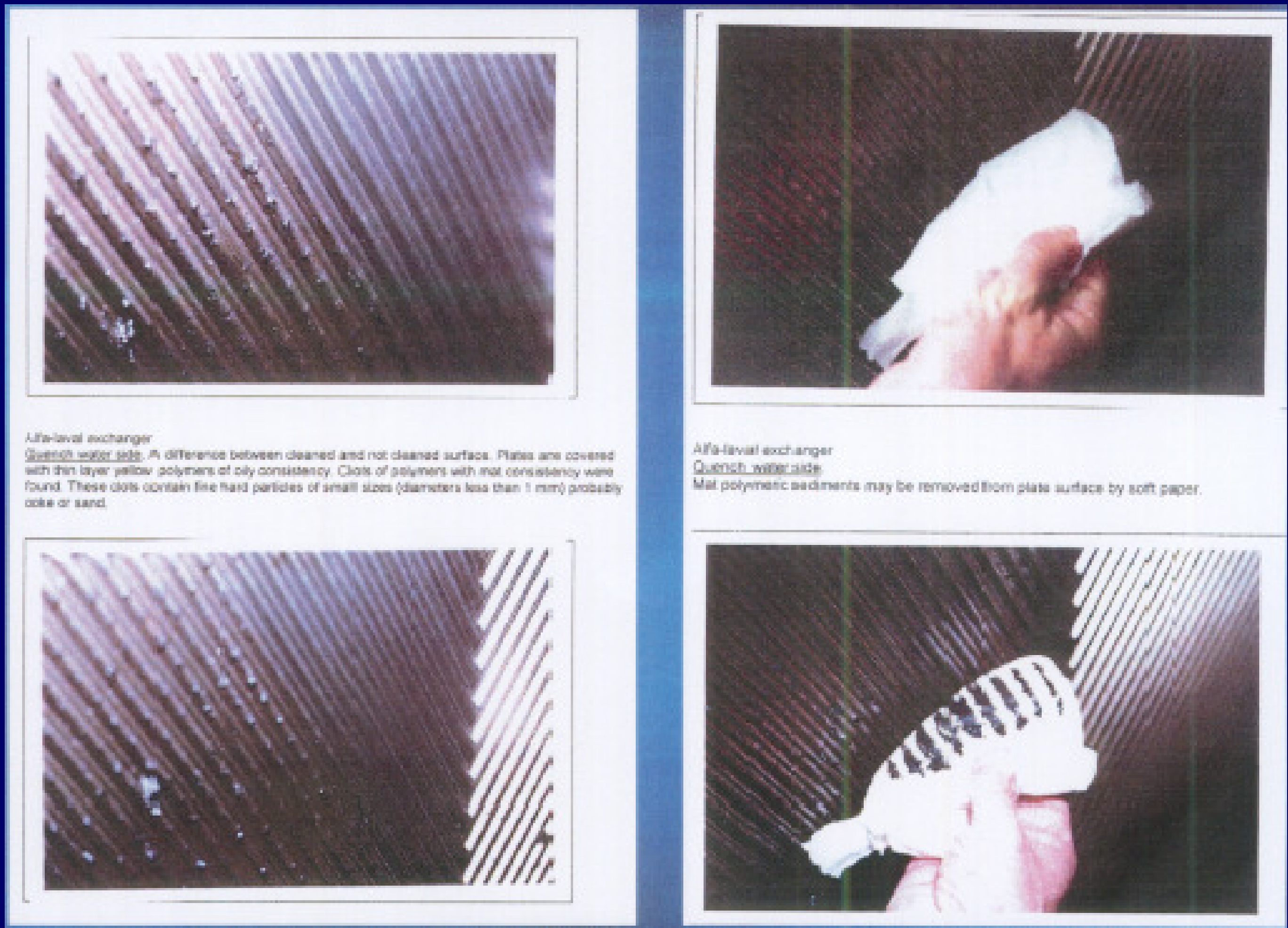


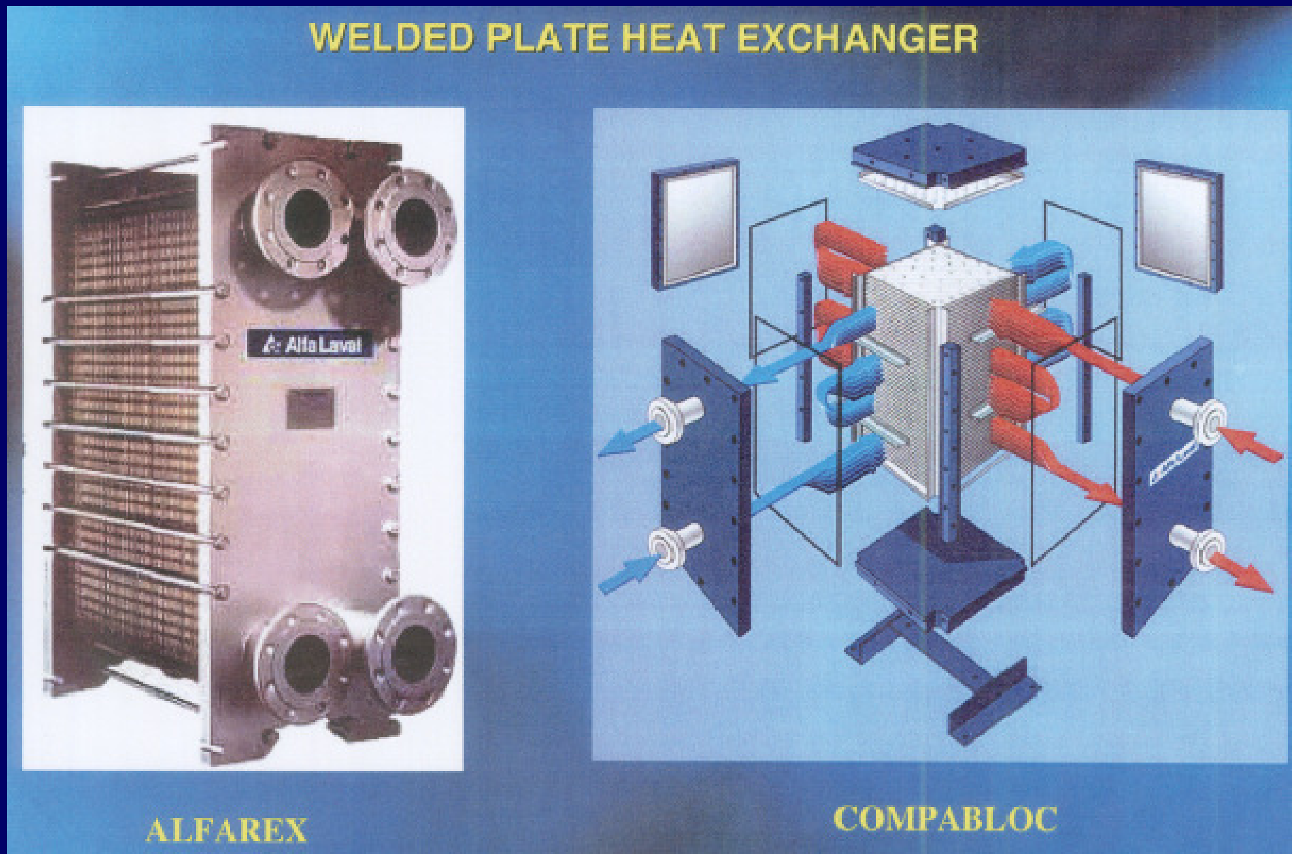
PLATE AND FRAME HEAT EXCHANGER


Alfa-laval exchanger
Quench water side. A difference between cleaned and not cleaned surface. Plates are covered with thin layer yellow polymers of oily consistency. Clots of polymers with mat consistency were found. These clots contain fine hard particles of small sizes (diameters less than 1 mm) probably coke or sand.

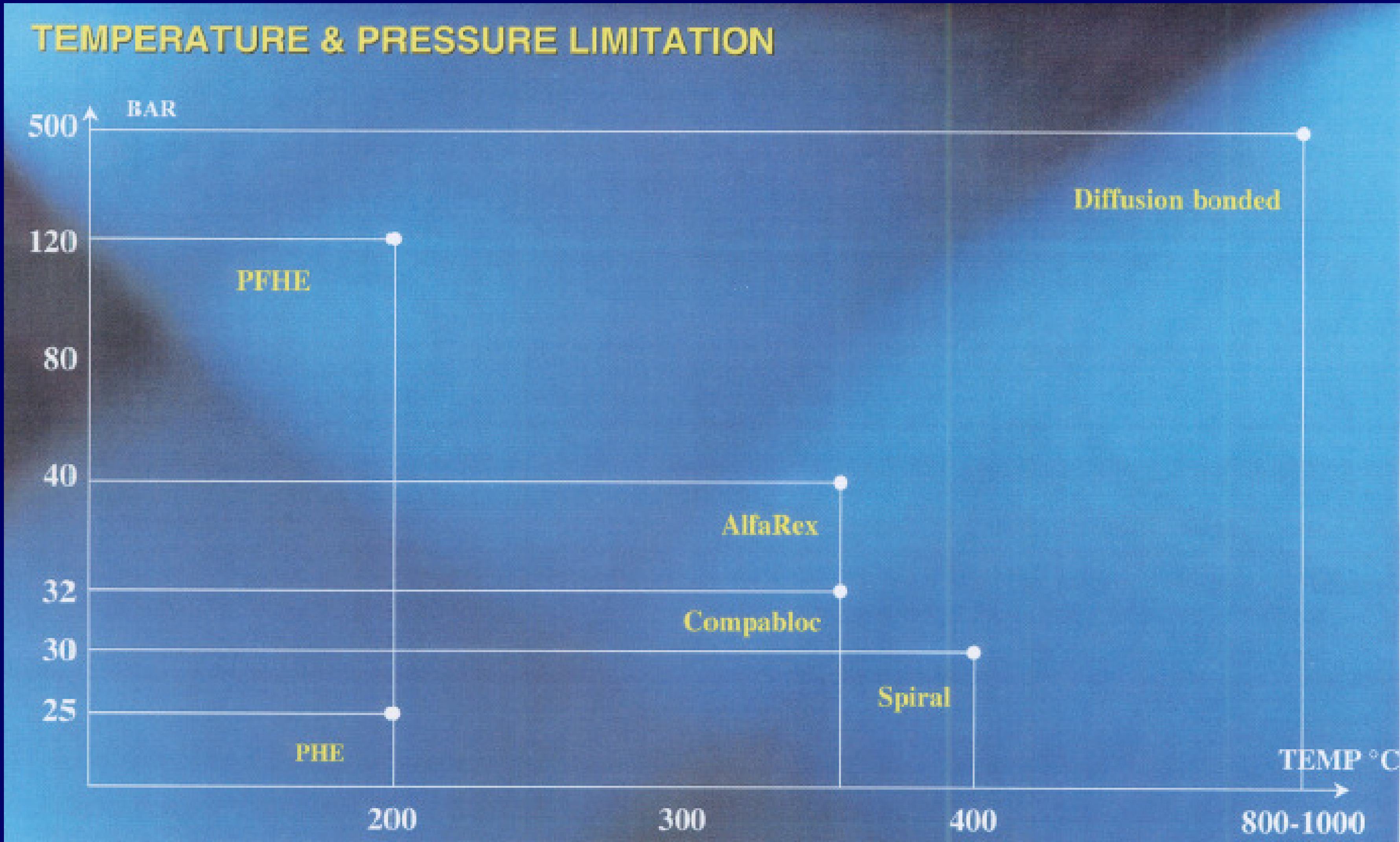
Alfa-laval exchanger
Quench water side
Mat polymeric sediments may be removed from plate surface by soft paper.

WELDED PLATE HEAT EXCHANGER

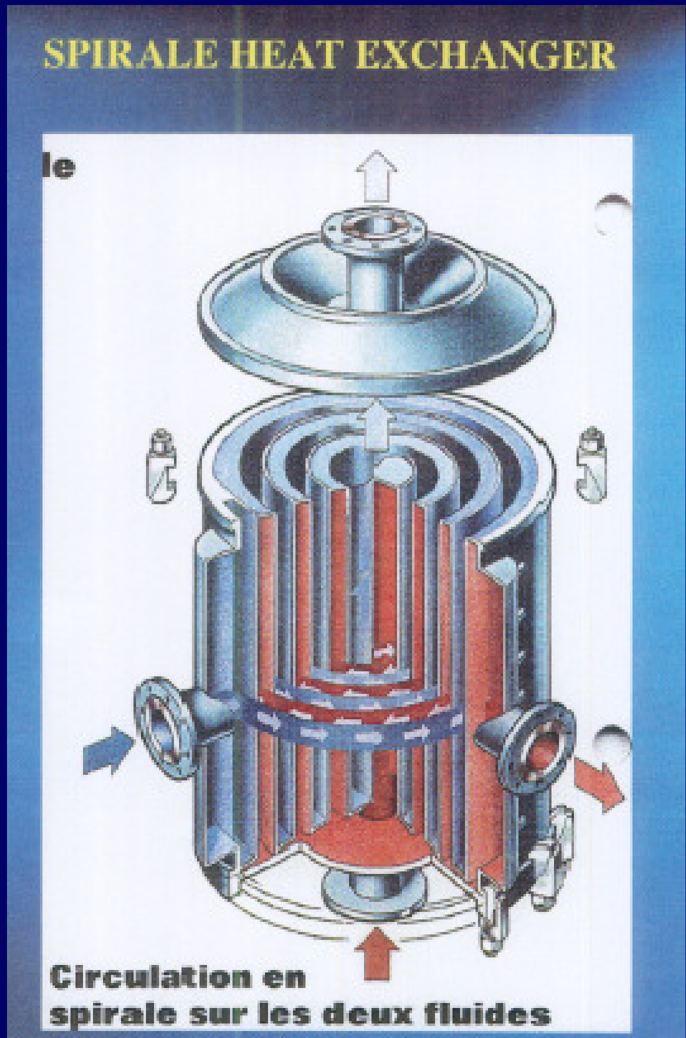
- Cross flow (Alfarex or Compabloc)



TEMPERATURE AND PRESSURE LIMITATION

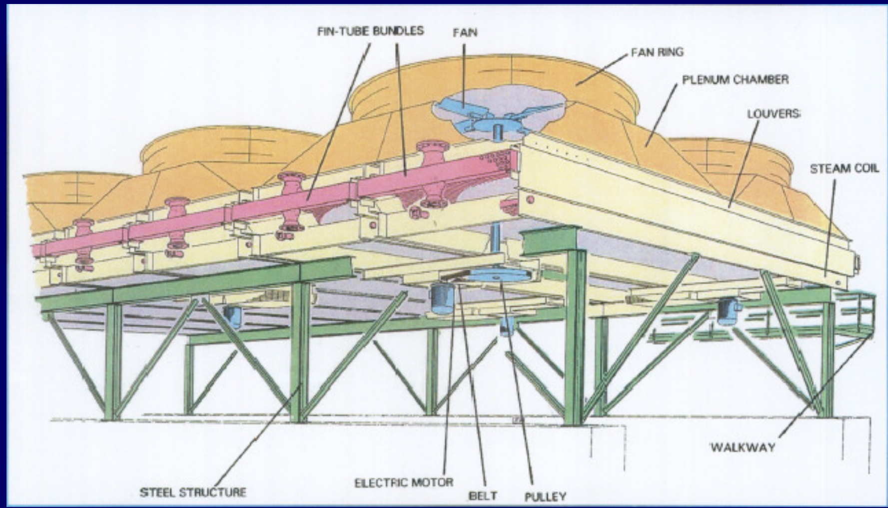


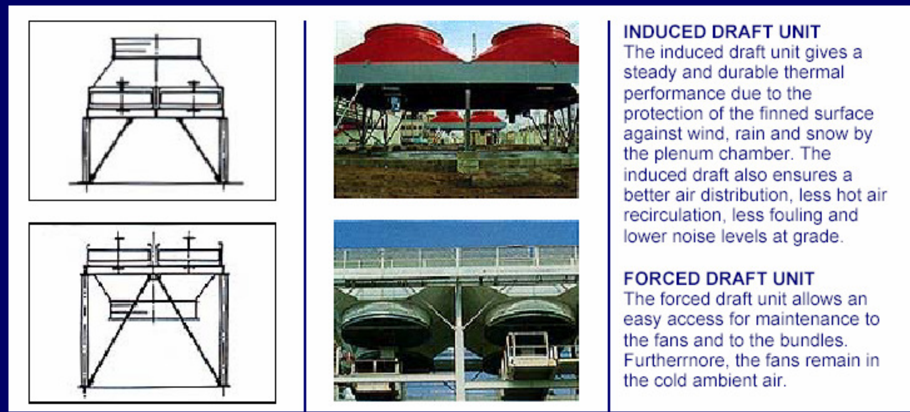
SPIRAL PLATE HEAT EXCHANGER



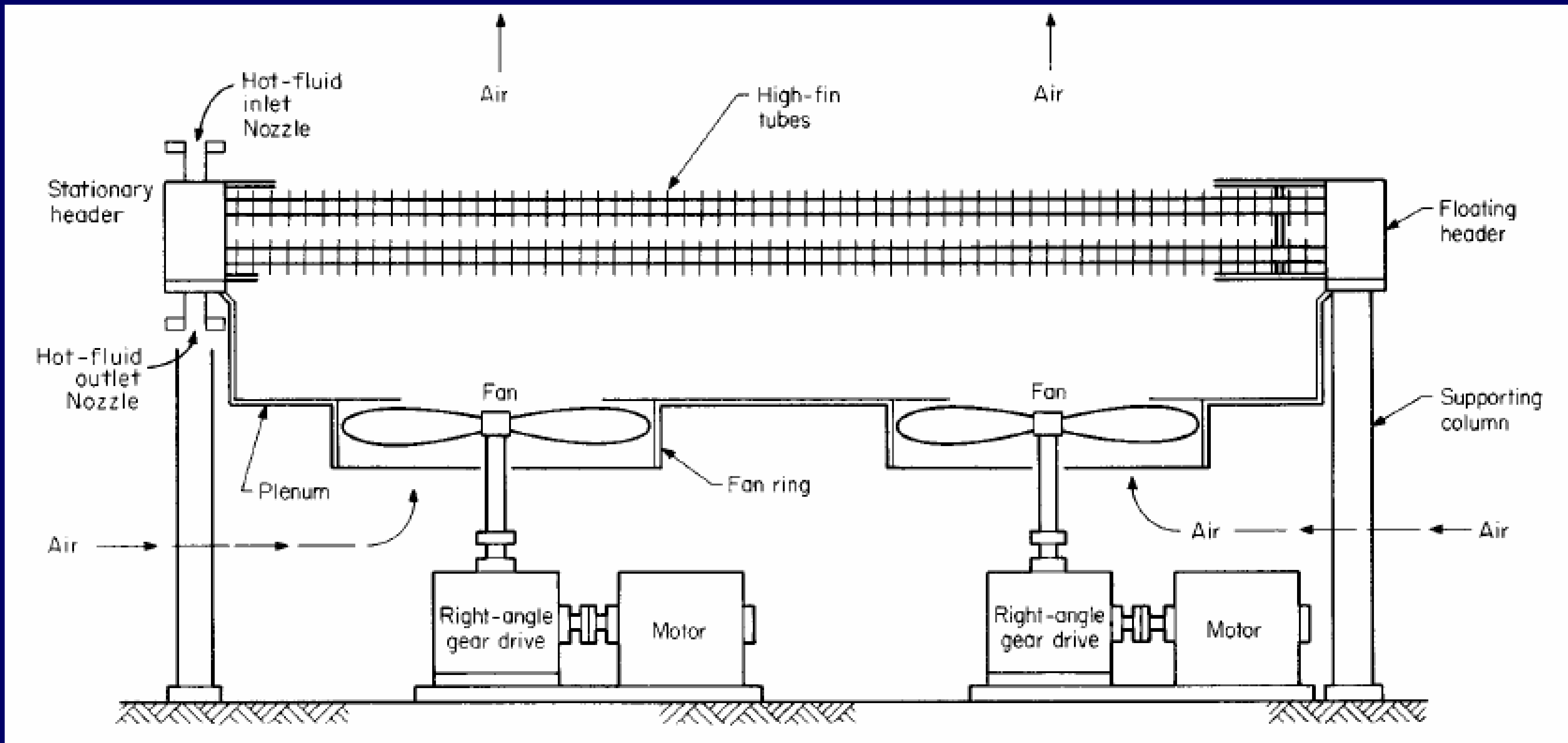
AIR COOLERS

- Q = U A LMTD, F close to 1
- Can be induced draft or forced draft
- Induced
  - Less recirculation
  - Bundle protection
  - Good natural convection
- Forced
  - Easy access for maintenance
  - Lower power consumption
  - No outlet temperature limitation





AIR COOLERS



Air
Air
Hot-fluid
inlet
Nozzle
High-fin
tubes
Stationary
header
Floating
header
Hot-fluid
outlet
Nozzle
Fan
Fan
Supporting
column
Plenum
Fan ring
Air
Air
Air
Right-angle
gear drive
Motor
Right-angle
gear drive
Motor

AIR COOLERS

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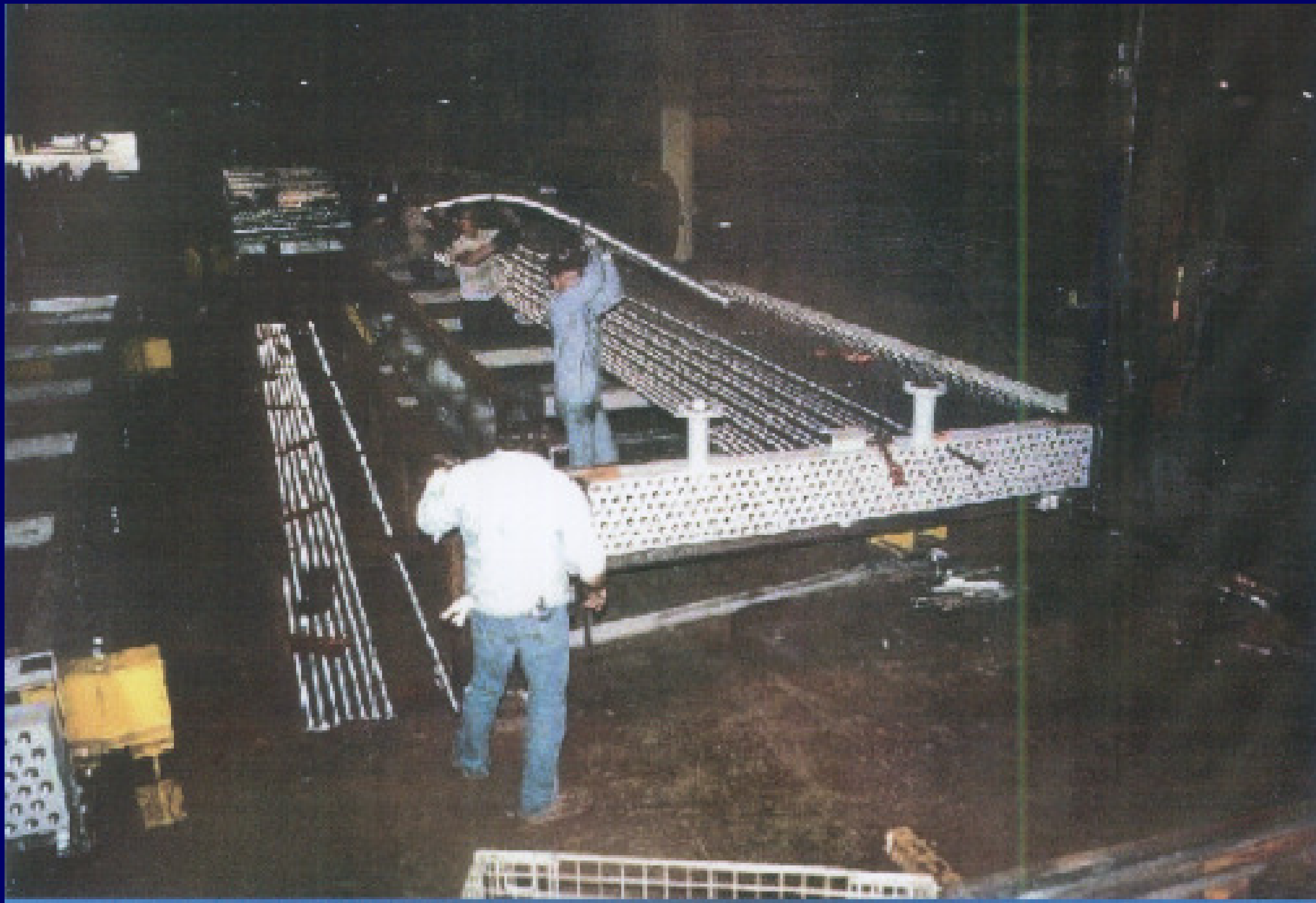
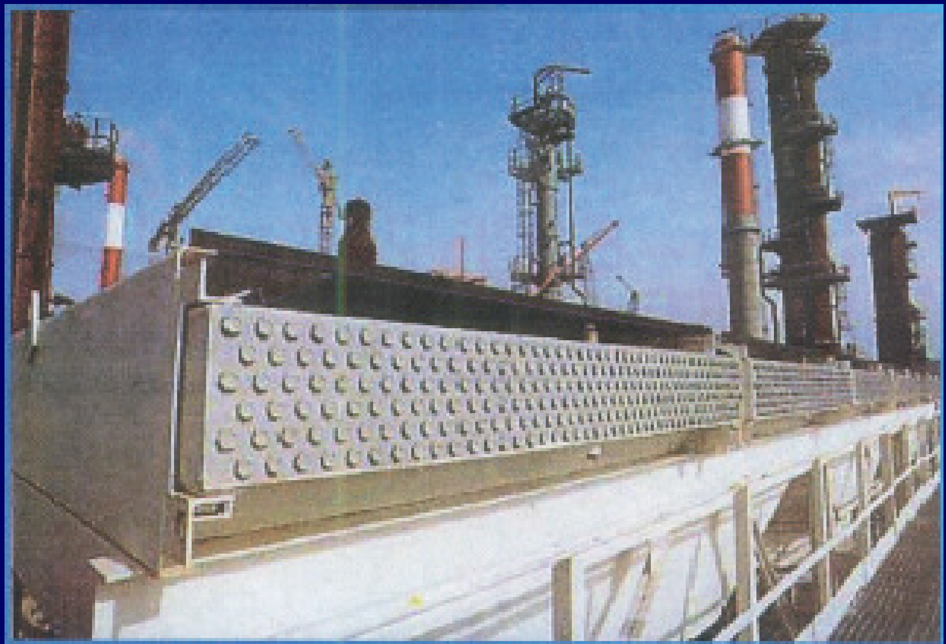
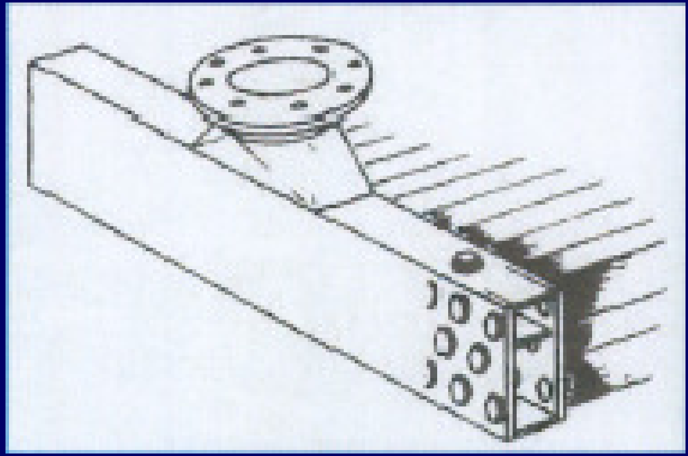
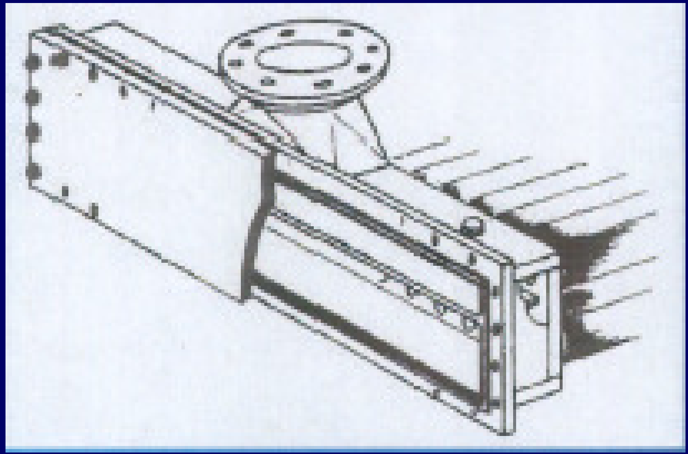
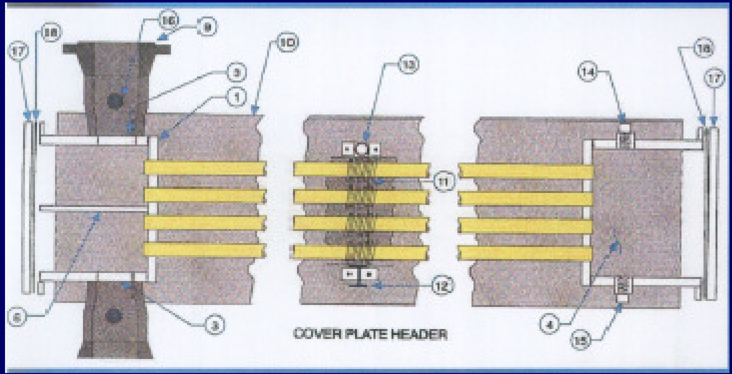


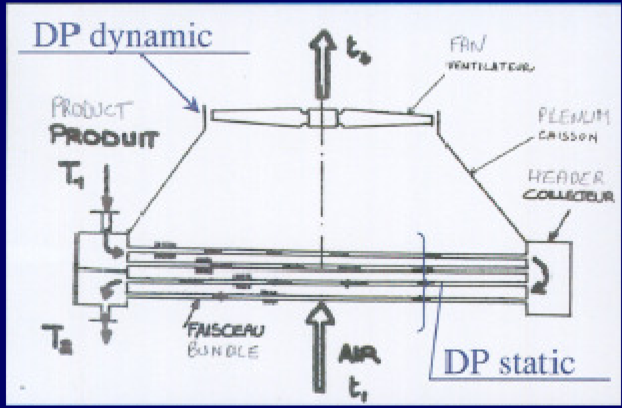


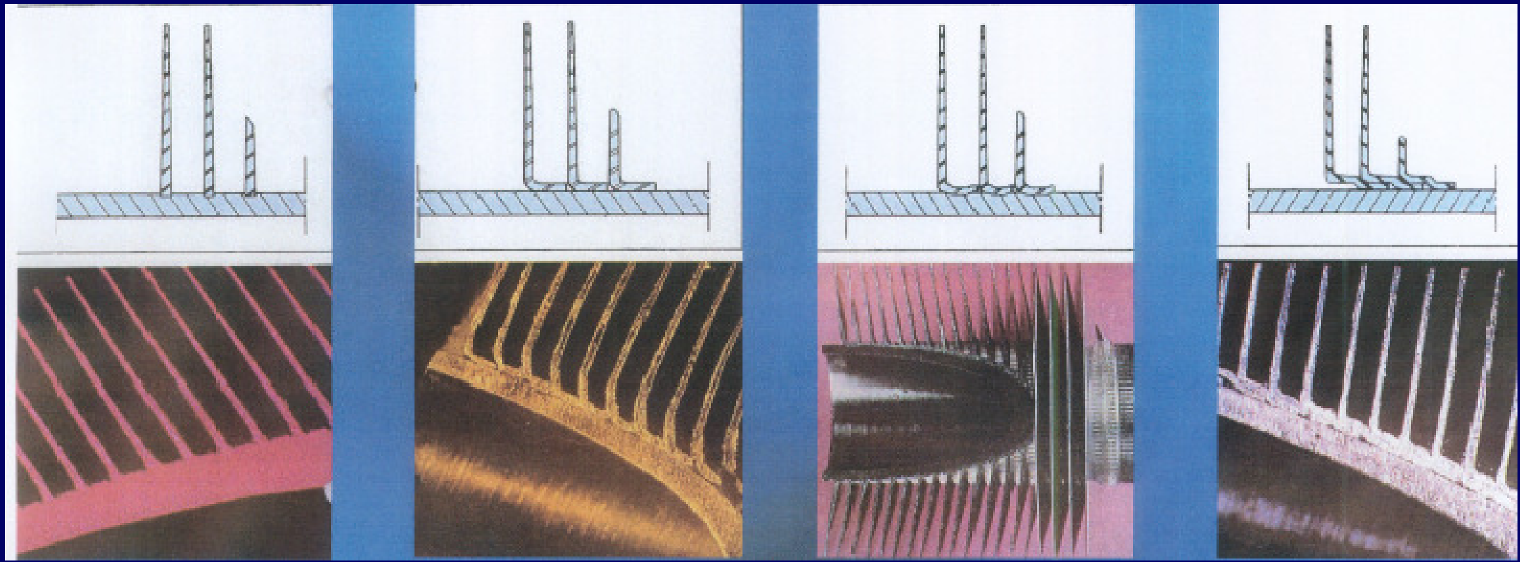




AIR COOLERS


COVER PLATE HEADER


DP dynamic
FAN
VENTILATEUR
PRODUCT
PRODUIT
PLENUM
CAISSON
HEADER
COLLECTEUR
FAISCEAU
BUNDLE
AIR
DP static



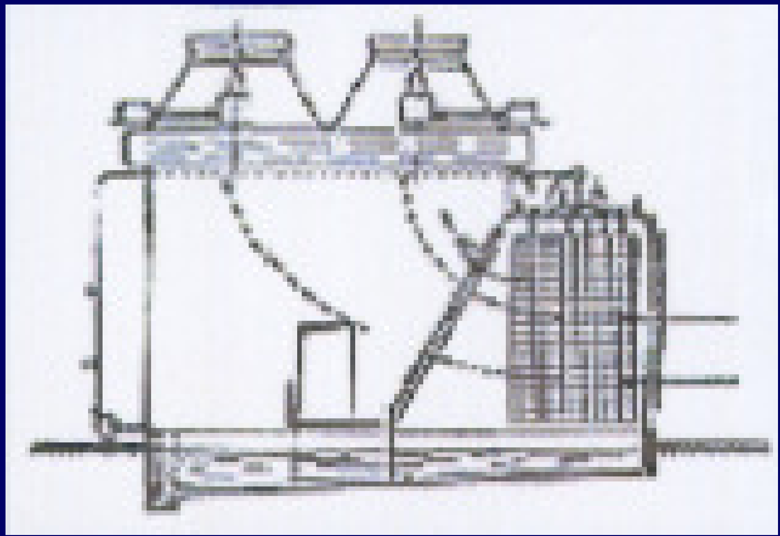
AIR COOLERS

Control Precision	Control device
+/- 10°C	*On / Off FAN*
+/- 5°C	*Automatic or manual Louvers*
+/- 3°C	*50% Fan with auto-variable blades*
+/- 1°C	*100%* fans with auto-vari. blades
"	*Variable speed motor*

COOLING TOWER

- The competitor of SW/CW P&F HX and Air cooler
- Used to cool down a semi-opened cooling water loop
- Efficiently used when big difference between dry bulb temperature and wet bulb temperature (not close to the sea)
- Operate with mass transfer and heat transfer together
- This imply:
  - Losses of water to compensate constantly
  - Pollution of the cooling water by air dust
  - Saturation of the cooling water in gas (corrosion issues)

COOLING TOWER



COOLING TOWER