Company: Walter Tosto spa
Location: Chieti
Service of Unit: R Our Reference:
Item No.: Your Reference: U_150
Date: 10/06/2016 Rev No.: Job No.:

Problem Definition

Description

Heading
Company: Walter Tosto spa
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Remarks

Application Options

Calculation mode	Rating / Checking
Location of hot fluid	Tube side
Select geometry based on this dimensional standard	SI
Calculation method	Standard method
Application	Condensation
Condenser type	Normal
Simulation calculation	Set default
Application	Program
Vaporizer type	Set default
Simulation calculation	Set default
Thermosiphon circuit calculation	Set default

Process Data

		Hot Side		Cold Side	
Fluid name		Tube side		Shell side	
		In	Out	In	Out
Mass flow rate	kg/h	554292		808600	
Temperature	°C	435,1	413,7	287,8	309,9
Vapor fraction					
Pressure	bar	152,6895	152,0913	7,3089	7,18141
Pressure at liquid surface in column	bar				
Heat exchanged	kcal/h		12980000		
Adjust if over-specified		Heat load		Heat load	
Estimated pressure drop	kgf/cm²	0,61		0,13	
Allowable pressure drop	kgf/cm²	0,657		0,352	
Fouling resistance	m²-h-C/kcal	0		0	

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Hot Side Properties

Hot Side Databank

Physical property package:	User specified properties
Hot side composition specification:	Weight flowrate or %
B-JAC VLE calculation method:	Ideal
B-JAC VLE calculation type:	Integral
Aspen property method:	
Aspen free-water method:	
Aspen water solubility:	
Aspen flash option:	Vapor-Liquid-Liquid
Aspen Plus or Aspen Properties run file:	

Pressures
kgf/cm2
147,2
155,7
163,5

Hot side - Stream properties

Temperature	Specific enthalpy	Vapor mass fraction
C	kcal/kg	
412,6	0	0,4059
415,2	2,86	0,4152
417,9	5,72	0,4217
420,5	8,58	0,4283
423,1	11,45	0,4351
425,8	14,31	0,4421
428,4	17,17	0,4493
431	20,03	0,4566
433,6	22,89	0,4641
436,1	25,75	0,4719

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Hot side - Liquid properties

Temperature	Liquid specific heat	Liquid thermal cond.	Liquid viscosity	Liquid density	Liquid surface tension
C	kcal/(kg*C)	kcal/(h*m*C)	cp	kg/m3	dynes/cm
412,6	0,75	0,096	0,188	624,6	7,3
415,2	0,75	0,096	0,186	622,1	7,2
417,9	0,75	0,096	0,183	619,6	7
420,5	0,76	0,096	0,18	617,1	6,9
423,1	0,76	0,096	0,178	614,5	6,8
425,8	0,76	0,096	0,176	612	6,6
428,4	0,76	0,096	0,173	609,4	6,5
431	0,76	0,096	0,171	606,8	6,4
433,6	0,76	0,095	0,169	604,2	6,2
436,1	0,77	0,095	0,166	601,6	6,1

Hot side - Vapor properties

Temperature	Vapor specific heat	Vapor thermal cond.	Vapor viscosity	Vapor density	Vapor molecular weight
C	kcal/(kg*C)	kcal/(h*m*C)	cp	kg/m3	
412,6	1,31	0,182	0,015	20	
415,2	1,3	0,182	0,016	20,22	
417,9	1,29	0,183	0,016	20,45	
420,5	1,28	0,183	0,016	20,68	
423,1	1,28	0,183	0,016	20,91	
425,8	1,27	0,184	0,016	21,15	
428,4	1,26	0,184	0,016	21,4	
431	1,25	0,185	0,016	21,66	
433,6	1,24	0,185	0,016	21,91	
436,1	1,24	0,185	0,016	22,18	

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Hot side - 2nd Liquid phase properties

Temperature	Liquid 2 specific heat	Liquid 2 thermal cond.	Liquid 2 viscosity	Liquid 2 density	Liquid 2 surface tension
C	kJ/(kg*K)	W/(m*K)	mPa*s	kg/m3	N/m
412,6					
415,2					
417,9					
420,5					
423,1					
425,8					
428,4					
431					
433,6					
436,1					

Cold Side Properties

Cold Side Databank

Physical property package: User specified properties

Cold side composition specification: Weight flowrate or %

B-JAC VLE calculation method: Ideal

Aspen property method:

Aspen free-water method:
Aspen water solubility:
Aspen flash option: Vapor-Liquid-Liquid
Aspen Plus or Aspen Properties run file:

Pressures
kgf/cm2
6,595
7,129
7,656

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Cold side - Stream properties

Temperature	Specific enthalpy	Vapor mass fraction
C	kcal/kg	
286,6	0	0,0019
289,4	1,96	0,0022
292,1	3,93	0,0025
294,8	5,89	0,0028
297,5	7,85	0,003
300,2	9,81	0,0033
302,9	11,77	0,0037
305,6	13,73	0,004
308,3	15,69	0,0043
310,9	17,66	0,0046

Cold side - Liquid properties

Temperature	Liquid specific heat	Liquid thermal cond.	Liquid viscosity	Liquid density	Liquid surface tension
C	kcal/(kg*C)	kcal/(h*m*C)	cp	kg/m3	dynes/cm
286,6	0,71	0,098	0,529	651,6	12,7
289,4	0,71	0,097	0,519	649,7	12,6
292,1	0,72	0,097	0,51	647,8	12,4
294,8	0,72	0,097	0,5	645,8	12,2
297,5	0,72	0,097	0,491	643,9	12
300,2	0,72	0,097	0,482	641,9	11,9
302,9	0,72	0,097	0,474	639,9	11,7
305,6	0,73	0,097	0,466	638	11,5
308,3	0,73	0,097	0,457	636	11,4
310,9	0,73	0,097	0,449	634	11,2

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Cold side - Vapor properties

Temperature	Vapor specific heat	Vapor thermal cond.	Vapor viscosity	Vapor density	Vapor molecular weight
C	kcal/(kg*C)	kcal/(h*m*C)	cp	kg/m3	
286,6	0,59	0,049	0,013	9,95	
289,4	0,59	0,049	0,013	10,17	
292,1	0,6	0,049	0,013	10,41	
294,8	0,6	0,049	0,013	10,67	
297,5	0,6	0,049	0,013	10,91	
300,2	0,6	0,049	0,013	11,16	
302,9	0,61	0,049	0,012	11,44	
305,6	0,61	0,049	0,012	11,71	
308,3	0,61	0,049	0,012	11,98	
310,9	0,62	0,049	0,012	12,25	

Cold side - 2nd Liquid phase properties

Temperature	Liquid 2 specific heat	Liquid 2 thermal cond.	Liquid 2 viscosity	Liquid 2 density	Liquid 2 surface tension
C	kJ/(kg*K)	W/(m*K)	mPa*s	kg/m3	N/m
286,6					
289,4					
292,1					
294,8					
297,5					
300,2					
302,9					
305,6					
308,3					
310,9					

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Geometry 1

Exchanger Type

Front head type	D - high pressure enclosure
Shell type	E - one pass shell
Rear head type	U - U-tube bundle
Exchanger position	Horizontal
Location of front head for vertical units	Set default
"E" shell flow direction (inlet nozzle location)	Near rear head

		ID	OD	Thickness	series	parallel
Shell(s)	mm	1275	1470	97,5	1	1
Front head	mm	1238		116		
RearHead	mm					
Kettle	mm					

Front cover type	Flat bolted	Front tubesheet thickness	mm	260,29
Rear cover type	Set default	Rear tubesheet thickness	mm	
Shell cover type	Ellipsoidal	Tube projection from front tubesheet	mm	3
Front cover welded to a cylinder	Yes	Tube projection from rear tubesheet	mm	3
Rear cover welded to a cylinder	Se	Distance from U-bend center to shell cover	mm	

Tubesheet type	Normal
Tube to tubesheet joint	Expanded & seal welded (2 grooves)(Ap
Include expansion joint	None
Flange type - hot side	Hub
Flange type - cold side	Hub

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Tubes

Number of tubes (total)		580	Tube pitch	mm	42,33
Number of tubes plugged		0	Tube pattern		90-Square
Tube length	mm	3658	Tube material		6625 Grd 2 Cls Sol. Smls. tube
Tube type		Plain	Tube surface		Smooth
Tube outside diameter	mm	31,75	Tube wall roughness	mm	
Tube wall thickness	mm	4,19	Tube cut angle (degrees)		
Wall specification		Average			
Lowfin Tube type		As specified	Longitudinal fins per tube		
Fin density	#/m		Longitudinal fin height	mm	
Tube wall thickness	mm	4,19	Longitudinal fin thickness	mm	
Tube root diameter	mm		Longitudinal root spacing	mm	
Fin height	mm		Longitudinal fin cut and twist length	mm	
Fin thickness	mm				
Outside/Inside surface area ratio			Twisted tube twist pitch	mm	
Distance unfinned at baffle	mm		Shell type: within shroud (convert to)		Set default
			Shroud inlet location		None
Tube insert type		None	Shroud inlet gap length	mm	
Twisted tape 360 degree twist pitch	mm		Shroud outlet gap length	mm	
Twisted tape thickness	mm		Shroud thickness	mm	3,18
Tube internal enhancement		Unspecified	Skid bar angle (deg)		60

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Baffles

Baffle type		Double segmental
Tubes are in baffle window		Yes
Baffle cut (% of diam.) outer		24,5
Align baffle cut with tubes		Yes
Multi-segmental baffle starting baffle		One piece
Baffle cut orientation		Vertical
Baffle thickness	mm	10
Baffle spacing center-center	mm	300
Number of baffles		10
Baffle spacing at inlet	mm	342,36
End length at front head (tube end to closest baffle)	mm	605,64
End length at rear head (tube end to closest baffle)	mm	352,36
Distance between baffles at central in/out for G,H,I,J shells	mm	
Distance between baffles at center of H shell	mm	

Special inlet nozzle support		yes	Number of supports at center of H shell	
Support or blanking baffle at rear end		yes (normal)	Number of supports at inlet/outlet for G, H, I, J shells	
Length of tube beyond support/blanking baffle	mm	10	Number of supports between central baffles	
Number of extra supports for U-bends		4	Number of supports at front head end space	
Support/baffle to tangent of U-bend distance	mm		Number of supports at rear head end space	
Baffle OD to shell ID diametric clearance	mm	6,35	Number of supports for K, X shells	
Baffle tube hole to tube OD diametric clearance	mm	0,79		

Longitudinal Baffle

Window length at rear head for F, G, H shells	mm	
Window length at front head for G, H shells	mm	
Window length at center for H shells	mm	
Baffle thickness	mm	
Percent leakage across longitudinal baffle		

Deresonating Baffles

Number of deresonating baffles		1
Largest deresonating baffle-baffle or baffle-shell distance	mm	741

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Geometry 2

Baffles

Number of regions for variable baffle pitch One region

Number of baffle spaces		
Baffle spacing	**mm**	
Baffle cut percent, outer		
Baffle cut percent, inner		
Baffle cut percent, intermediate		

Variable baffle pitch: First to last pitch ratio

Bundle

Tube layout option		New (optimum) layout
Main input / Tube layout inconsistencies		Use Layout value (warning)
Full or normal bundle		Normal bundle
Tube pattern		90-Square
Tube pitch	mm	42,33
Tube passes		2
Pass layout orientation		Standard (horizontal)
Pass layout		Quadrant (dbl.band)
Tube layout symmetry		Full symmetry
Number of sealing strip pairs		
Orientation of U-bends		Vertical
Minimum U-bend diameter	mm	95,25
Cleaning lane or tube alignment		Aligned for cleaning lanes
Number of tie rods		
Tie rod diameter	mm	12,7
Spacer diameter	mm	19,05

Open distance at top of layout	mm	
Open distance at bottom of layout	mm	
Open distance on left side of layout	mm	
Open distance on right side of layout	mm	
Shell ID to outer tube limit diametric clearance	mm	49,7
Outer tube limit diameter	mm	1225,3
Horizontal pass partition width	mm	63,5
Vertical pass partition width	mm	
Number of horizontal pass partition lanes		1
Number of vertical pass partition lanes		0

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Nozzles

	Shell Side	Tube Side
Shell side nozzle flange rating	1500 ANSI	2500 ANSI
Shell side nozzle flange type	Weld neck	Weld neck

Use separate outlet nozzles for hot side liquid/vapor flows	no
Use separate outlet nozzles for cold side liquid/vapor flows	no

Shell Side

Nominal pipe size		21	21
Nominal diameter	**mm**	457,2	457,2
Actual OD	**mm**	457,2	457,2
Actual ID	**mm**	398,48	398,48
Wall thickness	**mm**	29,36	29,36
Nozzle orientation		Top	Bottom
Distance to front tubesheet	**mm**		
Number of nozzles		1	1
Multiple nozzle spacing	**mm**		
Nozzle / Impingement type		Yes impingement	No impingement
Remove tubes below nozzle		Equate areas	Equate areas
Maximum nozzle RhoV2	**kg/(m*s2)**		
Nozzle ignore options			

Shell side nozzle location options	Opposite sides
Location of nozzle at U-bend	Set default
Nozzle diameter displayed on TEMA sheet	Nomin

Tube Side

Nominal pipe size		25	25
Nominal diameter	**mm**	660,4	660,4
Actual OD	**mm**	660,4	660,4
Actual ID	**mm**	635	635
Wall thickness	**mm**	12,7	12,7
Nozzle orientation		Top	Bottom
Distance to tubesheet	**mm**		
Centerline offset distance	**mm**		
Maximum nozzle RhoV2	**kg/(m*s2)**		
Nozzle ignore options			

Dome OD	**mm**
Vapor belt diametric clearance	**mm**
Vapor belt slot area	**m2**
Vapor belt axial length	**mm**

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Geometry 3

Impingement Protection

Impingement protection device		**Round plate**
Impingement plate diameter	mm	**400**
Impingement plate length (parallel to tube axis)	mm	
Impingement plate width (normal to tube axis)	mm	
Impingement plate thickness	mm	**6,35**
Impingement plate distance in from shell ID	mm	
Impingement plate clearance to tube edge	mm	**25**
Impingement plate perforated area %		**50**

Thermosiphon Piping

Pipework loss calculation		**Set default**
Percent of driving head lost in inlet line		
Percent of driving head lost in outlet line		
Height of column liquid level	mm	
Height of heat transfer region inlet	mm	
Height of return line to column	mm	

Inlet circuit element	
Internal diameter	**mm**
Length (pipe) or Radius (arc)	**mm**
Velocity heads (general element)	
Elements in series	
Elements in parallel	

Outlet circuit element	
Internal diameter	**mm**
Length (pipe) or Radius (arc)	**mm**
Velocity heads (general element)	
Elements in series	
Elements in parallel	

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Construction Spec

Materials

Cylinder - hot side	SA-387 K21590 Grd 22 Cls 2 Plate
Cylinder - cold side	SA-387 K21590 Grd 22 Cls 2 Plate
Tubesheet	SA-182 K21590 Grd F22 Cls 3 Forgings
Double tubesheet (inner)	Set Default
Baffles	SB-168 N06045 Cls Sol. Plate(G5)
Tube material	SB-444 N06625 Grd 2 Cls Sol. Smls. tube

Tube material thermal conductivity	W/(m-K)
Tube material density	kg/m³
Tube material modulus of elasticity	N/mm²

Tubesheet cladding - hot side
Tubesheet cladding - cold side
Gaskets - hot side
Gaskets - cold side

Specifications

Design Code	ASME Code Sec VIII Div 1
Service class	Lethal
TEMA class	R - refinery service
Material standard	ASME
Dimensional standard	ANSI - American

		Hot side	Cold side
Design pressure (gauge)	kgf/cm²	188	145
Design temperature	°C	454	420
Vacuum design pressure (gauge)	atm	1	1
Test pressure (gauge)	bar		
Corrosion allowance	mm	0	3
Radiography		Spot	Spot

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Program Options1

Design Options

Use shell ID or OD as reference	Set default
Shell side nozzle location options	Opposite sides
Location of nozzle at U-bend	Set default
Allow baffles under nozzles	No
Use proportional baffle cut	Set default
Number of tube rows between sealing strips	6
Percent of tubes to be plugged	
Remove tubes for vapor disengagement space in flooded evaporator	Set default
Percent of shell diameter for disengagement	
Number of regions for variable baffle pitch	One region
Variable baffle pitch: First to last pitch ratio	

		Increment	Minimum	Maximum
Shell diameter	mm			
Tube length	mm			
Tube passes		Set default		
Baffle spacing	mm			
Baffle cut (% of diameter)				
Shells in series				
Shells in parallel				
Use pipe for shells below this diameter	mm			

		Hot Side	Cold Side
Minimum fluid velocity	m/s		
Maximum fluid velocity	m/s		
Target % pressure drop in nozzles		15	15

Maximum exit entrainment ratio (mass liquid/vapor) (pool boilers only)	
Allow local temperature cross	Set default
Design search thoroughness options	Previous
Basis for design optimization	Set default
Highest cost or area ratio considered	
Minimum % excess surface area required	
Show units that meet minimum actual/required surface area ratio	
Show units that meet maximum actual/allowed hot side pressure drop ratio	
Show units that meet maximum actual/allowed cold side pressure drop ratio	
Optimisation item number to repeat	0

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Thermal Analysis Options

		Hot Side	Cold Side
Liquid heat transfer coefficient	W/(m²-K)		
Two phase heat transfer coefficient	W/(m²-K)		
Vapor heat transfer coefficient	W/(m²-K)		
Liquid heat transfer coefficient multiplier		1	1
Two phase heat transfer coefficient multiplier		1	1
Vapor heat transfer coefficient multiplier		1	1
Pressure drop multiplier		1	1
U-bend area will be considered effective for heat transfer			No
Fraction of tube area submerged for shell side condensers			
Weir height above bundle for kettle reboiler	mm		
Minimum allowable MTD Ft correction factor			
Fouling calculation options		Adjust both sides based on fouling input	

		Hot Side	Cold Side
Fouling layer thickness	mm		
Fouling thermal conductivity	W/(m-K)		

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Correlations

Pressure drop: friction / gravity, hot side		friction only
Pressure drop: friction / gravity, cold side		friction only
Vibration analysis method		HTFS and TEMA analysis
Tube axial stress	N/mm²	0
Effective cross flow fraction		
Lowfin tube calculation method		HTFS / ESDU
Single phase tubeside heat transfer method		HTFS recommended method
Condensation Options		
Desuperheating heat transfer method		Wet wall
Condensation heat transfer model		HTFS - Silver-Bell
Vapor shear heat transfer enhancement		Use vapor shear enhancement
Liquid subcooling heat transfer/vertical		Not Used
Priority for condenser outlet temperature (mixtures)		Vapor-Gas
Vaporization Options		
Subcooled boiling accounted for in		Heat transfer & pressure drop
Post dryout heat transfer determined		yes
Boiling Curve Correction		
Heat flux reference point	kW/m²	
Temperature difference (Delta T) reference point	°C	
Boiling curve exponent on Delta T		
Correction to boiling curve		Boiling curve not used
Falling film evaporation method		HTFS recommended method

Program Options 2

Enhancements

Shell side enhancements
Enhancement identification

Reynolds number
Colburn J-factor
Friction factor

Tube side enhancements
Enhancement identification

Reynolds number
Colburn J-factor
Friction factor

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CalculationOptions

Maximum number of Iterations	
Convergence tolerance - heat load	
Convergence tolerance - pressure	
Relaxation parameter	
Calculation grid resolution	set default
Convergence criterion	set default
Calculation step size	
Pressure calculation option - hot side	Predict outlet pressure
Pressure calculation option - cold side	Predict outlet pressure

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Warnings & Messages

	Description
Input Warning 1121	Input for Inlet pressure, 152,69 bar is beyond the expected range, from 0,01 bar to 150 bar
Input Warning 1121	Input for Tube Outstand (rear end), 3 mm is beyond the expected range, from 0 mm to 0 mm
Input Warning 1231	There is a full support baffle (blanking baffle) present (specified or default for S and T type rear heads), but the distance beyond this baffle has not been specified. The distance beyond the blanking baffle has been calculated as 10 mm. For U-bends, this distance is the estimated support plate thickness 10 mm. For S-type rear heads, the distance is two tubeplate thicknesses (0 mm) plus the greater of 100mm or the estimated support plate thickness. For all other rear head types, the calculated distance beyond the blanking baffle is the tubeplate thickness plus the greater of 100mm or the estimated support plate thickness.
Input Warning 1121	Input for Str.1 Pressure for Props, 152,69 bar is beyond the expected range, from 0,001 bar to 150 bar
Input Warning 1121	Input for Str.1 Pressure for Props, 160,34 bar is beyond the expected range, from 0,001 bar to 150 bar
Note 1826	P57: The dew (or bubble) points for Stream 1 at pressure levels 2 and 3 indicate a lower temperature at the higher pressure. This is unusual, though not impossible. Check the Physical Properties Temperature-Enthalpy-Quality data for this stream. Note. This message can apply to an extrapolated (effective) bubble or dew point. If so, and there are no obvious inconsistencies in the T-h-x data, the message can be ignored.
Note 1860	The consolidated process conditions for Stream 1, prior to the main calculations, give a heat load of -15139 kW, for a flow of 153,97 kg/s, with outlet temperature 413,7 C and quality (vapor mass fraction) 0,3971718.
Note 1860	The consolidated process conditions for Stream 2, prior to the main calculations, give a heat load of 15105 kW, for a flow of 224,6111 kg/s, with outlet temperature 309,9 C and quality (vapor mass fraction) 0,004012796.
Input Warning 1227	Shell&Tube has estimated a minimum endspace length of 798,69 mm, for a nozzle inside diameter of 398,48 mm. This is greater than the value 342,36 mm which was specified or calculated from an endlength of 605,64 mm. Check your input carefully.
Input Warning 1227	Shell&Tube has estimated a minimum endspace length of 467,2 mm, for a nozzle inside diameter of 398,48 mm. This is greater than the value 342,36 mm which was specified or calculated from an endlength of 352,36 mm. Check your input carefully.
Input Warning 1107	The tube count from the tube layout is 530, which differs from the effective tube count of 580 which you input. Your tube count will be used to determine heat transfer area and tubeside heat transfer and pressure drop.
Operation Warning 1372	The calculated tubeside pressure drop of 1,33442 bar exceeds the maximum allowable pressure drop of 0,6443 bar.
Note 1925	The outlet temperature of stream 1 has changed from the initially specified value 413,7 C, to 413,82 C. These temperatures relate respectively to the estimated outlet pressure 152,09 bar, and the calculated outlet pressure 151,36 bar. Design and Checking calculations are based on fixed heat load: temperatures can change when pressures change. If you want to avoid this change in temperature, set the estimated outlet pressure to 151,36 bar and repeat the calculation.

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Optimization Path

Current selected case: 1

	Shell	Tube Length			Pressure Drop				Baffle		Tube		Units		Total	
Item	**Size**	**Actual**	**Reqd.**	**Area ratio**	**Shell**	**Dp Ratio**	**Tube**	**Dp Ratio**	**Pitch**	**No.**	**Tube Pass**	**No.**	**P**	**S**	**Price**	**Design Status**
	mm	**mm**	**mm**		**bar**		**bar**		**mm**						**Dollar(US)**	
1	1275	3658	2107,8	1,74	0,31815	0,92	1,33442	2,07	300	10	2	580	1	1	1135088	Failed
1	1275	3658	2107,8	1,74	0,31815	0,92	1,33442	2,07	300	10	2	580	1	1	1135088	Failed

Company: Walter Tosto spa
Location: Chieti
Service of Unit: R Our Reference:
Item No.: Your Reference: U_150
Date: 10/06/2016 Rev No.: Job No.:

Recap of Design

Current selected case: K

		A	B	C	D
Shell size	**mm**	1275	1275	1275	1275
Tube length - actual	**mm**	3658	3658	3658	3658
Tube length - required	**mm**	2109,3	2057,6	2107,6	2107,8
Pressure drop, SS	**bar**	0,31897	0,28485	0,31815	0,31815
Pressure drop, TS	**bar**	1,3524	1,3524	1,36298	1,33442
Baffle spacing	**mm**	300	300	300	300
Number of baffles		10	10	10	10
Tube passes		2	2	2	2
Tube number		580	580	580	580
Number of units in series		1	1	1	1
Number of units in parallel		1	1	1	1
Total price	**Dollar(US)**	1129253	1129927	1133092	1135088
Program mode		Rating / Checking	Rating / Checking	Rating / Checking	Rating / Checking
Calculation method		Standard method	Standard method	Standard method	Standard method
Area Ratio (dirty)		1,73	1,78	1,74	1,74
Film coef overall, SS	**W/(m2*K)**	2381,2	2518,7	2385,1	2385,1
Film coef overall, TS	**W/(m2*K)**	4917,1	4916,2	4918,3	4916,7
Heat load	**kW**	15122,1	15122,1	15122,1	15122,1
Recap case fully recoverable		Yes	Yes	Yes	Yes

Company: Walter Tosto spa
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		E	F	G	H
Shell size	**mm**	1275	1275	1275	1275
Tube length - actual	**mm**	3658	3658	3658	3658
Tube length - required	**mm**	2107,8	2107,6	2107,8	4013,2
Pressure drop, SS	**bar**	0,31815	0,31815	0,31815	0,31894
Pressure drop, TS	**bar**	1,3492	1,36298	1,33442	1,33436
Baffle spacing	**mm**	300	300	300	300
Number of baffles		10	10	10	10
Tube passes		2	2	2	2
Tube number		580	580	580	580
Number of units in series		1	1	1	1
Number of units in parallel		1	1	1	1
Total price	**Dollar(US)**	1133746	1133092	1135088	1135088
Program mode		Rating / Checking	Rating / Checking	Rating / Checking	Rating / Checking
Calculation method		Standard method	Standard method	Standard method	Standard method
Area Ratio (dirty)		1,74	1,74	1,74	0,91
Film coef overall, SS	**W/(m2*K)**	2385,1	2385,1	2385,1	2212,9
Film coef overall, TS	**W/(m2*K)**	4917	4918,3	4916,7	4933
Heat load	**kW**	15122,1	15122,1	15122,1	15122,1
Recap case fully recoverable		Yes	Yes	Yes	Yes

Company: Walter Tosto spa
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		I	J	K
Shell size	**mm**	1275	1275	1275
Tube length - actual	**mm**	3658	3658	3658
Tube length - required	**mm**	2107,8	2107,8	2107,8
Pressure drop, SS	**bar**	0,31815	0,31815	0,31815
Pressure drop, TS	**bar**	1,33442	1,33442	1,33442
Baffle spacing	**mm**	300	300	300
Number of baffles		10	10	10
Tube passes		2	2	2
Tube number		580	580	580
Number of units in series		1	1	1
Number of units in parallel		1	1	1
Total price	**Dollar(US)**	1135088	1135088	1135088
Program mode		Rating / Checking	Rating / Checking	Rating / Checking
Calculation method		Standard method	Standard method	Standard method
Area Ratio (dirty)		1,74	1,74	1,74
Film coef overall, SS	**W/(m2*K)**	2385,1	2385,1	2385,1
Film coef overall, TS	**W/(m2*K)**	4916,7	4916,7	4916,7
Heat load	**kW**	15122,1	15122,1	15122,1
Recap case fully recoverable		Yes	Yes	Yes

Company: Walter Tosto spa
Location: Chieti
Service of Unit: R Our Reference:
Item No.: Your Reference: U_150
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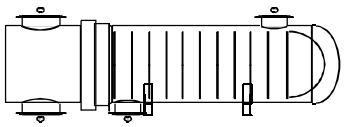
TEMA Sheet

Heat Exchanger Specification Sheet

1	Company: Walter Tosto spa					
2	Location: Chieti					
3	Service of Unit: R Our Reference:					
4	Item No.: Your Reference: U_150					
5	Date: 10/06/2016 Rev No.: Job No.:					
6	Size: 1275 - 3658 mm Type: DEU Horizontal Connected in: 1 parallel 1 series					
7	Surf/unit(eff.) 195,8 m² Shells/unit 1 Surf/shell(eff.) 195,8 m²					
8	**PERFORMANCE OF ONE UNIT**					
9	Fluid allocation		Shell Side		Tube Side	
10	Fluid name		Shell side		Tube side	
11	Fluid quantity, Total	kg/s	224,6111		153,97	
12	Vapor (In/Out)	kg/s	0,3464	0,9078	70,8441	60,1086
13	Liquid	kg/s	224,2648	223,7033	83,1259	93,8614
14	Noncondensable	kg/s	0	0	0	0
15						
16	Temperature (In/Out)	°C	287,8	309,92	435,1	413,82
17	Dew / Bubble point	°C				
18	Density Vapor/Liquid	kg/m³	10,57 / 651,1	12,5 / 634,96	22,83 / 600,47	20,72 / 621,92
19	Viscosity	mPa-s	0,013 / 0,5253	0,013 / 0,453	0,016 / 0,1653	0,0151 / 0,185
20	Molecular wt, Vap		70,45	86,31	9	5,64
21	Molecular wt, NC					
22	Specific heat	kJ/(kg-K)	2,47 / 2,973	2,554 / 3,056	5,234 / 3,206	5,5 / 3,14
23	Thermal conductivity	W/(m-K)	0,0588 / 0,114	0,0577 / 0,1124	0,2149 / 0,1114	0,2114 / 0,1119
24	Latent heat	kJ/kg	706,2	871,4	165,1	189,4
25	Pressure (abs)	bar	7,3089	6,99075	152,6895	151,3551
26	Velocity (Mean/Max)	m/s	1,54 / 1,73		25,27 / 26,06	
27	Pressure drop, allow./calc.	bar	0,34519	0,31815	0,6443	1,33442
28	Fouling resistance (min)	m²-K/W	0		0	0 Ao based
29	Heat exchanged 13002650 kcal/h MTD (corrected) 124,93 °C					
30	Transfer rate, Service 618,2 Dirty 1072,8 Clean 1072,8 W/(m²-K)					
31	**CONSTRUCTION OF ONE SHELL**				**Sketch**	
32			Shell Side	Tube Side		
33	Design/Vacuum/test pressure	bar	142,1964/ 1,01325 /	184,365 / 1,01325 /		
34	Design temperature	°C	420	454		
35	Number passes per shell		1	2		
36	Corrosion allowance	mm	3	0		
37	Connections In	mm	1 457,2 /1500 ANS	1 660,4 /2500 ANS		
38	Size/Rating Out		1 457,2 /1500 ANS	1 660,4 /2500 ANS		
39	Nominal Intermediate		/1500 ANS	/2500 ANS		
40	Tube No. 290 Us OD 31,75 TksAverage 4,19 mm Length 3658 mm Pitch 42,33 mm					
41	Tube type Plain #/m Material SB-444 2 Tube pattern 90					
42	Shell SA-387 22 ID 1275 OD 1470 mm Shell cover SA-387 22					
43	Channel or bonnet SA-387 22 Channel cover SA-387 22					
44	Tubesheet-stationary SA-182 F22 SB-168 Sol. Tubesheet-floating -					
45	Floating head cover - Impingement protection Round plate					
46	Baffle-cross SB-168 Sol. Type Double segmental Cut(%d) 25,1 Verti Spacing: c/c 300 mm					
47	Baffle-long - Seal Type Inlet 342,36 mm					
48	Supports-tube U-bend 4 Type					
49	Bypass seal Tube-tubesheet joint Expanded & seal welded (2 grooves)(App.A 'f')					
50	Expansion joint - Type None					
51	RhoV2-Inlet nozzle 5448 Bundle entrance 9892 Bundle exit 8119 kg/(m-s²)					
52	Gaskets - Shell side Flat Metal Jacket Fibe Tube side SB-168 Sol.					
53	Floating head -					
54	Code requirements ASME Code Sec VIII Div 1 TEMA class R - refinery service					
55	Weight/Shell 57023,3 Filled with water 62828,2 Bundle 10546,4 kg					
56	Remarks					
57						
58						



Aspen Exchanger Design and Rating Shell & Tube Mech V8.8.2

Printed: 01/07/2016 at 10:43:33

Company: Walter Tosto spa
Location: Chieti
Service of Unit: R Our Reference:
Item No.: Your Reference: U_150
Date: 10/06/2016 Rev No.: Job No.:

Overall Summary

1	Size	1275	X	3658	mm	Type	DEU	Hor		Connected in	1	parallel	1	series	
2	Surf/Unit (gross/eff/finned)			233,6	/ 195,8	/			m²	Shells/unit	1				
3	Surf/Shell (gross/eff/finned)			233,6	/ 195,8	/			m²						
4	Rating / Checking									PERFORMANCE OF ONE UNIT					
5				Shell Side		Tube Side				Heat Transfer Parameters					
6	**Process Data**			**In**	**Out**	**In**	**Out**			Total heat load			kcal/h	13002650	
7	Total flow		kg/s	224,6111		153,97				Eff. MTD/ 1 pass MTD			°C	124,93 / 125,51	
8	Vapor		kg/s	0,3464	0,9078	70,8441	60,1086			Actual/Reqd area ratio - fouled/clean				1,74 / 1,74	
9	Liquid		kg/s	224,2648	223,7033	83,1259	93,8614								
10	Noncondensable		kg/s	0		0				**Coef./Resist.**		W/(m²-K)		m²-K/W	%
11	Cond./Evap.		kg/s	0,5614		10,7354				Overall fouled		1072,8		0,00093	
12	Temperature		°C	287,8	309,92	435,1	413,82			Overall clean		1072,8		0,00093	
13	Dew / Bubble point		°C							Tube side film		4916,7		0,0002	21,82
14	Quality			0	0	0,46	0,39			Tube side fouling				0	0
15	Pressure (abs)		bar	7,3089	6,99075	152,6895	151,3551			Tube wall		3230,8		0,00031	33,2
16	DeltaP allow/cal		bar	0,34519	0,31815	0,6443	1,33442			Outside fouling				0	0
17	Velocity		m/s	1,54	1,73	26,06	24,54			Outside film		2385,1		0,00042	44,98
18	**Liquid Properties**									**Shell Side Pressure Drop**				bar	%
19	Density		kg/m³	651,1	634,96	600,47	621,92			Inlet nozzle				0,03876	12,19
20	Viscosity		mPa-s	0,5253	0,453	0,1653	0,185			InletspaceXflow				0,02869	9,02
21	Specific heat		kJ/(kg-K)	2,973	3,056	3,206	3,14			Baffle Xflow				0,12268	38,57
22	Therm. cond.		W/(m-K)	0,114	0,1124	0,1114	0,1119			Baffle window				0,06724	21,14
23	Surface tension		N/m	0,0127	0,0113	0,0061	0,0072			OutletspaceXflow				0,03098	9,74
24	Molecular weight			115,01	115,05	12,69	12,14			Outlet nozzle				0,02975	9,35
25	**Vapor Properties**									Intermediate nozzles					
26	Density		kg/m³	10,57	12,5	22,83	20,72			**Tube Side Pressure Drop**				bar	%
27	Viscosity		mPa-s	0,013	0,013	0,016	0,0151			Inlet nozzle				0,02238	1,65
28	Specific heat		kJ/(kg-K)	2,47	2,554	5,234	5,5			Entering tubes				0,08113	5,97
29	Therm. cond.		W/(m-K)	0,0588	0,0577	0,2149	0,2114			Inside tubes				1,12337	82,68
30	Molecular weight			70,45	86,31	9	5,64			Exiting tubes				0,11639	8,57
31	**Two-Phase Properties**									Outlet nozzle				0,01549	1,14
32	Latent heat		kJ/kg	706,2	871,4	165,1	189,4			Intermediate nozzles					
33	**Heat Transfer Parameters**									**Velocity / Rho*V2**			m/s		kg/(m-s²)
34	Reynolds No. vapor			3453,51	9052,18	831904	749152,4			Shell nozzle inlet			3,02		5448
35	Reynolds No. liquid			55339,26	64010,36	94504,27	95332,38			Shell bundle Xflow		1,54	1,73		
36	Prandtl No. vapor			0,55	0,58	0,39	0,39			Shell baffle window		1,14	1,28		
37	Prandtl No. liquid			13,7	12,31	4,75	5,19			Shell nozzle outlet			3,4		6118
38	**Heat Load**				kW		kW			Shell nozzle interm					
39	Vapor only				0		0						m/s		kg/(m-s²)
40	2-Phase vapor				34,6		-7429,7			Tube nozzle inlet			10,23		4975
41	Latent heat				242,4		-1777			Tubes		26,06	24,54		
42	2-Phase liquid				14828		-5932,4			Tube nozzle outlet			9,77		4748
43	Liquid only				0		0			Tube nozzle interm					
44	**Tubes**							**Baffles**				**Nozzles: (No./OD)**			
45	Type				Plain			Type	Double segmental				**Shell Side**		**Tube Side**
46	ID/OD		mm	23,37	/ 31,75			Number		10		Inlet	mm	1 / 457,2	1 / 660,4
47	Length act/eff		mm	3658	/ 3384,7			Cut(%d)	25,1	14,94		Outlet		1 / 457,2	1 / 660,4
48	Tube passes			2				Cut orientation		V		Intermediate		/	/
49	Tube No.			580				Spacing: c/c	mm	300		Impingement protection		Round plate	
50	Tube pattern			90				Spacing at inlet	mm	342,36					
51	Tube pitch		mm	42,33				Spacing at outlet	mm	342,36					
52	Insert				None										
53	Vibration problem				No / No							RhoV2 violation			No

Aspen Exchanger Design and Rating Shell & Tube Mech V8.8.2

Printed: 01/07/2016 at 10:43:33

Company: Walter Tosto spa
Location: Chieti
Service of Unit: R Our Reference:
Item No.: Your Reference: U_150
Date: 10/06/2016 Rev No.: Job No.:

Overall Performance

Rating / Checking		Shell Side		Tube Side	
Total mass flow rate	kg/s	224,6111		153,97	
Vapor mass flow rate (In/Out)	kg/s	0,3464	0,9078	70,8441	60,1086
Liquid mass flow rate	kg/s	224,2648	223,7033	83,1259	93,8614
Vapor mass quallity		0	0	0,46	0,39
Temperatures	°C	287,8	309,92	435,1	413,82
Dew point / Bubble point	°C				
Operating Pressures	bar	7,3089	6,99075	152,6895	151,3551
Film coefficient	W/(m²-K)	2385,1		4916,7	
Fouling resistance	m²-K/W	0		0	
Velocity (highest)	m/s	1,73		26,06	
Pressure drop (allow./calc.)	bar	0,34519 / 0,31815		0,6443 / 1,33442	

Total heat exchanged	kcal/h	13002650	Unit	DEU	2	pass	1	ser	1	par
Overall clean coeff. (plain/finned)	W/(m²-K)	1072,8 /	Shell size	1275	-	3658	mm		Hor	
Overall dirty coeff. (plain/finned)	W/(m²-K)	1072,8 /	Tubes	Plain						
Effective area (plain/finned)	m²	195,8 /	Insert	None						
Effective MTD	°C	124,93	No.	580	OD	31,75	Tks	4,19	mm	
Actual/Required area ratio (dirty/clean)		1,74 / 1,74	Pattern	90		Pitch	42,33	mm		
Vibration problem		No	Baffles	Double segmental			Cut(%d)	25,1		
RhoV2 problem		No	Total cost	1135088		Dollar(US)				

Heat Transfer Resistance

Shell side / Fouling / Wall / Fouling / Tube side

Resistance Distribution

Overall Coefficient / Resistance Summary			Clean	Dirty	Max Dirty
Area required		m²	112,8	112,8	195,8
Area ratio: actual/required			1,74	1,74	1
Overall coefficient		W/(m²-K)	1072,8	1072,8	618,2
Overall resistance		m²-K/W	0,00093	0,00093	0,00162
Shell side fouling		m²-K/W	0.0	0	0,00034
Tube side fouling			0.0	0	0,00034
Resistance Distribution	W/(m²-K)	m²-K/W	%	%	%
Shell side film	2385,1	0,00042	44,98	44,98	25,92
Shell side fouling		0		0	21,19
Tube wall	3230,8	0,00031	33,2	33,2	19,13
Tube side fouling *		0		0	21,19
Tube side film *	4916,7	0,0002	21,82	21,82	12,57

* Based on outside surface - Area ratio: Ao/Ai = 1,36

Company: Walter Tosto spa
Location: Chieti
Service of Unit: R Our Reference:
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Date: 10/06/2016 Rev No.: Job No.:

Shell by Shell Conditions

		Shell 1
Shell heat load	**kW**	15105,1
Shell inlet temperature	**C**	287,8
Shell outlet temperature	**C**	309,92
Tube inlet temperature	**C**	435,1
Tube outlet temperature	**C**	413,82
Shell inlet vapor fraction		0
Shell outlet vapor fraction		0
Tube inlet vapor fraction		0,46
Tube outlet vapor fraction		0,39
Shell inlet pressure	**bar**	7,3089
Shell outlet pressure	**bar**	6,99075
Tube inlet pressure	**bar**	152,6895
Tube outlet pressure	**bar**	151,3551
Shell pressure drop	**bar**	0,31815
Tube pressure drop	**bar**	1,33442
Mean shell metal temperature	**C**	299,19
Mean tube metal temperature	**C**	376,05
Minimum tube metal temperature	**C**	370,1
Maximum tube metal temperature	**C**	384,71

Company: Walter Tosto spa
Location: Chieti
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Hot Stream Composition

Stream mass fractions	
Liquid mass fractions at inlet	
Liquid mass fractions at outlet	
Vapor mass fractions at inlet	
Vapor mass fractions at outlet	
Liquid 2 mass fractions at inlet	
Liquid 2 mass fractions at outlet	
Stream mole fractions	
Liquid mole fractions at inlet	
Liquid mole fractions at outlet	
Vapor mole fractions at inlet	
Vapor mole fractions at outlet	
Liquid-2 mole fractions at inlet	
Liquid-2 mole fractions at outlet	
Stream mass flow	**kg/s**
Liquid mass flow at inlet	**kg/s**
Liquid mass flow at outlet	**kg/s**
Vapor mass flow at inlet	**kg/s**
Vapor mass flow at outlet	**kg/s**
Liquid 2 mass flow at inlet	**kg/s**
Liquid 2 mass flow at outlet	**kg/s**

Company: Walter Tosto spa
Location: Chieti
Service of Unit: R Our Reference:
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Date: 10/06/2016 Rev No.: Job No.:

Cold Stream Composition

Stream mass fractions	
Liquid mass fractions at inlet	
Liquid mass fractions at outlet	
Vapor mass fractions at inlet	
Vapor mass fractions at outlet	
Liquid 2 mass fractions at inlet	
Liquid 2 mass fractions at outlet	
Stream mole fractions	
Liquid mole fractions at inlet	
Liquid mole fractions at outlet	
Vapor mole fractions at inlet	
Vapor mole fractions at outlet	
Liquid-2 mole fractions at inlet	
Liquid-2 mole fractions at outlet	
Stream mass flow	**kg/s**
Liquid mass flow at inlet	**kg/s**
Liquid mass flow at outlet	**kg/s**
Vapor mass flow at inlet	**kg/s**
Vapor mass flow at outlet	**kg/s**
Liquid 2 mass flow at inlet	**kg/s**
Liquid 2 mass flow at outlet	**kg/s**

Heat Transfer Coefficients

Film coefficients W/(m²-K)		**Shell Side** Bare area (OD) / Finned area		**Tube Side** Bare area (OD) / ID area	
Overall film coefficients		2385,1 /		4916,7 /	6680,3
Vapor sensible		0 /		0 /	
Two phase		2385,1 /		4916,7 /	6680,3
Liquid sensible		0 /		0 /	
Heat Transfer Parameters		**In**	**Out**	**In**	**Out**
Prandtl numbers	Vapor	0,55	0,58	0,39	0,39
	Liquid	13,7	12,31	4,75	5,19
Reynolds numbers	Vapor Nominal	3453,51	9052,18	831904	749152,4
	Liquid Nominal	55339,26	64010,36	94504,27	95332,38

Fin Efficiency

Company: Walter Tosto spa
Location: Chieti
Service of Unit: R Our Reference:
Item No.: Your Reference: U_150
Date: 10/06/2016 Rev No.: Job No.:

MTD & Flux

Temperature Difference	°C	**Heat Flux (based on tube O.D)**	kW/m²
Overall effective MTD	124,93	Overall actual flux	134
One pass counterflow MTD	125,51	Critical heat flux (at highest ratio)	23569
LMTD based on end points	125,6	Highest actual flux	149,9
Effective MTD correction factor	0,99	Highest actual/critical flux	
Wall Temperatures	°C		
Shell mean metal temperature		299,19	
Tube mean metal temperature		376,05	
Tube wall temperatures (highest/lowest)		384,71 / 370,1	

Duty Distribution

Heat Load Summary	**Shell Side**		**Tube Side**	
	kW	**% total**	kW	**% total**
Vapor only	0	0	0	0
2-Phase vapor	34,6	0,23	-7429,7	49,08
Latent heat	242,4	1,61	-1777	11,74
2-Phase liquid	14828	98,17	-5932,4	39,19
Liquid only	0	0	0	0
Total	15105,1	100	-15139	100
Effectiveness	0,1764			

Pressure Drop

Pressure Drop bar	**Shell Side**			**Tube Side**		
Maximum allowed	0,34519			0,6443		
Total calculated	0,31815			1,33442		
Gravitational	0			0		
Frictional	0,3181			1,35876		
Momentum change	5E-05			-0,02434		
Pressure drop distribution	m/s	bar	**%dp**	m/s	bar	**%dp**
Inlet nozzle	3,02	0,03876	12,19	10,23	0,02238	1,65
Entering bundle	4,08			26,06	0,08113	5,97
Inside tubes				26,06 24,54	1,12337	82,68
Inlet space Xflow	1,35	0,02869	9,02			
Bundle Xflow	1,54 1,73	0,12268	38,57			
Baffle windows	1,14 1,28	0,06724	21,14			
Outlet space Xflow	1,52	0,03098	9,74			
Exiting bundle	3,91			24,54	0,11639	8,57
Outlet nozzle	3,4	0,02975	9,35	9,77	0,01549	1,14
Liquid outlet nozzle						
Vapor outlet nozzle						
Intermediate nozzles						

Company: Walter Tosto spa
Location: Chieti
Service of Unit: R Our Reference:
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Date: 10/06/2016 Rev No.: Job No.:

Flow Analysis

Shell Side Flow Fractions	Inlet	Middle	Outlet	Diameter Clearance mm
Crossflow	0,55	0,49	0,55	
Window	0,89	0,79	0,89	
Baffle hole - tube OD	0,07	0,13	0,07	0,79
Baffle OD - shell ID	0,04	0,08	0,04	6,35
Shell ID - bundle OTL	0,24	0,22	0,24	49,7
Pass lanes	0,1	0,09	0,1	

Rho*V2 Analysis	Flow Area mm²	Velocity m/s	Density kg/m³	Rho*V2 kg/(m-s²)	TEMA limit kg/(m-s²)
Shell inlet nozzle	124707	3,02	595,47	5448	744
Shell entrance	191748	1,97	595,47	2304	5953
Bundle entrance	92546	4,08	595,47	9892	5953
Bundle exit	108252	3,91	530,28	8119	5953
Shell exit	199814	2,12	530,28	2383	5953
Shell outlet nozzle	124707	3,4	530,28	6118	
	mm²	m/s	kg/m³	kg/(m-s²)	kg/(m-s²)
Tube inlet nozzle	316692	10,23	47,51	4975	8928
Tube inlet	124374	26,06	47,51	32258	
Tube outlet	124374	24,54	50,46	30374	
Tube outlet nozzle	316692	9,77	49,78	4748	

Thermosiphons and Kettles

Thermosiphons

Thermosiphon stability

Vertical tube side thermosiphons
- Flow reversal criterion - top of the tubes (should be > 0.5)
- Flooding criterion - top of the tubes (should be > 1.0)
- Fraction of the tube length flooded
- Kutateladze Number in axial nozzle (should be > 3.2)

Kettles

Recirculation ratio
Quality at top of bundle
Entrainment fraction

Company: Walter Tosto spa
Location: Chieti
Service of Unit: R Our Reference:
Item No.: Your Reference: U_150
Date: 10/06/2016 Rev No.: Job No.:

Thermal Details - Vibration Analysis - Fluid Elastic Instability HTFS

Shell number: Shell 1

Fluid Elastic Instability Analysis

Vibration tube number		1	2	4	6	7
Vibration tube location		Inlet row, centre	Outer window, left	Baffle overlap	Inlet row, end	Inner window
Vibration		No	No	No	No	No
W/Wc for heavy damping (LDec=0.1)		0,19	0,18	0,05	0,18	0,16
W/Wc for medium damping (LDec=0.03)		0,34	0,33	0,09	0,33	0,3
W/Wc for light damping (LDec=0.01)		0,59	0,58	0,16	0,58	0,52
W/Wc for estimated damping		0,22	0,21	0,05	0,21	0,19
Estimated log Decrement		0,07	0,07	0,09	0,07	0,07
Tube natural frequency	**cycle/s**	182,5	182,5	702,1	182,5	182,5
Natural frequency method		Dominant Span	Dominant Span	Dominant Span	Dominant Span	Dominant Span
Dominant span		Outlet	Outlet	U-bend	Outlet	Outlet
Tube effective mass	**kg/m**	3,71	3,71	3,71	3,71	3,71

Note: W/Wc = ratio of actual shellside flowrate to critical flowrate for onset of fluid-elastic instability

Tube material density:	kg/m³	8442,39
Tube axial stress:	N/mm²	0
Tube material Young's Modulus:	N/mm²	184258,9
U-bend longest unsupported length:	mm	305,9

Company: Walter Tosto spa
Location: Chieti
Service of Unit: R Our Reference:
Item No.: Your Reference: U_150
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Resonance Analysis (HTFS)

Shell number: Shell 1
Resonance Analysis

Vibration tube number		1	1	1	2
Vibration tube location		Inlet row, centre	Inlet row, centre	Inlet row, centre	Outer window, left
Location along tube		Inlet	Midspace	Outlet	Inlet
Vibration problem		No	No	No	No
Span length	**mm**	600	600	642,36	407,36
Frequency ratio: Fv/Fn		0,26	0,16	0,16	0,26
Frequency ratio: Fv/Fa		0,5	0,34	0,4	0,5
Frequency ratio: Ft/Fn		0,19	0,11	0,11	0,19
Frequency ratio: Ft/Fa		0,36	0,24	0,29	0,36
Vortex shedding amplitude	**mm**				
Turbulent buffeting amplitude	**mm**				
TEMA amplitude limit	**mm**				
Natural freq., Fn	**cycle/s**	182,5	182,5	182,5	182,5
Acoustic freq., Fa	**cycle/s**	95,46	84,54	71,01	95,46
Flow velocity	**m/s**	4,08	2,31	2,42	4,08
X-flow fraction		1	0,79	0,79	0,79
RhoV2	**kg/(m*s2)**	9880	2962	3105	9880
Strouhal No.		0,38	0,38	0,38	0,38

Company: Walter Tosto spa
Location: Chieti
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Vibration tube number		2	2	4	4
Vibration tube location		Outer window, left	Outer window, left	Baffle overlap	Baffle overlap
Location along tube		Midspace	Outlet	Inlet	Midspace
Vibration problem		No	No	No	No
Span length	**mm**	600	600	300	342,36
Frequency ratio: Fv/Fn		0,16	0,16	0,07	0,04
Frequency ratio: Fv/Fa		0,34	0,4	0,5	0,34
Frequency ratio: Ft/Fn		0,11	0,11	0,05	0,03
Frequency ratio: Ft/Fa		0,24	0,29	0,36	0,24
Vortex shedding amplitude	**mm**				
Turbulent buffeting amplitude	**mm**				
TEMA amplitude limit	**mm**				
Natural freq., Fn	**cycle/s**	182,5	182,5	702,1	702,1
Acoustic freq., Fa	**cycle/s**	84,54	71,01	95,46	84,54
Flow velocity	**m/s**	2,31	2,42	4,08	2,31
X-flow fraction		0,79	0,79	0,79	0,79
RhoV2	**kg/(m*s2)**	2962	3105	9880	2962
Strouhal No.		0,38	0,38	0,38	0,38

Company: Walter Tosto spa
Location: Chieti
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Vibration tube number		4	6	6	6	7
Vibration tube location		Baffle overlap	Inlet row, end	Inlet row, end	Inlet row, end	Inner window
Location along tube		Outlet	Inlet	Midspace	Outlet	Inlet
Vibration problem		No	No	No	No	No
Span length	**mm**	300	407,36	600	600	600
Frequency ratio: Fv/Fn		0,04	0,26	0,16	0,16	0,14
Frequency ratio: Fv/Fa		0,4	0,5	0,34	0,4	0,28
Frequency ratio: Ft/Fn		0,03	0,19	0,11	0,11	0,1
Frequency ratio: Ft/Fa		0,29	0,36	0,24	0,29	0,2
Vortex shedding amplitude	**mm**					
Turbulent buffeting amplitude	**mm**					
TEMA amplitude limit	**mm**					
Natural freq., Fn	**cycle/s**	702,1	182,5	182,5	182,5	182,5
Acoustic freq., Fa	**cycle/s**	71,01	95,46	84,54	71,01	95,46
Flow velocity	**m/s**	2,42	4,08	2,31	2,42	2,07
X-flow fraction		0,79	0,79	0,79	1	0,79
RhoV2	**kg/(m*s2)**	3105	9880	2962	3105	2557
Strouhal No.		0,38	0,38	0,38	0,38	0,38

Company: Walter Tosto spa
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Vibration tube number		7	7
Vibration tube location		Inner window	Inner window
Location along tube		Midspace	Outlet
Vibration problem		No	No
Span length	**mm**	600	642,36
Frequency ratio: Fv/Fn		0,16	0,16
Frequency ratio: Fv/Fa		0,34	0,4
Frequency ratio: Ft/Fn		0,11	0,11
Frequency ratio: Ft/Fa		0,24	0,29
Vortex shedding amplitude	**mm**		
Turbulent buffeting amplitude	**mm**		
TEMA amplitude limit	**mm**		
Natural freq., Fn	**cycle/s**	182,5	182,5
Acoustic freq., Fa	**cycle/s**	84,54	71,01
Flow velocity	**m/s**	2,31	2,42
X-flow fraction		0,79	0,79
RhoV2	**kg/(m*s2)**	2962	3105
Strouhal No.		0,38	0,38

Company: Walter Tosto spa
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Simple Amplitude and Acoustic Analysis (TEMA)

Amplitude Vibration Analysis

		Inlet	C-C Window	C-C Overlap	Outlet
Vortex shedding indication		No	No	No	No
Turbulent buffeting indication		No	No	No	No
Tube natural frequency, fn	**cycle/s**	246,85	182,69	730,77	249,42
Vortex shedding frequency, fvs	**cycle/s**	49,18	28,04	28,04	47,37
Vortex shedding amplitude	**mm**	0	0	0	0
Vortex shedding amplitude limit	**mm**	0	0	0	0
Turbulent buffetting amplitude	**mm**	0	0	0	0
Turbulent buffetting amplitude limit	**mm**	0,64	0,64	0,64	0,64

Acoustic Vibration Analysis

		Inlet	C-C Window	C-C Overlap	Outlet
Acoustic resonance indication		No	No	No	No
Crossflow velocity	**m/s**	4,08	2,32	2,32	3,93
Strouhal number		0,38	0,38	0,38	0,38
Acoustic frequency, fa	**cycle/s**				
Vortex shedding frequency, fvs	**cycle/s**	49,18	28,04	28,04	47,37
Turbulent buffetting frequency, ftb	**cycle/s**	33,98	19,37	19,37	32,73
Condition A fa/fvs		0	0	0	0
Condition A fa/ftb		0	0	0	0
Condition B velocity	**m/s**				
Condition C velocity	**m/s**				
Condition C					

Company: Walter Tosto spa
Location: Chieti
Service of Unit: R Our Reference:
Item No.: Your Reference: U_150
Date: 10/06/2016 Rev No.: Job No.:

Methods Summary

	Hot Side	Cold Side
Heat transfer coefficient multiplier	No	No
Heat transfer coefficient specified	No	No
Pressure drop multiplier	No	No
Pressure drop calculation option	friction only	friction only
Calculation method	Standard method	
Desuperheating heat transfer method	Wet wall	
Multicomponent condensing heat transfer method	HTFS - Silver-Bell	
Vapor shear enhanced condensation	Yes	
Liquid subcooling heat transfer (vertical shell)	Not Used	
Subcooled boiling accounted for in	Heat transfer & pressure drop	
Post dryout heat transfer accounted for in	Yes	
Correction to user-supplied boiling curve	Boiling curve not used	
Falling film evaporation method	HTFS recommended method	
Single phase tube side heat transfer method	HTFS recommended method	
Lowfin Calculation method	HTFS / ESDU	
Tube Pass Multiplier	1	

Company: Walter Tosto spa
Location: Chieti
Service of Unit: R Our Reference:
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Date: 10/06/2016 Rev No.: Job No.:

Basic Geometry

Unit Configuration					
Exchanger type		DEU	Tube number		580
Position		Hor	Tube length actual	mm	3658
Arrangement	1 parallel	1 series	Tube passes		2
Baffle type		Double segmental	Tube type		Plain
Baffle number		10	Tube O.D.	mm	31,75
Spacing (center-center)	mm	300	Tube pitch	mm	42,33
Spacing at inlet	mm	342,36	Tube pattern		90

		Shell	Kettle	Front head	Rear Head
Outside diameter	mm	1470		1470	
Inside diameter	mm	1275		1238	

		Shell Side			Tube Side	
Nozzle type		Inlet	Outlet		Inlet	Outlet
Number of nozzles		1	1		1	1
Actual outside diameter	**mm**	457,2	457,2		660,4	660,4
Inside diameter	**mm**	398,48	398,48		635	635
Height under nozzle	**mm**	150,68	150,68			
Dome inside diameter	**mm**					
Vapor belt inside diameter	**mm**					
Vapor belt inside width	**mm**					
Vapor belt slot area	**mm2**					
Impingement protection		Yes	No			
Distance to tubesheet	**mm**	3410	825			

Company: Walter Tosto spa
Location: Chieti
Service of Unit: R Our Reference:
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Tubes

Tubes

Type		Plain	Total number of tubes		580
Outside diameter	mm	31,75	Number of tubes plugged		0
Inside diameter	mm	23,37	Tube length actual	mm	3658
Wall thickness	mm	4,19	Tube length effective	mm	3384,7
Area Ratio Ao/Ai		1,358696	Front tubesheet thickness	mm	260,29
Pitch	mm	42,33	Rear tubesheet thickness	mm	
Pattern		90	Material		SB-444 2
External enhancement			Thermal conductivity	W/(m-K)	15,7214
Internal enhancement					
Low fins			**Longitudinal fins**		
Fin density	#/m		Fin number		0
Fin height	mm		Fin thickness	mm	
Fin thickness	mm		Fin height	mm	
Tube root diameter	mm		Fin spacing	mm	
Tube wall thickness under fin	mm		Cut and twist length	mm	
Tube inside diameter under fins	mm				
Other (high) fins					
High Fin Type		Default	High Fin Thick	mm	
High Fin Tip Diameter	mm		High Fin Frequency	#/m	

Company: Walter Tosto spa
Location: Chieti
Service of Unit: R Our Reference:
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Baffles

Baffles								
Type		Double segmental	Baffle cut: inner/outer/interm					
Tubes in window		Yes	Actual (% diameter)	14,94	/	25,1	/	
Number		10	Nominal (% diameter)	15	/	24,5	/	
Spacing (center-center)	mm	300	Actual (% area)	18,74	/	19,66	/	
Spacing at inlet	mm	342,36	Cut orientation					V
Spacing at outlet	mm	342,36	Thickness			mm		10
Spacing at center in/out for G,H,I,J	mm		Tube rows in baffle overlap					5
Spacing at center for H shell	mm		Tube rows in baffle window					14
End length of the front head	mm	605,64	Baffle hole - tube od diam clearance			mm		0,79
End length of the rear head	mm	352,36	Shell id - tube od diam clearance			mm		6,35

Variable Baffle Spacings

Baffle spacing	**mm**
Baffle cut percent, outer	
Baffle cut percent, inner	
Number of baffle spaces	
Baffle region length	**mm**
Baffle cut area percent, outer	
Baffle cut area percent, inner	

Supports-Misc. Baffles

Supports - tube		**Longitudinal Baffle**	
Supports in endspace at front head	0	Thickness	mm
Supports in endspace at rear head	0	Window length at front end	mm
Supports between baffles	0	Window length at center	mm
Support blanking baffle	Yes	Window length at rear end	mm
Supports at U-bend	4		
Supports at each G,H,J shell inlet and I shell outlet	0		
Supports at center of H shell	0		
Supports for K,X shells	0		
Special support at inlet nozzle	Yes		

Company: Walter Tosto spa
Location: Chieti
Service of Unit: R Our Reference:
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Bundle

Bundle					
Shell ID to center 1st tube row	mm		Tube passes		2
From top		150,68	Tube pass layout		Quadrant (dbl.band)
From bottom		150,68	Tube pass orientation		Vertical
From right		28,98	U-bend orientation		Vertical
From left		28,98	Horizontal pass lane width	mm	63,5
Impingement protection		Round plate	Vertical pass lane width	mm	
Impingement distance	mm		Interpass tube alignment		Yes
Impingement plate diameter	mm	400	Deviation in tubes/pass		0
Impingement plate width	mm	400	Outer tube limit	mm	1225,3
Impingement plate length	mm		Shell id - bundle otl diam clearance	mm	49,7
Impingement plate thickness	mm	6,35	Tie rod number		10
Gross surface area per shell	m²	233,6	Tie rod diameter	mm	12,7
Effective surface area per shell	m²	195,8	Sealing strips (pairs)		2
Bare tube area per shell	m²	195,8	Tube to Tubesheet joint		I wld 2 grv
Finned area per shell	m²	0	Tube projection from front tsht	mm	3
U-bend area per shell	m²	22	Tube projection from rear tsht	mm	0

Enhancements

Inserts & Internal enhancements		
Tube insert type		None
Twist tape 360 deg twist pitch	mm	
Twisted tape thickness	mm	
hiTRAN part number		

Company: Walter Tosto spa
Location: Chieti
Service of Unit: R Our Reference:
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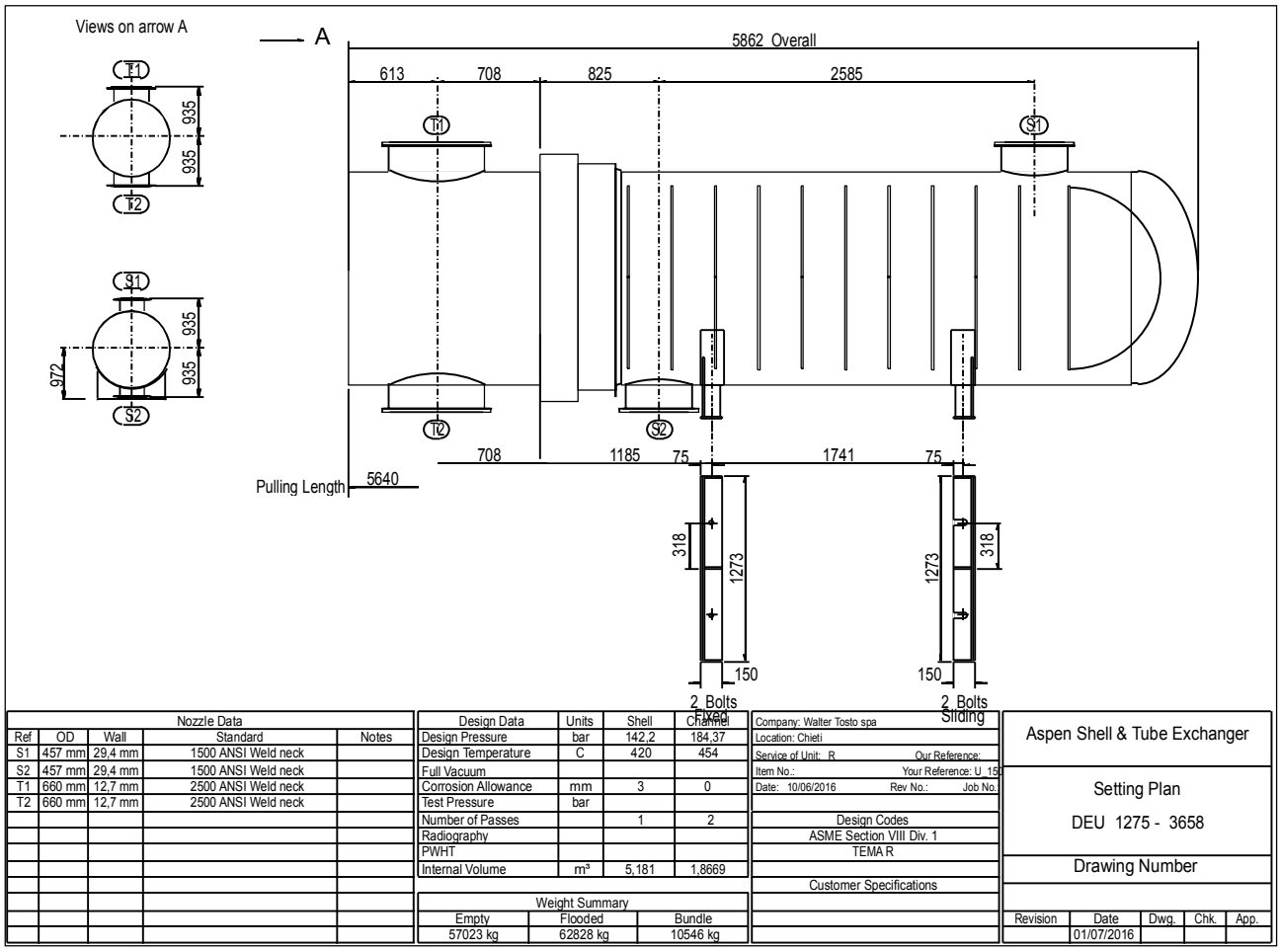
Setting Plan



Nozzle Data				
Ref	OD	Wall	Standard	Notes
S1	457 mm	29,4 mm	1500 ANSI Weld neck	
S2	457 mm	29,4 mm	1500 ANSI Weld neck	
T1	660 mm	12,7 mm	2500 ANSI Weld neck	
T2	660 mm	12,7 mm	2500 ANSI Weld neck	

Design Data	Units	Shell	Channel
Design Pressure	bar	142,2	184,37
Design Temperature	C	420	454
Full Vacuum			
Corrosion Allowance	mm	3	0
Test Pressure	bar		
Number of Passes		1	2
Radiography			
PWHT			
Internal Volume	m³	5,181	1,8669

Weight Summary		
Empty	Flooded	Bundle
57023 kg	62828 kg	10546 kg

Company: Walter Tosto spa
Location: Chieti
Service of Unit: R Our Reference:
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Date: 10/06/2016 Rev No.: Job No.:

Design Codes
ASME Section VIII Div. 1
TEMA R

Customer Specifications

Aspen Shell & Tube Exchanger

Setting Plan

DEU 1275 - 3658

Drawing Number

Revision	Date	Dwg.	Chk.	App.
	01/07/2016			

Company: Walter Tosto spa
Location: Chieti
Service of Unit: R Our Reference:
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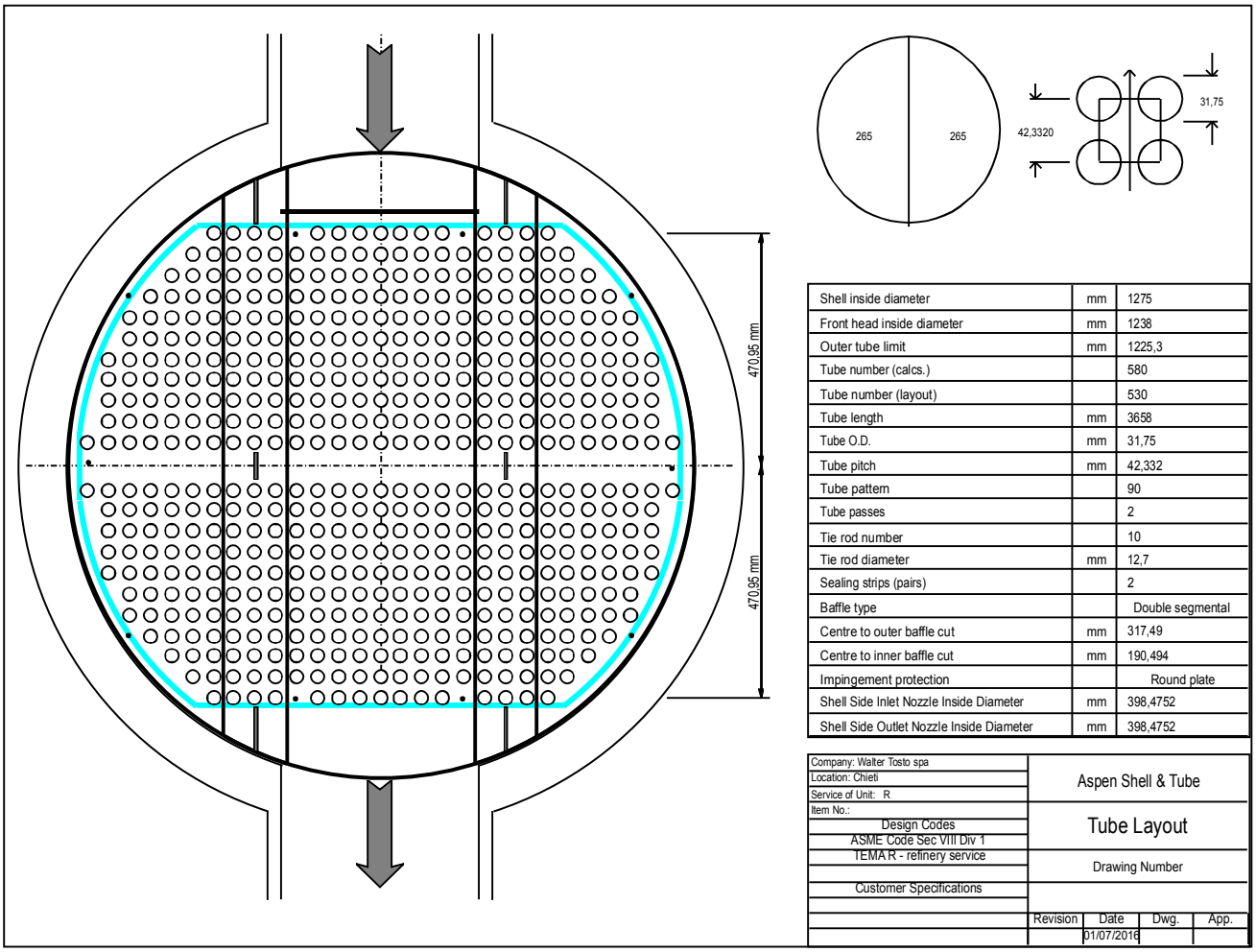
Tubesheet Layout



Shell inside diameter	mm	1275
Front head inside diameter	mm	1238
Outer tube limit	mm	1225,3
Tube number (calcs.)		580
Tube number (layout)		530
Tube length	mm	3658
Tube O.D.	mm	31,75
Tube pitch	mm	42,332
Tube pattern		90
Tube passes		2
Tie rod number		10
Tie rod diameter	mm	12,7
Sealing strips (pairs)		2
Baffle type		Double segmental
Centre to outer baffle cut	mm	317,49
Centre to inner baffle cut	mm	190,494
Impingement protection		Round plate
Shell Side Inlet Nozzle Inside Diameter	mm	398,4752
Shell Side Outlet Nozzle Inside Diameter	mm	398,4752

Company: Walter Tosto spa	Aspen Shell & Tube
Location: Chieti	
Service of Unit: R	
Item No.:	Tube Layout
Design Codes	
ASME Code Sec VIII Div 1	
TEMA R - refinery service	Drawing Number
Customer Specifications	

Revision	Date	Dwg.	App.
	01/07/2016		

Costs/Weights

Weights	kg	**Cost data**	Dollar(US)
Shell	21345,8	Labor cost	221789
Front head	25131,1	Tube material cost	643369
Rear head	0	Material cost (except tubes)	269930
Shell cover			
Bundle	10546,4		
Total weight - empty	57023,3	Total cost (1 shell)	1135088
Total weight - filled with water	62828,2	Total cost (all shells)	1135088

Company: Walter Tosto spa
Location: Chieti
Service of Unit: R Our Reference:
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Analysis along Shell - Interval Analysis

Point No.	Shell No.	Shell Pass No.	Distance from End	SS Bulk Temp.	SS Fouling Surface Temp	Tube Metal Temp	SS Pressure	SS Vapor fraction	SS void fraction	SS Heat Load
			mm	C	C	C	bar			kW
1	1	1	3385	287,8	356,37	376,76	7,27014	0	0,07	0
2	1	1	3310	288,3	356,38	376,77	7,2641	0	0,08	327,7
3	1	1	3235	288,78	350,56	372,71	7,25807	0	0,08	655,3
4	1	1	3160	289,32	350,21	372,46	7,25146	0	0,08	1014,3
5	1	1	3085	289,86	349,86	372,22	7,24485	0	0,09	1373,2
6	1	1	3012	290,38	349,84	372,21	7,23967	0	0,09	1726,2
7	1	1	2939	290,9	349,81	372,19	7,2345	0	0,09	2079,2
8	1	1	2870	291,39	349,1	371,69	7,22961	0	0,09	2412,8
9	1	1	2802	291,88	348,38	371,19	7,22472	0	0,09	2746,4
10	1	1	2731	292,39	348,91	371,55	7,21992	0	0,09	3092
11	1	1	2660	292,89	349,44	371,9	7,21512	0	0,1	3437,5
12	1	1	2588	293,39	350,15	372,39	7,21038	0	0,1	3778,5
13	1	1	2517	293,88	350,85	372,89	7,20564	0	0,1	4119,6
14	1	1	2448	294,36	351,6	373,41	7,2009	0	0,1	4443,3
15	1	1	2379	294,83	352,34	373,94	7,19616	0	0,11	4766,9
16	1	1	2300	295,36	352,8	374,26	7,19084	0	0,11	5129,8
17	1	1	2222	295,9	353,25	374,58	7,18552	0	0,12	5492,8
18	1	1	2137	296,46	353,72	374,9	7,17949	0	0,13	5881,5
19	1	1	2051	297,03	354,18	375,23	7,17345	0	0,14	6270,2
20	1	1	1985	297,47	354,54	375,48	7,16883	0	0,15	6568,1
21	1	1	1919	297,91	354,89	375,73	7,16421	0	0,16	6866
22	1	1	1858	298,31	355,21	375,95	7,15972	0	0,17	7139,3
23	1	1	1797	298,71	355,53	376,18	7,15524	0	0,18	7412,7
24	1	1	1703	299,31	355,88	376,43	7,14845	0	0,18	7825,9
25	1	1	1610	299,92	356,23	376,68	7,14167	0	0,18	8239,2
26	1	1	1505	300,59	356,66	377,01	7,13401	0	0,18	8697
27	1	1	1400	301,26	357,09	377,33	7,12635	0	0,18	9154,9
28	1	1	1348	301,59	357,29	377,47	7,12252	0	0,18	9383,6
29	1	1	1295	301,93	357,49	377,62	7,11869	0	0,18	9612,3

Company: Walter Tosto spa
Location: Chieti
Service of Unit: R Our Reference:
Item No.: Your Reference: U_150
Date: 10/06/2016 Rev No.: Job No.:

Point No.	SS Heat flux	SS Film Coef.	SS flow pattern
	kW/m2	W/(m2*K)	
1	131,8	1921,7	Bubbly
2	131,8	1935	Bubbly
3	143,1	2316,3	Bubbly
4	143,8	2361,5	Bubbly
5	144,5	2407,6	Bubbly
6	144,5	2430,7	Bubbly
7	144,6	2454	Bubbly
8	146	2529,9	Bubbly
9	147,4	2608,4	Bubbly
10	146,2	2586,9	Bubbly
11	145,1	2565,6	Bubbly
12	143,7	2532,5	Bubbly
13	142,4	2499,8	Bubbly
14	141	2462,6	Bubbly
15	139,5	2426	Bubbly
16	138,7	2414	Bubbly
17	137,8	2402,1	Bubbly
18	136,9	2390,9	Bubbly
19	136	2379,9	Bubbly
20	135,3	2371,3	Bubbly
21	134,6	2362,7	Bubbly
22	134	2355,6	Bubbly
23	133,4	2348,4	Bubbly
24	132,8	2347,3	Bubbly
25	132,1	2346,1	Bubbly
26	131,5	2344,2	Bubbly
27	130,8	2342,4	Bubbly
28	130,4	2341,8	Bubbly
29	130,1	2341,3	Bubbly

Company: Walter Tosto spa
Location: Chieti
Service of Unit: R Our Reference:
Item No.: Your Reference: U_150
Date: 10/06/2016 Rev No.: Job No.:

Point No.	Shell No.	Shell Pass No.	Distance from End	SS Bulk Temp.	SS Fouling Surface Temp	Tube Metal Temp	SS Pressure	SS Vapor fraction	SS void fraction	SS Heat Load
			mm	C	C	C	bar			kW
30	1	1	1248	302,23	357,66	377,75	7,11526	0	0,18	9815,2
31	1	1	1201	302,52	357,84	377,87	7,11182	0	0,18	10018,1
32	1	1	1088	303,23	358,27	378,19	7,10363	0	0,17	10501,8
33	1	1	975	303,94	358,71	378,5	7,09544	0	0,16	10985,5
34	1	1	844	304,75	359,18	378,85	7,08604	0	0,14	11540,2
35	1	1	713	305,56	359,66	379,19	7,07665	0	0,13	12094,8
36	1	1	682	305,76	359,76	379,27	7,07442	0	0,13	12226,8
37	1	1	650	305,95	359,86	379,34	7,07219	0	0,13	12358,7
38	1	1	623	306,11	359,91	379,38	7,07029	0	0,13	12471,6
39	1	1	596	306,28	359,97	379,42	7,06839	0	0,12	12584,5
40	1	1	460	307,12	359,62	379,2	7,05873	0	0,09	13158,2
41	1	1	324	307,96	359,28	378,98	7,04907	0	0,07	13731,9
42	1	1	162	308,95	359,39	379,09	7,03472	0	0,06	14418,5
43	1	1	0	309,91	357,41	377,73	7,02038	0	0,05	15105,1

Company: Walter Tosto spa
Location: Chieti
Service of Unit: R Our Reference:
Item No.: Your Reference: U_150
Date: 10/06/2016 Rev No.: Job No.:

Point No.	SS Heat flux	SS Film Coef.	SS flow pattern
	kW/m2	W/(m2*K)	
30	129,8	2340,7	Bubbly
31	129,5	2340,2	Bubbly
32	128,7	2337,9	Bubbly
33	127,9	2335,6	Bubbly
34	127,1	2334,4	Bubbly
35	126,2	2333,3	Bubbly
36	126	2334	Bubbly
37	125,9	2334,7	Bubbly
38	125,8	2338	Bubbly
39	125,7	2341,4	Bubbly
40	126,5	2409,6	Bubbly
41	127,3	2480,1	Bubbly
42	127,2	2521,8	Bubbly
43	131,2	2763,4	Bubbly

Company: Walter Tosto spa
Location: Chieti
Service of Unit: R Our Reference:
Item No.: Your Reference: U_150
Date: 10/06/2016 Rev No.: Job No.:

Analysis along Shell - Physical Properties

Temperature	**C**	287,8	289,86	291,88	293,88	295,9	297,91	299,92	301,93	303,94
Pressure	**bar**	7,27014	7,24484	7,22471	7,20562	7,1855	7,1642	7,14166	7,11869	7,09545
Vapor fraction		0	0	0	0	0	0	0	0	0
Liquid density	**kg/m3**	651,09	649,66	648,24	646,76	645,3	643,87	642,39	640,94	639,47
Liquid specific heat	**kJ/(kg*K)**	2,973	2,973	2,973	3	3,014	3,014	3,014	3,014	3,031
Liquid thermal cond.	**W/(m*K)**	0,114	0,1138	0,1127	0,1125	0,1125	0,1125	0,1125	0,1125	0,1125
Liquid viscosity	**mPa*s**	0,5252	0,5179	0,5108	0,504	0,4958	0,4876	0,4829	0,477	0,4709
Surface tension	**N/m**	0,0127	0,0126	0,0124	0,0123	0,0121	0,012	0,0119	0,0118	0,0116
Latent heat	**kJ/kg**	706,3	653	594,8	533,9	405	283,6	237,5	229,7	255,2
Vapor density	**kg/m3**	10,55	10,71	10,88	11,05	11,23	11,4	11,58	11,76	11,95
Vapor specific heat	**kJ/(kg*K)**	2,47	2,47	2,47	2,498	2,512	2,512	2,512	2,539	2,554
Vapor thermal cond.	**W/(m*K)**	0,0588	0,0588	0,0588	0,0588	0,0588	0,0588	0,0588	0,0588	0,0588
Vapor viscosity	**mPa*s**	0,013	0,013	0,013	0,013	0,013	0,013	0,013	0,013	0,013

Temperature	**C**	305,95	307,96	309,91
Pressure	**bar**	7,07227	7,04917	7,0205
Vapor fraction		0	0	0
Liquid density	**kg/m3**	637,97	636,48	634,97
Liquid specific heat	**kJ/(kg*K)**	3,056	3,056	3,056
Liquid thermal cond.	**W/(m*K)**	0,1125	0,1125	0,1125
Liquid viscosity	**mPa*s**	0,465	0,459	0,453
Surface tension	**N/m**	0,0115	0,0114	0,0113
Latent heat	**kJ/kg**	299	569,5	849,8
Vapor density	**kg/m3**	12,15	12,34	12,52
Vapor specific heat	**kJ/(kg*K)**	2,554	2,554	2,554
Vapor thermal cond.	**W/(m*K)**	0,0588	0,0588	0,0578
Vapor viscosity	**mPa*s**	0,013	0,013	0,013

Company: Walter Tosto spa
Location: Chieti
Service of Unit: R Our Reference:
Item No.: Your Reference: U_150
Date: 10/06/2016 Rev No.: Job No.:

Analysis along Tubes - Interval Analysis

Shell No.	Tube Pass No.	Distance from End	SS Bulk Temp	SS Fouling surface temp.	Tube Metal Temp	TS Fouling surface temp	TS Bulk Temp.	TS Pressure	TS Vapor fraction	TS void fraction
		mm	C	C	C	C	C	bar		
1	2	0	309,91	353,92	372,04	390,16	413,81	151,4561	0,39	0,89
1	2	162	308,95	355,63	373,36	391,1	414,24	151,4816	0,39	0,89
1	2	324	307,96	355,46	373,38	391,29	414,68	151,5071	0,39	0,89
1	2	460	307,12	355,8	373,72	391,64	415,04	151,5286	0,4	0,89
1	2	596	306,28	356,15	374,07	391,99	415,41	151,5502	0,4	0,89
1	2	623	306,11	356,12	374,07	392,02	415,48	151,5544	0,4	0,89
1	2	650	305,95	356,09	374,07	392,05	415,55	151,5587	0,4	0,89
1	2	682	305,76	356,03	374,05	392,07	415,64	151,5637	0,4	0,89
1	2	713	305,56	355,96	374,03	392,09	415,73	151,5687	0,4	0,89
1	2	844	304,75	355,66	373,92	392,17	416,08	151,5895	0,4	0,89
1	2	975	303,94	355,36	373,81	392,25	416,44	151,6103	0,4	0,89
1	2	1088	303,23	355,08	373,7	392,32	416,76	151,6285	0,4	0,89
1	2	1201	302,52	354,8	373,59	392,38	417,08	151,6468	0,4	0,89
1	2	1248	302,23	354,69	373,55	392,41	417,21	151,6545	0,4	0,89
1	2	1295	301,93	354,57	373,5	392,44	417,34	151,6622	0,4	0,89
1	2	1348	301,59	354,44	373,45	392,47	417,49	151,6709	0,4	0,89
1	2	1400	301,26	354,31	373,41	392,5	417,64	151,6796	0,4	0,89
1	2	1505	300,59	354	373,24	392,48	417,95	151,6963	0,41	0,9
1	2	1610	299,92	353,69	373,08	392,47	418,26	151,713	0,41	0,9
1	2	1703	299,31	353,46	373	392,55	418,53	151,7282	0,41	0,9
1	2	1797	298,71	353,24	372,94	392,63	418,82	151,7434	0,41	0,9
1	2	1858	298,31	353,01	372,83	392,65	419	151,7535	0,41	0,9
1	2	1919	297,91	352,79	372,74	392,68	419,19	151,7636	0,41	0,9
1	2	1985	297,47	352,53	372,62	392,7	419,39	151,7746	0,41	0,9
1	2	2051	297,03	352,27	372,5	392,73	419,6	151,7857	0,41	0,9
1	2	2137	296,46	351,94	372,35	392,76	419,87	151,7993	0,41	0,9
1	2	2222	295,9	351,6	372,2	392,79	420,14	151,8129	0,41	0,9
1	2	2300	295,36	351,27	372,04	392,81	420,39	151,8256	0,41	0,9
1	2	2379	294,83	350,93	371,88	392,83	420,65	151,8384	0,41	0,9

Company: Walter Tosto spa
Location: Chieti
Service of Unit: R Our Reference:
Item No.: Your Reference: U_150
Date: 10/06/2016 Rev No.: Job No.:

Shell No.	TS Heat Load	TS Heat flux	TS Film Coef.	TS Cond. Coef.	SS Film Coef.	TS flow pattern
	kW	kW/m2	W/(m2*K)	W/(m2*K)	W/(m2*K)	
1	-15139	-117,1	4949,9	13378,8	2660,7	Annular disp. Liq.
1	-14827,6	-114,6	4950,4	13406,6	2454,4	Annular disp. Liq.
1	-14516,2	-115,8	4950,9	13436,5	2437,2	Annular disp. Liq.
1	-14252,6	-115,8	4947,6	13462,4	2378,9	Annular disp. Liq.
1	-13989,1	-115,8	4944,2	13489	2322,1	Annular disp. Liq.
1	-13937,2	-116	4943,1	13494,7	2319,5	Annular disp. Liq.
1	-13885,3	-116,2	4941,9	13500,3	2316,9	Annular disp. Liq.
1	-13824	-116,4	4940,5	13507	2316,4	Annular disp. Liq.
1	-13762,8	-116,7	4939,1	13513,7	2316	Annular disp. Liq.
1	-13504,9	-118	4933,2	13541,7	2316,9	Annular disp. Liq.
1	-13247	-119,2	4927,4	13569,8	2317,7	Annular disp. Liq.
1	-13020,1	-120,3	4922,2	13594,5	2320	Annular disp. Liq.
1	-12793,2	-121,4	4917	13619,2	2322,2	Annular disp. Liq.
1	-12698	-121,9	4914,8	13629,6	2323,1	Annular disp. Liq.
1	-12602,7	-122,3	4912,6	13639,9	2323,9	Annular disp. Liq.
1	-12494,6	-122,9	4910,1	13651,7	2324,8	Annular disp. Liq.
1	-12386,5	-123,4	4907,6	13663,5	2325,7	Annular disp. Liq.
1	-12169,6	-124,3	4883,2	13691,1	2328,1	Annular disp. Liq.
1	-11952,6	-125,3	4859	13718,9	2330,5	Annular disp. Liq.
1	-11755,4	-126,3	4860,2	13746,1	2332,4	Annular disp. Liq.
1	-11558,1	-127,3	4861,3	13773,3	2334,3	Annular disp. Liq.
1	-11427,4	-128,1	4862	13791,5	2341,4	Annular disp. Liq.
1	-11296,7	-128,9	4862,7	13809,6	2348,6	Annular disp. Liq.
1	-11153,5	-129,8	4863,5	13829,5	2357,3	Annular disp. Liq.
1	-11010,2	-130,7	4864,2	13849,4	2366	Annular disp. Liq.
1	-10822,6	-131,9	4865,3	13875,5	2377,4	Annular disp. Liq.
1	-10634,9	-133,1	4866,3	13901,5	2388,8	Annular disp. Liq.
1	-10458,8	-134,2	4866,5	13922,7	2401,1	Annular disp. Liq.
1	-10282,7	-135,4	4866,8	13943,8	2413,5	Annular disp. Liq.

Company: Walter Tosto spa
Location: Chieti
Service of Unit: R Our Reference:
Item No.: Your Reference: U_150
Date: 10/06/2016 Rev No.: Job No.:

Shell No.	Tube Pass No.	Distance from End	SS Bulk Temp	SS Fouling surface temp.	Tube Metal Temp	TS Fouling surface temp	TS Bulk Temp.	TS Pressure	TS Vapor fraction	TS void fraction
		mm	C	C	C	C	C	bar		
1	2	2448	294,36	350,3	371,51	392,71	420,87	151,8498	0,41	0,9
1	2	2517	293,88	349,67	371,13	392,59	421,1	151,8612	0,42	0,9
1	2	2588	293,39	349,08	370,79	392,49	421,34	151,8733	0,42	0,9
1	2	2660	292,89	348,49	370,44	392,39	421,58	151,8854	0,42	0,9
1	2	2731	292,39	348,09	370,27	392,46	421,82	151,8971	0,42	0,9
1	2	2802	291,88	347,68	370,1	392,52	422,06	151,9089	0,42	0,9
1	2	2870	291,39	348,45	370,71	392,97	422,3	151,9202	0,42	0,9
1	2	2939	290,9	349,22	371,32	393,42	422,52	151,9316	0,42	0,9
1	2	3012	290,38	349,34	371,48	393,62	422,77	151,9437	0,42	0,9
1	2	3085	289,86	349,46	371,63	393,81	423,02	151,9558	0,42	0,9
1	2	3160	289,32	349,91	372,03	394,15	423,27	151,9681	0,42	0,9
1	2	3235	288,78	350,36	372,42	394,49	423,52	151,9804	0,42	0,9
1	2	3310	288,3	356,27	376,62	396,97	423,75	151,9964	0,42	0,9
1	2	3385	287,8	356,36	376,76	397,15	423,98	152,0124	0,42	0,9
1	1	3385	287,8	356,38	376,77	397,16	423,98	152,0124	0,42	0,9
1	1	3310	288,3	356,5	376,93	397,35	424,21	152,0284	0,43	0,9
1	1	3235	288,78	350,77	373	395,22	424,44	152,0444	0,43	0,9
1	1	3160	289,32	350,52	372,9	395,28	424,69	152,0621	0,43	0,9
1	1	3085	289,86	350,26	372,8	395,34	424,94	152,0797	0,43	0,9
1	1	3012	290,38	350,33	372,93	395,53	425,19	152,0971	0,43	0,9
1	1	2939	290,9	350,4	373,06	395,71	425,44	152,1145	0,43	0,9
1	1	2870	291,39	349,74	372,67	395,59	425,68	152,1251	0,43	0,9
1	1	2802	291,88	349,08	372,28	395,48	425,92	152,1357	0,43	0,9
1	1	2731	292,39	349,73	372,81	395,89	426,17	152,1468	0,43	0,9
1	1	2660	292,89	350,38	373,34	396,3	426,41	152,1578	0,43	0,9
1	1	2588	293,39	351,2	373,98	396,77	426,66	152,1688	0,43	0,9
1	1	2517	293,88	352,01	374,63	397,24	426,91	152,1797	0,43	0,9
1	1	2448	294,36	352,88	375,3	397,73	427,14	152,1901	0,43	0,9
1	1	2379	294,83	353,75	375,98	398,22	427,37	152,2006	0,44	0,9
1	1	2300	295,36	354,32	376,46	398,6	427,64	152,2129	0,44	0,9

Company: Walter Tosto spa
Location: Chieti
Service of Unit: R Our Reference:
Item No.: Your Reference: U_150
Date: 10/06/2016 Rev No.: Job No.:

Shell No.	TS Heat Load	TS Heat flux	TS Film Coef.	TS Cond. Coef.	SS Film Coef.	TS flow pattern
	kW	kW/m2	W/(m2*K)	W/(m2*K)	W/(m2*K)	
1	-10125,1	-137	4865,2	13955,9	2449,2	Annular disp. Liq.
1	-9967,4	-138,7	4863,6	13967,9	2485,6	Annular disp. Liq.
1	-9800,7	-140,3	4861,9	13980,4	2518,2	Annular disp. Liq.
1	-9633,9	-141,8	4860,3	13992,9	2551,2	Annular disp. Liq.
1	-9464	-143,4	4882,1	14006	2573,7	Annular disp. Liq.
1	-9294	-144,9	4903,9	14018,9	2596,4	Annular disp. Liq.
1	-9129,7	-143,8	4904,6	14028,8	2521	Annular disp. Liq.
1	-8965,3	-142,8	4905,4	14039	2448	Annular disp. Liq.
1	-8789,9	-143	4905,9	14050,6	2426	Annular disp. Liq.
1	-8614,5	-143,3	4906,3	14062,3	2404,3	Annular disp. Liq.
1	-8436,1	-142,9	4908,3	14074,5	2359,4	Annular disp. Liq.
1	-8257,7	-142,6	4910,3	14086,8	2315,4	Annular disp. Liq.
1	-8093,5	-131,5	4911,7	14099	1934,8	Annular disp. Liq.
1	-7929,3	-131,8	4913	14111,2	1922,1	Annular disp. Liq.
1	-7929,3	-131,8	4912,8	14111,2	1921,3	Annular disp. Liq.
1	-7765	-132	4914,8	14123,3	1935,2	Annular disp. Liq.
1	-7600,8	-143,6	4916,8	14135,3	2317,2	Annular disp. Liq.
1	-7419,6	-144,6	4918,4	14149,2	2363,6	Annular disp. Liq.
1	-7238,3	-145,6	4920	14162,9	2410,9	Annular disp. Liq.
1	-7059,8	-146	4921,8	14176,1	2435,4	Annular disp. Liq.
1	-6881,4	-146,4	4923,6	14189,2	2460	Annular disp. Liq.
1	-6711,4	-148,1	4923,7	14203,4	2538,8	Annular disp. Liq.
1	-6541,5	-149,9	4923,9	14217,4	2620,5	Annular disp. Liq.
1	-6365,1	-149,1	4924,4	14232,2	2600,1	Annular disp. Liq.
1	-6188,7	-148,3	4925	14247,1	2580	Annular disp. Liq.
1	-6013,6	-147,2	4925,6	14261,5	2546,8	Annular disp. Liq.
1	-5838,6	-146,1	4926,3	14276	2514	Annular disp. Liq.
1	-5671,8	-144,9	4926,9	14289,5	2476	Annular disp. Liq.
1	-5505,1	-143,7	4927,5	14303,2	2438,6	Annular disp. Liq.
1	-5317,4	-143,1	4928	14318,9	2426,9	Annular disp. Liq.

Company: Walter Tosto spa
Location: Chieti
Service of Unit: R Our Reference:
Item No.: Your Reference: U_150
Date: 10/06/2016 Rev No.: Job No.:

Shell No.	Tube Pass No.	Distance from End	SS Bulk Temp	SS Fouling surface temp.	Tube Metal Temp	TS Fouling surface temp	TS Bulk Temp.	TS Pressure	TS Vapor fraction	TS void fraction
		mm	C	C	C	C	C	bar		
1	1	2222	295,9	354,89	376,94	398,99	427,9	152,2252	0,44	0,9
1	1	2137	296,46	355,48	377,44	399,4	428,18	152,2385	0,44	0,9
1	1	2051	297,03	356,07	377,93	399,8	428,47	152,2517	0,44	0,9
1	1	1985	297,47	356,52	378,32	400,12	428,68	152,2619	0,44	0,9
1	1	1919	297,91	356,98	378,7	400,43	428,9	152,2721	0,44	0,9
1	1	1858	298,31	357,38	379,05	400,72	429,1	152,2815	0,44	0,9
1	1	1797	298,71	357,79	379,4	401	429,31	152,2909	0,44	0,9
1	1	1703	299,31	358,27	379,82	401,38	429,61	152,3056	0,44	0,9
1	1	1610	299,92	358,75	380,25	401,75	429,91	152,3202	0,44	0,9
1	1	1505	300,59	359,29	380,73	402,18	430,25	152,3366	0,44	0,9
1	1	1400	301,26	359,83	381,21	402,6	430,59	152,3529	0,45	0,9
1	1	1348	301,59	360,09	381,45	402,81	430,76	152,3611	0,45	0,9
1	1	1295	301,93	360,36	381,69	403,02	430,93	152,3692	0,45	0,9
1	1	1248	302,23	360,59	381,9	403,2	431,09	152,3765	0,45	0,9
1	1	1201	302,52	360,83	382,11	403,39	431,24	152,3838	0,45	0,9
1	1	1088	303,23	361,41	382,62	403,84	431,6	152,4016	0,45	0,9
1	1	975	303,94	362	383,14	404,29	431,96	152,4194	0,45	0,9
1	1	844	304,75	362,65	383,72	404,8	432,38	152,4399	0,45	0,9
1	1	713	305,56	363,3	384,3	405,31	432,8	152,4605	0,45	0,9
1	1	682	305,76	363,44	384,43	405,42	432,9	152,4654	0,45	0,9
1	1	650	305,95	363,58	384,56	405,54	433	152,4703	0,45	0,9
1	1	623	306,11	363,65	384,63	405,62	433,09	152,4745	0,45	0,9
1	1	596	306,28	363,73	384,71	405,7	433,17	152,4787	0,45	0,9
1	1	460	307,12	363,34	384,58	405,81	433,61	152,4996	0,45	0,91
1	1	324	307,96	362,97	384,45	405,93	434,05	152,5204	0,46	0,91
1	1	162	308,95	362,96	384,6	406,24	434,58	152,5456	0,46	0,91
1	1	0	309,91	360,64	383,14	405,64	435,11	152,5709	0,46	0,91

Company: Walter Tosto spa
Location: Chieti
Service of Unit: R Our Reference:
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Shell No.	TS Heat Load	TS Heat flux	TS Film Coef.	TS Cond. Coef.	SS Film Coef.	TS flow pattern
	kW	kW/m2	W/(m2*K)	W/(m2*K)	W/(m2*K)	
1	-5129,8	-142,5	4928,6	14334,8	2415,4	Annular disp. Liq.
1	-4927,8	-141,9	4929,1	14351,2	2404,5	Annular disp. Liq.
1	-4725,9	-141,3	4929,7	14367,8	2393,7	Annular disp. Liq.
1	-4570,6	-140,9	4930,4	14378,4	2385,3	Annular disp. Liq.
1	-4415,3	-140,4	4931,1	14389,1	2376,8	Annular disp. Liq.
1	-4272,1	-140	4931,6	14398,3	2369,7	
1	-4128,8	-139,6	4932,2	14407,6	2362,6	
1	-3911,9	-139,3	4933	14421,7	2362,2	
1	-3695	-138,9	4933,8	14435,9	2361,8	
1	-3453	-138,6	4934,7	14451,6	2360,4	
1	-3211	-138,2	4935,6	14467,2	2359	
1	-3089,9	-138	4936,1	14475	2358,8	
1	-2968,8	-137,8	4936,5	14482,8	2358,6	
1	-2860,7	-137,7	4936,6	14489,5	2358,4	
1	-2752,6	-137,5	4936,6	14496,1	2358,2	
1	-2494,7	-137,1	4936,5	14511,6	2355,8	
1	-2236,8	-136,6	4936,4	14527,2	2353,4	
1	-1938,8	-136,2	4936,3	14545,5	2352	
1	-1640,8	-135,7	4936,3	14563,8	2350,6	
1	-1569,8	-135,6	4936,2	14568	2351,6	
1	-1498,8	-135,6	4936,2	14572,2	2352,6	
1	-1437,6	-135,6	4936,1	14575,9	2356,6	
1	-1376,3	-135,6	4936,1	14579,6	2360,6	
1	-1064,8	-137,2	4935,9	14610,6	2440,3	
1	-753,4	-138,8	4935,8	14640,8	2523,1	
1	-376,7	-139,8	4935,3	14695,4	2589,1	
1	0	-145,4	4934,8	14745,8	2866,1	

Company: Walter Tosto spa
Location: Chieti
Service of Unit: R Our Reference:
Item No.: Your Reference: U_150
Date: 10/06/2016 Rev No.: Job No.:

Analysis along Tubes - Physical Properties

Temperature	**C**	435,11	433,17	431,24	429,31	427,37	425,44	423,52	421,58
Pressure	**bar**	152,5709	152,4786	152,3837	152,2909	152,2006	152,1144	151,9803	151,8852
Vapor fraction		0,46	0,45	0,45	0,44	0,44	0,43	0,42	0,42
Liquid density	**kg/m3**	600,49	602,68	604,64	606,65	608,64	610,56	612,37	614,3
Liquid specific heat	**kJ/(kg*K)**	3,206	3,182	3,182	3,182	3,182	3,182	3,182	3,182
Liquid thermal cond.	**W/(m*K)**	0,1114	0,1115	0,1116	0,1116	0,1116	0,1117	0,1117	0,1117
Liquid viscosity	**mPa*s**	0,1653	0,1674	0,1689	0,1704	0,1723	0,1744	0,1759	0,1774
Surface tension	**N/m**	0,0061	0,0062	0,0063	0,0064	0,0065	0,0066	0,0067	0,0068
Latent heat	**kJ/kg**	163,5	166,2	169,2	172,7	174,2	175	162,3	149,5
Vapor density	**kg/m3**	22,82	22,62	22,41	22,2	22,01	21,82	21,64	21,45
Vapor specific heat	**kJ/(kg*K)**	5,233	5,239	5,27	5,301	5,331	5,362	5,391	5,397
Vapor thermal cond.	**W/(m*K)**	0,2149	0,2149	0,2149	0,2141	0,2137	0,2136	0,2127	0,2126
Vapor viscosity	**mPa*s**	0,016	0,016	0,016	0,016	0,016	0,016	0,016	0,016

Temperature	**C**	419,6	417,64	415,73	413,81
Pressure	**bar**	151,7854	151,6791	151,5682	151,456
Vapor fraction		0,41	0,4	0,4	0,39
Liquid density	**kg/m3**	616,31	618,26	620,06	621,9
Liquid specific heat	**kJ/(kg*K)**	3,167	3,14	3,14	3,14
Liquid thermal cond.	**W/(m*K)**	0,1118	0,1118	0,1119	0,1119
Liquid viscosity	**mPa*s**	0,1793	0,1814	0,183	0,185
Surface tension	**N/m**	0,0069	0,007	0,0071	0,0072
Latent heat	**kJ/kg**	153,3	160,6	179,2	187,3
Vapor density	**kg/m3**	21,26	21,07	20,91	20,73
Vapor specific heat	**kJ/(kg*K)**	5,411	5,442	5,471	5,501
Vapor thermal cond.	**W/(m*K)**	0,2126	0,2125	0,2116	0,2114
Vapor viscosity	**mPa*s**	0,016	0,0159	0,0153	0,0151