Education Institute for

Equipment & Process Design

T-6001

Design and Principles

Process data

Description		Shell Side Inlet	Shell Side Outlet	Tube Side Inlet	Tube Side Outlet	Units
Fluids	3)	MP Saturated Steam		NG + PC		
Quantity: total		255864		588608		kg/h
liquid	14)		255864	435863	263724	kg/h
gas		255864		152745	324884	kg/h
Operating temperature		240	240	168	226	°C
Operating pressure		32,7		43,3		bar g
Liquid: molecular weight			18,02	18,02	18,02	kg/kmol
density			814	900	834	kg/m³
viscosity			0,114	0,163	0,121	cP
specific heat capacity			4,775	4,35	4,643	kJ/kg/°C
thermal conductivity			0,6314	0,6842	0,6464	W/m/°C
boiling temperature						°C
Gas: molecular weight		18,02		16,90	17,47	kg/kmol
density		16,9		21,1	20	kg/m³
viscosity		0,018		0,016	0,018	cP
specific heat capacity		3,518		2,552	3,066	kJ/kg/°C
thermal conductivity		0,0426		0,0553	0,0532	W/m/°C
dew point		240		241		°C

Heating and Cooling Table

Shell side

Temperature °C	Gas fraction wt %	Duty profile MW	Liquid density kg/m³	Liquid viscosity cP	Liquid heat capacity kJ/kg/°C	Liquid thermal conductivity W/m/°C	Surface tension dyn/cm
240	100,00	0,0					
240	88,89	-6,9	814	0,114	4,776	0,6313	29
240	77,78	-13,8	814	0,114	4,776	0,6313	29
240	66,67	-20,7	814	0,114	4,776	0,6313	29
240	55,56	-27,6	814	0,114	4,776	0,6313	29
240	44,44	-34,5	814	0,114	4,776	0,6313	29
240	33,33	-41,4	814	0,114	4,776	0,6313	29
240	22,22	-48,3	814	0,114	4,776	0,6313	29
240	11,11	-55,1	814	0,114	4,776	0,6313	29
240	0,00	-62,0	814	0,114	4,776	0,6313	29

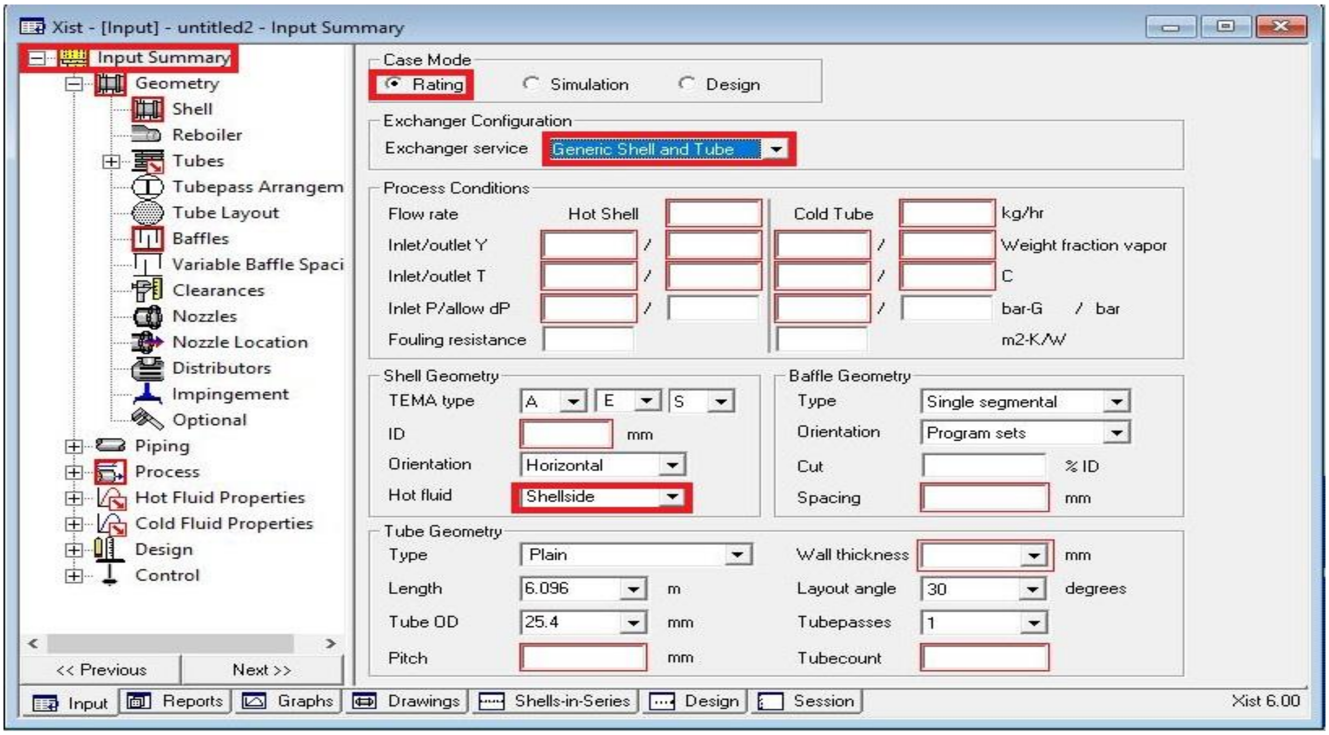
Temperature °C	Gas fraction wt %	Duty profile MW	Gas density kg/m³	Gas viscosity cP	Gas heat capacity kJ/kg/°C	Gas thermal conductivity W/m/°C
240	100,00	0,0	16,8	0,018	3,512	0,0426
240	88,89	-6,9	16,8	0,018	3,512	0,0426
240	77,78	-13,8	16,8	0,018	3,512	0,0426
240	66,67	-20,7	16,8	0,018	3,512	0,0426
240	55,56	-27,6	16,8	0,018	3,512	0,0426
240	44,44	-34,5	16,8	0,018	3,512	0,0426
240	33,33	-41,4	16,8	0,018	3,512	0,0426
240	22,22	-48,3	16,8	0,018	3,512	0,0426
240	11,11	-55,1	16,8	0,018	3,512	0,0426
240	0,00	-62,0				

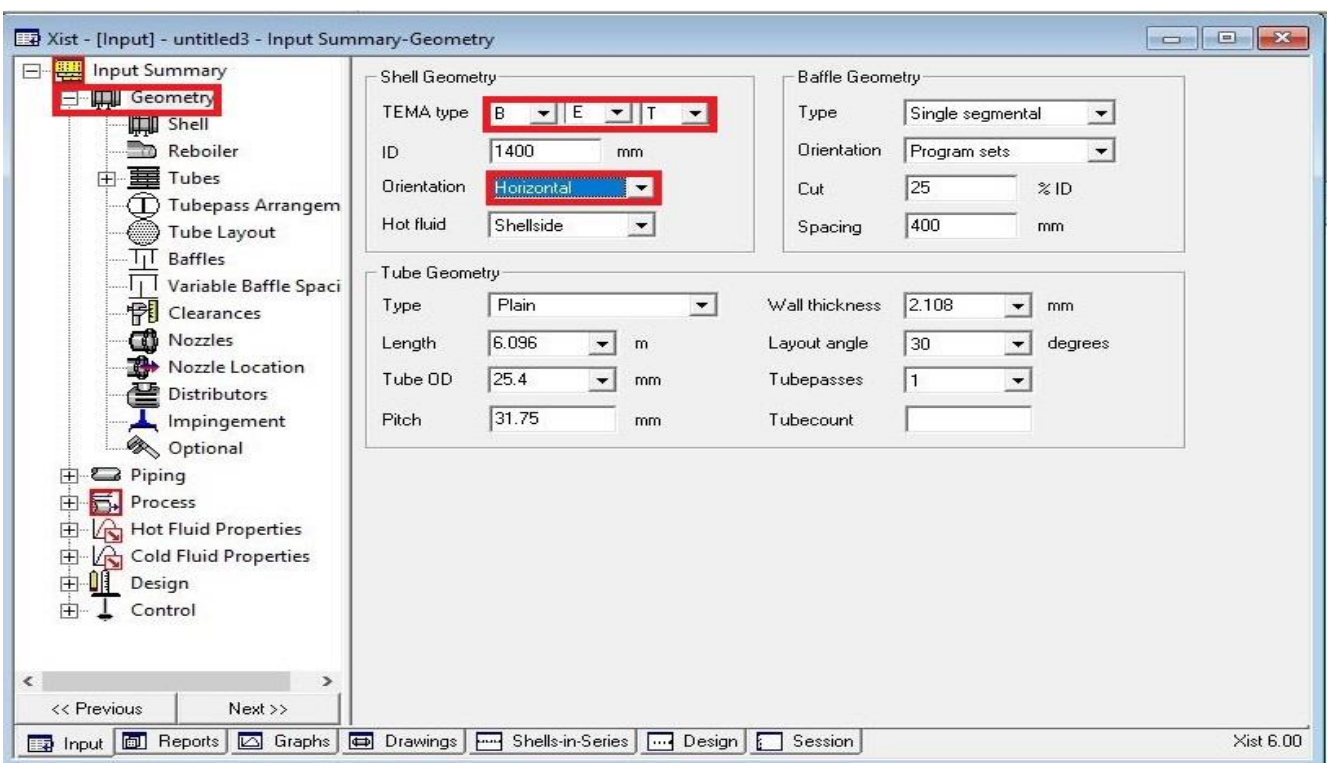
Tube side							
Temperature	Gas fraction	Duty profile	Liquid density	Liquid viscosity	Liquid heat capacity	Liquid thermal conductivity	Surface tension
°C	wt %	MW	kg/m³	cP	kJ/kg/°C	W/m/°C	dyn/cm
226	55,20	0,0	834	0,121	4,643	0,6464	29
223	51,05	6,9	838	0,122	4,622	0,6493	29
220	47,05	13,8	842	0,124	4,597	0,6526	29
216	43,22	20,7	847	0,127	4,57	0,6563	29
211	39,60	27,6	853	0,13	4,54	0,6604	29
205	36,23	34,5	860	0,133	4,507	0,6650	30
198	33,15	41,4	868	0,138	4,471	0,6699	30
190	30,40	48,3	878	0,144	4,432	0,6750	30
180	28,01	55,1	888	0,152	4,392	0,6799	30
168	26,02	62,0	900	0,163	4,351	0,6842	30
Temperature	Gas fraction	Duty profile	Gas density	Gas viscosity	Gas heat capacity	Gas thermal conductivity	
°C	wt %	MW	kg/m³	cP	kJ/kg/°C	W/m/°C	
226	55,20	0,0	20	0,018	3,066	0,0532	
223	51,05	6,9	20	0,018	3,017	0,0537	
220	47,05	13,8	20	0,018	2,964	0,0541	
216	43,22	20,7	20	0,017	2,908	0,0546	
211	39,60	27,6	20	0,017	2,848	0,0550	
205	36,23	34,5	20,1	0,017	2,787	0,0555	
198	33,15	41,4	20,2	0,017	2,725	0,0558	
190	30,40	48,3	20,3	0,017	2,664	0,0559	
180	28,01	55,1	20,5	0,016	2,606	0,0557	
168	26,02	62,0	20,9	0,016	2,552	0,0552	

Education Institute for

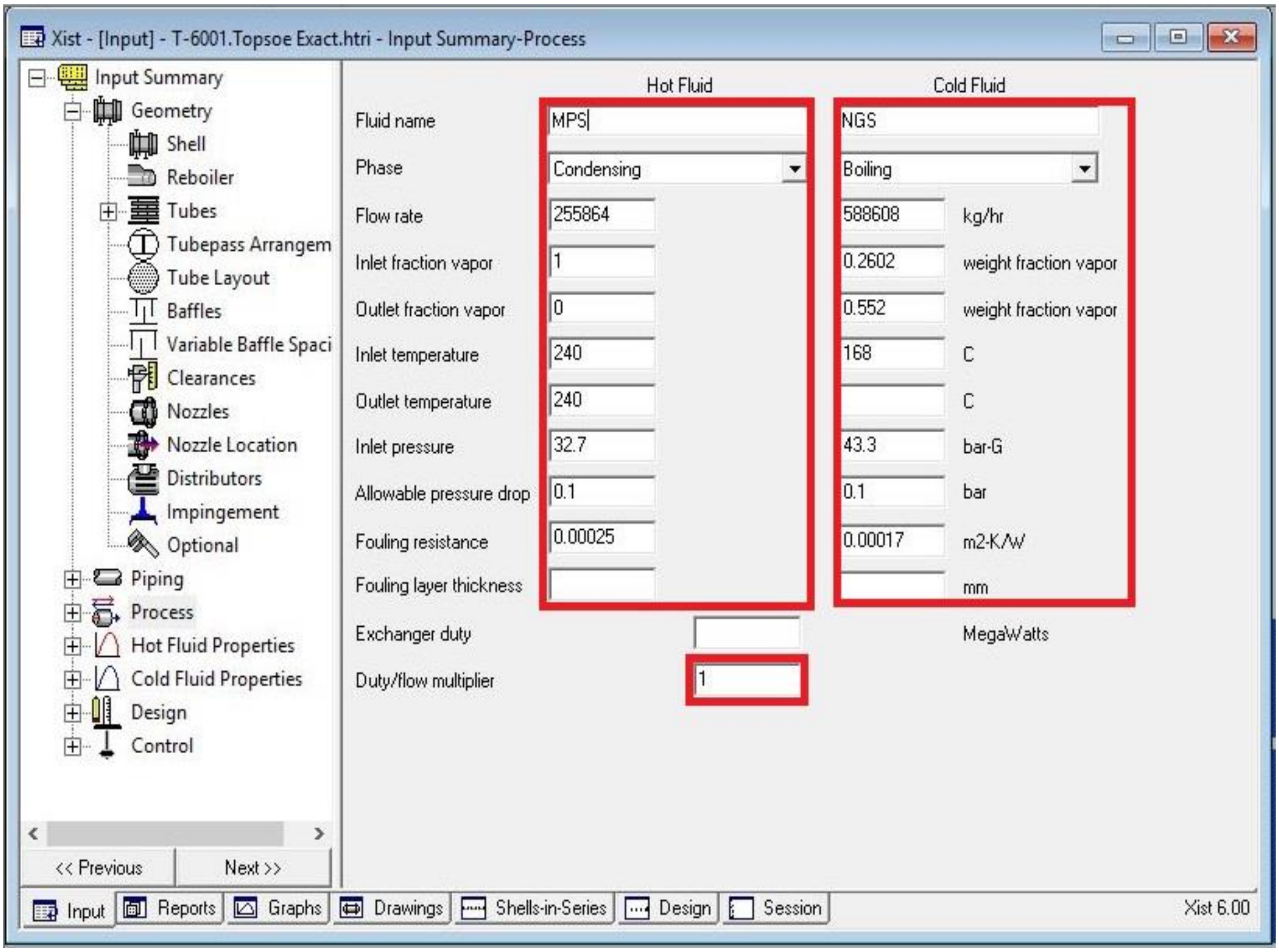
Equipment & Process Design

Open HTRI and Input Summery sheet and enter data in red areas

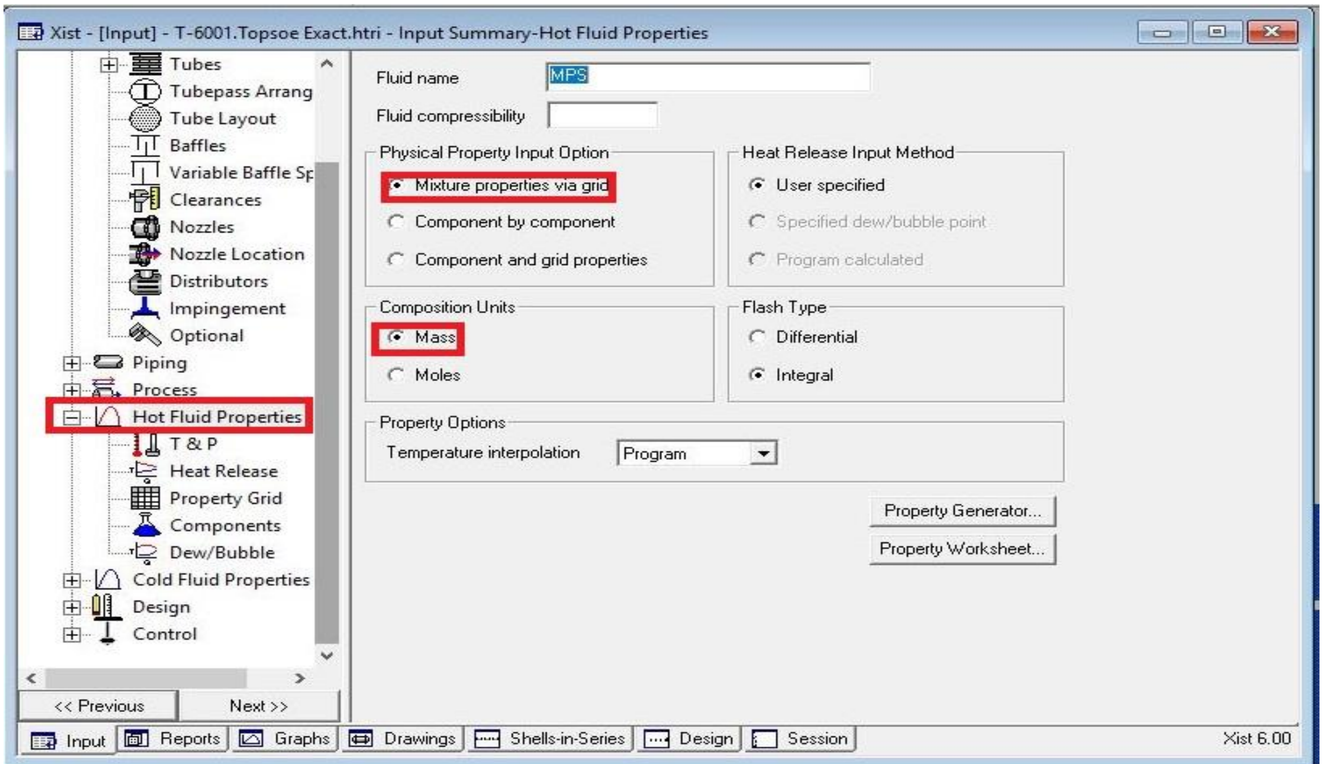


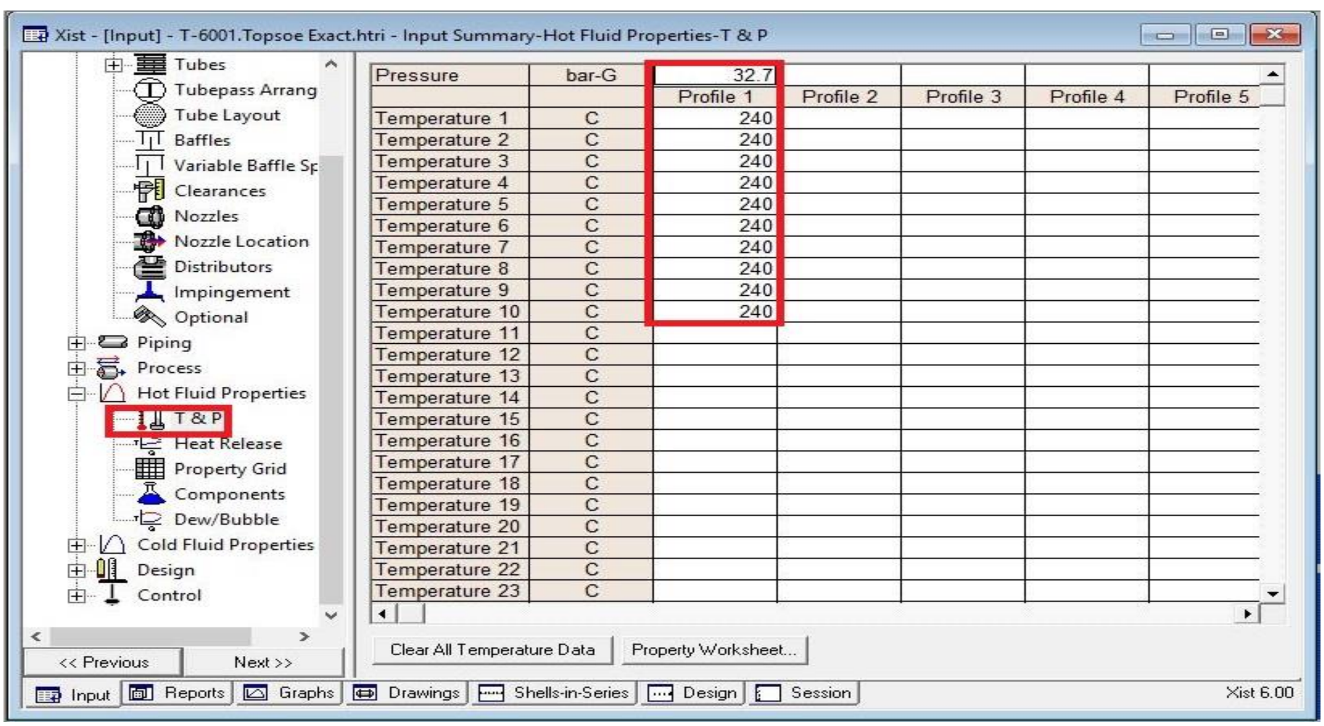


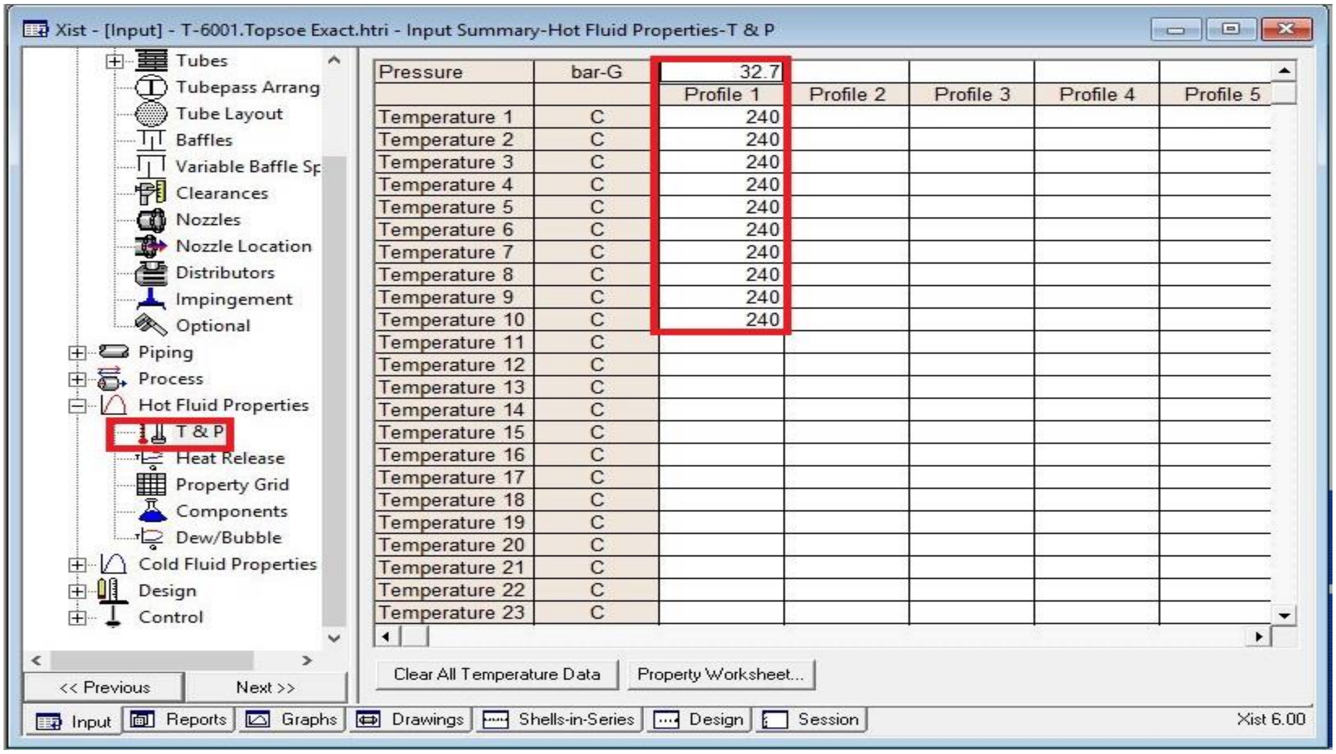
Enter operating data in process sheet in red areas

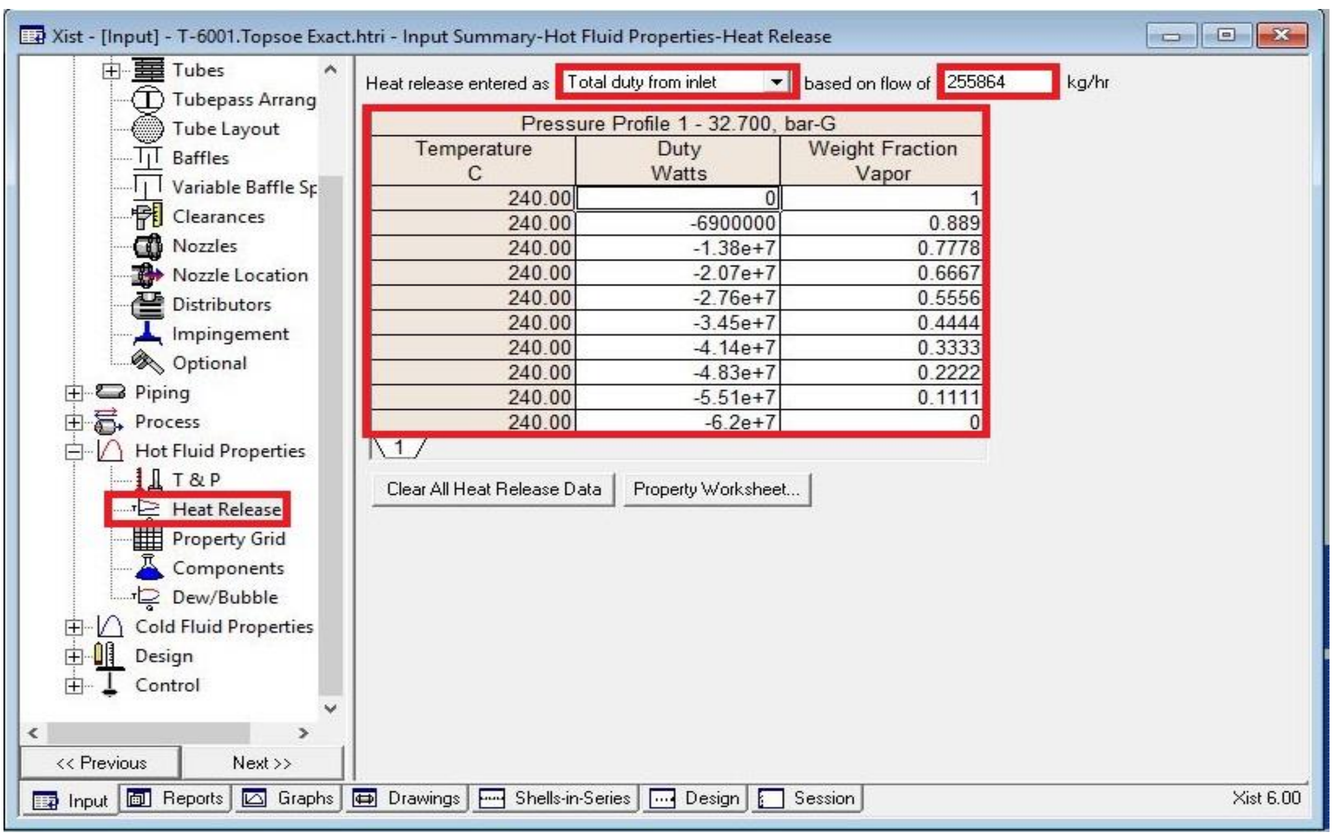


Enter heating and cooling table data in hot and cold fluid properties in red areas





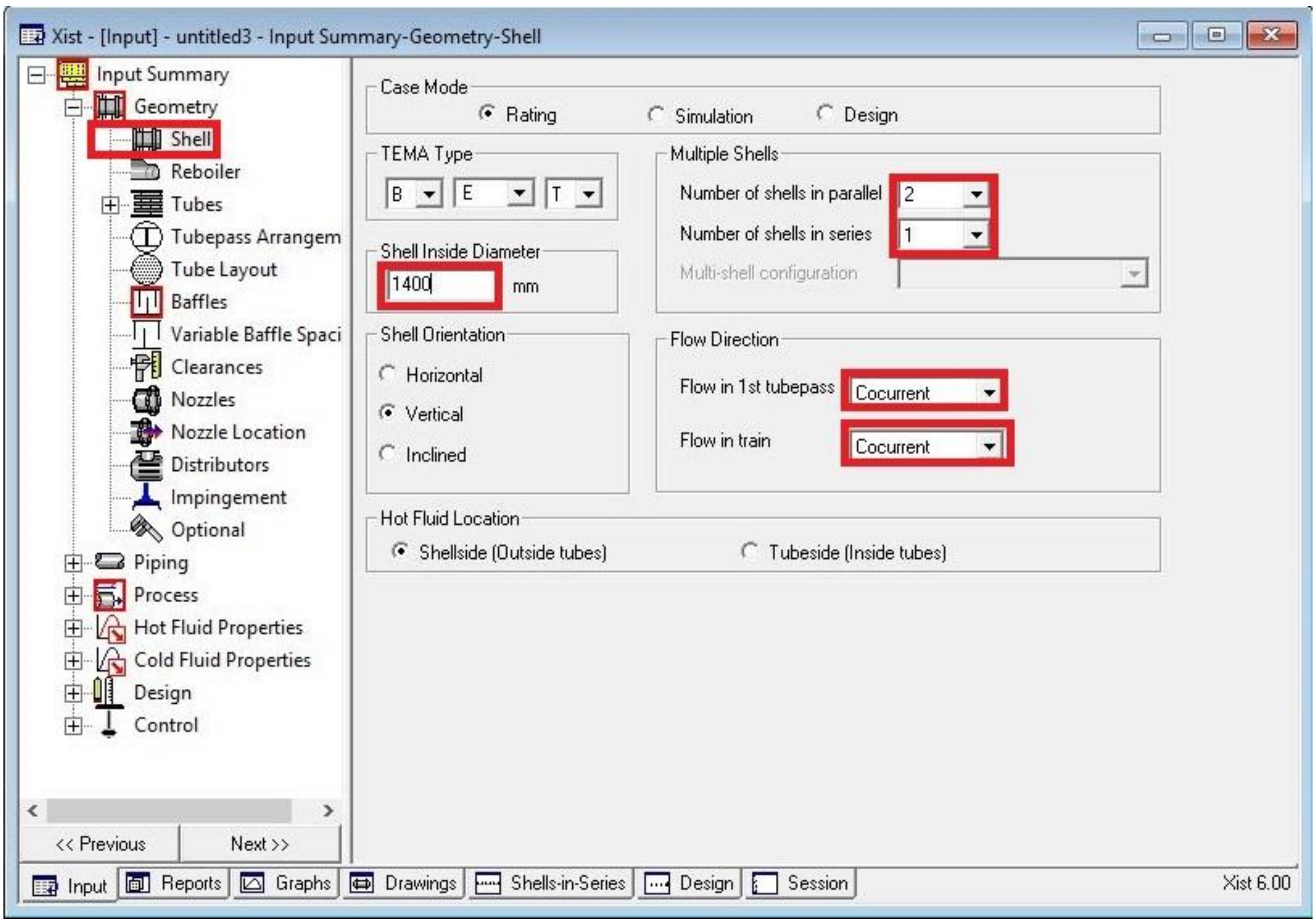

Xist - [Input] - T-6001.Topsoe Exact.htri - Input Summary-Hot Fluid Properties-T & P
Tubes
Tubepass Arrang
Tube Layout
Baffles
Variable Baffle Sp
Clearances
Nozzles
Nozzle Location
Distributors
Impingement
Optional
Piping
Process
Hot Fluid Properties
T & P
Heat Release
Property Grid
Components
Dew/Bubble
Cold Fluid Properties
Design
Control
<< Previous
Next >>
Pressure bar-G 32.7
Profile 1 Profile 2 Profile 3 Profile 4 Profile 5
Temperature 1 C 240
Temperature 2 C 240
Temperature 3 C 240
Temperature 4 C 240
Temperature 5 C 240
Temperature 6 C 240
Temperature 7 C 240
Temperature 8 C 240
Temperature 9 C 240
Temperature 10 C 240
Temperature 11 C
Temperature 12 C
Temperature 13 C
Temperature 14 C
Temperature 15 C
Temperature 16 C
Temperature 17 C
Temperature 18 C
Temperature 19 C
Temperature 20 C
Temperature 21 C
Temperature 22 C
Temperature 23 C
Clear All Temperature Data
Property Worksheet...
Input
Reports
Graphs
Drawings
Shells-in-Series
Design
Session
Xist 6.00


Xist - [Input] - T-6001.Topsoe Exact.htri - Input Summary-Hot Fluid Properties-Heat Release
Tubes
Tubepass Arrang
Tube Layout
Baffles
Variable Baffle Sp
Clearances
Nozzles
Nozzle Location
Distributors
Impingement
Optional
Piping
Process
Hot Fluid Properties
T & P
Heat Release
Property Grid
Components
Dew/Bubble
Cold Fluid Properties
Design
Control
<< Previous
Next >>
Heat release entered as Total duty from inlet based on flow of 255864 kg/hr
Pressure Profile 1 - 32.700, bar-G
Temperature C | Duty Watts | Weight Fraction Vapor
240.00 | 0 | 1
240.00 | -6900000 | 0.889
240.00 | -1.38e+7 | 0.7778
240.00 | -2.07e+7 | 0.6667
240.00 | -2.76e+7 | 0.5556
240.00 | -3.45e+7 | 0.4444
240.00 | -4.14e+7 | 0.3333
240.00 | -4.83e+7 | 0.2222
240.00 | -5.51e+7 | 0.1111
240.00 | -6.2e+7 | 0
1
Clear All Heat Release Data
Property Worksheet...
Input
Reports
Graphs
Drawings
Shells-in-Series
Design
Session
Xist 6.00

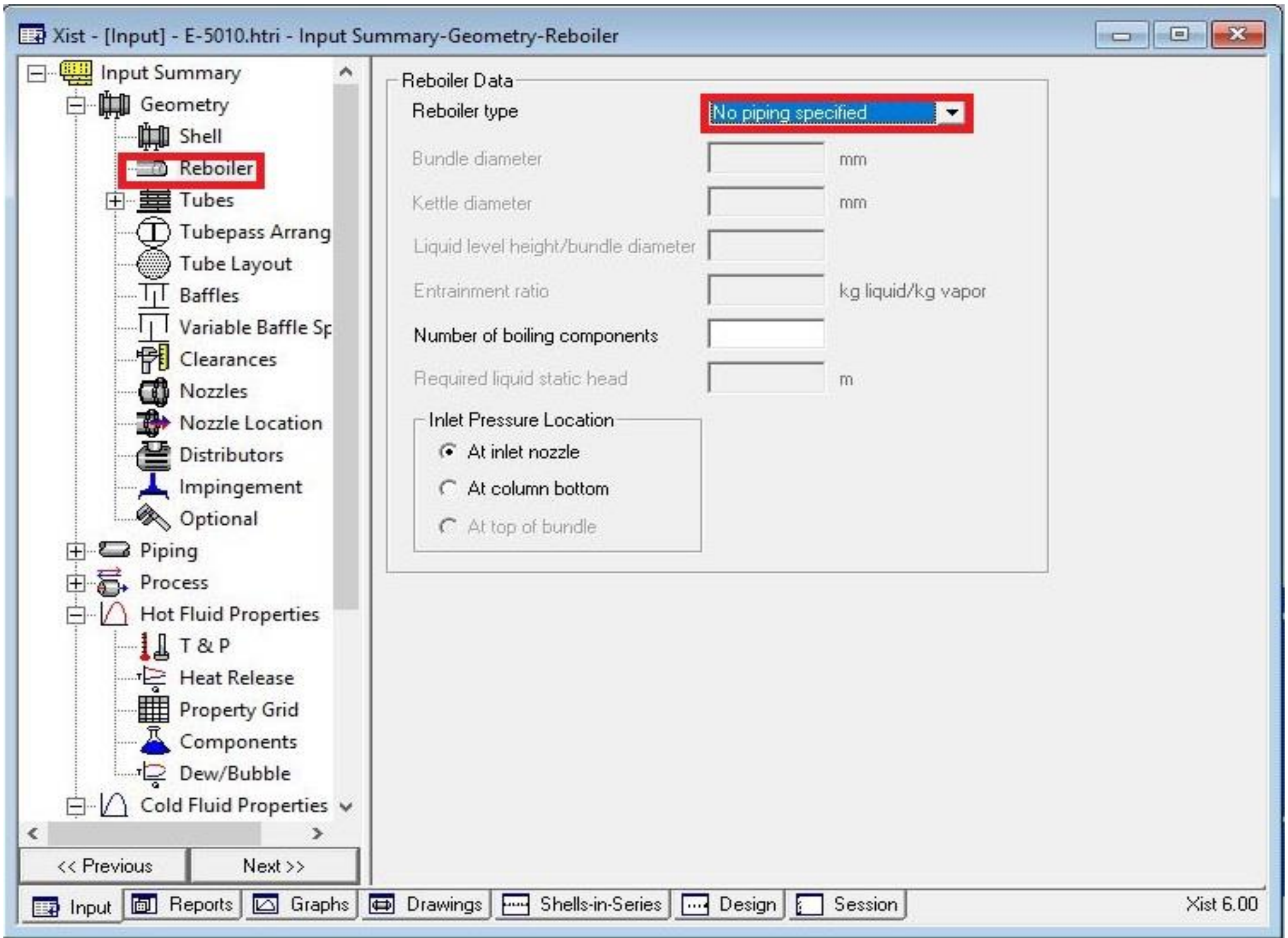
Put shell info in shell sheet in red areas

Note:

- 1. Initially estimate shell ID between 1.5-3 times tube-side pipeline ID, here it is 18 inch so first estimation would be 55 inch.
- 2. Because of its capacity two heat exchangers in parallel are selected.
- 3. Cocurrent direction is considered as flow direction since the orientation is vertical it is solely viable for MPS to enter from top to be condensed at bottom and the same happens to water in tube to be flowed because of gravity.



In Reboiler Sheet do not enter an input

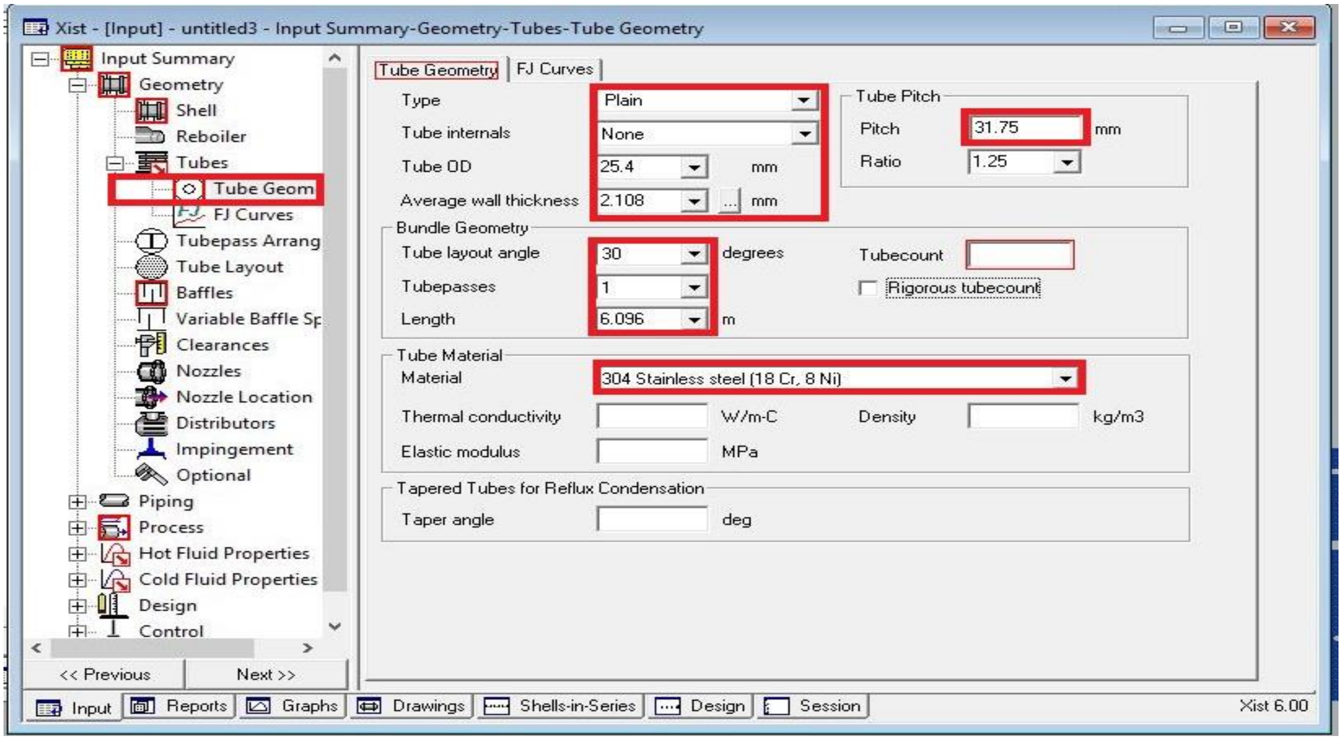


Put Tube mechanical data

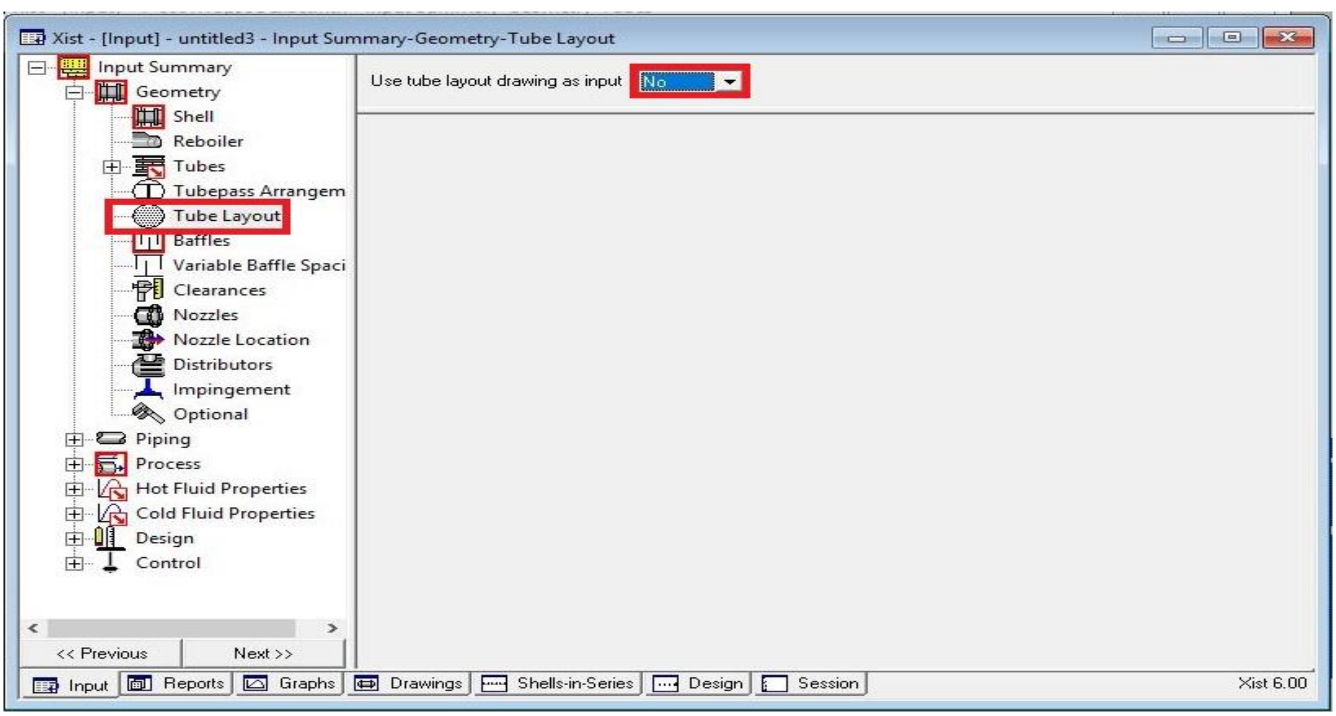
- Note that since mixing between water and natural gas is going to happen, tube with 25.4 OD is selected
- Since Tube material is SS due to presence of CO_2, Tube thickness 2.11 is selected according to table below
- Select Pitch 31.7 to pass TEMA R.2.5

Table 1.3 Typical diameters, thicknesses and pitch arrangement of tubes

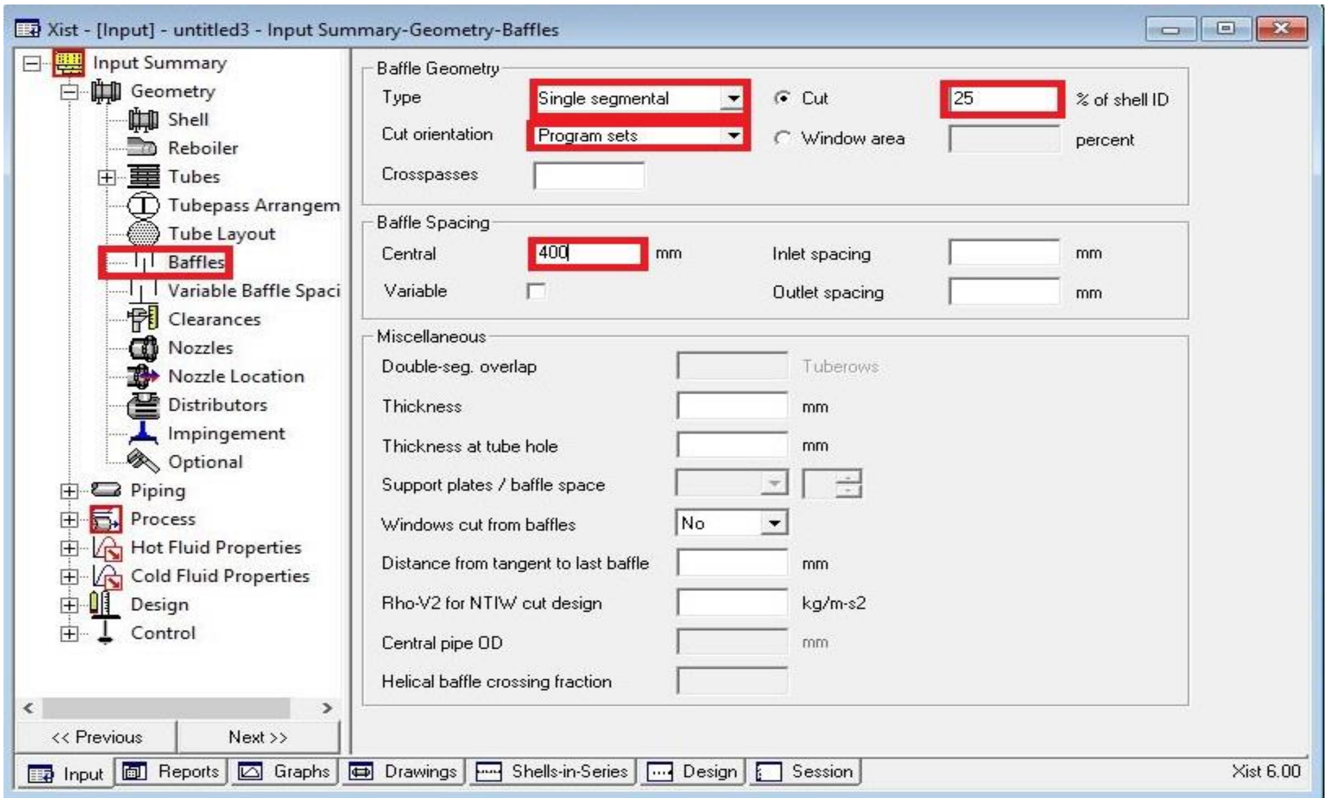
Tube outside diameter		mm	15.88	19.05	25.40	31.75
		in	5/8	3/4	1	1 1/4
Tube thickness	Carbon and low-alloy steels	mm	1.65	2.11	2.77	3.40
		in	0.065	0.083	0.109	0.134
		b.w.g.	16	14	12	10
	Stainless steels, aluminium, copper and nickel alloys	mm	1.24	1.65	2.11	2.77
		in	0.049	0.065	0.083	0.109
		b.w.g.	18	16	14	12
Minimum tube pitch	Clean service (30° or 60°)	mm	19.84	23.81	31.75	39.69
		in	25/32	15/16	1 1/4	1 9/16
	Fouling service (45° or 90°)	mm	22.22	25.40	31.75	39.69
		in	7/8	1	1 1/4	1 9/16



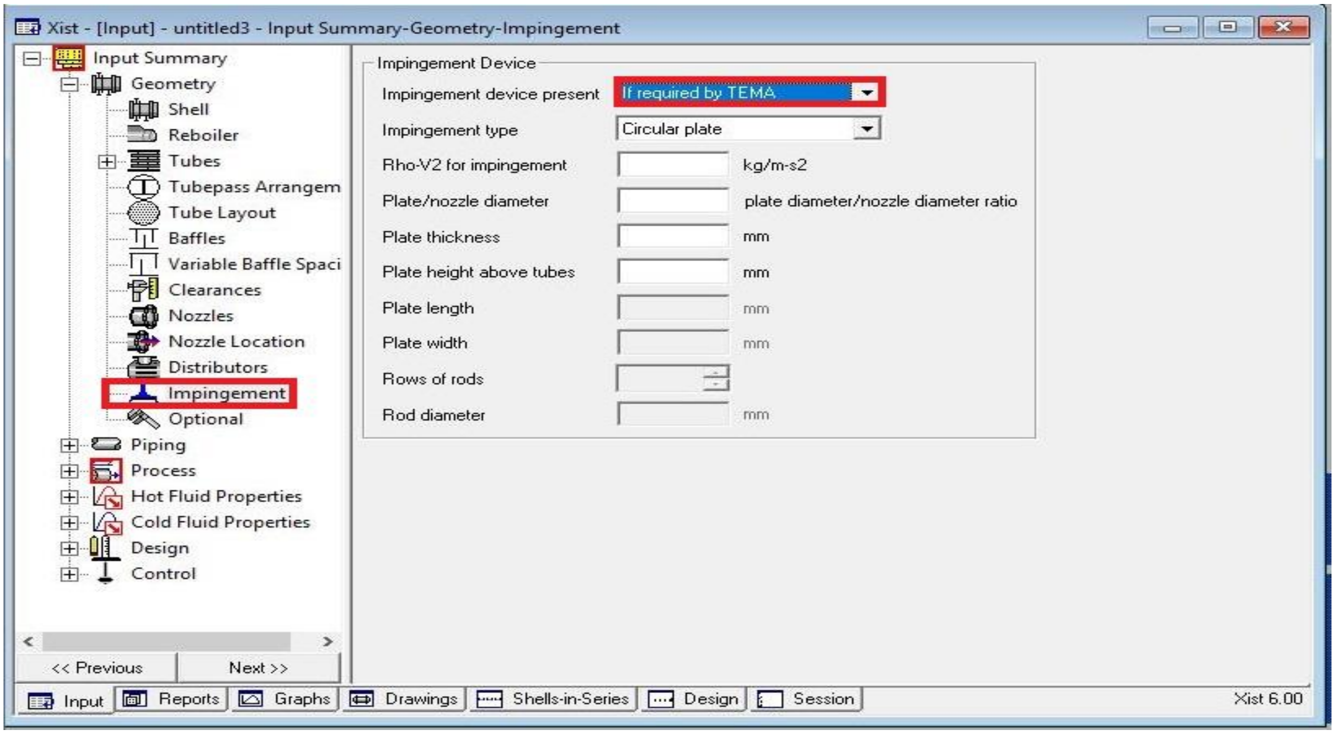
Act like below

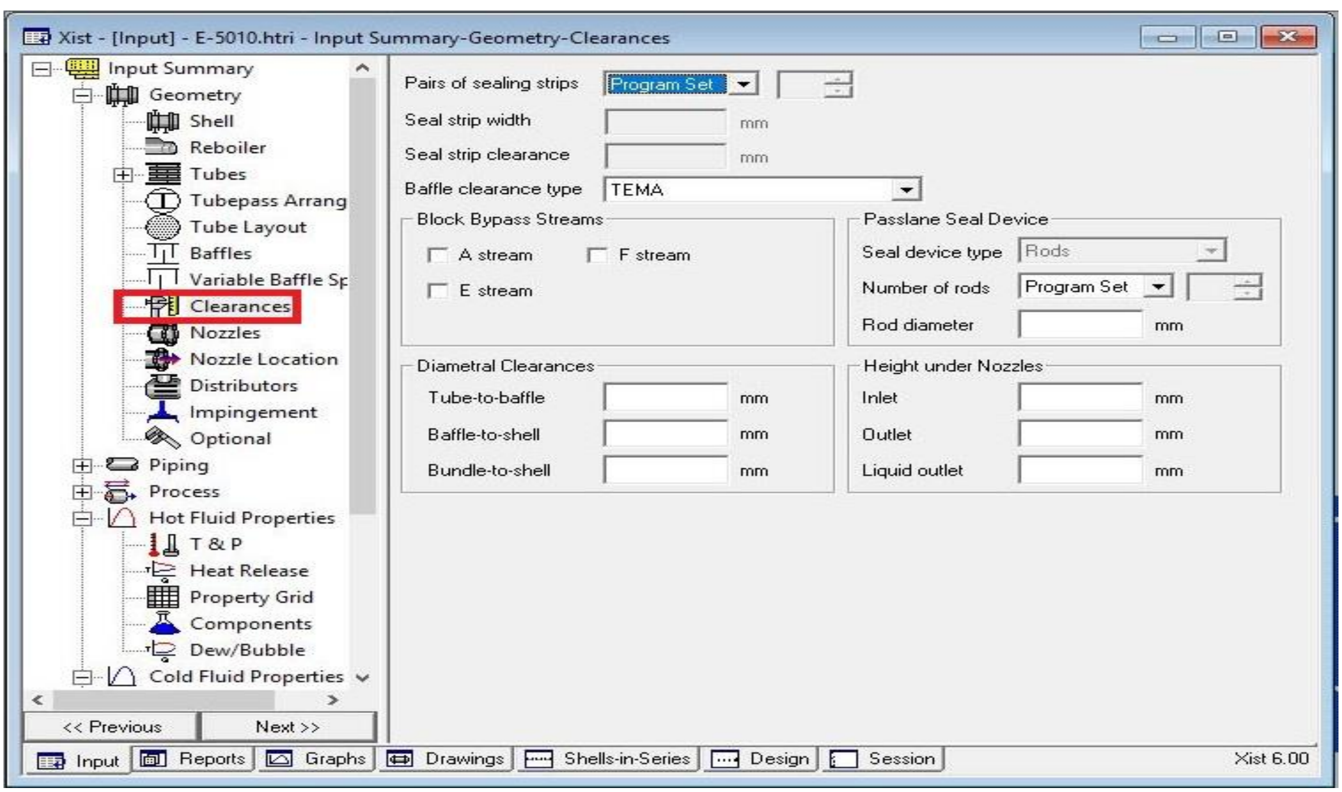


Put baffle info in baffle sheet in red areas like below

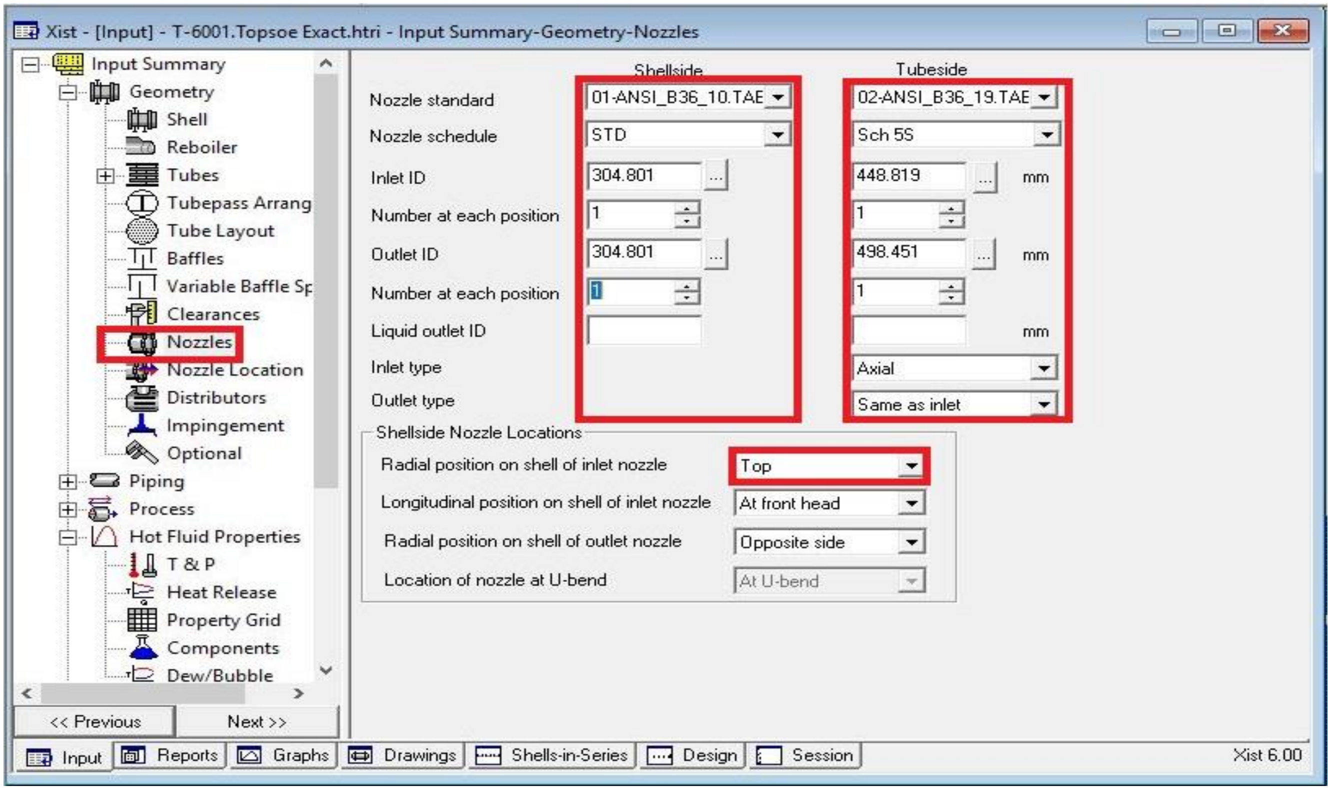


Act exactly like below for impingement sheet and Clearance



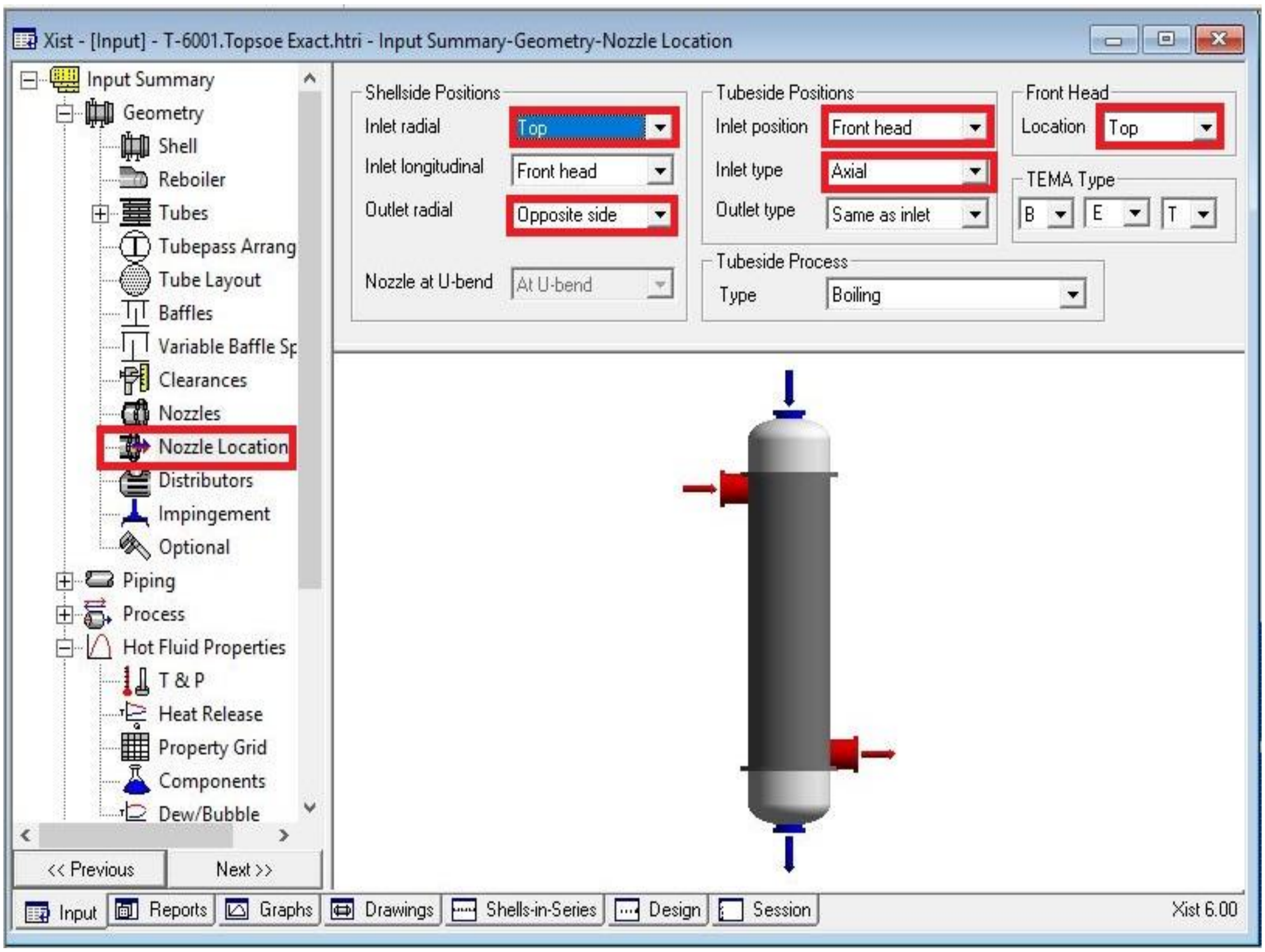


Enter nozzle info from piping info



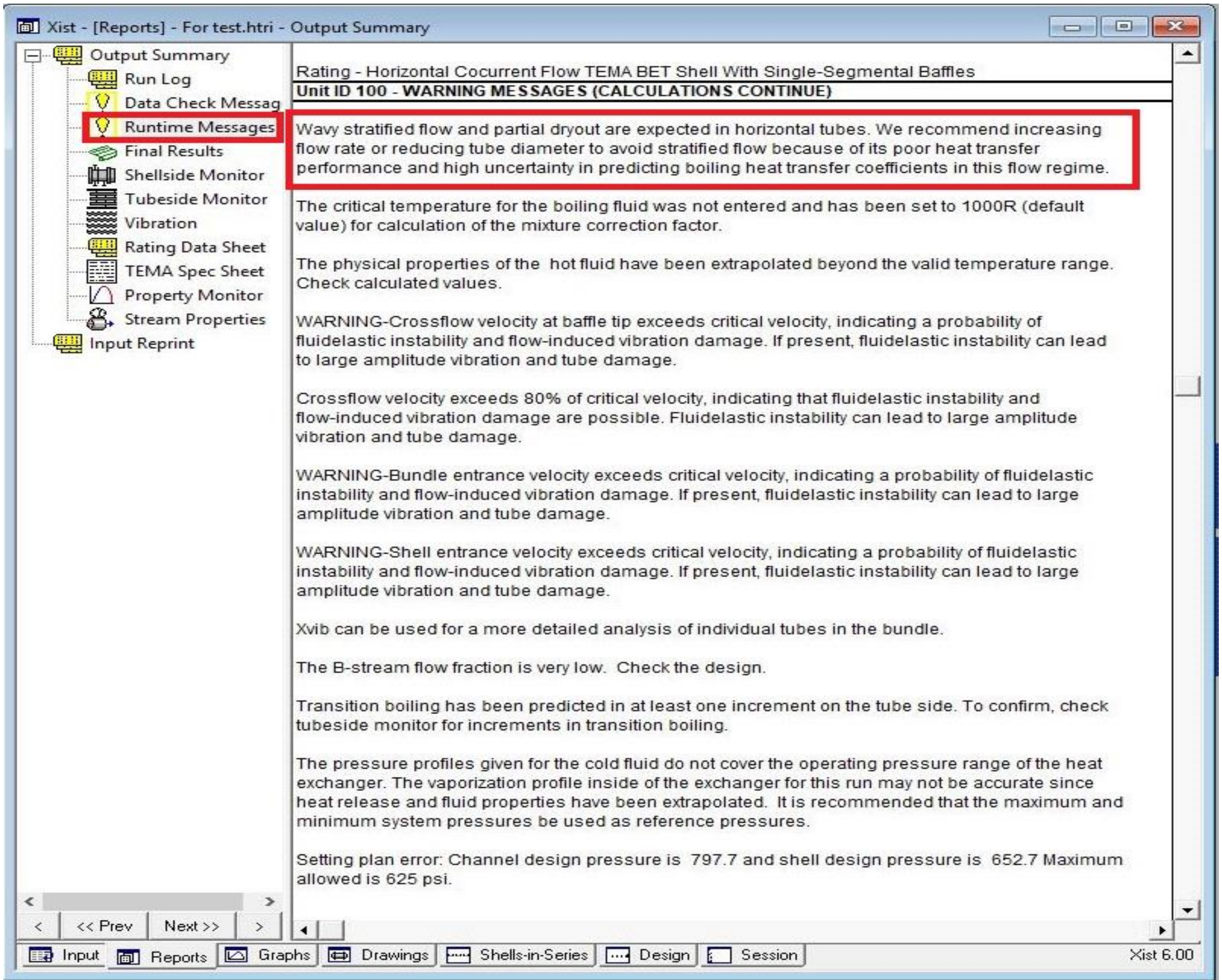
Set nozzle location

- Remember that first sketch is horizontal one but due to some warnings vertical one is selected and therefor the last sketch is put below.



Results:

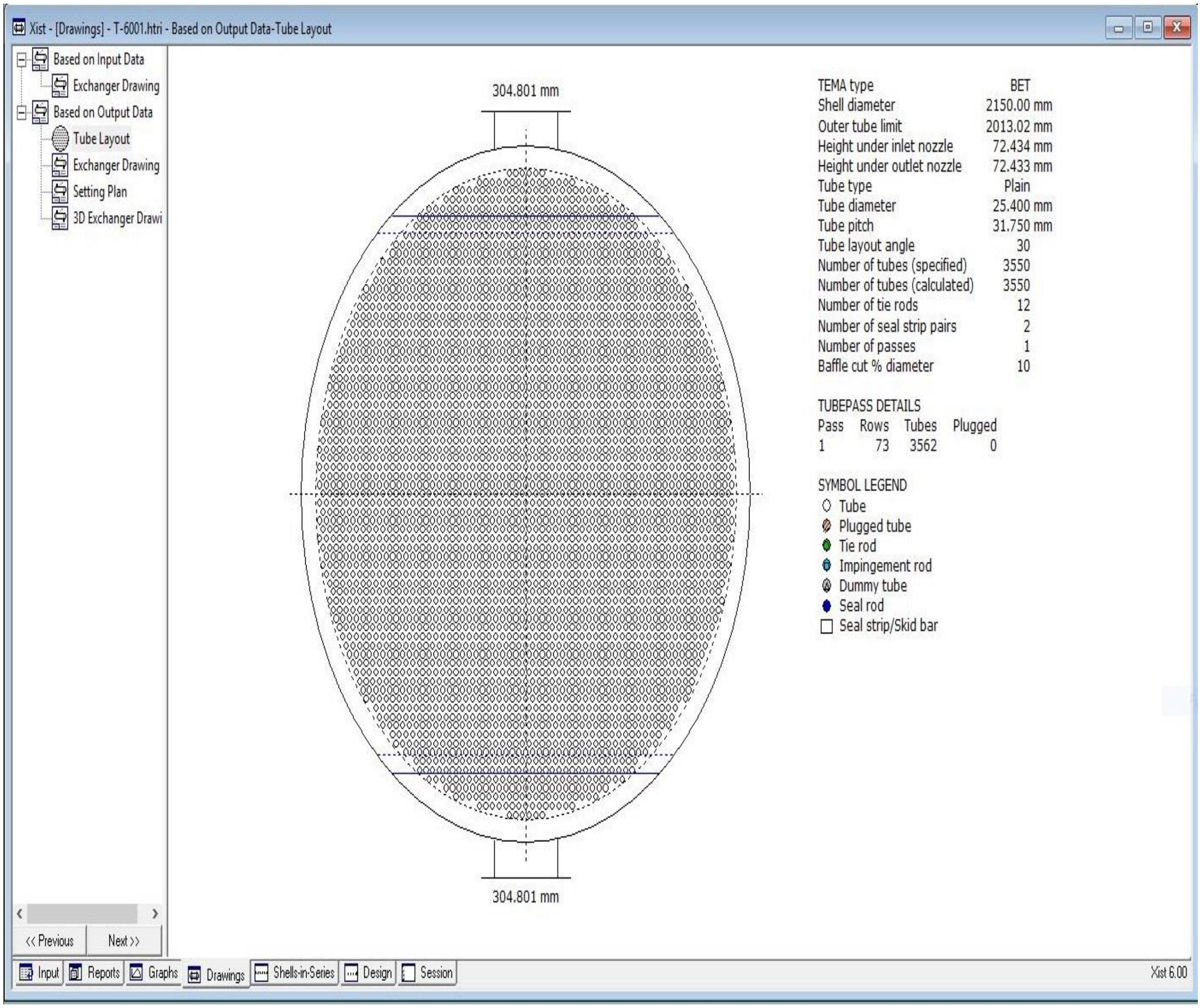
Now run and it results with following run messages



- Due to flow regime vertical orientation is selected and the warning disappears.
- By looking at overdesign factor and dp around shell side it appears that shell ID should be increased.
- At first it is increased to 1700 mm and then to 2000. The resultant is that dp decreases to a good point but not satisfactory but overdesign factor reaches to -30 %. For now, it seems better to increase tube length 9.75m which results in an increase in oversize factor by 32.5 % but dp increases to 0.25. As for next step the segmental baffle is changed to double segmental baffle to decrease dp to 0.07. Cross-pass is decreased from 25 to 20 to not only pass minimum TEMA baffle spacing limit but also increase B-stream.

Now it is time to increase overdesign factor. For doing so at first shell ID is increased to 2150 and as a result, overdesign factor increases to 4.5%. So, tube length is increased to 12.1 m to increase its overdesign factor and this results in 17% overdesign factor.

In order to eliminate two warnings in next pages about 800 tubes were eliminated and during elimination since the surface area is reduced the overdesign factor is also reduced therefore tube length is increased to 13m to counteract that.


Xist - [Drawings] - T-6001.htri - Based on Output Data-Tube Layout
Based on Input Data
Exchanger Drawing
Based on Output Data
Tube Layout
Exchanger Drawing
Setting Plan
3D Exchanger Drawi
304.801 mm
304.801 mm
TEMA type BET
Shell diameter 2150.00 mm
Outer tube limit 2013.02 mm
Height under inlet nozzle 72.434 mm
Height under outlet nozzle 72.433 mm
Tube type Plain
Tube diameter 25.400 mm
Tube pitch 31.750 mm
Tube layout angle 30
Number of tubes (specified) 3550
Number of tubes (calculated) 3550
Number of tie rods 12
Number of seal strip pairs 2
Number of passes 1
Baffle cut % diameter 10
TUBEPASS DETAILS
Pass Rows Tubes Plugged
1 73 3562 0
SYMBOL LEGEND
Tube
Plugged tube
Tie rod
Impingement rod
Dummy tube
Seal rod
Seal strip/Skid bar
<< Previous
Next >>
Input
Reports
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Drawings
Shells-in-Series
Design
Session
Xist 6.00

HTRI

Runtime Messages Page 1

Released to the following HTRI Member Company:

mekpco

Behrouzi

Xist E Ver. 6.00 8/10/2022 12:25 SN: Vals100+ **MEKPCO Units**

Rating - Vertical Cocurrent Flow TEMA BET Shell With Double-Segmental Baffles

Unit ID 100 - WARNING MESSAGES (CALCULATIONS CONTINUE)

Based on the existing correlations, some pressure recovery may be expected on the tube side. The pressure drop was set to zero for printout purposes.

WARNING-Bundle entrance velocity exceeds critical velocity, indicating a probability of fluidelastic instability and flow-induced vibration damage. If present, fluidelastic instability can lead to large amplitude vibration and tube damage.

WARNING-Shell entrance velocity exceeds critical velocity, indicating a probability of fluidelastic instability and flow-induced vibration damage. If present, fluidelastic instability can lead to large amplitude vibration and tube damage.

The areas in the window for multi-segmental baffles are not equal. Check the specified baffle cut and overlap. The program uses the average window area for calculating shellside pressure drop and heat transfer.

Transition boiling has been predicted in at least one increment on the tube side. To confirm, check tubeside monitor for increments in transition boiling.

The pressure profiles given for the cold fluid do not cover the operating pressure range of the heat exchanger. The vaporization profile inside of the exchanger for this run may not be accurate since heat release and fluid properties have been extrapolated. It is recommended that the maximum and minimum system pressures be used as reference pressures.

Setting plan error: Channel design pressure is 797.7 and shell design pressure is 652.7 Maximum allowed is 625 psi.

HTRI

Output Summary

Page 1

Released to the following HTRI Member Company:

mekpco

Behrouzi

Xist E Ver. 6.00 8/10/2022 12:25 SN: Vals100+ **MEKPCO Units**

Rating - Vertical Cocurrent Flow TEMA BET Shell With Double-Segmental Baffles

See Data Check Messages Report for Warning Messages.

See Runtime Message Report for Warning Messages.

Process Conditions		**Hot Shellside**		**Cold Tubeside**	
Fluid name			MPS		NGS
Flow rate	(kg/hr)		255865		588610
Inlet/Outlet Y	(Wt. frac vap.)	1.000	0.000	0.260	0.552
Inlet/Outlet T	(Deg C)	240.00	240.00	168.00	226.00
Inlet P/Avg	(bar-G)	32.700	32.665	43.301	43.301
dP/Allow.	(bar)	0.071	0.100	0.000	0.100
Fouling	(m2-K/W)		0.000250		0.000170

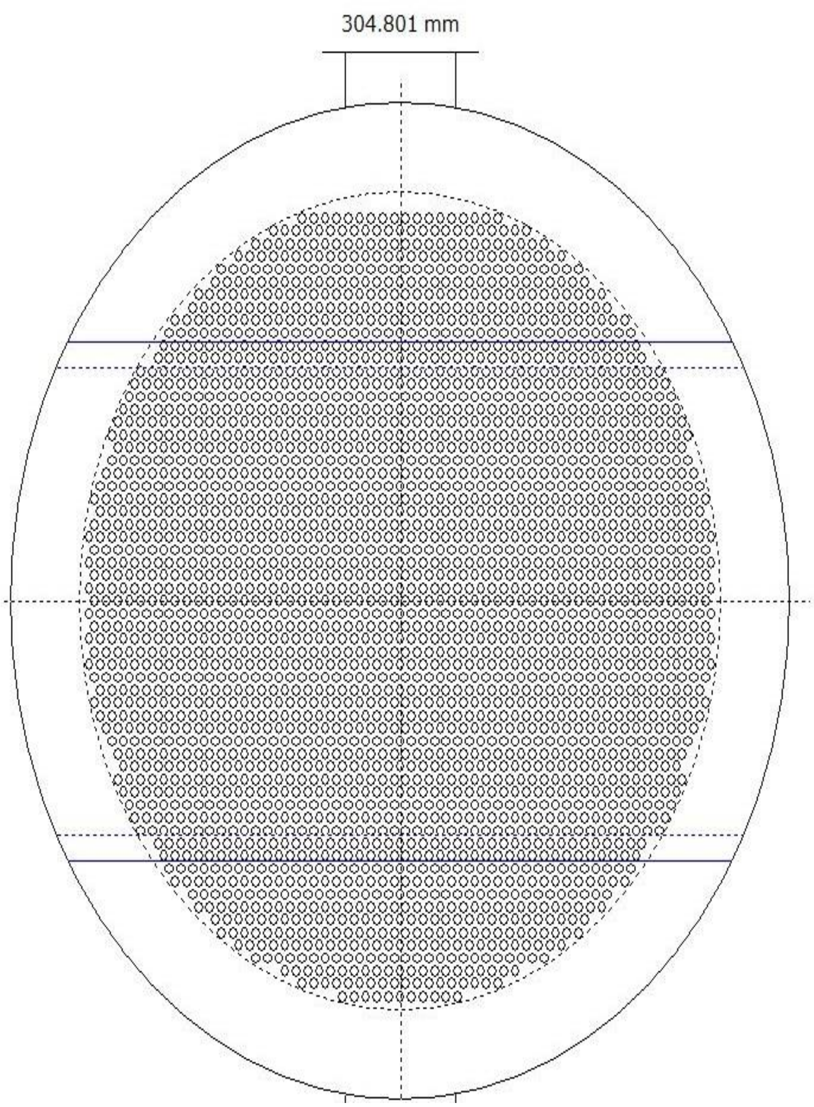
Exchanger Performance

Shell h	(W/m2-K)	8542.09	Actual U	(W/m2-K)	382.48
Tube h	(W/m2-K)	624.89	Required U	(W/m2-K)	327.36
Hot regime	(--)	Gravity	Duty	(MegaWatts)	61.9613
Cold regime	(--)	Tran	Area	(m2)	6604.08
EMTD	(Deg C)	28.7	Overdesign	(%)	16.84

Shell Geometry			**Baffle Geometry**		
TEMA type	(--)	BET	Baffle type	(--)	Double-Seg.
Shell ID	(mm)	2150.00	Baffle cut	(Pct Dia.)	10.00
Series	(--)	1	Baffle orientation	(--)	Perpend.
Parallel	(--)	2	Central spacing	(mm)	544.424
Orientation	(deg)	90.00	Crosspasses	(--)	20

Tube Geometry			**Nozzles**		
Tube type	(--)	Plain	Shell inlet	(mm)	304.801
Tube OD	(mm)	25.400	Shell outlet	(mm)	304.801
Length	(m)	12.192	Inlet height	(mm)	72.434
Pitch ratio	(--)	1.2500	Outlet height	(mm)	72.433
Layout	(deg)	30	Tube inlet	(mm)	448.819
Tubecount	(--)	3550	Tube outlet	(mm)	498.451
Tube Pass	(--)	1			

After eliminations of tubes, it results like below:



TEMA type	BET
Shell diameter	2150.00 mm
Outer tube limit	1766.29 mm
Height under inlet nozzle	237.612 mm
Height under outlet nozzle	209.714 mm
Tube type	Plain
Tube diameter	25.400 mm
Tube pitch	31.750 mm
Tube layout angle	30
Number of tubes (specified)	2711
Number of tubes (calculated)	2711
Number of tie rods	12
Number of seal strip pairs	2
Number of passes	1
Baffle cut % diameter	24

TUBEPASS DETAILS

Pass	Rows	Tubes	Plugged
1	62	2723	0

SYMBOL LEGEND

- Tube
- Plugged tube
- Tie rod
- Impingement rod
- Dummy tube
- Seal rod
- Seal strip/Skid bar

HTRI

Output Summary Page 1

Released to the following HTRI Member Company:

mekpco

Behrouzi

Xist E Ver. 6.00 8/4/2022 14:48 SN: Vals100+ **MEKPCO Units**

Rating - Vertical Cocurrent Flow TEMA BET Shell With Double-Segmental Baffles

See Data Check Messages Report for Warning Messages.

See Runtime Message Report for Warning Messages.

Process Conditions		Hot Shellside		Cold Tubeside	
Fluid name			MPS		NGS
Flow rate	(kg/hr)		255865		588610
Inlet/Outlet Y	(Wt. frac vap.)	1.000	0.000	0.260	0.552
Inlet/Outlet T	(Deg C)	240.00	240.00	168.00	226.00
Inlet P/Avg	(bar-G)	32.700	32.685	43.301	43.301
dP/Allow.	(bar)	0.031	0.100	0.000	0.100
Fouling	(m2-K/W)		0.000250		0.000170

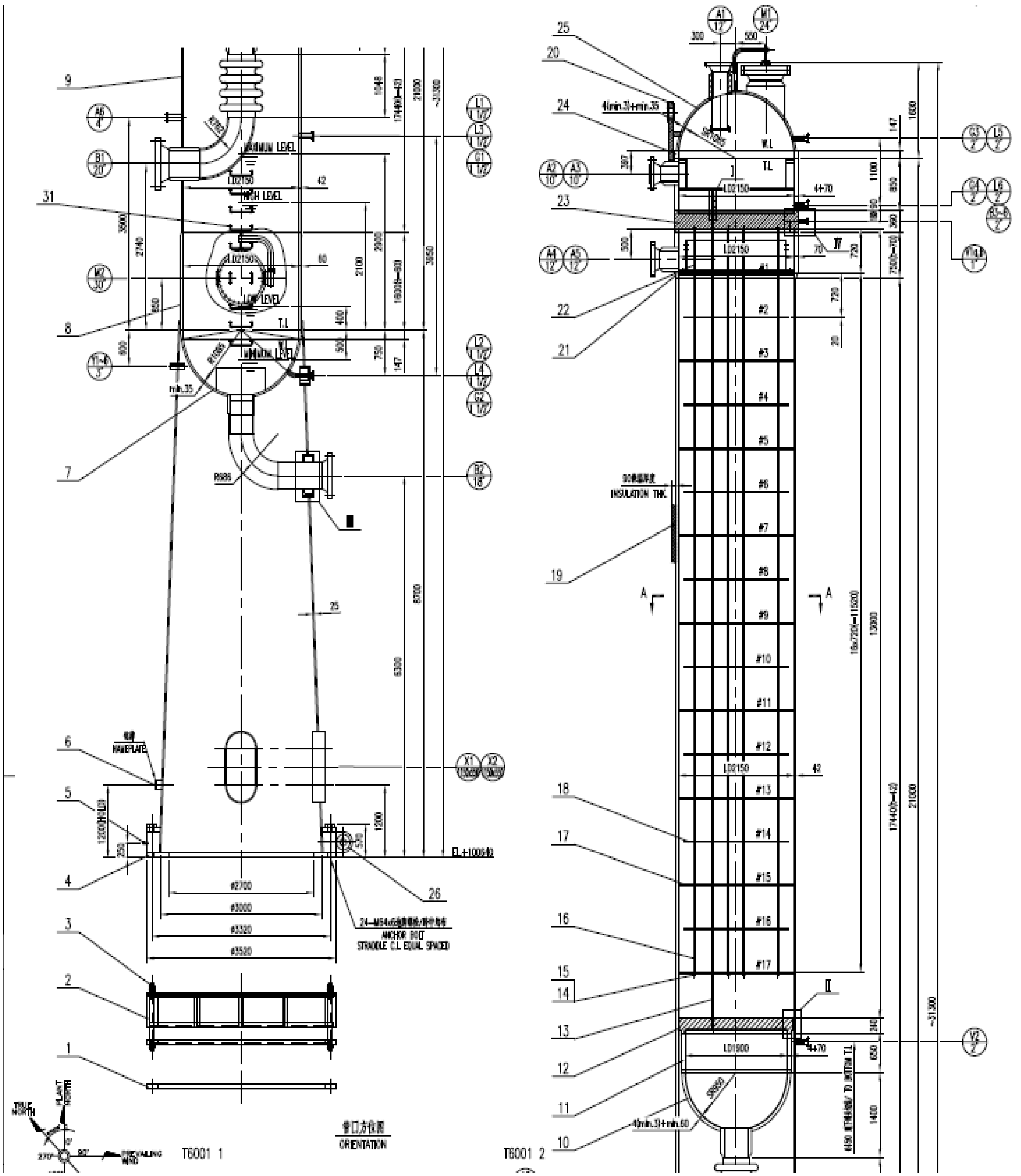
Exchanger Performance

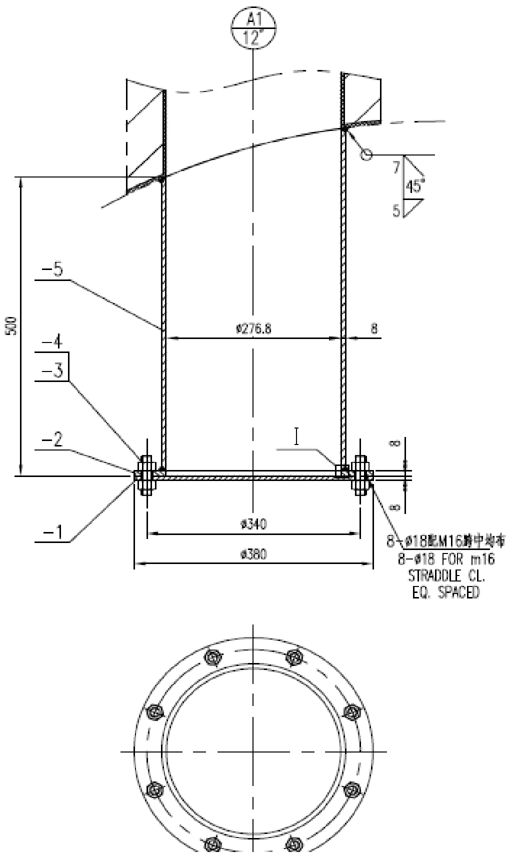
Shell h	(W/m2-K)	8547.50	Actual U	(W/m2-K)	437.67
Tube h	(W/m2-K)	754.51	Required U	(W/m2-K)	401.61
Hot regime	(--)	Gravity	Duty	(MegaWatts)	61.9613
Cold regime	(--)	Tran	Area	(m2)	5392.86
EMTD	(Deg C)	28.6	Overdesign	(%)	8.98

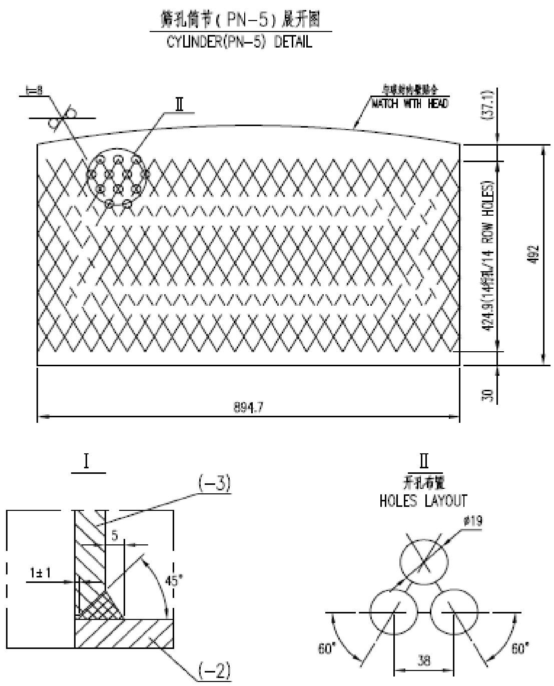
Shell Geometry			Baffle Geometry		
TEMA type	(--)	BET	Baffle type	(--)	Double-Seg.
Shell ID	(mm)	2150.00	Baffle cut	(Pct Dia.)	24.00
Series	(--)	1	Baffle orientation	(--)	Perpend.
Parallel	(--)	2	Central spacing	(mm)	662.976
Orientation	(deg)	90.00	Crosspasses	(--)	18

Tube Geometry			Nozzles		
Tube type	(--)	Plain	Shell inlet	(mm)	304.801
Tube OD	(mm)	25.400	Shell outlet	(mm)	304.801
Length	(m)	13.000	Inlet height	(mm)	237.612
Pitch ratio	(--)	1.2500	Outlet height	(mm)	209.714
Layout	(deg)	30	Tube inlet	(mm)	448.819
Tubecount	(--)	2711	Tube outlet	(mm)	498.451
Tube Pass	(--)	1			

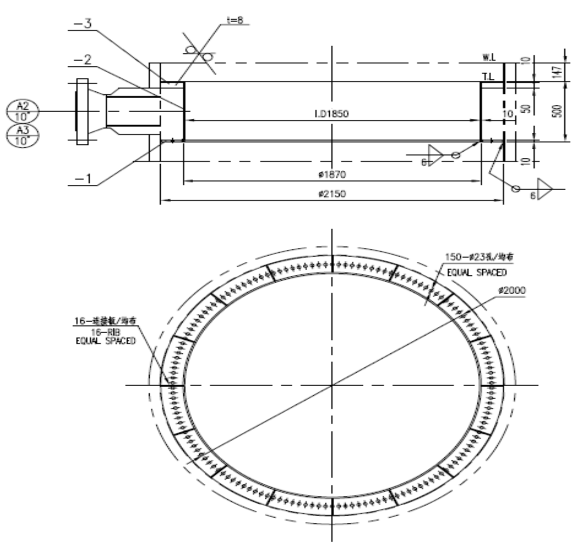
Thermal Resistance, %		Velocities, m/s		Flow Fractions	
Shell	5.12	Shellside	2.06	A	0.016
Tube	69.55	Tubeside	1.81	B	0.840
Fouling	19.86	Crossflow	0.93	C	0.014
Metal	5.46	Window	0.82	E	0.130
				F	0.000


MAXIMUM LEVEL
HIGH LEVEL
LOW LEVEL
MINIMUM LEVEL
NAMEPLATE
ANCHOR BOLT
STRADDLE C.L EQUAL SPACED
ORIENTATION
INSULATION THK.
T6001 1
T6001 2





−5		筛孔筒节 t=8 CYLINDER	1	SA−240 304L	
−4	ASME B18.2.4.6M−2010	重型螺母 M16 HEAVY HEX NUT	16	SA−194 Gr.8	0.05
−3	ASME B18.31.1M−2008	全螺纹螺柱 M16x70 CONTINUOUS STUDS	8	SA−193 Gr.B8	0.11
−2		环板 ø380/ø276.8 t=8 CYLINDER	1	SA−240 304L	
−1		盖板 ø380x8 COVER PLATE	1	SA−240 304L	



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