2022

Overview of the TEMA Standard

Heat Exchanger World

Pasadena, TX

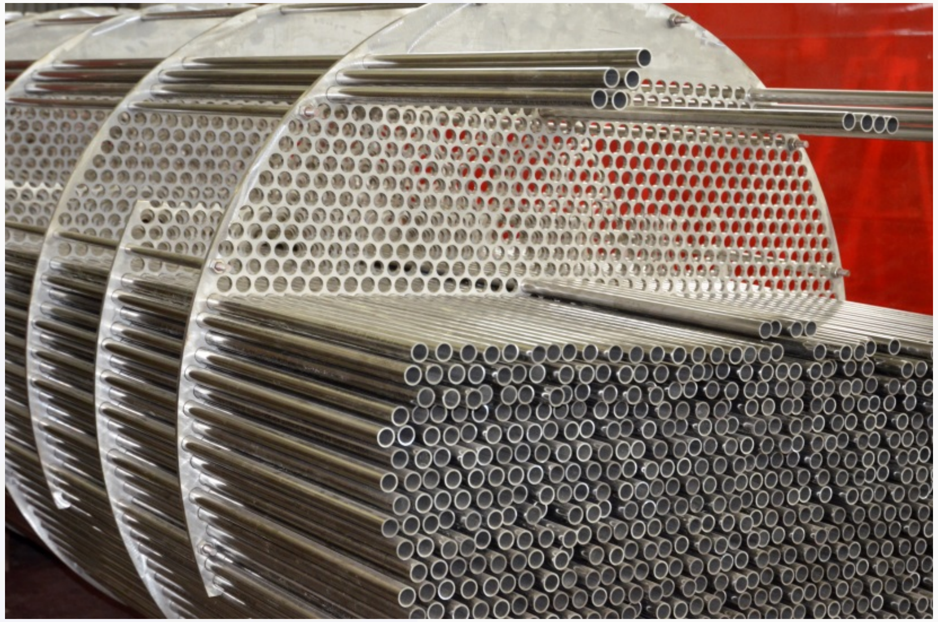
November 2022

Sponsored by:

Sangeeta Bakshi & Wade Armer - TEMA Technical Committee

TEMA: The Tubular Exchanger Manufacturer's Association

- TEMA is a trade association of the world's leading manufacturers of shell and tube heat exchangers, who have pioneered the research and development of heat exchangers for over 80 years.
- TEMA publishes a Standard for thermal and mechanical design of high-quality heat exchangers.



HEAT EXCHANGER WORLD CONFERENCE & EXPO AMERICAS

2022

TEMA Member Companies

FABSCO

Energy Exchanger Company

KRUEGER ENGINEERING & MFG.CO.INC.

RAS PROCESS EQUIPMENT

Brask, Inc. - IEE

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WARD VESSEL & EXCHANGER

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Sponsored by: Brask, Inc. The Heat Exchanger People; CUST-O-FAB; DUNN HEAT EXCHANGERS; ELLIOTT TOOL TECHNOLOGIES; Flexitallic; Ohmstede Industrial Services Inc.; SUPERIOR PLANT RENTALS; TEADIT Sealing for a Safer and Greener Tomorrow; VAHTERUS; WARD VESSEL & EXCHANGER

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The TEMA Standard

TEMA® standards

- Current: 10th Edition, published in 2019.
- The Standard contains 10 sections:
    1. N – Nomenclature
    2. F – Fabrication Tolerances
    3. G – General Fabrication and Performance Information
    4. E – Installation, Operation, and Maintenance
    5. RCB – Mechanical Standards Class RCB Heat Exchangers
    6. V – Flow Induced Vibration
    7. T – Thermal Relations
    8. P – Physical Properties of Fluids
    9. D – General Information
    10. RGP – Recommended Good Practice

HEAT EXCHANGER WORLD
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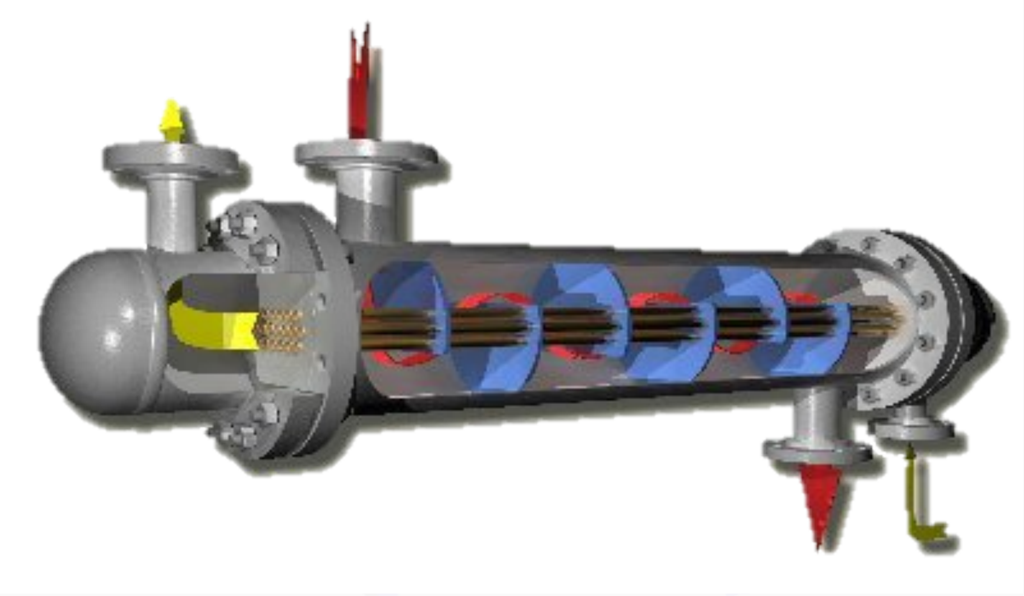
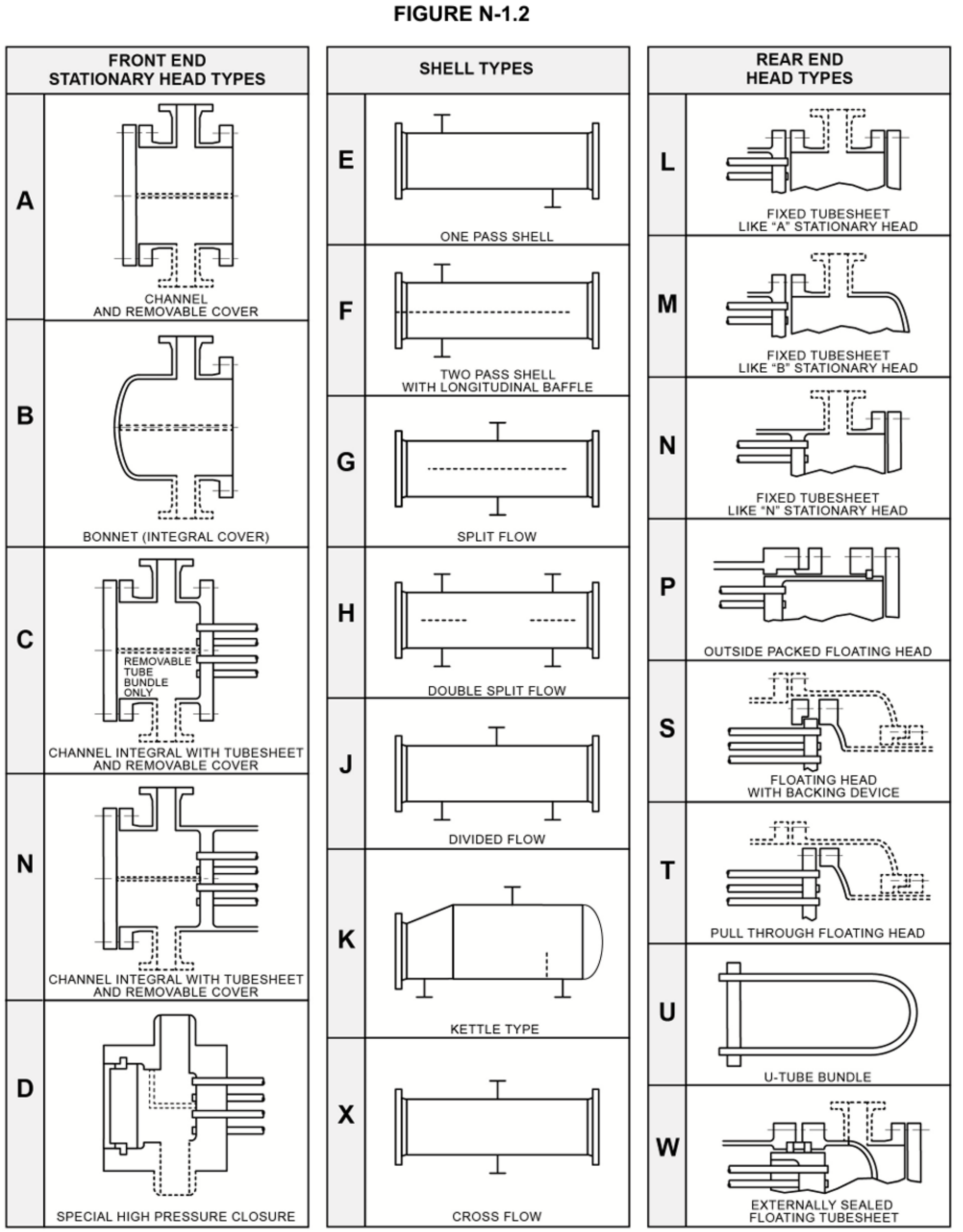
Section 1: N - Nomenclature

Describes naming and type standards for exchangers, as well as all components of exchangers





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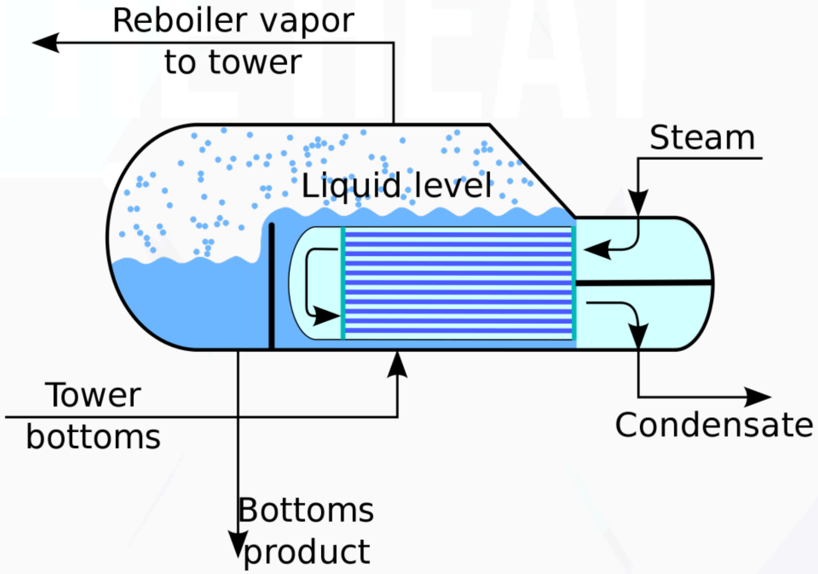
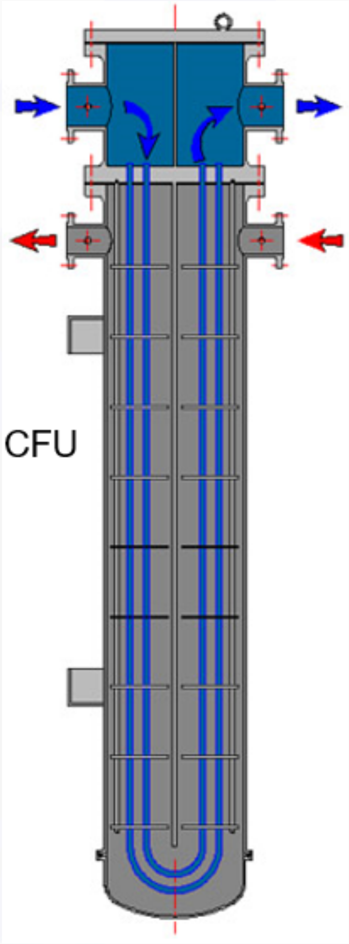
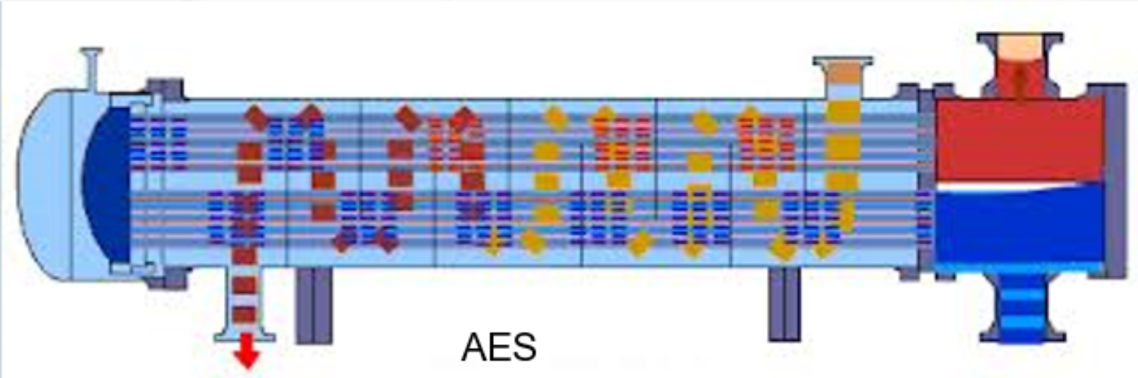
Examples of TEMA Type Exchangers

Examples:			
AEU	AES	AET	NEN
BEU	BES	BET	BEM
BKU	AJS	AKU	AJU







Section 2: F – Fabrication Tolerances

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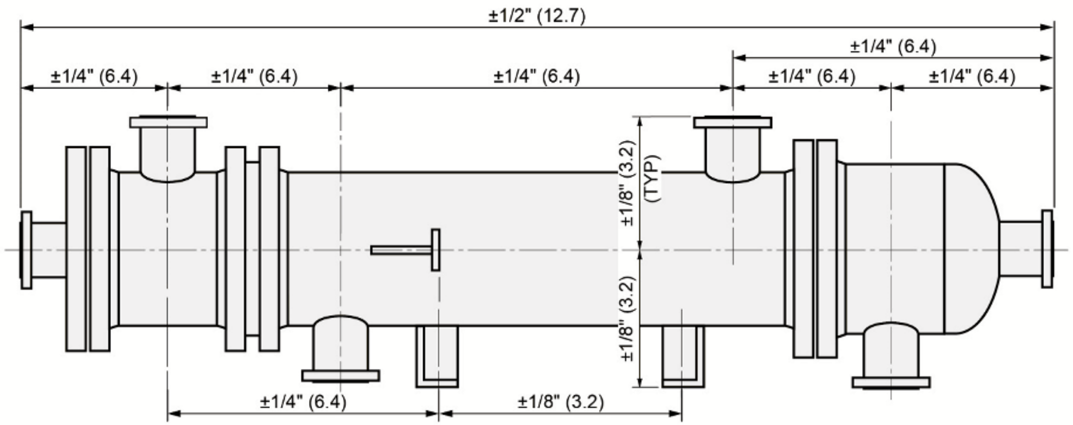
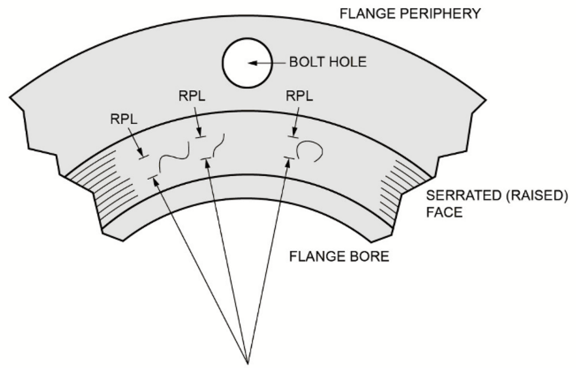
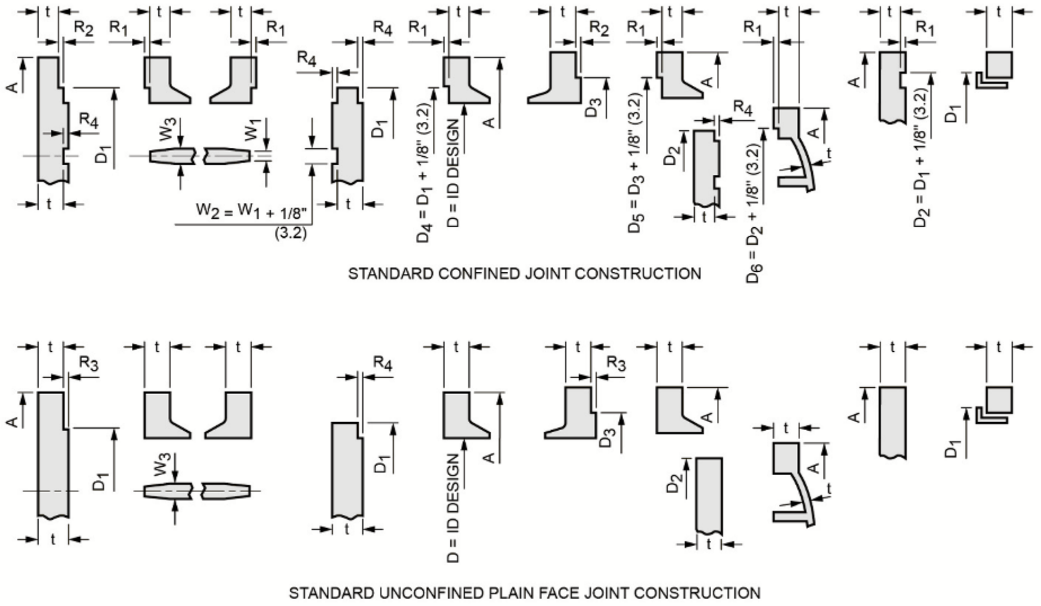
FIGURE F-1





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

FIGURE F-3



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Section 3: G - General Fabrication and Performance Information

Provides definitions, specification sheet, documentation standards, and standard performance guarantees.

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	ρv^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				

Section 3: G - General Fabrication and Performance Information

- Operating conditions req'd
  - Normal
  - Start-Up
  - Shut-Down
  - Steam Out
  - Upset
- Leads to Mean metal temps
  - Calculate thermal expansion

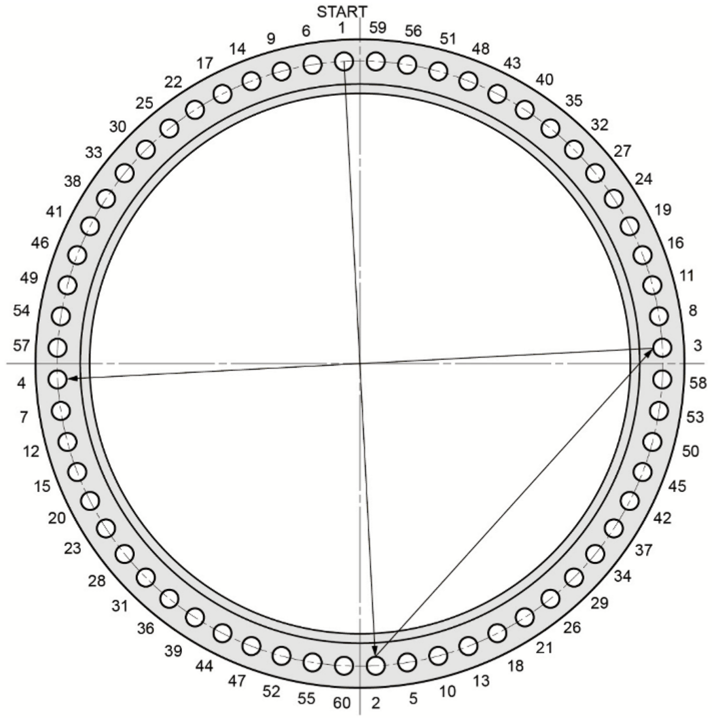
This may happen if you don't give the fabricator the correct info.

Section 4: E – Installation, Operation, and Maintenance

2022

- Installation guidelines
- Start-up/shut-down recommendations
- Bolted joint tightening
- Maintenance and cleaning
- Locating tube leaks
- Bundle removal

FIGURE E-3.2.5.5



Section 5 – RCB-1 - SCOPE OF TEMA STANDARDS

Applicable to shell and tube heat exchangers which do NOT exceed the following criteria –

1. Inside diameters of 100”
2. Design pressures exceeding 3000 psi

Intent is to limit the max wall thickness to 3” & max stud diameter to 4”.

Section 5 – RCB-1 - SCOPE OF TEMA STANDARDS

RCB Definitions – 3 classes for design and fabrication

1. Class “R”
   - Generally severe requirements of petroleum and related processing applications
2. Class “C”
   - Generally moderate requirements of commercial and general processing applications
3. Class “B”
   - Chemical process service

Section 5 – RCB-2 - 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.

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

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.

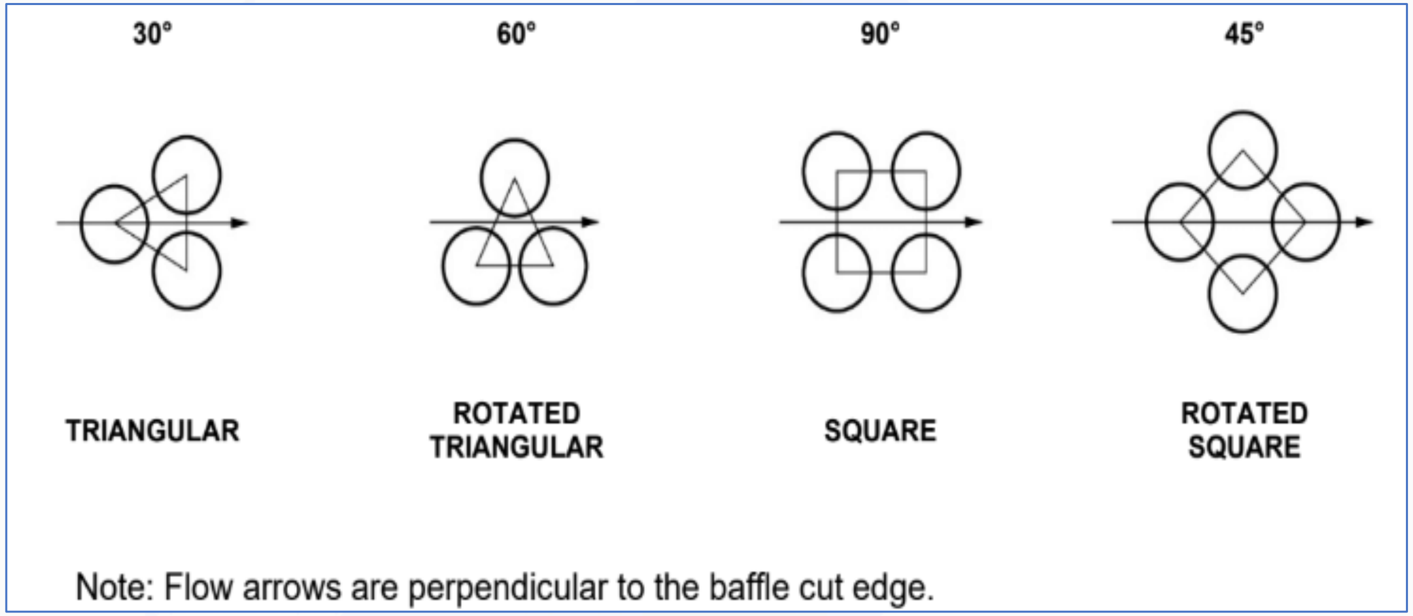
Note: different constants may be used based upon other considerations of tube thinning and previous experience.

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

Section 5 – RCB-2 - TUBES

RCB-2.3.4 TUBE PATTERN

- Square Pattern
  - Removable bundle units
  - Mechanical cleaning req'd
  - Tube lanes to be continuous
- Triangular Pattern
  - Should NOT be used when shellside is to be cleaned mechanically



Section 5 – RCB-3 - SHELLS & SHELL COVERS

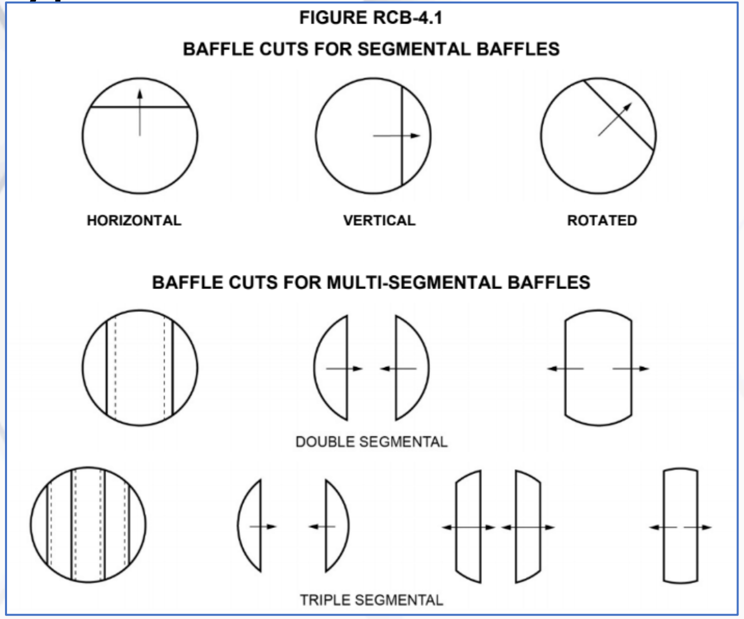
Minimum shell thickness – ASME Code compliance req'd but no less than -

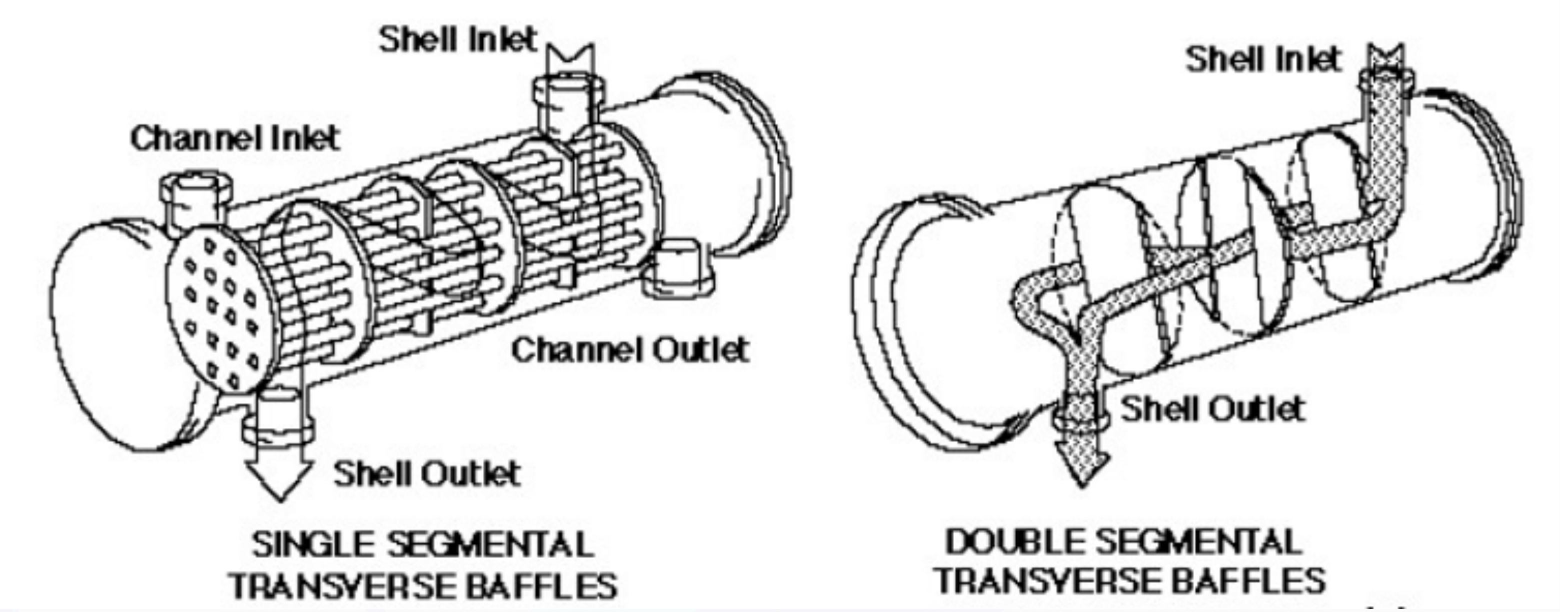
TABLE R-3.1.3
MINIMUM SHELL THICKNESS
Dimensions in Inches (mm)

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)

Section 5 – RCB-4 - BAFFLES & SUPPORT PLATES

Types of Transverse Baffles -





Section 5 – RCB-4 - BAFFLES & SUPPORT PLATES

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)

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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Section 5 – RCB-4 - BAFFLES & SUPPORT PLATES

RCB-4.5 –
Spacing of Baffles & Support Plates

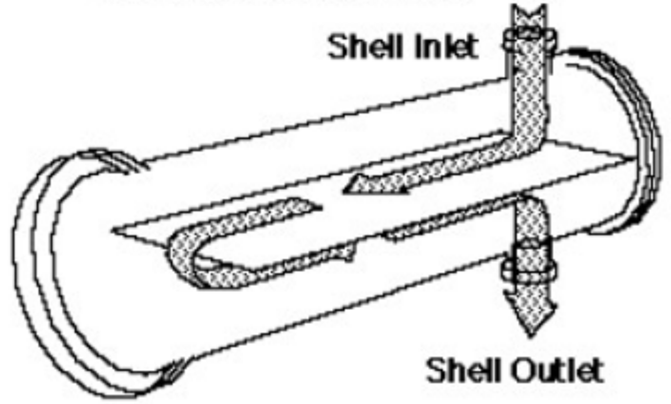
TABLE RCB-4.5.2

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)

Section 5 – RCB-4 - BAFFLES & SUPPORT PLATES

RCB-4.4 –
Thickness of Baffles & Support Plates



LONGITUDINAL BAFFLE

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)

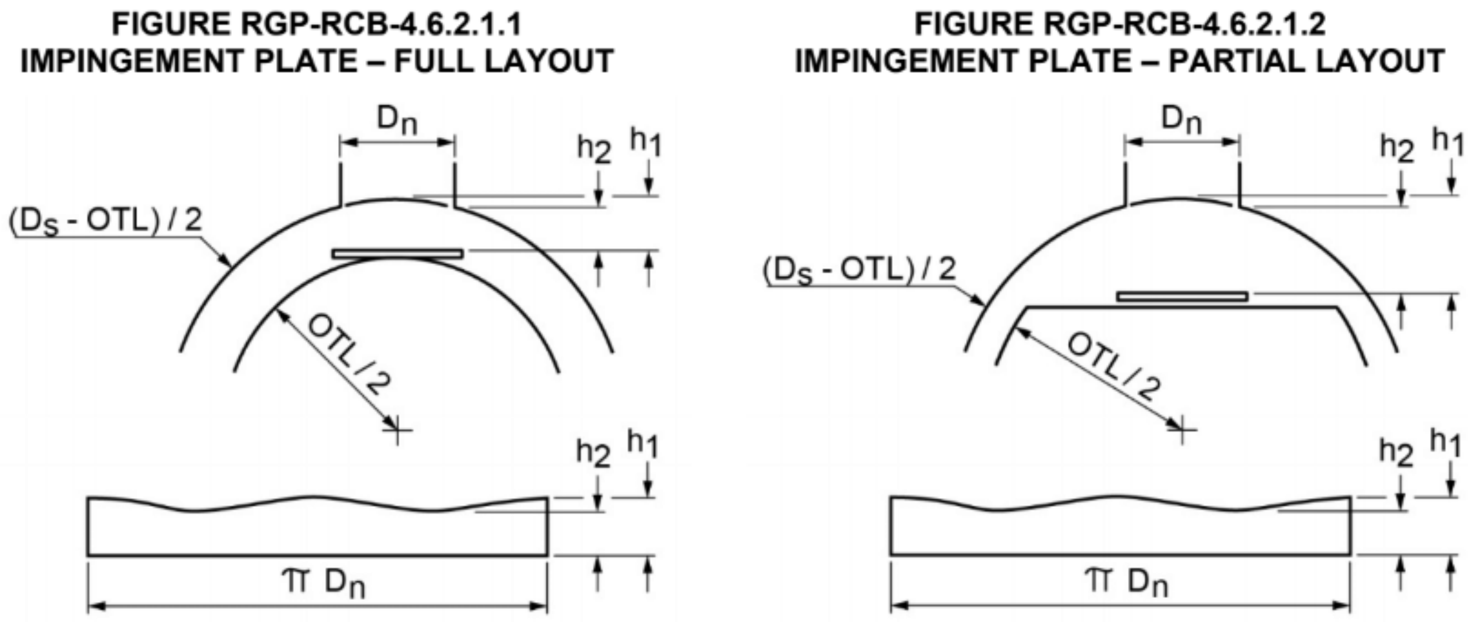
a = Plate dimension. See Table RCB-9.1.3.2, in. (mm)

Section 5 – RCB-4 - BAFFLES & SUPPORT PLATES

RCB-4.6 – Impingement baffles & Erosion Protection

- Guidelines to prevent erosion at entrance & exit areas

SHELL ENTRANCE OR EXIT AREA



Section 5 – RCB-4 - BAFFLES & SUPPORT PLATES

RCB-4.7 –

Tie Rods & Spacers

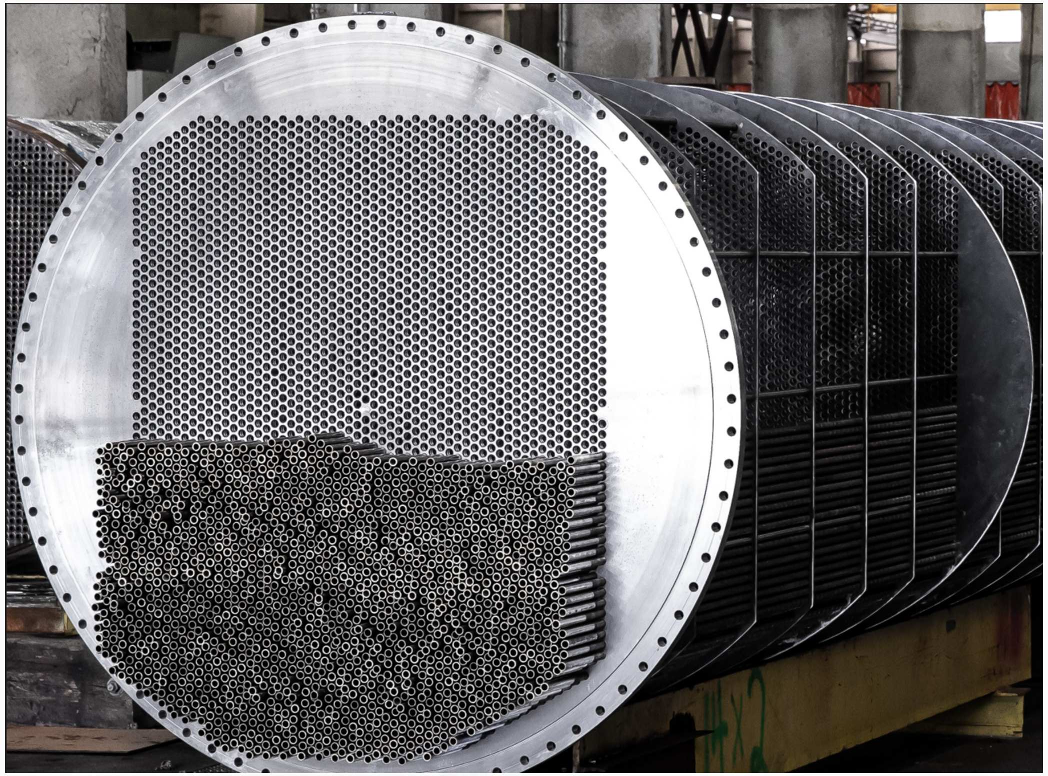
- # & size of tie rods
- Any baffle segment
  - min 3 pts of support

TABLE R-4.7.1

TIE ROD STANDARDS

Dimensions in Inches (mm)

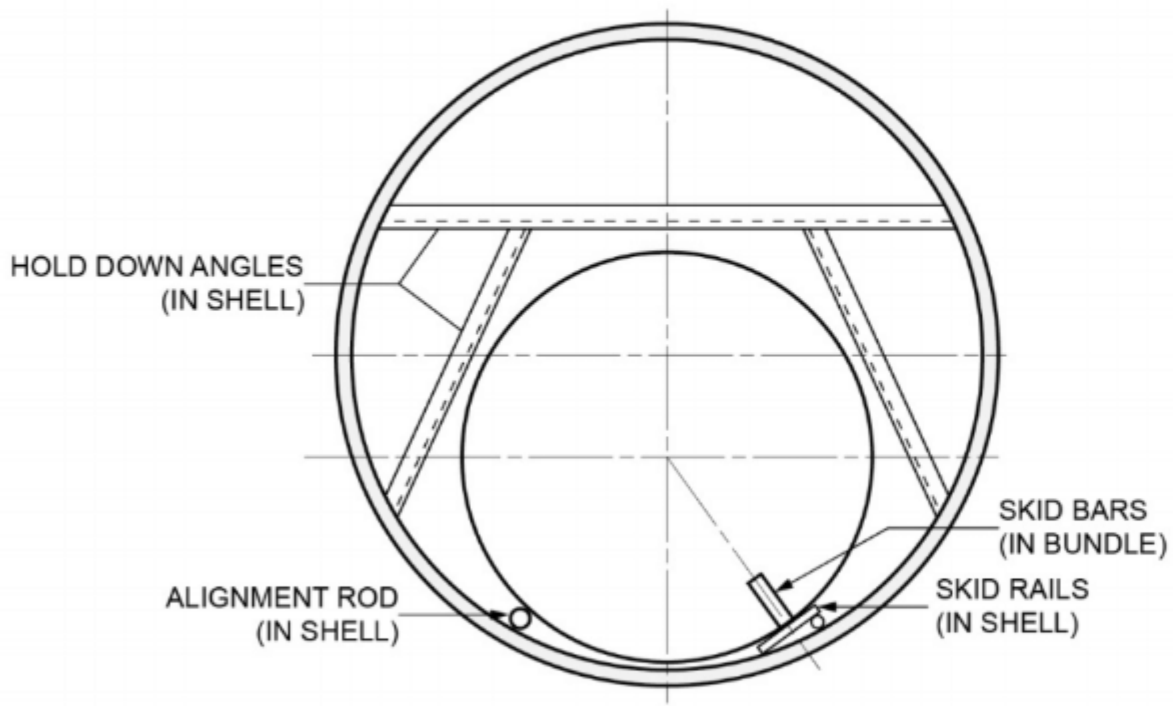
Nominal Shell Diameter		Tie Rod Diameter		Minimum Number of Tie Rods
6 – 15	(152-381)	3/8	(9.5)	4
16 – 27	(406-686)	3/8	(9.5)	6
28 – 33	(711-838)	1/2	(12.7)	6
34 – 48	(864-1219)	1/2	(12.7)	8
49 – 60	(1245-1524)	1/2	(12.7)	10
61 – 100	(1549-2540)	5/8	(15.9)	12



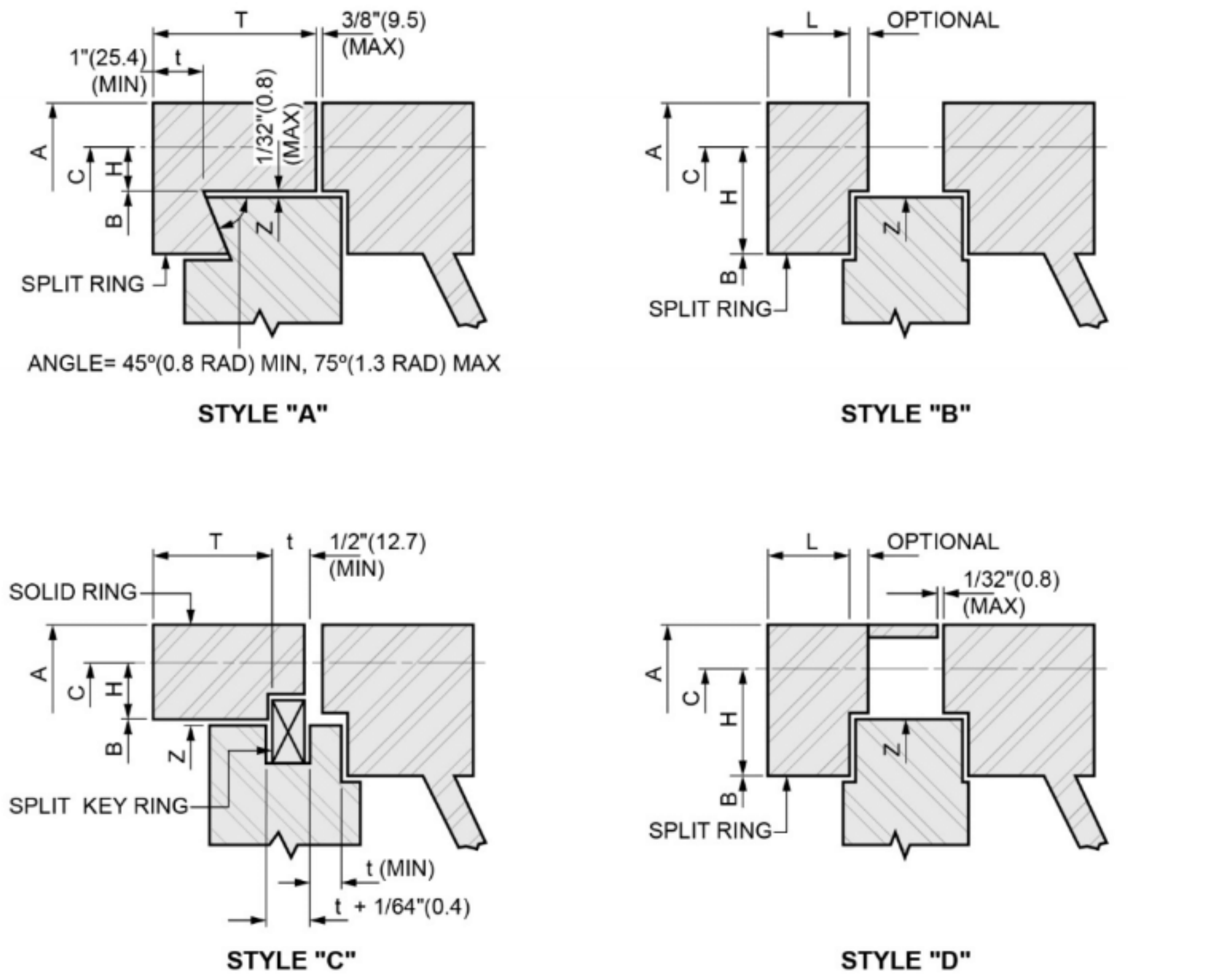
Section 5 – RCB-4 - BAFFLES & SUPPORT PLATES

RCB-4.9 –
Kettle Type Reboilers

FIGURE RCB-4.9

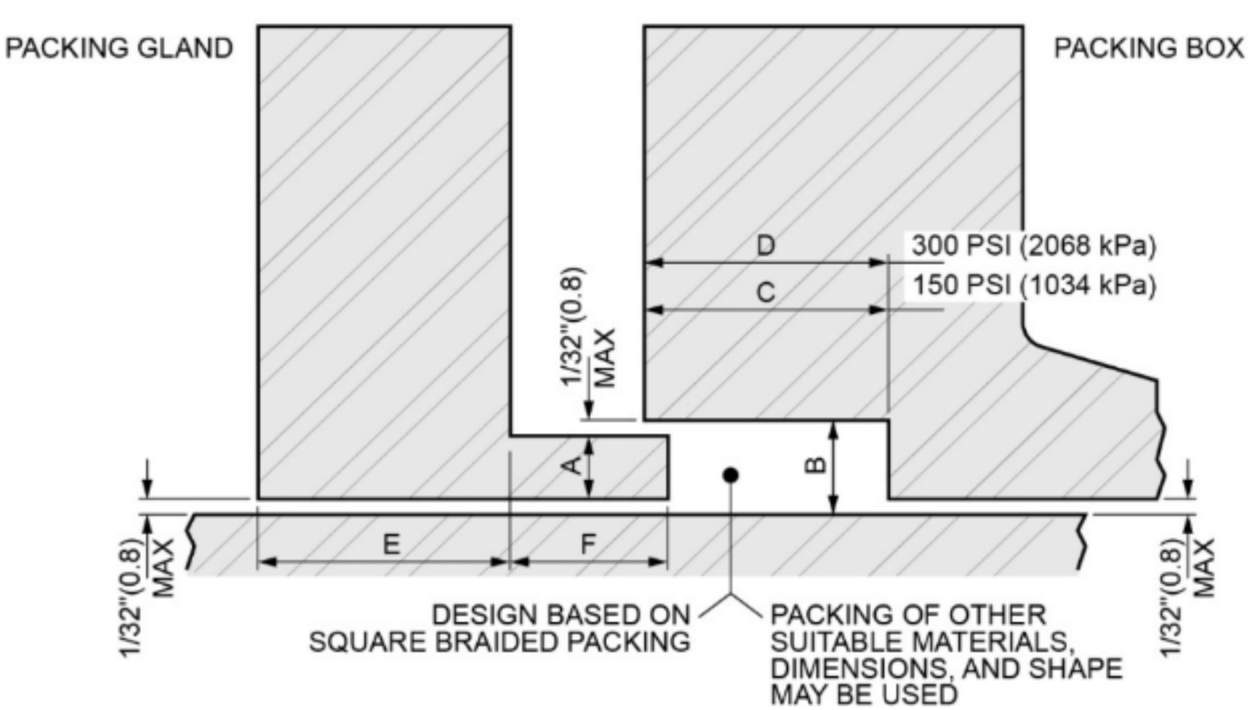


Section 5 – RCB-5 - FLOATING END CONSTRUCTION



Section 5 – RCB-5 - FLOATING END CONSTRUCTION

FIGURE RCB-5.2.2



Section 5 – RCB-6 - GASKETS

- Min gasket width
- Confined vs Unconfined

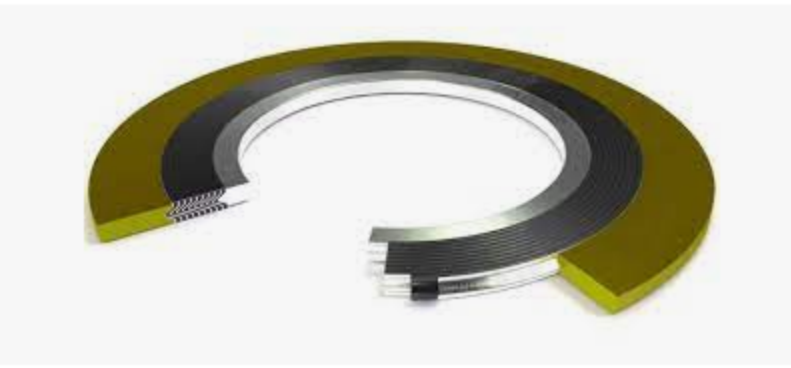
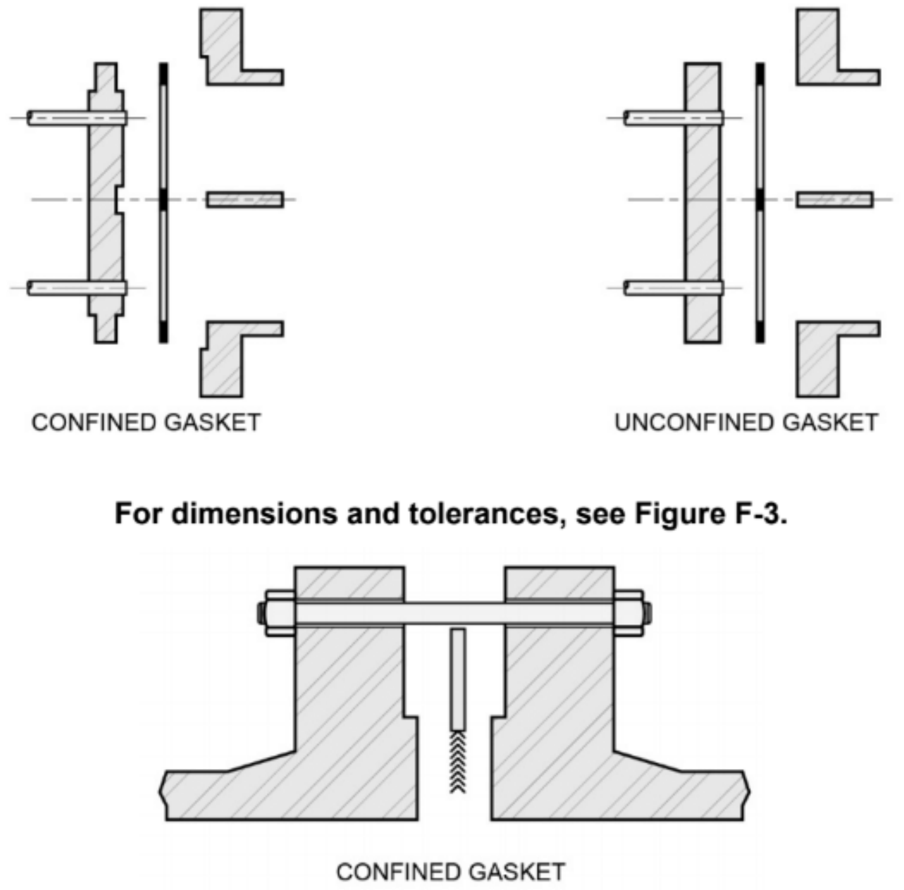


FIGURE RCB-6.5



SPIRAL WOUND GASKET WITH OUTER METAL RING

Section 5 – RCB-7 - TUBESHEETS

- Tubesheet thk per ASME code
- When code rules don't apply, consider TEMA Appendix A.
- Min tubesheet req's when expanding tubes
- Double tubesheet design rules -

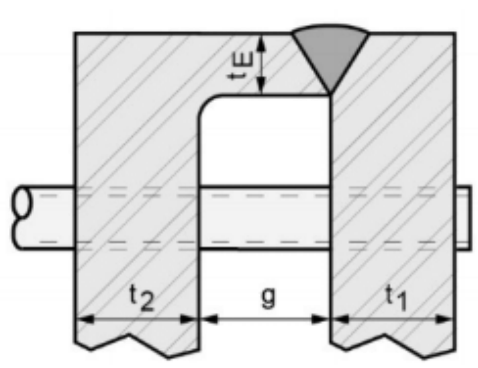


FIGURE RCB-7.1.2.4

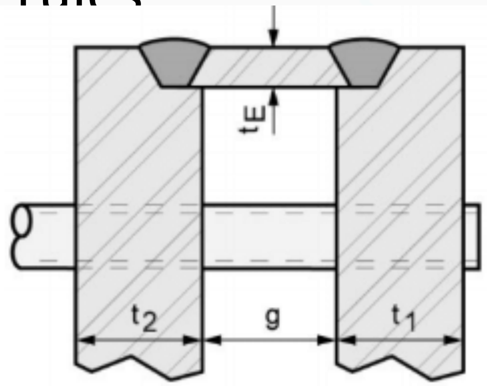


FIGURE RCB-7.1.2.5

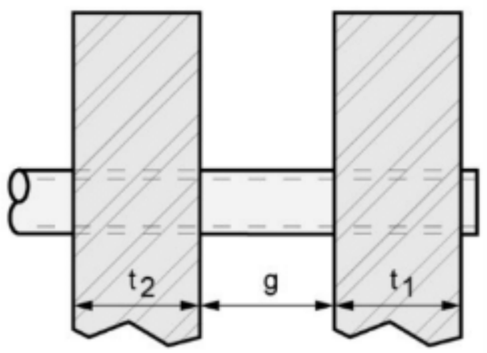


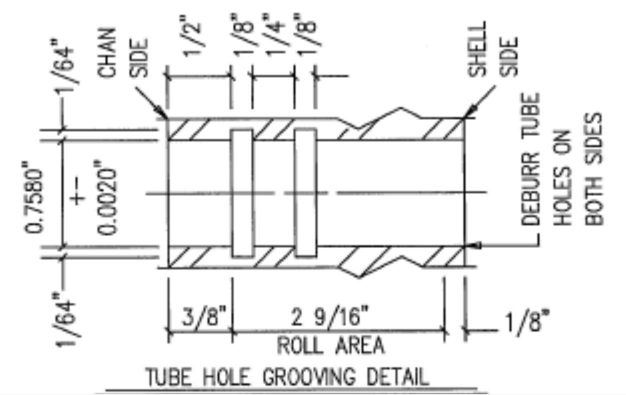
FIGURE RCB-7.1.2.6

Section 5 – RCB-7 - TUBESHEETS

TABLE RCB-7.2.1

TUBE HOLE DIAMETERS AND TOLERANCES
(All Dimensions in Inches)

Nominal Tube OD	Nominal Tube Hole Diameter and Under Tolerance				Over Tolerance; 96% of tube holes must meet value in column (c). Remainder may not exceed value in column (d)	
	Standard Fit (a)		Special Close Fit (b)			
	Nominal Diameter	Under Tolerance	Nominal Diameter	Under Tolerance	(c)	(d)
1/4	0.259	0.004	0.257	0.002	0.002	0.007
3/8	0.384	0.004	0.382	0.002	0.002	0.007
1/2	0.510	0.004	0.508	0.002	0.002	0.008
5/8	0.635	0.004	0.633	0.002	0.002	0.010
3/4	0.760	0.004	0.758	0.002	0.002	0.010
7/8	0.885	0.004	0.883	0.002	0.002	0.010
1	1.012	0.004	1.010	0.002	0.002	0.010
1 1/4	1.264	0.006	1.261	0.003	0.003	0.010
1 1/2	1.518	0.007	1.514	0.003	0.003	0.010
2	2.022	0.007	2.018	0.003	0.003	0.010
2 1/2	2.528	0.010	2.523	0.004	0.004	0.010
3	3.033	0.012	3.027	0.004	0.004	0.010



Section 5 – RCB-7 - TUBESHEETS

- RCB 7.3 – Tube-to-tubesheet joints

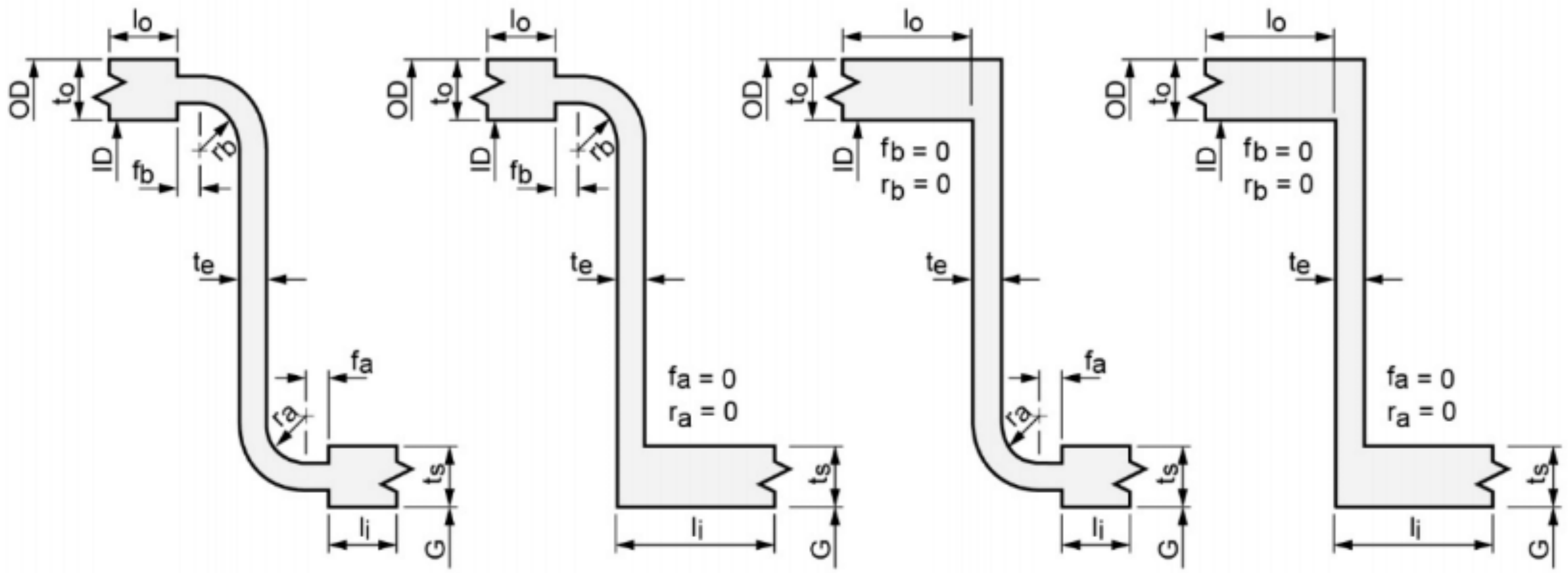
Tubing Material	Target Percent Wall Reduction
Carbon steel and low alloy steel	5 to 8
Stainless steel	5 to 8
Duplex stainless steel	4 to 6
Titanium and work hardening non-ferrous	4 to 6
Admiralty and non-work hardening non-ferrous	6 to 9
Copper and copper alloys	7 to 10

These suggested amounts are based on industry standards. The optimal amount of expansion could vary from these amounts, and should be agreed upon between the owner and manufacturer. Higher pin-count expanders should be considered for titanium tubes when size permits. Please see RGP-RCB-7.3 for factors that may affect the optimum amount of wall reduction.

Section 5 – RCB-8 – FLEXIBLE SHELL ELEMENTS

Figure RCB-8.2 defines the nomenclature used in the following paragraphs based upon nominal dimensions of the flexible elements.

FIGURE RCB-8.2



Section 5 – RCB-9 – CHANNELS, COVERS, & BONNETS

TABLE RCB-9.1.3.1

NOMINAL PASS PARTITION PLATE THICKNESS
Dimensions are in Inches (mm)

Nominal Diameter	Carbon Steel	Alloy Material
Less than 24 (610)	3/8 (9.5)	1/4 (6.4)
24 to 60 (610-1524)	1/2 (12.7)	3/8 (9.5)
61 to 100 (1549-2540)	5/8 (15.9)	1/2 (12.7)

RCB-9.1.3.2 PASS PARTITION PLATE FORMULA

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

Section 5 – RCB-11 – END FLANGES AND BOLTING

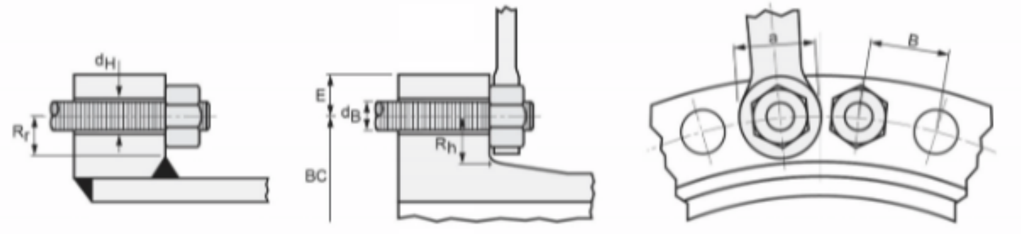
- MIN BOLT SIZE
  - Class R = 3/4”
  - Class C = 1/2”
  - Class B = 5/8”

- SECTION 9, Table D-5

TABLE D-5
BOLTING DATA – RECOMMENDED MINIMUM

(dimensions in inches unless noted)

bolt Size dB	Threads		Nut Dimensions		Bolt Spacing B	Radial Distance Rh	Radial Distance Rr	Edge Distance E	Wrench Diameter a	Bolt Hole dH	bolt Size dB
	No. of Threads	Root Area in²	Across Flats	Across Corners							
1/2	13	0.126	7/8	0.969	1 1/4	13/16	5/8	5/8	1 1/2	5/8	1/2
5/8	11	0.202	1 1/16	1.175	1 1/2	15/16	3/4	3/4	1 3/4	3/4	5/8
3/4	10	0.302	1 1/4	1.383	1 3/4	1 1/8	13/16	13/16	2 1/16	7/8	3/4
7/8	9	0.419	1 7/16	1.589	2 1/16	1 1/4	15/16	15/16	2 3/8	1	7/8
1	8	0.551	1 5/8	1.796	2 1/4	1 3/8	1 1/16	1 1/16	2 5/8	1 1/8	1
1 1/8	8	0.728	1 13/16	2.002	2 1/2	1 1/2	1 1/8	1 1/8	2 7/8	1 1/4	1 1/8
1 1/4	8	0.929	2	2.209	2 13/16	1 3/4	1 1/4	1 1/4	3 1/4	1 3/8	1 1/4
1 3/8	8	1.155	2 3/16	2.416	3 1/16	1 7/8	1 3/8	1 3/8	3 1/2	1 1/2	1 3/8
1 1/2	8	1.405	2 3/8	2.622	3 1/4	2	1 1/2	1 1/2	3 3/4	1 5/8	1 1/2
1 5/8	8	1.680	2 9/16	2.828	3 1/2	2 1/8	1 5/8	1 5/8	4	1 3/4	1 5/8
1 3/4	8	1.980	2 3/4	3.035	3 3/4	2 1/4	1 3/4	1 3/4	4 1/4	1 7/8	1 3/4
1 7/8	8	2.304	2 15/16	3.242	4	2 3/8	1 7/8	1 7/8	4 1/2	2	1 7/8
2	8	2.652	3 1/8	3.449	4 1/4	2 1/2	2	2	4 3/4	2 1/8	2
2 1/4	8	3.423	3 1/2	3.862	4 3/4	2 3/4	2 1/4	2 1/4	5 1/4	2 3/8	2 1/4
2 1/2	8	4.292	3 7/8	4.275	5 1/4	3 1/16	2 1/2	2 3/8	5 7/8	2 5/8	2 1/2
2 3/4	8	5.259	4 1/4	4.688	5 3/4	3 3/8	2 3/4	2 5/8	6 1/2	3	2 3/4
3	8	6.324	4 5/8	5.102	6 1/4	3 5/8	3	2 7/8	7	3 1/4	3
3 1/4	8	7.487	5	5.515	6 5/8	3 3/4	3 1/4	3	7 1/4	3 1/2	3 1/4
3 1/2	8	8.749	5 3/8	5.928	7 1/8	4 1/8	3 1/2	3 1/4	8	3 3/4	3 1/2
3 3/4	8	10.108	5 3/4	6.341	7 5/8	4 7/16	3 3/4	3 1/2	8 5/8	4	3 3/4
4	8	11.566	6 1/8	6.755	8 1/8	4 5/8	4	3 5/8	9	4 1/4	4



Nut dimensions are based on American National Standard ASME B18.2.2

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Section 5 – RCB-11 – END FLANGES AND BOLTING

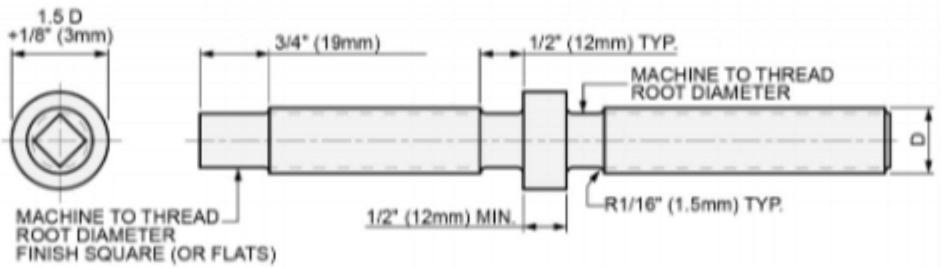


FIGURE RCB-11.8.1
TYPE I COLLAR STUD (SOLID TYPE)

FIGURE RCB-11.8.2
TYPE II COLLAR STUD (NUT TYPE)

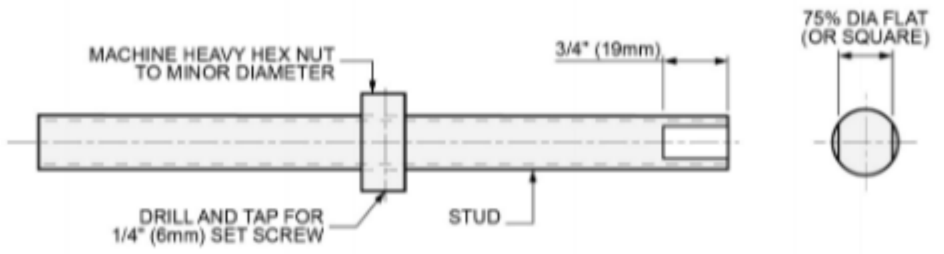


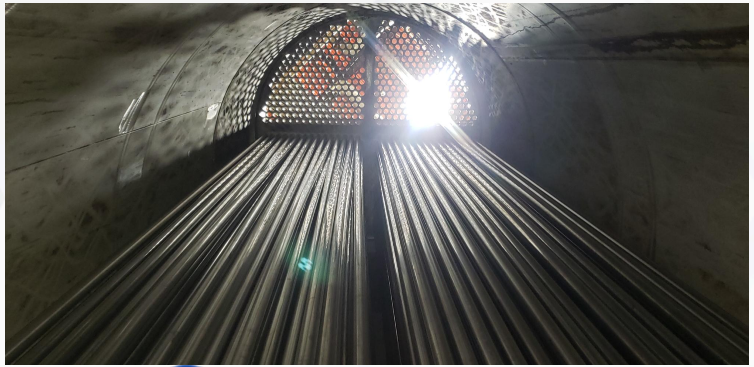
FIGURE RCB-11.8.3
ASSEMBLY AND DRILLING DETAILS (TYPES I AND II)

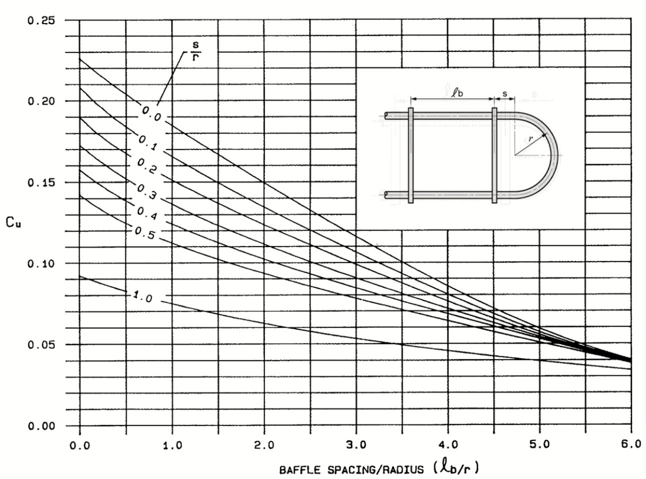
Section 6: V – Flow Induced Vibration

- Shell side fluid flow can sometimes cause tubes to vibrate and become damaged.
- This phenomenon is very complex.
- This section defines the basic data which should be considered when evaluating vibration problems.

TABLE V-5.3
FUNDAMENTAL NATURAL FREQUENCY

Span Geometry	Equation	Nomenclature	
(1) BAFFLES; ℓ; EDGE CONDITION: BOTH ENDS SIMPLY SUPPORTED	$f_n = 10.838 \dfrac{AC}{l^2}\left[\dfrac{EI}{w_0}\right]^{1/2}$	A = Tube axial stress multiplier. See Paragraph V-6 C = Constant depending on edge condition geometry.	
(2) TUBESHEET, BAFFLE; ℓ; EDGE CONDITION: ONE END FIXED, OTHER END SIMPLY SUPPORTED		Span Geometry	C
(3) TUBESHEETS; ℓ; EDGE CONDITION: BOTH ENDS FIXED		1	9.9
		2	15.42
		3	22.37





Section 7: T – Thermal Relations

- The basic size and configuration of a heat exchanger needed to achieve the required heat transfer is determined in the thermal design.
- This section provides procedures for thermal design including effects of fouling and determination of mean metal temperatures for mechanical design.

T-1.2 BASIC HEAT TRANSFER RELATION

$$A_0 = \frac{Q}{U \Delta t_m}$$

where

$A_0 =$ Required effective outside heat transfer surface, ft²

$Q =$ Total heat to be transferred, BTU/hr

$U =$ Overall heat transfer coefficient, referred to tube outside surface BTU/hr ft² °F

$\Delta t_m =$ Corrected mean temperature difference, °F

T-4.3.2 TUBE MEAN METAL TEMPERATURE

The tube mean metal temperature is dependent not only on the tube fluid average temperature, but also the shell fluid average temperature, the shell and tube heat transfer coefficients, shell and tube fouling resistances, and tube metal resistance to heat transfer, according to the following relationship

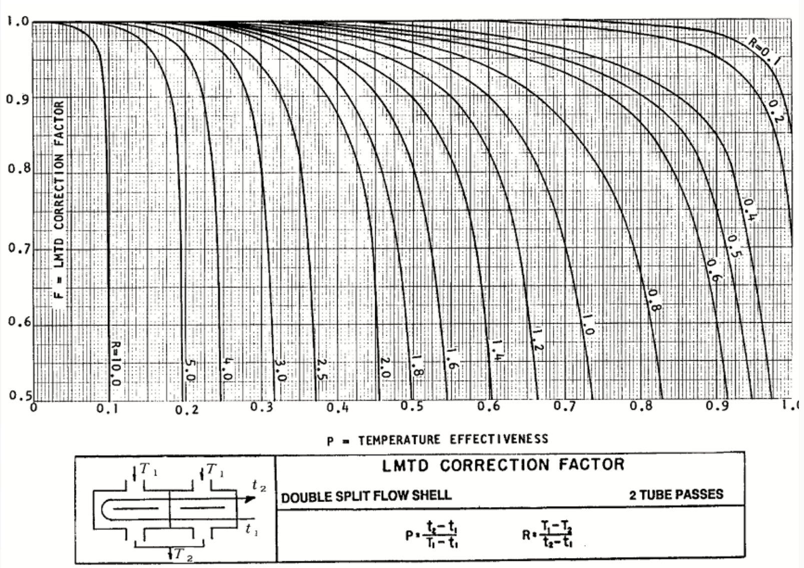
$$t_M = \bar{T} - \left[\frac{\left(\frac{1}{h_o} + r_o\right)\left(\frac{1}{E_f}\right) + \frac{r_w}{2}}{\left(\frac{1}{h_o} + r_o\right)\left(\frac{1}{E_f}\right) + r_w + \left(r_i + \frac{1}{h_i}\right)\left(\frac{A_o}{A_i}\right)} \right] \left[\bar{T} - \bar{t}\right]$$

where

$t_M =$ Tube mean metal temperature, °F

$\bar{t} =$ Tube side fluid average temperature, °F (see Paragraph T-4.4)

All other terms are as defined by Paragraphs T-1.3 and T-4.3.1.



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Section 8: P – Physical Properties of Fluids

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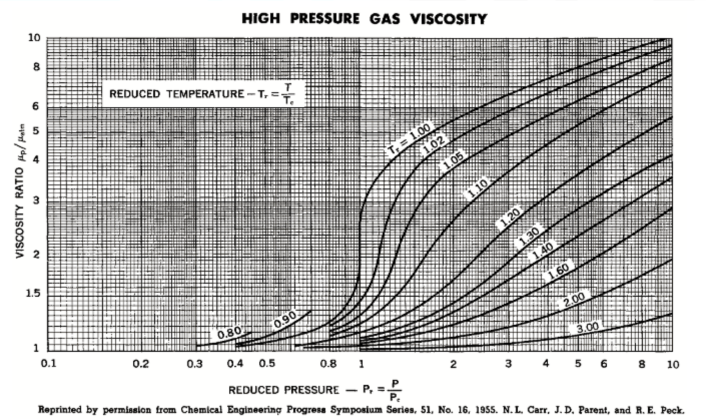
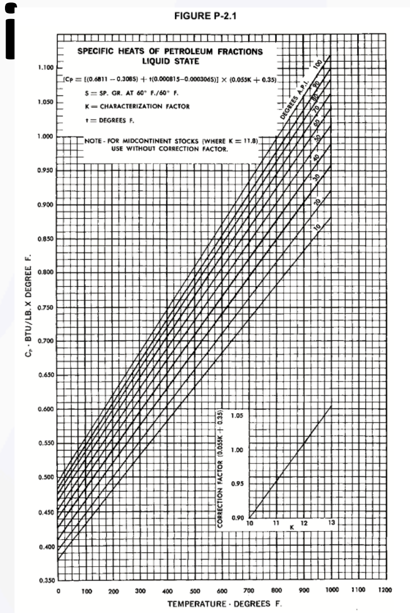
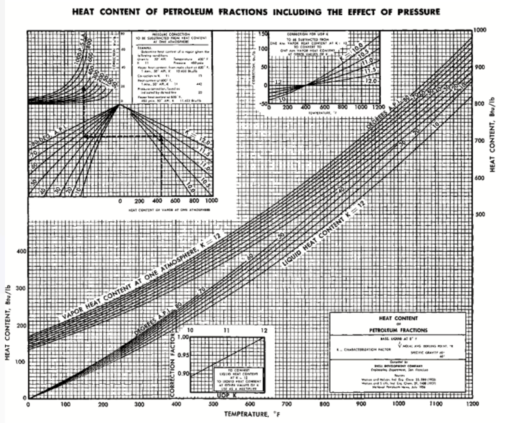
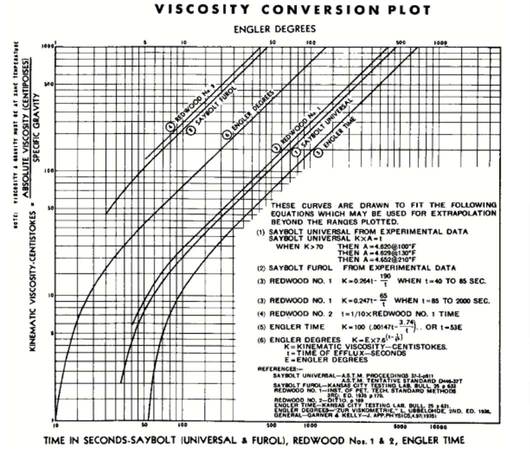
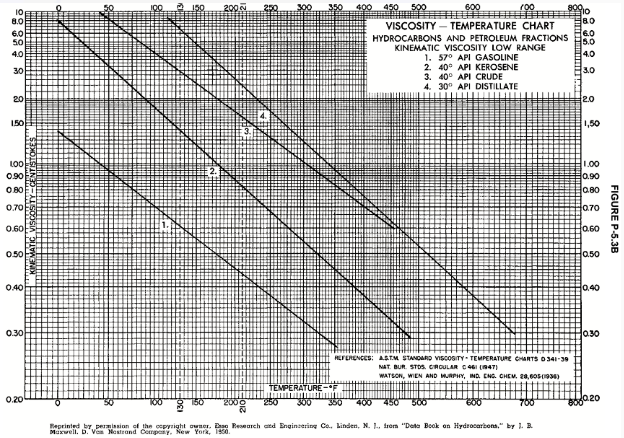




- Many charts of fluid properties, mostly used for thermal design.







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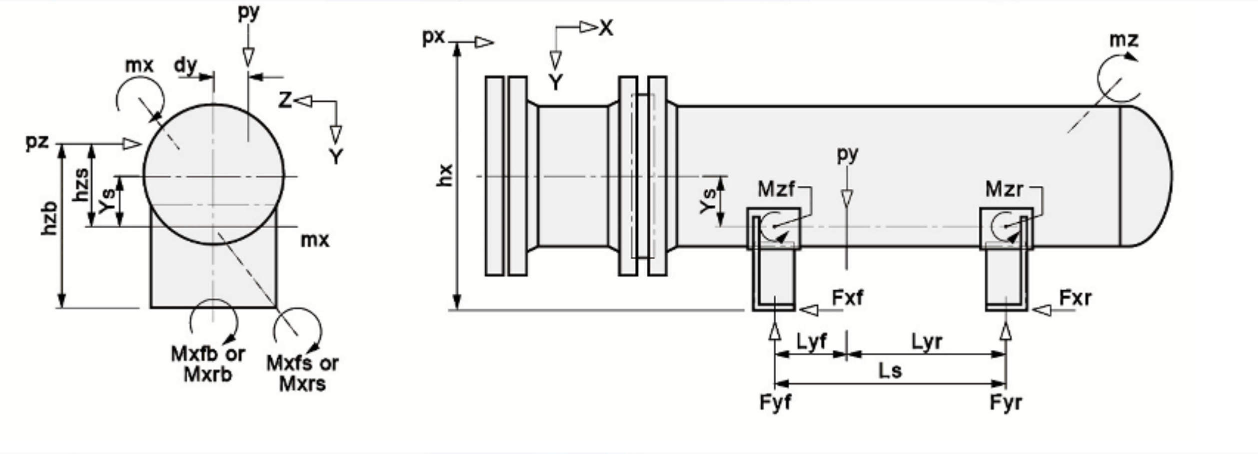
Section 10: RGP – Recommended Good Practice

- Additional information and guidance relative to design of exchangers.
- Information should be considered but is not required.

Example: Support Design



Section 10: RGP – Recommended Good Practice

Example: Fouling Factors

RGP-T-2.1 TYPES OF FOULING

Currently five different types of fouling mechanisms are recognized. They are individually complex, often occurring simultaneously, and their effects may increase pressure drop, accelerate corrosion and decrease the overall heat transfer coefficient.

(1) Precipitation Fouling

Crystallization is one of the most common types of precipitation fouling. It occurs in many process streams, cooling water and chemical streams. Crystallization scale forms as the result of over-saturation of a relatively insoluble salt. The most common, calcium carbonate, forms on heat transfer surfaces as a result of the thermal decomposition of the bicarbonate ion and the subsequent reaction with calcium ions.

(2) Particulate Fouling

Sedimentation is the most common form of particulate fouling. Particles of clay, sand, silt, rust, etc. are initially suspended in the fluid and form deposits on the heat transfer surfaces. Sedimentation is frequently superimposed on crystallization and possibly acts as a catalyst for certain types of chemical reaction fouling.

(3) Chemical Reaction Fouling

Surface temperatures and the presence of oxidation promoters are known to significantly influence the rate of build up of this fouling type. Coking, the hard crust deposit of hydrocarbons formed on high temperature surfaces, is a common form of this type of fouling.

(4) Corrosion Fouling

Iron oxide, the most common form of corrosion product, is the result of an electro-chemical reaction and forms as a scale on iron-containing, exposed surfaces of the heat exchanger. This scale produces an added thermal resistance to the base metal of the heat transfer surface.

(5) Biological Fouling

Organic material growth develops on heat transfer surfaces in contact with untreated water such as sea, river, or lake water. In most cases, it will be combined or superimposed on other types of fouling such as crystallization and sedimentation. Biological growth such as algae, fungi, slime, and corrosive bacteria represent a potentially detrimental form of fouling. Often these micro-organisms provide a sticky holding medium for other types of fouling which would otherwise not adhere to clean surfaces.

Fouling Resistances for Industrial Fluids

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

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Non-Mandatory Appendix A: Tubesheet Design

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- Legacy tubesheet design method that has been superseded by ASME Part UHX for most new exchangers.
- Method may apply to existing exchangers, designs not in the scope of UHX, or exchangers not requiring ASME code design.

A.1.3.1 TUBESHEET FORMULA – BENDING

$$T = \frac{FG}{3}\sqrt{\frac{P}{\eta S}}$$

where

T = Effective tubesheet thickness, in. (mm)

S = Code allowable stress in tension, psi (kPa), for tubesheet material at design metal temperatures (see Paragraph RCB-1.4.2)

For outside packed floating head exchangers (Type P), P shall be as defined in Paragraph A.1.4.1, psi (kPa).

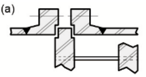
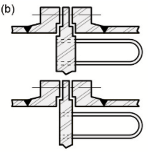
For packed floating end exchangers with lantern ring (Type W), for the floating tubesheet, P shall be as defined in Paragraph A.1.4.2, psi (kPa).

For fixed tubesheet exchangers, P shall be as defined in Paragraph A.1.5.3, A.1.5.4, or A.1.5.5, psi (kPa).

For other type exchangers, P shall be the design pressure, shell side or tube side, corrected for vacuum when present on the opposite side, or differential pressure when specified by the purchaser, psi (kPa).

For U-tube tubesheets (Type U) and for stationary tubesheets where the opposite tubesheet is a floating tubesheet, where the tubesheet is extended as a flange for bolting to heads or shells with ring type gaskets, P psi (kPa) is given by the following:

TABLE A.1.3.2

	TUBESHEET THICKNESS FOR SHEAR		
	$T = \left[\frac{0.31 D_L}{(1-d_0/Pitch)}\right]\left(\frac{P}{S}\right)$		Note: Must be calculated for shell side or tube side pressure, whichever is controlling.
	d0 = Outside tube diameter, in. (mm). For integrally finned tubes, the OD of the tube in the tubesheet shall be used.	Pitch = Tube spacing, center-to-center, in. (mm)	S = Code allowable stress in tension, psi (kPa). For tubesheet material at design metal temperature. (See Paragraph RCB-1.4.2)
	P		D_L
(a) 	Design pressure, psi (kPa), shell side or tube side, corrected for vacuum when present on opposite side, or differential pressure when specified by customer.		$D_L = 4\left(\frac{A}{C}\right)$ C = Perimeter of tube layout measured stepwise in increments of one tube-to-tube pitch center-to-center of the outermost tubes, in. (mm). See Figure A.1.3.2 A = total area enclosed by C, in^2 (mm^2). See Figure A.1.3.2
(b) 	Design pressure, psi (kPa), shell side or tube side, corrected for vacuum when present on opposite side, or differential pressure when specified by customer.		
	Design pressure, psi (kPa), shell side or tube side,		

A.1.5.4 EFFECTIVE TUBE SIDE DESIGN PRESSURE

The effective tube side design pressure is to be taken as the greatest absolute value of the following:

$$P = \frac{P_t' + P_{Bt} + P_d}{2} \qquad \text{or } P = P_t' + P_{Bt} \qquad \text{when } P_s' \text{ is positive}$$

$$P = \frac{P_t' - P_s' + P_{Bt} + P_d}{2} \qquad \text{or } P = P_t' - P_s' + P_{Bt} \qquad \text{when } P_s' \text{ is negative}$$

where

$$P_t' = P_t\left[\frac{1 + 0.4JK(1.5 + f_t)}{1 + JKF_q}\right]$$

P_t = Tube side design pressure, psi (kPa) (For vacuum design, P_t is negative.)

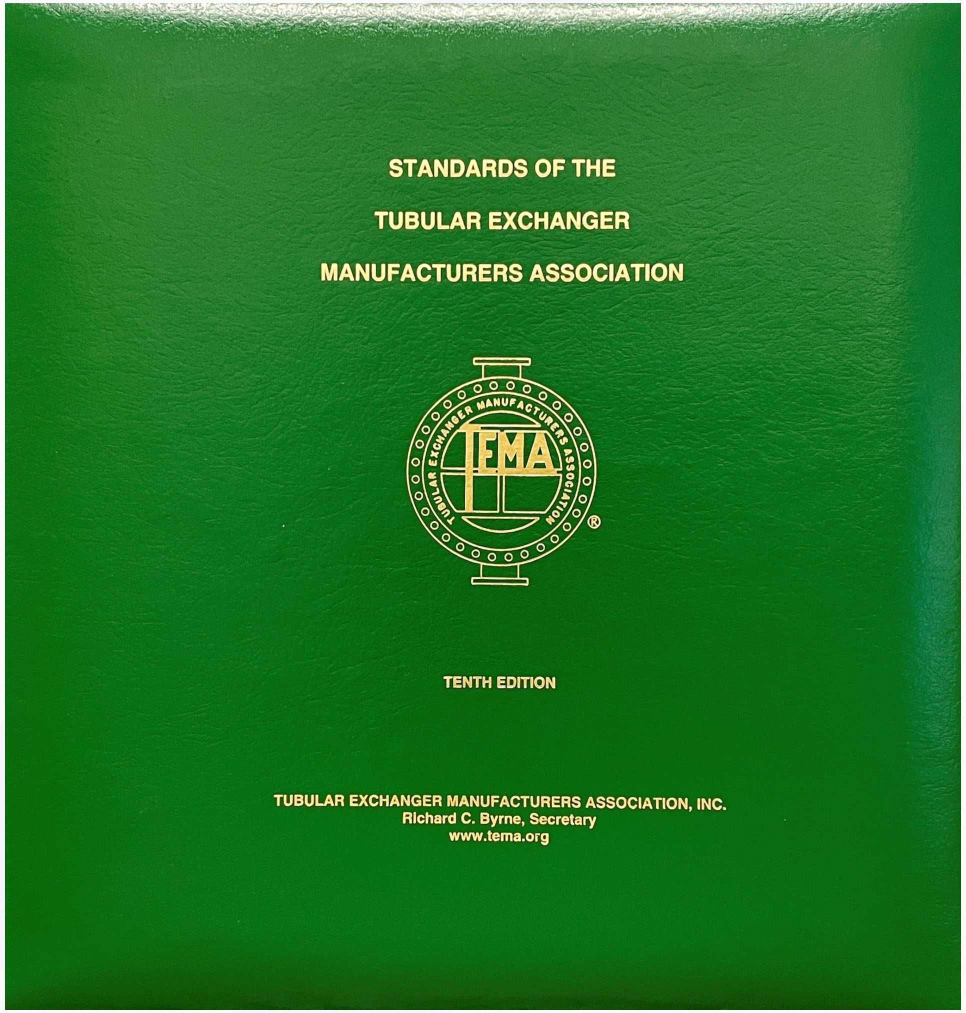
$$f_t = 1 - N\left(\frac{d_0 - 2t_t}{G}\right)^2$$

Conclusion

- Along with design codes, the TEMA Standard is used worldwide as the construction standard for shell and tube heat exchangers.
- Specify your next exchanger be built to TEMA Standards to ensure industry-leading quality, reliability, and performance.

Conclusion

- Purchase the TEMA Standard at:
  - 💻shop.tema.org
  - 📞(914) 332-0040
  - 📧 info@tema.org



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