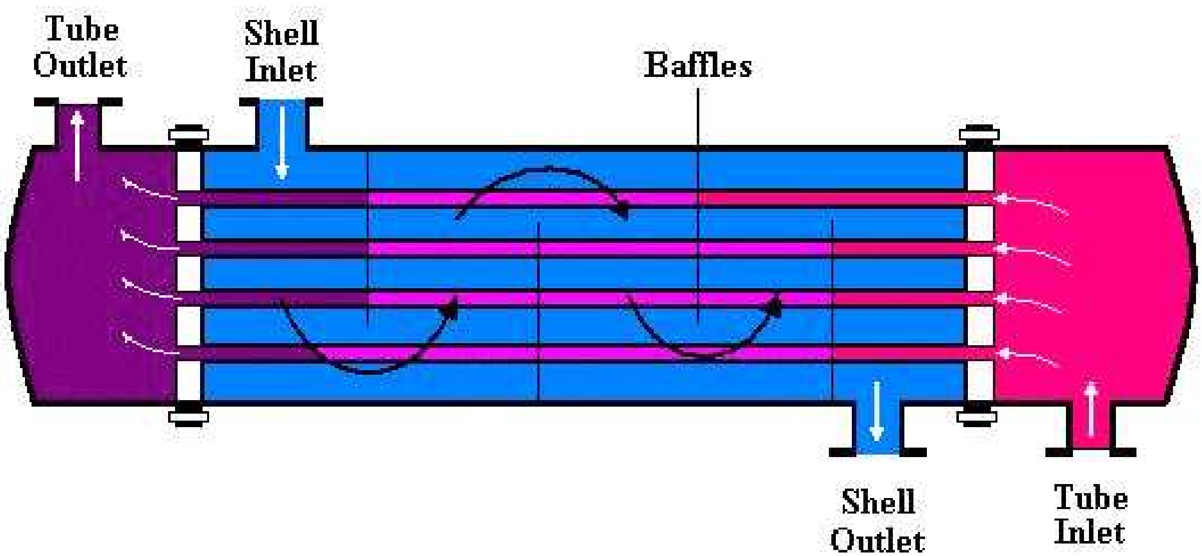
SHELL & TUBE HEAT EXCHANGERS



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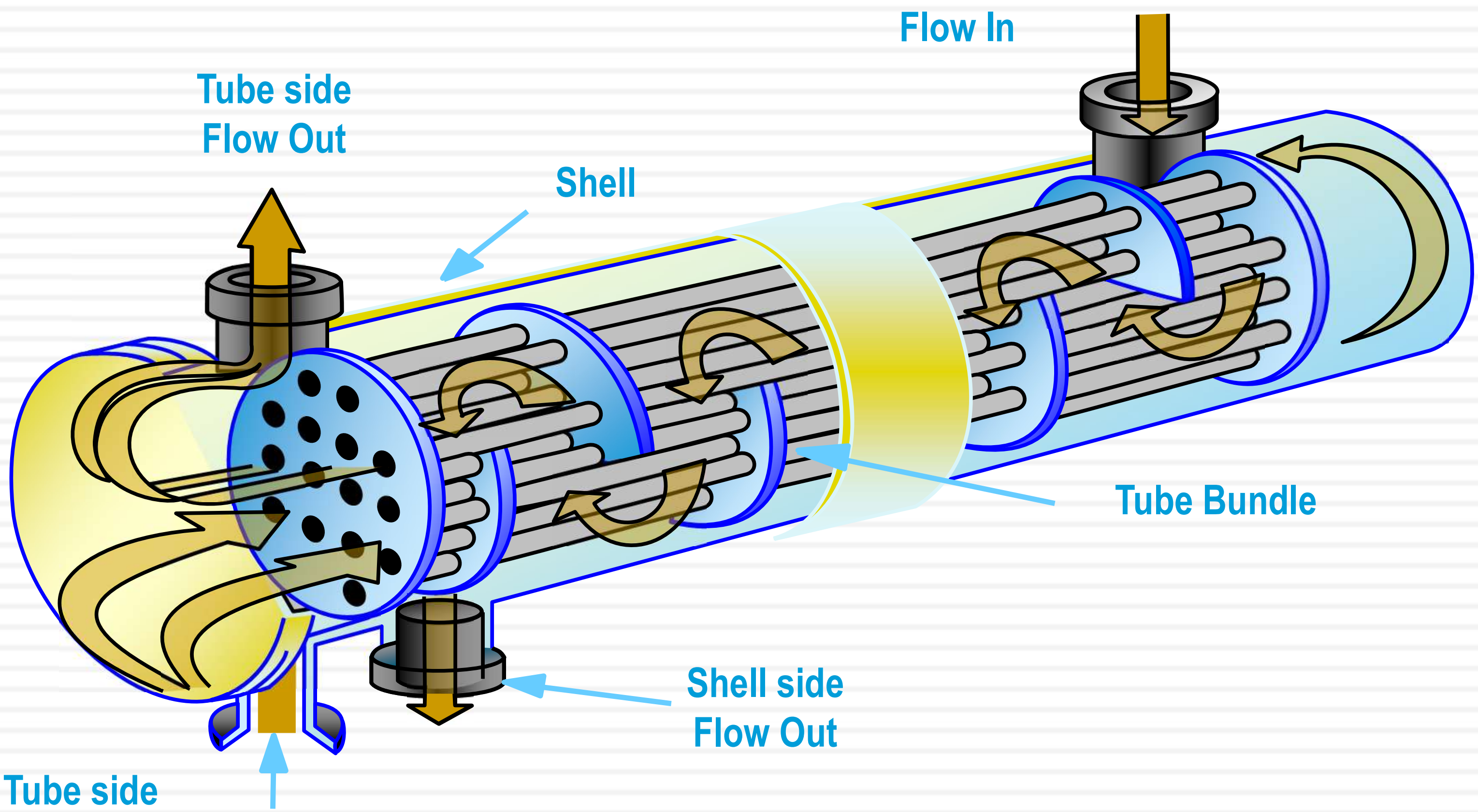
INTRODUCTION

- The shell-and-tube heat exchanger is by far the most common type of heat exchanger used in industry.
- It can be fabricated from a wide range of materials both metallic and non-metallic.
- Design pressures range from **full vacuum to 6,000 psig**.
- Design temperatures range from **-250^{o}C to 800^{o}C**.
- The shell-and-tube design is more rugged than other types of heat exchangers. It can stand more (physical and process) abuse.
- Shell & Tube Heat Exchangers can be used as condensers, reboilers, process heaters and coolers.

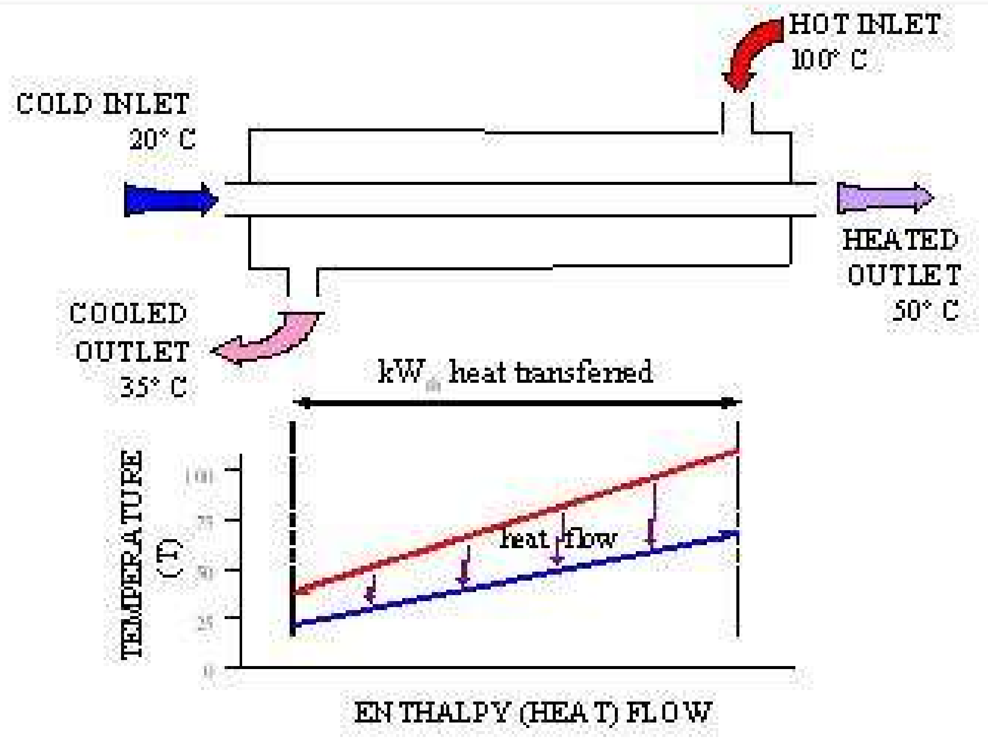
FLOW PATTERN IN A SIMPLE SHELL & TUBE HEAT EXCHANGER



WORKING PRINCIPLE / GOVERNING EQUATION

Simplified heat exchanger concepts :

- Heat exchangers work because heat naturally flows from higher temperature to lower temperatures. Therefore if a hot fluid and a cold fluid are separated by a heat conducting surface , heat can be transferred from the hot fluid to the cold fluid.



- The rate of heat flow at any point (kW/m^2 of transfer surface) depends on:
  1) Heat transfer coefficient (U), itself a function of the properties of the fluids involved, fluid velocity, materials of construction, geometry and cleanliness of the exchanger
  2) Temperature difference between hot and cold streams

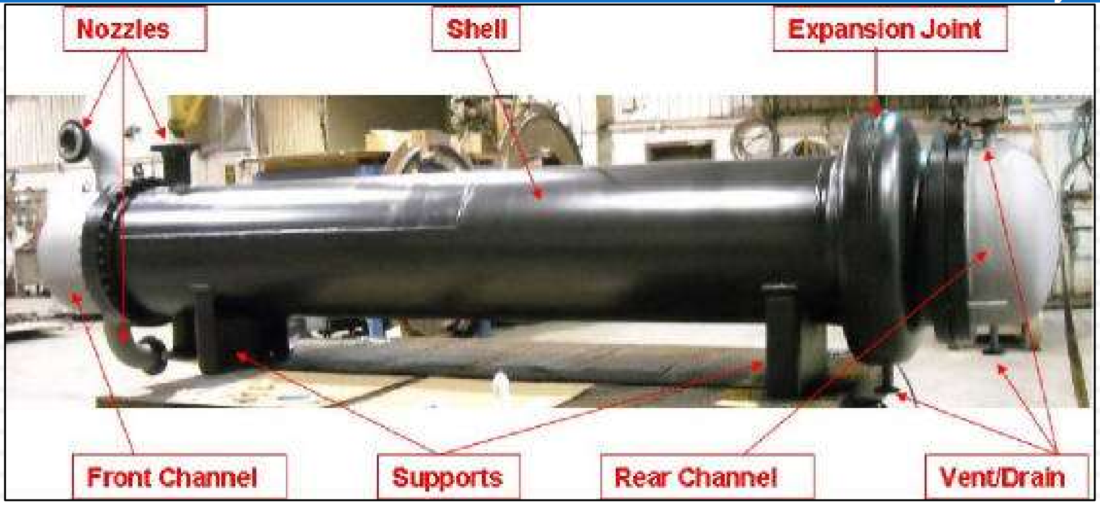
- Total heat transferred (Q) depends on:
  1) Heat transfer surface area (A)
  2) Heat transfer coefficient (U)
  3) Average temperature difference between the streams, strictly the log mean (ΔT_{LM})

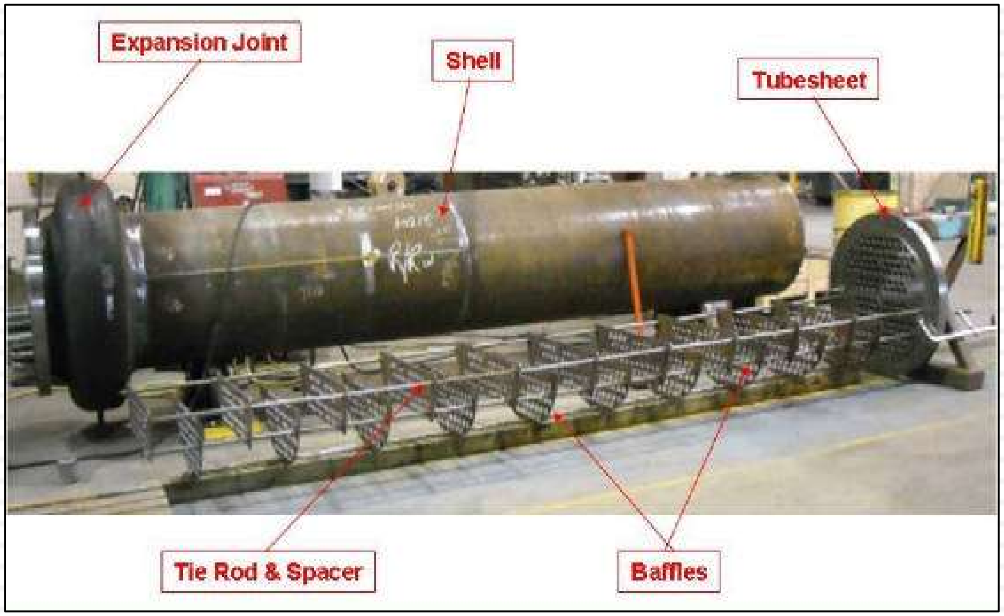
- Thus total heat transferred : $Q = UA\,\Delta T_{LM}$

But the larger the area the greater the cost of the exchanger

Therefore there is a trade-off between the amount of heat transferred and the exchanger cost

HEAT EXCHANGER:PICTORIAL VIEW



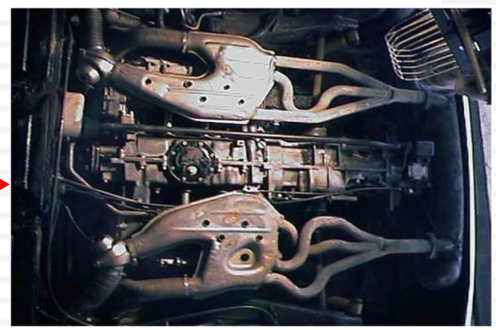


OTHER TYPES OF HEAT EXCHANGERS

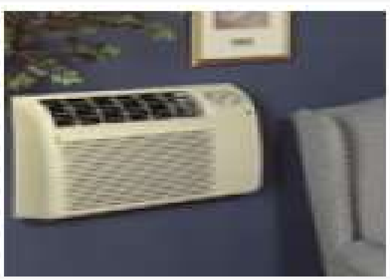
- Gasketed / Welded plate and frame heat exchanger
- Spiral heat exchanger
- Tubular heat exchanger
- Plate coils heat exchanger
- Scraped surface heat exchanger

APPLICATIONS OF HEAT EXCHANGERS

Heat exchangers are used in Industry for heat transfer



Heat Exchangers prevent car engine overheating and increase efficiency



Heat exchangers are used in AC and furnaces

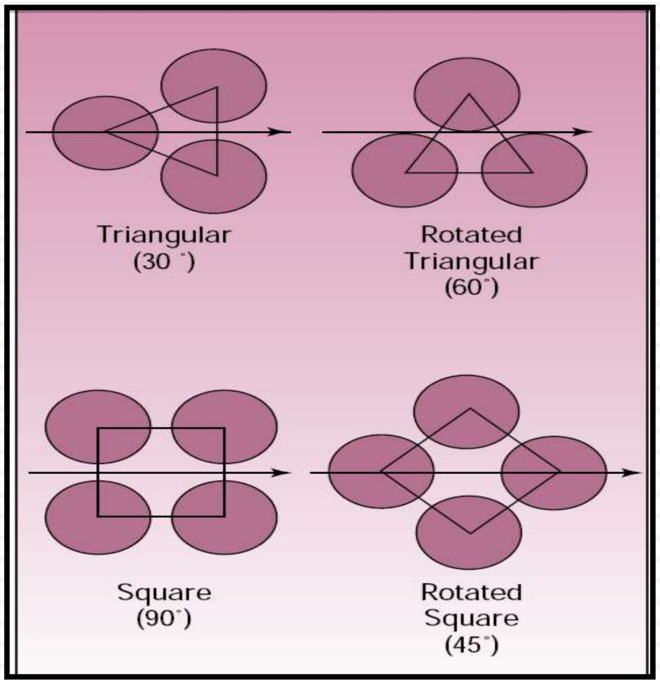
DIFFERENT PARTS OF A TYPICAL HEAT EXCHANGER

- **SHELL –** The Shell is simply a container for the shell side fluid. The shell cylinder can be fabricated from rolled plate or from piping (up to 24 inch diameters).

- **TUBES / TUBE BUNDLE -**
  1) Tubing may be seamless or welded.
  2) Normal tube diameters are 5/8 inch, 3/4 inch and 1 inch.
  3) The normal tube wall thickness ranges from 12 to 16 BWG (from 0.109 inches to 0.065 inches thick).
  4) Tubing may be finned to provide more heat transfer surface.

TUBESHEETS -

1) Tubesheets are plates or forgings drilled to provide holes through which tubes are inserted.
2) Tubes are appropriately secured to the tubesheet so that the fluid on the shell side is prevented from mixing with the fluid on the tube side.
3) The distance between the centers of the tube hole is called the **tube pitch**; **normally the tube pitch is 1.25 times the outside diameter of the tubes.**



Square Pitch – When the shell side fluid is fouling and mechanical cleaning is required.
Triangular Pitch – When the shell side fluid is clean.
Rotated Triangular Pitch – Seldom used. Offers no advantage over triangular pitch.
Rotated Square Pitch – When higher turbulence is required i.e. when Reynolds Number is low (< 2000)

BAFFLES –

1) Baffles serve three functions:
   - ✓ Support the tube.
   - ✓ Maintain the tube spacing.
   - ✓ Direct the flow of fluid in the desired pattern through the shell side.

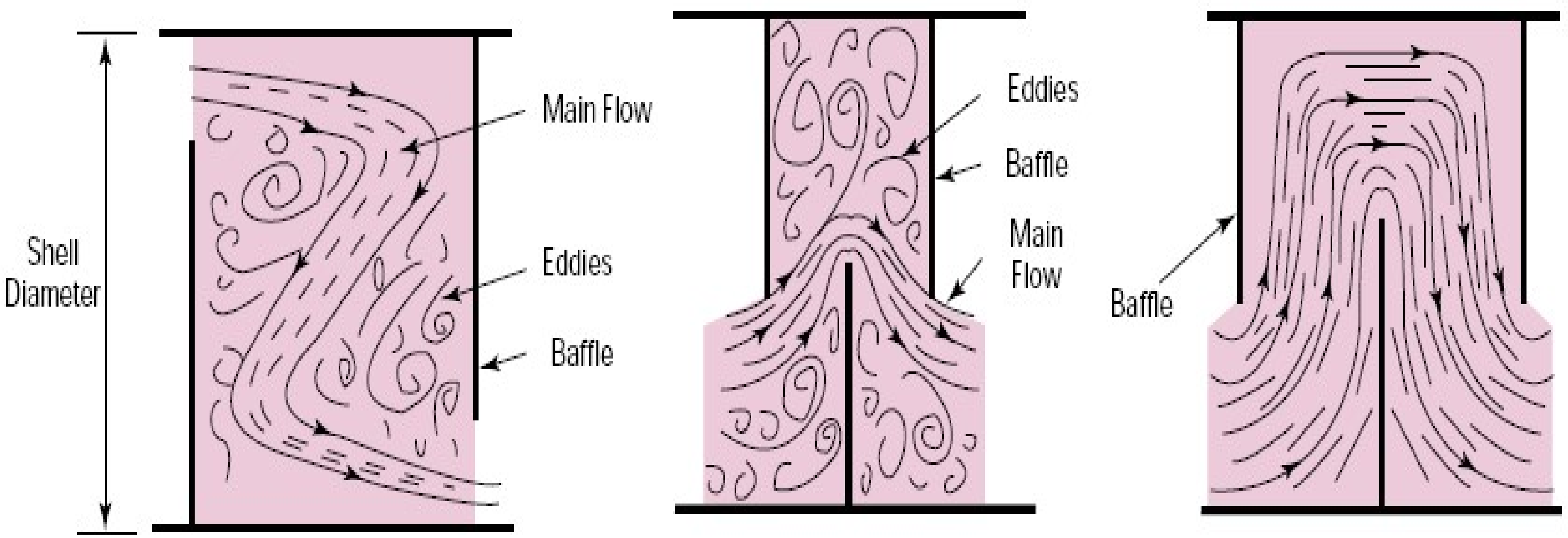
2) A segment, called the baffle cut, is cut away to permit the fluid to flow parallel to the tube axis as it flows from one baffle space to another.

3) The spacing between segmental baffles is called the **baffle pitch**.

4) When the **shell side heat transfer is sensible** heating or cooling with no phase change, **the baffle cut should be horizontal**. This causes the fluid to follow an up-and-down path and prevents stratification with warmer fluid at the top of the shell and cooler fluid at the bottom of the shell.

5) For **shell side condensation, the baffle cut is vertical** to allow the condensate to flow towards the outlet without significant liquid holdup by the baffle. **For shell side boiling, the baffle cut may be either vertical or horizontal.**

EFFECTS OF BAFFLE CUT

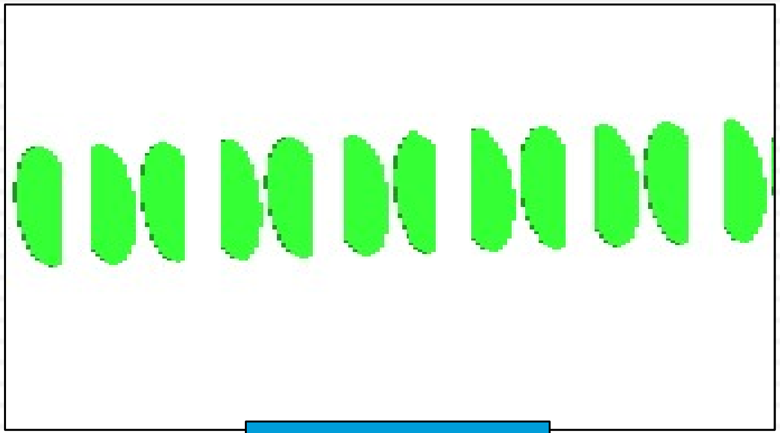


a. Small Baffle Cut

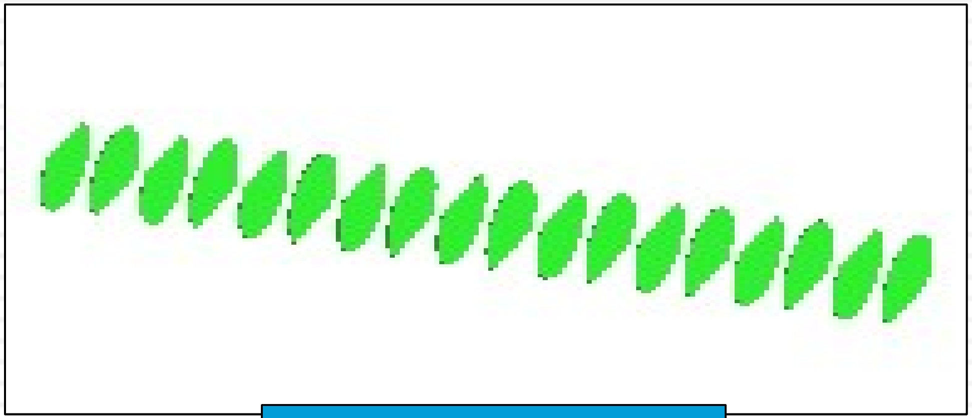
b. Large Baffle Cut

c. Ideal Baffle Cut and Baffle Spacing

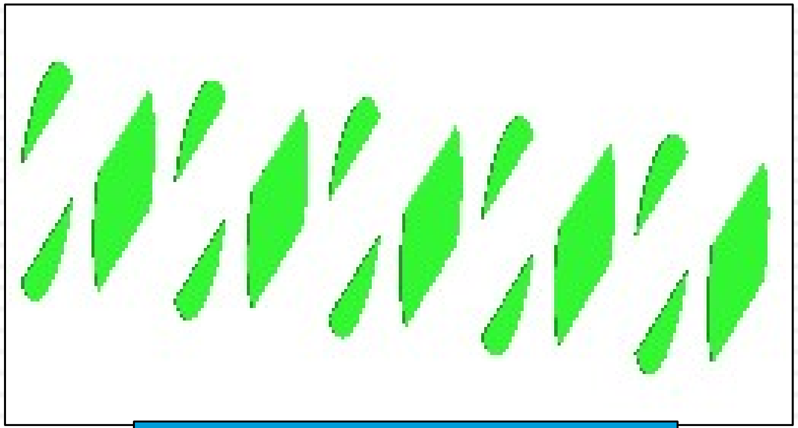
TYPES OF BAFFLE ARRANGEMENT



PARALLEL

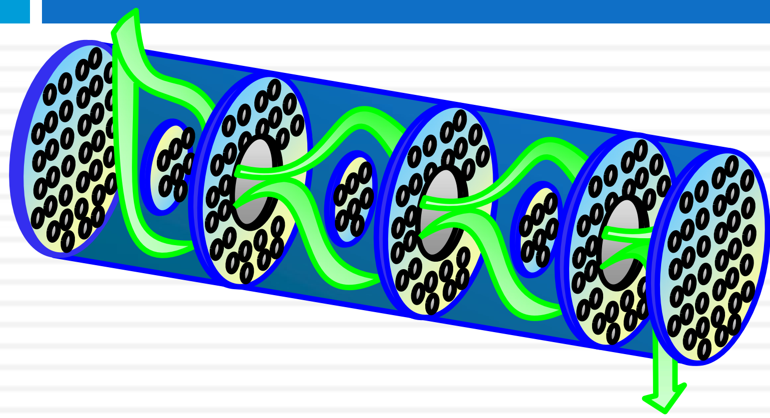


PERPENDICULAR

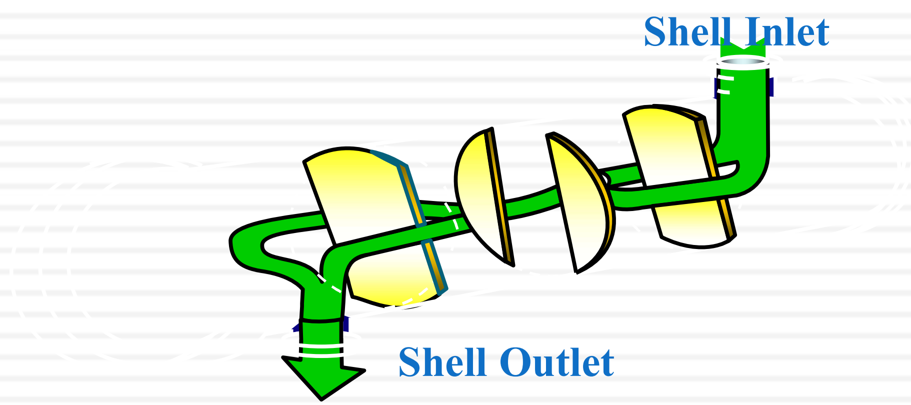


DOUBLE SEGMENTAL

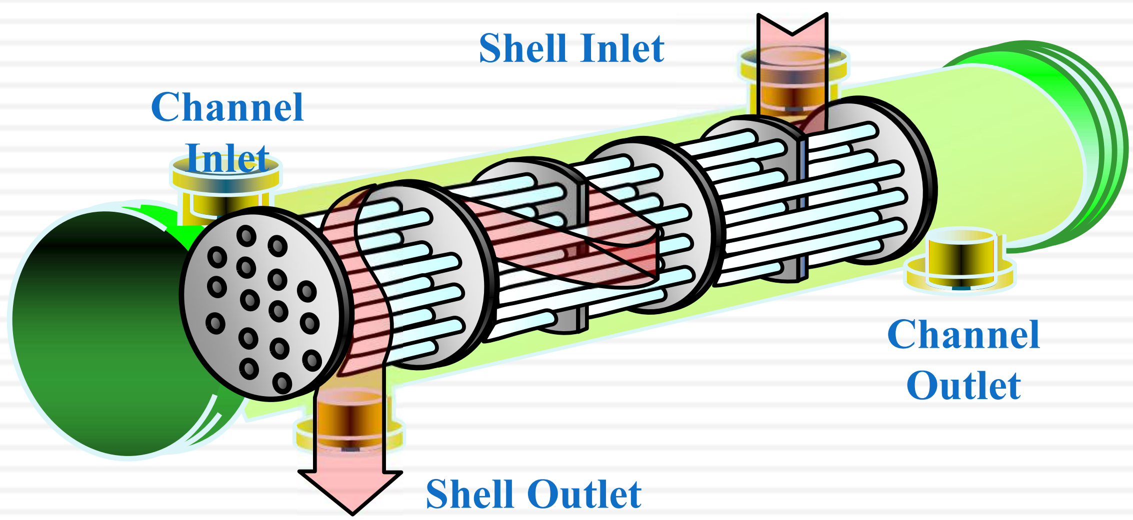
FLOW PATTERN IN DIFFERENT TYPES OF BAFFLES



Doughnut and Disc Type Baffles



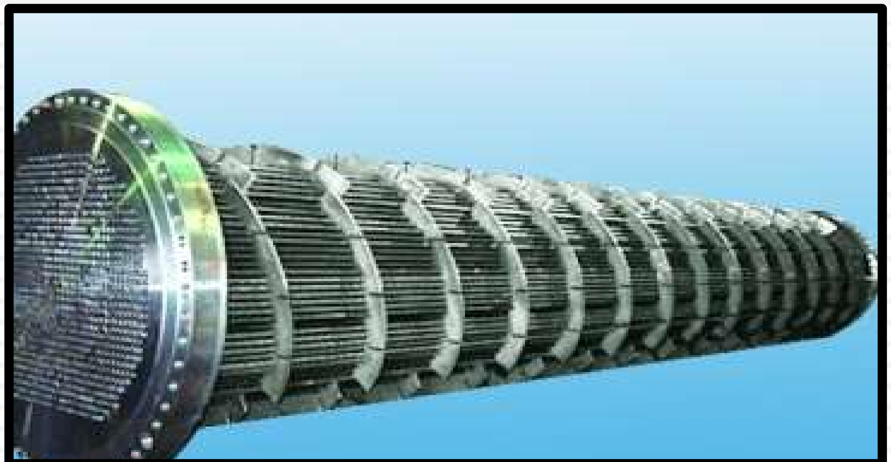
Double Segmental Transverse Baffles



Single Segmental Transverse Baffles

TYPES OF BAFFLES

ROD BAFFLE



SPIRAL BAFFLE

DOUBLE SEGMENTAL BAFFLE

EM BAFFLE

- **TIE RODS & SPACERS -** Tie rods and spacers are used for two reasons:
  1) Hold the baffle assembly together
  2) Maintain the selected baffle spacing.

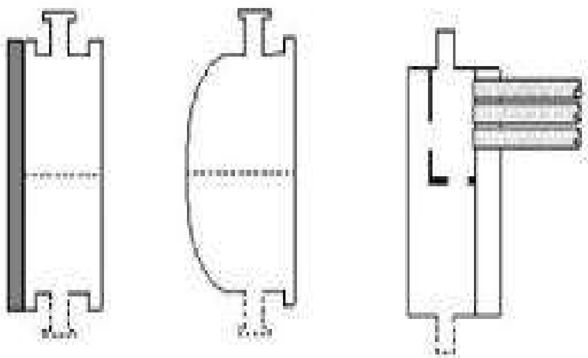
- **CHANNELS (HEADS) –**
  1) Channels or heads are required for shell-and-tube heat exchangers to contain the tube side fluid
  2) To provide the desired flow path.
  3) The three (3) letters TEMA (Tubular Exchanger Manufacturers Association) designation is the standard method for identifying the type of channels and the type of shell of shell-and-tube heat exchangers.
  4) The channel type is selected based on the application.
  5) The most commonly used channel type is the **bonnet**. It is used for services which do not require frequent removal of the channel for inspection or cleaning.
  6) **Removable cover** channels are provided when frequent cleaning is required.

TEMA CLASS FOR CHANNELS

TEMA CLASS FOR CHANNELS	APPLICATION
R	Severe requirements of petroleum and related process applications
C	Moderate requirements of commercial and general process applications
B	Chemical process service

TEMA FRONT & REAR HEADS

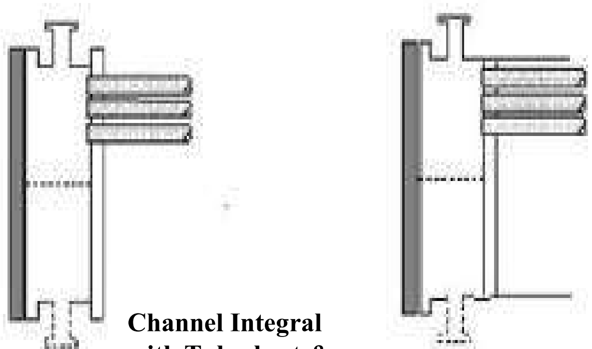
TEMA FRONT HEAD



A
Channel & Removable Cover

B
Bonnet (Integral Cover)

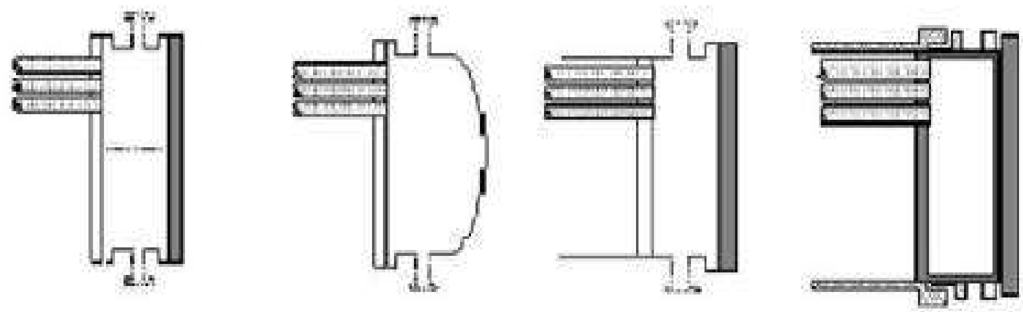
D
Special High Pressure Closure



C
Channel Integral with Tubesheet & Removable Cover

N

TEMA REAR HEAD

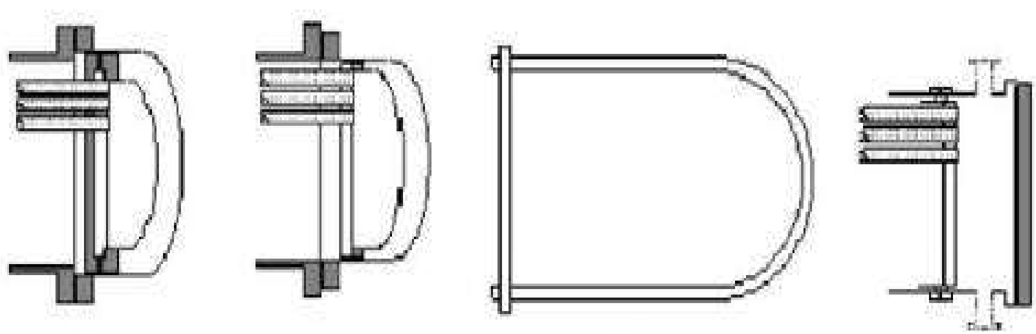


L
Fixed Tubesheet Stationary Head

M
Fixed Tubesheet Stationary Head

N
Fixed Tubesheet Stationary Head

P
Outside Packed Floating Head



S
Floating Head with Backing Device

T
Pull Through Floating Head

U
U-Tube Bundle

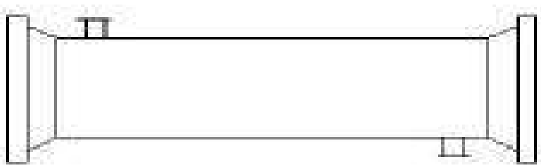
W
Externally Sealed Floating Tubesheet

SELECTION OF HEADS

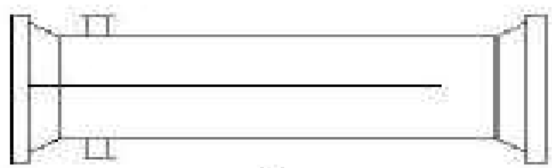
TEMA Front Head Selection	
A	Easy to open for tube side access. For low pressure applications.
B	For Higher-pressure applications, preferred with clean tube side fluid. It is less expensive than Type A.
C	Tube side is corrosive, toxic or hazardous and when removable tube bundle is required. It is normally used for low-pressure operations.
N	For application where tube side is corrosive, toxic or hazardous and shell side fluid is clean and any leakage possibility is to be eliminated.
D	Very High-pressure applications.
TEMA Rear Head Selection	
L,M,N	Fixed Head , Should be used when thermal differential expansion of the shell and tubes is low and shell side fluid is clean.
L	For low pressure applications.
M	For Higher-pressure applications, not requiring frequent maintenance.
N	For application where tube side is Corrosive, toxic or hazardous and where leakage of shell to tube side fluid and vice versa, is to be eliminated.
U	For thermal differential expansion of the shell and tubes is higher and tube side fluid is clean. For high-pressure applications or, with hazardous/ toxic fluid on shell side.
P,S,T,W	Should be used when shell side fluid or both shell and tube side fluid are Dirty.
P	Pressure is low and shell side fluid is not toxic or hazardous. Where risk of internal flange leakage is to be avoided.
S	Normal Pressure requirements, relatively lesser maintenance requirements .
T	High-pressure requirements, frequent need to takeout the tube bundle.
W	For low-pressure application.

TEMA SHELL TYPES

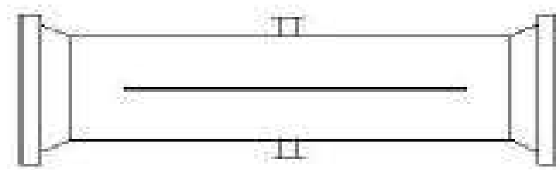
TEMA SHELL TYPES



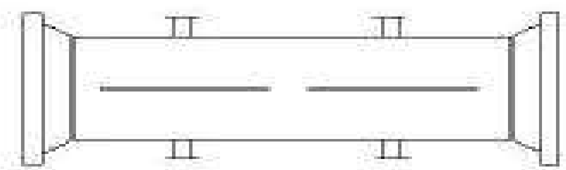
E
One Pass Shell



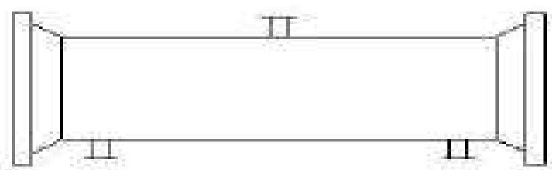
F
Two Pass Shell with Longitudinal Baffle



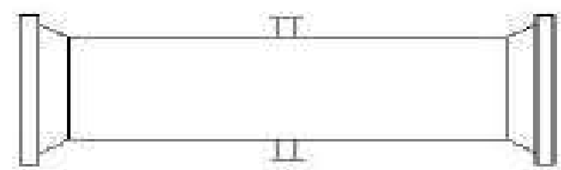
G
Split Flow



H
Double Split Flow



J
Divided Flow



X
Cross Flow

Common TEMA type of Shell & Tube Heat Exchangers :

- ✓ AES
- ✓ BEU
- ✓ BHU
- ✓ BXU
- ✓ BEM
- ✓ AKU
- ✓ AET
- ✓ AEL

SELECTION OF SHELL

TEMA Shell Selection	
E	The E shell is the most common as it is inexpensive and simple.
F	F shell is rarely used in practice because there are many problems associated with the design. It is difficult to remove/replace the tube bundle, problems of fabrication and maintenance, internal leakage, unbalanced thermal expansion in case of large temperature difference between inlet & outlet.
G & H	To accommodate high inlet velocities. They are used as horizontal thermosiphon reboilers, condensers, and other phase-change applications.
J	Used for low pressure drop applications such as a condenser in vacuum.
K	The K shell is used for partially vaporizing the shell fluid. It is used as a kettle reboiler in the process industry and as a flooded chiller in the refrigeration industry. They are used when essentially 100% vaporization is required.
X	It is used for gas heating and cooling and for vacuum condensation. It is also used when shell flows are large.

ALLOCATION OF STREAMS

- **HIGH PRESSURE** – If one of the stream is at a high pressure, it is desirable to put that stream **inside the tubes**. In this case, only the tubes and tube side fittings need to be designed to withstand high pressure, whereas the shell may be made of lighter weight metal.

- **CORROSION –** Corrosion generally dictates the choice of material of construction, rather than exchanger design. However, since most corrosion resistant alloys are more expensive than the ordinary materials of construction, the corrosive fluid will normally be placed **inside the tubes** to reduce the cost by avoiding use of corrosion resistant alloys for the shell side.

- **VISCOSITY –** Highly viscous fluid is placed at **shell side** so that turbulence can be induced by introducing baffles in shell side.

- **FOULING –** Fouling enters into the design of almost every process exchanger to a measurable extent, but certain streams foul so badly that the entire design is dominated by features which seek a) to minimize fouling or b) to facilitate cleaning .

- **LOW HEAT TRANSFER COEFFICIENT –** If one stream has an inherently low heat transfer coefficient (such as low pressure gases or viscous liquids), this stream is preferentially put on the **shell side**.

- **FLOW RATE –** Generally smaller flow rate fluid is placed on the **shell side**. This facilitates provision of adequate turbulence by increasing number of baffles.

- **PHASE OF FLUID –** Two phase fluid should be placed in **shell side**.

MAJOR PRACTICAL PROBLEMS ENCOUNTERED IN HEAT EXCHANGERS

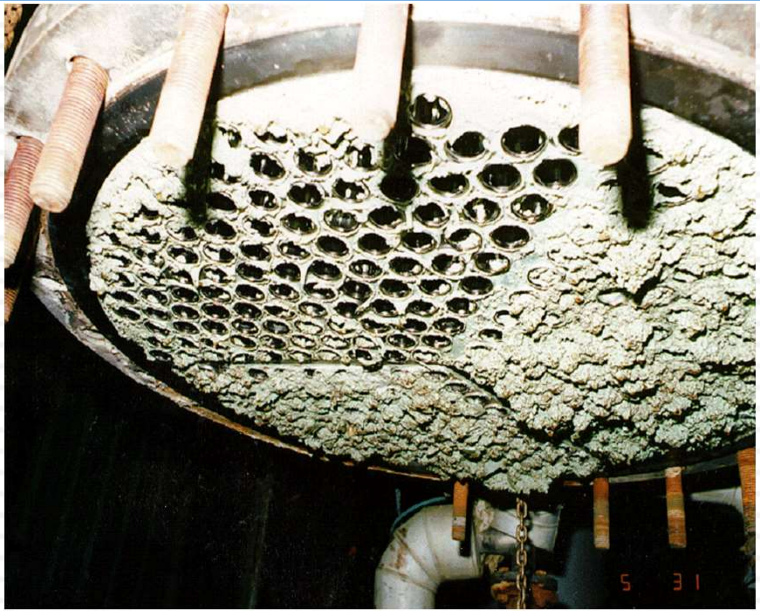
- **FOULING -** Fouling is generally defined as the accumulation of unwanted materials on the surfaces of processing equipment. It has been recognized as a nearly universal problem in design and operation and affects the operation of equipment in two ways:

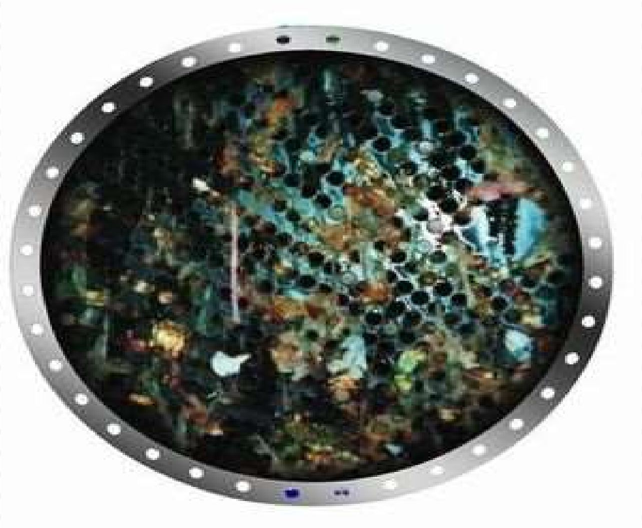
1) The fouling layer has a low thermal conductivity. This increases the resistance to heat transfer and reduces the effectiveness of heat exchangers – increasing temperature.
2) As deposition occurs, the cross-sectional area is reduced, which causes an increase in pressure drop across the exchanger.

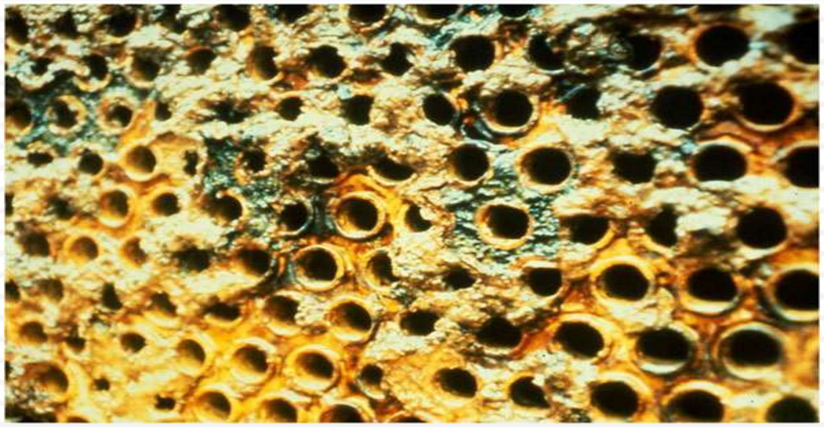
Fouling can be caused by :

1) Frequent use of the heat exchanger
2) Not cleaning the heat exchanger regularly
3) Reducing the velocity of the fluids moving through the heat exchanger
4) Over-sizing of the heat exchanger

FOULED HEAT EXCHANGER TUBES

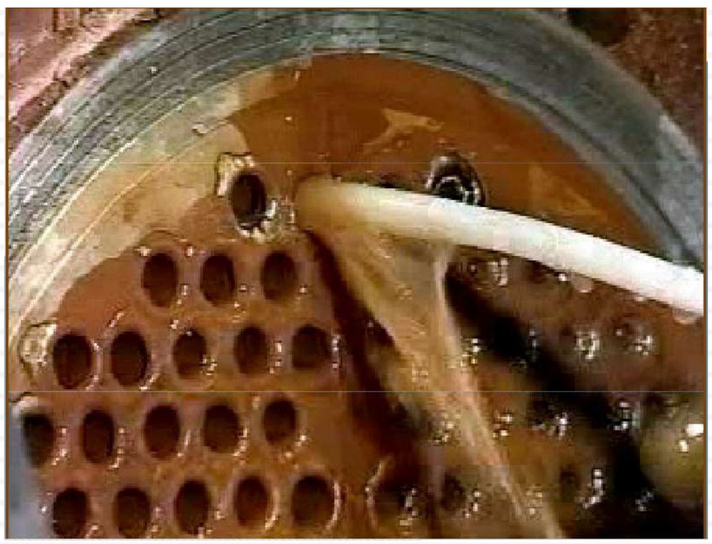


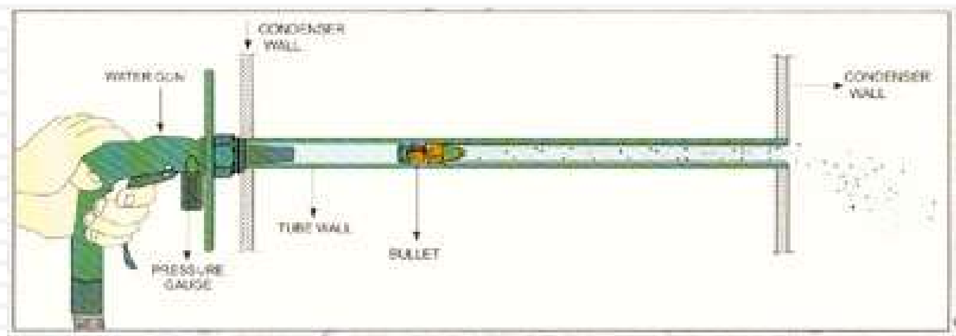




- **FOULING TREATMENT -** Tubular heat exchangers can be cleaned by such methods as chemical cleaning, sandblasting, high pressure water jet, bullet cleaning, or drill rods.

  In large-scale cooling water systems for heat exchangers, water treatment such as purification, addition of chemicals, and testing is used to minimize fouling of the heat exchanger.





Bullet Cleaning : How it works?

FOULING RESISTANCES FOR INDUSTRIAL FLUIDS

Oils:	
Fuel Oil #2	0.002
Fuel Oil #6	0.005
Transformer Oil	0.001
Engine Lube Oil	0.001
Quench Oil	0.004
Gases And Vapors:	
Manufactured Gas	0.010
Engine Exhaust Gas	0.010
Steam (Non-Oil Bearing)	0.0005
Exhaust Steam (Oil Bearing)	0.0015-0.002
Refrigerant Vapors (Oil Bearing)	0.002
Compressed Air	0.001
Ammonia Vapor	0.001
CO_2 Vapor	0.001
Chlorine Vapor	0.002
Coal Flue Gas	0.010
Natural Gas Flue Gas	0.005
Liquids:	
Molten Heat Transfer Salts	0.0005
Refrigerant Liquids	0.001
Hydraulic Fluid	0.001
Industrial Organic Heat Transfer Media	0.002
Ammonia Liquid	0.001
Ammonia Liquid (Oil Bearing)	0.003
Calcium Chloride Solutions	0.003
Sodium Chloride Solutions	0.003
CO_2 Liquid	0.001
Chlorine Liquid	0.002
Methanol Solutions	0.002
Ethanol Solutions	0.002
Ethylene Glycol Solutions	0.002

All Values in HR FT^2 °F / BTU

FOULING RESISTANCES FOR CHEMICAL PROCESSING STREAMS

Gases And Vapors:	
Acid Gases	0.002-0.003
Solvent Vapors	0.001
Stable Overhead Products	0.001
Liquids:	
MEA And DEA Solutions	0.002
DEG And TEG Solutions	0.002
Stable Side Draw And Bottom Product	0.001-0.002
Caustic Solutions	0.002
Vegetable Oils	0.003

Fouling Resistances For Natural Gas-Gasoline Processing Streams

Gases And Vapors:	
Natural Gas	0.001-0.002
Overhead Products	0.001-0.002
Liquids:	
Lean Oil	0.002
Rich Oil	0.001-0.002
Natural Gasoline And Liquified Petroleum Gases	0.001-0.002

FOULING RESISTANCES FOR OIL REFINERY STREAMS

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

	0 to 250 ° F VELOCITY FT/SEC			250 to 350 ° F VELOCITY FT/SEC		
	<2	2-4	>4	<2	2-4	>4
DRY	0.003	0.002	0.002	0.003	0.002	0.002
SALT*	0.003	0.002	0.002	0.005	0.004	0.004
	350 to 450 ° F VELOCITY FT/SEC			**450 ° F and over VELOCITY FT/SEC**		
	<2	2-4	>4	<2	2-4	>4
DRY	0.004	0.003	0.003	0.005	0.004	0.004
SALT*	0.006	0.005	0.005	0.007	0.006	0.006

*Assumes desalting @ approx. 250 ° F

Gasoline	0.002
Naphtha And Light Distillates	0.002-0.003
Kerosene	0.002-0.003
Light Gas Oil	0.002-0.003
Heavy Gas Oil	0.003-0.005
Heavy Fuel Oils	0.005-0.007
Asphalt And Residuum:	
Vacuum Tower Bottoms	0.010
Atmosphere Tower Bottoms	0.007
Cracking And Coking Unit Streams:	
Overhead Vapors	0.002
Light Cycle Oil	0.002-0.003
Heavy Cycle Oil	0.003-0.004
Light Coker Gas Oil	0.003-0.004
Heavy Coker Gas Oil	0.004-0.005
Bottoms Slurry Oil (4.5 Ft/Sec Minimum)	0.003
Light Liquid Products	0.002

Catalytic Hydro Desulfurizer:	
Charge	0.004-0.005
Effluent	0.002
H.T. Sep. Overhead	0.002
Stripper Charge	0.003
Liquid Products	0.002
HF Alky Unit:	
Alkylate, Deprop. Bottoms, Main Fract. Overhead Main Fract. Feed	0.003
All Other Process Streams	0.002

Catalytic Reforming, Hydrocracking And Hydrodesulfurization Streams:	
Reformer Charge	0.0015
Reformer Effluent	0.0015
Hydrocracker Charge And Effluent*	0.002
Recycle Gas	0.001
Hydrodesulfurization Charge And Effluent*	0.002
Overhead Vapors	0.001
Liquid Product Over 50 ° A.P.I.	0.001
Liquid Product 30 - 50 ° A.P.I.	0.002
*Depending on charge, characteristics and storage history, charge resistance may be many times this value.	
Light Ends Processing Streams:	
Overhead Vapors And Gases	0.001
Liquid Products	0.001
Absorption Oils	0.002-0.003
Alkylation Trace Acid Streams	0.002
Reboiler Streams	0.002-0.003
Lube Oil Processing Streams:	
Feed Stock	0.002
Solvent Feed Mix	0.002
Solvent	0.001
Extract*	0.003
Raffinate	0.001
Asphalt	0.005
Wax Slurries*	0.003
Refined Lube Oil	0.001
*Precautions must be taken to prevent wax deposition on cold tube walls.	
Visbreaker:	
Overhead Vapor	0.003
Visbreaker Bottoms	0.010
Naphtha Hydrotreater:	
Feed	0.003
Effluent	0.002
Naphthas	0.002
Overhead Vapors	0.0015

FOULING RESISTANCE FOR WATER

Temperature Of Heating Medium	Up To 240° F		240 to 400° F	
Temperature Of Water	125 °F		Over 125° F	
	Water Velocity Ft/Sec		Water Velocity Ft/Sec	
	3 and Less	Over 3	3 and Less	Over 3
Sea Water	0.0005	0.0005	0.001	0.001
Brackish Water	0.002	0.001	0.003	0.002
Cooling Tower And Artificial Spray Pond:				
Treated Make Up	0.001	0.001	0.002	0.002
Untreated	0.003	0.003	0.005	0.004
City Or Well Water	0.001	0.001	0.002	0.002
River Water:				
Minimum	0.002	0.001	0.003	0.002
Average	0.003	0.002	0.004	0.003
Muddy Or Silty	0.003	0.002	0.004	0.003
Hard (Over 15 Grains/Gal.)	0.003	0.003	0.005	0.005
Engine Jacket	0.001	0.001	0.001	0.001
Distilled Or Closed Cycle				
Condensate	0.0005	0.0005	0.0005	0.0005
Treated Boiler Feedwater	0.001	0.0005	0.001	0.001
Boiler Blowdown	0.002	0.002	0.002	0.002

- **VIBRATIONS -** Fluid flowing through a heat exchanger can cause the heat exchanger tubes to vibrate.

  Different types of vibration mechanisms are as follows:

1) **FLUID ELASTIC INSTABILITY :** Fluid elastic instability is important for **both gases & liquids.** This occurs above a critical flow velocity. There are different methods to avoid fluid elastic instability such as:
   - ✓ Decreasing the span lengths
   - ✓ Increasing the tube diameter
   - ✓ Reducing clearance between tube & baffle
   - ✓ Increasing tube pitch also helps in minimizing tube vibrations
   - ✓ Tubes in the window region can be removed so that all tubes are supported.

2) **VORTEX SHEDDING :** Vortex shedding is caused by the periodic shedding of the vortices from the tubes and can lead to damage of tubes if vibrations coincide with the tube natural frequency. Some measures such as changing span lengths can be taken to avoid vibrations.

3) **ACOUSTIC RESONANACE :** Acoustic resonance is very **important in case of gases**. It occurs when the frequency of an acoustic wave in the heat exchanger coincides with tube natural frequency. Even if acoustic wave does not cause any vibrations, it can lead to intolerable noise. It can be avoided by changing span lengths. Generally deresonating baffles are placed in all cross passes of the heat exchanger parallel to both the direction of crossflow and the centerline of the tubes, which increases the acoustic frequency of the acoustic wave thus, eliminating acoustic vibration problem.

4) **TURBULENT BUFFETING :** Turbulent buffeting mechanism is very **important in case of two-phase flow.** The turbulence in the flowing fluid contains a broad range of frequencies and can coincide with the tube natural frequency to cause tube vibrations.

5) **FLOW PULSATION :** Flow pulsation is because of periodic variations in the flow. This can become very **important in case of two-phase flow.**

TABLE FOR SELECTION

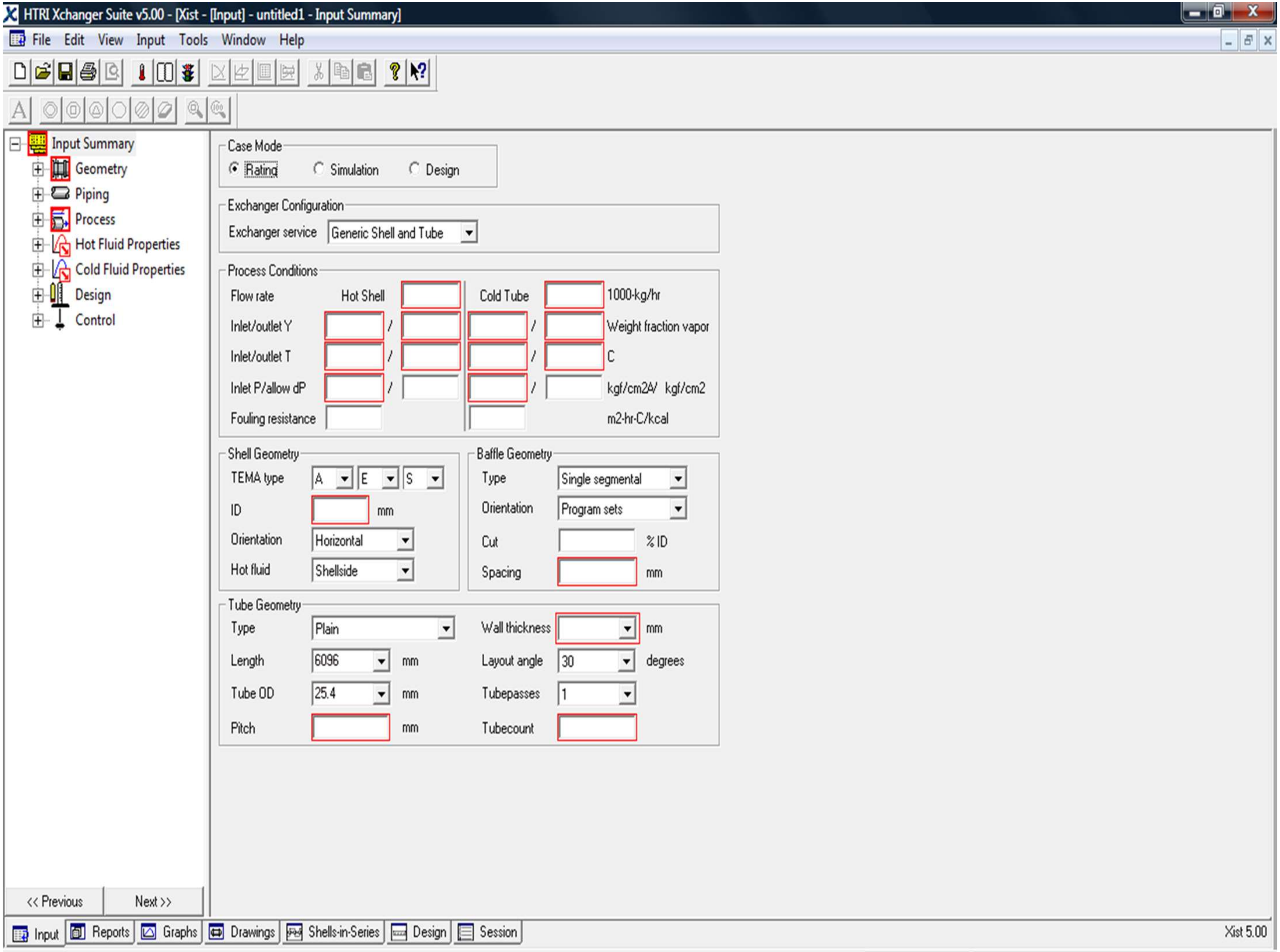
Shell and Tube Exchanger Selection Guide (Cost Increases from Left to Right)

Type of Design	"U" Tube	Fixed Tubesheet	Floating Head Outside Packed	Floating Head Split Backing Ring	Floating Head Pull-Through Bundle
Provision for differential expansion	individual tubes free to expand	expansion joint in shell	floating head	floating head	floating head
Removeable bundle	yes	no	yes	yes	yes
Replacement bundle possible	yes	not practical	yes	yes	yes
Individual tubes replaceable	only those in outside row	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
Tube exteriors with triangular pitch cleanable	chemically only	chemically only	chemically only	chemically only	chemically only
Tube exteriors with square pitch cleanable	yes, mechanically or chemically	chemically only	yes, mechanically or chemically	yes, mechanically or chemically	yes, mechanically or chemically
Number of tube passes	any practical even number possible	normally no limitations	normally no limitations	normally no limitations	normally no limitations
Internal gaskets eliminated	yes	yes	yes	no	no

THERMAL DESIGNING & RATING OF HEAT EXCHANGERS

- Designing & Rating of Heat Exchangers is carried out by using following softwares :
  1) HTRI Exchanger Suite
  2) HTFS - Heat Transfer and Fluid Flow Service
  3) CC THERM

- HTRI Exchanger Suite 5.0 (latest version) is developed by Heat Transfer Research Inc.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Exchanger service
Generic Shell and Tube
Process Conditions
Flow rate
Hot Shell
Cold Tube
1000-kg/hr
Inlet/outlet Y
Weight fraction vapor
Inlet/outlet T
C
Inlet P/allow dP
kgf/cm2A/ kgf/cm2
Fouling resistance
m2-hr-C/kcal
Shell Geometry
TEMA type
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S
ID
mm
Orientation
Horizontal
Hot fluid
Shellside
Baffle Geometry
Type
Single segmental
Orientation
Program sets
Cut
% ID
Spacing
mm
Tube Geometry
Type
Plain
Wall thickness
mm
Length
6096
mm
Layout angle
30
degrees
Tube OD
25.4
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1
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- **INPUTS REQUIRED -** Before proceeding in either designing or rating of Heat Exchangers, there are some essential inputs required from the client. These are :

1) Complete and latest Process datasheet . Also, old Process datasheet in case of rating of Heat Exchanger. Essential data includes:
   - ✓ Total Heat Duty
   - ✓ Flowrates , temperatures, pressures for both sides
   - ✓ Fluid properties including: density, specific heat, thermal conductivity, and viscosity for at least two points.
   - ✓ For condensers and evaporators, data such as a condensing curve, boiling point elevation, and/or other parameters may be required.
   - ✓ Process conditions and limitations such as fouling resistance, pressure drop limitations, MOC etc.

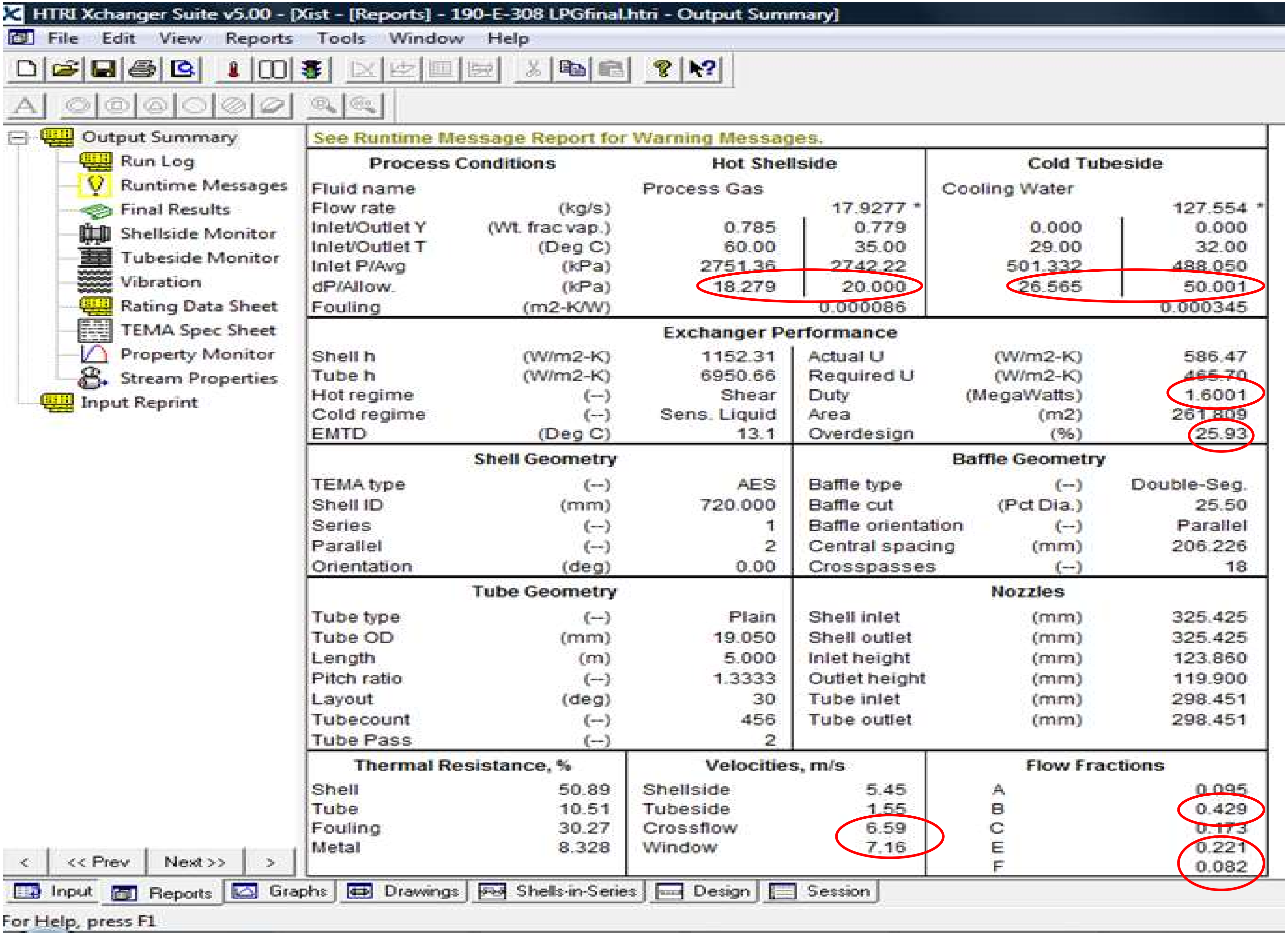
2) Specifications and other special requirements/limitations.
3) Exchanger drawings & old TEMA datasheet in case of rating of Heat Exchanger.

- **OUTPUTS DELIVERED -** When an Exchanger is designed following are the deliverables to the client :

1) TEMA Datasheet
2) Rating Report stating the adequacy of the Heat Exchanger

HTRI OUTPUT / RESULTS INTERPRETATION

- Output of HTRI is interpreted in various ways depending upon the type of problem i.e. type of service, type of exchanger, any special guideline/limitation from the client, etc. Normally, an output is studied for the following parameters :
  1) Heat duty
  2) Allowable pressure drop
  3) B & F flow fractions
  4) Vibrations
  5) Shell side, Tube side, Cross flow, Wind flow velocities
  6) Overdesign percentage
  7) Runtime messages (if any)
  8) Rho-V^2 values



HTRI Xchanger Suite v5.00 - [Xist - [Reports] - 190-E-308 LPGfinal.htri - Output Summary]

See Runtime Message Report for Warning Messages.

Process Conditions		Hot Shellside		Cold Tubeside	
Fluid name		Process Gas		Cooling Water	
Flow rate	(kg/s)		17.9277 *		127.554 *
Inlet/Outlet Y	(Wt. frac vap.)	0.785	0.779	0.000	0.000
Inlet/Outlet T	(Deg C)	60.00	35.00	29.00	32.00
Inlet P/Avg	(kPa)	2751.36	2742.22	501.332	488.050
dP/Allow.	(kPa)	18.279	20.000	26.565	50.001
Fouling	(m2-K/W)		0.000086		0.000345

Exchanger Performance

Shell h	(W/m2-K)	1152.31	Actual U	(W/m2-K)	586.47
Tube h	(W/m2-K)	6950.66	Required U	(W/m2-K)	465.70
Hot regime	(--)	Shear	Duty	(MegaWatts)	1.6001
Cold regime	(--)	Sens. Liquid	Area	(m2)	261.809
EMTD	(Deg C)	13.1	Overdesign	(%)	25.93

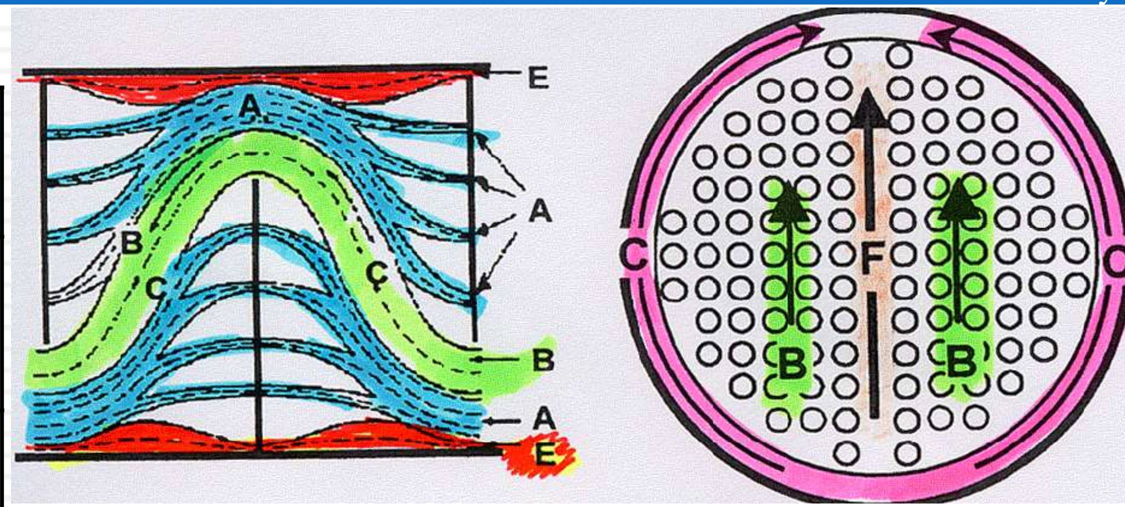
Shell Geometry			Baffle Geometry		
TEMA type	(--)	AES	Baffle type	(--)	Double-Seg.
Shell ID	(mm)	720.000	Baffle cut	(Pct Dia.)	25.50
Series	(--)	1	Baffle orientation	(--)	Parallel
Parallel	(--)	2	Central spacing	(mm)	206.226
Orientation	(deg)	0.00	Crosspasses	(--)	18

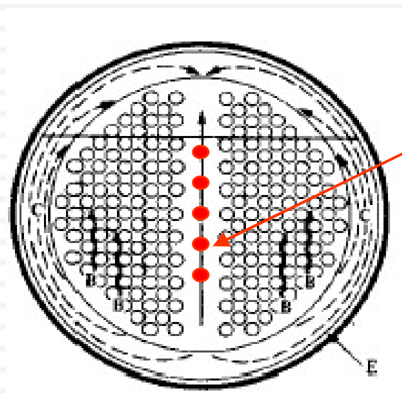
Tube Geometry			Nozzles		
Tube type	(--)	Plain	Shell inlet	(mm)	325.425
Tube OD	(mm)	19.050	Shell outlet	(mm)	325.425
Length	(m)	5.000	Inlet height	(mm)	123.860
Pitch ratio	(--)	1.3333	Outlet height	(mm)	119.900
Layout	(deg)	30	Tube inlet	(mm)	298.451
Tubecount	(--)	456	Tube outlet	(mm)	298.451
Tube Pass	(--)	2			

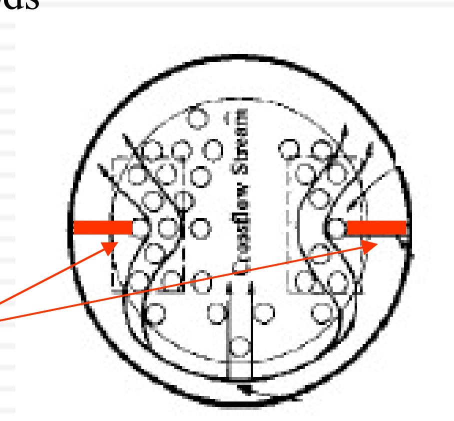
Thermal Resistance, %		Velocities, m/s		Flow Fractions	
Shell	50.89	Shellside	5.45	A	0.095
Tube	10.51	Tubeside	1.55	B	0.429
Fouling	30.27	Crossflow	6.59	C	0.173
Metal	8.328	Window	7.16	E	0.221
				F	0.082

FLOW FRACTIONS/STREAMS

STREAM/ FLOW FRACTION	DESCRIPTION
A	Through gap between tube & baffle.
B	Between tubes across the bundle. Most effective stream for heat transfer.
C	Through gap between bundle & shell.
E	Through gap between baffle & shell.
F	Through pass partition lane







HTRI Xchanger Suite v5.00 - [Xist - [Reports] - 190-E-308 LPGfinal.htri - Output Summary-Final

File Edit View Reports Tools Window Help

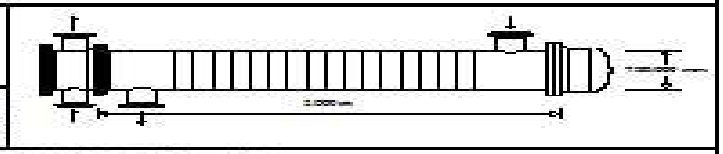
- Output Summary
  - Run Log
  - Runtime Messages
  - Final Results
  - Shellside Monitor
  - Tubeside Monitor
  - Vibration
  - Rating Data Sheet
  - TEMA Spec Sheet
  - Property Monitor
  - Stream Properties
- Input Reprint

Fluid name		Process Gas			Cooling Water	
Fluid condition			Cond. Vapor			Sens. Liquid
Total flow rate	(kg/s)		17.9277 *			127.554 *
Weight fraction vapor, In/Out	(--)	0.765	0.779		0.000	0.000
Temperature, In/Out	(Deg C)	60.00	35.00		29.00	32.00
Temperature, Average/Skin	(Deg C)	47.5	37.39		30.5	32.03
Wall temperature, Min/Max	(Deg C)	31.13	44.05		30.74	41.62
Pressure, In/Average	(kPa)	2751.36	2742.22		501.332	488.050
Pressure drop, Total/Allowed	(kPa)	18.279	20.000		26.565	50.000
Velocity, Mid/Max allow	(m/s)	5.45			1.55	
Mole fraction inert	(--)		0.777			
Average film coef.	(W/m2-K)		1152.31			6950.66
Heat transfer safety factor	(--)		1.000			1.000
Fouling resistance	(m2-K/W)		0.000086			0.000345

Overall Performance Data

Overall coef., Reqd/Clean/Actual	(W/m2-K)	465.70	/	841.00	/	586.47
Heat duty, Calculated/Specified	(MegaWatts)	1.6001	/			
Effective overall temperature difference	(Deg C)	13.1				
EMTD = (MTD) * (DELTA) * (F/G/H)	(Deg C)	13.89	*	0.9446	*	1.0000

See Runtime Messages Report for warnings.



Exchanger Fluid Volumes

Approximate shellside	(L)	1387.3
Approximate tubeside	(L)	1003.2

Shell Construction Information

TEMA shell type		AES		Shell ID	(mm)	720.000
Shells Series	1	Parallel	2	Total area	(m2)	272.900
Passes Shell	1	Tube	2	Eff. area	(m2/shell)	130.904
Shell orientation angle (deg)		0.00				
Impingement present		Rectangular plate		Imp. length/width (mm)		358 / 358
Pairs seal strips		2		Passlane seal rods (mm)	No. 4	
Shell expansion joint		No		Head to support distance (mm)		
Weight estimation Wet/Dry/Bundle	9641.1	/	7252.3	/	2234.0	(kg/shell)

Baffle Information

Type		Parallel Double-Seg.		Baffle cut (% dia) 25.50		
Crosspasses/shellpass		18	No.	Pct Area)	(mm) to C.L	
Central spacing	(mm)	206.226	1	39.86	176.400	
Inlet spacing	(mm)	762.000	2	16.04	44.406	
Outlet spacing	(mm)	735.138	Baffle overlap		(mm)	131.994
Baffle thickness	(mm)	4.763				

Tube Information

Tube type		Plain	Tubecount per shell		456
Overall length	(m)	5.000	Pct tubes removed (both)		20.83
Effective length	(m)	4.797	Outside diameter	m)	19.050
Total tubesheet	(mm)	101.600	Wall thickness	(mm)	1.880
Area ratio	(out/in)	1.2459	Pitch (mm) 25.4000	Ratio	1.3333
Tube metal		Alloy 2205 (S31803)	Tube pattern (deg)		30

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1 - Final Results | 2 | 3

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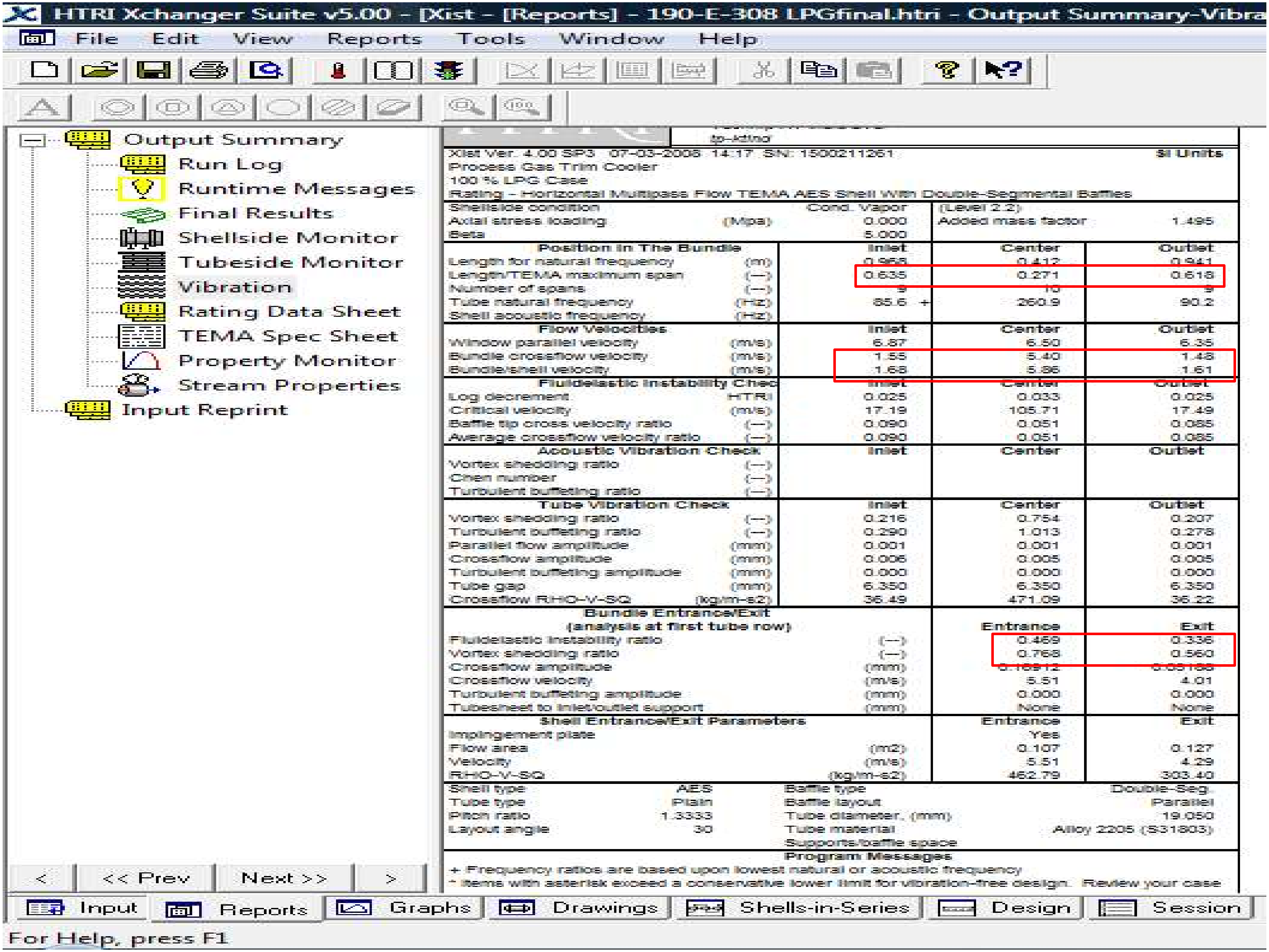
For Help, press F1



Xist Ver. 4.00 SP3 07-03-2006 14:17 SN: 1500211261 — SI Units

Process Gas Trim Cooler

100 % LPG Case

Rating - Horizontal Multipass Flow TEMA AES Shell With Double-Segmental Baffles

Shellside condition		Cond. Vapor	(Level 2.2)	
Axial stress loading	(Mpa)	0.000	Added mass factor	1.495
Beta		5.000		

Position In The Bundle		Inlet	Center	Outlet
Length for natural frequency	(m)	0.958	0.412	0.941
Length/TEMA maximum span	(--)	0.635	0.271	0.618
Number of spans	(--)	9	10	9
Tube natural frequency	(Hz)	85.6 +	260.9	90.2
Shell acoustic frequency	(Hz)			
Flow Velocities		**Inlet**	**Center**	**Outlet**
Window parallel velocity	(m/s)	6.87	6.50	6.35
Bundle crossflow velocity	(m/s)	1.55	5.40	1.48
Bundle/shell velocity	(m/s)	1.68	5.86	1.61
Fluidelastic Instability Chec		**Inlet**	**Center**	**Outlet**
Log decrement	HTRI	0.025	0.033	0.025
Critical velocity	(m/s)	17.19	105.71	17.49
Baffle tip cross velocity ratio	(--)	0.090	0.051	0.085
Average crossflow velocity ratio	(--)	0.090	0.051	0.085
Acoustic Vibration Check		**Inlet**	**Center**	**Outlet**
Vortex shedding ratio	(--)			
Chen number	(--)			
Turbulent buffeting ratio	(--)			
Tube Vibration Check		**Inlet**	**Center**	**Outlet**
Vortex shedding ratio	(--)	0.216	0.754	0.207
Turbulent buffeting ratio	(--)	0.290	1.013	0.278
Parallel flow amplitude	(mm)	0.001	0.001	0.001
Crossflow amplitude	(mm)	0.006	0.005	0.005
Turbulent buffeting amplitude	(mm)	0.000	0.000	0.000
Tube gap	(mm)	6.350	6.350	6.350
Crossflow RHO-V-SQ	(kg/m-s2)	36.49	471.09	36.22

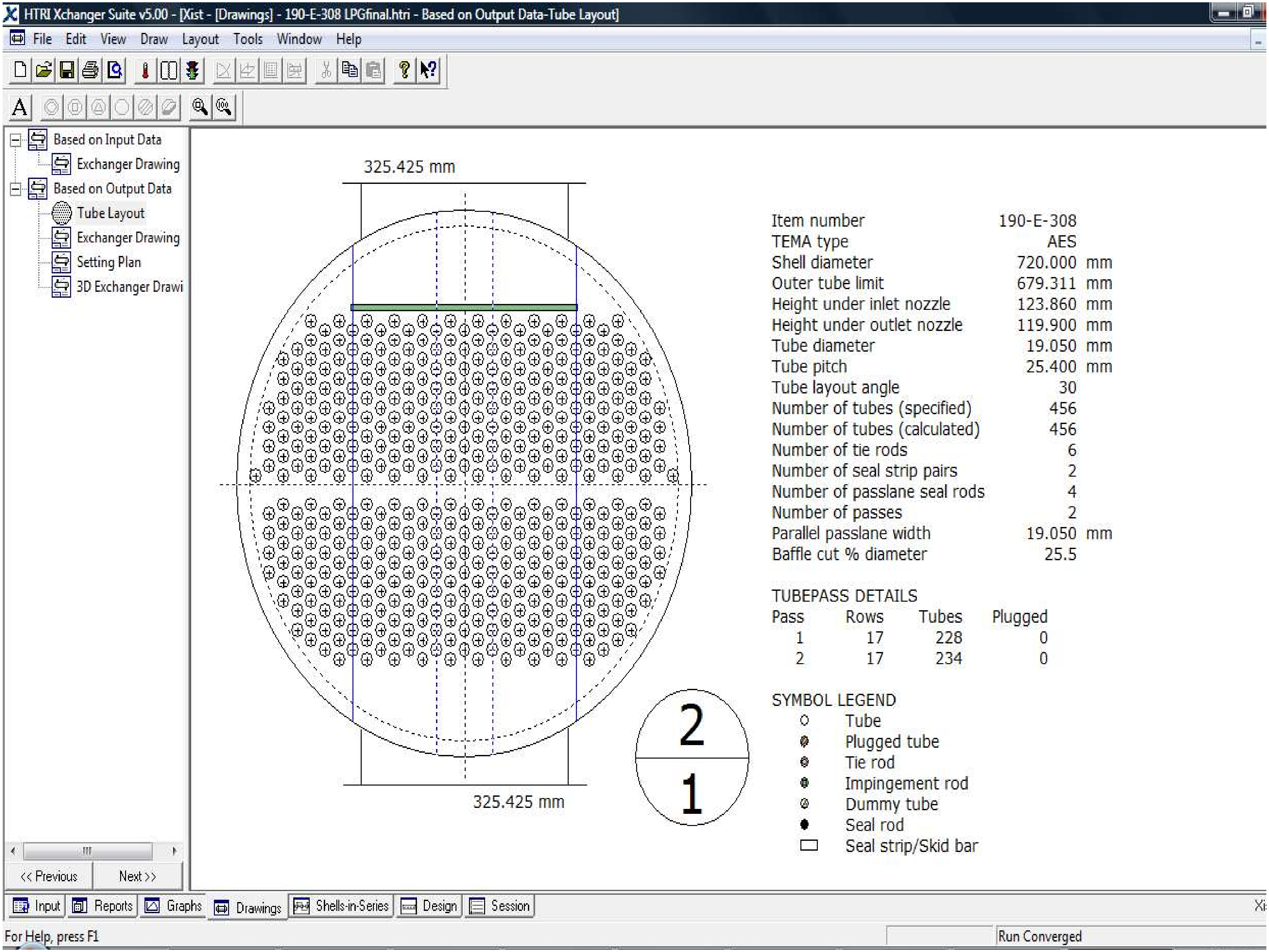
Bundle Entrance/Exit (analysis at first tube row)		Entrance	Exit
Fluidelastic instability ratio	(--)	0.469	0.336
Vortex shedding ratio	(--)	0.768	0.560
Crossflow amplitude	(mm)	[illegible]	[illegible]
Crossflow velocity	(m/s)	5.51	4.01
Turbulent buffeting amplitude	(mm)	0.000	0.000
Tubesheet to inlet/outlet support	(mm)	None	None
Shell Entrance/Exit Parameters		**Entrance**	**Exit**
Impingement plate		Yes	
Flow area	(m2)	0.107	0.127
Velocity	(m/s)	5.51	4.29
RHO-V-SQ	(kg/m-s2)	462.79	303.40

Shell type	AES	Baffle type	Double-Seg.
Tube type	Plain	Baffle layout	Parallel
Pitch ratio	1.3333	Tube diameter, (mm)	19.050
Layout angle	30	Tube material	Alloy 2205 (S31803)
		Supports/baffle space	

Program Messages

+ Frequency ratios are based upon lowest natural or acoustic frequency

* Items with asterisk exceed a conservative lower limit for vibration-free design. Review your case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3D Exchanger Drawi
<< Previous
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325.425 mm
325.425 mm
2
1
Item number 190-E-308
TEMA type AES
Shell diameter 720.000 mm
Outer tube limit 679.311 mm
Height under inlet nozzle 123.860 mm
Height under outlet nozzle 119.900 mm
Tube diameter 19.050 mm
Tube pitch 25.400 mm
Tube layout angle 30
Number of tubes (specified) 456
Number of tubes (calculated) 456
Number of tie rods 6
Number of seal strip pairs 2
Number of passlane seal rods 4
Number of passes 2
Parallel passlane width 19.050 mm
Baffle cut % diameter 25.5
TUBEPASS DETAILS
Pass Rows Tubes Plugged
1 17 228 0
2 17 234 0
SYMBOL LEGEND
Tube
Plugged tube
Tie rod
Impingement rod
Dummy tube
Seal rod
Seal strip/Skid bar
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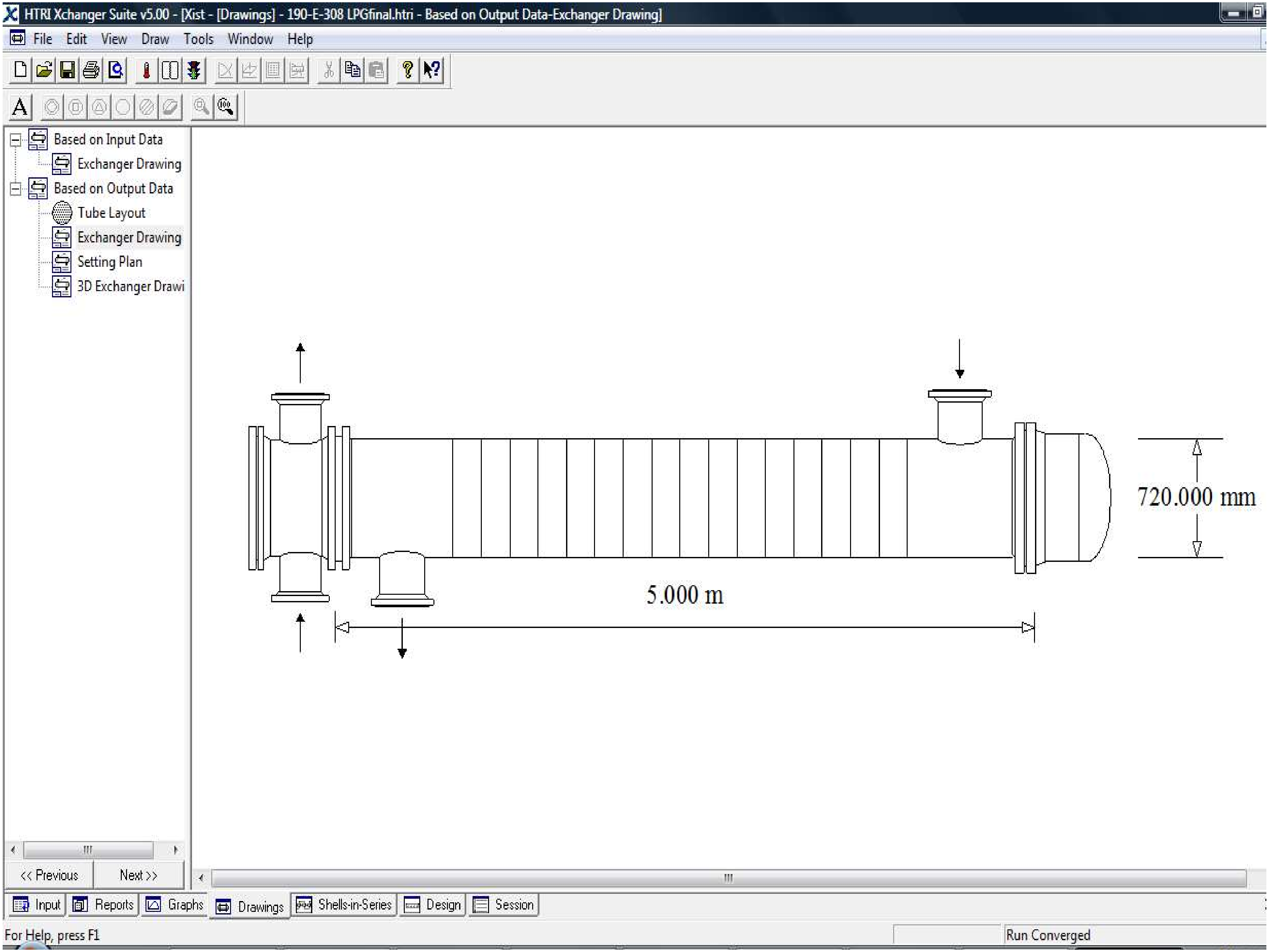
For Help, press F1
Run Converged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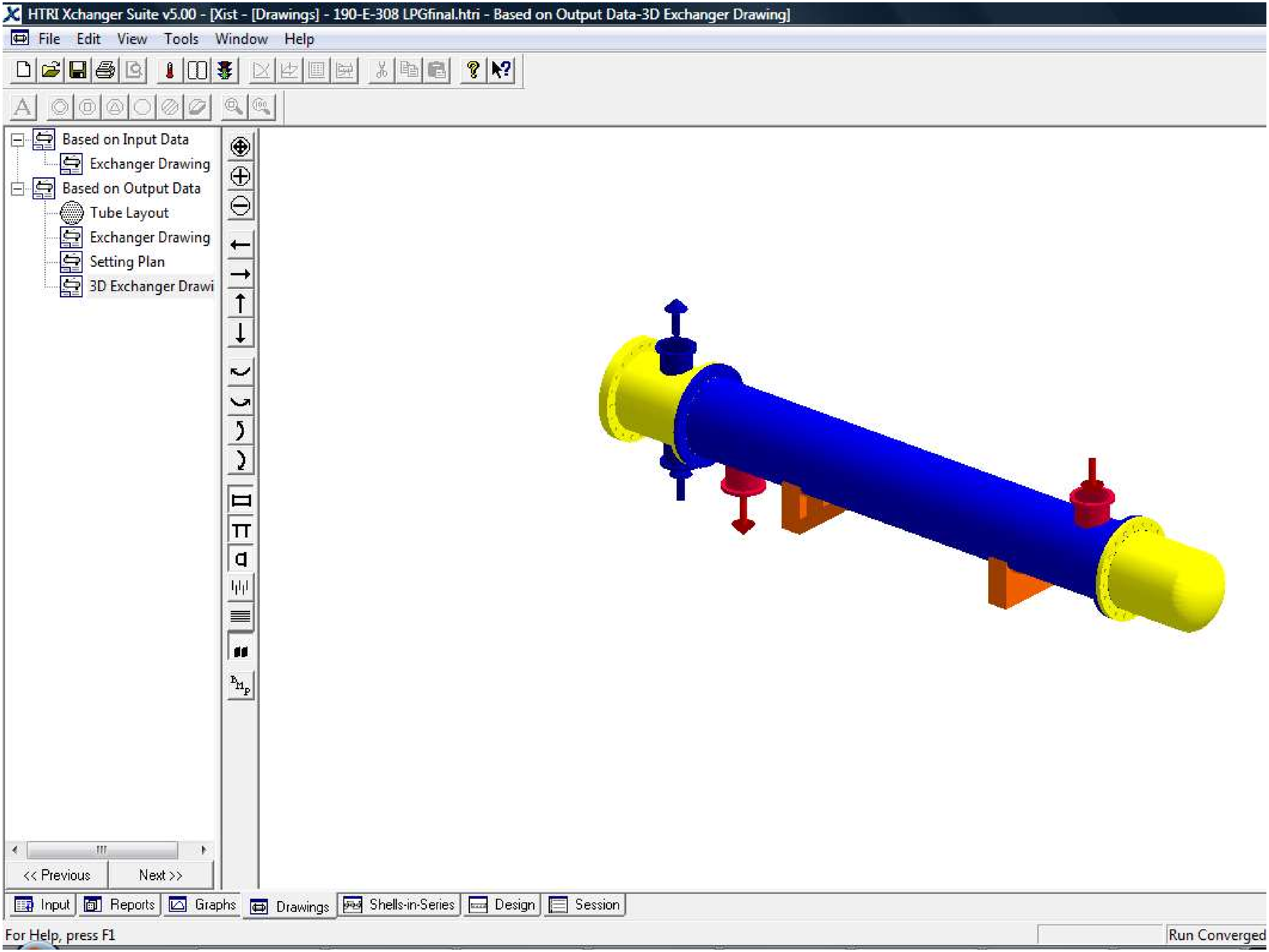
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THANK YOU