

METAL RESISTANCE

FOR BARE TUBE;

$$(1) \quad V_m = \frac{t_w D_o}{12(K_m)(D_o - t_w)}$$

AVERAGE

D_o = TUBE O.D.,

t_w = WALL THICKNESS

K_m = METAL
THER.

CONDUCTIVITY

FOR EX:

$\frac{3}{4}$ " O.D. CARBON STEEL TUBE 14 BWG (0.083" TK)
 $K_m \approx 30 \text{ BTU/HR FT}^2/\text{°F(FT)}$

$$\begin{aligned} V_m &= \frac{0.083(0.75)}{12(30)(0.75 - 0.083)} \\ &= \underline{0.000259} \text{ (HR } \text{°F FT}^2\text{/BTU)} \end{aligned}$$

FOULING RESISTANCES.

$\gamma_{\text{dirt SHELL}}$ or $\gamma_{\text{dirt TUBE}}$

- OPER. EXPERIENCE
- EST'D FROM TABLES
SUCH AS IN "TEMA"

FLUID FILM RESISTANCES $r_{\text{SHELL}}^f, r_{\text{TUBE}}^f$

ARE DETERMINED FROM:

CORRELATIONS INVOLVING

- TUBE DIAM.
- FLUID FLOW
- VISCOSITY
- THER. CONDUCTIVITY
- SPECIFIC H.T.

FOR EXAMPLE: TUBE SIDE TRANSFER,
COEFF. CAN BE CALCD
FROM:

DITTUS-BOELTER EQ: $\frac{h_t D}{K_b} = 0.023 \left(\frac{DG}{\mu_b} \right)^{0.8} \left(\frac{c_p \mu_b}{K_b} \right)^{0.4}$

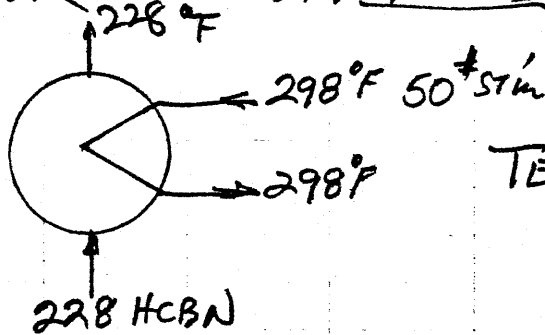
$\swarrow$ N_{Nu} $\swarrow$ N_{Re} $\swarrow$ N_{Pr}

LOG MEAN TEMP. DIFFERENCE

$$Q = UA \Delta T_m$$

$$\Delta T_m = \frac{GTTD - LTTD}{\ln \frac{GTTD}{LTTD}}$$

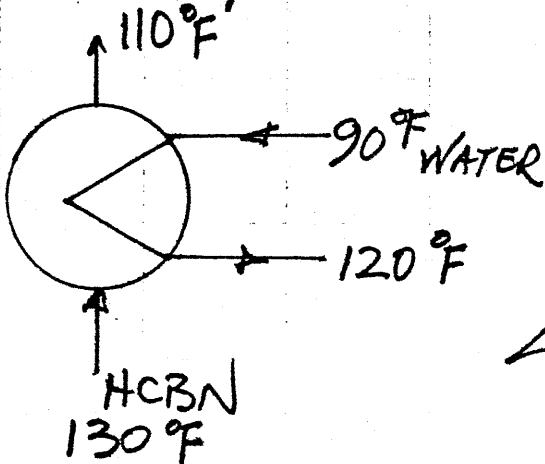
FOR STIM HEATED REBOILER



$$\text{TEMP. DIFF} \left\{ \begin{array}{l} 298^\circ\text{F} \\ - 228 \\ \hline 70^\circ\text{F} \end{array} \right.$$

IS LIMITED

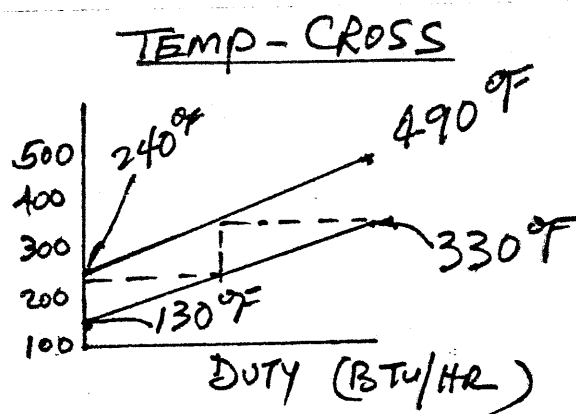
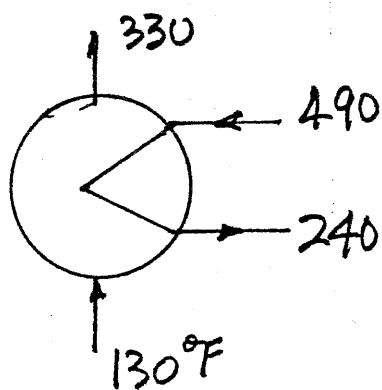
NORMALLY:



$$\begin{array}{rcl} 130 & \rightarrow & 110^\circ\text{F} \leftarrow \text{HCBN} \\ 120 & \leftarrow & 90^\circ \leftarrow \text{WATER} \\ \hline 10 & & 20 \end{array}$$

$$\Delta T_m = \frac{20 - 10}{\ln \frac{20}{10}} = \underline{\underline{14.4^\circ\text{F}}}$$

HOW TO CALCULATE CORRECTED LMTD



$$\begin{array}{rcl}
 490 \rightarrow 240 & = & 250 \\
 330 \leftarrow 130 & = & 200 \\
 \hline
 160 & & 110
 \end{array}
 \quad
 \begin{array}{l}
 \Delta T \\
 250 \\
 200 \\
 360
 \end{array}
 \quad
 \begin{array}{l}
 250 / 200 = 1.25 = R \\
 200 / 360 = 0.555 = P
 \end{array}$$

$$\begin{aligned}
 \Delta T_m &= \frac{160 - 110}{\ln \frac{160}{110}} \\
 &= \frac{50}{0.375} \\
 &= 133.4
 \end{aligned}$$

FROM TEMA CHARTS
(2 SHELL PASSES)
 $F = 0.87$

$$\begin{aligned}
 \text{OR } R' &= 1/R = \frac{200}{250} = 0.8 \\
 P' &= PR = \frac{250}{360} = 0.694 \\
 F' &= 0.87 = F
 \end{aligned}$$

$$\Delta T_c = \Delta T_m \times F = 133.4 \times 0.87 = \underline{\underline{116^\circ F}}$$

EXCHANGERS

NOT TRUE COUNTERFLOW

- ① WHEN TUBE PASSES NOT EQUAL
TO SHELL PASSES

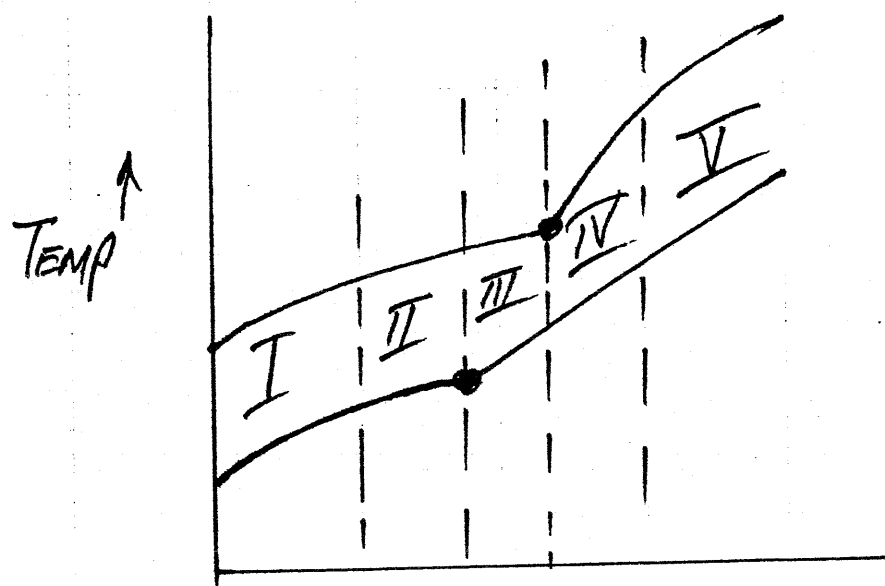
FOR EX: (1 SHELL PASS WITH 2 OR MORE
TUBE PASSES)

- ② THEN, USE LMTD CORRECTION
FACTOR OF 0.8 OR HIGHER

HOW TO CALCULATE WTD, MTD

- REQUIRED WHEN PROFILE GRAPH IS NON-LINEAR
- DIVIDE GRAPH INTO CONVENIENT ZONES (SECTIONS)
- BE SURE TO GO THROUGH DEFLECTION pts
points

FOR EXAMPLE: DIVIDE AS FOLL:



SEE
EXAMPLE (EXHIBIT 2B)
CALC:

UOP

Process Division • UOP Inc.

20 UOP Plaza — Algonquin & Mt. Prospect Roads • Des Plaines, Illinois 60016 • U.S.A.

PROJECT SPECIFICATION

NUMBER

REVISION

— 402 —

SHEET

OF

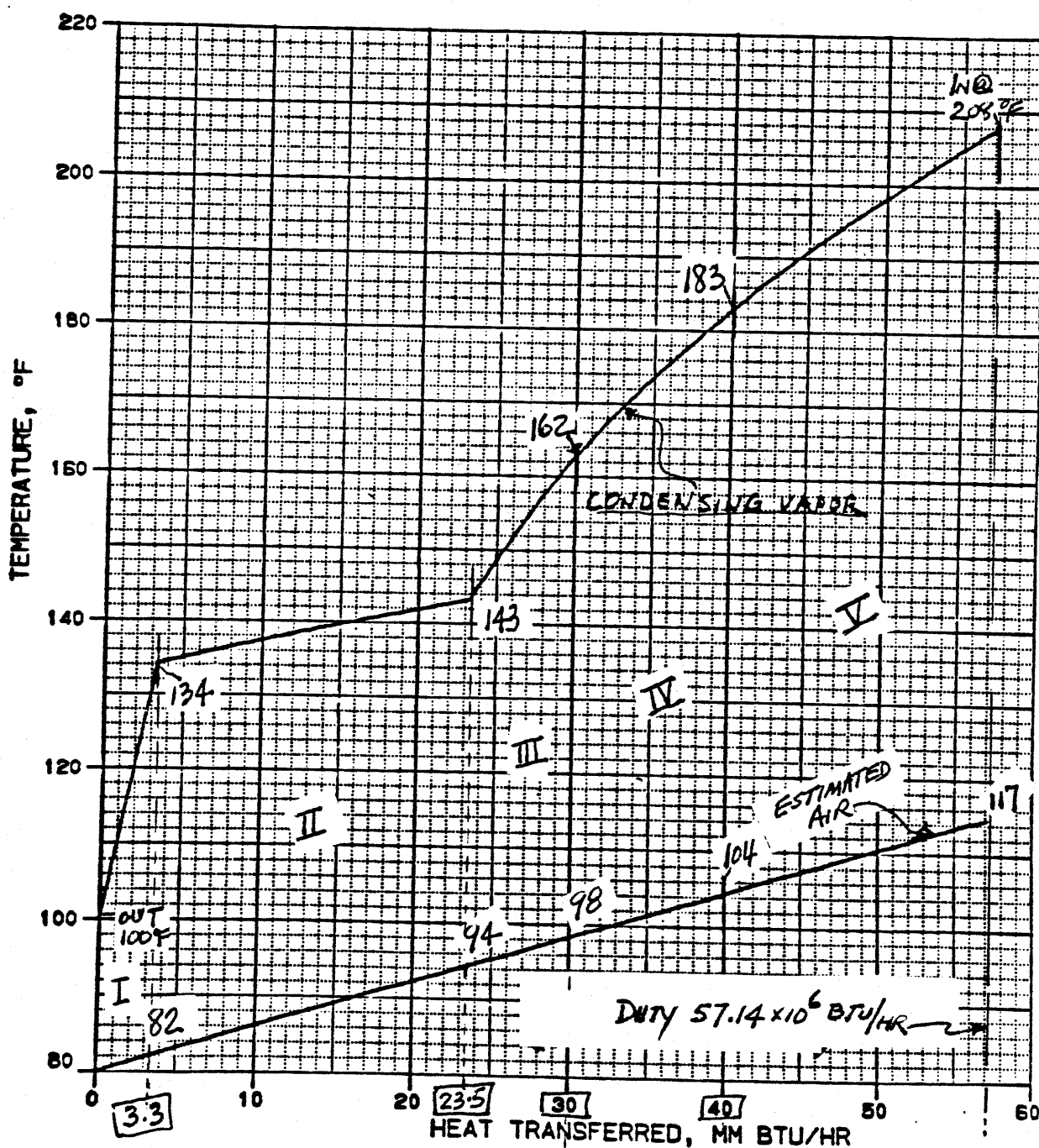
BY

APP'D

DATE

AIR COOLED EXCHANGERSEXHIBIT 2AHEAT RELEASE CURVES(RECOVERY COLUMN CONDENSER)

→ SAMPLE; WTD, MTD.



NOTE — These data are confidential and the property of UOP Process Division and shall not be disclosed to others or reproduced in any manner or used for any purpose whatsoever except by written permission or as provided in a signed agreement with UOP Process Division relating to such data.

EXHIBIT 2B

SAMPLE CALCULATION OF WEIGHTED LMTD

Q-UAOT

(1) DIVIDE PROFILE INTO CONVENIENT ZONES:

	V	IV	III	II	I	
$\Delta Q, \text{BTU/HR}, 10^6$	17.14	10	6.5	20.2	3.3	$\Sigma Q = 57.14 \times 10^6$
	208 → 183	183 → 162	162 → 143	143 → 134	134 → 100	°F HC
	117 ← 104	104 ← 98	98 ← 94	94 ← 82	82 ← 80	°F AIR
	91	79	64	49	52	20
MTD =	84.9	71.2	56.2	50.5	33.5	

(2) DIVIDE EACH ZONE BY MTD FOR THAT ZONE

$$\left(\frac{Q}{T}\right)_V + \left(\frac{Q}{T}\right)_IV + \left(\frac{Q}{T}\right)_III + \left(\frac{Q}{T}\right)_II + \left(\frac{Q}{T}\right)_I$$

$$10^6, \quad 0.2019 + 0.1404 + 0.1156 + 0.40 + 0.098 = \Sigma \left(\frac{Q}{T}\right)$$

(3) WTD MTD (UNCORRECTED) = $\frac{Q_{\text{TOTAL}}}{\left(\frac{Q}{T}\right)_I + \left(\frac{Q}{T}\right)_II + \dots}$

$$\frac{57.14 \times 10^6}{0.9564 \times 10^6} = \underline{59.7^\circ\text{F}}$$

(4) IF STRAIGHT LINE MTD: $\frac{208 \rightarrow 100}{117 \leftarrow 80}$ (UNCORRECTED)

$Q = UA \Delta T_m$

(5) % SURFACE SAVED:

$$\frac{(59.7 - 46.9)}{46.9} \times 100 = \underline{27.3\%}$$

$\frac{Q}{A} = U \Delta T_m$

(EXHIBIT 2C)

HEAT RELEASE CURVES

HOT SIDE DRY DEW POINT 195°F, PRESS 5 PSIG
HOT SIDE BUBBLE POINT 111°F, PRESS -1 PSIG
HOT SIDE H2O DEW POINT 162°F, PRESS 4 PSIG

(STRIPPER OVERHEAD CONDENSER)

HEAT TRANSFERRED 19.82 MM BTU/HR

ESTIMATED WEIGHTED COUNTERFLOW MTD 45°F ←

NOTE: IF STRAIGHT LINE MTD:

228 → 105

121 ← 80

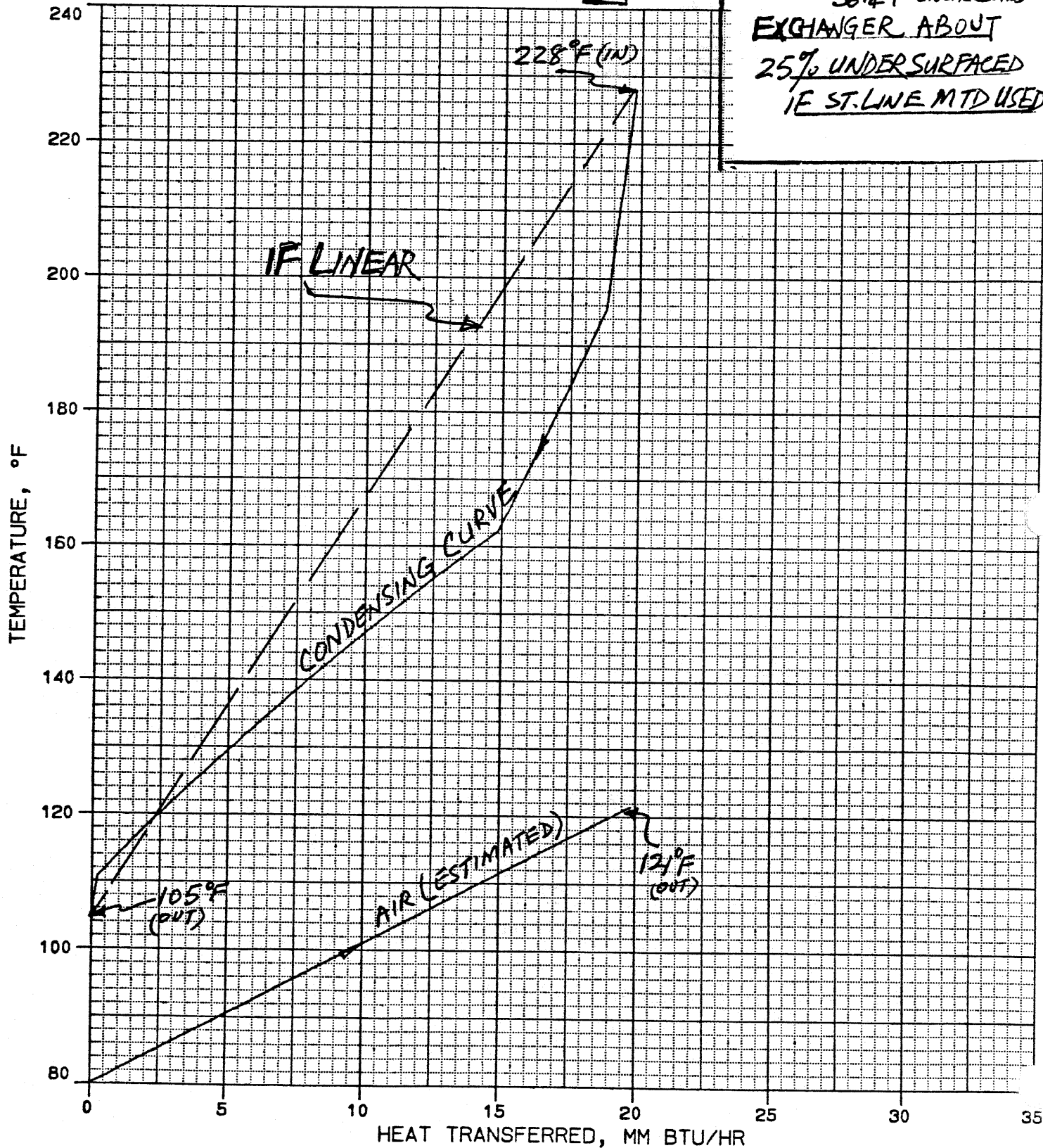
107 25

56.4°F UNCORRECTED

EXCHANGER ABOUT

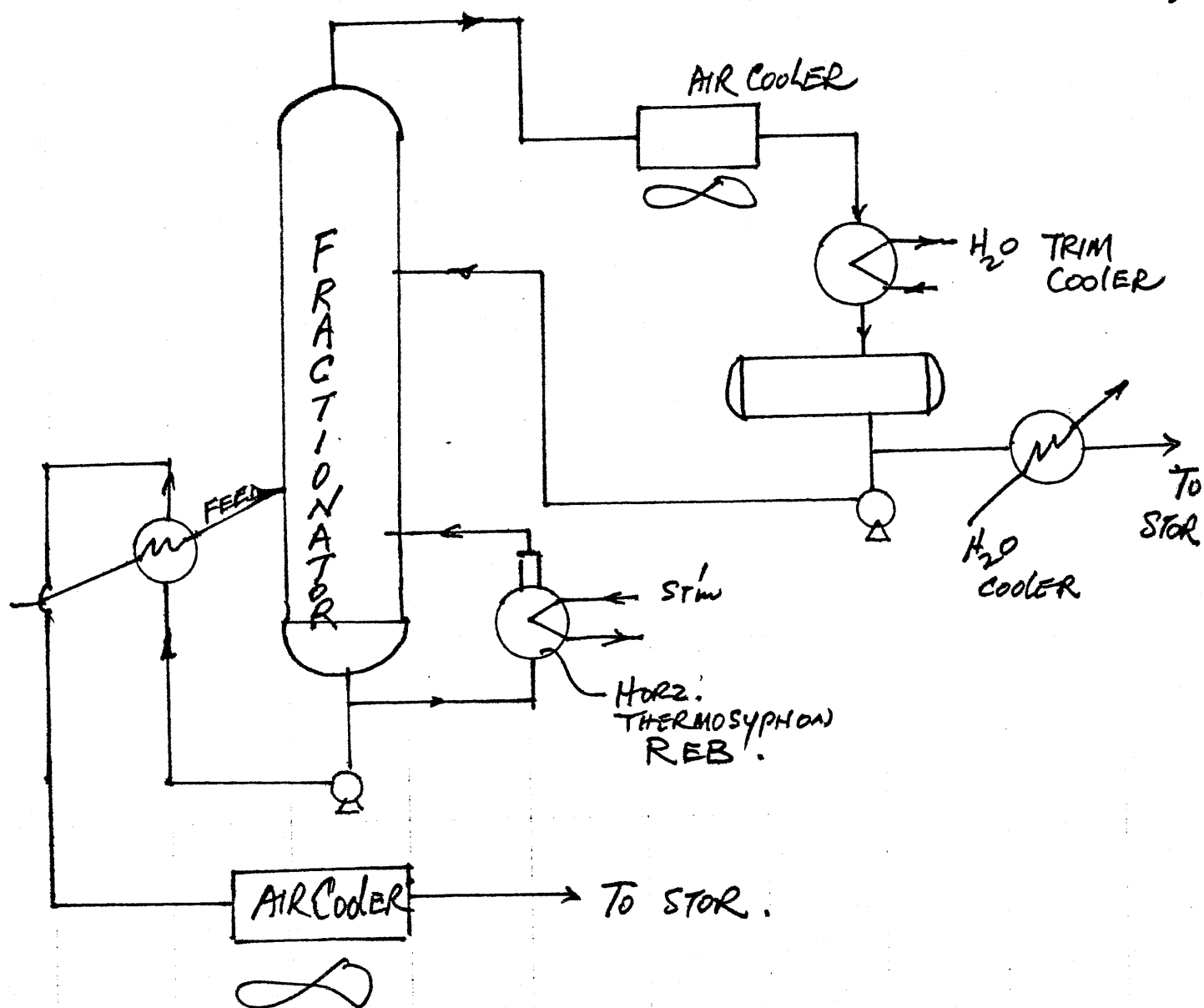
25% UNDERSURFACED

IF ST. LINE MTD USED



TYPICAL USE OF EXCHANGERS

(PROCESS CONSIDERATIONS)



TEMPERATURE OF PRODUCT TO STORAGE

IN GENERAL, LIGHTER HYDROCARBON
GOES TO STORAGE COLDER

EXAMPLES:

- GASOLINE, BUTANES, $\approx 100^{\circ}\text{F}$
- KEROSENE; MID-DISTILLATES $\approx 125^{\circ}\text{F}$
- VACUUM GAS OIL $\approx 150^{\circ}\text{F}$
- REDUCED CRUDE ≈ 175 TO 200°F

↓
water vapor ~~from~~ open
↓
* STEAM OR N

GRADED METALS

Rough Guid line.

LATEST (For partial pressure $H_2 \leq 200$ psi).

Above 525°F $\cdot$ $1\frac{1}{2}$ CR - $1\frac{1}{2}$ Mo or

FLUID ROUTING

IN GENERAL

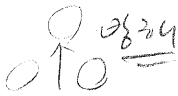
- MECHANICAL REASON
& PROCESS REASON
BOTH SIDE
- FOULING FLUIDS
 - HIGH PRESSURE SIDE
 - SLURRY (FCC UNIT)
 - COOLING WATER
 - STEAM
 - HIGH TEMP. FLUID
 - CORROSIVE FLUID
(Ex: HF. ACID)
- IN TUBES

- HIGH VISCOSITY FLUIDS
(≥ 5 CENTIPOISE)
 - LOW FLOW
- ON SHELL
SIDE

TUBE PATTERN

IN GENERAL

- SQ. PITCH FOR REBOILERS
(IF SHELL SIDE BOILING)



SQ PITCH

- SQUARE OR ROTATED SQ. PITCH
WHEN SHELL SIDE FLUID IS FOULING
($\geq 0.002 \text{ HR}^\circ\text{F FT}^2/\text{BTU}$)
THIS ALLOWS MECHANICAL CLEANING

- TRIANGULAR PITCH CAN BE
USED FOR CLEANER FLUIDS
IN SHELL ($\leq 0.0015 \text{ HR}^\circ\text{F FT}^2/\text{BTU}$)

TRIANGULAR

- ALSO, 15 TO 30% MORE TUBES
FOR SAME SIZE SHELL

1" OD

3/4" OD

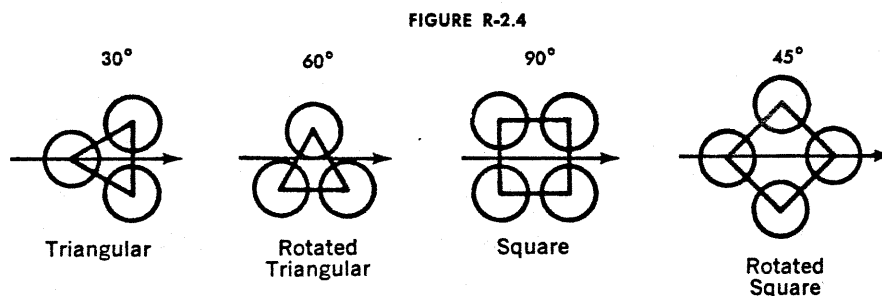
SECTION 5

Mechanical Standards TEMA Class "R" Heat Exchangers

R-2 TUBES—(Continued)

R-2.4 TUBE PATTERN

Standard tube patterns are shown in Figure R-2.4.



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

R-2.41 SQUARE PATTERN

In removable bundle units, when the tubes are laid out on a square or a rotated square pattern, tube lanes should be continuous throughout the bundle.

R-2.42 TRIANGULAR PATTERN

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

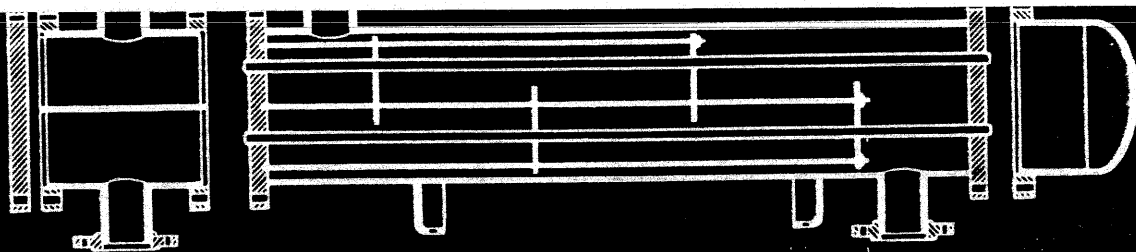
R-2.5 TUBE PITCH

Tubes shall be spaced with a minimum center-to-center distance of 1.25 times the outside diameter of the tube. When tubes are on a square pattern, a minimum cleaning lane of $\frac{1}{4}$ " shall be provided. Tolerances shown in Paragraph R-7.2 will apply.

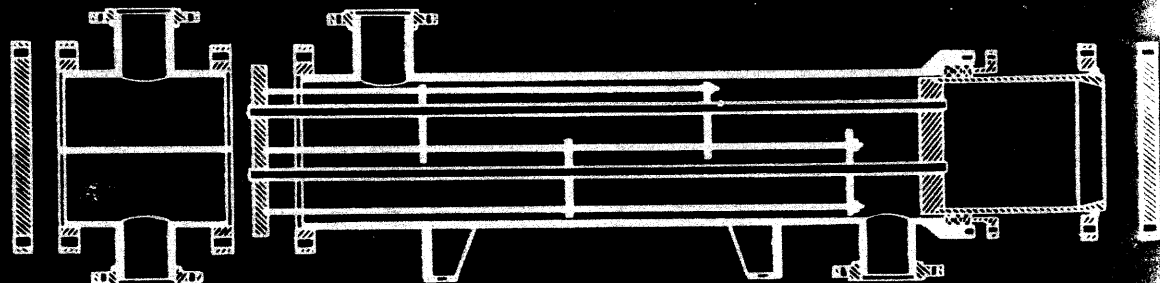
R-2.6 TUBE LAYOUT

The tube layout should minimize by-passing around the tube bundle. See Paragraph R-4.8.

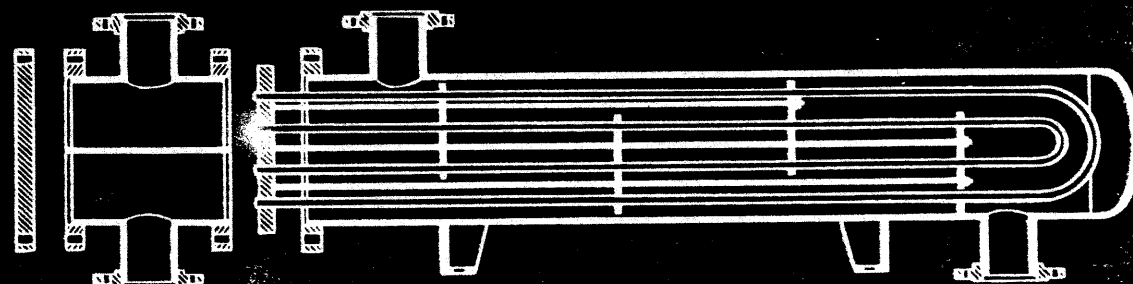
FIXED TUBE SHEET



EXTERNALLY PACKED FLOATING HEAD



U"-TUBE REMOVABLE BUNDLE



D-15A

TUBE COUNT TABLES

The Tube Count Tables on these pages may be effectively applied with the type of heat exchangers depicted above.

The number of tubes shown is the optimum number of tubes that can be installed in the size and type of heat exchangers listed. These tube counts are based on TEMA nominal baffle and tube-to-shell clearances and TEMA bundle entrance and exit area requirements. The shell side nozzle sizes are approximately $1/5$ of the shell diameter with an impingement plate beneath the entrance nozzle and a ρV^2 value of 1500 in the nozzles.

3/4" TUBES ON 15/16" PITCH

SHELL I. D. (INCHES)	FIXED TUBE SHEET				OUTSIDE PACKED FLOATING HEAD				U-TUBE		
	NO. OF PASSES				NO. OF PASSES				NO. OF PASSES		
	1	2	4	8	1	2	4	8	2	4	8
17.25	254	236	224	212	229	216	200	188	101	98	92
19.25	330	322	300	272	301	290	268	244	141	130	120
21.25	387	370	348	336	358	346	324	316	163	160	152
23.25	483	472	448	412	450	436	412	384	213	202	190
25.00	565	544	512	480	522	502	472	432	246	238	216
27.00	658	634	608	560	612	598	568	520	294	280	260
29.00	763	740	704	660	719	698	656	616	343	326	308
31.00	875	848	808	756	827	800	768	716	394	382	356
33.00	993	964	932	872	942	918	880	824	450	438	408
35.00	1118	1086	1044	1020	1064	1034	988	956	510	494	484
37.00	1266	1248	1208	1144	1221	1184	1144	1088	587	570	542
39.00	1426	1396	1344	1272	1351	1328	1280	1220	660	640	606
42.00	1641	1602	1548	1488	1569	1538	1480	1420	759	740	706
45.00	1906	1864	1808	1736	1837	1792	1732	1664	887	868	834
48.00	2188	2142	2088	2004	2102	2062	2000	1912	1026	1002	966
51.00	2480	2440	2376	2292	2396	2356	2292	2204	1171	1140	1104
54.00	2769	2716	2652	2568	2672	2626	2564	2480	1304	1282	1226
60.00	3451	3396	3320	3220	3345	3288	3208	3116	1642	1608	1562
64.00	3921	3860	3792	3676	3798	3744	3668	3560	1869	1840	1784
68.00	4432	4366	4284	4160	4305	4244	4148	4032	2114	2086	2020
72.00	5023	4956	4868	4744	4878	4816	4732	4600	2406	2372	2306
76.00	5578	5506	5412	5276	5449	5374	5284	5156	2680	2640	2574
80.00	6179	6100	5996	5868	6031	5964	5868	5720	2968	2930	2862
84.00	6868	6788	6688	6544	6717	6644	6532	6384	3313	3272	3198
90.00	7873	7798	7680	7528	7724	7634	7520	7376	3809	3762	3686
96.00	9019	8926	8812	8632	8849	8762	8644	8472	4368	4320	4238
108.00	11377	11272	11132	10928	11196	11096	10968	10788	5524	5470	5382
120.00	14186	14068	13924	13720	13982	13888	13732	13516	6913	6846	6748

D-15 B

TUBE COUNT TABLES

CHARTS INDICATE
NUMBER OF TUBES

3/4" O.D. TUBES ON 1" PITCH

SHELL I. D. (INCHES)	FIXED TUBE SHEET				OUTSIDE PACKED FLOATING HEAD				U-TUBE		
	NO. OF PASSES				NO. OF PASSES				NO. OF PASSES		
	1	2	4	8	1	2	4	8	2	4	8
17.25	229	220	208	184	204	192	176	164	94	90	80
19.25	283	272	260	248	260	250	228	212	120	114	110
21.25	350	334	324	300	322	310	292	268	149	142	132
23.25	426	406	392	364	394	382	364	336	183	176	162
25.00	491	476	452	420	450	440	412	384	217	208	192
27.00	576	562	532	500	537	524	492	456	256	248	228
29.00	674	650	620	600	633	610	580	552	299	290	280
31.00	771	746	712	672	727	704	676	628	347	336	314
33.00	875	852	820	768	827	812	776	728	398	386	360
35.00	985	960	928	896	934	914	876	848	448	438	428
37.00	1109	1074	1044	1016	1052	1026	984	952	521	492	484
39.00	1234	1236	1192	1144	1179	1172	1128	1080	583	568	542
42.00	1457	1418	1376	1316	1391	1358	1316	1252	670	656	628
45.00	1657	1650	1604	1540	1589	1588	1540	1476	787	768	742
48.00	1910	1872	1824	1780	1845	1800	1752	1716	910	876	858
51.00	2176	2142	2088	2016	2094	2062	2004	1940	1026	1006	968
54.00	2427	2378	2332	2284	2341	2308	2248	2200	1162	1122	1106
60.00	2985	2996	2928	2844	2903	2894	2828	2744	1441	1420	1376
64.00	3467	3408	3340	3252	3357	3308	3240	3140	1646	1622	1576
68.00	3913	3858	3792	3680	3795	3738	3672	3572	1865	1842	1792
72.00	4383	4330	4256	4148	4268	4208	4144	4024	2104	2072	2014
76.00	4878	4876	4792	4664	4771	4756	4676	4576	2371	2338	2282
80.00	5419	5352	5260	5204	5289	5228	5152	5092	2633	2574	2538
84.00	6031	5972	5884	5760	5902	5832	5748	5620	2909	2876	2808
90.00	6920	6860	6760	6632	6801	6726	6636	6492	3351	3312	3242
96.00	7897	7810	7712	7620	7736	7658	7568	7492	3818	3780	3746
108.00	9991	9888	9776	9704	9822	9740	9628	9548	4884	4804	4762
120.00	12413	12310	12180	12068	12246	12142	12016	11932	6090	5998	5942

3/4" O.D. TUBES ON 1" PITCH

SHELL I. D. (INCHES)	FIXED TUBE SHEET				OUTSIDE PACKED FLOATING HEAD				U-TUBE		
	NO. OF PASSES				NO. OF PASSES				NO. OF PASSES		
	1	2	4	8	1	2	4	8	2	4	8
17.25	203	192	180	176	180	168	160	148	80	82	76
19.25	251	240	228	220	226	216	204	204	103	104	100
21.25	300	294	288	256	276	272	264	228	130	128	114
23.25	368	360	356	324	340	336	324	304	162	160	146
25.00	426	400	392	380	398	376	360	344	190	180	172
27.00	508	472	468	456	468	442	432	420	228	214	212
29.00	592	560	540	532	550	520	508	492	268	256	246
31.00	670	648	628	584	627	610	592	556	296	298	278
33.00	767	740	720	680	719	700	680	648	342	342	322
35.00	870	840	824	776	816	802	784	736	392	390	368
37.00	972	944	928	912	927	900	884	868	444	438	432
39.00	1086	1064	1036	1020	1036	1014	992	968	498	498	484
42.00	1257	1220	1212	1184	1204	1176	1148	1120	579	574	562
45.00	1452	1436	1412	1352	1396	1380	1360	1308	683	678	652
48.00	1666	1634	1608	1576	1602	1574	1540	1516	778	772	762
51.00	1880	1868	1848	1784	1814	1800	1768	1716	890	888	862
54.00	2125	2096	2064	2000	2051	2020	1988	1928	998	988	962
60.00	2608	2596	2568	2496	2532	2512	2468	2412	1246	1244	1208
64.00	2996	2982	2936	2868	2892	2884	2840	2776	1436	1424	1390
68.00	3375	3328	3288	3260	3270	3232	3188	3164	1605	1598	1588
72.00	3826	3752	3720	3676	3714	3648	3608	3560	1842	1806	1790
76.00	4270	4196	4152	4112	4170	4088	4052	4008	2060	2030	2004
80.00	4715	4664	4624	4528	4614	4560	4524	4424	2266	2260	2212
84.00	5223	5168	5120	5028	5109	5056	5000	4916	2512	2498	2454
90.00	5992	5964	5912	5816	5870	5844	5796	5680	2908	2900	2844
96.00	6852	6812	6780	6648	6720	6688	6636	6508	3331	3318	3256
108.00	8682	8618	8552	8412	8543	8476	8412	8288	4214	4198	4134
120.00	10782	10704	10636	10488	10634	10560	10492	10344	5252	5242	5164

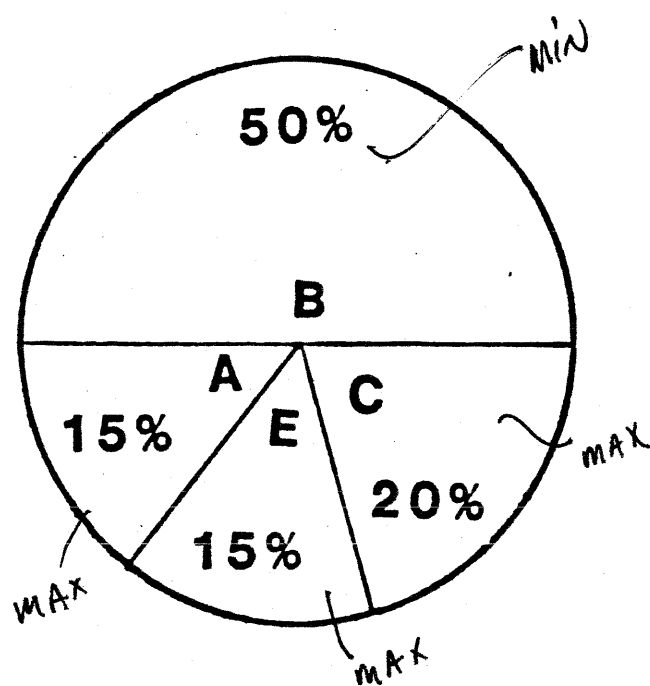
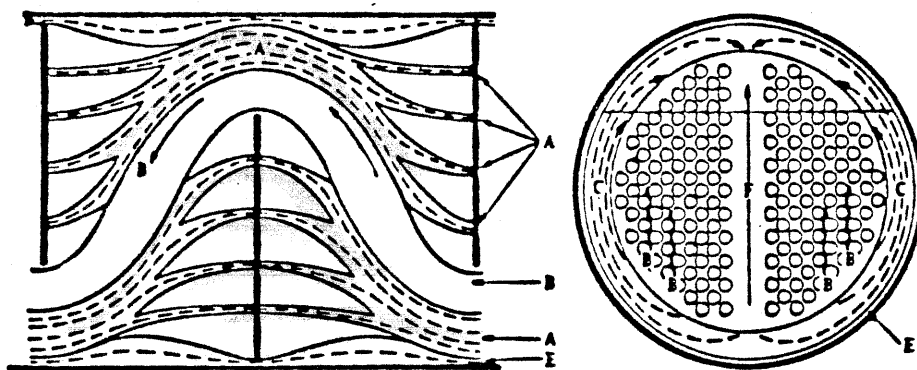
1" O.D. TUBES ON 1-1/4" PITCH

SHELL I. D. (INCHES)	FIXED TUBE SHEET				OUTSIDE PACKED FLOATING HEAD				U-TUBE		
	NO. OF PASSES				NO. OF PASSES				NO. OF PASSES		
	1	2	4	8	1	2	4	8	2	4	8
17.25	143	130	124	104	130	118	112	96	53	50	44
19.25	177	170	160	152	159	152	144	132	69	66	62
21.25	208	216	200	180	192	196	184	168	92	86	76
23.25	254	262	244	220	241	238	224	212	112	104	96
25.00	304	290	276	264	285	272	252	240	126	120	114
27.00	359	350	324	316	341	322	304	292	154	144	138
29.00	422	404	384	372	396	382	364	348	181	174	168
31.00	483	472	452	424	455	444	428	396	213	206	190
33.00	565	544	524	484	526	512	484	456	246	238	220
35.00	611	614	588	556	588	582	564	520	277	268	254
37.00	695	698	676	628	658	664	632	600	321	310	290
39.00	783	784	748	716	748	744	716	672	349	346	326
42.00	905	906	880	832	863	868	832	792	420	408	386
45.00	1069	1038	1008	956	1020	998	964	924	484	472	452
48.00	1219	1182	1152	1124	1168	1136	1104	1076	553	540	530
51.00	1391	1370	1328	1264	1343	1312	1276	1232	644	626	596
54.00	1556	1538	1484	1428	1510	1478	1436	1388	721	704	676
60.00	1914	1876	1832	1788	1849	1812	1772	1744	891	876	856
64.00	2200	2158	2108	2064	2126	2090	2044	2008	1030	1008	992
68.00	2494	2456	2400	2336	2420	2384	2336	2260	1175	1152	1112
72.00	2777	2778	2724	2644	2702	2690	2648	2552	1331	1304	1270
76.00	3117	3062	3008	2960	3038	2996	2936	2888	1471	1450	1428
80.00	3471	3418	3364	3276	3388	3346	3284	3200	1646	1620	1582
84.00	3846	3792	3736	3632	3751	3710	3644	3540	1829	1802	1754
90.00	4391	4342	4276	4232	4309	4252	4188	4124	2096	2070	2046
96.00	5047	4984	4912	4804	4942	4892	4812	4700	2416	2382	2328
108.00	6386	6310	6232	6104	6285	6224	6148	6032	3070	3038	2982
120.00	7905	7900	7800	7660	7784	7788	7684	7556	3849	3808	3744

1" O.D. TUBES ON 1-1/4" PITCH

SHELL I. D. (INCHES)	FIXED TUBE SHEET				OUTSIDE PACKED FLOATING HEAD				U-TUBE		
	NO. OF PASSES				NO. OF PASSES				NO. OF PASSES		
	1	2	4	8	1	2	4	8	2	4	8
17.25	124	110	104	96	109	100	92	92	49	44	44
19.25	151	144	136	132	136	132	124	104	59	56	52
21.25	186	186	176	160	174	168	164	132	78	74	66
23.25	228	228	220	204	216	208	204	188	96	98	88
25.00	263	252	240	228	242	232	228	216	108	106	106
27.00	319	302	292	288	296	280	276	256	132	132	126
29.00	373	360	348	320	345	336	324	300	158	160	146
31.00	416	400	392	380	390	376	368	356	176	180	170
33.00	486	468	452	440	459	442	424	420	208	208	202
35.00	546	532	520	488	518	508	492	468	241	236	224
37.00	614	606	592	560	584	576	556	532	276	272	260
39.00	688	676	672	640	652	648	636	600	313	308	294
42.00	806	768	752	740	766	732	712	708	353	352	346
45.00	924	912	896	856	884	876	864	824	423	420	398
48.00	1063	1040	1024	980	1027	1000	992	944	484	480	462
51.00	1208	1180	1164	1148	1163	1140	1108	1100	552	550	542
54.00	1350	1320	1308	1288	1300	1278	1256	1236	622	620	608
60.00	1658	1638	1608	1596	1606	1580	1556	1544	776	768	760
64.00	1904	1882	1868	1812	1840	1822	1808	1752	896	892	868
68.00	2157	2120	2092	2068	2092	2060	2040	2012	1008	1008	994
72.00	2424	2408	2388	2312	2352	2340	2312	2256	1153	1144	1116
76.00	2720	2662	2640	2608	2648	2600	2576	2552	1274	1274	1260
80.00	3002	2994	2956	2888	2940	2912	2888	2816	1436	1420	1392
84.00	3317	3280	3244	3216	3245	3204	3188	3144	1576	1552	1558
90.00	3834	3764	3736	3700	3756	3680	3648	3628	1815	1804	1792
96.00	4360	4338	4296	4216	4278	4252	4232	4140	2098	2092	2050
108.00	5524	5486	5448	5412	5444	5404	5352	5328	2666	2646	2632
120.00	6891	6828	6804	6684	6794	6736	6712	6608	3325	3318	3264

Shellside Flow Distribution



ALLOWABLE PRESSURE DROP

D-17

- COOLING WATER IN TUBES; 8 TO 10 PSI PER EXCHANGER
(VELOCITY: 3 TO 5 FT/SEC)
- MULTIPLE SHELLS IN SERIES SUCH AS
HYDROTREATING COMBINED/FEED EXCHANGERS
IF 6 IN SERIES; ALLOW 8 PSI PER EXCHGR
OR 48 PSI TOTAL DELTA-P.

⇒ IN GENERAL

TUBE SIDE : ALLOW 5 TO 10 PSI PER EXCHGR

SHELL SIDE : 2 TO 5 PSI PER EXCHGR

SPECIAL CASES SUCH AS (HIGH VISCIOUS MATERIAL) VACUUM BOTTOMS ETC
NEED MORE DELTA-P (15 PSI/SHELL)

REBOILERS : SHELL SIDE BOILING 0.5 TO 1.0 PSI
TUBE SIDE BOILING 2 TO 3.5 PSI
(VERT. REB)

CONDENSERS : LOW PRESSURE OPERATION OR
VACUUM SERVICE 0.5 TO 1.0 PSI

SPECIAL VERT. (SINGLE PASS) EXCHANGERS

10 PSI DELTA-P (SIZE APPROX: 60" x 65')
{ 2 PSI TUBE SIDE }
{ 8 PSI SHELL SIDE }

REBOILERS

IN GENERAL:

LIMIT TO ABOUT 33% VAPORIZATION

→ EXCEPT KETTLE & STAB-IN TYPE
(UP TO 80% VAPORIZATION)

→ FOR KETTLE & STAB-IN

LIMIT FLUX $\frac{Q}{A}$ $\left(\frac{\text{BTU}}{\text{HR. FT}^2} \right)$ TO

12,000 FOR HOT OIL } AS HEATING
15,000 FOR STEAM } MEDIUM.

↑
DRIVING FORCE IS IMPORTANT

$$Q = UA\Delta T$$

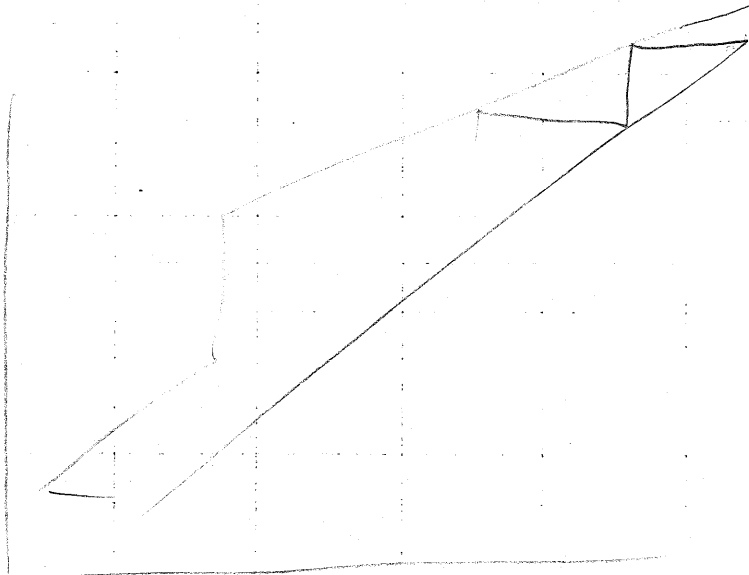
$$\frac{Q}{A} = U\Delta T$$

SUMMARY

PROCESS CONSIDERATIONS

II

- A PURPOSE (WHY USE HT. EXCHG'RS)
- B TEMP. APPROACHES.
- C PRODS. TO STORAGE.
- D FLUID ROUTING (TUBE/SHELL)
- E ALLOWABLE PRESSURE DROP
- F VARIOUS TYPES OF REBOILERS



MATERIAL OF CONSTRUCTION

→ DEPENDS ON PROCESS FLUIDS:

- HYDROGEN
- WET H_2S
- SEA WATER **
- TEMP / PRESSURE / SULFUR LEVEL ▲▲
- HF ACID ▲
- SLURRY (SUCH AS FCC. UNITS)

** SEA WATER REQUIRES NON-FERROUS MATERIALS
SUCH AS 70/30 Cu/Ni; AL-BRASS; TITANIUM; MONEL

▲ HF ACID CAN USE: KILLED C. STEEL (COLD TEMP.)
MONEL (HIGH TEMP.)

▲▲ TEMP / SULFUR LEVEL CAN REQUIRE UPGRADE

FROM CARBON STEEL → 1/4CR-1/2MO → 5CR-1/2MO → TP440/TP430



TP 304 SS

MECHANICAL CONSIDERATION

GENERAL: TREAT EXCHANGER SHELL AS VESSEL
PER ASME SECT VIII PRESSURE
& VESSEL CODE

— USE TEMA CLASS "R"

DESIGN PRESSURE: MAX. OPERATING PLUS 25 PSI (MIN).

OR OPERATING PLUS 50 PSI (CHECK FLANGE RATING)

OR OPERATING PRESSURE + 10%

SPECIAL CASE: DIFFERENTIAL PRESSURE DESIGN.

THIS ALLOWS THINNER TUBE SHEET.

EXAMPLE: NAPHTHA HYDROTREATER:

→ [COMBINED FEED/EFFLUENT EXCHANGE]

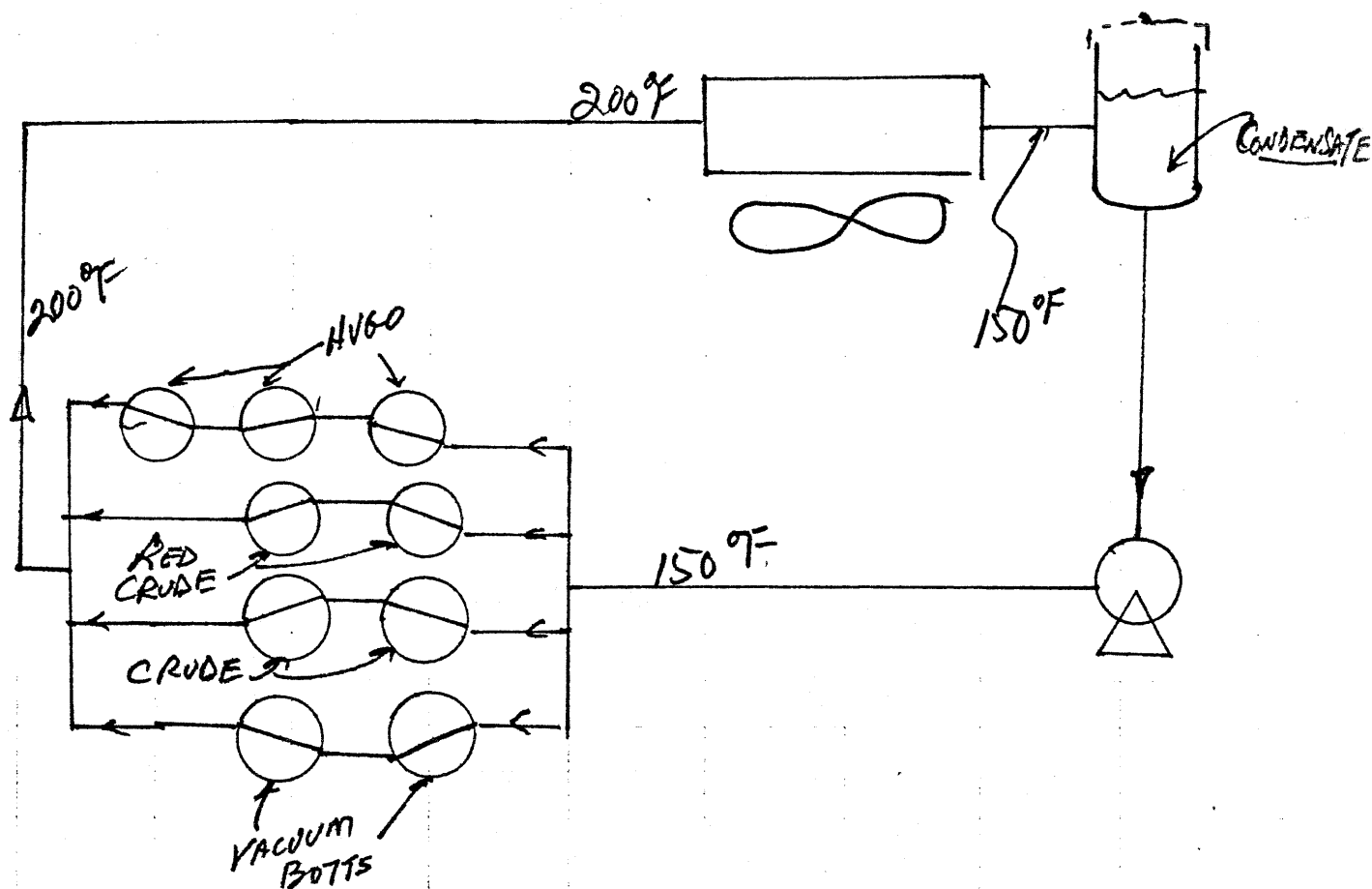
DESIGN TEMPERATURE

→ USUALLY OPERATING TEMP. PLUS 50°F

→ WATER SIDE; USUALLY 250°F

TYPICAL TEMPERED WATER SYSTEM

→ USED FOR HIGH POUR PT MATERIAL
≠ HIGH VISCOSITY "



REVAMP

- TO INCREASE THROUGH-PUT WITH EXISTING EQUIPMENT
- MAY HAVE TO PARALLEL/SERIES WITH EXISTING
- CHECK PRESSURE / TEMPERATURE DESIGN LIMITS
- CAN RATIO FLOWS, DENSITY ETC;

SEE 'NGPSA' TABLE FIG. F-7

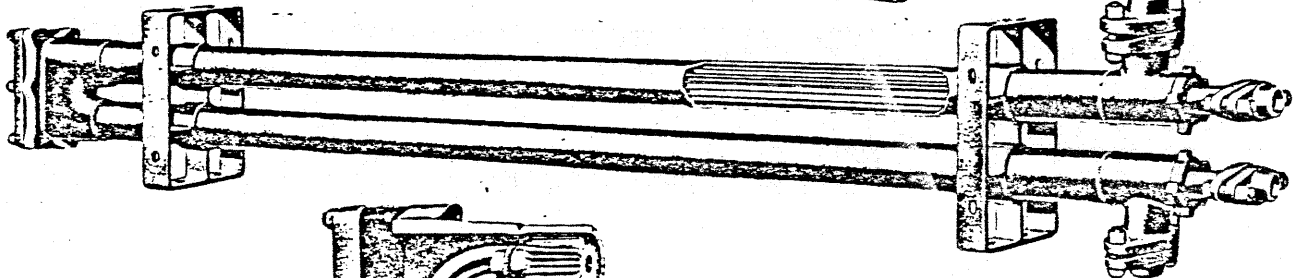
APPENDIX 'A' (EXHIBIT 4).

Brown Fintube

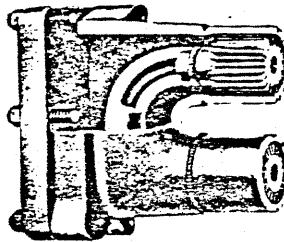
TYPE "O"—3" LO

EXHIBIT 5

Shell to Tube Closure
and Tubeside Joint

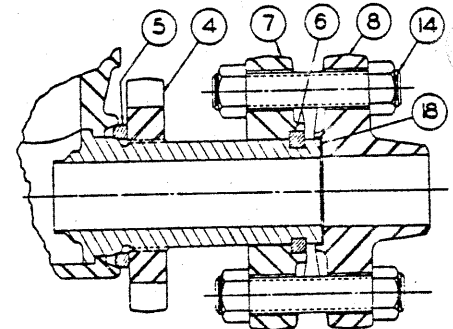
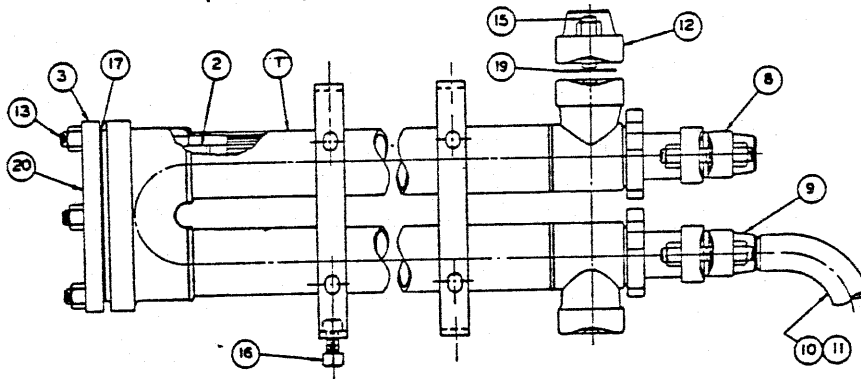


Return Bend
Housing Construction



PARTS LIST

When ordering parts, furnish serial number as shown on the nameplate and designate parts required by number and name as shown in the following tables.



1. Shell Assembly
2. Tube Assembly
3. Cover. Plate
4. Compression Flange
5. Sealing Ring
6. Split Ring
7. Fintube Fitting Flange
8. Fintube Stub End Flange
9. } Tube Return Bend Connector
10. }
11. }
12. Shell Nozzle Companion Flange
13. Cover Plate Bolting
14. Tubeside Bolting

15. Shell Nozzle Bolting
16. Bracket Bolts
17. Cover Gasket
18. Fintube Gasket
19. Shell Nozzle Gasket
20. Nameplate

RECOMMENDED SPARE PARTS INVENTORY PER SECTION

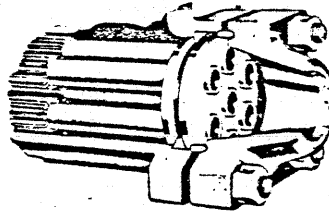
Two Cover Gaskets (17) Four Sealing Rings (5)
Four Fintube Gaskets (18) Two Split Rings (6)

FOR ADDITIONAL SUGGESTIONS ON INSTALLATION

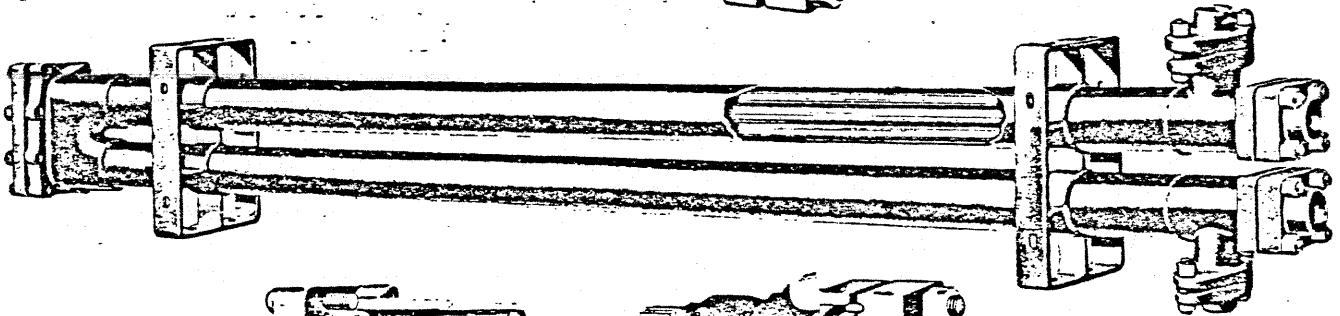
Brown Fintube

TYPES 2, 4, 6 and 8-4" LOW

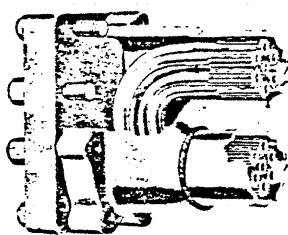
EXHIBIT 6



Shell to Tube Closure and
Tubeside Joint of Multi-Tube Section



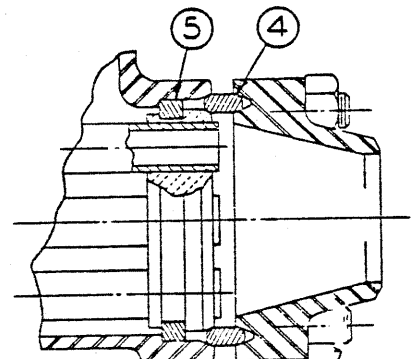
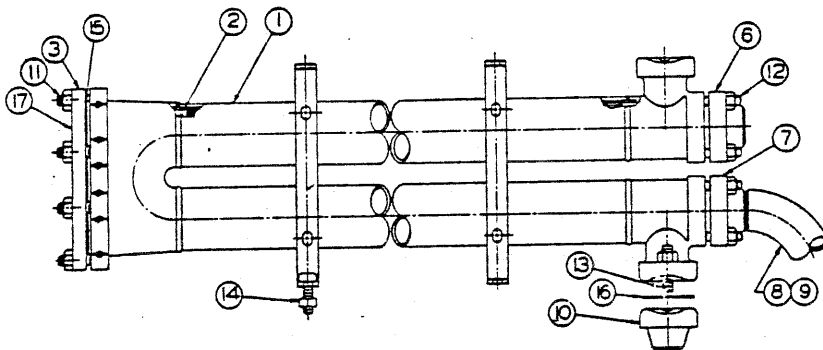
Return Bend Housing Construction
of Multi-Tube Section



Shell to Tube Closure and
Tubeside Joint of Single Tube Section

PARTS LIST

When ordering parts, furnish serial number as shown on the nameplate and designate parts required by number and name as shown in the following tables.



1. Shell Assembly
2. Tube Assembly
3. Cover Plate
4. Sealing Ring
5. Split Ring
6. Fintube Stub End Flange
7. } Tube Return Bend Connector
8. }
9. }
10. Shell Nozzle Companion Flange
11. Cover Plate Bolting
12. Tubeside Bolting
13. Shell Nozzle Bolting

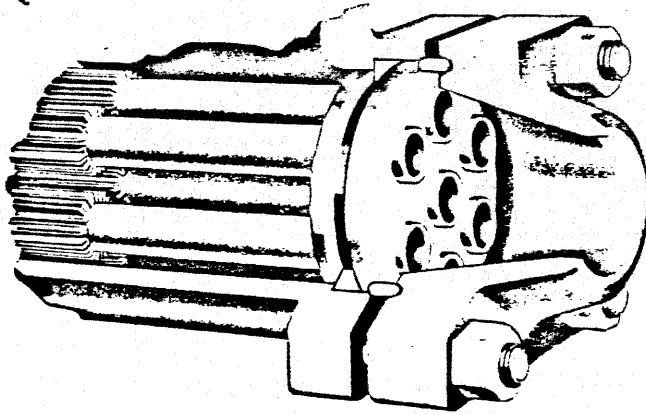
14. Bracket Bolts
15. Cover Gasket
16. Nozzle Gasket
17. Nameplate

RECOMMENDED SPARE PARTS INVENTORY PER SECTION

Two Cover Gaskets (15) Four Sealing Rings (4)
Two Split Rings (5)

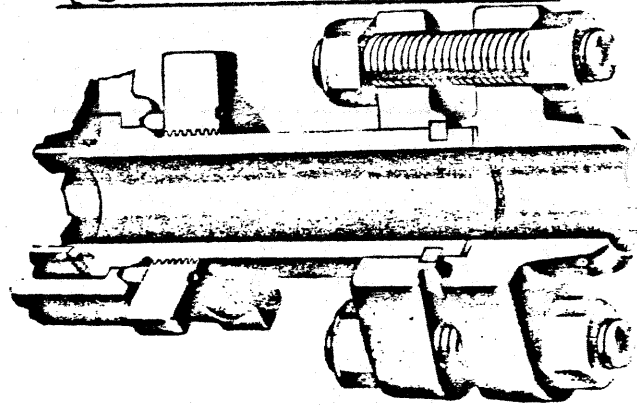
FOR ADDITIONAL SUGGESTIONS ON INSTALLATION

(MULTI-TUBE)

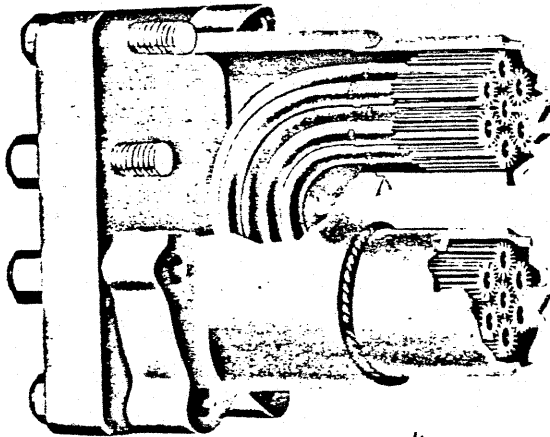


Shell to Tube Closure and Tubeside Joint of 4" Multi-tube Finned Low Pressure Section

(DOUBLE PIPE)

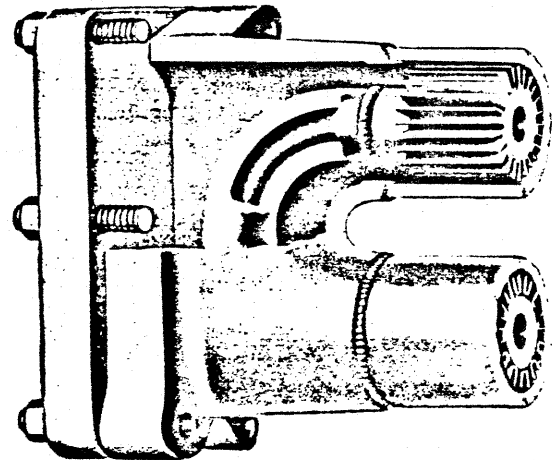


Shell to Tube Closure and Tubeside Joint of 3" Low Pressure Section.



"BROWN-FIN"

Cut-Away Sectional View Showing 4" Low Pressure (Return Bend Housing)

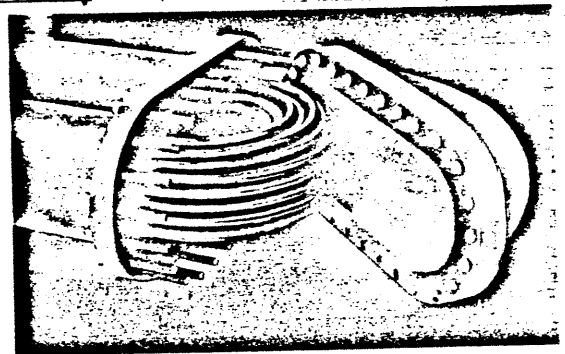
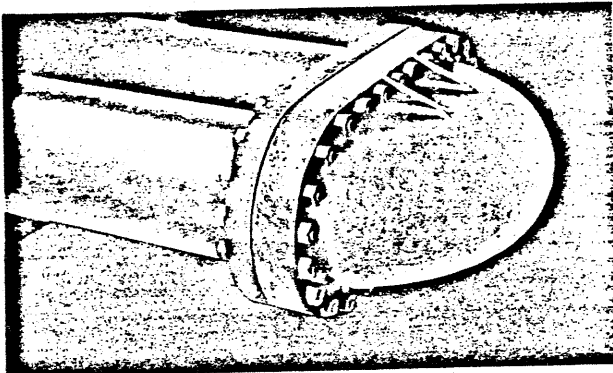


Cut-Away Sectional View Showing Low Pressure (Return Bend Housing Construction.)

↓ BASTEX CORP ↓

The full floating U-tube bundle compensates for the differential shell-tube expansion.

Only one casting is used in a Bas-Tex section and it is of simple design.



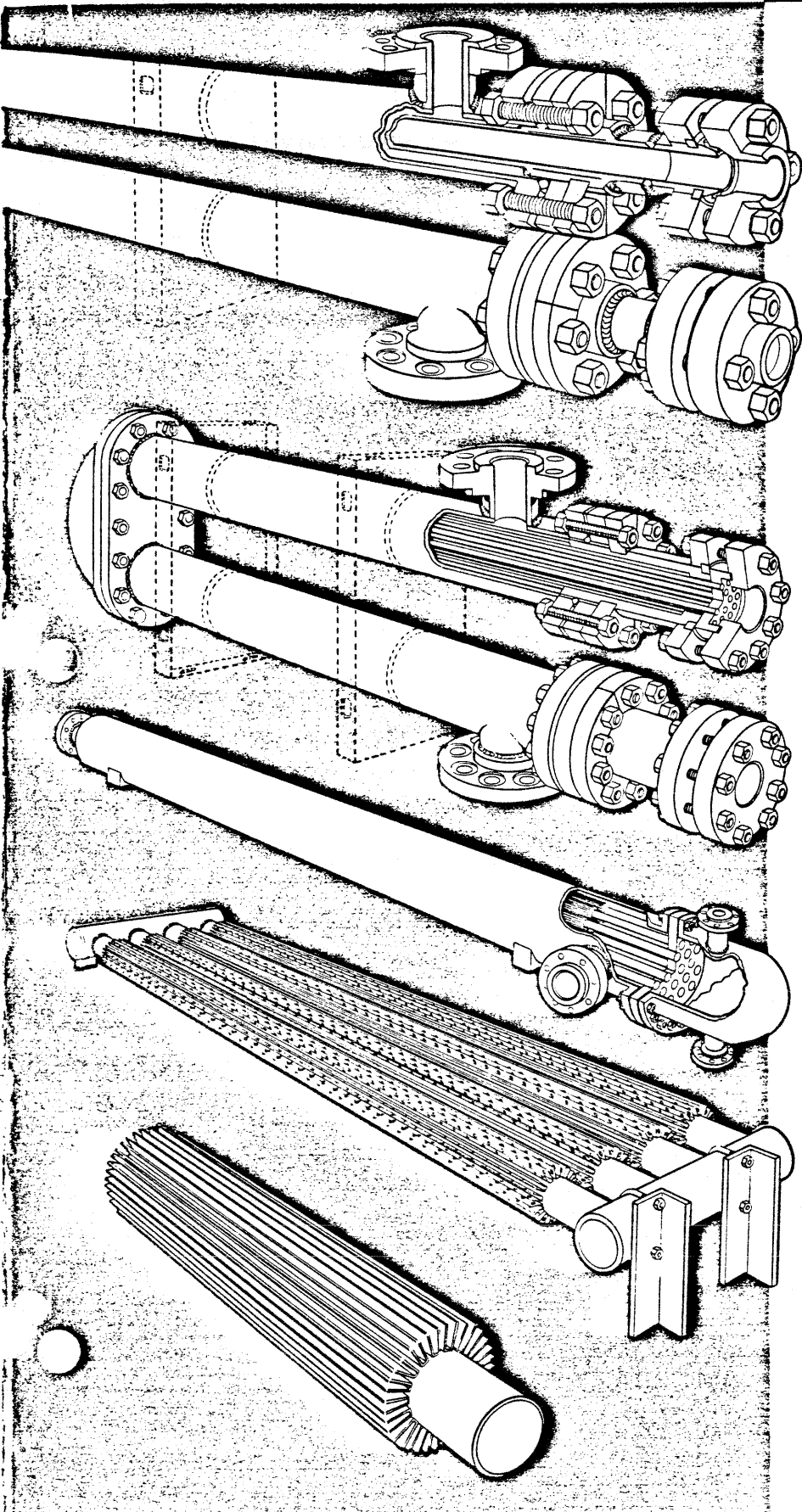
Return End Bonnet Closure is a conservative through bolted design. When the bonnet is removed the U-bends of the tubes are completely exposed to permit full field inspection.

BAS-TEX CORPORATION

**Quality heat exchangers
for petroleum, petrochemical,
power and general
industry applications**

EXHIBIT 6B

BULLETIN 60



Double pipe fintube heat exchangers
Bas-Tex double pipe exchangers feature the patented Bas-Tex closure — a combination of external split flange and compression ring flange — for easy removal and positive alignment. Through-bolt design cuts maintenance.

Multi-tube hairpin heat exchangers
These exchangers also feature the Bas-Tex patented split flange closure for easy removal of tube bundle. Quality construction assures dependability and long life in high and low pressure services. Full range of sizes for most applications.

Line and Suction heaters
Efficient for all viscous fluids. Features of Bas-Tex heaters include: heavy wall-12 BWG longitudinal fin tube surface, tapped and through bolted tube sheets which permit removal of bonnets without disturbing the shell seal, rugged full penetration welding, and ASME Code and TEMA Construction. A wide range of temperature-pressure ratings is available.

Horizontal and vertical fintube tank heaters
Bas-Tex design provides better steam dispersion, greater heating surface. Fewer welds mean lower maintenance and longer trouble-free operation. Compact design saves space, displaces less product. Both horizontal and vertical models available for a wide variety of applications.

Fintubes and custom equipment
Bas-Tex method of resistance welding assures welded fins in one piece with the tube, with maximum resistance to thermal shock. Available in carbon steel, stainless, monel, inconel, nickel and other weldable metals in a full range of sizes.

AIR COOLERS

- OBVIOUSLY USED WHERE WATER IS SCARCE.
- OFTEN USED IN TANDEM WITH WATER TRIM COOLER
- CAN BE ECONOMICAL, ESPECIALLY WHERE ONLY SEA WATER IS AVAILABLE
- TWO TYPES (BASICALLY)
 - ① FORCED DRAFT (WITH FAN BELOW TUBE BUNDLE)

AIR IS FORCED OR PUSHED ACROSS TUBES



- ② INDUCED DRAFT (WITH FAN ABOVE TUBE BUNDLE)

AIR IS PULLED ACROSS TUBES

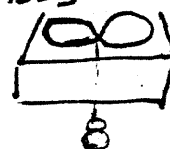


EXHIBIT 7A

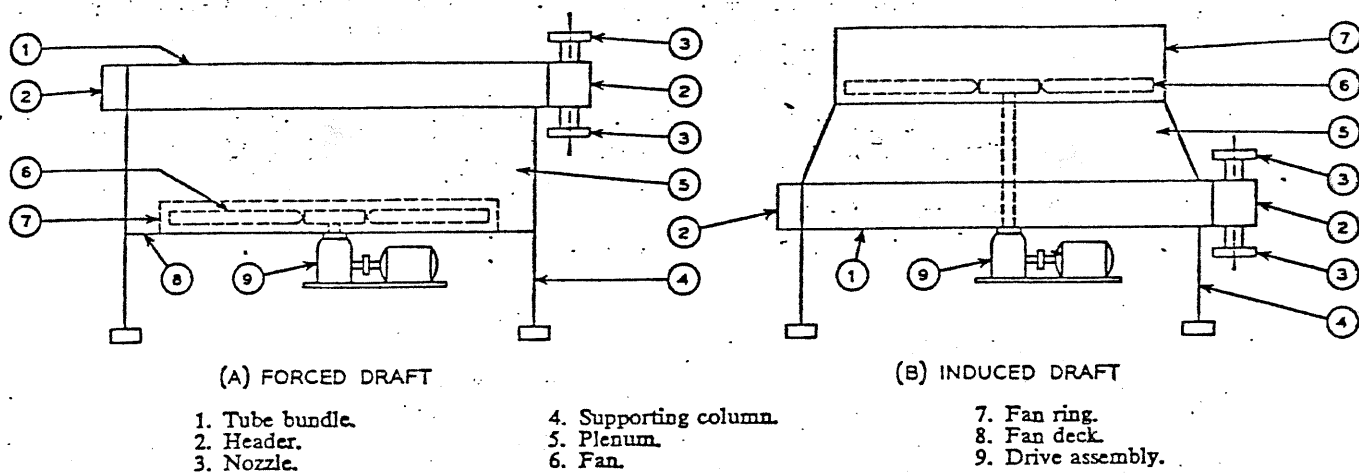


FIG. 1—Typical Components of an Air-Cooled Heat Exchanger.

9522 46342 24222

EXHIBIT 7B

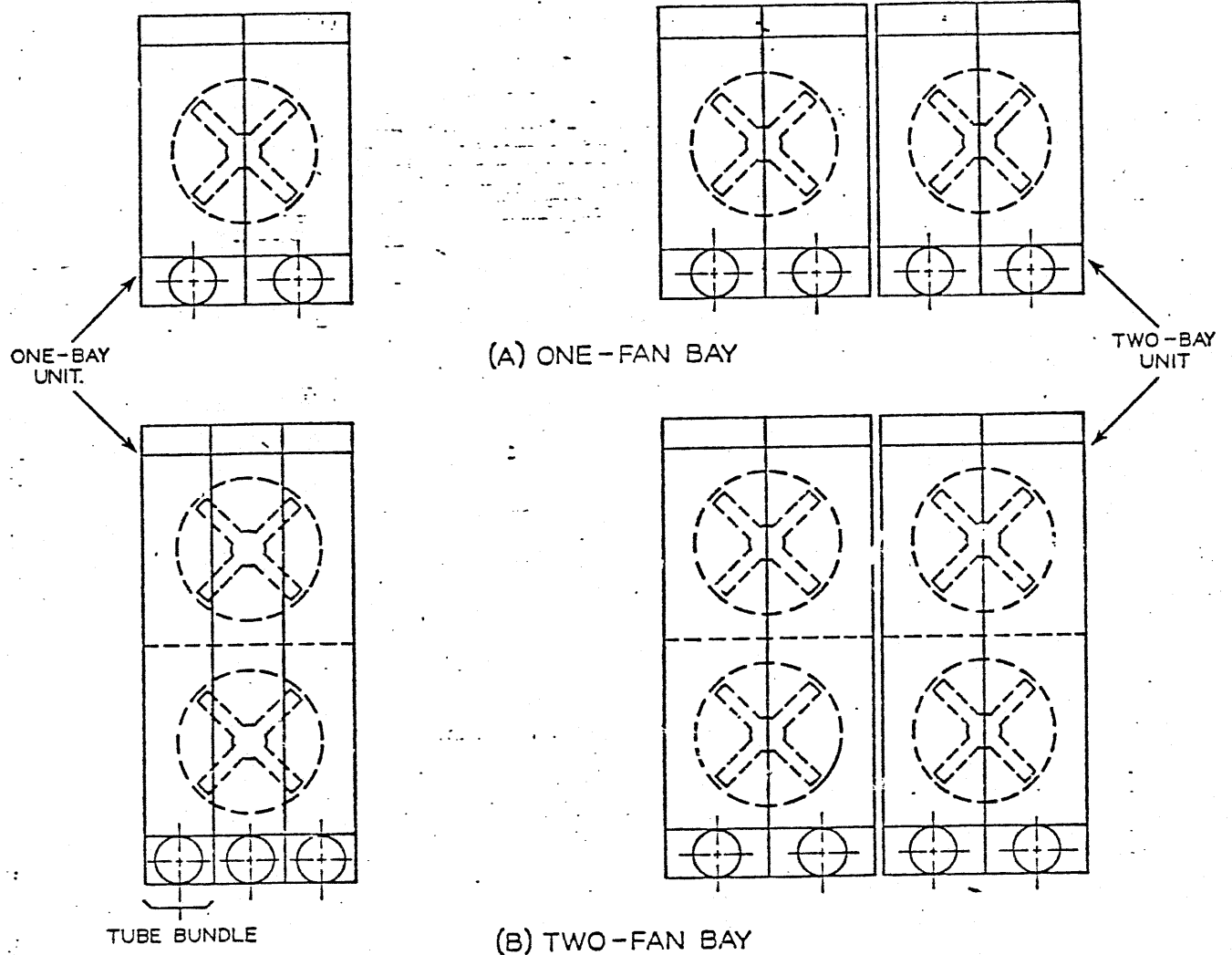


FIG. 2—Typical Bay Arrangements.

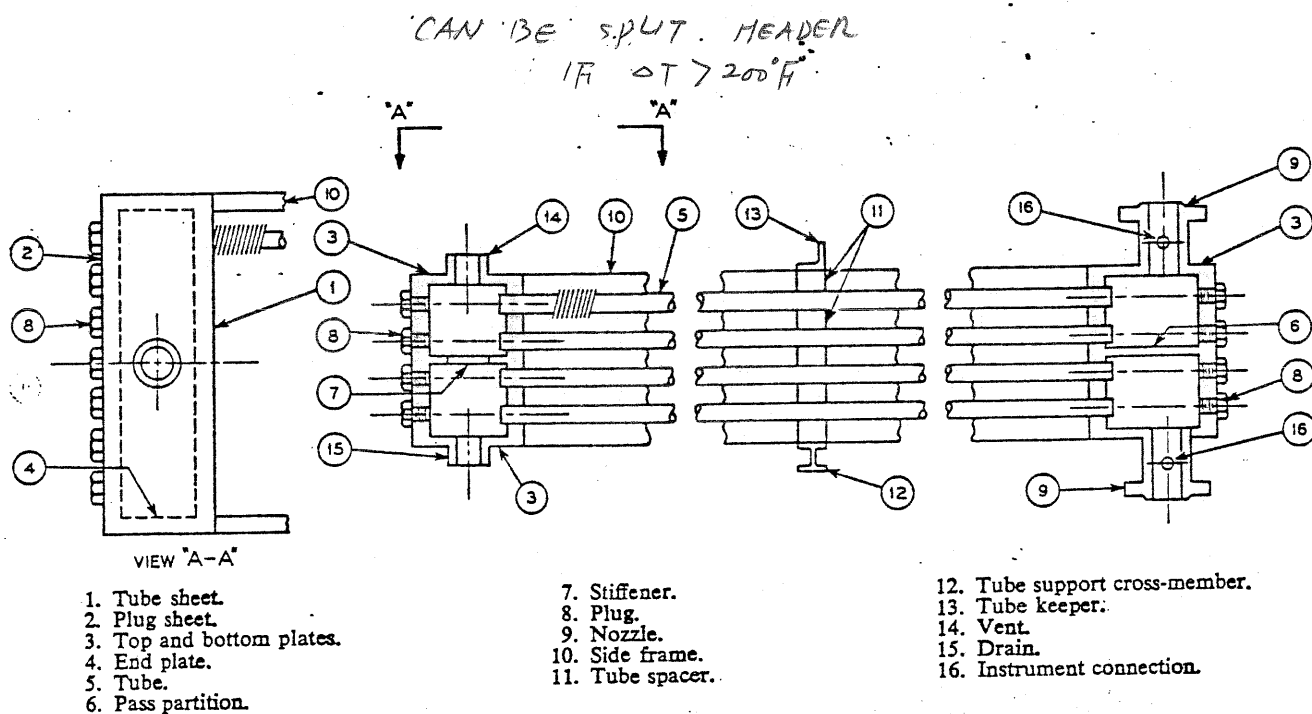


FIG. 5—Typical Construction of a Tube Bundle with Plug Headers.

EXHIBIT 7C

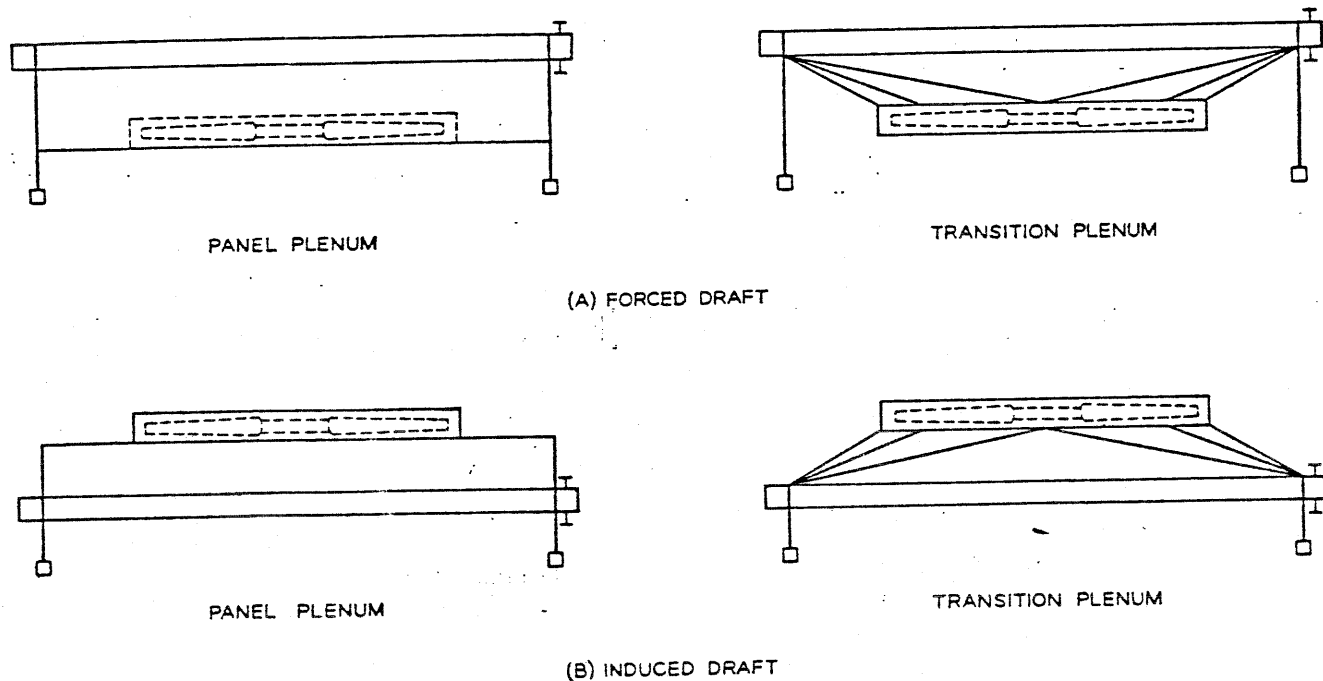


FIG. 6—Typical Plenum Arrangements.

EXHIBIT 7D

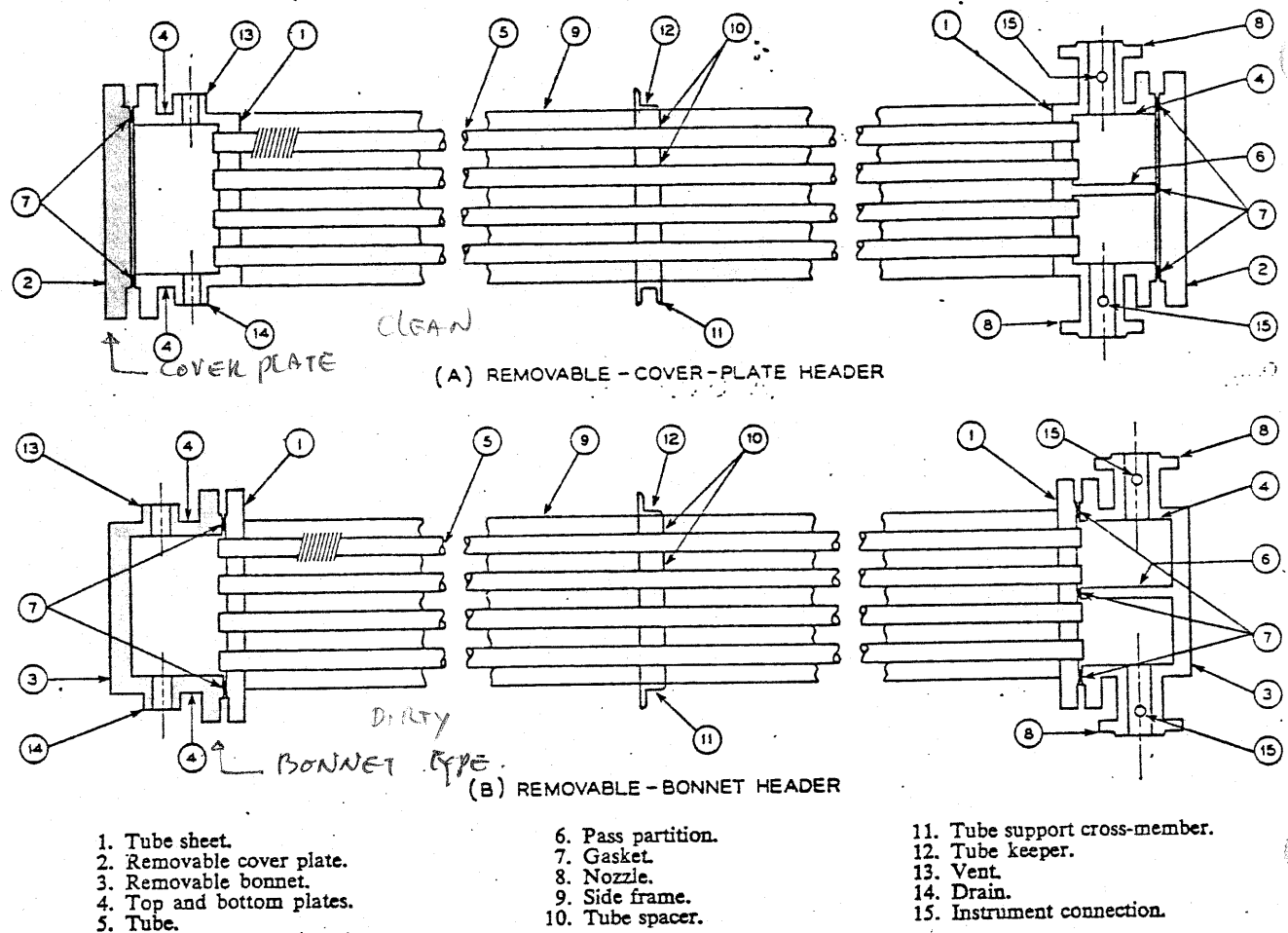


FIG. 3—Typical Construction of Tube Bundles with Removable-Cover-Plate and Removable-Bonnet Headers.

EXHIBIT 7E

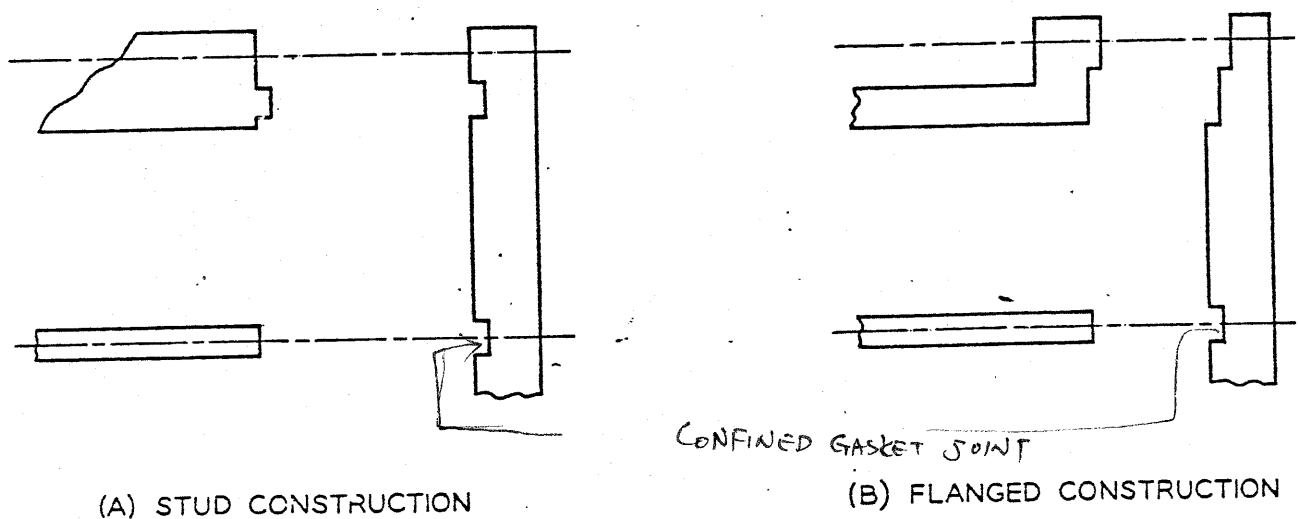
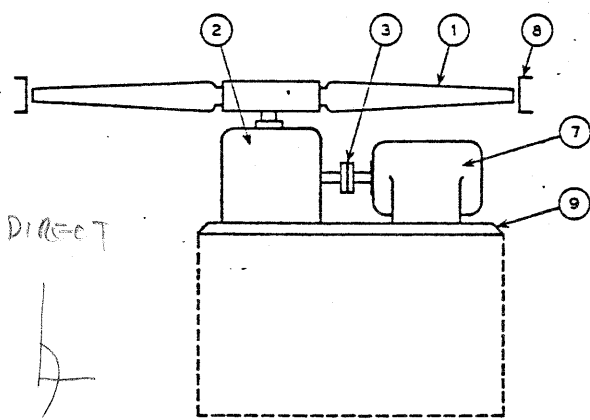
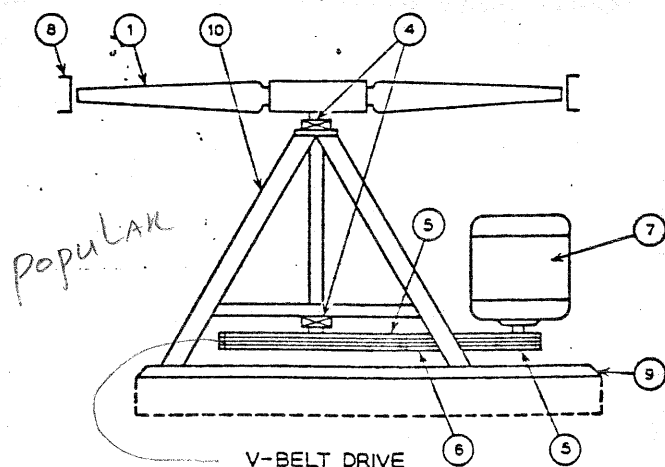


FIG. 4—Typical Confined Gasket Joint Details.

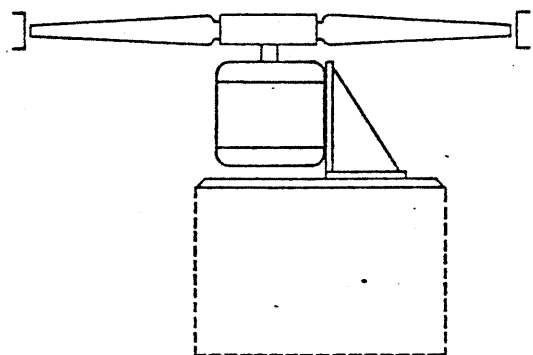
EXHIBIT 7F



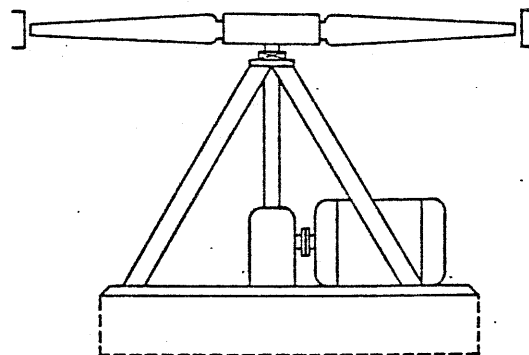
DIRECT RIGHT-ANGLE GEAR DRIVE



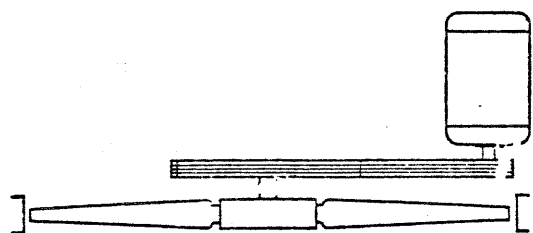
V-BELT DRIVE



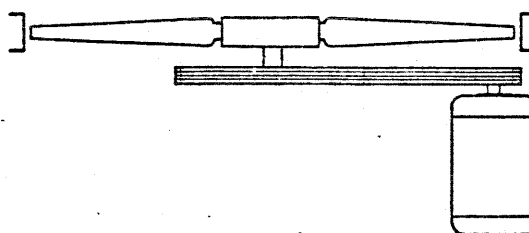
DIRECT MOTOR DRIVE



RIGHT-ANGLE GEAR DRIVE WITH FAN SUPPORT



TOP-SUSPENDED V-BELT DRIVE



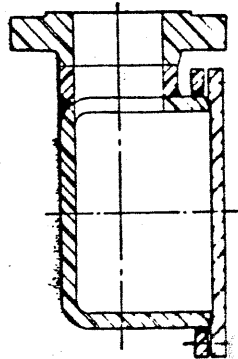
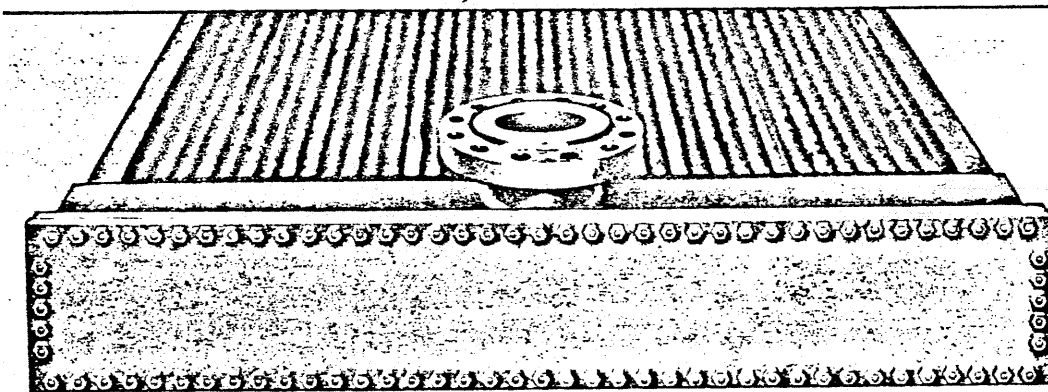
BOTTOM-SUSPENDED V-BELT DRIVE

1. Fan.
2. Gear.
3. Coupling.
4. Bearing.
5. Sheave.

6. V-belts.
7. Motor.
8. Fan ring.
9. Base plate.
10. Fan support.

FIG. 7—Typical Drive Arrangements.

EXHIBIT 7 G



Coverplate Header

The Coverplate Header design finds its greatest use in high fouling conditions where more complete access to the tubes and headers is required. This design is applicable to installations of moderate pressures. It is available in single or multiple pass designs, with drains for each pass.

FIN FAN COOLERS

Floating End
(For Expansion)

Cooler
Guide
& Case

Slot
to Allow
Expansion

Header
Detail
Showing
Open Baffle

Ring Groove to
Expand Tube Into

Shoulder Type Plug
With Solid Metal Gasket
Opposite Each Tube End.

Inlet

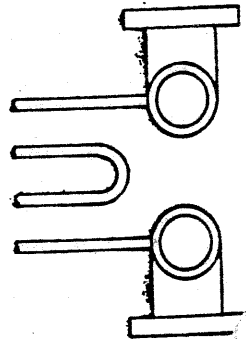
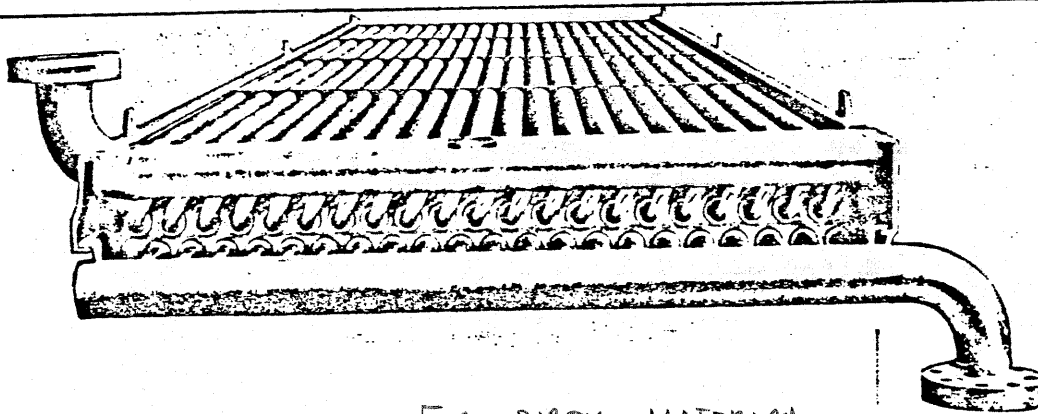
Bracket With Stainless
Steel Name Plate

Fixed End

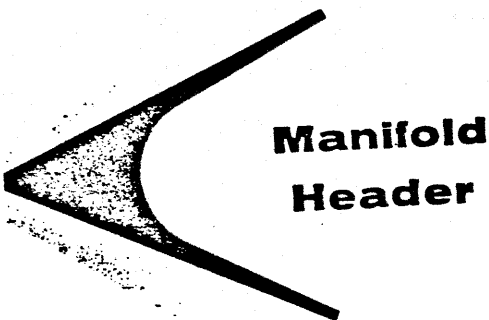
Baffle

Out

Tubes are expanded into tube sheet



FOR DIRTY MATERIAL
Flow

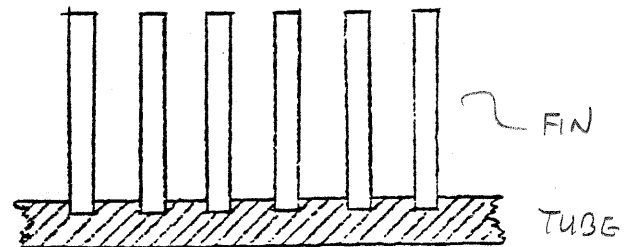


**Manifold
Header**

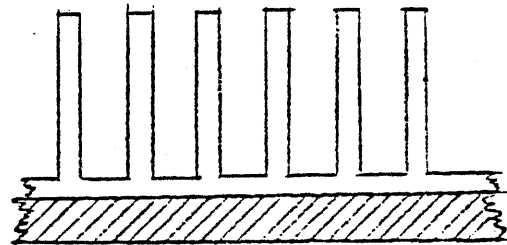
The Manifold Header is an all-welded design and is particularly adaptable to high pressure service. It is available in single or multiple pass designs that can be furnished in self draining and self venting types. The unit is available with welded or flanged connections.

EXHIBIT BSEVERAL TYPES OF FINNED TUBING USED IN AIR COOLED
HEAT EXCHANGERS

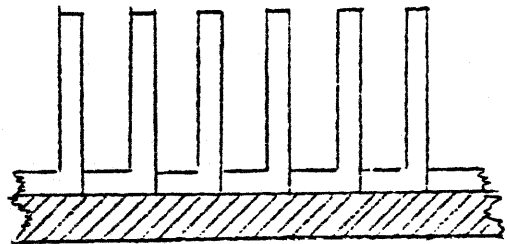
a) EMBEDDED

MAX. METAL TEMP ($\approx 700^{\circ}\text{F}$)

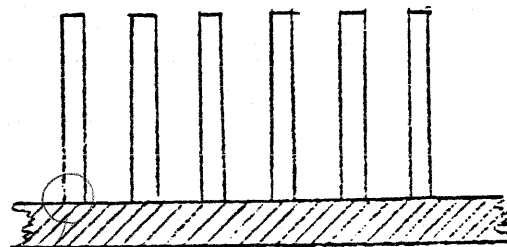
b) EXTRUDED

($\approx 500^{\circ}\text{F}$)

c) FOOTED

($\approx 400^{\circ}\text{F}$)

d) WRAPPED - ON

($\approx 250^{\circ}\text{F}$)

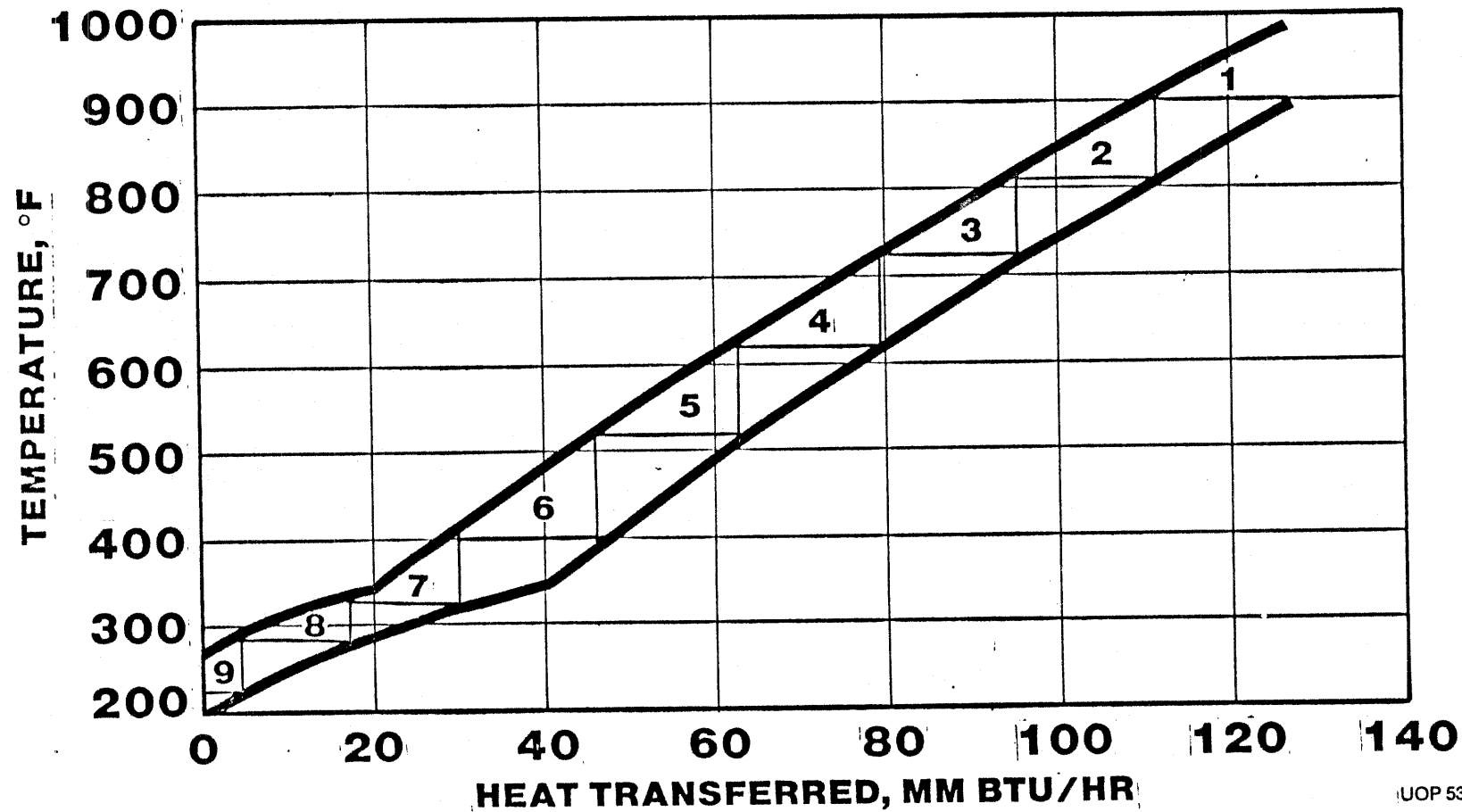
High Temp air separate zone

TABLE 1
EARLY UNITS

<u>DWG DATE</u>	<u>USER</u>	<u>SIZE</u>	<u>SURFACE</u>	<u>MFGR</u>
FEB 1966	SHELL OIL (WOODRIVER)	2 PAR 51" X 60'	21000 FT2 EA	IND FAB CO
MAY '69	NCRA (KANSAS)	40" X 40'	6017 FT2	WESTERN SUPPLY
OCT '69	COASTAL STATES (TEX)	2 PAR 56" X 20'	8500 FT2 EA	IND FAB CO

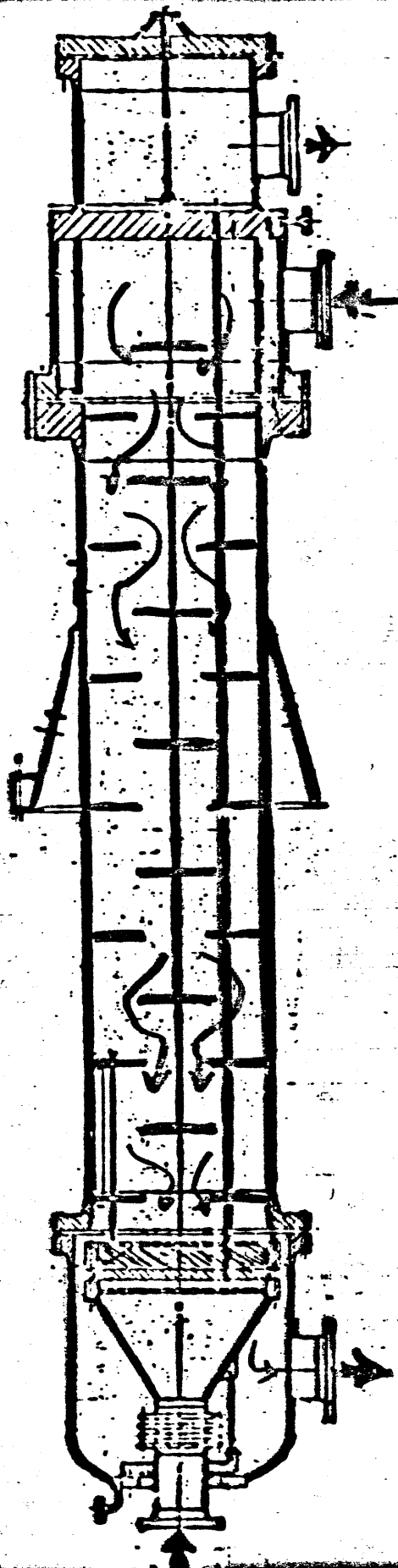
I UOP 537B-4

HEAT RELEASE CURVES



UOP 537B-32

5-29

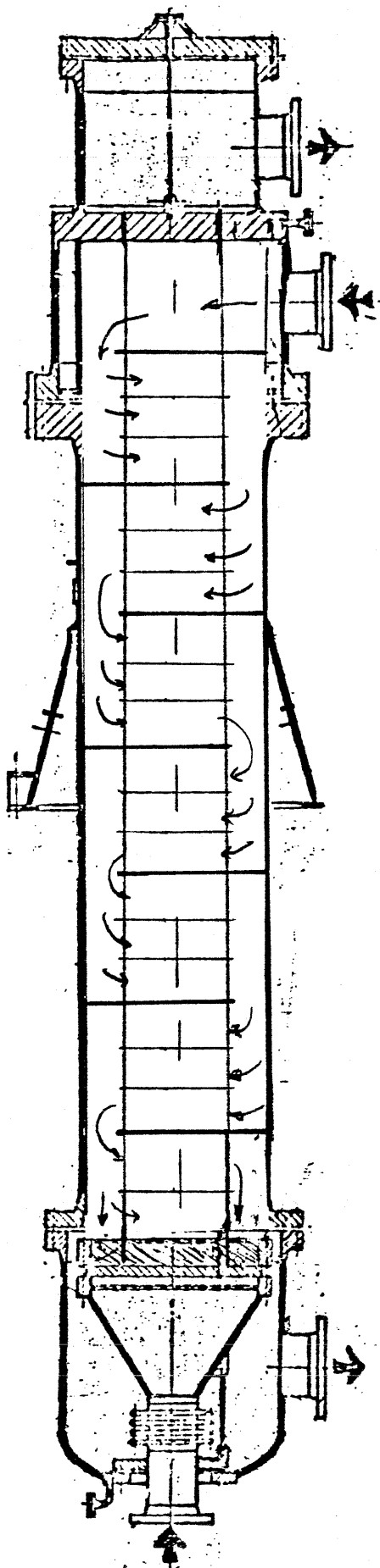


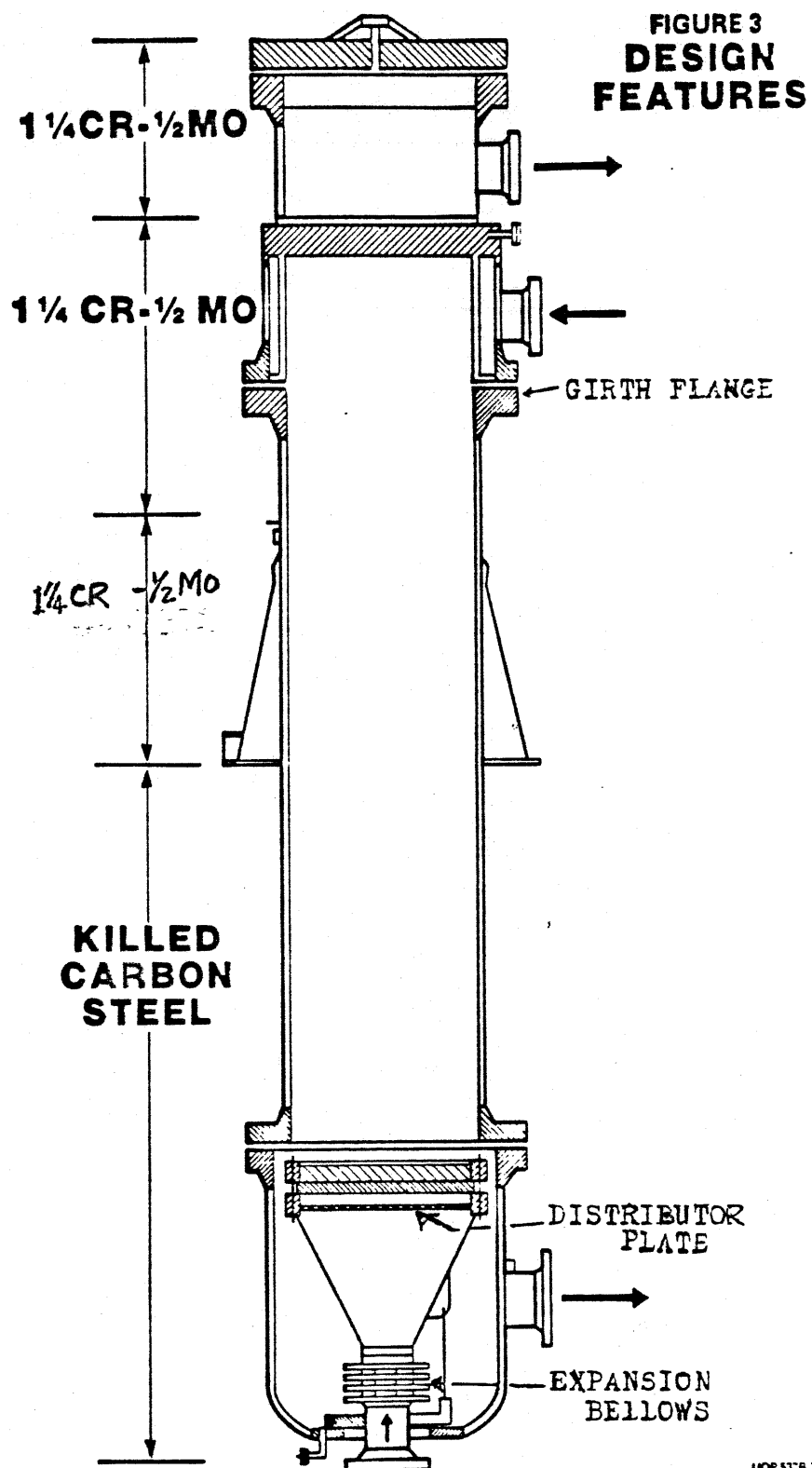
DESIGN
FEATURES

DOUBLE
SEGMENTAL

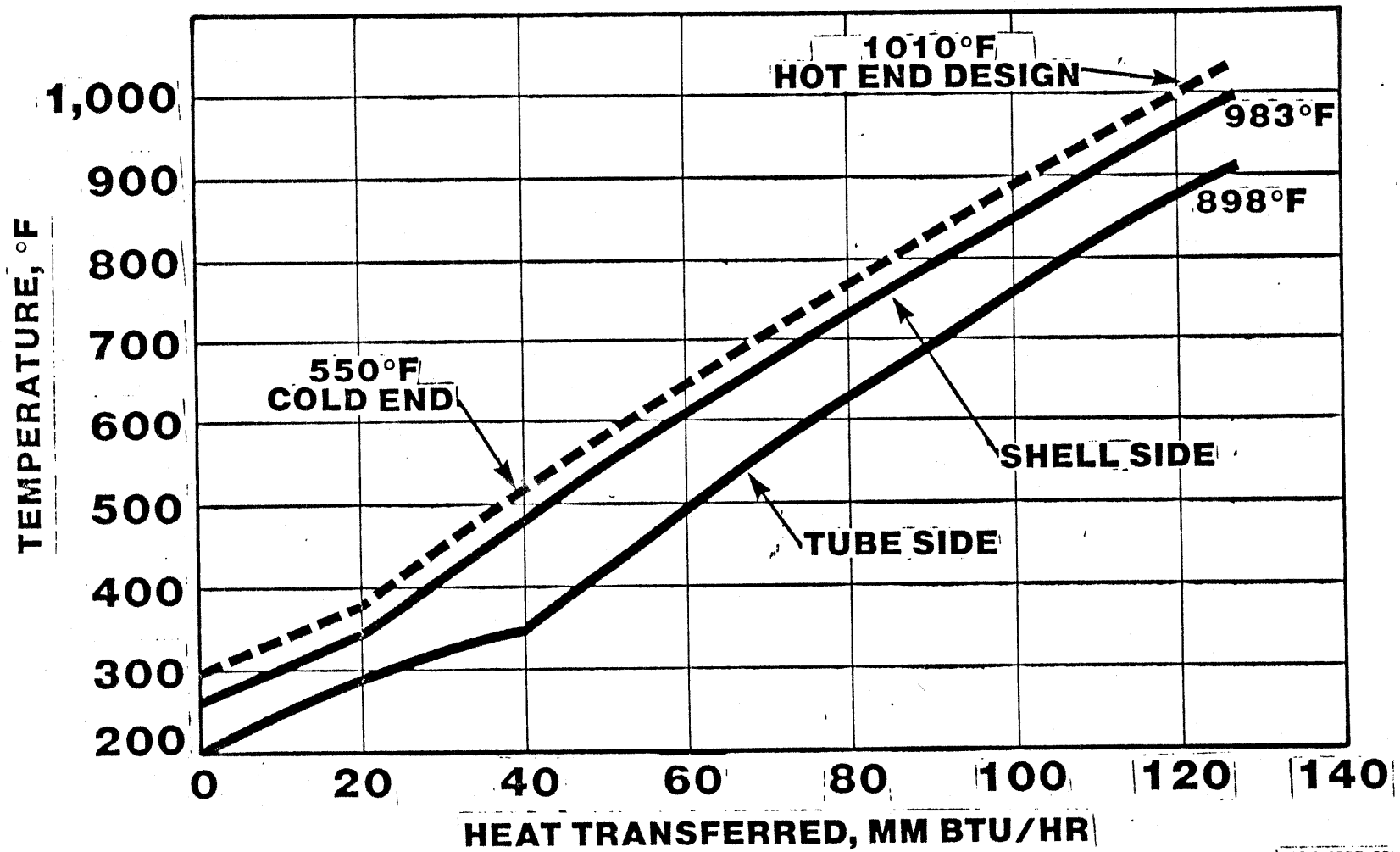
D 31

NTIW
DESIGN





OPERATING & MECH. DESIGN TEMPS



UOP 537B-22

GRADED METALS

MAX. OPER. TEMPS.

LATEST (FOR PARTIAL PRESSURE H₂ ≤ 200 PSI)

ABOVE 525°F

1 1/4 CR-1/2 MO OR 1 CR-1/2 MO

≤ 525°F

KILLED CARBON STEEL

UOP 537B-5

SUMMARY

DESIGN FEATURES

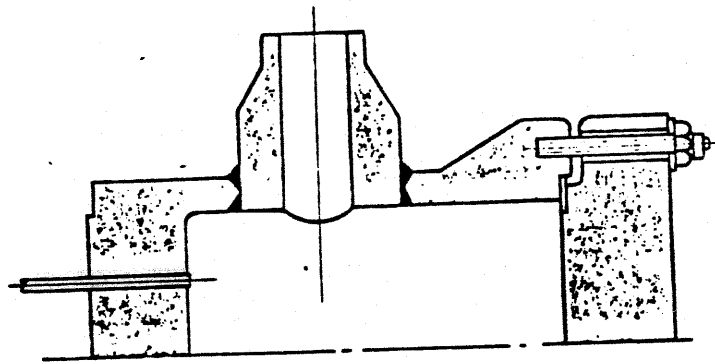
- **CONICAL INLET WITH DISTRIBUTOR PLATE**
- **INTERNAL EXPANSION BELLOWS**
- **SHELL GIRTH FLANGE**
- **GRADED METALS IN SHELL**
- **TEMP. BREAK PT. FOR METALS**
- **DOUBLE SEGMENTAL OR NTIW DESIGN**
- **DERESONATING (LONG) BAFFLE**
- **CLOSE TOLERANCES FOR TUBE HOLES IN BAFFLES**

UOP 537B-7

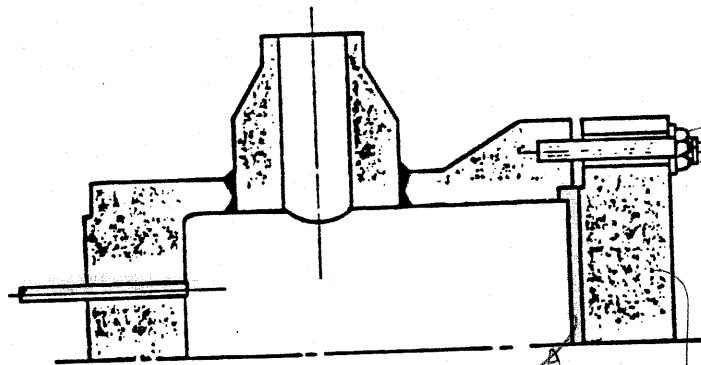
D35

Closures for High Pressure Service

FLAT GASKET CLOSURE



SEAL WELDED DIAPHRAGM CLOSURE



SET SCREW

CHANNEL COVER

DIAPHRAM

GASKET

D37

UOP

Process Division • UOP Inc.

20 UOP Plaza — Algonquin & Mt. Prospect Roads • Des Plaines, Illinois 60016 • U.S.A.

TUBULAR EXCHANGERS

PROJECT SPECIFICATION

NUMBER

REVISION

— 401 —

SHEET

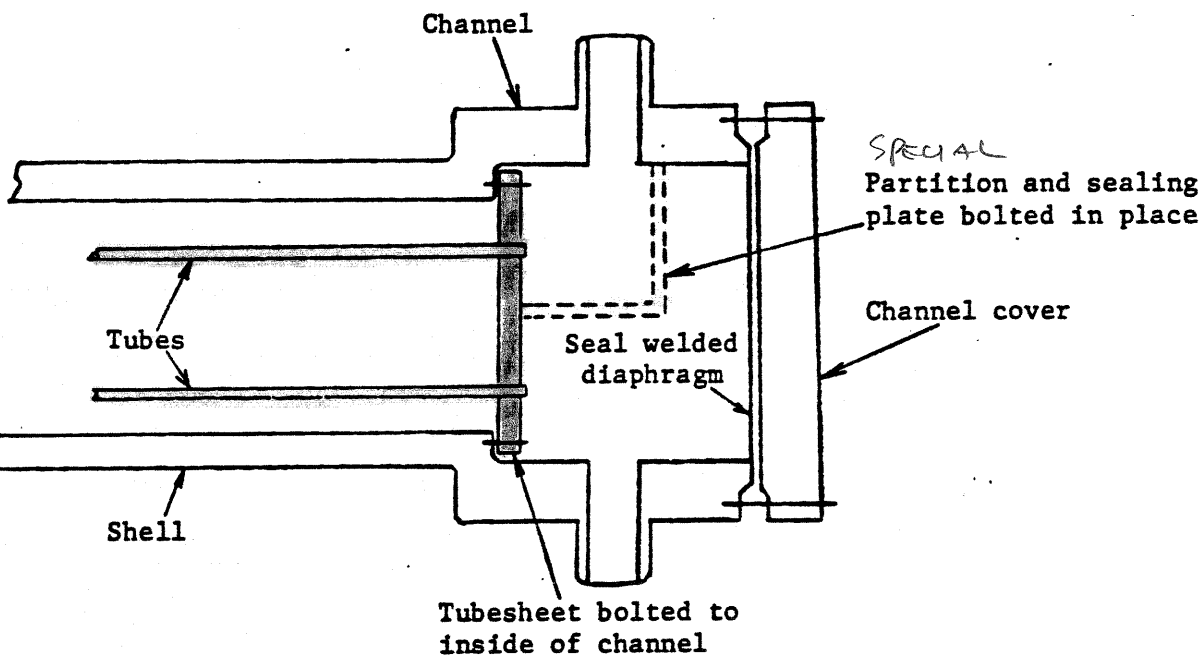
OF

BY

APP'D

DATE

SUGGESTED DESIGN: TYPE "MODIFIED DEU" EXCHANGERS

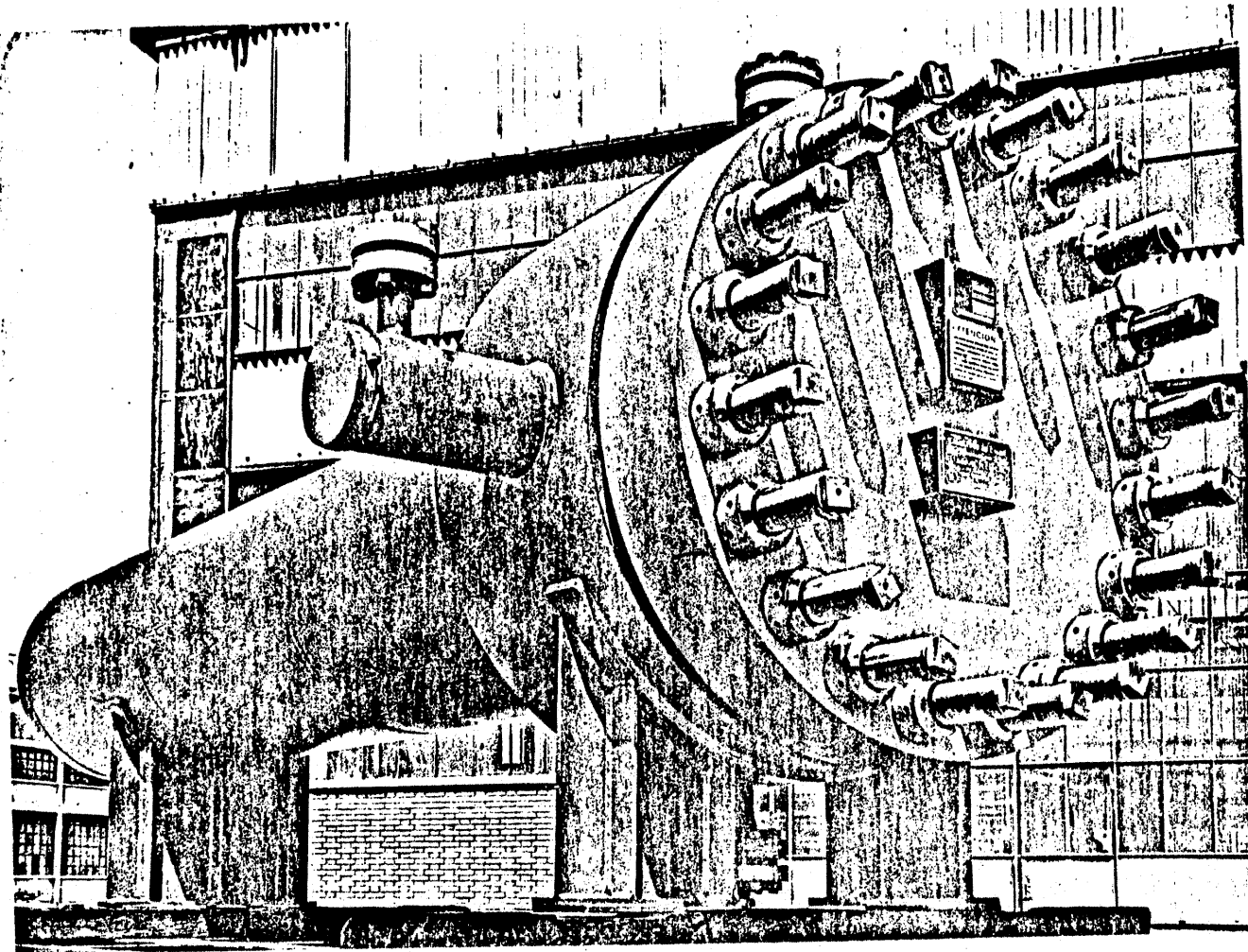


High Pressure Service

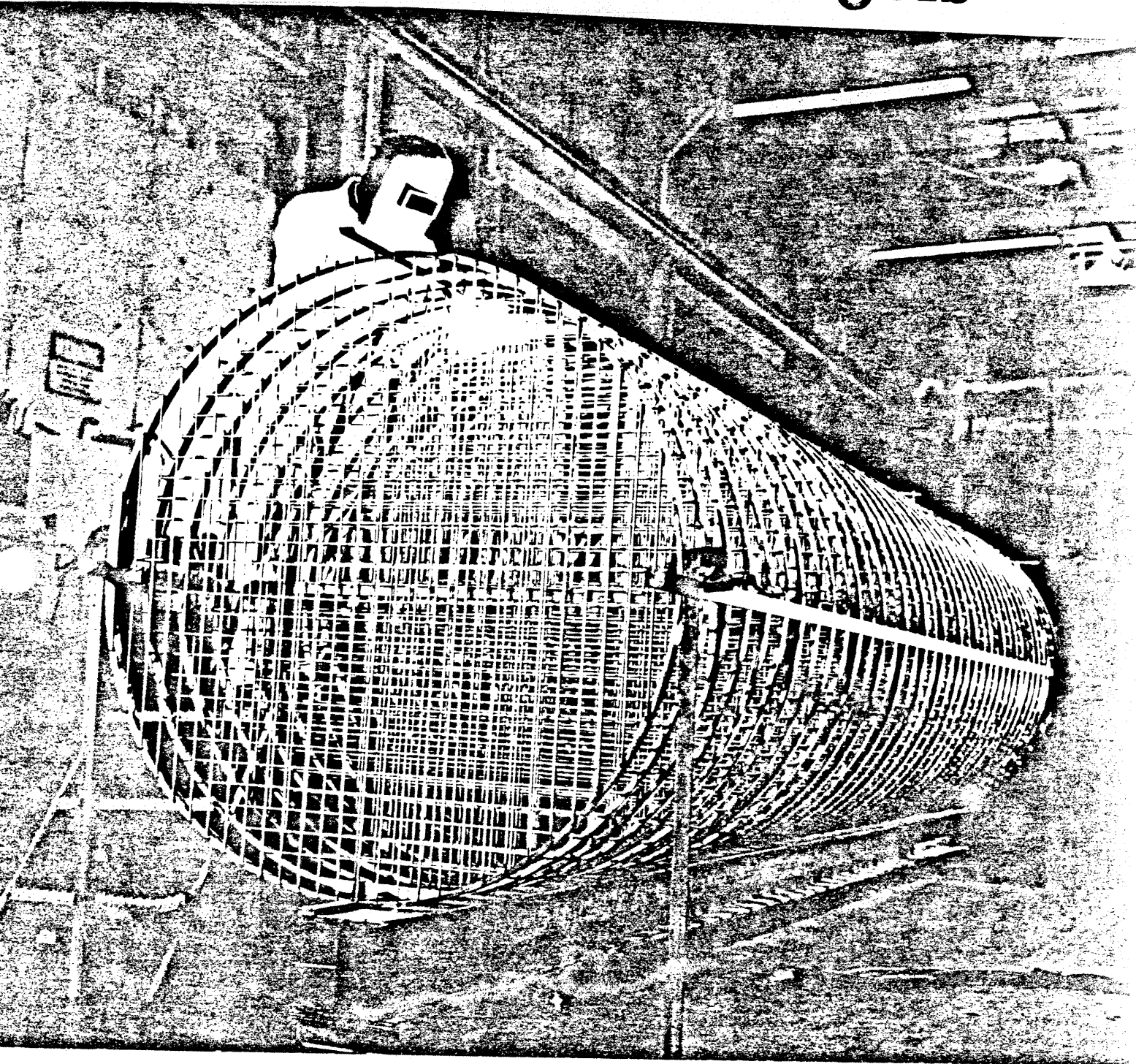
~ 2000 psi

These data are confidential and the property of UOP Process Division and shall not be disclosed to others or reproduced in any manner or used for any purpose whatsoever except by written permission or as provided in a signed agreement with UOP Process Division relating to such data.

high pressure and high temperature heat exchangers



RODbaffle Heat Exchangers



UOP Inc.

Algonquin & Mt. Prospect Roads • Box 5017 • Des Plaines, Illinois 60017-5017 • U.S.A.

WELDED PLATE TYPE EXCHANGERS "PACKINOX"

PROJECT SPECIFICATION

NUMBER

REVISION

- 416 -

SHEET

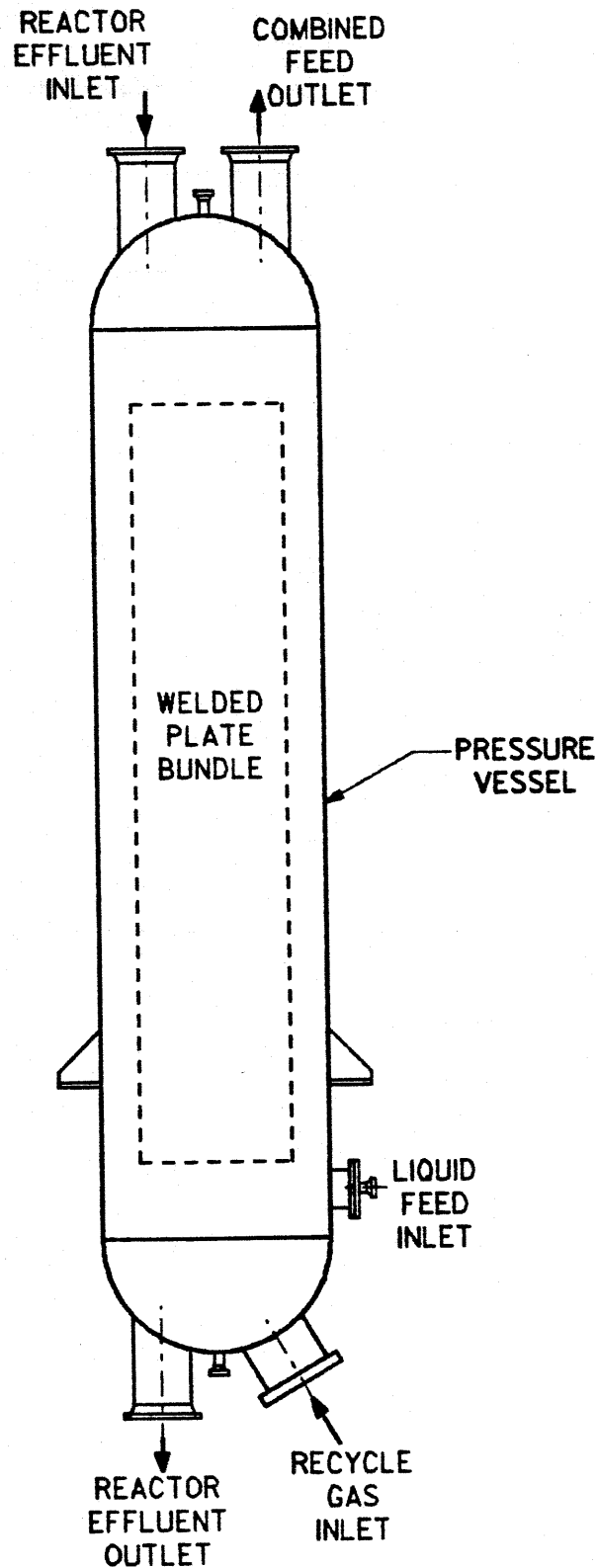
OF

BY

APP'D

DATE

TYPICAL ARRANGEMENT FOR WELDED PLATE EXCHANGERS ITEM NO. _____

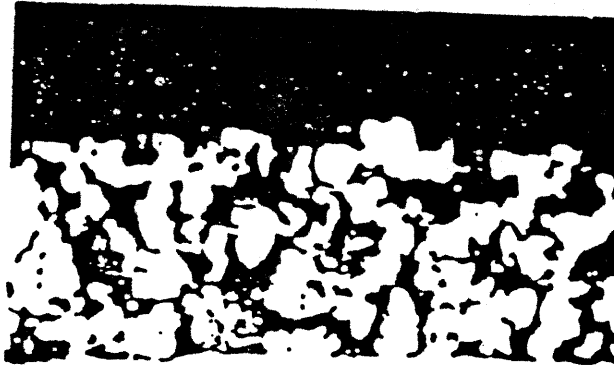


CI3417A

NOTE - These data are confidential and the property of UOP Inc. and shall not be disclosed to others or reproduced in any manner or used for any purpose whatsoever except by written permission or as provided in a signed agreement with UOP Inc. relating to such data.

HIGH FLUX TUBING

- POROUS METAL FILM APPLIED TO I.D. OR O.D. OF TUBES.



CROSS SECTION OF
HIGH FLUX SURFACE
(100 X)

- IMPROVES BOILING COEFFICIENT 10 X OR MORE.
USED ONLY IN BOILING SERVICES.
- IMPROVES OVERALL TRANSFER RATE 2 - 4 TIMES
- AVAILABLE IN MOST ALLOYS. MAY BE COMBINED WITH
FLUTED CONDENSING ENHANCEMENT.
- WIDELY APPLIED IN PETROCHEMICALS, REFINERY AND REFRIGERATION
INDUSTRIES.
- RESISTANT TO FOULING - OVER 1,700 UNITS IN SERVICE.
- REDUCES CAPITAL OR OPERATING COST OF EXCHANGERS.

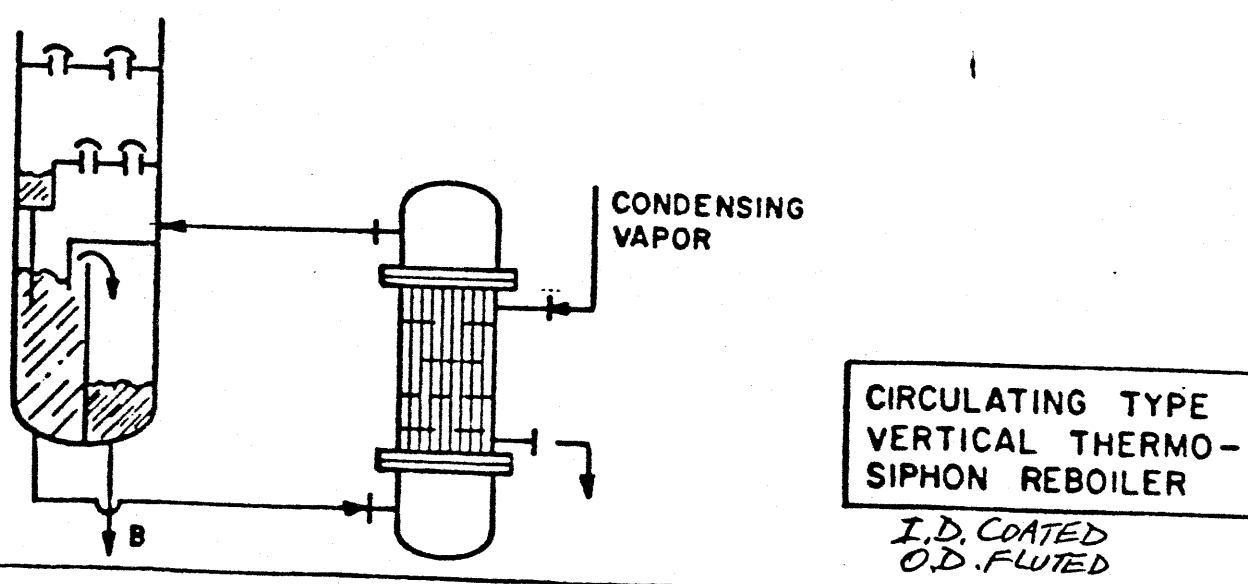
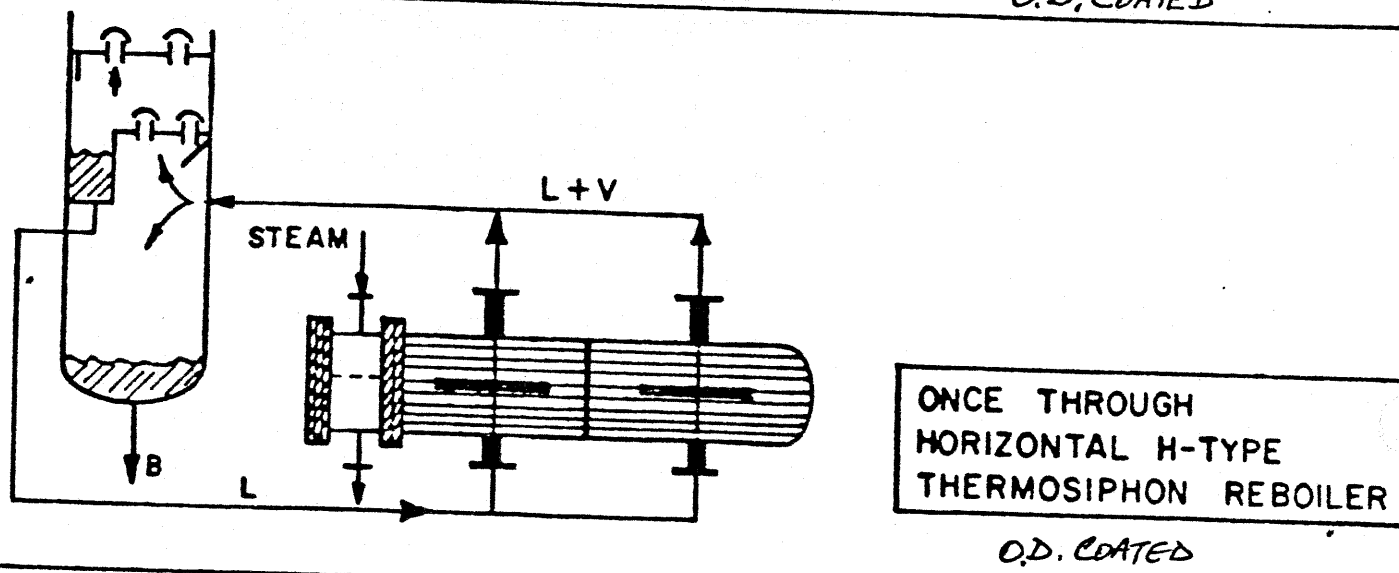
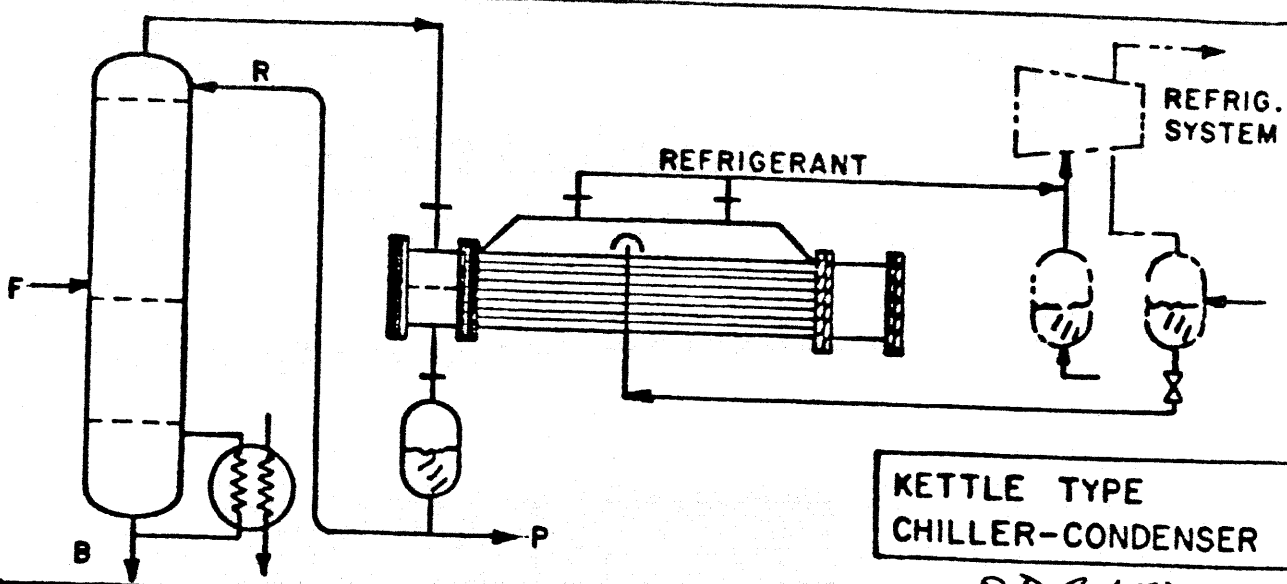
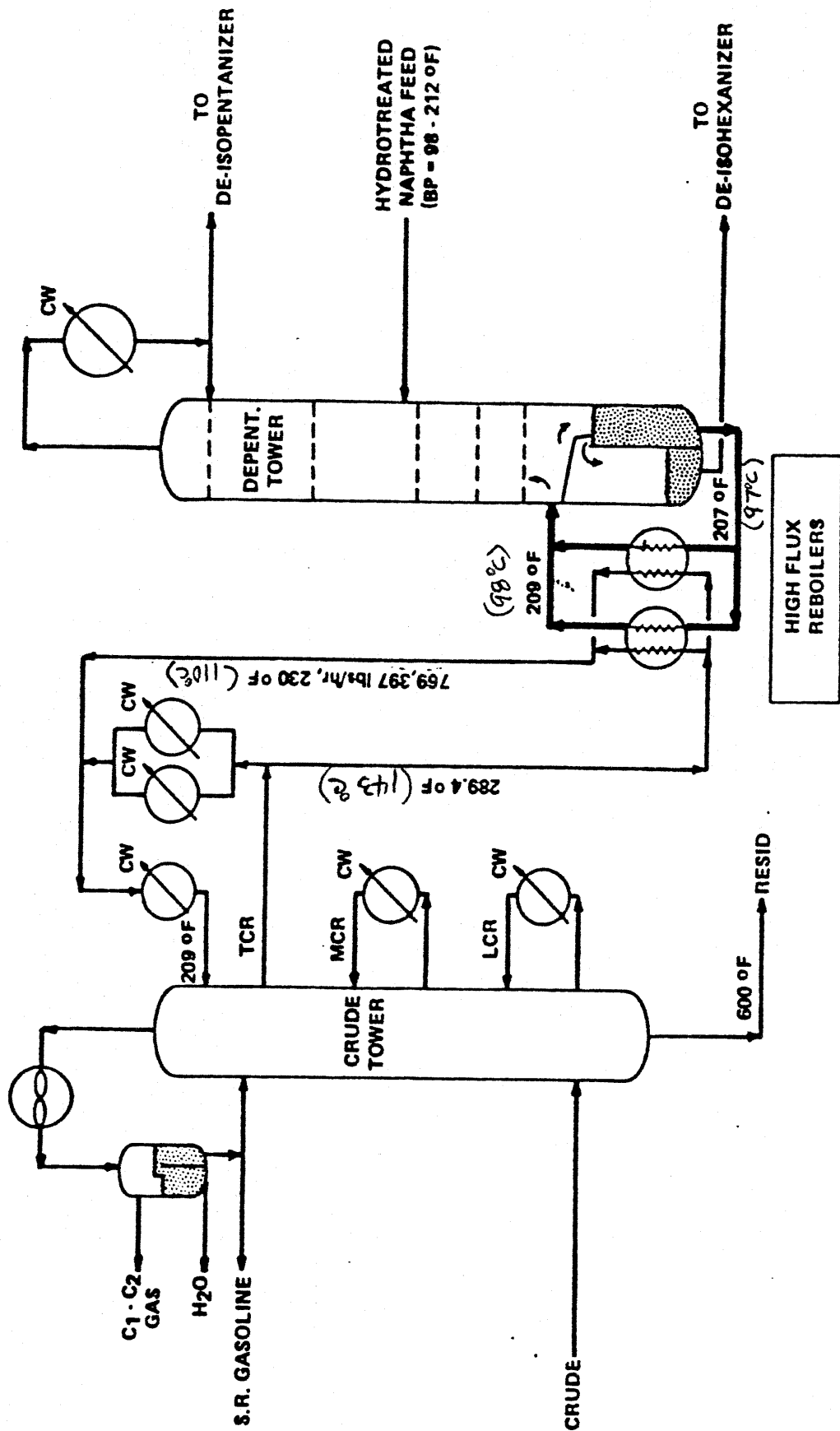


FIGURE 1 COMMON 'HIGH FLUX' HEAT EXCHANGER LAYOUTS

CASE HISTORY
DEPENTANIZER REBOILER RETROFIT

- REVAMP OF PETROLEUM REFINERY REBOILERS TO IMPROVE HEAT RECOVERY.
- REBOILERS DRIVEN BY TOP CIRCULATING REFLUX (TCR) STREAM COMING FROM CRUDE TOWER.
- ORIGINAL TCR FLOW TO REBOILERS = 500,000 KG/HR.
- CHANGES IN REFINERY CRUDE & OTHER MODIFICATIONS REDUCED TCR FLOW TO REBOILERS TO 350,000 KG/HR.
- HEAT DUTY OF REBOILERS DROPPED.
- DEBOTTLENECK OF REBOILERS ACHIEVED BY RETUBING EXISTING REBOILERS WITH HIGH FLUX TUBING USING SAME SHELL, HEADS AND PIPING.

FIGURE 2
SIMPLIFIED FLOWSHEET
CRUDE UNIT/DEPENTANIZER HEAT INTEGRATION



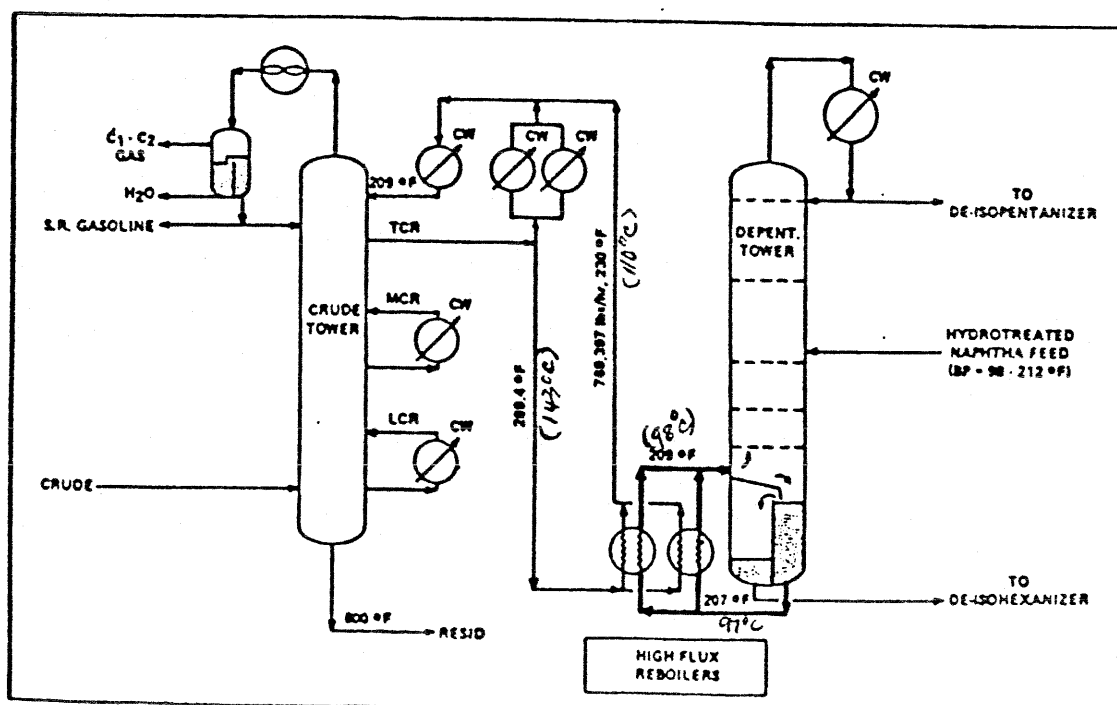
HIGH FLUX REPLACEMENT DUNDLES IN DEPENTANIZER REBOILERS ALLOWED A 41% INCREASE IN HEAT DUTY

TABLE 1: COMPARISON OF ORIGINAL AND REVAMPED DEPENTANIZER REBOILER OPERATION

ITEM	BARE TUBE REBOILERS		HIGH FLUX REBOILERS	
	E-702 A/B			
	As Designed (1969)	Actual Operation (1980)	As Designed (1981)	Max. Expected
Heating TCR Flow Kg/Hr	488,800	349,250	349,250	349,250
TCR Inlet Temp °C	149	143	143	143
TCR Outlet (°C)	126	120	110	106
Depent. Bottoms °C	103	97	97.3	97.3
Overall ΔT °C	33.1	33.2	25.8	22.3
Reboiler Surface, M ²	484	484	484	484
Overall U, K cal/Hr M ² C	<u>429</u>	<u>305</u>	<u>552</u>	<u>713</u>
Reboiler Duty MM K cal/Hr	6.875	<u>4.908</u> *	<u>6.875</u> *	7.701

**SIMPLIFIED
FLOW SHEET,
CD6 UNIT,**

*(40% INCREASE
IN DUTY
WITH
HI-FLUX)



HIGH FLUX REBOILER APPLICATION IN UOP PARA-XYLENE (PAREX) EXTRACTION SYSTEM

<u>ITEM</u>	<u>UNIT A</u>	<u>UNIT B</u>
LOCATION	FRANCE	USA
REBOILER SIZE	* 1-65"x240"	2-53"x240"
BOILING	XYLENES + EB	XYLENES + EB
CONDENSING	TOLUENE	TOLUENE
HEAT DUTY MM BTU/HR	45.0	71.8
EXCHANGER ORIENTATION	<u>VERTICAL</u>	<u>HORIZONTAL</u>
OVERALL U BTU/HR FT ² °F	210	185
TUBE TYPE	* < OD FLUTED (1 1/4") ID COATED	UD COATED
BENEFIT	FUEL SAVINGS	FUEL SAVINGS
STARTUP	2/84	1982

* IF BARE 1" OD TUBES

U-VALUE APPROX: 85 BTU/HR FT²

REQUIRE 2 EXCHANGERS EACH APPROX: 65"x240"

OR

4

"

"

"

48"x240"