STANDARDS OF THE

TUBULAR EXCHANGER

MANUFACTURERS ASSOCIATION

TENTH EDITION

TUBULAR EXCHANGER MANUFACTURERS ASSOCIATION, INC.
Richard C. Byrne, Secretary
www.tema.org

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PREFACE

Tenth Edition – 2019

The Tenth Edition of the TEMA Standards was prepared by the Technical Committee of the Tubular Exchanger Manufacturers Association. In addition to updated graphics and charts with a modernized appearance, numerical analysis of flexible shell elements, comprehensive rules for the design of horizontal saddle supports, dimensional data for various standard flanges, guidelines for distributor belts, and a fouling mitigation design study have been added.

The Editor acknowledges with appreciation the contributions by Tony Paulin and Fred Hendrix at Paulin Research Group (PRG) for assistance with the Flexible Shell Element numerical analysis, and the Heat Transfer Research Institute (HTRI) for their guidance on distributor belts and with fouling mitigation.

The Editor also acknowledges with appreciation the many years of service and contributions by Jim Harrison to the TEMA Technical Committee.

Daniel Gaddis, Editor

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NOTES TO USERS OF THE TEMA STANDARDS

Three classes of Mechanical Standards, R, C, and B, reflecting acceptable designs for various service applications, are presented. The user should refer to the definition of each class and choose the one that best fits the specific need.

Corresponding subject matter in the three classes of Mechanical Standards is covered by paragraphs identically numbered except for the class prefix letter. Paragraph numbers preceded by RCB indicates that all three classes are identical. Any reference to a specific paragraph must be preceded by the class designation.

The Recommended Good Practice section has been prepared to assist the designer in areas outside the scope of the basic Standards. Paragraphs in the Standards having additional information in the RGP section are marked with an asterisk (*). The reference paragraph in the RGP section has the identical paragraph number, but with an "RGP" prefix.

It is the intention of the Tubular Exchanger Manufacturers Association that this edition of its Standards may be used beginning with the date of issuance, and that its requirements supersede those of the previous edition six months from such date of issuance, except for heat exchangers contracted for prior to the end of the six month period. For this purpose, the date of issuance is April 8, 2019.

Questions by registered users on interpretation of the TEMA Standards should be submitted online at www.tema.org. Questions requiring development of new or revised technical information will only be answered through an addendum or a new edition of the Standards.

Upon agreement between purchaser and fabricator, exceptions to TEMA requirements are acceptable. An exchanger may still be considered as meeting TEMA requirements as long as the exception is documented.

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N-1 SIZE NUMBERING AND TYPE DESIGNATION - RECOMMENDED PRACTICE

It is recommended that heat exchanger size and type be designated by numbers and letters as described below.

N-1.1 SIZE

Sizes of shells (and tube bundles) shall be designated by numbers describing shell (and tube bundle) diameters and tube lengths, as follows:

N-1.1.1 NOMINAL DIAMETER

The nominal diameter shall be the inside diameter of the shell in inches (mm), rounded to the nearest integer. For kettle reboilers the nominal diameter shall be the port diameter followed by the shell diameter, each rounded to the nearest integer.

N-1.1.2 NOMINAL LENGTH

The nominal length shall be the tube length in inches (mm). Tube length for straight tubes shall be taken as the actual overall length. For U-tubes the length shall be taken as the approximate straight length from end of tube to bend tangent.

N-1.2 TYPE

Type designation for complete assemblies shall be by letters describing front end stationary head types, shell types, and rear end head types, in that order, as indicated in Figure N-1.2. Type designations shall be used as applicable for partial heat exchanger assemblies.

N-1.3 TYPICAL EXAMPLES

N-1.3.1

Split-ring floating head exchanger with removable channel and cover, single pass shell, 23 1/4" (591 mm) inside diameter with tubes 16' (4877 mm) long. SIZE 23-192 (591-4877) TYPE AES.

N-1.3.2

U-tube exchanger with bonnet type stationary head, split flow shell, 19" (483 mm) inside diameter with tubes 7' (2134 mm) straight length. SIZE 19-84 (483-2134) TYPE BGU.

N-1.3.3

Pull-through floating head kettle type reboiler having stationary head integral with tubesheet, 23" (584 mm) port diameter and 37" (940 mm) inside shell diameter with tubes 16' (4877 mm) long. SIZE 23/37-192 (584/940 -4877) TYPE CKT.

N-1.3.4

Fixed tubesheet exchanger with removable channel and cover, bonnet type rear head, two pass shell, 33 1/8" (841 mm) inside diameter with tubes 8' (2438 mm) long. SIZE 33-96 (841-2438) TYPE AFM.

N-1.3.5

Fixed tubesheet exchanger having stationary and rear heads integral with tubesheets, single pass shell, 17" (432 mm) inside diameter with tubes 16' (4877 mm) long. SIZE 17-192 (432-4877) TYPE NEN.

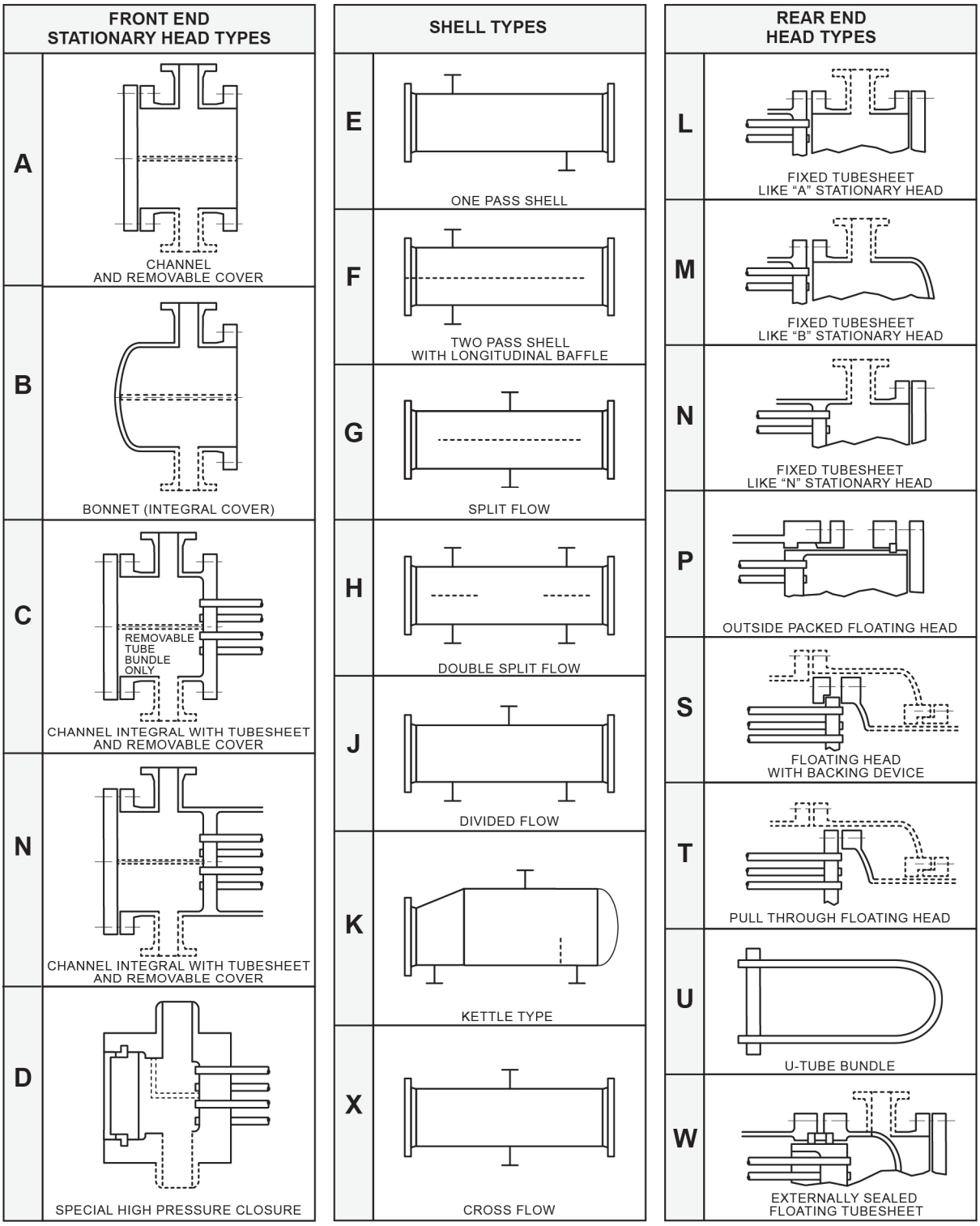
N-1.4 SPECIAL DESIGNS

Special designs are not covered and may be described as best suits the manufacturer. For example, a single tube pass, fixed tubesheet exchanger with conical heads may be described as "TYPE BEM with Conical Heads". A pull-through floating head exchanger with an integral shell cover may be described as "TYPE AET with Integral Shell Cover".

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FIGURE N-1.2



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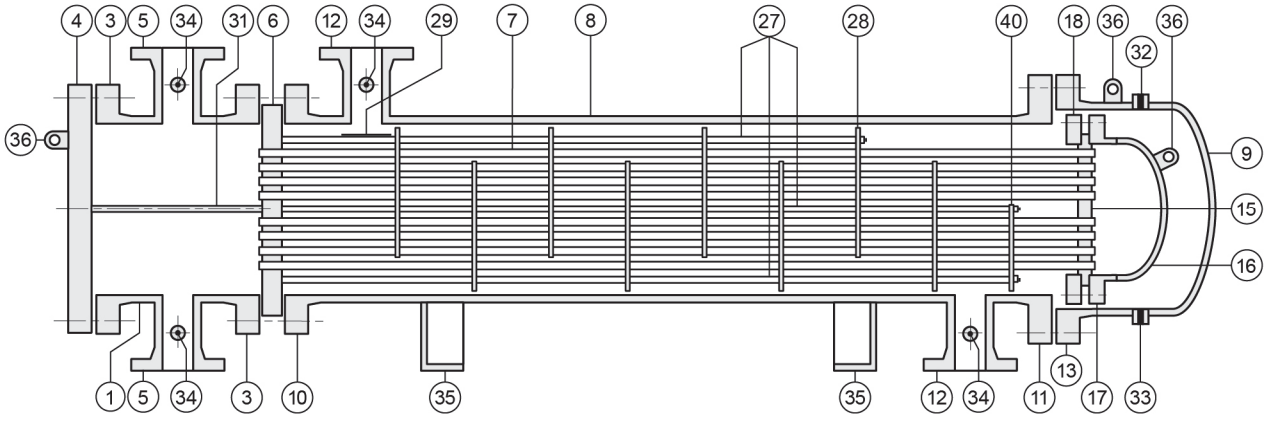
N-2 NOMENCLATURE OF HEAT EXCHANGER COMPONENTS

For the purpose of establishing standard terminology, Figure N-2 illustrates various types of heat exchangers. Typical parts and connections, for illustrative purposes only, are numbered for identification in Table N-2.

TABLE N-2

1. Stationary Head-Channel
2. Stationary Head-Bonnet
3. Stationary Head Flange-Channel or Bonnet
4. Channel Cover
5. Stationary Head Nozzle
6. Stationary Tubesheet
7. Tubes
8. Shell
9. Shell Cover
10. Shell Flange-Stationary Head End
11. Shell Flange-Rear Head End
12. Shell Nozzle
13. Shell Cover Flange
14. Expansion Joint
15. Floating Tubesheet
16. Floating Head Cover
17. Floating Head Cover Flange
18. Floating Head Backing Device
19. Split Shear Ring
20. Slip-on Backing Flange
21. Floating Head Cover-External
22. Floating Tubesheet Skirt
23. Packing Box
24. Packing
25. Packing Gland
26. Lantern Ring
27. Tierods and Spacers
28. Transverse Baffles or Support Plates
29. Impingement Plate
30. Longitudinal Baffle
31. Pass Partition
32. Vent Connection
33. Drain Connection
34. Instrument Connection
35. Support Saddle
36. Lifting Lug
37. Support Bracket
38. Weir
39. Liquid Level Connection
40. Floating Head Support

FIGURE N-2

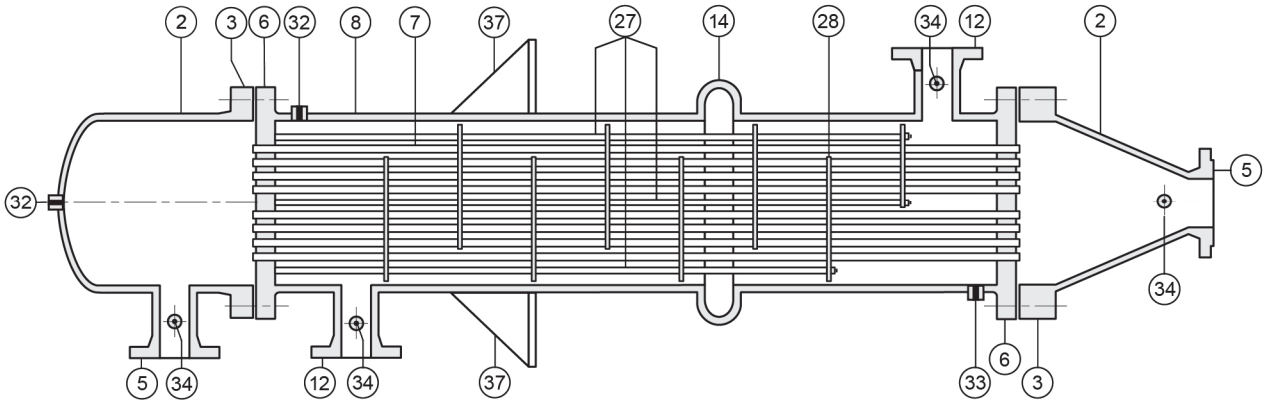


AES

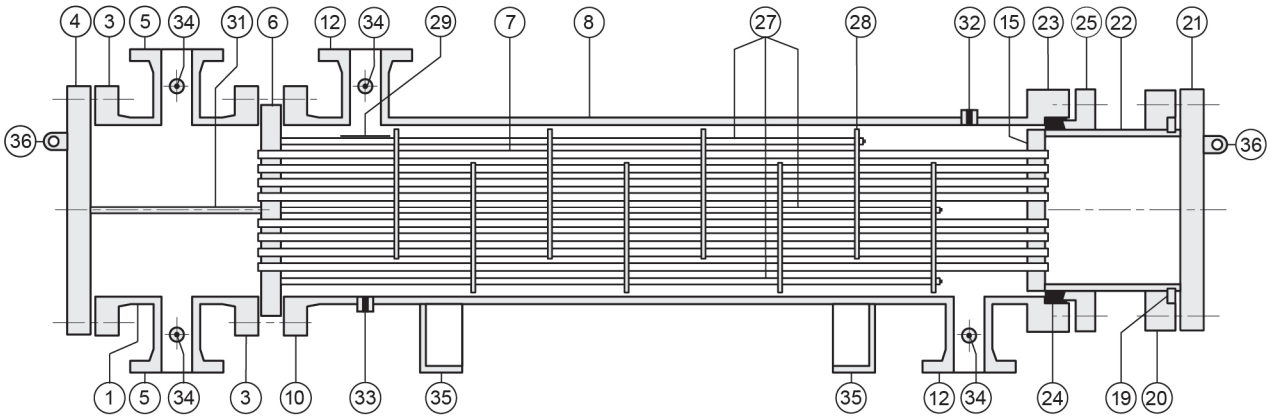
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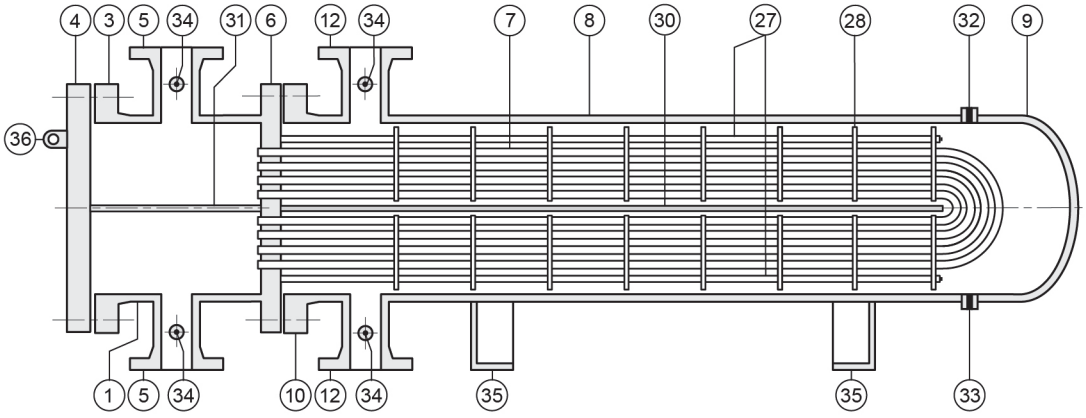
FIGURE N-2 (continued)



BEM



AEP

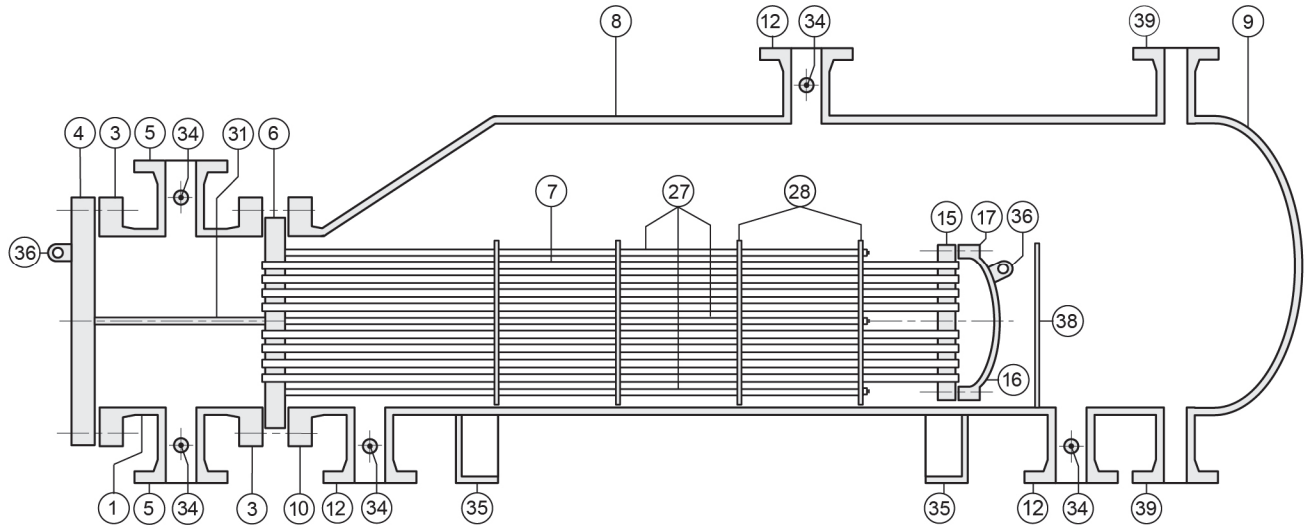


CFU

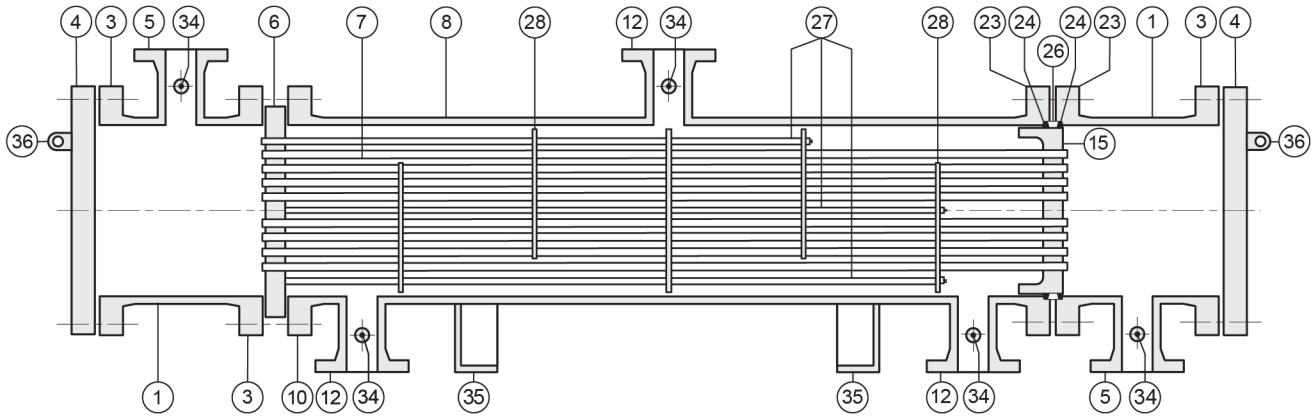
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FIGURE N-2 (continued)



AKT



AJW

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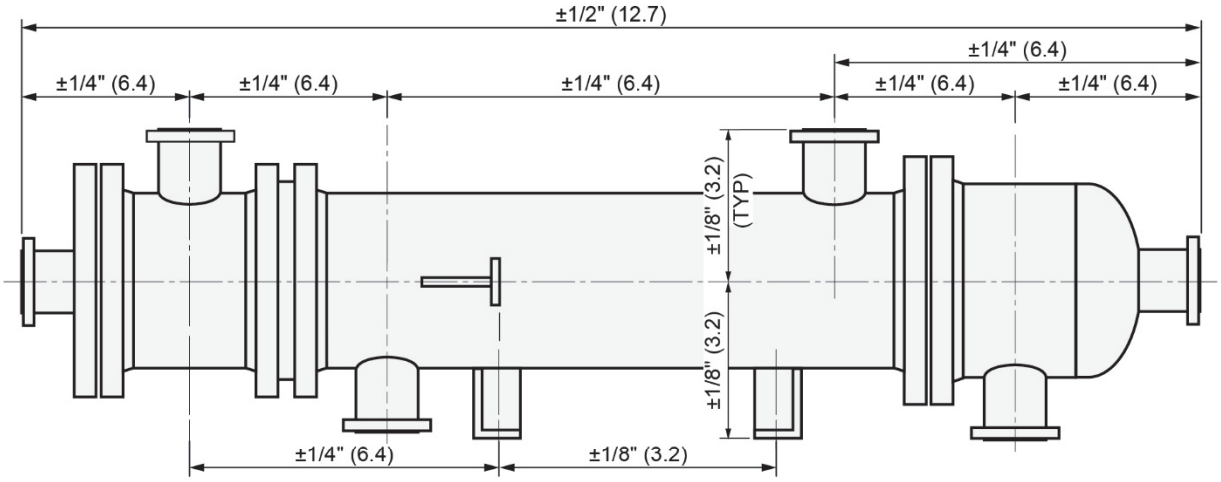
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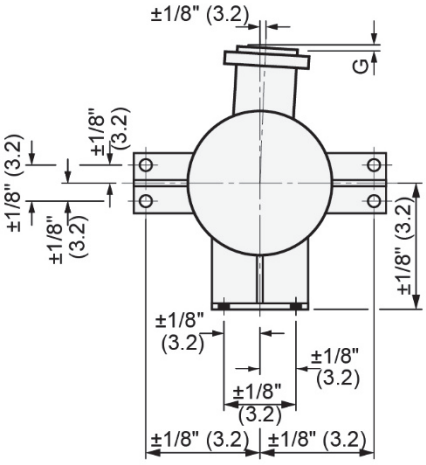
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F-1 EXTERNAL DIMENSIONS, NOZZLE AND SUPPORT LOCATIONS

Standard tolerances for process flow nozzles and support locations and projections are shown in Figure F-1. Dimensions in ( ) are millimeters.

FIGURE F-1

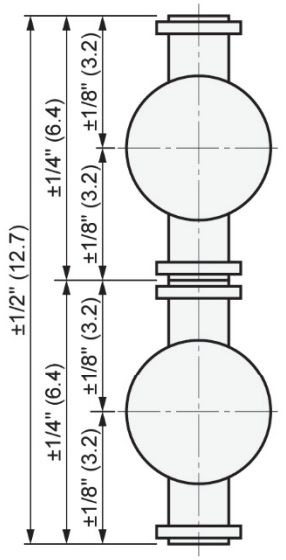




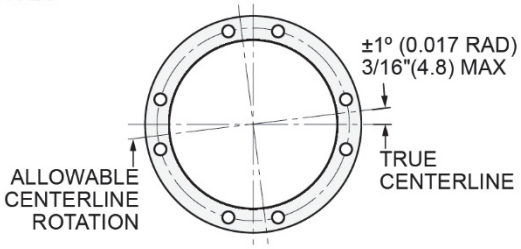
CONNECTION NOZZLE ALIGNMENT AND SUPPORT TOLERANCES

NOMINAL NOZZLE SIZE	G MAX
2" - 4" INCLUSIVE	1/16" (1.6)
6" - 12" INCLUSIVE	3/32" (2.4)
14" - 36" INCLUSIVE	3/16" (4.8)
OVER 36"	1/4" (6.4)

NOTE: THIS TABLE APPLIES TO NOZZLES CONNECTING TO EXTERNAL PIPING ONLY.



STACKED EXCHANGERS



ROTATIONAL TOLERANCE ON NOZZLE FACES AT BOLT CIRCLE

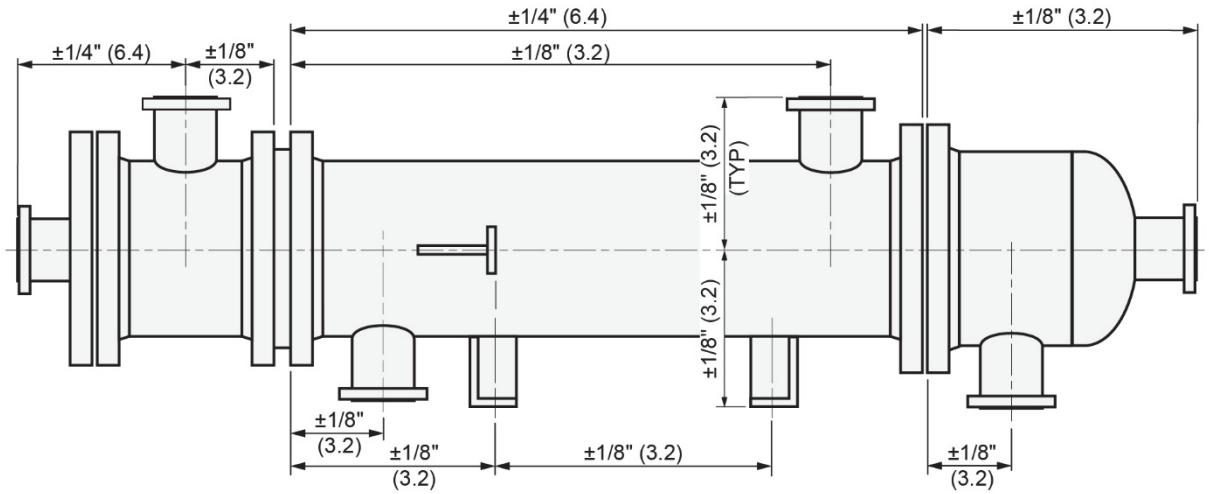
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F-2 RECOMMENDED FABRICATION TOLERANCES

Fabrication tolerances normally required to maintain process flow nozzle and support locations are shown in Figure F-2. These tolerances may be adjusted as necessary to meet the tolerances shown in Figure F-1. Dimensions in ( ) are millimeters.

FIGURE F-2



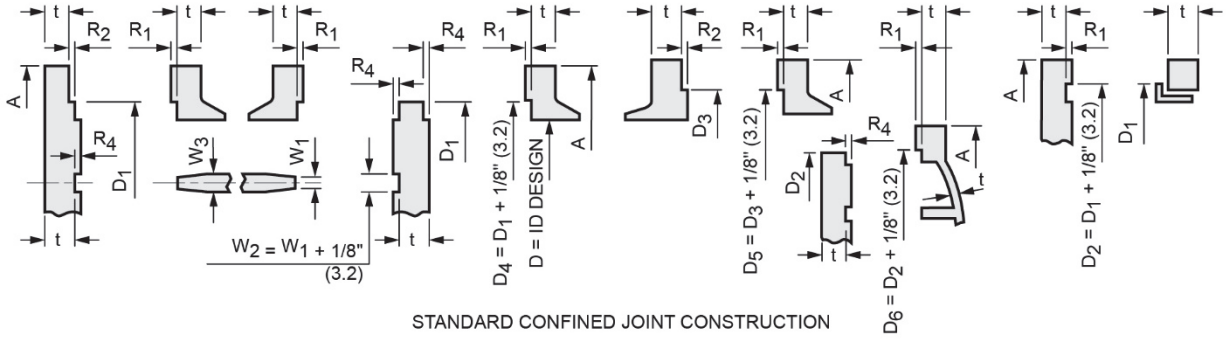
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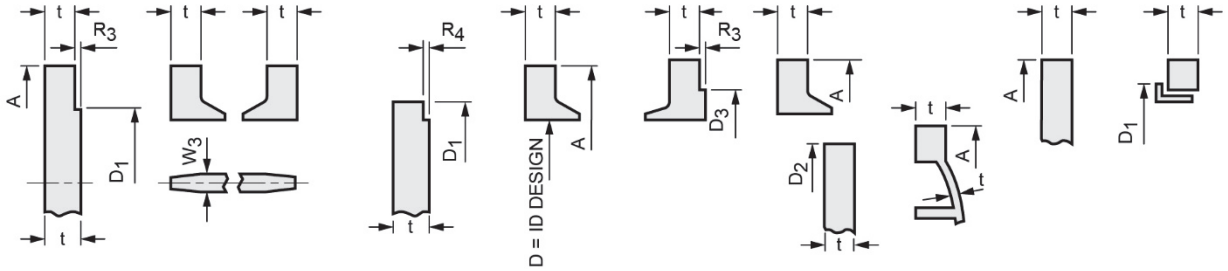
F-3 TUBESHEETS, PARTITIONS, COVERS, AND FLANGES

The standard clearances and tolerances applying to tubesheets, partitions, covers and flanges are shown in Figure F-3. Dimensions in ( ) are millimeters.

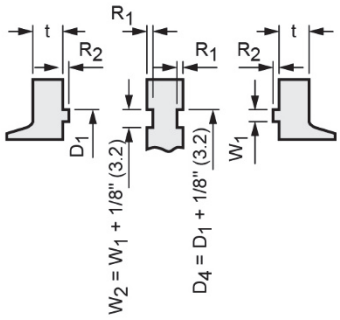
FIGURE F-3



STANDARD CONFINED JOINT CONSTRUCTION



STANDARD UNCONFINED PLAIN FACE JOINT CONSTRUCTION



ALTERNATE TONGUE AND GROOVE JOINT

DIMENSIONS		TOLERANCES	
A		+1/4" -1/8"	(+6.4 -3.2)
D_1 D_2 D_3 D_4 D_5 D_6		±1/32"	(±0.8)
t		±1/16"	(±1.6)
R_1 = 3/16"	(4.8)	+0" -1/32"	(+0 -0.8)
R_2 = 1/4"	(6.4)	+1/32" -0"	(+0.8 -0)
R_3 = 1/16"	(1.6)	+1/32" -0"	(+0.8 -0)
R_4 = 3/16"	(4.8)	-1/32"	(-0.8) (SEE NOTE 1)
W_1 W_2 W_3		±1/32"	(±0.8)

1. THIS FIGURE IS NOT INTENDED TO PROHIBIT UNMACHINED TUBESHEET FACES AND FLAT COVER FACES. THEREFORE, NO PLUS TOLERANCE IS SHOWN FOR R4.
2. NEGATIVE TOLERANCE SHALL NOT BE CONSTRUED TO MEAN THAT FINAL DIMENSIONS CAN BE LESS THAN THAT REQUIRED BY DESIGN CALCULATIONS.
3. FOR PERIPHERAL GASKETS, "CONFINED" MEANS "CONFINED ON THE OD."
4. DETAILS ARE TYPICAL AND DO NOT PRECLUDE THE USE OF OTHER DETAILS WHICH ARE FUNCTIONALLY EQUIVALENT.
5. FOR UNITS OVER 60" (1524) TO 100" (2540) DIAMETER, TOLERANCES "D" AND "W" MAY BE INCREASED TO ± 1/16" (1.6).

F-4 FLANGE FACE PERMISSIBLE IMPERFECTIONS

Imperfections in the flange facing finish, for ASME B16.5 flanges with ASME B16.20 gasket sizes used either for nozzle or body flanges, shall not exceed the dimensions shown in Figure F-4. For custom flanges, it is recommended that permissible imperfections should be per ASME PCC-1 Appendix D.

F-5 PERIPHERAL GASKET SURFACE FLATNESS

Peripheral gasket contact surfaces shall have a flatness tolerance of 1/32" (0.8 mm) maximum deviation from any reference plane. This maximum deviation shall not occur in less than a 20° (0.3 Rad) arc.

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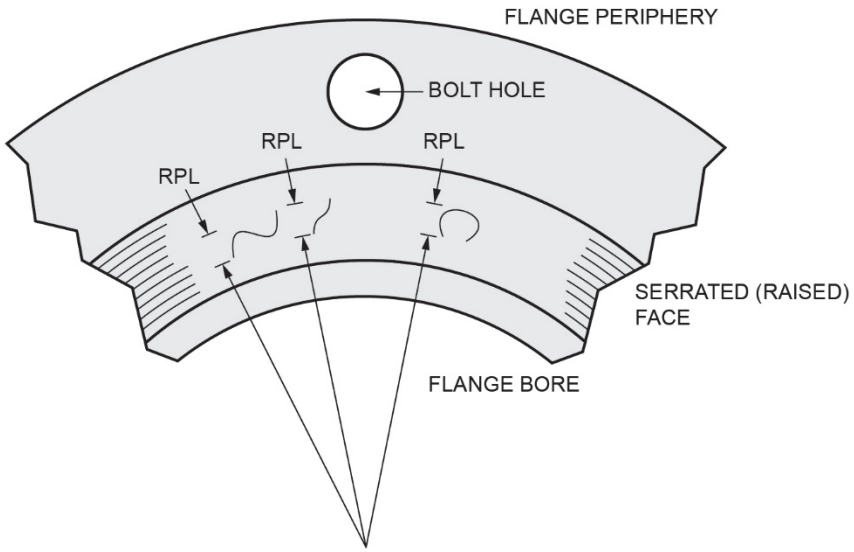
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FIGURE F-4

PERMISSIBLE IMPERFECTIONS IN FLANGE FACING FINISH
FOR RAISED FACE AND LARGE MALE AND FEMALE FLANGES [1,2]

NPS	Maximum Radial Projections of Imperfections Which Are No Deeper Than the Bottom of the Serrations, in.(mm)	Maximum Depth and Maximum Radial Projection of Imperfections Which Are Deeper Than the Bottom of the Serrations, in.(mm)
1/2	1/8 (3.2)	1/16 (1.6)
3/4	1/8 (3.2)	1/16 (1.6)
1	1/8 (3.2)	1/16 (1.6)
1 1/4	1/8 (3.2)	1/16 (1.6)
1 1/2	1/8 (3.2)	1/16 (1.6)
2	1/8 (3.2)	1/16 (1.6)
2 1/2	1/8 (3.2)	1/16 (1.6)
3	3/16 (4.8)	1/16 (1.6)
3 1/2	1/4 (6.4)	1/8 (3.2)
4	1/4 (6.4)	1/8 (3.2)
5	1/4 (6.4)	1/8 (3.2)
6	1/4 (6.4)	1/8 (3.2)
8	5/16 (7.9)	1/8 (3.2)
10	5/16 (7.9)	3/16 (4.8)
12	5/16 (7.9)	3/16 (4.8)
14	5/16 (7.9)	3/16 (4.8)
16	3/8 (9.5)	3/16 (4.8)
18	1/2 (12.7)	1/4 (6.4)
20	1/2 (12.7)	1/4 (6.4)
24	1/2 (12.7)	1/4 (6.4)

NOTES:
(1) Imperfections must be separated by at least four times the permissible radial projection.
(2) Protrusions above the serrations are not permitted



SKETCH SHOWING RADIAL PROJECTED LENGTH (RPL) SERRATED GASKET FACE DAMAGE

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DEFINITIONS

1. Baffle is a device to direct the shell side fluid across the tubes for optimum heat transfer.
2. Double Tubesheet Construction is a type of construction in which two (2) spaced tubesheets or equivalent are employed in lieu of the single tubesheet at one or both ends of the heat exchanger.
3. Effective Shell and Tube Side Design Pressures are the resultant load values expressed as uniform pressures used in the determination of tubesheet thickness for fixed tubesheet heat exchangers and are functions of the shell side design pressure, the tube side design pressure, the equivalent differential expansion pressure and the equivalent bolting pressure.
4. Equivalent Bolting Pressure is the pressure equivalent resulting from the effects of bolting loads imposed on tubesheets in a fixed tubesheet heat exchanger when the tubesheets are extended for bolting as flanged connections.
5. Equivalent Differential Expansion Pressure is the pressure equivalent resulting from the effect of tubesheet loadings in a fixed tubesheet heat exchanger imposed by the restraint of differential thermal expansion between shell and tubes.
6. Expanded Tube Joint is the tube-to-tubesheet joint achieved by mechanical or explosive expansion of the tube into the tube hole in the tubesheet.
7. Expansion Joint "J" Factor is the ratio of the spring rate of the expansion joint to the sum of the axial spring rate of the shell and the spring rate of the expansion joint. Refer to section A.1.5.1
8. Flange Load Concentration Factors are factors used to compensate for the uneven application of bolting moments due to large bolt spacing.
9. Minimum and Maximum Baffle and Support Spacings are design limitations for the spacing of baffles to provide for mechanical integrity and thermal and hydraulic effectiveness of the bundle. The possibility for induced vibration has not been considered in establishing these values.
10. Normal Operating Conditions of a shell and tube heat exchanger are the thermal and hydraulic performance requirements generally specified for sizing the heat exchanger.
11. Pulsating Fluid Conditions are conditions of flow generally characterized by rapid fluctuations in pressure and flow rate resulting from sources outside of the heat exchanger.
12. Seismic Loadings are forces and moments resulting in induced stresses on any member of a heat exchanger due to pulse mode or complex waveform accelerations to the heat exchanger, such as those resulting from earthquakes.
13. Shell and Tube Mean Metal Temperatures are the average metal temperatures through the shell and tube thicknesses integrated over the length of the heat exchanger for a given steady state operating condition.
14. Shut-Down is the condition of operation which exists from the time of steady state operating conditions to the time that flow of both process streams has ceased.
15. Start-Up is the condition of operation which exists from the time that flow of either or both process streams is initiated to the time that steady state operating conditions are achieved.
16. Support plate is a device to support the bundle or to reduce unsupported tube span without consideration for heat transfer.
17. Tubesheet Ligament is the shortest distance between edge of adjacent tube holes in the tube pattern.
18. Welded Tube Joint is a tube-to-tubesheet joint where the tube is welded to the tubesheet.

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FIGURE G-5.2 HEAT EXCHANGER SPECIFICATION SHEET

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

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FIGURE G-5.2M HEAT EXCHANGER SPECIFICATION SHEET

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

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SECTION 3 GENERAL FABRICATION AND PERFORMANCE INFORMATION

G-1 SHOP OPERATION

The detailed methods of shop operation are left to the discretion of the manufacturer in conformity with these Standards.

G-2 INSPECTION

G-2.1 MANUFACTURER'S INSPECTION

Inspection and testing of units will be provided by the manufacturer unless otherwise specified. The manufacturer shall carry out the inspections required by the Code, customer specifications, and also inspections required by state and local codes when the purchaser specifies the plant location.

G-2.2 PURCHASER'S INSPECTION

The purchaser shall have the right to make inspections during fabrication and to witness any tests when he has so requested. Advance notification shall be given as agreed between the manufacturer and the purchaser. Inspection by the purchaser shall not relieve the manufacturer of his responsibilities. Any additional tests required by the purchaser, above those already agreed to, will be to the purchaser’s account. Cost for remedial work as a result of these additional tests will also be to the purchaser’s account.

G-3 NAMEPLATES

G-3.1 MANUFACTURER'S NAMEPLATE

A suitable manufacturer's nameplate of corrosion resistant material shall be permanently attached to the head end or the shell of each TEMA exchanger. The nameplate may be attached via a bracket welded to the exchanger, and shall be visible outside any insulation.

G-3.1.1 NAMEPLATE DATA

In addition to all data required by the Code, a nameplate shall also include the following (if provided):

User's equipment identification

User's order number

G-3.1.2 SUPPLEMENTAL INFORMATION

The manufacturer shall supply supplemental information where it is pertinent to the operation or testing of the exchanger. This would include information pertaining to differential design and test pressure conditions, restrictions on operating conditions for fixed tubesheet type exchangers, or other restrictive conditions applicable to the design and/or operation of the unit or its components. Such information can be noted on the nameplate or on a supplemental plate attached to the exchanger at the nameplate location.

G-3.2 PURCHASER'S NAMEPLATE

Purchaser's nameplates, when used, are to be supplied by the purchaser and supplement rather than replace the manufacturer's nameplate.

G-4 DRAWINGS AND ASME CODE DATA REPORTS

G-4.1 DRAWINGS FOR APPROVAL AND CHANGE

The manufacturer shall submit an outline drawing containing information necessary for the customer to locate piping to the exchanger and footings or structure necessary to support the exchanger. The outline shall be submitted for the customer's approval and shall show the following information as a minimum: nozzles sizes and locations, flange ratings for nozzles, overall dimensions, support locations and base plate dimensions, and exchanger weight. Other drawings may be furnished as agreed upon by the purchaser and the manufacturer. The drawing will be submitted electronically, in PDF format, unless another format is agreed upon by the purchaser and the manufacturer. It is anticipated that a reasonable number of minor changes may be required due to customer comments to this initial submittal. Any changes that cause additional expense are chargeable to the customer and it is the manufacturer's responsibility to advise the customer of the commercial impact. Purchaser's approval of drawings does not relieve the manufacturer of responsibility for compliance with this Standard and applicable Code requirements. The

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manufacturer shall not make any changes on the approved drawings without express agreement of the purchaser.

G-4.2 DRAWINGS FOR RECORD

After approval of drawings, the manufacturer shall furnish drawings for record. The drawings will be submitted electronically, in PDF format, unless another format is agreed upon by the purchaser and the manufacturer.

G-4.3 PROPRIETARY RIGHTS TO DRAWINGS

The drawings and the design indicated by them are to be considered the property of the manufacturer and are not to be used or reproduced without his permission, except by the purchaser for his own internal use.

G-4.4 CODE DATA REPORTS

After completion of fabrication and inspection of an exchanger to its Code, the manufacturer shall furnish copies of the Code Manufacturer's Data Report or Certification, as agreed upon by the purchaser and the manufacturer.

G-5 GUARANTEES

G-5.1 GENERAL

The specific terms of the guarantees should be agreed upon by the manufacturer and purchaser. Unless otherwise agreed upon by the manufacturer and purchaser in writing, the following paragraphs in this section will be applicable and will govern even over the contrary terms of any other writing between the manufacturer and the purchaser unless that writing specifically states that it is intended to override the provisions of this section.

G-5.2 PERFORMANCE

The purchaser shall, in writing, furnish the manufacturer with all information needed for clear understanding of performance requirements, including any special requirements. The manufacturer shall guarantee thermal performance and mechanical design of a heat exchanger, when operated at the design conditions specified by the purchase order, or shown on the exchanger specification sheet furnished by the manufacturer (Figure G-5.2, G-5.2M). This guarantee shall extend for a period of twelve (12) months after shipping date. Notwithstanding this guarantee, the manufacturer shall have no responsibility or liability for excessive fouling of the apparatus by material such as coke, silt, scale, or any foreign substance that may be deposited, and the manufacturer shall have no responsibility or liability for any other performance problem wholly or partially caused by circumstances beyond the manufacturer’s complete control or that the manufacturer did not have the ability to prevent. Without limiting the generality of the foregoing, such circumstances shall include (i) faulty installation of the exchanger by anyone other than the manufacturer, (ii) any modification or repair made to the exchanger by the purchaser or anyone other than the manufacturer and (iii) combination of the exchanger with other equipment not furnished by the manufacturer. The thermal guarantee shall not be applicable to exchangers where the thermal performance rating was made by anyone other than the manufacturer.

G-5.2.1 THERMAL PERFORMANCE TEST

A performance test shall be made if it is established after operation for a sufficient period of time that the performance of the exchanger does not meet the written performance requirements previously furnished by the purchaser to the manufacturer, provided the thermal performance rating was made by the manufacturer. Test conditions and procedures shall be selected by agreement between the purchaser and the manufacturer to permit extrapolation of the test results to the specified design conditions.

G-5.2.2 DEFECTIVE PARTS

The manufacturer shall repair or replace F.O.B. his plant any parts proven defective within the guarantee period, but does not assume liability for the cost of removing defective parts or reinstalling replacement parts. The manufacturer shall be responsible only for the direct costs associated with repair of its defect or non-conforming product. Finished materials and accessories purchased from other manufacturers, including tubes, are warranted only to the extent of the original manufacturer's warranty to the heat exchanger fabricator. The manufacturer will endeavor to provide the purchaser with a copy of any warranty.

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information given to the manufacturer by suppliers of parts incorporated into the exchanger by the manufacturer, but cannot be responsible for the accuracy or completeness of that information.

G-5.3 DAMAGES EXCLUSION

In no event shall the manufacturer be held liable for any indirect, special, incidental, punitive, exemplary or consequential damages, such as damages for loss of goodwill, work stoppage, lost profits, lost revenue, loss of clients, lost business or lost opportunity, or any other similar damages of any and every nature, under any theory of liability, whether in contract, tort, strict liability, or any other theory.

G-5.4 CORROSION AND VIBRATION

The manufacturer assumes no responsibility for deterioration of any part or parts of the equipment due to corrosion, erosion, flow induced tube vibration, or any other causes, regardless of when such deterioration occurs after leaving the manufacturer's premises, except as provided for in Paragraphs G-5.2 and G-5.2.2.

G-5.5 REPLACEMENT AND SPARE PARTS

When replacement or spare tube bundles, shells, or other parts are purchased, the manufacturer guarantees satisfactory fit of such parts only if he was the original manufacturer. Parts fabricated to drawings furnished by the purchaser shall be guaranteed to meet the dimensions and tolerances specified.

G-5.6 DISCLAIMER OF WARRANTY

While the manufacturer provides guarantees as specifically offered by the manufacturer to the purchaser in writing, the manufacturer makes no other warranties or guarantees and assumes no liability in connection with any other warranty or guarantee, express or implied. WITHOUT LIMITING THE GENERALITY OF THE FOREGOING, THE MANUFACTURER SPECIFICALLY DISCLAIMS ANY IMPLIED WARRANTY OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE IN CONNECTION WITH THE SALE OF EXCHANGERS, WHETHER OR NOT THE MANUFACTURER HAS BEEN ADVISED OF SUCH PURPOSE.

G-5.7 AGGREGATE LIABILITY

The aggregate total liability of manufacturer to customer for any direct loss, cost, claim, or damages of any kind related to any failure of performance by a heat exchanger shall not exceed the amount the purchaser has paid to the manufacturer for the exchanger.

G-5.8 INDEMNIFICATION

Notwithstanding any other contract language to the contrary, the manufacturer shall have no liability to indemnify, defend or hold the purchaser harmless against third-party claims, costs, losses and expenses relating in any way to the transaction between the manufacturer and the purchaser or to heat exchanger performance.

G-6 PREPARATION OF HEAT EXCHANGERS FOR SHIPMENT

G-6.1 CLEANING

Internal and external surfaces are to be free from loose scale and other foreign material that is readily removable by hand or power brushing.

G-6.2 DRAINING

Water, oil, or other liquids used for cleaning or hydrostatic testing are to be drained from all units before shipment. This is not to imply that the units must be completely dry.

G-6.3 FLANGE PROTECTION

All exposed machined contact surfaces shall be coated with a removable rust preventative and protected against mechanical damage by suitable covers.

G-6.4 THREADED CONNECTION PROTECTION

All threaded connections are to be suitably plugged.

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G-6.5 DAMAGE PROTECTION

The exchanger and any spare parts are to be suitably protected to prevent damage during shipment.

G-6.6 EXPANSION JOINT PROTECTION

External thin walled expansion bellows shall be equipped with a protective cover which does not restrain movement.

G-7 GENERAL CONSTRUCTION FEATURES OF TEMA STANDARD HEAT EXCHANGERS

G-7.1 SUPPORTS

All heat exchangers are to be provided with supports. The supports should be designed to accommodate the weight of the unit and contents, including the flooded weight during hydrostatic test.

For purposes of support design, forces from external nozzle loadings, wind and seismic events are assumed to be negligible unless the purchaser specifically details the requirements. When these additional loads and forces are required to be considered, they need not be assumed to occur simultaneously unless combinations are specifically defined.

The references under Paragraph G-7.1.3 may be used for calculating resulting stresses in the support structure and attachment. Acceptable methods for horizontal supports and vertical lugs are shown in the RGP section.

*G-7.1.1 HORIZONTAL UNITS

For units with removable tube bundles, supports should be designed to withstand a pulling force equal to 1-1/2 times the weight of the tube bundle.

Horizontal units are normally provided with at least two saddle type supports, with holes for anchor bolts. The holes in all but one of the supports are to be elongated to accommodate axial movement of the unit under operating conditions. Other types of support may be used if all design criteria are met, and axial movement is accommodated.

*G-7.1.2 VERTICAL UNITS

Vertical units are to be provided with supports adequate to meet design requirements. The supports may be of the lug, annular ring, leg or skirt type. If the unit is to be located in a supporting structure, the supports should be of sufficient size to allow clearance for the body flanges.

G-7.1.3 REFERENCES

(1) Zick, L. P., "Stresses in Large Horizontal Cylindrical Pressure Vessels on Two Saddle Supports," Pressure Vessel and Piping; Design and Analysis, ASME, 1972.

(2) Vinet, R., and Dore, R., "Stresses and Deformations in a Cylindrical Shell Lying on a Continuous Rigid Support," Paper No. 75-AM-1, Journal of Applied Mechanics, Trans. ASME.

(3) Krupka, V., "An Analysis for Lug or Saddle Supported Cylindrical Pressure Vessels," Proceedings of the First International Conference on Pressure Vessel Technology, pp. 491-500.

(4) Singh, K. P., Soler, A. I., "Mechanical Design of Heat Exchangers and Pressure Vessel Components," Chapter 17, Arcturus Publishers, Inc.

(5) Bijlaard, P. P., "Stresses from Local Loadings in Cylindrical Pressure Vessels," Trans. ASME, Vol. 77, No. 6, (August 1955).

(6) Wichman, K. R., Hopper, A. G., and Mershon, J. L., "Local Stresses in Spherical and Cylindrical Shells due to External Loadings," Welding Research Council, Bulletin No. 107, Rev. 1.

(7) Rodabaugh, E. C., Dodge, W. G., and Moore, S. E., "Stress Indices at Lug Supports on Piping Systems," Welding Research Council Bulletin No. 198.

(8) Brownell, L. E., and Young, E. H., "Process Equipment Design," John Wiley & Sons Inc.

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(9) Jawad, M. H., and Farr, J. R., "Structural Analysis and Design of Process Equipment," John Wiley and Sons, Inc., 1984.
(10) Bednar, H. H., "Pressure Vessel Design Handbook," Van Nostrand Reinhold Company.
(11) Blodgett, O. W., "Design of Welded Structures," The James F. Lincoln Arc Welding Foundation, 1966.
(12) Moss, Dennis R., "Pressure Vessel Design Manual: Illustrated Procedures for Solving Major Pressure Vessel Design Problems" Edition: 3, Publisher: Gulf Pub Co (December 18, 2003).
(13) ASME Section VIII, Division 2, Part 4.15.3

***G-7.2 LIFTING DEVICES**

Channels, bonnets, and covers which weigh over 60 lbs. (27.2 Kg) are to be provided with lifting lugs, rings or tapped holes for eyebolts. Unless otherwise specified, these lifting devices are designed to lift only the component to which they are directly attached.

Lugs for lifting the complete unit are not normally provided. When lifting lugs or trunnions are required by the purchaser to lift the complete unit, the device must be adequately designed.

(1) The purchaser shall inform the manufacturer about the way in which the lifting device will be used. The purchaser shall be notified of any limitations of the lifting device relating to design or method of rigging.
(2) Liquid penetrant examination of the lifting device attachment weld should be considered on large heavy units.
(3) The design load shall incorporate an appropriate impact factor.
(4) Plate-type lifting lugs should be oriented to minimize bending stresses.
(5) The hole diameter in the lifting device must be large enough to accept a shackle pin having a load rating greater than the design load.
(6) The effect on the unit component to which the lifting device is attached should be considered. It may be necessary to add a reinforcing plate, annular ring or pad to distribute the load.
(7) The adequacy of the exchanger to accommodate the lifting loads should be evaluated.

***G-7.3 WIND & SEISMIC DESIGN**

For wind and seismic forces to be considered in the design of a heat exchanger, the purchaser must specify the design requirements in the inquiry. The "Recommended Good Practice" section of these Standards provides the designer with a discussion on this subject and selected references for design application.

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E-1 PERFORMANCE OF HEAT EXCHANGERS

Satisfactory operation of heat exchangers can be obtained only from units which are properly designed and have built-in quality. Correct installation and preventive maintenance are user responsibilities.

E-1.1 PERFORMANCE FAILURES

The failure of heat exchanger equipment to perform satisfactorily may be caused by one or more factors, such as:
(1) Excessive fouling.
(2) Air or gas binding resulting from improper piping installation or lack of suitable vents.
(3) Operating conditions differing from design conditions.
(4) Maldistribution of flow in the unit.
(5) Excessive clearances between the baffles and shell and/or tubes, due to corrosion.
(6) Improper thermal design.
The user's best assurance of satisfactory performance lies in dependence upon manufacturers competent in the design and fabrication of heat transfer equipment.

E-2 INSTALLATION OF HEAT EXCHANGERS

E-2.1 HEAT EXCHANGER SETTINGS

E-2.1.1 CLEARANCE FOR DISMANTLING

For straight tube exchangers fitted with removable bundles, provide sufficient clearance at the stationary head end to permit removal of the bundle from the shell and provide adequate space beyond the rear head to permit removal of the shell cover and/or floating head cover.

For fixed tubesheet exchangers, provide sufficient clearance at one end to permit withdrawal and replacement of the tubes, and enough space beyond the head at the opposite end to permit removal of the bonnet or channel cover.

For U-tube heat exchangers, provide sufficient clearance at the stationary head end to permit withdrawal of the tube bundle, or at the opposite end to permit removal of the shell.

E-2.1.2 FOUNDATIONS

Foundations must be adequate so that exchangers will not settle and impose excessive strains on the exchanger. Foundation bolts should be set to allow for setting inaccuracies. In concrete footings, pipe sleeves at least one size larger than bolt diameter slipped over the bolt and cast in place are best for this purpose, as they allow the bolt center to be adjusted after the foundation has set.

E-2.1.3 FOUNDATION BOLTS

Foundation bolts should be loosened at one end of the unit to allow free expansion of shells. Slotted holes in supports are provided for this purpose.

E-2.1.4 LEVELING

Exchangers must be set level and square so that pipe connections may be made without forcing.

E-2.2 CLEANLINESS PROVISIONS

E-2.2.1 CONNECTION PROTECTORS

All exchanger openings should be inspected for foreign material. Protective plugs and covers should not be removed until just prior to installation.

E-2.2.2 DIRT REMOVAL

The entire system should be clean before starting operation. Under some conditions, the use of strainers in the piping may be required.

E-2.2.3 CLEANING FACILITIES

Convenient means should be provided for cleaning the unit as suggested under "Maintenance of Heat Exchangers," Paragraph E-4.

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E-2.3 FITTINGS AND PIPING

E-2.3.1 BY-PASS VALVES

It may be desirable for purchaser to provide valves and by-passes in the piping system to permit inspection and repairs.

E-2.3.2 TEST CONNECTIONS

When not integral with the exchanger nozzles, thermometer well and pressure gage connections should be installed close to the exchanger in the inlet and outlet piping.

E-2.3.3 VENTS

Vent valves should be provided by purchaser so units can be purged to prevent vapor or gas binding. Special consideration must be given to discharge of hazardous or toxic fluids.

E-2.3.4 DRAINS

Drains may discharge to atmosphere, if permissible, or into a vessel at lower pressure. They should not be piped to a common closed manifold.

E-2.3.5 PULSATION AND VIBRATION

In all installations, care should be taken to eliminate or minimize transmission of fluid pulsations and mechanical vibrations to the heat exchangers.

E-2.3.6 SAFETY RELIEF DEVICES

When specified by the purchaser, the manufacturer will provide the necessary connections for the safety relief devices. The size and type of the required connections will be specified by the purchaser. The purchaser will provide and install the required relief devices.

E-3 OPERATION OF HEAT EXCHANGERS

E-3.1 DESIGN AND OPERATING CONDITIONS

Equipment must not be operated at conditions which exceed those specified on the nameplate(s).

E-3.2 OPERATING PROCEDURES

Before placing any exchanger in operation, reference should be made to the exchanger drawings, specification sheet(s) and nameplate(s) for any special instructions. Local safety and health regulations must be considered. Improper start-up or shut-down sequences, particularly of fixed tubesheet units, may cause leaking of tube-to-tubesheet and/or bolted flanged joints.

E-3.2.1 START-UP OPERATION

Most exchangers with removable tube bundles may be placed in service by first establishing circulation of the cold medium, followed by the gradual introduction of the hot medium. During start-up all vent valves should be opened and left open until all passages have been purged of air and are completely filled with fluid. For fixed tubesheet exchangers, fluids must be introduced in a manner to minimize differential expansion between the shell and tubes.

E-3.2.2 SHUT-DOWN OPERATION

For exchangers with removable bundles, the units may be shut down by first gradually stopping the flow of the hot medium and then stopping the flow of the cold medium. If it is necessary to stop the flow of cold medium, the circulation of hot medium through the exchanger should also be stopped. For fixed tubesheet exchangers, the unit must be shut down in a manner to minimize differential expansion between shell and tubes. When shutting down the system, all units should be drained completely when there is the possibility of freezing or corrosion damage. To guard against water hammer, condensate should be drained from steam heaters and similar apparatus during start-up or shut-down. To reduce water retention after drainage, the tube side of water cooled exchangers should be blown out with air.

E-3.2.3 TEMPERATURE SHOCKS

Exchangers normally should not be subjected to abrupt temperature fluctuations. Hot fluid must not be suddenly introduced when the unit is cold, nor cold fluid suddenly introduced when the unit is hot.

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E-3.2.4 BOLTED JOINTS

Heat exchangers are pressure tested before leaving the manufacturer's shop in accordance with Code requirements. However, normal relaxing of the gasketed joints may occur in the interval between testing in the manufacturer's shop and installation at the jobsite. Therefore, all external bolted joints may require retightening after installation and, if necessary, after the exchanger has reached operating temperature.

E-3.2.4.1 It is possible for the bolt stress to decrease after initial tightening, because of slow creep or relaxation of the gasket, particularly in the case of the softer gasket materials.

E-3.2.4.2 Excessive initial bolt stress can cause yielding of the bolt itself. This is especially likely with bolts of small diameter or bolting having relatively low yield values such as stainless steels.

E-3.2.4.3 ASME PCC-1 Appendices N and P provide additional guidance for the reuse of bolts and for troubleshooting flanged joint leakage incidents.

E-3.2.4.4 Selection of the appropriate bolt stress and/or torque shall be done so as to provide sufficient preload to seat the gasket within the capacity of the flange. Acceptable methods for this selection include, but are not limited to, past experience, recommendations from gasket manufacturers, considerations from ASME Code Appendix S, using guidelines from ASME PCC-1 Section 10 and Appendix O, or using WRC Bulletin 538. When using the Joint Component Approach as shown in ASME PCC-1 O-4 or WRC-538, it is recommended that this approach be performed during the flange design as this approach may increase flange thickness. Gasket seating stress values for use in ASME PCC-1 O-4 can be found from gasket manufacturers and PVP papers PVP2013-97900 for service sheet/non-asbestos gaskets and PVP2014-28434 for GMGC, CMGC, and Spiral wound gaskets. Acceptable methods for converting bolt stress to target torque include, but are not limited to, ASME PCC-1 Section 12 and Appendices J and K.

E-3.2.5 RECOMMENDED BOLT TIGHTENING PROCEDURE

E-3.2.5.1 All gasket joint surfaces shall be clean and free of oil or debris. If the gasket requires assistance to be held in place for installation, grease shall not be used. Any tape applied to a spiral wound gasket for shipping or assembly shall be removed prior to installing the gasket. No tape, string or other object will be allowed to remain on the gasket surface once assembly is complete. ASME PCC-1 Section 6 provides additional guidance for the installation of gaskets.

E-3.2.5.2 Thoroughly clean threads, nut faces and the flange where nut face bears. If roughness, burrs or any irregularity is present, dress it out to as smooth a surface as possible.

E-3.2.5.3 Thoroughly lubricate threads on studs, nuts and contacting surfaces on nuts and flange. ASME PCC-1 Section 7 provides additional guidance for the lubrication of fasteners.

E-3.2.5.4 The joint shall be snugged up squarely so the entire flange face bears uniformly on the gasket. ASME PCC-1 Section 5 and Appendix E provide additional guidance for the alignment of joints.

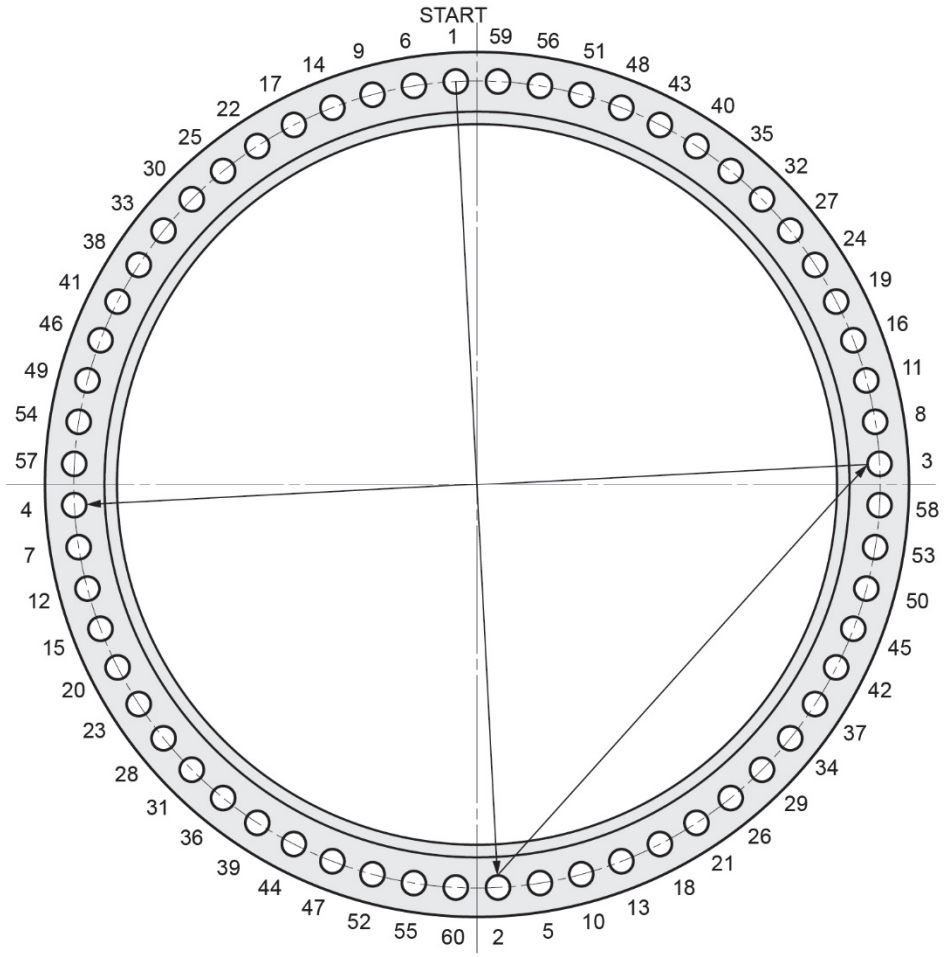
E-3.2.5.5 Tightening of the bolts shall be applied in at least three equally spaced increments using a cross bolting pattern as illustrated in Figure E-3.2.5.5 or a pattern as recommended by ASME PCC-1 Sections 8 through 11.

E-3.2.5.6 When the cross bolting pattern is used and is complete; a circular chase pattern shall be applied until no nut rotation occurs.

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FIGURE E-3.2.5.5



E-4 MAINTENANCE OF HEAT EXCHANGERS

E-4.1 INSPECTION OF UNIT

At regular intervals and as frequently as experience indicates, an examination should be made of the interior and exterior condition of the unit. Neglect in keeping all tubes clean may result in complete stoppage of flow through some tubes which could cause severe thermal strains, leaking tube joints, or structural damage to other components. Sacrificial anodes, when provided, should be inspected to determine whether they should be cleaned or replaced.

E-4.1.1 INDICATIONS OF FOULING

Exchangers subject to fouling or scaling should be cleaned periodically. A light sludge or scale coating on the tube greatly reduces its efficiency. A marked increase in pressure drop and/or reduction in performance usually indicates cleaning is necessary. The unit should first be checked for air or vapor binding to confirm that this is not the cause for the reduction in performance. Since the difficulty of cleaning increases rapidly as the scale thickness or deposit increases, the intervals between cleanings should not be excessive.

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E-4.1.2 DISASSEMBLY FOR INSPECTION OR CLEANING

Before disassembly, the user must assure himself that the unit has been depressurized, vented and drained, neutralized and/or purged of hazardous material.

To inspect the inside of the tubes and also make them accessible for cleaning, the following procedures should be used:

(1) Front End Stationary Head
  (a) Type A, C, D & N, remove cover only
  (b) Type B, remove bonnet

(2) Rear End Head
  (a) Type L, N & P, remove cover only
  (b) Type M, remove bonnet
  (c) Type S & T, remove shell cover and floating head cover
  (d) Type W, remove channel cover or bonnet

E-4.1.3 LOCATING TUBE LEAKS

The following procedures may be used to locate perforated or split tubes and leaking joints between tubes and tubesheets. In most cases, the entire front face of each tubesheet will be accessible for inspection. The point where water escapes indicates a defective tube or tube-to-tubesheet joint.

(1) Units with removable channel cover: Remove channel cover and apply hydraulic pressure in the shell.

(2) Units with bonnet type head: For fixed tubesheet units where tubesheets are an integral part of the shell, remove bonnet and apply hydraulic pressure in the shell. For fixed tubesheet units where tubesheets are not an integral part of the shell and for units with removable bundles, remove bonnet, re-bolt tubesheet to shell or install test flange or gland, whichever is applicable, and apply hydraulic pressure in the shell. See Figure E-4.1.3-1 for examples of some typical test flanges and test glands.

FIGURE E-4.1.3-1



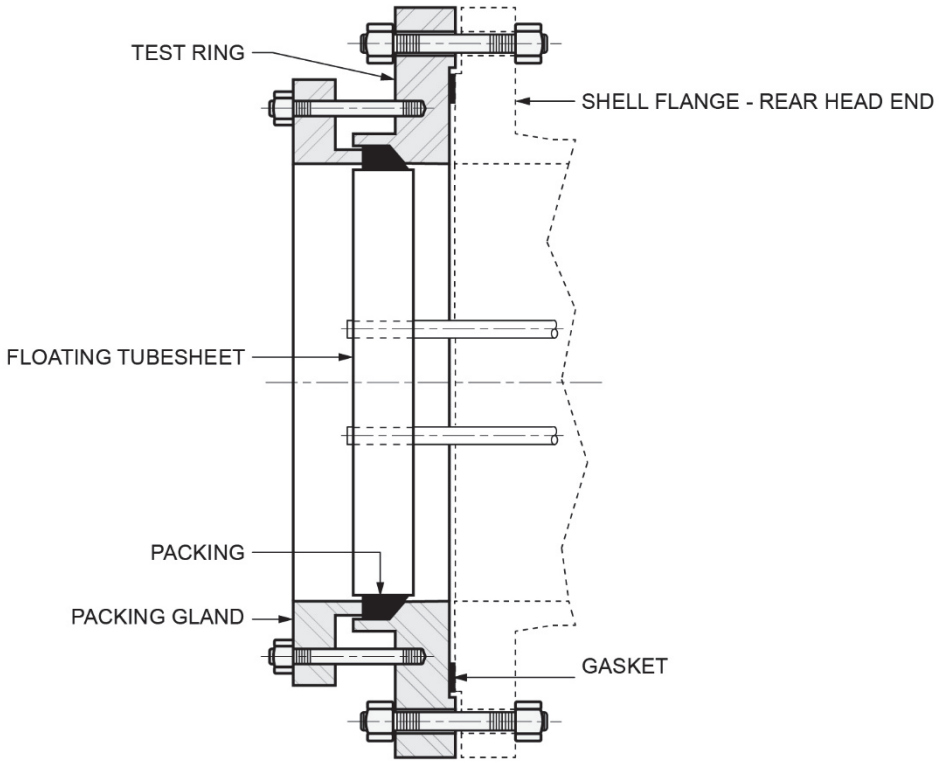
(3) Units with Type S or T floating head: Remove channel cover or bonnet, shell cover and floating head cover. Install test ring and bolt in place with gasket and packing. Apply hydraulic pressure in the shell. A typical test ring is shown in Figure E-4.1.3-2. When a test ring is not available it is possible to locate leaks in the floating head end by removing the shell cover and applying hydraulic pressure in the tubes. Leaking tube joints may then be located by sighting through the tube lanes. Care must be exercised when testing partially assembled exchangers to prevent over extension of expansion joints or overloading of tubes and/or tube-to-tubesheet joints.

(4) Hydrostatic test should be performed so that the temperature of the metal is over 60°F (16°C) or as permitted by the applicable code.

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FIGURE E-4.1.3-2



E-4.2 TUBE BUNDLE REMOVAL AND HANDLING

To avoid possible damage during removal of a tube bundle from a shell, a pulling device should be attached to eyebolts screwed into the tubesheet. If the tubesheet does not have tapped holes for eyebolts, steel rods or cables inserted through tubes and attached to bearing plates may be used. The bundle should be supported on the tube baffles, supports or tubesheets to prevent damage to the tubes.

Gasket and packing contact surfaces should be protected.

E-4.3 CLEANING TUBE BUNDLES

E-4.3.1 CLEANING METHODS

The heat transfer surfaces of heat exchangers should be kept reasonably clean to assure satisfactory performance. Convenient means for cleaning should be made available.

Heat exchangers may be cleaned by either chemical or mechanical methods. The method selected must be the choice of the operator of the plant and will depend on the type of deposit and the facilities available in the plant. Following are several cleaning procedures that may be considered:

(1) Circulating hot wash oil or light distillate through tubes or shell at high velocity may effectively remove sludge or similar soft deposits.

(2) Some salt deposits may be washed out by circulating hot fresh water.

(3) Commercial cleaning compounds are available for removing sludge or scale provided hot wash oil or water is not available or does not give satisfactory results.

(4) High pressure water jet cleaning.

(5) Scrapers, rotating wire brushes, and other mechanical means for removing hard scale, coke, or other deposits.

(6) Employ services of a qualified organization that provides cleaning services. These organizations will check the nature of the deposits to be removed, furnish proper solvents and/or acid solutions containing inhibitors, and provide equipment and personnel for a complete cleaning job.

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E-4.3.2 CLEANING PRECAUTIONS

(1) Tubes should not be cleaned by blowing steam through individual tubes since this heats the tube and may result in severe expansion strain, deformation of the tube, or loosening of the tube-to-tubesheet joint.

(2) When mechanically cleaning a tube bundle, care should be exercised to avoid damaging the tubes.

(3) Cleaning compounds must be compatible with the metallurgy of the exchanger.

E-4.4 TUBE EXPANDING

A suitable tube expander should be used to tighten a leaking tube joint. Care should be taken to ensure that tubes are not over expanded.

E-4.5 GASKET REPLACEMENT

Gaskets and gasket surfaces should be thoroughly cleaned and should be free of scratches and other defects. Gaskets should be properly positioned before attempting to retighten bolts. It is recommended that when a heat exchanger is dismantled for any cause, it be reassembled with new gaskets. This will tend to prevent future leaks and/or damage to the gasket seating surfaces of the heat exchanger. Composition gaskets become dried out and brittle so that they do not always provide an effective seal when reused. Metal or metal jacketed gaskets, when compressed initially, flow to match their contact surfaces. In so doing they are work hardened and, if reused, may provide an imperfect seal or result in deformation and damage to the gasket contact surfaces of the exchanger.

Bolted joints and flanges are designed for use with the particular type of gasket specified. Substitution of a gasket of different construction or improper dimensions may result in leakage and damage to gasket surfaces. Therefore, any gasket substitutions should be of compatible design. Any leakage at a gasketed joint should be rectified and not permitted to persist as it may result in damage to the gasket surfaces.

Metal jacketed type gaskets are widely used. When these are used with a tongue and groove joint without a nubbin, the gasket should be installed so that the tongue bears on the seamless side of the gasket jacket. When a nubbin is used, the nubbin should bear on the seamless side.

E-4.6 DIAPHRAGM INSTALLATION PROCEDURE

(1) Position diaphragm and tighten to remove all voids between diaphragm and component to which it will be welded. This may be accomplished by bolting the cover in place, by a series of clamps or any other means that guarantees that the diaphragm will not move during final bolt-up and crack the weld.

(2) Make the diaphragm to component weld and liquid penetrant inspect.

(3) Install cover and tighten studs to required torque or tension.

(4) Liquid penetrant inspect weld again after tightening studs.

E-4.7 SPARE AND REPLACEMENT PARTS

The procurement of spare or replacement parts from the manufacturer will be facilitated if the correct name for the part, as shown in Section 1, Table N-2, of these Standards is given, together with the serial number, type, size, and other information from the nameplate. Replacement parts should be purchased from the original manufacturer.

E-4.8 PLUGGING OF TUBES

In U-tube heat exchangers, and other exchangers of special design, it may not be feasible to remove and replace defective tubes. Defective tubes may be plugged using commercially available tapered plugs with ferrules or tapered only plugs which may or may not be seal welded. Excessive tube plugging may result in reduced thermal performance, higher pressure drop, and/or mechanical damage. It is the user's responsibility to remove plugs and neutralize the bundle prior to sending it to a shop for repairs.

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E-5 CHANGES TO CONFIGURATION OF HEAT EXCHANGERS

It may be desirable to change the configuration of the heat exchanger, upgrade materials, increase the design pressures and/or temperatures, or change the gasket types when replacing or reworking components of an existing heat exchanger. Reasons for these changes may range from a need to increase performance, to take advantage of new alloys, to support changes in other parts of the plant, to solve chronic problems in the heat exchanger itself or for economic considerations. Whenever changes are made to components of the heat exchanger, consideration should be given to the effect on the overall design of the heat exchanger. It is always advisable to consult the rules of the jurisdiction where the equipment is installed prior to making any changes. The requirements of the Code and TEMA shall also be satisfied. Some particular areas of concern are flange rating, material thickness, unsupported tube length, channel nozzle locations, pass partition configuration, and clearance between the end of the removable bundle and the shell.

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RCB-1 SCOPE AND GENERAL REQUIREMENTS

RCB-1.1 SCOPE OF STANDARDS

RCB-1.1.1 GENERAL

The TEMA Mechanical Standards are applicable to shell and tube heat exchangers which do not exceed any of the following criteria:

(1) inside diameters of 100 in. (2540 mm)

(2) product of nominal diameter, in. (mm) and design pressure, psi (kPa) of 100,000 (17.5×10^6)

(3) a design pressure of 3,000 psi (20684 kPa)

The intent of these parameters is to limit the maximum shell wall thickness to approximately 3 in. (76 mm), and the maximum stud diameter to approximately 4 in. (102 mm). Criteria contained in these Standards may be applied to units which exceed the above parameters.

R-1.1.2 DEFINITION OF TEMA CLASS "R" EXCHANGERS

The TEMA Mechanical Standards for Class "R" heat exchangers specify design and fabrication of unfired shell and tube heat exchangers for the generally severe requirements of petroleum and related processing applications.

C-1.1.2 DEFINITION OF TEMA CLASS "C" EXCHANGERS

The TEMA Mechanical Standards for Class "C" heat exchangers specify design and fabrication of unfired shell and tube heat exchangers for the generally moderate requirements of commercial and general process applications.

B-1.1.2 DEFINITION OF TEMA CLASS "B" EXCHANGERS

The TEMA Mechanical Standards for Class "B" heat exchangers specify design and fabrication of unfired shell and tube heat exchangers for chemical process service.

RCB-1.1.3 CONSTRUCTION CODES

Unless otherwise specified, the individual vessels shall comply with the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code, Section VIII, Division 1. The chosen construction code is hereinafter referred to as the Code. Where references to specific sections of ASME Section VIII, Division 1 are made, these are hereinafter referred to as the ASME Code.

RCB-1.1.4 MATERIALS - DEFINITION OF TERMS

For purposes of these Standards, "carbon steel" shall be construed as any steel or low alloy falling within the scope of Part UCS of the ASME Code. Metals not included by the foregoing (except cast iron) shall be considered as "alloys" unless otherwise specifically named. Materials of construction, including gaskets, should be specified by the purchaser. The manufacturer assumes no responsibility for deterioration of parts for any reason.

RCB-1.2 DESIGN PRESSURES

Design pressures for the shell and tube sides shall be specified separately by the purchaser.

RCB-1.3 TESTING

RCB-1.3.1 STANDARD TEST

The exchanger shall be hydrostatically tested with water. The test pressure shall be held for at least 30 minutes. The shell side and the tube side are to be tested separately in such a manner that leaks at the tube joints can be detected from at least one side. Welded joints are to be sufficiently cleaned prior to testing the exchanger to permit proper inspection during the test. The minimum hydrostatic test pressure and temperature shall be in accordance with the Code.

Liquids other than water may be used as a testing medium if agreed upon between the purchaser and the manufacturer.

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RCB-1.3.2 PNEUMATIC TEST

When liquid cannot be tolerated as a test medium the exchanger may be given a pneumatic test in accordance with the Code. It must be recognized that air or gas is hazardous when used as a pressure testing medium. The pneumatic test pressure and temperature shall be in accordance with the Code.

RCB-1.3.3 SUPPLEMENTARY AIR TEST

When a supplementary air or gas test is specified by the purchaser, it shall be preceded by the hydrostatic test required by Paragraph RCB-1.3.1. The test pressure and temperature shall be as agreed upon by the purchaser and manufacturer, but shall not exceed that required by Paragraph RCB-1.3.2.

RCB-1.4 METAL TEMPERATURES

RCB-1.4.1 METAL TEMPERATURE LIMITATIONS FOR PRESSURE PARTS

The metal temperature limitations for various metals are those prescribed by the Code.

RCB-1.4.2 DESIGN TEMPERATURE OF HEAT EXCHANGER PARTS

RCB-1.4.2.1 FOR PARTS NOT IN CONTACT WITH BOTH FLUIDS

Design temperatures for the shell and tube sides shall be specified separately by the purchaser. The Code provides the allowable stress limits for parts to be designed at the specified design temperature.

RCB-1.4.2.2 FOR PARTS IN CONTACT WITH BOTH FLUIDS

The design temperature is the design metal temperature and is used to establish the Code stress limits for design. The design metal temperature shall be based on the operating temperatures of the shell side and the tube side fluids, except when the purchaser specifies some other design metal temperature. When the design metal temperature is less than the higher of the design temperatures referred to in Paragraph RCB-1.4.2.1, the design metal temperature and the affected parts shall be shown on the manufacturer's nameplate(s) as described in Paragraph G-3.1.

RCB-1.4.2.3 MINIMUM DESIGN METAL TEMPERATURE

The minimum design metal temperature shall be specified by the purchaser. Consideration should be given to operating temperatures, low ambient temperatures, and upset conditions such as auto refrigeration when specifying the minimum design metal temperatures. Minimum design metal temperatures shall be used to evaluate if impact testing is required for the various heat exchanger components.

RCB-1.4.3 MEAN METAL TEMPERATURES

RCB-1.4.3.1 FOR PARTS NOT IN CONTACT WITH BOTH FLUIDS

The mean metal temperature is the calculated metal temperature, under normal operating conditions, of a part in contact with a fluid. It is used to establish metal properties under operating conditions. The mean metal temperature is based on the specified operating temperatures of the fluid in contact with the part.

RCB-1.4.3.2 FOR PARTS IN CONTACT WITH BOTH FLUIDS

The mean metal temperature is the calculated metal temperature, under normal operating conditions, of a part in contact with both shell side and tube side fluids. It is used to establish metal properties under operating conditions. The mean metal temperature is based on the specified operating temperatures of the shell side and tube side fluids. In establishing the mean metal temperatures, due consideration shall be given to such factors as the relative heat transfer coefficients of the two fluids contacting the part and the relative heat transfer area of the parts contacted by the two fluids.

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RCB-1.5 STANDARD CORROSION ALLOWANCES

The standard corrosion allowances used for the various heat exchanger parts are as follows, unless the conditions of service make a different allowance more suitable and such allowance is specified by the purchaser.

RCB-1.5.1 CARBON STEEL PARTS

R-1.5.1.1 PRESSURE PARTS

All carbon steel pressure parts, except as noted below, are to have a corrosion allowance of 1/8" (3.2 mm).

CB-1.5.1.1 PRESSURE PARTS

All carbon steel pressure parts, except as noted below, are to have a corrosion allowance of 1/16" (1.6 mm).

RCB-1.5.1.2 INTERNAL FLOATING HEAD COVERS

Internal floating head covers are to have the corrosion allowance on all wetted surfaces except gasket seating surfaces. Corrosion allowance need not be added to the recommended minimum edge distance in Table D-5 or D-5M.

RCB-1.5.1.3 TUBESHEETS

Tubesheets are to have the corrosion allowance on each side with the provision that, on the grooved side of a grooved tubesheet, the depth of the gasketed groove may be considered as available for corrosion allowance.

RCB-1.5.1.4 EXTERNAL COVERS

Where flat external covers are grooved, the depth of the gasketed groove may be considered as available for corrosion allowance.

RCB-1.5.1.5 END FLANGES

Corrosion allowance shall be applied only to the inside diameter of flanges where exposed to the fluids.

RCB-1.5.1.6 NONPRESSURE PARTS

Nonpressure parts such as tie-rods, spacers, baffles and support plates are not required to have corrosion allowance.

RCB-1.5.1.7 TUBES, BOLTING AND FLOATING HEAD BACKING DEVICES

Tubes, bolting and floating head backing devices are not required to have corrosion allowance.

RCB-1.5.1.8 PASS PARTITION PLATES AND WELDED-IN LONG BAFFLES

Pass partition plates and welded-in long baffles are not required to have corrosion allowance.

RCB-1.5.2 ALLOY PARTS

Alloy parts are not required to have corrosion allowance.

R-1.5.3 CAST IRON PARTS

Cast iron pressure parts shall have a corrosion allowance of 1/8" (3.2 mm).

CB-1.5.3 CAST IRON PARTS

Cast iron pressure parts shall have a corrosion allowance of 1/16" (1.6 mm).

RCB-1.6 SERVICE LIMITATIONS

RB-1.6.1 CAST IRON PARTS

Cast iron shall be used only for water service at pressures not exceeding 150 psi (1034 kPa).

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C-1.6.1 CAST IRON PARTS

Cast iron shall not be used for pressures exceeding 150 psi (1034 kPa), or for lethal or flammable fluids at any pressure.

RCB-1.6.2 EXTERNAL PACKED JOINTS

Packed joints shall not be used when the purchaser specifies that the fluid in contact with the joint is lethal or flammable.

RCB-1.7 ANODES

Selection and placement of anodes is not the responsibility of the heat exchanger manufacturer. If a heat exchanger is to be furnished with anodes, when requesting a quotation, the purchaser is responsible for furnishing the heat exchanger manufacturer the following information:

(1) Method of anode attachment.

(2) Quantity of anodes required.

(3) Size and manufacturer of the anodes.

(4) Anode material.

(5) Sketch of anode locations and spacing.

If the heat exchanger manufacturer chooses to install anodes for a customer, the manufacturer is not responsible for the suitability of the anodes for the service it is installed in, the life of the anodes, the corrosion protection provided by the anode, or any subsequent damage to the heat exchanger attributed to the anode, the method of anode installation, or the installed location of the anode in the heat exchanger.

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*RCB-2 TUBES

RCB-2.1 TUBE LENGTH

The following tube lengths for both straight and U-tube exchangers are commonly used: 96 (2438), 120 (3048), 144 (3658), 192 (4877) and 240 (6096) in. (mm). Other lengths may be used. Also see Paragraph N-1.1.2.

RCB-2.2 TUBE DIAMETERS AND GAGES

RCB-2.2.1 BARE TUBES

Table RCB-2.2.1 lists common tube diameters and gages for bare tubes of copper, steel and alloy. Other diameters and gages are acceptable.

TABLE RCB-2.2.1

BARE TUBE DIAMETERS AND GAGES			
O.D. in. (mm)	Copper and Copper Alloys	Carbon Steel, Aluminum and Aluminum Alloys	Other Alloys
	B.W.G.	B.W.G.	B.W.G.
1/4 (6.4)	27 24 22	- - -	27 24 22
3/8 (9.5)	22 20 18	- - -	22 20 18
1/2 (12.7)	20 18	- -	20 18
5/8 (15.9)	20 18 16	18 16 14	20 18 16
3/4 (19.1)	20 18 16	16 14 12	18 16 14
7/8 (22.2)	18 16 14 12	14 12 10 -	16 14 12 -
1 (25.4)	18 16 14	14 12 -	16 14 12
1 1/4 (31.8)	16 14	14 12	14 12
1 1/2 (38.1)	16 14	14 12	14 12
2 (50.8)	14 12	14 12	14 12

Notes:

1. Wall thickness shall be specified as either minimum or average.
2. Characteristics of tubing are shown in Tables D-7 and D-7M.

RCB-2.2.2 INTEGRALLY FINNED TUBES

The nominal fin diameter shall not exceed the outside diameter of the unfinned section. Tubes shall be specified as both thickness under fin and at plain end.

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RCB-2.3 U-TUBES

RCB-2.3.1 U-BEND REQUIREMENTS

When U-bends are formed, it is normal for the tube wall at the outer radius to thin. Unless the minimum tube wall thickness in the bend can be otherwise guaranteed, the required tube wall thickness in the bent portion before bending shall be verified by the following formula:

$$t_o = t_1\left[1+\frac{d_o}{CR}\right]$$

where

t_0 = Required tube wall thickness prior to bending, in. (mm)

t_1 = Minimum tube wall thickness calculated by Code rules for a straight tube subjected to the same pressure and metal temperature, in. (mm)

d_0 = Outside tube diameter, in. (mm)

C = Thinning constant:

= 4, typical for the following materials: carbon steel, low alloy, ferritic stainless, austenitic stainless, other relatively non-work-hardening materials, and copper alloys.

= 2, typical for the following materials: martensitic stainless, duplex stainless, super austenitic stainless, titanium, high nickel alloys, and other work-hardening materials.

Note: different constants may be used based upon other considerations of tube thinning and previous experience.

R = Mean radius of bend, in. (mm)

More than one tube gage, or dual gage tubes, may be used in a tube bundle.

Flattening at the bend shall not exceed 10% of the nominal tube outside diameter.

For tube bends with $R < 2d_0$, flattening may exceed 10% when the material is highly susceptible to work hardening or when the straight tube thickness is < $d_0/12$. Special consideration, based upon bending experience, may be required.

Special consideration may also be required for materials having low ductility.

RCB-2.3.2 BEND SPACING

RCB-2.3.2.1 CENTER-TO-CENTER DIMENSION

The center-to-center dimensions between parallel legs of U-tubes shall be such that they can be inserted into the baffle assembly without damage to the tubes.

RCB-2.3.2.2 BEND INTERFERENCE

The assembly of bends shall be of workmanlike appearance. Metal-to-metal contact between bends in the same plane shall not be permitted.

RCB-2.3.3 HEAT TREATMENT

Cold work in forming U-bends may induce embrittlement or susceptibility to stress corrosion in certain materials and/or environments. Heat treatment to alleviate such conditions may be performed by agreement between manufacturer and purchaser.

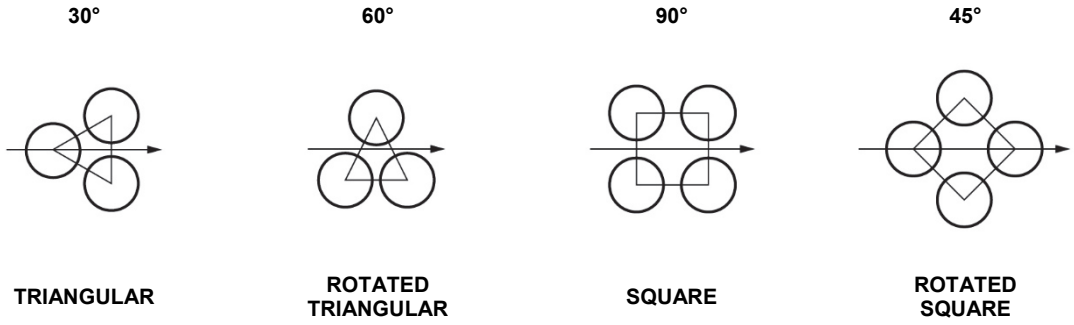
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RCB-2.4 TUBE PATTERN

Standard tube patterns are shown in Figure RCB-2.4.

FIGURE RCB-2.4



Note: Flow arrows are perpendicular to the baffle cut edge.

RCB-2.4.1 SQUARE PATTERN

In removable bundle units, when mechanical cleaning of the tubes is specified by the purchaser, tube lanes should be continuous.

RCB-2.4.2 TRIANGULAR PATTERN

Triangular or rotated triangular pattern should not be used when the shell side is to be cleaned mechanically.

R-2.5 TUBE PITCH

Tubes shall be spaced with a minimum center-to-center distance of 1.25 times the outside diameter of the tube. When mechanical cleaning of the tubes is specified by the purchaser, minimum cleaning lanes of 1/4" (6.4 mm) shall be provided.

C-2.5 TUBE PITCH

Tubes shall be spaced with a minimum center-to-center distance of 1.25 times the outside diameter of the tube. Where the tube diameters are 5/8" (15.9 mm) or less and tube-to-tubesheet joints are expanded only, the minimum center-to-center distance may be reduced to 1.20 times the outside diameter.

B-2.5 TUBE PITCH

Tubes shall be spaced with a minimum center-to-center distance of 1.25 times the outside diameter of the tube. When mechanical cleaning of the tubes is specified by the purchaser and the nominal shell diameter is 12 in. (305 mm) or less, minimum cleaning lanes of 3/16" (4.8 mm) shall be provided. For shell diameters greater than 12 in. (305 mm), minimum cleaning lanes of 1/4" (6.4 mm) shall be provided.

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RCB-3 SHELLS AND SHELL COVERS

RCB-3.1 SHELLS

RCB-3.1.1 SHELL DIAMETERS

It shall be left to the discretion of each manufacturer to establish a system of standard shell diameters within the TEMA Mechanical Standards in order to achieve the economies peculiar to its individual design and manufacturing facilities.

RCB-3.1.2 TOLERANCES

RCB-3.1.2.1 PIPE SHELLS

The inside diameter of pipe shells shall be in accordance with applicable ASTM/ASME pipe specifications.

RCB-3.1.2.2 PLATE SHELLS

The inside diameter of any plate shell shall not exceed the design inside diameter by more than 1/8" (3.2 mm) as determined by circumferential measurement.

RCB-3.1.3 MINIMUM SHELL THICKNESS

Shell thickness is determined by the Code design formulas, plus corrosion allowance, but in no case shall the nominal thickness of shells be less than that shown in the applicable table. The nominal total thickness for clad shells shall be the same as for carbon steel shells.

TABLE R-3.1.3
MINIMUM SHELL THICKNESS
Dimensions in Inches (mm)

Nominal Shell Diameter		Minimum Thickness			
		Carbon Steel		Alloy *	
		Pipe	Plate		
6	(152)	SCH. 40	-	1/8	(3.2)
8-12	(203-305)	SCH. 30	-	1/8	(3.2)
13-29	(330-737)	SCH. STD	3/8 (9.5)	3/16	(4.8)
30-39	(762-991)	-	7/16 (11.1)	1/4	(6.4)
40-60	(1016-1524)	-	1/2 (12.7)	5/16	(7.9)
61-80	(1549-2032)	-	1/2 (12.7)	5/16	(7.9)
81-100	(2057-2540)	-	1/2 (12.7)	3/8	(9.5)

TABLE CB-3.1.3
MINIMUM SHELL THICKNESS
Dimensions in Inches (mm)

Nominal Shell Diameter		Minimum Thickness			
		Carbon Steel		Alloy *	
		Pipe	Plate		
6	(152)	SCH. 40	-	1/8	(3.2)
8-12	(203-205)	SCH. 30	-	1/8	(3.2)
13-23	(330-584)	SCH. 20	5/16 (7.9)	1/8	(3.2)
24-29	(610-737)	-	5/16 (7.9)	3/16	(4.8)
30-39	(762-991)	-	3/8 (9.5)	1/4	(6.4)
40-60	(1016-1524)	-	7/16 (11.1)	1/4	(6.4)
61-80	(1549-2032)	-	1/2 (12.7)	5/16	(7.9)
81-100	(2057-2540)	-	1/2 (12.7)	3/8	(9.5)

*Schedule 5S is permissible for 6 inch (152 mm) and 8 inch (203 mm) shell diameters.

RCB-3.2 SHELL COVER THICKNESS

Nominal thickness of shell cover heads, before forming, shall be at least equal to the thickness of the shell as shown in the applicable table.

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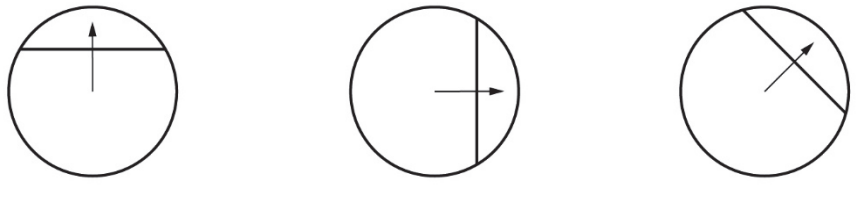
RCB-4 BAFFLES AND SUPPORT PLATES

RCB-4.1 TYPE OF TRANSVERSE BAFFLES

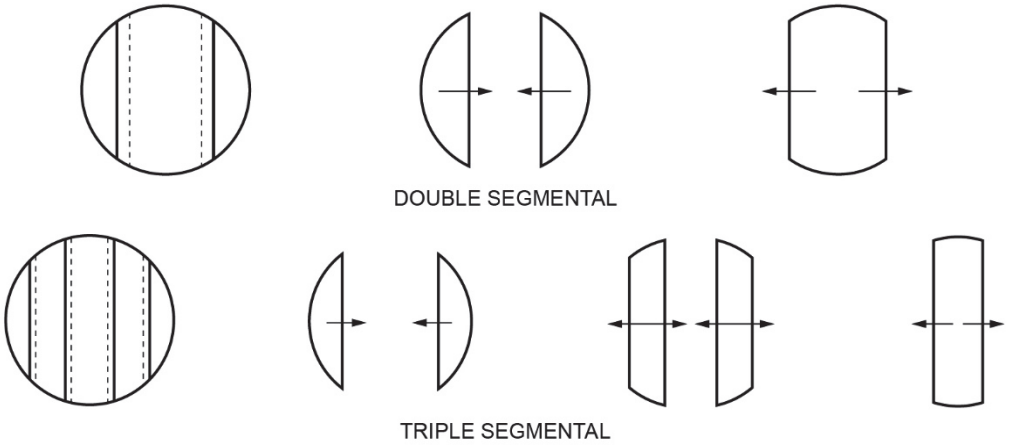
The segmental or multi-segmental type of baffle or tube support plate is standard. Other type baffles are permissible. Baffle cut is defined as the segment opening height expressed as a percentage of the shell inside diameter or as a percentage of the total net free area inside the shell (shell cross sectional area minus total tube area). The number of tube rows that overlap for multi-segmental baffles should be adjusted to give approximately the same net free area flow through each baffle. Baffles shall be cut near the centerline of a row of tubes, of a pass lane, of a tube lane, or outside the tube pattern. Baffles shall have a workmanlike finish on the outside diameter. Typical baffle cuts are illustrated in Figure RCB-4.1. Baffle cuts may be vertical, horizontal or rotated.

FIGURE RCB-4.1

BAFFLE CUTS FOR SEGMENTAL BAFFLES



BAFFLE CUTS FOR MULTI-SEGMENTAL BAFFLES



RCB-4.2 TUBE HOLES IN BAFFLES AND SUPPORT PLATES

Where the maximum unsupported tube length is 36 in. (914 mm) or less, or for tubes larger in diameter than 1 1/4 in. (31.8 mm) OD, standard tube holes are to be 1/32 inch (0.8 mm) over the OD of the tubes. Where the unsupported tube length exceeds 36 in. (914 mm) for tubes 1 1/4 in. (31.8 mm) diameter and smaller, standard tube holes are to be 1/64 inch (0.4 mm) over the OD of the tubes. For pulsating conditions, tube holes may be smaller than standard. Any burrs shall be removed and the tube holes given a workmanlike finish. Baffle holes will have an over-tolerance of 0.010 inch (0.3 mm) except that 4% of the holes are allowed an over-tolerance of 0.015 inch (0.4 mm).

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RCB-4.3 TRANSVERSE BAFFLE AND SUPPORT PLATE TO SHELL CLEARANCE

The transverse baffle and support plate clearance shall be such that the difference between the shell design inside diameter and the outside diameter of the baffle shall not exceed that indicated in Table RCB-4.3. However, where such clearance has no significant effect on shell side heat transfer coefficient or mean temperature difference, these maximum clearances may be increased to twice the tabulated values. (See Paragraph RCB-4.4.3.)

TABLE RCB-4.3

STANDARD TRANSVERSE BAFFLE AND SUPPORT PLATE TO SHELL CLEARANCES
Dimensions in Inches (mm)

Nominal Shell ID	Design ID of Shell Minus Baffle OD
6-17 (152-432)	1/8 (3.2)
18-39 (457-991)	3/16 (4.8)
40-54 (1016-1372)	1/4 (6.4)
55-69 (1397-1753)	5/16 (7.9)
70-84 (1778-2134)	3/8 (9.5)
85-100 (2159-2540)	7/16 (11.1)

The design inside diameter of a pipe shell is defined as the nominal outside diameter of the pipe, minus twice the nominal wall thickness. The design inside diameter of a plate shell is the specified inside diameter. In any case, the design inside diameter may be taken as the actual measured shell inside diameter.

RCB-4.4 THICKNESS OF BAFFLES AND SUPPORT PLATES

RCB-4.4.1 TRANSVERSE BAFFLES AND SUPPORT PLATES

The following tables show the minimum thickness of transverse baffles and support plates applying to all materials for various shell diameters and plate spacings.

The thickness of the baffle or support plates for U-tube bundles shall be based on the unsupported tube length in the straight section of the bundle. The U-bend length shall not be considered in determining the unsupported tube length for required plate thickness.

TABLE R-4.4.1

BAFFLE OR SUPPORT PLATE THICKNESS
Dimensions in Inches (mm)

Nominal Shell ID	Plate Thickness									
	Unsupported tube length between central baffles. End spaces between tubesheets and baffles are not a consideration.									
	24 (610) and Under		Over 24 (610) to 36 (914) Inclusive		Over 36 (914) to 48 (1219) Inclusive		Over 48 (1219) to 60 (1524) Inclusive		Over 60 (1524)	
6-14 (152-356)	1/8	(3.2)	3/16	(4.8)	1/4	(6.4)	3/8	(9.5)	3/8	(9.5)
15-28 (381-711)	3/16	(4.8)	1/4	(6.4)	3/8	(9.5)	3/8	(9.5)	1/2	(12.7)
29-38 (737-965)	1/4	(6.4)	5/16	(7.9)	3/8	(9.5)	1/2	(12.7)	5/8	(15.9)
39-60 (991-1524)	1/4	(6.4)	3/8	(9.5)	1/2	(12.7)	5/8	(15.9)	5/8	(15.9)
61-100 (1549-2540)	3/8	(9.5)	1/2	(12.7)	5/8	(15.9)	3/4	(19.1)	3/4	(19.1)

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TABLE CB-4.4.1

BAFFLE OR SUPPORT PLATE THICKNESS
Dimensions in Inches (mm)

Nominal Shell ID	Plate Thickness					
	Unsupported tube length between central baffles. End spaces between tubesheets and baffles are not a consideration.					
	12 (305) and Under	Over 12 (305) to 24 (610) Inclusive	Over 24 (610) to 36 (914) Inclusive	Over 36 (914) to 48 (1219) Inclusive	Over 48 (1219) to 60 (1524) Inclusive	Over 60 (1524)
6-14 (152-356)	1/16 (1.6)	1/8 (3.2)	3/16 (4.8)	1/4 (6.4)	3/8 (9.5)	3/8 (9.5)
15-28 (381-711)	1/8 (3.2)	3/16 (4.8)	1/4 (6.4)	3/8 (9.5)	3/8 (9.5)	1/2 (12.7)
29-38 (737-965)	3/16 (4.8)	1/4 (6.4)	5/16 (7.9)	3/8 (9.5)	1/2 (12.7)	5/8 (15.9)
39-60 (991-1524)	1/4 (6.4)	1/4 (6.4)	3/8 (9.5)	1/2 (12.7)	5/8 (15.9)	5/8 (15.9)
61-100 (1549-2540)	1/4 (6.4)	3/8 (9.5)	1/2 (12.7)	5/8 (15.9)	3/4 (19.1)	3/4 (19.1)

R-4.4.2 LONGITUDINAL BAFFLES

R-4.4.2.1 LONGITUDINAL BAFFLES WITH LEAF SEALS

Longitudinal baffles with leaf (or other type) seals shall not be less than 1/4” (6.4 mm) nominal metal thickness.

R-4.4.2.2 WELDED-IN LONGITUDINAL BAFFLES

The thickness of longitudinal baffles that are welded to the shell cylinder shall not be less than the thicker of 1/4" (6.4 mm) or the thickness calculated using the following formula:

$$t = b\sqrt{\frac{qB}{1.5S}}$$

where

t = Minimum baffle plate thickness, in. (mm)

B = Table value as shown in Table RCB-9.1.3.2 (linear interpolation may be used)

q = Maximum pressure drop across baffle, psi (kPA)

S = Code allowable stress in tension, at design temperature, psi (kPa)

b = Plate dimension. See Table RCB-9.1.3.2, in. (mm)

a = Plate dimension. See Table RCB-9.1.3.2, in. (mm)

The designer shall consider the effects of pressure drop and unsupported span and perform a calculation for the portion of the long baffle that will require the greatest thickness. The longitudinal baffle shall be considered fixed along the two sides where it is welded to the shell cylinder. It shall be considered simply supported along the sides where it is supported by the tubesheet groove or transverse baffle.

R-4.4.2.3 LONGITUDINAL BAFFLE WELD SIZE

Welded-in longitudinal baffles shall be attached with fillet welds on each side with a minimum leg of 3/4 t from Paragraph R-4.4.2.2. Other types of attachments are allowed but shall be of equivalent strength.

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CB-4.4.2 LONGITUDINAL BAFFLES

CB-4.4.2.1 LONGITUDINAL BAFFLES WITH LEAF SEALS

Longitudinal carbon steel baffles with leaf (or other type) seals shall not be less than 1/4” (6.4 mm) nominal metal thickness.

Longitudinal alloy baffles with leaf (or other type) seals shall not be less than 1/8” (3.2 mm) nominal metal thickness.

CB-4.4.2.2 WELDED-IN LONGITUDINAL BAFFLES

The thickness of longitudinal baffles that are welded to the shell cylinder shall be determined as shown in Paragraph R-4.4.2.2.

CB-4.4.2.3 LONGITUDINAL BAFFLE WELD SIZE

Welded-in longitudinal baffles shall be attached with fillet welds on each side with a minimum leg of 3/4 t from Paragraph R-4.4.2.2. Other types of attachments are allowed but shall be of equivalent strength.

RCB-4.4.3 SPECIAL PRECAUTIONS

Special consideration should be given to baffles, tube supports and bundles if any of the following conditions are applicable:

(1) Baffles and support plates subjected to pulsations.

(2) Baffles and support plates engaging finned tubes.

(3) Longitudinal baffles subjected to large differential pressures due to high shell side fluid pressure drop.

(4) Support of tube bundles when clearances allowed by RCB-4.3 or RCB-4.5 are exceeded.

Solutions may include any of the following:

(1) Decreasing the baffle spacing within the allowable pressure drop.

(2) Providing ears on the baffles to capture additional tube rows in the inlet and outlet spaces.

(3) Providing additional supports in the baffle spaces that do not hinder fluid flow in the bundle.

(4) Modifying the baffle type.

RCB-4.5 SPACING OF BAFFLES AND SUPPORT PLATES

The following are general guidelines for determining maximum and minimum baffle/support spacing and unsupported tube lengths. The actual baffle spacing should be determined by a designer competent in the thermal/hydraulic design of shell and tube heat exchangers (see E-1.1). Consideration shall be given to operating conditions, heat load, elimination of flow induced vibration (see Section 6), available tube length, and nozzle locations when determining the spacing of the baffle and support plates.

RCB-4.5.1 MINIMUM SPACING

Segmental baffles normally should not be spaced closer than 1/5 of the shell ID or 2 in. (51 mm), whichever is greater. However, special design considerations may dictate a closer spacing.

RCB-4.5.2 MAXIMUM SPACING

Tube support plates shall be so spaced that the unsupported tube span does not exceed the value indicated in Table RCB-4.5.2 for the tube material used.

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TABLE RCB-4.5.2

MAXIMUM UNSUPPORTED STRAIGHT TUBE SPANS
Dimensions in Inches (mm)

Tube OD	Tube Materials and Temperature Limits ° F (° C)	
	Carbon Steel & High Alloy Steel, 750 (399) Low Alloy Steel, 850 (454) Nickel-Copper, 600 (316) Nickel, 850 (454) Nickel-Chromium-Iron, 1000 (538)	Aluminum & Aluminum Alloys, Copper & Copper Alloys, Titanium Alloys At Code Maximum Allowable Temperature
1/4 (6.4)	26 (660)	22 (559)
3/8 (9.5)	35 (889)	30 (762)
1/2 (12.7)	44 (1118)	38 (965)
5/8 (15.9)	52 (1321)	45 (1143)
3/4 (19.1)	60 (1524)	52 (1321)
7/8 (22.2)	69 (1753)	60 (1524)
1 (25.4)	74 (1880)	64 (1626)
1 1/4 (31.8)	88 (2235)	76 (1930)
1 1/2 (38.1)	100 (2540)	87 (2210)
2 (50.8)	125 (3175)	110 (2794)
2 1/2 (63.5)	125 (3175)	110 (2794)
3 (76.2)	125 (3175)	110 (2794)

Notes:

(1) Above the metal temperature limits shown, maximum spans shall be reduced in direct proportion to the fourth root of the ratio of elastic modulus at design temperature to elastic modulus at tabulated limit temperature.

(2) In the case of circumferentially finned tubes, the tube OD shall be the diameter at the root of the fins and the corresponding tabulated or interpolated span shall be reduced in direct proportion to the fourth root of the ratio of the weight per unit length of the tube, if stripped of fins to that of the actual finned tube.

(3) The maximum unsupported tube spans in Table RCB-4.5.2 do not consider potential flow induced vibration problems. Refer to Section 6 for vibration criteria.

RCB-4.5.3 BAFFLE SPACING

Baffles normally shall be spaced uniformly, spanning the effective tube length. When this is not possible, the baffles nearest the ends of the shell, and/or tubesheets, shall be located as close as practical to the shell nozzles. The remaining baffles normally shall be spaced uniformly.

RCB-4.5.4 U-TUBE REAR SUPPORT

The support plates or baffles adjacent to the bends in U-tube exchangers shall be so located that, for any individual bend, the sum of the bend diameter plus the straight lengths measured along both legs from supports to bend tangents does not exceed the maximum unsupported span determined from Paragraph RCB-4.5.2. Where bend diameters prevent compliance, special provisions in addition to the above shall be made for support of the bends.

RCB-4.5.5 SPECIAL CASES

When pulsating conditions are specified by the purchaser, unsupported spans shall be as short as pressure drop restrictions permit. If the span under these circumstances approaches the maximum permitted by Paragraph RCB-4.5.2, consideration should be given to alternative flow arrangements which would permit shorter spans under the same pressure drop restrictions.

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RCB-4.5.6 TUBE BUNDLE VIBRATION

Shell side flow may produce excitation forces which result in destructive tube vibrations. Existing predictive correlations are inadequate to ensure that any given design will be free of such damage. The vulnerability of an exchanger to flow induced vibration depends on the flow rate, tube and baffle materials, unsupported tube spans, tube field layout, shell diameter, and inlet/outlet configuration. Section 6 of these Standards contains information which is intended to alert the designer to potential vibration problems. In any case, and consistent with Paragraph G-5, the manufacturer is not responsible or liable for any direct, indirect, or consequential damages resulting from vibration.

*RCB-4.6 IMPINGEMENT BAFFLES AND EROSION PROTECTION

The following paragraphs provide limitations to prevent or minimize erosion of tube bundle components at the entrance and exit areas. These limitations have no correlation to tube vibration and the designer should refer to Section 6 for information regarding this phenomenon.

In this section, V is defined as the linear velocity of the fluid in feet per second (meters per second) and ρ is its density in pounds per cubic foot (kilograms per cubic meter)

*RCB-4.6.1 SHELL SIDE IMPINGEMENT PROTECTION REQUIREMENTS

An impingement plate, or other means to protect the tube bundle against impinging fluids, shall be provided for all shell side inlet nozzle(s), unless the product of ρV^2 in the inlet nozzle does not exceed the following limits:

1500 (2232) for non-abrasive, single phase fluids (liquids, gases, or vapors);
500 (744) for all other liquids, including a liquid at its boiling point;

For all other gases and vapors, including steam and all nominally saturated vapors, and for liquid vapor mixtures, impingement protection is required.

A properly designed diffuser may be used to reduce line velocities at shell entrance. For distributor belt type diffusers, see RGP section.

*RCB-4.6.2 SHELL OR BUNDLE ENTRANCE AND EXIT AREAS

For shell or bundle entrance and exit areas, in no case can ρV^2 be over 4,000 (5953). This requirement is independent of impingement protection.

*RCB-4.6.2.1 SHELL ENTRANCE OR EXIT AREA WITH IMPINGEMENT PLATE

When an impingement plate is provided, the flow area shall be considered as the unrestricted area between the inside diameter of the shell at the nozzle and the face of the impingement plate.

*RCB-4.6.2.2 SHELL ENTRANCE OR EXIT AREA WITHOUT IMPINGEMENT PLATE

For determining the area available for flow at the entrance or exit of the shell where there is no impingement plate, the flow area between the tubes within the projection of the nozzle bore and the actual unrestricted radial flow area from under the nozzle or dome measured between the tube bundle and shell inside diameter may be considered.

*RCB-4.6.2.3 BUNDLE ENTRANCE OR EXIT AREA WITH IMPINGEMENT PLATE

When an impingement plate is provided under a nozzle, the flow area shall be the unrestricted area between the tubes within the compartments between baffles and/or tubesheet.

*RCB-4.6.2.4 BUNDLE ENTRANCE OR EXIT AREA WITHOUT IMPINGEMENT PLATE

For determining the area available for flow at the entrance or exit of the tube bundle where there is no impingement plate, the flow area between the tubes within the compartments between baffles and/or tubesheet may be considered.

*RCB-4.6.2.5 ROD TYPE IMPINGEMENT PROTECTION AREAS

For determining the shell or bundle exit or entrance areas, the methods used for calculating these areas for bundles without impingement plates may be used, substituting the rod pitch and diameter for the tube pitch and diameter.

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