Good Practice For Heat Exchanger Selection And Design.

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Introduction

A Quiz is an unconventional yet effective methodology, to enlighten the reader (audience) and provide influential training on known subject. The same technique has been successfully experimented, in the past on courses such as *"Information required for good HX design"* and *"Steps for designing Shell and tube heat exchanger"*. It is our endeavour to use this technique to make the same topics more interesting and challenging to the reader (audience). This can be accomplished by, participation of reader (audience); by answering the questions during reading (training). (Instead of a long story, 'told by the speaker' or 'written in the book'.)

"Information required for good HX design" explains the importance of heat transfer and vibration fundamental, heat exchanger parts selection, practical values of HTC, TEMA[1], mechanical design constraint, fabrication issue, transport and piping limitation. (Instead of just designing HX in isolation, using any software.)

"Steps for designing Shell and tube heat exchanger" explains the step by step procedure, for selection and design of HX; covering detail methodology of analyzing HX design, using manual techniques in conjunction with HTFS+ software.

"Lesson Learned : Real life examples"

1) BEM type HX was used, where shell side mechanical cleaning was required. (BEM is fixed tube-sheet HX.) Usage of 'software default values' can be Dangerous!
2) Many times, certain users uses NTIW (No Tubes In Window) for removing any tube vibration; even without trying changing baffle spacing / cut or using double segmental baffle or changing tube pitch or increasing tube pitch ratio or increasing tube diameter or tube thickness. Penalty of using NTIW is bigger shell diameter. (Expensive, more space and heavier.)
3) Try to utilize full ΔP by putting 8 tube passes in 2ft diameter HX. This gives huge pass partition leakage (F) and thus poor heat transfer at shell side. In this case mechanical design is more difficult and expensive.
4) Usage of correct shell, head types and other component not understood correctly.
5) Less awareness about special types of HX and HX components for special applications. Examples : Hair pin HX, spiral baffle, twisted tubes, tubes with insert, rod baffle.
6) For TEMA and tube vibration, JUST depend on software!!!
7) Results with NO ERRORS – Design is perfect!!!

To overcome above situation, one should have Sound knowledge and good experience on this subject. Traditional way to achieve sound knowledge and good experience on this subject are :

- ✓ Above can be achieved by reading various books and articles.
- ✓ And working with experience person on many projects.

HTFS+ gives new break through method, to substitute above traditional method. Using following HTFS+ tools, one can gain excellent knowledge and good experience.

- o Most important and valuable is "Aspen HTFS Research Network information"
- o HTFS+ / Tasc+ Help
  - ✓ HTFS+ Advisory messages and Operation Warning
  - ✓ HTFS+ Warning and Error messages
  - ✓ HTFS+ Input range checking warning or error
- o HTFS+ Manuals
- o Knowledge base site
- o Web seminar
- o Power point / training presentation on Knowledge base site

Aspen HTFS Research Network has HTFS Handbook, HTFS Design Reports, HTFS Research Reports and HTFS HEATFLO HTFS Tools. DR – 18 Part 1 has selection of type of heat transfer equipment. DR – 18 Part 2 (Selection and preliminary design of shell and tube heat exchangers) has following topics.

- ✓ Allocation of fluid
- ✓ Selection of shell type
- ✓ Selection of Front and rear End Head type
- ✓ Selection for mechanical cleaning requirement
- ✓ Selection of exchanger Geometry
- ✓ Re-boilers
- ✓ Quick sizing of heat exchangers

Great details on vibration theories and fundamentals can be fond out in DR48 (Tube vibration in shell and tube heat exchangers) and HTFS Handbook Volume 3, Chapter V.

"Information required for good HX design"

Following are ten important facts; one has to be aware of for designing good HX. A bracket value indicates importance of each item.

1. **$$** Fundamentals of heat transfer and vibration theory. **(20 %)**
2. **$$** Knowledge of heat exchanger parts and selection and other types of HX available in market. **(20 %)**
3. Practical values of fouling factor, HTC and heat flux. **(10 %)**
4. Familiarity with TEMA[1] standard. **(10 %)**
5. Project specific guide lines such as DEP and Saudi Aramco (engineering standards). **(10 %)**
6. Mechanical design constraints and fabrication issues. **(5 %)**
7. HX piping, material availability and cost. **(5 %)**
8. Layout and other constraints. **(5 %)**
9. **$$** HX cleaning and maintenance issues. **(5 %)**
10. **$$** Software knowledge. (HTFS+) **(10 %)** (Manuals and Help)

$$: Aspen HTFS Research Network and Advisory message

"Steps for designing Shell and tube heat exchanger"

1. Understand the Process / Application in detail.
2. Collect all required data.
3. Analyze the data.
4. Before you start software, know your answer first !!!!
5. Find out overall heat transfer coefficient (U) for that application from past projects, books, literature or internet.
6. Similarly, check the values of fouling factor from TEMA[1], books or literature.
7. Draw the temperature profile on piece of paper. Check whether heat transfer is possible or not?
8. Do quick hand calculations for heat duty, LMTD, surface area and utility flow rates. (Or use Hysys or Aspen +)
9. Spend some time for selection of HX components and MOC based on service / application.
10. Do fluid allocations to shell side and tube side.
11. Check mechanical cleaning requirements, if any.
12. Check layout and piping constraints (e.g. space required for bundle removal and cleaning.)
13. Check weight constraints for type of crane available in existing plant.
14. Check for fabrication or transportation issues.
15. Analyze the control philosophy for various cases (e.g. startup, turn down)
    After going through all above steps, start designing the HX using HTFS+ software. Before issuing data sheet to vendor, once again check your HX design with respect to above '15 points'.

- Do one more run in rating mode, by putting fouling factor zero and check followings ..
    - ✓ If tube to shell metal temperature difference of 50ºC (90ºF) or more, then it indicates requirement for *Expansion joint or floating head*, in hot service.
    - ✓ And % over design

- Do one more run in simulation mode, putting fouling factor zero and check following
    - ✓ What is outlet conditions for both sides, process and utility. This will help you, for *selecting good control scheme.*
    - ✓ If you have multiple case, then check multiple cases using this approach.

Quiz :

The following twenty questions **initiate** the HX designer to think on various aspects, as mentioned in *"Information required for good HX design"* and *"Steps for designing Shell and tube heat exchanger"*.

Question 1 : Which are the two major differences IN DESIGN METHOD, between HTFS+ (Tasc+) and Text book method ?

Hint – Heat Transfer Coefficient and Pressure drop.

Answer 1 :
a) HTFS+ (Tasc+) calculates HTC and ΔP in small increments, throughout tube length, shell diameter and tube rows. The text book method calculates overall HTC and ΔP for entire heat exchanger. HTC and ΔP varies with change in velocity and fluid property. Fluid property varies with temperature. Velocity can change due to change in liquid fraction or change in fluid density. Thus HTFS+ calculates fluid property and velocity in every small increment and calculates local HTC and ΔP for that increment. Finally HTFS+ integrates HTC and ΔP for entire heat exchanger.

B) The Text book method does not account for any fluid leakages for HTC and ΔP calculations as compared to HTFS+ (Tasc+) method. HTFS+ determines actual flow passing through the tube bundle and other leakages as listed below. HTFS+ use actual flow going through the tube bundle for HTC and ΔP calculations instead of using total shell side flow rate.

(Cross flow : 30 to 70%
Window flow = Cross flow + C + pass partition leakage
Baffle hole – tube OD : Primary leakage stream - A
Baffle OD – Shell ID : Secondary leakage stream - E
Shell ID – Bundle OTL : By pass stream - C
Pass lanes : Bypass flow in pass partition lanes)

Question 2 :

What is Ft (LMTD correction factor) ?
What is the significance of Ft factor ? (What does it indicate?)
What are the allowable values for Ft ?
What is the measure of a LOW Ft factor ?

Answer 2 :

LMTD formula assumes pure countercurrent flow. Ft is correction factor, on LMTD for co-current and cross-flow heat exchangers. Ft is one for pure countercurrent flow. Minimum value of Ft should be between 0.9 and 0.95. Ft is a measure of heat transfer efficiency and temperature cross. A low value of Ft indicates reverse heat flow in some part of the exchanger.

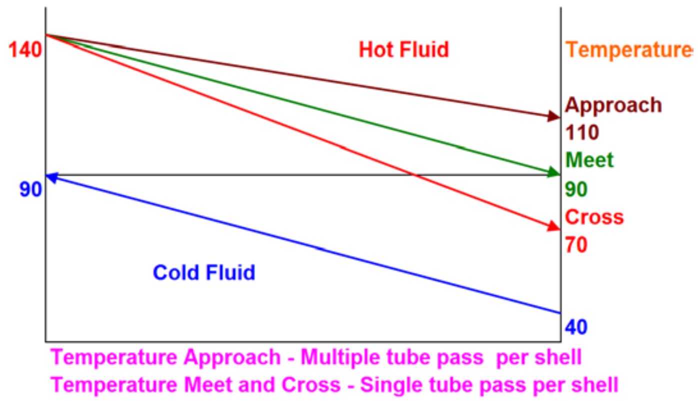

Figure 1. Different temperature profiles in heat exchanger

Following are different solution for reverse heat flow or temperature cross.

- Use one tube pass per shell (Pure counter current).
- Use shells in series.
- Use F, two pass shell. (Two exchangers in series can be modeled in one shell.)
- Double pipe or hair pin heat exchanger. (Good model for exchangers in series.)
- Change temperature levels (e.g. change cooling water return temperature to 35°C instead of 38°C).
- Change utility (e.g. use chilled water instead of cooling water).

Question 3 : Place following applications in sequence from lowest U at top and highest U at bottom.

U – Overall heat transfer coefficient

- Air cooler : Condensation of low Pressure steam
- S & T : Shell side – Atm Gas and Tube side – Liquid
- S & T : Shell side – Steam and Tube side – HC Boiling
- S & T : Shell side – Liquid and Tube side – Liquid

Answer 3 : Lowest U at top and highest U at bottom.

U – Overall heat transfer coefficient, W/m².K

- S & T : Shell side – Atm Gas and Tube side – Liquid (15 – 70)
- S & T : Shell side – Liquid and Tube side – Liquid (150 – 1200)
- Air cooler : Condensation of low Pressure steam (700 – 850)
- S & T : Shell side – Steam and Tube side – HC Boiling (900 – 3000)

(Source for U value : http://www.cheresources.com/uexchangers.shtml)

Applied process design for chemical and petrochemical plants, Volume 3, chapter 10, (Heat Transfer) has given wide rage of U values for different applications and different types of heat exchanger.

To answer question from 4 to 6, refer TEMA[1] Figure N-1.2.

Question 4 : Match Front heads with correct application. (From HTFS+ DR18 Part2)
(Cleaning means mechanical cleaning)

- A — Tube side high pressure : 200 barg
- B — One tube pass exchanger
- C — Tube side Hazardous & Shell side clean
- N — Tube side dirty
- D — Tube side clean
- Conical — Shell Side frequent cleaning compared to tube side cleaning

Answer 4 : Following Front heads are matched with correct application.

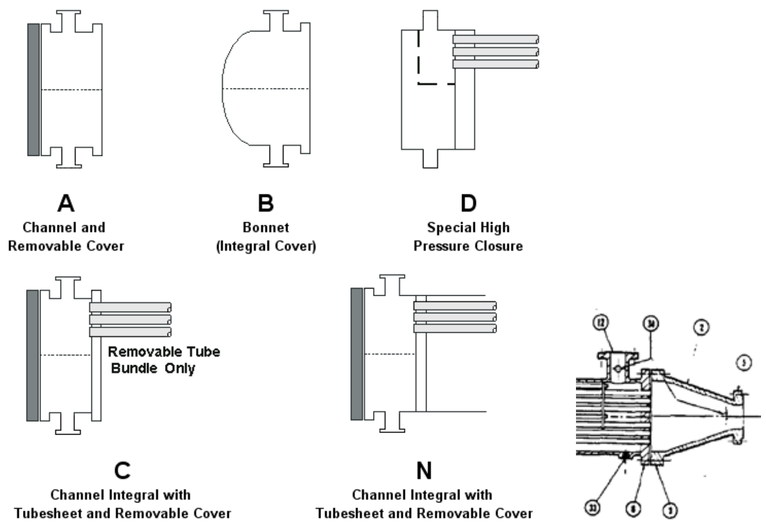

Figure 2. Different Front end heads

- A		Tube side dirty
- B		Tube side clean
- C		Shell side frequent cleaning compared to tube side cleaning
  (Removable shell for hazardous tube side fluid.)
- N		Tube side Hazardous & Shell side clean
- D		Tube side high pressure : 200 barg (>150 barg)
- Conical		One tube pass exchanger

Question 5 : Match Rear heads with correct application. (From HTFS+ DR18 Part2)
(Cleaning means mechanical cleaning)

- L		Not suitable for hazardous / high P on any side
- S		Tube side is clean
- T		Shell side : HCl & Tube side : CW (No mixing)
- U		Removal bundle (Shell side dirty)
- W		Shell side is clean
- Double Tube sheets		Kettle re-boiler

Answer 5 : Following Rear heads are matched with correct application.

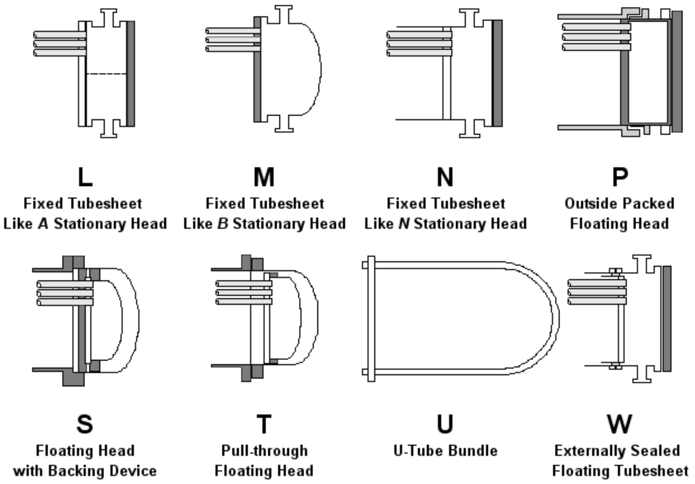

Figure 3. Different rear end heads

- L		Shell side is clean
- S		Removal bundle (Shell side dirty)
- T		Kettle re-boiler
- U		Tube side is clean
- W		Not suitable for hazardous / high P on any side
- Double Tube sheets Shell side : HCl & Tube side : CW (No mixing).

Question 6 : Place following shells in sequence from highest ΔP at top and lowest ΔP at bottom at shell side.

- X
- E
- J
- H
- G

Answer 6 : Highest ΔP at top and lowest ΔP at bottom at shell side.

- E is one pass shell with multiple cross flow baffles
- J is divided flow shell with multiple cross flow baffles
- G has single split flow at shell side, has no cross flow baffles
- H has a double split flow at shell side, has no cross flow baffles
- X is pure cross flow heat exchanger (has no cross flow baffles)

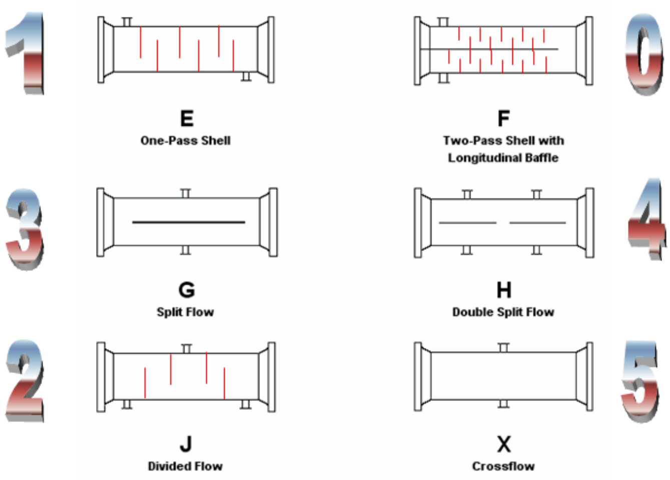

Figure 4. Shell side pressure drop decreasing from '0' to '5'

Question 7 : Make fluid allocation either at shell side Vs Tube Side

- 60 bar H_2 and cooling water
- Sour Naphtha and sea water
- Tar and steam
- Thermo-siphon re-boiler - HC and Steam
- Gas condensation with cooling water

Answer 7 : Fluid allocation – shell side Vs Tube Side

- Tube side 60 bar H_2 and Shell side cooling water (High pressure fluid at tube side is good for mechanical design.)
- Sour Naphtha and sea water – ANY (Both are corrosive so any combination can work. More information on temperature, pressure and fouling is required to make correct selection.)
- Tube side Tar and shell side steam (Viscous or dirty service at tube side, for easy mechanical cleaning.)
- Thermo-siphon re-boiler - HC and Steam (Fluid allocation depends on HX orientation.)
- \- Horizontal Type – HC at Shell side and steam at tube side
- \- Vertical Type – HC at Tube side and steam at shell side
- Gas condensation on shell side, for easy removal of condensate and reduce two phase pressure drop. Cooling water at Tube side to obtain higher HTC and easy mechanical cleaning at tube side.

Question 8 : Which of following shell/s can not be used for thermo-siphon re-boiler ?

- E
- F
- G
- H
- J
- X
- K

Answer 8 : Following shells can not be used for thermo-siphon re-boiler.

- F is two pass shell with longitudinal baffle, can not be used for thermo-siphon re-boiler
- K is kettle type re-boiler should be used for pool boiling and acts as vapor liquid separator device.

(Following shells **can be** used for thermo-siphon re-boiler.

- E can be used for vertical thermo-siphon re-boiler
- G, H, J & X can be used for horizontal thermo-siphon re-boiler **)**

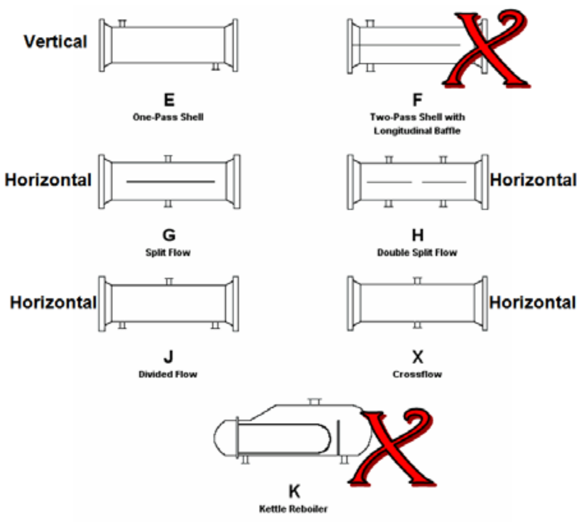

Figure 5. Shells suitable for thermo-siphon re-boilers

Question 9 : Place following re-boiler in sequence from lowest % vaporization at top and highest % vaporization at bottom.

- Kettle re-boiler
- Horizontal Thermo-siphon re-boiler
- Vertical Thermo-siphon re-boiler
- Forced re-boiler

Answer 9 : Re-boiler types in sequence from lowest % vaporization at top and highest % vaporization at bottom.

- Vertical Thermo-siphon re-boiler (< 30)
- Horizontal Thermo-siphon re-boiler (< 40)
- Forced re-boiler (Can be anywhere 25 - 60)
- Kettle re-boiler (> 60)

Question 10 : Place following service in sequence from lowest fouling factor at top and highest fouling factor at bottom.

- Naphtha from naphtha hydrotreater
- Treated boiler feed water
- Heavy fuel oil
- DEG and TEG solution
- Vacuum Tower Bottoms
- Atmosphere tower bottoms

Answer 10 : Following service in sequence from lowest fouling factor at top and highest fouling factor at bottom.

- Treated boiler feed water – 0.001
- Naphtha from naphtha hydrotreater – 0.002
- DEG and TEG solution - 0.002
- Heavy fuel oil – 0.005 – 0.007
- Atmosphere tower bottoms – 0.007
- Vacuum Tower Bottoms – 0.01

(Source : TEMA. Fouling factor in ft².h.°F/Btu)

Question 11 : Which of the following item/s are not important for REBOILER selection and design?

- Viscosity
- Fouling
- % vaporization

- Heat flux
- HTC
- Tube length
- Space availability
- Vapor Shear enhancement
- Static height
- Density
- Pressure drop
- Two phase Flow regime
- Delta T between Shell side and tube side
- Turn down and startup issues

Answer 11 : "Vapor Shear enhancement" is only used for condenser design, **not for** re-boiler deign. So except "Vapor Shear enhancement", all items are important for REBOILER selection and design.

- Viscosity (Determines forced versus thermo-siphon re-boiler.) For a viscosity grater than 2cP, forced type re-boiler is used.
- Fouling (Requirement of mechanical cleaning.)
- % vaporization (Type of re-boiler, refer question 9)
- Heat flux (Based on fluid service and type of re-boiler, heat flux should be within particular rage.) 2,000 – 30,000 Btu/ft^2.h
- HTC (Based on fluid service and type of re-boiler, HTC should be within particular rage.) 200 – 1,000 Btu/ft^2.h.°F
- Tube length (Type of re-boiler and pressure drop). For vertical thermo-siphon re-boiler maximum tube length recommended is 20 ft and normal tube length can be from 8 to 12 ft.
- Space availability (Selection of re-boiler orientation - horizontal versus vertical)
- Static height (Determines flow circulation and boiling point.)
- Density (Mixture density at re-boiler outlet is critical for thermo-siphon re-boiler.)
- Pressure drop (Critical for thermo-siphon re-boiler. Thermo-siphon versus Forced type re-boiler selection)
- Two phase Flow regime (Performance of re-boiler is indirectly depend on flow regime at outlet of re-boiler.) Annular flow is generally recommended.
- Delta T between Shell side and tube side (Decides natural convection, nucleate boiling, transition or film boiling.)
- Turn down and startup issues (Very critical for thermo-siphon re-boiler design.)

Question 12 : Match the following

• Viscosity	Vibration
• Specific heat	Two phase flow regime
• Thermal conductivity	Heat Duty
• Surface tension	Heat transfer coefficient
• Density	Pressure drop

Answer 12 : Following are matched

• Viscosity	Pressure drop
• Specific heat	Heat Duty
• Thermal conductivity	Heat transfer coefficient
• Surface tension	Two phase flow regime
• Density	Vibration

Question 13 : Due to tube vibration, which things can occur ?

- Baffle cutting
- Tubes whirling
- Shell to nozzle leakage
- Tube fatigue
- Tube sheet leakage
- Tube expansion

- Tube collision
- Tube cutting
- Sound from HX
- HX support fails
- HX vibration

Answer 13 : Due to tube vibration, following things can occur.

- Baffle cutting
- Tubes whirling
- Tube fatigue
- Tube sheet leakage
- Tube collision
- Tube cutting
- Sound from HX
- HX vibration

(Due to tube vibration, following things **can not** occur.

- Shell to nozzle leakage can not occur due to tube vibration.
- Tube expansion is not affected by tube vibration but it can occur due to high temperature difference between shell side fluid and tube side fluid.
- HX support can not fail due to tube vibration, but it can fail due to incorrect mechanical or piping design.**)**

Question 14 : In which scenarios vibration can occur ?

- Ratio of baffle tip velocity to critical velocity greater than two.
- Cross flow amplitude exceeds 15% of tube gape.
- Cross flow grater than 5200 kg/ms^2.
- Chen number less than 1000
- Baffle spacing less than shell diameter
- Tube pitch ratio less than 1.5
- Tube frequency match with external frequency
- Shell side liquid velocity greater than 6 m/s

Answer 14 : In the following scenario vibration **can** occur.

- Ratio of baffle tip velocity to critical velocity greater than **<u>one</u>**.
- Cross flow amplitude exceeds **<u>10%</u>** of tube gape.
- Cross flow grater than 5200 kg/ms^2.
- Tube frequency match with external frequency

The following criteria **do not** necessarily indicate vibration.

- Chen number less than 1000
- Baffle spacing less than shell diameter
- Tube pitch ratio less than 1.5
- Shell side liquid velocity greater than 6 m/s

Question 15 : Which of the following item/s can reduce vibration possibility.

- Decrease tube diameter
- Increase tube thickness
- Decrease delta T between shell and tube side
- Decrease tube pitch ratio
- Decrease tube side flow rate
- Increase number of cross passes
- Use support baffles
- Decrease baffle cut

- Use Rod baffle
- Use floating head exchanger
- Use FIVER baffle
- Use J Shell

Answer 15 : Following item/s can reduce vibration possibility.

- Increase tube thickness
- Increase number of cross passes (Increase tube support)
- Use support baffles
- Use Rod baffle
- Use FIVER baffle
- Use J Shell

Following **does not** reduce vibration possibility.

- Decrease tube diameter
- Use floating head exchanger
- Decrease delta T between shell and tube side
- Decrease tube pitch ratio
- Decrease tube side flow rate
- Decrease baffle cut

Question 16 : In TEMA[(1)] '**R**-6.33' or '**CB**-6.33', indicates what ?

Answer 16 : Alphabet '**R**' specifies that paragraph is written for TEMA[(1)] class '*R*' exchanger. Alphabet '**C**' & '**B**' specifies that paragraph is written for TEMA[(1)] class '*C*' & '*B*' exchangers.

Question 17 : Which of the following items are addressed by TEMA[(1)] ?

- Mean metal temperatures of shell and tubes
- Effects of fouling
- Disassembly for inspection or cleaning
- Ft (LMTD correction) charts
- Fluid property tables and graphs (density, specific heat)
- Conversions
- Chart for solving LMTD formula
- Tube natural frequency
- Flow induced vibration.
- Recommended U
- Fouling table
- General formula to calculate U

Answer 17 : TEMA[(1)] covers the following things.

- Mean metal temperatures of shell and tubes (Section 7, T-4)
- Effects of fouling (Section 7, T-2.2)
- Disassembly for inspection or cleaning (Section 4, E-4.12)
- Ft (LMTD correction) charts (Section 7, Figure T-3.2A to Figure T-3.2M)
- Fluid property tables and graphs (density, specific heat) (Section 8)
- Conversions (Section 9, Table D-15)
- Chart for solving LMTD formula (Section 7, Figure T-3.1)
- Tube natural frequency (Section 6, V-5)
- Flow induced vibration. (Section 6)
- Fouling table (Section 10, RGP-T-2.4)
- General formula to calculate U (Section 7, T-1-3)

- **(Recommended U is not given in TEMA)**

Question 18 : In which conditions TEMA[1] is not applicable ?

- Tube length greater than 40 ft (12.2 m)
- Shell ID greater than 100 inch
- Hair pin heat exchanger
- Diesel boiler
- Vertical reflux condenser
- Tubes with inserts
- Design pressure greater than 3000 PSI (206.8 bar)
- Spiral baffle
- HX greater than 500 tons
- Tube sheet greater than 5 inch thick

Answer 18 : TEMA[1] **can not** be used for ….

- Shell ID greater than 100 inch
- Diesel boiler
- Design pressure greater than 3000 PSI (206.8 bar)

(TEMA[1] **can** be used for ….

- Tube length greater than 40 ft (12.2 m)
- Hair pin heat exchanger
- Vertical reflux condenser
- Tubes with inserts
- Spiral baffle
- HX greater than 500 tons
- Tube sheet greater than 5 inch thick **)**

Question 19 : Which of the following tables can be found in TEMA[1] ?

- Minimum shell thickness
- Number of tie rods and tie rod diameter
- Tube frequency table for different MOC
- Standard cross baffle and support plate clearance
- Baffle or support plate thickness
- Minimum tube sheet thickness table
- Tube thickness table
- Maximum unsupported straight tube spans
- Tube hole diameter and tolerances
- Minimum number of supports

Answer 19 : TEMA[1] has the following tables ….

- Minimum shell thickness (Table R-3.13 & CB-3.13)
- Number of tie rods and tie rod diameter (Table R-4.71, CB-4.71)
- Standard cross baffle and support plate clearance (Table RCB-4.3)
- Baffle or support plate thickness (Table R-4.41, CB-4.41)
- Tube thickness table (Table RCB-2.21)
- Maximum unsupported straight tube spans (Table RCB-4.52)
- Tube hole diameter and tolerances (Table RCB-7.41)

(TEMA[1] Eighth Edition, 1999)

TEMA[1] **does not have** the following **tables** ….

- Tube frequency table for different MOC
- Minimum tube sheet thickness table
- Minimum number of supports

Question 20 : Match the following HX / HX device with appropriate application.

HX / HX device	Application
Spiral baffle	De-bottlenecking of existing HX, by increasing shell side heat transfer coefficient.
Two HX in series	Condenser requires huge sub cooling. (First for condenser and second for sub-cooling.)
Reducing baffle spacing	For condenser HTC can be improved by vapor shear enhancement outside the tubes.
Stub in re-boiler	Small heat duty for column re-boiler.
Hair pin exchanger	For temperature cross service and high flow rate ratios between shell and tube side fluids, hair pin exchangers are more suitable.
X Type shell	Vacuum service for low ΔP.
NTIW (No tubes in window)	To reduce tube vibrations.
Fin tube heat exchanger	For N_2 / Air cooler at shell side
Vertical baffle cut	To remove liquid from condenser.
Jacketed pipe	Very small heat duty or to maintain fluid temperature.
Vapor belt feed device	For uniform distribution of fluid in big shell diameter HX. (Vapor belt also known as 'annular distributor'.)
Two exchanger in parallel	When exchanger exceeds allowable diameter for big heat duty.
Tube inserts	To increase velocity (HTC) at tube side for viscous fluid.
Vertical condenser	Small heat duty for column condenser.
Replace CW by chilled water	Either condensing temperature has been lowered because of inlet composition change or to increase LMTD for de-bottlenecking exchanger for heat transfer area.
Control valve at inlet of thermo-siphon re-boiler	To control recirculation rate, for handling multiple cases and huge turn down requirements.
Exchanger By pass control	To handle huge turn down and easy temperature control, 'by pass control' is more popular and this can be found in Process to Process heat exchangers.

Answer 20 : All above HX / HX device are already matched with appropriate application.

Nomenclature

CW – Cooling water
DEG – Di-Ethylene Glycol
Delta T – Difference in temperature
DEP – Shell Group Design and Engineering Practice
H_2 – Hydrogen
HC – Hydro carbon
HTC – Heat Transfer Coefficient
HTFS – Heat Transfer fluid service
HX – Heat Exchanger
ID – Internal diameter
IMP – Important
LMTD – Log mean temperature difference
MOC – Material of construction
N_2 – Nitrogen
PSI – Pressure, Pounds per square inch
T – Temperature
TEG – Tri-Ethylene Glycol
TEMA - Tubular Exchanger Manufacturers Association, Inc.
U – Overall heat transfer coefficient
Tasc+ – Module of HTFS+ for designing shell and tube heat exchanger.
Δ P – Pressure drop

References

1) TEMA - Tubular Exchanger Manufacturers Association, Inc. Eighth Edition, 1999
2) HTFS+ - Design guidelines
3) Applied process design for chemical and petrochemical plants, Volume 3, chapter 10.