Design of Process Equipment

Heat Exchanger

Lecture

doc. Ing. Martin Juriga, PhD.
Bratislava, February 2024

Process design

- ❖Info about cold/hot media on both sides
- ❖Physical and chemical data
- ❖Fouling
- ❖Presence of particles (PSD - particle size distribution)

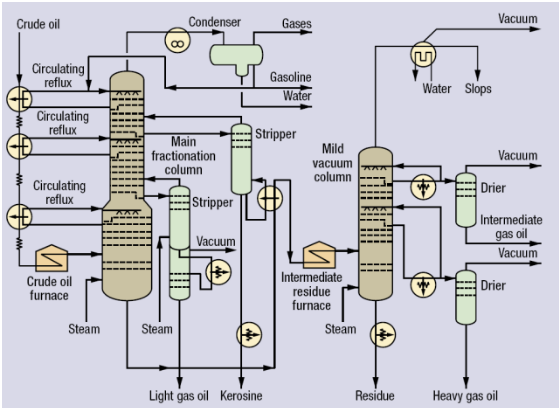
MEDIUM

PROCESS

- ❖Desired/searched temperature
- ❖Maximum pressure loss

CONSTRUCTION

- ❖Knowledge of the basic types of HE



Process design

$$Q = W_h c_h (T_1 - T_2)$$

Balance

$$Q = UA\Delta T_m$$

Kinetic

Q = heat transferred per unit time, W,
U = the overall heat transfer coefficient, W/m^2°C,
A = heat-transfer area, m^2,
ΔT_m = the mean temperature difference, the temperature driving force, °C.

Resistence

$$\frac{1}{U_o} = \frac{1}{h_o} + \frac{1}{h_{od}} + \frac{d_o \ln\left(\frac{d_o}{d_i}\right)}{2k_w} + \frac{d_o}{d_i} \times \frac{1}{h_{id}} + \frac{d_o}{d_i} \times \frac{1}{h_i}$$

U_o = the overall coefficient based on the outside area of the tube, W/m^2°C
h_o = outside fluid film coefficient, W/m^2°C,
h_i = inside fluid film coefficient, W/m^2°C,
h_{od} = outside dirt coefficient (fouling factor), W/m^2°C,
h_{id} = inside dirt coefficient, W/m^2°C,
k_w = thermal conductivity of the tube wall material, W/m°C,
d_i = tube inside diameter, m,
d_o = tube outside diameter, m.

Process design

Table 12.1. Typical overall coefficients

Shell and tube exchangers

Hot fluid	Cold fluid	U (W/m^2°C)
Heat exchangers		
Water	Water	800–1500
Organic solvents	Organic solvents	100–300
Light oils	Light oils	100–400
Heavy oils	Heavy oils	50–300
Gases	Gases	10–50
Coolers		
Organic solvents	Water	250–750
Light oils	Water	350–900
Heavy oils	Water	60–300
Gases	Water	20–300
Organic solvents	Brine	150–500
Water	Brine	600–1200
Gases	Brine	15–250
Heaters		
Steam	Water	1500–4000
Steam	Organic solvents	500–1000
Steam	Light oils	300–900
Steam	Heavy oils	60–450
Steam	Gases	30–300
Dowtherm	Heavy oils	50–300
Dowtherm	Gases	20–200
Flue gases	Steam	30–100
Flue	Hydrocarbon vapours	30–100
Condensers		
Aqueous vapours	Water	1000–1500
Organic vapours	Water	700–1000
Organics (some non-condensables)	Water	500–700
Vacuum condensers	Water	200–500
Vaporisers		
Steam	Aqueous solutions	1000–1500
Steam	Light organics	900–1200
Steam	Heavy organics	600–900

Air-cooled exchangers

Process fluid	
Water	300–450
Light organics	300–700
Heavy organics	50–150
Gases, 5–10 bar	50–100
10–30 bar	100–300
Condensing hydrocarbons	300–600

Jacketed vessels

Jacket	Vessel	
Steam	Dilute aqueous solutions	500–700
Steam	Light organics	250–500
Water	Dilute aqueous solutions	200–500
Water	Light organics	200–300

Gasketed-plate exchangers

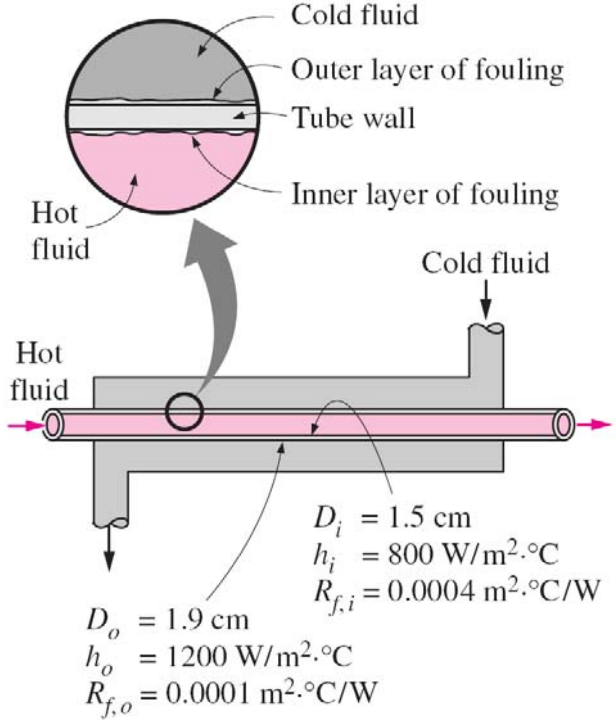
Hot fluid	Cold fluid	
Light organic	Light organic	2500–5000
Light organic	Viscous organic	250–500
Viscous organic	Viscous organic	100–200
Light organic	Process water	2500–3500
Viscous organic	Process water	250–500
Light organic	Cooling water	2000–4500
Viscous organic	Cooling water	250–450
Condensing steam	Light organic	2500–3500
Condensing steam	Viscous organic	250–500
Process water	Process water	5000–7500
Process water	Cooling water	5000–7000
Dilute aqueous solutions	Cooling water	5000–7000
Condensing steam	Process water	3500–4500

Process design

Table 12.2. Fouling factors (coefficients), typical values

Fluid	Coefficient (W/m^2°C)	Factor (resistance) (m^2°C/W)
River water	3000–12,000	0.0003–0.0001
Sea water	1000–3000	0.001–0.0003
Cooling water (towers)	3000–6000	0.0003–0.00017
Towns water (soft)	3000–5000	0.0003–0.0002
Towns water (hard)	1000–2000	0.001–0.0005
Steam condensate	1500–5000	0.00067–0.0002
Steam (oil free)	4000–10,000	0.0025–0.0001
Steam (oil traces)	2000–5000	0.0005–0.0002
Refrigerated brine	3000–5000	0.0003–0.0002
Air and industrial gases	5000–10,000	0.0002–0.0001
Flue gases	2000–5000	0.0005–0.0002
Organic vapours	5000	0.0002
Organic liquids	5000	0.0002
Light hydrocarbons	5000	0.0002
Heavy hydrocarbons	2000	0.0005
Boiling organics	2500	0.0004
Condensing organics	5000	0.0002
Heat transfer fluids	5000	0.0002
Aqueous salt solutions	3000–5000	0.0003–0.0002

Fouling



Notes:

For example, with a fouling factor of 0.0001 (fouling factor)it's like adding a 0.2 mm layer of limestone with a thermal conductivity of 2.9 W/m°C to the surface

Process design

$$\Delta T_m = F_t \Delta T_{\text{lm}}$$

where ΔT_m = true temperature difference, the mean temperature difference for use in the design equation 12.1,

F_t = the temperature correction factor.

Log mean temperature

LMTD

$$\Delta T_{\text{lm}} = \frac{(T_1 - t_2) - (T_2 - t_1)}{\ln \dfrac{(T_1 - t_2)}{(T_2 - t_1)}}$$

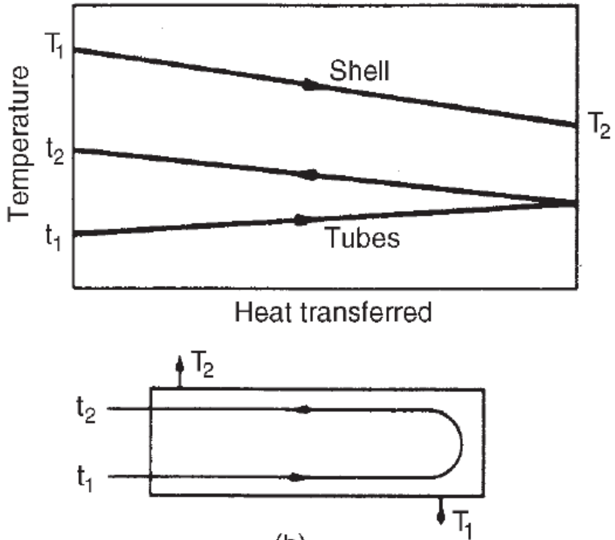
where ΔT_{lm} = log mean temperature difference,

T_1 = hot fluid temperature, inlet,

T_2 = hot fluid temperature, outlet,

t_1 = cold fluid temperature, inlet,

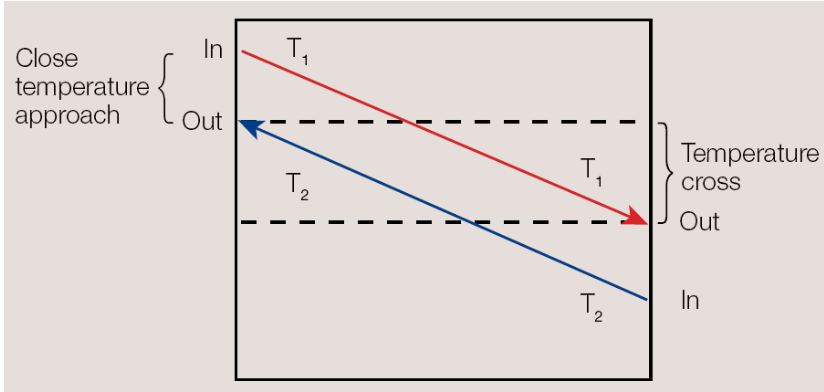
t_2 = cold fluid temperature, outlet.



(b)

Process design

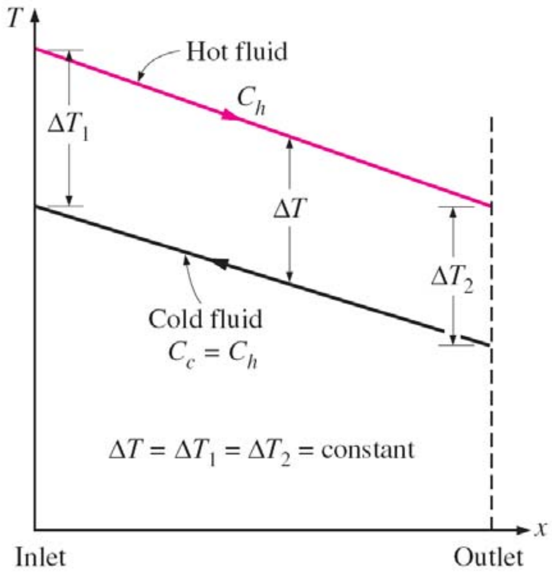
- ❖ Area Density /Parameter β/
- ❖ Temperature approach
- ❖ Temperature cross /Cross-flow/

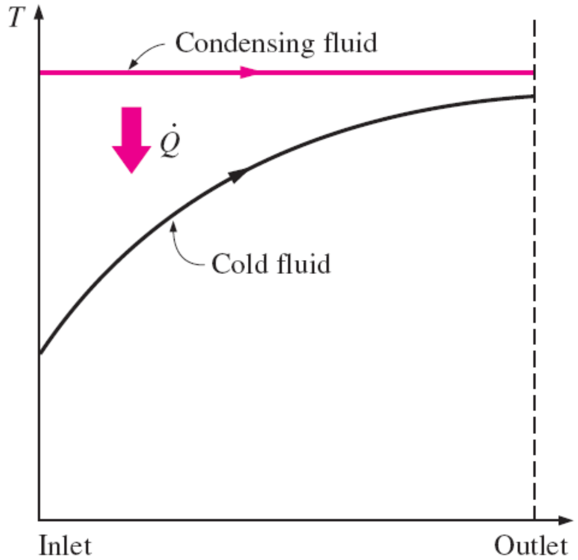


β–ratio of the heat exchange surface to the total volume of the heat exchanger::

β–700 m^2/m^3 compact HE

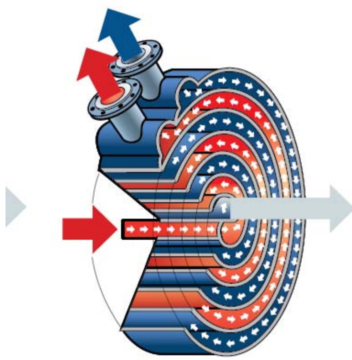
β- 6000 m^2/m^3 ceramic HE
β- 20 000 m^2/m^3 human lungs HE

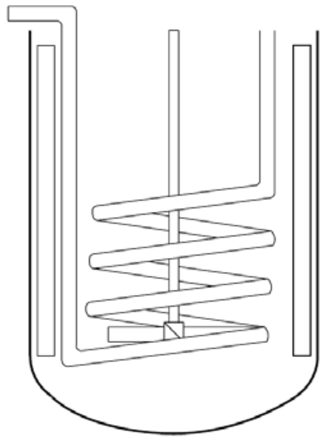




Types of Heat Exchangers.

- ❖Heater
- ❖Cooler
- ❖Boiler
- ❖Condenser





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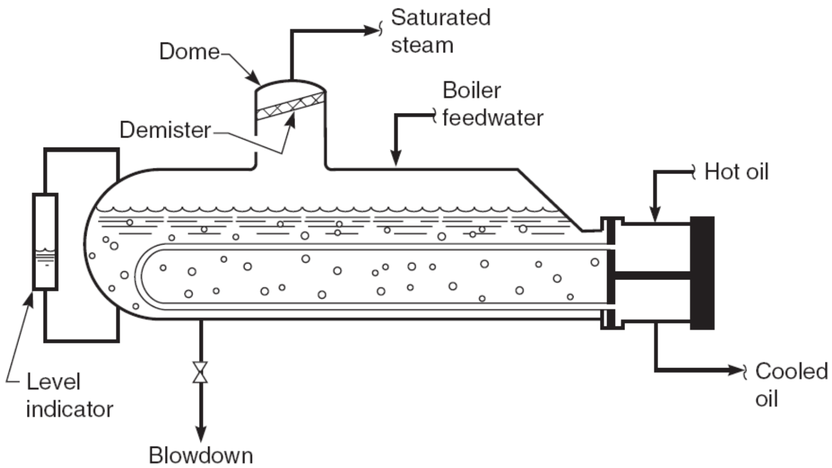
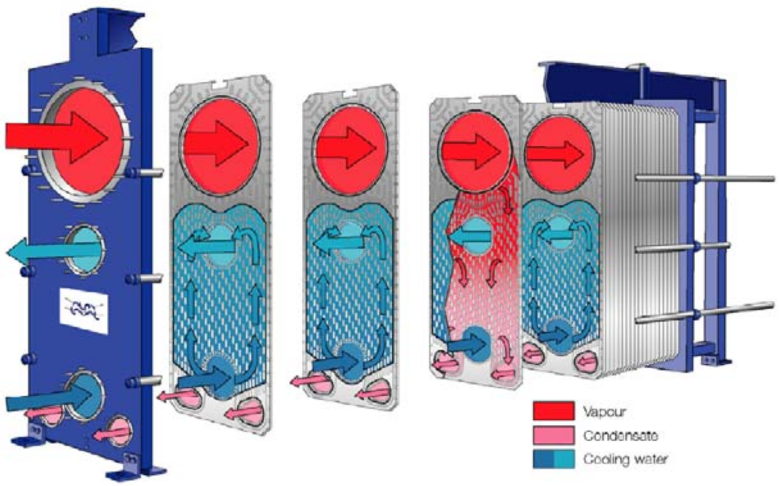
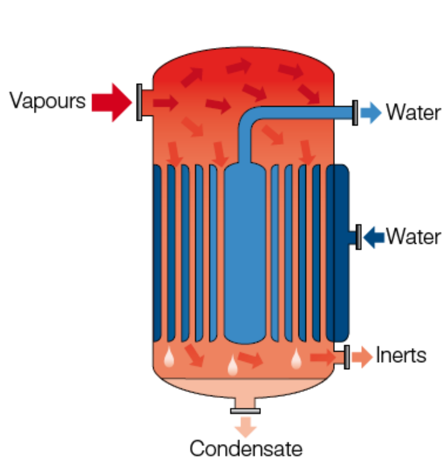
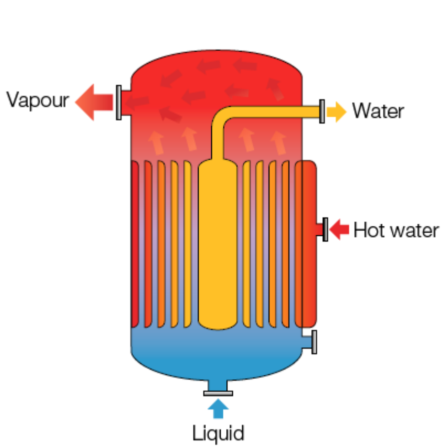


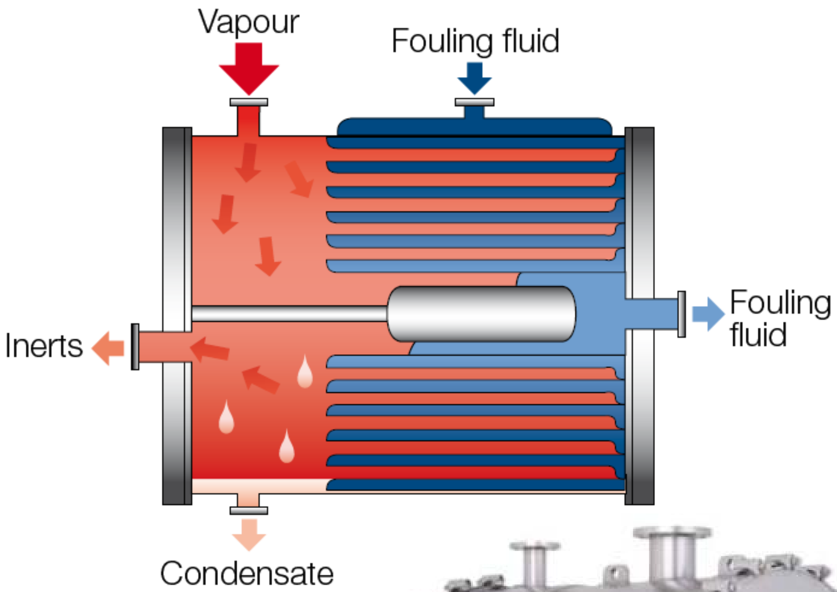


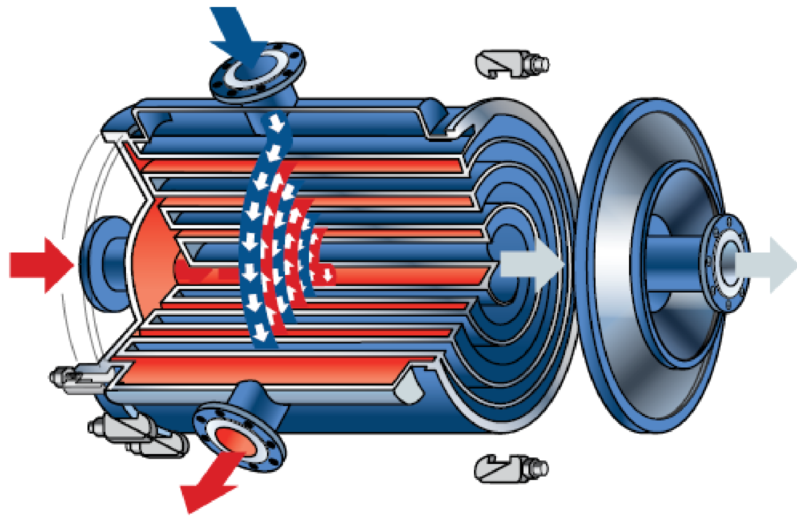




Types of Heat Exchangers

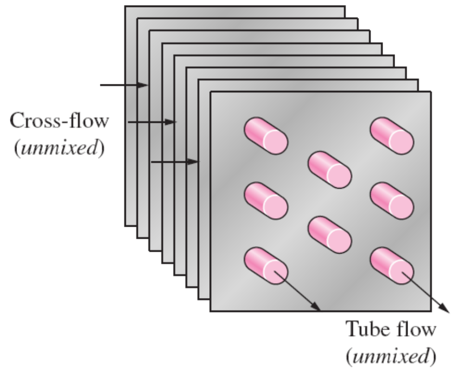
- ❖Without change of state (heaters, coolers)
- ❖With change of state (boilers, condensers)

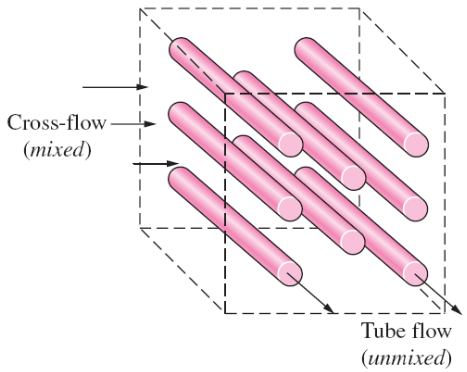


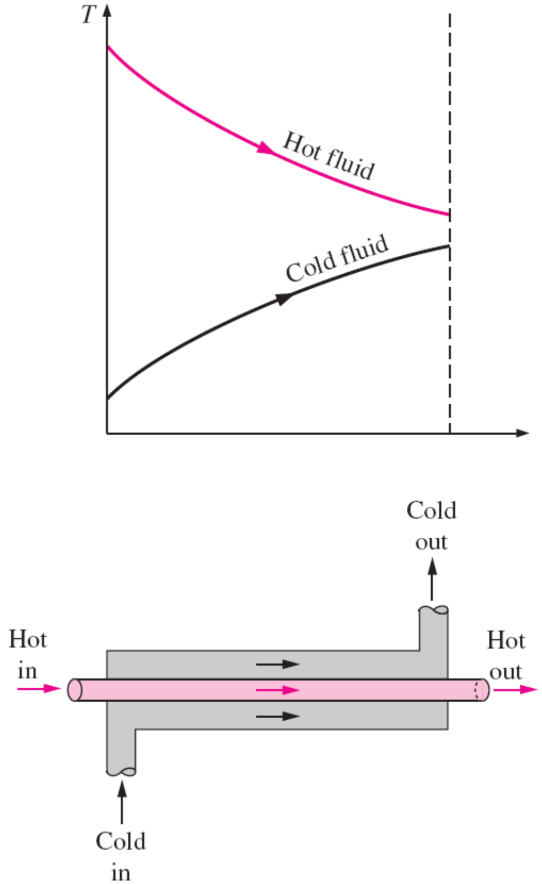


Types of Heat Exchangers

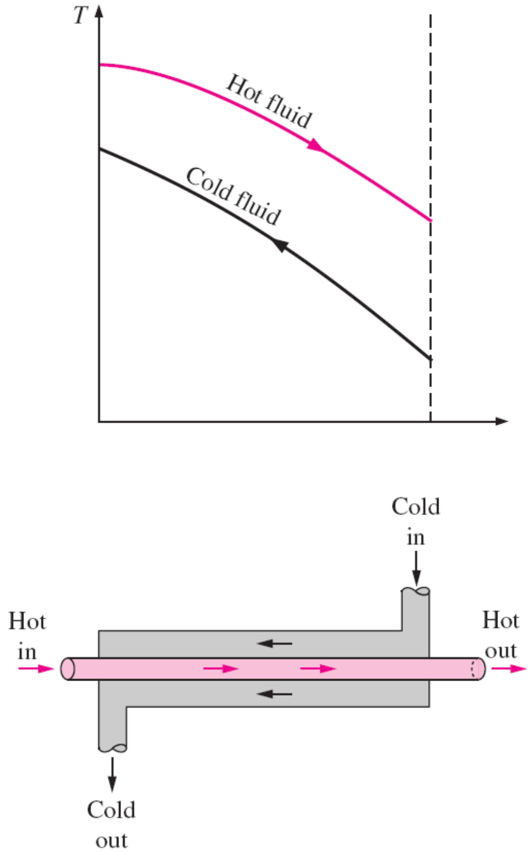
- Parallel
- Counter
- Cross-flow
- Combination







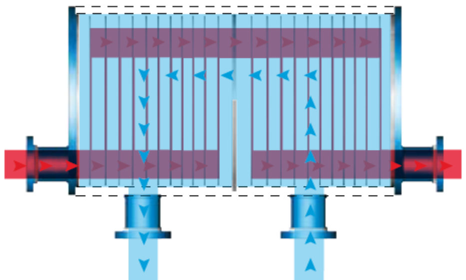
Co-current configuation

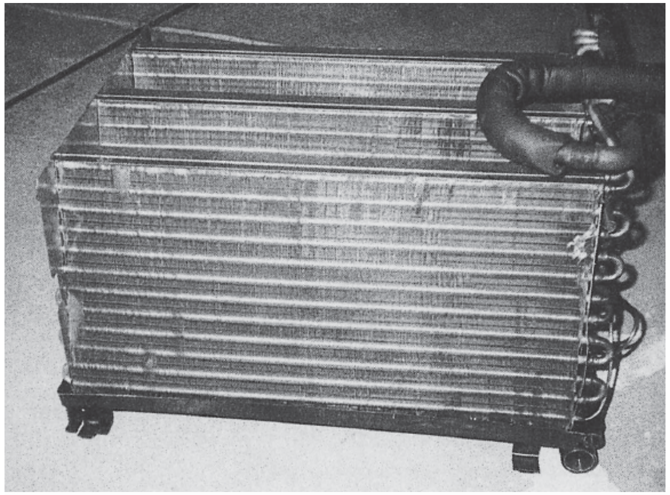


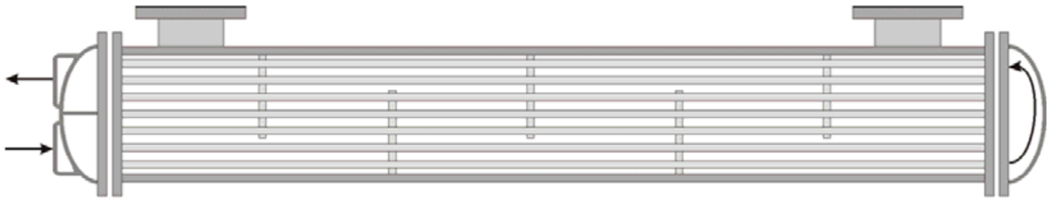
Countercurrent configuartion

Types of Heat Exchangers

- Parallel
- Counter
- Cross-flow
- Combination

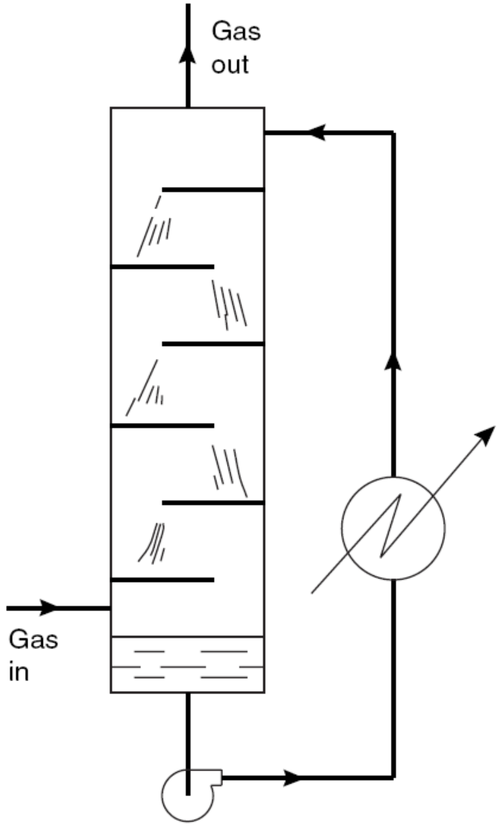


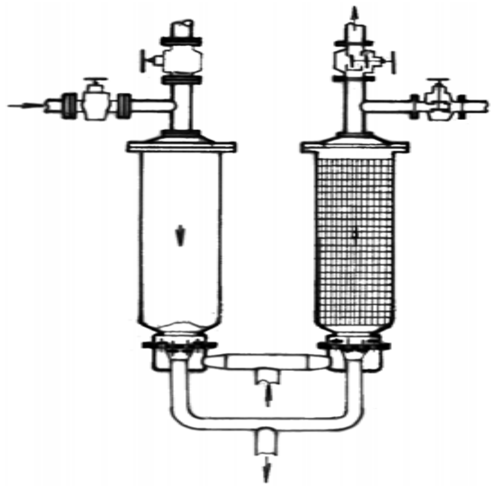




Types of Heat Exchangers

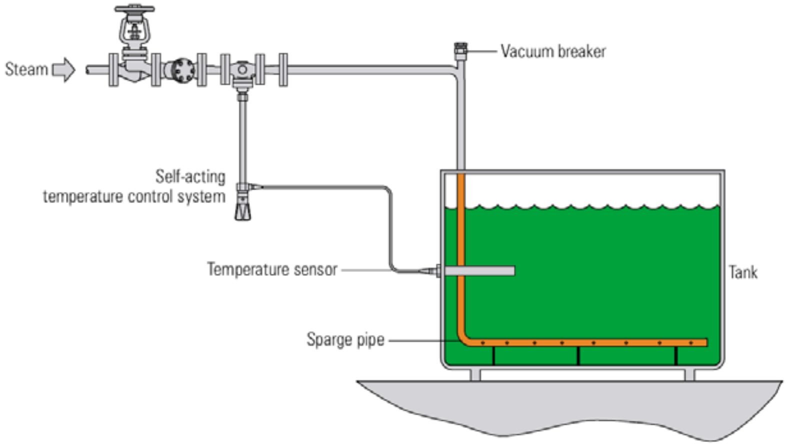
- ❖Direct /without heat exchange surface/
- ❖Regenerative /common heat-exchange surface/
- ❖Recuperative / one heat-exchange surface separating the media/





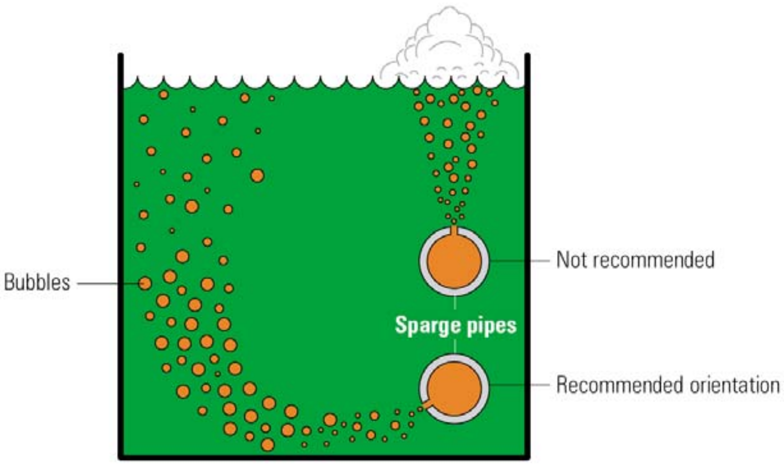
Types of HE - Direct

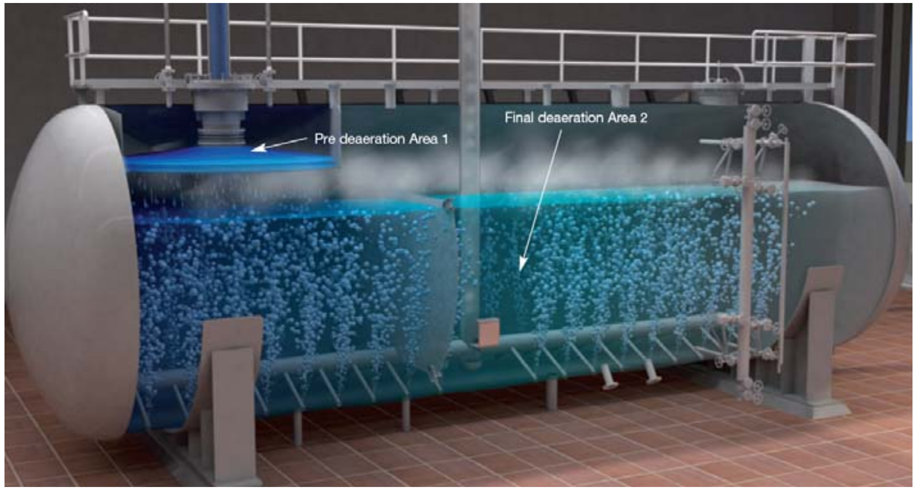
- Direct steam injection



Notes:

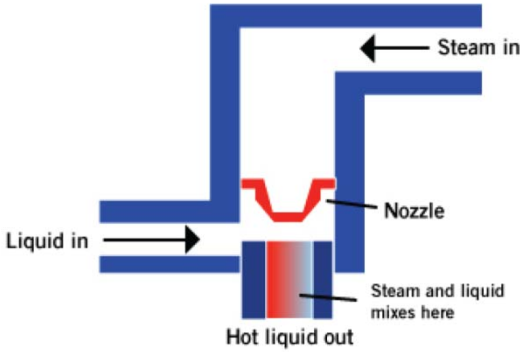
- minimum pressure difference
- bubble size ->low vapor pressure
- max. hydrostatic pressure

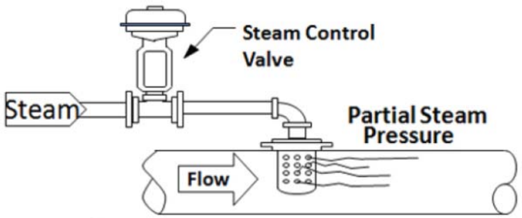


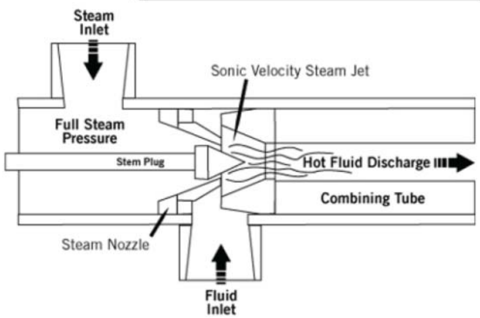


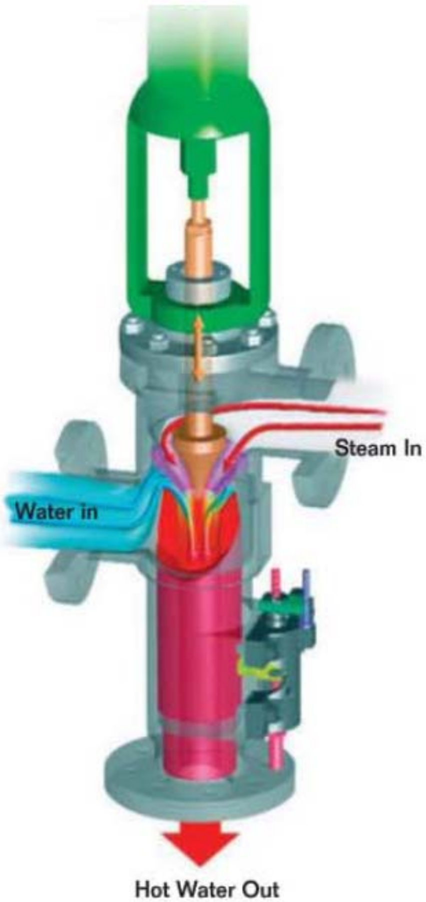
Types of HE - Direct

❖Direct steam injection



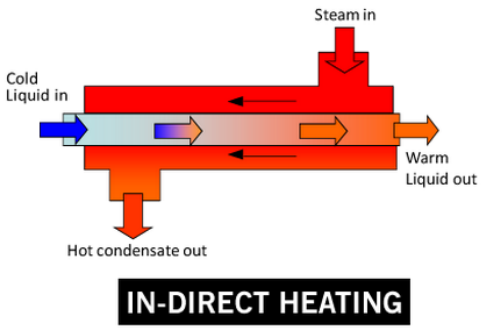


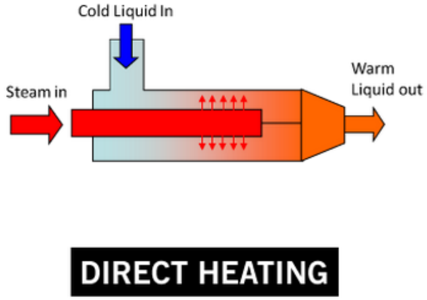




Notes:

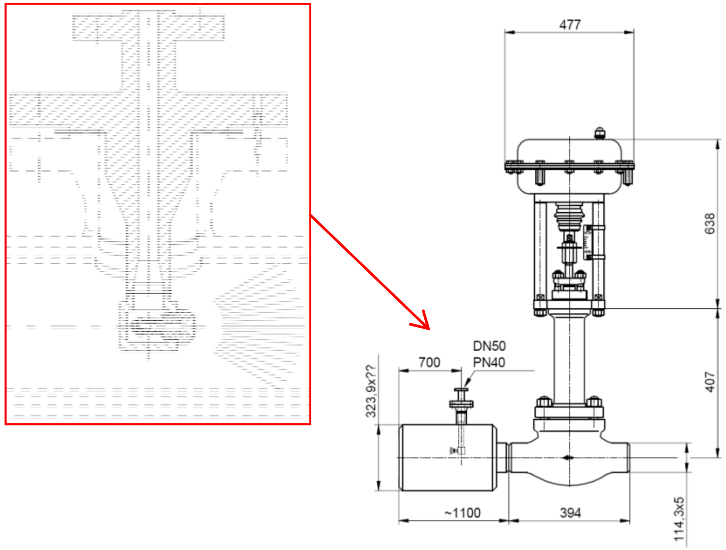
- ❖ the most efficient way of heating
- ❖ energy saving (20-30%)
- ❖ mostly simple device
- ❖ small space requirements
- ❖ only steam
- ❖ sensitive
- ❖ external/internal modulation





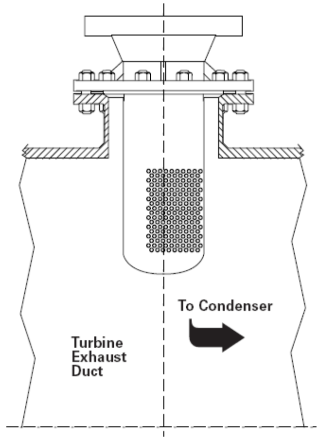
Types of HE - Direct

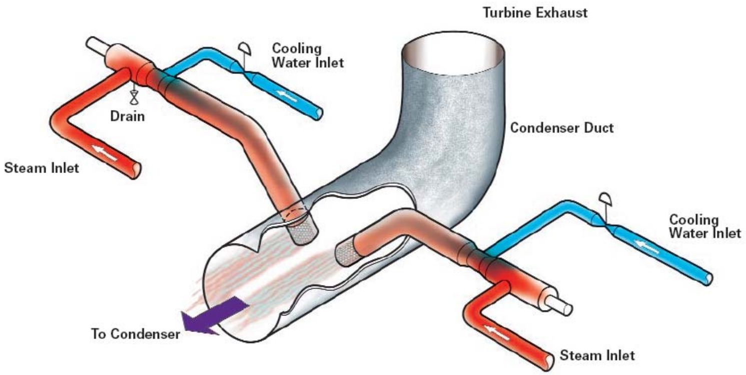
❖Direct water injection



Notes:

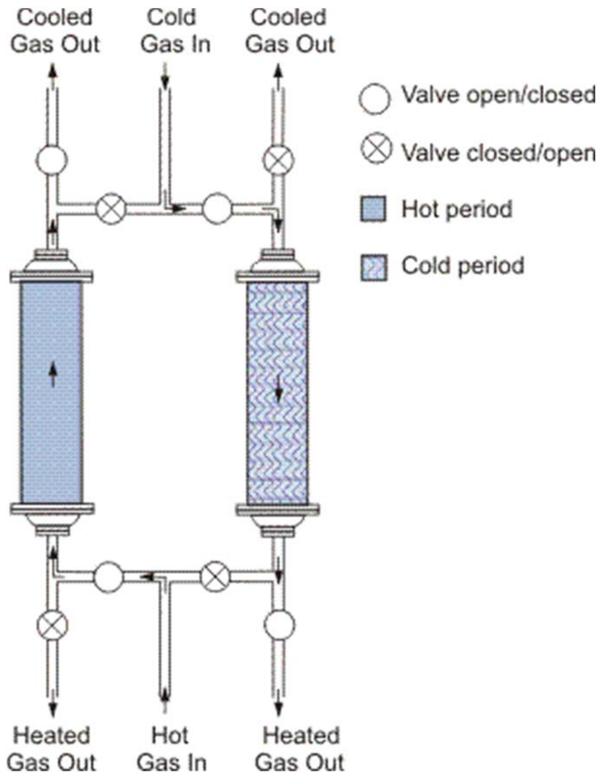
❖ Turbine bypass system i.e.
❖ injection valve
❖ Water cooling

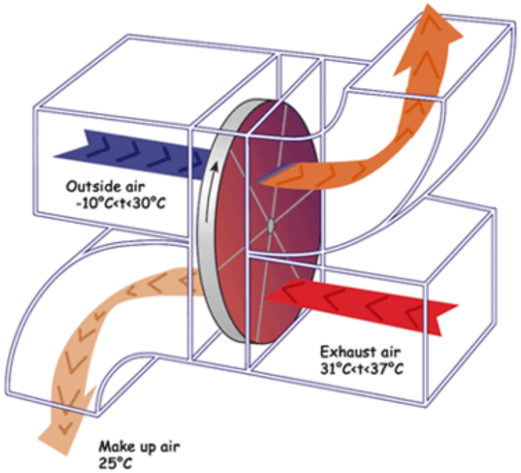


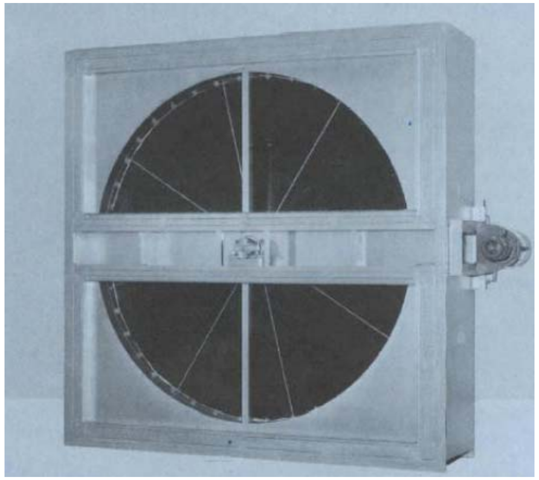


Types of HE - Regenerative

❖ Fixed or rotating heat-exchange surface







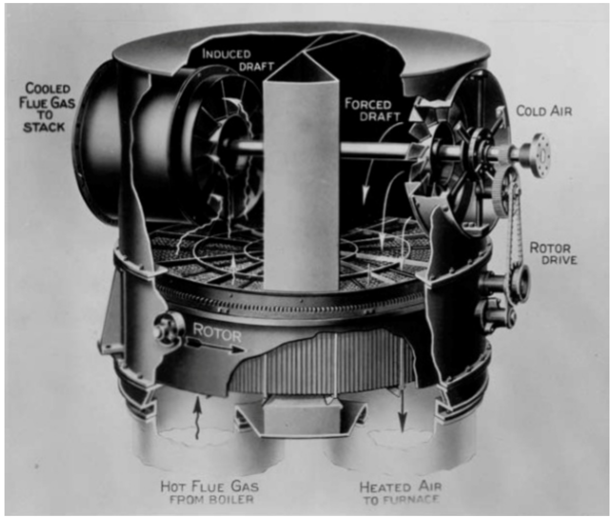
The use:
(g)-(g) at ↑↑ for volumetric flow up to 150 m3/s.
25m, 1600 tons.

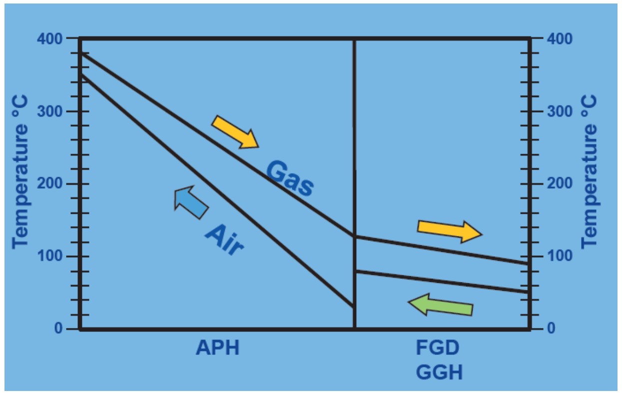
Advantages:
- also suitable for low temperatures,
-small temperature differences can be achieved,
- for large volume flows.

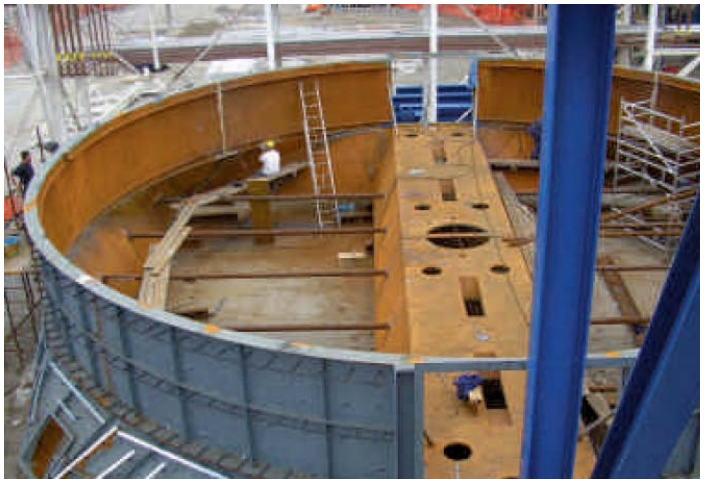
Disadvantages:
-losses during connection,
-mixing of gases (residues),
- difficult to clean.

Types of HE - Regenerative

❖Fixed or rotating heat-exchange surface





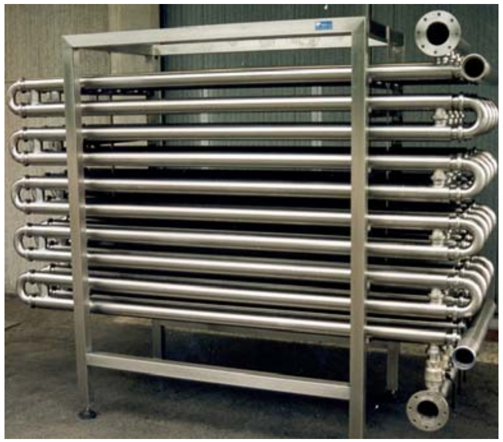


Regenerative Heat Exchangers with *Rotating Heating Surfaces* (ROTHEMÜHLE-Rotor System, first described by Fredrik Ljungström)

Regenerative Heat Exchangers with *Stationary Heating Surfaces* (ROTHEMÜHLE-Stator System)

Types of HE - Recuperative

❖ Double pipe HE /Hairpin/	DPHE	Výmenník rúrka v rúrke
❖ Shell and Tube HE	STHE	Rúrkový výmenník tepla
❖ Scraped-Surface HE	SSHE	VT so stieraným povrchom
❖ Plate HE	PHE	Doskový výmenník tepla
❖ Shell Plate HE	SPHE	Doskový opláštľovaný VT
❖ All-welded HE	AWHE	Celozváraný doskový VT
❖ Block HE	BHE	Blokový výmenník tepla
❖ Spiral HE	SHE	Špirálový výmenník tepla
❖ Air HE	AHE	Vzduchové výmenník tepla




β–700 m^2/m^3
compact VT

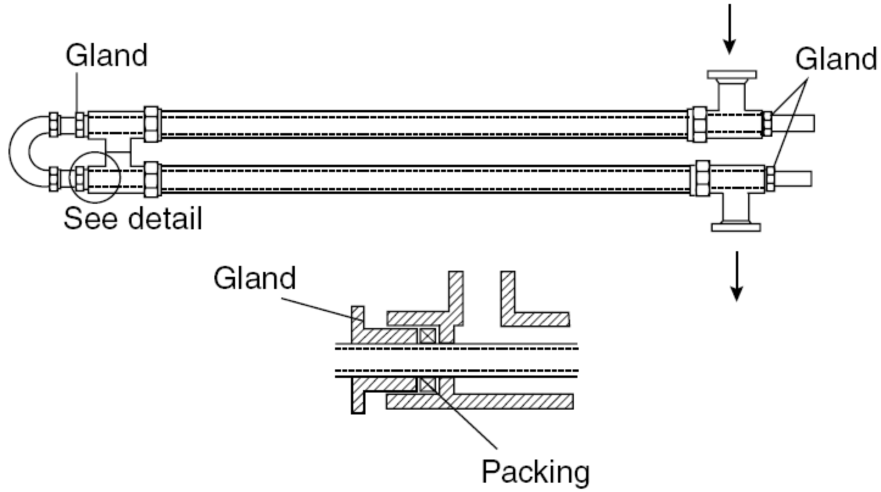
Recuperative HE - Double pipe.

The range of pressures and temperatures normally up to:
β = 0,6 - 5 m^2/m^3,

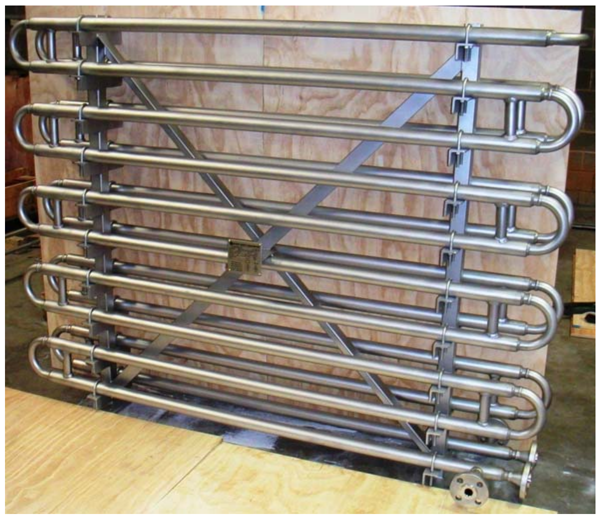
The use:
(g)-(g), (g)-(l),

Advantages :
- it is possible to achieve clean co-current and counter-current flow,
-realization of a large temperature difference between the inner and outer tube,
-variability of material use,
-good possibility of cleaning both surfaces.

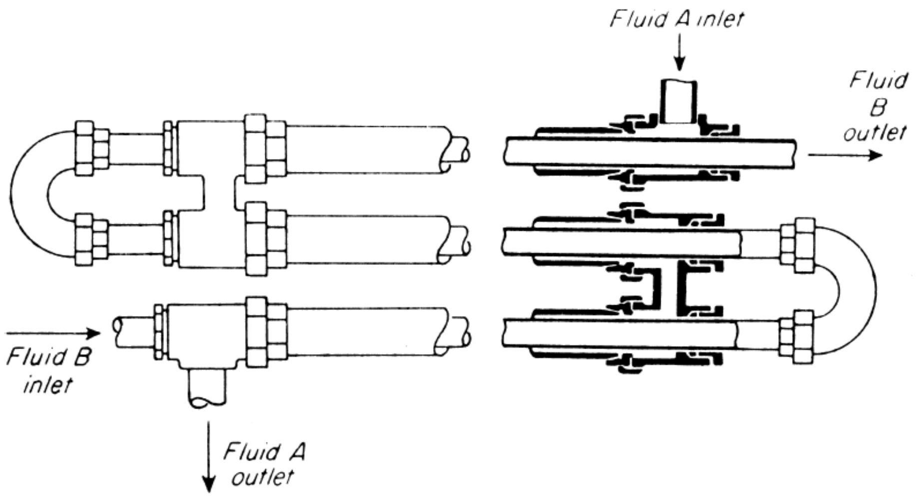
Disadvantages :
- high requirements for material and built-up area.
- low β

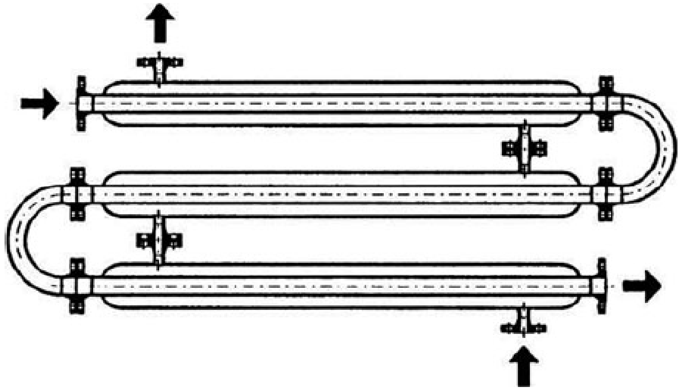


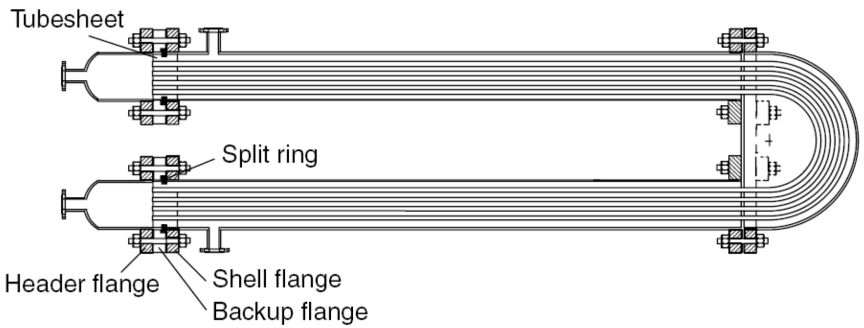
(a) Single hairpin



Recuperative HE - Double pipe.







Recuperative HE - Shell and tube HE

The range of pressures and temperatures normally up to:
p=4 MPa (max. 60 MPa – tube)
T=500 ^{o}C

- For tube diameter *d*=20 mm: β= 100 m^2/m^3,
- For tube diameter *d*=25 mm: β= 75 m^2/m^3.

The use:
(l)-(l), (g)-(l), (l)-(g), rarely (g)-(g)

Advantages :
-material version /steel, plastic, glass, graphite/,
-theory, almost 100 years of tradition, operational experience,
-use in a wide range of temperatures and pressures,
-less demanding production,
-possibility of mechanical cleaning.

Disadvantages :
- relative ↑↑ pressure loss /multipass HE/,
-tube heat exchangers have more weight,
- high requirements for material and built-up area.
- low β

↑↑

Recuperative HE - Shell and tube HE

TEMA
The Tubular Exchanger Manufacturers Association

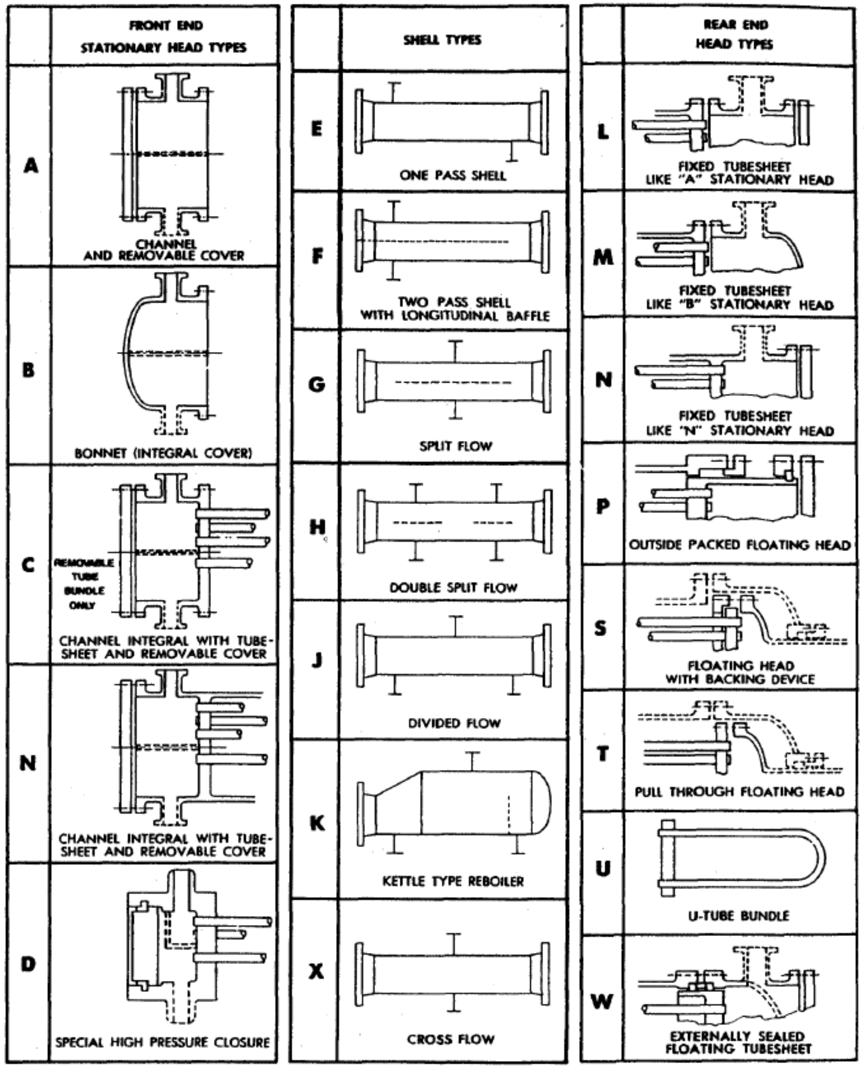
globally recognized and used method of designing tubular heat exchangers

complex method of strength calculation

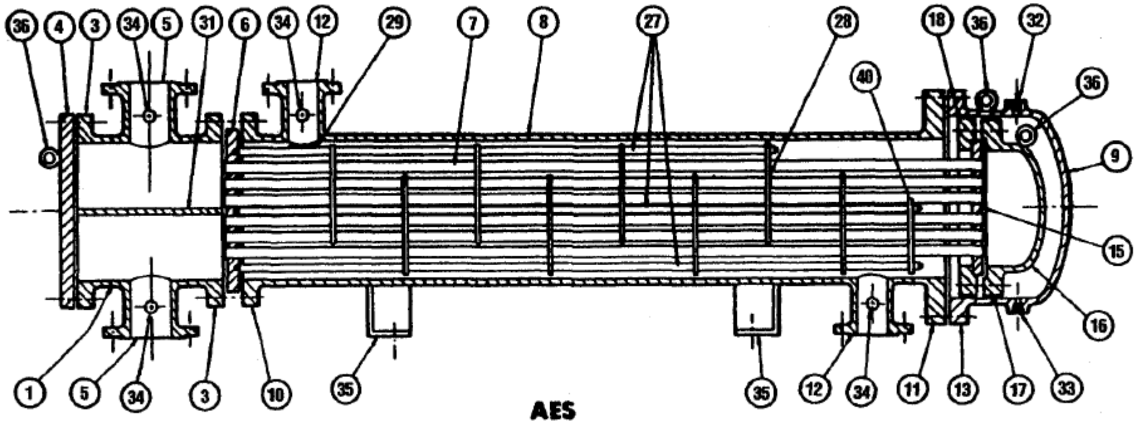
geometric characterization

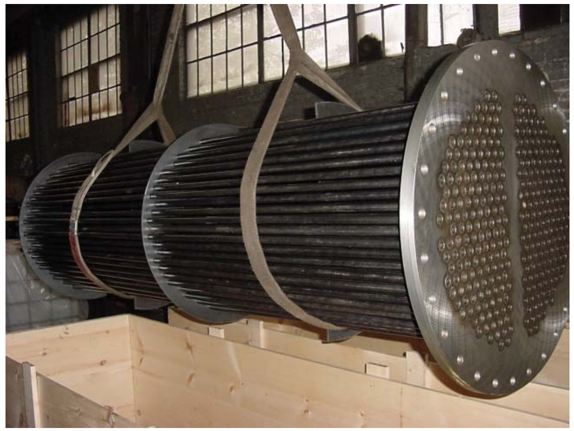
TEMA sheet

Recommended values for fouling



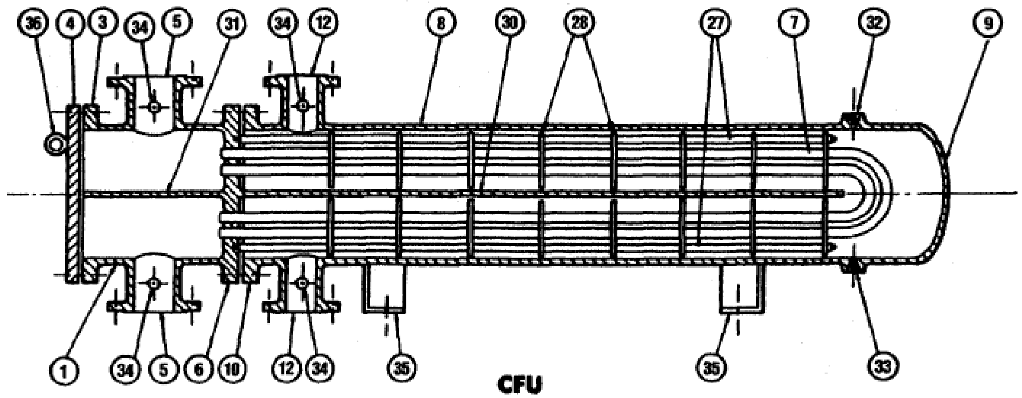
Recuperative HE - Shell and tube HE

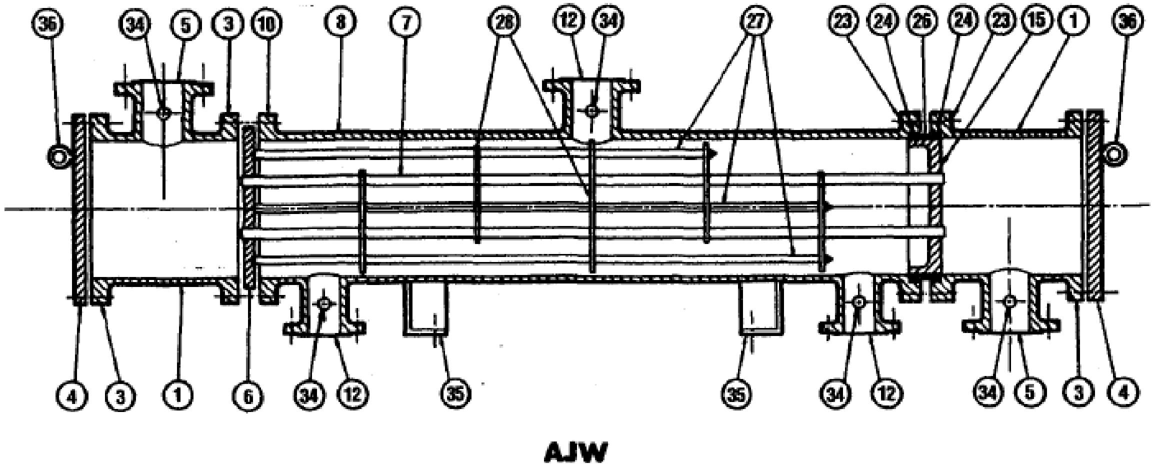




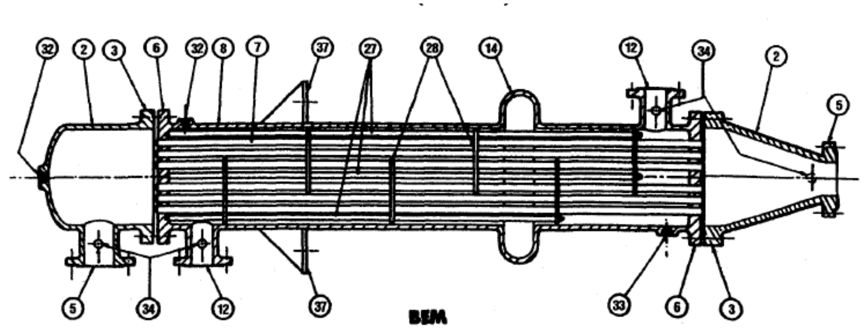
1. Stationary Head-Channel
2. Stationary Head-Bonnet
3. Stationary Head Flange-Channel or Bonnet
4. Channel Cover
5. Stationary Head Nozzle
6. Stationary Tubesheet
7. Tubes
8. Shell
9. Shell Cover
10. Shell Flange-Stationary Head End
11. Shell Flange-Rear Head End
12. Shell Nozzle
13. Shell Cover Flange
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
40. Floating Head Support

Recuperative HE - Shell and tube HE





Recuperative HE - Shell and tube HE



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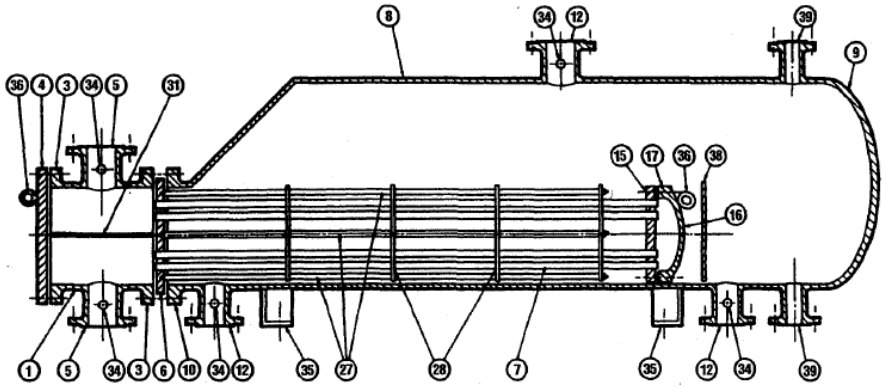
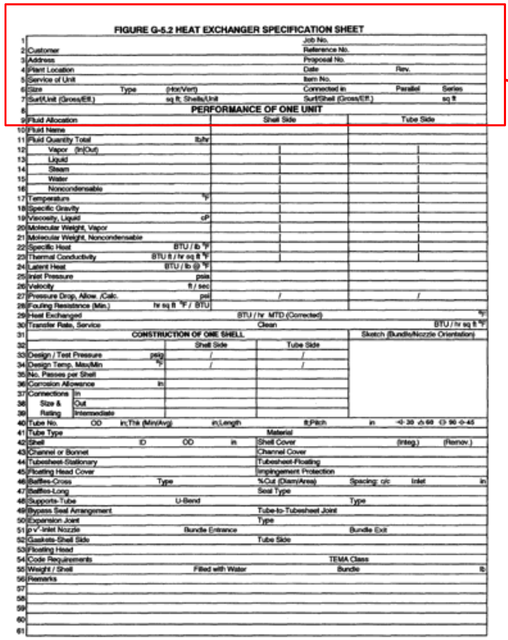


AKT

FIGURE G-5.2 HEAT EXCHANGER SPECIFICATION SHEET

1		Job No.	
2	Customer	Reference No.	
3	Address	Proposal No.	
4	Plant Location	Date	Rev.
5	Service of Unit	Item No.	
6	Size Type (Hor/Vert)	Connected in	Parallel Series
7	Surf/Unit (Gross/Eff.) sq ft; Shells/Unit	Surf/Shell (Gross/Eff.)	sq ft
8	PERFORMANCE OF ONE UNIT		
9	Fluid Allocation	Shell Side	Tube Side
10	Fluid Name		
11	Fluid Quantity Total lb/hr		
12	Vapor (In|Out)		
13	Liquid		
14	Steam		
15	Water		
16	Noncondensable		
17	Temperature °F		
18	Specific Gravity		
19	Viscosity, Liquid cP		
20	Molecular Weight, Vapor		
21	Molecular Weight, Noncondensable		
22	Specific Heat BTU / lb °F		
23	Thermal Conductivity BTU ft / hr sq ft °F		
24	Latent Heat BTU / lb @ °F		
25	Inlet Pressure psia		
26	Velocity ft / sec		
27	Pressure Drop, Allow. /Calc. psi	/	/
28	Fouling Resistance (Min.) hr sq ft °F / BTU		
29	Heat Exchanged	BTU / hr MTD (Corrected)	°F
30	Transfer Rate, Service	Clean	BTU / hr sq ft °F
31	CONSTRUCTION OF ONE SHELL		Sketch (Bundle/Nozzle Orientation)
32		Shell Side	Tube Side
33	Design / Test Pressure psig	/	/
34	Design Temp. Max/Min °F	/	/
35	No. Passes per Shell		
36	Corrosion Allowance in		
37	Connections In		
38	Size & Out		
39	Rating Intermediate		
40	Tube No. OD in;Thk (Min/Avg) in;Length	ft;Pitch in	⊲30 △60 ⊟90 ◇45
41	Tube Type	Material	
42	Shell ID OD in	Shell Cover	(Integ.) (Remov.)
43	Channel or Bonnet	Channel Cover	
44	Tubesheet-Stationary	Tubesheet-Floating	
45	Floating Head Cover	Impingement Protection	
46	Baffles-Cross Type	%Cut (Diam/Area)	Spacing: c/c Inlet in
47	Baffles-Long	Seal Type	
48	Supports-Tube U-Bend		Type
49	Bypass Seal Arrangement	Tube-to-Tubesheet Joint	
50	Expansion Joint	Type	
51	ρv^2-Inlet Nozzle Bundle Entrance		Bundle Exit
52	Gaskets-Shell Side	Tube Side	
53	Floating Head		
54	Code Requirements	TEMA Class	
55	Weight / Shell Filled with Water	Bundle	lb
56	Remarks		
57			
58			
59			
60			
61			

Recuperative HE - Shell and tube HE



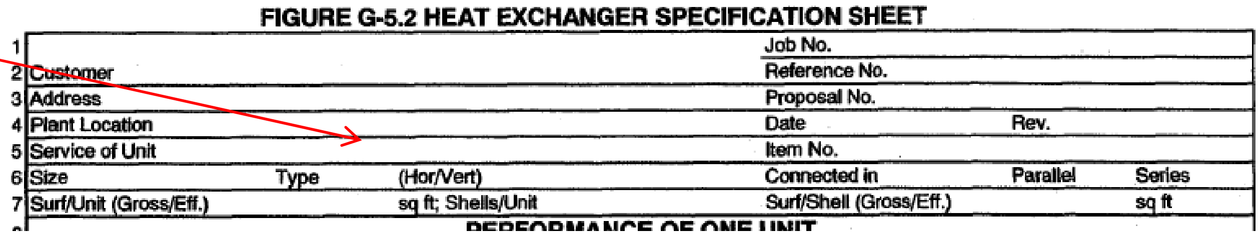


FIGURE G-5.2 HEAT EXCHANGER SPECIFICATION SHEET

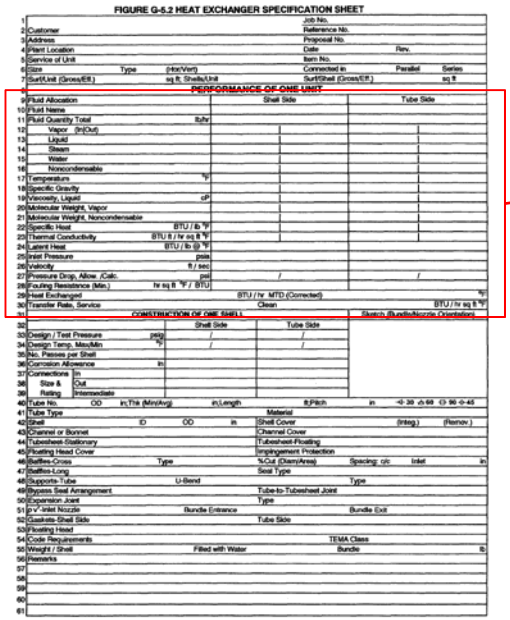
1				Job No.			
2	Customer			Reference No.			
3	Address			Proposal No.			
4	Plant Location			Date		Rev.	
5	Service of Unit			Item No.			
6	Size	Type	(Hor/Vert)	Connected in		Parallel	Series
7	Surf/Unit (Gross/Eff.)		sq ft; Shells/Unit	Surf/Shell (Gross/Eff.)			sq ft

TEMA Sheet

3 Blocks of information

1)
Heat exchanger identification.
Parallel / Series
Basic dimensional parameters
Total heat exchange surface

Recuperative HE - Shell and tube HE

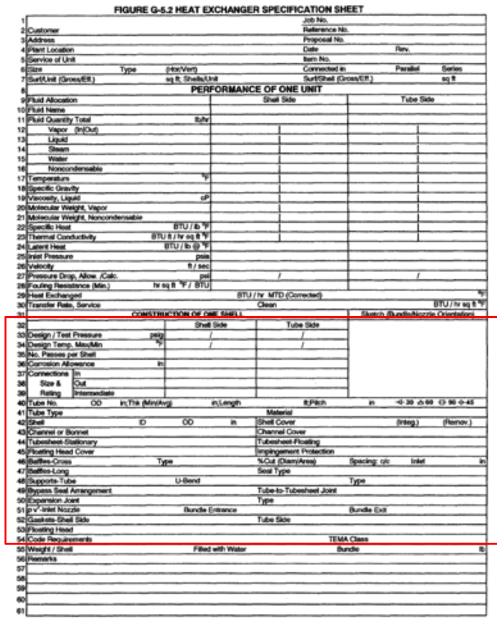


8	PERFORMANCE OF ONE UNIT			
9	Fluid Allocation		Shell Side	Tube Side
10	Fluid Name			
11	Fluid Quantity Total	lb/hr		
12	Vapor (In|Out)		|	|
13	Liquid		|	|
14	Steam		|	|
15	Water		|	|
16	Noncondensable		|	|
17	Temperature	°F	|	|
18	Specific Gravity		|	|
19	Viscosity, Liquid	cP	|	|
20	Molecular Weight, Vapor		|	|
21	Molecular Weight, Noncondensable		|	|
22	Specific Heat	BTU / lb °F	|	|
23	Thermal Conductivity	BTU ft / hr sq ft °F	|	|
24	Latent Heat	BTU / lb @ °F		
25	Inlet Pressure	psia		
26	Velocity	ft / sec		
27	Pressure Drop, Allow. /Calc.	psi	/	/
28	Fouling Resistance (Min.)	hr sq ft °F / BTU		
29	Heat Exchanged		BTU / hr MTD (Corrected)	°F
30	Transfer Rate, Service		Clean	BTU / hr sq ft °F

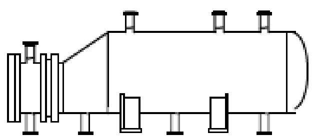
TEMA Sheet

-HE process parameters
- physical and chemical parameter of medium.
-Overall performance (Dirty / Clean) depending on the selected Fouling Resistance..

Recuperative HE - Shell and tube HE



31	CONSTRUCTION OF ONE SHELL				Sketch (Bundle/Nozzle Orientation)
32			Shell Side	Tube Side	
33	Design / Test Pressure	psig	/	/	
34	Design Temp. Max/Min	°F	/	/	
35	No. Passes per Shell				
36	Corrosion Allowance	in			
37	Connections	In			
38	Size &	Out			
39	Rating	Intermediate			
40	Tube No. OD	in;Thk (Min/Avg)	in;Length	ft;Pitch	in ⊲30 △60 ⊟90 ◇45
41	Tube Type			Material	
42	Shell	ID	OD in	Shell Cover	(Integ.) (Remov.)
43	Channel or Bonnet			Channel Cover	
44	Tubesheet-Stationary			Tubesheet-Floating	
45	Floating Head Cover			Impingement Protection	
46	Baffles-Cross		Type	%Cut (Diam/Area)	Spacing: c/c Inlet in
47	Baffles-Long			Seal Type	
48	Supports-Tube		U-Bend		Type
49	Bypass Seal Arrangement			Tube-to-Tubesheet Joint	
50	Expansion Joint			Type	
51	ρv^2-Inlet Nozzle		Bundle Entrance		Bundle Exit
52	Gaskets-Shell Side			Tube Side	
53	Floating Head				
54	Code Requirements				TEMA Class
55	Weight / Shell		Filled with Water		Bundle lb
56	Remarks				



TEMA Sheet

- Construction parameters of HE

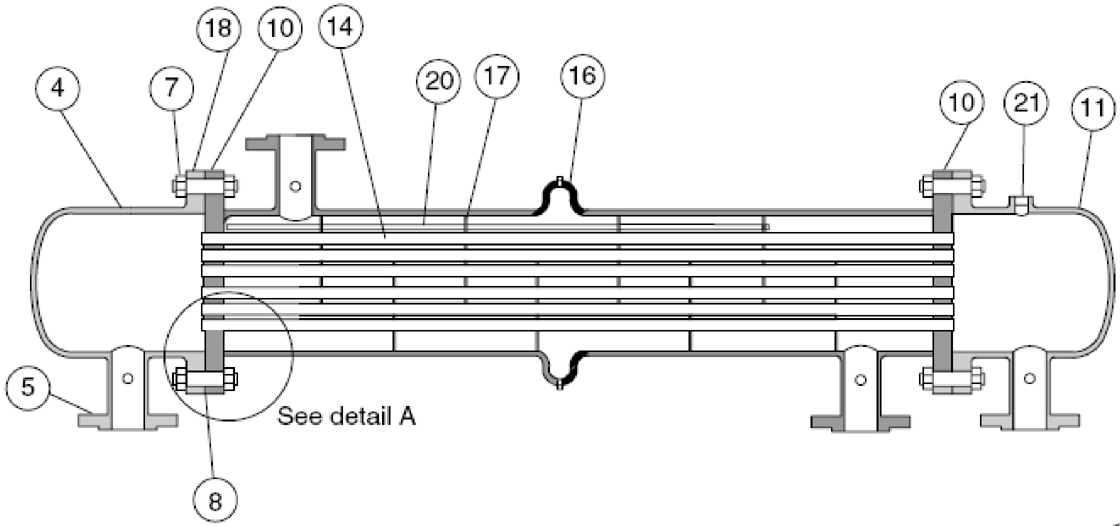
Recuperative HE - Shell and tube HE

Type of Design	U-Tube (Type U)	Fixed Tubesheet (Types L, M, and N)	Pull-Through Floating Head (Type T)	Floating-Head Outside-Packed Lantern Ring (Type W)	Split-Backing-Ring Floating-Head (Type S)	Floating-Head Outside-Packed Stuffing Box (Type P)
Relative cost increases from A (least expensive) through E (most expensive)	A	B	C	C	D	E
Provision for differential expansion	Individual tubes free to expand	Expansion joint in shell	Floating head	Floating head	Floating head	Floating head
Removable bundle	Yes	No	Yes	Yes	Yes	Yes
Individual tubes replaceable	Only those in outside rows	Yes	Yes	Yes	Yes	Yes
Tube interiors cleanable	Difficult to do mechanically; can do chemically	Yes, mechanically or chemically	Yes, mechanically or chemically	Yes, mechanically or chemically	Yes, mechanically or chemically	Yes, mechanically or chemically
Tube exteriors with triangular pitch cleanable	Chemically only	Chemically only	Chemically only	Chemically only	Chemically only	Chemically only
Tubes exterior with sqare pitch cleanable	Yes, mechanically or chemically	Chemically only	Yes, mechanically or chemically	Yes, mechanically or chemically	Yes, mechanically or chemically	Yes, mechanically or chemically
Number of tube passes	Any practical even number possible	No practical limitations	No practical limitations (single-pass floating-head requires packing joint)	Limited to single- or double-pass	No practical limitations (single-pass floating-head requirespacking joint)	No practical limitations
Internal gaskets eliminated	Yes	Yes	No	Yes	No	Yes

Recuperative HE - Shell and tube HE

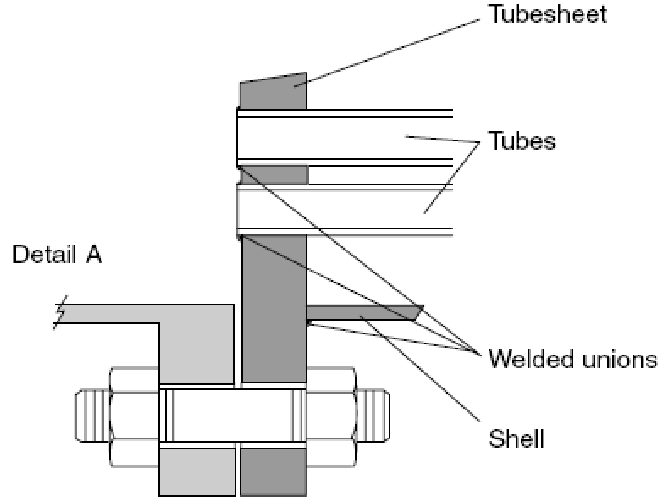
Tubular heat exchanger without phase change

BEM



Fixed tubesheet heat exchanger

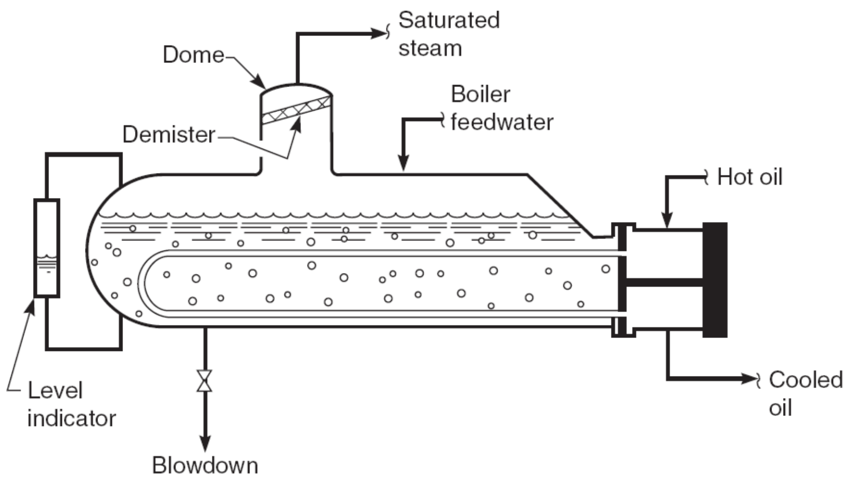
TEMA TYPE BEM
For parts nomenclature see Table 6-1



Recuperative HE - Shell and tube HE

Tubular heat exchanger with phase change

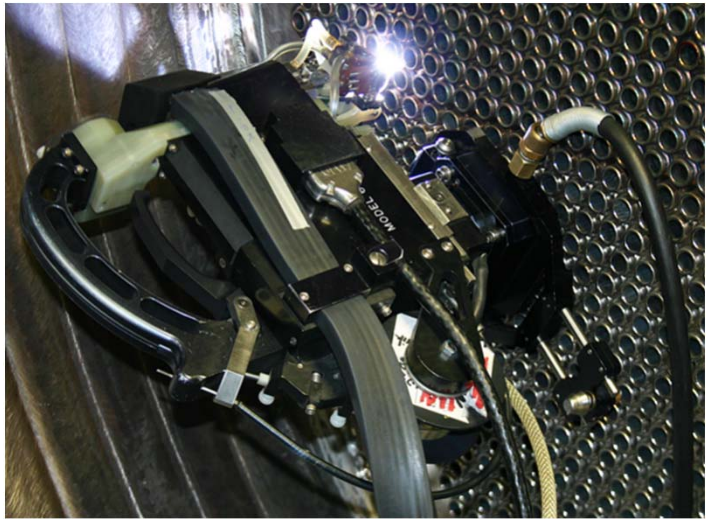
AKT



Recuperative HE - Shell and tube HE

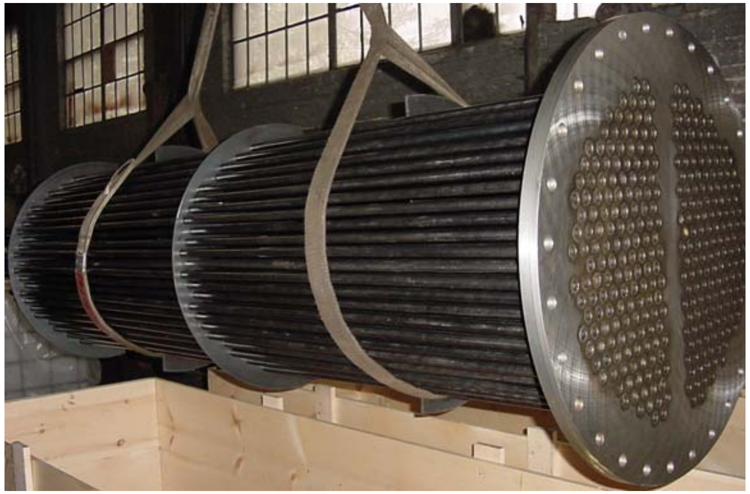
Tubesheet

- generally the most expensive part of HE
- welded or pressed pipes.



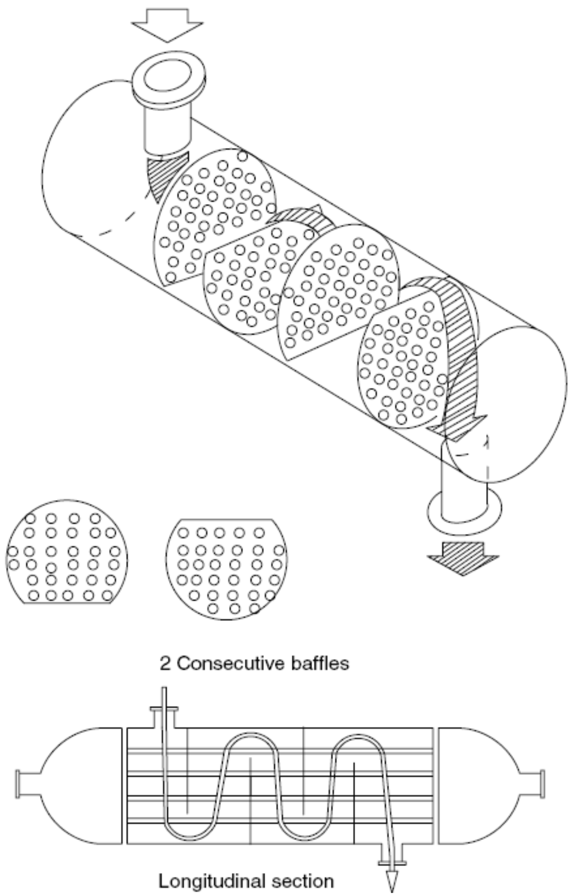
Recuperative HE - Shell and tube HE

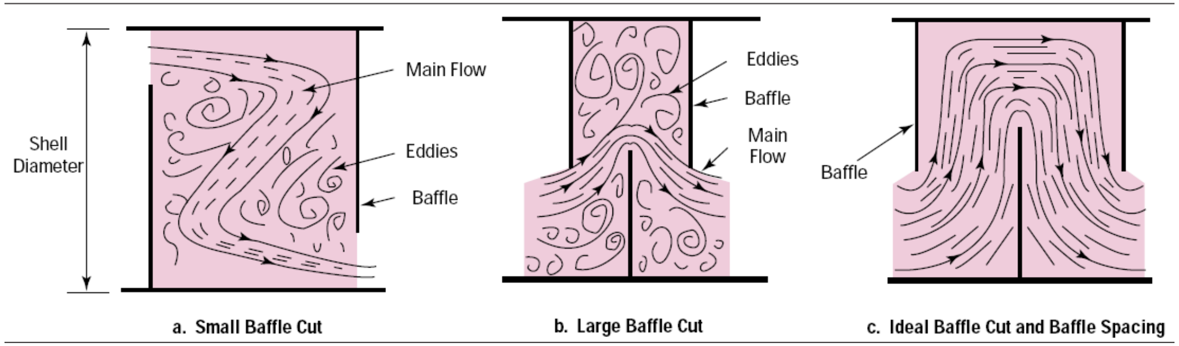
Tube bundle

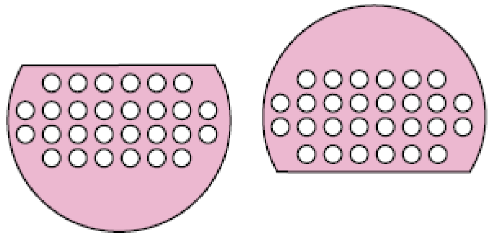


Recuperative HE - Shell and tube HE

Baffles

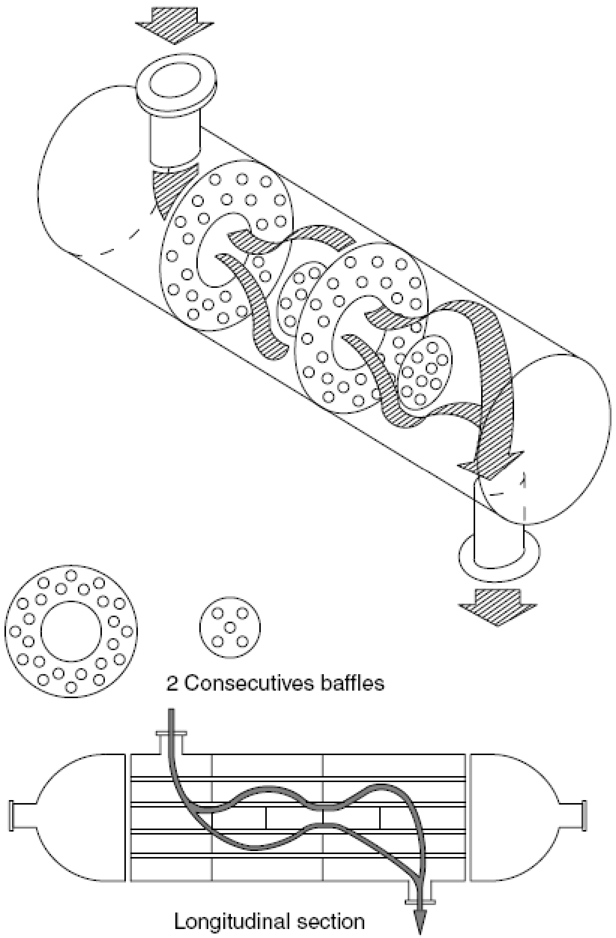


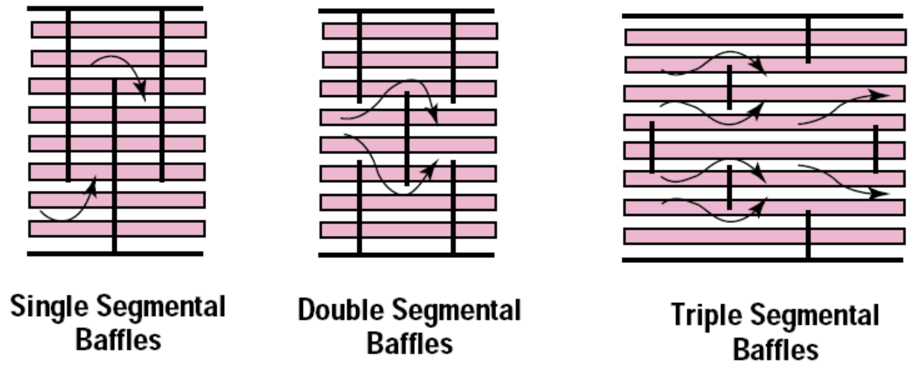


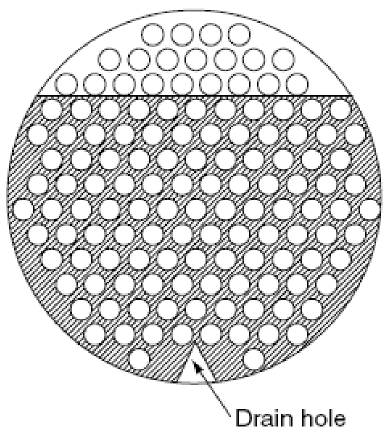


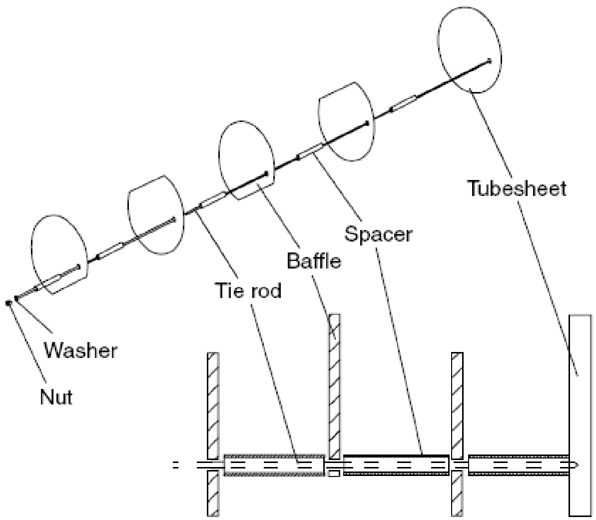
Recuperative HE - Shell and tube HE

Baffles









Recuperative HE - Shell and tube HE

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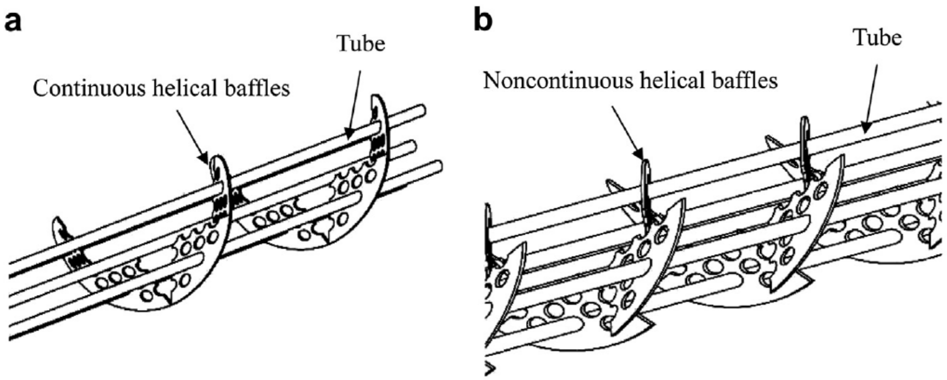

Recuperative HE - Shell and tube HE

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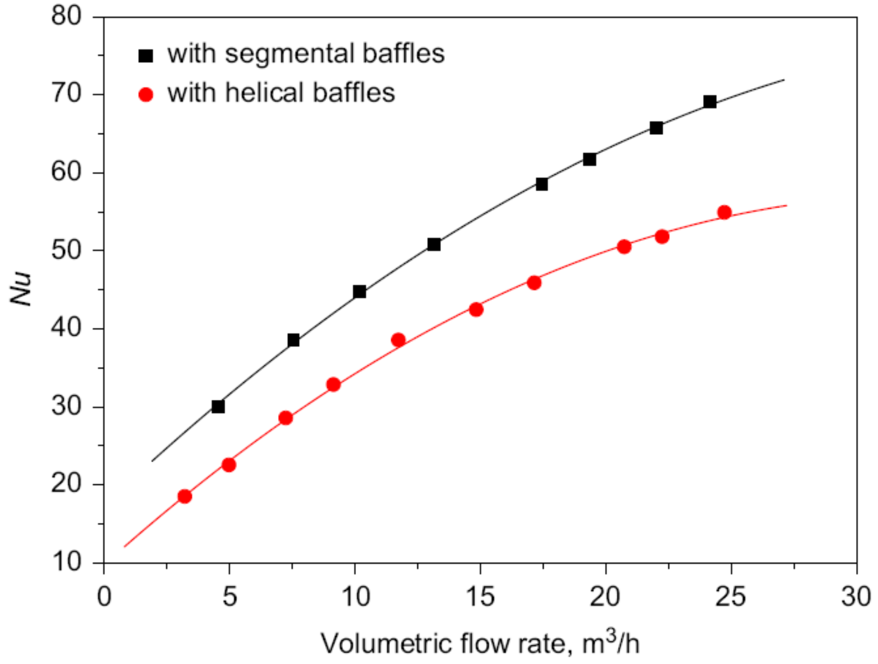
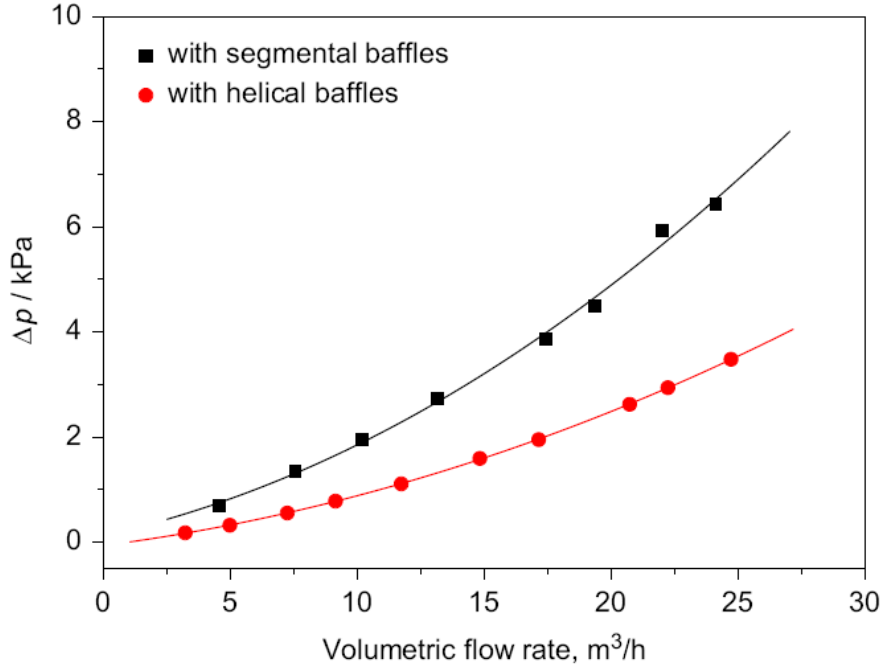




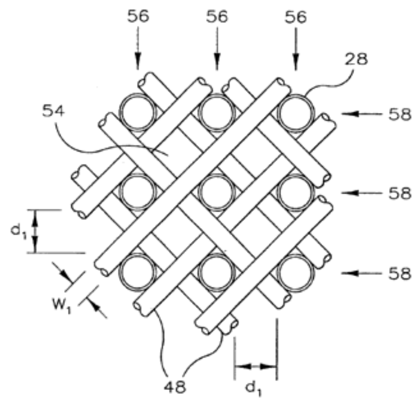
Recuperative HE - Shell and tube HE

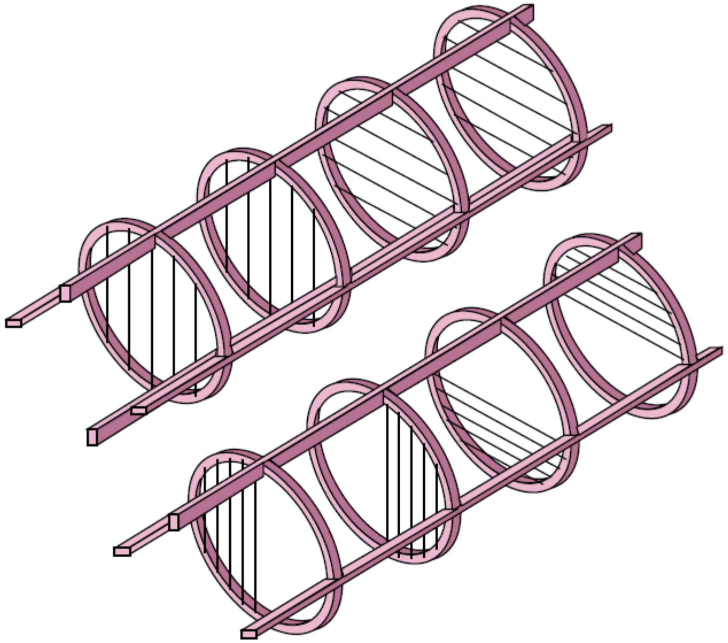
Baffles

1975
Phillips Petroleum Company

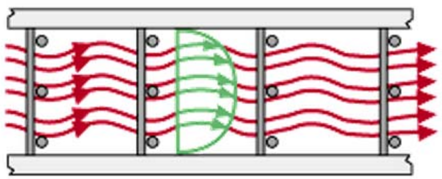
50% ↓↓ pressure drop

↓↓ - vibration damage 4 point contact





Uniform Flow Pattern



RODbaffle

Flow Reversal Pattern

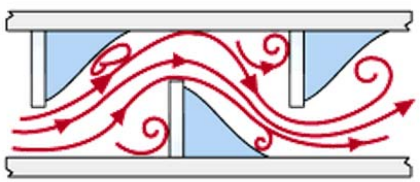
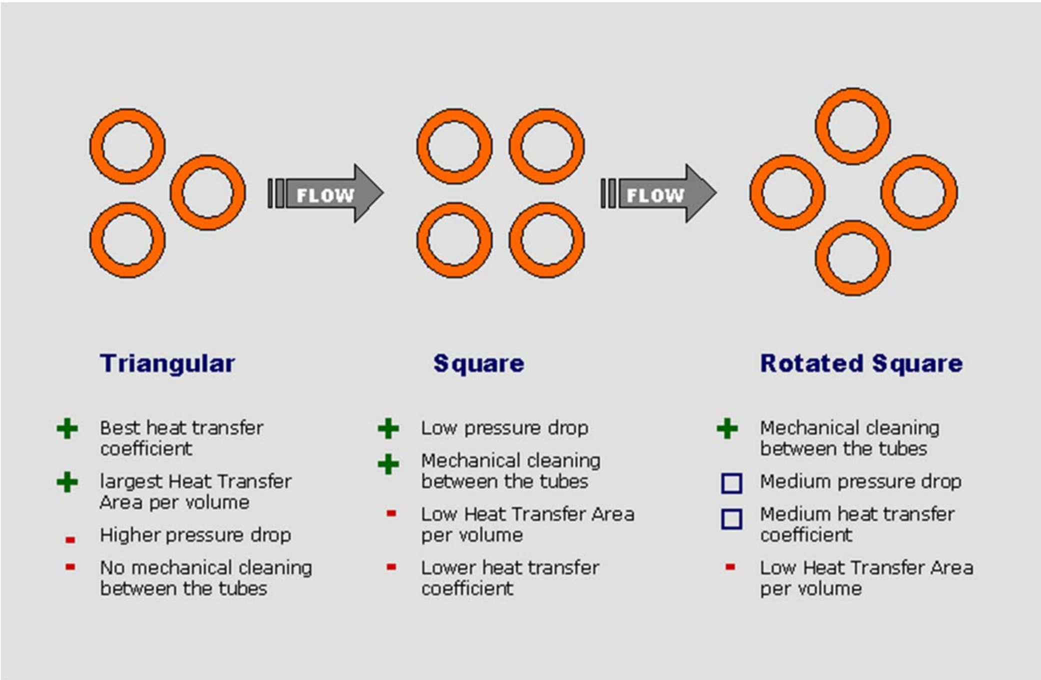


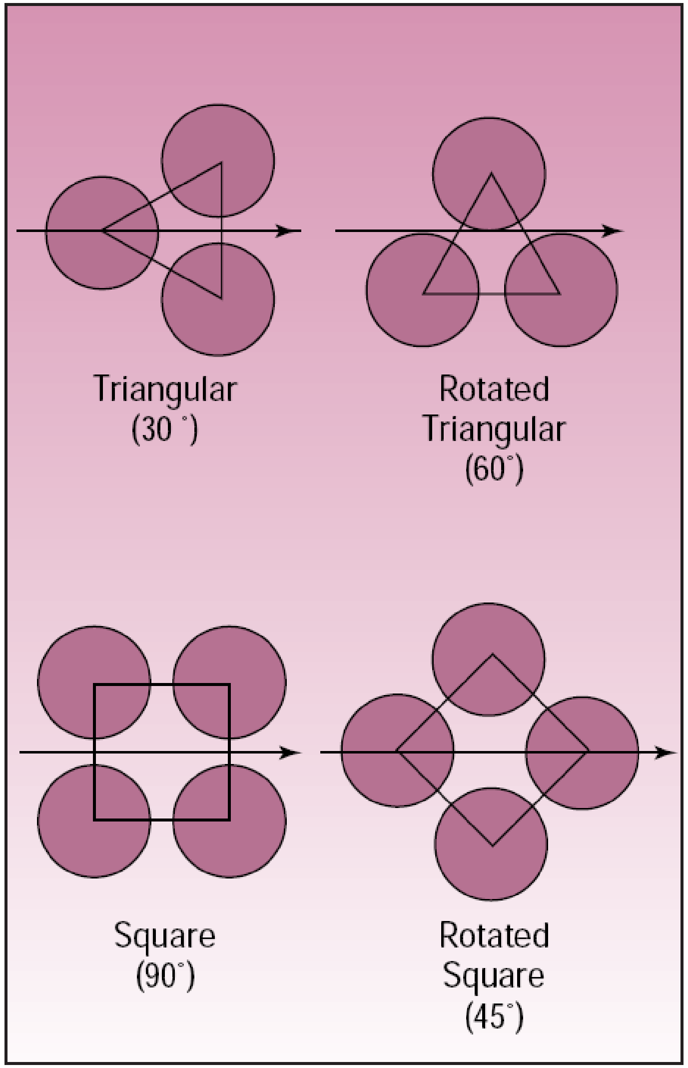
Plate-Baffle

Recuperative HE - Shell and tube HE

Tube pattern

Cleanability
Paramater β
Pressure loss
Heat transfer coefficient





Recuperative HE - Shell and tube HE

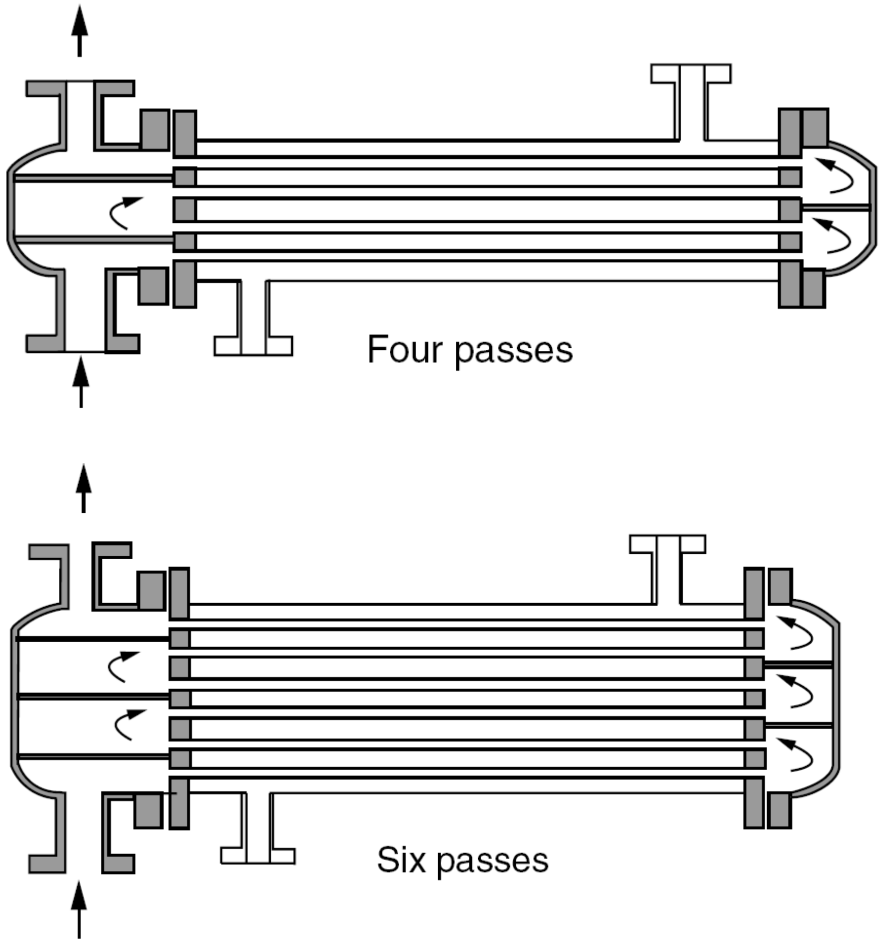
Number of Passes

Number of connected HEs:

Serially
Parallel

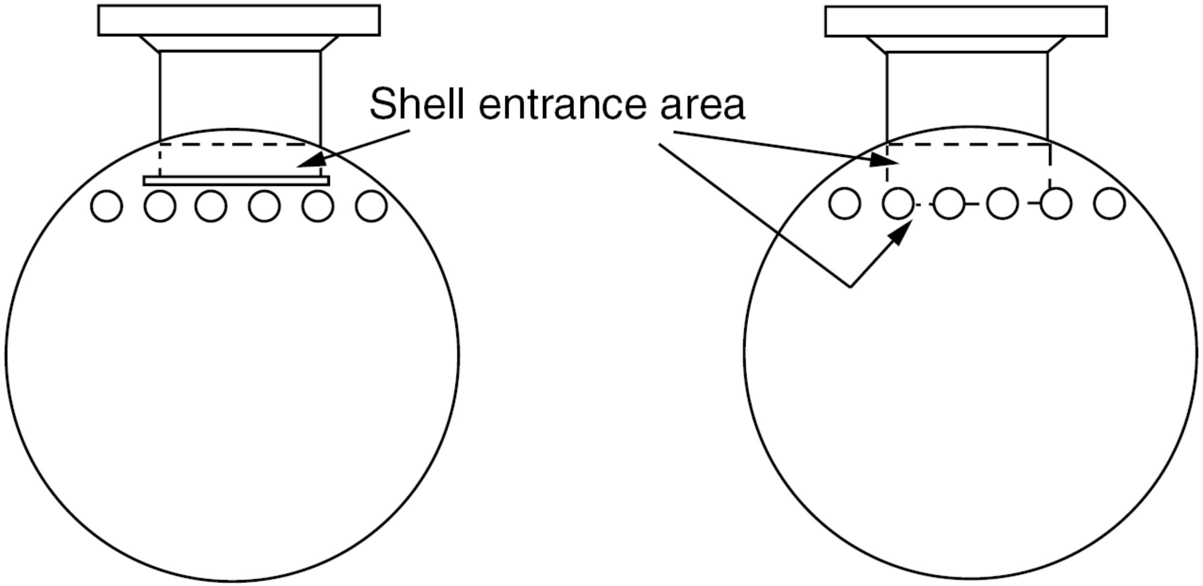
Sealing
Separating
Partition

Calculation of the correction factor F



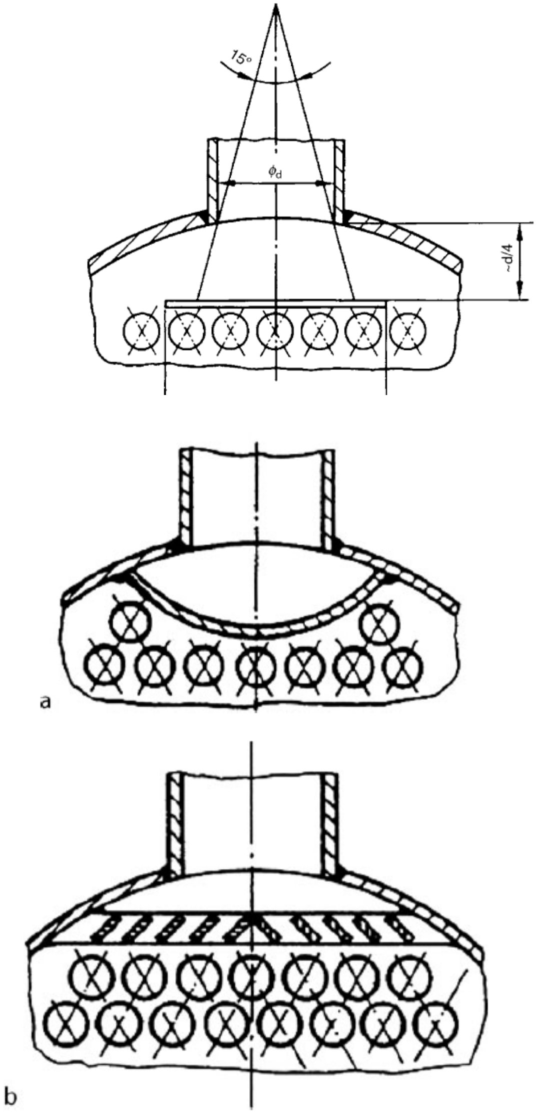
Recuperative HE - Shell and tube HE

Enter Nozzle



With impingement protection

Without impingement protection



TEMA:

$\rho.v^2$ – 740 kg/m.s^2 for media with the presence of particles

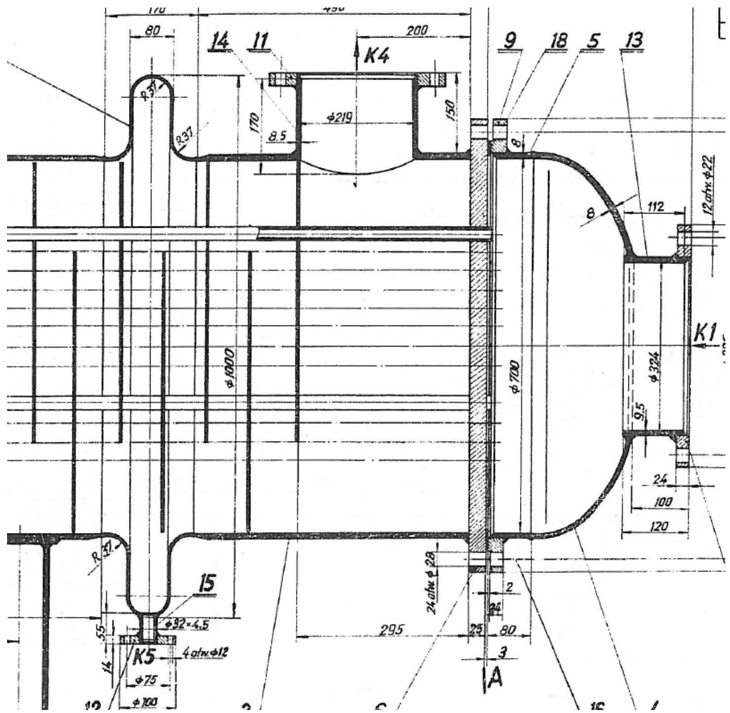
$\rho.v^2$ – 2232 kg/m.s^2 for a particle-free medium

Recuperative HE - Shell and tube HE

Expansion joint

It compensates for the differential thermal expansion of the shell/pipe

↑↑ Tube, ↓↓ Shell ~23 °C
↓↓ Tube, ↑↑ Shell ~83°C

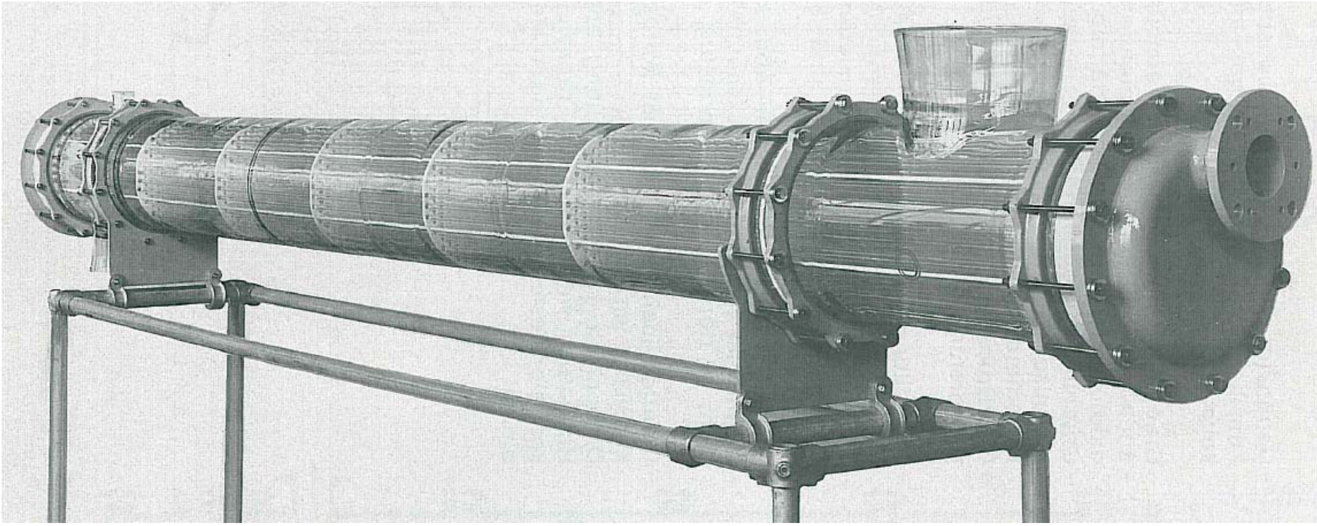


Recuperative HE - Shell and tube HE

Material

Metal materials
-iron
-non-ferrous

Non-metal materials



Recuperative HE - Shell and tube HE

Fouling, Fouling resistance

Suitable heat exchanger
Emphasis on compliance with the correct operating parameters

Fouling factor
Selection of appropriate cleaning/ chemical, mechanical/

Fouling Resistances For Oil Refinery Streams

Crude And Vacuum Unit Gases And Vapors:	
Atmospheric Tower Overhead Vapors	0.001
Light Naphthas	0.001
Vacuum Overhead Vapors	0.002
Crude And Vacuum Liquids:	
Crude Oil	

Recuperative HE - Shell and tube HE

Fouling, Fouling factor



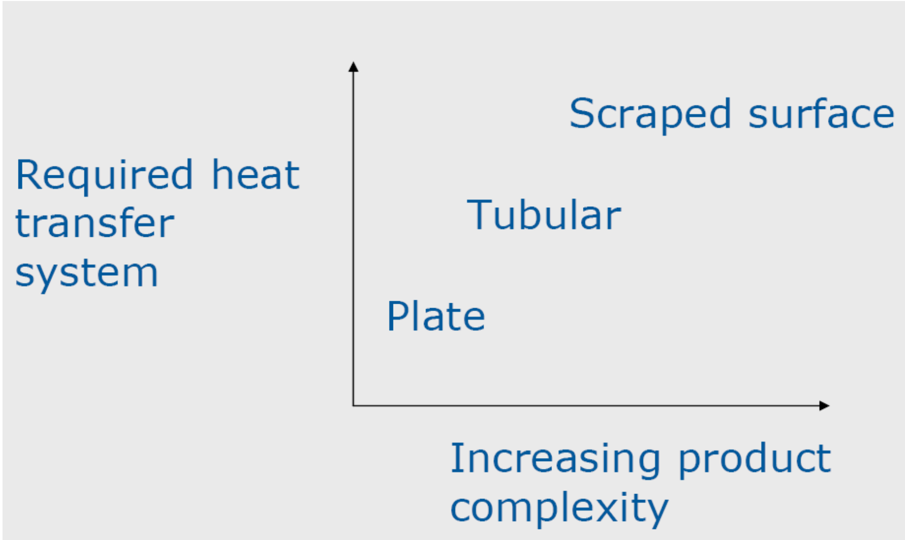

Recuperative HE - Scraped surface HE

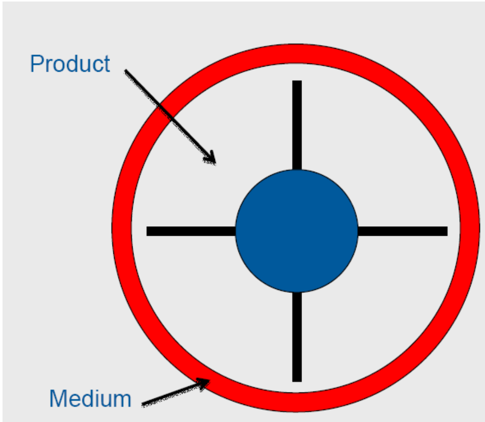
A heat exchanger with a scraped surface - a good solution for heat-sensitive substances (slow heating) but also for substances that are sticky, dense, with the presence of particles, crystallizing
$\beta = 0,6 - 5\ m^2/m^3$,

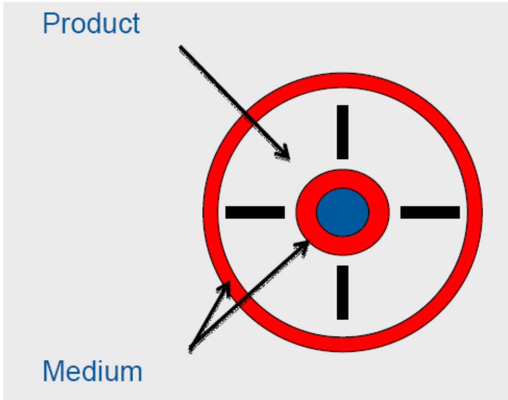
Use in the system:
(l)-(l), (l)-(g),

Advantages:
- For extremely viscous substances
- particles up to approx. 25 mm,
- demountable, /cleanability/.

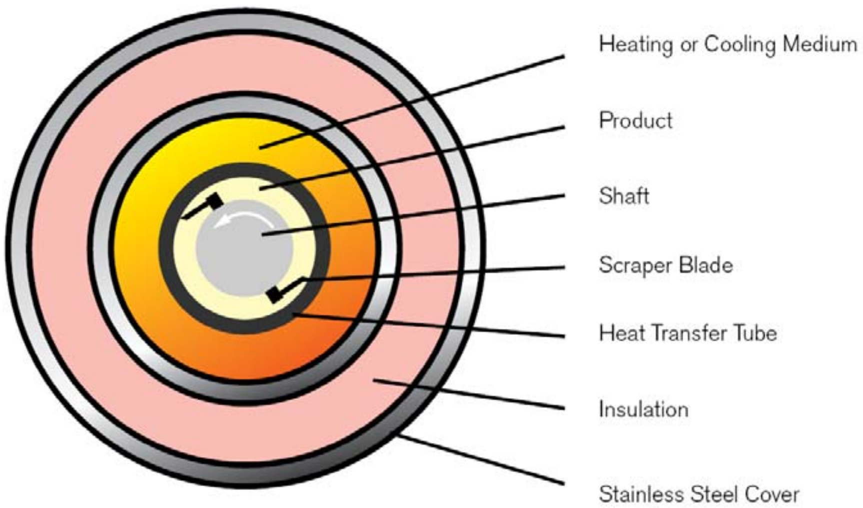
Disadvantages:
- high price, complicated,
- lower max. pressure in the wiped section
- low β,
-requires a motor.

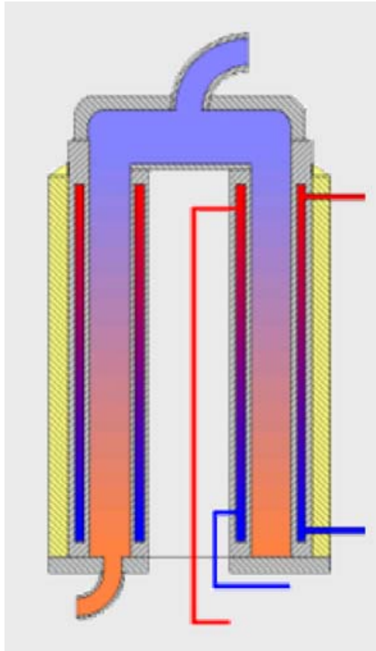


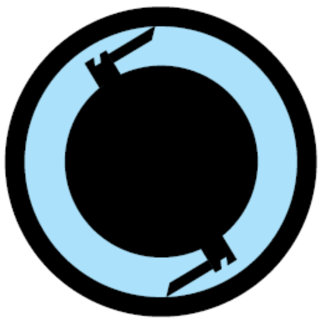




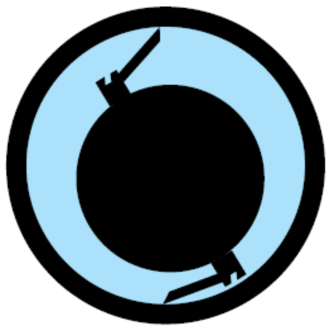
Recuperative HE - Scraped surface HE







CONCENTRIC



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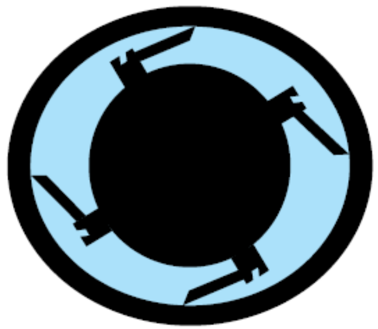
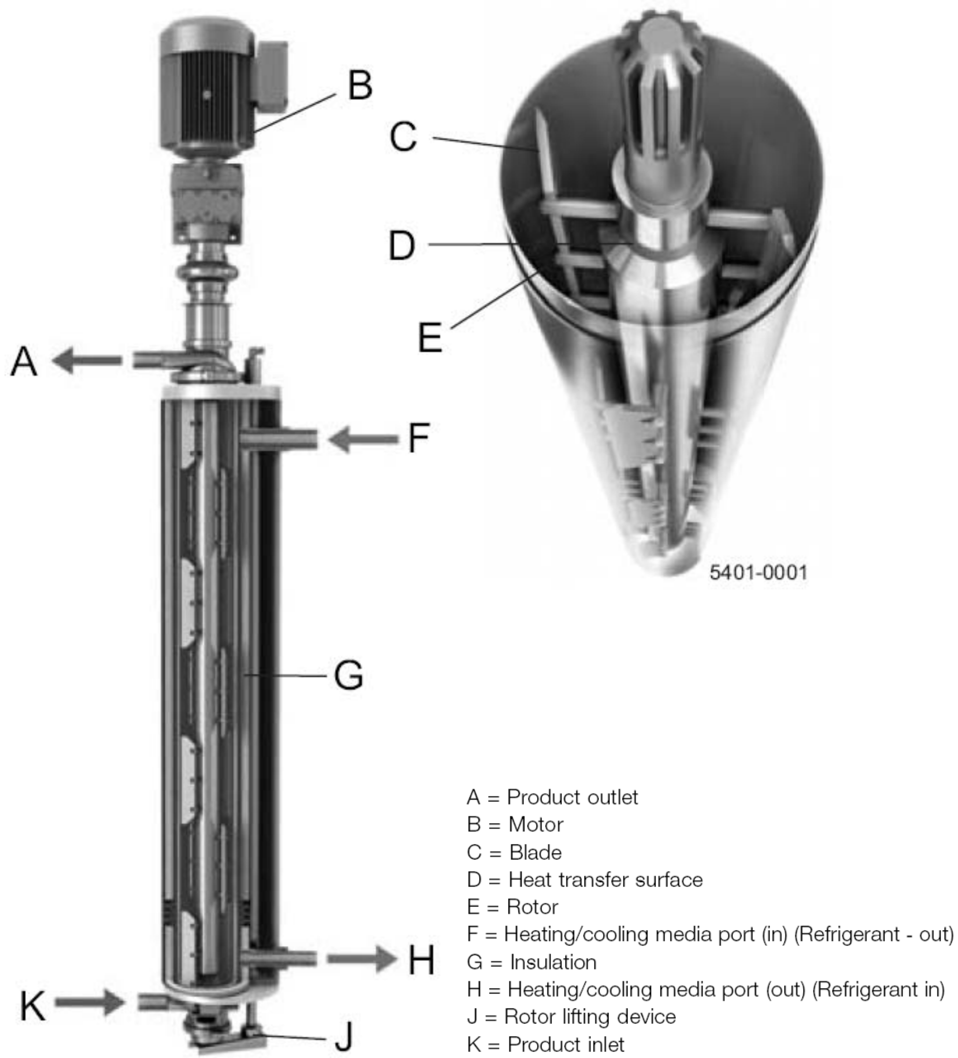


OVAL TUBES

Recuperative HE - Scraped surface HE



Recuperative HE - Plate HE

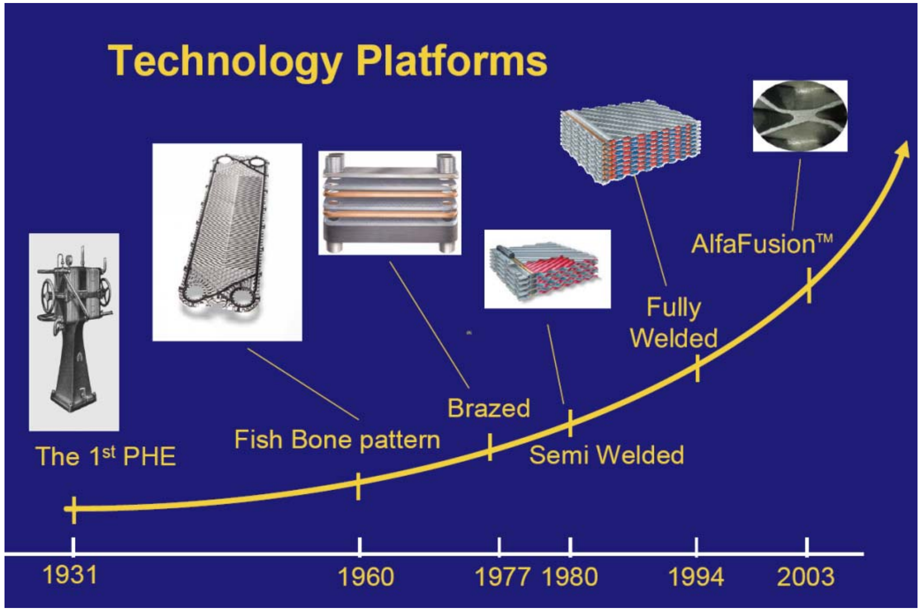
Plate heat exchangers include a wide range of heat exchangers that use a "plate" as a heat exchange surface.

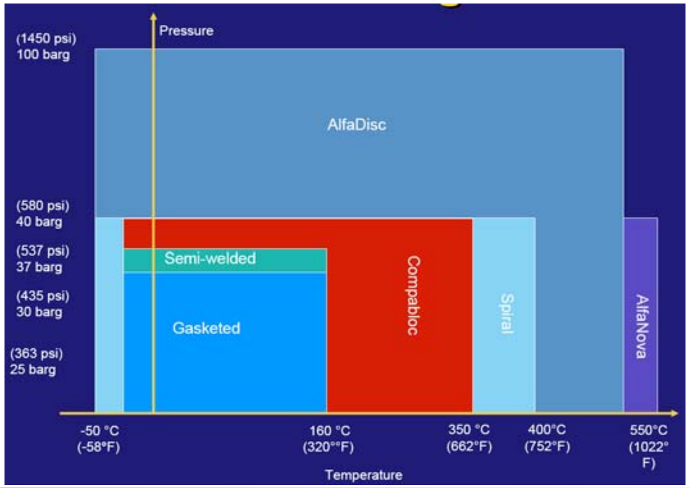
Types:
-removable (with seal)
- not disassembled (without seal)

Plate’s shape:
- rectangular shape
- circular shape

Currently, the most progressive area of HE research and development.

Currently /range of pressures and temperatures/:
p=10 MPa
T=500 °C





Recuperative HE - Plate HE

Patent from 1878 (Germany)

The range of pressures and temperatures normally up to:

p= 0,4 MPa
T= 160 ^{o}C

β: 250-700 m^2/m^3
α: (l)-(l):500-2000 W/m^2K

Gasketed plate heat exchanger /GPHE/

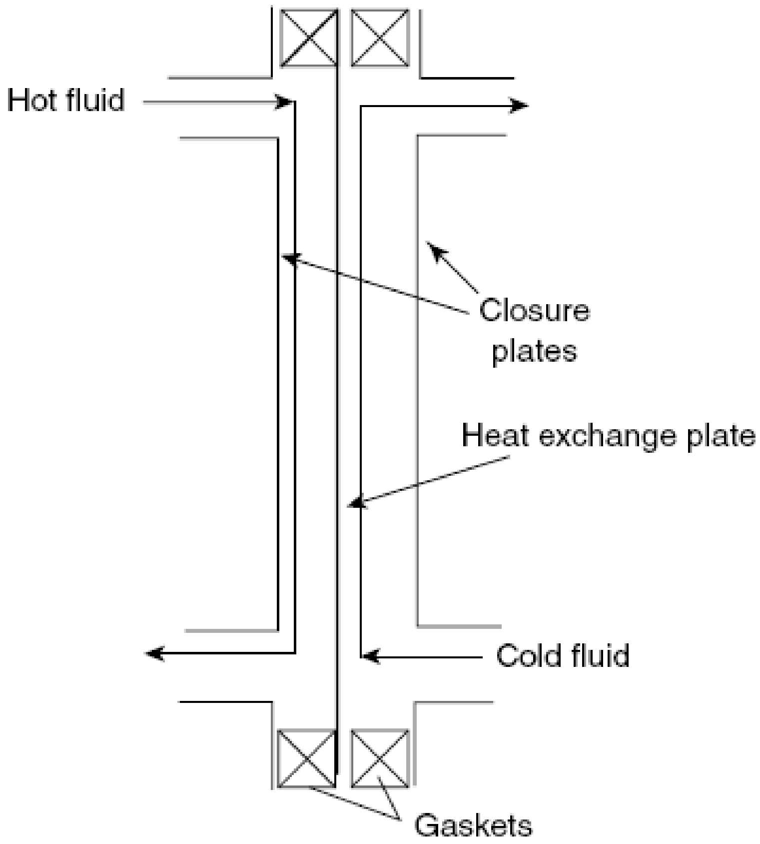
Use in the system:
(l)-(l), (l)-(g), (g)-(l).

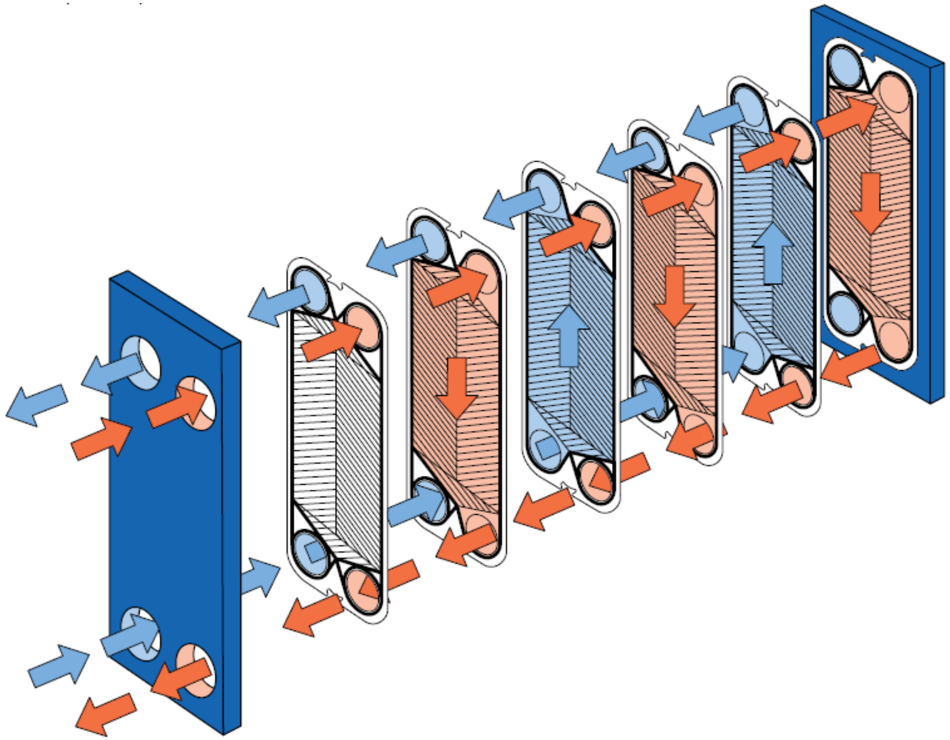
Advantages:
it is possible to increase or decrease the heat exchange surface according to requirements,
the profiling of the plates leads to turbulent flow even at low speeds,
short retention times,
very good cleaning option,
hygienic.

Disadvantages:
limited range of temperatures and pressures (given by the material of the seal and the stiffness of the boards),
sealing (long sealing surfaces).

Recuperative HE - Plate HE

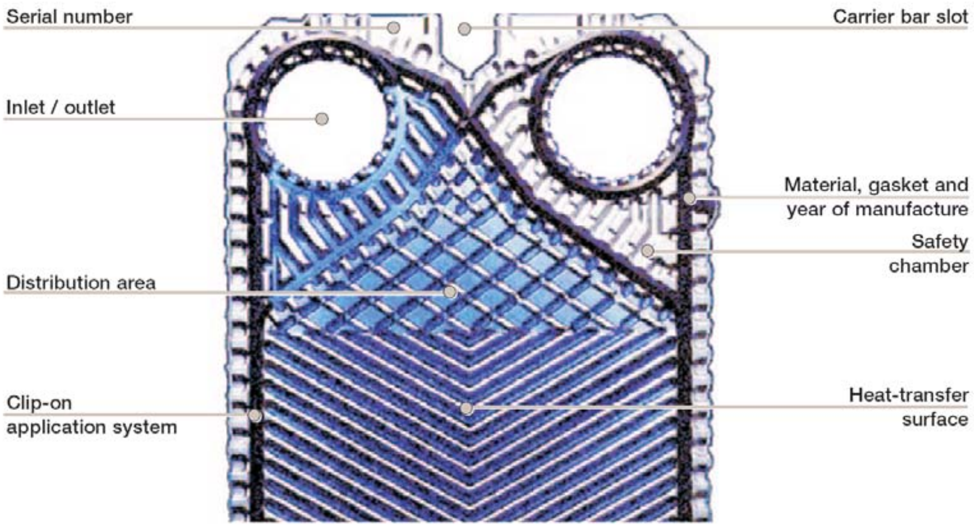
Design

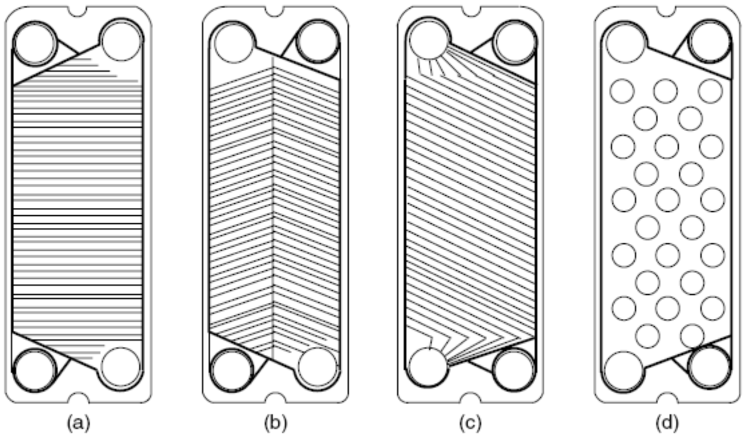


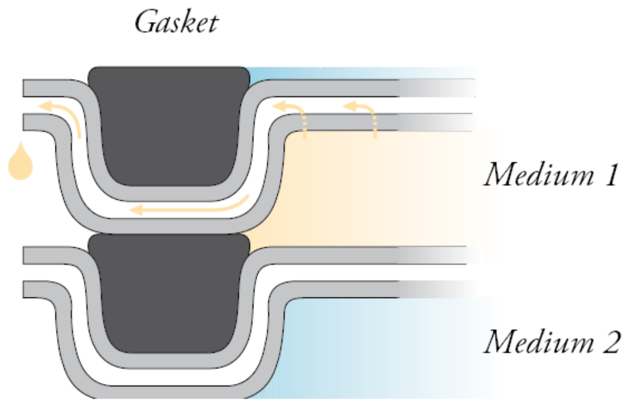


Recuperative HE - Plate HE

Plates

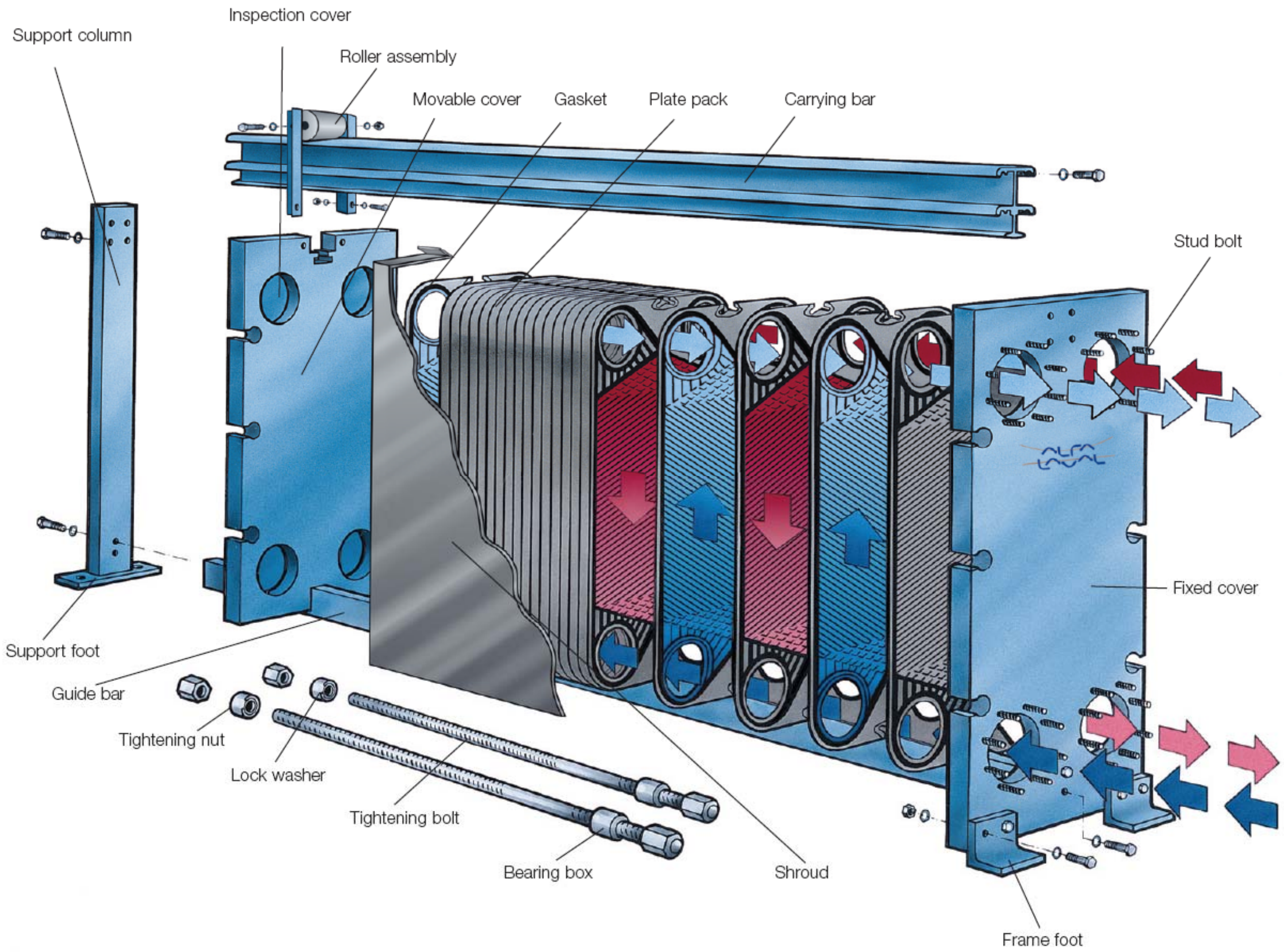


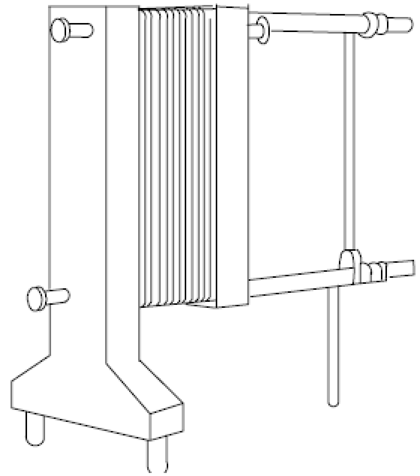


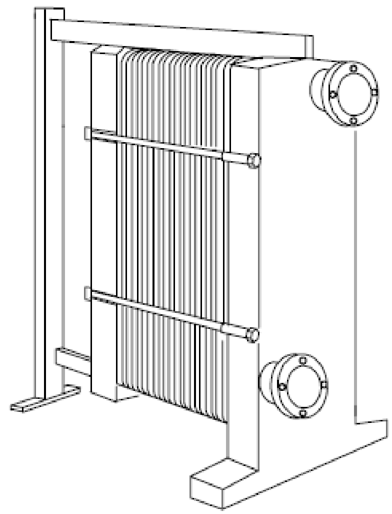


Recuperative HE - Plate HE

Frame

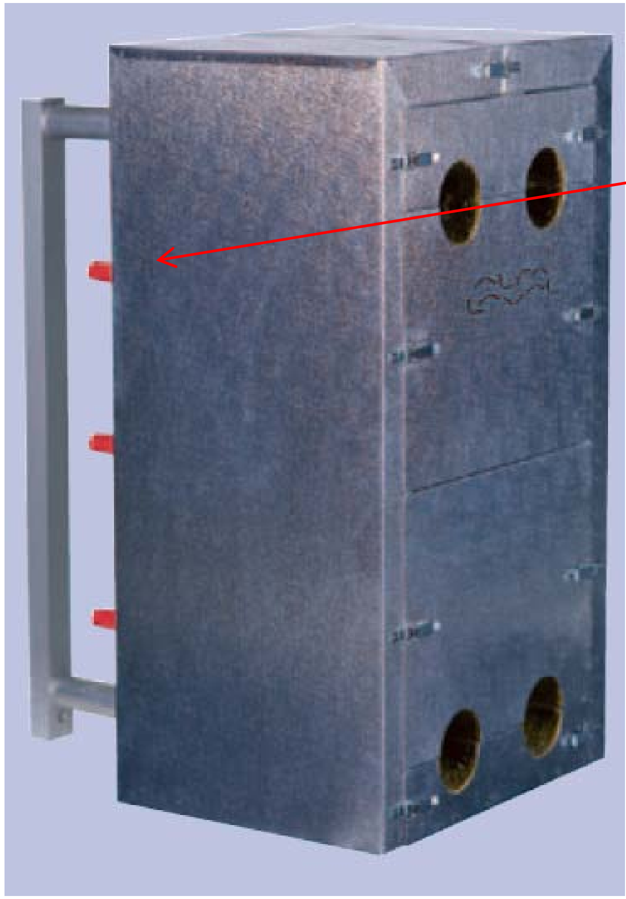






Recuperative HE - Plate HE

Connection, Insulation Frame



Recuperative HE - Plate HE

Alfa-Laval's first brazed HE in 1977

The range of pressures and temperatures normally up to:

p= 30 bar
T= 200 °C / - 190 °C

β - 250-700 m^2/m^3

Braze: Copper

Brazed plate heat exchanger /BHE, BPHE/

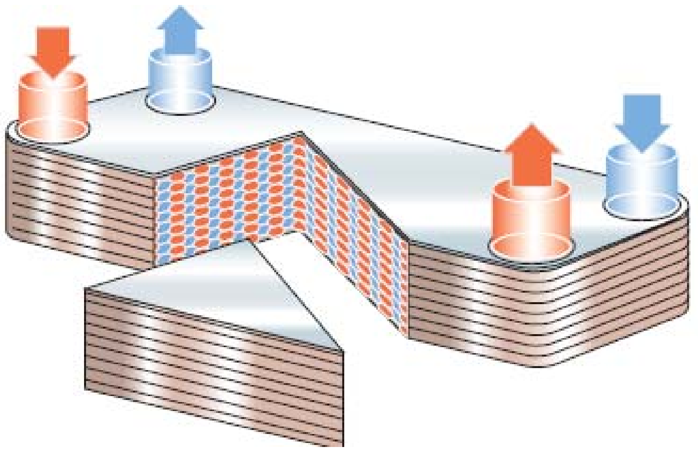
Use in the system:
(l)-(l). Ideal for clean medium

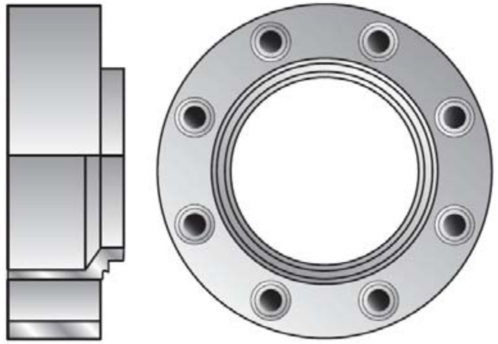
Advantages:
without a seal - reliability,
low price and installation and connection costs,
small built-up area compared to e.g. STHE(10-20%)
minimal maintenance (self-cleaning effect),short retention times,
suitable for cryogenic applications.

Disadvantages:
cannot be disassembled (cleaning only chemically - CIP)
not suitable for media with particles
max. pressures of about 30 bar.
in case of clogging – uncleanable

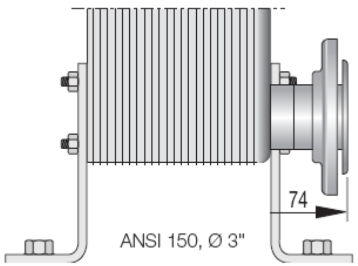
Recuperative HE - Plate HE

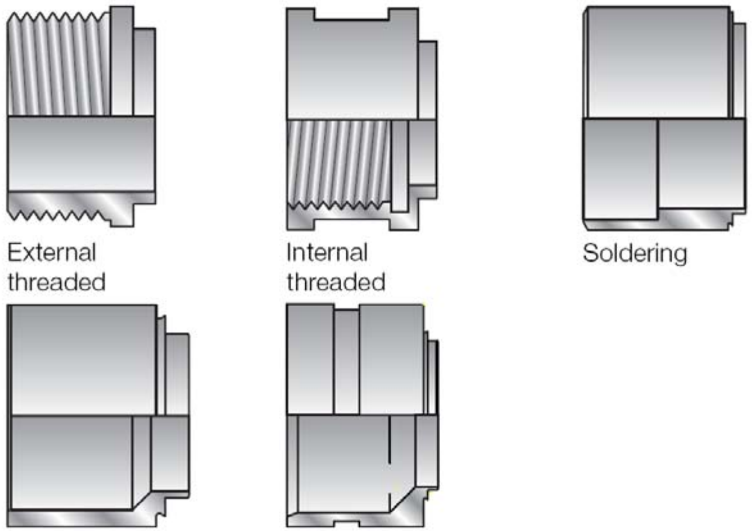
Connection





Compact flanges





External threaded

Internal threaded

Soldering

Welding

Vitaulic

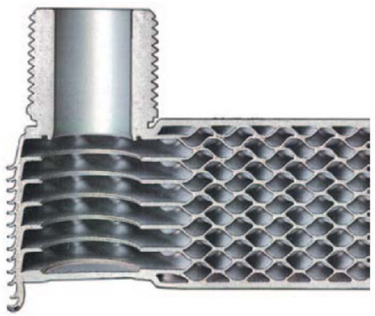
Recuperative HE - Plate HE

All-stainless HE. Significant improvement of brazed HE.

The range of pressures and temperatures normally up to:
p= 40 bar
T= 500 ^{o}C

β - 250-700 m^2/m^3

Alfa – Fusion. technology



Fusion-Bonded plate heat exchanger /FBHE, FBPHE/

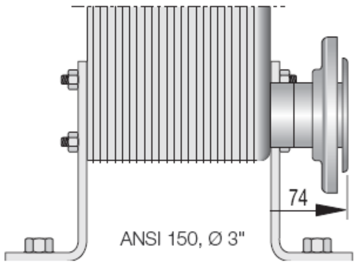
Use in the system:
(l)-(l). Ideal for clean medium

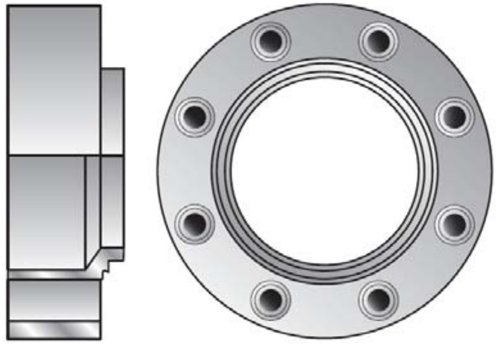
Advantages:
for high temperature applications,
without sealing, without soldering - reliability,
minimal maintenance (self-cleaning effect),
resistance to pressure shocks,
corrosion.

Disadvantages:
cannot be disassembled (cleaning only chemically - CIP)
not suitable for media with particles
in case of clogging – uncleanable

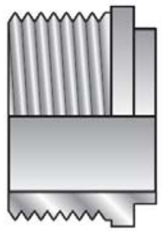
Recuperative HE - Plate HE

Connection

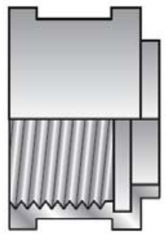




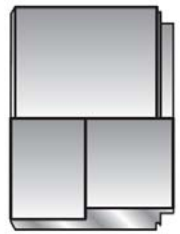
Compact flanges



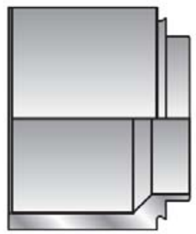
External threaded



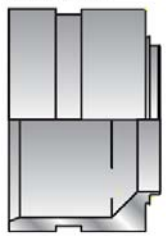
Internal threaded



Soldering



Welding



Vitaulic

Recuperative HE - Plate HE

Welded plate VT.STHE's biggest competitor also in areas of high temperatures and pressures.

The range of pressures and temperatures normally up to:

p= 100 bar
T= 900 ^{o}C

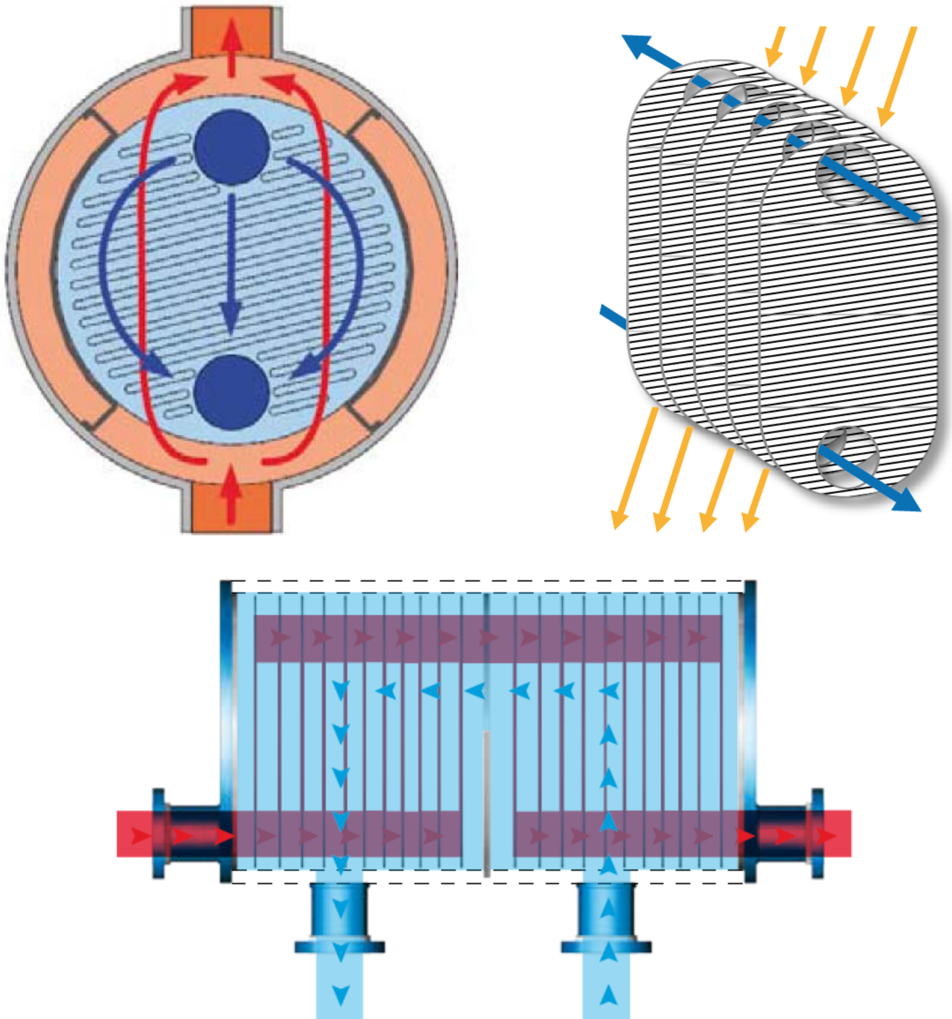
Shell Plate Heat Exchanger /SPHE/

<u>Use in the system:</u>
(l)-(l), (l)-(g).

<u>Advantages:</u>
for high temperature and high pressure applications,
compact,
possibility of cleaning.

Recuperative HE - Plate HE

Design



Shell Plate Heat Exchanger
/SPHE/

Plate:
Circular plates
Oval plates

Recuperative HE - Plate HE

Welded plate VT.STHE's biggest competitor also in areas of high temperatures and pressures.

The range of pressures and temperatures normally up to:

p= 70 bar
T= 350 ^{o}C

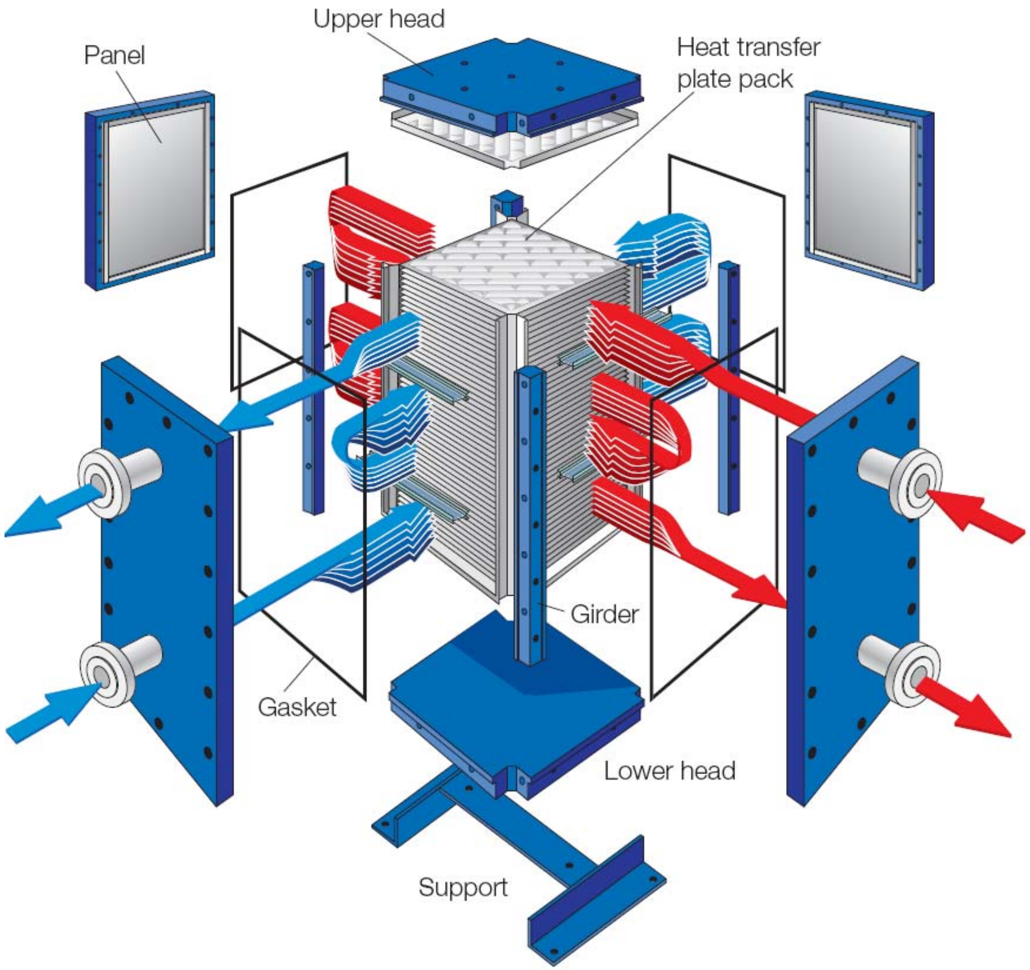
Welded Plate Heat Exchanger /WPHE/

Use in the system :
(l)-(l), (l)-(g).

Advantages :
all the accuracies of the plate heat exchanger for high temperature and high pressure applications,
compact,
1/6 of the built-up area, 1/6 of the weight compared to STHE,
heat exchange area up to 320 m2,
easy cleaning.

Recuperative HE - Plate HE

Design

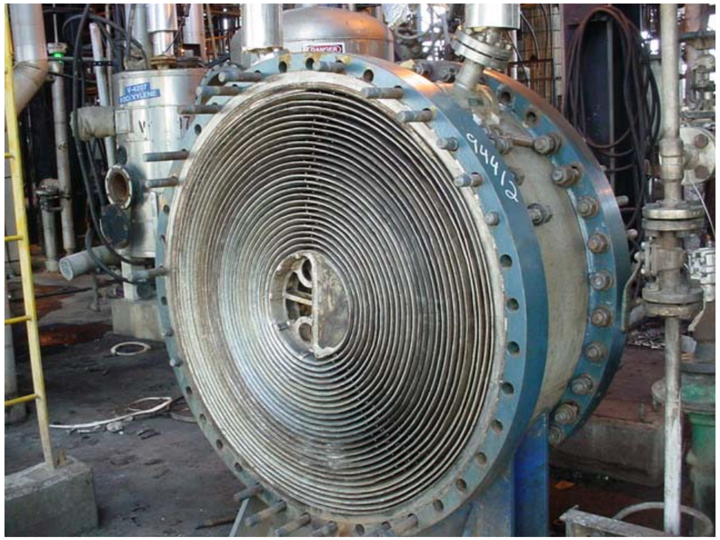


Recuperative HE - Spiral HE

... more than 70 years on the market

The range of pressures and temperatures normally up to:
p= 40 bar
T= 400°C

Indicative values α in system:
(l)-(l): 700-2500 W/m^2K
(l)-(g): 900-3500 W/m^2K



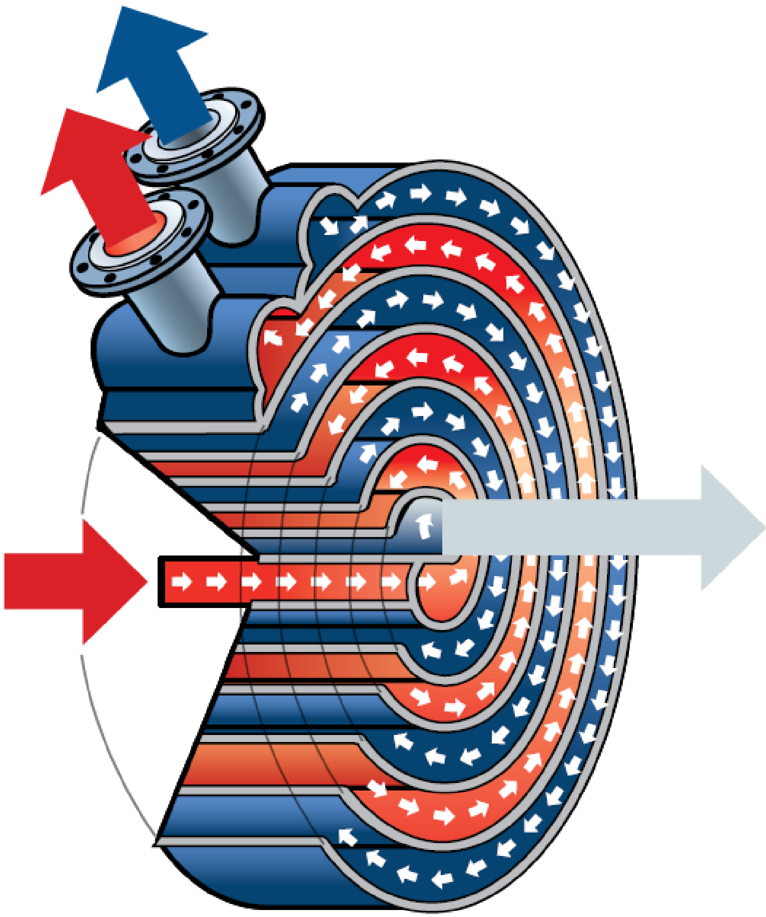
Use in the system :
(l)-(l), (g)-(l)

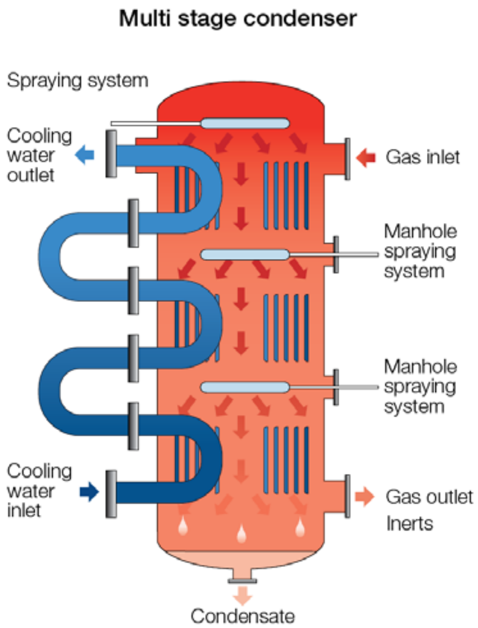
Advantages :
little pollution of the heat exchange surface even with fluids prone to forming deposits,
- possibility of mechanical cleaning,
- no "dead" spots
- high values of heat transfer coefficients.

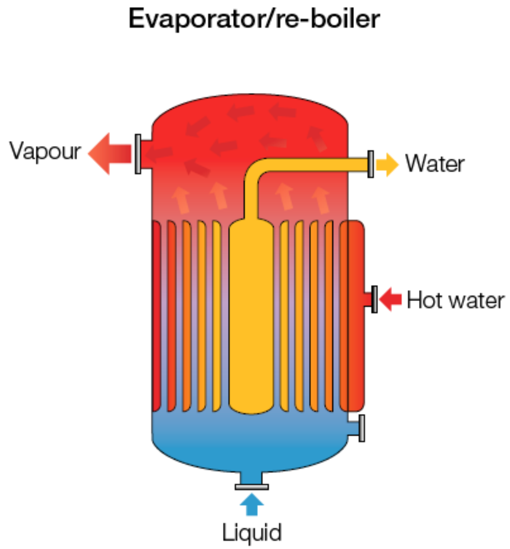
Disadvantages :
limited range of temperatures and pressures,
more demanding production - higher price.

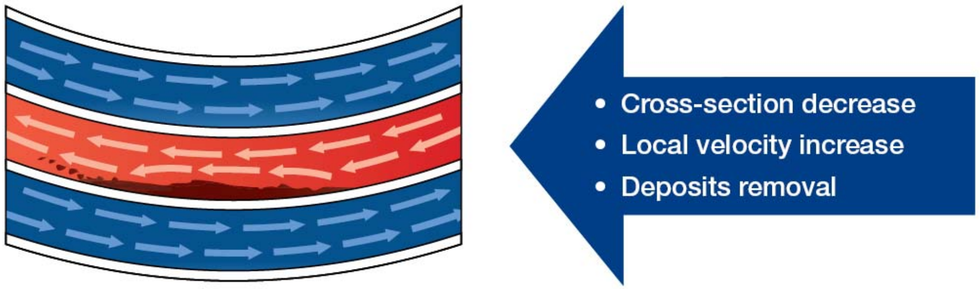
Recuperative HE - Spiral HE

Design









Recuperative HE - Spiral HE

Design

Horizontal
Vertical

Recuperative HE - Air cooled HE

EN: Air cooled HE, Fin Fan HE, ...
The cooling medium is always air blown onto the finned tubes (or perforated block).

The range of pressures and temperatures normally up to:
p= 16 bar (higher for tube)
T= 400°C

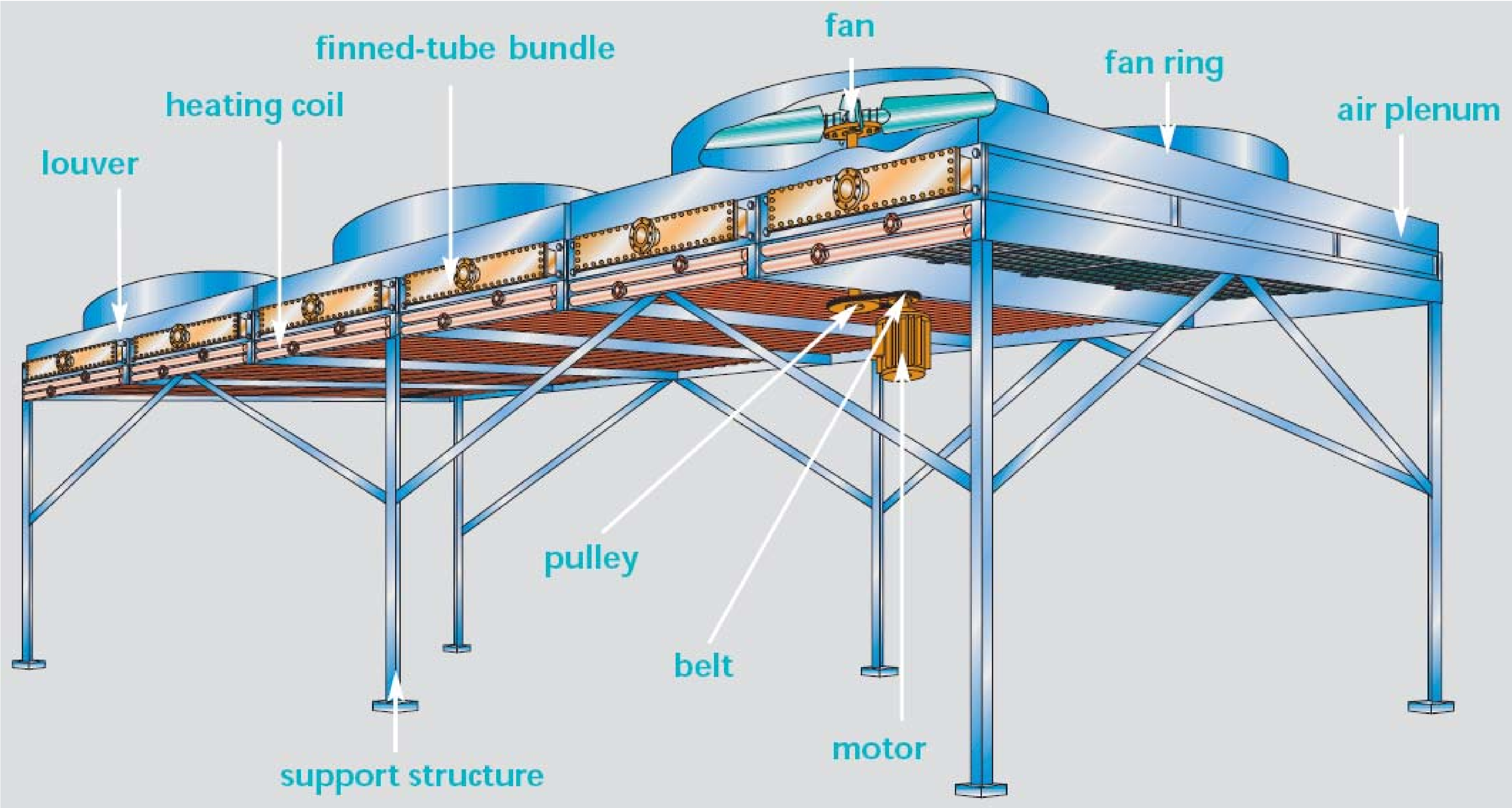
Use in the system :
(l)-(g) – on one side /air, gas/

Advantages :
situations where air is the most economical cooling medium,
also for high pressures,
the possibility of using a wide range of materials for ribs and tubes,
large outputs in MW.

Disadvantages :
restrictions - max. air temperature
more demanding production,
large built-up area,
noise,
low heat transfer coefficients.

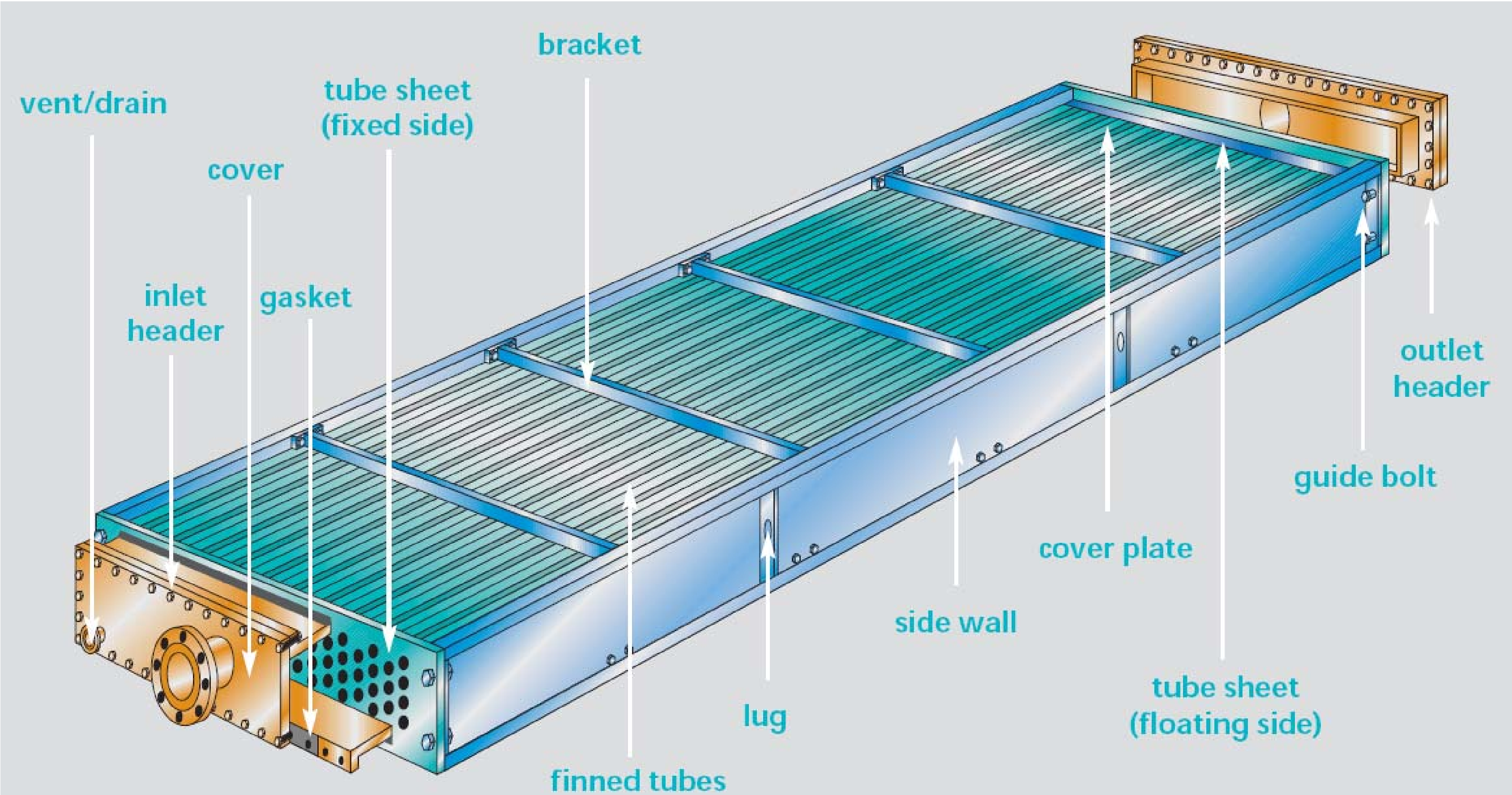
Recuperative HE - Air cooled HE

Basic parts



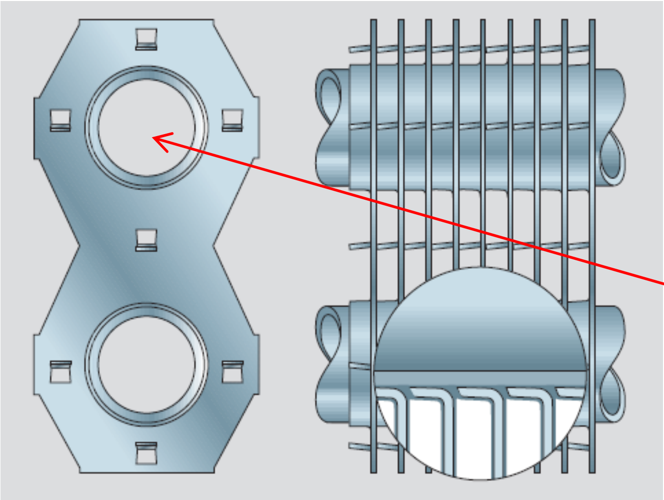
Recuperative HE - Air cooled HE

Basic parts

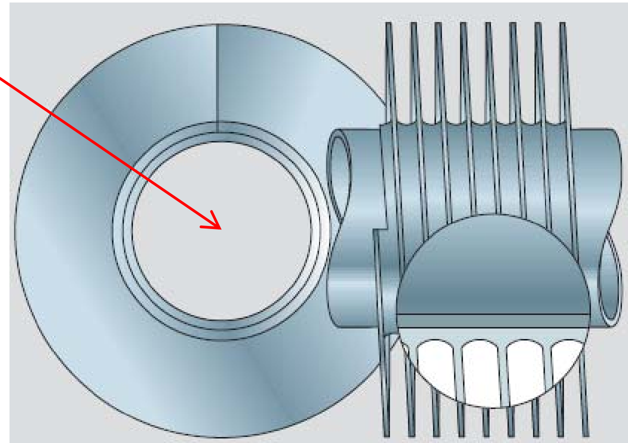


Recuperative HE - Air cooled HE

Heat transfer surface

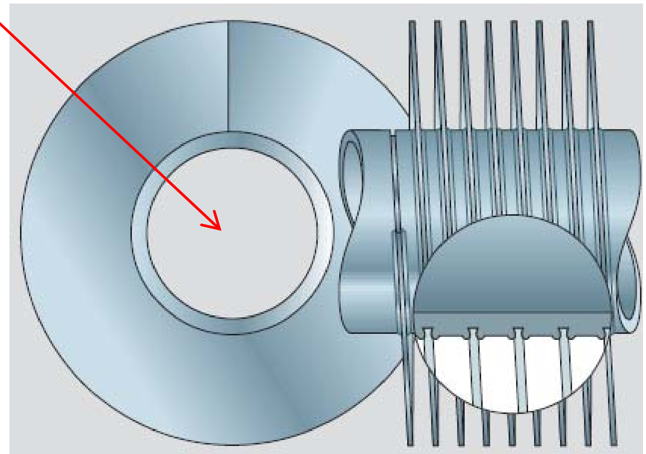


Tube: bez obmedzenia
Ribs: Al
T= 250°C

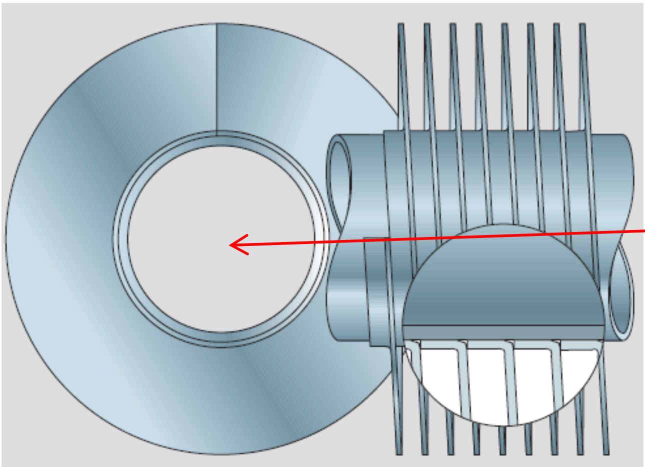


Tube : SS
Ribs : SS
T= 360°C

Tube : SS
Ribs : Al
T= 400°C

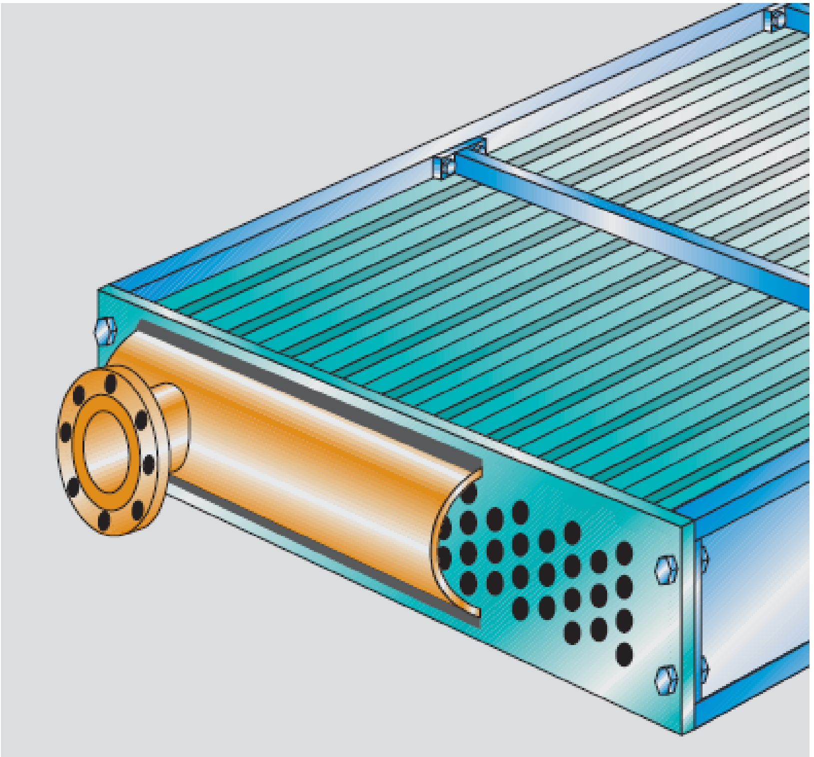


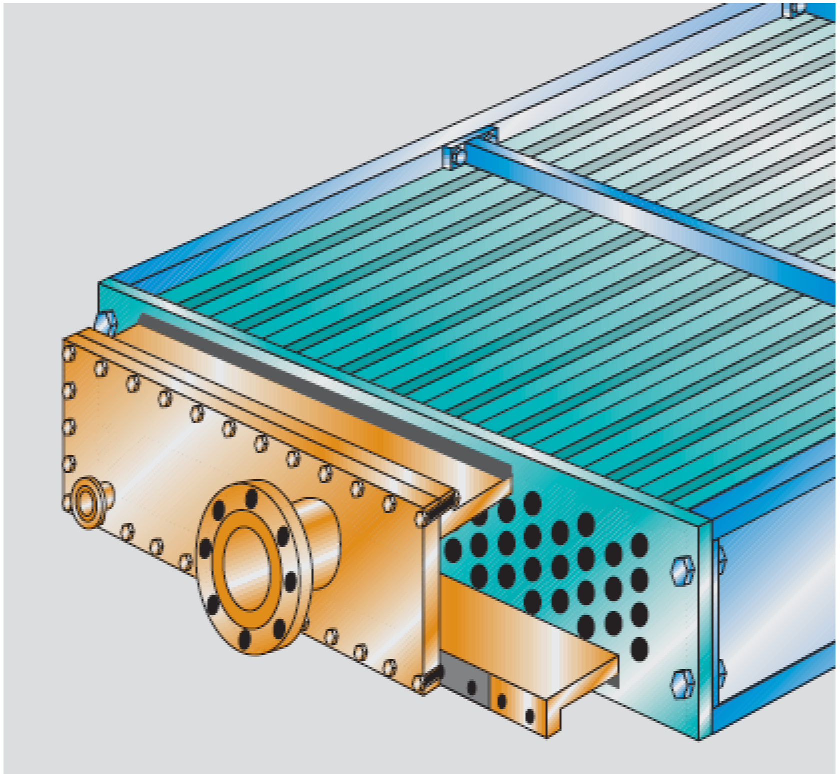
Tube : -
Ribs : Al
T= 130°C



Recuperative HE - Air cooled HE

Tubesheet - Distributor





Design of distributor:
demountable
demountable (without the possibility of cleaning the pipes)

Recuperative HE - Heating coil

EN: Heating Coil,

The range of pressures and temperatures normally up to:
p= 120 bar
T= 600°C

β- 10 m^2/m^3

Indicative values α in system:
(l)-(l): 700-2500 W/m^2K
(l)-(g): 900-2500 W/m^2K

<u>Use in the system :</u>
(l)-(g), (l)-(l), kond.

<u>Advantages :</u>
simple production,
variable and high α.
(questionable is α on the other side)

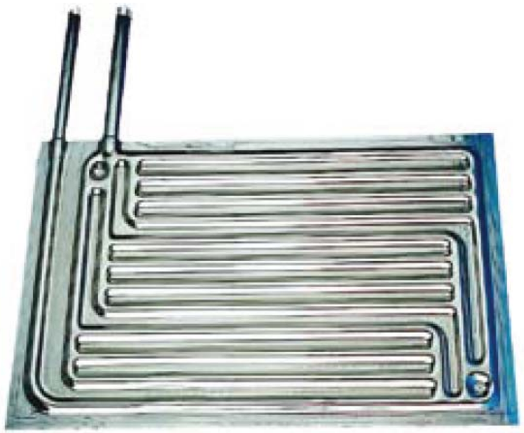
<u>Disadvantages :</u>
higher pressure loss,
small mass flows,
installed inside the device / cleaning problem/ .

Recuperative HE - Platecoil

EN: Heating Coil,

The range of pressures and temperatures normally up to:
p= 20 bar.
T= 250°C

β- 50 or more m^2/m^3

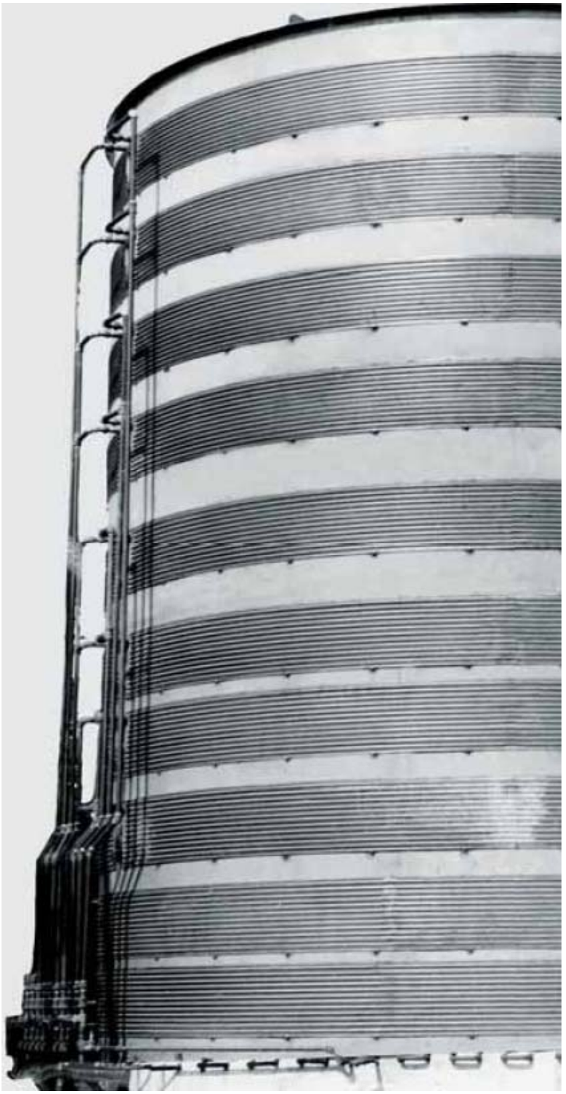


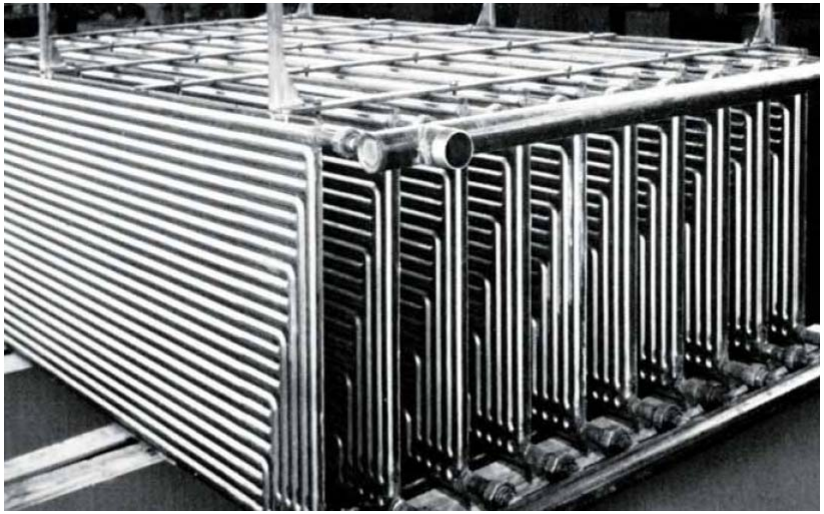
Use in the system :
(l)-(g), (l)-(l), kond.

Advantages :
variable
will adjust as needed

Disadvantages :
higher pressure loss,
small mass flows,

Recuperative HE - Platecoil





Recuperative HE - Block HE graphite

EN: Block HE,

The range of pressures and temperatures normally up to:
p= 6 bar
T= 200°C

β- 10 a viac m^2/m^3

<u>Use in the system:</u>
(l)-(g), (l)-(l)
extremely corrosive environment

<u>Advantages :</u>
applications where no other material can be used

<u>Nevýhody:</u>
high price
for lower pressures

Recuperative HE - Block HE graphite