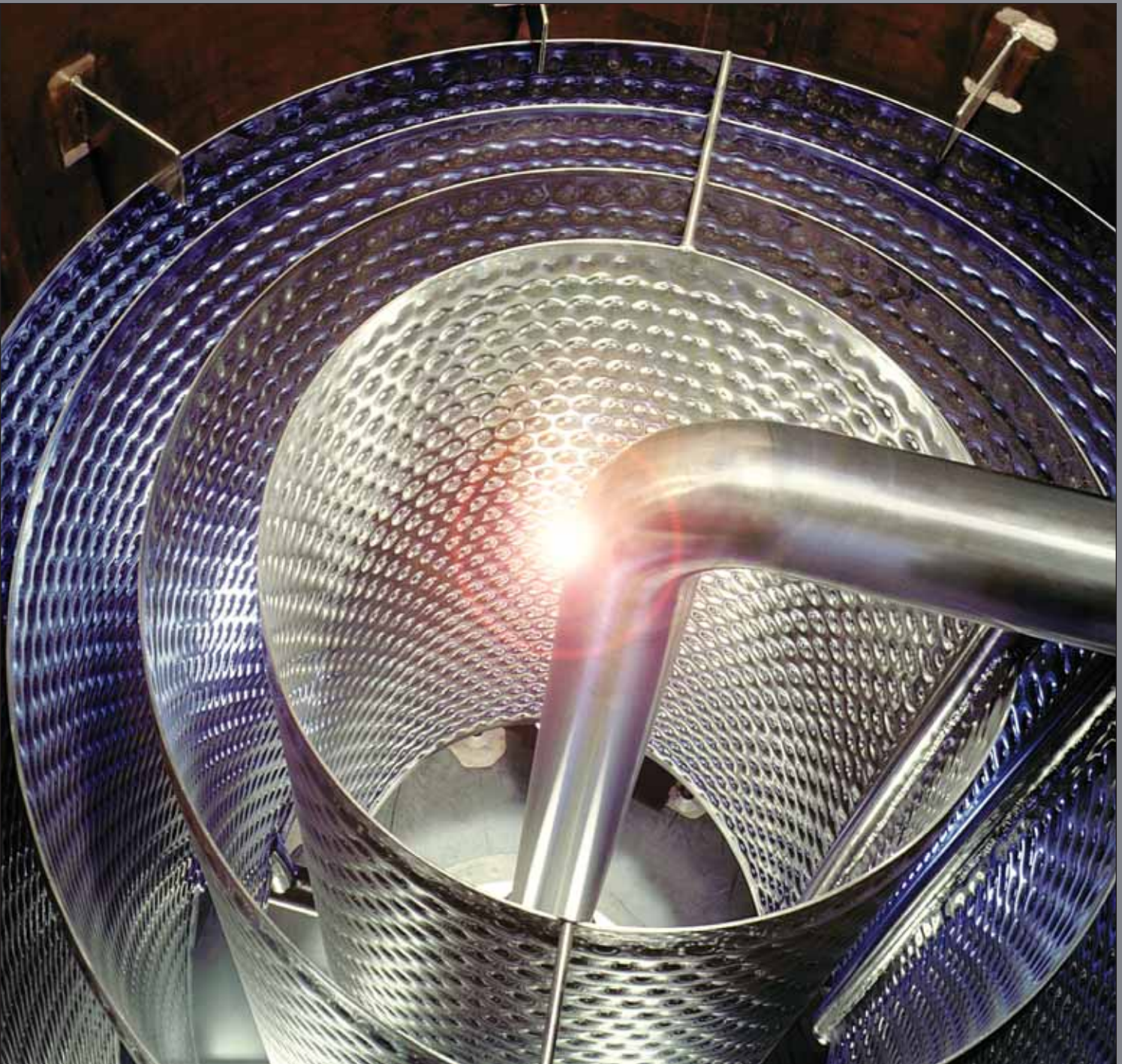


ALL ABOUT TEMP-PLATE®

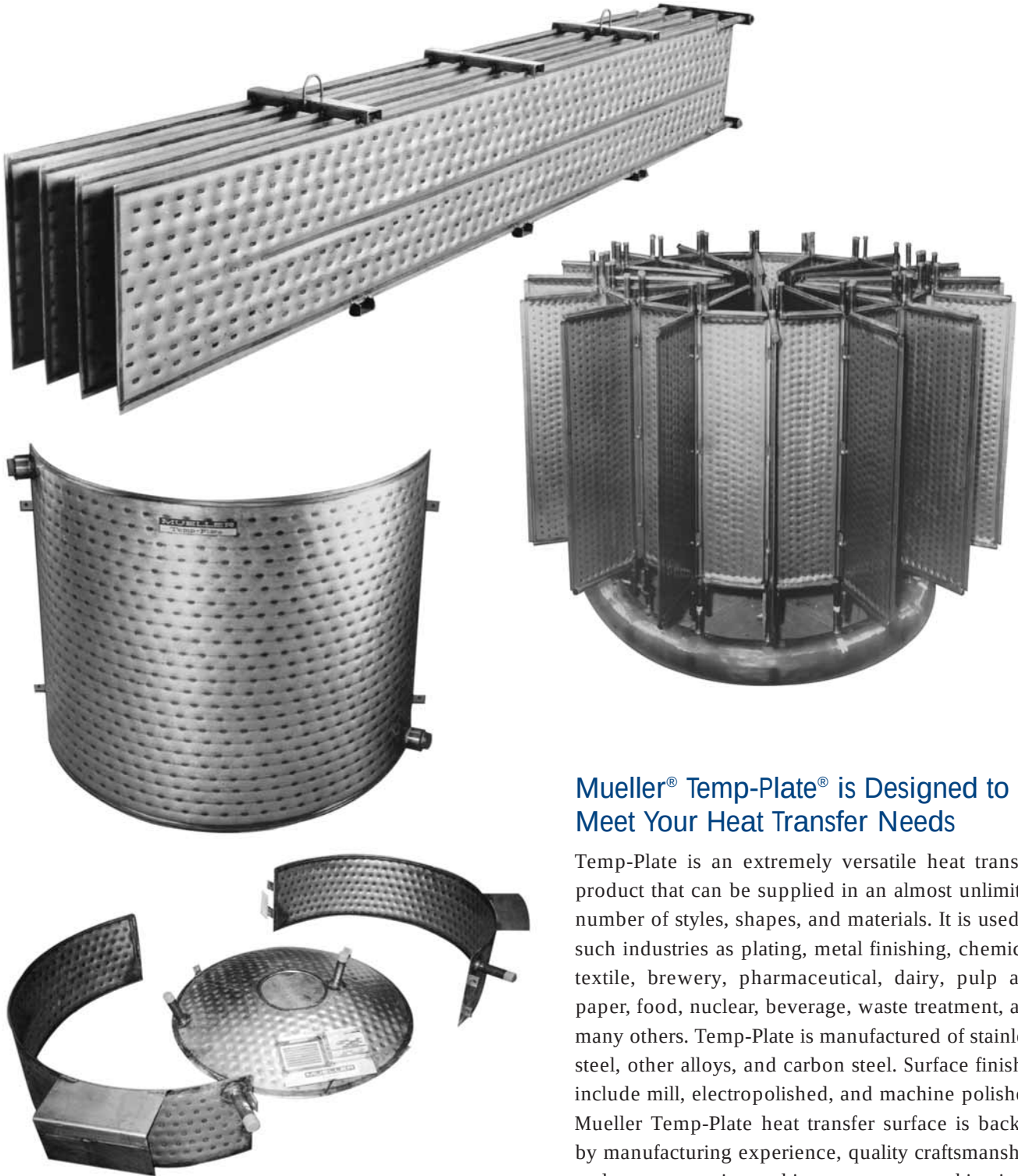


MUELLER®

HEAT TRANSFER PRODUCTS

TABLE OF CONTENTS

What Is Mueller® Temp-Plate®?	1
Styles of Mueller Temp-Plate	2
Temp-Plate Designs	3
Advantages of Mueller Temp-Plate	4
Size Selection of Mueller Temp-Plate	5
How to Order	6
Type 9 Mueller Temp-Plate	7
Type 8 Mueller Temp-Plate	8
Type 7 Mueller Temp-Plate	9
Type 6 Mueller Temp-Plate	10
Type 5 Mueller Temp-Plate	11
Optional Features and Accessories	12
Materials, Metal Thicknesses, and Design Pressures	13
Pressure Drop Curves	14
Metric Conversion Table - Glossary of Symbols	15
Solving Heat Transfer Problems	16
Properties of Materials	19
Overall Heat Transfer Coefficient “U”	20
LMTD Nomograph	21
Vessel Surface Heat Loads	22
Properties of Saturated Refrigerants	22
Properties of Saturated Steam - Steam Requirements	23
Heating Application Curves	24
Cooling Load vs. Water Flow and Refrigeration Capacity	25
Positioning, Piping, and Trapping for Steam Heating	26
Cleaning, Maintenance, and Repairs	28
Thermal Expansion	30
Corrosion Resistance Table	31
The Problems of Corrosion	38
Product Applications	42
Immersion Sections	44
Clamp-On Sections	45
Jacketed Shell and Head Sections	46
(Supplied for Use as an integral Part of the Vessel)	47
Special Applications	48
Energy Conservation	50
Food Service Display Units	51



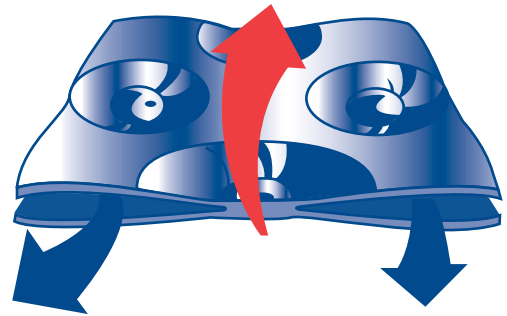
Mueller® Temp-Plate® is Designed to Meet Your Heat Transfer Needs

Temp-Plate is an extremely versatile heat transfer product that can be supplied in an almost unlimited number of styles, shapes, and materials. It is used in such industries as plating, metal finishing, chemical, textile, brewery, pharmaceutical, dairy, pulp and paper, food, nuclear, beverage, waste treatment, and many others. Temp-Plate is manufactured of stainless steel, other alloys, and carbon steel. Surface finishes include mill, electropolished, and machine polished. Mueller Temp-Plate heat transfer surface is backed by manufacturing experience, quality craftsmanship, and constant testing and improvements, making it the most versatile, dependable, and economical heat transfer surface available.

STYLES OF MUELLER TEMP-PLATE

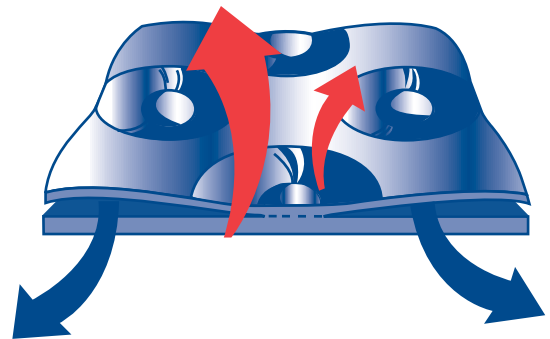
Double-Embossed Surface

Inflated Both Sides — Commonly used in immersion applications, the Mueller Temp-Plate double-embossed construction maximizes the heating and cooling process by utilizing both sides of the heat transfer plate. Inflated both sides and using two sheets of material the same thickness, the double-embossed design is available in stainless steel, other alloys, and carbon steel; in many material gauges and working pressures.



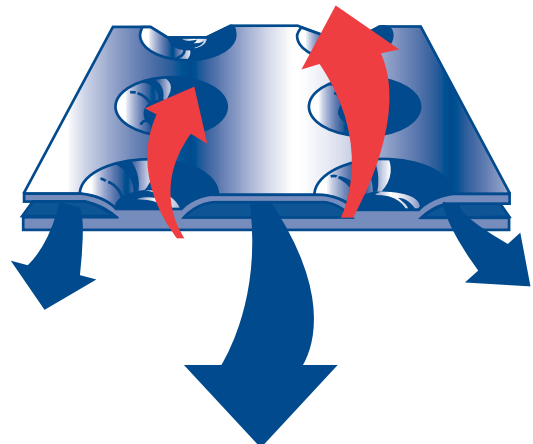
Single-Embossed Surface

Inflated One Side — Mueller Temp-Plate single-embossed heat transfer surface is an economical type to utilize for interior tank walls, conveyor beds, and when a flat side is required. The single-embossed design uses two sheets of material of different thicknesses and is available in stainless steel, other alloys, and carbon steel; in many material gauges and working pressures.



Dimpled Surface

Dimpled One Side — Dimpled Mueller Temp-Plate construction is machine punched and swaged prior to welding to increase the flow area in the passages. It is available in stainless steel, other alloys, and carbon steel; in many material gauges and working pressures; and in both MIG plug welding and resistance spot welding processes.

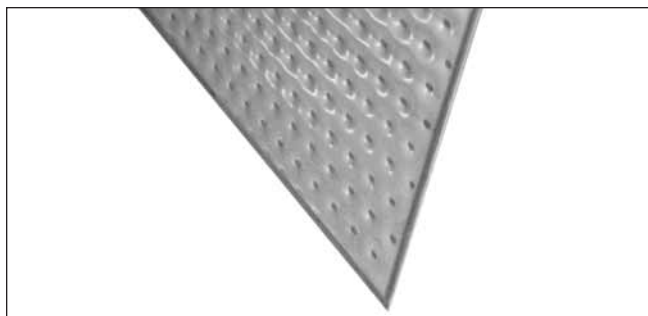


Welding Methods Used to Fabricate Mueller Temp-Plate Heat Transfer Surface

Temp-Plate is usually welded by the resistance spot welding process (RSW) and/or the resistance seam welding process (RSEW).

In resistance spot welding, the metal is pressed together with two electrodes. After pressure is applied, a current is passed through the two pieces of base metal; and due to the resistance to electrical flow at the two base metal contact surfaces, this area heats up and forms a small molten puddle. Pressure is retained and the current shut off; then the molten puddle freezes forming the weldment between the two pieces. After the nugget is solid, pressure is released and the part then indexes to the next spot location for a repeat of the weld cycle.

Resistance seam welding is produced by a series of overlapping spot welds. Current passes through the metal as the wheel-shaped electrode, with pressure applied, rolls over it. The current can also be switched on and off at preset timed intervals so that a spot weld effect is made. The width and length of these spot welds can be controlled by the width of the electrode and current on-off time.



Photograph shows resistance spot and resistance seam welding.

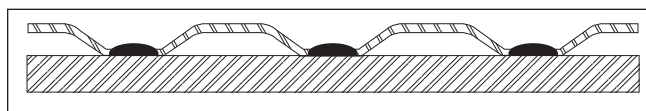
The perimeter of the RSW Temp-Plate is resistance seam welded (RSEW) or using a conventional arc-welding method (i.e.: GTAW, GMAW, etc.).

Single, round resistance spot welds are used where back-up plate thickness does not exceed $\frac{1}{4}$ ".

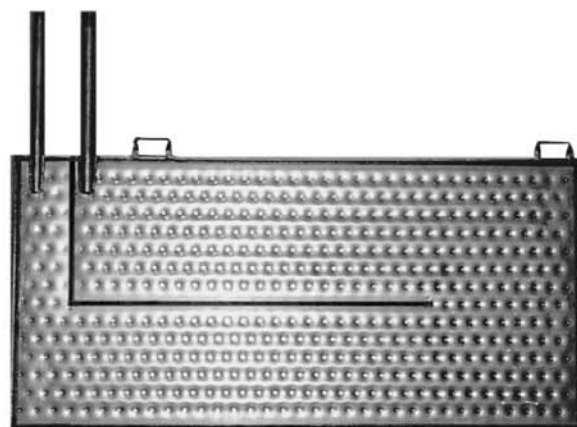
Gas metal-arc welding (GMAW-MIG) is required if back-up plate is heavier than $\frac{1}{4}$ ". This process may also be used on material lighter than $\frac{1}{4}$ " plate when installing Temp-Plate on a vessel that has already been formed (i.e., shell sections, heads, etc.) or when alloy combinations are not suited for resistance welding.

In this process, $\frac{1}{2}$ " diameter holes are evenly spaced and filled with the GMAW process or GTAW process filler metal. In filling these holes, fusion of the jacket material to the bottom or heavier section is accomplished. This style of Temp-Plate is referred to as dimpled jacket, and the perimeter is usually welded with the GMAW process.

An alternate method now available offers the ability to resistance spot weld the dimpled jacket-style Temp-Plate with a perimeter weldment made with the GMAW process.



Section showing gas metal arc welding (MIG) on a dimpled jacket-style Temp-Plate. Also available with resistance spot welding.



Mueller Temp-Plate serpentine pattern.



Mueller Temp-Plate steam pattern.

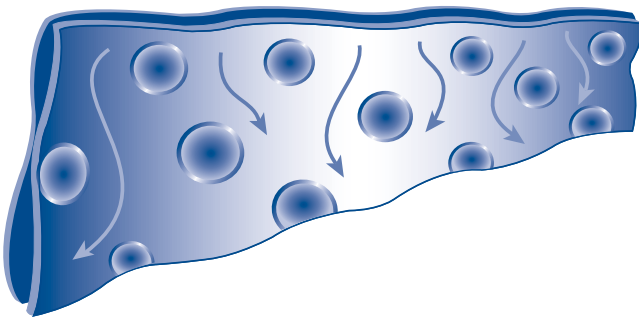
ADVANTAGES OF MUELLER TEMP-PLATE

Double-Embossed Design Maximizes Heating / Cooling Efficiency

Inflated on both sides, double-embossed immersion sections are available in stainless steel, other alloys, and carbon steel; in many gauges and working pressures.

Unique Temp-Plate Design Reduces Condensate Build-Up

Mueller's inflated design reduces condensate build-up common with typical "header" and "multiple-header," die-formed, embossed plate heat exchangers.



Free-Flow Pattern Reduces Fatigue Failure

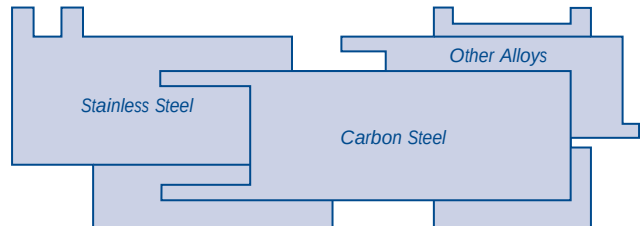
Significantly reduces "fatigue failure" due to condensate build-up — problems common to conventional, preformed heat transfer surfaces — by utilizing Mueller's inflated Temp-Plate immersion sections.

Built-In Performance and Craftsmanship

Mueller immersion sections are backed by manufacturing experience, quality craftsmanship, constant testing and improvements, and proven customer satisfaction. Whatever the industry, our units have proven to be the most versatile, dependable, and economical heat transfer sections available.

Wide Variety of Designs and Materials Immediately Available

Our wide variety of designs and materials are available in mill, electropolished, and machine polished surface finishes.



Some Important Facts You Should Know About Temp-Plate

In addition to the variety of sizes carried in stock, Mueller can fabricate any special size to order.

The size of Temp-Plate required for specific heating applications can be calculated from the chart below and on the following page. Temp-Plate is interchangeable with the die-formed, embossed plate heat exchangers when specified.

Mueller Temp-Plate is capable of being designed for safe operating pressures up to 350 psi for 16-gauge stainless steel and up to 240 psi for 14-gauge carbon steel. For actual application, consult other tables within this catalog or call the Paul Mueller Company Heat Transfer Products Division for further details.

Standard types and sizes of Mueller Temp-Plate are shown on pages 7 thru 11.

HEAT TRANSFER AREAS (All styles in square feet. Larger sizes available.)

Nominal Width in Inches	Length in Inches																
	18	23	29	35	47	59	71	83	95	107	119	131	143	155	167	179	191
12	3.1	3.9	5.0	6.0	8.1	10.1	12.2	14.2	16.3	18.4	20.4	22.5	24.5	26.6	28.7	30.7	32.8
24		7.9	10.0	12.0	16.1	20.3	24.4	28.5	32.6	36.7	40.9	45.0	49.1	53.2	57.3	61.5	65.6
36				18.0	24.2	30.4	36.6	42.7	48.9	55.1	61.3	67.5	73.6	79.8	86.0	92.2	98.4
48					32.3	40.5	48.8	57.0	65.2	73.5	81.7	90.0	98.2	106.4	114.7	122.9	131.2

SIZE SELECTION OF MUELLER TEMP-PLATE

WEIGHT CHART

Nominal Width in Inches	Length in Inches											
	23	29	35	47	59	71	83	95	107	119	131	143
12	12	15	10	25	32	38	44	51	57	64	70	76
24	26	34	41	55	68	83	97	111	125	139	155	167
36	37	47	57	77	96	116	136	157	176	196	216	235
48	54	65	78	103	128	153	178	203	228	254	279	304

Note: Approximate weights (in pounds) based on No. 14 gauge; for No. 16 gauge multiply by .8; or for No. 12 gauge multiply by 1.4.

PIPE OR COUPLING SIZES

Temp-Plate Size Pipe or Coupling Sizes*		Type 7 & 9 Supply	Return	Type 8 Supply & Return	Type 5 & 6 Supply & Return
Width	Up to 17"	1"	3/4"	1"	3/4"
Length	All Lengths				
Width	18" thru 25"	1"	3/4"	1"	3/4"
Length	Thru 47" Long				
Width	18" thru 25"	1 1/2"	3/4"	1 1/2"	3/4"
Length	Over 47" Long				
Width	26" thru 47"	2"	1"	2"	1"
Length	All Lengths				

*Double embossed only.

TEMP-PLATE SIZE / STYLES 7,8,9

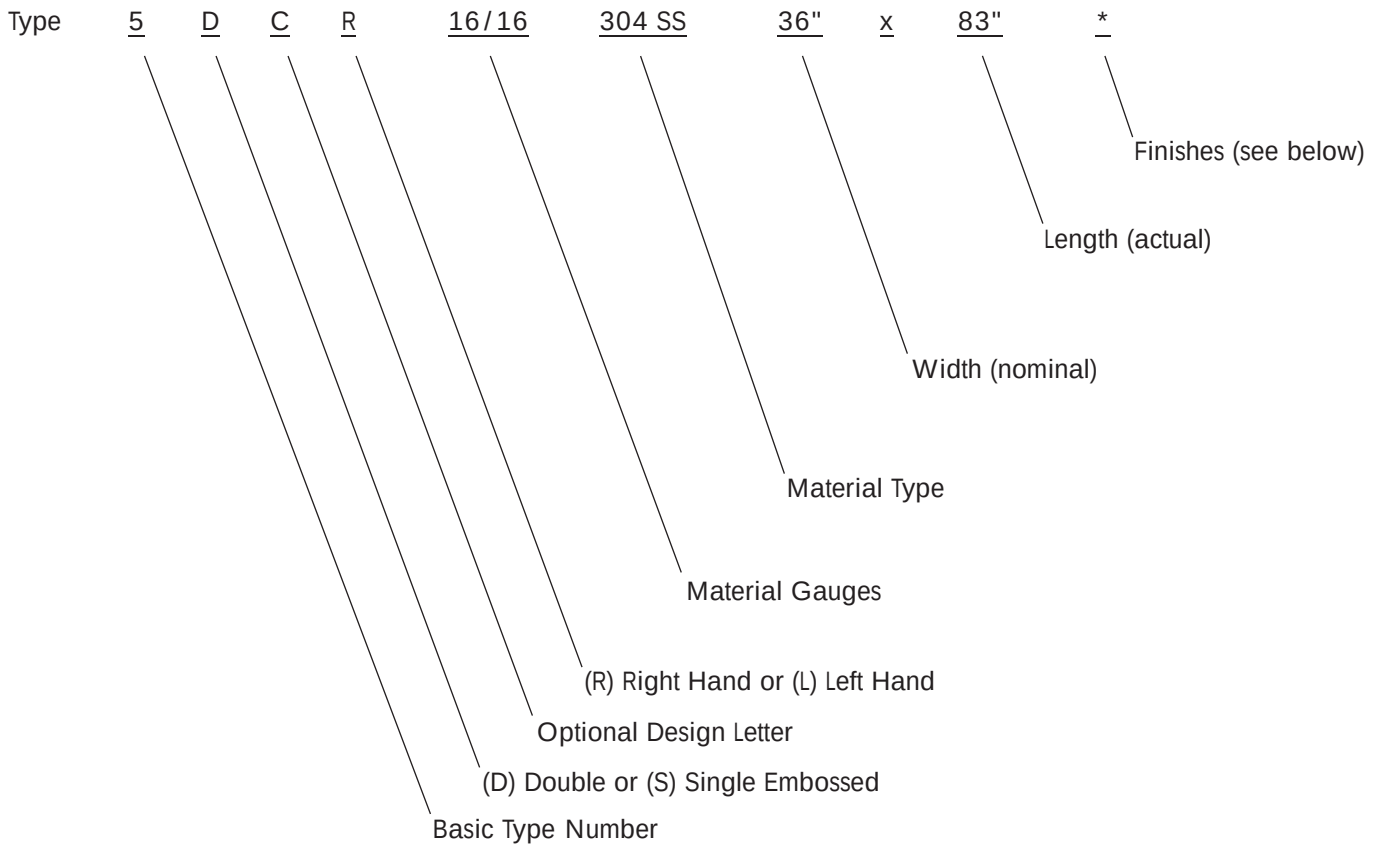
		Heating Water from 60°F in One Hour Using steam	Width	12"			24"								36"								
PSI	Temp. °F		Length	29"	35"	47"	29"	35"	47"	59"	71"	83"	95"	35"	47"	59"	71"	83"	95"	107"	119"	131"	143"
15	160	Btuh x 1,000		104	124	166	207	249	334	421	506	591	676	373	502	630	759	886	1014	1143	1271	1400	1526
15	160	Gal. Water/Hr		124	149	199	249	298	400	505	607	709	811	448	602	756	910	1062	1216	1370	1524	1679	1830
15	160	Condensate – #/Hr		110	132	176	219	263	353	446	535	625	715	395	531	667	803	937	1073	1209	1345	1481	1615
15	180	Btuh x 1,000		93	111	149	186	224	300	378	455	531	607	335	451	566	682	796	911	1027	1142	1258	1371
15	180	Gal. Water/Hr		93	111	149	223	268	360	453	545	637	728	402	541	679	818	954	1092	1231	1369	1508	1644
15	180	Condensate – #/Hr		99	118	158	197	237	317	400	481	562	643	355	477	599	722	842	964	1086	1209	1331	1451
15	200	Btuh x 1,000		81	97	130	163	195	262	330	397	463	530	293	393	494	595	694	795	896	997	1098	1197
15	200	Gal. Water/Hr		70	84	111	195	234	314	396	476	556	636	351	472	593	714	832	953	1074	1195	1316	1435
15	200	Condensate – #/Hr		86	103	138	172	206	277	349	420	490	561	310	416	523	630	735	841	948	1055	1161	1266
25	160	Btuh x 1,000		117	141	188	235	282	378	477	573	669	766	423	568	714	859	1003	1148	1294	1439	1585	1728
25	160	Gal. Water/Hr		141	169	226	282	338	453	572	687	802	918	507	681	856	1031	1202	1377	1551	1726	1901	2072
25	160	Condensate – #/Hr		126	151	201	251	302	405	510	613	717	820	453	608	764	920	1074	1229	1385	1541	1697	1850
25	180	Btuh x 1,000		107	129	172	215	257	345	435	523	611	699	386	519	652	785	916	1049	1182	1315	1448	1579
25	180	Gal. Water/Hr		107	129	172	257	309	414	522	628	733	839	463	622	782	941	1098	1258	1417	1577	1736	1893
25	180	Condensate – #/Hr		114	138	184	230	276	370	466	560	655	749	413	556	698	841	981	1123	1266	1408	1550	1690
25	200	Btuh x 1,000		96	115	154	192	231	310	390	469	548	627	346	465	585	704	821	941	1060	1179	1298	1416
25	200	Gal. Water/Hr		82	99	132	231	277	371	468	563	657	752	415	558	701	844	985	1128	1271	1414	1557	1698
25	200	Condensate – #/Hr		103	124	165	206	247	332	418	503	587	671	371	498	626	754	879	1007	1135	1262	1390	1516
50	160	Btuh x 1,000		142	171	228	284	341	458	577	694	811	927	512	688	865	1041	1214	1391	1567	1744	1920	2093
50	160	Gal. Water/Hr		171	205	273	341	409	549	692	832	972	1112	614	825	1037	1248	1456	1668	1879	2091	2302	2510
50	160	Condensate – #/Hr		156	187	249	312	374	502	633	761	889	1017	561	755	948	1141	1332	1525	1718	1912	2105	2295
50	180	Btuh x 1,000		133	159	212	265	318	427	538	647	755	864	477	641	806	970	1132	1296	1460	1625	1789	1951
50	180	Gal. Water/Hr		133	159	212	318	381	512	645	775	906	1036	572	769	966	1163	1357	1554	1751	1948	2145	2339
50	180	Condensate – #/Hr		145	174	232	291	349	468	590	709	828	947	523	703	884	1064	1241	1421	1601	1782	1962	2139
50	200	Btuh x 1,000		122	147	196	245	294	394	497	597	697	797	440	592	744	895	1044	1196	1348	1499	1651	1800
50	200	Gal. Water/Hr		105	126	168	293	352	472	595	716	836	956	528	710	892	1073	1252	1434	1616	1798	1980	2158
50	200	Condensate – #/Hr		134	161	214	268	322	432	544	654	764	874	483	649	815	982	1145	1311	1478	1644	1810	1974
100	160	Btuh x 1,000		174	209	278	348	417	560	706	848	991	1133	626	841	1057	1272	1485	1700	1916	2131	2347	2559
100	160	Gal. Water/Hr		209	250	334	417	500	671	846	1017	1188	1359	750	1009	1267	1526	1780	2038	2297	2555	2814	3068
100	160	Condensate – #/Hr		197	237	316	395	474	635	801	963	1125	1286	710	955	1200	1444	1685	1930	2174	2419	2664	2904
100	180	Btuh x 1,000		165	196	263	329	395	530	668	803	938	1073	593	797	1001	1205	1406	1610	1814	2018	2222	2423
100	180	Gal. Water/Hr		165	196	263	395	474	636	801	963	1125	1287	711	955	1200	1445	1686	1930	2175	2420	2665	2905
100	180	Condensate – #/Hr		187	224	299	374	448	602	759	912	1065	1218	673	904	1136	1368	1596	1827	2059	2291	2522	2750
100	200	Btuh x 1,000		155	186	248	310	372	499	629	756	883	1010	558	750	942	1134	1323	1515	1707	1899	2091	2280
100	200	Gal. Water/Hr		133	159	213	372	446	598	754	907	1059	1211	669	899	1129	1360	1586	1817	2047	2277	2508	2734
100	200	Condensate – #/Hr		176	211	281	352	422	566	714	858	1002	1147	633	851	1069	1287	1502	1720	1938	2156	2374	2588
(u=155)		Area-Approx. Square Feet		5.0	6.0	8.0	10.0	12.0	16.1	20.3	24.4	28.5	32.6	18.0	24.2	30.4	36.6	42.7	48.9	55.1	61.3	67.5	73.6

HOW TO ORDER

How to Order Mueller Temp-Plate Heat Transfer Surface

Specific Temp-Plate designs and options are indicated by a combination of numbers and letters. See the example below for an analysis of these combinations. Be sure to include all of this information when ordering Temp-Plate.

Example:



Finishes:

MATERIAL FINISHES

- 2B - Cold Reduced from Mill
- No. 4 - Belt Polished - 150 Grit (320 Grit Polish Available)
- EP - Electropolished

WELD FINISHES

- A1 - Weld Discoloration Left On
- Weld Discoloration Removed
- SB - Sandblast
- GB - Glassbead Blast
- Grind to a Specified Grit

TYPE 9 MUELLER TEMP-PLATE

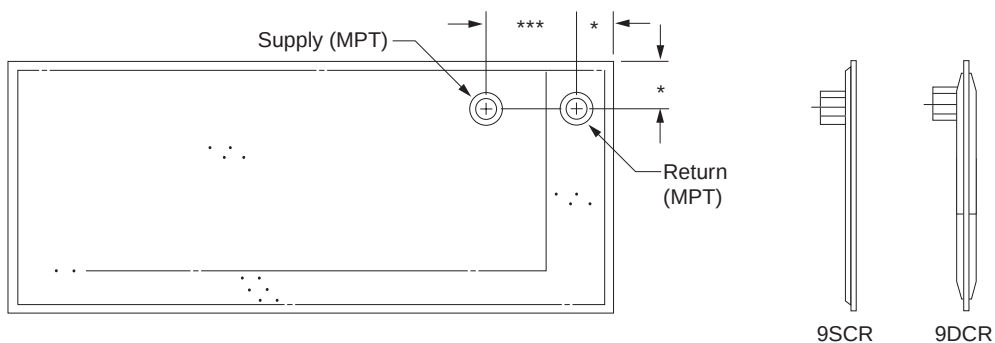
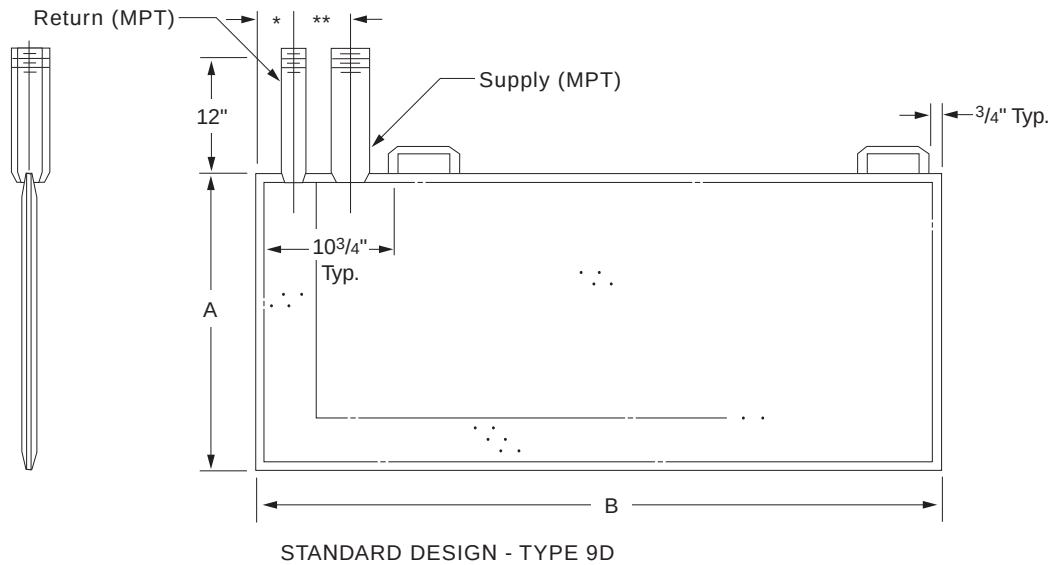
Double- or Single-Embossed

Type 9 Temp-Plate is designed for heating with steam as a medium. Hangers are available for installing Temp-Plate with handles on inner walls of tanks.

Note: Consult factory for connection sizes if length B exceeds 143".

PIPE OR COUPLING SIZES

Temp-Plate Size	Supply	Return
A Up to 17"	1"	3/4"
B All Lengths		
A 18" thru 25"	1"	3/4"
B Thru 47" Long		
A 18" thru 25"	1 1/2"	3/4"
B Over 47" Long		
A 26" thru 47"	2"	1"
B All Lengths		



*Dimension will be held to a practical minimum unless otherwise requested.

**4" with 1" or 1 1/2" inlet; 6" with 2" inlet.

***4" with 1" inlet "Supply"; 5" with 1 1/2" inlet "Supply"; 6" with 2" inlet "Supply."

Notes: 1. Dimensions, arrangement, and fittings may be changed to satisfy practically all requirements.

Notes: 2. Drawings are for illustrations; they do not represent actual inflation dimensions.

TYPE 8 MUELLER TEMP-PLATE

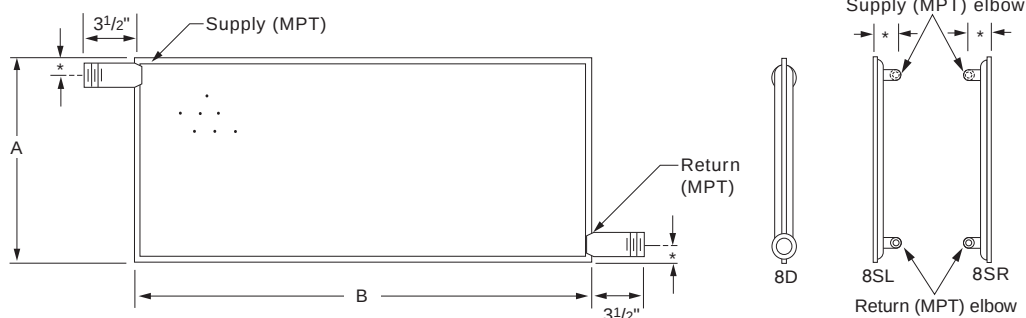
Double- or Single-Embossed

Type 8 Temp-Plate design may be used for steam, refrigerants, or liquids. It is ideal if requirement is for a high liquid flow rate with minimal pressure drop. Inlet and outlet connections are identically sized for versatility.

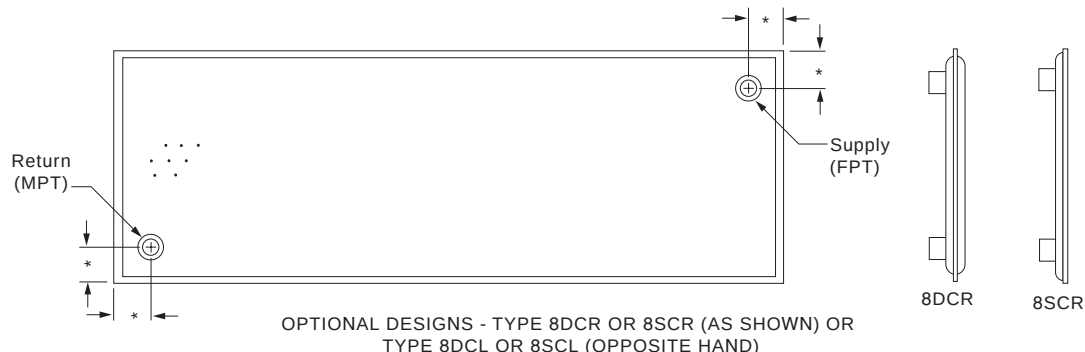
Note: Consult factory for connection sizes if length B exceeds 143".

PIPE OR COUPLING SIZES

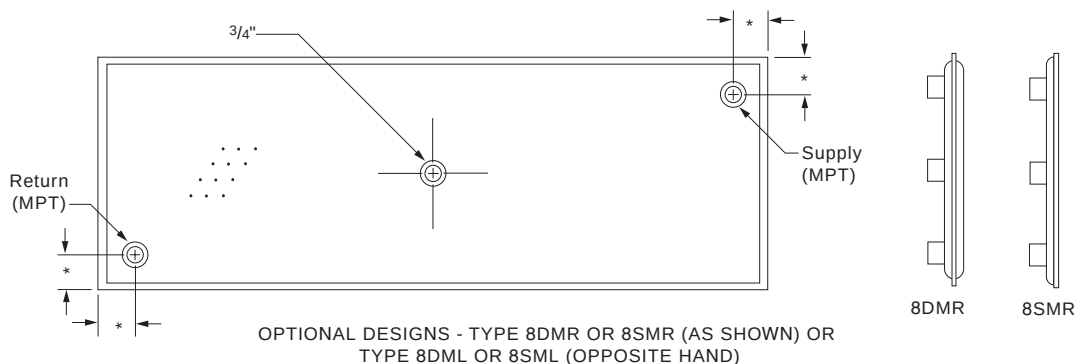
Temp-Plate Size	Supply	Return
A Up to 17"	1"	3/4"
B All Lengths		
A 18" thru 25"	1"	3/4"
B Thru 47" Long		
A 18" thru 25"	1 1/2"	3/4"
B Over 47" Long		
A 26" thru 47"	2"	1"
B All Lengths		



STANDARD DESIGN - TYPE 8D (AS SHOWN BOTH VIEWS)
OPTIONAL DESIGNS - TYPE 8SR OR 8SL (FITTINGS DEPICTED CORRECTLY IN END VIEWS ONLY)



OPTIONAL DESIGNS - TYPE 8DCR OR 8SCR (AS SHOWN) OR
TYPE 8DCL OR 8SCL (OPPOSITE HAND)



OPTIONAL DESIGNS - TYPE 8DMR OR 8SMR (AS SHOWN) OR
TYPE 8DML OR 8SML (OPPOSITE HAND)

*Dimension will be held to a practical minimum unless otherwise requested.

Notes: 1. Dimensions, arrangement, and fittings may be changed to satisfy practically all requirements.

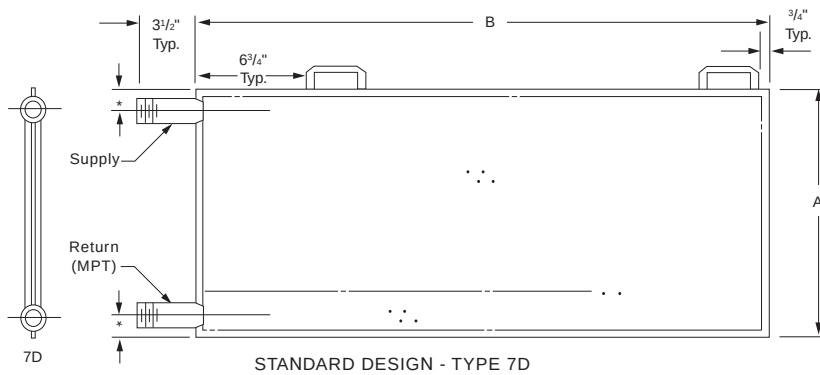
2. Drawings are for illustrations, they do not represent actual inflation dimensions.

TYPE 7 MUELLER TEMP-PLATE

Double- or Single-Embossed

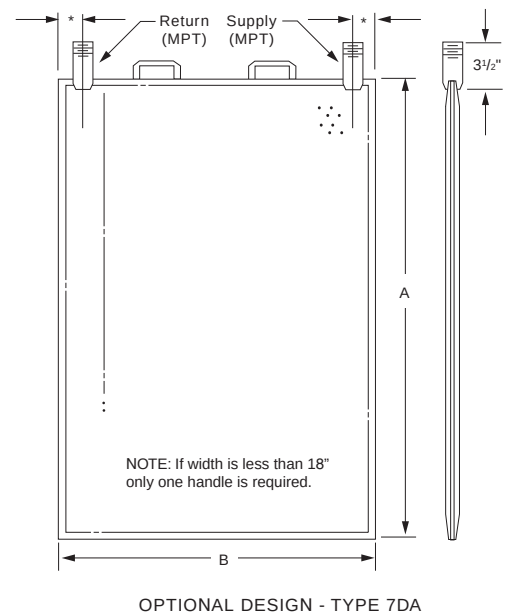
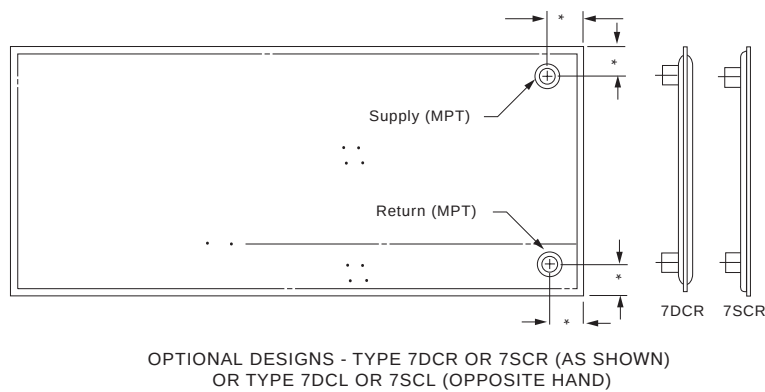
Type 7 Temp-Plate is designed for steam. Several can be grouped in a bank with a common manifold, or a single Temp-Plate can be piped in a variety of ways.

Note: Consult factory for connection sizes if length B exceeds 143".



CONNECTIONS FOR DOUBLE-EMBOSSED PIPE OR COUPLING SIZES

Temp-Plate Size	Supply	Return
A Up to 17"	1"	3/4"
B All Lengths		
A 18" thru 25"	1"	3/4"
B Thru 47" Long		
A 18" thru 25"	1 1/2"	3/4"
B Over 47" Long		
A 26" thru 47"	2"	1"
B All Lengths		



*Dimension will be held to a practical minimum unless otherwise requested.

Notes: 1. Dimensions, arrangement, and fittings may be changed to satisfy practically all requirements.
2. Drawings are for illustrations, they do not represent actual inflation dimensions.

TYPE 6 MUELLER TEMP-PLATE

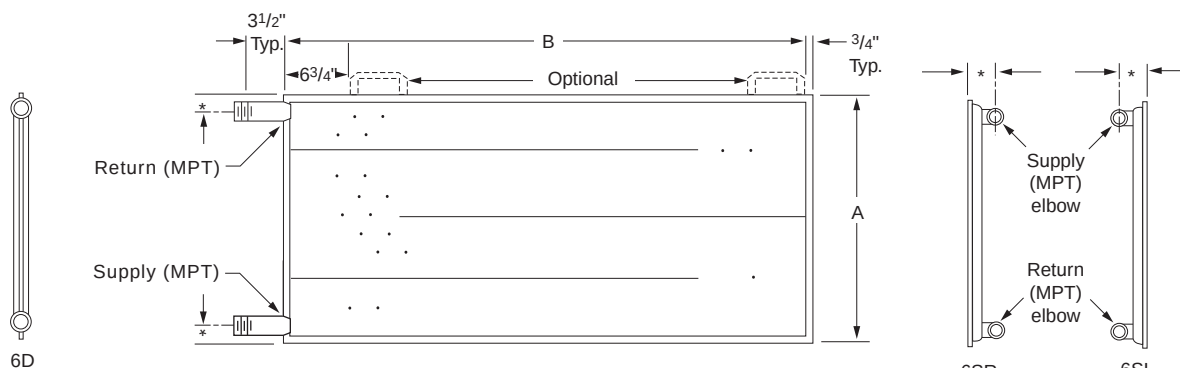
Double- or Single-Embossed

Type 6 Temp-Plate is arranged for serpentine flow. It is designed for increased velocities resulting in accelerated heat transfer when using hot or cold water, hot oil, flooded refrigerants, etc.

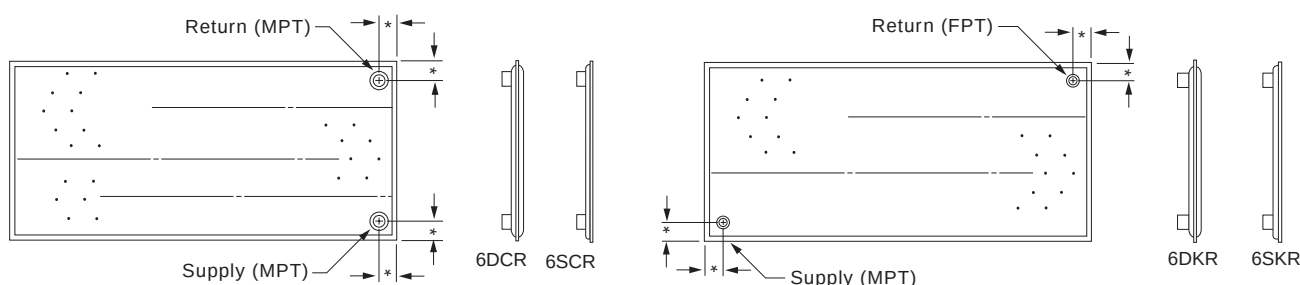
PIPE OR COUPLING SIZES

Temp-Plate Size	Double-Embossed Supply & Return	Single-Embossed Supply & Return
A Thru 25"	3/4"	1/2"
B All Lengths		
A 26" thru 47"	1"	3/4"
B All Lengths		

Note: Consult factory for connection sizes if length B exceeds 143".

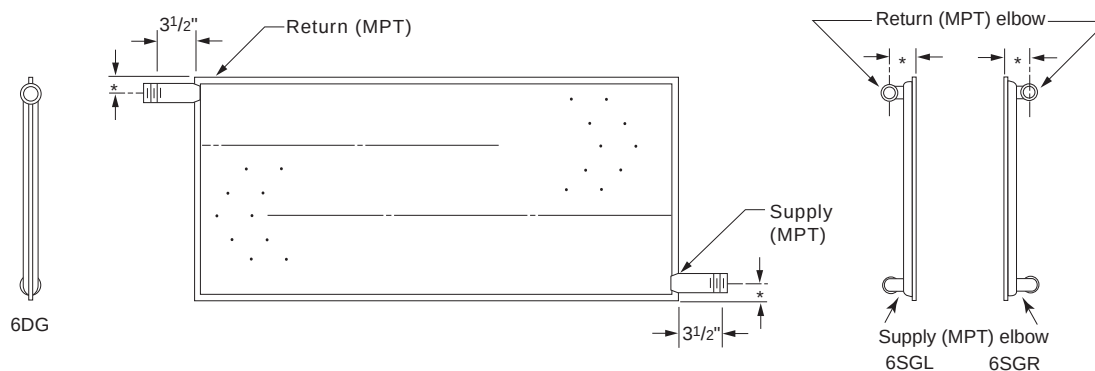


STANDARD DESIGN - TYPE 6D (AS SHOWN BOTH VIEWS)
OPTIONAL DESIGNS - TYPE 6SR OR 6SL (FITTINGS DEPICTED CORRECTLY IN END VIEWS ONLY)



OPTIONAL DESIGNS - TYPE 6DCR OR 6SCR (AS SHOWN)
OR TYPE 6DCL OR 6SCL (OPPOSITE HAND)

OPTIONAL DESIGNS - TYPE 6DKR OR 6SKR (AS SHOWN)
OR TYPE 6DKL OR 6SKL (OPPOSITE HAND)



OPTIONAL DESIGN - TYPE 6DG (AS SHOWN BOTH VIEWS)
OR TYPE 6SGR OR 6SGL (FITTINGS DEPICTED CORRECTLY IN END VIEWS ONLY)

*Dimension will be held to a practical minimum unless otherwise requested.

Notes: 1. Dimensions, arrangement, and fittings may be changed to satisfy practically all requirements.

2. Number of passes will depend on design conditions.

3. Drawings are for illustrations, they do not represent actual inflation dimensions.

TYPE 5 MUELLER TEMP-PLATE

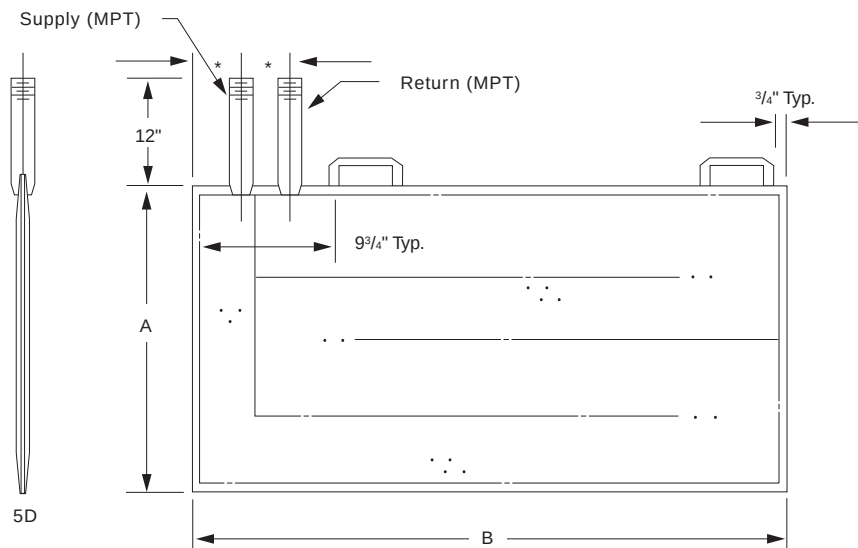
Double- or Single-Embossed

Type 5 Temp-Plate is designed mainly for use inside tanks for heating or cooling with various liquid heat transfer media. The serpentine flow pattern effects rapid heat transfer.

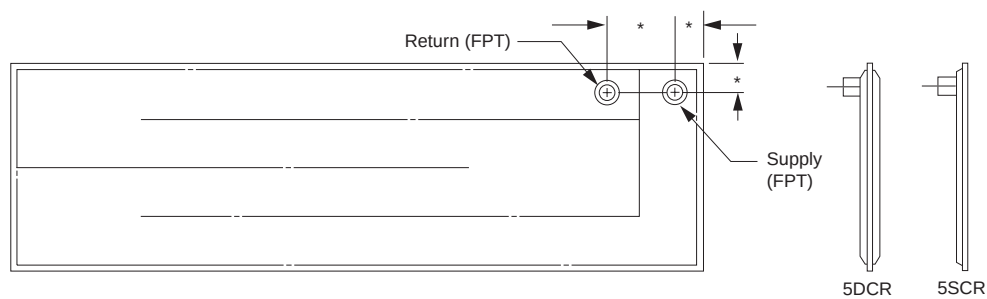
Note: Consult factory for connection sizes if length B exceeds 143".

PIPE COUPLING SIZES

Temp-Plate Size	Supply & Return
A Thru 25"	3/4"
B All Lengths	
A 26" thru 47"	1"
B All Lengths	



STANDARD DESIGN - TYPE 5D



OPTIONAL DESIGN - TYPE 5DCR OR 5SCR (AS SHOWN)
OR TYPE 5DCL OR 5SCL (OPPOSITE HAND)

**Dimension will be held to a practical minimum unless otherwise requested.*

Notes: 1. Dimensions, arrangement, and fittings may be changed to satisfy practically all requirements.

2. Number of passes will depend on design conditions.

3. Drawings are for illustrations, they do not represent actual inflation dimensions.

OPTIONAL FEATURES AND ACCESSORIES

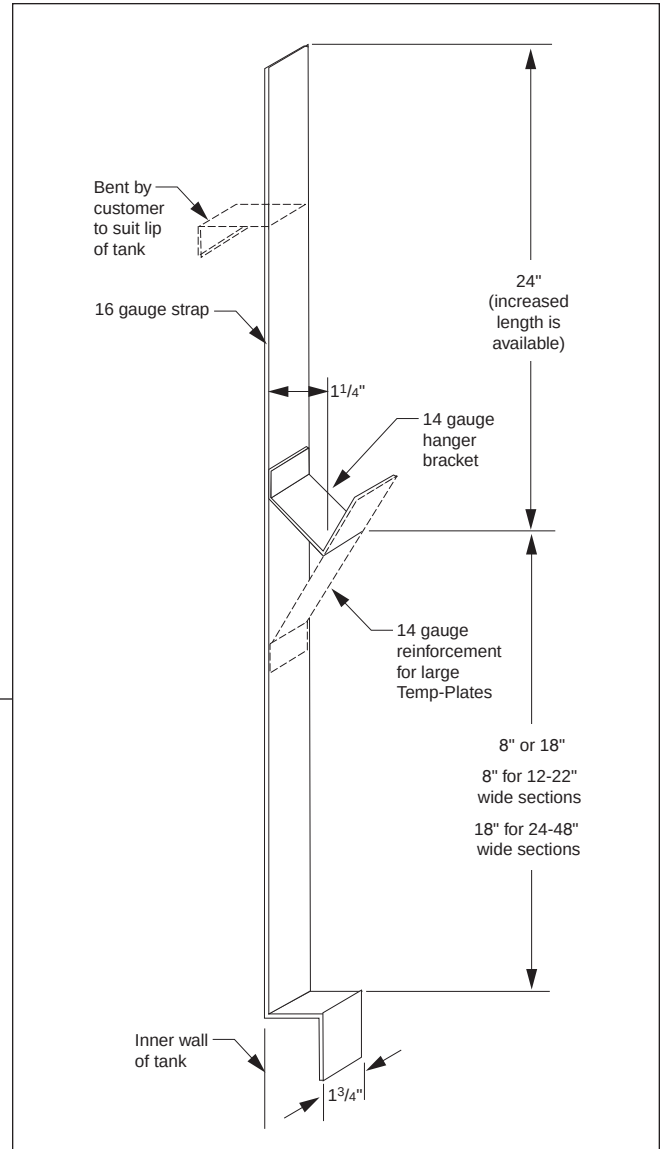
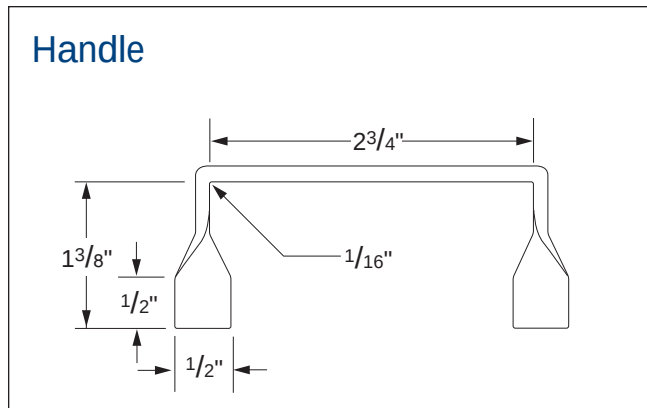
Standard Temp-Plate production size limits are 72" x 192". For larger custom designs, odd shapes and sizes, or cutouts, contact Paul Mueller Company.

Hangers

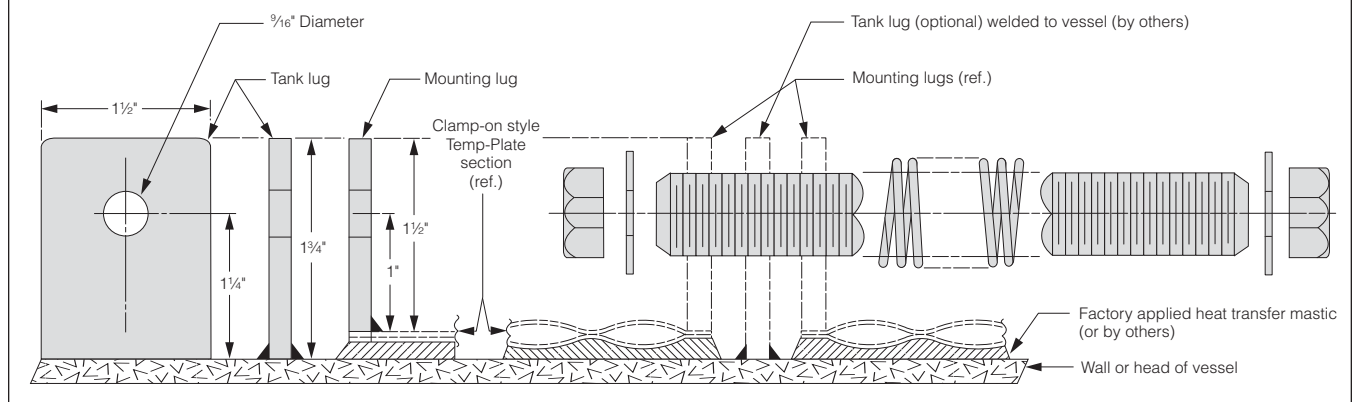
Hangers provide an inexpensive means of mounting Mueller Temp-Plate inside tanks. They maintain correct spacing between tank walls and the Temp-Plate.

Handles on the Temp-Plate are hooked onto hanger brackets on the tank wall. The hangers are made from either Type 316L stainless steel, titanium, or carbon steel.

Reinforcements for hanger brackets are required for Temp-Plate weighing in excess of 200 pounds. It may be necessary that the bent tab at the top of the hanger be bolted to the lip of the tank for support of an exceptionally heavy Temp-Plate.



Spring-Loaded Bolt Assemblies and Mounting Lugs



MATERIALS, METAL THICKNESSES, AND DESIGN PRESSURES

DOUBLE EMBOSSED (See Note 2)

Materials	Gauges (MM)	Maximum Operating Pressure PSIG @ 400°F (See Note 4)	
		Non-ASME	ASME
304, 316	20 on 20 (.902 on .902)	170	(See Note 1)
304, 316	18 on 18 (1.22 on 1.22)	240	140
304, 316	16 on 16 (1.51 on 1.51)	450	190
304, 316	14 on 14 (1.91 on 1.91)	500	210
304, 316	12 on 12 (2.67 on 2.67)	1,000	400
A-620 Carbon Steel	14 on 14 (1.91 on 1.91)	633	273
A-620 Carbon Steel	12 on 12 (2.67 on 2.67)	665	290
Titanium, Grade 1	20 on 20 (.902 on .902)	175	(See Note 1)
Titanium, Grade 1	16 on 16 (1.51 on 1.51)	245	(See Note 5)

SINGLE EMBOSSED (See Note 2)

Materials	Gauges (MM)	Maximum Operating Pressure PSIG @ 400°F (See Note 4)	
		Non-ASME	ASME
304, 316	20 on 14 (.902 on 1.91)	170	(See Note 1)
304, 316	20 on 12 (.902 on 2.67)	170	(See Note 1)
304, 316	18 on 12 (1.22 on 2.67)	400	185
304, 316	18 on 10 (1.22 on 3.43)	400	185
304, 316	18 on 7 (1.22 on 4.94)	400	185

DIMPLED TYPE

Materials	Gauges (MM)	Maximum Operating Pressure PSIG @ 400°F (See Note 4)	
		Non-ASME	ASME
304, 316	16 on 10 (1.51 on 3.43)	275	142 ⁶
304, 316	16 on 3/16" (1.51 on 4.76)	325	135 ⁶
304, 316	16 on 1/4" (1.51 on 6.35)	325	135 ⁶
304, 316	14 on 10 (1.91 on 3.43)	400	142
304, 316	14 on 3/16" (1.91 on 4.76)	400	250
A-620 Carbon Steel	14 on 3/16" (1.91 on 4.76)	300	180
A-620 Carbon Steel	12 on 3/16" (2.67 on 4.76)	300	180

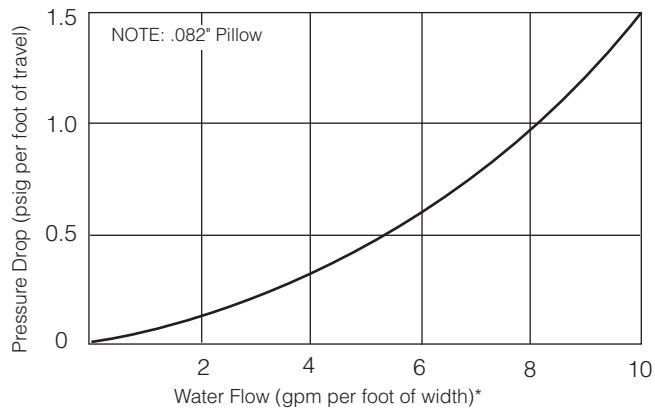
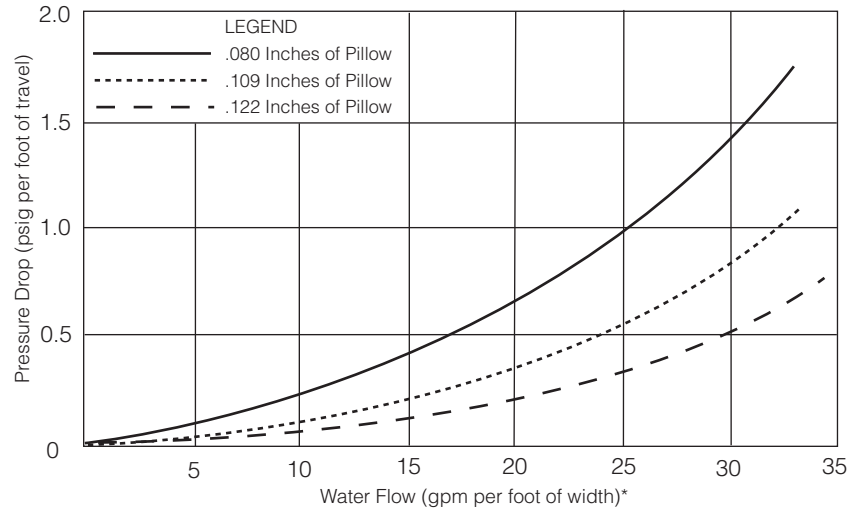
Notes:

1. ASME code requires a minimum of 18-gauge metal thicknesses for resistance-welded designs.
2. Standard circuiting is shown on pages 7-11. Special circuits are available.
3. 1" is the maximum thickness for the heavier side of roll-formed Temp-Plate (single embossed) and dished Temp-Plate heads (single embossed).
4. Higher operating pressures are available. Contact Paul Mueller Company.
5. Contact Paul Mueller Company for ASME availability and pressures.
6. Resistance welded.

PRESSURE DROP CURVES

Inflated Double-Embossed Pressure Drop Test 422

* Water pressure drop data for double-embossed Temp-Plate: 16 ga on 16 ga, 1 7/8" X 1 7/8" spot spacing

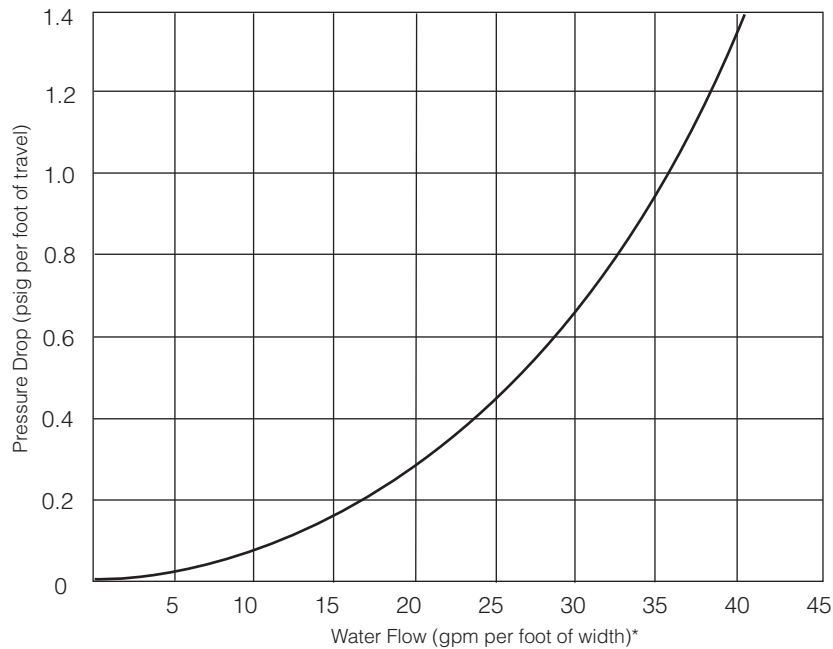


Single-Embossed Pressure Drop

*Water pressure drop data for double-embossed Temp-Plate: 24 ga on 12 ga, 1 1/2" X 1 1/2" spot spacing

Dimpled Pressure Drop Test 329B

*Pressure drop of water in 1/4"-deep dimpled Temp-Plate



Note: The pressure drop curves shown are for information only. For specific data to meet your requirements, consult Paul Mueller Company.

METRIC CONVERSION TABLE — GLOSSARY OF SYMBOLS

UNIT CONVERSION TABLE

	To Convert	Into	Multiply By
Length	Feet	Meters	0.3048
	Inches	Millimeters	25.40
	Meters	Feet	3.281
	Millimeters	Inches	0.03937
Area	Square Feet	Square Meters	0.09290
	Square Meters	Square Feet	10.76
Volume	Gallons	Hectoliters	0.03785
	Gallons	Liters	3.785
	Hectoliters	Gallons	26.42
	Liters	Gallons	0.2642
Weight	Grams	Pounds	0.002205
	Kilograms	Pounds	2.205
	Pounds	Grams	453.6
	Pounds	Kilograms	0.4536
Pressure	Atmospheres	Pounds/Square Inch	14.70
	Bars	Pounds/Square Inch	14.50
	Pascal	Pounds/Square Inch	0.000145
	Pounds/Square Inch	Pascal	6894.0
	Pounds/Square Inch	Atmospheres	0.06804
	Pounds/Square Inch	Bars	0.0649
Power	Btuh	Watts	0.2931
	Horsepower	Watts	745.7
	Watts	Btuh	3.4129
	Watts	Horsepower	0.001341
Energy	Btuh	Kilocalories	0.2520
	Kilocalories	BTU	3.968
Temperature Conversion		$\frac{^{\circ}\text{F} - 32}{9} = \frac{^{\circ}\text{C} \times 9}{5} + 32$	$\frac{^{\circ}\text{C} \times 9}{5} = \frac{^{\circ}\text{F} - 32}{9}$

GLOSSARY OF SYMBOLS

"k"	=	Wall thermal conductivity, Btu per (hr) (sq ft) (°F per ft)
x ₂	=	Wall thickness, ft
"Q"	=	Total heat transfer, Btu
"q"	=	Time rate of heat transfer, Btu per hr
t.d.	=	Temperature difference or change of a material's temperature, °F
△t	=	Temperature difference at given instance on opposite sides of wall, °F
△t ₁	=	(GTD) Greatest temperature between product and medium for heating or cooling, °F
△t ₂	=	(LTD) Least temperature between product and medium for heating or cooling, °F
△T _m	=	(LMTD) Log mean temperature difference, °F
t ₁	=	Higher temperature, °F
t ₂	=	Lower temperature, °F
"R"	=	Thermal resistance, (hr) (sq ft) (°F) per Btu
"A"	=	Area, sq ft
"V"	=	Total volume of vessel, cu ft
"x"	=	Insulating material thickness, ft
"U"	=	Overall heat transfer coefficient, Btu per (hr) (sq ft) (°F)
"c _p "	=	Specific heat of product, Btu per (lb) (°F)
"W"	=	Total weight of product, lb
sp. gr.	=	Specific gravity (water equals 1.0)
h _o	=	Film conductance (outside), Btu per (hr) (sq ft) (°F)
h _i	=	Film conductance (inside), Btu per (hr) (sq ft) (°F)
Btuh	=	British thermal units per hour

SOLVING HEAT TRANSFER PROBLEMS

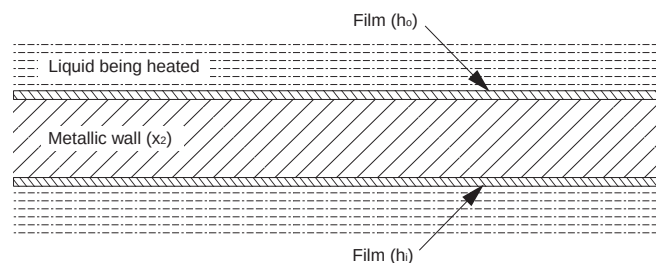
What Is Heat Transfer?

In general, heat transfer is the flow of heat from one substance to another. The flow of heat is always from the higher temperature to the lower temperature.

The general formula for heat transfer is $Q = A \times U \times \Delta t$ (see Glossary of Symbols, page 15). Expressed in more

$$U = \frac{1}{1/h_o + x_2/k + 1/h_i} \quad \text{or} \quad U = \frac{1}{\text{Summation of resistance to heat flow}}$$

exact terms, with $1/h_o$ equal to film resistance on one side of a wall and $1/h_i$ the film resistance on the other side and x_2/k the wall resistance between the films. It should be noted that in most cases the film resistance will be higher than the wall resistance.



Although it is possible to compute the “U” factor, it is an involved process and the results are only accurate when all of the controlling factors are considered. The usual method to obtain a given “U” factor is to test the given materials under normal conditions encountered in the industry. Through extensive testing, the “U” factors given in table (see page 20) are recommended for Temp-Plate as safe design coefficients (i.e., scale deposits, film factors, and vapor film coefficients have been taken into account as well as a safety factor added).

Solving Heat Transfer Problems

Generally, in industrial applications, the equation $Q = A \times U \times \Delta t$ is rewritten to establish “A”, the area required to perform a given heat transfer job, and assumes the form:

$$A = \frac{Q}{U \times \Delta t}$$

This equation can generally be solved in four steps, as follows:

1. Determine “Q” where $Q = V \times (62.4 \times \text{sp. gr.})^* \times c_p \times \text{t.d.}$:

V = Volume of vessel in cubic feet

c_p = Specific heat of product

$\text{t.d.} = t_1 - t_2$ = Temperature change

**Can be expressed in pounds per cubic foot.*

2. Determine “U” from Table on page 20.
3. Determine effective temperature difference “ Δt .” In actual practice and in order to obtain accuracy, in place of “ Δt ” we use the log mean temperature difference, ΔT_m . This can be computed by applying the equation:

$$\Delta T_m = \frac{\Delta t_1 - \Delta t_2}{\ln \frac{\Delta t_1}{\Delta t_2}}$$

but for simplicity, the ΔT_m (see page 21) can be used for Temp-Plate, and by interpolation reasonable accuracy can be obtained.

4. Solve equation $A = \frac{Q}{U \times (\Delta T_m)}$

Note: The entire heat transfer solution as determined in the preceding heat transfer steps can be solved simultaneously by combining the entire formulas from steps 1, 2, and 3 and solving for:

$$A = \frac{W \times c_p \times \text{t.d.}}{\text{HRS} \times U \times (\Delta T_m)}$$

or if the area is known, the equation can be solved for the time required. See Examples 1, 2, and 3.

$$\text{HRS} = \frac{W \times c_p \times \text{t.d.}}{A \times U \times (\Delta T_m)}$$

Example 1:

Find the amount of Temp-Plate required to heat 10% phosphoric acid and water solution from 110° to 180°F. continuously using 100 psig steam in a 3' x 4' x 10' tank with 2" of insulation. The flat plates will be immersed in a vertical position, and the solution will be pumped through the tank at 50 gallons per minute.

Following the steps explained in the text:

1. q_t = Total load (i.e., load of heating the product plus heat lost to surroundings)

$$q_t = q_p + q_w$$

W = Weight of product = 8.8 lbs/gal
(estimated using table on page 19)

c_p = sp. ht. of product = .93 Btu/lb/°F
(estimated using table on page 19)

q_p = Weight per hour x sp. ht. x temperature difference = $W \times c \times (t_1 - t_2)$

$$q_p = 50 \text{ gpm} \times 60 \text{ min} \times 8.8 \times .93 (180^\circ - 110^\circ) = 1,718,640 \text{ btuh}$$

$$\begin{aligned} \text{Area of Exterior} &= 2 (3' \times 4') = 24 \text{ sq ft} \\ &2 (4' \times 10') = 80 \text{ sq ft} \\ &2 (3' \times 10') = 60 \text{ sq ft} \\ &= 164 \text{ sq ft} \end{aligned}$$

If surroundings are 60°F, then $180^\circ - 60^\circ = 120^\circ$. At 120° t.d., heat leaves tank at 25 Btuh/sq ft (see table on page 22).

$$\begin{aligned} q_w &= \text{wall loss load} = 164 \text{ sq ft} \times 25 \text{ Btuh/sq ft} \\ &= 4,100 \text{ Btuh} \end{aligned}$$

$$q_t = q_p + q_w = 1,718,640 + 4,100 = 1,722,740 \text{ Btuh}$$

2. From table on page 20 select an average "U" factor from steam to water in the agitated column.

$$U = 210 \text{ Btuh/°F/sq ft}$$

3. Find log mean temperature difference ΔT_m from chart on page 21 as follows:

Temperature of 100 psi steam = 338°F (table, page 23).

Assume mixture temp. of $\frac{180^\circ + 110^\circ}{2}$ or 145° at end

of tank where solution is entering.

$$\Delta t_1 = 338^\circ - 145^\circ = 193^\circ$$

$$\Delta t_2 = 338^\circ - 180^\circ = 158^\circ$$

Using chart on page 21 to connect 193° on GTD scale to 158° on LTD Scale and read 176°F on LMTD scale.

4. Solve for total surface required, $A = \frac{Q_t}{U \times \Delta T_m}$

$$A = \frac{1,722,740}{210 \times 176} = 46.6 \text{ sq ft required}$$

As both sides of the Temp-Plate are in contact with the acid solution,

$$\text{plate area required} = \frac{46.6}{2} = 23.3 \text{ sq ft}$$

SOLVING HEAT TRANSFER PROBLEMS

Example 2:

Find the amount of Temp-Plate needed to cool 1,000 gallons of syrup (50° Brix sucrose solution) from 150° to 50°F in six hours. Temp-Plate will form the side walls of the cylindrical tank holding the syrup, and the tank will have 2" insulation. Water entering at 34°F will be circulated in the Temp-Plate. The sugar solution will be mechanically agitated. Tank dimensions are approximately 70" OD x 93" long.

Following the steps explained in the text:

1. W = Weight of product = 10.25 lbs/gal (see table on page 19) = $1,000 \times 10.25 = 10,250$ lbs

$$c = \text{sp. ht. of product} = .65 \text{ Btu/lb/}^\circ\text{F (see table on page 19)}$$

$$t.d. = 150^\circ - 50^\circ = 100^\circ\text{F}$$

$$\text{Product load, } q_p = \frac{10,250 \times .65 \times 100}{6} = 111,042$$

$$\text{Exterior area} = 195 \text{ sq ft}$$

$$\text{Assume } 80^\circ\text{F ambient, then average temperature difference} = \frac{(150^\circ + 50^\circ)}{2} - 80^\circ = 20^\circ\text{F}$$

$$\text{At } 20^\circ \text{ t.d., wall loss factor for 2" insulation} = 4 \text{ Btu/h/sq ft (see table on page 22)}$$

$$\text{Wall losses, } q_w = 4 \times 195 = 780 \text{ Btu/h}$$

Note: As average product temperature is greater than ambient, the 780 Btu/h may be subtracted from the average cooling required.

$$\text{Total Load, } q_t = 111,042 - 780 = 110,262 \text{ Btu/h}$$

2. From table on page 20 select overall heat transfer coefficient "U" of 60 Btu/h/°F/sq ft (midway between maximum and minimum shown for agitated moderately viscous solution being cooled with water).
3. The greatest temperature difference at start is $150^\circ - 34^\circ = 116^\circ$. If the average temperature rise of the water being circulated is assumed to be around 3° , we may use as the least temperature difference $50^\circ - 37^\circ = 13^\circ$. Find ΔT_m of 44° on chart, page 21.
4. $A = \frac{q_t}{U \times (\Delta T_m)} = \frac{110,262}{60 \times 44} = 41.8 \text{ sq ft}$

Example 3:

Determine the amount of clamp-on Temp-Plate required to hold an uninsulated 20,000-gallon tank of fuel oil at 40°F in ambient temperature that could go to -10°F minimum. Use 15 psig steam as the heating medium. The vessel is pad mounted, 12' diameter by 24' high. There is no agitation.

Due to the relatively high thermal resistance at the interface of the Temp-Plate and tank wall, low "U" factors are expected. Assuming that a heat transfer mastic is used to obtain better contact, then select "U" of 30 Btu/h/°F/sq ft.

$$\text{Surface area} = 1,018 \text{ ft}^2 \text{ (ignore heat transfer on bottom of pad-mounted vessel)}$$

$$t.d. = 40 - (-10) = 50^\circ\text{F}$$

$$\text{Wall loss factor} = 90 \text{ Btu/h/sq ft (table on page 22)}$$

$$\text{Then } q_w = 90 \times 1,018 = 91,620 \text{ Btu/h}$$

$$\text{Steam temperature @ 15 psig} = 250^\circ\text{F (table, page 23)}$$

$$\text{Then } A = \frac{91,620}{30 \times (250 - 40)} = 14.54 \text{ sq ft}$$

Better performance would result, particularly on an unagitated tank, if Temp-Plate is properly placed completely around the vessel. This would require approximately 38 sq ft if a one-foot-high band is utilized.

See table on page 22 for the benefit of using insulation.

PROPERTIES OF MATERIAL

Name of Material	State	Specific Heat* (Btu/Lb/°F)	Density	
			Lb/Cu Ft	(Lb/Gal)
Acetic Acid	Liquid	.52	66	8.82
Air	Gas	.24	.08	
Alcohol - Ethyl	Liquid	.55		
Aluminum	Solid	.23	170	
Asphalt	Solid	.4	80	10.70
Brine 20% CaCl ₂	Liquid	.74	74.0	9.89
Brine 21%	Liquid	.81	72	9.63
Copper	Solid	.095	557	
Cork	Solid	.49	15	
Creosote	Liquid	.35	75	10.03
Dowtherm A	Liquid	.63	62	8.29
Dowtherm C	Liquid	.50 Avg.	69	9.22
Ethylene Glycol	Liquid	.58	70	9.36
Fuel Oil	Liquid	.40	60	8.02
Glue (Water Ratio 2/1)	Liquid	.9	68	9.09
Gasoline	Liquid	.5	38	5.08
Glass	Solid	.18 Avg.	175 Avg.	
Hydrochloric Acid, 8° BE	Liquid	.75	66	8.82
Honey	Liquid	.35		
Ice Cream (12% Solids)	Liquid	.8	71	9.49
Ice	Solid	.49	56	
Iron	Solid	.1	445	
Insulation: Glass Wool	Solid	.16	.3	
Magnesia	Solid	.27	13	
Cork	Solid	.49	15	
Kerosene	Liquid	.5	51	6.82
Lard	Solid	.64	58	
Lead	Solid	.03	710	
Maple Syrup	Liquid	.49		
Milk	Liquid	.93	64	8.6
Nitric Acid	Liquid	.76	66	8.82
Oil: Fuel (Bunker "C")	Liquid	.40	59	7.89
Transformer, Medium	Liquid	.42	57	7.62
Cotton Seed	Liquid	.47	59	7.89
Linseed	Liquid	.44	58	7.75
Olive	Liquid	.47	57	7.62
Machine	Liquid	.40	58	7.75
Oleo Margarine	Solid	.28 Avg.		
Paraffin	Solid	.62	56 Avg.	
Phosphoric Acid (10%)	Liquid	.93	65.5	8.80
Refrigerant 113	Liquid	.21	98	13.10
Seawater	Liquid	.94	64.3	8.57
Sodium Hydroxide (9% Solution)	Liquid	.91	68.5	9.16
Sugar Solution	Liquid	.3	104	13.90
Sugar Solution (50° Brix)	Liquid	.65	104	10.25
Steel	Solid	.12	487	
Steel, Stainless	Solid	.12	501	
Sulphur	Solid	.20	125	
Turpentine	Liquid	.41	54	7.22
Tar, Coal	Solid	.40	75	
Water	Liquid	1.0	62.4	8.34
Wine	Liquid	.9	64	8.56
Zinc	Solid	.10	440	

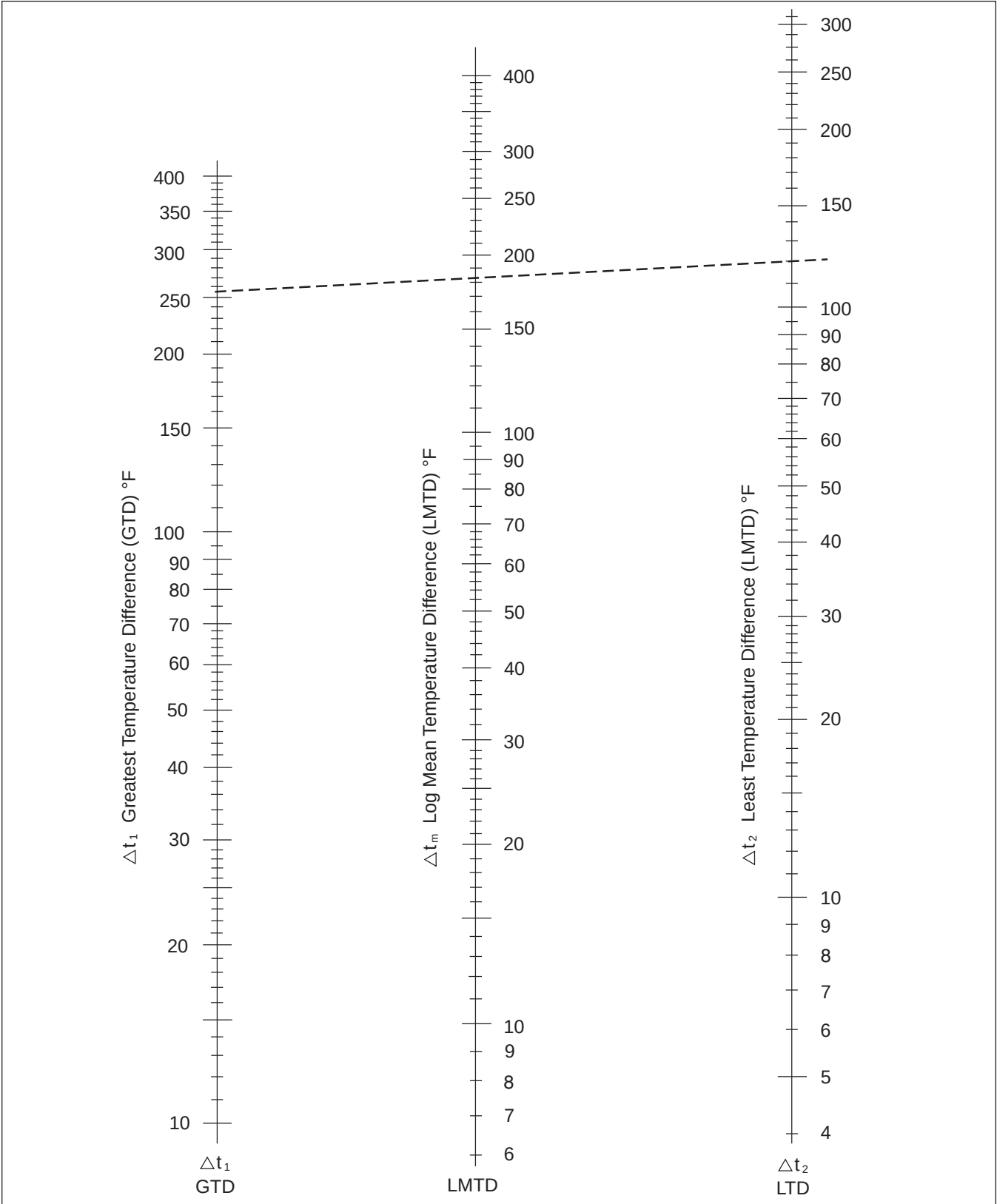
*Specific heat of water is one Btu per pound per degree Fahrenheit.

OVERALL HEAT TRANSFER COEFFICIENT “U”

Heat Transfer Medium	Product	Coefficient “U” (Btuh/ft ² /°F)			
		Heating		Cooling	
		Not Agitated	Agitated	Not Agitated	Agitated
Water	Watery Solution	30-85	105-135	25-80	100-130
	Moderately Viscous Solution	15-50	60-100	10-30	40-80
	Medium Oil	5-35	25-80	4-9	10-30
	Tar	5-12	15-20		
Glycol	Watery Solution			25-65	85-105
Steam	Watery Solution	100-225	120-300		
	Moderately Viscous Solution	30-60	70-120		
	Medium Oil	8-40	35-95		
	Tar	10-30	45-65		
Direct Expansion Refrigerant (R-12, R-22, ammonia)	Watery Solution			30-55	60-110
	Moderately Viscous Solution			10-30	30-70
	Medium Oil			1-8	6-18
	Watery Solution in Very Large Tank, Temp-Plate Integral with Side Wall			15-22	35-45
Heat Transfer “Oil”	Viscous Solution	8-15	25-45		
Most Fluids (excluding gas)	Air or Gas	1-3	3-7	1-3	3-7
		Without Heat Transfer Mastic	With Heat Transfer Mastic	Without Heat Transfer Mastic	With Heat Transfer Mastic
Clamp-On Temp-Plate with Most Fluids (excluding gas)*	Watery Solution	10-25	20-35	5-15	15-25
	Viscous Solution	5-10	10-20	2-6	5-10
	Air or Gas	1-3	1-3	1-3	1-3

* Recommended for maintaining temperature only. If used for moderate heat up or cool down, use 50% of “U” value shown and consult Paul Mueller Company. We recommend use of heat transfer mastic applied approximately 1/8" thick between clamp-on and wall of tank.

LOGARITHMIC MEAN TEMPERATURE DIFFERENCE NOMOGRAPH



To find LMTD (Logarithmic Mean Temperature Difference), lay straight edge from greater temperature difference (left scale) to lesser temperature difference (right scale) and read LMTD on center scale.

VESSEL SURFACE HEAT LOADS/REFRIGERANT PROPERTIES

VESSEL SURFACE HEAT LOADS

Temp. Difference* °F	Heat Load, Btuh/sq ft of tank wall area**				Heat Load, Btuh/sq ft***	
	No Insulation	1" Insulation	2" Insulation	3" Insulation	Water Surface	Oil Surface
0	0	0	0	0		
20	33	8	4	3		
30	50	12	6	4	130	100
40	70	15	8	6	230	130
50	90	19	10	7	330	160
60	110	23	12	9	470	200
70	135	27	14	10	615	240
80	160	31	17	12	820	270
90	180	34	18	13	1,040	300
100	210	38	21	15	1,310	340
110	235	42	23	16	1,615	370
120	260	46	25	17	2,000	410
130	290	50	27	19	2,450	450
140	320	53	29	20	3,000	490
150	350	57	31	22	3,590	530
160	380	61	33	23		570
190						690
240						860
340						1,360
440						1,870

*Difference in temperature between product in vessel and ambient air.

**Heat transferred through tank walls.

***Heat transferred to the room atmosphere from the horizontal liquid surface of uncovered tanks.

Note: This chart is based on no air flow across fluid surface.

PROPERTIES OF SATURATED REFRIGERANTS

°F	°C	PSIG			°F	°C	PSIG		
		R-134a	R-22	R-717 (Ammonia)			R-134a	R-22	R-717 (AMMONIA)
-50	-45.6	18.6*	6.0*	14.3*	24	-4.4	21.4	47.9	37.9
-45	-42.8	16.7*	2.6*	11.7*	26	-3.3	22.9	50.2	40.2
-40	-40.0	14.7*	0.6	8.7*	28	-2.2	24.5	52.7	42.6
-35	-37.2	12.3*	2.7	5.4*	30	-1.1	26.1	55.2	45.0
-30	-34.4	9.7*	5.0	1.6*	32	0	27.8	57.8	47.6
-28	-33.3	8.6*	6.0	0.0	34	1.1	29.5	60.5	50.2
-26	-32.2	7.4*	7.0	0.8	36	2.2	31.3	63.3	52.9
-24	-31.1	6.2*	8.1	1.7	38	3.3	33.1	66.1	55.7
-22	-30.0	4.9*	9.2	2.6	40	4.4	35.0	69.0	58.6
-20	-28.9	3.6*	10.3	3.6	45	7.2	40.0	77.0	66.3
-18	-27.8	2.2*	11.5	4.6	50	10.0	45.4	84.7	74.5
-16	-26.7	0.7*	12.7	5.6	55	12.8	51.2	93.2	83.4
-14	-25.6	0.4	13.9	6.7	60	15.6	57.4	102.5	92.9
-12	-24.4	1.2	15.2	7.9	65	18.3	64.1	112.0	103.1
-10	-23.3	2.0	16.6	9.0	70	21.1	71.1	122.5	114.1
-8	-22.2	2.8	18.0	10.3	75	23.9	75.7	133.8	125.8
-6	-21.1	3.7	19.4	11.6	80	26.7	86.7	145.0	138.3
-4	-20.0	4.6	20.9	12.9	85	29.4	95.2	158.0	151.7
-2	-18.9	5.5	22.5	14.3	90	32.2	104.3	170.1	165.9
-0	-17.8	6.5	24.1	15.7	95	35.0	114.0	184.8	181.1
2	-16.7	7.5	25.7	17.2	100	37.8	124.1	197.9	197.2
4	-15.6	8.6	27.4	18.8	105	40.6	135.0	213.1	214.2
6	-14.4	9.7	29.2	20.4	110	43.3	146.4	228.7	232.3
8	-13.3	10.8	31.0	22.1	115	46.1	158.4	246.0	251.5
10	-12.2	12.0	32.9	23.8	120	48.9	171.1	262.6	271.7
12	-11.1	13.2	34.9	25.6	125	51.7	184.5	280.5	293.1
14	-10.0	14.4	36.9	27.5	130	54.4	198.7	298.8	315.0
16	-8.9	15.7	39.0	29.4	135	57.2	213.5	317.9	335.0
18	-7.8	17.1	41.1	31.4	140	60.0	229.2	338.0	365.0
20	-6.7	18.4	43.3	33.5	145	62.8	245.6	359.6	390.0
22	-5.6	19.9	45.5	35.7	150	65.6	262.8	384.3	420.0

*Indicates vacuum (inches of mercury).

SATURATED STEAM PROPERTIES/STEAM REQUIREMENTS

PROPERTIES OF SATURATED STEAM

Pressure psig	Temperature °F	Heat of the Liquid Btu/lb	Latent Heat of Evaporation Btu/lb	Total Heat of Steam Btu/lb	Specific Volume cu ft/lb
0.0	212.0	180.07	970.3	1,150.4	26.80
0.3	213.03	181.11	969.7	1,150.8	26.29
1.3	216.32	184.42	967.6	1,152.0	24.75
2.3	219.44	187.56	965.5	1,153.1	23.39
3.3	222.41	190.56	963.6	1,154.2	22.17
4.3	225.24	193.42	961.9	1,155.3	21.08
5.3	227.96	196.16	960.1	1,156.3	20.089
6.3	230.57	198.79	958.4	1,157.2	19.192
7.3	233.07	201.33	956.8	1,158.1	18.375
8.3	235.49	203.78	955.2	1,159.0	17.627
9.3	237.82	206.14	953.7	1,159.8	16.938
10.3	240.07	208.42	952.1	1,160.6	16.303
15.3	250.33	218.82	945.3	1,164.1	13.746
20.3	259.28	227.91	939.2	1,167.1	11.898
25.3	267.25	236.03	933.7	1,169.7	10.498
30.3	274.44	243.36	928.6	1,172.0	9.401
35.3	281.01	250.09	924.0	1,174.1	8.515
40.3	287.07	256.30	919.6	1,175.9	7.787
45.3	292.71	262.09	915.5	1,177.6	7.175
50.3	297.97	267.50	911.6	1,179.1	6.655
60.3	307.60	277.43	904.5	1,181.9	5.816
70.3	316.25	286.39	897.8	1,184.2	5.168
80.3	324.12	294.56	891.7	1,186.2	4.652
90.3	331.36	302.10	886.0	1,188.1	4.232
100.3	338.07	309.11	880.6	1,189.7	3.882
125.3	353.02	324.82	868.2	1,193.0	3.220
151.3	366.48	339.05	856.6	1,195.7	2.736
175.3	377.51	350.79	846.8	1,197.6	2.404
200.3	387.89	361.91	837.4	1,199.3	2.134
250.3	406.11	381.60	820.1	1,201.7	1.7422

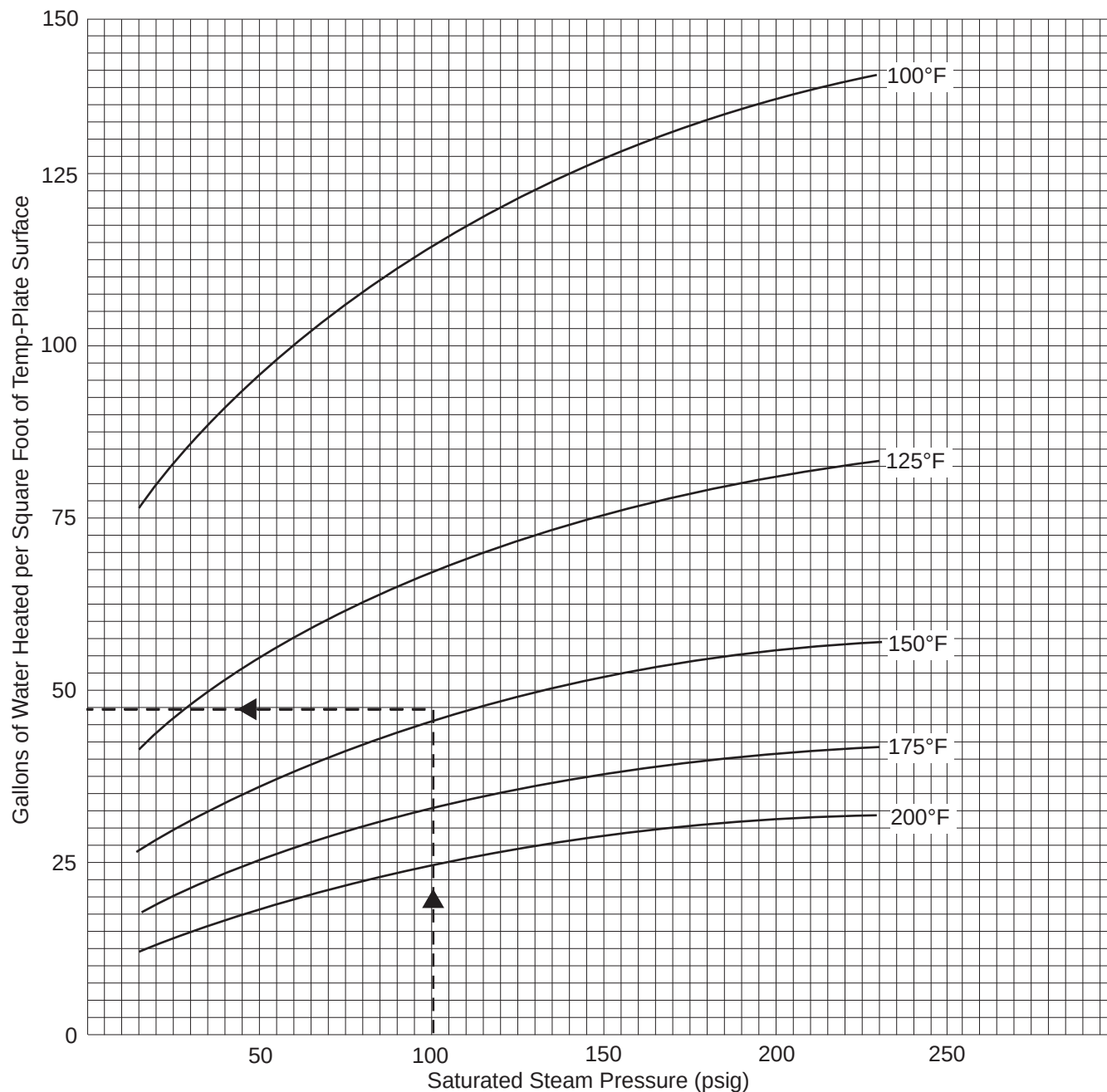
STEAM REQUIREMENTS

Total Load Btuh	Steam Required (lbs/hour) Steam Pressure			Total Load Btuh	Steam Required (lbs/hour) Steam Pressure		
	15 psig	60 psig	100 psig		15 psig	60 psig	100 psig
100	.105	.111	.113	15,000	15.87	16.58	16.88
200	.212	.221	.225	20,000	21.16	22.14	22.54
500	.529	.553	.563	25,000	26.45	27.65	28.16
750	.794	.830	.845	30,000	31.74	33.18	33.79
1,000	1.05	1.11	1.13	40,000	42.33	44.25	45.05
1,500	1.59	1.66	1.69	50,000	52.91	55.31	56.31
2,000	2.12	2.21	2.25	75,000	79.36	82.96	84.47
2,500	2.65	2.77	2.82	100,000	105.78	110.66	112.75
3,000	3.17	3.32	3.38	250,000	264.62	276.56	281.68
4,000	4.23	4.42	4.50	500,000	529.10	553.09	563.07
5,000	5.29	5.53	5.63	750,000	793.66	829.64	844.63
6,000	6.35	6.64	6.76	1,000,000	1,058.20	1,106.19	1,126.13
7,000	7.41	7.74	7.88	1,250,000	1,322.75	1,382.74	1,407.66
8,000	8.47	8.85	9.01	1,500,000	1,587.30	1,659.29	1,689.10
9,000	9.52	9.96	10.14	1,750,000	1,851.85	1,935.84	1,970.72
10,000	10.57	11.06	11.27	2,000,000	2,116.40	2,212.39	2,252.25

Steam in lbs/hr = $\frac{\text{total load}}{\text{latent heat of steam}}$ (1) boiler hp = 34.5 lbs steam / hr

HEATING APPLICATION CURVES

Heating Application Curves for Heating Water from 60°F to Curve Temperature in One Hour for Immersed Plates Only (Without Agitation)



Example:

Problem — How many square feet of Temp-Plate are required to heat the water in a 3' wide x 9' long x 2¹/₂' deep tank from 60°F to 150°F in two hours using 100 psig saturated steam? Plates are immersed and in a vertical position without mechanical agitation.

Solution — Volume of tank equals 3' x 9' x 2' (to liquid level) = 54 cubic feet. 54 cu. ft. x 7.48 (gal/cu ft) = 404 gallons of water. Using above chart, start at 100 psig on bottom scale; read up to 150°F curve and moving to left, read 47 gal. heated per sq ft. Therefore, $404 \div 47 = 8.6$ sq ft (total water contact surface) required for one hour. Divide 8.6 by 2 to give surface required for two hours.

COOLING LOAD VS. WATER FLOW AND REFRIGERATION CAPACITY

Total Load Btuh	Water Required (gpm)					Refrigeration Capacity (any refrigerant) Tons
	Water Temperature Change*					
	2°	4°	6°	8°	10°	
100	.1					.008
200	.2	.1				.017
500	.5	.25	.17			.042
750	.75	.38	.25			.063
1,000	1	.5	.3	.25		.083
1,500	1.5	.75	.5	.4	.3	.125
2,000	2	1	.7	.5	.4	.166
2,500	2.5	1.3	.8	.63	.5	.208
3,000	3	1.5	1	.75	.6	.250
4,000	4	2	1.4	1	.8	.333
5,000	5	2.5	1.7	1.3	1	.416
6,000	6	3	2	1.5	1.2	.500
7,000	7	3.5	2.4	1.8	1.4	.583
8,000	8	4	2.7	2	1.6	.667
9,000	9	4.5	3	2.3	1.8	.750
10,000	10	5	3.4	2.5	2	.833
15,000	15	7.5	5	3.8	3	1.250
20,000	20	10	6.7	5	4	1.667
25,000	25	12.5	8.4	6.3	5	2.083
30,000	30	15	10	7.5	6	2.500
40,000	40	20	13.3	10	8	3.333
50,000	50	25	16.7	12.5	10	4.167
75,000	75	37.5	25	18.8	15	6.250
100,000	100	50	33.4	25	20	8.333
250,000	250	125	83.4	62.5	50	20.833
500,000	500	250	166.7	125	100	41.667
750,000	750	375	250	188	160	62.500
1,000,000	1,000	500	333.3	250	200	83.333
1,250,000	1,250	625	416	313	250	104.167
1,500,000	1,500	750	500	375	300	125.000
1,750,000	1,750	875	583	438	350	145.833
2,000,000	2,000	1,000	666.6	500	400	166.667

$$\text{Water in gpm} = \frac{\text{total load}}{60 \times 8.34 \times \text{T.R.}^*}$$

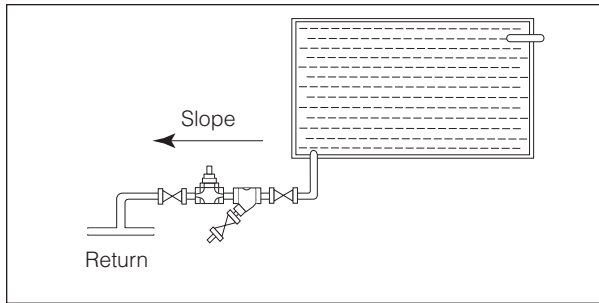
$$\text{Tons} = \frac{\text{Btuh}}{12,000}$$

*Difference in temperature between water entering and leaving Temp-Plate passageways.

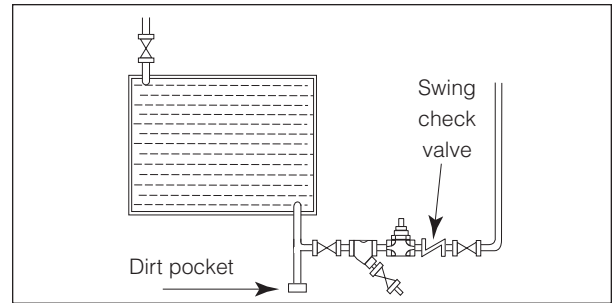
POSITIONING, PIPING, AND TRAPPING FOR STEAM HEATING

Positioning, Piping, and Trapping For Steam Heating

1. Install trap below the equipment being drained so condensate will drain by gravity to the trap inlet. Pitch horizontal lines toward trap inlet. This will allow condensate to first fill inlet at trap and prevent water hammer in the line. Strainers are recommended ahead of the steam trap.



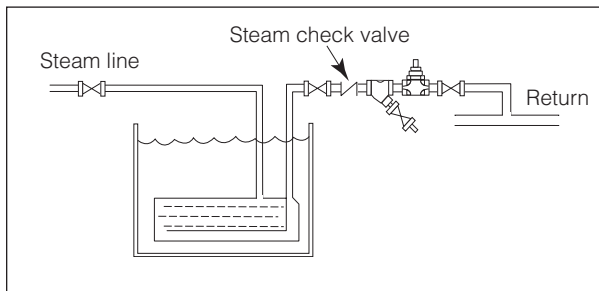
- c. Wherever possible, install a vertical drip leg or dirt pocket ahead of the trap as shown below. This provides a condensate reservoir ahead of the trap, as well as a dirt pocket to collect excess scale and dirt. This dirt leg should be blown out periodically by removing the pipe cap or plug at the bottom.



- a. Where it is not possible to install trap at a low point, provide a lift fitting or water seal at the low point.

An immersion-type heat transfer surface, which has the water seal/lift fitting built into it, is shown below.

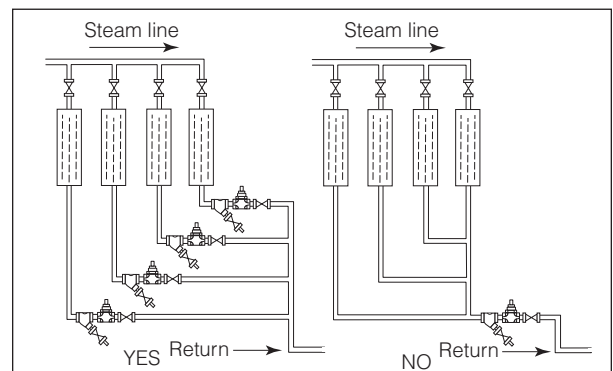
A swing check valve should be installed just before the trap to prevent back flow.



2. Place trap as close to equipment as possible except in the case of thermostatic traps that require a cooling leg ahead of the trap).
3. Install trap in an accessible location for servicing and maintenance.
4. Before installing trap, be sure to thoroughly blow out piping under full steam pressure to eliminate scale, chips, and other foreign material. It is also advisable to install a "Y" strainer ahead of the steam trap and repeat this procedure by blowing down the strainer after the hook-up is completed.
5. Trap each piece of apparatus individually. If more than one heat transfer surface or piece of apparatus is drained by a single trap, short circuiting is liable to occur as pressure drops may differ. The heat transfer surface with the least pressure drop will short circuit the one with the greatest drop, resulting in uneven heating and inefficient operation.

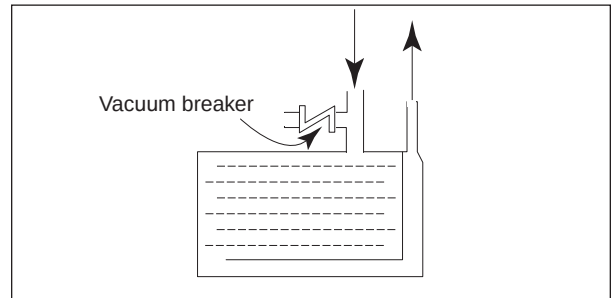
- b. **Overhead Discharge** — If the condensate is to be discharged to an overhead return line or against a lift, it is advisable to install a swing check valve in the discharge line just beyond the trap at the bottom of the lift. Otherwise, condensate may flow back into the equipment on shutdowns and, in some cases, blanket the heat transfer surfaces during operation.

The only exception to this recommendation would be in the case of certain types of traps that incorporate a check valve within the trap itself.

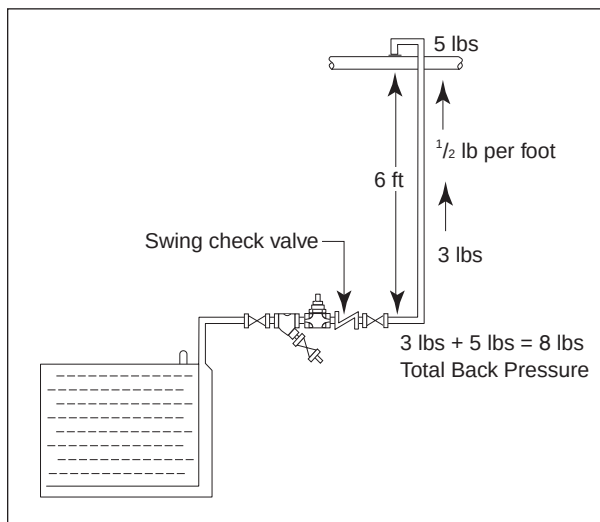


POSITIONING, PIPING, AND TRAPPING FOR STEAM HEATING

6. Always use inlet and discharge piping at least as large as the pipe connections in the trap.
7. When several traps discharge into a common header, install a swing check valve between each trap and the header to prevent reverse flow during shutdown or possible blocking off of one trap by another when they are discharging.
8. Bypasses have been largely eliminated nowadays due to expense of installations and loss of steam when left open by the operator. Where a bypass is necessary, locate it at a higher level than the trap to avoid loss of prime with bucket traps.
9. To allow for flash steam and prevent overloading, discharge piping should be amply sized. For short discharge lines, use pipe equal to trap size; for longer lines, use one size larger.
10. If discharge is to overhead return, make sure pressure at trap discharge is sufficient to overcome lift (calculate $\frac{1}{2}$ pound per vertical foot) plus pressure in overhead return line and pressure drop through the heat transfer surface. It is necessary to size the steam trap based on inlet pressure of the trap for proper operation. Also, make sure total back pressure is within allowable limit for the particular make of trap.
11. Bucket traps should be primed before starting; otherwise they will blow steam. Close outlet valve and open inlet valve slowly until condensate fills body of trap. If insufficient condensate is present to prime properly, pour in water through test outlet.
12. Gate valves are recommended for lines leading to and from the trap in order to provide free flow and reduce flashing. For strainer blow down or test tee, either gate or globe valves are satisfactory.
13. Vacuum breaker - where specified by the equipment manufacturer or where the piping arrangement is such that condensate will be drawn back into the equipment due to the vacuum caused by condensation of steam on shutdown, install a vacuum breaker at a high point in the apparatus or piping.



14. Auxiliary air vent - where especially large volumes of air must be eliminated on start up and piping is such that air will not readily flow toward the trap, install an air vent at a high point opposite the steam inlet.



Reprinted with the permission of Yarway Corporation from their "Industrial Steam Trapping Course."

Temp-Plate — Cleaning and Maintenance

Temp-Plate is a well constructed, durable piece of equipment, but the frequency with which it is subjected to severe operating conditions demands that some precautions must be taken. Proper choice of material for a given application, in conjunction with a sensible cleaning and maintenance program, will ensure maximum performance and life.

There are two basic reasons for maintaining a clean surface: corrosion prevention and minimizing heat transfer resistance. Scale build-up on the surface reduces the heat transfer rate significantly because of the poor conductivity of the scale. The thermal resistance of the scale can easily be an order of magnitude or greater than the metal wall of the Temp-Plate itself.

Corrosion may be of a general or localized nature. Some general corrosion may be acceptable based on economic considerations involving more resistant materials and it may occur on clean surfaces. However, it is possible that a very resistant material in a given environment may have localized corrosion problems due to contamination of the surface. This is particularly true for stainless steel, which apparently receives its corrosion resistance from a passive film on the surface that occurs when clean stainless steel is exposed to oxygen. Any barrier on the surface, such as scale or dirt, inhibits this oxidation, with a resulting reduction in corrosion resistance. Such conditions are likely to cause pitting, a form of localized corrosion.

Other forms of localized corrosion are: intergranular, crevice, galvanic, and stress corrosion cracking. However, solutions to these problems have more basis in proper choice of material, fabrication procedures, and design, as well as care in the use of dissimilar metals than in surface cleanliness. Initial considerations are important here, and some assistance may be obtained by referring to the Corrosion Section of this manual or numerous other good references on corrosion. Improved surface finish, such as that obtained by electropolishing, will discourage scale build-up and the resulting problems.

Basically, the techniques for cleaning Temp-Plate are chemical, mechanical, or a combination of these. Mechanical cleaning may involve spraying with water under high pressure, wire brushing, or direct blows to the Temp-Plate to break the scale loose. The latter is not recommended because carelessness could damage the Temp-Plate; but if it must be done due to some emergency, use a mallet of more resilient material (such as leather) than that of Temp-Plate. Under no circumstances should carbon steel tools or materials be brought into contact with the stainless steel. Wire brushing of stainless steel must be done with a stainless steel brush.

The surface of inflated Temp-Plate, with its gentle, pillowed effect, is relatively easy to clean, and swabbing, brushing, or spraying are preferred cleaning procedures when deposits are soft enough to be removed by these methods. However, some applications, such as in the metal finishing industry, lead to scale on the Temp-Plate that requires the use of chemical cleaning. Precautions must be taken, as chemicals effective for the scale removal may induce corrosion on the Temp-Plate.

An acid solution that is safe at colder temperatures may prove to have a detrimental effect on Temp-Plate at higher temperatures. The variety of sources for problem scale and the variety of materials used in construction of Temp-Plate dictates that each application be considered specifically. Suppliers of chemicals used in processes that produce scale should be good consultants regarding logical choices of chemicals and procedures to employ for scale removal.

A regular cleaning program is of paramount importance, but if loss of production due to downtime is a major factor, it may be economically wise to invest in an extra Temp-Plate so that production and cleaning can occur simultaneously. This could be accomplished by alternating production between two systems or rotating Temp-Plate within a system on a scheduled basis.

Temp-Plate — Repairs

The following repair techniques are recommended whenever defects arise due to accidental damage, such as leaks, etc.:

1. PRIOR TO REPAIR:

Remove any contamination that might be present in the defect area. There are various solvents and/or mechanical means (grinding, brushings, etc.) that are effective in removing this foreign matter. After initial area cleaning, the defect itself needs to be removed to assure that good sound metal is present. Once good metal is reached, proceed with the weld repairs.

2. WELD REPAIR INFORMATION:

A. Temp-Plate, Stainless Steel — Normally one of the conventional welding processes is used for repairing defects.

(1) For Type 304 stainless, use one of the following:

- a. Manual Shielded Metal Arc Welding (SMAW, stick): Use either $\frac{3}{32}$ " or $\frac{1}{8}$ " diameter E308-16 (AC-DC) electrode per AWS A5.4 specifications.
- b. Semi-Automatic Gas Metal Arc Welding (GMAW, short arc, MIG): Use .035" diameter or .045" ER308-type filler wire meeting AWS A5.9 specifications.
- c. Manual Gas Tungsten Arc Welding (GTAW - TIG - heliarc): Use $\frac{1}{16}$ " or $\frac{3}{32}$ " diameter ER308 bare filler rod meeting AWS 5.9 specifications.

(2) For Type 316 stainless, use one of the following:

- a. SMAW Process: Use $\frac{3}{32}$ " or $\frac{1}{8}$ " diameter ER316-16 (AC-DC) electrodes meeting AWS A5.4 specifications.

b. GMAW Process: Use .035" or .045" diameter ER316-type filler wire meeting AWS A5.9.

c. GTAW Process: use $\frac{1}{16}$ " or $\frac{3}{32}$ " diameter ER316 bare filler rod meeting AWS A5.9 specifications.

(3) For low-carbon grades stainless steel base materials, use L-grade-type filler metal to match the corrosion resistant characteristics.

(4) For austenitic stainless steel, the weld deposit must be cooled to below 800°F within one minute after welding in order to keep the carbide precipitation to a minimum.

B. Temp-Plate, Carbon Steel — The conventional method normally selected is the Shielded Metal Arc Welding process (SMAW - stick). The all-position electrodes E60XX or E70XX series, AWS A5.1-type electrodes are generally recommended. A typical selection would be an $\frac{1}{8}$ " diameter, AC or DC reverse polarity electrode.

C. Temp-Plate, Other Alloy Materials — Contact Paul Mueller Company personnel on such repairs or with the original manufacturer of that grade of material.

3. AFTER WELD REPAIR IS COMPLETED:

A general cleaning, either mechanical or with chemical solvents, should be done to remove any contaminants remaining. Paul Mueller Company's pickling paste is recommended for removing weld surface oxides and restoring corrosion resistance on stainless steel Temp-Plate.

THERMAL EXPANSION

Thermal Expansion

Allowance must be made for thermal expansion when Temp-Plate, used as a heating surface, is fastened to rigid supports which expand at a slower rate than the Temp-Plate. Depending on the type of installation, several methods, such as flexible joints, slotted lugs, etc., can be used to prevent the Temp-Plate from buckling and possible damage. We can offer recommendations for your specific installation of Temp-Plate.

COEFFICIENTS OF LINEAR EXPANSION - INCHES/FOOT/°F

Material	Instantaneous Values (approximate)				
	-260°F	-50°F	-70°F	300°F	500°F
Carbon Steel (1020)	0.000042	0.000070	0.000077	0.000086	0.000098
Stainless Steel (300 series)	0.000067	0.000098	0.000102	0.000113	0.000119
Inconel® Alloy 600			0.000070	0.000090	0.000101
Monel® Alloy 400			0.000077	0.000096	0.000104
Nickel 200			0.000070	0.000096	0.000108
Incoloy® Alloy 825			0.000073	0.000094	0.000101

Mean Values (approximate)				
Stainless Steel (410)	.32°F	0.0000660	212°F	
Stainless Steel (430)	.32°F	0.0000696	212°F	
Hastelloy® Alloy B	.70°F	0.000077	600°F	
Hastelloy Alloy C	.70°F	0.000084	600°F	
Hastelloy Alloy F	.70°F	0.000104	600°F	

Corrosion Resistance Table

This table shows the resistance of a number of materials to the more common chemicals. Many factors influence the resistance of materials to various solutions. Factors which must be given consideration for service in corrosive environments are: temperature, concentration, aeration, influence of recirculation, solids in suspension, velocity, frequency of use, and equipment design.

The influence of contaminants is probably the most important from a commercial standpoint. Few corrosive solutions will be free of all contaminants. The majority of these contaminants have no influence on corrosion, but those that do generally affect the conditions greatly.

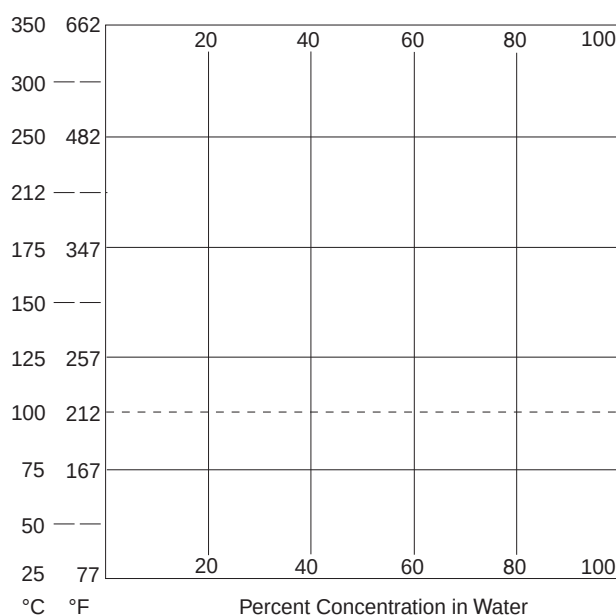
The corrosion data for all grades except Alloy 20 is reprinted from Corrosion Data Survey, 1974 Edition, published by the National Association of Corrosion Engineers. The corrosion rates for Alloy 20 represent a composite of the NACE Corrosion Data Survey and more current data developed in CarTech's Corrosion Laboratory.

Your process may require a specific material type for proper corrosion protection. Contact a consulting metallurgist for a recommendation.

Paul Mueller Company is not responsible for corrosion or suitability for use of any material in any particular application! The corrosion resistance and suitability for use of a material is dependent on operating environment and conditions, cleaning practices, and many other factors beyond the control of the equipment fabricator. The user of the equipment bears total responsibility for corrosion or suitability for use of all materials in their particular application!

Code

- Corrosion rate less than 0.002" per year
- Corrosion rate less than 0.020" per year
- Corrosion rate from 0.020" to 0.050" per year
- ✕ Corrosion rate greater than 0.050" per year



Corrodent	Alloy 20	Type 316	Hastelloy* B	Hastelloy* C	Monel**
Acetic Acid Aerated	7, 12	24	25	25	
Acetic Acid No Air		8 9	25	25	xxxxxxx
Acetic Acid Vapor		9			2
Acetic Anhydride In Acetic Acid	4, 7, 9				3 20 26
Acetone	4				
Aluminum Chloride	8, 13	4 5	27		16
Aluminum Potassium Sulfate	10		28 29	23 29	2 28
Aluminum Sulfate		7			28
Ammonium Carbonate					
Ammonium Chloride	4	4 5		x	315C 1
Ammonium Nitrate	3, 4				30
Ammonium Sulfate					31
Amyl Acetate	4				
Aniline	1, 7, 9				
Aniline Sulfite					
Arsenic Acid	1				
Barium Carbonate	1		815C	815C	

Corrodent	Alloy 20	Type 316	Hastelloy* B	Hastelloy* C	Monel**
Barium Chloride	13	4 5	86	86	
Barium Hydroxide	1		815C	815C	
Barium Nitrate	4	4	815C		
Barium Sulfate	1, 4		815C		
Benzene	16				4
Benzene Sulfonic Acid	2				2
Benzoic Acid					
Boric Acid	4	4	800C	800C	2
Butyl Acetate	4, 7, 9				
Butyric Acid					2
Cadmium Sulfate					
Calcium Bisulfite	36 37				
Calcium Carbonate			815C	815C	
Calcium Chlorate	10	10			
Calcium Chloride	4	4 5	39 815C	4 815C	4 815C
Calcium Sulfate					
Camphor					

*Hastelloy B and Hastelloy C are registered trademarks of Cabot Corporation. **Monel is a registered trademark of International Nickel Company.

Corrodent	Alloy 20	Type 316	Hastelloy* B	Hastelloy* C	Monel**
Carbonic Acid 6, 9	20	816C			40 41
Carbon Disulfide 1, 4, 9, 15					
Carbon Monoxide 1, 4	600C	500C	780 1100C	400C	42 800C 33
Carbon Tetra- chloride 1, 9	1	5			
Chlorine 1, 16		4 1 5			43 87
Chloroform 1, 9		4 5 1			
Chloro- sulfonic Acid 1, 7, 11		4			
Chromic Acid 7, 10	44	8 44			5
Chromic Sulfates					
Citric Acid		4 45			2 46
Copper Nitrate 1, 10					
Copper Sulfate 1		9 10			2
Cupric Cyanide 1					
Ethanol			31	31	31
Ethyl Acetate 4					
Ethyl- Chloride 4		1 5			
Ethylene Di- bromide 1, 8, 9	4	4			

Corrodent	Alloy 20	Type 316	Hastelloy* B	Hastelloy* C	Monel**
Ethylene Dichloride 4, 9	48	21 1		22	
Ferric Nitrate 4					
Ferric Sulfate					
Ferrous Sulfate		8			49
Fluorine Gas 1, 4, 17					450C 32
Fluosilicic Acid 1	4	4 8	5	5	5 50
Formal- dehyde 2, 4, 6, 8		20			7
Formic Acid 3, 7, 9		4 51	52		2
Furfural 4					
Gallic Acid					
Glutamic Acid		4 5 8	54	54	
Glycerol	4 53 8				
Hexa- methylene Tetramine 4, 7					
Hydro- chloric (Aerated) 1, 6, 7, 9	4		55		10
Hydro- chloric Acid (No Air) 4			55		
Hydrocy- anic Acid + Hydrogen Cyanide 3, 4, 7, 9	14	6	56 57		56 57
Hydrofluoric Acid (Aerated) 1, 7, 9					5

Corrodent	Alloy 20	Type 316	Hastelloy* B	Hastelloy* C	Monel**
Hydrogen	58 59 60 61 4	58 59 60 61 4	1100C	1100C	62
Hydrogen Chloride (Anhydrous)	300C 7, 9	300C 7, 9		370C	
Hydrogen Fluoride (Anhydrous)		482C			63 64
Hydrogen Peroxide	23 3, 7	23 3, 7		23	22
Hydrogen Sulfide - Dry	538C 1, 4	538C 1, 4			
Lactic Acid	4-16 8 9	4-16 8 9			2
Lead Acetate	1, 6				
Lead Nitrate	1, 10				
Lithium Chloride	1	4 5			2
Lithium Hydroxide					
Magnesium Chloride	5	5			2 5
Magnesium Chloride + Calcium Chloride	17 20	4 6			17
Magnesium Hydroxide Or Magnesium Oxide					
Magnesium Sulfate	10	5	5		
Maleic Acid	1, 7				2
Malic Acid		5			2
Manganese Chloride					

Corrodent	Alloy 20	Type 316	Hastelloy* B	Hastelloy* C	Monel**
Mercuric Nitrate	1				5
Mercury	1				5 400C 66
Methane	3, 4				
Methanol	1, 4, 9	1			
Methyl Chloride	1, 4, 9				
Methylene Chloride	6, 7	4 5	4	4	23
Mixed Acids H ₂ SO ₄ + HNO ₃		68			
Mono-ethanol-amine					16
Naphthalene	4				
Naphthenic Acid					2 33
Nickel Chloride					2
Nickel Nitrate	4				1
Nickel Sulfate					2
Nitric Acid	1, 6, 7, 18	9 69 37			
Nitric Acid - Red Fuming	7, 9, 18				
Nitric + Hydro-fluoric Acids					
Nitriding Gases					

Corroident	Alloy 20	Type 316	Hastelloy* B	Hastelloy* C	Monel**
Nitro-Benzene 1, 7, 9	22 				
Nitro-glycerin 3					
Nitrous Acids					
Nitrous Oxide					
Oleic Acid 20					
Oxalic Acid 1, 7		9 			3
Per-chloric Acid 7, 18, 19		1 			
Per-chloro-ethylene 9		4 			
Phenol 1, 7		385C 		385C 	
Phosphoric Acid (Aerated) 7		9 			
Phosphorus 1, 4, 7, 20					
Phthalic Anhydride 7		16 	400C 		
Phthalic Anhydride (Pure) + Maleic Anhydride					
Picric Acid 1, 3, 4					
Potassium Bromide 13		4 			2
Potassium Carbonate			900C 	900C 	
Potassium Chlorate 1, 10					

Corroident	Alloy 20	Type 316	Hastelloy* B	Hastelloy* C	Monel**
Potassium Chloride 4	4 	4 5 22 			
Potassium Chromate					
Potassium Cyanide 1, 6, 7		23 			2 23
Potassium Dichromate 1, 7			816C 	816C 	
Potassium Ferri-cyanide 1		71 			
Potassium Ferro-cyanide 1					
Potassium Hydroxide 1, 5, 7, 8, 21	2 19 380C 	5 			2 5
Potassium Nitrate 4, 10					
Potassium Oxalate					
Potassium Permanganate 4, 10					
Potassium Peroxide 3, 4, 10					
Potassium Sulfate					
Propionic Acid					2
Pyridine 4, 9					
Pyrogalllic Acid					
Pyro-ligneous Acid					2
Rosin 4					

Corrodent	Alloy 20	Type 316	Hastelloy* B	Hastelloy* C	Monel**
Salicylic Acid 22					
Silver Nitrate 1, 7					
Sodium Acetate					
Sodium Aluminum Sulfate					
Sodium Bicarbonate					
Sodium Bichromate 5, 6					
Sodium Bisulfate					
Sodium Bisulfite					
Sodium Bromide					
Sodium Carbonate					
Sodium Chlorate 4					
Sodium Chloride					
Sodium Chromate					
Sodium Citrate					
Sodium Cyanide					
Sodium Ferri-cyanide					
Sodium Formal-dehyde Sulfoxylate					

Corrodent	Alloy 20	Type 316	Hastelloy* B	Hastelloy* C	Monel**
Sodium Hydro-sulfide 1, 7, 9					
Sodium Hydroxide 1, 6					
Sodium Meta-silicates					
Sodium Nitrate 10					
Sodium Perborate					
Sodium Perchlorate 3, 4					
Sodium Phosphate					
Sodium Phosphate (Tribasic)					
Sodium Silicates					
Sodium Sulfate					
Sodium Sulfide					
Sodium Sulfite					
Stannous Chloride					
Stearic Acid					
Sulfate Black Liquor					
Sulfate Green Liquor					
Sulfite Liquor with 10% Sulfur Dioxide					

Corrodent	Alloy 20	Type 316	Hastelloy [®] B	Hastelloy [®] C	Monel [®]
Sulfur 4, 23	454C 13 440C			440C	440C
Sulfur Chloride 9	1	1			
Sulfur Containing Oils					
Sulfur Dioxide 6	81 4 80				1
Sulfuric Acid Aerated 1, 7, 24	82	82			82
Sulfuric Acid Fuming 1, 6					
Sulfuric Acid No Air-Static	9	82			
Sulfurous Acid 6, 9	83 370C	5 83 370C			
Sulfur Trioxide 3, 6, 7, 9, 21					
Tall Oil					
Tannic Acid					84
Tetra-phosphoric Acid					
Titanium Tetrachloride 9, 21					
Toluene 4, 9					
Trichloro-ethylene 9		4			4
Trichloro-monofluoro-ethane					
Trichloro-propane					

Corrodent	Alloy 20	Type 316	Hastelloy [®] B	Hastelloy [®] C	Monel [®]
Trichloro-trifluoro-ethane					
Triphenyl Phosphite					
Uric Acid	1				
Vinyl Chloride 4	500C 475C				450C
Zinc Carbonate					
Zinc Chloride	4 8-16	4 8-16			1 2
Zinc Sulfate	4 8-16	4 8-16			2

FOOTNOTES -

CORROSIVES

- Poison
- Toxic
- Explosive
- Flammable
- Ingestion poison
- Inhalant poison
- Attacks skin
- Irritant
- Vapor harmful
- Ignites organics
- Fuming liquid
- Hygroscopic
- Liberates HCl in water
- Narcotic
- Volatile
- Hazardous under pressure
- Ignites combustibles
- Fire Hazard
- Explosive over 70%
- Ignites in moist air at 30°C
- Exothermic in water
- Dust explodes
- Explosive dust
- Exothermic with water

- May discolor
- May catalyze
- May pit
- May stress crack
- Transgranular attack
- Vapor
- Aerated
- Catalyzes
- Static
- Agitated
- ~7 pH
- <7 pH
- >7 pH
- No HCl, H₂SO₄, NaCl
- No ferric chloride
- ~0.1% acetic acid
- Also sludge
- No iron salts
- No sulfuric acid
- Explosive
- With H₂SO₄
- With steam
- No sulfur
- No stress
- No ammonia
- 300 psi
- Stress relieved
- No HCl, Cu, Fe ions
- No Cu, Ni ions
- Over 70% air
- 20-70% air, 530 psi
- With sulfur <340°C

- >2.25% Mo
- Erratic
- With NaCl
- With NaCl, HCl, H₂O₂
- No Fe, Cl
- With +~0.05-1% H₃PO₄ or H₂SO₄
- +SO₂ or HCOOH
- <RC 22, 60,000
- Annealed
- No cold work
- No H₂S
- Permeable to H₂
- Unsulfated
- With or without steam
- 240 psi
- Cold worked
- >80% copper
- >20% sulfuric, bal. nitric acid
- No Mo; low C
- Red fuming
- Pits in chlorides
- Over 400°C
- Steam and air
- 75-100% concentration
- Low NaCl
- With HCl
- <17% zinc
- <0.23%, 200 psi
- 300 psi
- No SO₃
- No NaCl
- High pressure
- 75-120 psi
- No sodium sulfite
- + ammonia
- Avoid hydroxides
- Saturated

FOOTNOTES - DATA SQUARES

- No water
- No air, oxygen
- Low air, oxygen
- Pits
- Stress cracks
- Stress corrosion
- Discolors
- Crevice attack
- Intergranular attack
- No chlorides
- <10 mg/l
- No H₂SO₄
- <60 psi
- No sulfides
- <20% zinc
- Trace HCl
- pH 2 to 3.5
- Annealed, immersed

THE PROBLEMS OF CORROSION

The engineer, metallurgist, or chemist with the problem of developing a product or designing a machine or structure subject to corrosive conditions must know how corrosion works and its relation to all types of metals and alloys that are commercially available. Only then will the most satisfactory and economical results be assured. This information may be classified in relation to the following factors:

1. Cost of original installation, including raw materials and fabrication. The corrosive-resistant metals may range in cost from that of noble metals (gold, platinum, silver, etc.) down to that of common metals such as tin, lead, and ordinary iron. Methods of fabrication may involve welding, riveting, forming, spinning, machining, etc.
2. Availability of the metals which would solve the problem.
3. The type of corrosion likely to be encountered and the rate of attack which can be allowed. This can be roughly divided into three classes:
 - a. Conditions in which color, taste, or odor of the final product are of most importance. This is encountered in the chemical, food, beverage, dairy, and other similar industries, and the metals used must be highly resistant to corrosion from the products that are handled.
 - b. Parts for display or ornamental purposes where surface appearance of the finished part is of most importance and freedom from discoloration is vital.
 - c. Parts used in industry which must remain physically intact over economical periods of service operation and in which the rate of corrosion and the life of the assembly are of most interest.

Stainless steel, in its many ramifications of alloy content which impart varying degrees of corrosion resistance and physical properties, has proved to be an engineering tool that meets a wide variety of conditions just mentioned.

It is primarily an alloy of iron and chromium, a minimum of about 12% chromium being necessary to meet corrosive-resistant requirements. In addition to iron and chromium, copper and molybdenum are sometimes added to improve corrosive-resistant qualities. Nickel is also added to improve corrosion resistance, provide

strength at elevated temperatures and ease fabrication. The chromium-iron alloys without nickel (Alloy 20) offer ample protection for many types of applications and in general are the least expensive to buy. However, on many jobs, the fabricating requirements or corrosive conditions may be such that alloys of chromium and nickel will be most economical. These chrome-nickel alloys (Alloy 20) contain chromium in percentages from 16 to 25 and nickel from 7 up to as high as 20%. These austenitic stainless steels are non-magnetic and are characterized by high ductility. They are not susceptible to improvement in physical properties by heat treatment but can be so improved by cold working. For extreme corrosive conditions, the resistance of the chrome-nickel alloys is further enhanced by the addition of molybdenum (i.e., Alloy 20. Titanium and columbium is added to Alloy 20 to eliminate carbide precipitation).

There is another group of alloys containing approximately 30% nickel, 20% chromium with additions of copper, molybdenum, and silicon that is superior to the 18-8-type alloys in handling sulphuric acid, hot acetic acid, crude phosphoric acid, etc. One such alloy is Alloy 20, a non-magnetic alloy with the same high strength and ductility characteristics of the 18-8 alloys.

Types of Corrosion

Some of the types of corrosion that may be encountered in the use of stainless steels are:

Intergranular corrosion
Galvanic corrosion
Concentration cell corrosion
General corrosion
Pitting corrosion
Stress corrosion cracking

An understanding of the types of corrosion and how they occur can prevent expensive equipment failures if they are considered when equipment is designed and construction materials specified.

Stainless steels are inherently corrosion resistant because of their ability to form a protective coating on their surfaces. This protective coating is commonly called a "passive film." Corrosion theory does not agree as to whether this "passive film" is an absorbed layer of oxygen or an invisible oxide coating. When the "passive film" is penetrated, corrosive attack develops at a point on the surface.

1. Intergranular corrosion of stainless steels is confined solely to the non-magnetic chrome-nickel-type steels of Group "C" with the exception of the stabilized grades and Alloy 20. Briefly, the non-stabilized austenitic chrome-nickel grades, when heated in (or cooled slowly through) the temperature range between 800° and 1,650°F, tend to deposit carbide in the grain boundaries. Under these conditions, the transformed grain boundary areas are subject to attack under some conditions of service. For example, in the processes of welding, there is a "transformation zone" in proximity to the weld. This area is more subject to attack from intergranular corrosion than either the weld metal itself or the balance of the assembly.

Such difficulty can be avoided by two procedures:

- a. By giving the welded assembly a heat treatment after welding. This treatment consists of heating to a temperature of 1,750 to 2,050°F, depending upon the exact composition of the alloy, then rapidly cooling to room temperature.
- b. By using Alloy 20 chrome-nickel stainless steels for the assembly. These grades are resistant to carbide precipitation and can be used in the as-welded conditions. For continuous service in temperatures from 800° to 1,650°F, columbium and tantalum or titanium stabilized alloys are suggested.

Chrome-nickel stainless steels, unless otherwise specified, are in the annealed condition and will be entirely free from susceptibility to intergranular corrosion. The above precautions should be observed in connection with the fabrication of parts by welding and should be taken into account in the use of parts which are exposed to elevated temperatures in service.

2. Galvanic corrosion is common to all metals. This is brought about when two dissimilar metals are in contact in a liquid capable of carrying electric current. This includes practically all aqueous solutions. Under these conditions, an electric current is set up through the solution and tends to accelerate the corrosion of one of the metals and protect the other. For example, where both copper or copper alloys and stainless

steel are in intimate contact in a solution of salt water, the current will tend to accelerate the attack upon the stainless steel portion and lessen the attack upon the copper alloys. In general, the corrosion resistance of stainless is reduced when in contact with lead, nickel, copper, copper alloys, or graphite. On the other hand, it is improved at the expense of the other metal when in contact with iron, steel, aluminum, zinc, or cadmium. The solution to this problem lies in using, so far as possible, metals of the same composition for complete assemblies when this condition is encountered. In some cases, an insulating lacquer can be used to form a separation between the two metals at the point of contact.

The list that follows shows the galvanic behavior of stainless steels with other metals when tested in seawater.

GALVANIC SERIES OF METALS AND ALLOYS

Corroded End (anodic, or at least noble)

Magnesium
Magnesium Alloys
Zinc
Aluminum
Cadmium
Steel or Iron
Cast Iron
Chromium-Iron (active)¹
18-8 Chromium-Nickel-Iron (active)¹
18-8-3 Chromium-Nickel-Molybdenum-Iron (active)¹
Alloy 20
Titanium (active)
Lead-Tin Solders
Lead
Tin
Nickel (active)¹
Brasses
Copper
Bronzes
Copper-Nickel Alloys
Silver Solder
Nickel (passive)¹
Chromium-Iron (passive)¹
18-8 Chromium-Nickel-Iron (passive)¹
18-8-3 Chromium-Nickel-Molybdenum-Iron (passive)¹
Alloy 20
Titanium (passive)
Silver
Graphite
Zirconium
Gold
Platinum
Protected End (cathodic, or most noble)

¹Stainless is "active" in the presence of any combination of chemicals which are reducing and do not allow the formation of an oxide film. A "passive" condition is obtained when the surface of a stainless part had developed the protective oxide film. Treating stainless steels in a passivating solution will accelerate the formation of the film.

THE PROBLEMS OF CORROSION

3. Concentration cell corrosion is somewhat similar to galvanic corrosion in that it is caused by an electric current set up between various parts of the same vessel in which different concentrations of the corrodent exist. This type of corrosion is often associated with crevices such as the space between loosely joined plates or gaskets. The corrodent in such areas tends to stagnate, which causes an increase in ionization. The difference in potential between these spots and adjacent areas is so great that current begins to flow. The stagnant area being anodic soon shows signs of corrosion. This type of trouble can usually be avoided by welding joints or sealing them by caulking.
4. General corrosion: Under ordinary conditions of service at normal temperatures, stainless steels are immune to corrosion by the atmosphere. However, in polluted atmospheres (particularly in hot climates) corrosion is sometimes encountered. Under these conditions, the most corrosion resistant of stainless steels should be employed. The alloys containing chromium, nickel, and molybdenum (Alloy 20) are particularly recommended. In oxidizing atmospheres at elevated temperatures, scaling may be encountered. Stainless steels have a much lower rate of scale formation than ordinary steels. The degree of scaling at a given temperature depends upon the exact composition of the stainless steels employed and the composition of the atmosphere to which the metal is exposed. In a general way, the higher the chromium content, the greater the degree of scale resistance. It has been found by experience that repeated heating and cooling cycles are much more damaging than continuous heating. In applying the chrome-nickel stainless alloys (Alloy 20) to high temperature service, the problem of intergranular corrosion described previously should be taken into consideration.
5. Pitting: Under certain conditions of service, stainless steels which are apparently immune to attack by certain solutions will fail by corroding deeply in individual spots. This type of failure is known as “pit” corrosion. All the causes and correctives of this condition are not well understood at the present time, but several factors are known to accelerate it. The presence of bruises, dents, rough spots, nicks, and foreign deposits on the metal could conceivably promote the formation of pits. If the “protective film” were broken, a pit might start at this point. A pit once formed becomes a concentration cell, and the corrosion is accelerated at this point. In general, the answer when this condition occurs would indicate the selection of a stainless steel having a higher degree of corrosion resistance than that in which the pitting has been encountered. Molybdenum-bearing grades, namely, Alloy 20, are less susceptible to pitting. When pitting occurs, a careful examination of operating conditions is essential.
6. Stress corrosion cracking: As the name suggests, this form of corrosive attack results from the combination of a selected corrosive environment and stresses in the material. Both ferrous and non-ferrous alloys are subject to stress corrosion cracking. The stresses may result from cold working, quenching after heat treatment, or from an externally applied stress. As mentioned previously, the environment to promote stress corrosion cracking is very selective. Chloride-containing solutions or vapors usually promote this type of failure in austenitic stainless steels.

Stress corrosion cracking may be minimized by reducing fabrication stresses, removing harmful contaminants from the environment, or selecting materials which are resistant to this type of failure.

Factors Affecting Corrosion

Some of the factors that influence corrosion, other than the composition of the metal and corrodent itself, are as follows:

1. The presence of impurities in the corrosive medium. Inasmuch as pure chemicals or solutions are seldom encountered in commercial work, the presence of even minor percentages of impurities is of most importance and should be considered when using published corrosion tables.
2. The temperature of the corrodent. As a rule, the degree of corrosion increases with increase in temperature. There are numerous cases where metals satisfactory for cold solutions are entirely unsuitable for these same solutions at more elevated temperatures.
3. The degree of aeration to which a corrodent is exposed. Liquids kept in closed containers from which air or a circulation of air is excluded will cause different degrees of corrosion than these same liquids when freely exposed to the atmosphere. This applies also to the presence of atmospheric gases which may sometimes change the corrosive behavior of metals to a marked degree.
4. Velocity of corrodent. Since published corrosion tables are usually based on static tests, the corrosion actual service may differ due to the effect of the velocity.

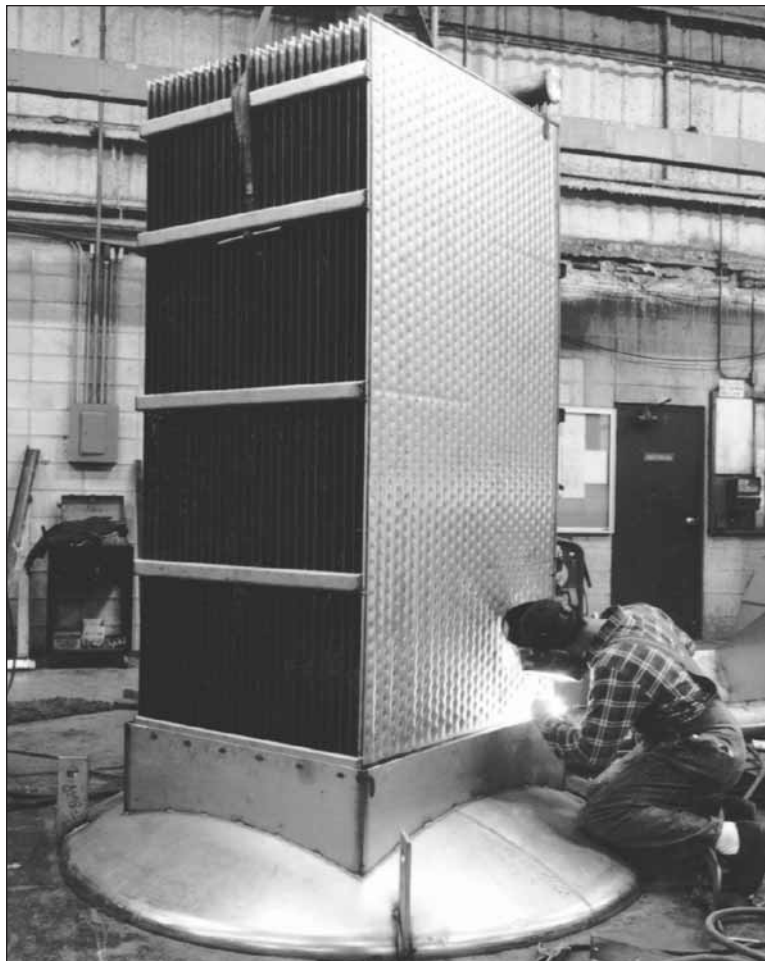
Importance of Passivating

The corrosive-resistant qualities of stainless steels are inherent in the metal itself. However, the contamination of the surface by adhering dirt or scale will have a deleterious effect. For this reason, it is essential that all scale be completely removed and the parts be kept clean while in service.

PRODUCT APPLICATIONS

Mueller Temp-Plate heat transfer surface, which provides for efficient heating or cooling of a product, is used by the following industries:

Aerospace	Aircraft
Aluminum	Appliance
Automotive	Beverage
Chemical	Cosmetic
Dairy	Engineering Firms
Film	Food Processing
Glass	Ice-making
Laundries	Meat Packing
Metal Finishing	Nuclear Power
Pharmaceutical	Plating
Pulp and Paper	Steel
Sugar	Textile
University Laboratories	Utilities



Inflated Temp-Plate bank assembly for heat recovery from hot gas.



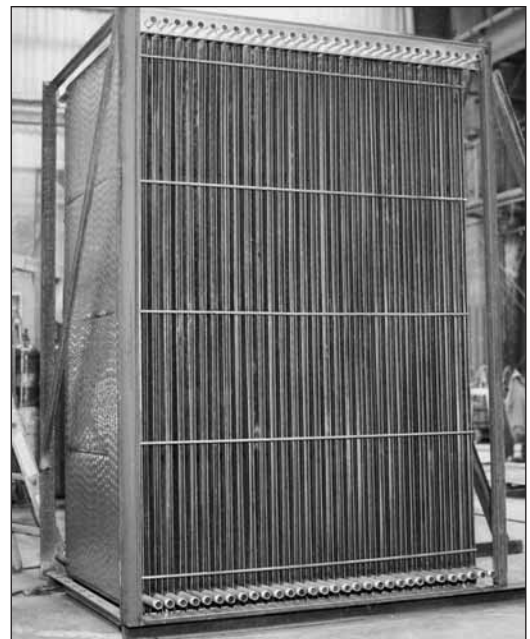
Inflated Temp-Plate cone sections.

Temp-Plate heat transfer surface has multiple applications in industries. Paul Mueller Company manufactures Temp-Plate in a great variety of styles, sizes, and materials for a multitude of purposes. For example:

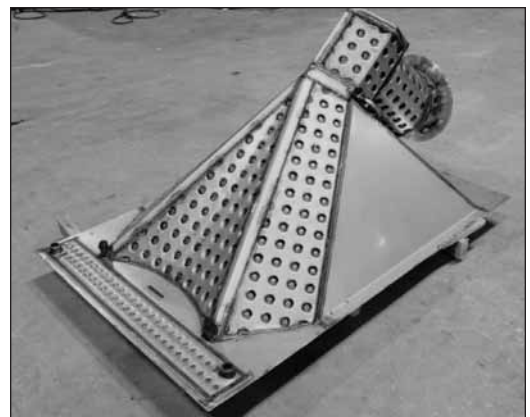
- Banks of Temp-Plate for: cooling coffee extract, cooling quench oil, cooling waste water while heating make-up water, cooling water for fish hatcheries, heating a city's water supply with boiler condenser water, heating lard, separating moisture from crude oil
- Circular flat sections for inside bottoms of processing tanks
- Clamp-on sections for shells, cones, and heads
- Cooling cone for aerospace program
- Cooling shell sections for field-erected brewery fermenting tanks
- Cryogenic shrouds for mirror fusion energy
- Drying shelves for textiles and pharmaceuticals
- Evaporator pans for paper producers
- Frost and steam pans for cafeteria lines
- Fluidized bed dryers
- Freeze-drying shelves
- Ice-making plates
- Immersion sections for: brine chilling, chilling wine, cooling anodizing solutions, drying powdered milk, heating spray phosphate tanks, heating or cooling metal cleaning and plating tanks, heating wire drawing solutions, ore recovery
- Internal baffles for tanks with agitators
- Interior cooling sections for yeast propagators
- Jacketed cylinders
- Jacketed heads and cones
- Jacketed troughs
- Large internal baffle assemblies for cooling vegetable oil
- Liquid natural gas vaporizers
- Liquid oxygen vaporizers
- Pan sections for cooling candy
- Tank covers
- Trough sections for cooking foods
- Vacuum drums
- Water chillers



Inflated Temp-Plate troughs for poultry industry.

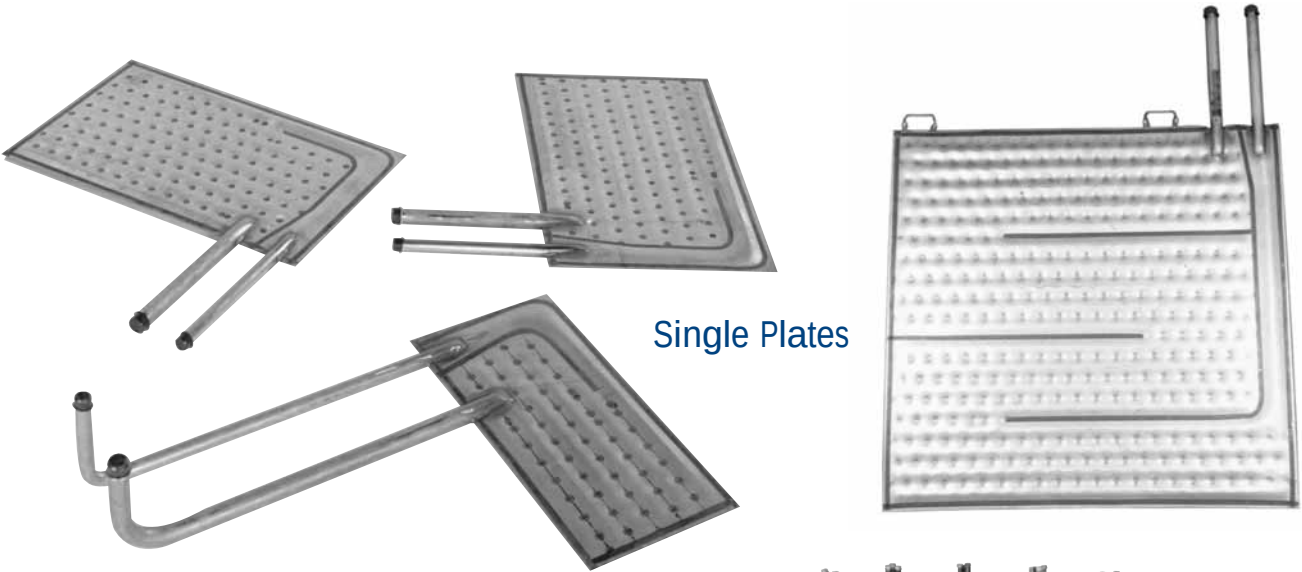


Temp-Plate bank assembly.



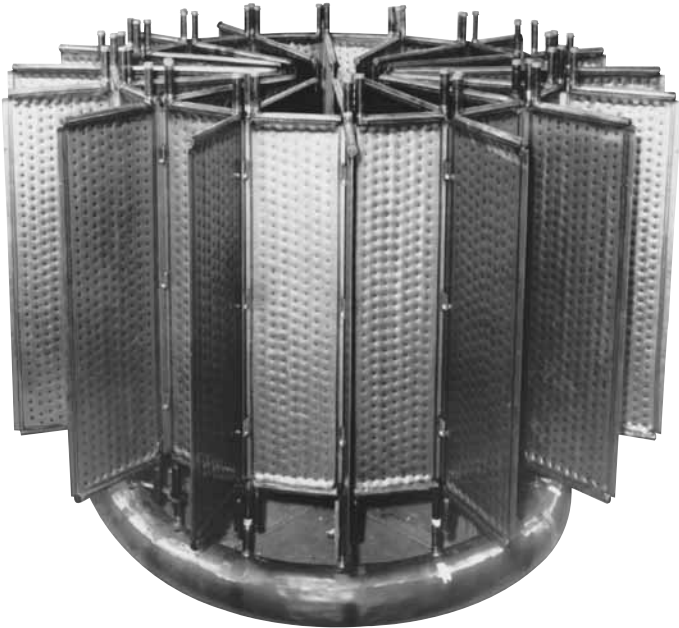
Inflated / dimpled Temp-Plate chute assembly.

IMMERSION SECTIONS

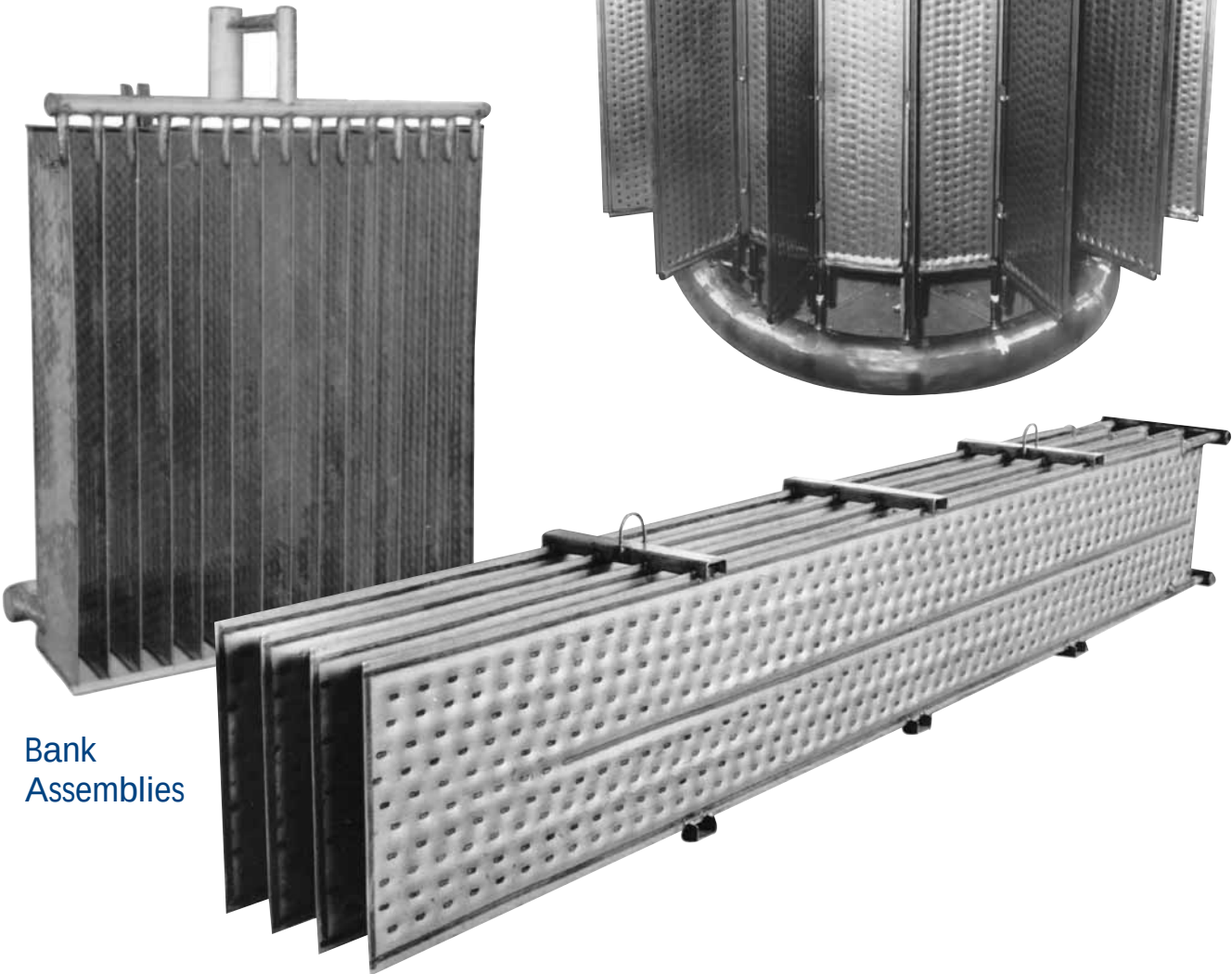


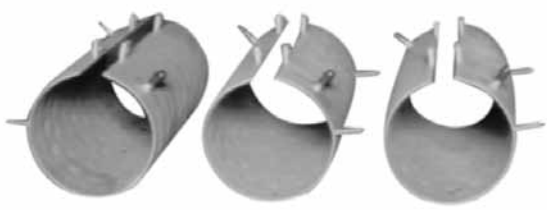
Single Plates

Baffles

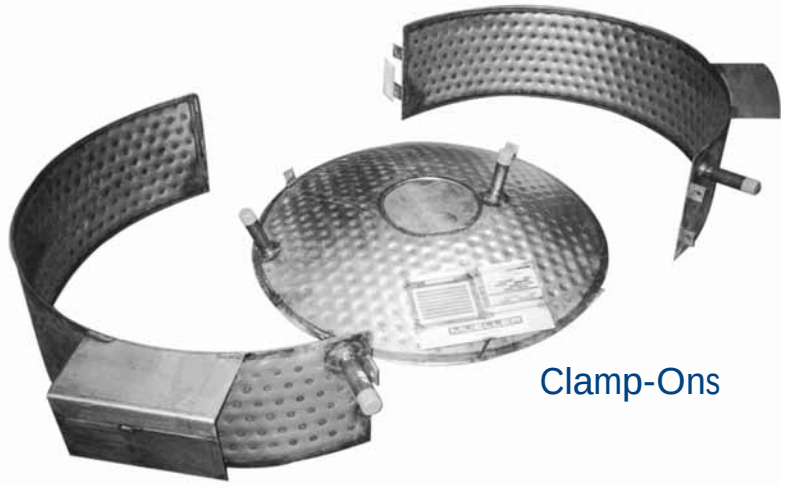


Bank
Assemblies

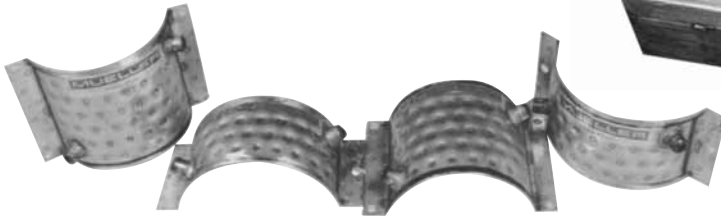




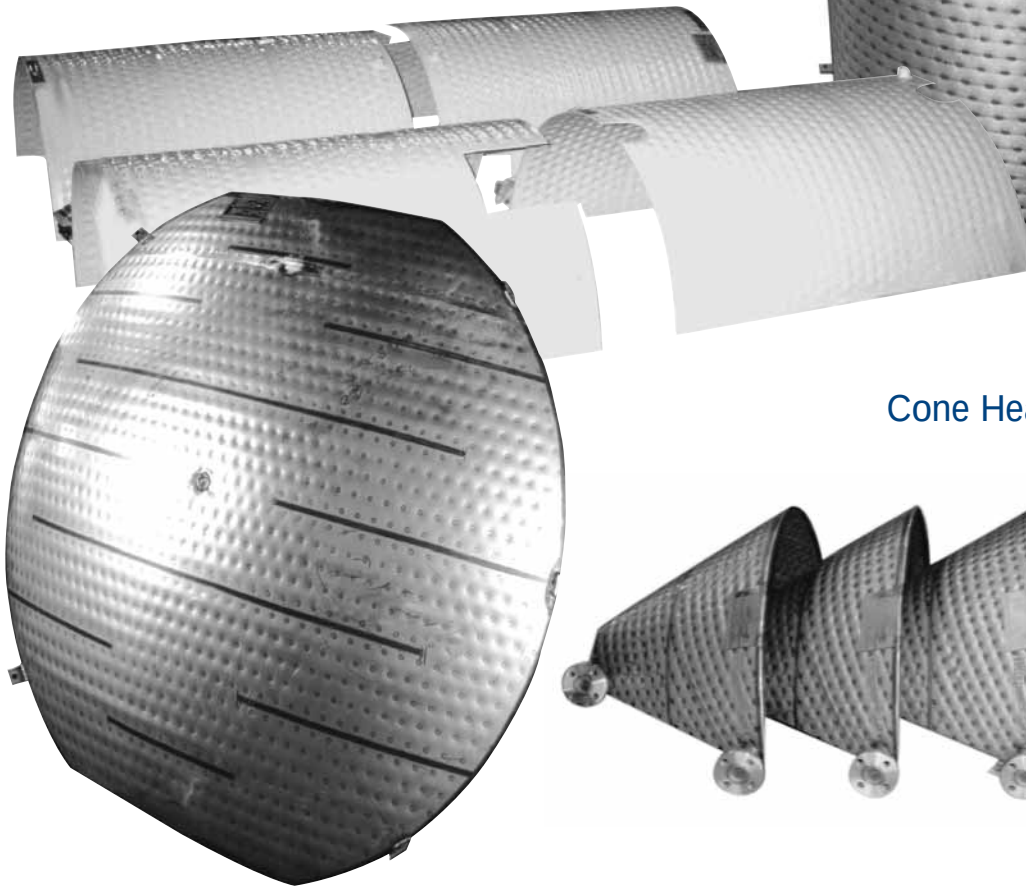
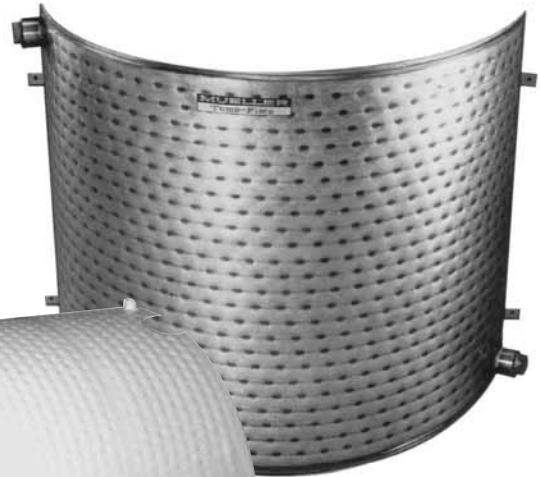
Pipe Clamp-Ons



Clamp-Ons

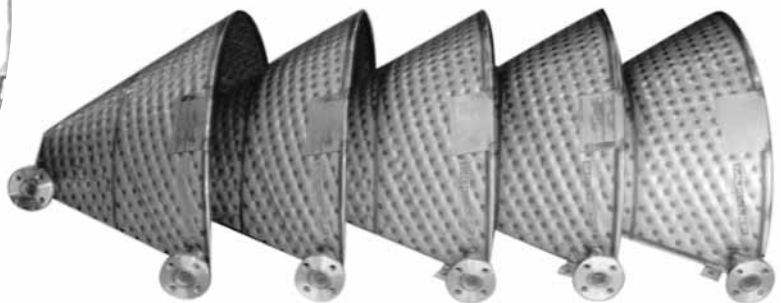


Shell Clamp-Ons

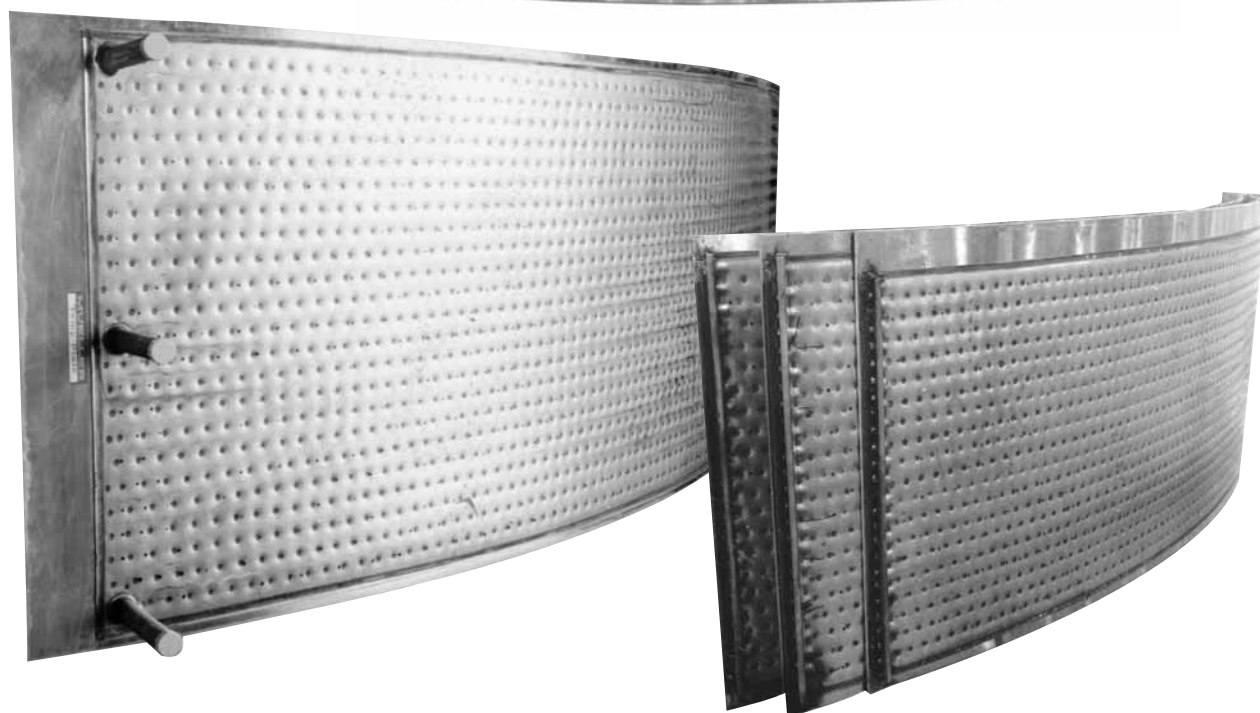
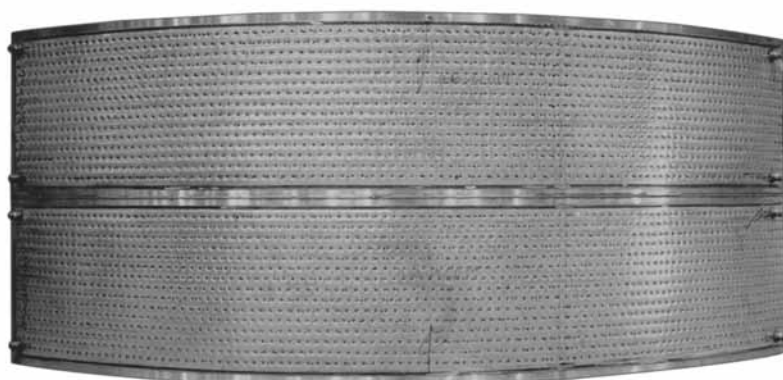
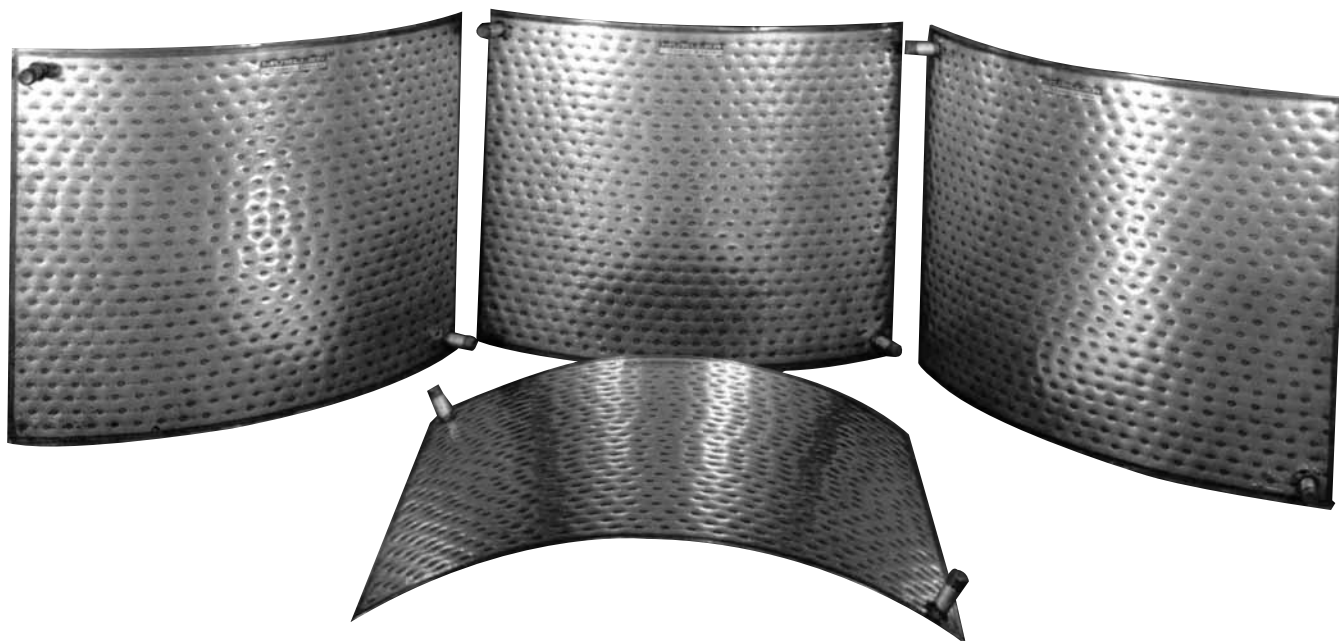


Head Clamp-On

Cone Heads



JACKETED SHELL AND HEAD SECTIONS



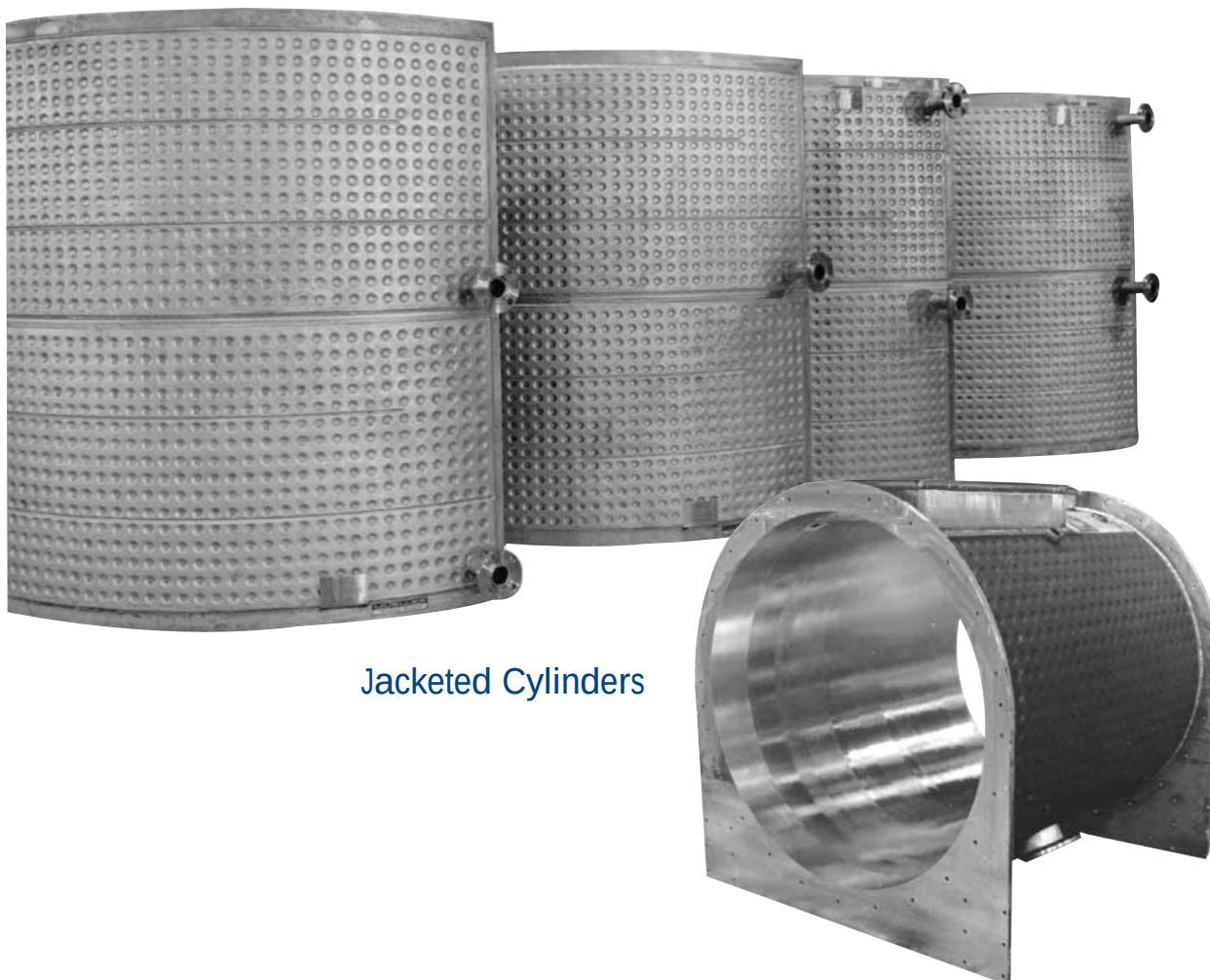
SUPPLIED FOR USE AN AS INTEGRAL PART OF A VESSEL



Jacketed Head

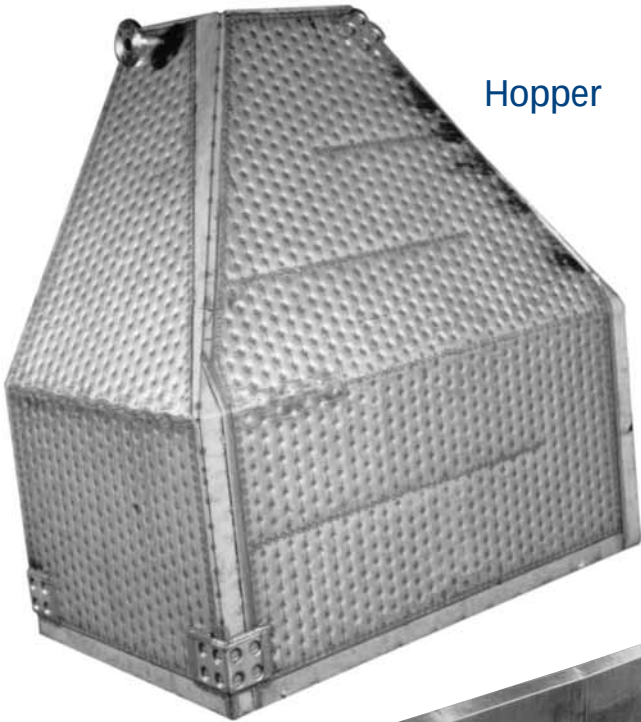


Jacketed Trough

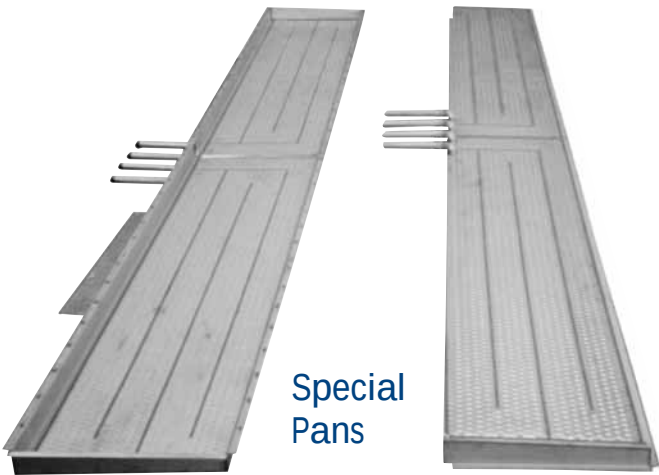


Jacketed Cylinders

SPECIAL APPLICATIONS



Hopper



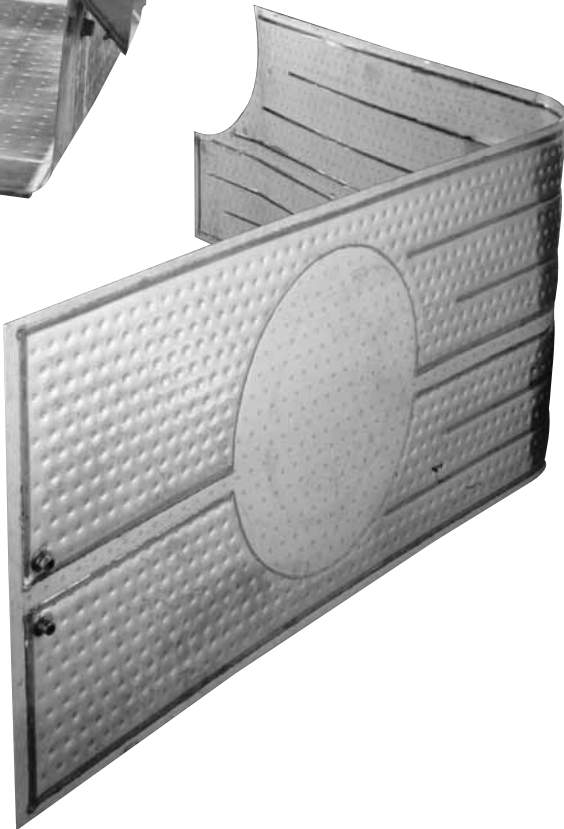
Special
Pans



Food Cooker

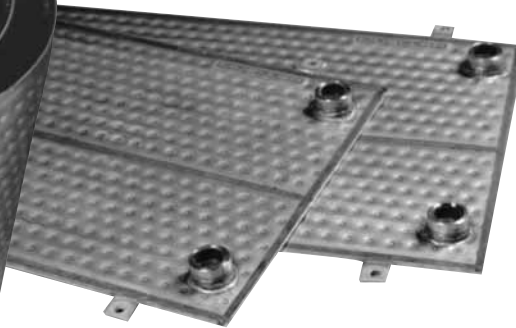


Heat Shields

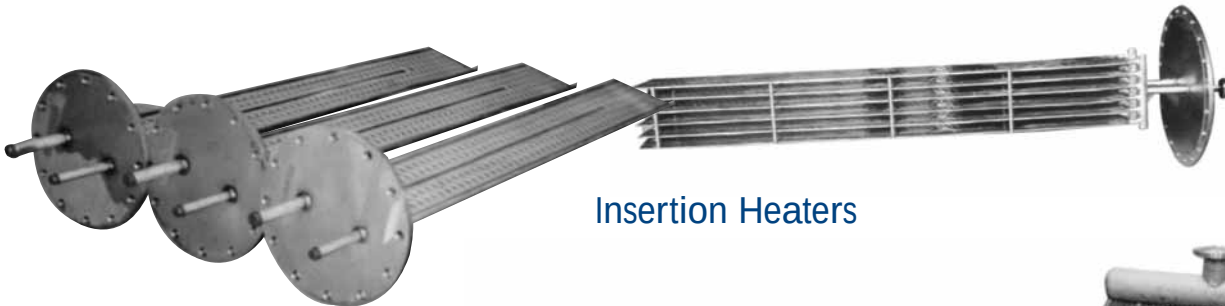




Calandria



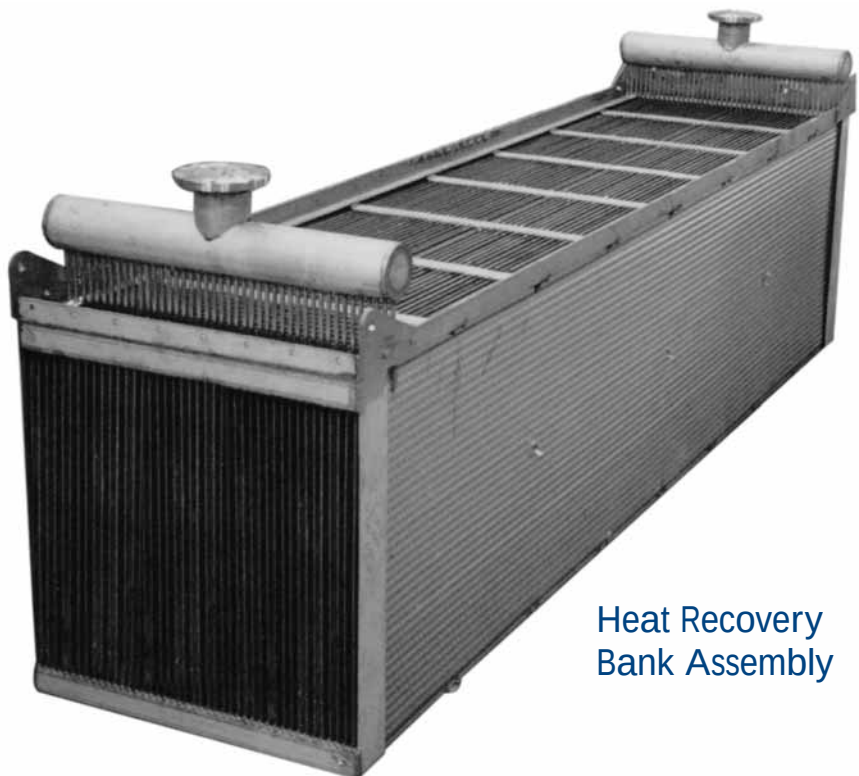
Flat Clamp-Ons



Insertion Heaters



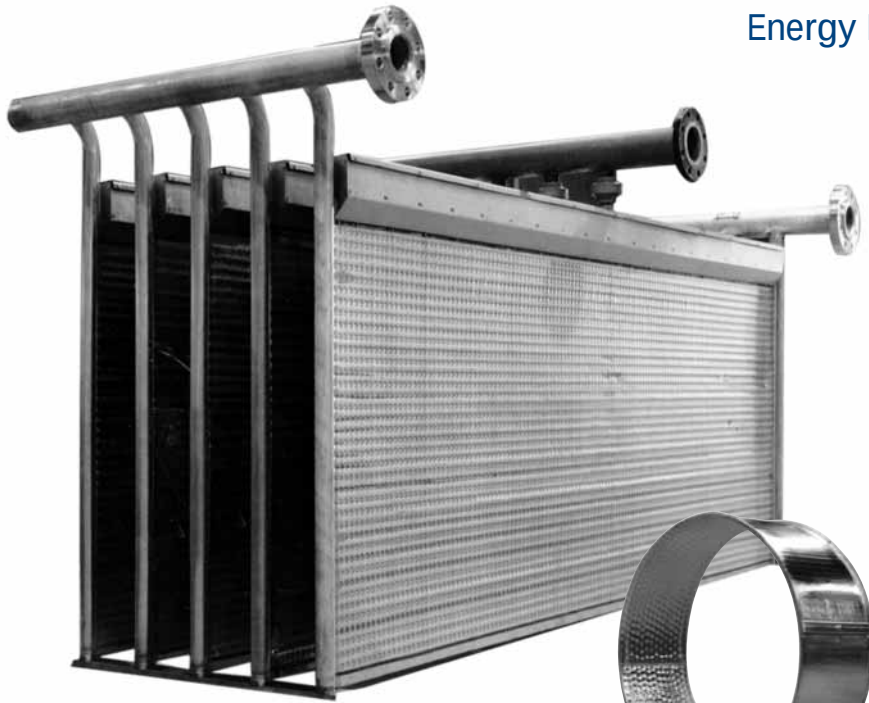
Cooling Shrouds



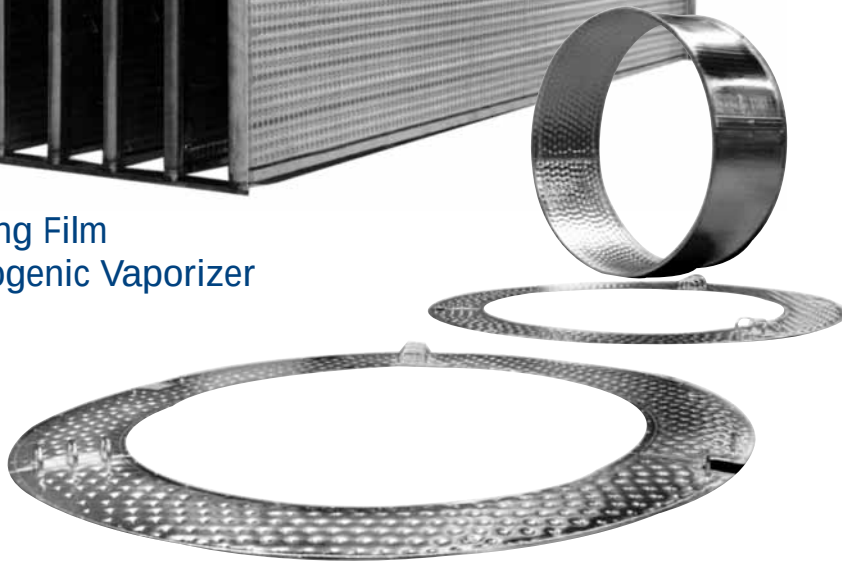
Heat Recovery
Bank Assembly

ENERGY CONSERVATION

Energy Bank



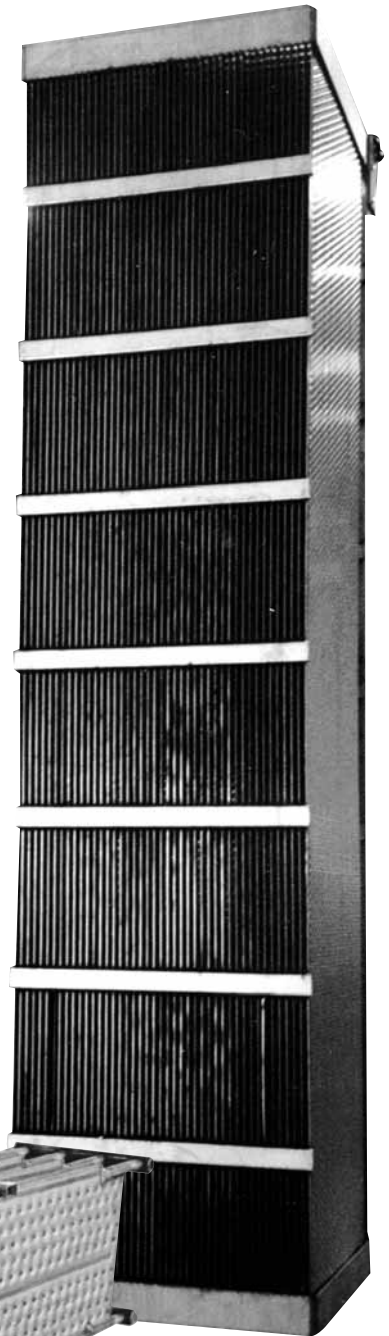
Falling Film
Cryogenic Vaporizer



Cryogenic Shrouds for Mirror Fusion



Cooling Waste Water While
Preheating Make-Up Water



FOOD SERVICE DISPLAY UNITS

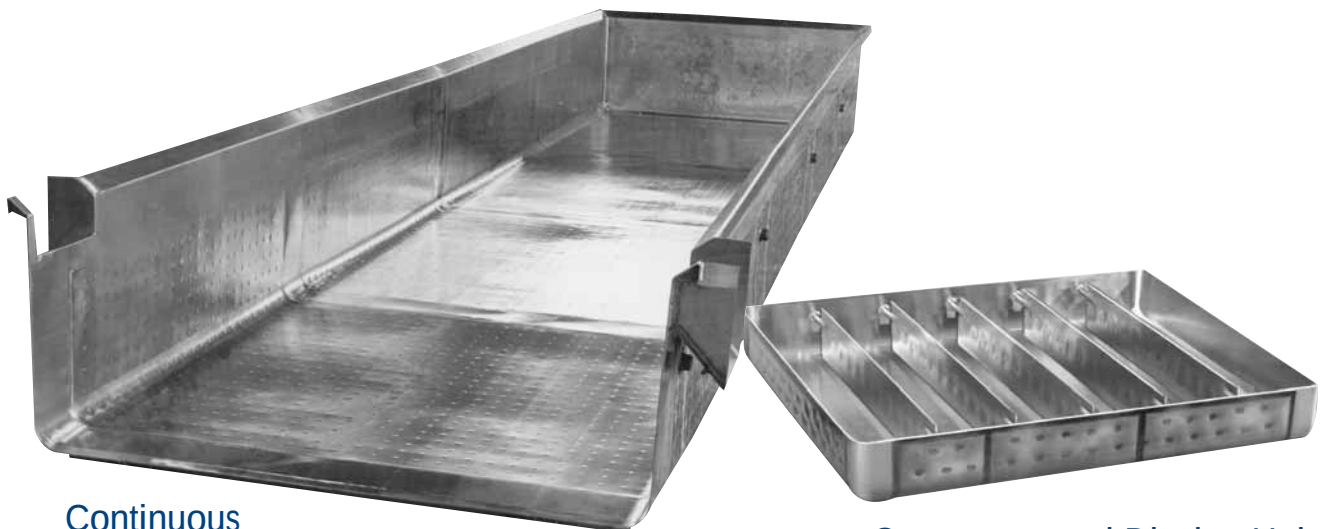


Salad Display Unit

"Lazy Susan"
Display Unit



Two-Level Salad
Display Unit



Continuous
Cooker Shell

Compartmental Display Unit

NOTES



**Visit our
Web site at
www.hxrx.com!**

All products, specifications, and features listed herein are representative of the final product and are intended as reference only. We reserve the right to make alterations without notice.

MUELLER®

1600 West Phelps Street • Springfield, Missouri 65802, U.S.A.
Phone: (417) 575-9000 • 1-800-MUELLER • Fax: (417) 575-9885
www.muel.com • E-mail: heattransfer@muel.com