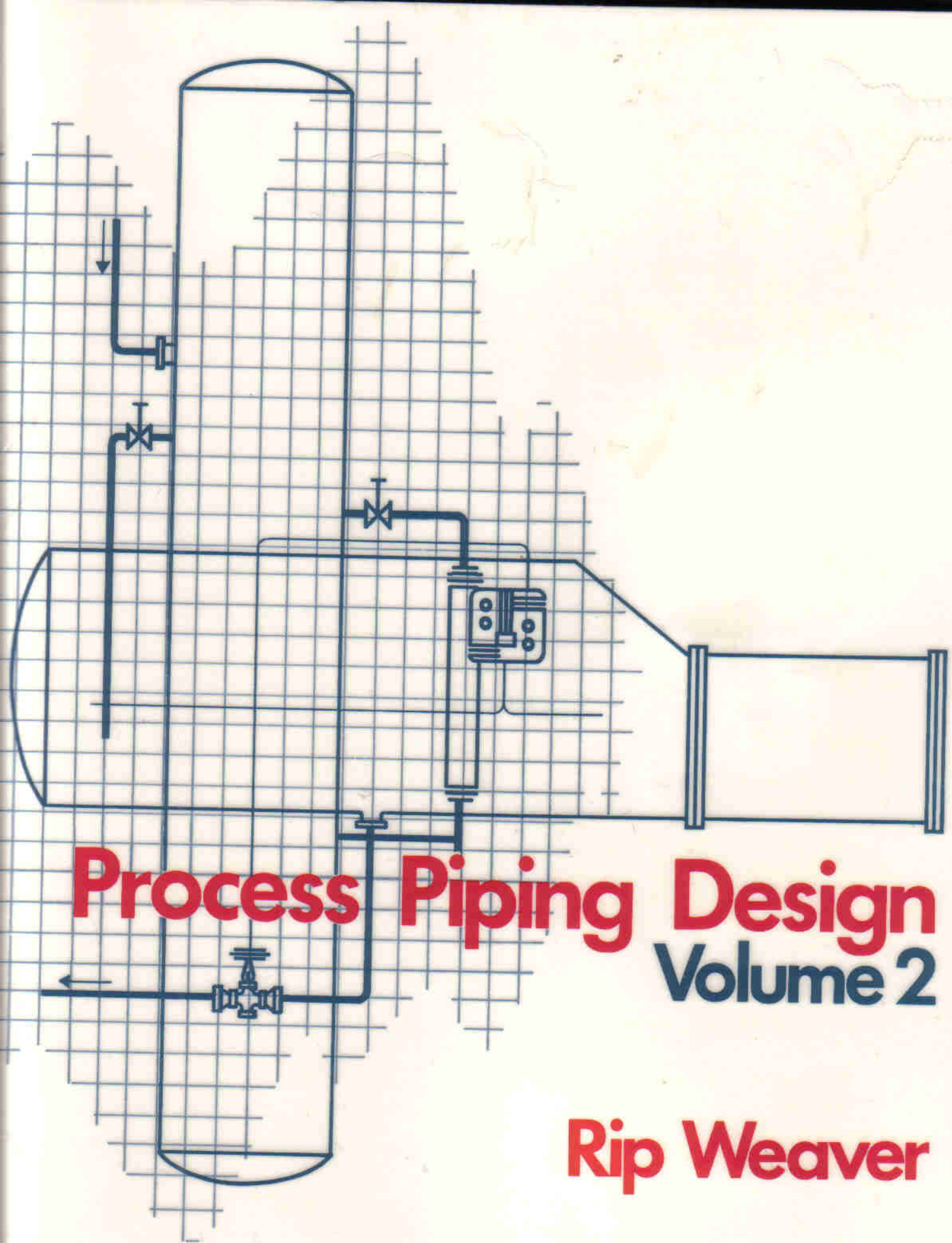




Process Piping Design

Volume 2

Rip Weaver

Process Piping Design

By
Rip Weaver

1 Pumps and Turbines

The work horses of refineries and chemical plants are pumps—mechanical equipment used to propel liquid under pressure from one location to another through piping. In process plants this liquid usually is moved from one vessel to another, increasing the liquid pressure as it circulates through the pump. Pipe lines, transporting fluid for miles across the country, have pumping stations every few miles to boost the liquid along its way.

Turbines are engines or motors driven by the pressure of steam, water or air against the curved vanes of a wheel or rotor. Process plants often use steam turbines to drive pumps, although electric motors are more common. Steam-driven turbines are also used for generating electricity. Huge gas-fired turbines are specified for electrical generators where fuel gas is inexpensive.

Pump Types

The three basic pump-types are centrifugal, reciprocating and rotary. *Centrifugal* pumps comprise over 90% of process pump installations. They have proven to be the most economical in service and require much less maintenance than the others. Centrifugal force creates the rise in pressure used to move liquid by forcing it into a rotating impeller and literally throwing it out the discharge nozzle

producing a smooth, non-pulsating flow in the piping system.

Reciprocating pumps have plungers that go back and forth like a car's pistons to displace liquid, forcing it violently out of the discharge nozzle. These pumps operate at a much lower rpm (rounds per minute) and each plunger's thrust causes a pulsation in suction and discharge piping.

A common piping error is the assumption that the discharge line pulsates because the pump is pushing pulsating liquid into it. Actually, the pump is taking in liquid at the same rate at which it is discharging liquid, and by the same reciprocating action; thereby causing the suction line to pulsate too. This pulsating action causes the piping to jump, sometimes several inches, and if not held down, it will eventually fatigue. Rpm and pulsation rate vary with each service, but whether the pipe jumps twice a minute or 100 times a minute, the designer must have hold-downs installed at regular intervals to dampen pulsation. Distances between hold-downs should vary with pulsation intervals and line size, but all elbows within 10-ft. of a pump must have them. Hold-downs must be closer together for smaller line sizes.

Rotary pumps are used for moving extremely heavy or viscous commodities such as grease, asphalt, heavy fuel oils and sometimes heavy crude oils. Instead of centrifugal force or reciprocating

action, rotary pumps use various mechanical means to move liquid. The three main types of rotary pumps are gear, cam and screw.

Pump Performance

Pumps are installed to perform a certain job, moving liquid of a certain specific gravity a set volume at a specific pressure. Volume is usually expressed as *gpm* (gallons per minute). There are many other ways to express this measurement. Table 1-1, defines other volumetric quantities and supplies equivalents for *gpm* quantities.

Pump performance is usually specified in *feet of water head* (See Volume 1, Chapter 2). This is converted to *psig* (pounds per square inch gage) by multiplying the liquid's specific gravity by the expressed head and dividing by 2.31. This formula is expressed:

$$\text{psig} = \frac{\text{sg} \times H}{2.31}$$

If pump performance is expressed as *psig*, conversion to head is made by:

$$H = \frac{\text{psig} \times 2.31}{\text{sg}}$$

where:

H = static head expressed in feet

sg = specific gravity of liquid

Brake horsepower is the amount of energy input to the pump shaft. Each pumping service has a required brake horsepower. Brake horsepower is based on the pumps duty and is calculated:

$$\text{bhp} = \frac{\text{gpm} \times \text{sg} \times H}{3960 \times \text{pe}}$$

This might also be expressed as:

$$\text{bhp} = \frac{\text{bh} \times \text{pdp}}{2450 \times \text{pe}}$$

where:

bhp = brake horsepower

gpm = gallons per minute

sg = specific gravity

H = head in feet

pe = pump efficiency

bh = barrels per hour

pdp = pump differential pressure (psi)

As an example, a pump moving 3000 *gpm* of liquid at 0.62 specific gravity, 90% efficiency, discharging 425 ft. of head will require what brake horsepower? To solve:

$$\begin{aligned} \text{bhp} &= \frac{\text{gpm} \times \text{sg} \times H}{3960 \times \text{pe}} \\ &= \frac{3000 \times 0.62 \times 425}{3960 \times .90} \end{aligned}$$

$$\text{bhp} = 221.8$$

Before specification of the amount of motor horsepower to be purchased, the motor's efficiency must be known. In this case a 250hp motor would probably be purchased.

Capacity, head and horsepower all change as pump speed slows. Centrifugal pumps are often purchased with oversized casings to allow for later installation of a larger impeller to increase throughput. With each pump purchased the manufacturer supplies a performance curve for that particular model. Most curves are expressed in feet of head of water (which has a specific gravity of 1.0). The numbers given must be multiplied by the specific gravity of the pumped liquid.

Centrifugal Pumps

Centrifugal pumps have one fault—they must have flooded suction. At no time should the piping allow any way for air bubbles to enter the pump casing. Suction piping must flow continuously down from an overhead source, never rising before arriving at the suction nozzle. The only exception to this rule is when the pump is moving a *sub-cooled* liquid, one that has been cooled considerably below its equilibrium point. Even then, it is better to avoid vapor pockets in suction lines.

Vapor in the pump casing due to poorly designed piping can cause *cavitation*, displacing liquid from one or more areas of the pump and unbalancing it—reducing its efficiency. The vapor offers less

Table 1-1
Pump Equivalents—Gallons Per Minute

Gal per min	Gal per hr	Gal per day*	Cu ft per sec	Cu ft per min	Cu ft per hr	Cu ft per day*	Gal per min	Gal per hr	Gal per day*	Bbl per min	Bbl per hr	Bbl per day*	†Bbl per min	†Bbl per hr	Bbl per day*
10	600	14,400	1.337	80.22	481.3	11,552	200	12,000	288,000	26.67	1,600	38,400	4.76	283	6,857
12	720	17,280	1.604	96.26	577.5	13,862	240	14,400	345,600	32.00	1,920	46,080	5.71	339	8,228
14	840	20,160	1.872	112.3	676.8	16,214	280	16,800	403,200	37.33	2,240	53,760	6.67	395	9,771
16	960	23,040	2.139	128.4	775.2	18,616	320	19,200	460,800	42.67	2,560	61,440	7.62	451	10,942
18	1,080	25,920	2.407	144.4	873.6	21,018	360	21,600	518,400	48.00	2,880	69,120	8.58	507	12,556
20	1,200	28,800	2.674	160.4	972.0	23,420	400	24,000	576,000	53.33	3,200	76,800	9.53	563	13,985
22	1,320	31,680	2.941	176.5	1,070.4	25,822	440	26,400	633,600	58.67	3,520	84,480	10.48	619	15,414
24	1,440	34,560	3.208	192.6	1,168.8	28,224	480	28,800	691,200	64.00	3,840	92,160	11.43	675	16,843
26	1,560	37,440	3.476	208.6	1,267.2	30,626	520	31,200	748,800	69.33	4,160	99,840	12.38	731	18,272
28	1,680	40,320	3.744	224.6	1,365.6	33,028	560	33,600	806,400	74.67	4,480	107,520	13.33	787	19,701
30	1,800	43,200	4.011	240.7	1,464.0	35,430	600	36,000	864,000	80.00	4,800	115,200	14.29	843	21,130
32	1,920	46,080	4.278	256.7	1,562.4	37,832	640	38,400	921,600	85.33	5,120	122,880	15.24	899	22,559
34	2,040	48,960	4.546	272.7	1,660.8	40,234	680	40,800	979,200	90.67	5,440	130,560	16.19	955	23,988
36	2,160	51,840	4.813	288.8	1,759.2	42,636	720	43,200	1,036,800	96.00	5,760	138,240	17.14	1,011	25,417
38	2,280	54,720	5.081	304.8	1,857.6	45,038	760	45,600	1,094,400	101.33	6,080	145,920	18.09	1,067	26,846
40	2,400	57,600	5.348	320.9	1,956.0	47,440	800	48,000	1,152,000	106.67	6,400	153,600	19.04	1,123	28,275
42	2,520	60,480	5.616	336.9	2,054.4	49,842	840	50,400	1,209,600	112.00	6,720	161,280	19.99	1,179	29,704
44	2,640	63,360	5.883	352.9	2,152.8	52,244	880	52,800	1,267,200	117.33	7,040	168,960	20.94	1,235	31,133
46	2,760	66,240	6.151	368.9	2,251.2	54,646	920	55,200	1,324,800	122.67	7,360	176,640	21.89	1,291	32,562
48	2,880	69,120	6.418	385.0	2,349.6	57,048	960	57,600	1,382,400	128.00	7,680	184,320	22.84	1,347	33,991
50	3,000	72,000	6.686	401.0	2,448.0	59,450	1,000	60,000	1,440,000	133.33	8,000	192,000	23.79	1,403	35,420
52	3,120	74,880	6.953	417.0	2,546.4	61,852	1,040	62,400	1,497,600	138.67	8,320	200,640	24.74	1,459	36,849
54	3,240	77,760	7.221	433.0	2,644.8	64,254	1,080	64,800	1,555,200	144.00	8,640	208,320	25.69	1,515	38,278
56	3,360	80,640	7.488	449.0	2,743.2	66,656	1,120	67,200	1,612,800	149.33	8,960	216,000	26.64	1,571	39,707
58	3,480	83,520	7.756	465.0	2,841.6	69,058	1,160	69,600	1,670,400	154.67	9,280	223,680	27.59	1,627	41,136
60	3,600	86,400	8.023	481.0	2,940.0	71,460	1,200	72,000	1,728,000	160.00	9,600	231,360	28.54	1,683	42,565
62	3,720	89,280	8.291	497.0	3,038.4	73,862	1,240	74,400	1,785,600	165.33	9,920	239,040	29.49	1,739	43,994
64	3,840	92,160	8.558	513.0	3,136.8	76,264	1,280	76,800	1,843,200	170.67	10,240	246,720	30.44	1,795	45,423
66	3,960	95,040	8.826	529.0	3,235.2	78,666	1,320	79,200	1,900,800	176.00	10,560	254,400	31.39	1,851	46,852
68	4,080	97,920	9.093	545.0	3,333.6	81,068	1,360	81,600	1,958,400	181.33	10,880	262,080	32.34	1,907	48,281
70	4,200	100,800	9.361	561.0	3,432.0	83,470	1,400	84,000	2,016,000	186.67	11,200	269,760	33.29	1,963	49,710
72	4,320	103,680	9.628	577.0	3,530.4	85,872	1,440	86,400	2,073,600	192.00	11,520	277,440	34.24	2,019	51,139
74	4,440	106,560	9.896	593.0	3,628.8	88,274	1,480	88,800	2,131,200	197.33	11,840	285,120	35.19	2,075	52,568
76	4,560	109,440	10.163	609.0	3,727.2	90,676	1,520	91,200	2,188,800	202.67	12,160	292,800	36.14	2,131	53,997
78	4,680	112,320	10.431	625.0	3,825.6	93,078	1,560	93,600	2,246,400	208.00	12,480	300,480	37.09	2,187	55,426
80	4,800	115,200	10.698	641.0	3,924.0	95,480	1,600	96,000	2,304,000	213.33	12,800	308,160	38.04	2,243	56,855
82	4,920	118,080	10.966	657.0	4,022.4	97,882	1,640	98,400	2,361,600	218.67	13,120	315,840	38.99	2,299	58,284
84	5,040	120,960	11.233	673.0	4,120.8	100,284	1,680	100,800	2,419,200	224.00	13,440	323,520	39.94	2,355	59,713
86	5,160	123,840	11.501	689.0	4,219.2	102,686	1,720	103,200	2,476,800	229.33	13,760	331,200	40.89	2,411	61,142
88	5,280	126,720	11.768	705.0	4,317.6	105,088	1,760	105,600	2,534,400	234.67	14,080	338,880	41.84	2,467	62,571
90	5,400	129,600	12.036	721.0	4,416.0	107,490	1,800	108,000	2,592,000	240.00	14,400	346,560	42.79	2,523	64,000
92	5,520	132,480	12.303	737.0	4,514.4	109,892	1,840	110,400	2,649,600	245.33	14,720	354,240	43.74	2,579	65,429
94	5,640	135,360	12.571	753.0	4,612.8	112,294	1,880	112,800	2,707,200	250.67	15,040	361,920	44.69	2,635	66,858
96	5,760	138,240	12.838	769.0	4,711.2	114,696	1,920	115,200	2,764,800	256.00	15,360	369,600	45.64	2,691	68,287
98	5,880	141,120	13.106	785.0	4,809.6	117,098	1,960	117,600	2,822,400	261.33	15,680	377,280	46.59	2,747	69,716
100	6,000	144,000	13.373	801.0	4,908.0	119,500	2,000	120,000	2,880,000	266.67	16,000	384,960	47.54	2,803	71,145
102	6,120	146,880	13.641	817.0	5,006.4	121,902	2,040	122,400	2,937,600	272.00	16,320	392,640	48.49	2,859	72,574
104	6,240	149,760	13.908	833.0	5,104.8	124,304	2,080	124,800	2,995,200	277.33	16,640	400,320	49.44	2,915	74,003
106	6,360	152,640	14.176	849.0	5,203.2	126,706	2,120	127,200	3,052,800	282.67	16,960	408,000	50.39	2,971	75,432
108	6,480	155,520	14.443	865.0	5,301.6	129,108	2,160	129,600	3,110,400	288.00	17,280	415,680	51.34	3,027	76,861
110	6,600	158,400	14.711	881.0	5,400.0	131,510	2,200	132,000	3,168,000	293.33	17,600	423,360	52.29	3,083	78,290
112	6,720	161,280	14.978	897.0	5,498.4	133,912	2,240	134,400	3,225,600	298.67	17,920	431,040	53.24	3,139	79,719
114	6,840	164,160	15.246	913.0	5,596.8	136,314	2,280	136,800	3,283,200	304.00	18,240	438,720	54.19	3,195	81,148
116	6,960	167,040	15.513	929.0	5,695.2	138,716	2,320	139,200	3,340,800	309.33	18,560	446,400	55.14	3,251	82,577
118	7,080	169,920	15.781	945.0	5,793.6	141,118	2,360	141,600	3,398,400	314.67	18,880	454,080	56.09	3,307	84,006
120	7,200	172,800	16.048	961.0	5,892.0	143,520	2,400	144,000	3,456,000	320.00	19,200	461,760	57.04	3,363	85,435
122	7,320	175,680	16.316	977.0	5,990.4	145,922	2,440	146,400	3,513,600	325.33	19,520	469,440	57.99	3,419	86,864
124	7,440	178,560	16.583	993.0	6,088.8	148,324	2,480	148,800	3,571,200	330.67	19,840	477,120	58.94	3,475	88,293
126	7,560	181,440	16.851	1,009.0	6,187.2	150,726	2,520	151,200	3,628,800	336.00	20,160	484,800	59.89	3,531	89,722
128	7,680	184,320	17.118	1,025.0	6,285.6	153,128	2,560	153,600	3,686,400	341.33	20,480	492,480	60.84	3,587	91,151
130	7,800	187,200	17.386	1,041.0	6,384.0	155,530	2,600	156,000	3,744,000	346.67	20,800	500,160	61.79	3,643	92,580
132	7,920	190,080	17.653	1,057.0	6,482.4	157,932	2,640	158,400	3,801,600	352.00	21,120	507,840	62.74	3,699	94,009
134	8,040	192,960	17.921	1,073.0	6,580.8	160,334	2,680	160,800	3,859,200	357.33	21,440	515,520	63.69	3,755	95,438
136	8,160	195,840	18.188	1,089.0	6,679.2	162,736	2,720	163,200	3,916,800	362.67	21,760	523,200	64.64	3,811	96,867
138	8,280	198,720	18.456	1,105.0	6,777.6	165,138	2,760	165,600	3,974,400	368.00	22,080	530,880	65.59	3,867	98,296
140	8,400	201,600	18.723	1,121.0	6,876.0	167,540	2,800	168,000	4,032,000	373.33	22,400	538,560	66.54	3,923	99,725
142	8,520	204,480	18.991	1,137.0	6,974.4	169,942	2,840	170,400	4,089,600	378.67	22,720	546,240	67.49	3,979	101,154
144	8,640	207,360	19.258	1,153.0	7,072.8	172,344	2,880	172,800	4,147,200	384.00	23,040	553,920	68.44	4,035	102,583
146	8,760	210,240	19.526	1,169.0	7,171.2	174,746	2,920	175,200	4						

resistance than the fluid being pumped, the impeller will not turn smoothly and uneven resistance may set up a slight eccentric rotation. Eventually, this will wear out bearings and seals and necessitate the shutting down of the pump.

There are three basic types of centrifugal pumps: horizontal, vertical in-line and vertical can. In each case the name of the type refers to shaft location. Horizontal pumps have horizontal shafts; and this type is the most common. Vertical in-line pumps are gaining popularity. This pump is called in-line because it is installed in the pipe line as a valve might be. Pumps with motors of 25hp or less can be supported by the pipe and dummy supports reaching to grade or floor. Larger pumps need a small concrete foundation. The vertical can type is specified when the NPSH (net positive suction head) would be inadequate for other styles. NPSH requirements for the particular pump and fluid are supplied by the pump manufacturer and are often expressed as feet of water. When they are the NPSH shown must be multiplied by the specific gravity of the liquid to be moved in order to make sure there will be adequate minimum NPSH.

Figure 1-1 contains basic flow information needed by the piping designer. Here an 8" line, 1100A—8" 1h, supplies suction to pumps P-100A and B. The pumps have only 4" suction nozzles so using an intermediate size gate valve (shown 6") is permissible to lower costs.

Suction Piping

Pump suction block valves must be one size larger than the pump nozzle size but not larger than line size. The combination of 4" nozzle, 6" block valve and 8" suction line follows this rule. If a 6" nozzle had been used, the size of the block valve could not have been reduced and would have had to remain at 8"—equaling the suction line size. Generally, suction piping should be one or two sizes larger than the pump suction nozzle. An experienced designer, seeing a suction line three or more sizes larger than the pump nozzle would question the line size. It is extremely rare to need a 10" suction line for a 4" pump nozzle. It might be necessitated by the pump's having a very long suction line, which is to be avoided. Sometimes a unit charge pump is placed inside a battery limit taking suction from a booster pump in the tank

farm. To minimize pressure drop, a 12" line might be run the several hundred feet to the charge pump's 4" nozzle. But that would be unusual; normally, centrifugal pumps are located very near their suction source.

Figure 1-2 shows both a plan view and how to picture suction piping on an isometric spool. In the plan view, line 1100 A—8" 1h goes directly to the pump's top suction. (The flow diagram, Figure 1-1, shows an end-suction pump but the top suction type is pictured in the pump outline drawing. Horizontal centrifugal pumps are always shown as the end suction type on flow diagrams.) The suction block valve handwheel is oriented over the pump. Notice that the pump or driver is not shown. Only the foundation outline, for clearances, and the nozzles are important to the piping designer—so they are all that is drawn.

The isometric view reveals that line reduction takes place as close to the block valve as possible and again as close to the suction nozzle as possible. This is very important. *All allowable suction piping reductions must occur as close to the pump nozzle as possible* so pump suction will not be starved.

Temporary Start-up Strainers

There must always be a temporary start-up strainer immediately below the block valve to catch any debris left in the line and to prevent damage to the pump. After the pump has run for several days the block valve can be closed and the strainer removed. The most common strainer used is the basket type (Figures 1-3a and 1-3b), however, flat, conical and bathtub strainers are also often specified. Bathtub strainers are also called T-type because they fit inside a tee.

Conical strainers (shown in Figures 1-4a and 1-4b) are longer than the basket type and are often difficult to insert in fitting-make-up piping. Flat strainers (Figure 1-5) have 5/16" holes staggered on 7/16" centers allowing only 46% open area and hindering pump suction. A very small amount of debris will restrict it even more. Flat strainers are usually specified for very short suction lines where no debris is expected.

Figure 1-6a and 1-6b bathtub type temporary strainer, is becoming much more popular. While more expensive, it does not require unbolting and

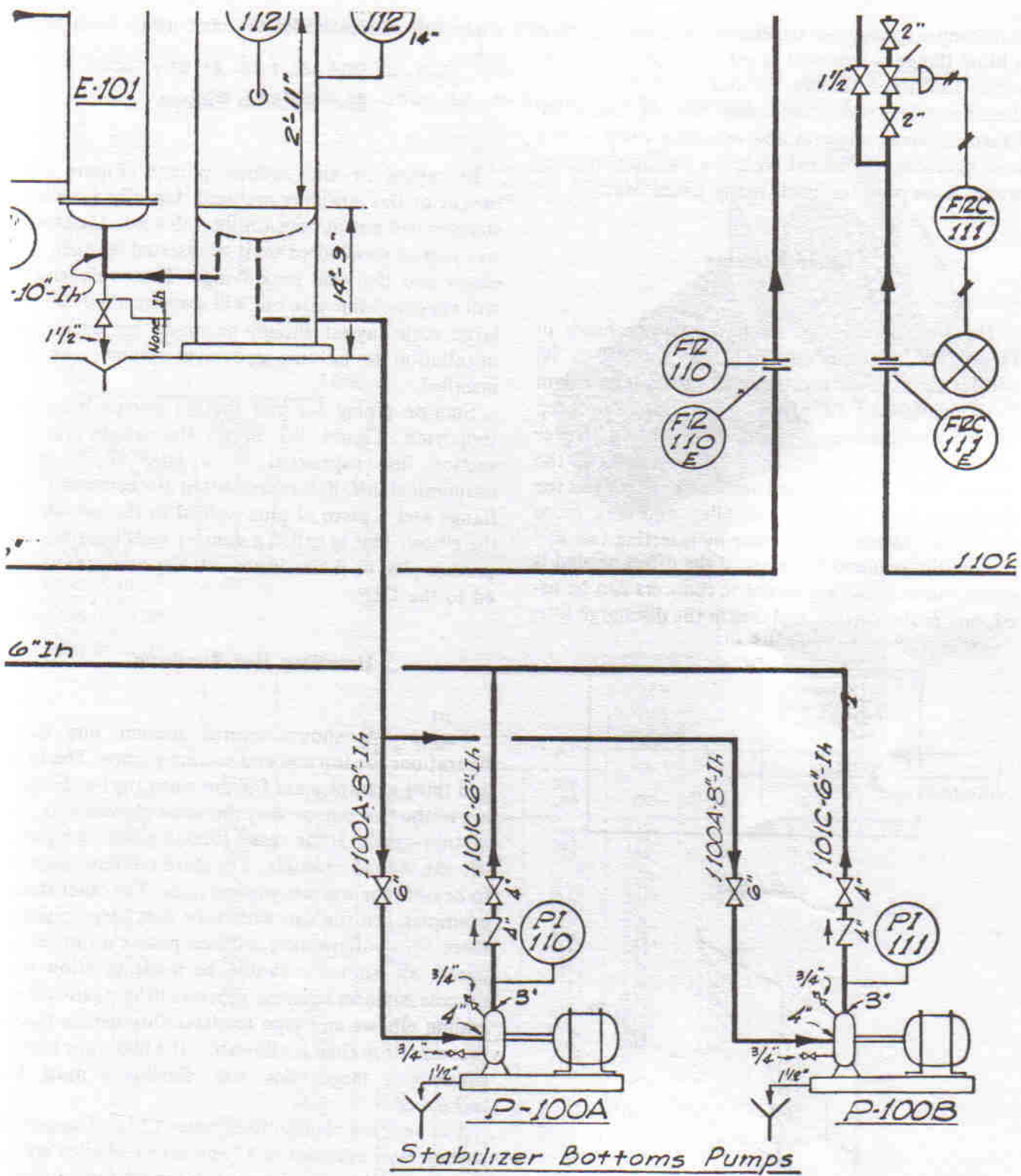


Figure 1-1. Horizontal centrifugal pumps shown on flow diagram. Courtesy of Fluor Engineers and Constructors, Inc.

removing a spool piece to remove the strainer. Only a blind flange is removed to get to the strainer. The main advantage though, is that strainer removal does not affect pump alignment. Should conical or basket strainer removal and rebolting cause pump misalignment, the added cost of a bathtub strainer would have paid for itself many times over.

Close Nozzles

The top suction, top discharge pump shown in Figure 1-2 has one disadvantage: sometimes its nozzles are so close together that piping larger than nozzle size must be offset at the pump to keep suction and discharge piping from hitting. Never offset both lines. Never place offset elbows in the suction line, causing added pressure drop. Offset the discharge line, which is smaller and has more allowable pressure loss, either by inserting two 45° elbows for the required offset or, if the offset needed is small, sometimes two eccentric reducers can be used, one in the suction and one in the discharge line,

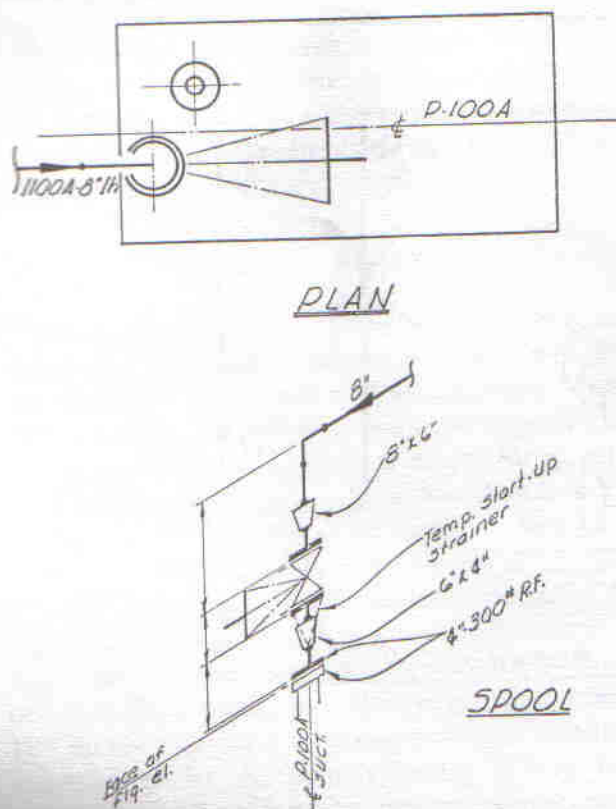


Figure 1-2. P-100A suction piping. Courtesy of Fluor Engineers and Constructors, Inc.

with their eccentricities directed away from each other.

End Suction Pumps

In piping at end suction pumps (Figure 1-7) basket or flat strainers are used. Usually a conical strainer will not fit beneath the valve into the elbow so a *pup* or spool piece must be inserted between the elbow and the weld neck flange. The pup's length will vary with line size but will average about 8". A large scale layout should be made for each size installation to be sure a conical strainer can be installed.

Suction piping for end suction pumps must be supported. Figure 1-7 shows the weight of the suction line supported by a base ell, a very economical installation consisting of a screwed 150# flange and a piece of pipe welded to the outside of the elbow. This is called a *dummy weld* because the process pipe or fitting is not cut. Supports are welded to the OD.

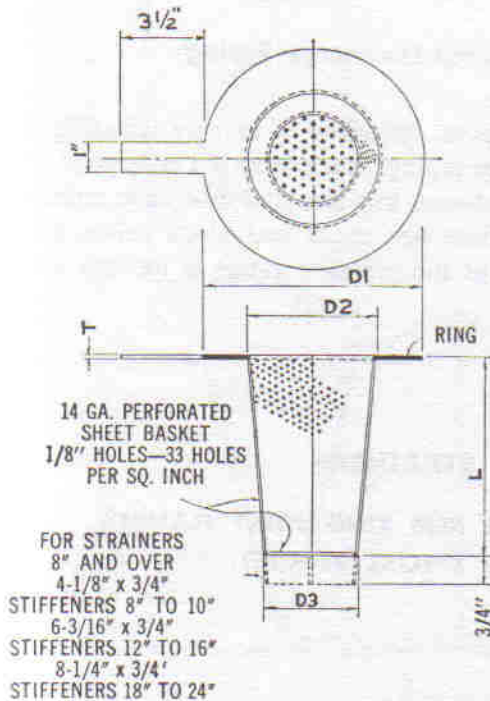
Handling Hot Suctions

Figure 1-8 shows several suction line configurations for top and end suction pumps. The first and third examples are for use when the header going to the two pumps is at the same elevation as the suction nozzle. If the vessel suction nozzle is higher, use the second example. The third configuration is to be used for warmer suction lines. The other three examples are for use with very hot, large piping. Once the configuration selected passes a flexibility check, an isometric should be made to allow the process engineer to check pressure drop. Quite often adding elbows and pipe for flexibility causes more pressure drop than is allowable. If a hydraulic check suggests a larger line size, flexibility must be rechecked.

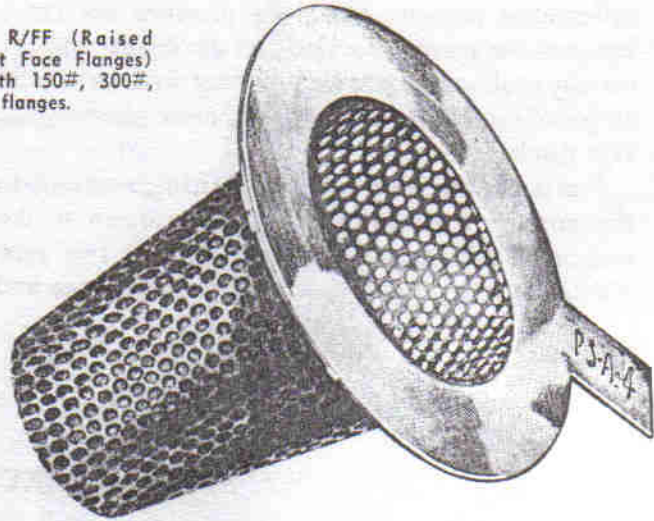
For very hot suction lines, sizes 12" and larger of carbon steel material or 8" and larger of alloy steel, investigate the use of spring-mounted top suction pumps located as near the suction point as possible with minimum horizontal piping. Spring-mounted pumps can be designed to allow varying lengths of down-growth; but very little horizontal growth is possible.

PERFORATED BASKET TEMPORARY STRAINERS

FOR 150 LB.-300 LB.-600 LB. FLAT FACE, RAISED FACE AND RING JOINT FLANGES
900 LB.-1500 LB.-2500 LB. AVAILABLE UPON SPECIAL REQUEST.



Series PB R/FF (Raised and/or Flat Face Flanges) for use with 150#, 300#, and 600# flanges.



Style	Pipe Size	D1				D2	D3	Please Specify Length	T
		FF & RF			RJ				
		150	300	600	300 600			PBS-150% PBL-200% (open area) L	
PBS.....	1 1/2"	3 1/8"	3 1/8"	3 1/8"	2 3/8"	1 1/4"	3/4"	2 1/2"	14 Ga.
PBL.....	1 1/2"	3 1/8"	3 1/8"	3 1/8"	2 3/8"	1 1/4"	3/4"	3 1/2"	"
PBS.....	2"	3 7/8"	4 1/8"	4 1/8"	2 13/16"	1 3/4"	1 1/4"	2 1/2"	"
PBL.....	2"	3 7/8"	4 1/8"	4 1/8"	2 13/16"	1 3/4"	1 1/4"	3 1/2"	"
PBS.....	2 1/2"	4 5/8"	4 7/8"	4 7/8"	3 9/16"	2 1/4"	1 1/2"	3"	"
PBL.....	2 1/2"	4 5/8"	4 7/8"	4 7/8"	3 9/16"	2 1/4"	1 1/2"	4"	"
PBS.....	3"	5 1/8"	5 5/8"	5 5/8"	4 7/16"	2 3/4"	2"	3 1/2"	"
PBL.....	3"	5 1/8"	5 5/8"	5 5/8"	4 7/16"	2 3/4"	2"	4 1/2"	"
PBS.....	3 1/2"	6 1/8"	6 1/8"	6 1/4"	4 3/4"	3 1/4"	2 1/4"	4"	"
PBL.....	3 1/2"	6 1/8"	6 1/8"	6 1/4"	4 3/4"	3 1/4"	2 1/4"	5 1/4"	"
PBS.....	4"	6 5/8"	6 7/8"	7 3/8"	5 7/16"	3 1/2"	2 1/2"	4 1/2"	"
PBL.....	4"	6 5/8"	6 7/8"	7 3/8"	5 7/16"	3 1/2"	2 1/2"	6"	"
PBS.....	5"	7 1/2"	8 1/4"	9 1/4"	6 11/16"	4 5/8"	3 1/4"	5 1/2"	"
PBL.....	5"	7 1/2"	8 1/4"	9 1/4"	6 11/16"	4 5/8"	3 1/4"	7 1/2"	"
PBS.....	6"	8 1/2"	9 5/8"	10 1/4"	7 7/8"	5 1/2"	4"	6 1/2"	"
PBL.....	6"	8 1/2"	9 5/8"	10 1/4"	7 7/8"	5 1/2"	4"	9"	"
PBS.....	8"	10 3/4"	11 7/8"	12 3/8"	10 3/16"	7 1/8"	5 5/8"	8 1/2"	"
PBL.....	8"	10 3/4"	11 7/8"	12 3/8"	10 3/16"	7 1/8"	5 5/8"	12"	"
PBS.....	10"	13 1/8"	14"	15 1/2"	12 5/16"	9"	7 1/4"	10"	"
PBL.....	10"	13 1/8"	14"	15 1/2"	12 5/16"	9"	7 1/4"	14"	"
PBS.....	12"	15 7/8"	16 3/8"	17 3/4"	14 9/16"	10 7/8"	8 7/8"	12"	"
PBL.....	12"	15 7/8"	16 3/8"	17 3/4"	14 9/16"	10 7/8"	8 7/8"	16 1/2"	"
PBS.....	14"	17 1/2"	18 7/8"	19 1/8"	16 1/16"	12 5/8"	10 3/8"	13"	"
PBL.....	14"	17 1/2"	18 7/8"	19 1/8"	16 1/16"	12 5/8"	10 3/8"	17"	"
PBS.....	16"	20"	21"	22"	18 1/16"	14 1/2"	11 3/4"	14"	"
PBL.....	16"	20"	21"	22"	18 1/16"	14 1/2"	11 3/4"	19"	"
PBS.....	18"	21 3/8"	23 1/4"	23 7/8"	20 3/16"	16 3/8"	13 1/2"	15"	"
PBL.....	18"	21 3/8"	23 1/4"	23 7/8"	20 3/16"	16 3/8"	13 1/2"	21"	"
PBS.....	20"	23 5/8"	25 1/2"	26 5/8"	22 1/2"	18 3/8"	15"	17"	"
PBL.....	20"	23 5/8"	25 1/2"	26 5/8"	22 1/2"	18 3/8"	15"	24"	"
PBS.....	24"	28"	30 1/4"	30 7/8"	26 5/8"	22 3/8"	18"	20"	"
PBL.....	24"	28"	30 1/4"	30 7/8"	26 5/8"	22 3/8"	18"	28"	"

Figures 1-3a and b. Perforated basket temporary strainers. Courtesy of Mack Iron Works Co.

Side Suction Pumps

Side-suction pumps are selected for large duty differential pressure (Δp), the pressure difference between the pumps' suction and discharge, and are usually multi-stage, the liquid going through several stages of increasing the pressure before reaching the side discharge nozzle.

Never connect an elbow-flange fitting make-up to the nozzle of a suction line coming down to the pump. Supply a straight piece of pipe two pipe diameters long, between the companion flange and

elbow to allow the fluid to flow straight into the pump's impeller. The two-diameter pup can be eliminated if the first elbow from the suction nozzle is horizontal.

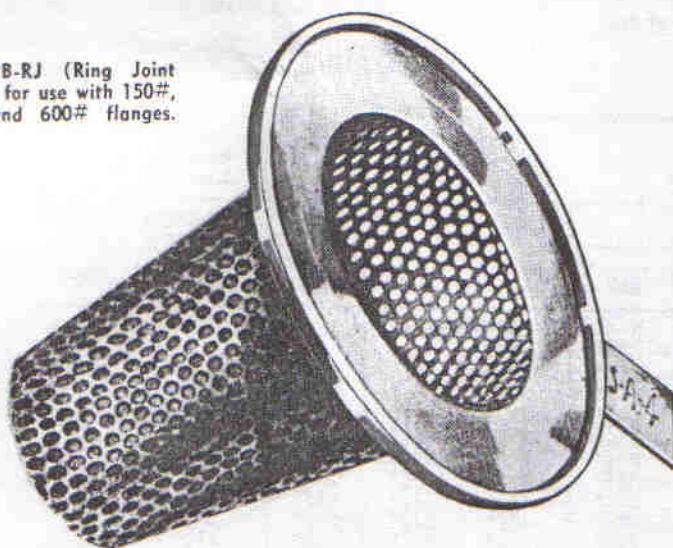
Pump Discharge Piping

Figure 1-9 is an isometric of correct centrifugal pump discharge piping. Since there is a difference of 2 pipe sizes between line size and discharge nozzle size, intermediate size check and block valves are used. Note that the pressure gauge is located up-

PERFORATED BASKET TEMPORARY STRAINERS

FOR 150 LB.-300 LB.-600 LB. FLAT FACE, RAISED FACE AND RING JOINT FLANGES
900 LB.-1500 LB.-2500 LB. AVAILABLE UPON SPECIAL REQUEST.

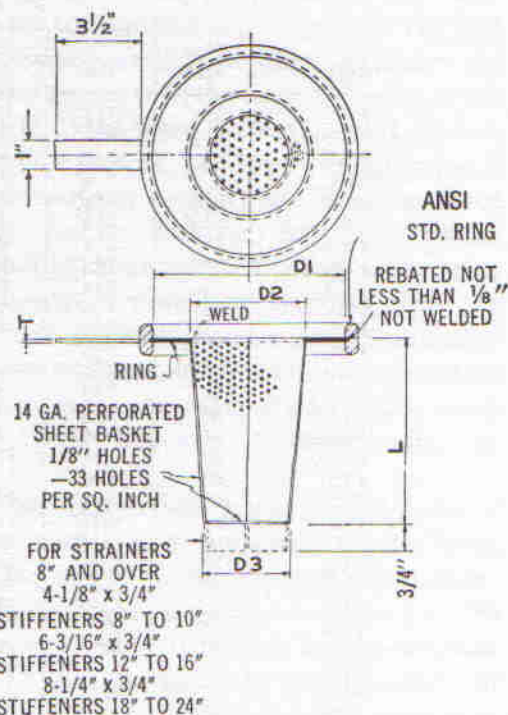
Series PB-RJ (Ring Joint Flanges) for use with 150#, 300#, and 600# flanges.



See Tabular Chart On Preceding Page For Specifications

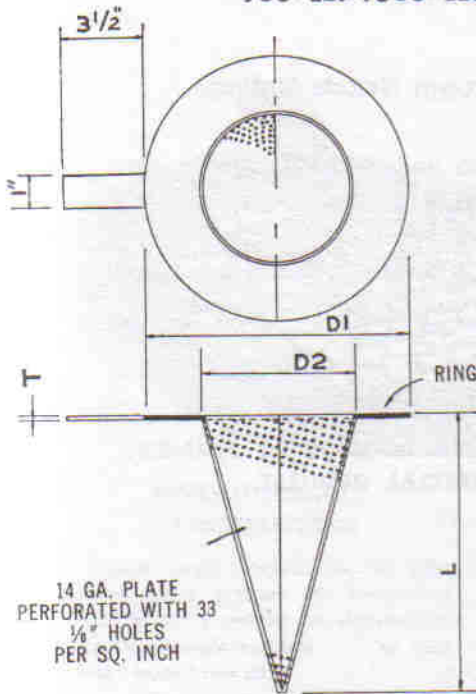
"MAC-IRON" TEMPORARY STRAINERS are of perforated plate or woven wire, all available in plain or cadmium plated carbon steel. Also available in stainless steel, aluminum, brass, bronze, copper, monel metal, Hastelloy and titanium.

Figures 1-3a and b continued.



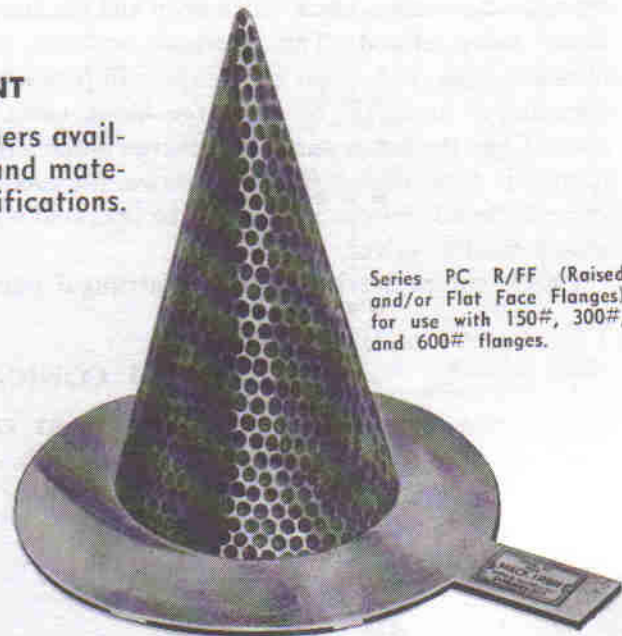
PERFORATED CONICAL TEMPORARY STRAINERS

FOR 150 LB.-300 LB.-600 LB. FLAT FACE, RAISED FACE AND RING JOINT FLANGES
900 LB.-1500 LB.-2500 LB. AVAILABLE UPON SPECIAL REQUEST.



IMPORTANT

Wire conical strainers available in mesh size and material to your specifications.



Series PC R/FF (Raised and/or Flat Face Flanges) for use with 150#, 300#, and 600# flanges.

Style	Pipe Size	D1				D2	Please Specify Length	T
		FF & RF			RJ		PCS-150% PCL-200% (open area) L	
		150	300	600	300 600			
PCS....	1½"	3⅛"	3½"	3½"	2⅜"	1¼"	4"	14 Ga.
PCL....	1½"	3⅛"	3½"	3½"	2⅜"	1¼"	5½"	"
PCS....	2"	3⅞"	4½"	4½"	2⅜"	1¾"	4½"	"
PCL....	2"	3⅞"	4½"	4½"	2⅜"	1¾"	6"	"
PCS....	2½"	4⅝"	4⅞"	4⅞"	3⅞"	2¼"	5½"	"
PCL....	2½"	4⅝"	4⅞"	4⅞"	3⅞"	2¼"	7"	"
PCS....	3"	5⅛"	5⅝"	5⅝"	4⅞"	2¾"	6½"	"
PCL....	3"	5⅛"	5⅝"	5⅝"	4⅞"	2¾"	9"	"
PCS....	3½"	6⅛"	6⅜"	6⅜"	4¾"	3¼"	7½"	"
PCL....	3½"	6⅛"	6⅜"	6¼"	4¾"	3¼"	10"	"
PCS....	4"	6⅝"	6⅞"	7⅝"	5⅞"	3½"	8½"	"
PCL....	4"	6⅝"	6⅞"	7⅝"	5⅞"	3½"	11¼"	"
PCS....	5"	7½"	8¼"	9¼"	6⅞"	4⅝"	10½"	"
PCL....	5"	7½"	8¼"	9¼"	6⅞"	4⅝"	14"	"
PCS....	6"	8½"	9⅝"	10¼"	7⅝"	5½"	13"	"
PCL....	6"	8½"	9⅝"	10¼"	7⅝"	5½"	17"	"
PCS....	8"	10¾"	11⅞"	12⅝"	10⅞"	7⅞"	17"	"
PCL....	8"	10¾"	11⅞"	12⅝"	10⅞"	7⅞"	23"	"
PCS....	10"	13⅛"	14"	15½"	12⅞"	9"	21"	"
PCL....	10"	13⅛"	14"	15½"	12⅞"	9"	27"	"
PCS....	12"	15⅞"	16¾"	17¾"	14⅞"	10⅞"	25"	"
PCL....	12"	15⅞"	16¾"	17¾"	14⅞"	10⅞"	32½"	"
PCS....	14"	17½"	18⅞"	19⅞"	16⅞"	12⅝"	26"	"
PCL....	14"	17½"	18⅞"	19⅞"	16⅞"	12⅝"	35"	"
PCS....	16"	20"	21"	22"	18⅞"	14½"	29½"	"
PCL....	16"	20"	21"	22"	18⅞"	14½"	39"	"
PCS....	18"	21⅜"	23¼"	23⅞"	20⅞"	16⅜"	33"	"
PCL....	18"	21⅜"	23¼"	23⅞"	20⅞"	16⅜"	44"	"
PCS....	20"	23⅝"	25½"	26⅝"	22⅞"	18⅝"	37"	"
PCL....	20"	23⅝"	25½"	26⅝"	22⅞"	18⅝"	49"	"
PCS....	24"	28"	30¼"	30⅞"	26⅝"	22⅞"	44"	"
PCL....	24"	28"	30¼"	30⅞"	26⅝"	22⅞"	58"	"

Figure 1-4a. Conical temporary strainers. Courtesy of Mack Iron Works Co.

Process

Volume 1

1. General Piping
2. Process Terms
3. Plant Arrangement and Storage Tanks
4. Process Unit Plot Plans
5. Piping Systems and Details
6. Pipe Fabrication
7. Vessels
8. Instrumentation

Volume 2

1. Pumps and Turbines
2. Compressors
3. Fired Heaters
4. Exchangers
5. Piping Flexibility

Piping Design

Volume 2

Rip Weaver



Gulf Publishing Company
Book Division
Houston, London, Paris, Zurich, Tokyo

Books by the Author

Process Piping Drafting
Process Piping Drafting Workbook
Process Piping Design, 2 Volumes
Modern Basic Drafting
Modern Basic Drafting Workbook,
Parts 1 and 2
Structural Drafting
Piper's Pocket Handbook

To all my friends at Fluor offices in Houston, Los Angeles, London, Haarlem (Holland) and Dusseldorf (Germany), and many other parts of the globe. Without your kindness and assistance my books would never have been written.

This edition
reviewed by the author and
reprinted March 1992.

**Process Piping Design
Volume 2**

Copyright © 1973 by Gulf Publishing Company, Houston, Texas. All rights reserved. Printed in the United States of America. This book, or parts thereof, may not be reproduced in any form without the permission of the publisher.

Library of Congress Catalog Card Number: 72-94062

ISBN 0-87201-995-0 (paperback series)
ISBN 0-87201-993-4 (paperback Volume 1)
ISBN 0-87201-994-2 (paperback Volume 2)

Gulf Publishing Company
Book Division
P.O. Box 2608, Houston, Texas 77252-2608

First Printing, July 1973
Second Printing, March 1974
Third Printing, August 1974
Fourth Printing, January 1978
Fifth Printing, April 1979
Sixth Printing, July 1982
Seventh Printing, April 1989
Eighth Printing, June 1990
Ninth Printing, March 1992

Printed on Acid Free Paper (∞)

Contents

Preface

Introduction

1 Pumps and Turbines, 1

Pump Types
Performance
Centrifugal
Pump Suction Piping
Temporary Startup Strainers
Close Nozzles
End Suction Pumps
Handling Hot Suctions
Side Suction Pumps
Pump Discharge Piping
Pump Nozzle Ratings
Pump Outline Drawings
Turbine Inlets and Outlets
Turbine Dimensions

2 Compressors, 42

Centrifugal
Case Design
Location
Lube and Seal Oil Consoles
Building Installations
Traveling Crane
Suction and Discharge Nozzles
Case Types
Turbine Details
Surface Condenser
Plot Arrangements
Reciprocating
Definitions
Driver Types
Compression Cylinders
Engine Utilities
Compressor Layout
Buildings
Foundations
Clearances
Suction and Discharge Piping
Pipe Support Spacing
Hold-Downs and Wedges

3 Fired Heaters, 78

- Heater Parts
- Passes
- Dual Purpose Heaters
- Flow
- Burner Piping
- Snuffing Steam
- Locations
- Arrangements
- Piping
- Symmetrical Piping
- Instrumentation
- Soot Blowers
- Decoking Tubes
- Heater Glossary

4 Exchangers, 116

- Double Pipe
- Shell and Tube
- Reboilers
- Vendor's Prints
- Condensers
- Nozzles
- Air Coolers
- Forced and Induced Draft
- Pipe Rack-Mounted Air Coolers
- Humidified Air Coolers
- Air Cooler Piping and Regulator Valves

5 Piping Flexibility, 142

- Purpose of Analysis
- Allowable Forces
- Stress Limitations
- Flexibility Design
- The Quick Check Method with Examples
- Cold Spring in Piping
- Definition of Terms

Index 164

Preface

This two-volume set on *Process Piping Design* has been written to supplement my first book, *Process Piping Drafting*. I have purposely used a very practical writing style for both of these efforts, applying my personal practical experience rather than trying to present the technical aspects of piping. In *Process Piping Design* I have elected to have each chapter self-sustaining. I have reproduced some charts and tables but only those required in learning the basics of piping design.

To become a competent piping designer requires many years of experience plus a talent for creative thinking. A piping designer must call on his knowledge for each design job but also must apply his own ingenuity daily. I like to call that *horse sense*.

Many piping designers have told me that their job is 25% knowledge, 25% experience and 50% horse sense. This book will try to deal with the first 25% and touch on the last 50%.

Fluor Corporation has been very farsighted by instigating piping drafting and piping design training classes and they have been very generous in allowing me to reproduce some of their instructional material. I wish to take this opportunity to thank Fluor for their assistance.

Introduction

In a refining or petrochemical complex, piping constitutes the major expenditure of all the design disciplines. Piping consumes about 50% of the design engineering manhours, 35% of the material cost of the plant and about 30% of the labor cost in the field. Inept piping design in the office can increase the cost of a plant.

The design engineering department of a contractor designing refinery or petrochemical complexes consists of four main functions: piping, structural, electrical and vessels. The piping section encompasses flow diagrams, model making, insulation and painting, piping material take-off, piping material control, instrument design and piping design itself.

An experienced piping designer knows the functions of all of these groups. He also must have a broad knowledge of the structural, electrical and vessel sections. And he must know the many pieces of equipment that he must pipe up, the numerous details of piping, the materials necessary for various services, piping flexibility basics and field construction practice. Then comes a general knowledge of plant operation and maintenance. When all of this is considered, it is easy to see why there is always a shortage of experienced, competent piping designers.

Ironically, piping design is the one subject that has been neglected in the school systems. This is largely due to the fact that adequate textbooks were not available. No book can teach a person to become a piping designer but they can teach him the fundamentals and how to apply them to become a designer.

stream of the check valve. Check and gate valves are flanged together.

With one pump running, the spare pump is started with suction block valve open and discharge block valve closed. The operator watches the pressure gage and when the spare pump reaches operational pressure the discharge block valve is opened and the other pump's discharge block valve is closed. After the pump is shut down, the suction valve is closed. Pumps must never be operated with closed suction valves.

Check valves are installed in centrifugal pump

discharges to prevent backflow into the pump, causing the impeller to turn backwards and possibly ruining the bearings.

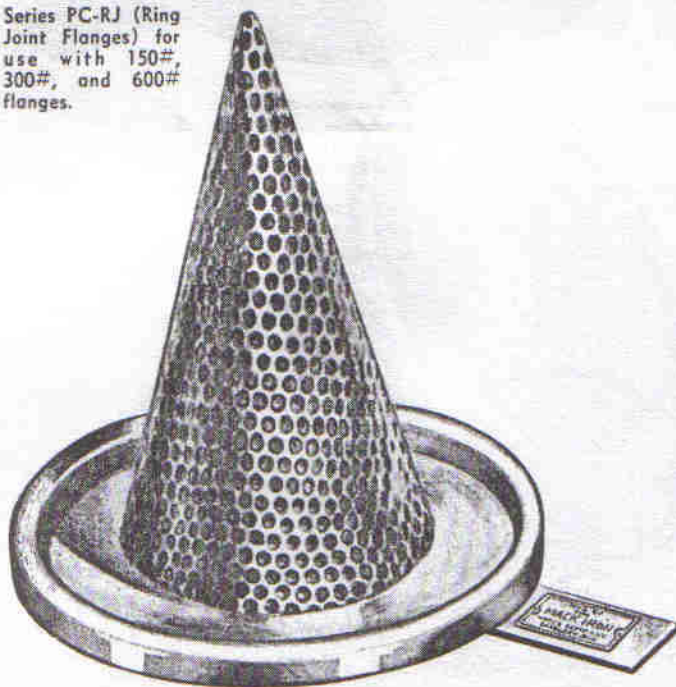
Pump Nozzle Ratings

Pump suction and discharge flange ratings are normally the same. Pumps are hydrotested to $1\frac{1}{2}$ times their design pressure by their manufacturer. The test requires not only the discharge but also the suction flange to contain this pressure. Pump

PERFORATED CONICAL TEMPORARY STRAINERS

FOR 150 LB.-300 LB.-600 LB. FLAT FACE, RAISED FACE AND RING JOINT FLANGES
900 LB.-1500 LB.-2500 LB. AVAILABLE UPON SPECIAL REQUEST.

Series PC-RJ (Ring Joint Flanges) for use with 150#, 300#, and 600# flanges.



See Tabular Chart On Preceding Page For Specifications

"MAC-IRON" TEMPORARY STRAINERS are of perforated plate or woven wire, all available in plain or cadmium plated carbon steel. Also available in stainless steel, aluminum, brass, bronze, copper, monel metal, Hastelloy and titanium.

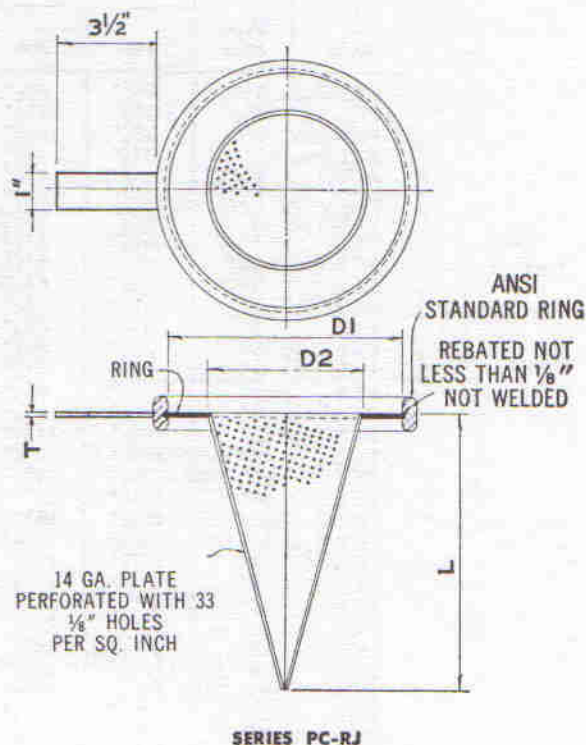


Figure 1-4b. Conical temporary strainers.

FLAT PERFORATED STRAINERS

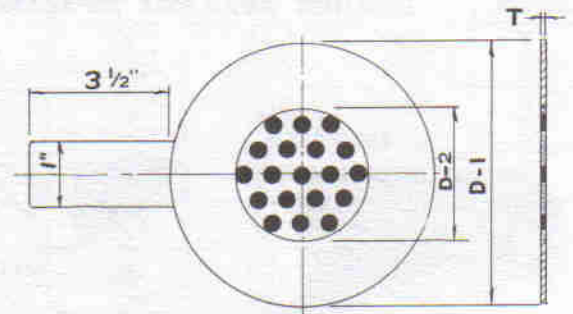
FOR 150 LB.-300 LB.-600 LB. FLAT FACE, RAISED FACE AND RING JOINT FLANGES
900 LB.-1500 LB.-2500 LB. AVAILABLE UPON SPECIAL REQUEST.

RAISED FACE

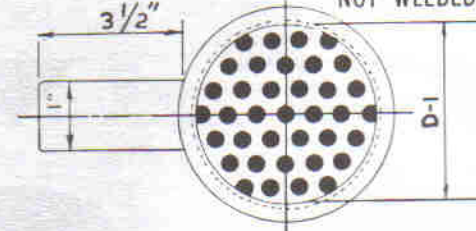
Series FP, F-RJ, and F-FP
 for use with 150#, 300#,
 and 600# flanges.

**REVOLUTIONARY
CONSTRUCTION**

Flange deeply rebated into ring joint
 gasket under pressure for tremendous
 strength and prevention of deformation.
 Smooth, accurate contours . . . no weld
 "blob" around ring edge.

**RAISED FACE FLANGES****SERIES FP**

REBATED NOT LESS THAN 1/8"
 NOT WELDED

**SERIES F-RJ****RING JOINT FLGS.**

Style	Pipe Size	150 Lb.			300 Lb.			300 & 600 Lb.			900 Lb.	
		D1	D2	T	D1	D2	T	Style	D1	T	D1	T
FP.....	1 1/4"	2 3/4"	1 1/4"	14-USGA	3"	1 1/4"	11-USGA	FRJ	2 1/16"	11-USGA	2 1/16"	11-USGA
FP.....	1 1/2"	3 1/8"	1 1/2"	"	3 1/2"	1 1/2"	"	FRJ	2 3/8"	"	2 3/8"	"
FP.....	2"	3 3/8"	2"	"	4 1/8"	2"	"	FRJ	2 13/16"	"	3 5/16"	"
FP.....	2 1/2"	4 5/8"	2 1/2"	"	4 7/8"	2 1/2"	"	FRJ	3 9/16"	"	3 13/16"	"
FP.....	3"	5 1/8"	3"	"	5 5/8"	3"	"	FRJ	4 7/16"	"	4 7/16"	"
FP.....	3 1/2"	6 1/8"	3 1/2"	"	6 1/8"	3 1/2"	"	FRJ	4 3/4"	"	4 3/4"	"
FP.....	4"	6 5/8"	4"	"	6 7/8"	4"	"	FRJ	5 1/16"	"	5 1/16"	"
FP.....	5"	7 1/2"	5"	13-USGA	8 1/4"	5"	"	FRJ	6 11/16"	"	6 11/16"	"
FP.....	6"	8 1/2"	6"	"	9 5/8"	6"	"	FRJ	7 3/8"	"	7 3/8"	"
FP.....	8"	10 3/4"	8"	"	11 7/8"	8"	11-USGA	FRJ	10 3/16"	"	10 3/16"	"
FP.....	10"	13 1/8"	10"	"	14"	10"	"	FRJ	12 5/16"	"	12 5/16"	"
FP.....	12"	15 7/8"	12"	11-USGA	16 3/8"	12"	"	FRJ	14 9/16"	"	14 9/16"	"
FP.....	14"	17 1/2"	13 1/4"	"	18 7/8"	13 1/4"	"	FRJ	16 1/16"	"	15 7/8"	"
FP.....	16"	20"	15 1/4"	"	21"	15 1/4"	"	FRJ	18 1/16"	"	17 7/8"	"
FP.....	18"	21 3/8"	17"	"	23 1/4"	17"	"	FRJ	20 9/16"	"	20 1/4"	"
FP.....	20"	23 3/8"	19"	"	25 1/2"	19"	"	FRJ	22 1/2"	"	22 1/4"	"
FP.....	24"	28"	23"	"	30 1/4"	23"	"	FRJ	26 5/8"	"	26 1/4"	"

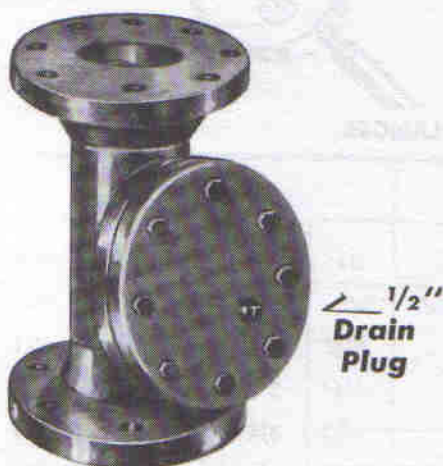
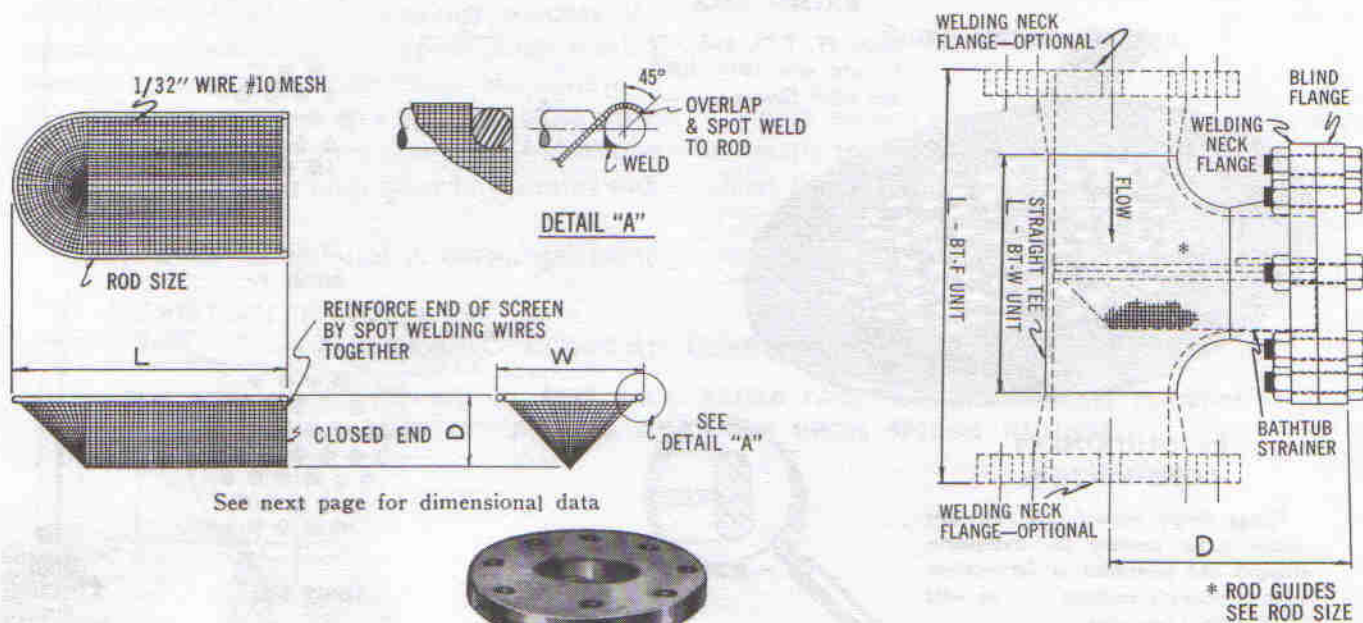
Larger sizes (above 24") and other plate specifications available upon application.

Figure 1-5. Perforated flat-type temporary strainers. Courtesy of Mack Iron Works Co.

BATHTUB UNIT TEMPORARY STRAINERS

STRAINER AVAILABLE SEPARATELY OR AS A COMPLETE UNIT

NOTE:
QUICK OPENING
TOP AVAILABLE
UPON REQUEST



Pipe Size	BT-F UNIT For Flange Connection				BT-W UNIT For Welded Connection			
	150 LB.		300 LB.		150 LB.		300 LB.	
	L	D	L	D	L	D	L	D
2"	10"	5 3/4"	10 1/2"	6 1/8"	5"	5 3/4"	5"	6 1/8"
2 1/2"	11 1/8"	6 5/8"	12"	7"	6"	6 5/8"	6"	7"
3"	12 1/4"	7 1/16"	13"	7 5/8"	6 3/4"	7 1/16"	6 3/4"	7 5/8"
4"	14 1/4"	8 1/16"	15"	8 3/4"	8 3/4"	8 1/16"	8 3/4"	8 3/4"
5"	16 3/4"	9 1/16"	17 1/2"	10 1/8"	9 3/4"	9 1/16"	9 3/4"	10 1/8"
6"	18 1/4"	9 1/8"	19"	10 1 3/16"	11 1/4"	9 1/8"	11 1/4"	10 1 3/16"
8"	22"	12 3/8"	22 3/4"	13"	14"	12 3/8"	14"	13"
10"	25"	13 1 1/16"	26 1/4"	15"	17"	13 1 1/16"	17"	15"
12"	29"	15 3/4"	30 1/4"	17 1/8"	20"	15 3/4"	20"	17 1/8"
14"	32"	17 3/8"	33 1/4"	18 3/4"	22"	17 3/8"	22"	18 3/4"
16"	34"	18 7/8"	35 1/2"	20"	24"	18 7/8"	24"	20"
18"	38"	20 1/16"	39 1/2"	22 1/8"	27"	20 1/16"	27"	22 1/8"
20"	41 3/8"	22 3/8"	42 3/4"	23 7/8"	30"	22 3/8"	30"	23 7/8"

Other mesh specifications available upon application.

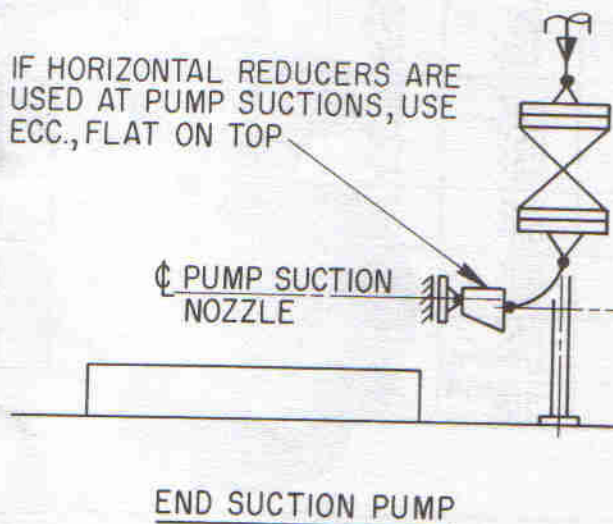
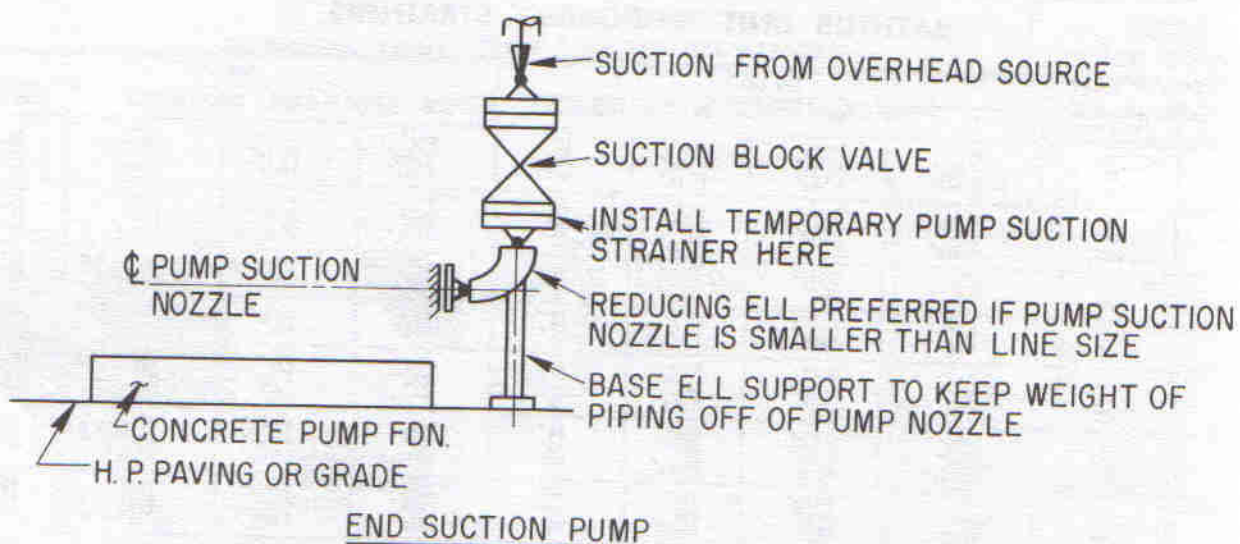
Figures 1-6a and b. Bathtub-type temporary strainers. Courtesy of Mack Iron Works Co.

BATHTUB UNIT TEMPORARY STRAINERS

Pipe Size	Schedule of Pipe	150 Lb.				300 Lb.			
		L	W	D	Rod Size	L	W	D	Rod Size
2"	40	6"	11 $\frac{1}{2}$ "	1 $\frac{1}{2}$ "	$\frac{1}{2}$ "	6 $\frac{1}{4}$ "	11 $\frac{1}{2}$ "	1 $\frac{1}{2}$ "	$\frac{1}{2}$ "
	80	5 $\frac{1}{2}$ "	11 $\frac{1}{2}$ "	1 $\frac{1}{2}$ "	$\frac{1}{2}$ "	6 $\frac{1}{2}$ "	11 $\frac{1}{2}$ "	1 $\frac{1}{2}$ "	$\frac{1}{2}$ "
2 $\frac{1}{2}$ "	40	6 $\frac{1}{2}$ "	12 $\frac{1}{2}$ "	1 $\frac{7}{8}$ "	$\frac{3}{4}$ "	7 $\frac{3}{4}$ "	12 $\frac{1}{2}$ "	1 $\frac{7}{8}$ "	$\frac{3}{4}$ "
	80	6 $\frac{1}{2}$ "	12 $\frac{1}{2}$ "	1 $\frac{7}{8}$ "	$\frac{3}{4}$ "	7 $\frac{3}{4}$ "	12 $\frac{1}{2}$ "	1 $\frac{7}{8}$ "	$\frac{3}{4}$ "
3"	40	7 $\frac{5}{8}$ "	13 $\frac{1}{2}$ "	1 $\frac{3}{4}$ "	$\frac{1}{2}$ "	8"	13 $\frac{1}{2}$ "	1 $\frac{3}{4}$ "	$\frac{1}{2}$ "
	80	7 $\frac{5}{8}$ "	13 $\frac{1}{2}$ "	1 $\frac{3}{4}$ "	$\frac{1}{2}$ "	7 $\frac{1}{2}$ "	13 $\frac{1}{2}$ "	1 $\frac{3}{4}$ "	$\frac{1}{2}$ "
3 $\frac{1}{2}$ "	40	8 $\frac{1}{2}$ "	14 $\frac{1}{2}$ "	2"	$\frac{3}{4}$ "	8 $\frac{1}{2}$ "	14 $\frac{1}{2}$ "	2"	$\frac{3}{4}$ "
	80	8 $\frac{1}{2}$ "	14 $\frac{1}{2}$ "	2"	$\frac{3}{4}$ "	8 $\frac{1}{2}$ "	14 $\frac{1}{2}$ "	2"	$\frac{3}{4}$ "
4"	40	9 $\frac{1}{2}$ "	15 $\frac{1}{2}$ "	2 $\frac{1}{4}$ "	$\frac{1}{2}$ "	9 $\frac{1}{2}$ "	15 $\frac{1}{2}$ "	2 $\frac{1}{4}$ "	$\frac{1}{2}$ "
	80	9"	15 $\frac{1}{2}$ "	2 $\frac{1}{4}$ "	$\frac{1}{2}$ "	9 $\frac{1}{2}$ "	15 $\frac{1}{2}$ "	2 $\frac{1}{4}$ "	$\frac{1}{2}$ "
5"	40	10 $\frac{3}{4}$ "	16 $\frac{1}{2}$ "	2 $\frac{3}{4}$ "	$\frac{3}{4}$ "	11 $\frac{1}{2}$ "	16 $\frac{1}{2}$ "	2 $\frac{3}{4}$ "	$\frac{3}{4}$ "
	80	10 $\frac{3}{4}$ "	16 $\frac{1}{2}$ "	2 $\frac{3}{4}$ "	$\frac{3}{4}$ "	11 $\frac{1}{2}$ "	16 $\frac{1}{2}$ "	2 $\frac{3}{4}$ "	$\frac{3}{4}$ "
6"	40	12 $\frac{1}{4}$ "	18 $\frac{1}{2}$ "	3 $\frac{3}{8}$ "	$\frac{3}{4}$ "	12 $\frac{1}{4}$ "	18 $\frac{1}{2}$ "	3 $\frac{3}{8}$ "	$\frac{3}{4}$ "
	80	12"	18 $\frac{1}{2}$ "	3 $\frac{3}{8}$ "	$\frac{3}{4}$ "	12 $\frac{1}{4}$ "	18 $\frac{1}{2}$ "	3 $\frac{3}{8}$ "	$\frac{3}{4}$ "
8"	30	15"	21 $\frac{1}{2}$ "	4 $\frac{1}{2}$ "	$\frac{3}{4}$ "	15 $\frac{1}{2}$ "	21 $\frac{1}{2}$ "	4 $\frac{1}{2}$ "	$\frac{3}{4}$ "
	40	14 $\frac{1}{2}$ "	21 $\frac{1}{2}$ "	4 $\frac{1}{2}$ "	$\frac{3}{4}$ "	15 $\frac{1}{2}$ "	21 $\frac{1}{2}$ "	4 $\frac{1}{2}$ "	$\frac{3}{4}$ "
10"	40	17 $\frac{1}{2}$ "	24 $\frac{1}{2}$ "	5 $\frac{1}{2}$ "	$\frac{3}{4}$ "	17 $\frac{1}{2}$ "	24 $\frac{1}{2}$ "	5 $\frac{1}{2}$ "	$\frac{3}{4}$ "
	80	17 $\frac{1}{2}$ "	24 $\frac{1}{2}$ "	5 $\frac{1}{2}$ "	$\frac{3}{4}$ "	17 $\frac{1}{2}$ "	24 $\frac{1}{2}$ "	5 $\frac{1}{2}$ "	$\frac{3}{4}$ "
12"	30	20 $\frac{1}{2}$ "	27 $\frac{1}{2}$ "	6 $\frac{3}{8}$ "	$\frac{3}{4}$ "	21 $\frac{1}{2}$ "	27 $\frac{1}{2}$ "	6 $\frac{3}{8}$ "	$\frac{3}{4}$ "
	40	20 $\frac{1}{2}$ "	27 $\frac{1}{2}$ "	6 $\frac{3}{8}$ "	$\frac{3}{4}$ "	21 $\frac{1}{2}$ "	27 $\frac{1}{2}$ "	6 $\frac{3}{8}$ "	$\frac{3}{4}$ "
14" OD	10	22 $\frac{3}{4}$ "	30 $\frac{1}{2}$ "	7 $\frac{3}{4}$ "	$\frac{1}{2}$ "	22 $\frac{3}{4}$ "	30 $\frac{1}{2}$ "	7 $\frac{3}{4}$ "	$\frac{1}{2}$ "
	20	22 $\frac{3}{4}$ "	30 $\frac{1}{2}$ "	7 $\frac{3}{4}$ "	$\frac{1}{2}$ "	22 $\frac{3}{4}$ "	30 $\frac{1}{2}$ "	7 $\frac{3}{4}$ "	$\frac{1}{2}$ "
16" OD	10	24 $\frac{3}{4}$ "	32 $\frac{1}{2}$ "	8 $\frac{1}{4}$ "	$\frac{1}{2}$ "	25 $\frac{1}{4}$ "	32 $\frac{1}{2}$ "	8 $\frac{1}{4}$ "	$\frac{1}{2}$ "
	20	24 $\frac{3}{4}$ "	32 $\frac{1}{2}$ "	8 $\frac{1}{4}$ "	$\frac{1}{2}$ "	25 $\frac{1}{4}$ "	32 $\frac{1}{2}$ "	8 $\frac{1}{4}$ "	$\frac{1}{2}$ "
18" OD	10	27 $\frac{1}{4}$ "	35 $\frac{1}{2}$ "	9 $\frac{3}{4}$ "	$\frac{1}{2}$ "	28 $\frac{1}{4}$ "	35 $\frac{1}{2}$ "	9 $\frac{3}{4}$ "	$\frac{1}{2}$ "
	20	27 $\frac{1}{4}$ "	35 $\frac{1}{2}$ "	9 $\frac{3}{4}$ "	$\frac{1}{2}$ "	28 $\frac{1}{4}$ "	35 $\frac{1}{2}$ "	9 $\frac{3}{4}$ "	$\frac{1}{2}$ "
20" OD	10	30 $\frac{1}{4}$ "	38 $\frac{1}{2}$ "	10 $\frac{3}{4}$ "	$\frac{1}{2}$ "	31"	38 $\frac{1}{2}$ "	10 $\frac{3}{4}$ "	$\frac{1}{2}$ "
	20	30 $\frac{1}{4}$ "	38 $\frac{1}{2}$ "	10 $\frac{3}{4}$ "	$\frac{1}{2}$ "	31"	38 $\frac{1}{2}$ "	10 $\frac{3}{4}$ "	$\frac{1}{2}$ "

Figures 1-6a and b continued.

Process Piping Design



NOTE:

- A. PUMPS TO BE LOCATED CLOSE TO THE VESSEL FROM WHICH THEY ARE TAKING SUCTION. KEEP SUCTION LINE SHORT AS POSSIBLE.
- B. SUCTION LINE TO FLOW CONTINUOUSLY DOWN FROM VESSEL SUCTION NOZZLE TO PUMP SUCTION NOZZLE. DO NOT LET THE LINE GO UP. THIS WOULD FORM AN AIR POCKET WHICH WOULD ACCUMULATE AN AIR BUBBLE WHICH COULD BE FORCED IN THE PUMP. AIR IN PUMPS CAUSE "CAVITATION" WHICH DAMAGES THE PUMPS.
- C. LINE REDUCTIONS ARE TO BE MADE DIRECTLY ON PUMP NOZZLES. DO NOT "CHOKE" ANY PUMP SUCTION.

Figure 1-7. Piping at end suction pumps.

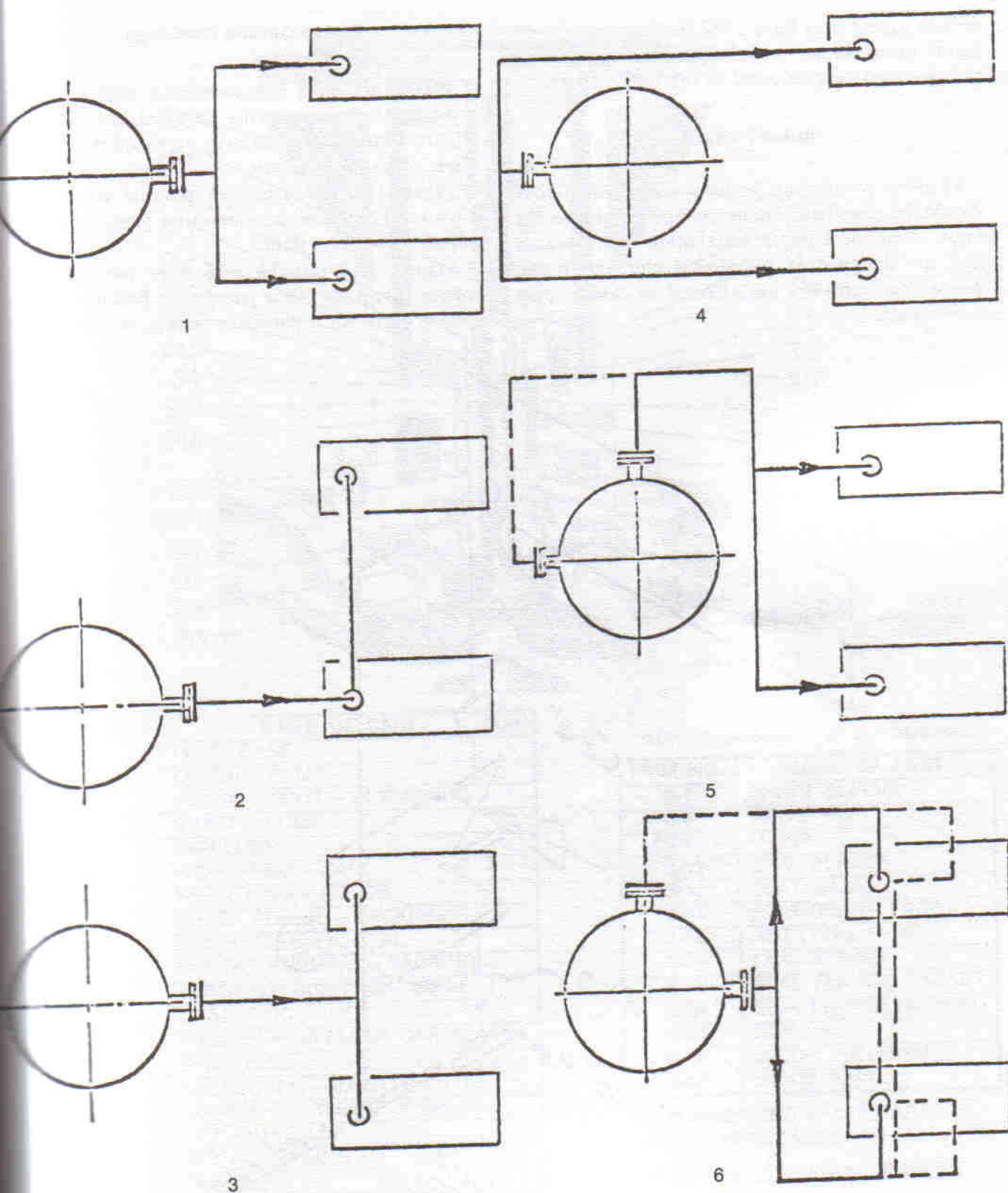


Figure 1-8. Pump suction configurations. Courtesy of Fluor Engineers and Constructors, Inc.

suction piping may have 150# flanges, but often a higher rating flange—equal to the discharge piping rating—must be connected to the pump nozzle.

Inline Pumps

If inline pumps can perform as required, they should be specified. Inline pumps constitute the most economical pump installation and, because they are designed as an integral unit, pump and driver alignments are not affected by small piping movements.

Pump Outline Drawings

Piping designers are always in need of pump drawings before receiving certified outline data. Figure 1-10 shows a cutaway view and defines the parts of an inline pump.

Figure 1-11 shows pump types and dimensions. Figure 1-12, outline drawing-inline pump-type INI, supplies the same data.

Figures 1-13 through 1-16 show pump performance curves for inline pumps. To find the performance curve for a particular pump, see pump size

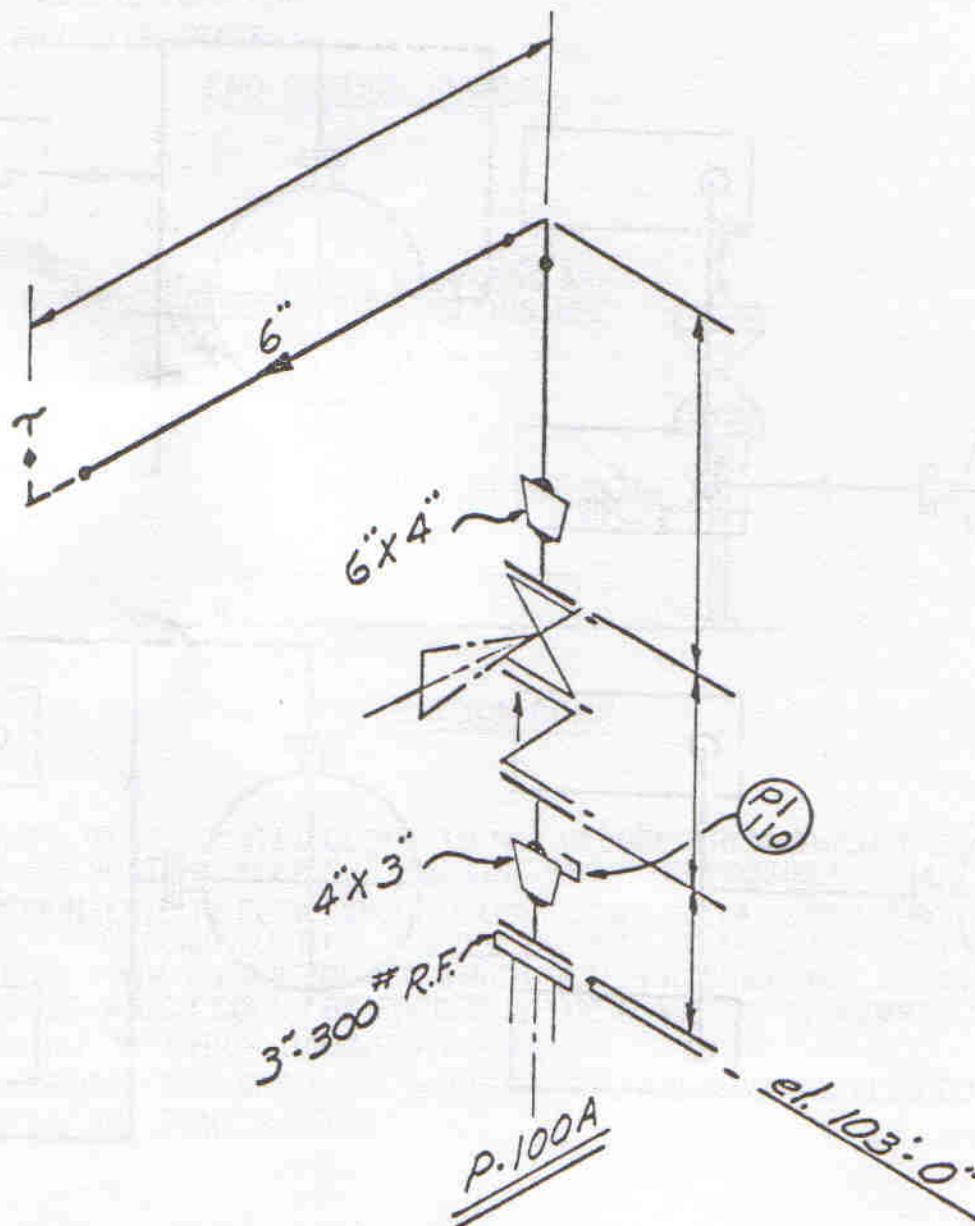
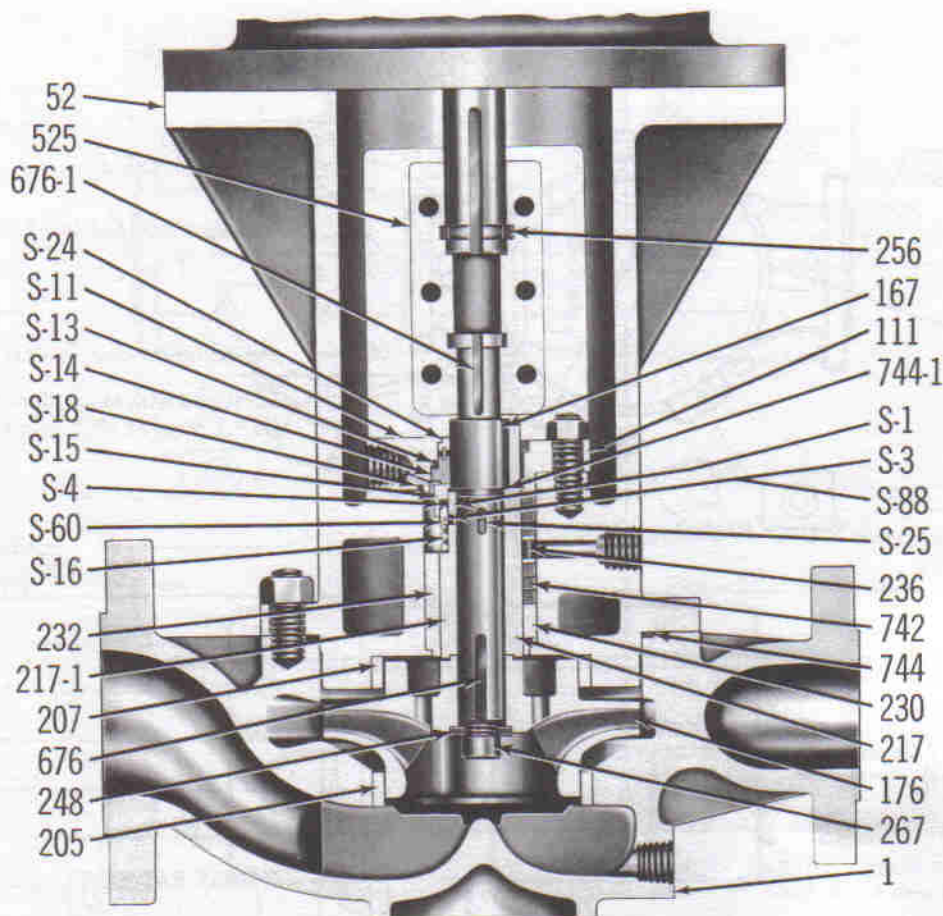


Figure 1-9. P-100A discharge piping. Courtesy of Fluor Engineers and Constructors.



ITEM NO.	NAME OF PART
1	PUMP CASE
52	COVER — PUMP
111	GLAND — SPLIT — W/BUSHING
167	SHAFT — PUMP
*176	IMPELLER
*105	WEAR RING — CASE
*207	WEAR RING — COVER
217	SHAFT SLEEVE — PACKING
217-1	SHAFT SLEEVE — SEAL
*230	THROAT BUSHING — PACKING
232	THROTTLE BUSHING — SEAL
236	CAGE RING
248	WASHER — IMPELLER CAP SCREW
256	SPLIT RING
267	LOCKSCREW — IMPELLER
525	COUPLING — SLEEVE TYPE
676	KEY — IMPELLER
676-1	KEY — COUPLING
*742	PACKING
*744	GASKET — CASE TO COVER
*744-1	GASKET — SHAFT SLEEVE

*RECOMMENDED SPARE PARTS WHERE APPLICABLE.

SEAL PARTS

(FOR BORG-WARNER "S" SEAL SHOWN)

ITEM NO.	NAME OF PART
S-1	SHAFT SLEEVE
S-3	DRIVE PIN
*S-4	U-CUP
S-11	SEAL FLANGE
*S-13	SEAT GASKET
*S-14	STATIONARY FACE
*S-15	ROTATING FACE
S-16	COIL SPRING
S-18	SEAL FLANGE GASKET
S-24	SEAL FLANGE BUSHING
S-25	KEY
S-60	U-CUP FOLLOWER
S-88	GUIDE PINS

*RECOMMENDED SPARE PARTS
WHERE APPLICABLE.

SEE MANUFACTURER'S DRAWING
FOR:

JOHN CRANE — TYPE 1B & 9B.

DURAMETALLIC — TYPE PT & PTO.

Figure 1-10. Sectional drawing of inline pump, Type IN. Courtesy of Byron Jackson Pump Division.

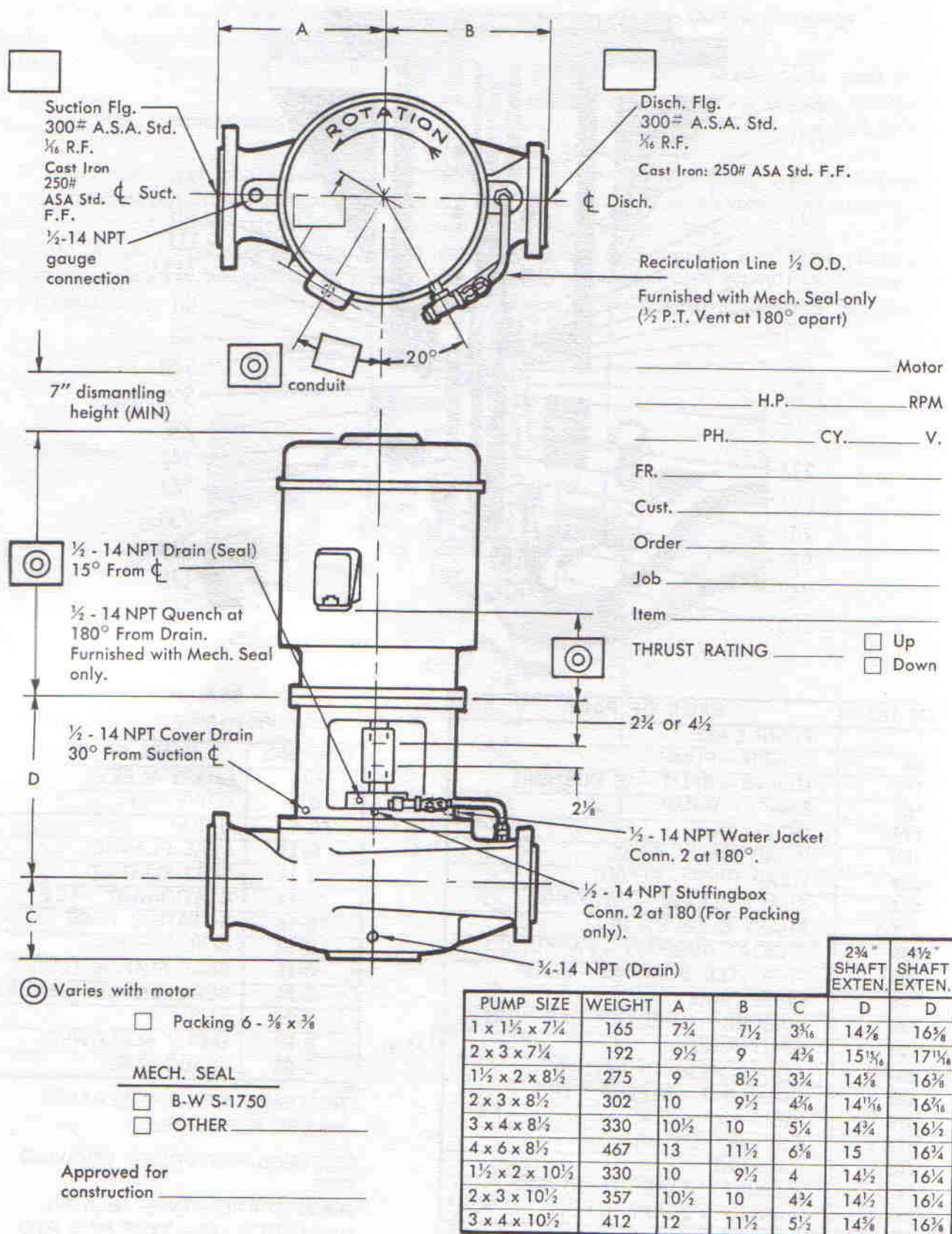


Figure 1-11. Outline dimensions of inline pump, Type IN. Courtesy of Byron Jackson Pump Division.

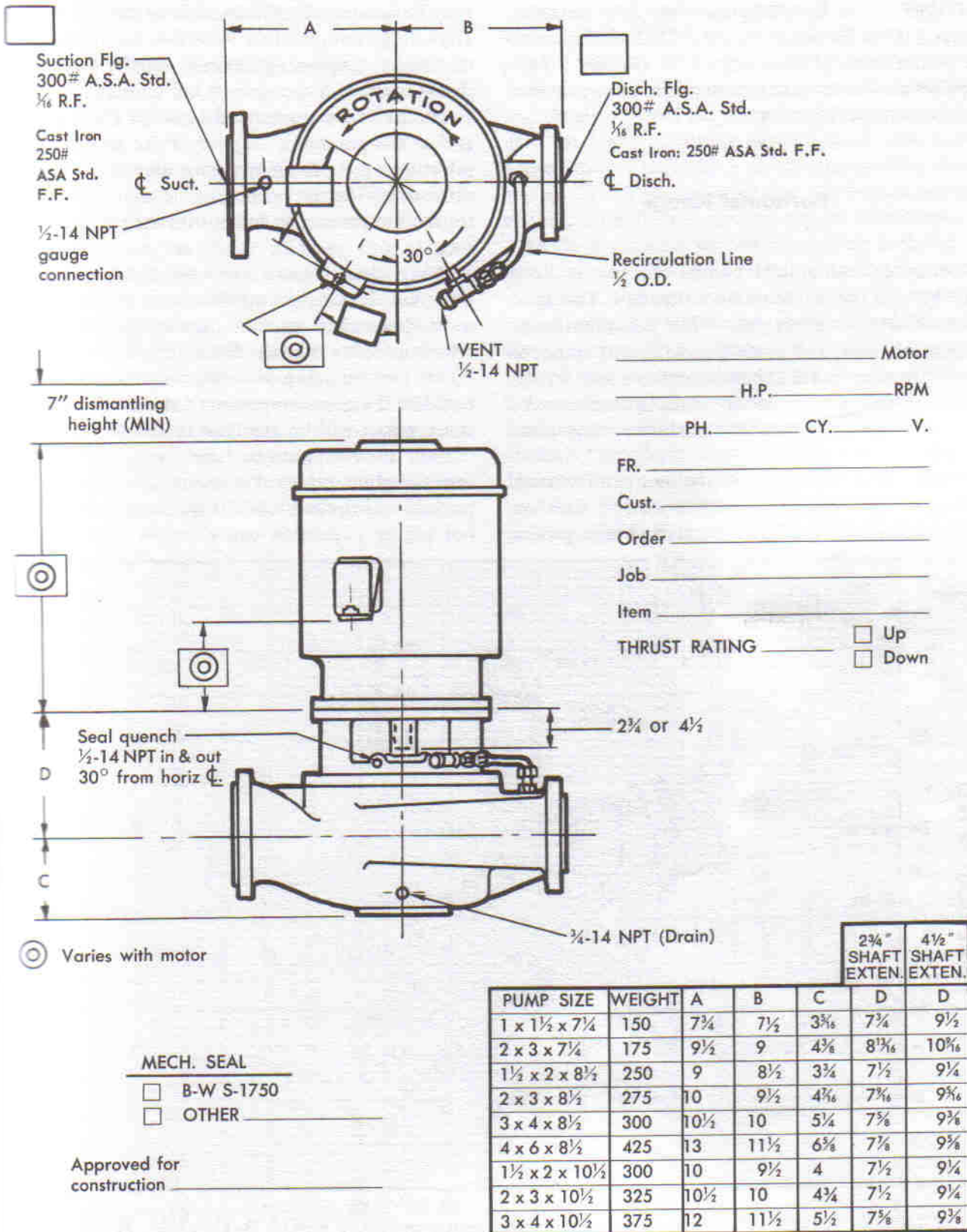


Figure 1-12. Outline dimensions of inline pump. Type INI Courtesy of Byron Jackson Pump Division.

and type listed in each drawing. For instance, Figure 1-13 is for a size $1 \times 1\frac{1}{2} \times 7\frac{1}{4}$ L. This means the casing has a 1" discharge, $1\frac{1}{2}$ " suction, a $7\frac{1}{4}$ " impeller maximum case size and is a lower pressure design than the H series.

Horizontal Pumps

Horizontal centrifugal pumps are specified for duty beyond the inline pump's capacity. This type has been used for many years while the inline design is relatively new, and many people specify horizontal pumps when a less expensive inline would do the job. For this reason pump manufacturers make horizontal pumps to fill the same duties as the inline design.

There are many types of pumps manufactured. Some have a single-stage, but heavier duty ones are of multi-stage design. Suction and discharge nozzles

may be located on the top, side or end of the case. High-stage pumps often have side suction and side discharge. Single-stage pumps usually have a top discharge set to one side of the pump's centerline. Suction nozzles are located at either the top or the end at the purchaser's option. Prior to final pump selection, the piping designer should do enough preliminary layout to determine the best location for the suction nozzle and inform the project department.

When three pumps are used for two separate pumping services, the middle pump is called a *common spare*. Top suction nozzles always simplify common spare piping. Since the common spare serves two pumping services, its capacity must be equal to the greater pumping duty. So the common spare pump will be identical to the larger pump.

End suction pumps have one great advantage—suction piping for them can easily be supported, taking dead load off the pump casing. Also, hot piping expansion can often be directed away

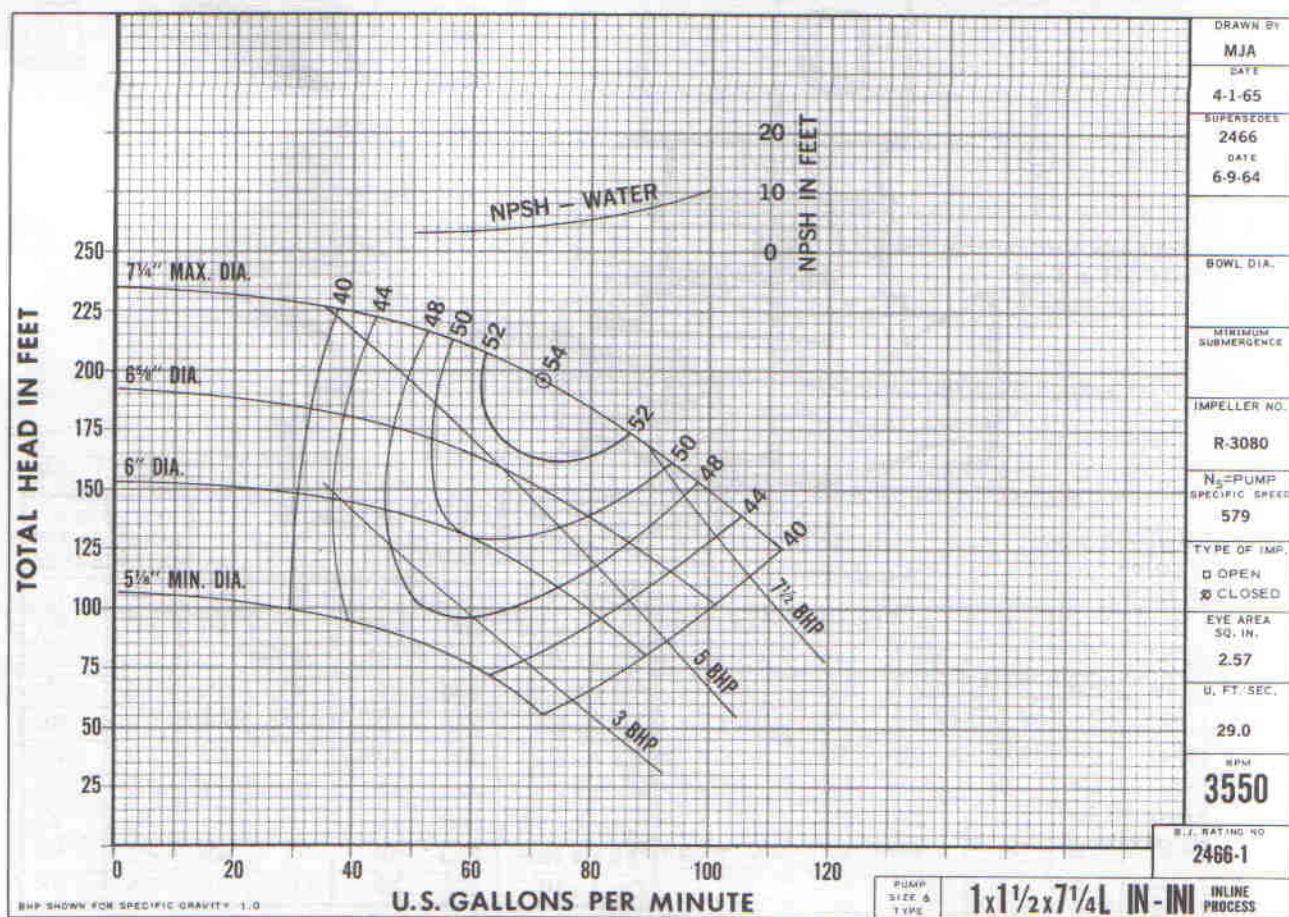


Figure 1-13. Performance curve for Type $1 \times 1 \times 7\frac{1}{4}$ L IN-INI pump. Courtesy of Byron Jackson Pump Division.

from the pump, thereby relieving the casing of thermal loading.

Figure 1-17 shows the pump, coupling and motor driver all mounted on a common base plate. This coupling has a screened *coupling guard* to protect personnel from its high speed rotation. Note that the motor and pump are individually supported from the base plate, requiring perfect alignment to keep the drive shaft straight. Also note that the case is supported from the center, allowing case expansion to go either up or down from the shaft. A hot fluid introduced into a bottom-supported case, will direct its growth upward, causing the pump shaft to go up. Any shaft movement—which may contribute to misalignment—is to be avoided.

Figure 1-18 allows a quick, preliminary size selection for a commonly used pump. When a designer knows the pump capacity and head he needs, he can choose a pump size, refer to the catalog outline dimensional chart and obtain preliminary dimensions.

Figures 1-19 and 1-20 show part names and construction details of the sizes listed for Type SJ pumps. Detail *A* shows the fan-cooled bearing design suitable for lower-temperature operation, and detail *B* shows the water-cooled bearing design used for higher pumping temperatures. The water-cooled model requires a circulating cooling water system in which water enters the bottom-tapped connection and exits the top-tapped connection.

In the main view, no bearing cooling is shown. It would be used for very low pumping temperatures.

Figures 1-21 through 1-28, show dimensional data for top and end suction pumps based on pump size selection (from Figure 1-18), driver size and type. These determine motor frame size which in turn sets base plate dimensions. Although item P-17 is noted as a $\frac{3}{4}$ " pipe tap gage connection on the discharge nozzle, it is not normally used for the PI. It is generally agreed that this close to the impeller the flow is too turbulent to give a dependable reading. This pump connection then should not be

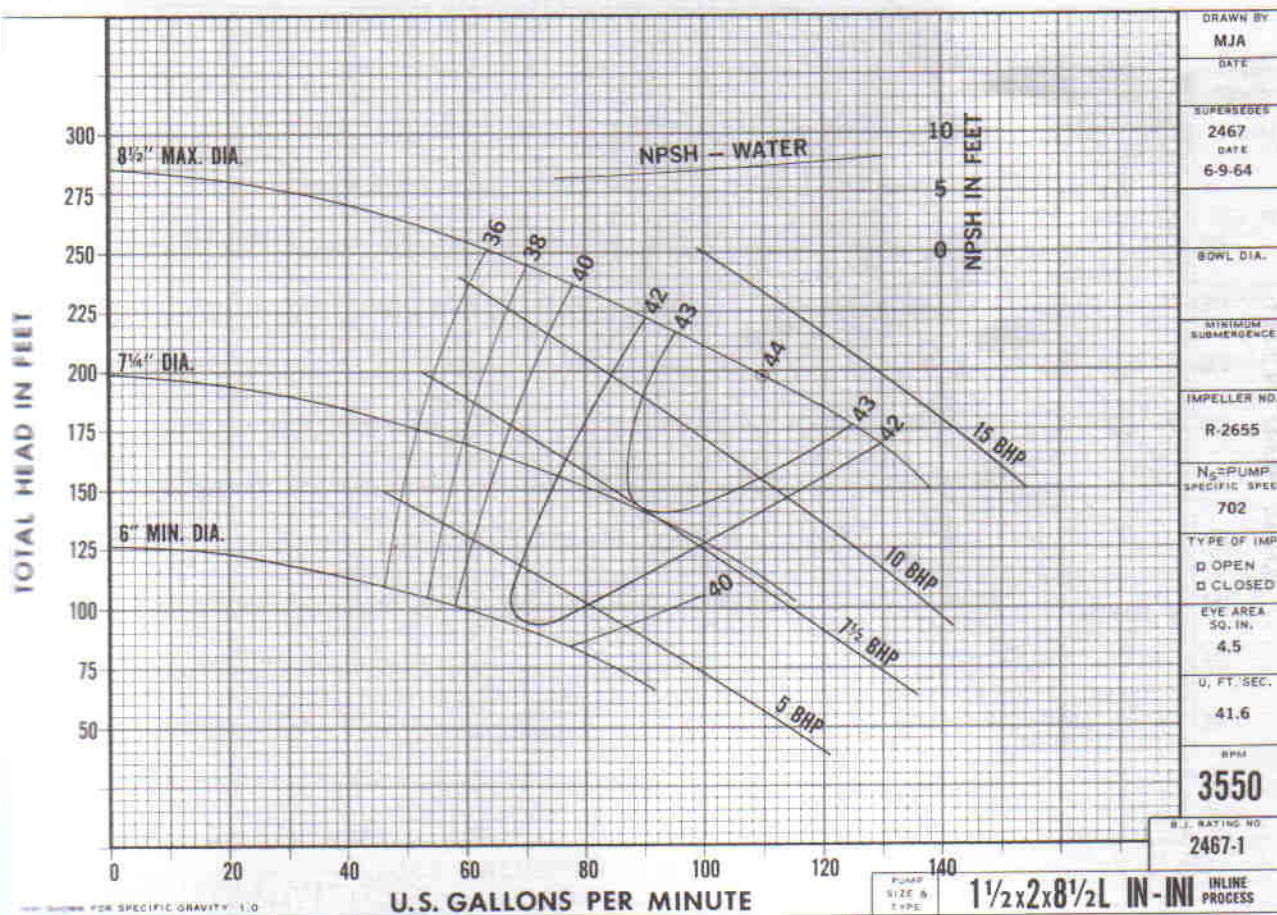


Figure 1-14. Performance Curve for Type 1 1/2 x 2 x 8 1/2 L IN-INI pump. Courtesy of Byron Jackson Pump Division.

tapped and the pressure indicator should be located in the discharge piping, upstream of the check valve.

Item P-6, pump casing drain is tapped. Piping should supply a valve and a line to a drain funnel located near the pump. Item P-7, base plate drain, must have piping to route these drips to a funnel.

Figure 1-29 shows top suction and top discharge pumps and their related piping. Here the designer had seven different pumps, pumping services and duties. Note the different motor sizes. To present a good appearance, all pump concrete is identical and lined up. Pump base plates were specified the same for all pumps. This made bases overhang smaller motors as shown by the pump in the foreground, but by lining up the front and back concrete, underground electrical power stub-ups and motor push button starters are lined up. Drain funnels are lined up at the pumps' fronts, to make drain piping less expensive. The extra cost of extended pump bases and concrete is offset by the reduced cost of drain piping and a better-looking installation. Drafting is

simplified by having one drawing for all seven foundations, and the concrete forms may be reused

Vertical Pumps

Vertical pumps, also called the *can type* or *barrage type*, are used when available NPSH is very low. The cooling tower water circulating pumps are usually vertical type with an electrically-driven operating pump and a steam turbine-driven spare.

Figure 1-30 shows a complete vertical pump in the foreground. In the background three electric motor driven vertical pumps are mounted on a cooling tower sump, taking suction from below grade.

Figure 1-31, showing the parts of a two-stage pump, items 176 and 176-1 are the two impellers. These pumps are available in various numbers of stages (a five stage pump has five impellers, etc.) depending on their specified duty.

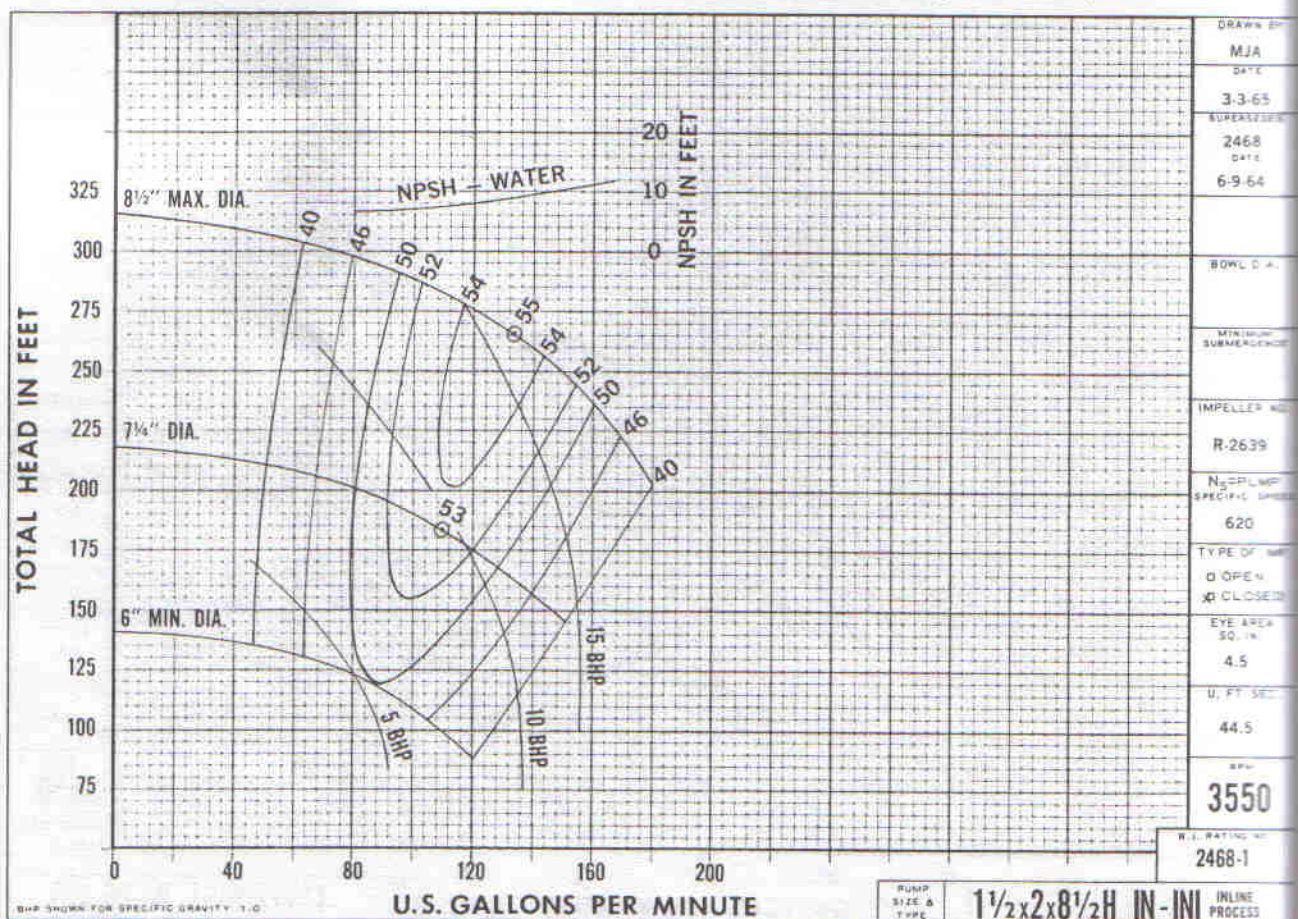


Figure 1-15. Performance curve for Type 1 1/2 x 2 x 8 1/2 H IN-INI pump. Courtesy of Byron Jackson Pump Division.

When locating vertical pumps, the main concern should be accessibility for maintenance. There must be areas above the pump left free of obstruction or overhead piping must have break-out joints or flanges for dismantling. Access must be provided for a small crane or Austin-Western to pull the pump up so it may be taken to the shop for repairs.

Turbines

Although there are many types of turbines—from the gas-fired turbines which drive huge compressors and generators to the smaller steam-driven turbines used as pump drivers, this section will deal only with the latter.

Figure 1-32 shows the inside construction of a turbine. At the top of the case are two connections. Directly on the center is a tapped hole for an eye bolt used when lifting the turbine. This tap does not

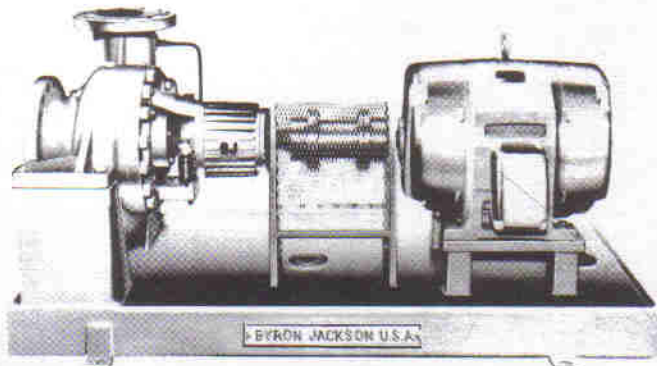


Figure 1-17. End suction horizontal pump. Courtesy of Byron Jackson Pump Division.

penetrate the case. The other connection is for a sentinel valve which is shown and furnished with the turbine. Sentinel valves are often mistaken for relief valves; but they are too small to relieve over-pressure. A properly sized relief valve installed on the exhaust system is necessary to protect exhaust

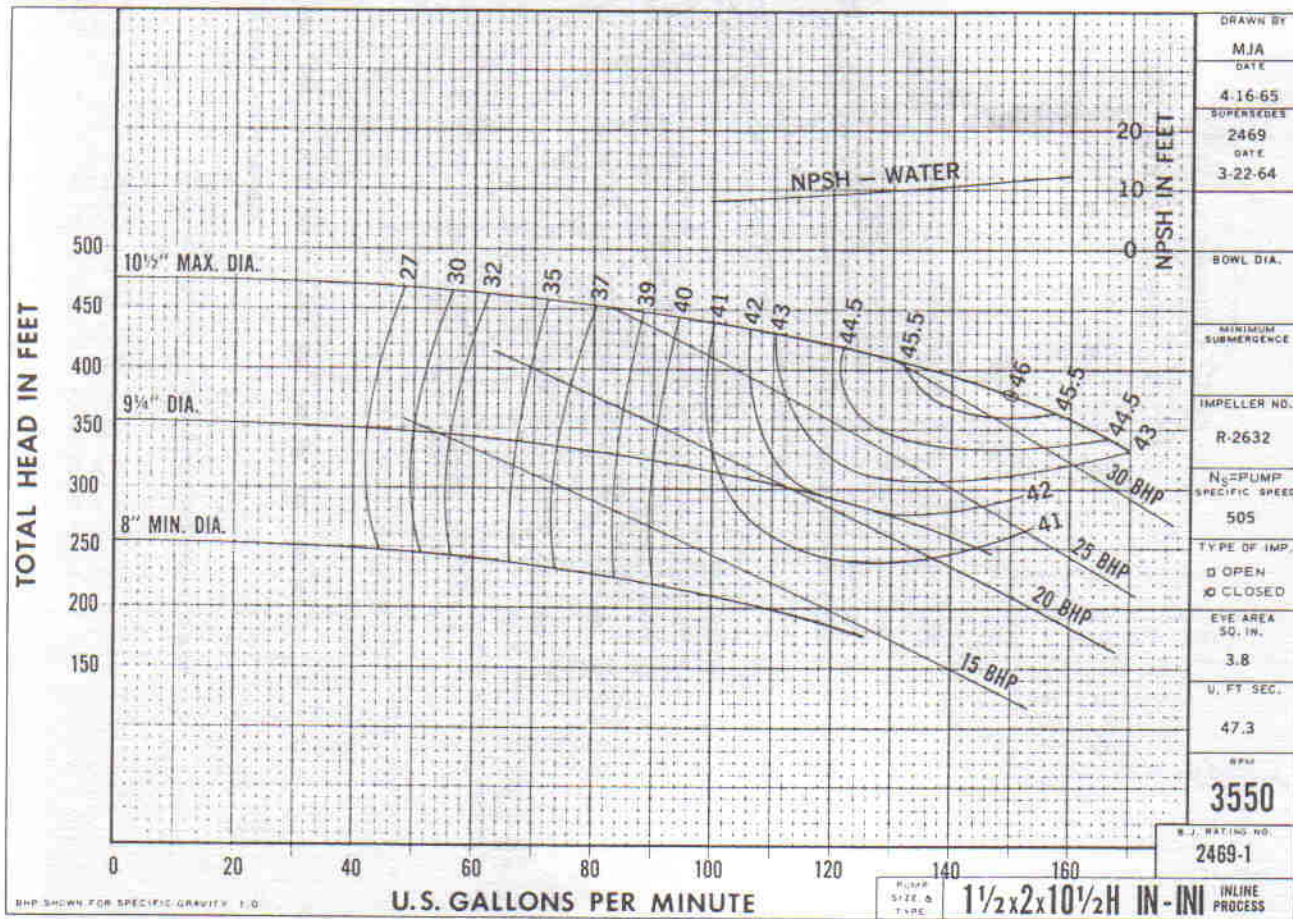
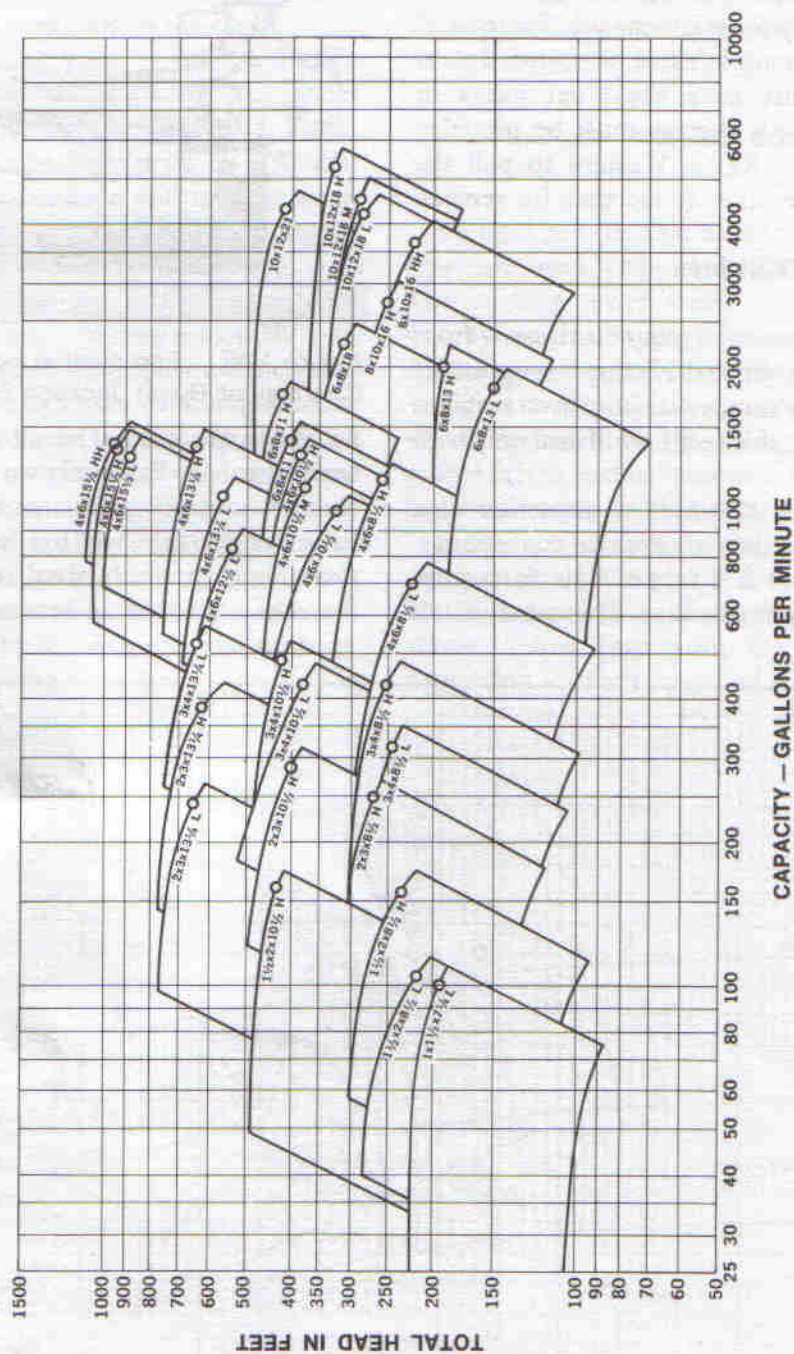
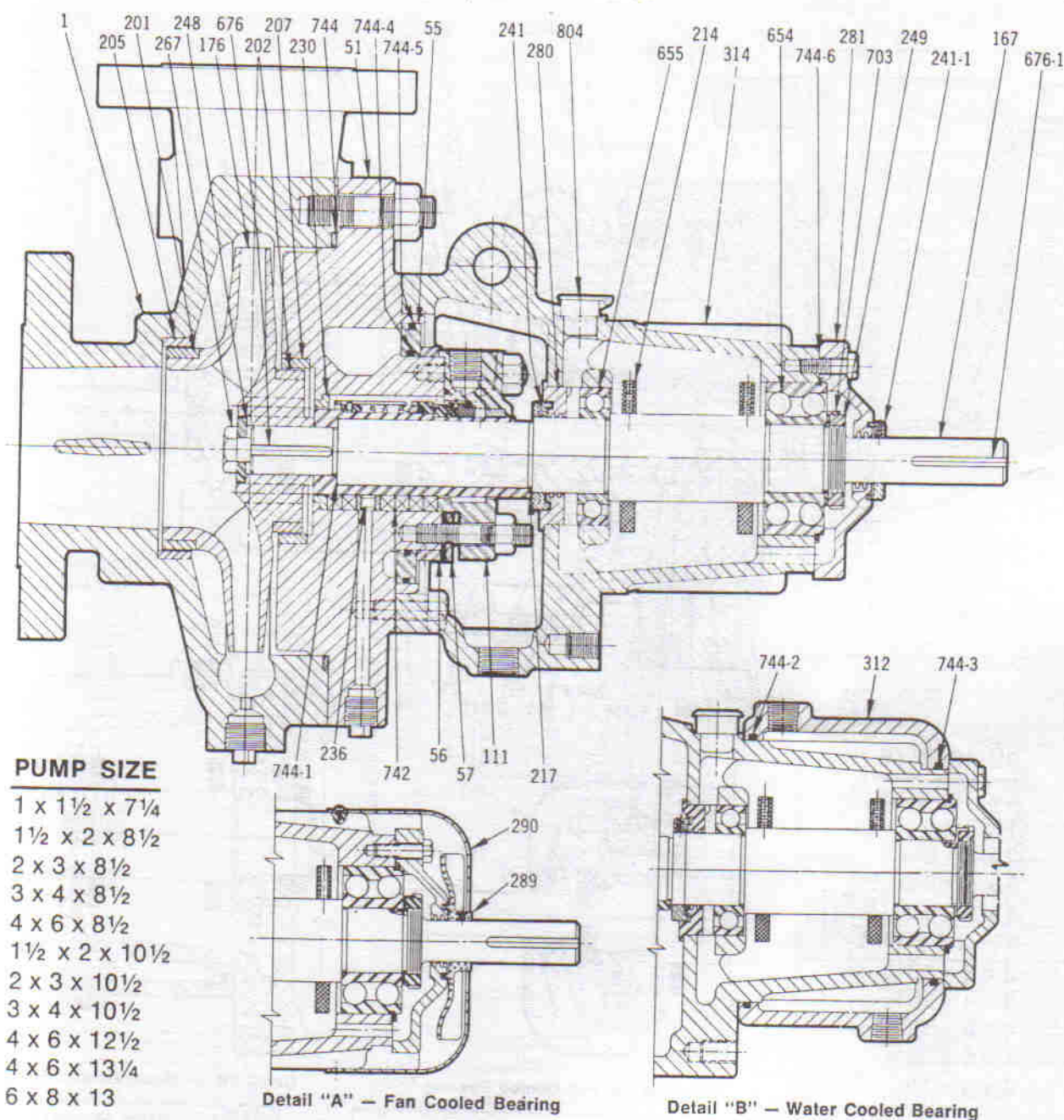


Figure 1-16. Performance curve for Type 1 1/2 x 2 x 10 1/2 H IN-INI pump. Courtesy of Byron Jackson Pump Division.

SINGLE STAGE PROCESS PUMPS Type SJ

QUICK SELECTION RANGE CHART





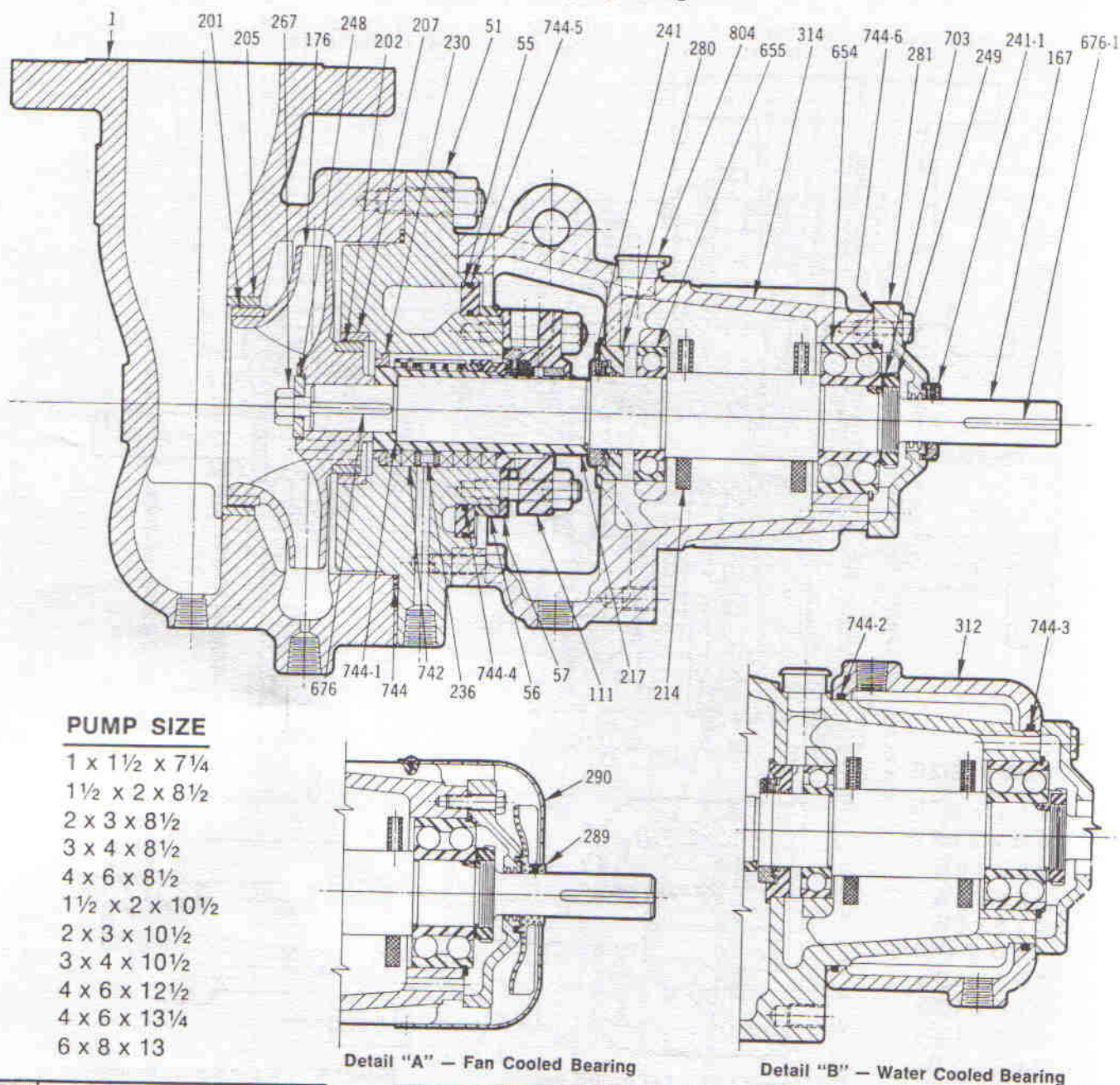
ITEM NO.	NAME OF PARTS
1	Case
51	Cover-Stuffing Box
55	Stuffing Box Water Jacket Closure
56	Retaining Ring-Water Jacket Closure
57	Locking Lug-Retaining Ring
67	Packing Gland
71	Shaft
76	Impeller
201	Wear Ring-Impeller
202	Wear Ring-Impeller Hub
205	Wear Ring-Case
207	Wear Ring-Cover
214	Oil Flinger
217	Shaft Sleeve

ITEM NO.	NAME OF PARTS
230	Throat Bushing
236	Cage Ring
241	Deflector-Inboard
241-1	Deflector-Outboard
248	Washer-Impeller
249	Locknut-Thrust Bearing
267	Lockscrew-Impeller
280	Bearing Cover-Inboard
281	Bearing Cover-Outboard
289	Fan
290	Fan Housing
312	Bearing Housing Water Jacket
314	Bearing Bracket

ITEM NO.	NAME OF PARTS
654	Ball Bearing-Thrust
655	Ball Bearing-Radial
676	Key-Impeller
676-1	Key-Coupling
703	Lockwasher-Thrust Bearing
742	Packing
744	Gasket-Case to Cover
744-1	Gasket-Shaft Sleeve
744-2	Gasket-Water Jacket-Inboard
744-3	Gasket-Water Jacket-Outboard
744-4	Gasket-Water Jacket I.D.
744-5	Gasket-Water Jacket O.D.
744-6	Gasket-Outboard Bearing Cover
804	Oil Filler Cup

Figure 1-19. Sectional drawing of end suction pump. Courtesy of Byron Jackson Pump Division.

Process Piping Design

**PUMP SIZE**

1 x 1½ x 7¼
 1½ x 2 x 8½
 2 x 3 x 8½
 3 x 4 x 8½
 4 x 6 x 8½
 1½ x 2 x 10½
 2 x 3 x 10½
 3 x 4 x 10½
 4 x 6 x 12½
 4 x 6 x 13¼
 6 x 8 x 13

Detail "A" — Fan Cooled Bearing

Detail "B" — Water Cooled Bearing

ITEM NO.	NAME OF PARTS
1	Case
51	Cover-Stuffing Box
55	Stuffing Box Water Jacket Closure
56	Retaining Ring-Water Jacket Closure
57	Locking Lug-Retaining Ring
111	Packing Gland
167	Shaft
176	Impeller
201	Wear Ring-Impeller
202	Wear Ring-Impeller Hub
205	Wear Ring-Case
207	Wear Ring-Cover
214	Oil Flinger
217	Shaft Sleeve

ITEM NO.	NAME OF PARTS
230	Throat Bushing
236	Cage Ring
241	Deflector-Inboard
241-1	Deflector-Outboard
248	Washer-Impeller
249	Locknut-Thrust Bearing
267	Lockscrew-Impeller
280	Bearing Cover-Inboard
281	Bearing Cover-Outboard
289	Fan
290	Fan Housing
312	Bearing Housing Water Jacket
314	Bearing Bracket

ITEM NO.	NAME OF PARTS
654	Ball Bearing-Thrust
655	Ball Bearing-Radial
676	Key-Impeller
676-1	Key-Coupling
703	Lockwasher-Thrust Bearing
742	Packing
744	Gasket-Case to Cover
744-1	Gasket-Shaft Sleeve
744-2	Gasket-Water Jacket-Inboard
744-3	Gasket-Water Jacket-Outboard
744-4	Gasket-Water Jacket I.D.
744-5	Gasket-Water Jacket O.D.
744-6	Gasket-Outboard Bearing Cover
804	Oil Filler Cup

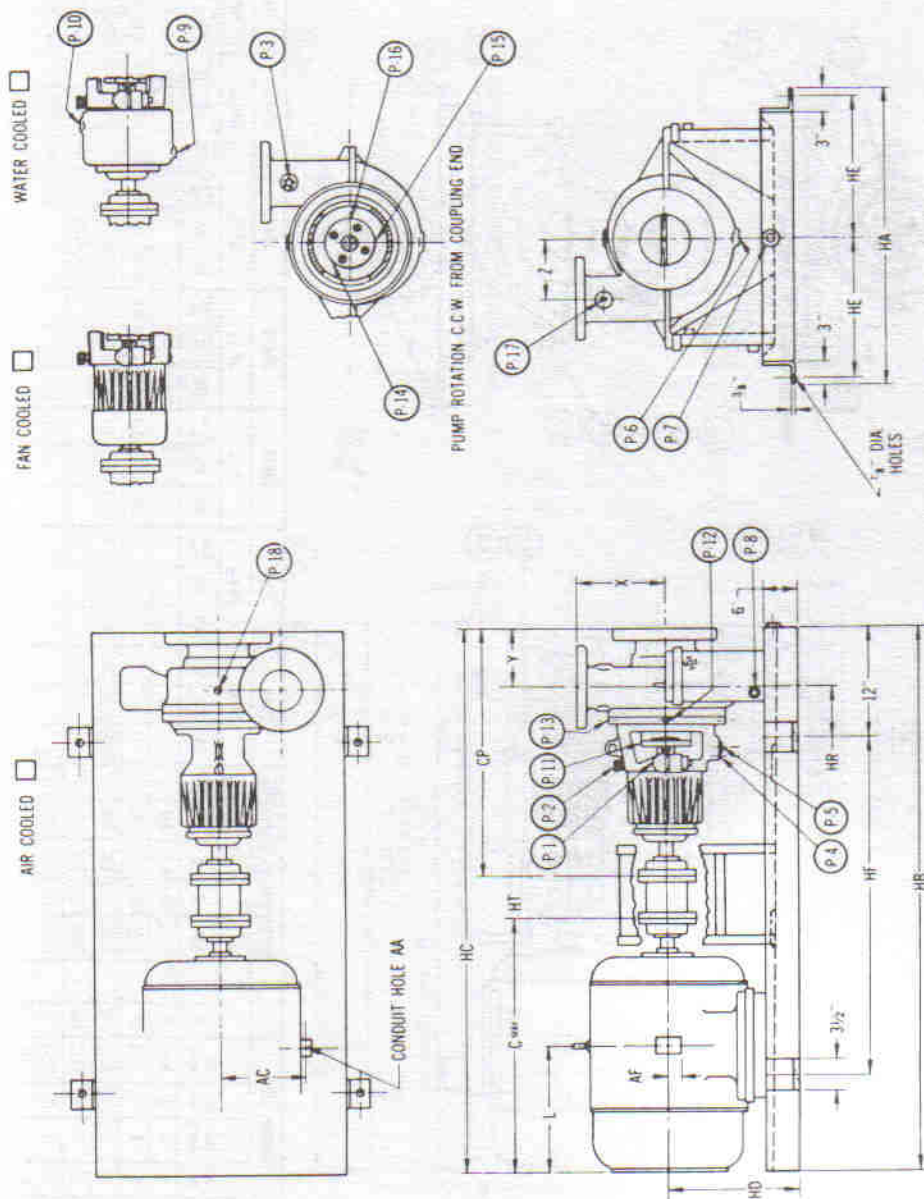
Figure 1-20. Sectional drawing of top suction pump. Courtesy of Byron Jackson Pump Division.

ITEM	SIZE	DESCRIPTION	YES/NO
P-1	4 OZ	OILER - FAR SIDE	X
P-2		OIL FILLER CUP	X
P-3	1/2 PT.	SEAL RECIRCULATION CASE TAP	X
P-4	1/2 PT.	OIL DRAIN - PLUGGED	X
P-5	3/4 PT.	DRAIN	X
P-6	3/4 PT.	CASE DRAIN - PLUGGED	X
P-7	1 1/2 PT.	BASE PLATE DRAIN	X
P-8	1/2 PT.	PED. COOL WATER IN & OUT	
P-9	1/2 PT.	INLET BRG. WATER JACKET	
P-10	1/2 PT.	OUTLET BRG. WATER JACKET	
P-11	1/4 PT.	PACKING GLAND QUENCH	
P-12	1/2 PT.	CAGE RING CONN. IN & OUT ON HORIZ. ϵ	
P-13	SEE NOTE 4	STUFF BOX WATER JACKET CLOSURE	
P-14	1/2 PT.	SEAL VENT OR QUENCH INLET	
P-15	1/2 PT.	SEAL QUENCH DRAIN	
P-16	1/2 PT.	SEAL INJECTION	
P-17	3/4 PT.	GAGE CONNECTION	
P-18	3/4 PT.	VENT CONNECTION	

NOTES:

1. PUMPS ARE SELF VENTING.
2. SUCT. & DISCH. FLGS. #300 A.S.A. 1/4 R.F.
3. THREE 4" DIA. GROUT HOLES (MIN) 1/2" DIA. VENT HOLES - 4 CORNERS OF BASE.
4. 1/2 PT. IN & OUT ON VERT. ϵ ALWAYS SUPPLIED WITH OR WITHOUT WATER JACKET CLOSURE.
5. BOSSES PROVIDED FOR ADDITION OF TAPS WHEN REQUIRED.
6. B1 STD. COUPLING GUARD MEETS CALIF. SAFETY REQUIREMENTS.
7. ALL CASE TAPS ON 1x1 1/2x7 1/4 WILL BE 1/2 PT.

BASEPLATE DIMENSIONS				
BASE NO.	HA	HB	HE	HF
S-1	31	60	14	16
S-2	36 1/2	63	16 1/4	39
S-3	36 1/2	78	16 1/4	54



PUMP SIZE		MOTOR FRAME SIZE												364TS		365TS	
		Line	Dis.	Suc.	Im.	HT	CP	X	Z	Y	HT	HR	C				
1	1 1/2	1	1 1/2	7 1/4	4	4 1/2	23 1/4	8	4	4 1/2	4 1/2	15 1/4	42 1/4	18 1/2	31 1/2	31 1/2	31 1/2
2	1 1/2	2	2	8 1/2	4 1/2	5	24 1/4	8 1/2	5	4 1/2	4 1/2	15 1/4	43 1/4	18 1/2	31 1/2	31 1/2	31 1/2
3	2	3	3	8 1/2	5 1/4	5	24 1/4	8 1/2	5	4 1/2	4 1/2	15 1/4	44	18 1/2	31 1/2	31 1/2	31 1/2
4	3	4	4	8 1/2	6	5 1/4	25 1/4	9	5 1/4	4 1/2	4 1/2	15 1/4	45 1/4	18 1/2	31 1/2	31 1/2	31 1/2
5	4	5	5	8 1/2	6	5 1/4	25 1/4	10 1/2	6 1/4	4 1/2	4 1/2	15 1/4	46 1/4	18 1/2	31 1/2	31 1/2	31 1/2
6	1 1/2	2	10 1/2	5 1/4	5 1/4	6	24 1/4	9	6	4 1/2	4 1/2	15 1/4	47 1/4	18 1/2	31 1/2	31 1/2	31 1/2
7	2	3	10 1/2	5 1/2	5 1/2	6	25 1/4	10	6	4 1/2	4 1/2	15 1/4	48 1/4	18 1/2	31 1/2	31 1/2	31 1/2
8	3	4	10 1/2	6	6	6	25 1/4	10 1/2	6 1/4	4 1/2	4 1/2	15 1/4	49 1/4	18 1/2	31 1/2	31 1/2	31 1/2

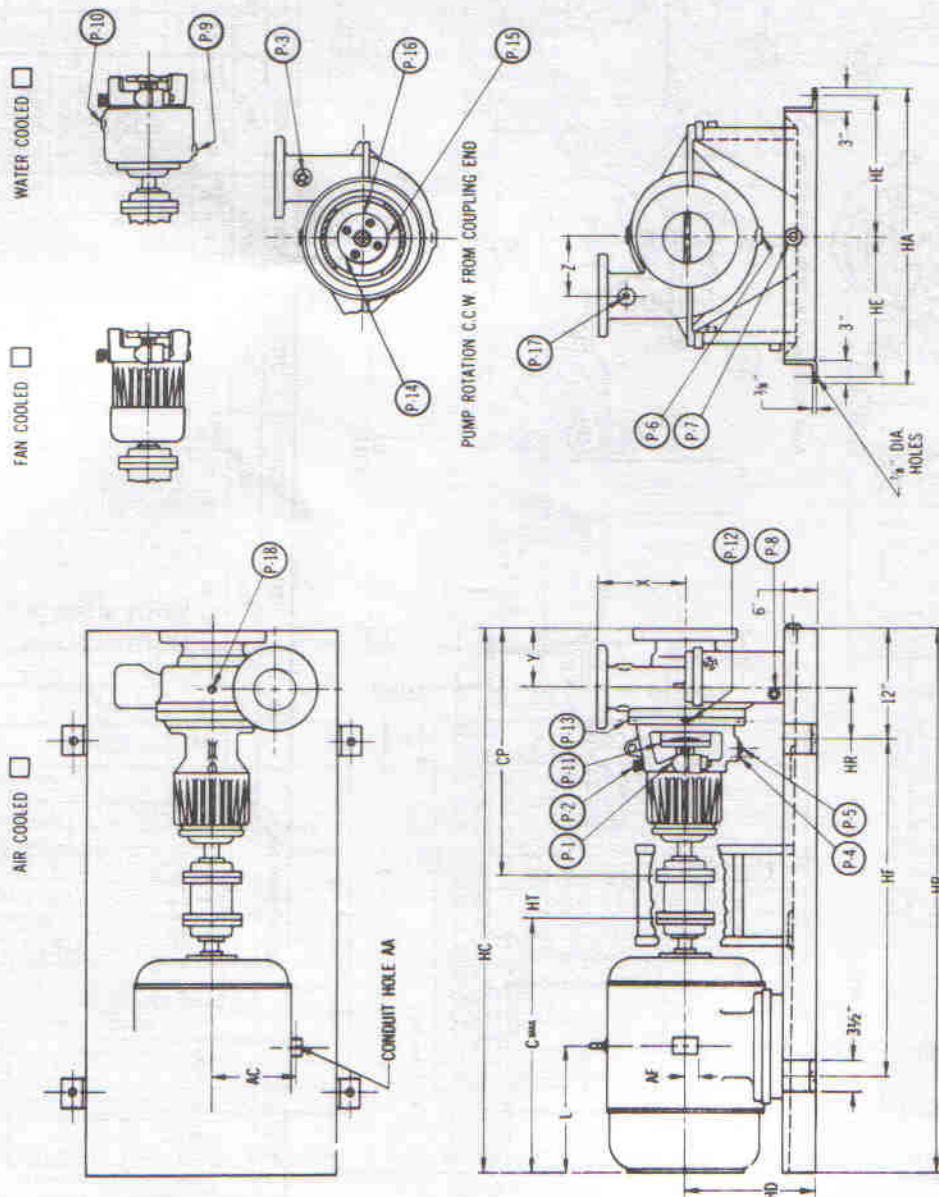
Figure 1-21. Pump outline dimensions, Type SJ. Courtesy of Byron Jackson Pump Division.

ITEM	SIZE	DESCRIPTION	YES/NO
P-1	4 OZ.	OILER — FAR SIDE	X
P-2		OIL FILLER CUP	X
P-3	1/2 P.T.	SEAL RECIRCULATION CASE TAP	X
P-4	1/2 P.T.	OIL DRAIN — PLUGGED	X
P-5	3/4 P.T.	DRAIN	X
P-6	3/4 P.T.	CASE DRAIN — PLUGGED	X
P-7	1 1/2 P.T.	BASE PLATE DRAIN	X
P-8	1/2 P.T.	FEED COOL. WATER IN & OUT	
P-9	1/2 P.T.	INLET BRG. WATER JACKET	
P-10	1/2 P.T.	OUTLET BRG. WATER JACKET	
P-11	1/4 P.T.	PACKING GLAND QUENCH	
P-12	1/2 P.T.	CAGE RING CONN. IN & OUT ON HORIZ. C.	Notes
P-13	SEE NOTE 4	STUFF. BOX WATER JACKET CLOSURE	
P-14	1/2 P.T.	SEAL VENT OR QUENCH INLET	
P-15	1/2 P.T.	SEAL QUENCH DRAIN	
P-16	1/2 P.T.	SEAL INJECTION	
P-17	3/4 P.T.	CAGE CONNECTION	
P-18	3/4 P.T.	VENT CONNECTION	

NOTES:

1. PUMPS ARE SELF VENTING.
2. SUCT. & DISCH. FLGS. #300 A.S.A. 1/4 R.F.
3. THREE 4" DIA. GROUT HOLES (MIN.) 1/2" DIA. VENT HOLES — CORNERS OF BASE.
4. 1/2 P.T. IN & OUT ON VERT. C. ALWAYS SUPPLIED WITH OR WITHOUT WATER JACKET CLOSURE.
5. BOSSES PROVIDED FOR ADDITION OF TAPS WHEN REQUIRED.
6. 6" STD. COUPLING GUARD MEETS CALIF. SAFETY REQUIREMENTS.

BASEPLATE DIMENSIONS					
BASE NO.	HA	HB	HE	HF	
S-3	36 1/2	78	16 1/4	54	
S-4	43 1/2	68	20 1/4	44	
S-5	43 1/2	86	20 1/4	62	



PUMP SIZE		MOTOR FRAME SIZE										444TS		445TS		447TS	
		Line No.	Dis-charge	Im- peller	Y	CP	X	Z	HT	C							
5	4	6	8 1/2	6	25 1/4	10 1/2	6 1/4	4 3/4	2	22 1/4	2	35 1/4	38 7/8	40 7/8	47 1/4		
9	4	6	10 1/2	7	31 1/2	10 1/2	7 1/4	4 3/4	2	28 1/4	2	35 1/4	38 7/8	40 7/8	47 1/4		
10	2	3	13 1/2	5 1/2	30 3/4	11	7 1/4	4 3/4	2	25 1/4	2	35 1/4	38 7/8	40 7/8	47 1/4		
11	3	4	13 1/2	5 1/2	30 3/4	11 1/2	7 1/4	4 3/4	2	25 1/4	2	35 1/4	38 7/8	40 7/8	47 1/4		
12	4	6	12 1/2	7	31 3/4	12	8 1/2	5	2	25 1/4	2	35 1/4	38 7/8	40 7/8	47 1/4		
13	4	6	13 1/2	7	31 3/4	12	8 1/2	5	2	25 1/4	2	35 1/4	38 7/8	40 7/8	47 1/4		

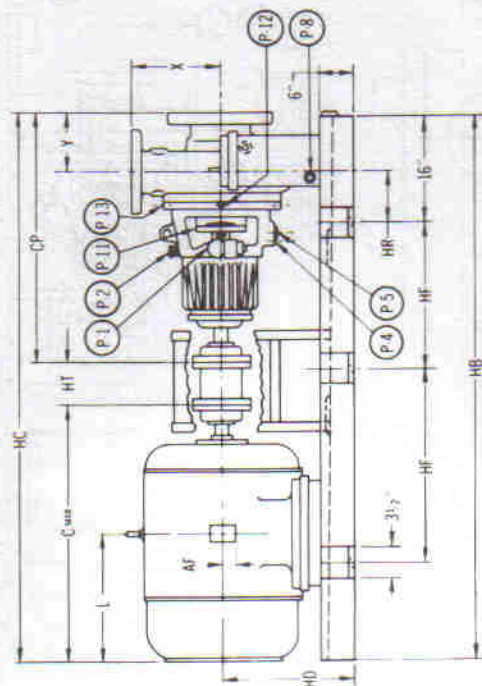
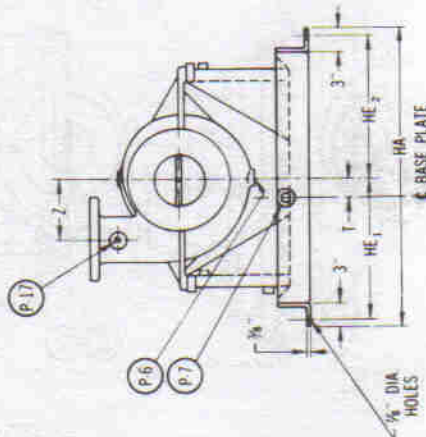
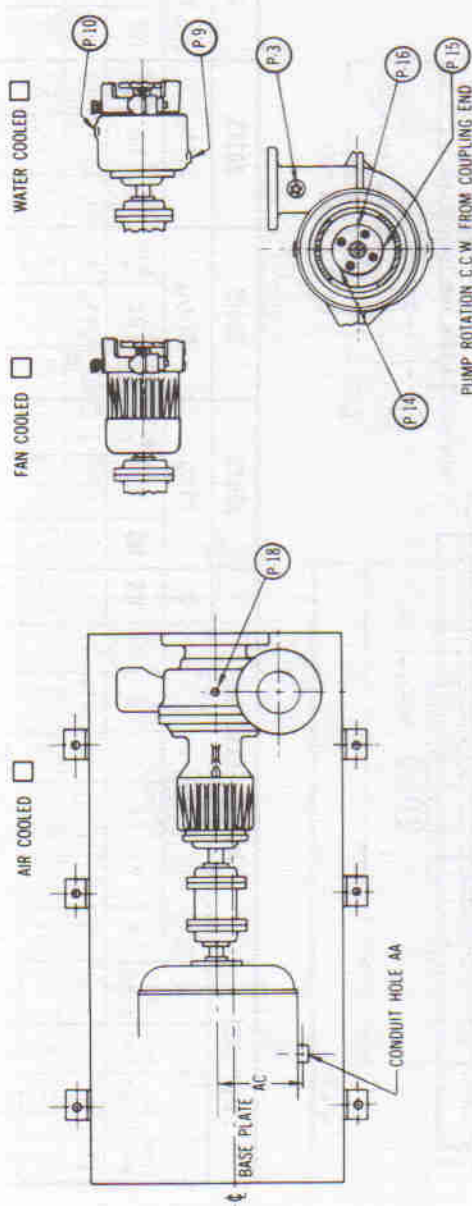
Figure 1-22. Pump outline dimensions, Type SJ. Courtesy of Byron Jackson Pump Division.

ITEM	SIZE	DESCRIPTION	YES/NO
P-1	4 OZ.	OILER - FAR SIDE	X
P-2		OIL FILLER CUP	X
P-3	1/2 P.T.	SEAL RECIRCULATION CASE TAP	X
P-4	1/2 P.T.	OIL DRAIN - PLUGGED	X
P-5	3/4 P.T.	DRAIN	X
P-6	3/4 P.T.	CASE DRAIN - PLUGGED	X
P-7	1 1/2 P.T.	BASE PLATE DRAIN	X
P-8	1/2 P.T.	RED. COOL. WATER IN & OUT	
P-9	1/2 P.T.	INLET BRG. WATER JACKET	
P-10	1/2 P.T.	OUTLET BRG. WATER JACKET	
P-11	1/2 P.T.	PACKING GLAND QUENCH	
P-12	1/2 P.T.	CAGE RING CONN. IN & OUT ON HORIZ. C.	
P-13	SEE NOTE 4	STUFF. BOX WATER JACKET CLOSURE	
P-14	1/2 P.T.	SEAL VENT OR QUENCH INLET	
P-15	1/2 P.T.	SEAL QUENCH DRAIN	
P-16	1/2 P.T.	SEAL INJECTION	
P-17	3/4 P.T.	GAGE CONNECTION	
P-18	3/4 P.T.	VENT CONNECTION	

NOTES:

1. PUMPS ARE SELF-VENTING.
2. SUCT. & DISCH. FLGS. #300 A.S.A. 3/4" R.F.
3. THREE 4" DIA. GROUT HOLES (MIN.) 1/2" DIA. VENT HOLES 4" CORNERS OF BASE.
4. 1/2" P.T. IN & OUT ON VERT. C. ALWAYS SUPPLIED WITH OR WITHOUT WATER JACKET CLOSURE.
5. BOSSES PROVIDED FOR ADDITION OF TAPS WHEN REQUIRED.
6. (B) STD. COUPLING GUARD MEETS CALIF. SAFETY REQUIREMENTS.

BASEPLATE DIMENSIONS					
BASE NO.	HA	HB	HE ₁	HE ₂	HF
S-6	47	96	23 3/8	20 3/8	32



PUMP SIZE			MOTOR FRAME SIZE												444TS			445TS			447TS														
Line No.	Dis-charge	Im-peller	C						324TS			326TS			364TS			355TS			405TS			38 7/8			407/8			47 1/4					
			Y	T	CP	X	Z	HT	HR	HD	HC	Base No.	HD	HC	Base No.	HD	HC	Base No.	HD	HC	Base No.	HD	HC	Base No.	HD	HC	Base No.	HD	HC	Base No.					
14	6	8	11	9	1 5/8	33 1/2	12	8 3/4	5	3 1/4		22 1/2	68 3/8	S-6	22 1/2	69 3/8	S-6	22 1/2	70 3/8	S-6	22 1/2	74 3/8	S-6	22 1/2	74 3/8	S-6	22 1/2	77 3/8	S-6	22 1/2	79 3/8	S-6	22 1/2	85 3/4	S-6
15	6	8	13	9	1 5/8	33 3/8	12	10 1/2	5	3 1/2	22 1/2	66 1/2	68	S-6	22 1/2	69 3/8	S-6	22 1/2	70 5/8	S-6	22 1/2	74 1/8	S-6	22 1/2	74 1/8	S-6	22 1/2	77 1/4	S-6	22 1/2	79 1/4	S-6	22 1/2	85 5/8	S-6
16	4	6	15 1/2	9	1 5/8	37 3/8	13 1/2	10	5	3 1/4	22 1/2	70 3/8	72 3/8	S-6	22 1/2	73 3/4	S-6	22 1/2	74 3/4	S-6	22 1/2	78 1/2	S-6	22 1/2	78 1/2	S-6	22 1/2	81 1/8	S-6	22 1/2	83 1/8	S-6	22 1/2	90 3/8	S-6

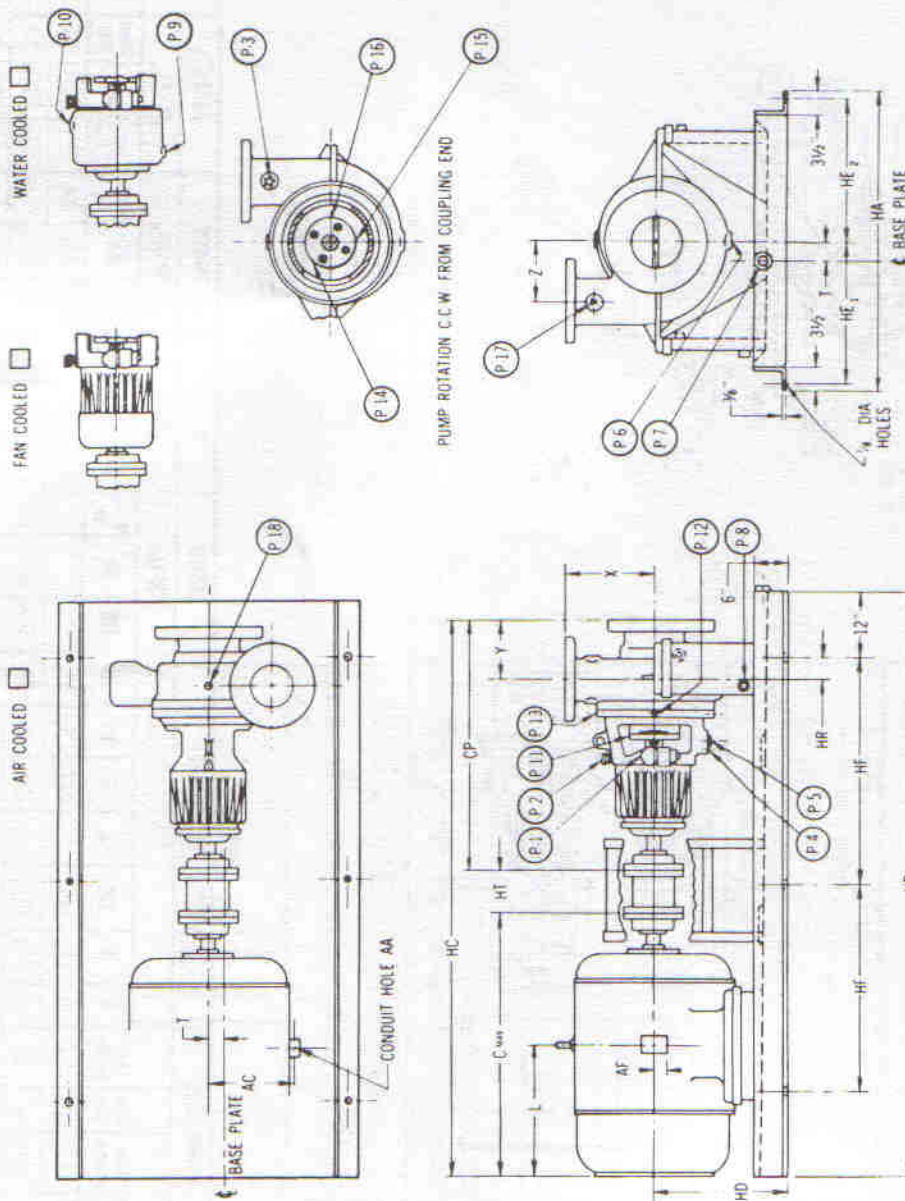
Figure 1-23. Pump outline dimensions, Type S.J. Courtesy of Byron Jackson Pump Division.

ITEM	SIZE	DESCRIPTION	YES/NO
P-1	4 OZ.	OILER - FAR SIDE	X
P-2		OIL FILLER CUP	X
P-3	1/2 P.T.	SEAL RECIRCULATION CASE TAP	X
P-4	1/2 P.T.	OIL DRAIN - PLUGGED	X
P-5	3/4 P.T.	DRAIN	X
P-6	3/4 P.T.	CASE DRAIN - PLUGGED	X
P-7	1/2 P.T.	BASE PLATE DRAIN	X
P-8	1/2 P.T.	RED. COOL. WATER IN & OUT	
P-9	1/2 P.T.	INLET BRG. WATER JACKET	
P-10	1/2 P.T.	OUTLET BRG. WATER JACKET	
P-11	1/2 P.T.	PACKING GLAND QUENCH	
P-12	1/2 P.T.	CAGE RING CONN. IN & OUT ON HORIZ. C.	
P-13	SEE NOTE 4	STUFF BOX WATER JACKET CLOSURE	
P-14	1/2 P.T.	SEAL VENT OR QUENCH INLET	
P-15	1/2 P.T.	SEAL QUENCH DRAIN	
P-16	1/2 P.T.	SEAL INJECTION	
P-17	3/4 P.T.	GAGE CONNECTION	
P-18	3/4 P.T.	VENT CONNECTION	

NOTES:

1. PUMPS ARE SELF-VENTING.
2. SUCT. & DISCH. FLGS. #300 A.S.A. 1/2 R.F.
3. THREE 4" DIA. GROUT HOLES (MIN); 1/2" DIA. VENT HOLES - 4" CORNERS OF BASE.
4. 1/2 P.T. IN & OUT ON VERT. C. ALWAYS SUPPLIED WITH OR WITHOUT WATER JACKET CLOSURE.
5. BUSES PROVIDED FOR ADDITION OF TAPS WHEN REQUIRED.
6. BI STD. COUPLING GUARD MEETS CALIF. SAFETY REQUIREMENTS.

BASEPLATE DIMENSIONS					
BASE NO.	HA	HB	HE ₁	HE ₂	HF
S-7	53	103	27 3/4	21 3/4	39 1/2



PUMP SIZE				MOTOR FRAME SIZE										445TS		447TS				
Line No.	Dis-charge	Suc-tion	Im-peller	C										444TS		447TS				
				Y	V	CP	X	Z	HT	HR	HD	HC	Base No.	HD	HC	Base No.	HD	HC	Base No.	
									</											

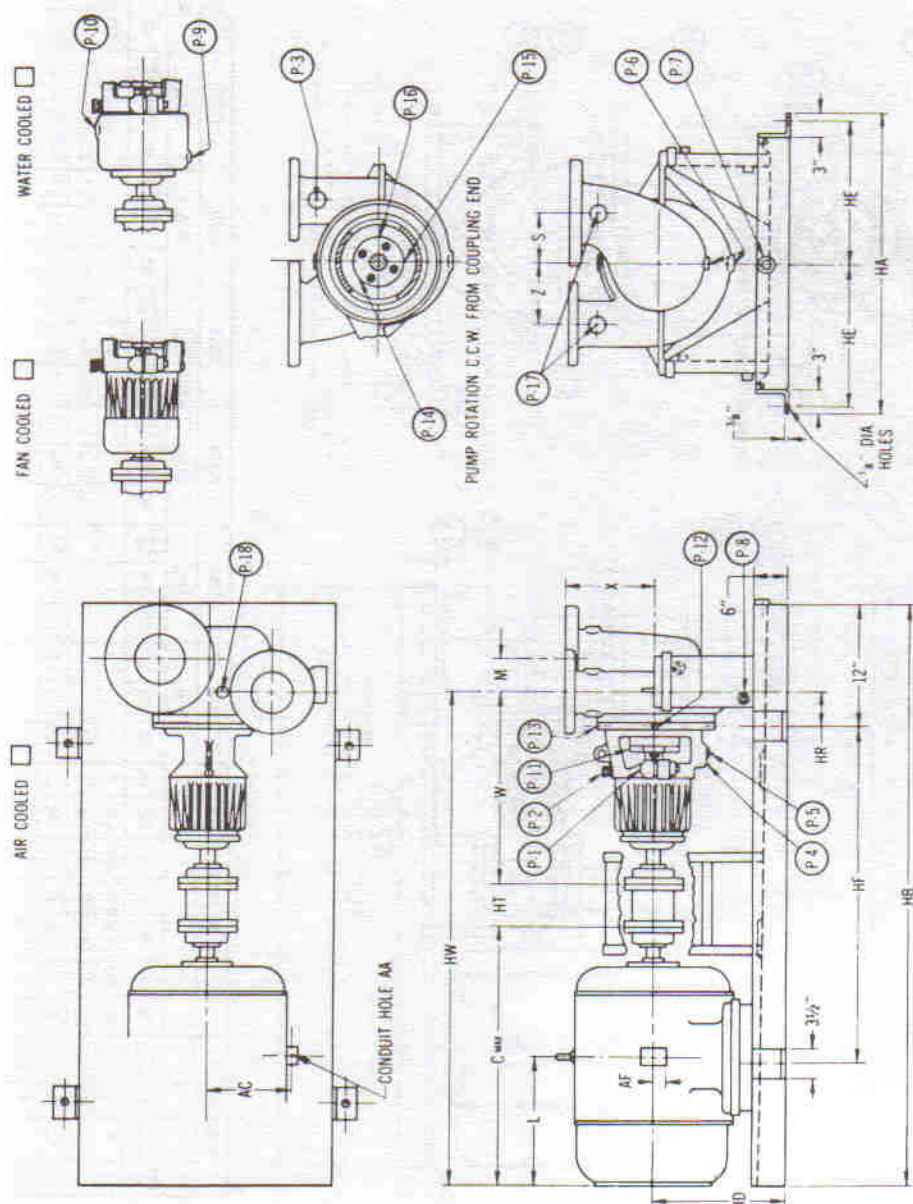
Figure 1-24. Pump outline dimensions, Type S.J. Courtesy of Byron Jackson Pump Division.

ITEM	SIZE	DESCRIPTION	YLS NO
P.1	4 OZ	OILER - FAR SIDE	X
P.2		OIL FILLER CUP	X
P.3	1/2 P.T.	SEAL RECIRCULATION CASE TAP	X
P.4	1/2 P.T.	OIL DRAIN - PLUGGED	X
P.5	3/4 P.T.	DRAIN	X
P.6	3/4 P.T.	CASE DRAIN - PLUGGED	X
P.7	1 1/2 P.T.	BASE PLATE DRAIN	X
P.8	1/2 P.T.	PED. COOL. WATER IN & OUT	
P.9	1/2 P.T.	INLET BRG. WATER JACKET	
P.10	1/2 P.T.	OUTLET BRG. WATER JACKET	
P.11	1/4 P.T.	PACKING GLAND QUENCH	
P.12	1/2 P.T.	CAGE RING CONN. IN & OUT ON HORIZ. C. SEE NOTE 4	
P.13		STUFF BOX WATER JACKET CLOSURE	
P.14	1/2 P.T.	SEAL VENT OR QUENCH INLET	
P.15	1/2 P.T.	SEAL QUENCH DRAIN	
P.16	1/2 P.T.	SEAL INJECTION	
P.17	3/4 P.T.	CAGE CONNECTION	
P.18	3/4 P.T.	VENT CONNECTION	

NOTES:

- PUMPS ARE SELF VENTING.
- SUCT. & DISCH. FLOS. #300 & S.A. 1/4" R.F.
- THREE 4" DIA. GROUT HOLES (MIN) 1/2" DIA. VENT HOLES - 4 CORNERS OF BASE
- 1/2" P.T. IN & OUT ON VERT. C. ALWAYS SUPPLIED WITH OR WITHOUT WATER JACKET CLOSURE.
- BOSSSES PROVIDED FOR ADDITION OF TAPS WHEN REQUIRED.
- BJ STD. COUPLING GUARD MEETS CALIF. SAFETY REQUIREMENTS.
- ALL CASE TAPS ON 1:1.127:1.4 WILL BE 1/2" P.T.

BASEPLATE DIMENSIONS				
BASE NO.	HA	HB	HE	HF
S.1	31	60	14	36
S.2	36 1/2	63	16 1/4	39
S.3	36 1/2	78	16 1/4	54



PUMP SIZE		MOTOR FRAME SIZE												364TS		365TS	
		Line No.	Dis. charge	Suc. bell	M	S	W	X	Z	HT	C	HR	HD	HW	Base No.	Base No.	Base No.
1	1 1/2	7 1/4	1 1/2	2	19 1/16	8	4 1/8	4 3/8	4 3/8	4 3/8	15 3/4	39 1/16	S.1	15 3/4	39 1/16	S.1	31 1/2
2	1 1/2	8 1/2	2 1/2	4 1/8	19 1/16	8 1/2	4 3/8	4 3/8	4 3/8	4 3/8	15 3/4	39 1/16	S.1	15 3/4	39 1/16	S.1	31 1/2
3	2	8 1/2	2 1/2	4 1/8	19 1/16	8 1/2	4 3/8	4 3/8	4 3/8	4 3/8	15 3/4	39 1/16	S.1	15 3/4	39 1/16	S.1	31 1/2
4	3	8 1/2	3	4 3/8	19 1/16	9	5 1/4	4 3/8	4 3/8	4 3/8	15 3/4	39 1/16	S.1	15 3/4	39 1/16	S.1	31 1/2
5	4	8 1/2	3 1/2	5 1/8	19 1/16	10 1/2	6 1/4	4 3/8	4 3/8	4 3/8	15 3/4	39 1/16	S.1	15 3/4	39 1/16	S.1	31 1/2
6	1 1/2	2	10 1/2	2	3 1/2	19 1/16	9	6	4 3/8	4 3/8	15 3/4	39 1/16	S.1	15 3/4	39 1/16	S.1	31 1/2
7	2	3	10 1/2	2	4	19 1/16	10	6	4 3/8	4 3/8	15 3/4	39 1/16	S.1	15 3/4	39 1/16	S.1	31 1/2
8	3	4	10 1/2	2 1/2	4 3/8	19 1/16	10	6 1/4	4 3/8	4 3/8	15 3/4	39 1/16	S.1	15 3/4	39 1/16	S.1	31 1/2

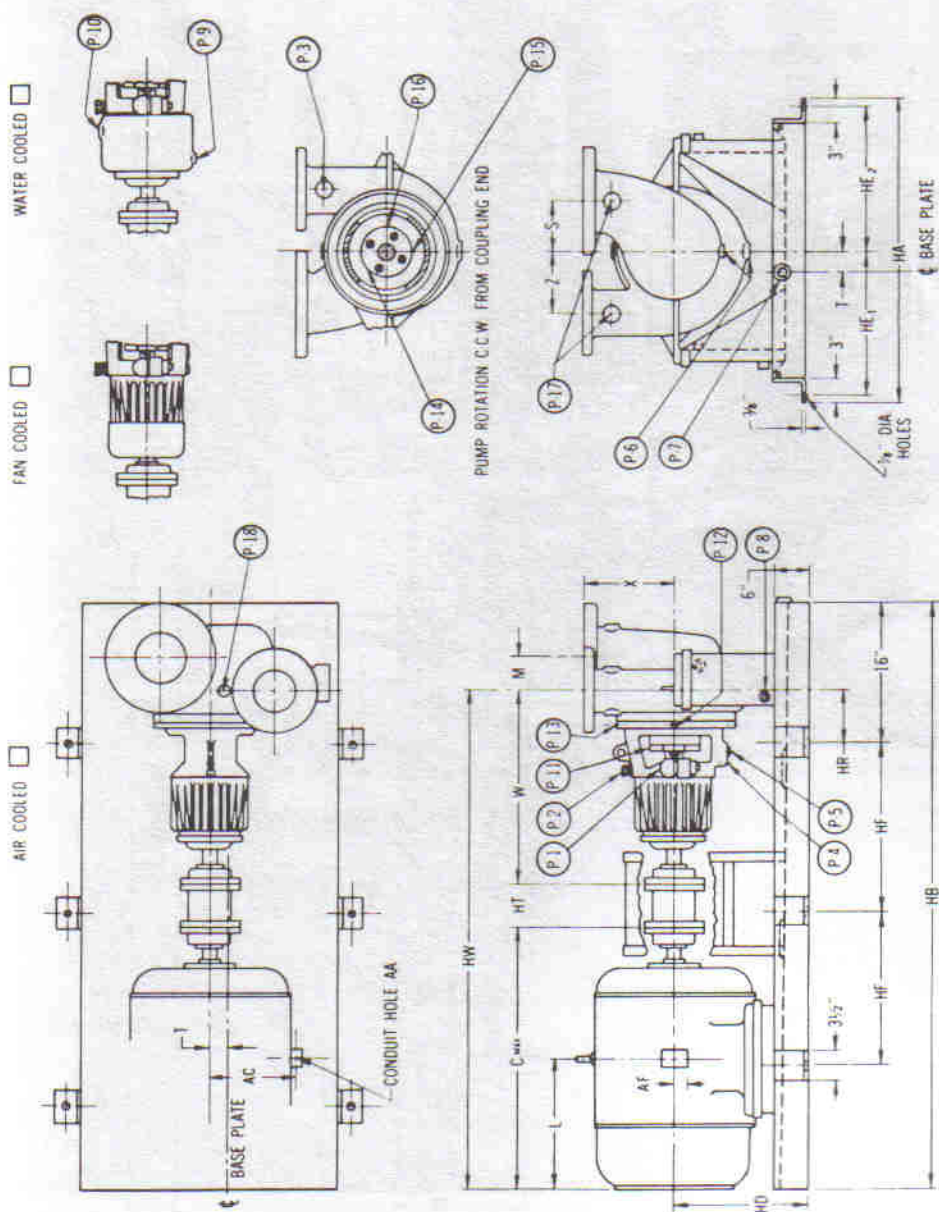
Figure 1-25. Pump outline dimensions, Type SJ. Courtesy of Byron Jackson Pump Division.

ITEM	SIZE	DESCRIPTION	YES/NO
P.1	4 DZ	OILER - FAR SIDE	X
P.2		OIL FILLER CUP	X
P.3	1/2 P.T.	SEAL RECIRCULATION CASE TAP	X
P.4	1/2 P.T.	OIL DRAIN - PLUGGED	X
P.5	3/4 P.T.	DRAIN	X
P.6	3/4 P.T.	CASE DRAIN - PLUGGED	X
P.7	1 1/2 P.T.	BASE PLATE DRAIN	X
P.8	1/2 P.T.	P.L.D. COOL WATER IN & OUT	
P.9	1/2 P.T.	INLET BRG. WATER JACKET	
P.10	1/2 P.T.	OUTLET BRG. WATER JACKET	
P.11	1/4 P.T.	PACKING GLAND QUENCH	
P.12	1/2 P.T.	CAGE RING CONN. IN & OUT ON HORIZ. C	
P.13	SEE NOTE 4	STUFF BOX WATER JACKET CLOSURE	
P.14	1/2 P.T.	SEAL VENT OR QUENCH INLET	
P.15	1/2 P.T.	SEAL QUENCH DRAIN	
P.16	1/2 P.T.	SEAL INJECTION	
P.17	3/4 P.T.	GAGE CONNECTION	
P.18	3/4 P.T.	VENT CONNECTION	

NOTES:

1. PUMPS ARE SELF VENTING.
2. SUCTION & DISCH. FLGS. #300 A.S.A. 1/4 R.F.
3. THREE 4" DIA. GROUT HOLES (MIN) 1/2 DIA. VENT HOLES - 4 CORNERS OF BASE.
4. 1/2 P.T. IN & OUT ON VERT. C ALWAYS SUPPLIED WITH OR WITHOUT WATER JACKET CLOSURE.
5. BOSSES PROVIDED FOR ADDITION OF TAPS WHEN REQUIRED.
6. B1 STD. COUPLING GUARD MEETS CALIF. SAFETY REQUIREMENTS.

BASEPLATE DIMENSIONS					
BASE NO.	HA	HB	HE ₁	HE ₂	HF
S-6	47	96	23 3/4	20 1/4	32



PUMP SIZE			MOTOR FRAME SIZE										324TS				326TS				364TS				365TS				405TS				444TS				445TS				447TS			
Line No.	Dis-charge	Suc- tion	C										28 1/8				29 5/8				30 1/2				31 1/2				35 1/4				38 7/8				40 7/8				47 1/4			
			M	S	W	X	Z	HT	HR	HD	HW	Base No.	HD	HW	Base No.	HD	HW	Base No.	HD	HW	Base No.	HD	HW	Base No.	HD	HW	Base No.	HD	HW	Base No.	HD	HW	Base No.	T										
14	6	8	11	4 1/2	6	24 1/2	12	8 3/4	5	3 1/4		22 1/2	59 1/8	S-6	22 1/2	60 7/8	S-6	22 1/2	61 7/8	S-6	22 1/2	62 1/2	S-6	22 1/2	63 1/2	S-6	22 1/2	63 1/2	S-6	22 1/2	68 3/8	S-6	22 1/2	70 3/8	S-6	22 1/2	76 3/4	S-6	1 5/8					
15	6	8	13	5	6	24 3/8	12	10 1/2	5	3 1/2	22 1/2	57 1/2	S-6	22 1/2	59	60 5/8	S-6	22 1/2	61 1/8	S-6	22 1/2	62 1/8	S-6	22 1/2	65 1/8	S-6	22 1/2	68 1/4	S-6	22 1/2	70 1/4	S-6	22 1/2	76 5/8	S-6	1 5/8								
16	4	6	15 1/2	4 1/2	6	28 1/2	13 1/2	10	5	3 1/4	22 1/2	61 1/8	S-6	22 1/2	63 3/4	64 3/8	S-6	22 1/2	65 1/4	S-6	22 1/2	66 1/4	S-6	22 1/2	69 1/2	S-6	22 1/2	72 1/4	S-6	22 1/2	74 1/4	S-6	22 1/2	81 1/4	S-6	1 5/8								

Figure 1-27. Pump outline dimensions, Type SJ. Courtesy of Byron Jackson Pump Division.

piping and the turbine casing. The small sentinel valve, whistling to signal overpressure in the casing only serves as an alarm. Never depend on this valve to protect the turbine.

Figure 1-33, shows a YR turbine with left-hand exhaust. Turbine inlets are usually on the right side facing the governor end; the purchaser can select either right or left-hand exhaust to best suit the exhaust piping system. This means the piping designer can place the exhaust connection either on the same side as or on the opposite side from the inlet.

Generally the opposite side location results in less piping congestion.

Inlet Piping

Steam inlets are furnished with strainers as part of the turbine for protection against large particles of scale, welding beads or other debris. Inlet piping must be designed with a breakaway piece to allow strainer removal.

Supply steam should, at all times, be moisture

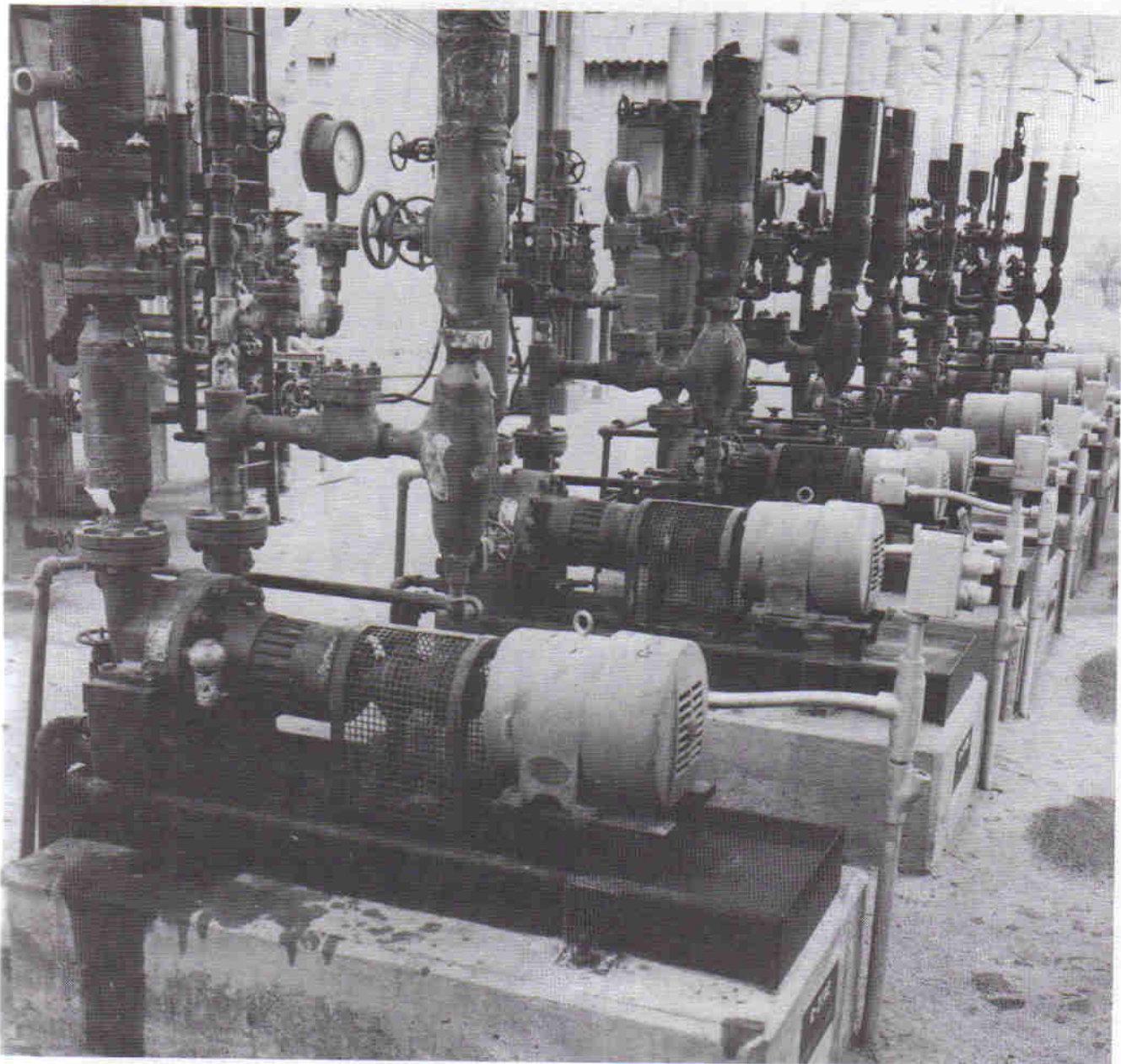


Figure 1-29. Pump installation. Courtesy of Byron Jackson Pump Division.

free (completely vaporized). Liquids entering the turbine while the rotor is turning will severely damage the blades. Since turbines are usually on stand-by service, special arrangements are necessary to keep the system moisture free when not operating.

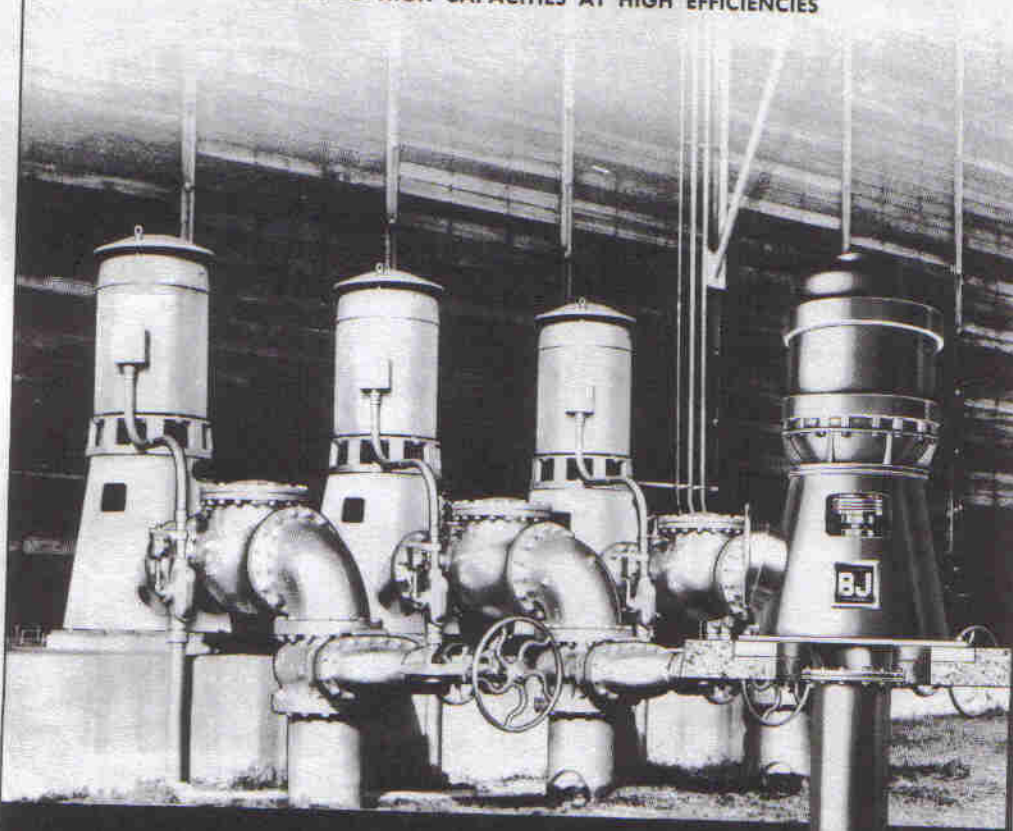
The two basic turbine installations are manual start-up and automatic start-up. The manual start-up will have a standard gate valve in the steam supply near the turbine inlet. Immediately upstream a

steam trap should be located to drain off any condensate which forms. The gate valve is normally closed, with live steam upstream. If the operator needs to start the turbine because the electric motor pump has stopped, he needs to get back on stream as soon as possible. A moisture-free inlet allows the operator to start the turbine immediately by opening the inlet gate valve.

The automatic start-up is accomplished by a motor-operated control valve installed in place of

VERTICAL CIRCULATING PUMPS—TYPE KX-RX

SINGLE OR MULTI-STAGE TURBINE TYPE PUMPS FOR
MEDIUM TO HIGH CAPACITIES AT HIGH EFFICIENCIES



	TYPE KX	TYPE RX
PUMP SIZES	16" to 56"	16" to 94"
CAPACITIES IN G.P.M.	to 40,000	to 130,000
TOTAL HEAD IN FEET	to 500'	to 250'
SPEED — R.P.M.	to 1760	to 1760
TYPES OF DRIVE	Motor or Right Angle Gear	

Figure 1-30. Vertical pump installation. Courtesy of Byron Jackson Pump Division.

VERTICAL CIRCULATING PUMPS - TYPE KX & RX

SECTIONAL DRAWING — OIL OR FRESH WATER LUBE — MULTI-STAGE

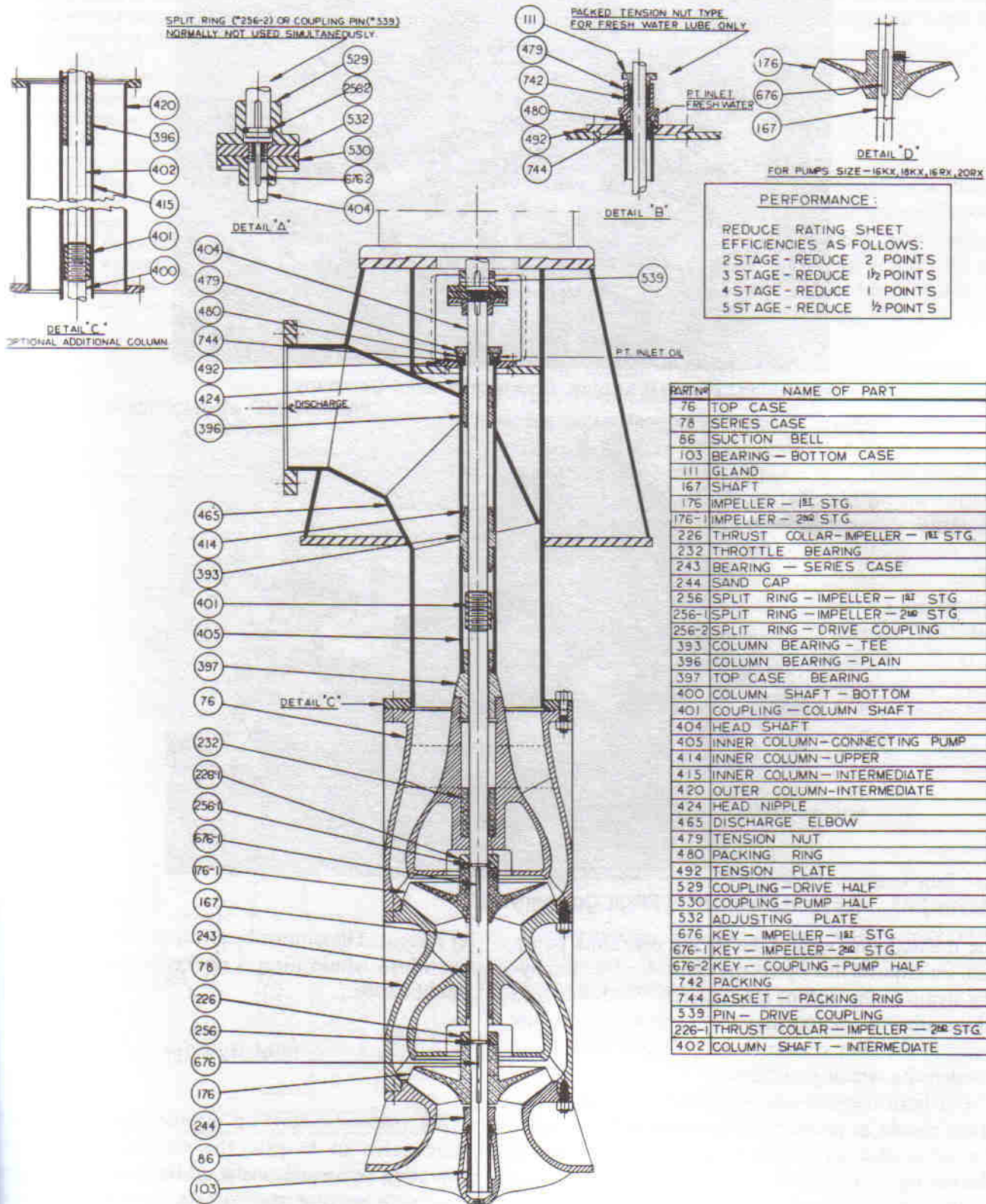


Figure 1-31. Vertical pump parts. Courtesy of Byron Jackson Pump Division.

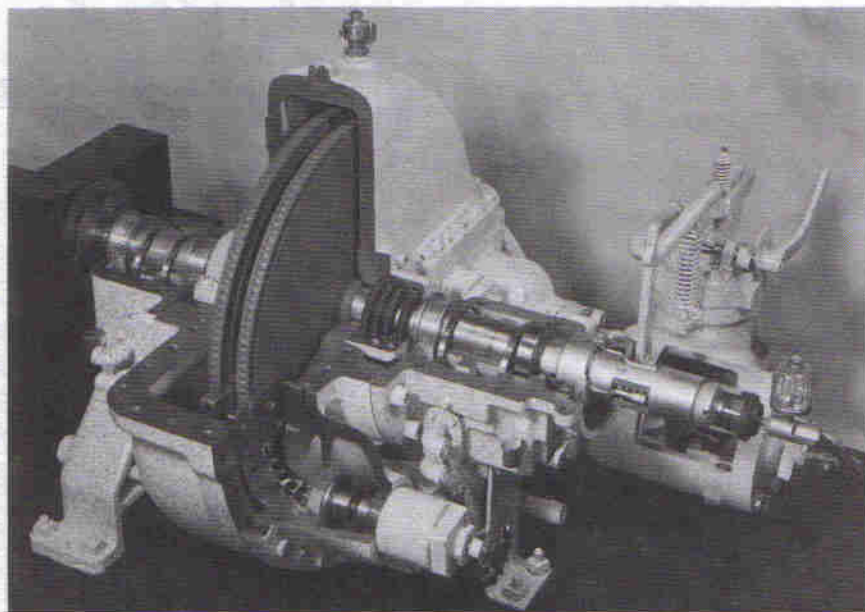


Figure 1-32. Cross section, Type YR turbine. Courtesy of Elliot Company.

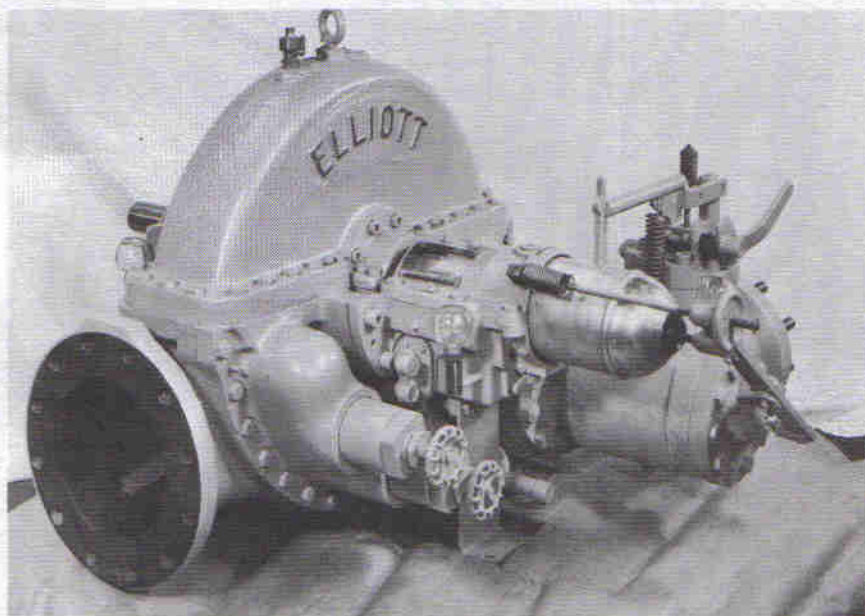


Figure 1.33. Turbine. Courtesy of Elliott Company.

the manual gate valve. Should the operating pump fail, an impulse line opens the control valve, supplying steam to the turbine immediately. With this type of installation, steam traps are supplied at every low point in the inlet system to immediately collect any condensate which may form.

For both manual and automatic start-up, steam traps should be provided to keep the turbine casing free of condensate. These can be installed either at the casing's low point if a connection is provided or on the outlet piping if the casing drains into the out-

let system. There must be a trap before any vertical rise which would form a pocket where condensate would collect.

Inlet By-pass

All automatic start-up turbines need a 1" globe body valve to by-pass the control valve. Many operating companies insist on the warm-up by-pass even with manual start-up. In both cases, the 1"

General Specifications

TYPE	AYR
Maximum initial pressure (psig)	700
Maximum initial temperature	750
Exhaust pressures (psig)	100
Speed range (rpm)	1000-5000
Wheel pitch diameter (in.)	14
Number of stages (impulse type)	1
Number of rows of rotating blades	2
Inlet sizes (in.)	3
Inlet location (facing governor)	right
Exhaust size (in.)	6
Exhaust location (r.h. or l.h.)	optional
Centerline height (in.)	12
Approximate range of capacities (hp)	to 750
Casing cover weight (lb)	85
Shipping weight (lb)	870

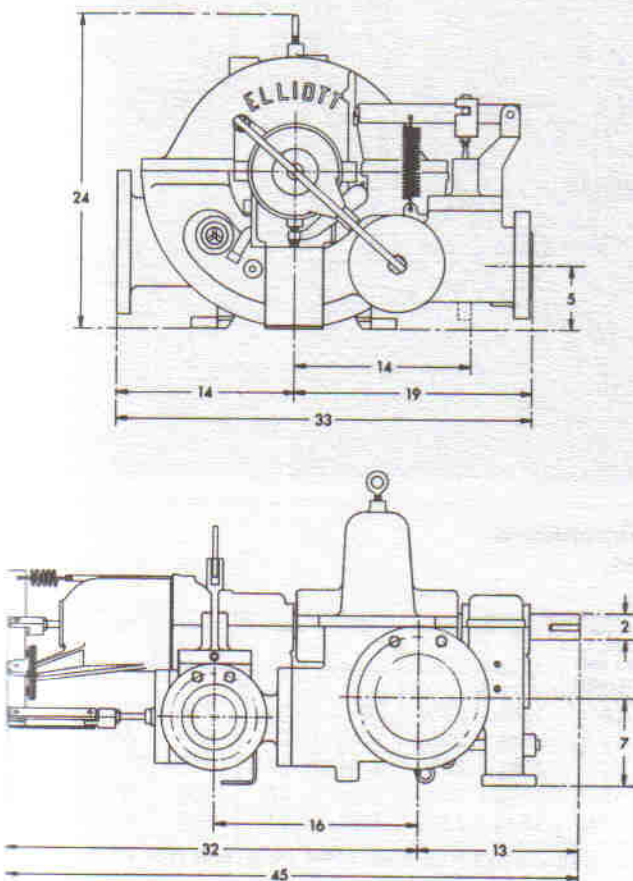
Approximate Dimensions
(in inches)

Figure 1-34. Approximate dimensions, Type AYR turbine. Courtesy of Elliot Company.

valve is *cracked*, or partially opened, allowing steam to go around the block or control valve to keep the turbine constantly warm and slowly turning to prevent the shock of hot steam entering a cold turbine. A steam trap on the casing keeps the system condensate-free.

Outlet Piping

Turbine exhausts are routed either to a closed exhaust steam system or to the atmosphere if a total condensing turbine is specified. The author recommends that when piping is routed to the exhaust steam system, the gate block valve be located *not* at grade near the turbine, but in the pipe rack, immediately before the line enters the exhaust steam header. The gate block valve should remain fully open except during turbine repairs. Locating the valve in the pipe rack greatly reduces the possibility of accidental closing.

Steam traps for outlet lines exhausting to atmosphere should not be installed on the turbine case because they must have some upstream pressure to operate. The turbine casing here will have only back-pressure in it; and that is not enough to make the trap work. In this type of installation install only a gate valve on the casing. With this valve cracked, condensate will drain off as it accumulates. Some steam will also bleed off but it isn't a loss since it is exhausting to the atmosphere anyhow.

Turbine Dimensions

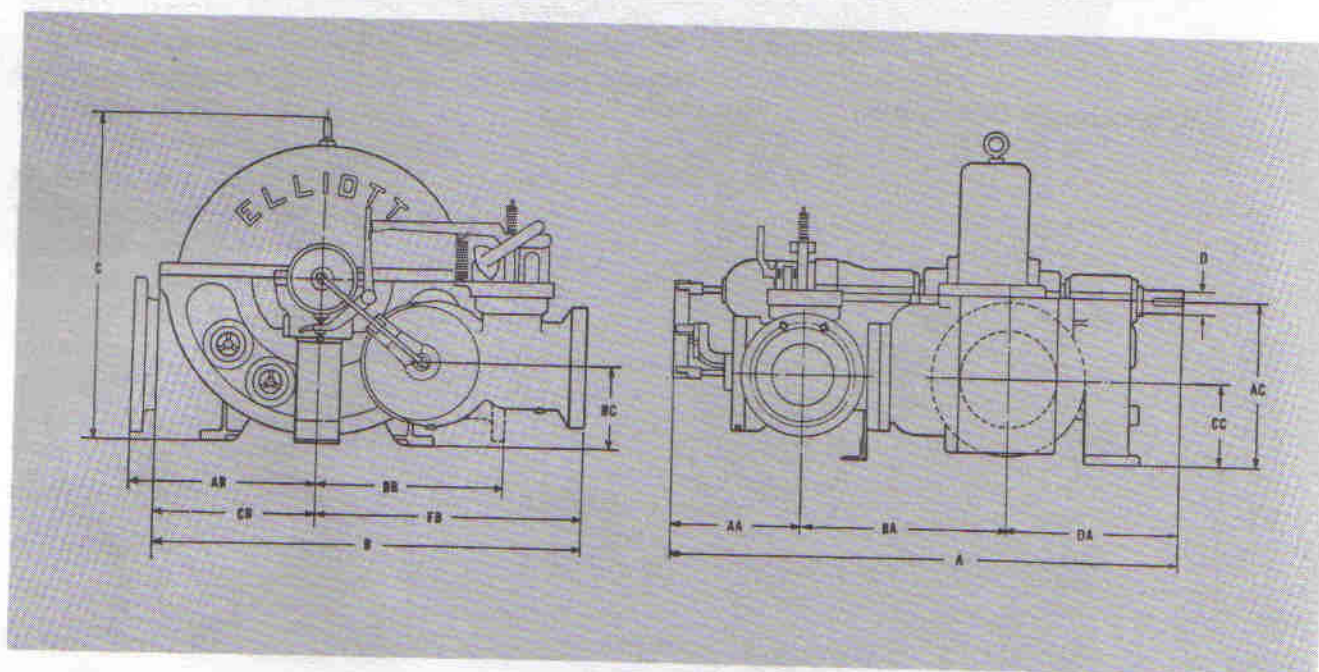
Figure 1-34 shows turbine dimensions and data of interest to piping designers. Figure 1-35 furnishes the designer with necessary preliminary data to be used until a certified outline drawing is received.

General Specifications

FRAME	BYR	CYR	DYR	BYRH	BYRHH
Maximum initial pressure (psig)	700	700	700	700	700
Maximum initial temperature (°F)	750	750	750	750	750
Maximum exhaust pressures (psig)	vac-125	vac-90	vac-75	250	375
Speed range (rpm)	800-7000	800-6760	800-6000	800-7350	800-7350
Wheel pitch diameter (in.)	18	22	28	18	18
Number of stages (impulse type)	1	1	1	1	1
Number of rows of rotating blades	2	2	2	2	2
Inlet sizes (in.)	2, 3 & 4	2, 3, 4 & 6	2, 3, 4 & 6	2, 3, 4 & 6	2, 3, 4 & 6
Inlet location (facing governor)	right	right	right	right	right
Exhaust size (in.)	8	10	12	8	8
Exhaust location (L. H. Standard)	R. H. optional	R. H. optional	R. H. optional	R. H. optional	R. H. optional
Centerline height (in.)	14	17	22	17	17
Approximate range of capacities (hp)	to 1400	to 2500	to 3500	to 3000	to 3000
Approximate shipping weight (lb.)	1275	2050	2600	2300	2300

See Bulletin H29 for BYRH and BYRHH details

See Bulletin H32 for AYR details

Approximate Dimensions
(in inches)

TYPE	A	AA	BA	DA	B*	AB	BB	CB	FB*	C	AC	BC	CC	D
						For Class I (except BYRH/HH)								
BYR	46 $\frac{1}{8}$	12 $\frac{1}{2}$	21 $\frac{1}{16}$	12 $\frac{7}{16}$	36 $\frac{1}{8}$	16 $\frac{1}{2}$	16 $\frac{1}{2}$	13 $\frac{5}{8}$	22 $\frac{1}{2}$	28	14	7 $\frac{3}{4}$	7	2
CYR	51 $\frac{1}{2}$	12 $\frac{1}{2}$	21 $\frac{1}{16}$	17 $\frac{1}{16}$	40 $\frac{1}{8}$	19 $\frac{7}{8}$	19 $\frac{7}{8}$	16 $\frac{5}{8}$	23 $\frac{1}{2}$	34 $\frac{1}{2}$	17	8 $\frac{1}{2}$	8 $\frac{1}{2}$	2 $\frac{1}{2}$
DYR	51 $\frac{1}{8}$	12 $\frac{1}{2}$	21 $\frac{1}{16}$	16 $\frac{1}{16}$	43 $\frac{1}{8}$	23	23	19 $\frac{5}{8}$	23 $\frac{1}{2}$	42 $\frac{5}{8}$	22	13 $\frac{1}{2}$	12	3
BYRH	55 $\frac{5}{8}$	12 $\frac{1}{2}$	27	16 $\frac{1}{8}$	39 $\frac{7}{8}$	18 $\frac{3}{4}$	18 $\frac{3}{4}$	16 $\frac{3}{8}$	23 $\frac{1}{2}$	32 $\frac{1}{2}$	17	8 $\frac{1}{2}$	9	2 $\frac{1}{2}$
BYRHH	55 $\frac{5}{8}$	12 $\frac{1}{2}$	27	16 $\frac{1}{8}$	39 $\frac{7}{8}$	18 $\frac{3}{4}$	18 $\frac{3}{4}$	16 $\frac{3}{8}$	23 $\frac{1}{2}$	32 $\frac{1}{2}$	17	8 $\frac{1}{2}$	9	2 $\frac{1}{2}$

*Class I BYR (3-in. inlet), CYR and DYR (4-in. inlet), BYRH and BYRHH (4-in. inlet)
Left hand exhaust (AB dimension) is standard

Figure 1-35. Approximate dimensions, other YR turbines. Courtesy of Elliot Company.

Review Test
Chapter 1

1. Define a pump's purpose. _____

2. Name three basic types of pumps. _____
3. Which type of pump causes pulsation? _____
4. The difference between horizontal and vertical pumps is the location of the _____
5. Define NPSH. _____
6. Normally the centrifugal pump suction line sizes are no more than _____ sizes greater than the pump suction nozzle.
7. What is the purpose of a temporary suction strainer? _____

8. Why do pump suction and discharge nozzles normally have the same rating? _____

9. For better piping, common spare and related pumps should have suction nozzles located where? _____

10. Define the purpose of a turbine sentinel valve. _____

11. For better turbine piping, a designer has an option for location of the (inlet) (outlet) nozzle _____

2 Compressors

Just as pumps are used to increase liquid pressure, compressors are the mechanical means to increase vapor pressure. There are two basic types of compressors: reciprocating and centrifugal. Each has one specific duty—to intake vapor at a relatively low pressure, compress it and discharge it at a higher pressure. The quantity of gas to be moved is usually the deciding factor in type selection.

Centrifugal Compressor

Centrifugal compression is the force converted to pressure when a gas is ejected by an impeller at increasing velocity. Centrifugal compressors are specified for large quantities of vapor. Pressure differential may be small or large.

There are two basic types of centrifugal compressors. Vertically split case types are used for high pressures; horizontally split case types are used for low to moderately high pressures. Case construction is important to a piping designer who must design piping to provide proper access for compressor maintenance. If the casing splits vertically, the front of the compressor must be left free of obstruction so the casing can easily be removed and pulled away. Since the horizontally split casing unbolts in the middle and raises for rotor blade access, overhead

piping must be designed to be easily removable.

Centrifugal compressors may have up to ten stages of compression within one casing. If more than ten stages are needed, two or more compressors, depending on total stages required, can be coupled together and powered by a common driver. This is called *tandem drive*. Although there is usually only one suction nozzle, a single casing may have one, two or rarely three discharge nozzles. An intermediate discharge (called a sidestream or slipstream) at one of the middle stages may be needed for the escape discharge of vapor to be used at a lower pressure than the final discharge pressure at the last stage. For instance, in a six stage machine, the intermediate discharge might come off the fourth stage.

Case Design

Centrifugal compressor manufacturers have basic case designs which change with rotor blade design to meet volume and pressure requirements. For this reason suction nozzles are sometimes much larger or smaller than the line sizes for hydrocarbon process applications. For example, a 30" suction nozzle may be furnished for the piping designer's 20" compressor suction line. The designer's first reaction is to ask the vendor to change the com-

pressor nozzle to 20", matching line size, but since this is a stock design case, the vendor can not make such a change without a complete redesign costing many thousands of dollars, so it becomes the piping designer's problem to increase the line size to 30" at the nozzle.

Make line-size changes at compressor suction nozzles as smoothly as possible. To the 30" casing-flanged nozzle attach a 30" flange and a *concentric reducer* to come down to line size. Never use a reducing flange here. This would introduce full velocity to the rotor blades at a turbulent condition.

Compressor Location

There are several factors to be considered in locating compressors: (1) Access by mobile equipment for maintenance. This usually means a road must be located to run alongside the compressor. (2) Suction line must be as short and direct as possible. (a) This is one of the largest and consequently most expensive lines in a basic process unit. (b) An excessively long suction line increases costs by consuming extra driver horsepower.

Compressors can be installed indoors, outdoors or under a tropical type shelter and since compressors require little maintenance, the author recommends outside installation for economy. When turnaround or maintenance is necessary, a temporary tropical shelter can be erected for workers and a crane rented at little expense.

Lube and Seal Oil Consoles

A major consideration in centrifugal compressor locations is the lube and seal oil console. It must be accessible from a road, must be lower than the compressor to allow gravity drain of oil to the console's oil storage tank, and must have cooling water for the oil coolers as well as electricity and steam for the oil pump drivers. Quite often, consoles are purchased as package units, furnished skid-mounted by the compressor vendor and installed by the piping designer.

Because the designer usually does not receive console data early enough, many educated guesses have to be made early in the plant layout stages.

How big is the console? Usually about 14' wide by 16' long will be ample.

What items are on the console? An oil tank collects oil at atmospheric pressure which gravity drains from the compressor. In cold climates the oil tank will have steam coils at the bottom to keep the oil warm. Taking suction from this tank is a motor driven oil pump and the spare pump, usually steam turbine—driven with automatic startup in case of an electrical power failure. These pumps discharge to an oil cooler to maintain proper oil temperature and to a filter to catch any solid items which could damage the compressor.

From filters to compressor, most companies insist on Type 304 stainless steel piping to keep rust particles from forming and finding their way into the compressor. With pipe sizes of 1 1/2" to 2" and with the console close-mounted, the extra cost of stainless steel piping is small.

Building Installations

Where climate conditions dictate permanently-housed compressors, two basic building types are common. In areas of heavy snow where blowing winds create tall drifts, the fully enclosed building is a necessity; for almost all U.S.A. locations, however, a tropical type shelter is adequate. This provides a roof with *drop curtains*, building walls extending from the eaves to within 8' of the floor line.

A tropical shelter houses the compressor, gear box and driver. The operating floor is set about 6' above grade to allow lube and seal oil to gravity drain to the grade-mounted console outside the shelter. An operational control panel is located at floor level. The panel will occupy about 2' by 3-1/2' of floor space and requires both front and rear access. Many floor layouts have been ruined by the designer's omission of the compressor control panel.

Traveling Crane

When a permanent shelter is specified, the piping designer must supply a traveling crane capable of handling the heaviest removable piece (usually the rotor assembly) of the compressor or gear assembly.

Hook height refers to the traveling crane's hook which should be set at early layout. The hook height will determine crane elevation which will set the building eave height, a necessary dimension for getting building estimates.

Traveling cranes are usually *not* used for handling compressor driver parts. Driver piece weights should be investigated and for a turbine may be within the crane's lifting capacity. Mobile equipment is normally used for handling electric motor drivers and large parts for other drivers.

Traveling crane rails should extend past the building floor to a *laydown* or *drop area* where trucks may enter, receive parts and transport them to a repair shop. Since some repair might be done at this area, ample clearance must be provided.

Suction and Discharge Nozzles

Suction and discharge nozzle locations will vary with the exact type of installation and compressor selected and will often be determined by the type of driver. If the driver is a non-condensing steam turbine, the compressor will be mounted as low as possible (considering drainage to console) and all compressor nozzles will be located on top of the casing. If the driver is a total-condensing turbine with exhaust to a surface condenser, the compressor may need to be elevated above the condenser. Here, it may be better to locate compressor nozzles on the bottom of the casing.

Case Types

Figure 2-1 shows casing types and nozzle locations for centrifugal compressors. For installations inside buildings, traveling crane hook height will normally be higher for the horizontally split case compressor. Here the case must be lifted above rotor blades and set down outside of the building. Vertically split case rotors are taken out the front. There must be no obstructions to rotor removal. The designer must locate piping, instruments, building columns and the compressor control panel out of the way.

Compressor Drivers

Centrifugal compressor drivers, often with horsepower ratings over 10,000, are usually either electric motors or steam turbines, although gas-fired turbines may be specified for large volume duty. Gas engines, sometimes called *power engines* are commonly used for reciprocating compressor drivers, but are seldom specified as centrifugal compressor drivers.

Electric-motor drivers make piping design easiest, but the designer must know the type, synchronous or induction, to determine approximate size during layout. If a transformer is necessary, it must be located near the motor. An electric motor is normally larger than the compressor it drives. The author recalls one motor of 13,000 HP that was 20' high and 20' wide. This motor determined the size of the building.

The designer is faced with two types of steam turbines: condensing and non-condensing. The non-condensing type uses high pressure steam and exhausts lower pressure steam to a steam header. The condensing turbine exhausts to a *surface condenser*, a large exchanger, to recover condensate, or to atmosphere if condensate recovery is not important. Surface condensers are often grade-mounted directly below the compressor turbine. This arrangement employs a turbine bottom outlet nozzle directly connected via an expansion joint to the surface condenser. Since the compressor, gear and turbine are elevated above the surface condenser, this is called a *mezzanine installation*. Figure 2-2 depicts a mezzanine-mounted installation with surface condenser below. Figure 2-3 shows how a mezzanine foundation might look.

The surface condenser also can be located above the turbine on a flat-roof tropical shelter. The compressor and driver are grade-mounted with only enough elevation for oil drainage to the console. Horizontal centrifugal pumps are used with the elevated surface condenser.

Surface condensers may also be grade-mounted alongside a grade-mounted compressor. With the low surface condenser and very little NPSH, a can or barrel type condensate pump is necessary.

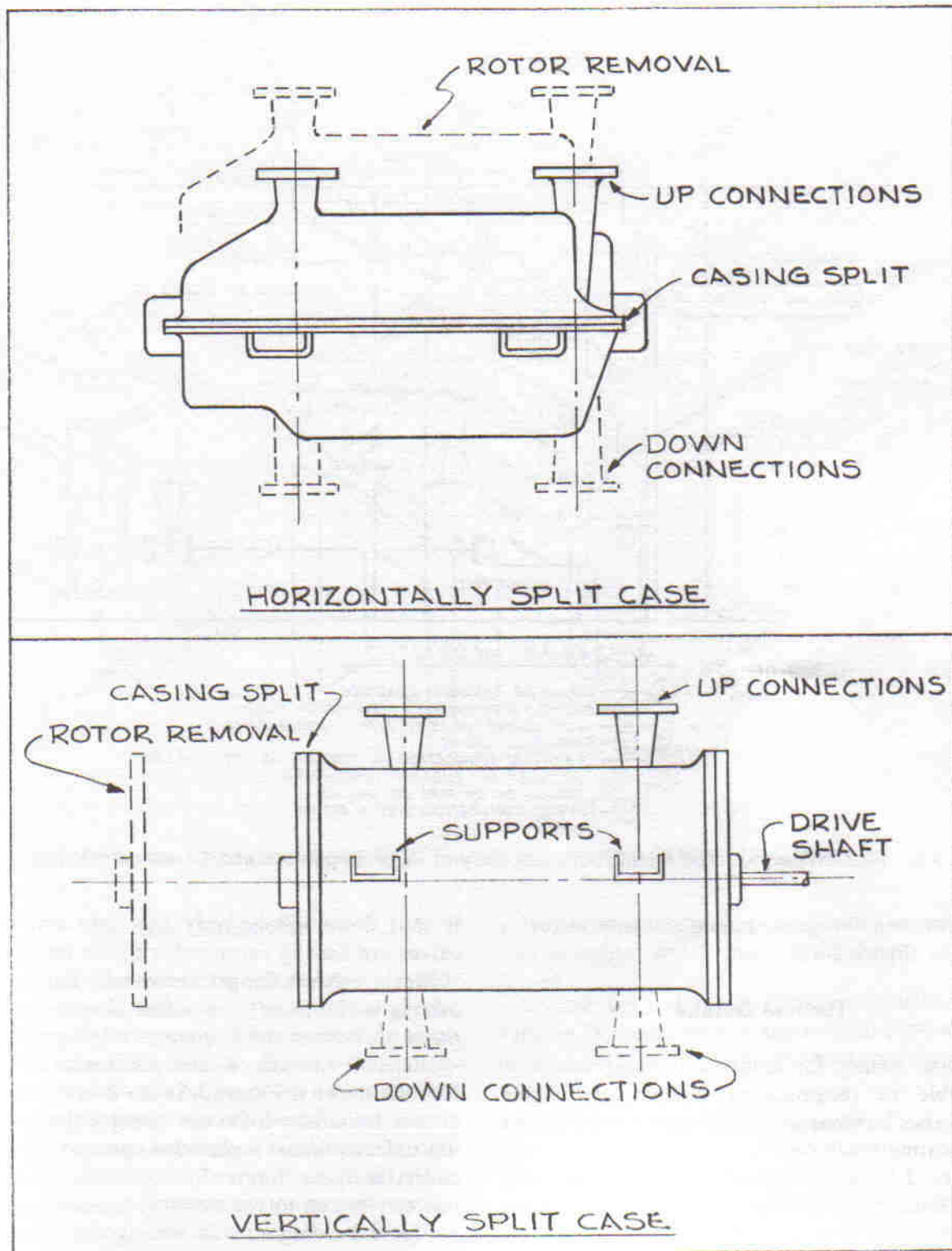


Figure 2-1. Casing types and nozzle locations for centrifugal compressors.

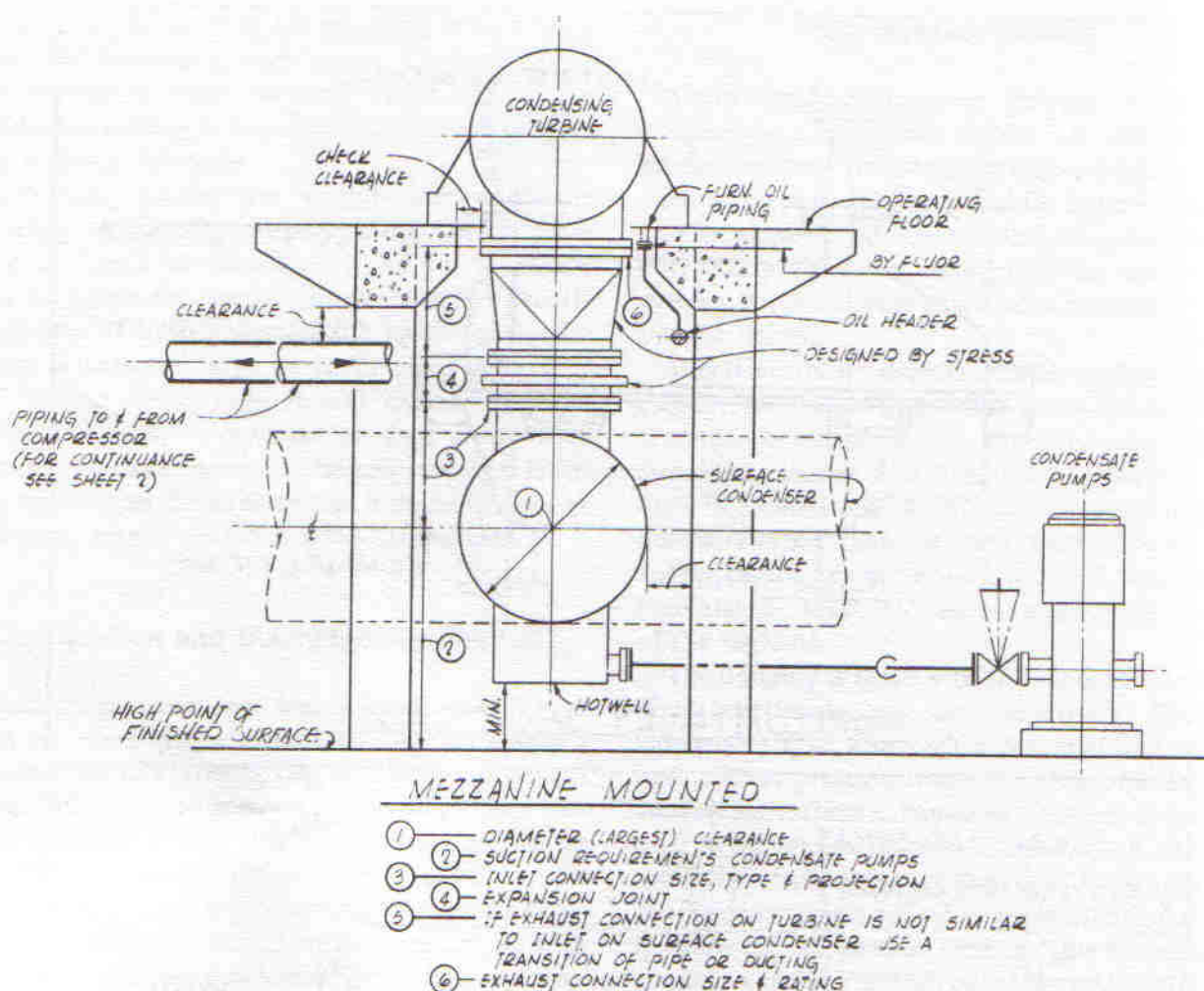


Figure 2-2. Mezzanine-mounted installation. Courtesy of Fluor Engineers and Constructors, Inc.

Platforming for grade-mounted compressors is shown in Figure 2-4.

Turbine Details

Turbine piping for centrifugal compressors is applicable to reciprocating compressor turbine drivers also; however, it is rare to see turbine-driven reciprocating machines.

Figure 2-5 shows typical turbine connections. Steam inlets may be rotated to the horizontal for better piping. Trip and throttle valves may be specified as angle valves allowing steam to come from above or below and eliminating the flanged elbow. Steam to these turbines is usually 600 psig or more with possibly some superheat. Very little condensate will form but complete precautions must be taken as condensate *will* form while the compressor

is shut down. Globe-body type trip and throttle valves are usually furnished with the turbine.

Steam-exhaust flanges are usually flat-faced, requiring a flat-faced companion flange and a full-faced gasket per ANSI piping code.

Items 1 through 4 and shaft-packing gland-leakoffs shown in Figure 2-5 should be run separately to a drain funnel. Do not combine them into one line unless a funnel is placed at operating floor level collecting these drains. From this funnel a single line can be run to the sewer system.

Figure 2-6 diagrams the sealing steam and gland condenser piping and the flow of steam to and from the turbine.

Figure 2-7, typical lube oil piping at compressor turbines, explains lubricating oil systems. Often both lube oil and sealing steam systems are furnished by the turbine vendor.

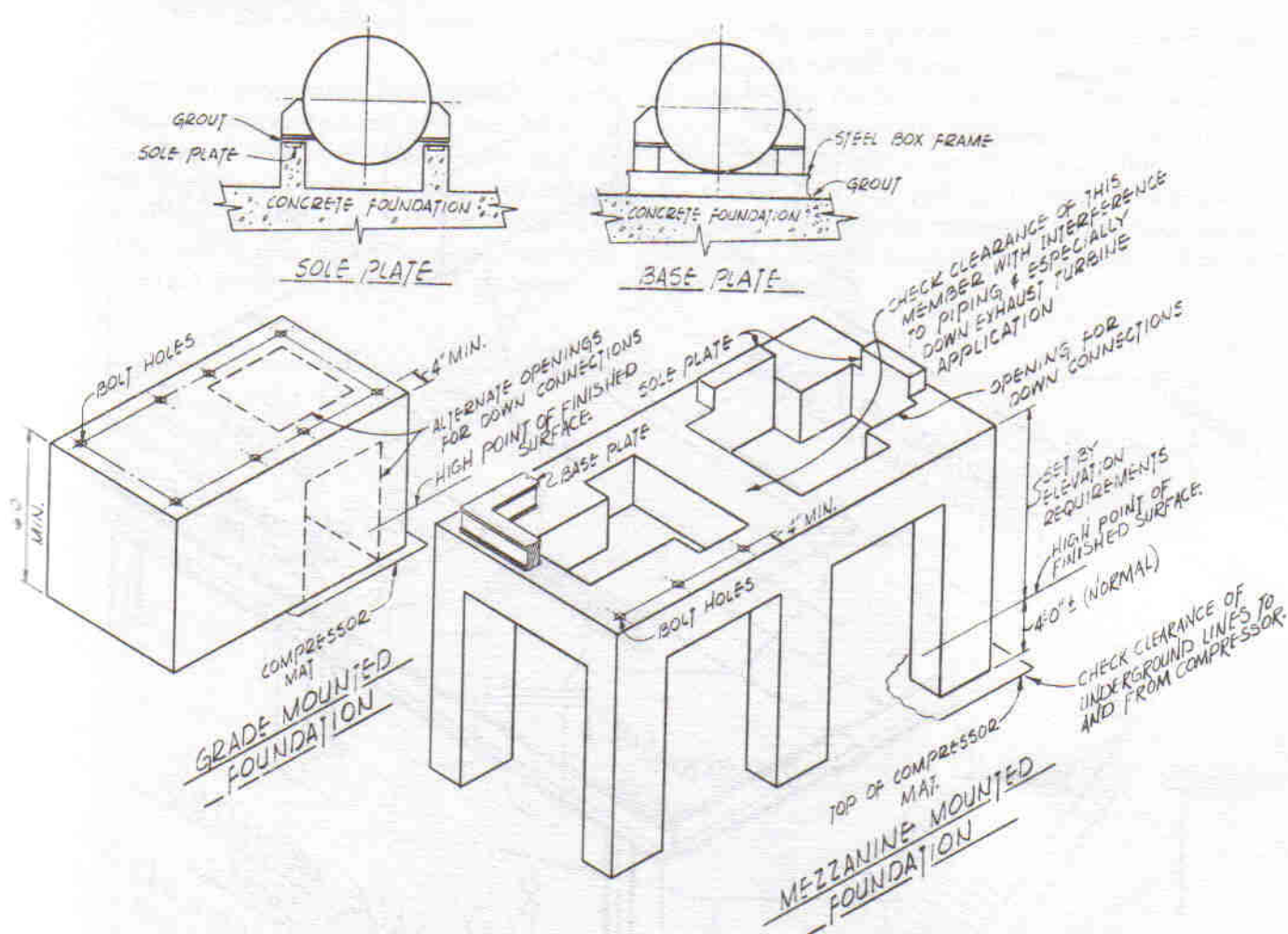


Figure 2-3. Mezzanine foundation. Courtesy of Fluor Engineers and Constructors, Inc.

Surface Condenser

The surface condenser is an integral part of a condensing turbine installation. It is a shell-and-tube type exchanger, usually with a fixed tube sheet (non-removable tubes). Figure 2-8 shows a mezzanine-mounted turbine exhausting down to its surface condenser and a grade-mounted turbine exhausting up to a grade-mounted surface condenser. In both installations an expansion joint is utilized to minimize forces and stresses on the turbine nozzle.

Also shown are a side elevation of a surface condenser, defining various parts and three types of commonly used relief valves attached to the surface condenser. The exhaust steam system and surface condenser operate on a vacuum and the relief valve is designed to open at the slightest positive pressure above atmospheric pressure. Note that each relief

valve has a water seal, a continuous water supply and overflow which must be routed to a drain funnel.

Figure 2-9 diagrammatically describes how vacuum is maintained in the surface condenser by continuous removal of air by ejectors.

Plot Arrangements

Relative relationships of centrifugal compressors and their auxiliaries are as varied as the horsepower available. Each case must be weighed with its own circumstances. As a guide for the designer, Figure 2-10 supplies three possible arrangements. Case 1 is for grade-mounted machines with grade-mounted surface condenser. While this arrangement requires the purchase of a low head condensate

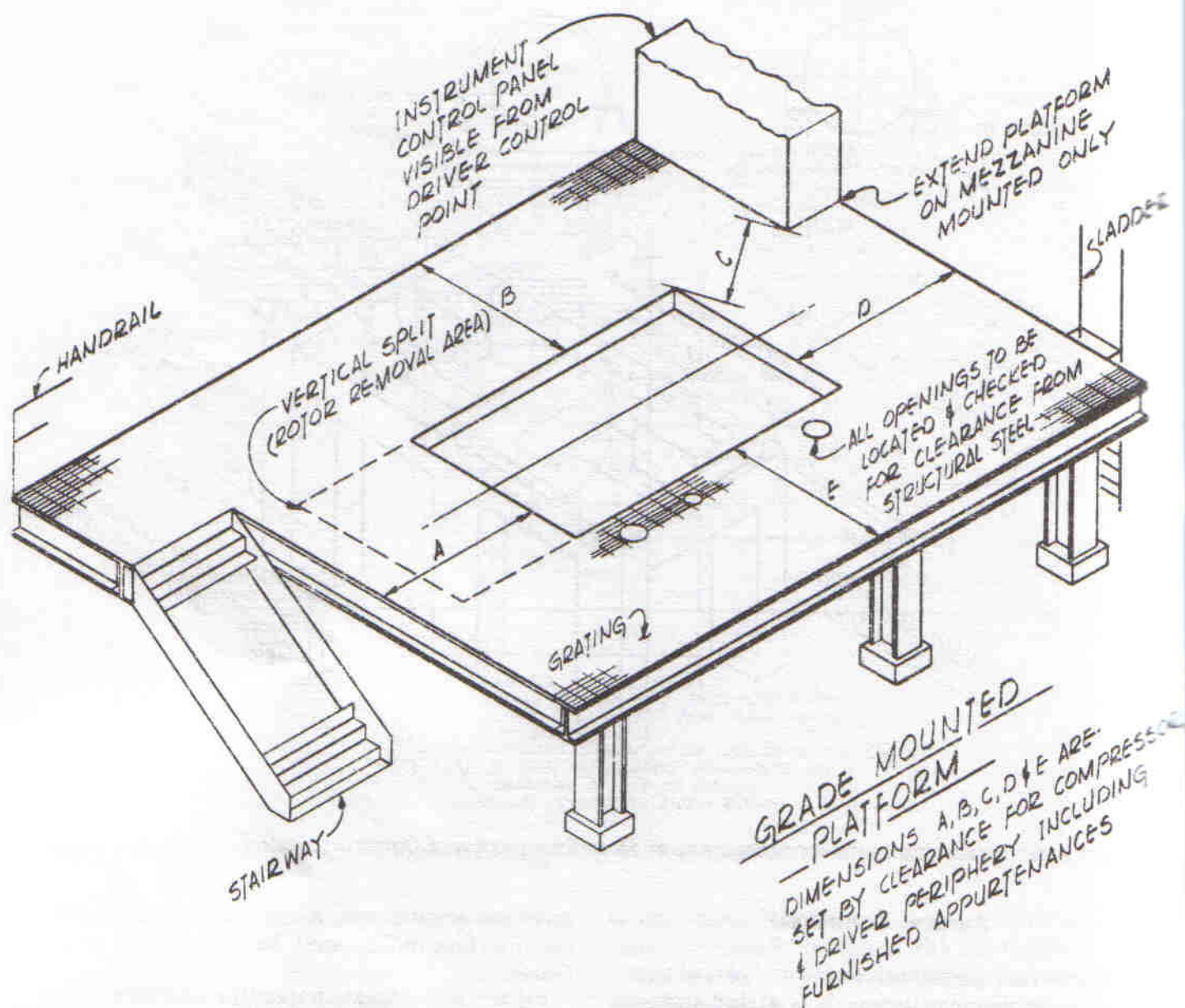


Figure 2-4. Platforming for grade-mounted compressors. Courtesy of Fluor Engineers and Constructors, Inc.

pump, it is probably the least costly. Separate lube and seal oil consoles are shown for various space requirements.

Case 2 deals with mezzanine-mounted compressors with consoles located at their sides. Case 3 is also concerned with mezzanine-mounted units with consoles located in front near the main pipeway. As an alternative, the compressor could be located near the rack with the console behind it—away from the rack. This would make discharge

line routing in the rack very short.

Figure 2-11 consists of three equipment layouts showing an electric motor or a non-condensing turbine which exhausts steam to a piping system.

Figure 2-12 depicts relative elevation requirements of compressor, console and operational platforming.

Figure 2-13 represents piping at top or bottom-located compressor nozzles.

Seal Oil Overhead Tank

All centrifugal compressors have seal oil piped to them. Process compressors of any size have an overhead seal oil tank that *rides* on the seal oil pressure and maintains a reserve supply of critical seal oil available should the system lose its source of power. The reserve will function a short time until operator action solves the power loss problem.

With the loss of pressure source, pressure loss in the seal oil system would cause immediate loss of flow. To keep the flow going during loss of pressure source, the seal oil tank is elevated 20' to 30' above the compressor centerline. The head in the line will be enough to force seal oil to flow to the compressor. Compressor manufacturers designate required minimum height of seal oil tanks for their specific machines.

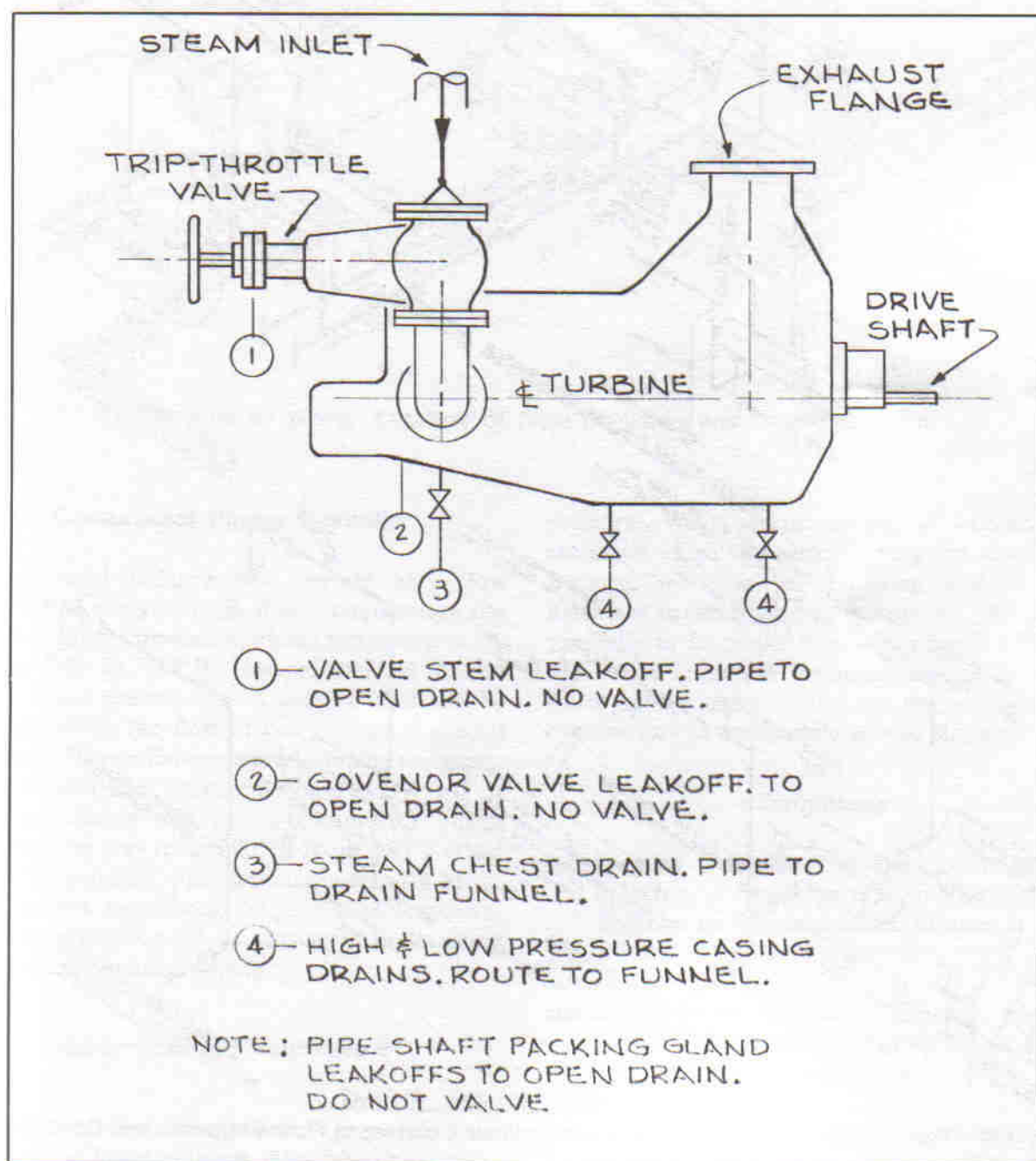


Figure 2-5. Typical turbine connections. Courtesy of Fluor Engineers and Constructors, Inc.

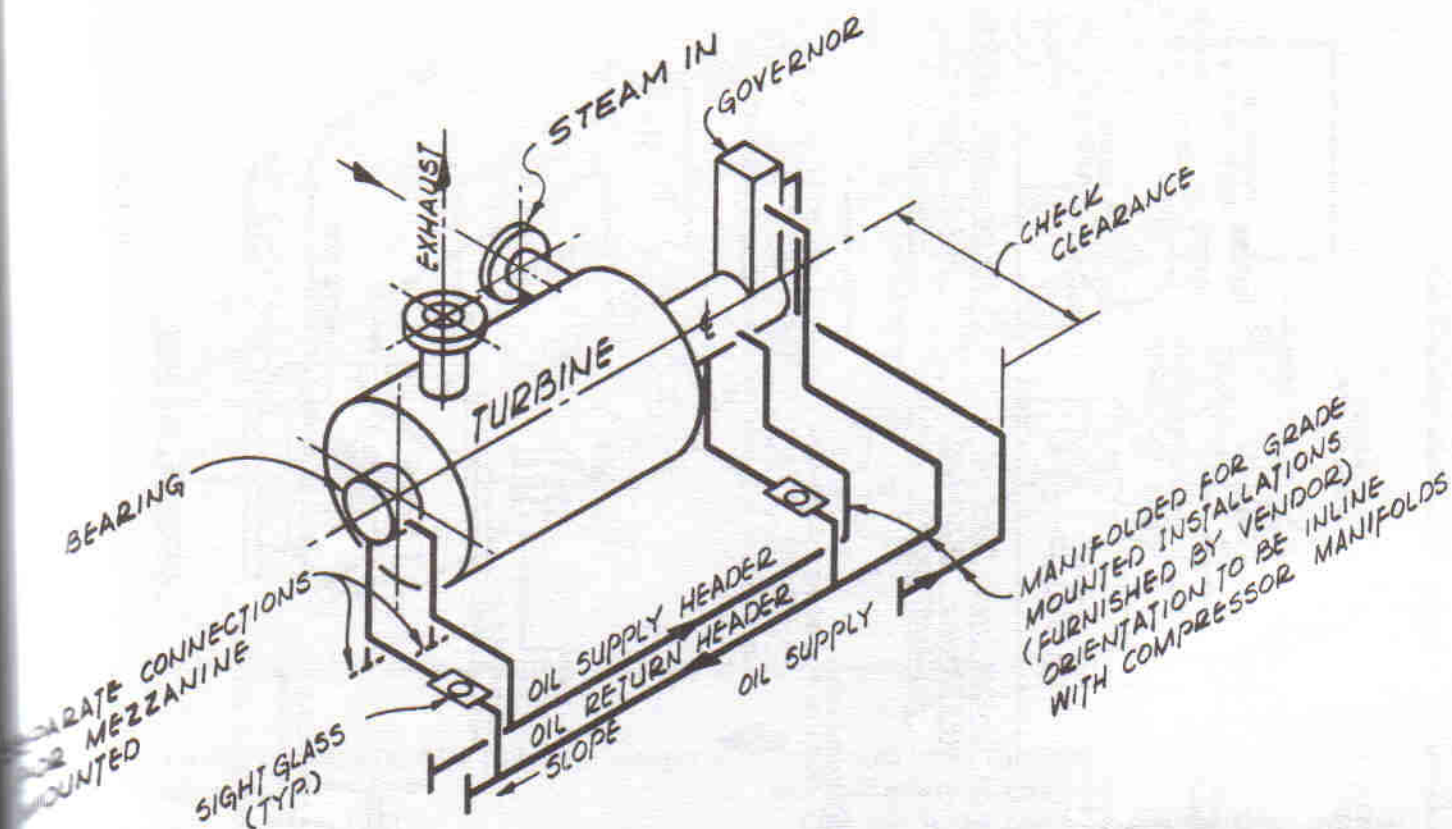


Figure 2-7. Typical lube oil piping. Courtesy of Fluor Engineers and Constructors, Inc.

Compressor Piping Flexibility

Centrifugal compressors operate at a low temperature and very little, if any, temperature rise occurs during compression. Piping temperatures are usually 100 to 130°F. Compressors, in a unit employing a reactor with a catalyst that can be regenerated by the flow of hot gas, are a special problem of immediate concern to piping designers. Regeneration may occur only once every year or two; but during this period compressor piping temperatures may reach 300°F. While 300°F is not a high temperature, when it is combined with 20" to 36" line sizes, large forces are generated. Regeneration temperatures must be considered in designing suction and discharge piping.

Reciprocating Compressors

Reciprocating compressors generally are specified for lower volumes than centrifugal com-

pressors. With several stages of compression, extremely high pressures may be developed. Because of their reciprocating action, these machines cause piping to pulsate, to vibrate and generally to fatigue if it is not properly designed. The most common reciprocating compressors, which anyone can examine, are the very small air compressors in automobile service stations.

Definitions

reciprocating Moving alternately backward and forward, or having parts so moving. Employing the rectilinear motion of one or more pistons in cylinders.

compressor frame Crankshaft housing. For gas-fired machines, the total driver. Does not include compression cylinders.

compression cylinders The part that intakes vapor at low pressure, compresses and discharges it

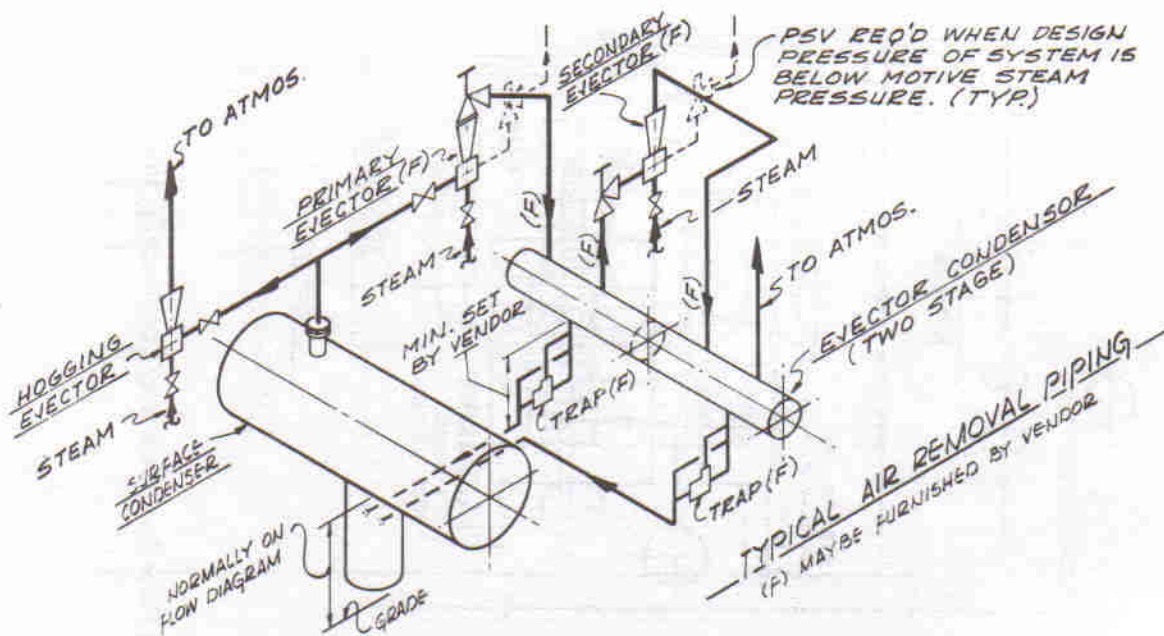


Figure 2-9. Typical air removal piping. Courtesy of Fluor Engineers and Constructors, Inc.

at a higher pressure. Also called the compression piston.

single-acting cylinder Having one suction, compression and discharge area per cylinder.

double-acting cylinder Having two suction, compression and discharge areas per cylinder. May compress two different vapors.

compression stages Number of times the vapor is compressed by going through a compression cylinder to increase pressure.

Compressor Driver Types

Reciprocating compressors utilize electric motors, steam turbines and gas-fired engines as drivers. Designer's problems with electric or steam turbine drivers have been discussed in the preceding pages, so only the gas-fired engine driver will be considered here. In practice this type is the most common.

A gas engine driver may have as few as two or as many as 16 or more firing cylinders. The higher horsepower machines may be turbocharged. Drivers up to 2,000 HP are common and larger ones are available. A gas engine driver may be easily

recognized by its flywheel, which regulates its speed and uniformity of motion.

Fuel gas is the common fuel for these internal combustion machines. Because the pistons fire and displace vapor, a reciprocating action occurs, causing vibration. A very heavy mass of concrete is required as a foundation to resist this vibration and keep the driver from rotating. Most compressor manufacturers suggest a concrete foundation about three to five times the total compressor weight. (Concrete weighs 4000 lbs. per cubic yard)

Compression Cylinders

Compression cylinders are attached to the crankshaft in necessary quantities and sizes to do the required gas compression. The size of the cylinders is the volume or the displacement, in cubic inches, of the compression area. This is calculated by multiplying the area of the cylinder by the stroke, or travel, of the piston.

Each cylinder of a compressor may be *single-acting*, with one compression chamber, or *double-acting*, with two compression chambers. *Angle type* cylinders are all located on one side of the driver crankshaft, *balanced-opposed type* have cylinders on both sides of the crankshaft. The balanced-

Process Piping Design

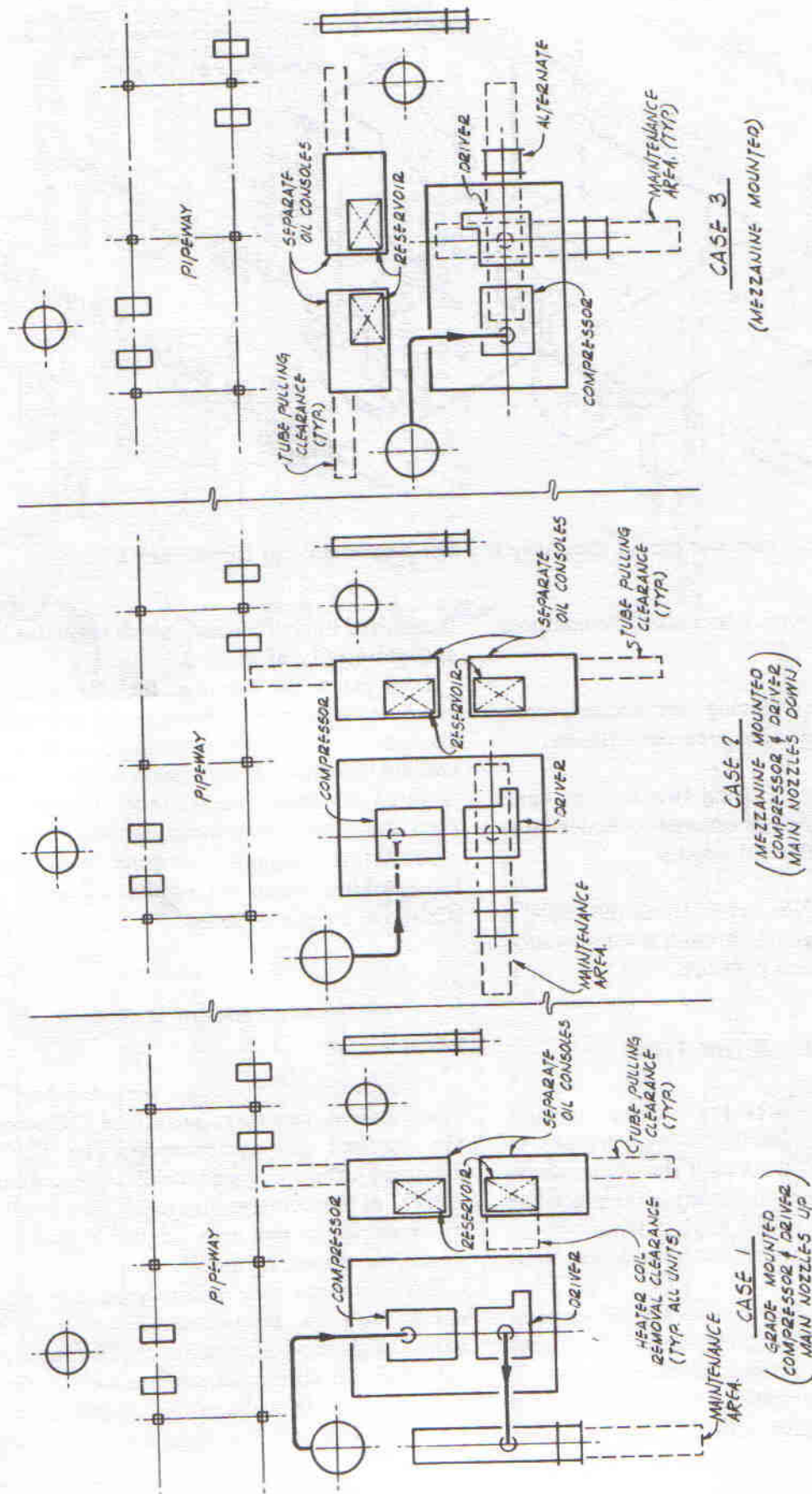


Figure 2-10. Condensing turbine driver and surface condenser arrangements. Courtesy of Fluor Engineers and Constructors, Inc.

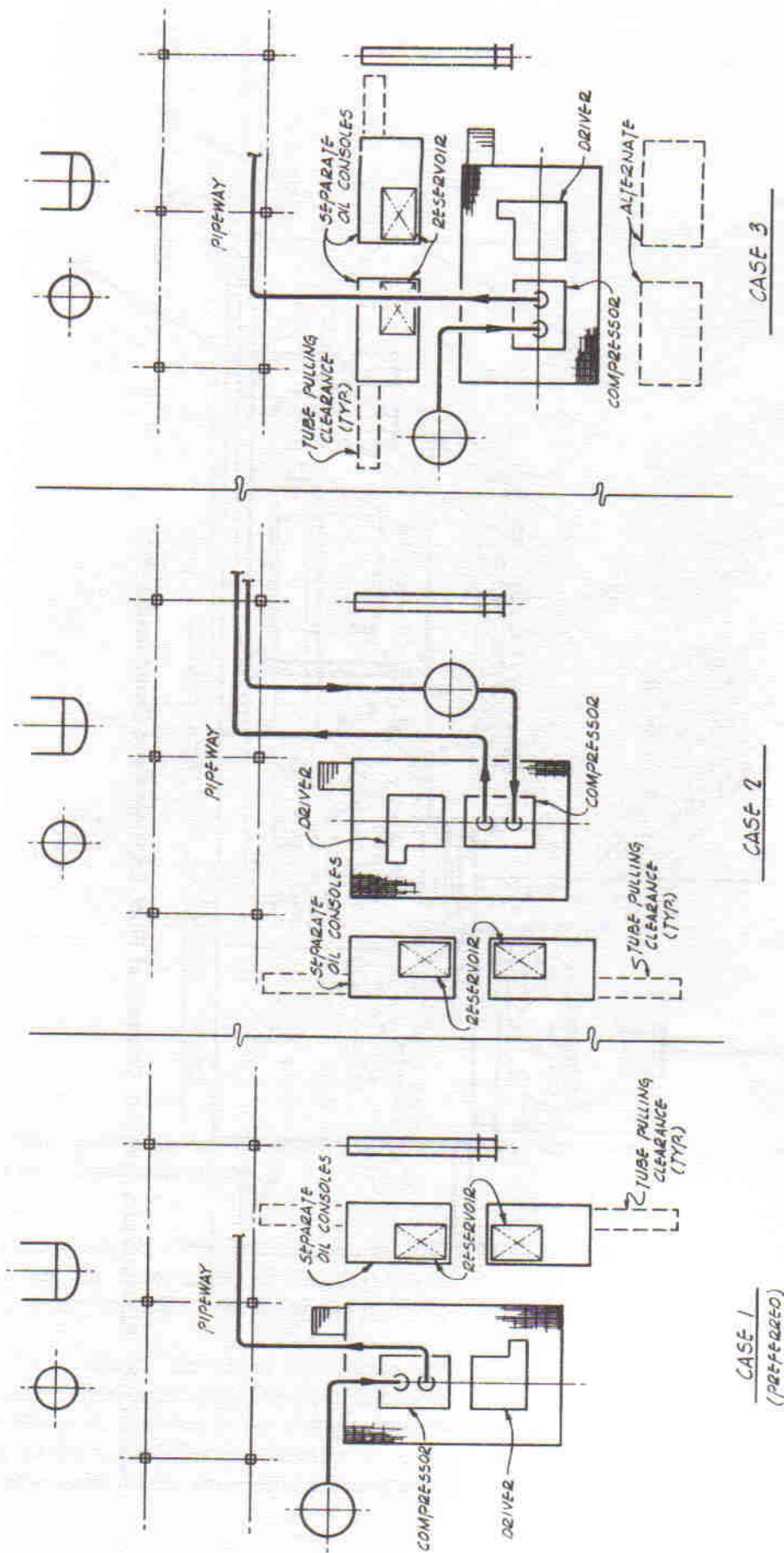


Figure 2-11. Motor or back pressure turbine arrangements. Courtesy of Fluor Engineers and Constructors, Inc.

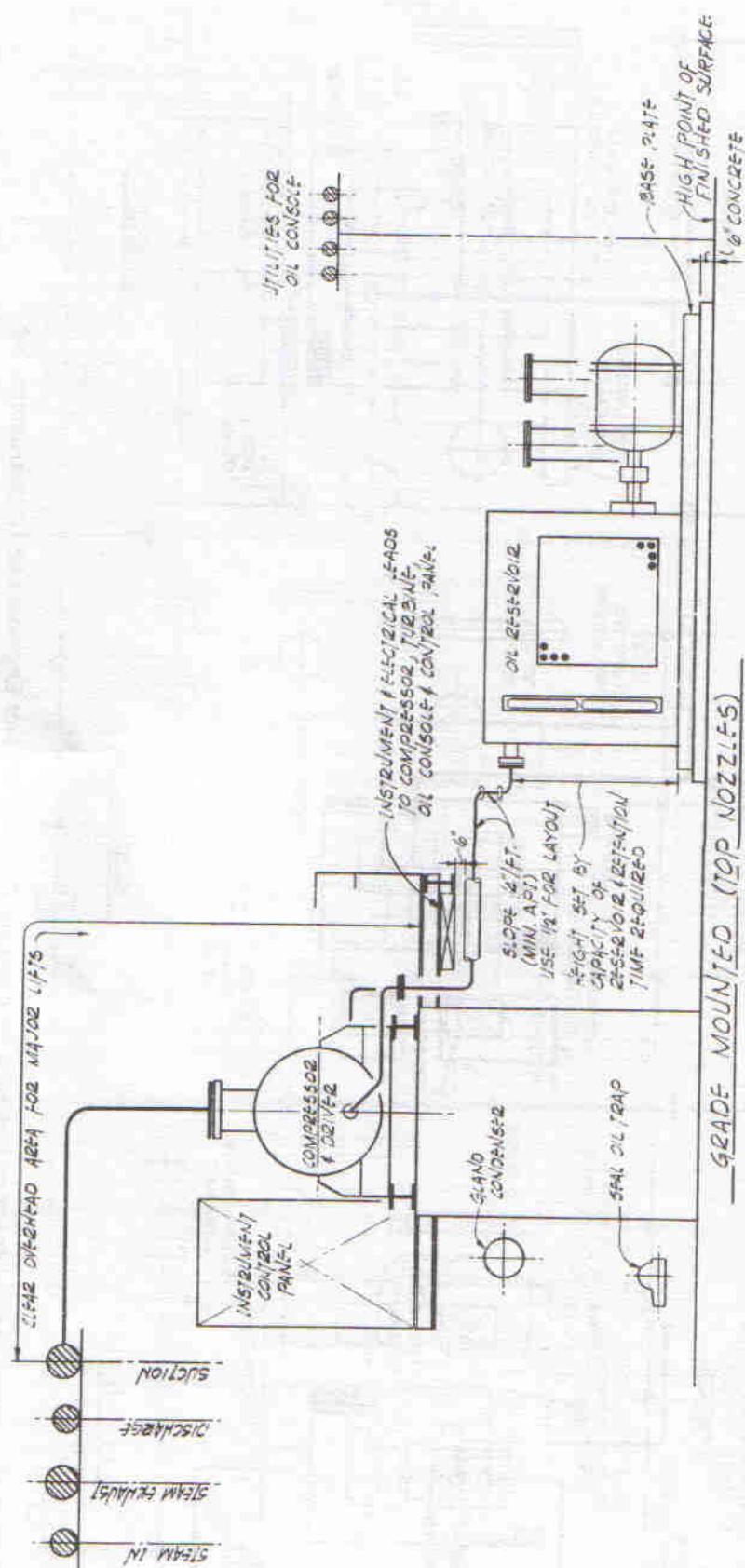


Figure 2-12. Elevation arrangement. Courtesy of Fluor Engineers and Constructors, Inc.

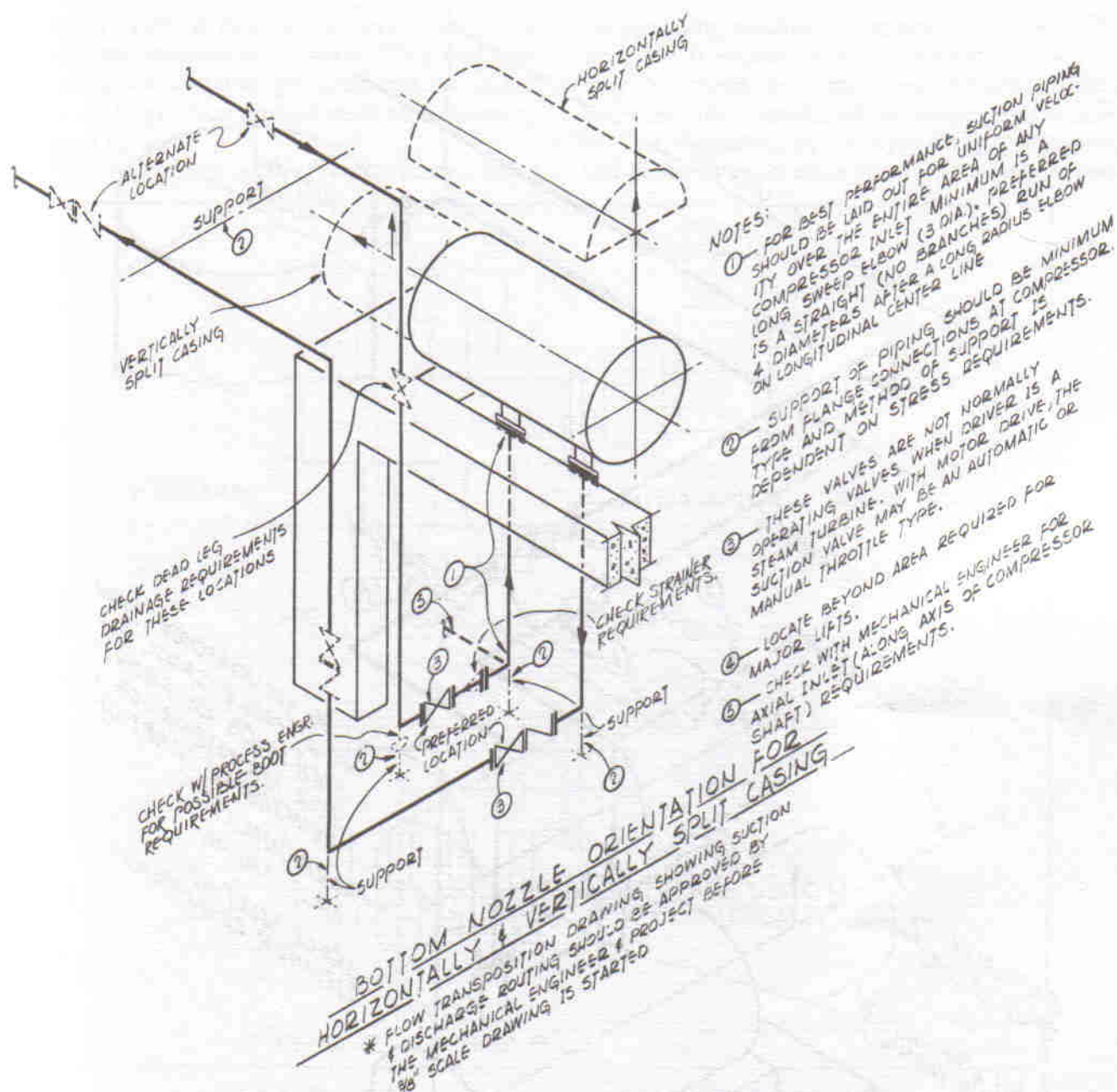


Figure 2-13a. Piping layout at centrifugal compressors—bottom nozzle orientation. Courtesy of Fluor Engineers and Constructors, Inc.

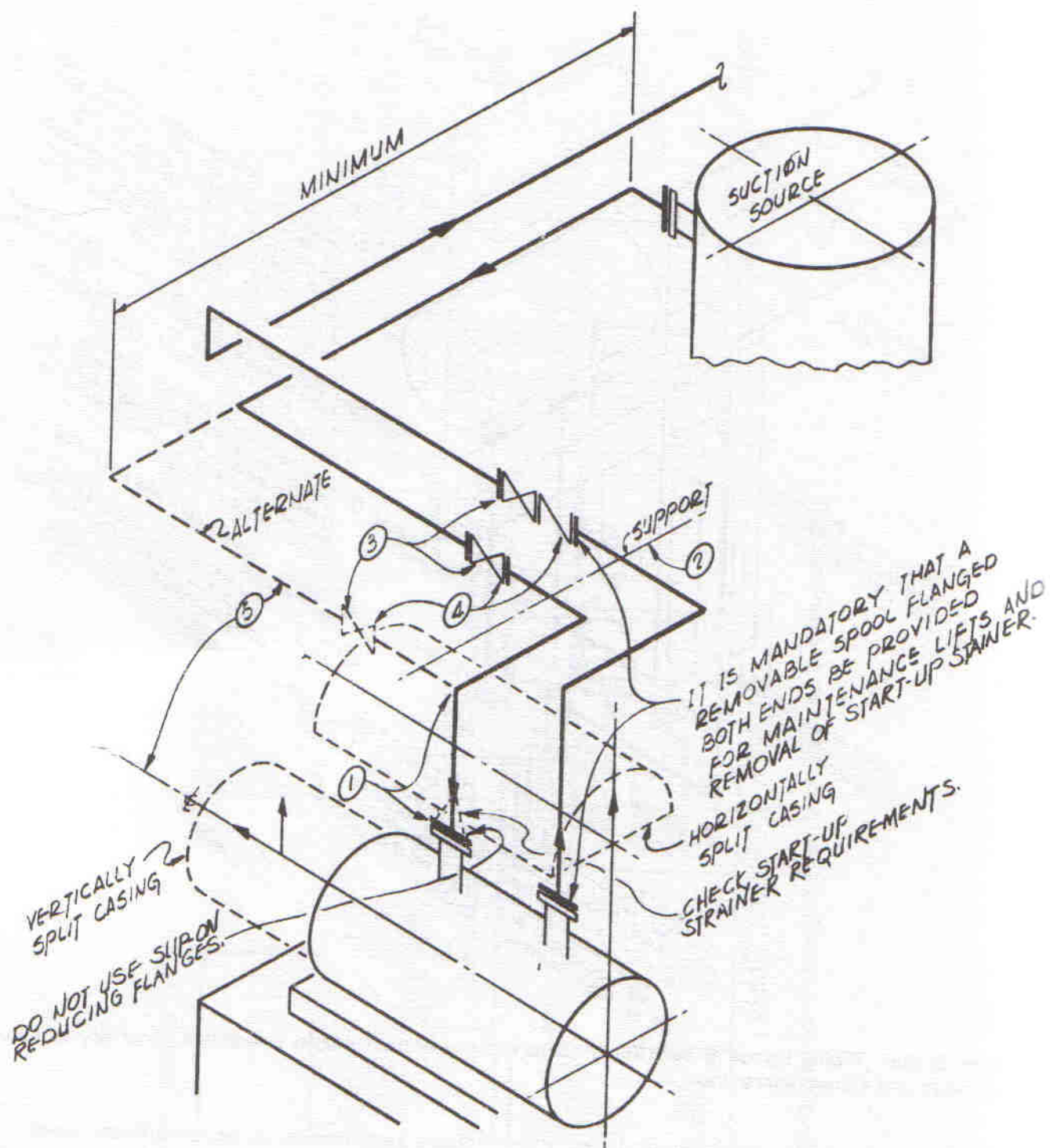
opposed type is usually electric-motor driven. Putting cylinders on both sides of the crankshaft produces a balancing effect which reduces machine vibration.

Figure 2-14 shows the three most common reciprocating compressor types. Type 1 is balanced-opposed. The gear depicted is not always needed, depending on the driver selected—electric motor or steam turbine—and on the frame and driver speeds.

Gears may increase or decrease frame speed.

Type 2 is a gas-fired angle-type engine. The compression cylinders are all on one side of the frame. In all compressors, cylinder diameters and lengths vary according to composition, pressure and volume of gas to be compressed. Dimensions from frame centerline to cylinder nozzles will vary with compression forces.

Type 3 is the horizontal or straight-line type,



TOP NOZZLE ORIENTATION FOR
HORIZONTALLY & VERTICALLY SPLIT CASING

* SEE NOTES ON BOTTOM NOZZLE ORIENTATION

Figure 2-13b. Piping layout at centrifugal compressors-top nozzle orientation.

commonly referred to as a *one-lunger* because it only has one compression cylinder. This type usually has severe vibration problems and the author suggests a larger than normal mass of concrete to withstand it.

Gas compression raises temperature. In a

reciprocating machine, compression is violent and heat rise is greater. Inlet temperatures of 100°F. may be raised by compression to over 200°F. Consequently, compression cylinders get extremely hot and, depending on the vapor being compressed, will probably need some form of cooling. A con-

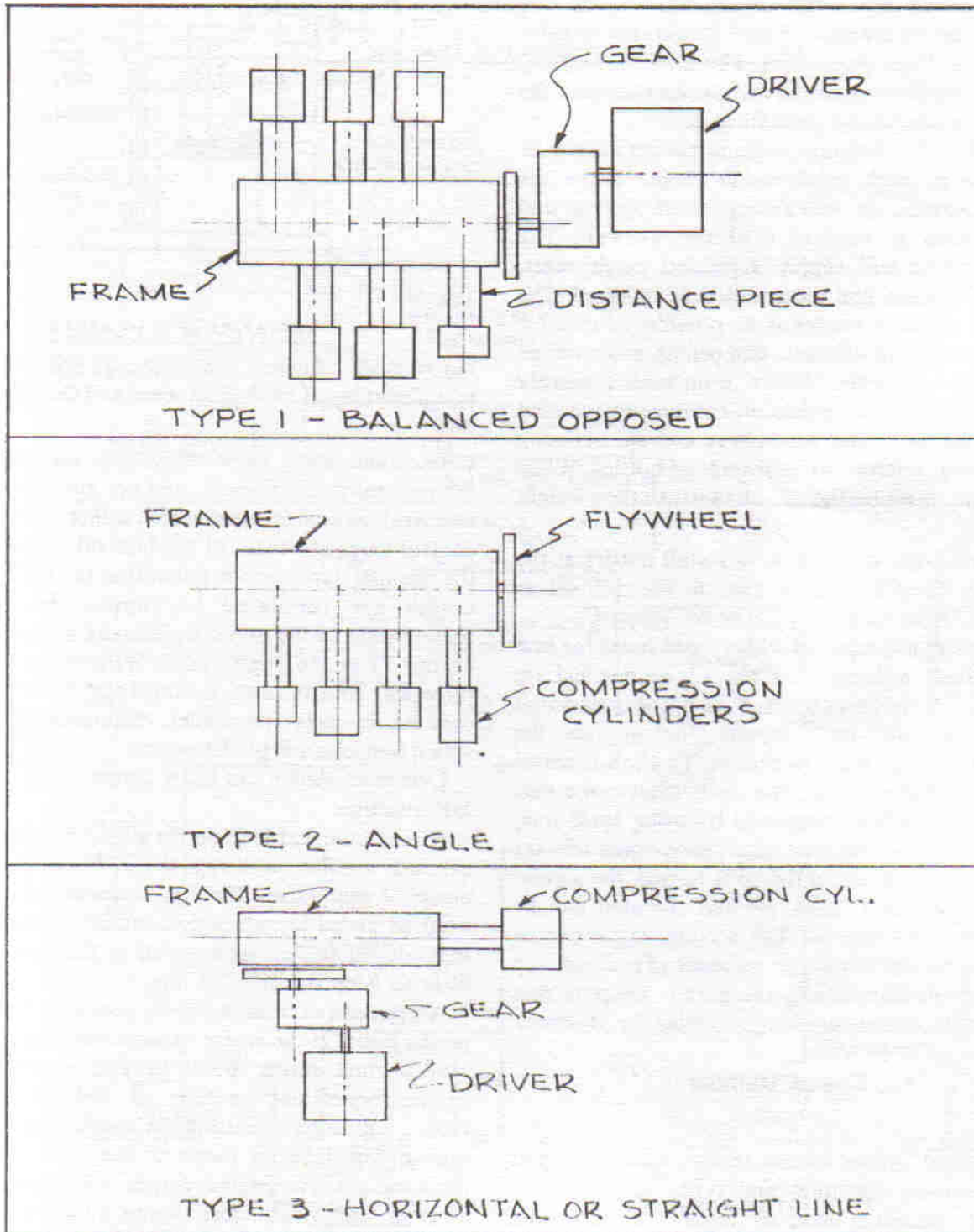


Figure 2-14. Reciprocating compressor types.

tinuous cooling water stream is needed for intense heat rises. For lower heat increases a glycol-filled jacket may suffice.

Cylinder support, independent of piping, is provided by a separate pipe connecting near the cylinder end and running to the concrete fastened to the top of the mat—often these supports are furnished with the machine. *Never* support the cylinder from operating—floor steel. The steel may spring slightly and the support be lost. *Always* support the cylinder if the vendor recommends it.

Suction and discharge volume bottles should be provided at each compression stage. There are many formulae for calculating bottle volume and each yields a slightly different answer. The manufacturer will supply suggested bottle sizes, often in volume, and these should be followed. The purpose of these bottles is to provide volume for rapid intake and exhaust, dampening pulsation as much as possible. Some companies supply computer-designed pulsation-dampening suction and discharge bottles which have internal baffling and piping, referred to as *trombone* bottles. While expensive, these bottles are often worth their weight in gold.

Figure 2-15 shows how to install bottles at the cylinder. Keep bottles as close to the cylinder as possible. Note location of cylinder support.

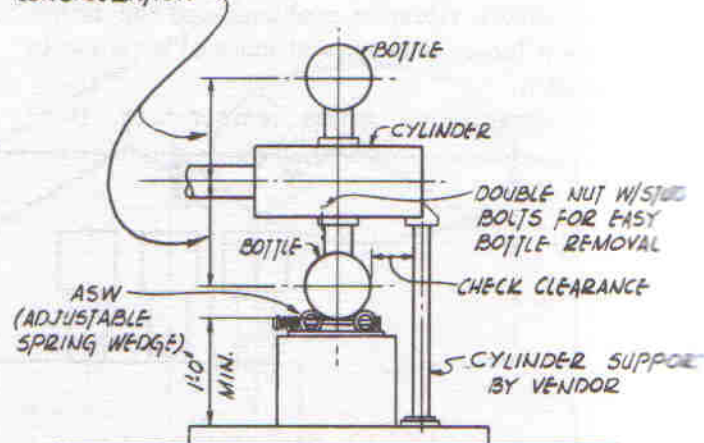
Cylinders are supplied with tapped holes for bolt studs. Studs with oversized threads on one end are screwed into the holes through the bottle companion flange; then nuts are tightened. Once in place, the studs are very difficult to remove. To allow removal of the discharge bottle, the studs must come out. Easy removal can be assured by using studs long enough to take two hex nuts. Then when the nut next to the companion flange is turned, the second nut will not let it back off and the stud can be loosened and removed. The suction bottle can be raised over the studs for removal. To avoid any possible mis-installation, the author suggests that both suction and discharge bottles be doubled-nutted.

Engine Utilities

Gas-fired engine drivers require several utilities for operation. Quantity and types vary with the specific machine, however Figures 2-16a and b, show utilities common to most machines.

Figure 2-16a pictures lube oil, air intake, engine

DIMENSION IS MINIMUM
WITH VALVE REMOVAL
CONSIDERATION



ELEVATION @ CYLINDER

Figure 2-15. Suction and discharge bottle installation. Courtesy of Fluor Engineers and Constructors, Inc.

exhaust and vents. Lube oil systems vary from the simple manual system shown to automatic temperature control types which utilize a three-way control valve upstream of the lube oil cooler. With the manual type, water quantities to the lube oil cooler are regulated to supply the proper temperature to the driver by keeping a close check on the TI at the engine inlet. With the automatic three-way control valve, the third port of the valve is used to by-pass the cooler, maintaining proper water temperature to the engine.

Line sizes shown are fairly common for a 2,000 HP machine.

It is economical to hang the air filter beneath the exhaust muffler, utilizing the H-frame for both pieces of equipment. The area underneath the filter must be paved to reduce dust intake. Sometimes a separate oil system is mounted at the base of the filter to keep the element oily.

An exhaust expansion joint is necessary to reduce piping forces at the engine exhaust manifold flange.

It is good design to use flexible hose for final engine connections for lube oil. This will greatly reduce vibration transmission possibilities in oil piping. The lube oil pump is furnished with and mounted on the engine driver. Consequently, it vibrates and, with steel piping connected to it, transmits these vibrations to piping.

Lube oil piping must also have a small drain valve

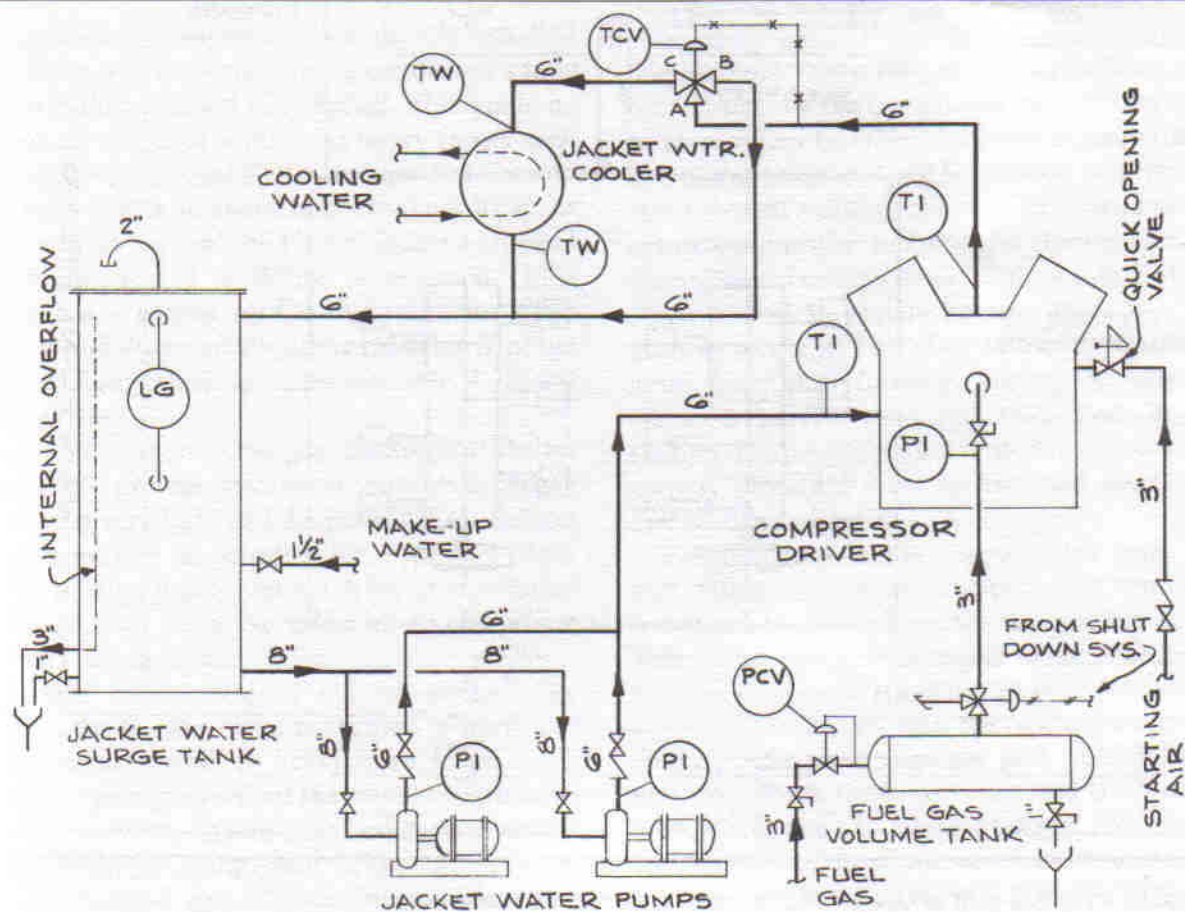
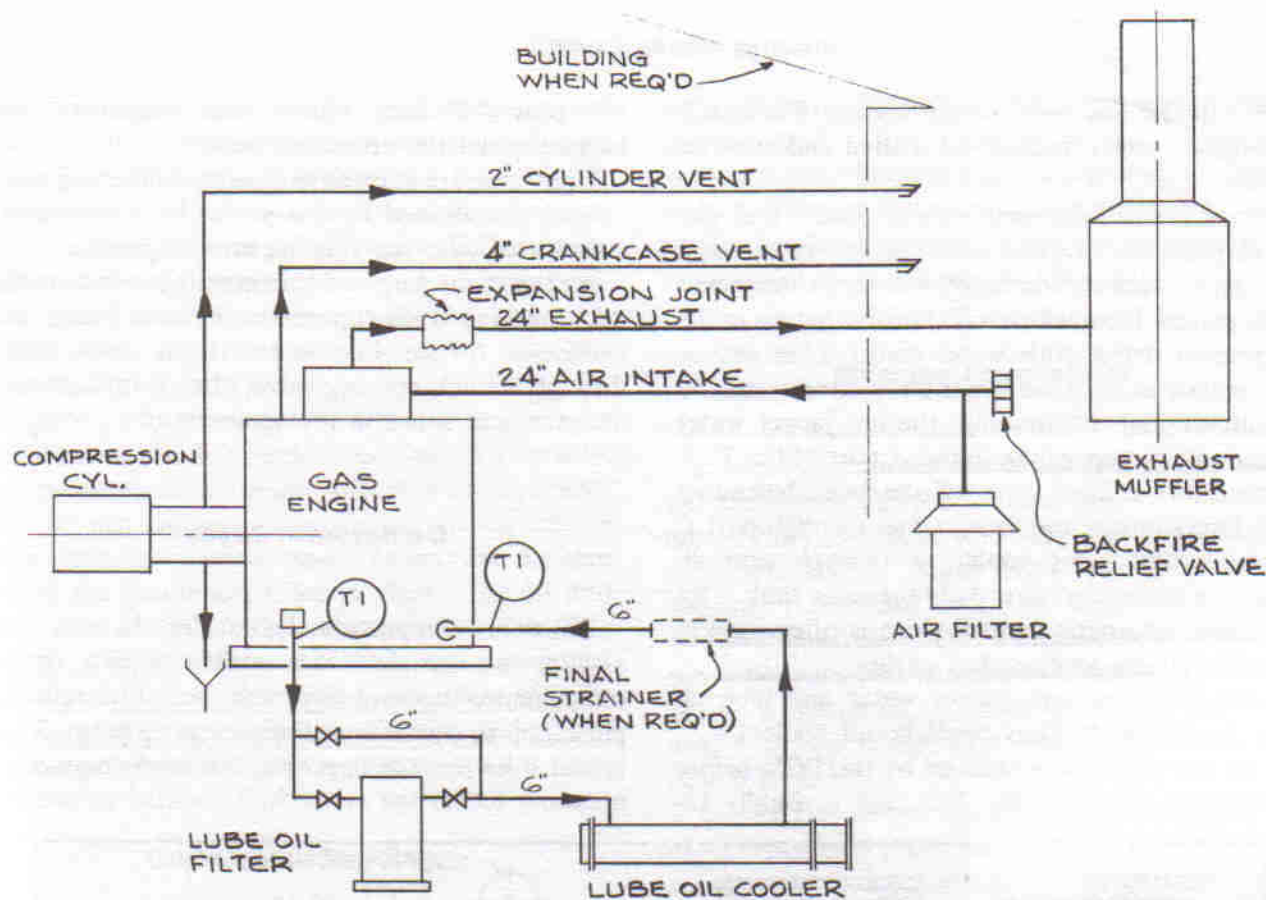


Figure 2-16a and b. Reciprocating compressor utility flow diagram.

located at the low point of the system. For initial start-up, a special flushing oil is used and must be drained.

Figure 2-16b represents jacket water, fuel gas and starting air. Starting at the jacket water surge tank, an 8" suction line supplies water to the jacket water pumps, from which a 6" line discharges to the compressor driver (this water controls the engine heat exactly as does the water circulating system in an automobile). Continuing, the hot jacket water comes out the top, going to the *A* port of the *TCV* (temperature control valve). From here, depending upon temperature, the flow can go through port *C* to the jacket water cooler or through port *B*, bypassing the cooler, directly to the surge tank. This three-way automatic control valve is often used in lube oil systems as described earlier.

Shell and tube type jacket water and lube oil coolers are shown. They could be air coolers.

Fuel gas pressure is reduced by the *PCV* before entering the volume tank. This tank is usually 12-

14" pipe 4-5' long, closed with weld caps and located under the operating floor.

High pressure starting air tanks, containing a set volume determined by the particular compressor, are located near the starting air compressor.

As the name implies, starting air is used to put the machine into operation before firing the cylinders. An air line is run from these tanks through a quick-opening valve, often furnished with the machine, and into the compressor.

Compressor Layout

Effective compressor layout results in cost savings on process and utility piping, good maintenance accessibility and possibly reduced pulsation in suction and discharge piping. Poor layout does just the opposite. For angle-type compressors, locate the crankshaft parallel to suction

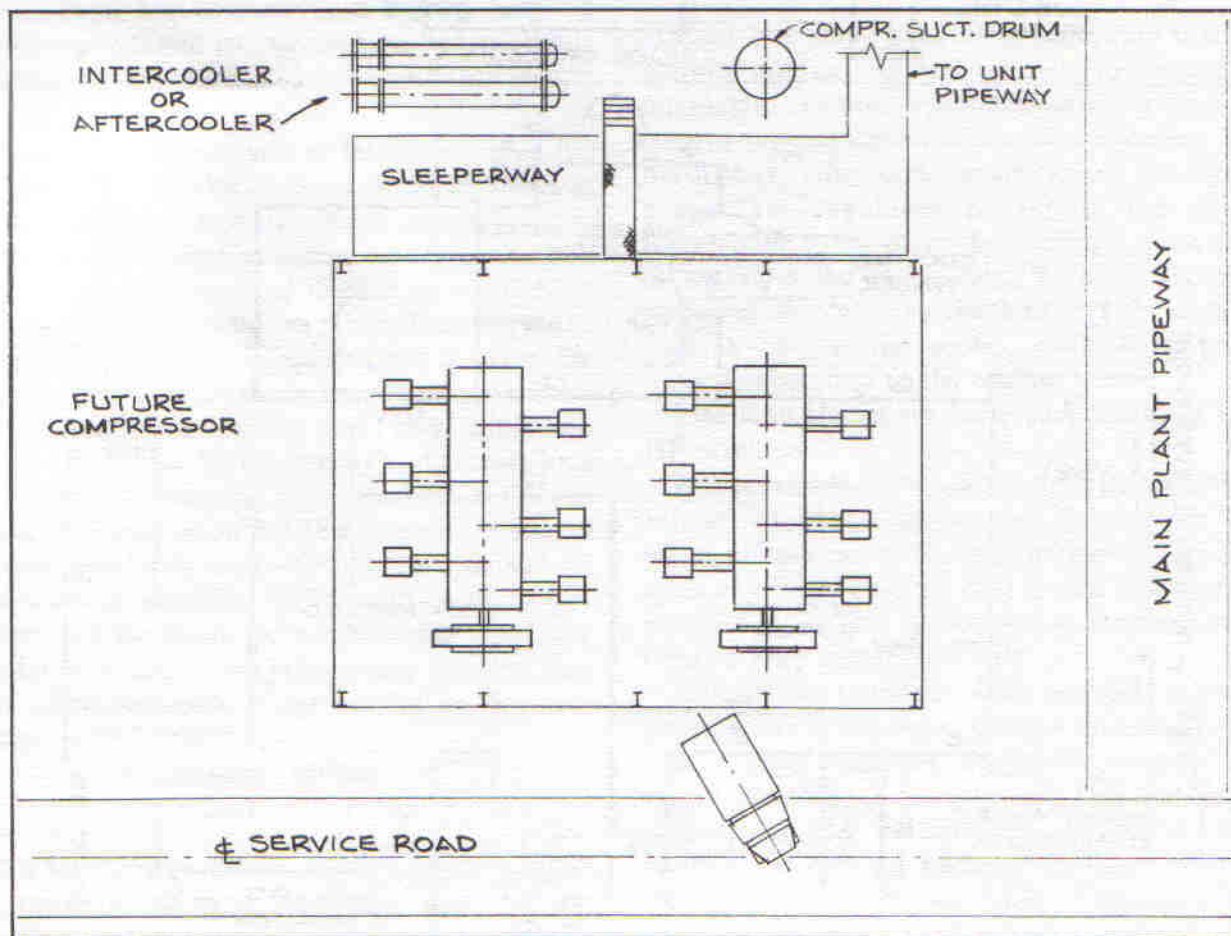


Figure 2-17 Typical plot arrangement for reciprocating compressors.

and discharge headers. For balanced-opposed machines, the crankshaft should run perpendicular to suction and discharge headers.

Figure 2-17 shows balanced-opposed reciprocating compressors with crankshafts perpendicular to the sleeperway. Lines to and from compression cylinders are shorter with this layout. A synchronous electric motor is shown for this compressor.

Figure 2-18 shows proper layout for angle-type compressors. With cylinders located on one side, process piping is minimized with this arrangement. For the gas engine driver shown, the air intake filter, exhaust silencer and coolers are located behind the machines. Coolers shown for oil and water may be either air coolers, with two cooling cells in a single unit (as pictured) or water-cooled exchangers. Intercoolers and aftercoolers may be water-cooled or air-cooled. Availability and cost of cooling water determines the type selected.

Compressor Buildings

Reciprocating compressors are usually installed in a building. For extreme climatic conditions a fully enclosed building should be specified. This would be for areas of very cold winter and heavy snows such as the northwest United States and most of Canada which have winter temperatures of minus 40°F. or lower. In most parts of the United States a tropical type, prefabricated building is selected. This building has a gabled roof with continuous ridge ventilator and drop-curtain siding to within 8' of the operating floor which is approximately 4' above normal grade.

Since compressors move gas, the tropical shelter is selected to provide maximum ventilation. When compressing very light and dangerous gases such as hydrogen grating is selected for operating floor material because it provides much better ventilation than a solid floor plate. Never design an area where gases may accumulate.

Buildings are provided, not to protect the machines, but to offer some protection to operators and maintenance men. In heavy snow areas, drifts might cover compressors but they would continue to perform. However, should plant operation require an adjustment in compressor speed or capacity, operators couldn't get to necessary machine con-

trols. With totally enclosed buildings, control valve stations and, often, lateral block valves—are located inside. These are the compression cylinder suction, discharge and start-up by-pass valves. Compressor headers are rarely located inside as this adds to unit cost by increasing building size.

Machine Foundations

Compressor foundation design is a science itself, but the piping designer should know a few basic design rules as it is he who supplies the general installation layout. Since reciprocating machines pulsate, foundation mass or weight is critical. Installed concrete weighs approximately 4,000 lbs. per cubic yard and compressor foundations should be, as a minimum, from three to five times the weight of the compressor—including driver, and gear if required.

Blocks rise above operating floor level and the compressor base plates rest on the blocks. Although compressor foundations should be unitized, mats (the spread out bearing-concrete which supports compressor blocks) must be combined for multiple compressors. Preferably, do not set building column foundations on the compressor mat. Vibrations can be transmitted from the machines through the block and mat into the column foundation and from there into the steel building column. This could cause the entire compressor building to vibrate and rattle. Compressor building floor framing is tied into both block and mat concrete because there is no other place to secure it. This often results in vibration and noise from steel framing, grating or floor plate. Noise is usually corrected after start-up by installing dampening gasket material where the noise occurs. Vibration must be tolerated since nothing can be done about it.

The discharge bottle support also rests on the mat. Often, suction and discharge line supports are connected to the mat within the building confines. This forces piping designers to make final locations early in the layout stage for all items connected to the mat. It is the first item the field crew will need to pour. After mat concrete has set, forms are removed, block forms are built and the block concrete is poured. To allow yourself the maximum design time and to minimize vibration do not locate anything on the compressor mat foundation that

does not have to be there. All items connecting to the mat must be located before the mat concrete is poured.

Clearances

Often, the compressor building must be sized very early in layout. Firm equipment data is unavailable. The designer may know the overall length of his machine is 20' and the width is 14'. From this he must size the building. To do this he must allow adequate clearance for maintenance plus possible control valve stations, lube oil equipment, local panel boards, etc.

A good rule of thumb at the early layout stage is to leave a 6' clearance all around the compressor. In practice, this 6' allowance provides for only 3-4' actual walkway in front or in back due to other items occupying floor space. With two or more machines, 6' between compression cylinders usually furnishes adequate piston removal length but this dimension

must be confirmed from the certified vendor drawing.

Clearance pocket valves sometimes project horizontally from the end of each compression cylinder. These valve handwheels will be about waist high and project from 1-2' from the end of the cylinder. The walkway must be outside their extremity. An experienced designer questions vendors about clearance pocket valve requirements which often are not shown on preliminary vendor drawings. If clearance dimensions are set at 3' according to preliminary vendor drawings and the building is purchased from this dimension and should the clearance pocket valves have to be added later the building must be extended, resulting in a higher building cost because it is a change order, not part of the original order.

One end of the building should be left open as a work area, with nothing occupying floor space. 20' from the machine extremity is a good working number. This space is used as a drop-down area. Machine parts are lifted with the traveling crane

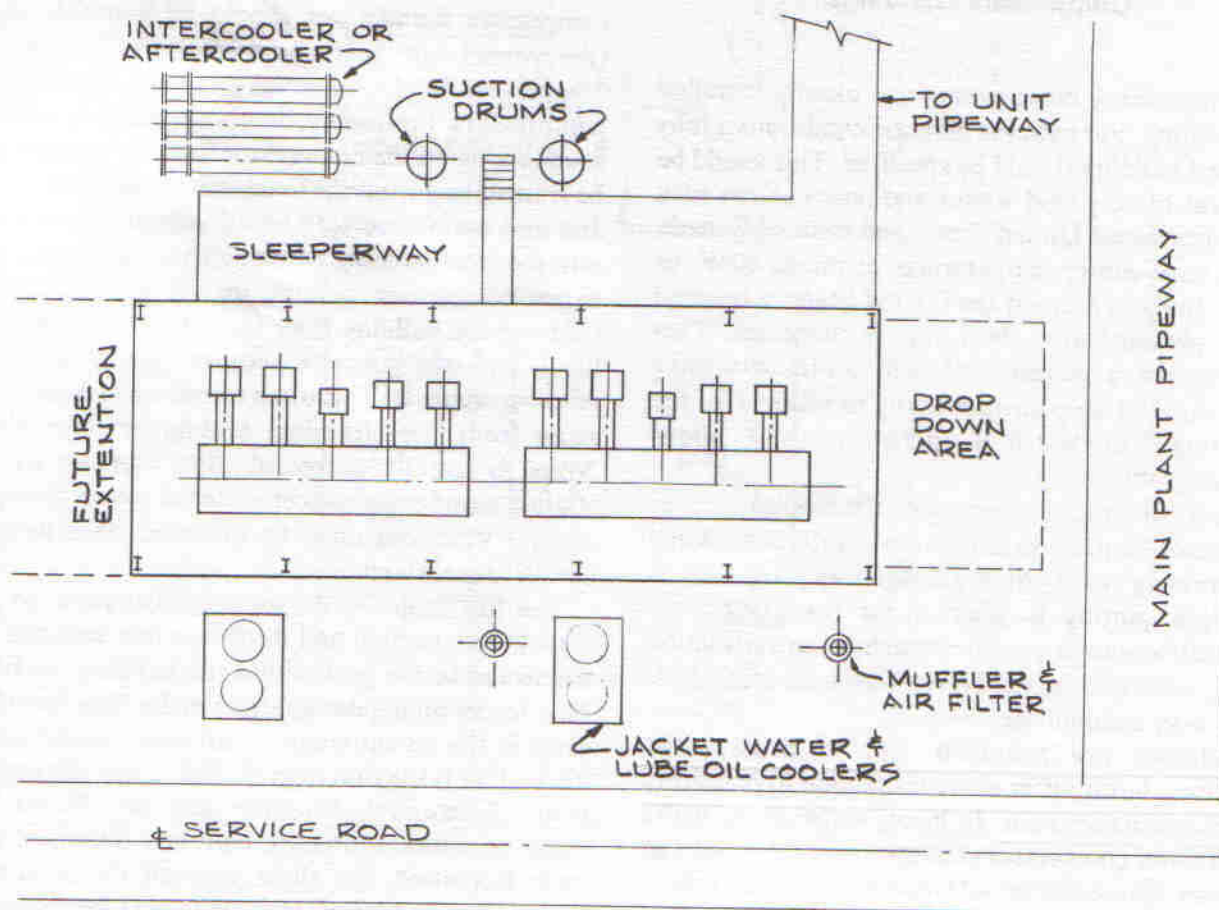


Figure 2-18. Angle-type compressor plot arrangement.

and minor repairs are done in this area. For more extensive repairs, parts are transported to a shop.

When two compressors are placed side by side with compression cylinders facing each other, cylinder removal distance of the longer requirement must be the minimum between the machines. Usually an extra 1' is added.

Suction and Discharge Piping

Except for special cases, suction piping is routed to the top of the cylinder and discharge piping from the bottom. The reverse arrangement is used, for instance, if a furnished intercooler is to be mounted directly on top of the compressor. Then suction would go in the bottom of the cylinder, out the top, directly into the overhead cooler, out the other end of the cooler and directly into the top of another cylinder for the next stage of compression. Since that is a special application this text can not

elaborate on it and will only consider normal compressor piping.

As mentioned earlier, liquids do not compress; so extensive precautions must be taken to ensure that absolutely no liquid enters the compression cylinder. A small quantity of liquid could do it extensive damage.

Figure 2-19 shows typical piping at compression cylinders. Make-up gas enters V-101, rises through the demister and goes out the top nozzle to the 8" compressor suction header. V-101 collects liquids which may be in the inlet line. In this case, the operator will periodically check the liquid level, observing the LG and manually draining any visible liquid by cracking the 1 1/2" globe valve. If inlet gas is a wet gas, one with great amounts of entrained liquid, a level controller should be added, activating a level control valve to automatically drain accumulated liquid.

Should liquid build up too high, the level alarm will sound. Warnings are usually sounded in the main or unit control building and may also sound

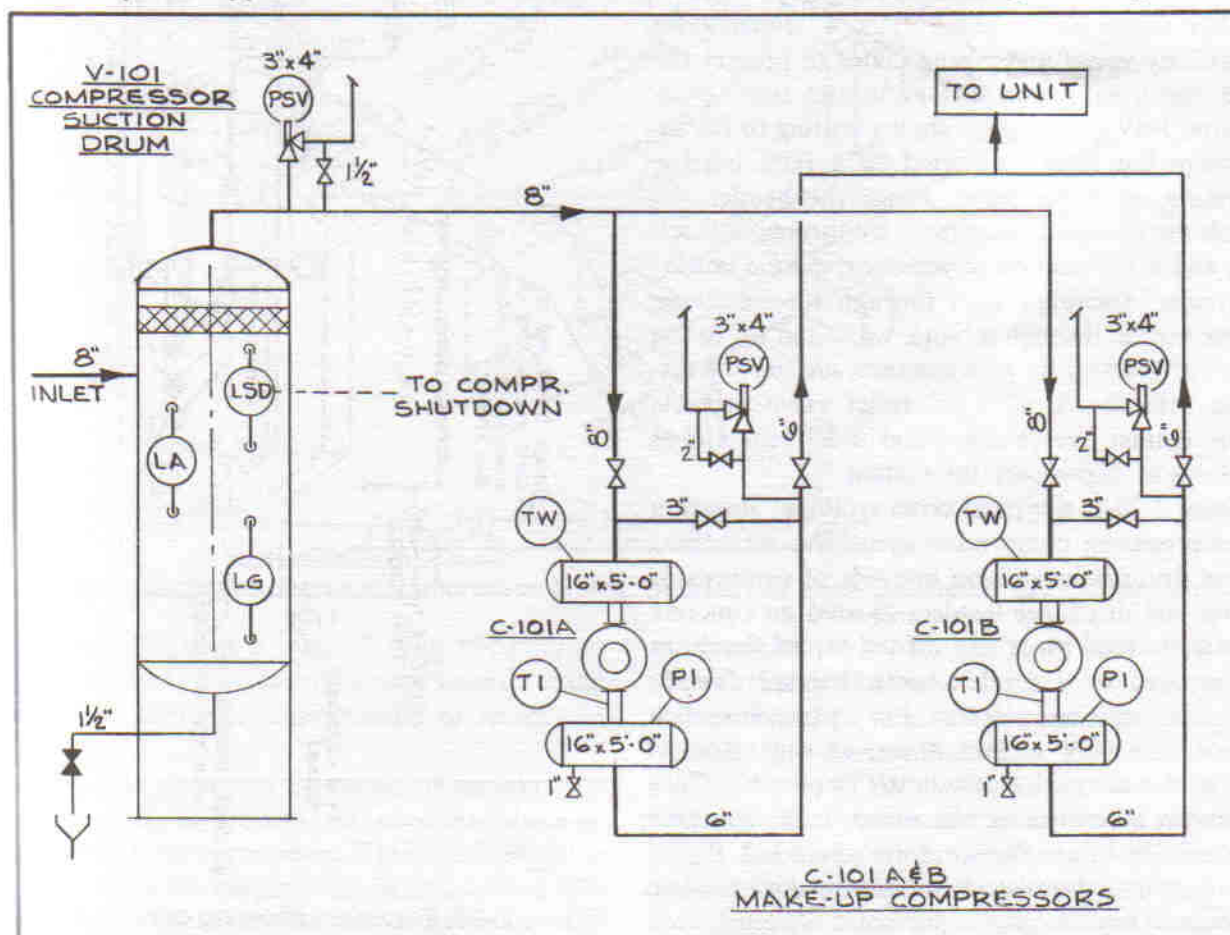


Figure 2-19. Reciprocating compressor flow diagram for process lines.

locally. If liquid level reaches an unsafe height, such that liquid could possibly enter the compressor suction header and be routed to a compression cylinder, a level shutdown is activated which cuts off power to compressor drivers and shuts down the machine.

C-101A and B are shown as two equal capacity machines, one normally in operation and one spare. Each machine is depicted as having one compression cylinder. In many instances two compression cylinders are needed to handle the required volume or *throughput*. If C-101A had two cylinders, both would connect into a common suction and discharge bottle. Suction and discharge piping would be no different but the bottles might have to be longer than 5'-0" to reach two cylinders.

Figure 2-19 shows the make-up gas cylinder piping. C-101A and B can have other compression cylinders with almost identical piping, each service having a compressor suction drum. Most compressors have four to six compression cylinders, compressing two or three different gases.

V-101 vapor outlet has a 3" x 4" relief valve required by vessel and piping codes to protect the vessel and compressor suction header from overpressure. PSV discharge is shown venting to the atmosphere but may be routed to a flare header, depending on vapor type. From the header, 8" laterals are routed to each machine through a block valve and a 16" suction *scrubber* or volume bottle.

Cylinder discharge goes through the discharge volume bottle, through a block valve and off to the unit. A 3" start-up by-pass connects suction and discharge laterals. A 3" x 4" relief valve protects piping against overpressure and a 2" vent allows operators to depressure the system.

Figure 2-20 is a typical cross sectional elevation of reciprocating compressor cylinders. A vertical suction drum is located on one side of compressor suction and discharge headers located on concrete sleepers. Lateral pipes rise off the top of the drum and proceed to a suction bottle located directly above compression cylinders. For hydrogen service Fluor locates the suction drum, or separator, as close to the suction volume bottle as possible. They are shown here directly connected to it. Also note the gas outlet line in the separator at the left. Piping from the normal outlet location may vibrate; often the internal line design can prevent a vibrating riser. The author has used the internal line design successfully on several compressor installations.

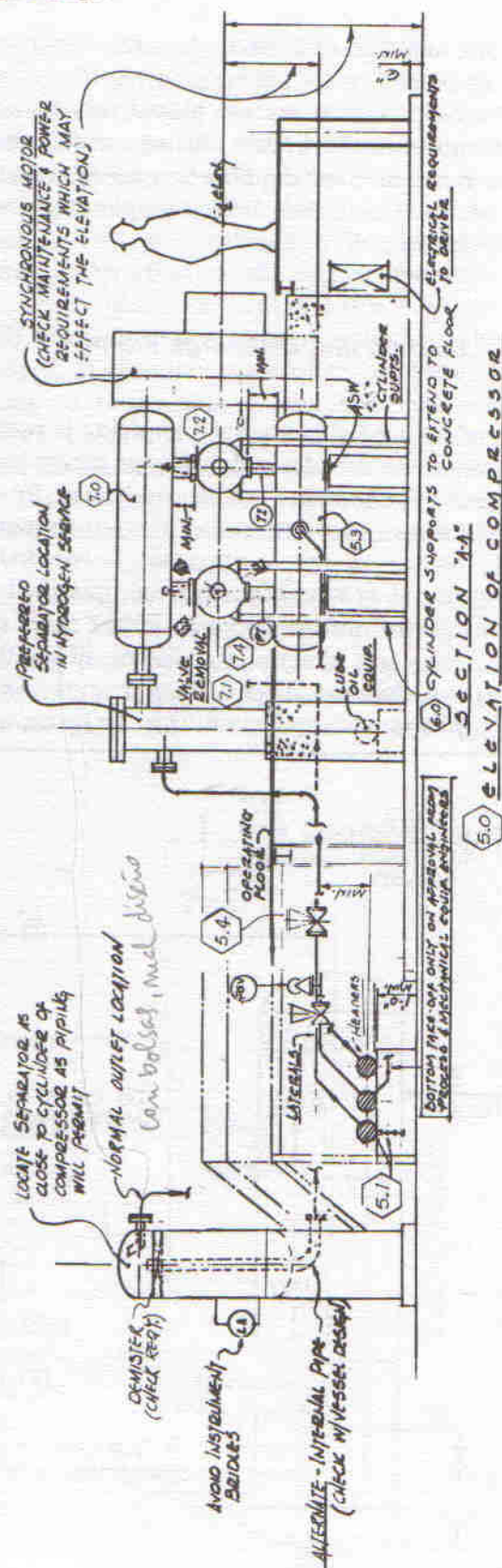
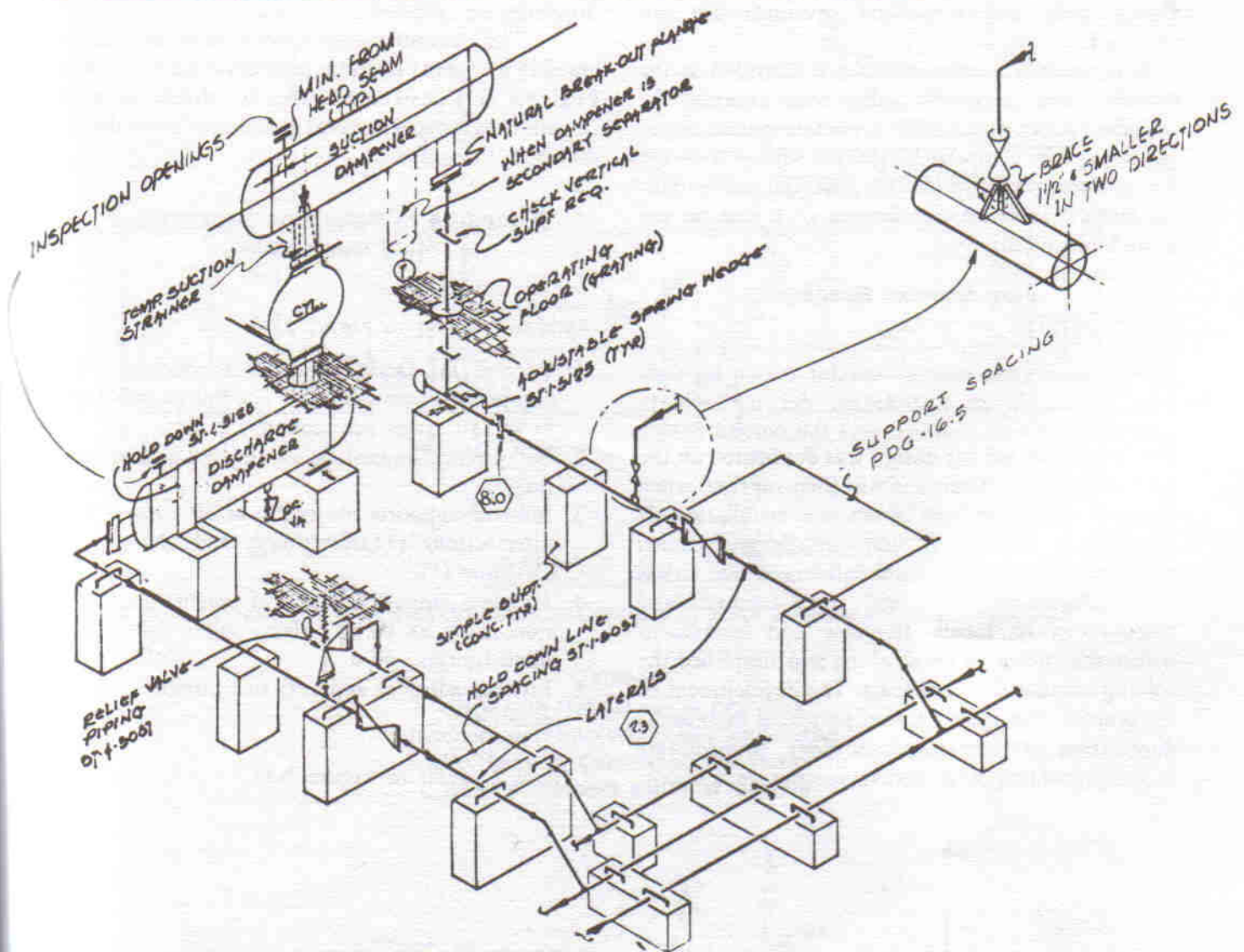


Figure 2-20. Elevation showing compressor piping. Courtesy of Fluor Engineers and Constructors, Inc.

(4.0) ARRANGEMENT OF LATERALS TO COMPRESSOR



TYPICAL PIPING ISOMETRIC

Figure 2-21. Isometric of typical compressor piping. Courtesy of Fluor Engineers and Constructors.

Generally, if the riser is over 12' long, the internal design is selected. The internal pipe is secured to the inside vessel wall with clips welded to vessel and pipe.

Figure 2-21 shows an isometric of suction, discharge and flare headers on concrete sleepers. Laterals rise from the headers. This arrangement is very important for keeping the suction lateral self-draining. If it ran from the header bottom, a low point would be formed, making a perfect place for liquids to build up and eventually be carried into the

compression cylinder. Only in very rare cases should this design be used.

Note how 1 1/2" and smaller piping is braced with wedges in two directions. Without wedges, vibrations would eventually fatigue these small connections and they would rupture at the connection point. Also note relief valve piping on the discharge lateral. It is kept as short and compact as possible to reduce vibration and lessen fatigue. Inspection openings shown on both bottles are required when the bottles must be built and stamped in accordance

*Mal diseño
con "bota" y nivel
de líquidos*

with the ASME Section VIII vessel code. Normally these bottles are built in accordance with the ANSI piping code and inspection openings are not required.

A temporary suction strainer is provided at the cylinder inlet to prevent solids from entering the cylinder. After running for a predetermined length of time, the compressor is shut down and the strainer removed. For this purpose, the suction bottle must have break-out flanges so it can be unbolted and lifted.

Pipe Support Spacing

For years, pipe support spacing was a hit-and-miss effort. If an installation did not vibrate excessively it was assumed that the correct design had been used and the design was duplicated on the next compressor. Everyone was then surprised when it didn't work very well in the new installation. It was finally discovered that the *design natural frequency* of the compressor influenced line pulsation. Engineers developed very complicated calculations to locate supports and holdowns before the computer came along and simplified the solving of pulsation problems. The development of the Analog computer allowed an actual theoretical duplication of operating conditions, immediately locating problem areas and suggesting ways to cor-

rect them. Today most compressor installations are proven feasible by an Analog run before fabrication drawings are released.

The computer and history have been combined in a support location plan developed by Fluor Engineer & Constructors, Inc. By simple manual calculations, proper support locations can be determined in three phases.

Procedure to Determine Support and Hold Down Points

Phase 1—refer to Figure 2-22.

1. Obtain (fn) Design Natural Frequency from compressor manufacturer. For this example use $fn = 140$ cycles per second.
2. Set piping dimensions on layout and space lines.
3. Indicate supports no. req'd. at all corners (2), intersections (2 sides only) and changes of elevation (1).
4. Locate a support at points of weight concentration, such as block valves, relief valves and blind flanges.
5. Line up adjacent supports to a common pier if possible.

Phase 2—refer to Figure 2-23.

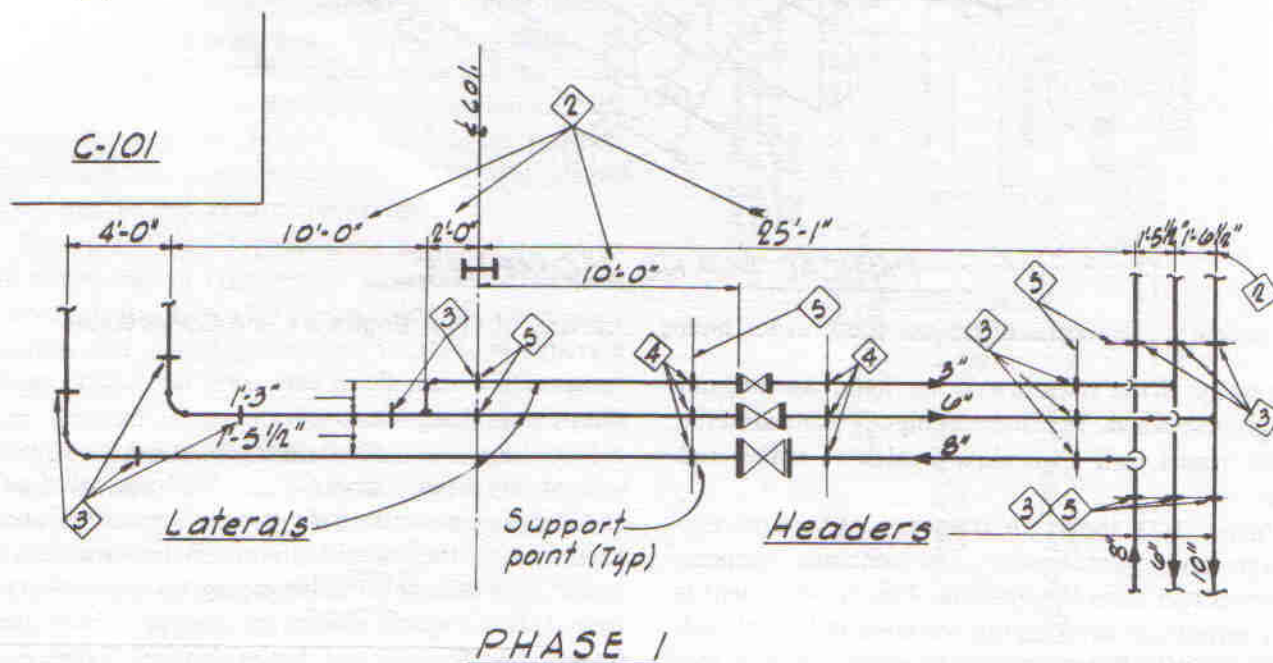


Figure 2-22. Phase 1 of pipe support spacing. Courtesy of Fluor Engineers and Constructors, Inc.

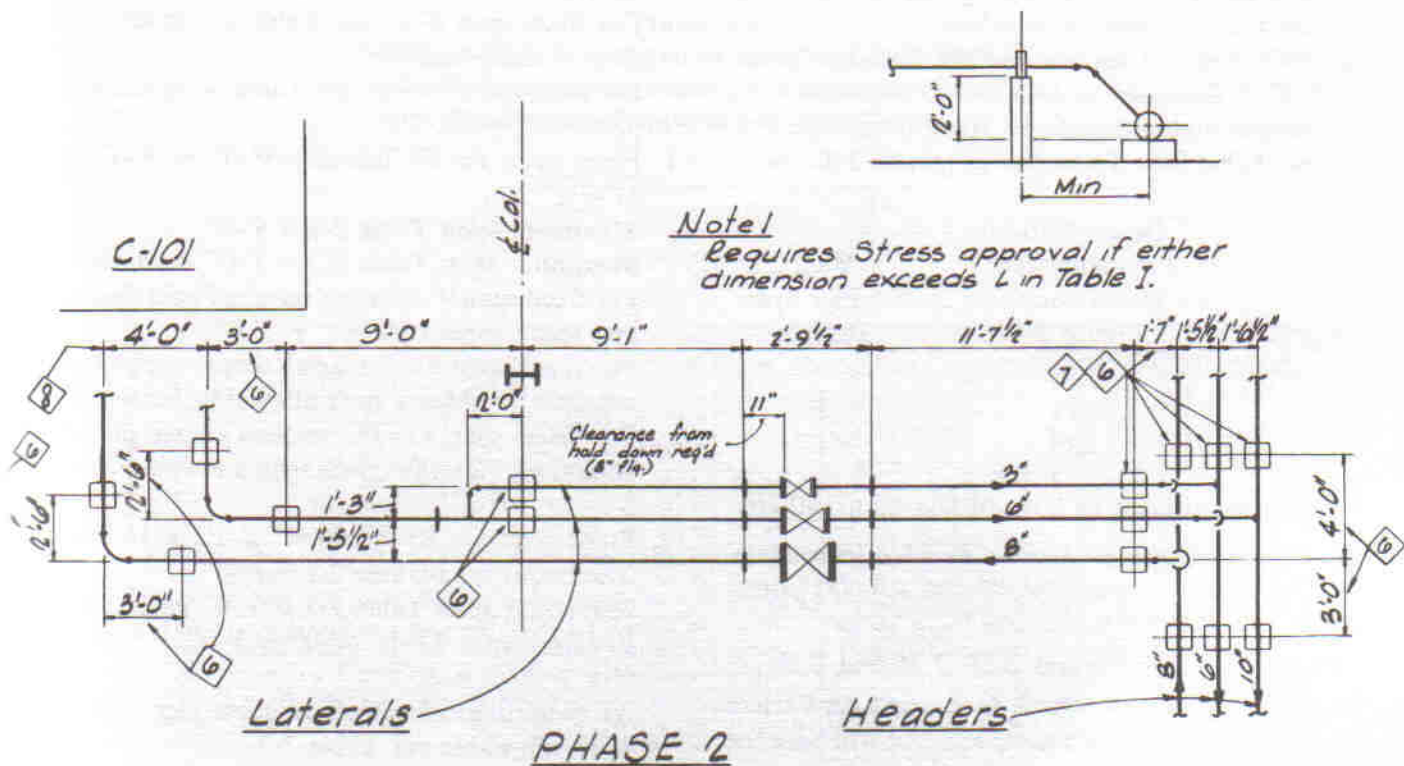


Figure 2-23. Phase 2 of pipe support spacing. Courtesy of Fluor Engineers and Constructors, Inc.

Table 2-1

Pipe with Hold-Down at One End
(Corners and Intersections) Cantilevered.
To Be Used for Calculating the Maximum
Span at Corners and Intersections

PIPE		L = PIPE SPAN - FEET									
SIZE	MAX. SCH.	2	3	4	5	6	7	8	9	10	
1	XX	70	31								
1 1/2	XX	105	47	26							
2	XX	135	60	34	21						
3	XX	202	90	51	32	23					
4	XX	268	119	67	43	30	22				
6	XX	398	177	100	64	44	33	25			
8	160	538	239	135	86	60	44	34	27		
10	160	665	296	166	107	74	54	42	33	27	
12	160	790	352	198	126	88	65	49	39	32	
14	160	893	397	223	143	99	73	56	44	36	
16	160	993	441	248	159	110	81	62	49	40	
18	160	1,122	499	281	180	125	92	70	55	45	
20	160	1,250	555	312	200	139	102	78	62	50	
24	160	1,500	666	374	239	166	122	94	74	60	
30	0.500 W.	2,030	900	507	325	225	166	127	100	81	
36	0.500 W.	2,040	1,080	610	390	271	199	152	120	98	

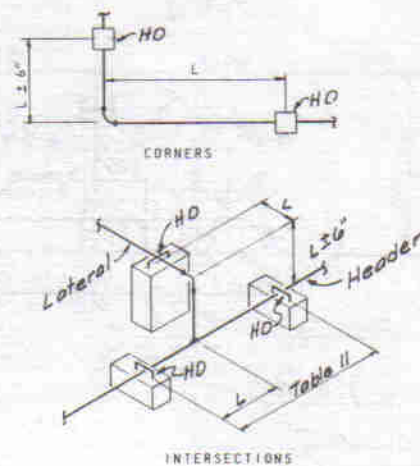


Figure 2-24. Maximum pipe spans at corners and intersections.

The preceding steps have simplified the system to a series of straight piping runs which is the basis for the pipe span tables.

6. Hold downs at corners and intersections. To establish dimensional location of hold downs at corners and intersections, Read from Figure 2-24, Table 2-10. Example: @ (fn) or 140 cps

Pipe Size	Design Natural Frequency (fn)* (from body of Figure 2-24)	Max. L = Pipe Span in feet
3"	202	2'-0"
6"	177	3'-0"
8"	239	3'-0"

*Value (fn) nearest to but not less than 140 cps.

7. Place supports as close as possible to headers.
8. Dimension between established support points in straight runs.

Phase 3—refer to Figures 2-25, 2-26 and 2-27.

9. When locating supports in straight runs select first the smallest diameter run as it will have the largest number of support points.
10. Fixed spans for 3" lateral = 9'-1" + 11'-7½" determine maximum span from Table 2-2 and 2-3, Figures 2-26 and 2-27
Maximum span Table 2-2 = 6'-0" (2 hold downs)

Maximum span Table 2-3 = 5'-0" each side (2 hold downs + simple support)

For fixed span 9'-1" use Table 2-3 space supports 4'-3½" + 4'-9½"

For fixed span 11'-7½" use Table 2-2 space supports 6'-0" + 5'-7½"

11. Fixed span for 6" lateral = 9'-0" + 9'-1" + 11'-7½"

Maximum span Table 2-2 = 8'-0"

Maximum span Table 2-3 = 7'-0" each side
For fixed span 9'-0" move required hold down 3 and space supports 4'-0" + 5'-0"

For fixed span 9'-1" extend simple support of adjacent 3". Meets span allowable Table 2-2.

For fixed span 11'-7½" extend center pier at adjacent 3" lateral; meets span allowable Table 2-3

12. Fixed span for 8" lateral = 22'-1" + 11'-7½"

Maximum span Table 2-2 = 9'-0"

Maximum span Table 2-3 = 8'-0" each side

For fixed span 22'-1" (4'-0" + 3'-0" + 9'-0" + 9'-1") - 3'-0" = 22'-1"

At centerline col extend adjacent pier span of 9'-1" allowable per Table 2-2

Fixed span of 22'-1" - 9'-1" = 13'-0".

Extend adjacent pier at 6" lateral. Meets span allowable Table 2-3

Figure 2-28 shows how natural frequency should match maximum spans to prevent excessive mechanical vibration.

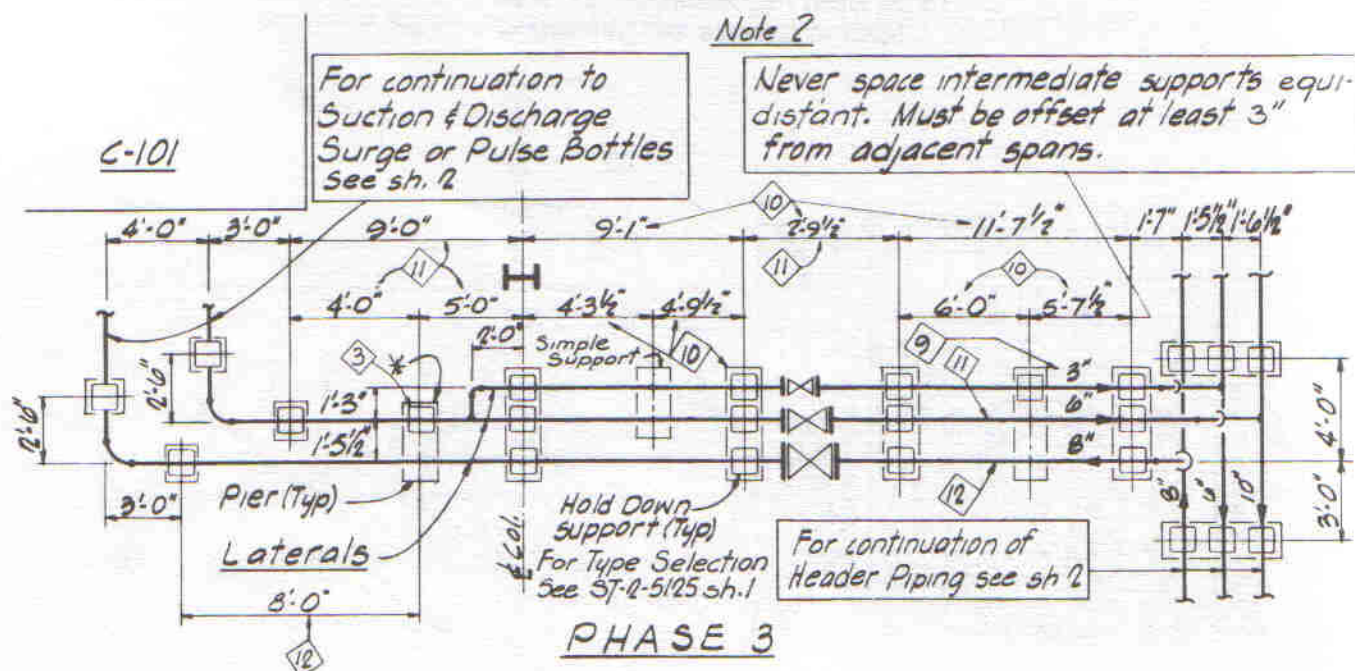


Figure 2-25. Phase 3 of pipe support spacing. Courtesy of Fluor Engineers and Constructors, Inc.

Table 2-2
Pipe Spans Hold-Down or Anchored Both Ends
To Be Used for Calculating the Maximum Span
Between the Supports with Hold-Downs



PIPE		L = PIPE SPAN - FEET																																
SIZE	MAX. SCH.	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	32			
1	XX	307	137	77	49	34	25																											
1½	XX	465	207	116	74	52	38	29	23																									
2	XX	600	267	150	94	67	49	38	30	24																								
3	XX	900	400	225	144	100	74	56	45	36	30	25																						
4	XX	1,175	523	294	188	131	96	74	58	47	39	33	28	24																				
6	XX	1,750	778	438	280	194	143	109	87	70	58	49	41	36	31	27	24																	
8	160	2,350	1,045	588	376	261	192	147	116	94	78	65	56	48	42	37	33	29	26															
10	160	2,875	1,278	719	460	320	235	180	142	115	95	80	68	59	51	45	40	36	32	29	26	24												
12	160	3,450	1,532	862	552	383	282	216	170	138	114	96	82	70	61	54	48	43	38	35	31	29	26											
14	160	3,900	1,732	975	624	434	319	244	193	156	129	108	92	80	69	61	54	48	43	39	35	32	30	27	25									
16	160	4,350	1,932	1,087	696	484	355	272	215	174	144	121	103	89	77	68	60	54	48	44	40	36	33	30	28	26	24							
18	160	4,900	2,180	1,226	784	544	400	306	242	196	162	136	116	100	87	77	68	61	54	49	45	41	37	34	31	29	27	25						
20	160	5,450	2,425	1,363	872	606	445	341	268	218	180	151	129	111	97	85	75	67	60	55	50	45	41	38	35	32	30	28	26	24				
24	160	6,530	2,900	1,632	1,042	725	533	408	323	261	216	181	154	133	116	102	90	81	72	65	59	54	49	45	42	39	36	33	31	29	25			
30	0.500 W.	8,850	3,935	2,210	1,416	986	722	553	437	354	292	246	210	180	157	138	122	109	98	89	80	73	67	62	57	52	49	45	42	39	35			
36	0.500 W.	10,650	4,730	2,680	1,703	1,182	870	666	526	426	352	296	252	217	189	166	147	131	118	107	97	88	81	74	68	63	59	54	51	47	42			

Figure 2-26. Pipe spans, hold-down or anchor both ends. Courtesy of Fluor Engineers and Constructors, Inc.

Table 2-3
Pipe Spans Hold-Down One End—Supported Other End
To Be Used for Calculating the Maximum Span
Between a Support with a Hold-Down
and an Intermediate Support without a Hold-Down



PIPE		L = PIPE SPAN - FEET																															
SIZE	MAX. SCH.	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	32		
1	XX	446	198	111	71	50	36																										
1½	XX	676	301	170	108	75	65	42	33																								
2	XX	864	385	216	139	96	71	54	43	35																							
3	XX	1,295	576	324	207	144	106	81	64	52	43	36																					
4	XX	1,695	750	424	271	188	139	106	84	68	56	47	40	35																			
6	XX	2,540	1,127	635	406	282	207	159	125	101	84	71	60	52	45	40	35																
8	160	3,410	1,515	852	545	379	278	213	168	136	113	95	81	70	61	53	47	42	38														
10	160	4,230	1,890	1,060	680	470	347	264	210	170	140	118	101	86	76	66	59	52	47	42	39	35											
12	160	5,020	2,235	1,256	804	558	410	314	248	201	166	140	119	103	89	79	70	62	56	50	46	42	38										
14	160	5,680	2,520	1,420	909	631	464	365	281	227	188	157	134	116	101	89	79	70	63	57	52	47	43	39	36								
16	160	6,330	2,820	1,581	1,013	703	516	395	313	253	209	176	160	129	112	99	88	78	70	63	57	52	48	44	40	38	35						
18	160	7,140	3,180	1,783	1,142	793	580	446	353	286	236	198	169	146	127	112	99	88	79	71	65	59	54	50	46	42	39	36					
20	160	7,930	3,520	1,981	1,267	882	648	496	392	317	262	220	187	162	141	124	110	98	88	79	72	66	60	55	51	47	43	40	38	35			
24	160	9,520	4,240	2,380	1,525	1,057	878	594	471	381	315	264	226	194	169	149	132	118	106	95	87	79	72	66	61	56	52	49	45	42	38		
30	0.500 W.	12,900	5,730	3,225	2,060	1,432	1,052	807	637	516	426	359	305	263	229	202	178	159	143	129	117	107	97	90	83	76	71	66	61	57	51		
36	0.500 W.	15,510	6,900	3,880	2,485	1,724	1,267	971	767	621	513	431	368	317	276	242	215	192	172	155	141	128	117	107	99	92	85	79	74	69	61		

Figure 2-27. Pipe spans, hold-down one end. Courtesy of Fluor Engineers and Constructors, Inc.

Hold-downs and Wedges

Because compressor suction and discharge headers and laterals pulsate, line vibration occurs. Concrete sleepers are located to support this piping but hold-downs are needed to restrain or resist the vibration and must be applied at each sleeper location. Compressor piping should be routed on low sleepers as far as possible, generally from the compressor house to a point where the piping must enter the elevated unit pipeway. As lines get farther from the compressor, vibration usually decreases due to the greater gas volume serving as a pulsation dampener.

There are many types of hold-downs commercially available. The author prefers a spring-loaded type which allows some thermal expansion. Some companies use a resilient compression washer which serves the same purpose as a spring. However, care must be taken not to flatten compression washers during installation. When too much force is applied and the washers are fully flattened, they do not return to their original resiliency.

Figure 2-29 shows the type of spring-loaded sup-

port used beneath a compressor discharge bottle. Before start-up, the wedge is installed with ample clearance from the bottle with the spring loose. The wedge should be located directly under the bottle inlet coming from the compression chamber. When the compressor is started the vertical discharge line from the cylinder to the bottle will get warm and will expand a small amount. The wedges will then be tightened so that they press firmly against the bottle with tension supplied by the spring. In Figure 2-21, the wedge is located under the cylinder; the other bottle support has a hold-down.

Figure 2-30, Type HD-1 and HD-2 Hold-down, shows some standard types for sizes $\frac{3}{4}$ " to 10" pipe. For structural strength to withstand vibration, compressor piping is usually sized as 2" minimum. The end elevation shows a steel plate imbedded in the sleeper, with the hold-down pieces welded to it. These pieces are all standard manufactured items. The steel plate procedure allows sleepers to be poured by construction before detail dimensions, locating piping, are final. This also allows much more tolerance during construction. With the old procedure of imbedded anchor bolts, there was very little chance for error.

LOCATION OF SUPPORTS

TO PREVENT EXCESSIVE MECHANICAL VIBRATION

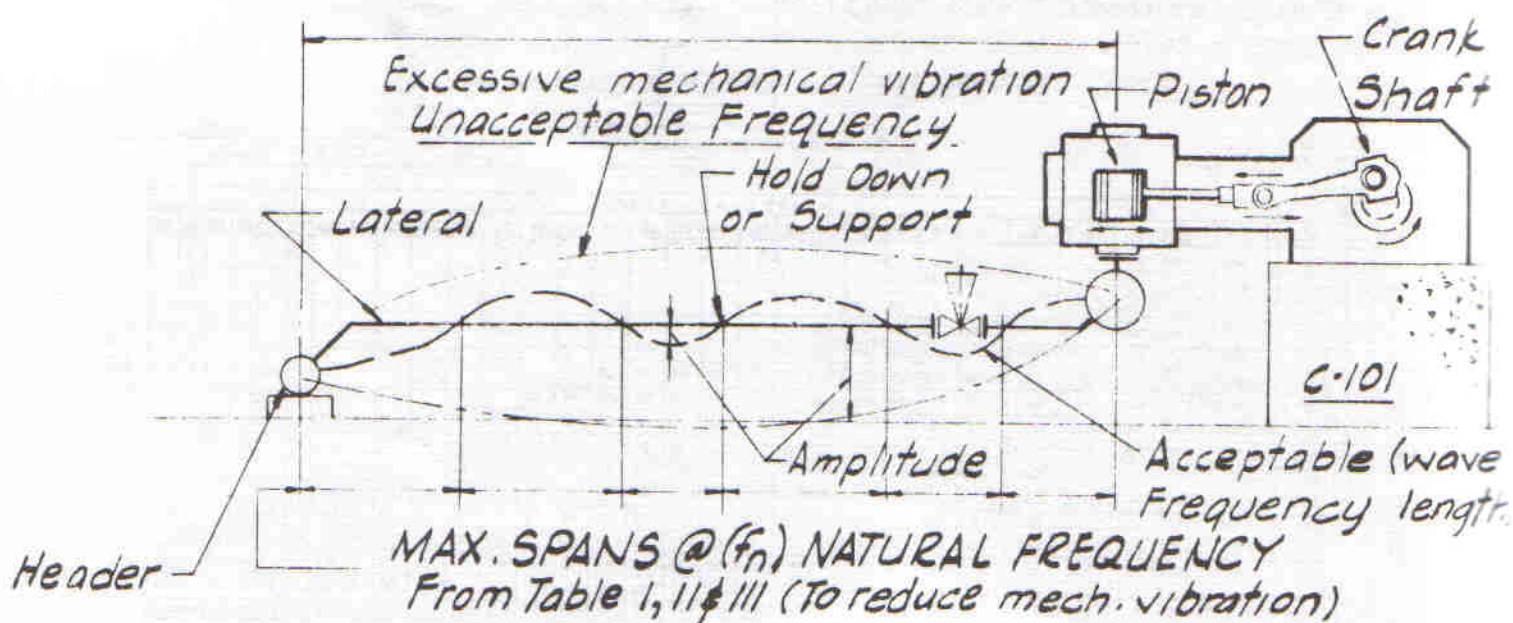
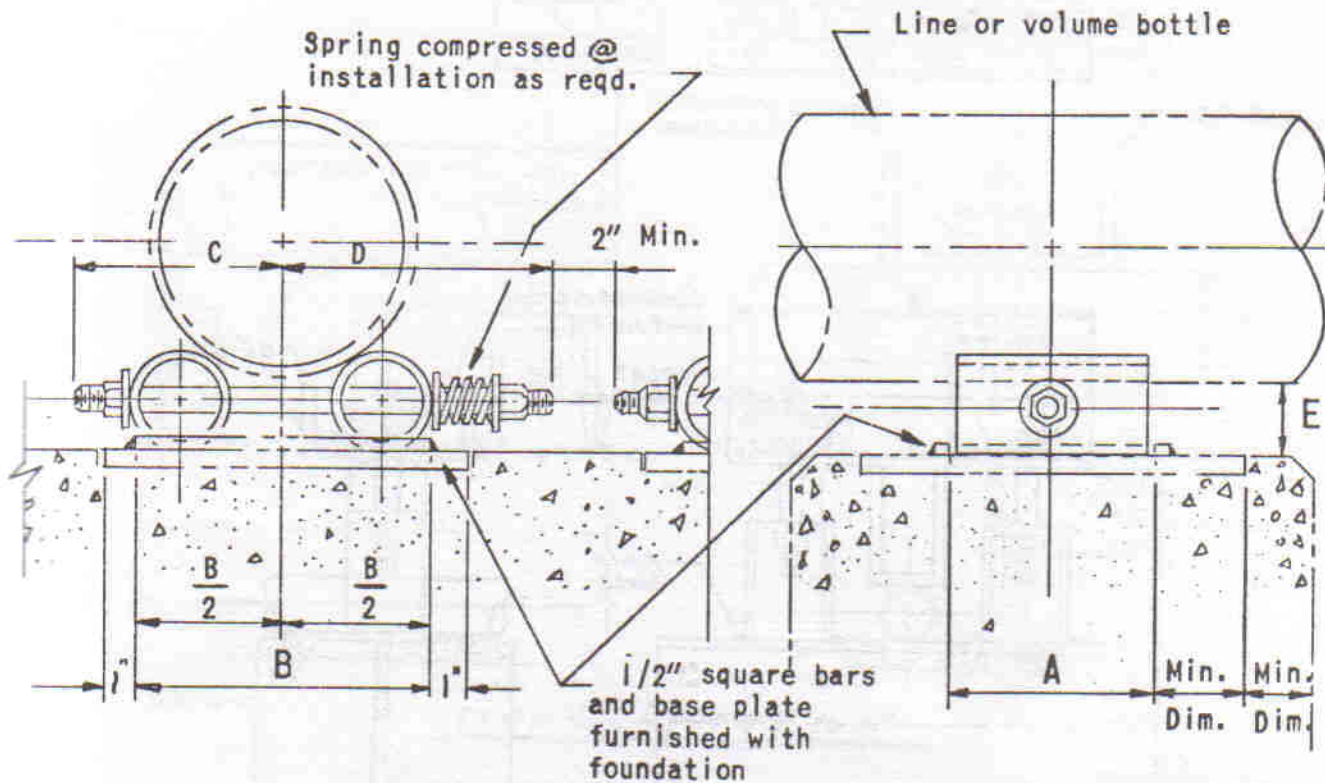


Figure 2-28. How natural frequency should match supports. Courtesy of Fluor Engineers and Constructors,



SYMBOLS FOR DWGS. & SPOOLS	TAG NUMBER	LINE OR BOTTLE NOM. SIZE	DIMENSIONS				
			A	B	C	D	E
DRAWING INDICATE COORD. ASW2	ASW1	2" thru 4"	6-1/4"	6-1/2"	4-1/2"	7"	1-11/16"
	ASW2	6" and 8"	6-1/4"	8"	5-1/4"	8-1/4"	1-13/16"
	ASW3	10" thru 14"	6-1/4"	11-1/2"	7-3/4"	10-3/4"	2-3/8"
	ASW4	16" thru 20"	9-1/4"	13"	8-1/2"	11-1/2"	2-3/8"
SPOOL INDICATE COORD. ASW2	ASW5	24" thru 32"	9-1/4"	15"	9-1/2"	14-1/2"	2-1/2"
	ASW6	34" thru 46"	9-1/4"	17-1/2"	10-1/2"	15-1/2"	2-1/2"
	ASW7	48" thru 60"	9-1/4"	19-1/2"	11-1/2"	16-1/2"	2-1/2"

1. Use wedges where required by vibration analysis on pulsating lines, volume bottles and pulsation dampeners at reciprocating pumps and compressors.
2. Fabrication and installation detail drawings (8-1/2" x 11") are used for each tag number shown. Detail drawing numbers correspond to the tag number.

Example: 0000-1-ASW2

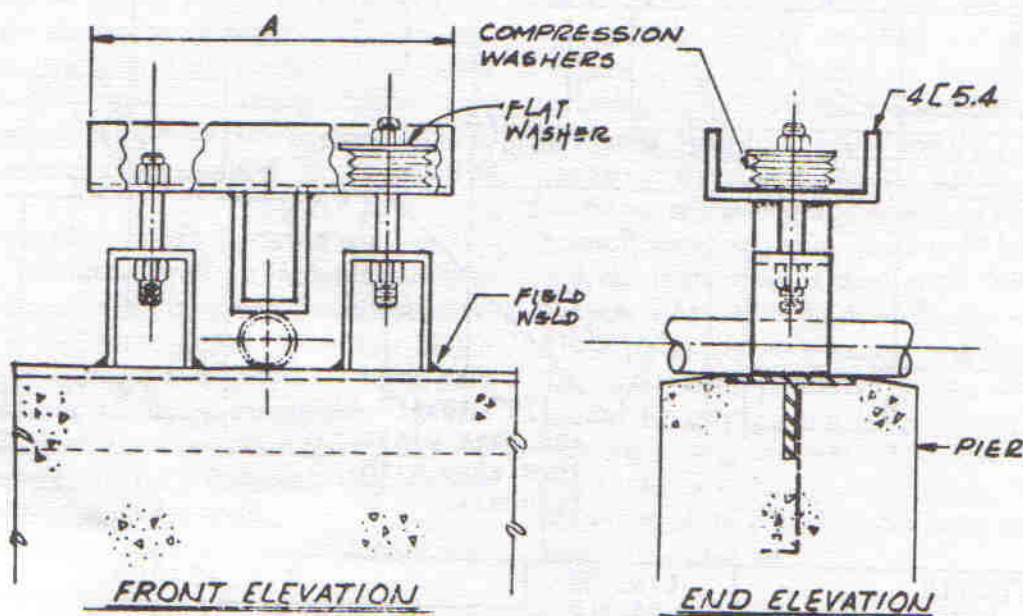
Contract No. ———

Dwg. Size ———

Tag & Dwg. No. ———

Figure 2-29. Adjustable spring wedges. Courtesy of Fluor Engineers and Constructors, Inc.

PIPE SIZE	$\frac{3}{4}$ "	1"	1½"	2"	3"
A	8½"	8½"	9"	9¾"	10½"



TYPE HD-1 - PIPE $\frac{3}{4}$ " TO 3"
 TEMPERATURE RANGE: 40°F TO 650°F
 *USE ONLY WITH APPROVAL FROM STRESS

Figure 2-30a. Type HD-1 hold down. Courtesy of Fluor Engineers and Constructors, Inc.

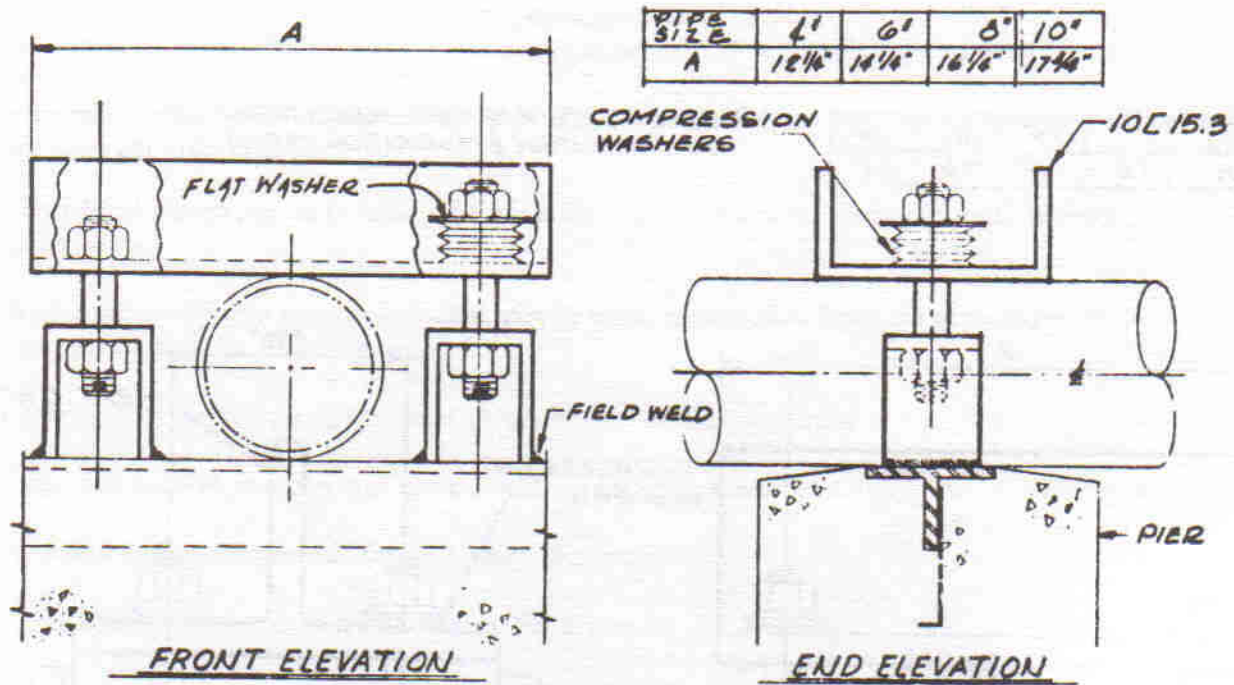
Note that in all of these hold-downs the pipe is restrained from moving up and down, but movement sideways and lengthwise is allowed. Temperature differentials occur from time of construction to start-up and from summer to winter causing piping to contract and expand. Any restraint design must provide for pipe expansion and contraction.

Figure 2-31 shows the design required for sizes 12" through 18". In Figure 2-32, the type HD-4 hold-down is for sizes 20" through 36"

Insulated lines have the insulation cut back at hold-downs. When, under special services, lines

require cold-insulation, it is not cut back at these points. Depending on the type of cold insulation, a steel cradle or, sometimes, wood blocks will be used at hold-downs. For cold-insulated lines, hold down size is *not* pipe size, but is pipe size plus twice the insulation thickness plus twice the cradle thickness if the cradle design is selected.

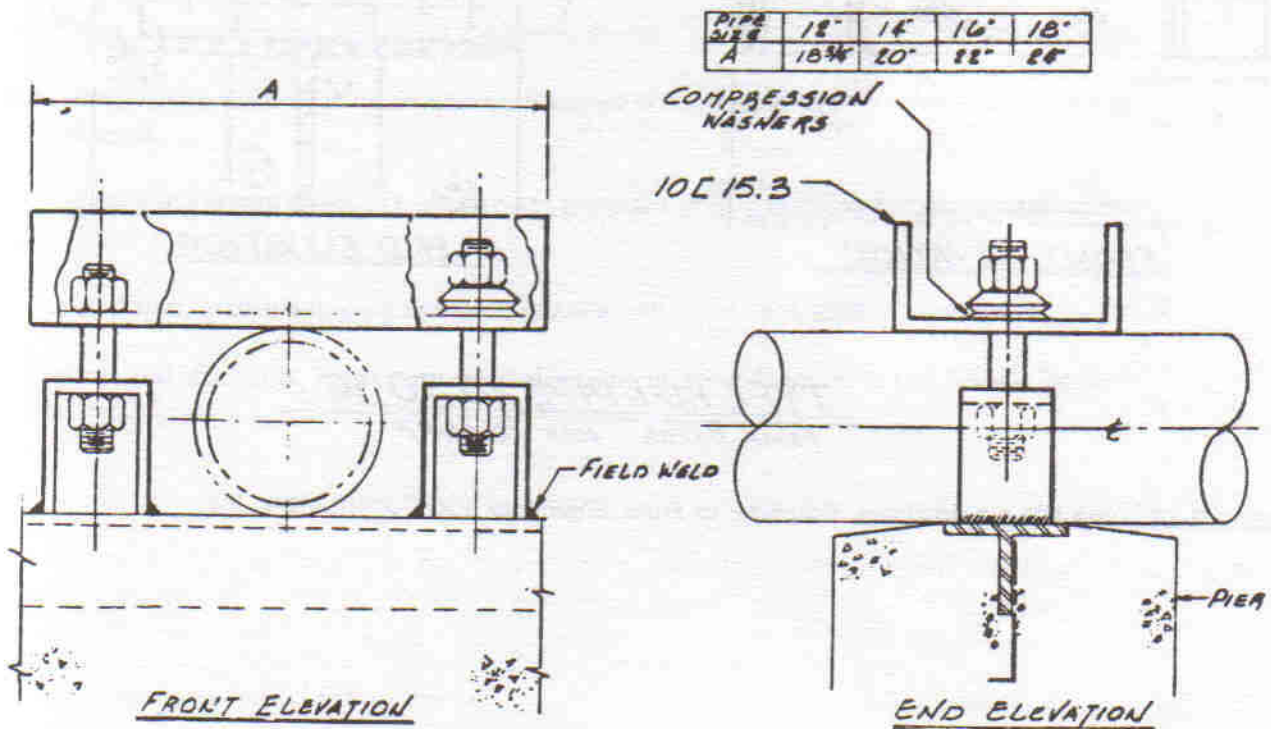
As noted earlier, field installation of compression washers is critical. Improper installation will ruin them. Normal procedure is to tighten all nuts by hand, only finger tight. Then a wrench is applied for a 45° turn for 1½" - 3" pipe sizes and a 90° turn for lines 4" and larger to supply ample load at the washers and without impairing their resiliency.



TYPE HD-2 + PIPE 4" TO 10"

TEMPERATURE RANGE: 40°F TO 650°F

Figure 2-30b. Type HD-2 hold-down.



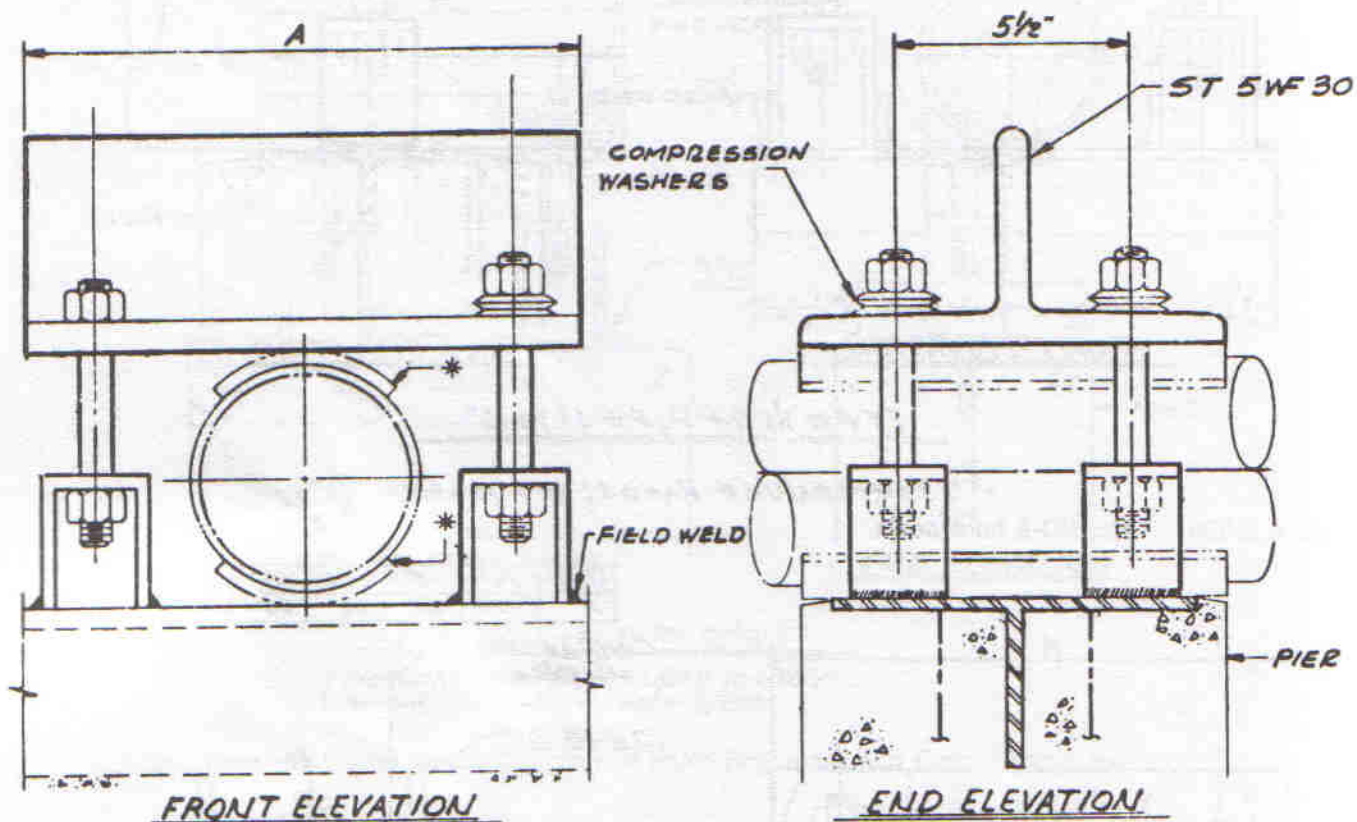
TYPE HD-3 + PIPE 12" TO 18"

TEMPERATURE RANGE: 40°F TO 650°F

Figure 2-31. Type HD-3 hold-down. Courtesy of Fluor Engineers and Constructors, Inc.

PIPE SIZE	20"	24"	30"	36"
A	26'	30'	36'	42'

*WEAR PLATE FOR THIN WALL PIPE
SEE INSTALLATION & FABRICATION DETAILS



TYPE HD-4 PIPE 20" TO 36"

TEMP. RANGE : 40°F TO 650°F

Figure 2-32. Type HD-4 hold-down. Courtesy of Fluor Engineers and Constructors, Inc.

Review Test Chapter 2

Do not refer to the book for answers. Should the student miss four or more questions, he should reread the chapter. Answer true or false.

- | | | |
|--|---|---|
| 1. Centrifugal compressors, because of their back and forth action, cause piping to pulsate and vibrate. | T | F |
| 2. With a vertically split compressor case, piping must be routed to leave the area above the compressor free for maintenance. | T | F |
| 3. Centrifugal compressors are limited to ten stages within one casing. | T | F |
| 4. Lube and seal oil consoles are needed with reciprocating compressors. | T | F |
| 5. A reciprocating compressor frame houses the crankshaft. | T | F |
| 6. A centrifugal compressor frame houses the driver. | T | F |
| 7. A centrifugal compressor has one or more compression cylinders. | T | F |
| 8. A surface condenser is used to recover steam from condensate. | T | F |
| 9. Surface condensers operate at a vacuum on the steam side. | T | F |
| 10. Exhaust steam does not go to a surface condenser. | T | F |
| 11. The angle type reciprocating compressor has all compression cylinders on one side of its crankshaft. | T | F |
| 12. Reciprocating compressors are usually not provided with a building because maintenance is seldom required. | T | F |
| 13. For multiple reciprocating compressor installations, mats are always combined. | T | F |
| 14. Suction and discharge bottles are normally built in accordance with the ASME Section VIII vessel code. | T | F |

3 Fired Heaters

Fired heaters come in many different sizes, shapes and types—from the oil field steam generator to huge hydrocarbon heaters in process plants. Those used exclusively for steam generation are not referred to as heaters; they are *boilers*. Most fired heaters in process plants are either the *vertical* type, so named because its radiant tubes are vertical, or the *box* or *horizontal* type, shaped like a box, in which radiant tubes are horizontal. Figure 3-1 and Figure 3-2 picture these two common types.

Heater Parts

Most heater part names are identical for vertical and horizontal types. Refer to Figures 3-1 and 3-2 for part locations for the definitions which follow.

convection section The heat transfer section located directly beneath the stack, utilizing heat from upward rising hot gases. Note that even in the vertical heater, convection tubes are horizontal.

radiant section The large part utilizing heat radiating from burners. Although in some horizontal heaters burner flames heat a ceramic wall which radiates heat to tubes, usually tubes receive heat directly from burners.

burners The heater part which burns fuel gas or fuel oil, sometimes both, producing a flame of intensive heat. Heaters are usually elevated, with burners on the bottom. However, horizontal heaters may have side-mounted burners. Quantity and size of burners are determined by the vendor according to the heaters use

tube-pulling trolley For vertical heaters only. A ring at the stack top used for replacing tubes. Since companies utilize mobile equipment for tube replacement today, few heaters have this trolley.

painter's trolley A ring near the stack top from which a steel cable stretches to grade level, to be used when painting the stack.

stack The cylindrical part used to transport waste heat to the atmosphere and at the same time produce a draft at the burners. Stack height is determined by required draft and ecological demands (fuel gas burns relatively cleanly but fuel oil produces some smoke). Stacks may be mounted on top of the heater or may be grade-mounted with large ducts routing waste heat to them. In heavily populated areas often several heaters have ducts going to a common grade-mounted stack which may be 300 feet high or more. With this design, the stack is usually concrete.

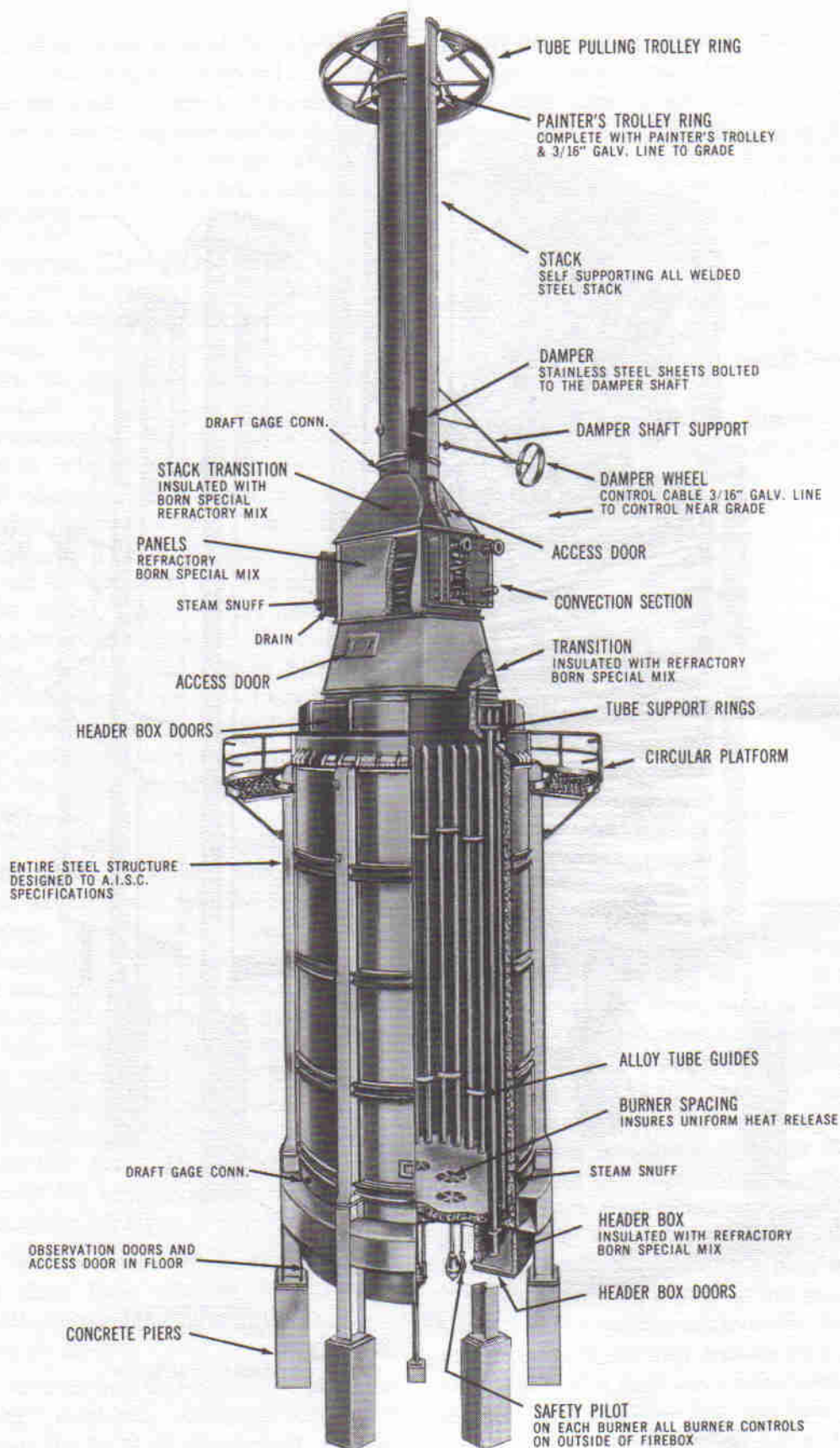


Figure 3-1. Vertical heater. Courtesy of Born Engineering Co.

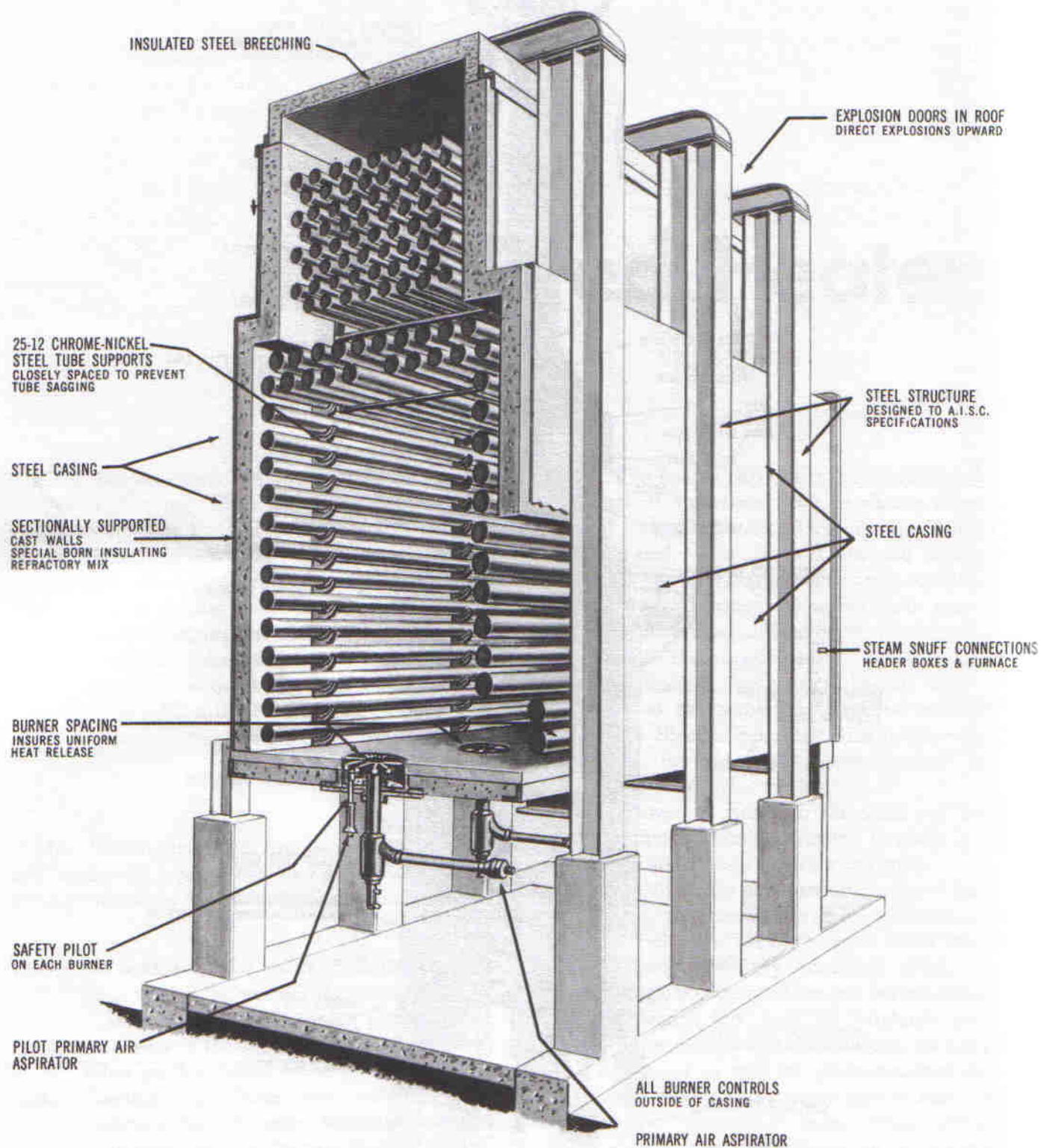


Figure 3-2. Horizontal heater. Courtesy of Born Engineering Co.

damper A flat steel plate located directly above the convection section, connected to a shaft and damper wheel. Control cables at grade allow operators to regulate burner draft by opening or closing the damper. Dampers can be connected so as to work automatically.

draft gage connection Usually a coupling located just beneath the damper and in the radiant section near burners. A differential pressure instrument, called a draft gage, is connected to these two couplings and measures the burner draft.

snuffing steam connection Usually a 2 in. coupling located in both the convection section and radiant sections. Live steam is used to extinguish (by smothering) flames. If tube rupture causes a fire, a snuffing steam valve is opened to introduce live snuffing steam into the heater. Large heaters have many snuffing steam connections.

stack transition A fabricated section below the stack effecting the transition from the rectangular heater shape to a cylindrical stack. Is also used below the convection section to reduce flow area between two rectangular patterns.

access door Removable door allowing entrance into the heater to inspect tubes or make repairs. Access doors must be kept clear.

tube support rings The ring that supports tubes in a vertical heater. Figure 3-1 shows this ring at the top, however tubes may be bottom-supported. Often, the piping designer can have tube support rings located to suit piping expansion thereby helping to alleviate stress problems.

header box Section at the end of the tube which contains 180° bends. Header box doors are removable for inspection and must not be obstructed by piping.

tube guides Merely direct the tubes' expansion, keeping them from *snaking*. For vertical heaters. In horizontal heaters, tube supports also serve as guides.

tube anchor A tube point that is firmly attached to something, anchored, directing expansion away from the point of attachment. Applies mainly to horizontal heaters.

observation doors Small doors opened by operators to view flame size and color and tube glow color. Burner control valves should be located near these doors so fuel flow can be regulated while watching burner flame. These doors may be located in the heater's sidewall and must not be obstructed by piping. They are commonly called *peep holes*.

heater floor Bottom steel plate of vertical and horizontal heaters.

pilot gas Constant burning small flame which ignites the burner fuel

crossovers Not shown in Figure 3-1 or 3-2, crossovers are piping connecting convection tubes to radiant tubes. Crossover piping may be located inside or outside the heater shell. External crossovers must be insulated. Such piping is usually (not always), furnished by the heater vendor, although he rarely supplies the insulation.

explosion doors Designed to give and relieve pressure in case of an internal heater explosion. Route piping clear of all explosion doors.

Heater Passes

The fired-heater manufacturer is given fluid inlet-temperature, quantities and pressure as well as outlet conditions. His responsibility is to provide a heater to meet the specifications, which include a maximum allowable pressure drop from heater inlet to heater outlet. He could get proper heat transfer by going through 32 tubes but this would cause too much pressure drop. Perhaps eight tubes are the limit, causing maximum allowable pressure drop. He must then size these eight tubes for proper heat transfer. Each eight-tube section will have an inlet and an outlet, comprising a heater pass. A 32-tube heater with eight tubes to the pass will have four passes, meaning the inlet fluid will be separated into four *equal* flow parts, each entering the heater via a separate nozzle and each leaving via a separate nozzle. Each heater pass contains an identical number of tubes with identical flow and heat transfer. The piping designer must provide means to divide flow equally among the passes.

Dual Purpose Heaters

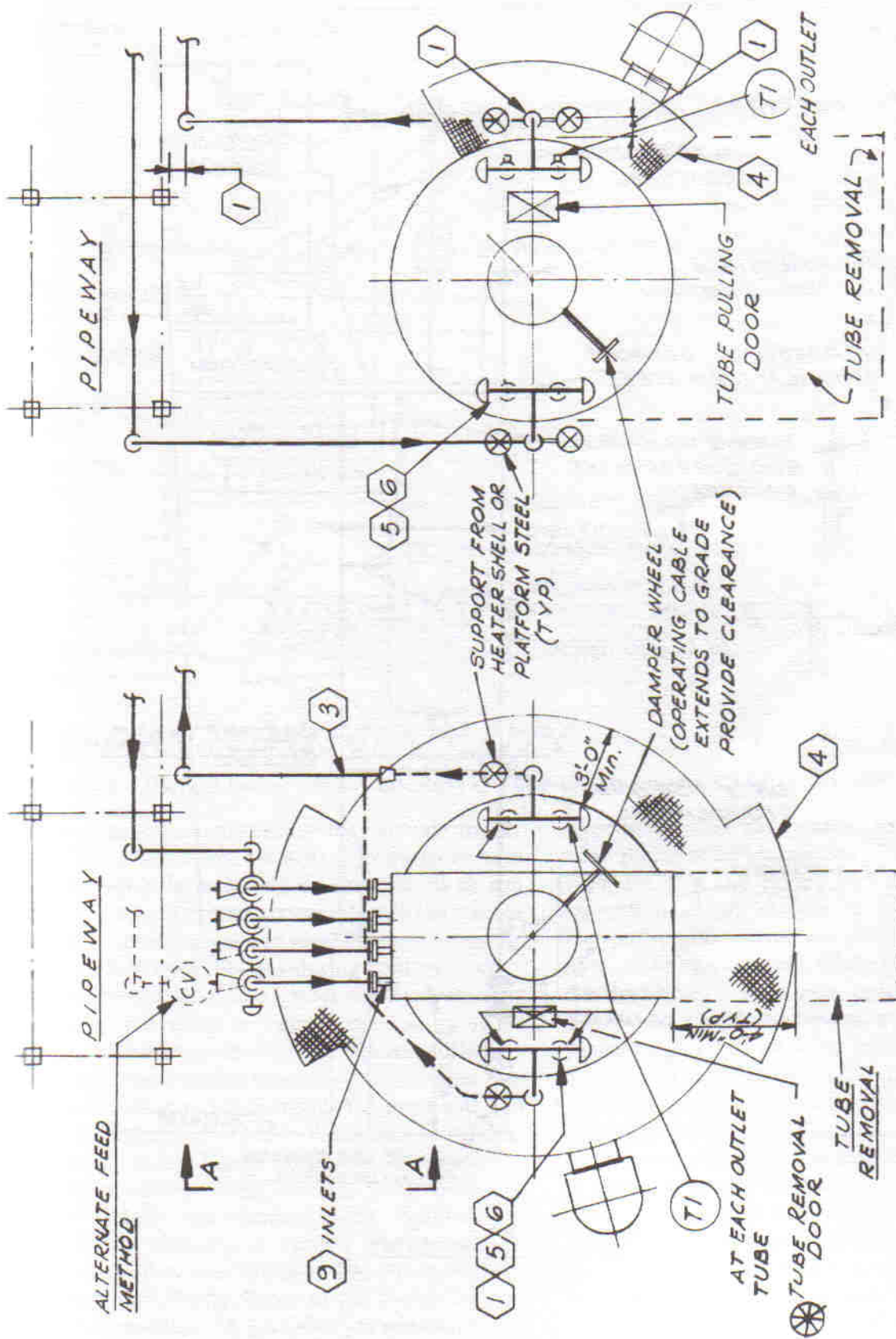
One fired heater may heat fluid for one or more services. It is very common to generate small steam quantities in fired heater convection tubes while radiant tubes are heating hydrocarbons. Especially in box heaters, one or two passes may heat the reactor feed stream while other passes serve as a fractionator reboiler. These heaters are called *dual purpose* or *dual service* heaters.

Flow Through Heaters

Hydrocarbons usually flow counter current to the hot *flue gas* flow. Flue gas is the hot gas flowing upward and out of the stack. The coldest oil usually enters the top of the heater, the convection section, unless steam is generated here; the hottest oil exits from the radiant section, usually at the bottom. With this flow, the coldest oil absorbs the last available heat from the flue gas, resulting in maximum heater efficiency. Not all heaters utilize the convection tube design and; some have only a radiant section.

Figure 3-3 shows the four-pass radiant-convection and the two-pass radiant type heaters. Figure 3-4 is of the radiant-convection type.

1. Locate outlet lines for adding snubbers near elbows, tees or size increases, or at vertical runs down heater to prevent excessive vibration, should it develop.
 2. Strong winds and grade changes can cause flue gases to be blown into adjacent areas, creating a hazardous condition. Stack height may need to be increased beyond draft requirements.
 3. Check with hydraulics engineer for symmetrical piping requirements, usually necessary only with two-phase flow.
 4. Supply minimum platform necessary for operation and maintenance.
 5. Tube movement should be directed to absorb expansion of hot lines to and from heater.
- Directional anchors shall be located, by heater vendor, near the convection section tube terminal connections to provide a minimum of 1 in. deflection in horizontal and vertical directions normal to centerline axis of tubes.
6. When economics and flexibility requirements dictate relocation of inlet or outlet connections to opposite end of heater is desirable, the installation of an additional tube shall be considered.
 7. Piping designer shall orient explosion doors away from operating areas and other equipment.
 8. Platforms and pipe supports are to be designed to transmit loads into the heater structure. Vendor must be appraised of location and amount of load.
 9. Beveled end connections for field welding may be used instead of flanges for heater inlets and outlets. If so, the piping designer must make sure the bevel matches his pipe bevel.
 10. Supply stairs to low level platforms at horizontal and vertical heaters. For box heater platforms, with areas of over 200 sq. ft., provide additional ladder escape from each platform at end opposite stairway.
 11. Route lines as close as possible to heater main structural members for supporting.
 12. Crossover piping - check clearances. Find out whose responsibility it is to specify and provide insulation.
- Figure 3-5 shows details of radiant and radiant-convection type heaters. Inlets and outlets are pictured at the heater top; however, bottom outlet connections may be supplied.
- Figures 3-6 and 3-7 furnish typical details for horizontal or box-type heaters.
- The heater manufacturer selects the proper burner size and quantity to match his heater's duty and purchases burners from a burner manufacturer.
- Burners may consume fuel gas, fuel oil or a combination of the two. The combination burners



RADIANT-CONVECTION TYPE
(FOUR PASS)

RADIANT TYPE
(TWO PASS)

PLAN
TYPICAL PROCESS PIPING @ VERTICAL HEATER

Figure 3-3. Vertical heater piping plan. Courtesy of Fluor Engineers and Constructors, Inc.

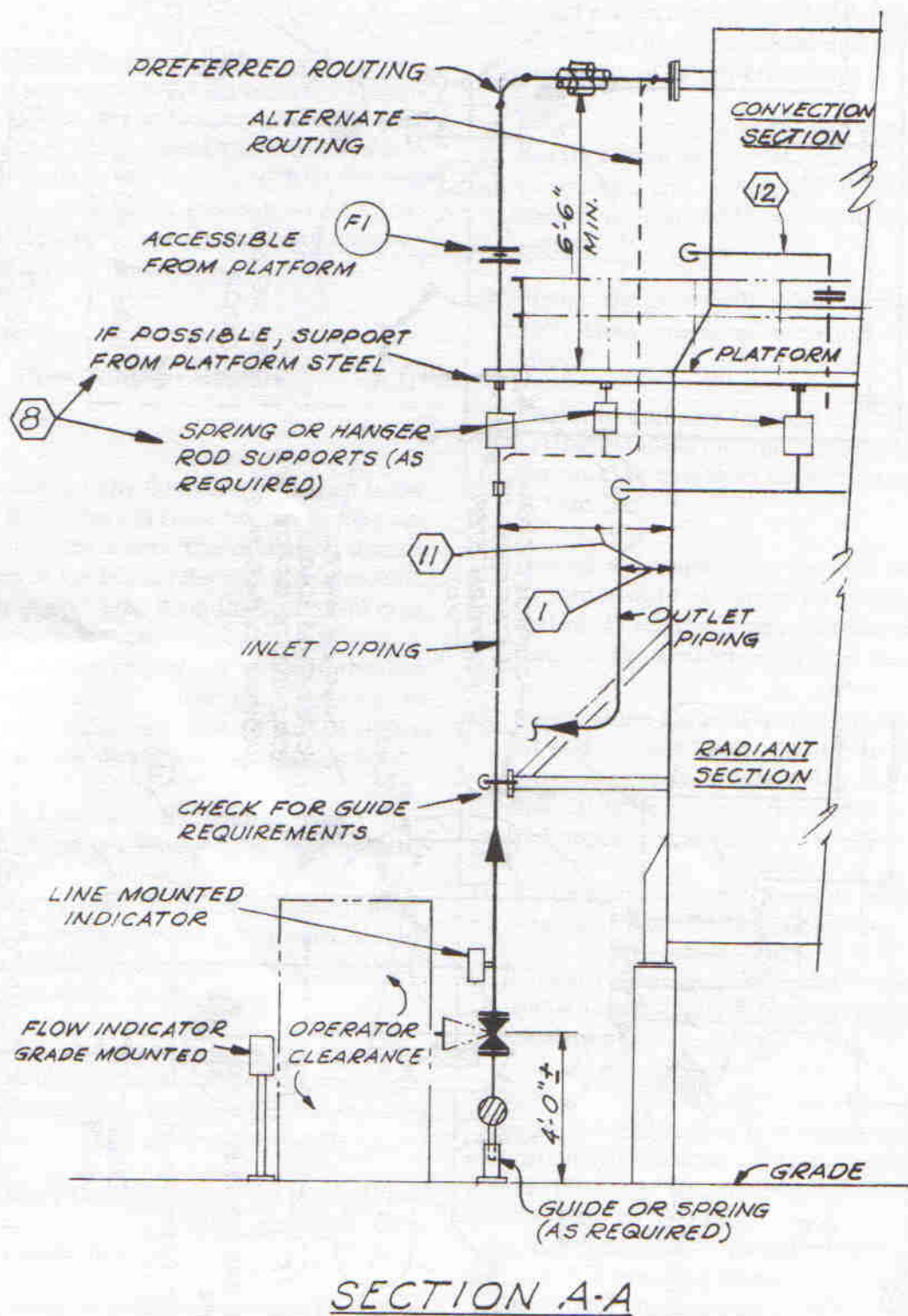


Figure 3-4. Section at vertical heater. Courtesy of Fluor Engineers and Constructors, Inc.

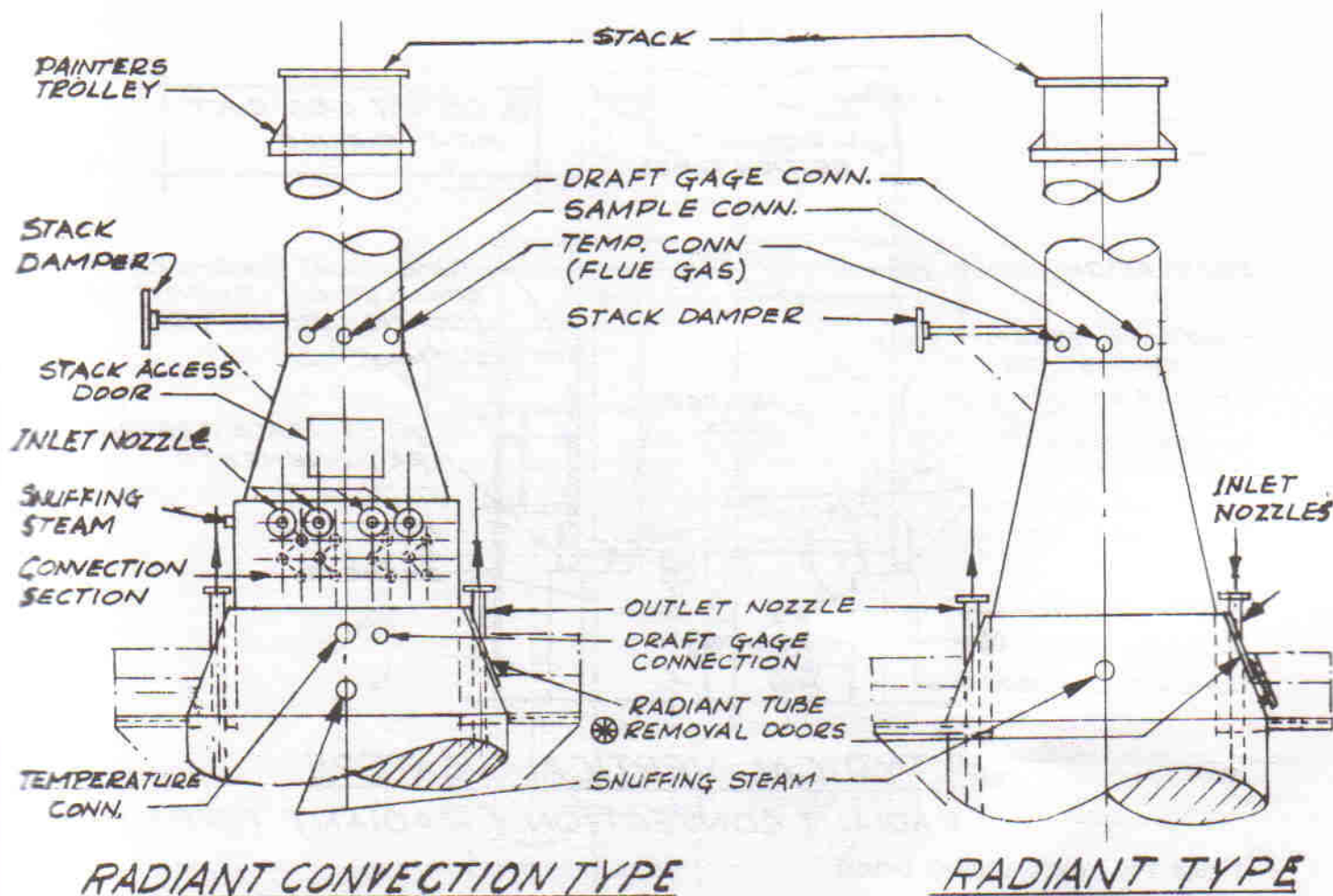


Figure 3-5. Vertical heater details. Courtesy of Fluor Engineers and Constructors, Inc.

are the most commonly used as they provide greater operational flexibility, allowing their owner to burn fuel gas when he is selling all the fuel oil he can make and to switch back to fuel oil when the market subsides. Since fuel oil is in great demand in winter, most heaters burn fuel gas during cold weather.

Fuel gas is a vapor and ignites readily. Fuel oil is a liquid, and often a viscous one. It must be vaporized to burn properly. This is accomplished by injecting atomizing steam and fuel oil together into the burner oil gun, which blends the two fluids and sends the combined vapor to the burner firing tips.

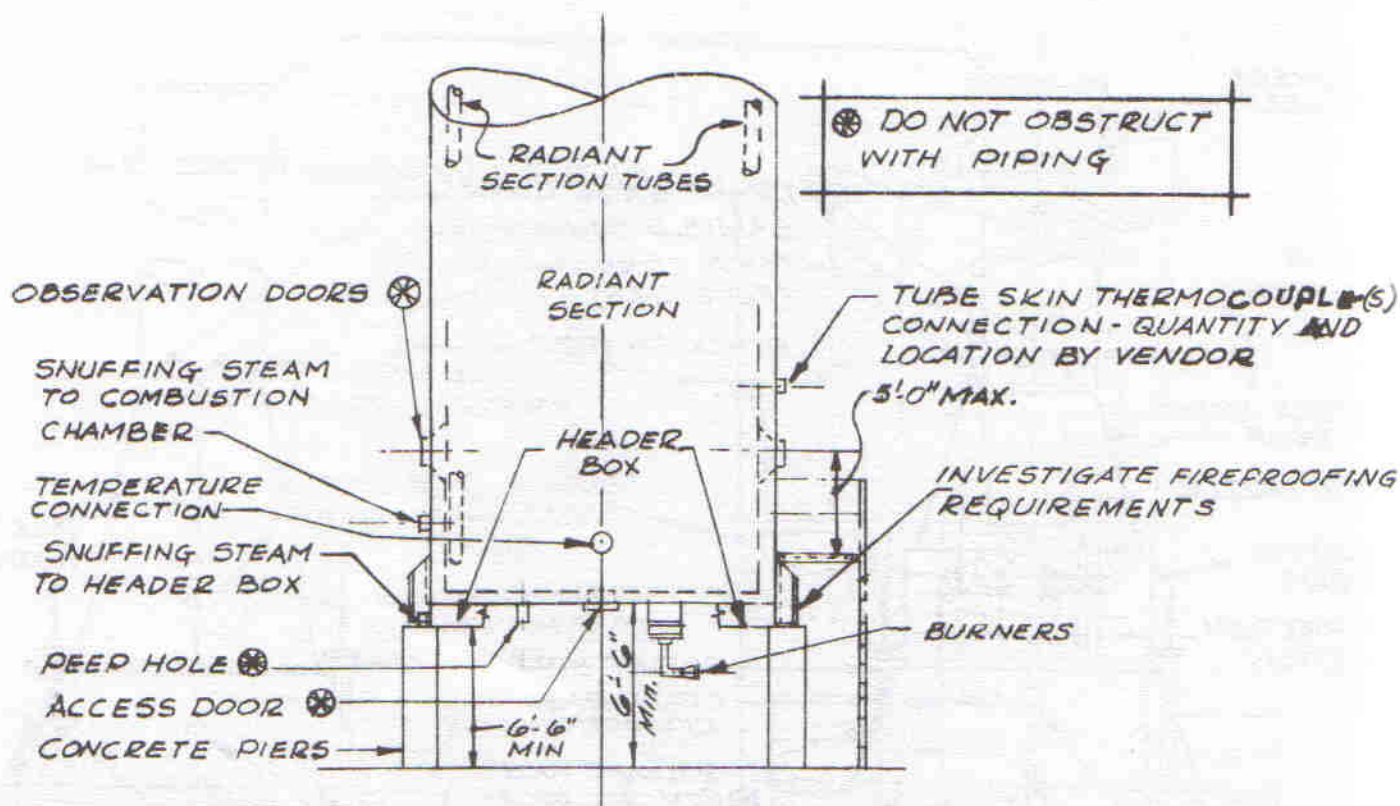
Figure 3-8 and Figure 3-9 give burner details for bottom-mounted installations. Side-mounted burner details are similar. Since burners are removed for cleaning or repairs, piping must be designed to allow their removal. The piping designer provides short flexible hoses to the burner oil gun tapped connections. Hoses to fuel gas connection are desirable to reduce vibration. If hoses are not

supplied for fuel gas, a union must be located to allow piping to be broken away for burner removal.

Figure 3-10 and Figure 3-11 give piping details for side-mounted burners in horizontal heaters. Normally, plug valves are provided for fuel and pilot gas burner controls. Globe valves are shown as the final throttling valve in fuel oil and atomizing steam lines. Fuel oil lines are shown as being steam-traced to keep the oil from solidifying in the lines during cold weather or shutdowns.

Figure 3-12 shows header piping required for box heater burners. The fuel oil comes in one side, circles around the back and returns to the rack. Fuel oil piping is usually a circulating system, constantly flowing, with supply and return header in the rack. Both headers are normally steam-traced. While only three burners are shown, this heater actually has eight burners, four on each side.

Figure 3-13 shows how fuel oil, fuel gas and atomizing steam headers are bent into rings circling



TYPICAL VERTICAL HEATERS (RADIANT CONVECTION & RADIANT TYPES)

Figure 3-5. Vertical Heater Details.

the vertical heater and supported from the structural frame members commonly called *buckstays*.

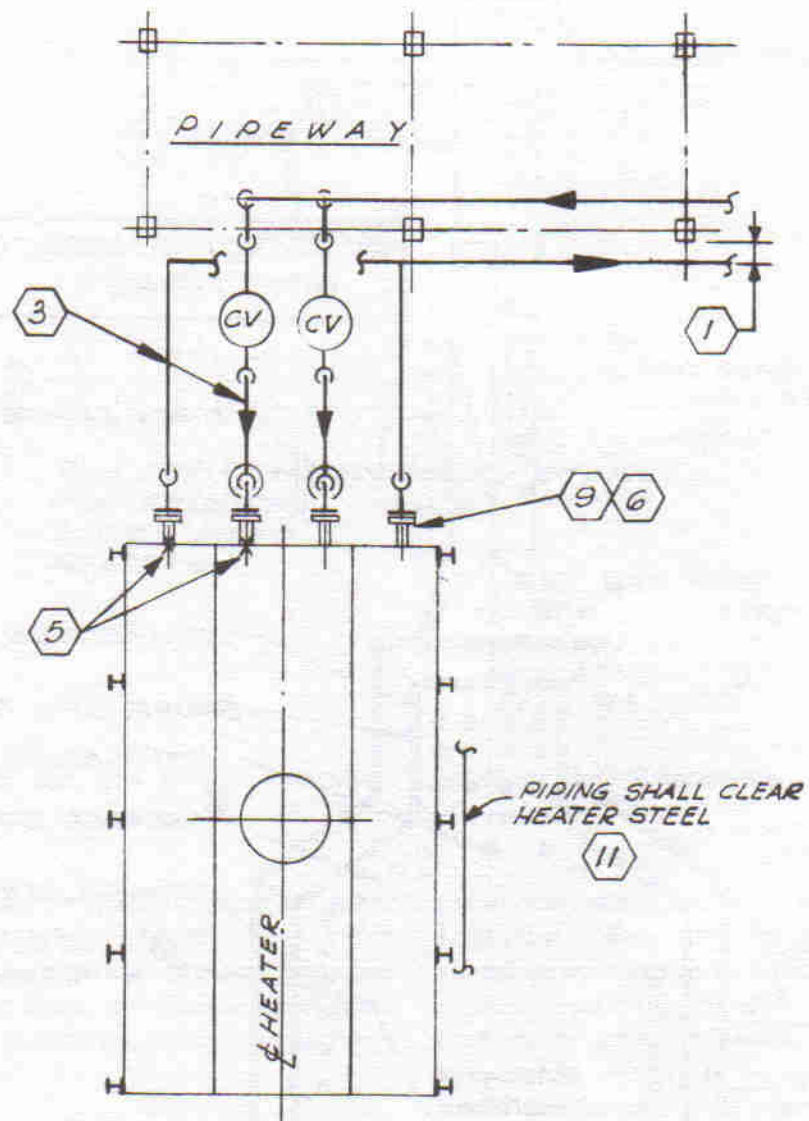
Figure 3-14 provides elevations at burner piping typical to Figures 3-12 and 3-13. Atomizing steam comes off the header top to keep condensate from going to the burner. Fuel gas headers could have hydrocarbon condensate in them so burner piping comes from the header top here, too. Pilot gas is usually a small, 1/2" or 3/4", line and can be easily supported from available platform. Pilot gas connections shall also come off the top.

Refer to Figures 3-10 through 3-14 for the following notes.

1. Ring headers around vertical furnace mounted above observation doors with vertical leads to burners. Shut-off valves for steam, oil and gas should be located in the vertical next to the observation doors.
2. Pilot gas line must connect with supply system

upstream of main gas control valve and high enough to insure dry gas supply to pilots.

3. Provide 3/4" valve at fuel gas header end to manually drain any accumulated condensate. This valve must be accessible from grade or platform. If the plant has a low pressure blow-down header, provide a line from this valve to the header.
4. Pilot gas to burners shall have valve accessible at burner.
5. Vertical heater access to observation doors may be by ladder only or may have a small platform supplied as shown.
6. On bottom-fired box heaters, the pilot gas header may be located under furnace floor. Keep piping clear of peep holes, access doors and burner removal area.



PLAN
PROCESS PIPING
BOX HEATER

Figure 3-6. Box heater typical plan. Courtesy of Fluor Engineers and Constructors, Inc.

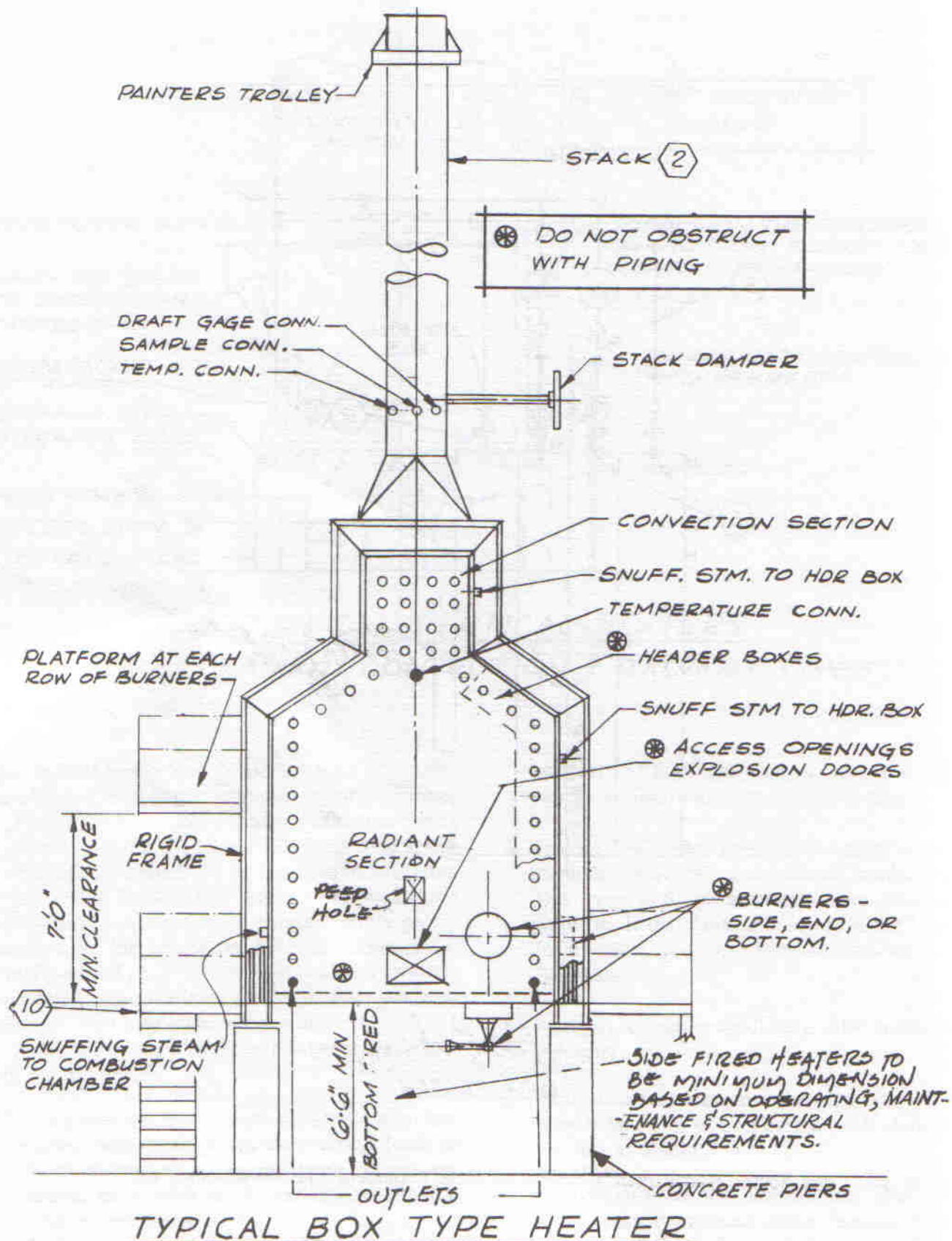


Figure 3-7. Box heater typical elevation. Courtesy of Fluor Engineers and Constructors, Inc.

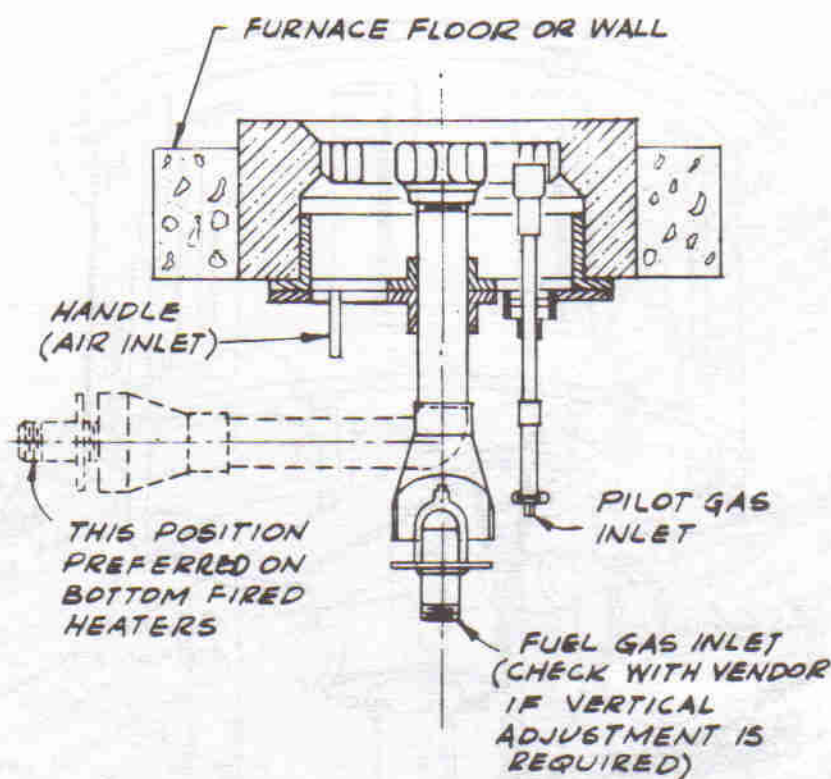


Figure 3-8. Typical fuel gas burner assembly. Courtesy of Fluor Engineers and Constructors, Inc.

7. For burners firing fuel gas only, shut-off valve may be located beneath heater. Keep valve clear of burner for operator protection in case of flash-back. If there is sufficient headroom, fuel gas header may be located below platform next to pilot gas.
8. For wet fuel gas, a local knock-out pot is often shown on flow diagrams. This pot should be located a minimum of 50' from heater flame. Main fuel gas shut-off valve shall also be 50' away.
9. Provide minimum hose length of 2'-0"

Snuffing Steam

Heater snuffing steam connections and purpose have previously been explained. Snuffing steam originates at a *snuffing steam manifold* which must be located a minimum of 50' from the heater. Figure 3-15 shows how steam from a medium

pressure header is routed to the manifold at grade. Individual valves and snuffing steam lines are routed to each heater's section connections. For instance, a heater may have three snuffing steam connections for the radiant section, two for the convection section and two in bottom header boxes. This would call for only three snuffing steam valves and lines, each line going to a section where fire could be. Snuffing steam lines are usually 2" size. Manifolds often serve three or four heaters and may have a dozen or more 2" lines going to heaters.

Since these lines are not normally under pressure, they are not field hydrotested from valve to heater. Consequently, spans between supports can be greater than for lines which contain liquid. High point vents are not needed. 1/4" holes are drilled at low points. Also note that there is no insulation supplied from valve to heater. Snuffing steam valves are only opened during an emergency; so insulating the lines would be a waste of money. When live steam is introduced rapidly, the lines will quickly expand, and guides must be provided to keep them from snaking.

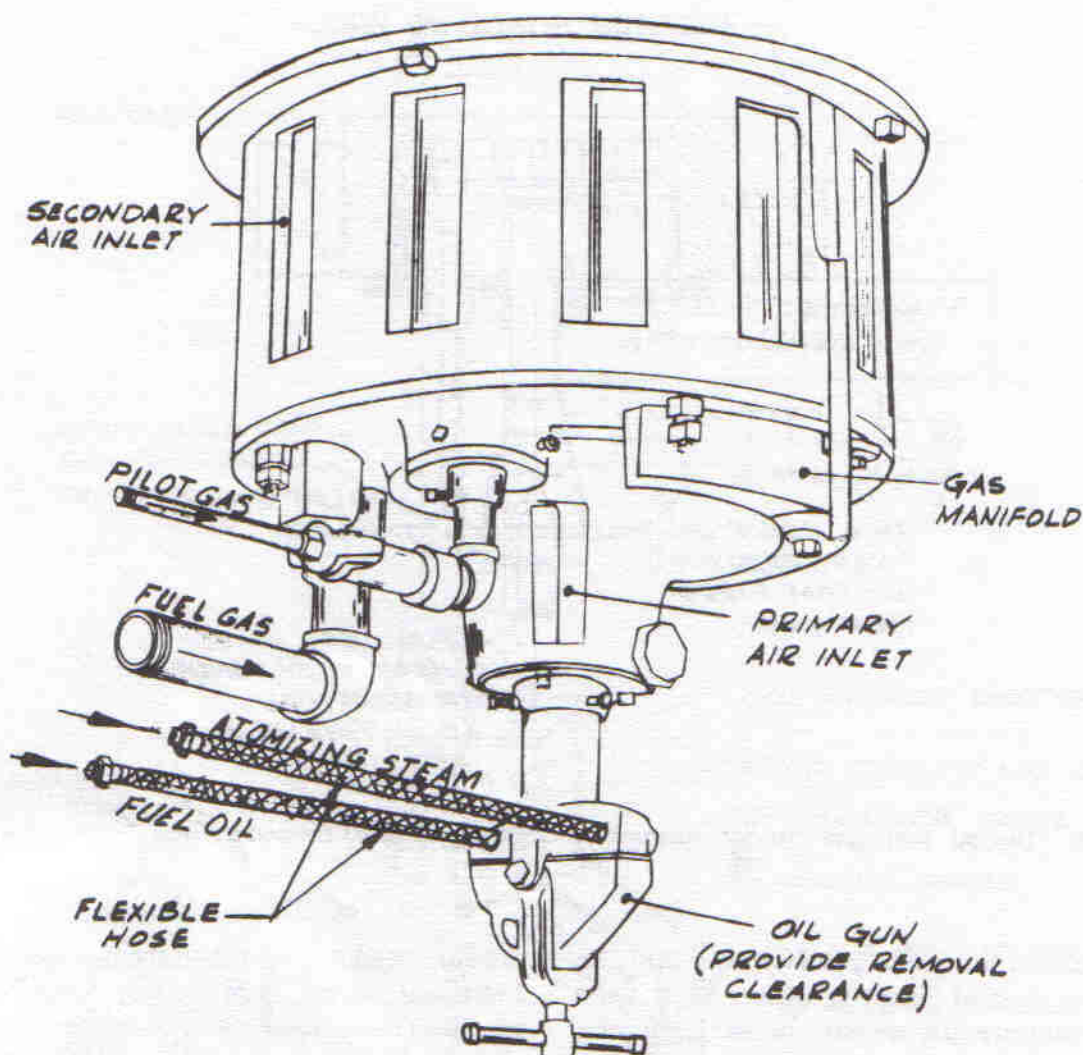


Figure 3-9. Typical combination burner assembly. Courtesy of Fluor Engineers and Constructors, Inc.

Heater Locations

Many factors must be considered for optimum heater location. Some items are mandatory due to safety and maintenance while others are desirable. It is desirable to have heaters located upwind of process units to blow any combustible leaks away from the open flame. While not mandatory, current codes recommend fired equipment be located at least 50' from any equipment which contains hydrocarbons. Most designers follow this policy

except for reactors which are usually located closer to keep expensive alloy lines as short as possible and to reduce piping stresses and forces. For maintenance, fired heaters must have road access to permit a crane to remove and replace tubing. Box heaters must have horizontal free area, equivalent to tube length plus 5' for tube pulling area. A roadway must be blocked off and can be considered as part of this tube removal area. Vertical heaters need only crane access area since their tubes pull up.

Figure 3-16 shows a typical horizontal heater location in relation to the pipeway and roads. Distance 5, determined by piping manifolds and

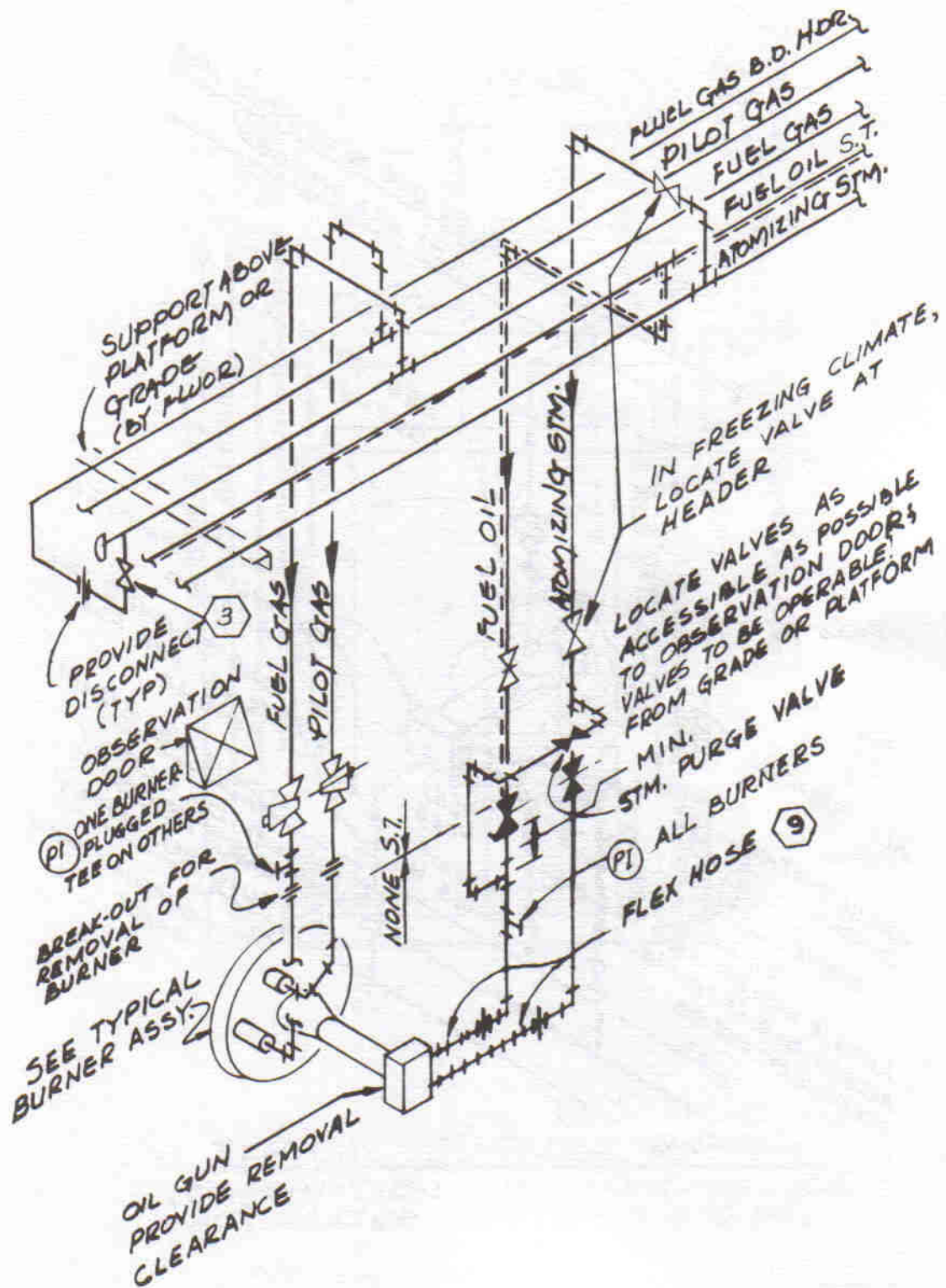


Figure 3-10. Typical burner piping with overhead supply. Courtesy of Fluor Engineers and Constructors, Inc.

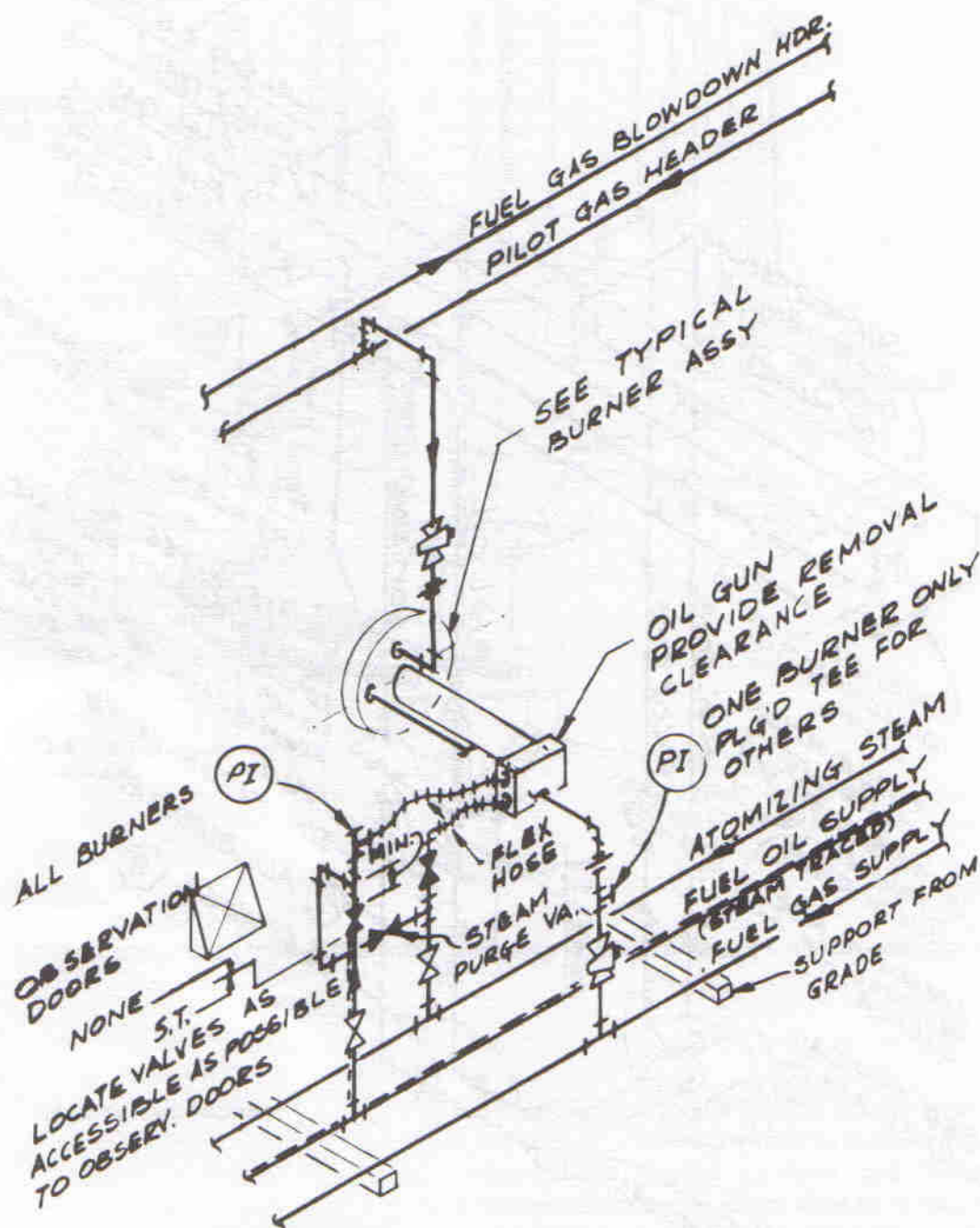
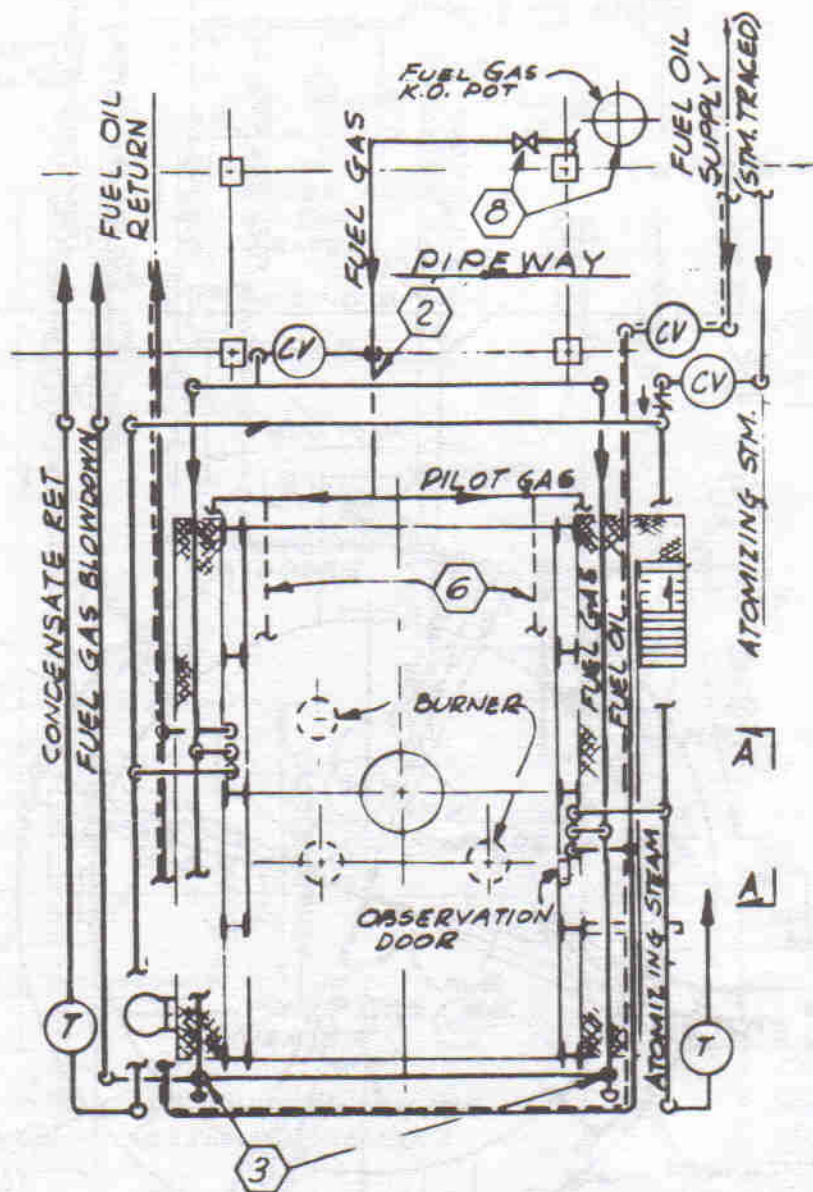


Figure 3-11. Typical burner piping with bottom supply. Courtesy of Fluor Engineers and Constructors, Inc.



TYPICAL BURNER PIPING
(COMBINATION FUEL GAS & FUEL OIL
BOX HEATER - BOTTOM & SIDE FIRED

Figure 3-12. Burner piping at box heater. Courtesy of Fluor Engineers and Constructors, Inc.

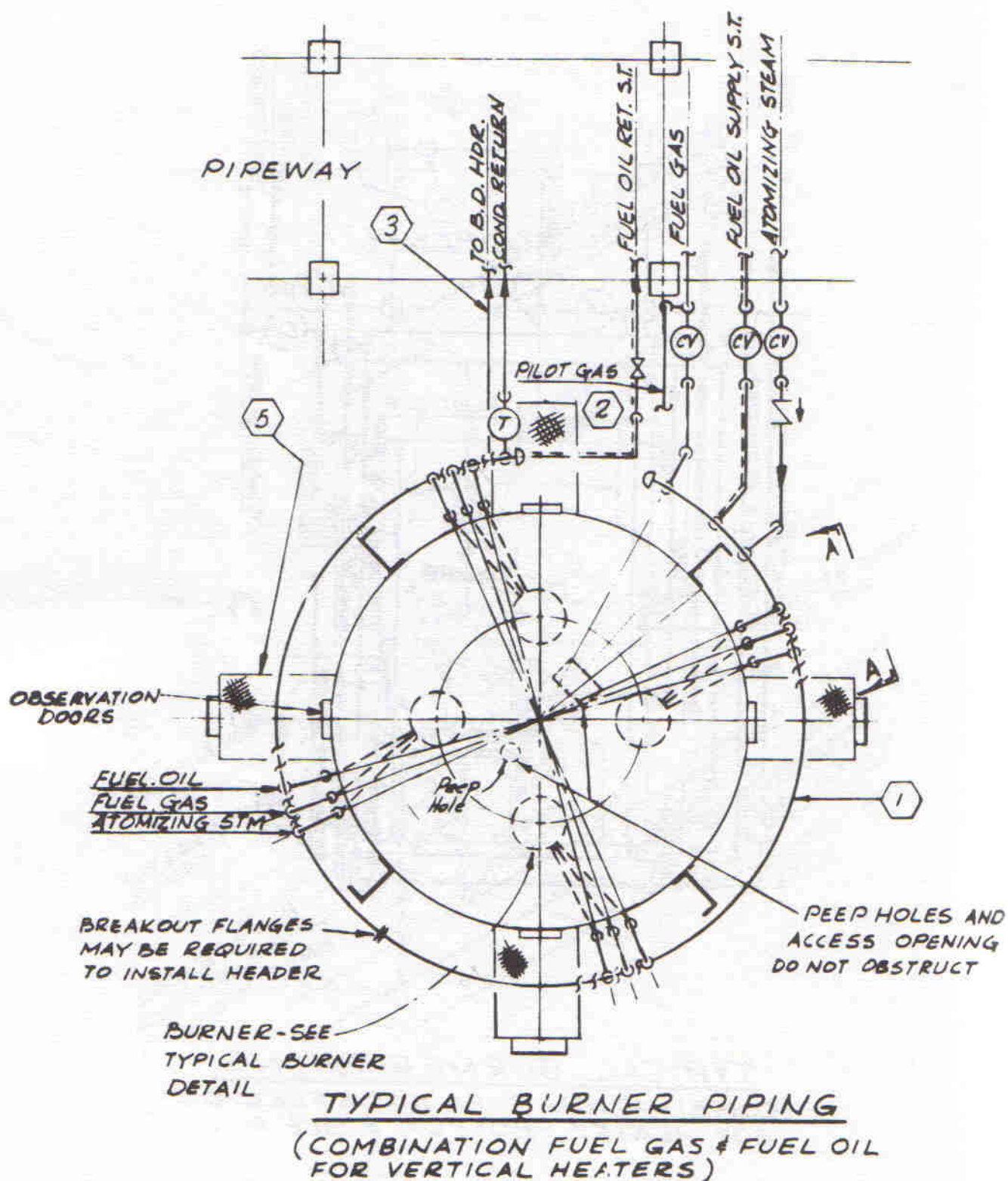
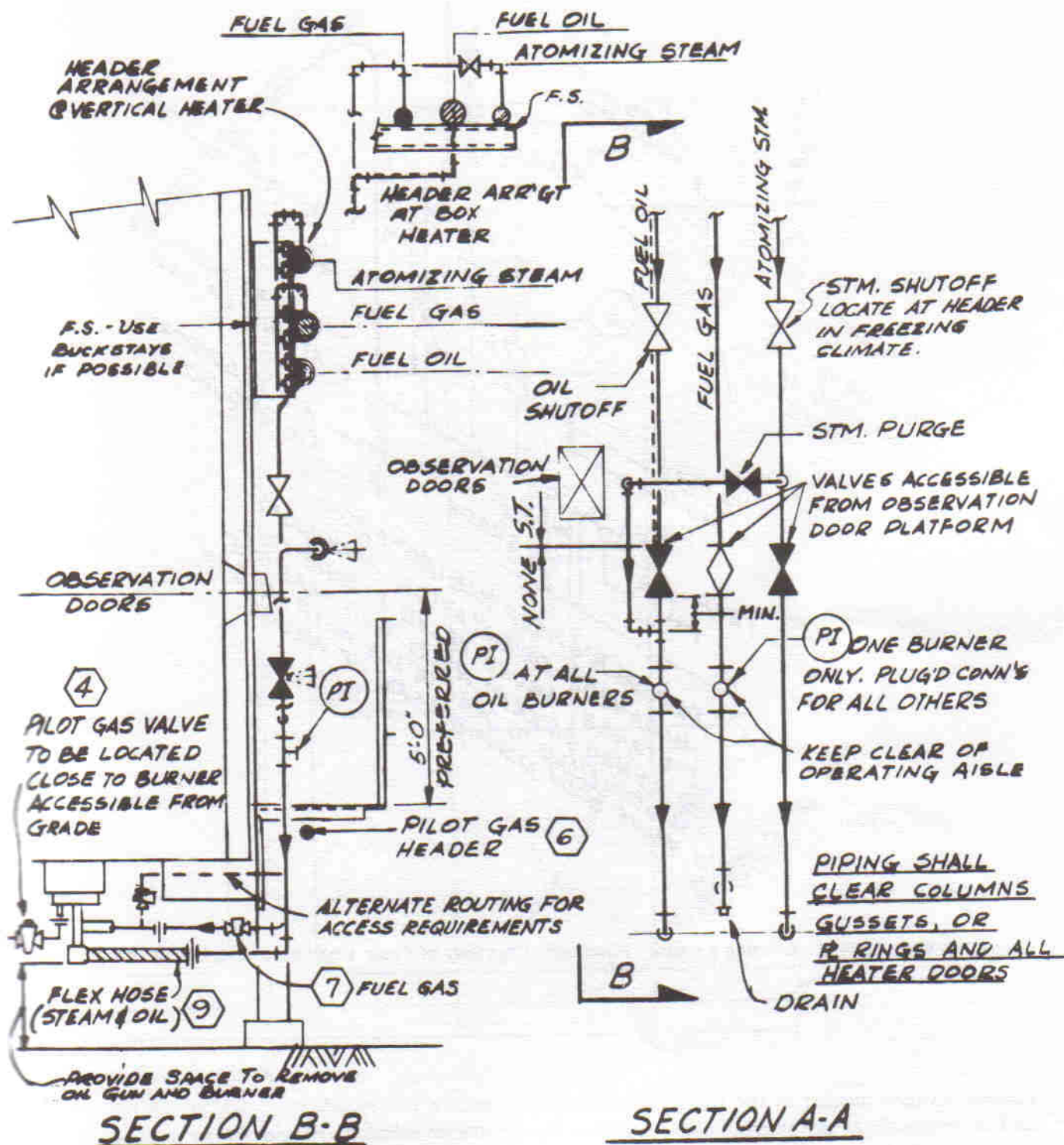


Figure 3-13. Burner piping at vertical heater. Courtesy of Fluor Engineers and Constructors, Inc.



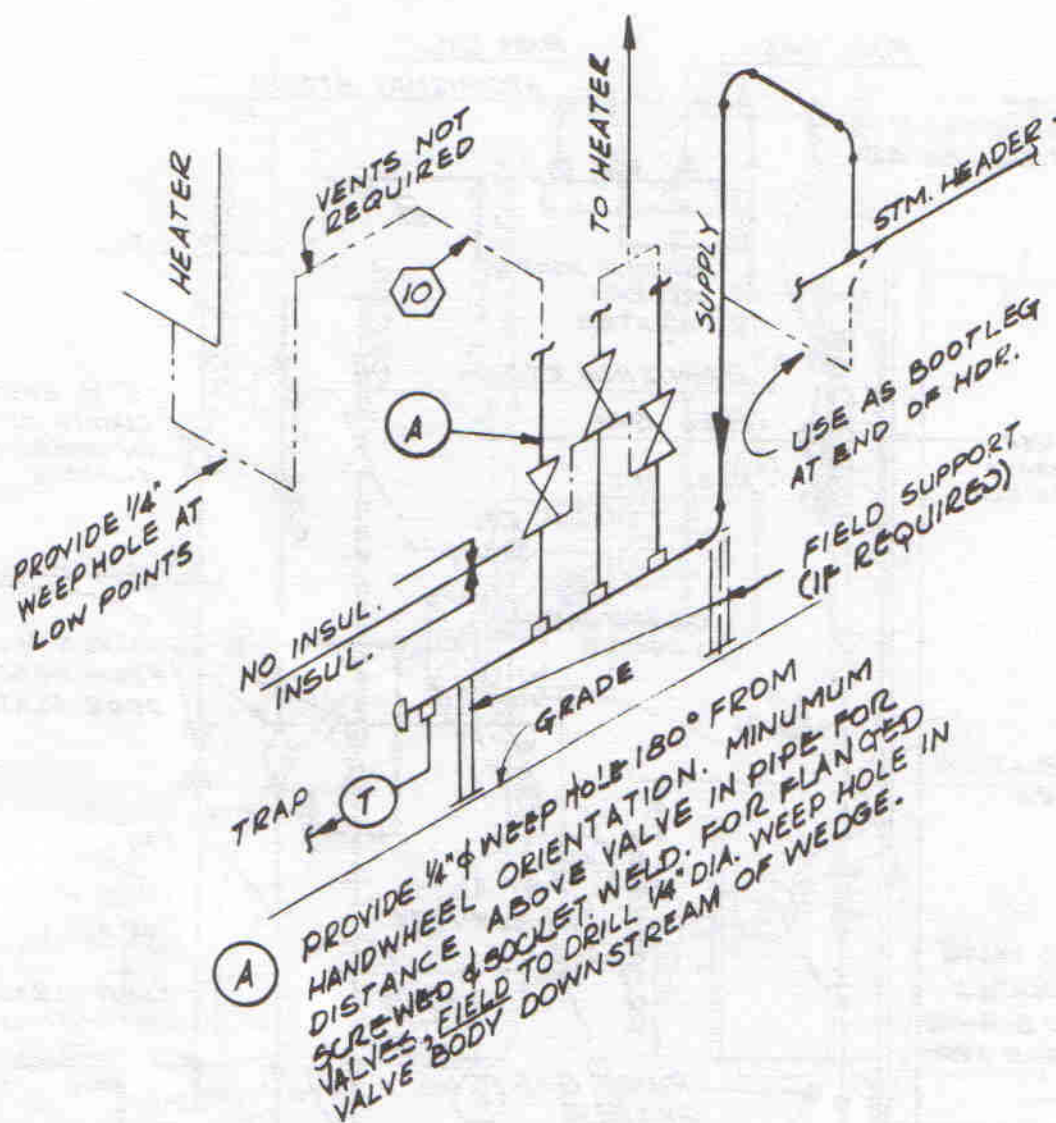


Figure 3-15. Typical snuffing steam manifold. Courtesy of Fluor Engineers and Constructors, Inc.

control stations located at the front of the heater and clearance from a possible heater platform, is usually 10-14'. Dimension 6 is a minimum of 10' but must utilize road width for a tube removal area. For a heater with 40' tube length and a 14' road, Dimension 6 would have to be 26' plus 5 ft—or 31'. Designers must not consider any area across the road as tube pulling area unless it is already a tube pulling area for fired heaters located within another

unit. In this situation a common pulling area is a sensible solution.

The other 10' dimension is shown to warn designers that this is the minimum distance any heater can be located from any road.

Figure 3-17 shows both vertical and horizontal heaters located in relation to a unit pipeway. Note 3 warns designers to locate hydrocarbon containing equipment a minimum of 50' from fired heaters.

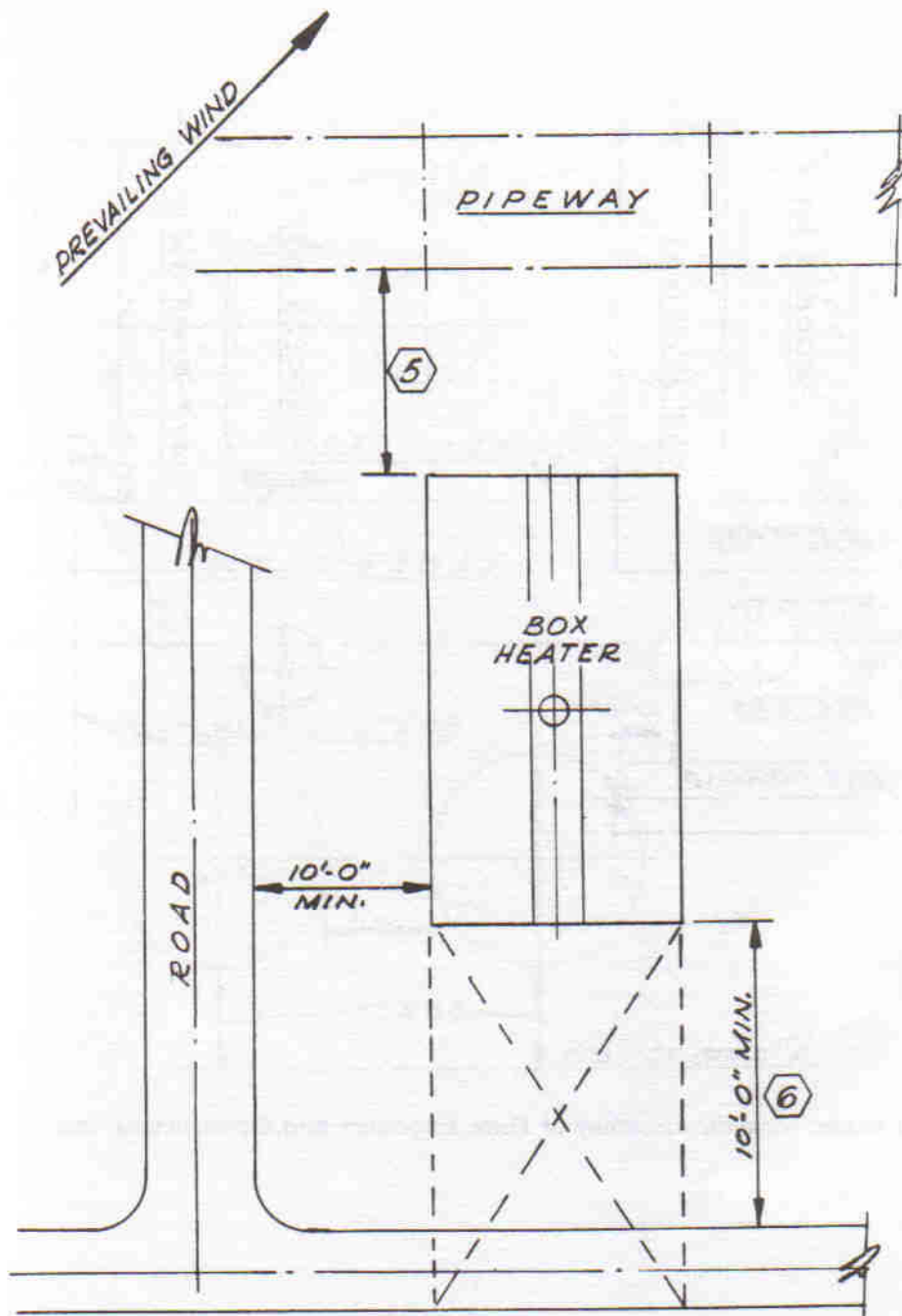


Figure 3-16. Box heater location. Courtesy of Fluor Engineers and Constructors, Inc.

Local codes and insurance regulations may dictate greater clearance and must be investigated. Distance between two vertical heaters is normally

10'. However, platform and foundation clearance must be checked. It is very desirable to combine platforms for multiple vertical heaters.

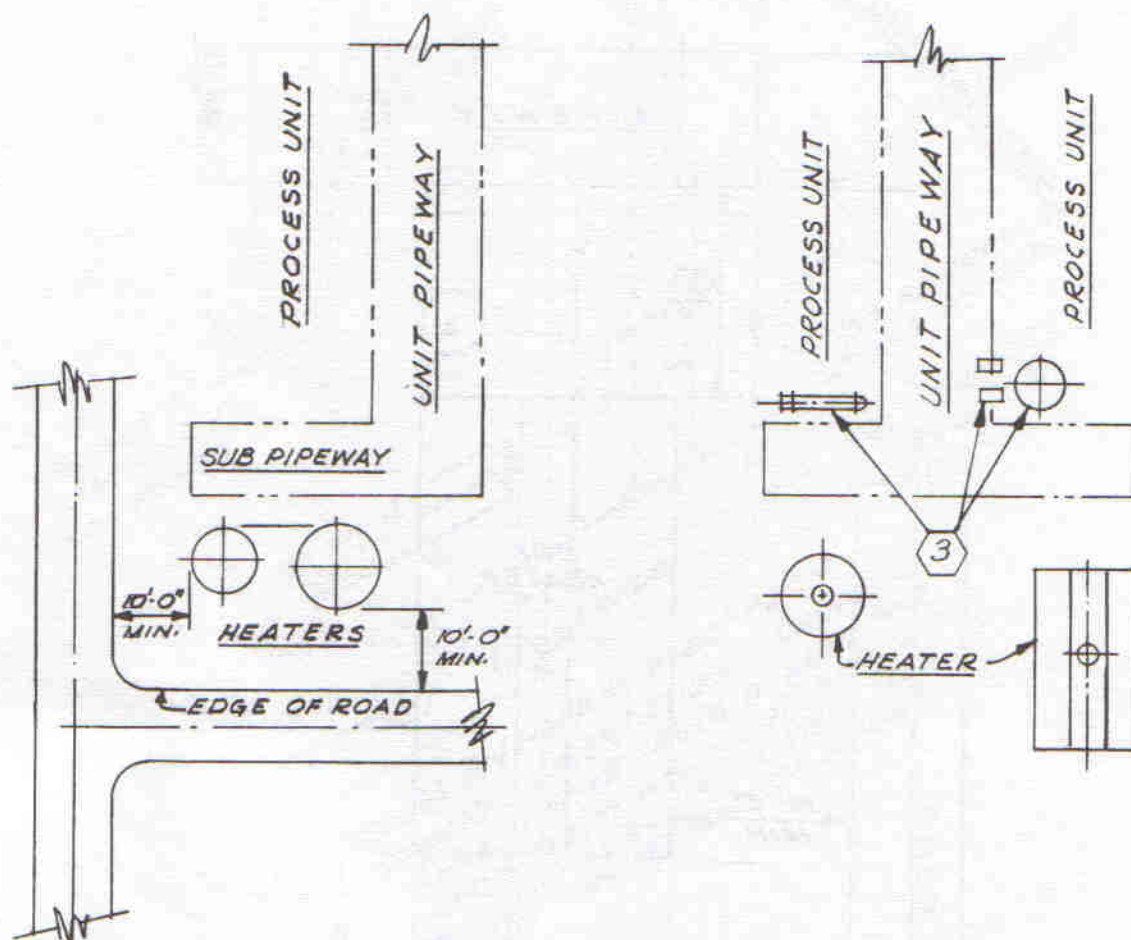


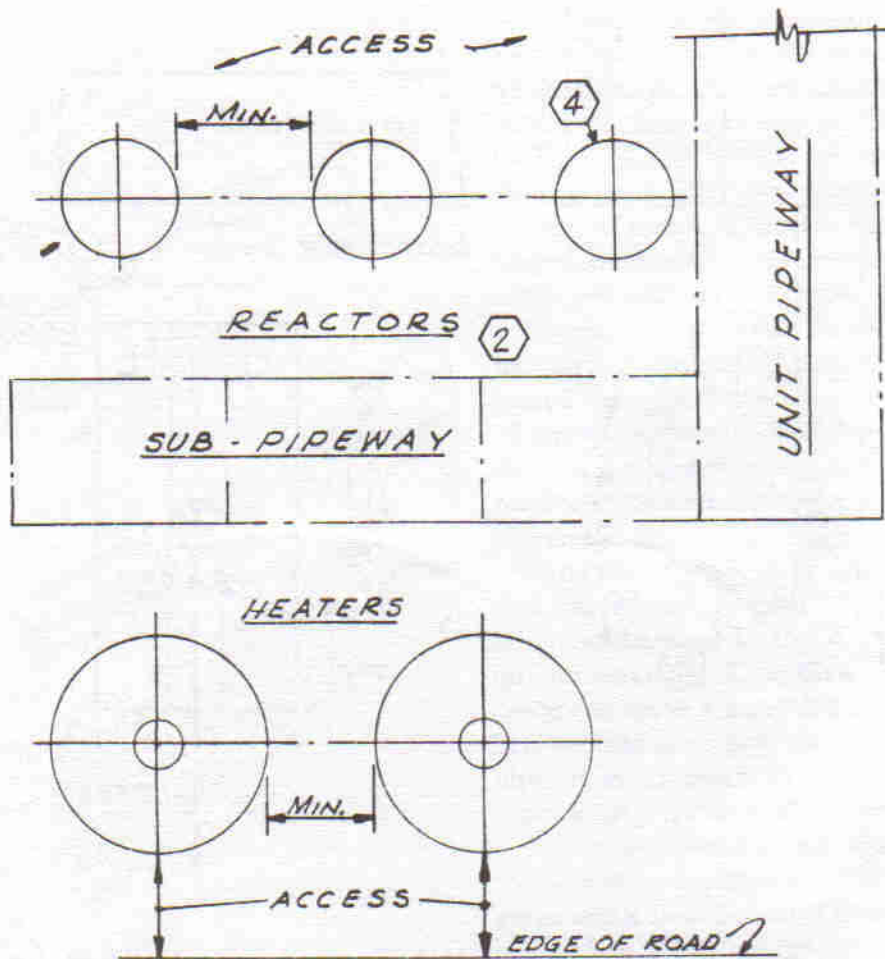
Figure 3-17. Vertical heater location. Courtesy of Fluor Engineers and Constructors, Inc.

Heater Arrangements

While fired heaters are often utilized as reboilers for fractionating towers, in today's units they more often provide heated feed to reactors in reformers, unifiners, platformers and hydrocracking units. Reboiler heaters normally have carbon steel piping but reactor-heater piping is usually an expensive steel alloy. For this reason, reactors are usually

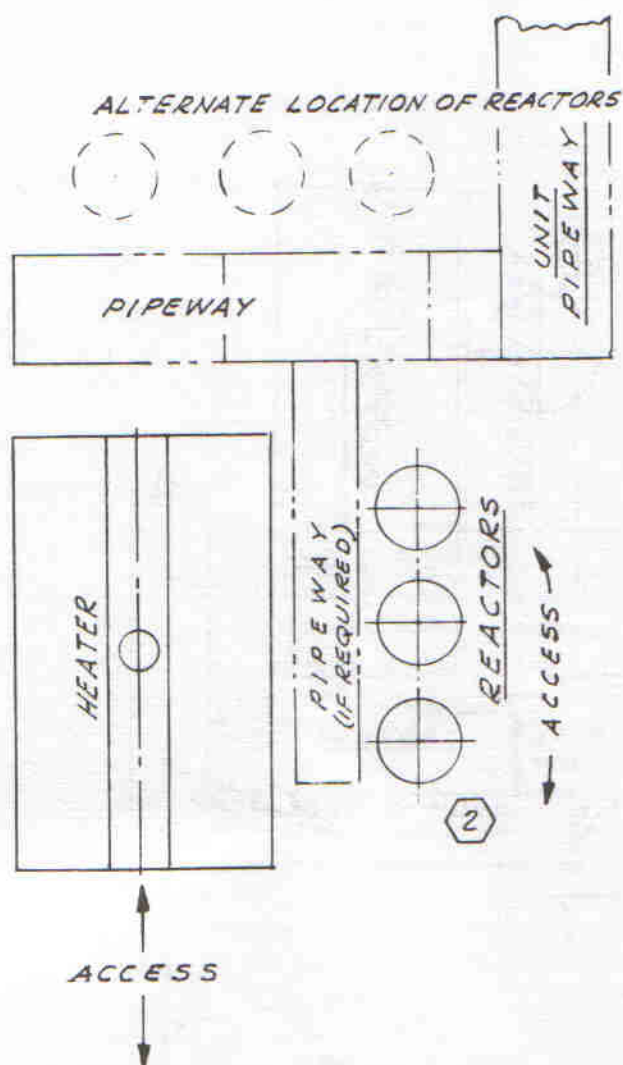
located within 20-25' of heaters, disregarding the normal 50' distance requirement. This is especially true for reforming units where flow is from reactor to heater to reactor, etc.

Figure 3-18 pictures vertical heaters and reactors such as might be found in a reforming unit. A sub-pipeway, located between heaters and reactors, contains heater auxiliary piping and supports reactor-heater alloy lines. Note 4 warns the designer to consider reactor access for removal and replace-



ARRANGEMENT "A"

Figure 3-18. Heater Arrangement A. Courtesy of Fluor Engineers and Constructors, Inc.



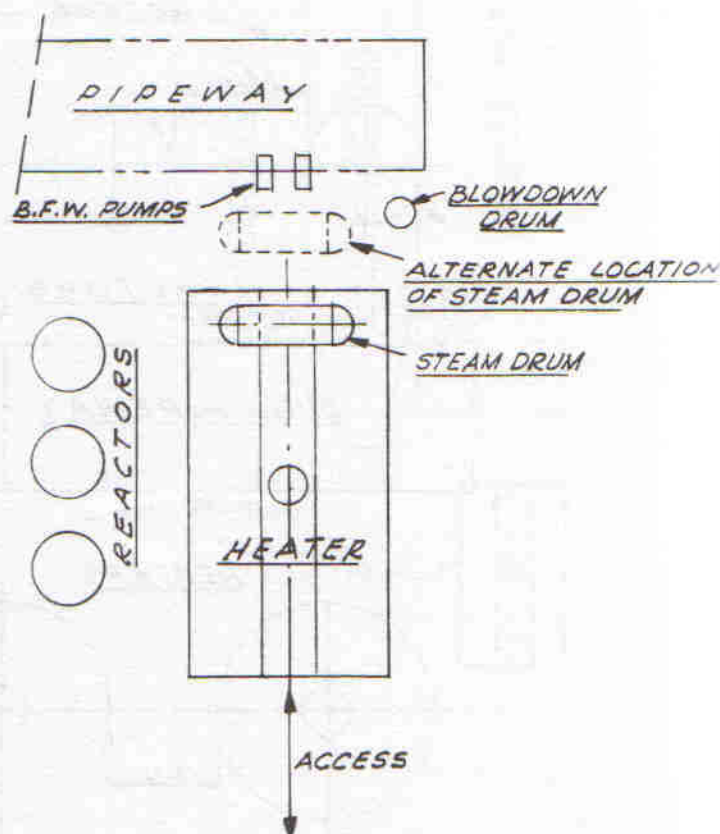
ARRANGEMENT "B"
MULTIPLE REACTORS
AND BOX HEATER

Figure 3-19. Heater arrangement B. Courtesy of Fluor Engineers and Constructors, Inc.

ment of catalyst. Combined top platforms and a single monorail may be desirable if all reactors are about the same height above grade.

Figure 3-19 shows multiple reactors with a box heater.

Figure 3-20 is a heater-reactor train with the ad-



ARRANGEMENT "C"
HEATER-REACTOR TRAIN
WITH STEAM GENERATION

Figure 3-20. Heater arrangement C. Courtesy of Fluor Engineers and Constructors, Inc.

dition of steam generation. Here the heater convection coils are utilized for steam generation. Note that boiler feedwater pumps and other steam equipment are placed near the heater. They may be within the 50' distance because they do not contain hydrocarbons. Another possible location for the steam drum is over the pipe rack.

Heater Piping

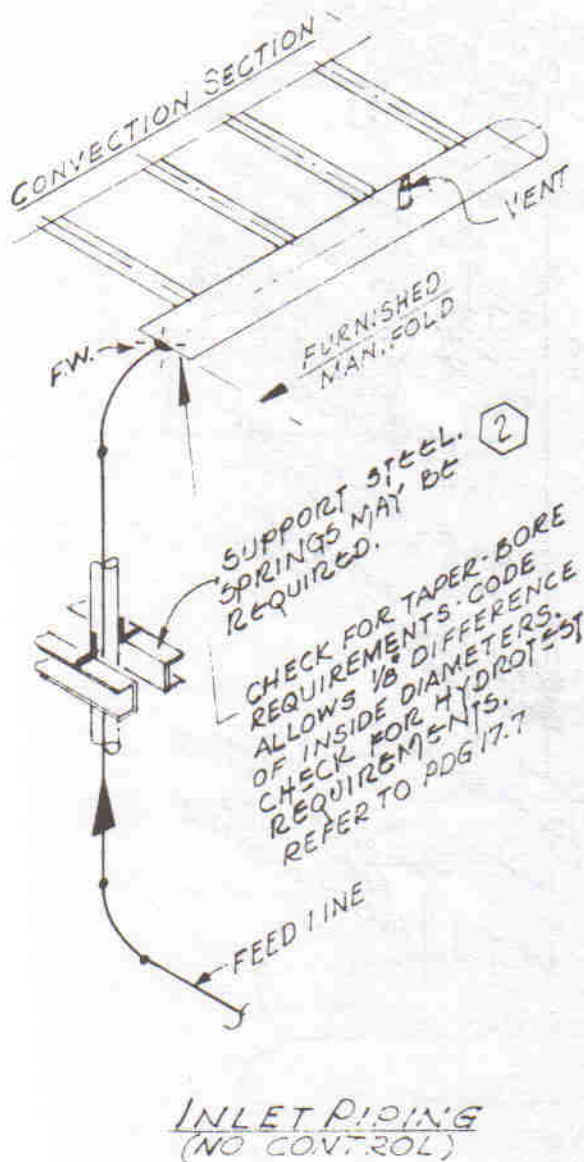


Figure 3-21. Inlet piping manifolded at convection section. Courtesy of Fluor Engineers and Constructors, Inc.

When a fired heater has convection tubes, inlets are normally in the convection section. If the convection section is used for steam generation, heater process steam inlets are usually at the top of the radiant section; they may be instead at the bottom, particularly with vertical heaters. Heaters may have one or more inlet connections depending on the number of passes; if the flow to each pass is not controlled, the heater vendor is often asked to manifold inlets and provide one piping connection.

Figure 3-21 shows a furnished manifold, with one piping connection, feeding four heater passes. Note 2 cautions the designer to notify heater vendor of piping load and to have him furnish the support steel. If a stress check indicates a spring hanger is required, the vendor must be aware of possible movement at the manifold connection point.

Fired heater tubing is designed in accordance with the ASME Section VIII code; piping to the heater is designed to the ANSI piping code. The different material allowable stresses under these two codes can cause a great difference in wall thickness between the inlet pipe and the furnished manifold pipe. If inside diameters differ more than 1/8 in. taper boring is required by the ANSI code.

Figure 3-22 shows four convection inlets with the flow to each pass controlled by a globe valve at grade and a flow indicator showing amount of flow in each line. Note that the indicator instrument is to be located at grade near the globe valve so the operator can read flow quantities while operating the valve. Normally, orifice flanges are located upstream of any control or throttling valve; here they are downstream. For this service precise measurement is not as important as relative flow. The operator needs to have the same flow in each pass. While quantities may not be indicated precisely, the flows will be relatively identical if orifice flanges are downstream of the globe valve. Locating orifice flanges here also saves considerable cost.

Note that the globe valve manifold header is not supported from grade but only guided. Support is accomplished at Note 2 with rod or spring hangers. A firm anchor might be located here with expansion going up and down from this point. Then the horizontal convection inlet legs would have to be long enough to withstand upward movement and

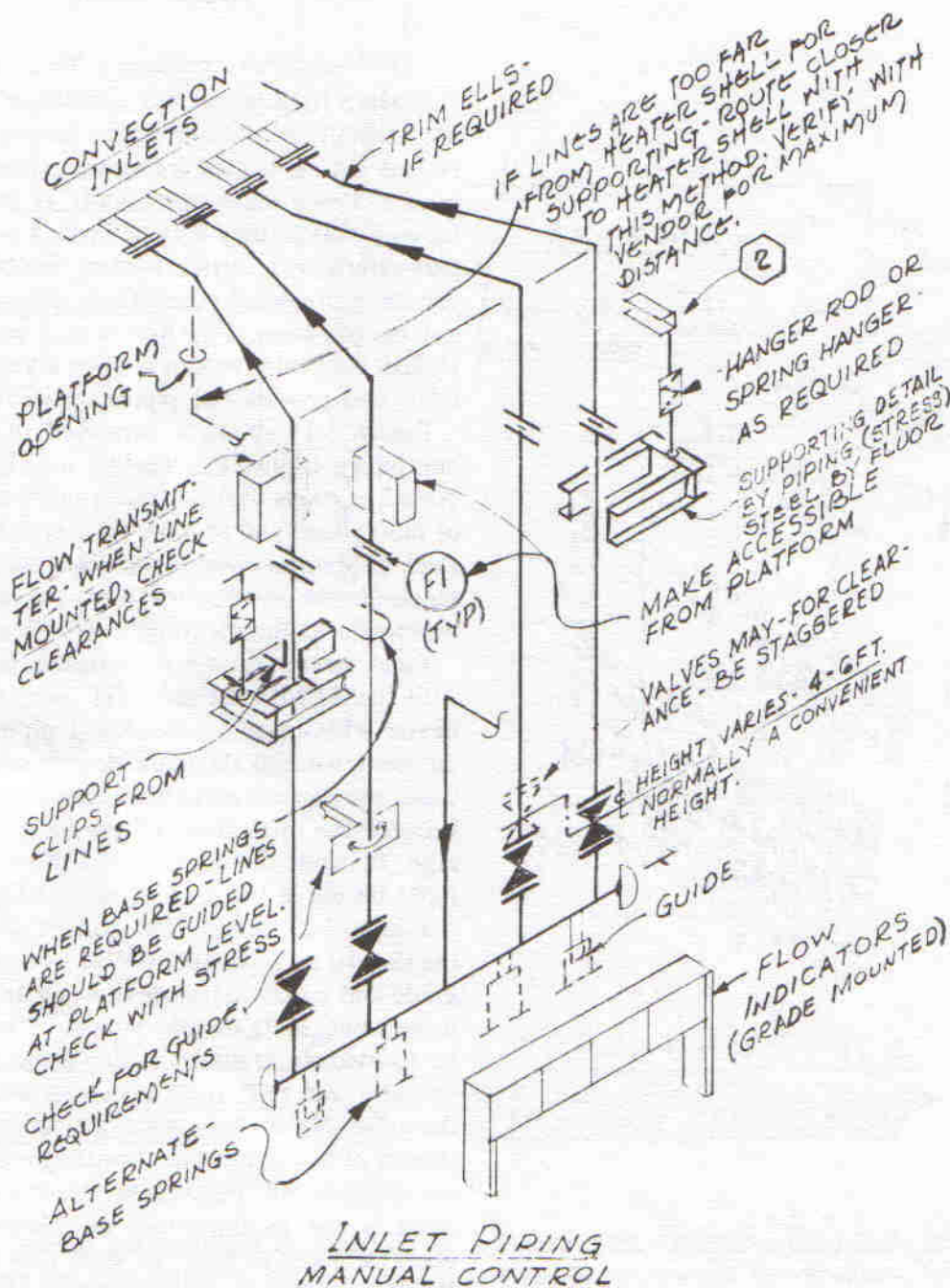
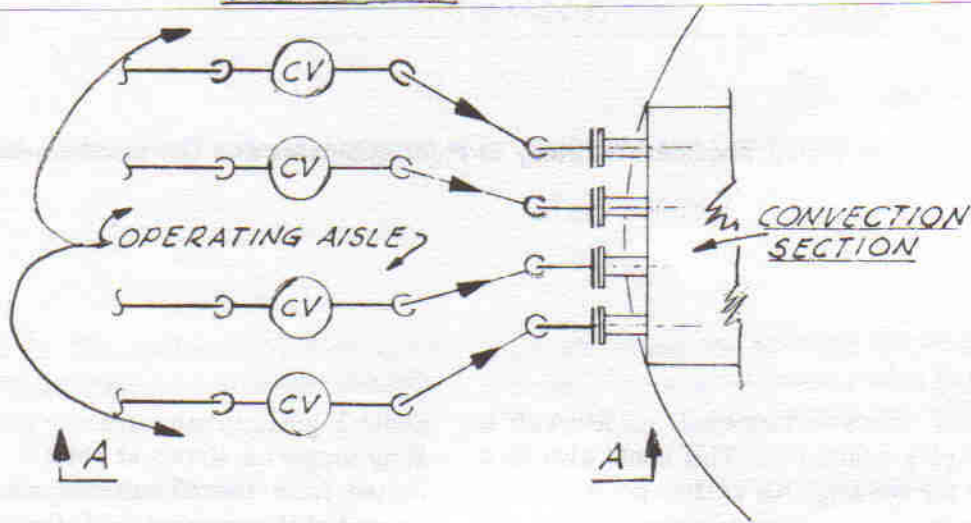
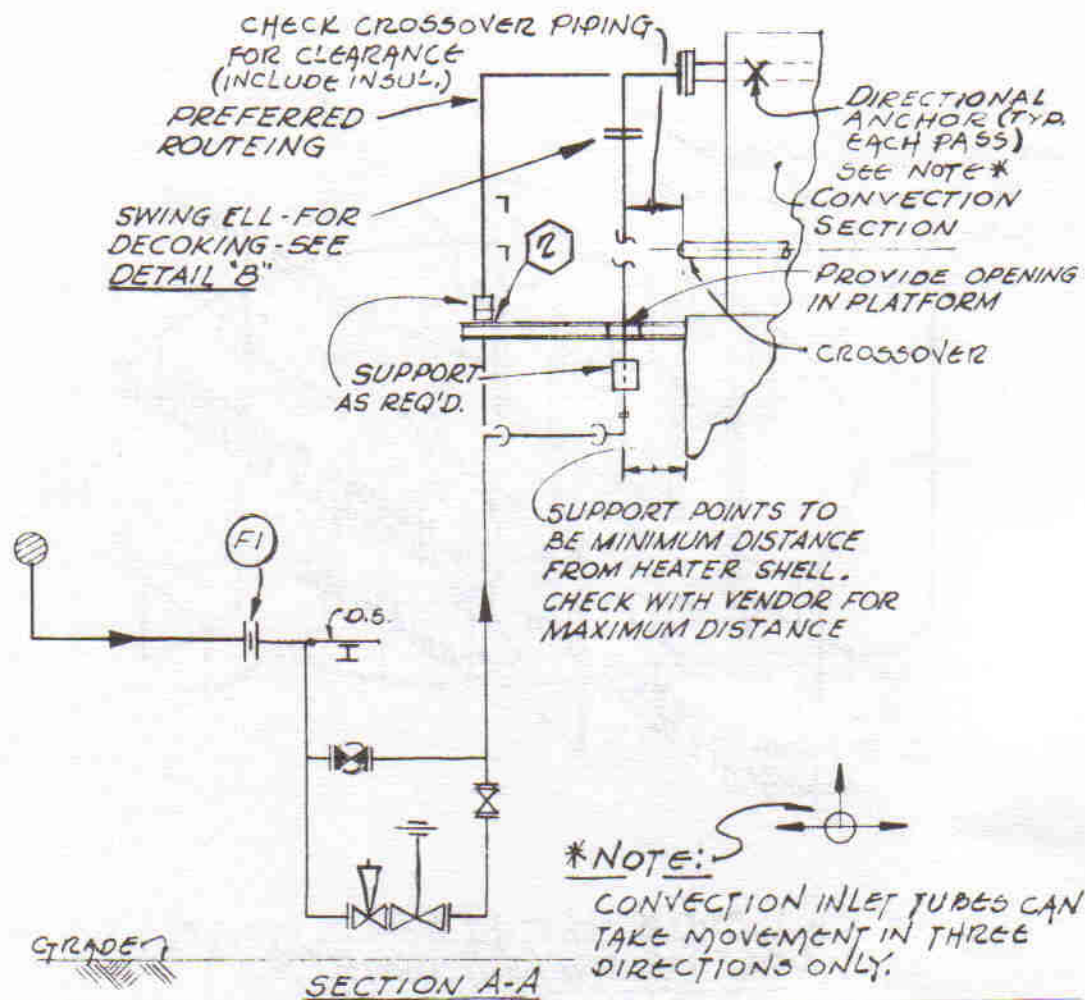


Figure 3-22. Inlet piping with manual control. Courtesy of Fluor Engineers and Constructors, Inc.

the bottom manifold guides or springs would take the downward expansion.

Figure 3-23 has piping again going to a four-pass convection section. Now, however, a control valve has been added to replace the globe valve of Figure 3-22 and the orifice flanges are upstream of

this control valve. This more expensive arrangement is desirable for certain services where precise control is necessary. Often these control stations are FRCs, flow recording controllers, with recording and controlling operations located in the main control building.



PLAN
INLET PIPING
AUTOMATIC CONTROL
(CYLINDRICAL HEATER)

Figure 3-23. Inlet piping with automatic control. Courtesy Fluor Engineers and Constructors, Inc.

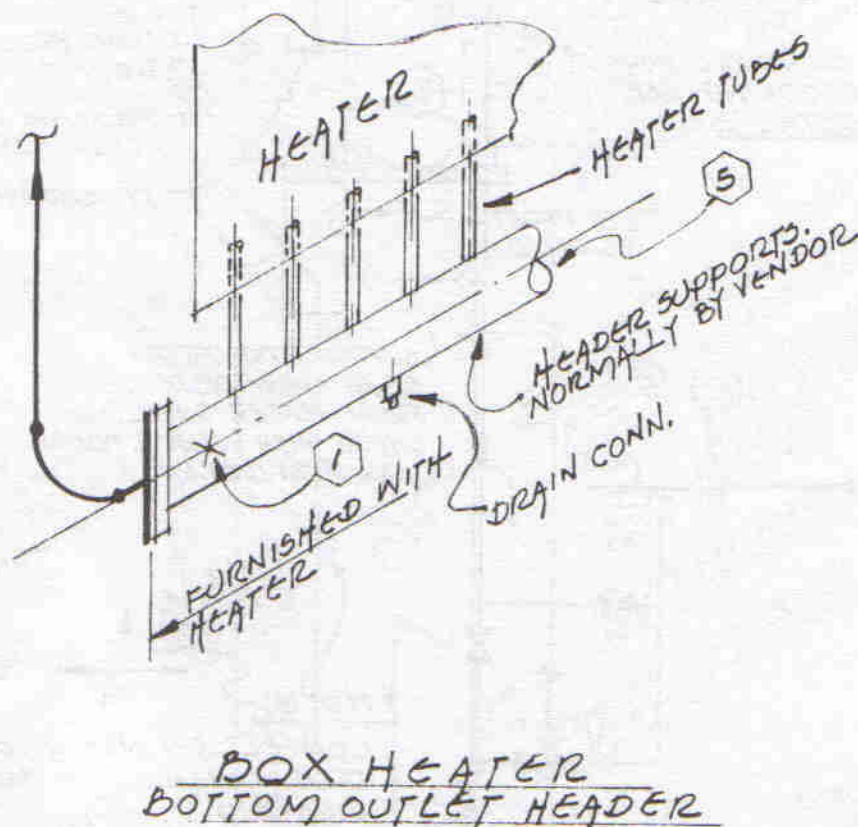
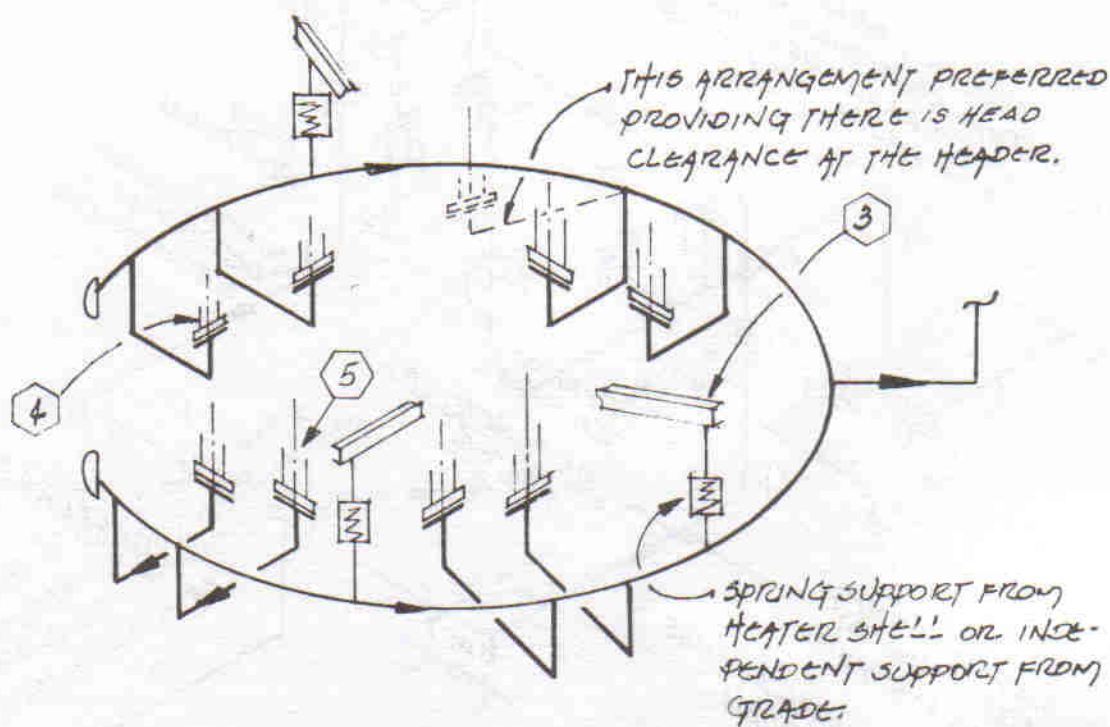


Figure 3-24. Outlet piping manifold. Courtesy of Fluor Engineers and Constructors, Inc.

Figure 3-24 shows a furnished header with a flange for piping connection. This could also be a beveled end for welding. An anchor point at #1 is desirable, with heater expansion absorbed by the heater vendor's design. While it is shown as the outlet, it could also be an inlet manifold.

Figure 3-25 depicts an eight-pass vertical heater with a ring header not provided by the heater vendor, collecting flow from eight bottom outlets. The piping designer has planned the ring with a radius

about 2' greater than extremity radius of the heater. Ring support is shown at point 3. If it is to be supported from the heater, the vendor must be informed of the expected load. Grade support is most common and has the advantage of keeping full control within the design office. Number 4 reminds the piping designer to have bottom-supported tubes with this arrangement so heater tube expansion is forced upward and not into the piping. Number 5 points out that, if possible, outlets or inlets may be



RADIANT-VERTICAL HEATER
BOTTOM OUTLETS OR INLETS
(8 PASSES)

Figure 3-25. Outlet piping ring header. Courtesy of Fluor Engineers and Constructors, Inc.

relocated to top by the vendor to provide more economical piping arrangements or satisfy flexibility requirements.

Two-Phase Flow

All piping discussed so far has been for single-phase flow which can be controlled with globe valves or control valve stations and verified through orifice flanges. Two-phase flow presents an entirely different problem. With both liquid and vapor flowing through the line at the same time, meter

runs are useless and flow can not be controlled by valving. How can two-phase piping be controlled so that each heater pass handles the same flow?

Symmetrical Piping

Two phase flow must have symmetrical piping for both inlet and outlet arrangements to divide flow equally to each heater pass. What is symmetrical piping? Piping designed so that the pressure drop is identical for each pass, no matter how many passes it is divided into, is symmetrical.

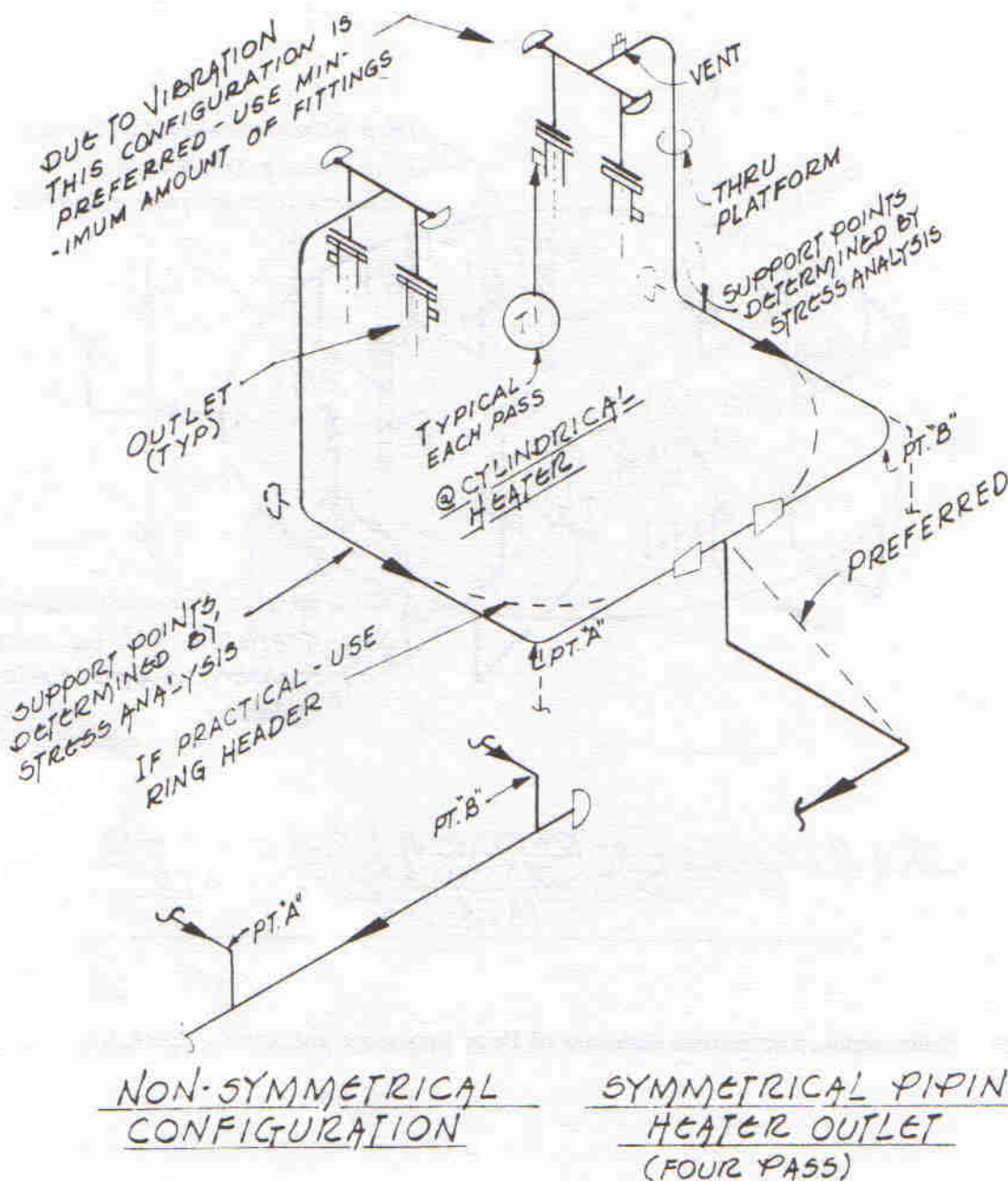
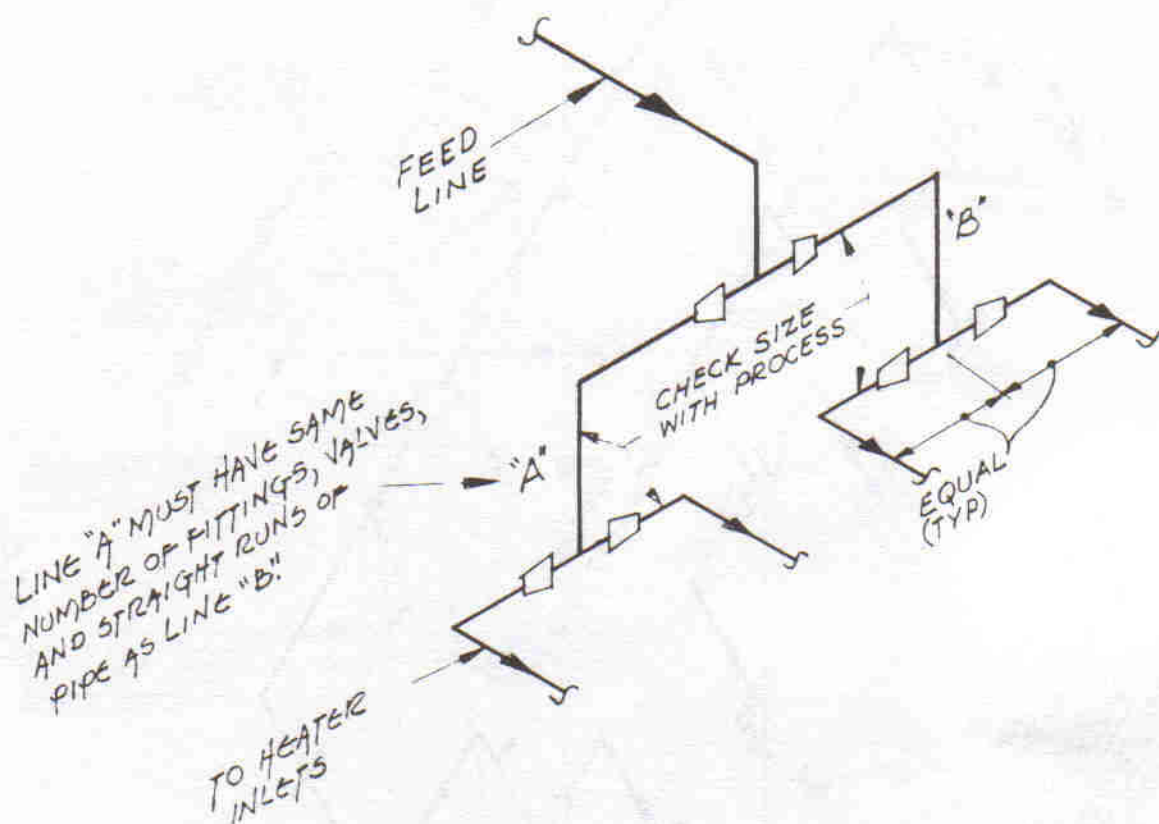


Figure 3-26. Symmetrical and nonsymmetrical piping. Courtesy of Fluor Engineers and Constructors, Inc.

Figure 3-26 shows a four-pass heater outlet at a vertical heater. Note that pipe length and number of fittings are identical with two outlets going into a short header and these two sub-headers are routed with identical pipe and fittings to the point where they connect into one outlet. Should points A and B

be connected into the manifold as pictured in the lower left, pressure drops for the two would not be the same. Since fluids take the path of least resistance, flow would not be identical in this non-symmetrical example.

Figure 3-27 shows another method for



SYMMETRICAL FLOW
FOUR PASS HEATER

Figure 3-27. Symmetrical flow at four-pass heater. Courtesy of Fluor Engineers and Constructors, Inc.

dividing flow equally. Here the single feed line is divided by horizontal tees into two streams and the same type arrangement divides each of these into two other equal flow streams. This division could be repeated several times depending upon the number of heater passes. Outlet piping should be similar to the inlet system. Two-phase flow piping must be symmetrical for both inlets and outlets, maintaining identical pressure drop for each pass from first stream split until the final outlet is combined into

one line.

Figure 3-28 shows how this flow can be broken down into eight equal passes. As can be seen, symmetrical piping employs extra pipe, fittings and welds. This makes it expensive and not to be used unless absolutely necessary. It is almost as bad to use symmetrical piping when it is not required as it is not to use it when it is needed. The only salvation in the former is that it *will work*. Both are design mistakes.

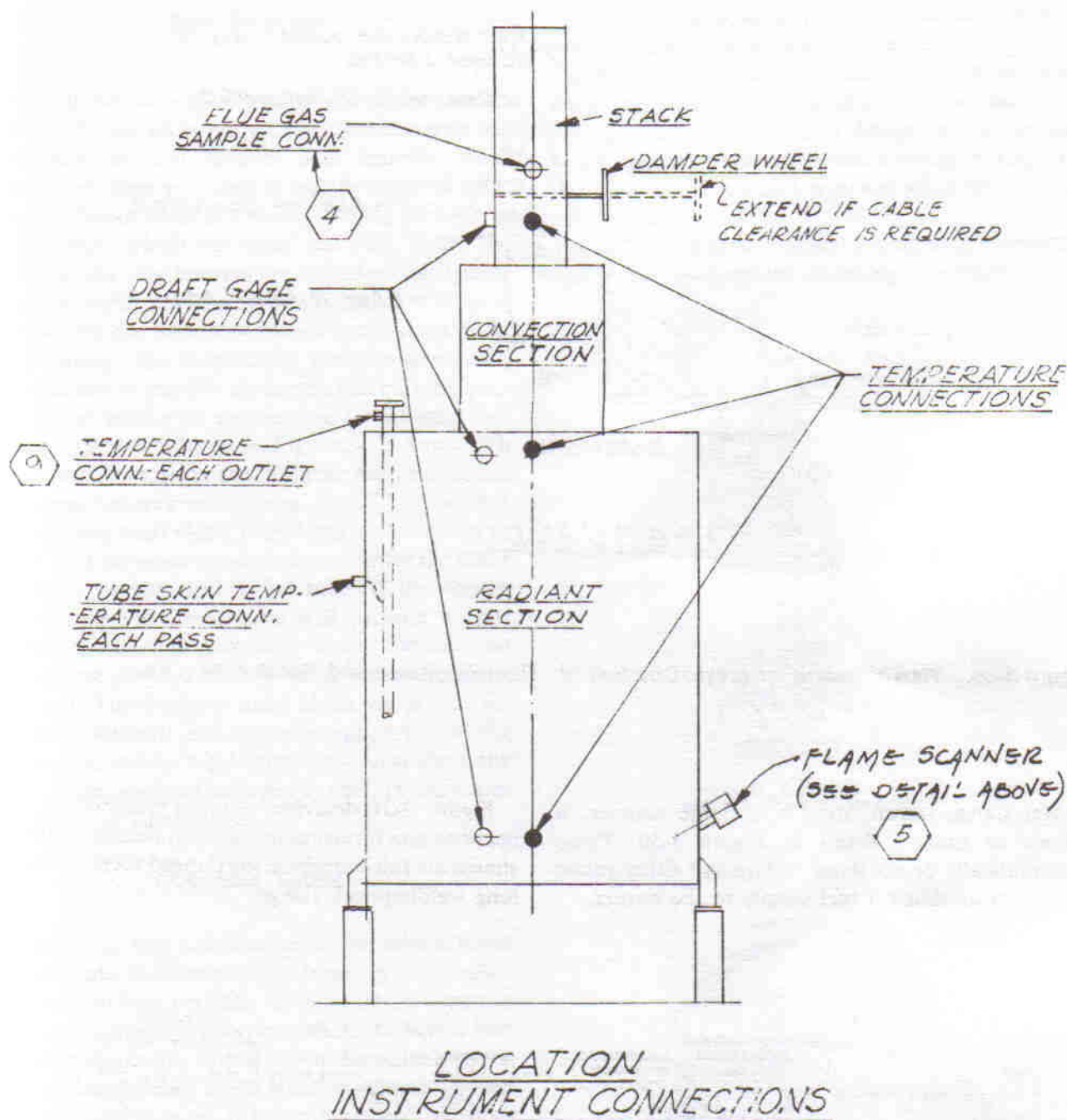


Figure 3-29. Heater instrument connections. Courtesy of Fluor Engineers and Constructors, Inc.

Heater Instrumentation

Certain minimum instrumentation is necessary to ensure proper check and control of heater performance whether box or vertical type. Figure 3-29 indicates usual instrument connection locations. Item

4, flue gas sample connection, consists of a coupling and valve and must be accessible from ladder or platform. Item 9, temperature connection at each outlet, is shown on the heater tube as a reminder that one is needed. It is not furnished by the heater vendor and must be located on piping after the

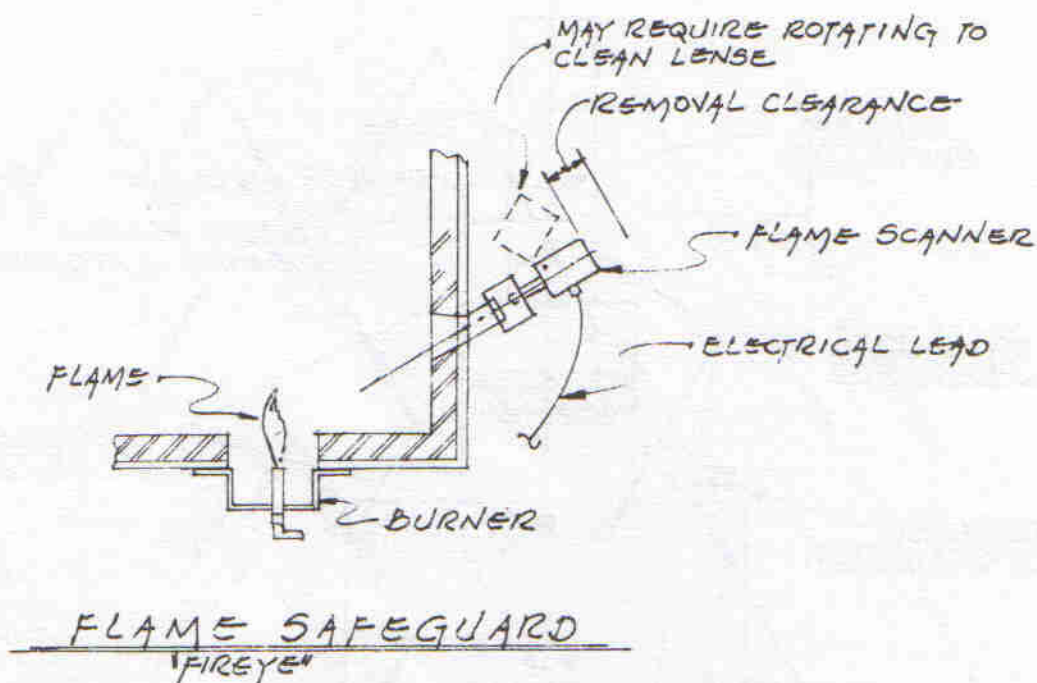


Figure 3-30. Flame scanner or fireeye. Courtesy of Fluor Engineers and Constructors, Inc.

heater flange shown. Item 5, a flame scanner, is shown in greater detail in Figure 3-30. These automatically detect flame failure and either sound an alarm or shut off fuel supply to the burner.

Figure 3-31 describes types of temperature connections and furnishes installation details. All those shown are full couplings; the flanged thermowell is a long welding-neck flange.

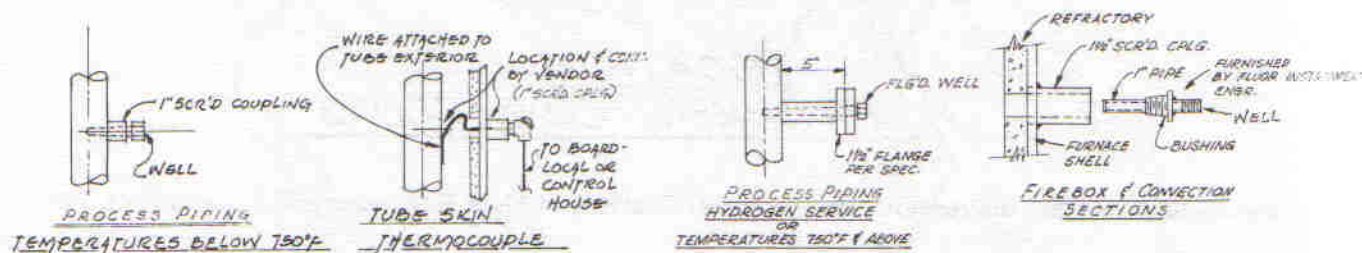


Figure 3-31. Thermowell connection details. Courtesy of Fluor Engineers and Constructors, Inc.

Soot Blowers

Soot blowers are specified for heaters that use oil for fuel. As the oil is burned, soot builds up on the tubes exterior and reduces heat transfer. Soot blowers are then activated to rid the tubes of soot. Steam is blown through a lance, striking the outside of the tubes which dislodges the soot. After the operation the soot blowers are turned off until needed again which may be several months.

There are two basic soot blower types, retractable and rotating, non-retractable. Both have a small motor which is usually air-driven but may be electric. Access platforms are required for maintenance of motors and soot blowers. Figure 3-32 shows both types. Item 9 reminds the designer not to obstruct lance removal area with piping. Item 17 shows that steam piping must slope away from soot blowers to ensure that no liquid condensate can enter the lance and make contact with a hot tube. If the vendor does not provide piping, he will provide a flow schematic showing necessary slope. When soot blowers are purchased they often have all piping furnished. The designer must check his layout for adequate support and provide supports on the heater. The vendor's schematic will also show the steam drain going to an open funnel. Do *not* connect this to a steam trap.

Decoking Tubes

While soot may accumulate on the tube exterior surface, coke builds up inside tubes, greatly reducing flow and heat transfer. Coke build-up occurs in very high temperature services where the heater feed is a relatively heavy hydrocarbon. Reboiler heaters, for instance, seldom coke. Heating services subject to coking are vacuum, crude charge, and reformer heaters.

Heater decoking is accomplished by shutting the heater down, ridding tubes of all hydrocarbon vapors and then heating the tubes from the outside while steam, injected into the tubes, blows coke from their inside walls. After steam has *spalled* (cracked) most of the coke from the tube, air is introduced to burn the remaining tube coke. Burning coke shows as a red, hot spot which progresses through the coil as coke burns and is visible from heater peep holes. Normally, one pass is decoked

while steam is flowing through the other passes to prevent tube damage due to overheating.

Figure 3-33 shows one method of accomplishing decoking. Although decoking *connections* normally are provided in the original design, steam, air and water piping is installed temporarily during the decoking operation and removed when decoking is completed.

Figure 3-34 shows typical piping at a horizontal heater and outlines the decoking procedure.

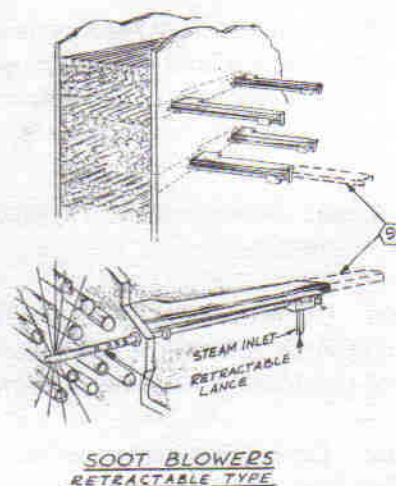
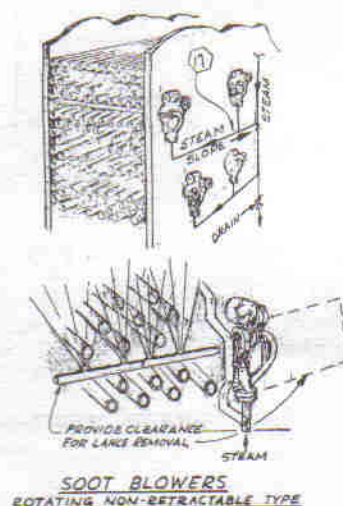
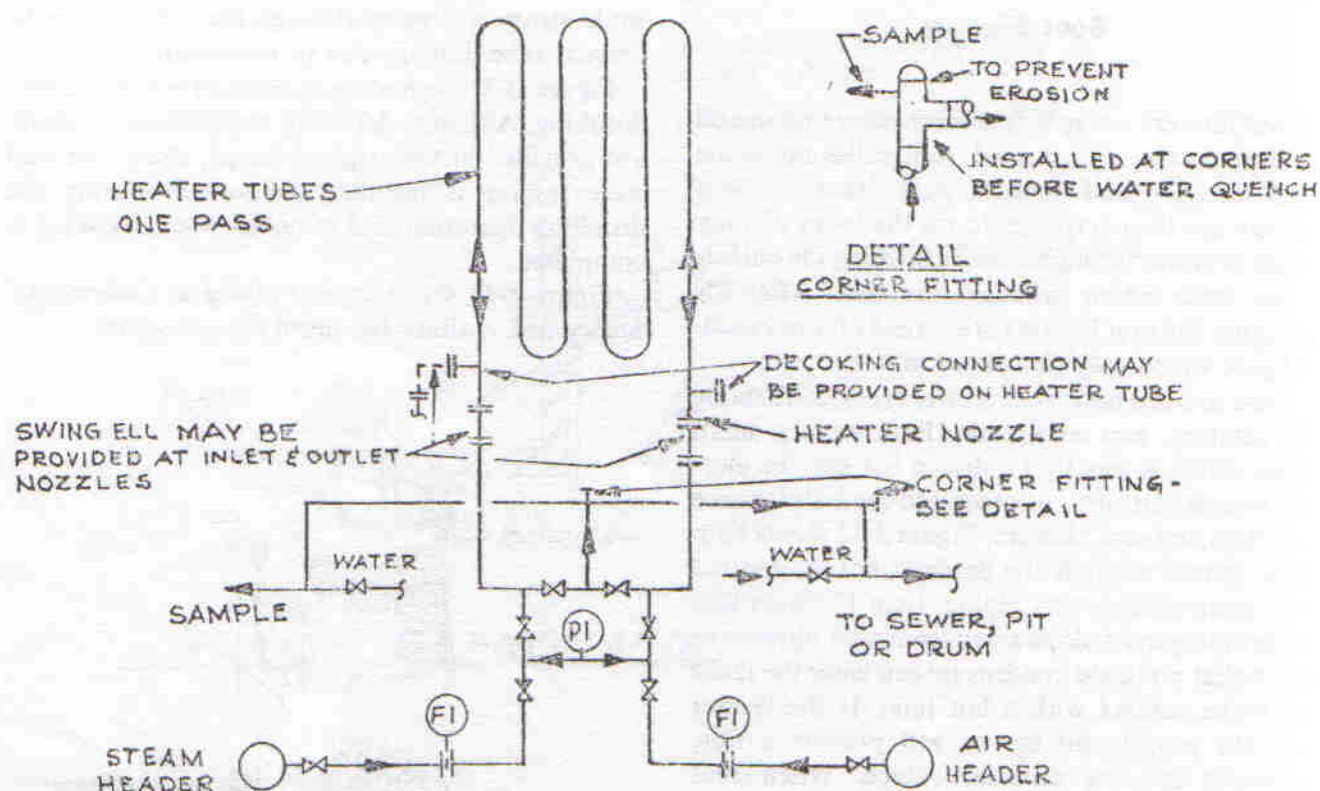


Figure 3-32. Soot blower installation. Courtesy of Fluor Engineers and Constructors, Inc.



Figures 3-33. Flow diagrams, steam-air decoking. Courtesy of Fluor Engineers and Constructors, Inc.

Heater Glossary

Many heater terms have been explained; some have only been stated. The piping designer must know heater terms. The following heater glossary will be a handy reference.

atomizing steam Steam used to vaporize the fuel oil at burners

air plenum Chamber enclosing burners underneath furnace. Equipped with louvers which control combustion air flow to burners.

air preheater Device that heats combustion air by utilizing flue gas as heat source.

arch Roof of radiant section.

breeching Ducting that connects one or more

heater stacks into a common stack. Also, ducting from sections of one heater that discharges into the heater stack.

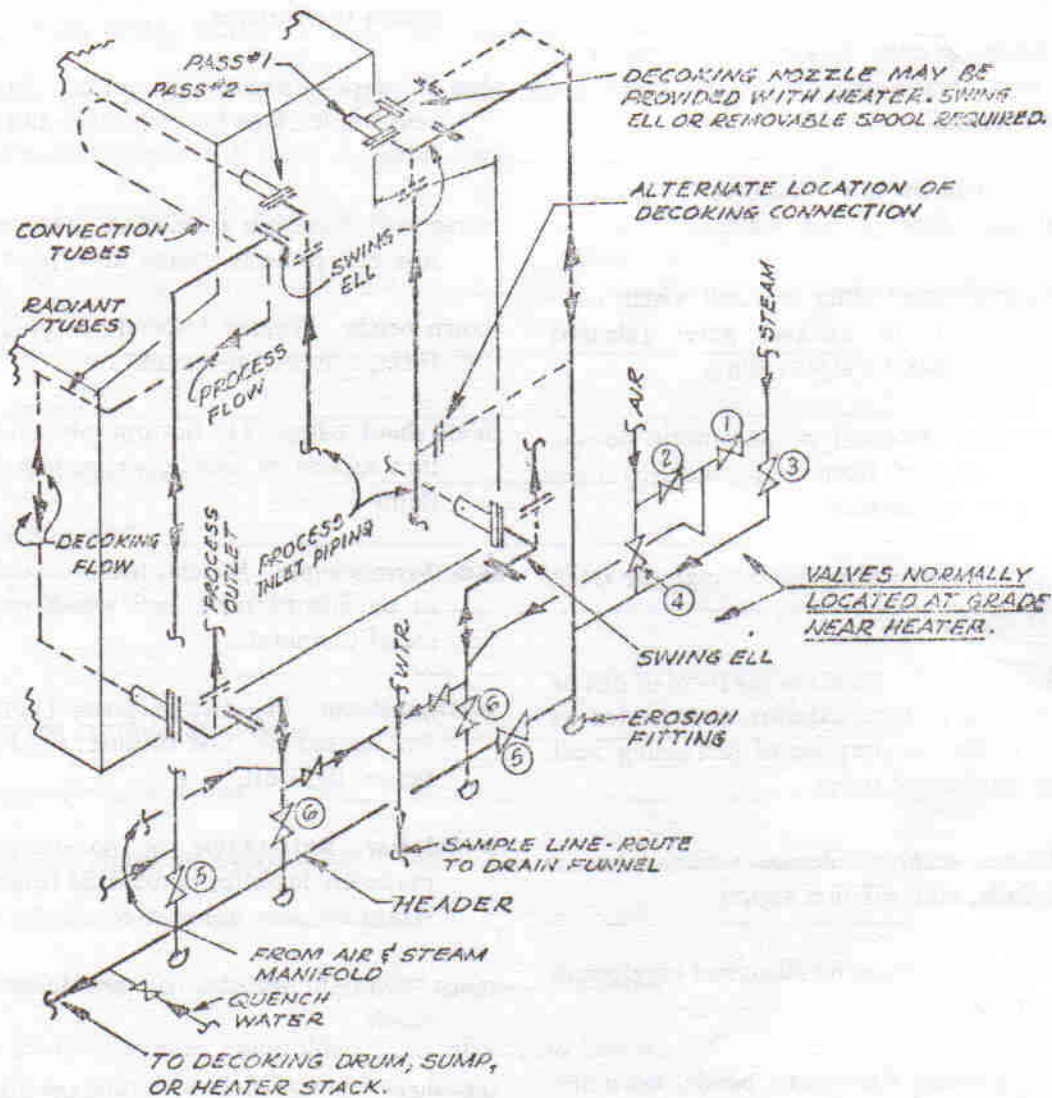
bridgewall Brick walls inside heater that divide the radiant section into separately fired zones.

buckstays External steel that forms the supporting framework of the heater.

burner Devices that feed fuels and air of proper mix to the radiant section of the heater. Burners can be either for fuel gas or oil or a combination of gas and oil.

casing Steel shell which encloses the heater.

convection section Section above radiant section that houses convection tubes which receive convection heat before flue gases pass out of the stack.



DECOCKING PROCEDURE

1. AFTER TUBES BECOME HEATED, STEAM IS INJECTED AT CONVECTION INLETS. VALVES #1, 2, 4 & 5 ARE CLOSED, #3 IS OPEN. TO START BURNING, STEAM FLOW IS REDUCED; AIR IS INTRODUCED BY OPENING VALVE #4.
2. FOR REVERSE FLOW, VALVES #2, 3, 4 & 6 ARE CLOSED #1 & 5 ARE OPEN. VALVE #2 IS OPENED ONLY IF REVERSE BURNING IS REQUIRED.
3. WHILE PASS #1 IS BEING DECOCKED, STEAM IS INJECTED INTO PASS #2 TO KEEP TUBES COOL.

Figure 3-34. Decoking piping arrangement. Courtesy of Fluor Engineers and Constructors, Inc.

- crossovers** Piping which connects convection tubes to the radiant tubes. Normally, crossovers are exterior of the casing.
- coil** (See **pass**.)
- decoking** Cleaning coke deposit from interior of tubes with steam and air as the tubes are heated externally.
- draft gage** Instrument that measures the pressure flow of gases through the heater.
- damper** Rotating steel plate in stack which controls the draft of exhaust gases released through the stack to atmosphere.
- damper controller** Manual or automatic device, normally operated from grade that regulates the position of the damper.
- flue gas** Spent gases which pass through the stack to atmosphere
- fins (extended surface)** Metal in the form of fins or studs welded to tube exterior or extruded as part of it for the purpose of increasing heat transfer surface of tubes
- fire eye** Flame scanning device which, when a burner fails, cuts off fuel supply.
- headers** Tubes and return bends joined together to form a pass.
- header box** Housing for return bends, normally provided when heater is equipped with plug-type return bends.
- lance doors** Access doors in convection section provided for insertion of a steam lance to clean exterior of convection tubes.
- manifold** Common header (external) into which all terminals from each pass are connected
- observation doors** Doors used to observe burner flames or heater tubes
- pass** Bank of consecutive tubes through which the fluid travels from the point it enters until it leaves the furnace
- plug headers** Special type return bends having removable plugs for inspection and cleaning of tubes
- refractory** Ceramic insulation that reduces heat loss and protects casing and structure.
- return bends** Welded U-bends or plugged, rolled fittings that connect tubes
- shield shock tubes** The bottom tubes in the convection section in close contact with the radiant flame
- skin thermocouple** Special thermocouple attached to outside of tube wall which measures the metal temperature
- snuffing steam** Has two purposes: (1) Extinguish a fire caused by tube rupture; (2) Purge heater before light-off.
- sootblower** Retractable or non-retractable permanently installed lances that rotate and spray steam to clean tube exterior
- tubes** Straight lengths of pipe joined by return bends
- tubesheet** Metal sheet with tube openings near the return bends for separating convection or radiant section from header box
- turbining** Mechanical cleaning device used to clean inside of tubes; normally a flexible hose with rotating or vibrating cleaning head on the end and driven by air
- terminals** Inlet and outlet connections

Review Test Chapter 3

The student should be able to answer the following questions without referring to the chapter.

1. The two main heater sections are _____ and _____.
2. In process heaters, steam is often generated in the _____ section.
3. A combination burner will burn _____ and _____.
4. What is the purpose of a draft gage? _____
5. Explain the purpose of snuffing steam. _____

6. Define *crossover*. _____
7. What is a heater *pass*? _____
8. What is flue gas? _____
9. Why do heaters need *sootblowers*? _____

10. What is the purpose of a *fireye*? _____
11. Define *symmetrical piping*. _____
12. Symmetrical piping is always used for _____
13. Heater tubes are designed in accordance with what code? _____
14. Horizontal heaters are commonly called _____ heaters.
15. Locate snuffing stream manifolds _____ feet from heater.
16. The clearance between two vertical heater shells is normally _____
17. Horizontal heaters should have tube-pulling free area equal to the tube length plus _____
18. Heaters should be located (upwind) (downwind) of process units. _____
19. What is the purpose of a *peep hole*? _____
20. What is a *buckstay*? _____

4 Exchangers

The heat exchanger is a device in which two fluids flowing in opposite directions can exchange heat through a solid boundary or surface. The rate of heat exchange between the hot and cold streams is determined by the fluids' physical properties, flow rates and temperatures and by the surface separating the two streams.

Of the many available heat exchangers, process plants most often employ the shell and tube, double pipe and air cooler types. Of these three types many designs may be specified. Proper piping design requires a good working knowledge of exchanger types and designs.

The basic rule for piping at all heat exchangers is: *fluid being heated shall flow up while fluid being cooled shall flow down*. This can also be expressed as *hot stream in at the top, cold stream in at the bottom*.

There are rare exceptions to this flow rule. Generally, if no condensing or vaporizing can occur during heat transfer, flow can be routed in any manner. However, for best heat transfer, *reverse flow* must be maintained. This means that if the flow is going in the bottom and out the top of the shell side, the tube side, or channel end, must have flow in the top and out the bottom.

Mechanical flow diagrams show proper flow through exchangers. Piping designers should always question flow patterns which violate the basic rule.

Double Pipe Exchangers

A double pipe or *fintube* exchanger consists of two pipes, one inside another. The inner tube is usually finned to provide a larger surface for heat transfer. Double pipe exchangers are used where flow and necessary temperature transfer are rather small.

Fintube exchangers are generally applicable when one fluid is gaseous, viscous or of small quantity. They are particularly desirable for high pressure services because their small diameter is conducive to low cost construction. Their modular design assures maximum flexibility of application since sections can be stacked vertically or horizontally or both to attain desired heat transfer. Also it is simple to reuse these units in other services, utilizing one or more sections as needed.

Figure 4-1 shows one tube. These U-shaped longitudinal fins are welded to the tube to form a unit. Fins can also be formed by an extrusion process. For special applications they may be on the inside or on both inside and outside of the parent pipe.

Figure 4.2 shows a complete single unit with parts named. The shell side is furnished with companion flanges so that piping can be connected to a beveled end. Tubeside connections are supplied with a flanged assembly to allow tube *hairpin* to be dis-

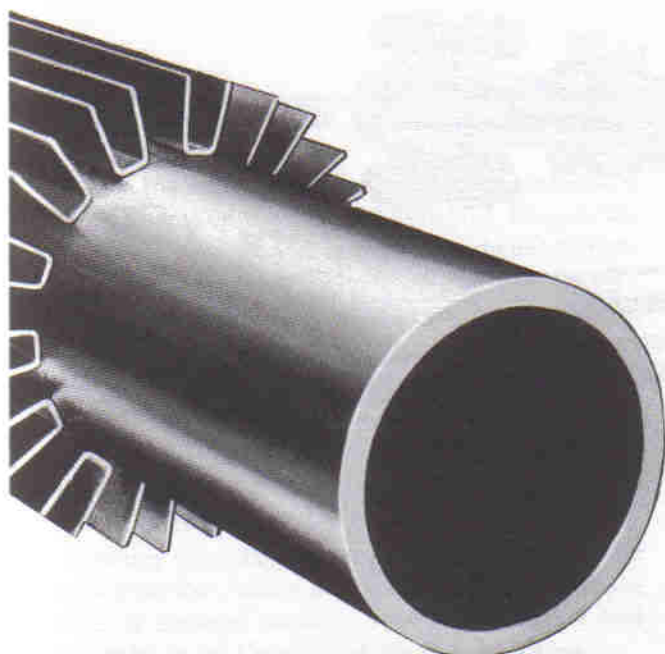


Figure 4-1. Integral one-piece fintube. Courtesy of Brown Fintube Co.

connected from piping. The tube or hairpin section will be pulled from the return bend housing end.

These units are almost always installed as multiple modules. They are normally spoken of in multiples such as "3 wide by 2 high", which refers to 6 modules to be installed in 2 layers of 3 side-by-side units each. Support saddles are provided with bolt holes on all four sides for modular bolting and are not fixed to the shell assembly, leaving foundation spacing to be determined by the piping designer. Sometimes one or two units are bolted to vertical steel columns and no separate concrete foundation is needed.

Figure 4-3 provides installation and disassembly procedure plus dimensions for the Type 40 fintube unit. Procedures listed are common for almost all double pipe heat exchangers. Notice that the 1 1/2" Schedule 80 tubeside weld connection is provided with a flanged disconnection joint (in other types this may be a union joint.) There is always some type of joint which can be disconnected to permit tube removal without disturbing connecting piping. The piping designer should *not* provide unions or flanges with his piping.

Figure 4-4 gives dimensional data for high pressure sections. The basic design is the same; however, notice that the shell side flanges are now 600# standard and no companion flange is provided. While RTJ facing is shown, any desired facing can

be provided. High pressure units are commonly specified for process plant installations. Low pressure units are usually limited to utility services.

Figure 4-5 gives fintube nomenclature and preliminary dimensional information. With this data the designer only needs the exchanger number to determine adequate dimensions to complete the piping layout. Final dimensions must come from the vendor's certified outline drawing.

Figure 4-6 is an isometric view of a piping arrangement at double pipe exchangers. With the series arrangement, the vendor supplies tube side return bends but the piping section must supply shell side interconnecting piping.

Shell and Tube Exchangers

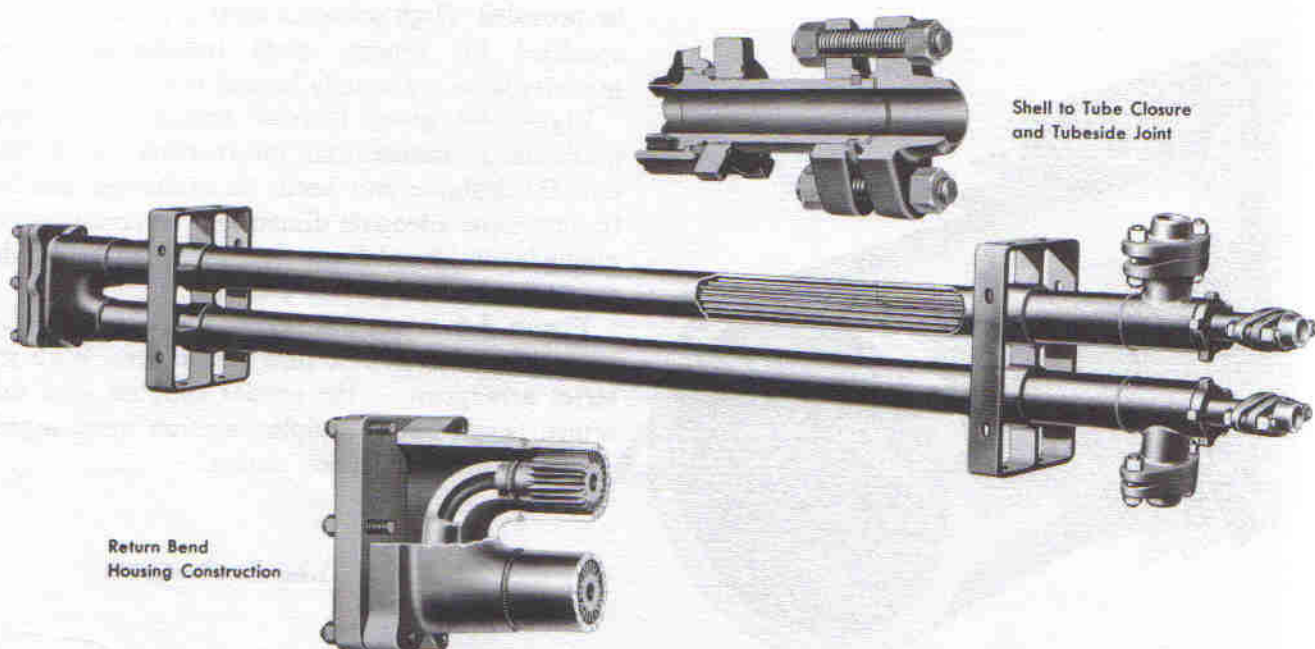
Shell and tube type exchangers are the ones most commonly specified for process plants today. These exchangers are designed in accordance with the TEMA (Tubular Exchanger Manufacturers Association) code. TEMA also specifies exchanger part types in a letter code which tells the designer what the exchanger looks like.

Figure 4-7 shows the letters and meanings for shell and tube exchangers. Before receiving any drawings, the piping designer gets an exchanger data sheet including the exchanger type, such as type *AKU*. By referring to Figure 4-7, the channel end will be type *A*, shell type is *K* and shell cover type is *U*. Putting them all together, the designer knows this is a kettle reboiler. This code can be deciphered for all exchanger types.

TEMA also supplies detailed design criteria as part of the TEMA code. TEMA *R* is the selected code for use in refineries and TEMA *C* is specified for most chemical plants. TEMA *C* design is for less severe operation and results in a lighter, less expensive exchanger. For students wanting full exchanger design data, the TEMA code is available from most technical book stores and exchanger fabricators.

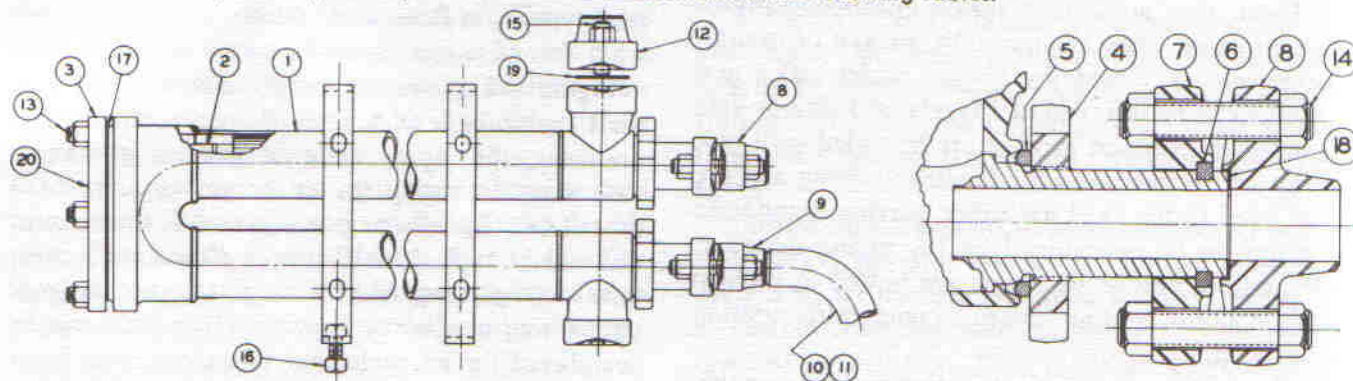
Basic Parts

Figure 4-8 shows basic exchanger parts. Flow entering the nozzle, item 4, at the channel or *tubeside* end meets the pass partition, Item 25, and



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)

Figure 4-2. Brown Type 40-3" fintube parts. Courtesy of Brown Fintube Co.

INSTALLATION PROCEDURE

1. Mount the sections as shown in the recommended arrangement on the certified drawings. Be sure the shell nozzle gaskets are in place, but do not tighten the shell nozzle bolts or the bracket bolts. Note the oblong holes in the brackets for alignment. Align the sections so that the fintube gasket faces are in the same plane.
2. Slip the fintube fitting flanges over the projection of the tube assembly, place the split rings in the groove provided in the fintube fitting and move the flange forward to hold the split ring in position.
3. Assemble the tube side return bend connectors. Be sure that the fintube gaskets are in place and the joint is centered so as to bear on the gasket and not ride up on the edge of the fintube fitting.
4. Tighten all tubeside bolting evenly.
5. Tighten shell nozzle bolting and bracket bolts. The bracket and shell nozzle bolts are left loose initially to provide the section with a little give, in case there is difficulty in connecting the tubeside return bend connectors. Once these connections have been bolted in place, all other bolting may be tightened.
6. Place the fintube gaskets in position in the inlet and outlet fintube stub end flanges and assemble, using the proper tube side bolting. If the sections are arranged in parallel, these stub end flanges will be attached to the manifolds. Tighten bolting.

Note that companion flanges are furnished on both the shell and tubeside of these sections, thus eliminating this expense for you. These companion flanges can be attached directly to any manifolding which may be required.

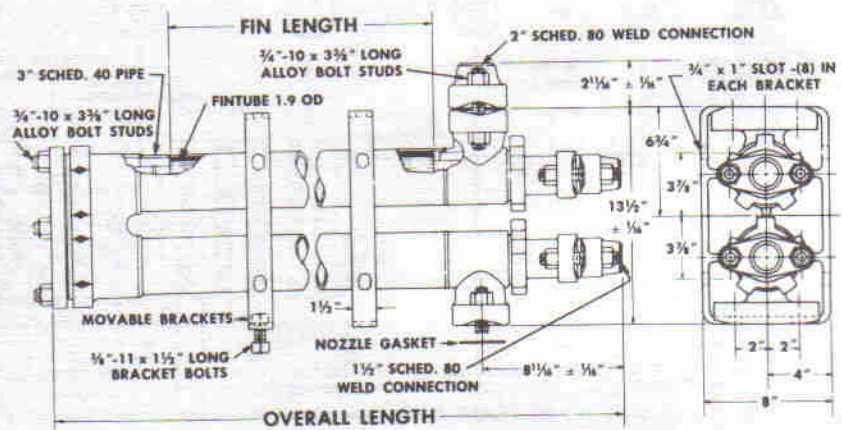
DISASSEMBLY PROCEDURE

Fintube hairpin elements are easily removed from the shells as follows:

1. Remove shell cover plate bolting and cover plate.
2. Remove the tube side bolting and tube return bend connectors and inlet and outlet connections.
3. Loosen and remove the compression flange by striking the lugs with a hammer in a counterclockwise direction. When re-assembling, place lubricant such as "Molykote" between sealing ring and face of compression flange.
4. Remove the sealing rings and push the tube element straight back through the shell. After the tube element return bend is outside the shell, the element may be pulled.

REMOVAL OF THE TUBE ELEMENTS FROM THE SHELLS CAN BE ACCOMPLISHED WITHOUT DISTURBING EITHER THE SHELL OR TUBE SIDE PIPING SINCE THE ELEMENT IS REMOVED STRAIGHT BACK THROUGH THE SHELL.

DIMENSIONS OF LOW PRESSURE TUBE SIDE - TYPE 40 (APPROXIMATE)



HEAT EXCHANGER NUMBER	OVERALL LENGTH	OVERALL WIDTH	OVERALL HEIGHT	FIN LENGTH	TO REMOVE HAIR PIN
40-1XXXX-X10	11'6"	8"	13½"	9'9¾"	11'3"
40-1XXXX-X20	21'7½"	8"	13½"	19'11½"	21'5"
40-1XXXX-X25	26'7½"	8"	13½"	24'11½"	26'5"

Figure 4-3. Installation, disassembly and dimensions. Courtesy of Brown Fintube Co.

is diverted into the tubes. The tubes, Item 8, route flow to the other end and back to the channel outlet nozzle.

Shellside fluid enters nozzle 6 and makes contact with the outside of the tubes. Transverse baffles, Item 11, are located so that they force this fluid to flow up and down, making the most efficient tube contact and therefore attaining maximum heat transfer on its way to the outlet nozzle.

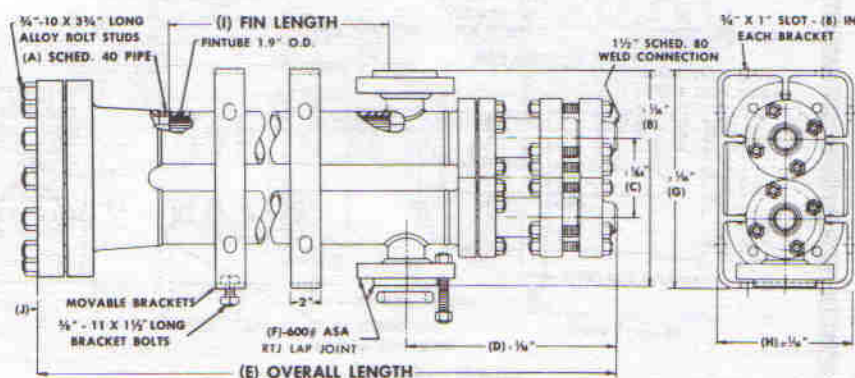
The *tube bundle* is comprised of the *tubesheet*, Item 5, and the tubes attached to the tubesheet. By removing the channel section the entire tube bundle can be pulled out from the exchanger for cleaning, repairs or total replacement. Not all exchangers have removable tube bundles. Nonremovable tube bundle exchangers are called *fixed tubesheet* types. Exchangers which have removable tube bundles must have a free and clear area provided for maintenance equipment to handle them. The clear area should measure five feet longer than the tube length, measuring straight out from the tubesheet. Truck access must be provided.

When exchangers are provided with a removable shell cover (See Figure 4-8, Item 16) the piping designer must provide a clear area to remove and handle this heavy item also. Since the shell cover is

usually lifted and carried from overhead by a small crane, piping should not be routed directly over it. Figure 4-9 provides parts nomenclature for kettle type reboilers. In this type of exchanger the heating fluid always enters the channel top flange, Item 4, and exits via the bottom channel nozzle. The main purpose of the shell side is to vaporize liquid entering Nozzle 7 near the shell flange. Vapor exits through Nozzle 7 at the top of the exchanger shell. The weir, Item 10, is a dam to keep the tube bundle covered with liquid at all times. Surplus liquid overflows the weir into the shell cover area. A level controller is piped to Connections 8 and maintains liquid level in this section at about half the weir height. Surplus liquid exits via the Nozzle 7 in this section. Normally a level gage allows visual examination of the liquid level behind the weir.

Vendor's Prints—Outline Drawings

Exchanger fabricators must make many detail drawings for use of their shop. First they must prepare an outline drawing for approval showing the basic exchanger, shell and channel nozzles, sup-



Heat Exchanger	Shell Size	Face to Face	Center to Center	C. Nozz. to Face of Stub End	Overall Length	Nozzle Size	Bracket Size		Fin. Length	To Remove Hairpin
TYPE	A	B	C	D	E	F	G	H	I	J
51-4XXX-X10	3"	14 $\frac{3}{4}$ "	5 $\frac{1}{4}$ "	14 $\frac{1}{4}$ "	11'-8 $\frac{3}{8}$ "	2"	14 $\frac{1}{2}$ "	9"	9'-9"	11'-5"
51-4XXX-X20	3"	14 $\frac{3}{4}$ "	5 $\frac{1}{4}$ "	14 $\frac{1}{4}$ "	21'-10 $\frac{3}{8}$ "	2"	14 $\frac{1}{2}$ "	9"	19'-11"	21'-7"
51-4XXX-X25	3"	14 $\frac{3}{4}$ "	5 $\frac{1}{4}$ "	14 $\frac{1}{4}$ "	26'-10 $\frac{3}{8}$ "	2"	14 $\frac{1}{2}$ "	9"	24'-11"	26'-7"
53-4XXX-X10	4"	17 $\frac{1}{4}$ "	6"	15 $\frac{1}{4}$ "	11'-9"	3"	18"	10"	9'-7 $\frac{1}{2}$ "	11'-5"
53-4XXX-X20	4"	17 $\frac{1}{4}$ "	6"	15 $\frac{1}{4}$ "	21'-10 $\frac{3}{8}$ "	3"	18"	10"	19'-9 $\frac{1}{4}$ "	21'-7"
53-4XXX-X25	4"	17 $\frac{1}{4}$ "	6"	15 $\frac{1}{4}$ "	26'-10 $\frac{3}{8}$ "	3"	18"	10"	24'-9 $\frac{1}{4}$ "	26'-7"

Type 54 like type 53 except 2 $\frac{1}{2}$ " IPS FINTUBE

Figure 4-4. Dimensional data for high pressure fintubes. Courtesy of Brown Fintube Co.

Section Type	Page	No. Tubes	Shell O.D.	Tube O.D.	Shell Nozzle			Tube Nozzle	Type Baffle or Support	Dimension A		Dimension B		App. Overall Length, Add To Nominal	
					Size	Low Press.	High Press. (5)			Shell Nozzle		Shell Nozzle			
										L. Press.	H. Press.	L.P.	H.P.		
02	7	1	4.5	1.9	2½	Two Bolt	(1)	1½ B.W.	UNIHEAD	(2)	16	—	10	—	1'-6"
04	7	1	4.5	2.875	2½	Two Bolt	(1)	2½ B.W.		(2)	16	—	10	—	1'-6"
05	11	7	4.5	0.750	2½	Two Bolt	(1)	2½ B.W.		Peripheral	16	16	10	10	1'-7"
06	10	7	4.5	0.875	2½	Two Bolt	(1)	2½ B.W.		Longitudinal Strip	16	—	10	—	1'-6"
07	11	7 (3)	4.5	0.875	2½	Two Bolt	(1)	2½ B.W.		Spider Support	16	16	10	10	1'-7"
08	10	7 (3)	4.5	1.0	2½	Two Bolt	(1)	2½ B.W.		Spider Support	16	—	10	—	1'-6"
15	11	7	4.5	0.750	3	600 # ASA.-R.F.	600 # ASA.-R.F.	2½ B.W.		Peripheral	16	16	10	10	1'-4"
16	10	7	4.5	0.875	3	600 # ASA.-R.F.	(1)	2½ B.W.		Longitudinal Strip	16	—	10	—	1'-4"
17	11	7 (3)	4.5	0.875	3	600 # ASA.-R.F.	600 # ASA.-R.F.	2½ B.W.	Spider Support	16	16	10	10	1'-4"	
18	10	7 (3)	4.5	1.0	3	600 # ASA.-R.F.	(1)	2½ B.W.	Spider Support	16	—	10	—	1'-4"	
40	6	1	3.5	1.9	2	Two Bolt	(1)	1½ B.W.	SEPARATED HEAD	(2)	13½	—	8	—	1'-6"
45	13	7	4.5	0.750	2½	Two Bolt	(1)	2½ S.W.		Peripheral	16(4)	16(4)	10	10	2'-0"
46	12	7	4.5	0.875	2½	Two Bolt	(1)	2½ B.W.		Longitudinal Strip	16	—	10	—	2'-0"
47	13	7 (3)	4.5	0.875	2½	Two Bolt	(1)	2½ S.W.		Spider Support	16(4)	16(4)	10	10	2'-0"
48	12	7 (3)	4.5	1.0	2½	Two Bolt	(1)	2½ B.W.		Spider Support	16	—	10	—	2'-0"
51	8	1	3.5	1.9	2	600 # ASA.-R.F.	600 # ASA.-RTJ.	1½ B.W.		(2)	13½	14½	8	9	1'-6"
53	8	1	4.5	1.9	3	600 # ASA.-R.F.	600 # ASA.-RTJ.	1½ B.W.		(2)	16	18	10	10	1'-6"
54	8	1	4.5	2.875	3	600 # ASA.-R.F.	600 # ASA.-RTJ.	2½ B.W.		(2)	16	18	10	10	1'-6"
55	13	7	4.5	0.750	3	600 # ASA.-R.F.	600 # ASA.-R.F.	2½ S.W.	SEPARATED HEAD	Peripheral	16(4)	16(4)	10	10	1'-8"
56	12	7	4.5	0.875	3	600 # ASA.-R.F.	(1)	2½ B.W.		Longitudinal Strip	16	—	10	—	1'-8"
57	13	7 (3)	4.5	0.875	3	600 # ASA.-R.F.	600 # ASA.-R.F.	2½ S.W.		Spider Support	16(4)	16(4)	10	10	1'-8"
58	12	7 (3)	4.5	1.0	3	600 # ASA.-R.F.	(1)	2½ B.W.		Spider Support	16	—	10	—	1'-8"
80	9	1	2.375	1.0	1½	600 # ASA.-R.F.	(1)	¾ B.W.	SEPARATED HEAD	(2)	12	—	7	—	1'-6"
84	9	1	4.5	2.375	3	600 # ASA.-R.F.	600 # ASA.-RTJ.	2 B.W.		(2)	16	18	10	10	1'-6"

NOTES: (1) Not Available. B.W. = Beveled For Welding. S.W. = Socket Weld. (2) Not Required on Single Tube Units. (3) Available with bare tubes only. (4) When Tube Side Design Pressure is over 1800 psi, add 2½ inches to dimension shown. (5) Flange rating may be increased to suit design conditions. (6) High Pressure tube side lens ring construction shown. Also available with other type gaskets for lower pressures.

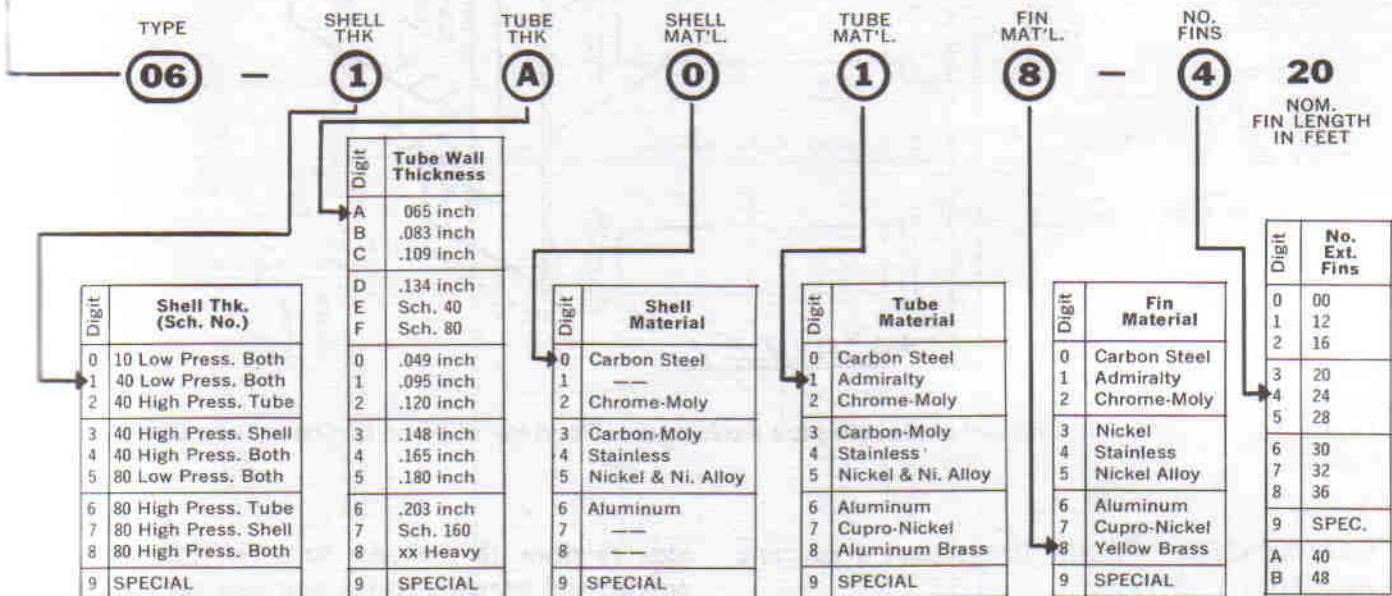


Figure 4-5. Fintube nomenclature and preliminary dimensions. Courtesy of Brown Fintube Co.

port location, layout dimensions and design data. Figure 4-10, is a certified outline drawing of a shell and tube exchanger.

Checking this drawing is basically the piping designer's responsibility. The design data section can be checked from the exchanger data sheet.

Exchanger nozzles and flow can be checked from the flow diagram. Support location and spacing must be checked. Always check any nozzles located on the bottom of the shell to make sure they clear not only the supporting saddle but also the supporting concrete or steel. Nozzle S2 flange is 3" lower

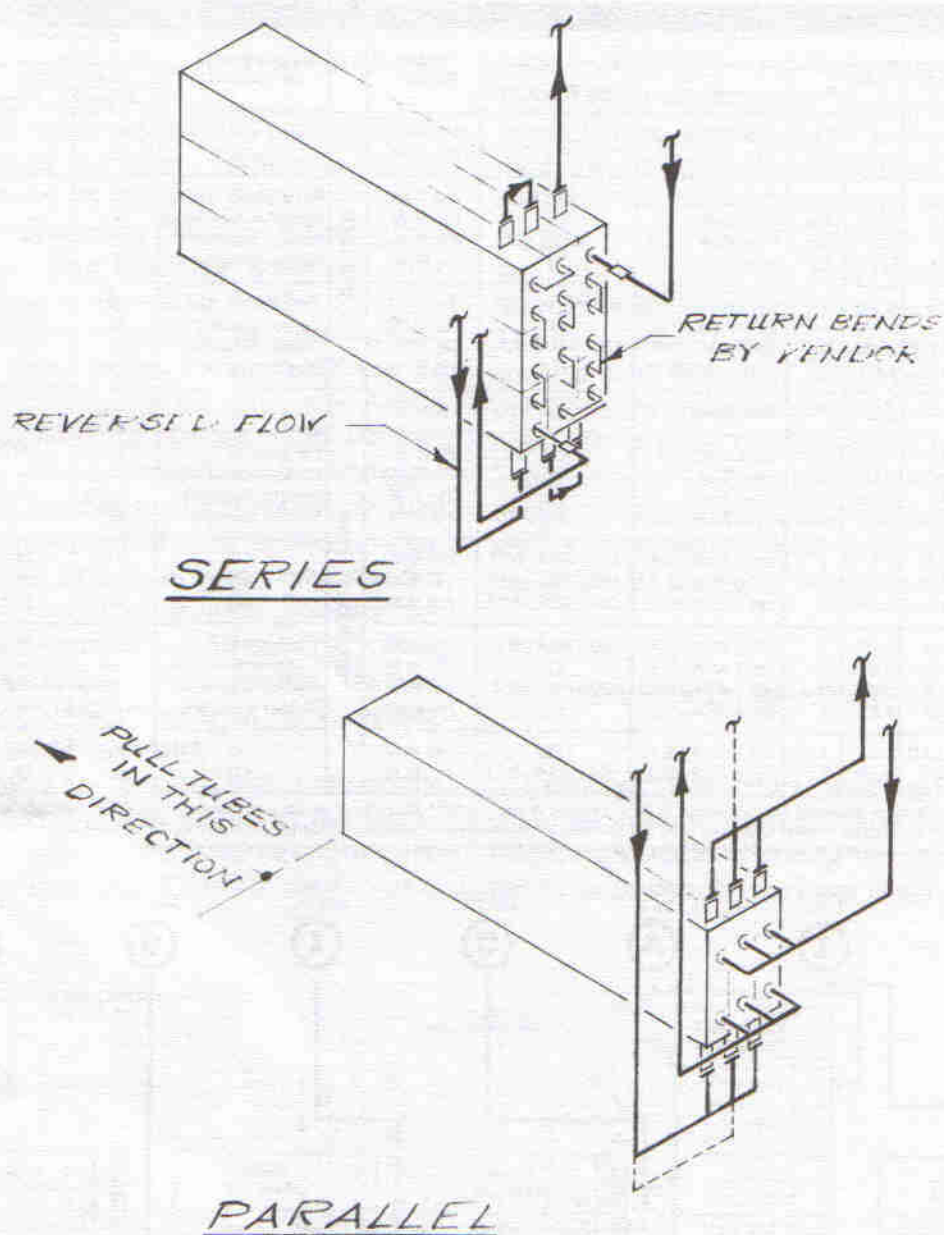


Figure 4-6. Piping Arrangement at double pipe exchangers. Courtesy of Fluor Engineers and Constructors, Inc.

than the saddle. Will the flange clear a concrete foundation 1'-6" wide?

Figure 4-11, is a preliminary outline drawing of a kettle reboiler which might come to a piping designer to be checked. An error has been built into this drawing. Find the error in nozzle location before reading any farther.

Notice that these outline drawings are not to scale. If a scale piping layout has not been made by the time this drawing has been received, it is a good

idea to draw the reboiler to scale, locating all nozzles and supports to see that they are actually located in the best possible positions. This exercise would immediately show that the level control nozzles, S6, are on the wrong side of the weir in Figure 4-11 and could not control the liquid level behind the weir. The student is to draw Figure 4-11 to scale and see what other items are pictured out of true relationship.

After the piping designer checks this preliminary

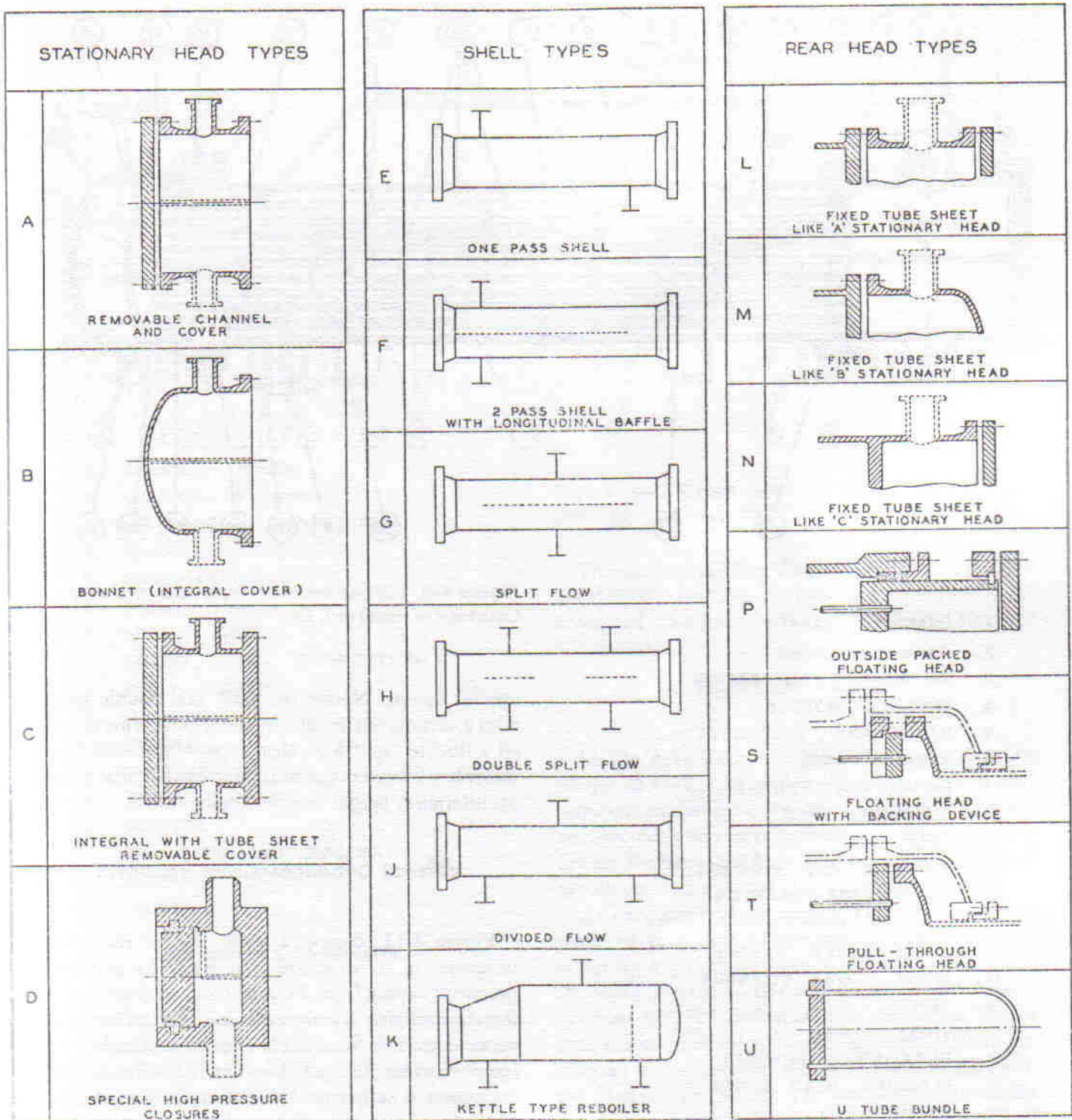


Figure 4-7. TEMA exchanger part definitions.

outline drawing, a marked print is returned to the vendor noting all errors. The fabricator will correct his drawing, an authorized engineer will sign it as certified and he will start his detail drawings. New certified outline drawings are also issued.

Thermosiphon Reboilers

Thermosiphon reboilers may be horizontal or vertical exchangers. Figure 4-12, A *horizontal thermosiphon reboiler outline drawing*, is a *BHU*

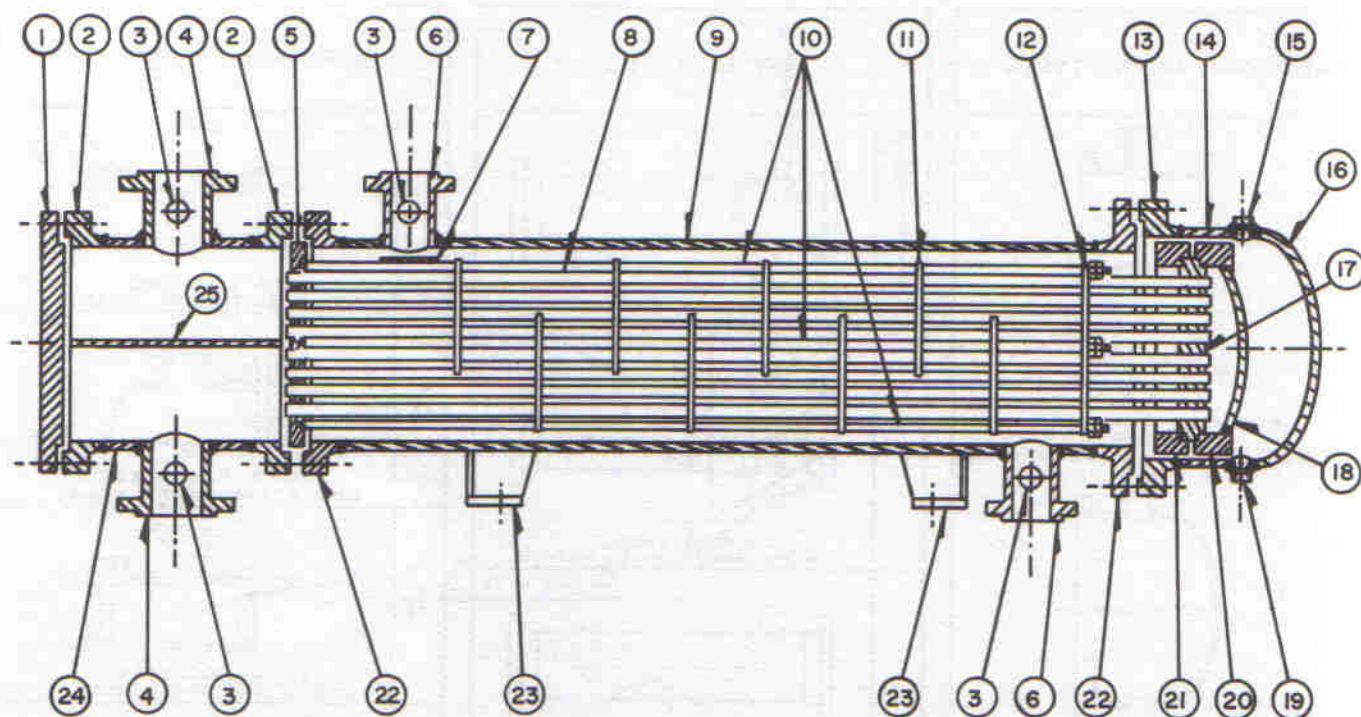


Figure 4-8. Cross section, Type AES exchanger.
Courtesy of HeaTran, Inc.

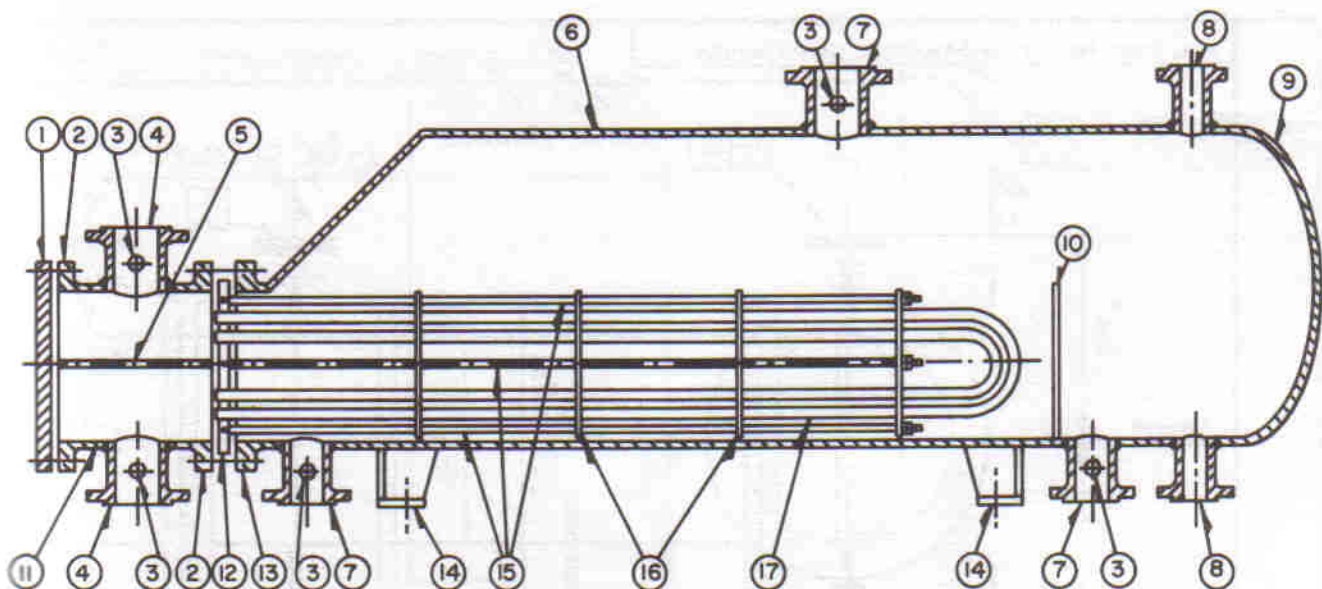
1. CHANNEL COVER
2. CHANNEL FLANGE
3. INSTRUMENT CONNECTION
4. CHANNEL NOZZLE
5. STATIONARY TUBESHEET
6. SHELL FLANGE
7. IMPINGEMENT PLATE
8. TUBES
9. SHELL
10. TIE RODS AND SPACERS.
11. TRANSVERSE BAFFLES
12. SUPPORT PLATE
13. SHELL COVER FLANGE
14. SHELL COVER CYLINDER
15. VENT
16. SHELL COVER
17. FLOATING TUBESHEET
18. FLOATING HEAD COVER
19. DRAIN
20. FLOATING HEAD COVER FLANGE
21. SPLIT RING
22. SHELL FLANGE
23. SUPPORT
24. CHANNEL
25. PASS PARTITION

special design. Notice the shell side double inlets with a vertical baffle splitting their flow. This is called a double split flow shell type. Horizontal thermosiphon reboilers are normally located near grade on minimum height concrete foundations.

Vertical Condensers and Reboilers

Figure 4-13, shows a type BEM exchanger mounted in a structure and used to condense overhead vapors from a Crude Column. Notice that the channel side is only one pass. The inflow is all vapor, entering Nozzle T1. Liquids and vapor exit from Nozzles T2 and T3. The 72" OD vertical exchanger is supported by four *lugs* shown in View X-X.

Vertical thermosiphon reboilers are very much like the one shown in Figure 4-13 except the flow is opposite—the tube inlet being at the bottom and the vapor outlet at the top. These reboilers normally have two lugs and are supported from the tower they serve.



1. CHANNEL COVER
2. CHANNEL FLANGE
3. INSTRUMENT CONNECTION
4. CHANNEL NOZZLE
5. PASS PARTITION
6. SHELL
7. SHELL NOZZLE
8. LIQUID LEVEL CONNECTION
9. SHELL COVER
10. WEIR
11. CHANNEL
12. TUBESHEET
13. SHELL FLANGE
14. SUPPORT
15. TIE RODS AND SPACERS
16. SUPPORT PLATES
17. TUBES

Horizontal Condensers

There are two basic horizontal condenser types: flooded and overhead; visibly, the difference is indistinguishable. The flooded exchanger is designed to have all tubes covered with the liquid being condensed. It is located at grade with the liquid outlet piping rising up to go into an elevated accumulator.

The overhead condenser operates with only part of its tubes covered with condensed liquid and must be elevated above the accumulator which receives its liquid—requiring an expensive structure to support it.

Figure 4-9. Cross section, type AKU reboiler. Courtesy HeaTran, Inc.

The mechanical flow diagram will show a flooded condenser located below the accumulator. Overhead condensers will be shown higher than the accumulator.

Exchanger Nozzles

In the past, little creativity has gone into the design of exchanger piping. Presented with a conventional exchanger drawing, showing conventional nozzles, designers have applied conventional piping design. Perhaps they have not realized the dozens of nozzle options available for creative piping.

An exchanger nozzle normally consists of a short piece of pipe and a terminating flange pointing either up or down for both shell and channel sides. In many situations horizontal nozzles or nozzles oriented 10°, 20°, 30° or so from the vertical would create a more economical piping layout. Often, adding an elbow between the short piece of pipe and the flange can reduce the necessary foundation height for nozzles 10" and larger at the bottom of the shell or channel side of the exchanger. Adding elbows to inbetween nozzles of stacked exchangers operating in different services will reduce the total height of the stack facilitating maintenance and reducing cost. Channel side tangential nozzles often save piping costs and make a neater design.

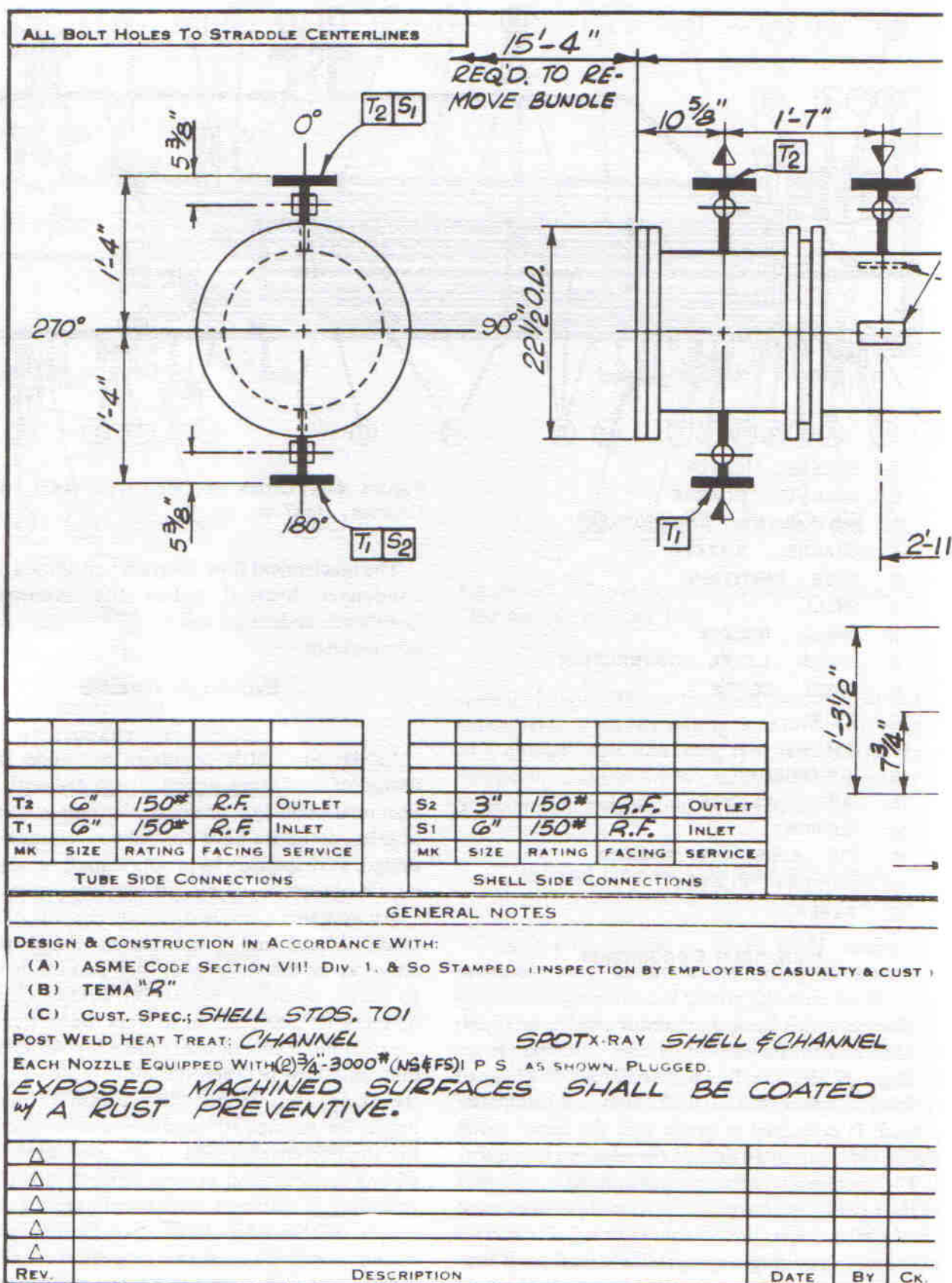


Figure 4-10. Brine heater outline drawing. Courtesy of HeaTran, Inc.



PAINTING REQUIREMENTS		DESIGN DATA			
NONE				SHELL	TUBE
INSULATION REQUIREMENTS		DESIGN PRESSURE	PSI	100	100
		HYDROSTATIC TEST PRESS	PSI	150	150
		DESIGN TEMPERATURE	°F.	400	200
BY OTHERS		CORROSION ALLOWANCE	IN.	1/16	1/8 (C.B.)
		NUMBER OF PASSES		ONE	TWO
ESTIMATED WEIGHT EACH		CUST.			
DRY	3600 LBS.	P. O.			
WET	5100 LBS.	SERVICE SPINE HEATER			
BUNDLE	1700 LBS.	HEATTRAN EQUIPMENT DIVISION			
		HOUSTON, TEXAS			
EFF TUBE SURFACE 453 SQ. FT. EA		OUTLINE DIMENSIONAL			
SIZE 17-458-16	TYPE AET	DWN. JACK	2-1-72	ITEM E-911B	DWG. H/T-3429
EXCHANGERS REQ'D: ONE		CK. [Signature]	2-9-72	JOB 8223	SHEET 1 OF 4

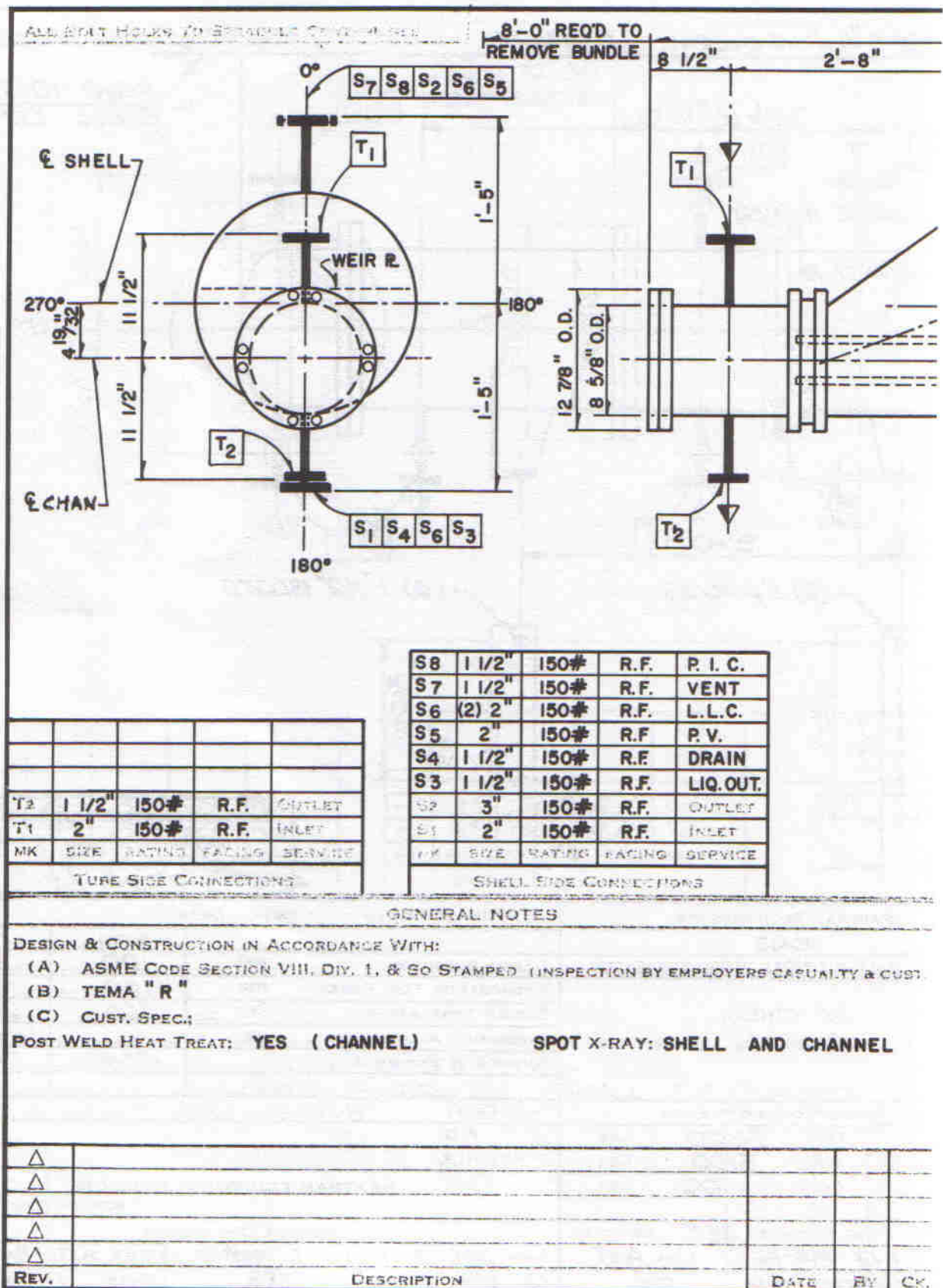
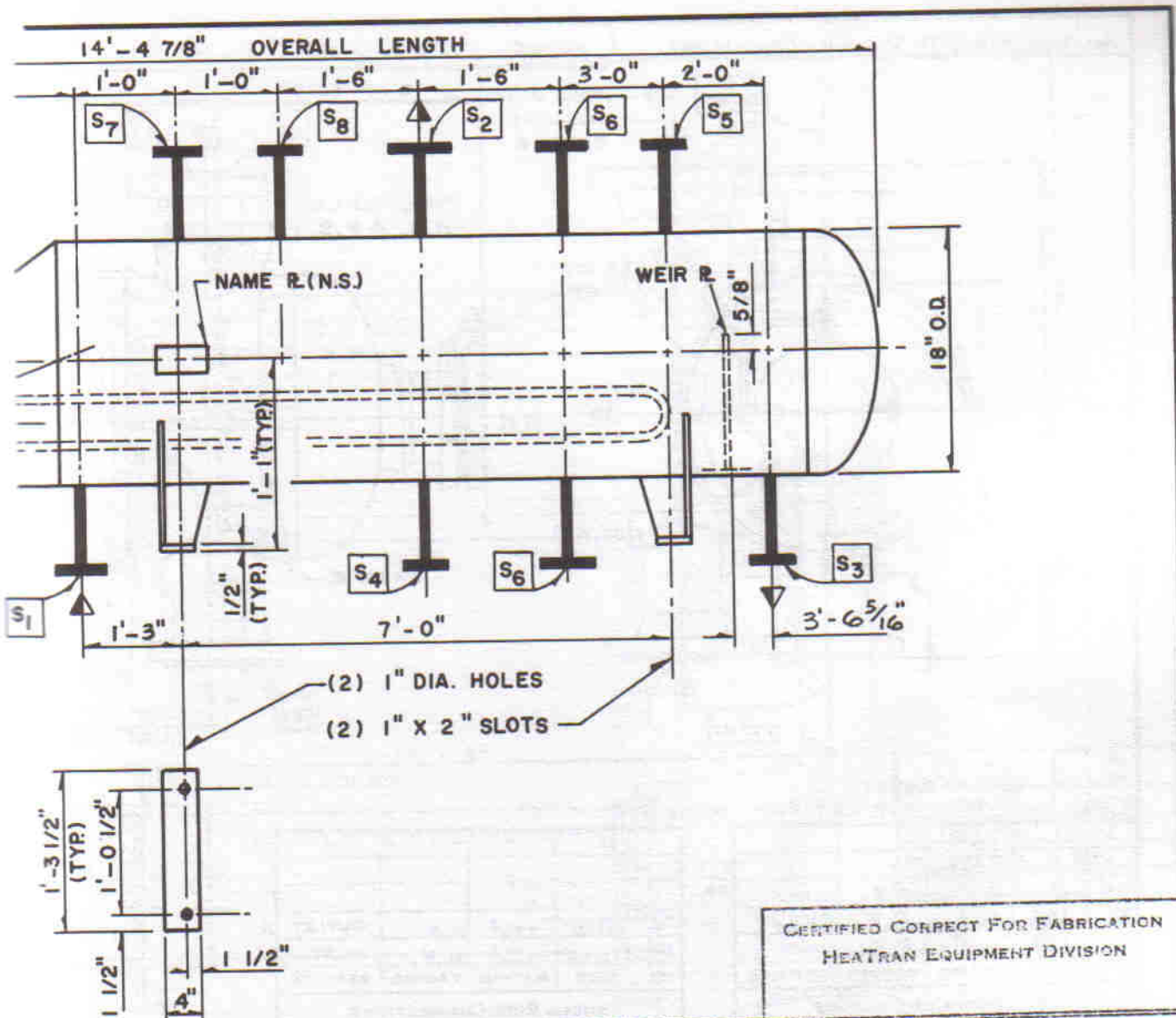


Figure 4-11. Kettle reboiler outline drawing. Courtesy of HeaTran, Inc.



PAINTING REQUIREMENTS			DESIGN DATA							
SANDBLAST TO NEAR WHITE METAL PER SSPC-SP 10 AND PAINT WITH ONE SHOP COAT OF EPONOL N ^o 53. DRY FILM TO BE 3 TO 4 MILS.					SHELL	TUBE				
			DESIGN PRESSURE		PSI	50	100			
			HYDROSTATIC TEST PRESS		PSI	75	150			
			DESIGN TEMPERATURE		°F.	500	500			
			CORROSION ALLOWANCE		IN.	1/8"	1/8"			
			NUMBER OF PASSES			KETTLE	TWO			
ESTIMATED WEIGHT EACH			CUST.							
DRY	1750	LBS.	P.O.							
WET	3100	LBS.	SERVICE							
BUNDLE	300	LBS.	HEATRAN EQUIPMENT DIVISION THE BELMAS CO., INC. HOUSTON, TEXAS							
GROSS TUBE SURFACE 44.5 SQ. FT. EA.										
			OUTLINE DIMENSIONAL							
DATE	8/17-45-8	TYPE	AKU	OWN.	RAJ	2-18-72	ITEM	E-IP-901	DWG. H/T-	3409
EXCHANGERS REQ'D:		ONE	CK.				JOB	8154	SHEET	1 OF 5

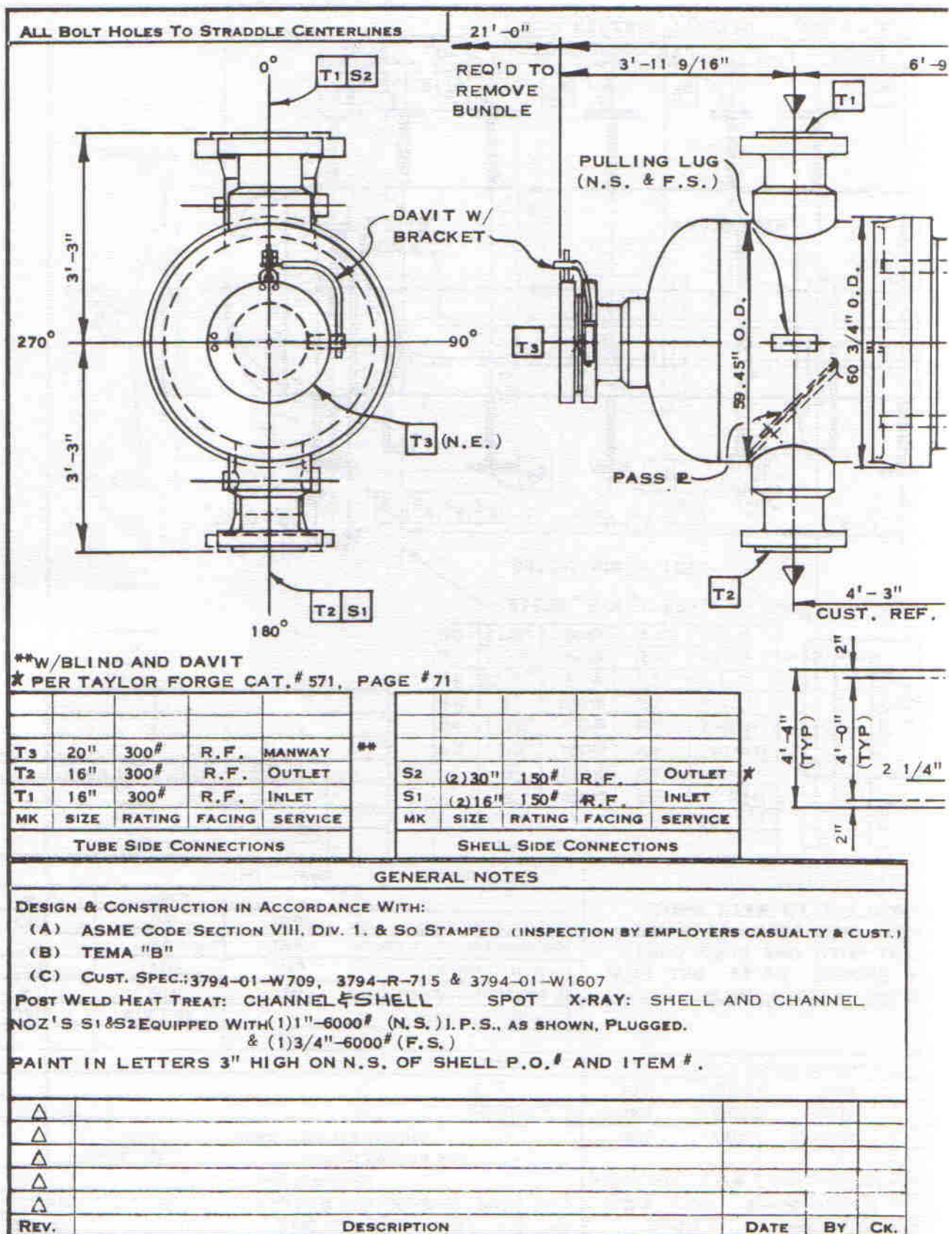
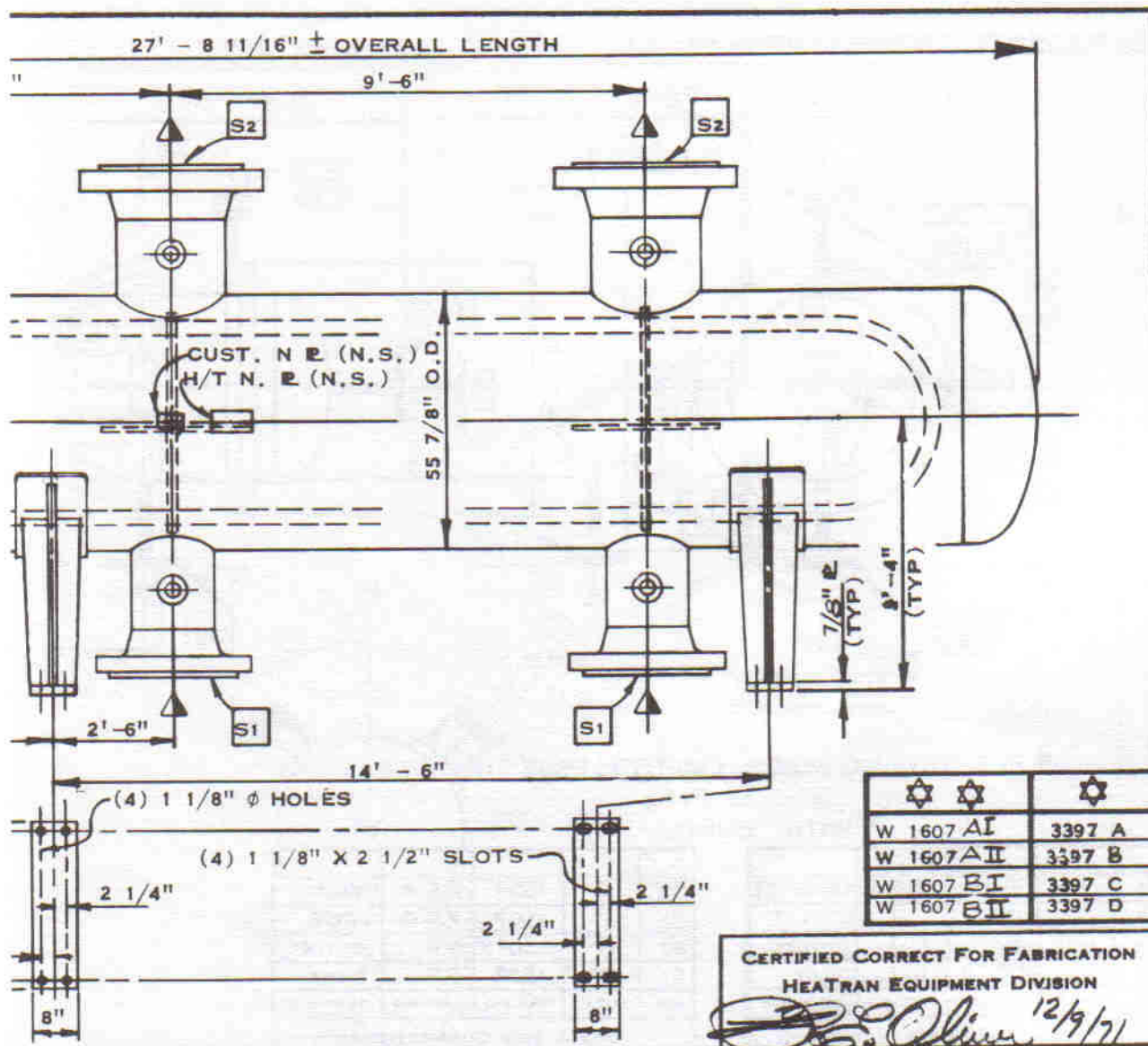


Figure 4-12. Horizontal thermosiphon reboiler outline drawing. Courtesy of HeaTran.



PAINTING REQUIREMENTS			DESIGN DATA		
SANDBLAST (SADDLES & FLANGE EDGES ONLY) PER SSPC-SP6 & PAINT w/ ONE COAT OF INORGANIC ZINC RICH PRIMER (3 MILS DRY FILM THK.)				SHALL	TUBE
			DESIGN PRESSURE	PSI	75
			HYDROSTATIC TEST PRESS	PSI	115
			DESIGN TEMPERATURE	°F.	260
			CORROSION ALLOWANCE	IN.	1/8
			NUMBER OF PASSES	DB, SPLIT	2
ESTIMATED WEIGHT EACH			CUST.		
DRY	37,900	Lbs.	P.O.		
WET	62,100	Lbs.	SERVICE		
BUNDLE	27,300	Lbs.	BEND-HELD SOLUTION REQUIRED		
EFF. TUBE SURFACE 5672 SQ. FT. EA.			HEATRAN EQUIPMENT DIVISION		
			BELMAS INDUSTRIES, INC., HOUSTON, TEXAS		
SIZE 55-5832-19 TYPE BHU*			OUTLINE DIMENSIONAL		
EXCHANGERS REQ'D: FOUR			DWN. JACK 12/9/71	ITEM ☆ ☆	DWG. H/T- ☆
			CK. [Signature] 12/9/71	JOB 7992	SHEET 1 of 6

*SPECIAL

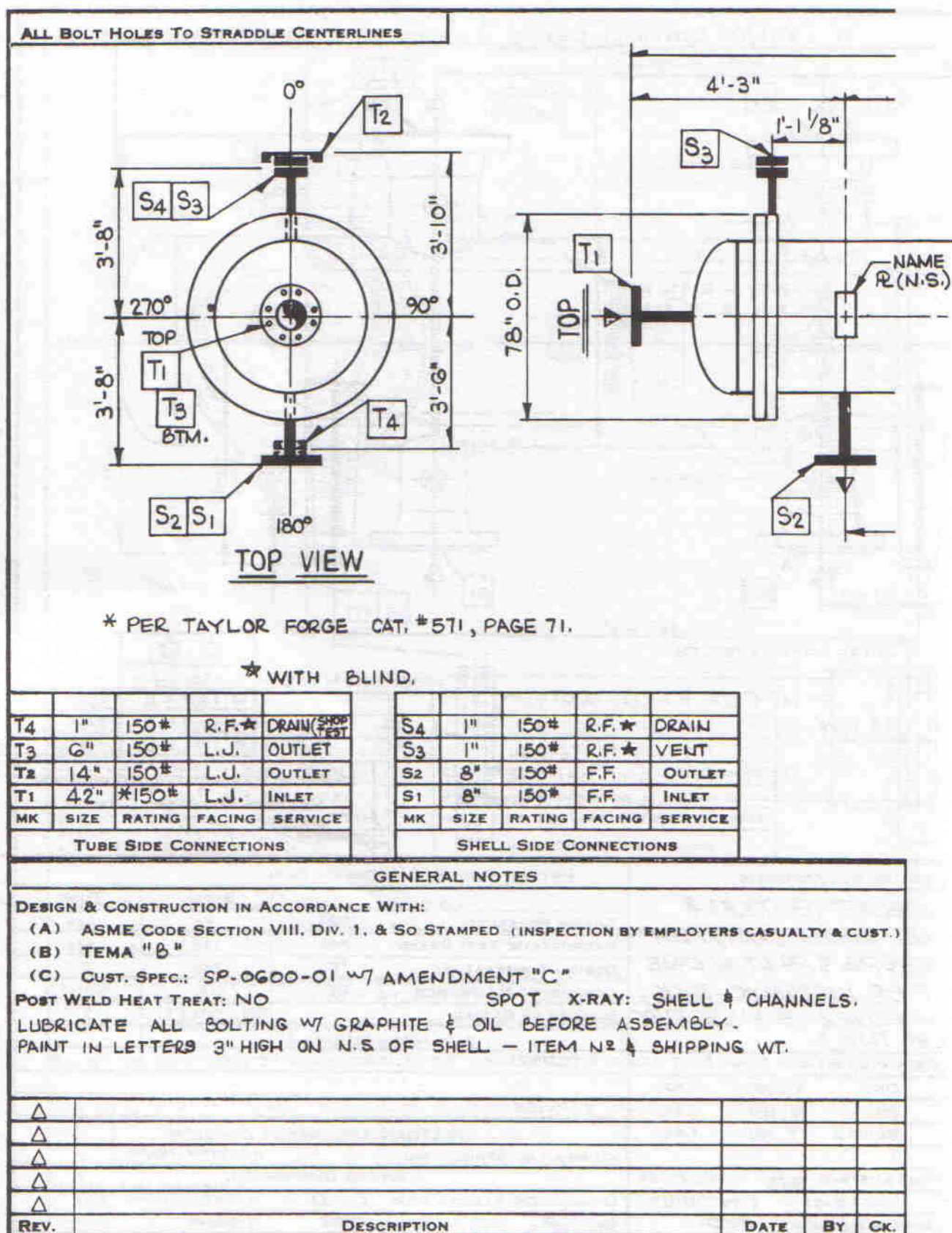
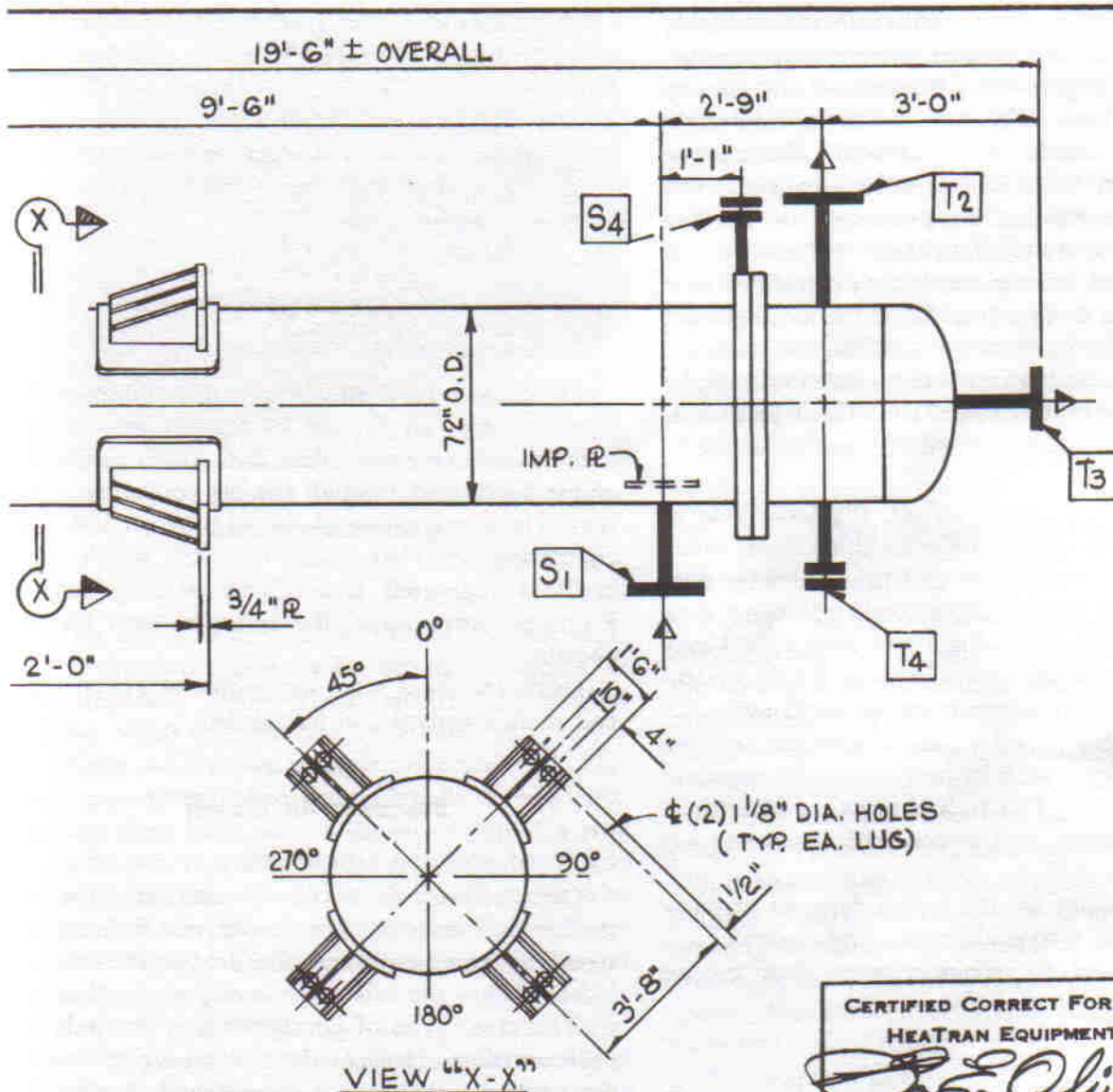


Figure 4-13. Vertical crude column condenser outline drawing. Courtesy of HeaTran, Inc.



PAINTING REQUIREMENTS			DESIGN DATA		
POWER TOOL CLEAN ALL EXPOSED CARBON STEEL PER SSPC-SP-3 & PAINT W/ (1) SHOP COAT OF PPG #G-204 ZINC CHROMATE PRIMER.				SHELL	TUBE
			DESIGN PRESSURE	PSI	75
			HYDROSTATIC TEST PRESS	PSI	113
			DESIGN TEMPERATURE	° F.	320
			CORROSION ALLOWANCE	IN.	1/8 C.S.
			NUMBER OF PASSES	ONE	ONE
ESTIMATED WEIGHT EACH			CUST.		
DRY	48,500	LBS.	P.O.		
WET	76,400	LBS.	SERVICE CRUDE COLUMN CONDENSER		
			HEATRAN EQUIPMENT DIVISION		
			BELMAS INDUSTRIES, INC., HOUSTON, TEXAS		
EFF. TUBE SURFACE 11009 SQ. FT. EA.			OUTLINE DIMENSIONAL		
SIZE 71-11582-12	TYPE BEM	DWN. RAJ	1-21-72	ITEM E-07-27	DWG. H/T- 3424
EXCHANGERS REQ'D: ONE		CK. <i>[Signature]</i>	1-21-72	JOB 8165	SHEET 1 OF 5

Heat is transferred more efficiently when meeting streams have the closest temperature range. Referring to Figure 4-8, this means that the top shell nozzle, Item 6, is where the hot stream might enter to be cooled or condensed. The cooling medium in the tubes will be at its warmest at this point, before leaving the exchanger by the top channel nozzle. However, in many services this rule can be violated and the nozzle may be located near the back shell flange, Item 22, if this arrangement produces better piping routing. If the shell side is a one-pass unit, the bottom outlet nozzle must also be relocated next to the channel end. This type of nozzle relocation must be cleared with and approved by the vendor.

To aid piping layout, the basic rule of routing may be broken when handling fluids which are all liquid or all vapor and heat exchange does not alter their states. These conditions being met, heated fluid may flow down and cooled fluid may flow up. But this can never be done if any condensing or vaporization occurs in the exchanger.

Furthermore, for all-liquid or all-vapor services, the reverse flow rule may be broken with approval from the vendor. This flow change can affect heat transfer efficiency and in non-critical services will be approved.

It is important for the piping designer to know that the above nozzle alternates are available; it is more important to recognize when they can be applied for better piping design.

Nozzle Reinforcement

Exchanger shell openings are usually reinforced to compensate for metal removed to accommodate the nozzle connection. Often extra reinforcement may be applied to withstand forces inflicted by the thermal action of connecting piping. Piping thermal forces must be calculated by the piping designer and, when greater than the normal allowable, must be transmitted to the exchanger manufacturer who can check reinforcement capability and often can add stiffness to nozzle and joint detail to withstand additional external forces. The added cost of additional reinforcement is offset by savings in the piping configuration.

The vendor will make every effort to comply with a customer's request, however he has his limitations. Usually thermal forces of 25-50% greater than the normal allowable can be handled by extra reinforcement. Larger forces require that the piping configuration be revised to reduce them to within allowable limits.

Air Coolers

Air coolers perform their cooling function by flowing cooler air around a bank of finned tubes such as those previously described. Great quantities of air are forced through the air cooler by large fans. The combination of finned tubes and the air circulating fan(s) has made *FIN-FAN*, which is actually a registered trade mark of the Hudson Products Corporation, the common term for air coolers.

There are three main categories of air coolers, coil shed, standard and humidified.

Standard Air Cooler

The standard air cooler is used in most installations. Figure 4-14 is a model of a forced draft type. The term comes from the fact that the fans are located below the tube cell, *forcing* air up through it. The other type of construction is the induced draft air cooler, in which the fans are located above the cooling cell, blowing upward and thereby *inducing* air to flow through the tubes.

The Cell

Figure 4-14 is a one-celled unit. A cell is a complete set of cooling coils with inlet and outlet nozzles for connecting piping. This unit is an even-pass cell with inlet and outlet nozzles on the same end. By even-pass, it is meant that the fluid passes from one end of the cell to the other an even number of times, usually two, four or six times. An odd-pass cell would have the inlet nozzle (the cell top nozzle) on the front side as shown; but the outlet nozzle (the cell bottom nozzle) would be on the opposite or back side.

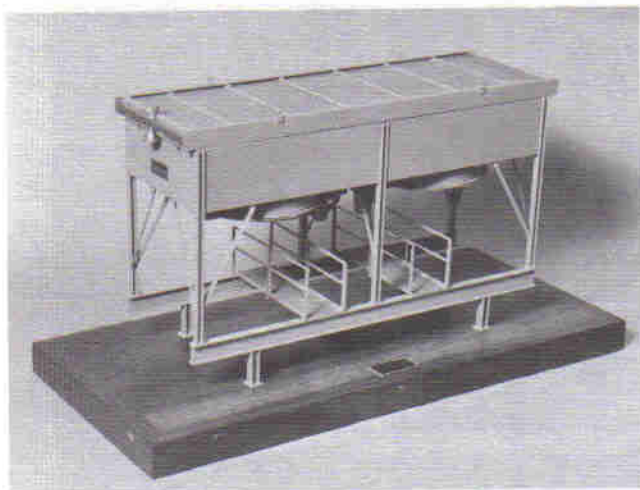


Figure 4-14. Forced draft air cooler model. Courtesy of Hudson Products Corp.

This unit is to be mounted on top of a pipe rack, hence the two walkways for fan motor access for maintenance. Two vertical electric motors are shown which turn the two horizontal fans.

Figure 4-15 shows a single air cooler cell. This cell, sometimes called a tube bundle, is odd pass, having three inlet nozzles shown on top of a plug type header. In a plug header each tube has a plug which can be unscrewed to allow cleaning rods to be inserted or the tube to be replaced. Flanged-type removable-cover header boxes are also available but are much more expensive.

An air cooler unit may have one or many cells. Separate products may be cooled in multiple cells in one air cooler frame. These cells are individual units lifted and set in place after the structural frame is erected. They are not secured in any way but merely rest on the structure. Notice the lifting eyes shown in Figures 4-14 and 4-15.

Figure 4-16 shows a forced draft, plug-type header, odd-pass unit being lifted. The horizontal steel members beneath the four legs are only for shipping stiffness and will be removed when the unit is finally set in place. The lifting eyes on each end will also be removed to allow free cell movement during operation.

Pipe-Rack Mounted Air Coolers

It is very common to mount air coolers on top of process unit pipe racks. Grade-mounted air coolers occupy valuable real estate. When the piping

designer elects to rack-mount air coolers, he must consider rack width and cell tube length. As a maximum, the pipe rack width should be the cell tube length minus 2'. For 32' tubes the maximum rack width would be 30'. For 30' tubes the maximum rack width would be 28'. This 2' distance will allow the cell supporting structure to be free and clear of inlet and outlet piping.

For adequate support of the air cooler structure the designer must also consider a minimum pipe rack width of $0.75 \times \text{tube length}$. With 32' tubes the rack width must be at least 24'. The maximum and minimum limitations must be remembered when rack-mounting air coolers.

Odd Versus Even Pass

Piping runs can often be minimized by having both inlet and outlet connections on the same end of the cooling cell. Sometimes the piping would be more economical if the connections were on opposite ends. The piping designer may specify the desirable number of passes to suit his piping. However, he must remember that the cell unit is designed to process specifications which allow a certain pressure drop through the unit. Changing the number of passes will require more pressure drop or possibly the addition of more tubes, which would increase the cost. If at all possible, it is better not to specify the number of passes and to accept the manufacturer's design.

An exception to this is generally made for rack-mounted air coolers. Since they are elevated, most installations require platforms at nozzles. By the specification of even-pass coolers, nozzles are all located on the same end, requiring only one platform. Odd-pass coolers require twice the platforming.

Induced Versus Forced Draft

When a choice exists between an induced or a forced draft unit, the designer should be aware of the inherent advantages of the induced draft unit. With the fan above them, the cells may be mounted directly on the pipe rack, eliminating the structural steel cell support. Figure 4-17 shows this type of

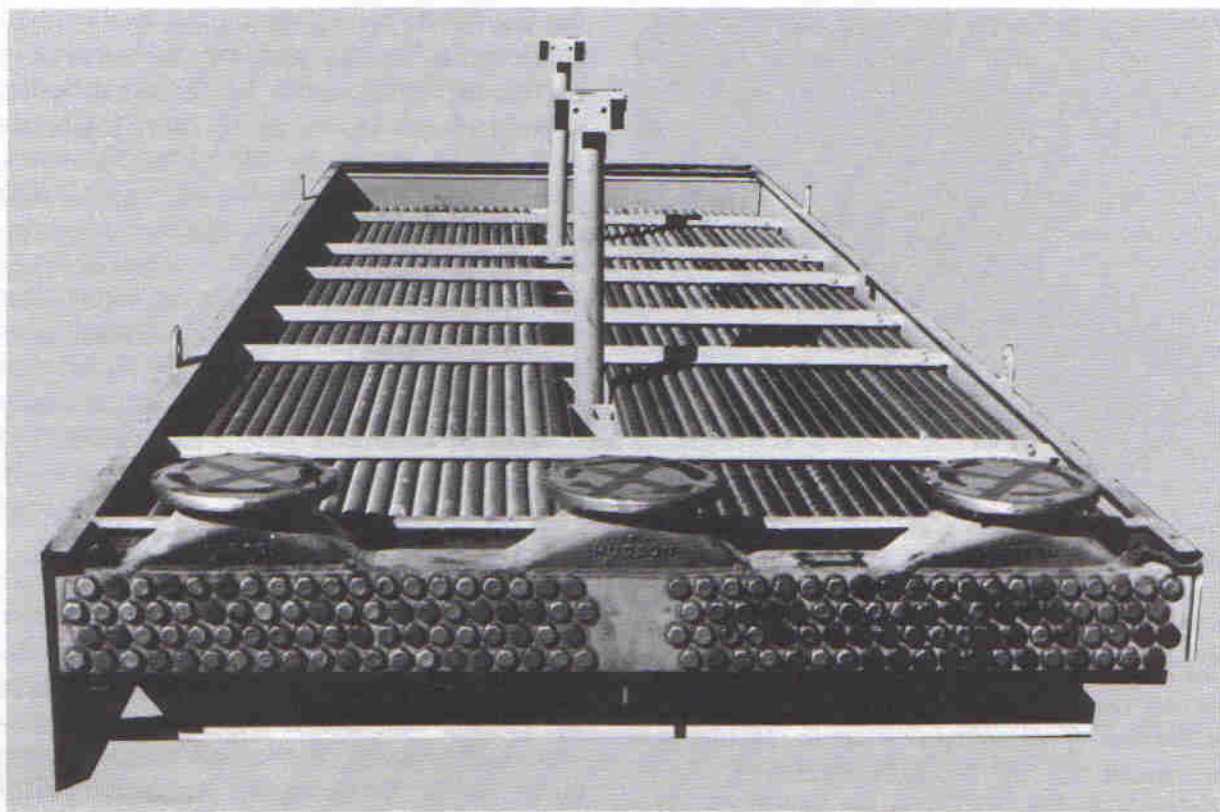


Figure 4-15. Odd-pass, plug-type header, air cooler cell. Courtesy of Hudson Products Corp.

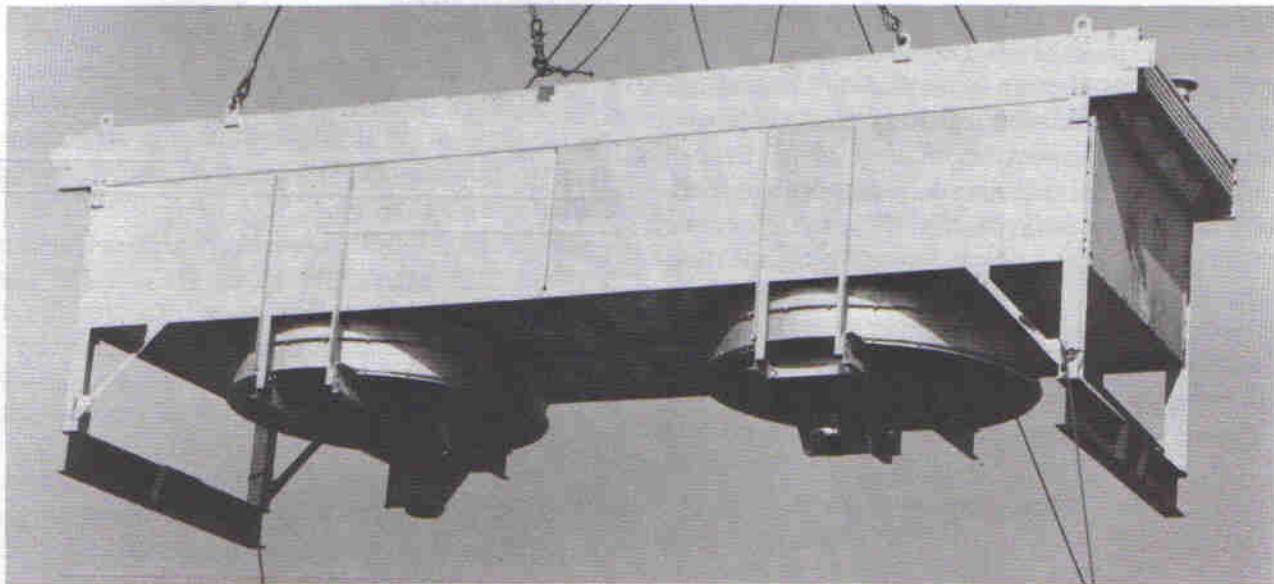


Figure 4-16. Air cooler being loaded for shipment. Courtesy of Hudson Products Corp.

installation. Pipe rack columns have been vertically extended to support two horizontal beams which in turn support a battery of air cooler cells. These horizontal beams are necessary to support the normal air cooler steel structure anyway. By adding

length to the vertical columns and using induced draft units, the steel structure has been eliminated. The results are lower material costs and greatly simplified field installation.

Recirculation of hot air is greatly reduced with

induced-draft units due to the higher air exit velocity compared to the forced-draft design. With the fan above the cell, hot air exits the top of the unit at 2.5 times the velocity possible in the forced draft unit where it must yet pass through the cell after leaving the fan. This minimizing of hot-air recirculation is vital to air cooler performance and provides protection from hot air to personnel on the header end walkway platforms.

The Humidified Air Cooler

Two types of air coolers utilize water to cool or to aid cooling. The humidified-air cooler has a separate, adjoining, circulating-water unit similar to a cooling tower, through which air passes before making contact with the tubes in the cell. Figure 4-

18 is a Hudson Combin-aire humidified-air cooler. Air enters the water circulation area, is washed, cooled and humidified, passes through the mist-eliminator and then is drawn up through the cells and out the fans at the top. During winter months, air does not pass through the water section but enters through open louvers shown on the left in Figure 4-18.

The Coil Shed

The other type of air cooler utilizing water is generally called a coil shed. Coils, or cooling cells, are located in a cooling tower and circulating water is sprayed directly on the tubes of the cells. The combination of water and flowing air produces cooling. Figure 4-19 describes an atmospheric cell section used in a coil shed.

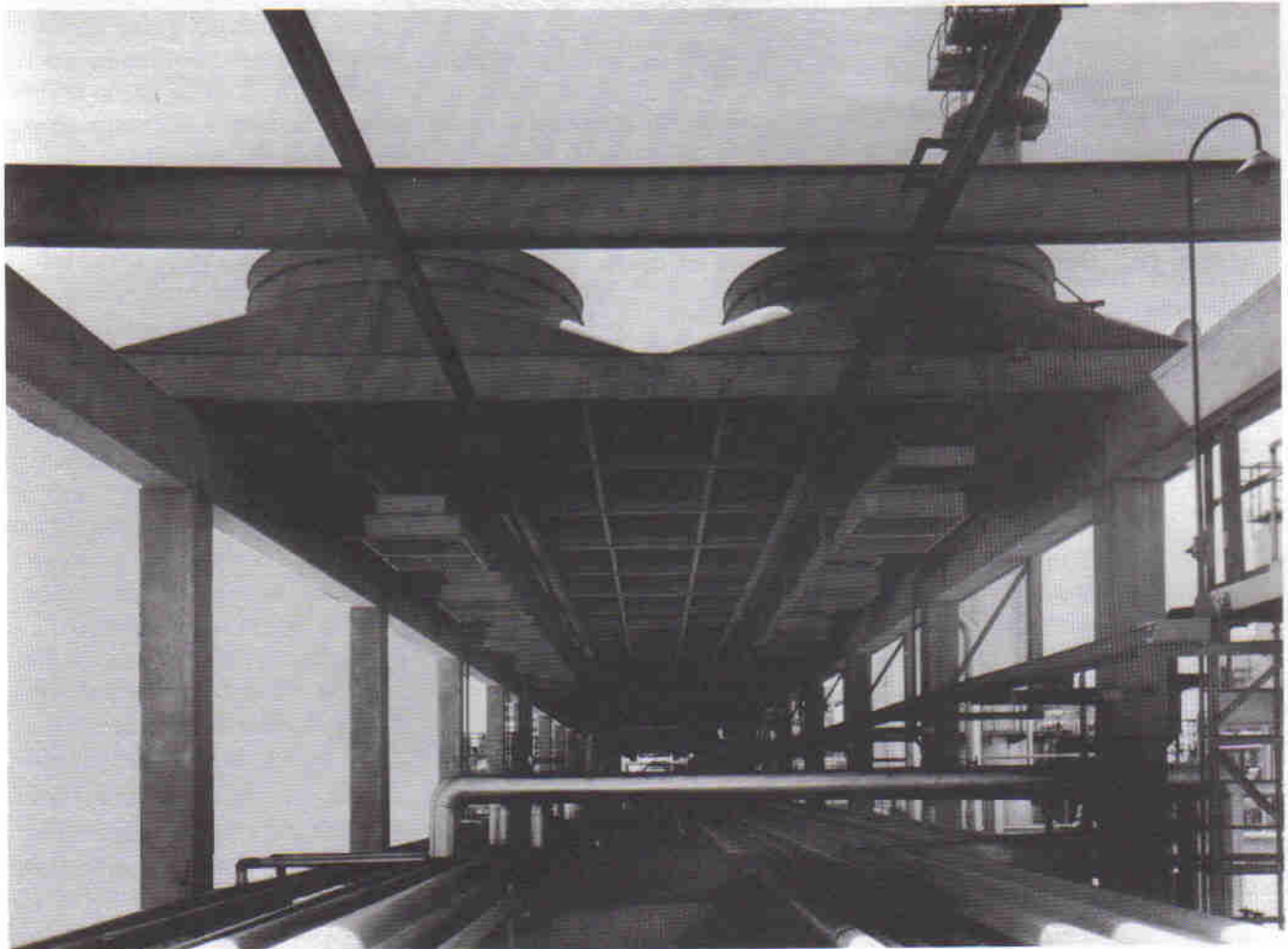


Figure 4-17. Induced draft air cooler mounted directly on rack.

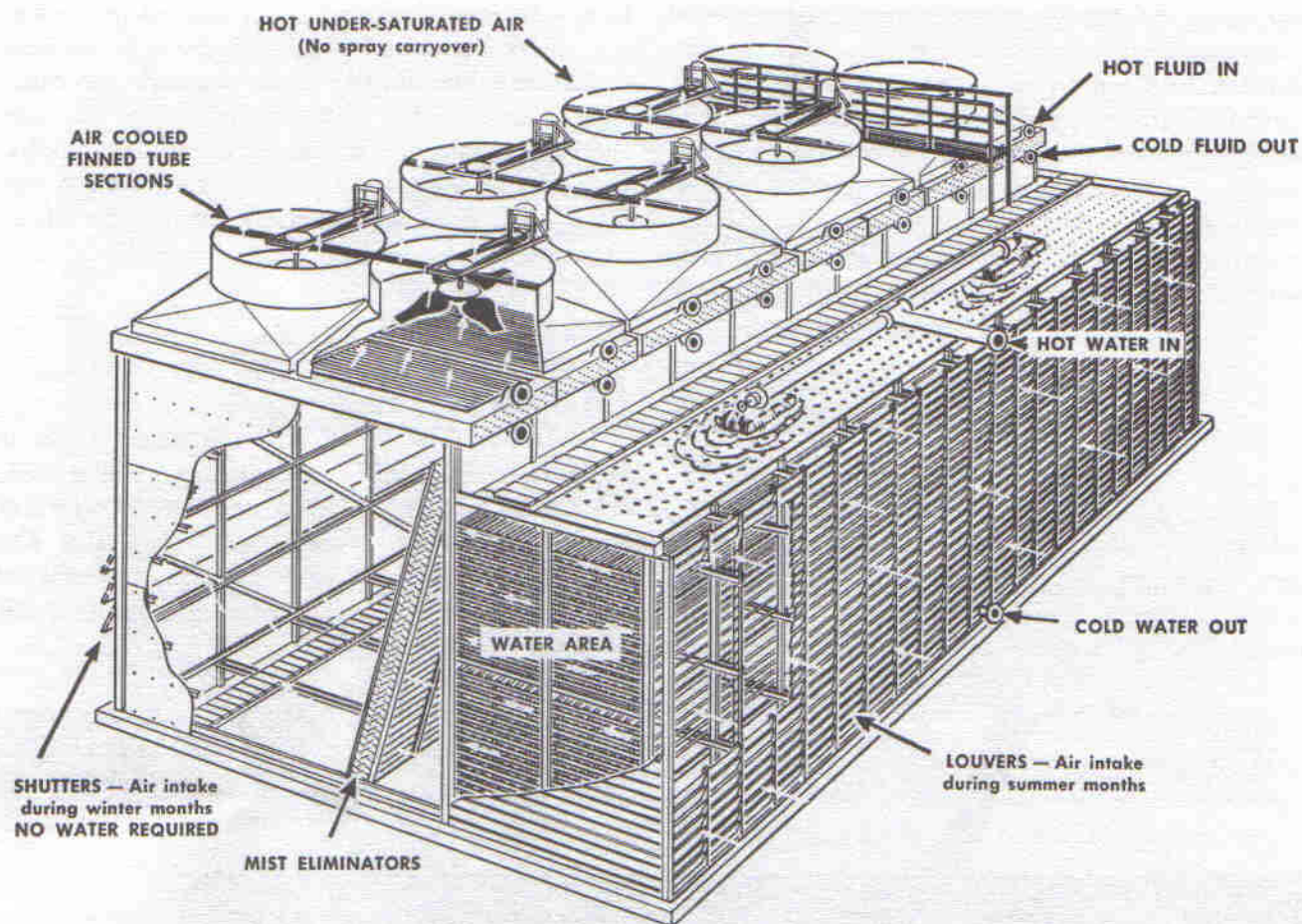


Figure 4-18. Hudson combin-air humidified air cooler. Courtesy of Hudson Products Corp.

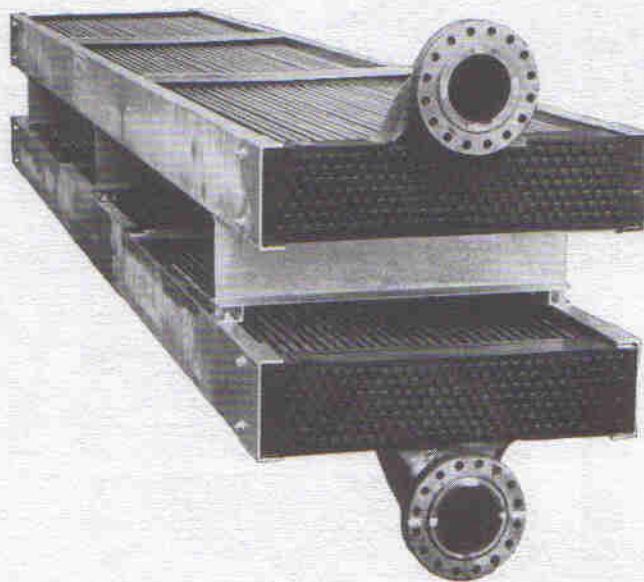


Figure 4-19. Coil shed atmospheric cell. Courtesy of Hudson Products Corp.

Air Cooler Piping

As in other exchanger piping, lines being cooled should flow down; so piping to the cell should enter the top nozzle and exit the bottom nozzle. Many air coolers are specified to condense fractionating tower overhead vapors. Air cooler lines must be routed so that there is a no liquid pocket between the top of the tower and the air cooler inlet. Ambient air temperature will cause some liquid to condense in the line to the cooler. If there is a pocket in the line, this liquid will accumulate and *slug* the cooler, resulting in possible damage to the cell and a cooling malfunction.

Condensed liquid-vapor from these cells must also flow down (or horizontally) to the accumulator. The necessity for downflow from the top of the tower through the air cooler to an elevated accumulator increases the desirability of rack-mounted air coolers.

When using humidified air coolers or coil sheds where circulating water systems are required, the weight of the unit plus water weight force them to be grade-mounted. However, the designer must make sure the cells are elevated enough to permit condensed outflow to have downflow routing to the accumulators.

Two-phase flow to air coolers must be piped as two-phase flow to any other piece of equipment, (See Volume I, Chapter 2), to ensure equal distribution of liquid and vapor to each section. In the case of a very large air cooler service with as many as ten or more inlet nozzles into multiple cells, care must be taken to ensure that piping does not contribute to unequal pressure drop through the cells. Symmetrical piping may sometimes be necessary on the inlet side although it is hardly ever needed on the outlet side if condensation is extensive.

Generally the best arrangement for six or fewer cell nozzles is a header placed over the six nozzles and entered at the center so that the flow must split to three nozzles in each direction. Cell outlet piping should employ the same design. This is normal single stage piping.

For more than six nozzles, the single process line must split to feed two headers capable of handling up to six nozzles each.

Up to three nozzles can be fed with piping coming

from one side. The outlet piping will leave the header from the other side.

Figure 4-20 shows flow patterns for air cooler piping.

Regulating Valves

When air coolers have six or more cell nozzles, some operating companies specify that flow regulating valves be installed at each inlet and outlet nozzle. The valves are usually of plug or butterfly pattern for throttling and to serve as block valves for shutting off a cell for repairs while the other cells remain in operation. Because flow regulating valves balance distribution among the cells, piping can be routed to the nozzle in any manner. If two-phase fluid is being handled, piping must still be symmetrical. *Valves can not distribute two-phase flow.*

When flow regulating valves are used, a temperature indicator is furnished in each cell outlet nozzle to aid in balancing flow. When each cell nozzle has the same outlet temperature, it means that each cell is passing the same quantity of fluid. Should flow quantities to the cooler change, regulation must be checked and probably changed. For this reason, it is suggested that regulating valves are usually more trouble than they are worth and should be eliminated. For the cost of these valves, distribution can be made with adequate piping configurations which will effectively balance flow regardless of changes in volume.

Piping Expansion

Always remember that inlet piping is hotter than outlet piping and will expand at a greater rate. Cells are merely resting in the air cooler frame and will move somewhat with line expansion. For very hot systems connecting to six or more nozzles, vendor prints must be checked to see just how much cell movement is permitted to compensate for line expansion. In any event, differential expansion between inlet and outlet piping headers must be checked. Usually an offset can easily be built into the outlet piping to compensate for this differential expansion.

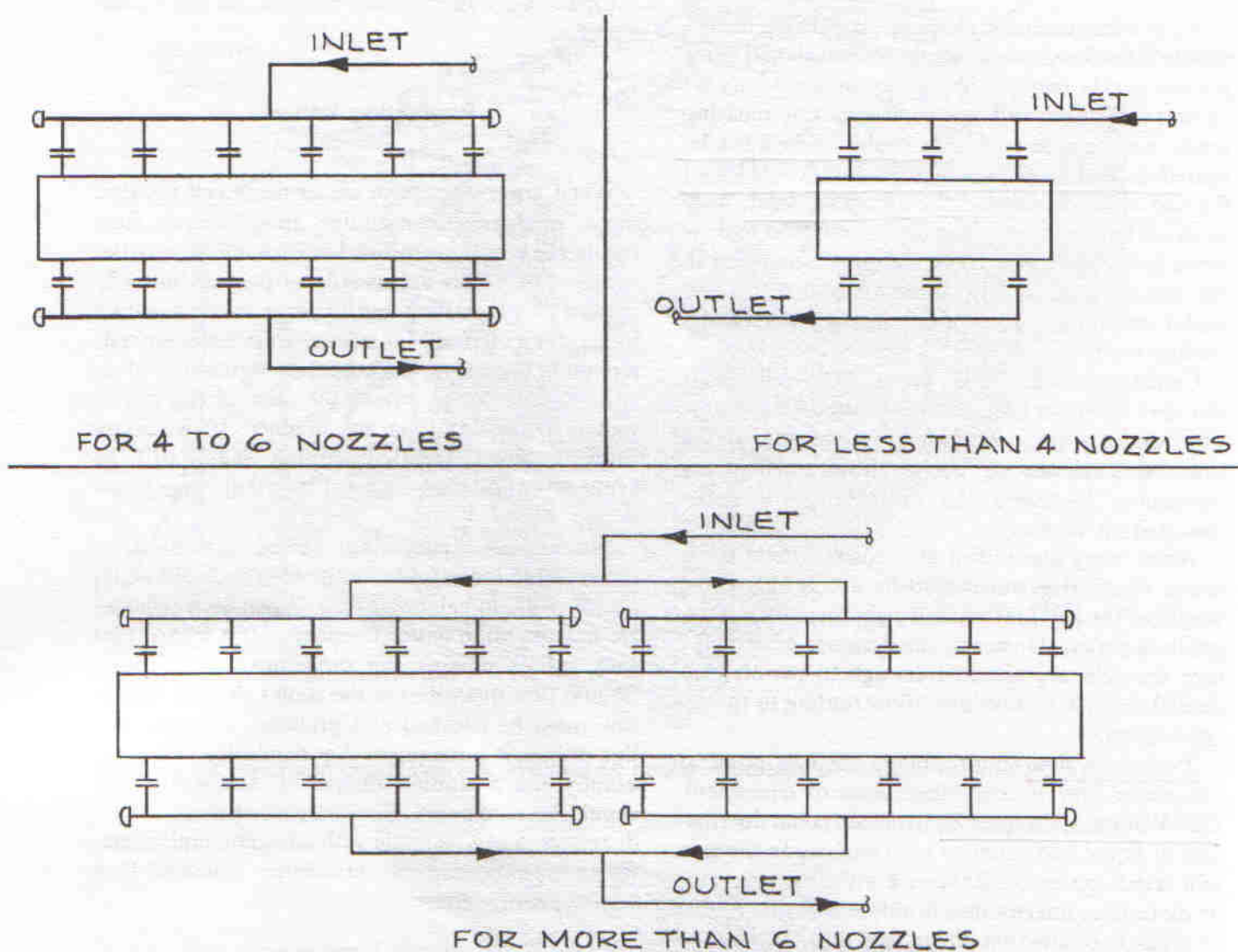


Figure 4-20. Flow patterns for air cooler piping.

Review Test Chapter 4

1. Fluid being heated shall flow _____ and fluid being cooled shall flow _____.
2. Double pipe exchangers are also called _____.
3. When double pipe exchangers are said to be "4 wide by 3 high" what does this mean? How many modules would this require? _____

4. TEMA is the abbreviation for _____.
5. The channel end of a shell and tube exchanger directs flow through the _____.
6. What is the purpose of the kettle reboiler weir? _____

7. Thermosiphon horizontal reboilers are located on a foundation _____ high.
8. The terms *forced draft* and *induced draft* refer to air coolers. Define these terms and explain their differences. _____

9. When rack-mounting air coolers, the maximum rack width is the air cooler tube length minus _____ The minimum rack width is the tube length plus _____.
10. What is meant by *odd* or *even* pass in an air cooler cell? _____

11. Piping from _____ to the condensing air cooler and from the air cooler to the _____ must have no liquid pockets.
12. Air cooler cell valves are not recommended. Why not? _____

5 Piping Flexibility

Piping flexibility is one of the most important, least understood functions of piping design. Today flexibility analysis, or stress analysis as it is often called, is delegated to a computer. Consequently, the piping designer's responsibility is normally limited to a quick check to determine if the piping layout is within reasonable tolerances. If the quick check shows it is outside these limits, he turns the problem over to stress specialists. A stress specialist translates data to an input sheet, turns this over to the computer group and later receives a computer output sheet. Then if the piping system is too rigid, the stress specialist may suggest corrective modifications; but the ultimate responsibility rests with the designer.

A computer run, including formulation of input and diagnosis of output, is expensive but certainly warranted if the quick check method suggests a need for it. However, thousands of dollars are wasted on computer analysis of lines of visibly adequate flexibility or of lines which would be accepted if a quick check method were used. Piping designers who know nothing about flexibility analysis are quick to request a full stress analysis rather than take a chance.

Although several books could be written on piping stress analysis, this chapter must be limited to presenting a quick check method and explaining it so that all readers can understand and apply it to their problems.

The competent piping designer will make every effort to provide adequate flexibility in his piping using a minimum number of fittings. When a quick check determines that the system is not flexible enough, he reviews the system to determine whether or not he can redesign, maybe adding an elbow or two to increase flexibility. Then he uses the quick check method again. If his system proves adequate, he has saved the expense of full analysis. If the system is still slightly rigid and the designer believes that computer analysis may prove his system to be within flexibility allowances then he should ask for the stress analysis.

The quick check method has a built-in safety factor; many arrangements which prove slightly stiff by the quick check method actually come out OK when full analysis is made.

Purpose of Analysis

A hot piping system will expand or elongate. A cold piping system will contract or shrink. Both of these actions create stress problems. A stress analysis determines the forces at anchor points, stresses in the piping system, and bending moment at any point. For any of these factors an allowable is known. For any force generated at an anchor point, often an equipment nozzle, there must be at least an equal resisting force. If a system throws 20,000

pounds of force into an anchor designed to withstand 15,000 pounds of force, it will give. If the anchor happens to be an equipment nozzle this *give* means a rupture and possibly an explosion and fire. Before designing piping systems for adequate flexibility, the designer must know what forces are allowable.

Allowable Forces

Allowable forces and moments are a nightmare to the piping designer responsible for providing a piping system that will not overstress the equipment to which it attaches. It is hard, sometimes, to find out just what the allowables are.

Specific equipment allowables must be obtained from equipment manufacturers. If the forces involved are figured and passed on to the vendor, the nozzle can often be reinforced to withstand forces greater than normal, but it must be remembered that even the manufacturer has force tolerance limitations.

Allowable forces described in this chapter are generally conservative and are offered as a guideline to be used until vendor allowables can be obtained.

Rotating Equipment

Table 5-1, provides symbols and definitions used in this section and other parts of this chapter, unless specifically noted.

To keep pump shaft coupling mis-alignment below the maximum allowable 0.002", pump vendors design casing support to withstand certain loads. For steel pumps with discharge nozzles of 4" IPS or smaller these loads are;

$$\begin{aligned} M_x &= 3w \\ &= \text{foot-pounds allowable} \\ &\quad (3,000 \text{ ft-lbs maximum}) \\ M_y &= 2w \\ &= \text{foot-pounds allowable} \\ &\quad (2,000 \text{ ft-lbs maximum}) \\ M_z &= 1.5w \\ &= \text{foot-pounds allowable} \\ &\quad (1,500 \text{ ft-lbs maximum}) \end{aligned}$$

Table 5-1
Symbol Definitions

F	= force = pounds
x	= the axis parallel to equipment shaft centerline
y	= the axis perpendicular to equipment shaft centerline
z	= the horizontal axis perpendicular to equipment shaft
r	= resultant
w	= weight of equipment = pounds
s	= suction or intake
d	= discharge or exhaust
F_r	= resultant shear force parallel to the flange face
D	= diameter, nominal diameter = I.P.S. = iron pipe size, in inches
M	= moment (foot pounds)
M_x	= moment in y - z plane
M_y	= moment in x - z plane
M_z	= moment in x - y plane
Sh	= basic allowable stress for the material of construction at maximum operating temperature (see ANSI B31.3)
D_c	= pipe size (I.P.S.) of the connection, in inches up to 8 in. in diameter. For 10 in. and larger use $(16 + D) \div 3$.
D_r	= diameter of a circular opening equal to the total areas of the inlet, extraction and exhaust openings up to a value of 9 in. in diameter. For values beyond this use a value of $(18 + \text{Equivalent diameter}) \div 2$.
D_o	= Outside diameter of pipe, in inches, rounded up to the nearest greater $\frac{1}{2}$ in.
h	= Length of shortest leg in feet
L	= Maximum length in feet (90° to the short leg)
T	= Temperature difference, Design $^\circ\text{F}$ - Installation $^\circ\text{F}$
A	= Coefficient for determining minimum leg permitted at design temperature in $^\circ\text{F}$.

Force, Moment and Stress Limitations Of Steel Pumps

At operating temperature, using the hot modulus E , resulting bending moments are permissible up to a value which causes a bending stress of $Sh \div 3$ in a connection having a section modulus equal to the connecting piping for the same size, where the connecting piping is 4" IPS or larger. On smaller size connections a value of $Sh \div 2$ is permitted.

The resultant shear force at the flange face and at any individual component should not exceed 2000 pounds. The resultant forces and individual components are further limited by the following:

1. Suction nozzles:
 $F_{rs} \leq 1.6w \leq 200D$
2. Discharge nozzles:
 $F_{rd} \leq (2w - F_{rs}) \leq 200D$

Top suction and discharge nozzles are further limited by:

Frs and $Frd = (Fx^2 + Fz^2)^{1/2}$
and the following;

For suction nozzles

- $Fxs \leq 1.3w \leq 160D$
- Fys (in compression) $\leq 1.2w \leq 200D$
- Fys (in tension) $\leq 0.5w \leq 100D$
- $Fzs \leq w \leq 130D$

For discharge nozzles

- $Fxd \leq (1.8w \pm Fxs) \leq 160D$
- Fyd (in compression) $\leq (2w \pm Fys) \leq 200D$
- Fyd (in tension) $\leq 0.5w \leq 100D$
- $Fzd \leq (w \pm Fzs) \leq 130D$

End suction and top discharge pump nozzles are limited by:

$$Frs = (Fzs^2 + Fys^2)^{1/2}$$

and

$$Frd = (Fxd^2 + Fzd^2)^{1/2}$$

and the following;

For suction nozzles

- $Fxs \leq 1.2w \leq 200D$
- $Fys \leq 0.6w \leq 130D$
- $Fzs \leq w \leq 160D$

For discharge nozzles

- $Fxd \leq (1.8w \pm Fxs) \leq 160D$
- Fyd (in compression) $\leq (2w \pm Fys) \leq 200D$
- Fyd (in tension) $\leq 0.5w \leq 100D$
- $Fzd \leq (w \pm Fzs) \leq 130D$

Side suction and top discharge pump nozzles are limited by:

$$Frs = (Fxs^2 + Fys^2)^{1/2}$$

and

$$Frd = (Fxd^2 + Fzd^2)^{1/2}$$

and by the following:

For suction nozzles

- $Fxs \leq 1.3w \leq 160D$
- $Fys \leq 0.6w \leq 130D$
- $Fzs \leq 1.2w \leq 200D$

For discharge nozzles

- $Fxd \leq (1.8w \pm Fxs) \leq 160D$
- Fyd (in compression) $\leq (2w \pm Fys) \leq 200D$
- Fyd (in tension) $\leq 0.5w \leq 100D$
- $Fzd \leq (w \pm Fzs) \leq 130D$

Cast Iron and Aluminum Pump Force, Moment and Stress Limitations

Cast iron and aluminum pumps are subject to the same limitations outlined for steel pumps except that allowable values are much lower. Bending stress is also limited by $Sh \div 3$ and $Sh \div 2$ as noted for steel pumps, but the resultant shear force is limited to a 500 pound maximum. Resultant forces are further limited by the following:

1. Suction nozzles:

$$Frs \leq 1.6w \leq 50D$$

2. Discharge nozzles:

$$Frd \leq (2w - Frs) \leq 50D$$

Top suction and top discharge nozzles are further limited by:

$$Frs \text{ and } Frd = (Fx^2 + Fz^2)^{1/2}$$

and the following;

For suction nozzles

- $Fxs \leq 1.3w \leq 40D$
- Fys (in compression) $\leq 1.2w \leq 50D$
- Fys (in tension) $\leq 0.54 \leq 25D$
- $Fzs \leq w \leq 35D$

For discharge nozzles

- $Fxd \leq (1.8w \pm Fxs) \leq 40D$
- Fyd (in compression) $\leq (2w \pm Fys) \leq 50D$
- Fyd (in tension) $\leq 0.54 \leq 25D$
- $Fzd \leq (w \pm Fzs) \leq D$

End suction and top discharge pumps are further limited by:

$$Frs = (Fzs^2 + Fys^2)^{1/2}$$

and

$$Frd = (Fxd^2 + Fzd^2)^{1/2}$$

and the following:

For suction nozzles

- a. $Fxs \leq 1.2w \leq 50D$
- b. $Fys \leq 0.6w \leq 35D$
- c. $Fzs \leq w \leq 40D$

For discharge nozzles

- a. $Fxd \leq (1.8w \pm Fxs) \leq 40D$
- b. Fyd (in compression) $\leq (2w \pm Fys) \leq 50D$
- c. Fyd (in tension) $\leq 0.5w \leq 25D$
- d. $Fzd \leq (w \pm Fzs) \leq 35D$

Steel Turbines, Force, Moment and Stress Limitations

At operating temperature, using the hot modulus E , resultant bending moments are permissible up to a value which causes a bending stress of $Sh \div 4$ in a connection having a section modulus equal to the connecting piping for the same size where the connecting piping is 4" IPS or larger. On smaller size connections a value of $Sh \div 3$ is permitted.

The resultant shear force at the flange face and at any individual component must not exceed 2000 pounds. The resultant forces and individual components are further limited by the following:

Individual components

- a. $Fx \leq 1.3w \leq 160D$
- b. $Fy \leq 0.6w \leq 130D$
- c. $Fz \leq w \leq 160D$

Resultant components

- a. Algebraic summation of $Frx \leq 1.6w$
- b. Algebraic summation of $Fry \leq w$
- c. Algebraic summation of $Frz \leq 1.6w$

Combined resultant

$$a. (Frx^2 + Fry^2 + Frz^2)^{1/2} \leq 2w$$

Using 100% cold spring and calculating using operating conditions, the total resultant force and total resultant moment imposed on the turbine at any connection must not exceed:

$$F \leq (500 D_c - M) \div 3$$

The combined resultant of forces and moments at the inlet, extraction and exhaust connections, resolved at the center lines of the exhaust connection and shaft, must not exceed:

$$Fr \leq (250 D_r - Mr) \div 2$$

Components of these resultants must not exceed:

- a. $Fxr \leq 50 D_r$,
 $Mxr \leq 250 D_r$
- b. $Fyr \leq 125 D_r$,
 $Myr \leq 125 D_r$
- c. $Fzr \leq 100 D_r$,
 $Mzr \leq 125 D_r$

For a turbine installation with a vertical exhaust and an unrestrained expansion joint at the exhaust, an additional amount of force caused by pressure loading is permitted. This force must be perpendicular to the exhaust flange face. For this type of application, calculate the vertical force component on the exhaust connection, excluding pressure loading, and compare with the value of $1/6$ the pressure loading on the exhaust. Use the larger of these two numbers for vertical force component on the exhaust connection in making calculations as noted above.

The force caused by the pressure loading on the exhaust is allowed, in addition to the values established by the preceding, up to a maximum value of the vertical force, in pounds, on the exhaust connection, including pressure loading, of 15.5 times the exhaust area in square inches.

The above values of force and moment pertain to the turbine structure only. Connecting piping must not exceed the allowable stress as defined by the piping code applicable to it.

Cast Iron or Aluminum Turbine Force, Moment and Stress Limitations

Cast iron and aluminum turbines are subject to the same limitations as for steel turbines except that allowable values are much lower. Allowable bending stress becomes $Sh \div 4$ and $Sh \div 3$ for the two categories noted in steel turbines and the resultant shear force maximum is limited to 500 pounds. Resultant forces are further limited by the following:

Individual components

- $F_x \leq 1.3w \leq 40D$
- $F_y \leq 0.6w \leq 35D$
- $F_z \leq w \leq 40D$

Resultant components

- Algebraic summation of
 $F_{rx} \leq 1.6w$
- Algebraic summation of
 $F_{ry} \leq w$
- Algebraic summation of
 $F_{rz} \leq 1.6w$

Combined resultant

- $(F_{rx}^2 + F_{ry}^2 + F_{rz}^2)^{1/2} \leq 2w$

Using 100% cold spring and calculating using both operating and installed conditions, the total resultant moment imposed on the turbine at any connection must not exceed:

$$F \leq (500 D_c - M) \div 3$$

The combined results of forces and moments at the inlet, extraction and exhaust connections, resolved at the center lines of the exhaust connections and shaft must not exceed:

$$Fr \leq (250 D_r - Mr) \div 2$$

Components of these resultants must not exceed:

- $F_{xr} \leq 50 D_r$,
 $M_{xr} \leq 250 D_r$
- $F_{yr} \leq 125 D_r$,
 $M_{yr} \leq 125 D_r$
- $F_{zr} \leq 100 D_r$,
 $M_{zr} \leq 125 D_r$

Stress and Force Limitations of Compressors With Steel Nozzles and Casings

At the operating temperature, using the hot modules E , resultant bending moments are permissible up to a value which would cause a bending stress of $Sh \div 4$ in a connection having a section modulus equal to the connecting piping for the same size where the connection is 4 in. IPS or larger. On smaller size connections a stress of $Sh \div 3$ shall be permitted.

The resultant shear force at the flange face and any individual component must not exceed 2000 pounds. The resultant forces and individual components shall be further limited by the following:

Individual components

- $F_x \leq 1.3w \leq 160D$
- $F_y \leq 0.6w \leq 130D$
- $F_z \leq w \leq 160D$

Resultant components

- Algebraic summation of
 $F_{rx} \leq 1.6w$
- Algebraic summation of
 $F_{ry} \leq w$
- Algebraic summation of
 $F_{rz} \leq 1.6w$

Combined resultant

- $(F_{rx}^2 + F_{ry}^2 + F_{rz}^2)^{1/2} \leq 2w$

Using 100% cold spring and calculating the operating condition, the total resultant force and moment imposed on the compressor at any connection must not exceed:

$$F \leq (925 D_c - M) \div 3$$

The combined resultants of forces and moments of the suction, interstage and discharge connections, resolved at the centerlines of the discharge connection must not exceed:

$$Fr \leq (463 D_r - Mr) \div 2$$

Components of these resultants shall not exceed:

- a. $F_{xr} \leq 92 D_r$,
 $M_{xr} \leq 460 D_r$
- b. $F_{yr} \leq 230 D_r$,
 $M_{yr} \leq 230 D_r$
- c. $F_{zr} \leq 185 D_r$,
 $M_{zr} \leq 230 D_r$

Stress and Force Limitations For Shell and Tube Exchangers

The stress on exchanger nozzles must be kept within the allowable stress range as determined by the ANS B31.3 piping code for the material of construction. The stress should be determined by considering the nozzle to be an unreinforced stub-in at a header having a diameter and thickness identical to that of the exchanger shell or that of the exchanger channel.

Forces which exert a thrust (on either footing) in excess of 30% of the weight of the exchanger on that footing require detailed stress analysis. Since exchanger footings are normally designed so that the channel end footing bears 60% and the shell end footing 40% of the total exchanger weight the forces are limited by:

$$\begin{aligned} \text{Channel end footing } F \\ &\leq 0.3 \times 0.6 \times w \\ \text{Shell end footing } F \\ &\leq 0.3 \times 0.4 \times w \end{aligned}$$

When forces exceed those discussed in the preceding paragraph, low friction slide plates inserted in the grout of the foundation often reduce such forces to allowable tolerances.

Piping Flexibility Design

It is preferable to provide adequate flexibility in piping systems by using loops or other configurations constructed of pipes and fittings. Sometimes space or cost is prohibitive and movement must be absorbed by expansion joints such as the bellows, Barco ball or sliding type. Piping flexibility should always be achieved with the minimum number of anchors and guides feasible. Axial expansion joints must be guided on each side and anchored at the end of pipe runs to withstand

hydrostatic testing thrust. U-type loops must be anchored on both sides of the pipe run to work.

- Lines which are to be purged by steam or hot gas must be checked to make sure that they will be adequately flexible during the purging operation.
- Closed relief systems and hot blowdown or pumpout system must also be carefully thought out.
- Temperatures in start-up lines often surpass operating temperatures.
- Exchanger by-passes may still be cold while the inlet and outlet lines are already hot, resulting in excessive stresses.
- Always review systems at their worst operating conditions such as during start-up when a hot line will be feeding into a cold tower or vice versa.

Unit systems, such as a steam system having a large diameter header in the unit pipeway and smaller size branches feeding into equipment, are often provided with unnecessary and expensive expansion loops and anchors. Before loops are designed, every effort should be made to make the branches flexible enough to withstand header expansion. An anchor placed near the center of the run can be used to direct header expansion by forcing 50% of the expansion to either side of and away from the anchor, distributing expansion along the header and thereby simplifying branch flexibility.

Flexibility must be considered from the beginning in every system designed. During the original layout—which may be freehand on a scratch pad—flexibility must be uppermost in the piping designer's mind. A quick check should be made of all lines 8" or larger during this initial stage. If flexibility appears to be a problem, smaller lines should be reviewed and quick checked, too. If a line is too stiff and must be rerouted, the time to find out is early in the design. Many dollars and manhours can be wasted making finished drawings of piping systems which are too stiff. When this happens and is finally discovered, the designer must start over completely.

One of the many differences between a draftsman and a designer is that while the draftsman can only draw the pipe, the designer knows flexibility, process, instrumentation, flow of fluids and many

other specifics which must be considered during the piping layout and design stage.

The Quick Check Method

The purpose of the quick check method is to determine whether or not a piping system is adequately flexible without the formal calculations required for a full stress analysis. Ordinarily if a system is within the quick check guidelines, no further flexibility analysis is required.

To make use of this method the piping designer must establish some basic facts.

- Anchor points must be known or assumed.
- Design pressures and temperatures, expansion coefficients for the metal involved and any branch or equipment restraints must be included.
- Special design conditions such as start-up, cyclic operation, steam tracing, etc. must be known.

The lengths of pipe solved for are based on standard weight carbon steel pipe. Alloy piping, other than austenitic stainless steel and aluminum, may be laid out on the same basis.

When pipe wall thickness differs from standard weight, a correction factor of ratioing moment of inertias must be applied. In this case:

Minimum h (adjusted)

$$= \frac{\text{moment of inertia, pipe specified}}{\text{moment of inertia, std. wt. pipe}}$$

x minimum h in the formula

When anchor expansion adds to the thrust from the L leg, a correction ratio of linear expansion must be applied. In this case:

Minimum h (adjusted)

$$= \frac{\text{Anchor movement} + \text{leg L movement}}{\text{leg L movement}}$$

x Minimum h in the formula

The minimum length of h leg required to provide an adequately flexible member must be tested by applying a factor A which corrects for design temperature. (See Table 5-1 for definitions) The formula is:

$$\text{Minimum } h = A \times D_o$$

For the A coefficient of carbon steel pipe, see Table 5-2.

For L-shaped configurations (see Figure 5-1) the following formulas apply:

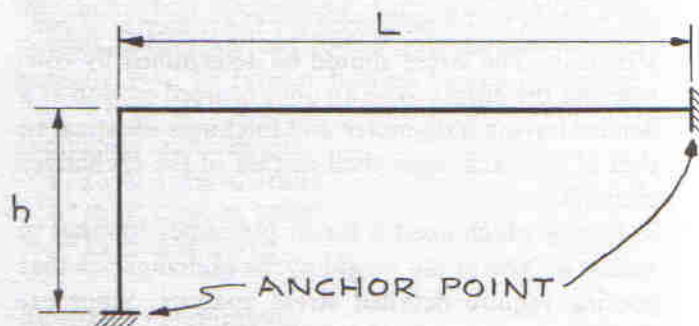


Figure 5-1. L-shaped configuration.

$$\text{Minimum } h^2 = 0.0025 D_o L T$$

$$\text{Maximum } L = \frac{400 (h)^2}{D_o T}$$

$$\text{Test } h = A \times D_o$$

Example No. 1, L-shaped configuration.

Pipe = 6" Sch. 40;

$D_o = 6.625"$ so use 7"

$L = 30'-0"$

$T = 650^\circ - 70^\circ = 580^\circ \text{ F}$

Applying the above formula the minimum h is calculated:

$$\begin{aligned} h^2 &= .0025 D_o L T \\ &= .0025 \times 7 \times 30 \times 580 \end{aligned}$$

$$\begin{aligned} h &= \sqrt{304.5} \\ &= 17'-5" \text{ which is the minimum short leg allowed} \end{aligned}$$

Test h for minimum length using the A coefficient:

Table 5-2
A Coefficients for Carbon Steel

Design Temp. °F	A	Design Temp. °F	A
150	0.4	600	2.20
200	0.6	700	2.50
300	1.0	800	2.80
400	1.4	900	2.95
500	1.8	1000	3.15

$$h = A \times D_o$$

A at 650°F (interpolated) is 2.35

$$\text{so } h = 2.35 \times 7$$

$$= 16.45'$$

$$= 16'-5''$$

16'-5'' < 17'-5'' so use the larger figure as the minimum.

Example No. 2: L-shaped configuration

Pipe = 12" Sch. 60;

$D_o = 12.75''$ so use 13"

$T = 500^\circ - 70^\circ$

$= 430^\circ\text{F.}$

Solve for h and L

$$\begin{aligned}\text{Test minimum } h &= A \times D_o \\ &= 1.8 \times 13 \\ &= 23.4'\end{aligned}$$

$$\text{Maximum } L = \frac{400 (23.4)^2}{13 \times 430}$$

$$= \frac{400 \times 547}{5590} = 39'$$

Since this pipe is not standard weight, the minimum h must be adjusted by the ratio of moment of inertias.

$$\text{factor} = \frac{I(12'' \text{ Sch. 60})}{I(12'' \text{ Std. Wt.)}}$$

$$= \frac{400.5}{279.3}$$

$$= 1.435$$

$$\begin{aligned}\text{then } h &= 23.4' \times 1.435 \\ &= 33.58'\end{aligned}$$

Since the minimum h has grown to 33.58', maximum L must be recalculated.

$$\text{Maximum } L = \frac{400 (33.58)^2}{13 \times 430}$$

$$= \frac{400 \times 1128}{5590}$$

$$= 80.7'$$

Since L must be greater than h , L can be as short as 34' or as long as 80.7'. The shorter lengths will cause smaller forces on connecting equipment.

Adaptations of L-Shaped Method

The L-shaped formulas are easily adaptable to more complicated shapes in one or three planes.

Example No. 3: Single plane problem. See Figure 5-2.

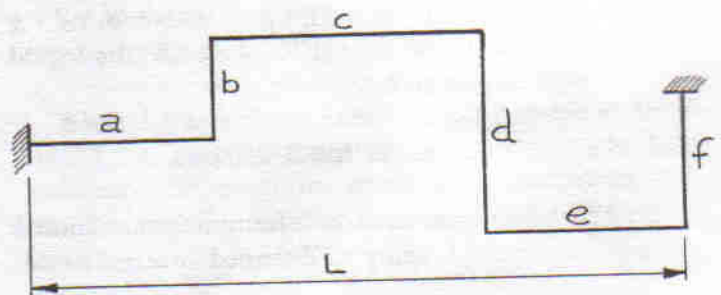


Figure 5-2. Single-plane configuration.

Step No. 1: Determine L , the major length of line at right angles between anchors.

$a + c + e$ is greater than $b + d + f$ so $L = a + c + e$

Step No. 2: Solve for minimum h using the formula described in example 2.

Step No. 3: Compare minimum h required with $\sqrt{b^2 + d^2 + f^2}$. If the square root of the sum of the squares equals or exceeds the required minimum h , flexibility is sufficient.

Example No. 4: Three plane problem. See Figure 5-3.

Step No. 1: Determine distances between anchors in the horizontal plane at right angles, and the vertical distance.

North-South distance $= a + e$

East-West distance $= c + g$

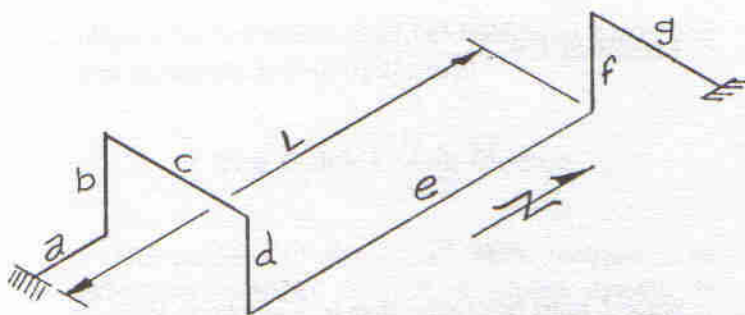


Figure 5-3. Three-plane configuration.

Vertical distance = $b - d + f$

Step No. 2: Determine L , the longest distance. $a + e > c + g > b - d + f$ therefore $L = a + e$.

Note: This example assumes L to be $a + e$. L must be the largest of the above three sums.

Step No. 3: Determine minimum h , the shortest distance. The sum of legs $b + c + d + f + g$ must equal or exceed h . These are the legs at right angles to L .

Formulas for Z-Shapes

The basic formulas for determining minimum h and maximum L apply to Z-shaped configurations:

$$\text{Minimum } h^2 = 0.0025 D_o L T$$

$$\text{Minimum } h = 0.05 \sqrt{D_o L T}$$

$$\text{Maximum } L = \frac{400 (h)^2}{D_o T}$$

To test for minimum h a test for leg ratio must also be made. Referring to Figure 5-4:

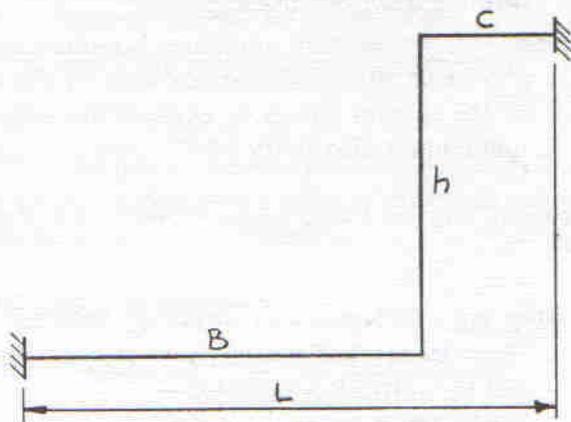


Figure 5-4. Z-shaped configuration.

$$\frac{B}{C} \geq 4 \quad L = B + C$$

Test both minimum h and leg B as equal to $A \times D_o$

Example: Z-shaped configuration, see Figure 5-4:

Pipe = 8" Sch. 40;

$D_o = 8.625"$ so use 9".

$T = 300^\circ - 70^\circ$

$= 230^\circ \text{F.}$

$L = 30'-0"$

To solve for minimum h :

$$h^2 = 0.0025 \times 9 \times 30 \times 230$$

$$= 155.25$$

$$= 12'-5\frac{1}{2}"$$

Test for minimum h :

$$h = A \times D_o = 1 \times 9$$

$$= 9'-0" \text{ minimum for } h \text{ and } B$$

Test B and C length ratio; Assume $B = 25'-0"$, $C = 5'-0"$

$$\frac{B}{C} = \frac{25}{5} = 5 \geq 4$$

so it is satisfactory.

Formulas for U-Shapes

Formulas for U-shapes differ somewhat from the L and Z shapes. For U-shaped configurations with equal legs h , the formulas are noted below. Refer to Figure 5-5.

$$\text{Minimum } h^2 = 0.0016 D_o L T \text{ or}$$

$$\text{Minimum } h = 0.04 \sqrt{D_o L T}$$

$$\text{Maximum } L = \frac{625 (h)^2}{D_o T}$$

To test for minimum h

$$h = \frac{A \times D_o}{1.25}$$

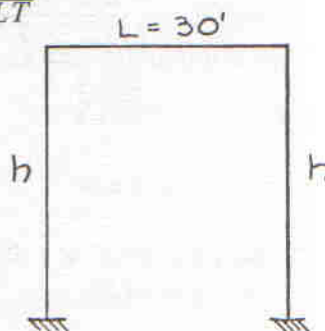


Figure 5-5. U-shaped configuration with equal legs.

Example: U-shape with equal legs, see Figure 5-5:

Pipe = 14" Sch. 30;

$D_o = 14$

$T = 470^\circ - 70^\circ$

$= 400^\circ \text{F.}$

$L = 30'-0''$

To solve for minimum h :

$$h^2 = 0.0016 D_o L T$$

$$= 0.0016 \times 14 \times 30 \times 400$$

$$h = \sqrt{268.8}$$

$$h = 16.4' \text{ say } 16'-6''.$$

Test for minimum h :

$$h = \frac{1.68 \times 14}{1.25}$$

$$= 18.8' \text{ use } 19'-0''$$

Since 19'-0" is larger than 16'-6", minimum h becomes 19'-0".

For U-shapes with unequal legs, see Figure 5-6, the following formulas apply:

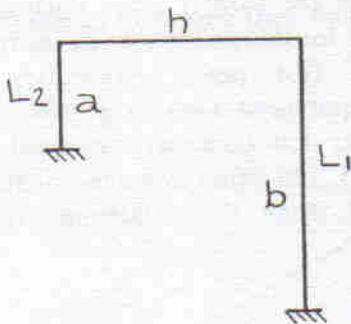


Figure 5-6. U-shaped configuration with unequal legs.

$$\text{Minimum } h^2 = 0.0021 D_o (L_1 - L_2) T \text{ or}$$

$$\text{Minimum } h = 0.045 \sqrt{D_o (L_1 - L_2) T}$$

$$\text{Maximum } L_1 - L_2 = \frac{500 (h)^2}{D_o T}$$

$$\text{To test for minimum } h + L_2 = A \times D_o$$

Example: U-shape with unequal legs, see Figure 5-6:

Pipe = 14" Sch. 30;

$D_o = 14$

$T = 470^\circ - 70^\circ = 400^\circ \text{F.}$

$L_1 = 25'-0''$

$L_2 = 5'-0''$

To solve for minimum h :

$$h = 0.045 \sqrt{14 (25 - 5) 400}$$

$$= 0.045 \times 335$$

$$= 15 \text{ ft}$$

Test for minimum $h + L_2$

$$= 1.68 \times 14$$

$$= 23.5'$$

Minimum L_1 also equals 23.5'

So minimum $h + L_2 = 15 + 5 = 20'$. Then 15' is too short. So use 20'-0" as minimum h .

When L_2 and h are known and L_1 needs to be solved for, use the approach given in example 3, L-shaped configuration, changing h (above) to L and L_1 and L_2 (above) to components of minimum h .

The formula then becomes:

$$\text{Minimum } h = 0.05 \sqrt{D_o L T} \\ \text{where minimum } h = \sqrt{a^2 + b^2}$$

Formula for Expansion Loop

Figure 5-7, Typical expansion loop, depicts a typical loop found in most hot piping systems which have too much expansion to be absorbed by a straight line. For this configuration:

$$\text{Minimum } h = 0.02 \sqrt{D_o L T} \text{ or}$$

$$\text{Minimum } h^2 = 0.0004 \times D_o \times L \times T$$

$$\text{Maximum } L = \frac{2500 (h)^2}{D_o T}$$

$$\text{Minimum } W = 0.5 h$$

$$\text{Preferred } W = 1.5 h$$

$$\text{To test for minimum } h: h = \frac{A \times D_o}{1.25}$$

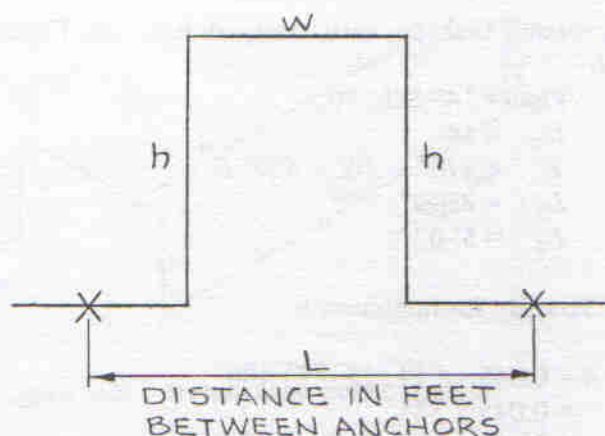


Figure 5-7. Typical expansion loop.

Example: Expansion loop, see Figure 5-7:

Pipe = 12" std. wt.;

$D_o = 12.75$ so use 13".

$T = 520^\circ - 70^\circ = 450^\circ\text{F}$.

$L = 200'$

To solve for minimum h :

$$h^2 = 0.0004 \times 13 \times 200 \times 450$$

$$h = \sqrt{468}$$

$$= 21.6'$$

$$\text{Minimum } W = 0.5 \times 21.6 \\ = 10.8'$$

$$\text{To test for minimum } h = \frac{1.88 \times 13}{1.25} \\ = 19.5'$$

use the larger 21.6'.

Expansion loop Stress and Anchor Force

As an expansion loop expands, forces are transmitted to the two anchor points. To calculate the anchor force and maximum pipe stress of the loop, refer to Figure 5-8 and the following example.

This example assumes use of LR elbows and is restricted to line sizes of 4" through 14".

For force at each anchor:

$$F = C \times E \times I_p$$

Maximum stress:

$$S = K \times E \times D$$

C = Constant to be obtained from Table 5-3

E = Expansion to be absorbed by the loop, in inches (should be limited to 10")

I_p = Moment of inertia, inches⁴

D = Outside diameter of pipe in inches

K = Constant to be obtained from Table 5-4

Need for Formal Stress Analysis

The need for formal stress analysis should be determined by designers with extensive flexibility experience. Hot piping connecting to strain-sensitive equipment such as pumps, compressors and turbines shall be closely reviewed for possible full analysis. For other systems full stress analysis is required when the following criteria is not satisfied:

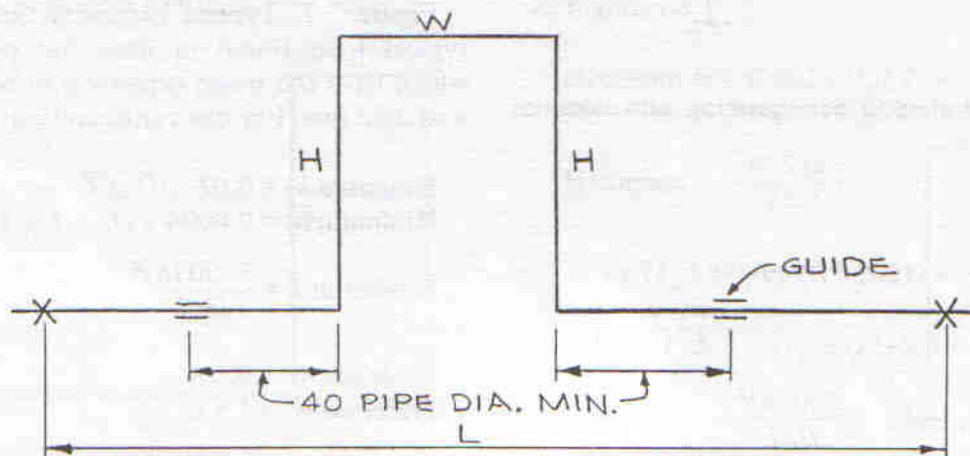


Figure 5-8. Guided expansion loop.

Table 5-3
Values for Constant C

Length of H in feet					
	20	19	18	17	16
20	1.64	1.54	1.46	1.39	1.33
19	1.92	1.80	1.70	1.61	1.56
18	2.20	2.06	1.95	1.84	1.78
17	2.47	2.31	2.19	2.08	2.00
16	2.75	2.57	2.44	2.31	2.22
15	3.03	2.83	2.68	2.55	2.44
14	3.41	3.18	3.02	2.88	2.74
13	4.02	3.76	3.54	3.36	3.20
12	4.83	4.51	4.25	4.04	3.84
11	5.86	5.45	5.11	4.89	4.66
10	7.10	6.60	6.23	5.91	5.65
	10	15	20	25	30
Length of W in feet					

$$\frac{DE}{(L - U)^2} \leq 0.03$$

D = Nominal pipe size, in inches

E = Expansion to be absorbed, in inches ($E = Ue$)

L = Developed length of line axis, in feet

U = Anchor distance, in feet = Length of straight line joining the anchors

e = Coefficient of expansion (See Table 5-5)

Example: See Figure 5-9

Pipe = 6" Sch. 40 Carbon Steel;

$D = 6$

Design Temperature = 400°F.

Step 1: Establish the distance between anchors in plan and elevation, in feet and decimals of a foot.

Y = Vertical elevation difference = 6' - 4' = 2'
(Difference in elevation between A_1 and A_2)

X = Total line length away from A_2 = 8' + 4' = 12'

Z = Total line length away from A_1 = 10' + 6' = 16'

Step 2: Determine length U , the straight length between points A_1 and A_2

$$\begin{aligned} U &= \sqrt{X^2 + Y^2 + Z^2} \\ &= \sqrt{12^2 + 2^2 + 16^2} \\ &= \sqrt{404} \\ &= 20.1 \text{ (say 20')} \end{aligned}$$

Step 3: Determine E .

$E = Ue$

From Table 5-5 at 400°F,

$e = 2.70$ in. per 100 ft. so

$e = 0.027$ in. per ft.

Then: $E = Ue$

$$= 20 \times 0.027$$

$$= 0.54''$$

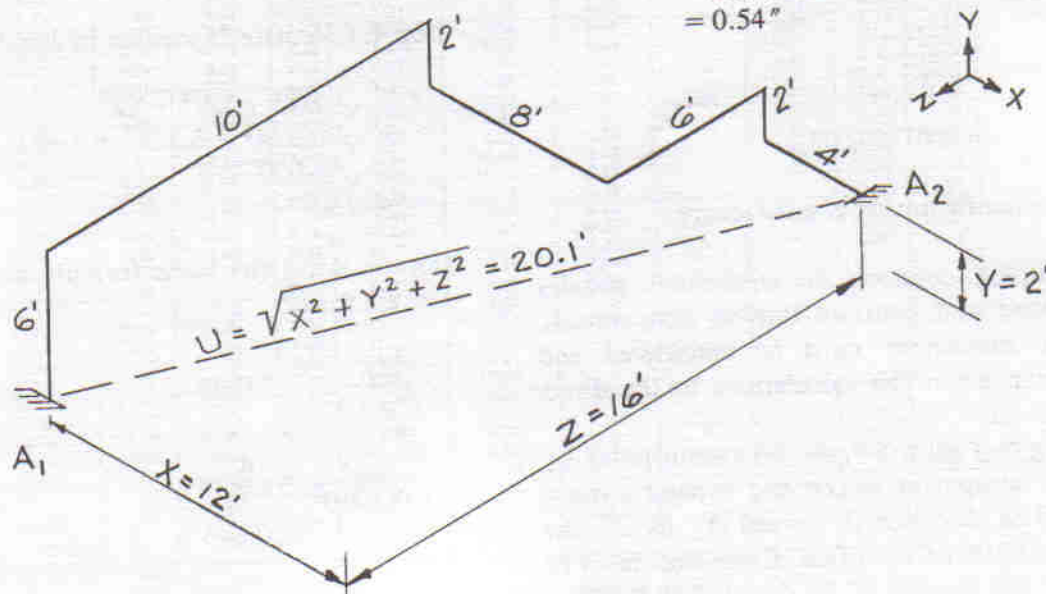


Figure 5-9. Example for quick-check stress analysis.

Table 5-4
Values for Constant *K*

Length of <i>H</i> in feet	20	337	295	270	248	230
	19	361	318	290	267	246
	18	385	341	310	285	263
	17	409	364	330	304	279
	16	433	387	350	322	296
	15	457	410	372	340	313
	14	487	437	396	362	330
	13	528	475	428	391	361
	12	582	521	471	429	395
	11	647	577	520	474	436
	10	725	642	578	526	484
	10	15	20	25	30	
Length of <i>W</i> in feet						

Step 4: Determine value of *L*, the total length of line.

$$L = 6 + 10 + 2 + 8 + 6 + 2 + 4 \\ = 38'$$

Step 5: Solve the formula which must be equal to or less than 0.03 or full stress analysis is needed.

$$\frac{DE}{(L - U)^2} \leq 0.03$$

$$\frac{6 \times 0.54}{(38 - 20)^2} = \frac{3.24}{18^2}$$

$$= \frac{3.24}{.324}$$

$$= 0.01 \leq 0.03$$

So the configuration is satisfactory.

When piping connects to equipment nozzles which expand and contract due to temperature, the nozzle movement must be considered and added to expansion (*E*) calculations in the direction they occur.

Referring to Figure 5-9, should anchor point *A*₁ become an equipment nozzle and expand upward 0.375" and in direction *Z* toward *A*₂ by 2", the calculations must be modified. Expansion must be figured for net lengths of *X*, *Y* and *Z* and anchor movements applied.

Step 1: Calculate expansion in direction *X*:

$$\Sigma X = 12 \times 0.027'' = 0.324''$$

Since there is no anchor movement in the direction *X*:

$$\Sigma X = 0.324'' + 0 \\ = 0.324''$$

Step 2: Calculate expansion in direction *Y*:

$$\Sigma Y = 2 \times 0.027'' \\ = 0.054''$$

Since *A*₁ is moving upward 0.375"

$$\Sigma Y = 0.054'' - 0.375'' \\ = -0.321''$$

So use 0.321" as this becomes the net anchor movement.

Step 3: Calculate expansion in direction *Z*:

$$\Sigma Z = 16 \times 0.027'' \\ = 0.432''$$

Since *A*₁ is moving 2" in the direction *Z*:

$$\Sigma Z = 0.432'' + 2'' \\ = 2.432''$$

Step 4: Calculate expansion in direction *U*:

$$E = \sqrt{\Sigma X^2 + \Sigma Y^2 + \Sigma Z^2} \\ = \sqrt{0.324^2 + 0.321^2 + 2.432^2} \\ = \sqrt{6.023} \\ = 2.45''$$

Step 5: Solve the basic formula using the new value for *E*:

$$\frac{DE}{(L - U)^2} \leq 0.03$$

$$\frac{6 \times 2.45}{(38 - 20)^2} = \frac{14.7}{324} \\ = 0.045''$$

which is larger than 0.03, so a stress analysis is required.

Table 5-5
Coefficients of Expansion

Linear Thermal Expansion between 70°F and Indicated Temperature, inches/100 feet*

Temperature deg F	MATERIAL												
	Carbon Steel Carbon-Moly Low-Chrome (thru 3 Cr Mo)	5 Cr Mo thru 9 Cr Mo	Austenitic Stainless Steels 18 Cr 8 Ni	12 Cr 17 Cr 27 Cr	25 Cr 20 Ni	Monel 67 Ni 30 Cu	3½ Nickel	Aluminum	Gray Cast Iron	Bronze	Brass	Wrought Iron	70 Cu 30 Ni
-325	-2.37	-2.22	-3.85	-2.04	-3.00	-2.62	-2.22	-4.68		-3.98	-3.88	-2.70	-3.15
-300	-2.24	-2.10	-3.63	-1.92	-2.83	-2.50	-2.10	-4.46		-3.74	-3.64	-2.55	-2.87
-275	-2.11	-1.98	-3.41	-1.80	-2.66	-2.38	-1.98	-4.21		-3.50	-3.40	-2.40	-2.70
-250	-1.98	-1.86	-3.19	-1.68	-2.49	-2.26	-1.86	-3.97		-3.26	-3.16	-2.25	-2.53
-225	-1.85	-1.74	-2.96	-1.57	-2.32	-2.14	-1.74	-3.71		-3.02	-2.93	-2.10	-2.36
-200	-1.71	-1.62	-2.73	-1.46	-2.15	-2.02	-1.62	-3.44		-2.78	-2.70	-1.95	-2.19
-175	-1.58	-1.50	-2.50	-1.35	-1.98	-1.90	-1.50	-3.16		-2.54	-2.47	-1.81	-2.12
-150	-1.45	-1.37	-2.27	-1.24	-1.81	-1.79	-1.38	-2.88		-2.31	-2.24	-1.67	-1.95
-125	-1.30	-1.23	-2.01	-1.11	-1.60	-1.59	-1.23	-2.57		-2.06	-2.00	-1.49	-1.74
-100	-1.15	-1.08	-1.75	-0.98	-1.39	-1.38	-1.08	-2.27		-1.81	-1.76	-1.31	-1.53
-75	-1.00	-0.94	-1.50	-0.85	-1.18	-1.18	-0.93	-1.97		-1.56	-1.52	-1.13	-1.33
-50	-0.84	-0.79	-1.24	-0.72	-0.98	-0.98	-0.78	-1.67		-1.32	-1.29	-0.96	-1.13
-25	-0.68	-0.63	-0.98	-0.57	-0.78	-0.77	-0.62	-1.32		-1.25	-1.02	-0.76	-0.89
0	-0.49	-0.46	-0.72	-0.42	-0.57	-0.57	-0.46	-0.97		-0.77	-0.75	-0.56	-0.66
25	-0.32	-0.30	-0.46	-0.27	-0.37	-0.37	-0.30	-0.63		-0.49	-0.48	-0.36	-0.42
50	-0.14	-0.13	-0.21	-0.12	-0.16	-0.20	-0.14	-0.28		-0.22	-0.21	-0.16	-0.19
70	0	0	0	0	0	0	0	0	0	0	0	0	0
100	0.23	0.22	0.34	0.20	0.28	0.28	0.22	0.46	0.21	0.36	0.35	0.26	0.31
125	0.42	0.40	0.62	0.36	0.51	0.52	0.40	0.85	0.38	0.66	0.64	0.48	0.56
150	0.61	0.58	0.90	0.53	0.74	0.75	0.58	1.23	0.55	0.96	0.94	0.70	0.82
175	0.80	0.76	1.18	0.69	0.98	0.99	0.76	1.62	0.73	1.26	1.23	0.92	1.07
200	0.99	0.94	1.46	0.86	1.21	1.22	0.94	2.00	0.90	1.56	1.52	1.14	1.33
225	1.21	1.13	1.75	1.03	1.45	1.46	1.13	2.41	1.08	1.86	1.83	1.37	1.59
250	1.40	1.33	2.03	1.21	1.70	1.71	1.32	2.83	1.27	2.17	2.14	1.60	1.86
275	1.61	1.52	2.32	1.38	1.94	1.96	1.51	3.24	1.45	2.48	2.45	1.83	2.13
300	1.82	1.71	2.61	1.56	2.18	2.21	1.69	3.67	1.64	2.79	2.76	2.06	2.40
325	2.04	1.90	2.90	1.74	2.43	2.44	1.88	4.09	1.83	3.11	3.08	2.29	2.68
350	2.26	2.10	3.20	1.93	2.69	2.68	2.08	4.52	2.03	3.42	3.41	2.53	2.96
375	2.48	2.30	3.50	2.11	2.94	2.91	2.27	4.95	2.22	3.74	3.73	2.77	3.24
400	2.70	2.50	3.80	2.30	3.20	3.25	2.47	5.39	2.42	4.05	4.05	3.01	3.52
425	2.93	2.72	4.10	2.50	3.46	3.52	2.69	5.83	2.62	4.37	4.38	3.25	
450	3.16	2.93	4.41	2.69	3.72	3.79	2.91	6.28	2.83	4.69	4.72	3.50	
475	3.39	3.14	4.71	2.89	3.98	4.06	3.13	6.72	3.03	5.01	5.06	3.74	
500	3.62	3.35	5.01	3.08	4.24	4.33	3.34	7.17	3.24	5.33	5.40	3.99	
525	3.86	3.58	5.31	3.28	4.51	4.61	3.57	7.63	3.46	5.65	5.75	4.25	
550	4.11	3.80	5.62	3.49	4.79	4.90	3.80	8.10	3.67	5.98	6.10	4.50	
575	4.35	4.02	5.93	3.69	5.06	5.18	4.03	8.56	3.89	6.31	6.45	4.76	
600	4.60	4.24	6.24	3.90	5.33	5.46	4.27	9.03	4.11	6.64	6.80	5.01	
625	4.84	4.47	6.55	4.10	5.60	5.75	4.51		4.34	6.96	7.16	5.27	
650	5.11	4.69	6.87	4.31	5.88	6.05	4.75		4.57	7.29	7.53	5.53	
675	5.37	4.92	7.18	4.52	6.16	6.34	4.99		4.80	7.62	7.89	5.80	
700	5.63	5.14	7.50	4.73	6.44	6.64	5.24		5.03	7.95	8.26	6.06	
725	5.90	5.38	7.82	4.94	6.73	6.94	5.50		5.26	8.28	8.64	6.32	
750	6.16	5.62	8.15	5.16	7.02	7.25	5.76		5.50	8.62	9.02	6.59	
775	6.43	5.86	8.47	5.38	7.31	7.55	6.02		5.74	8.96	9.40	6.85	
800	6.70	6.10	8.80	5.60	7.60	7.85	6.27		5.98	9.30	9.78	7.12	
825	6.97	6.34	9.13	5.82	7.89	8.16	6.54		6.22	9.64	10.17	7.40	
850	7.25	6.59	9.46	6.05	8.19	8.48	6.81		6.47	9.99	10.57	7.69	
875	7.53	6.83	9.79	6.27	8.48	8.80	7.08		6.72	10.33	10.96	7.97	
900	7.81	7.07	10.12	6.49	8.78	9.12	7.35		6.97	10.68	11.35	8.26	
925	8.08	7.31	10.46	6.71	9.07	9.44	7.72		7.23	11.02	11.75	8.53	
950	8.35	7.56	10.80	6.94	9.37	9.77	8.09		7.50	11.37	12.16	8.81	
975	8.62	7.81	11.14	7.17	9.66	10.09	8.46		7.76	11.71	12.57	9.08	
1000	8.89	8.06	11.48	7.40	9.95	10.42	8.83		8.02	12.05	12.98	9.36	
1025	9.17	8.30	11.82	7.62	10.24	10.75	9.18			12.40	13.39		
1050	9.46	8.55	12.16	7.95	10.54	11.09	9.54			12.76	13.81		
1075	9.75	8.80	12.50	8.18	10.83	11.43	9.89			13.11	14.23		
1100	10.04	9.05	12.84	8.41	11.12	11.77	10.24			13.47	14.65		
1125	10.31	9.28	13.18	8.63	11.41	12.11	10.59						
1150	10.57	9.52	13.52	8.86	11.71	12.47	10.94						
1175	10.83	9.76	13.86	9.09	12.01	12.81	11.29						
1200	11.10	10.00	14.20	9.32	12.31	13.15	11.64						
1225	11.38	10.26	14.54	9.55	12.59	13.50	11.99						
1250	11.66	10.53	14.88	9.78	12.88	13.86	12.34						
1275	11.94	10.79	15.22	10.01	13.17	14.22	12.69						
1300	12.22	11.06	15.56	10.24	13.46	14.58							
1325	12.50	11.30	15.90	10.47	13.75	14.94							
1350	12.78	11.55	16.24	10.70	14.05	15.30							
1375	13.06	11.80	16.58	10.93	14.35	15.66							
1400	13.34	12.05	16.92	11.16	14.65	16.02							
1425			17.30										
1450			17.69										
1475			18.08										
1500			18.47										

*These data are for information, and it is not to be implied that materials are suitable for all the temperatures shown.

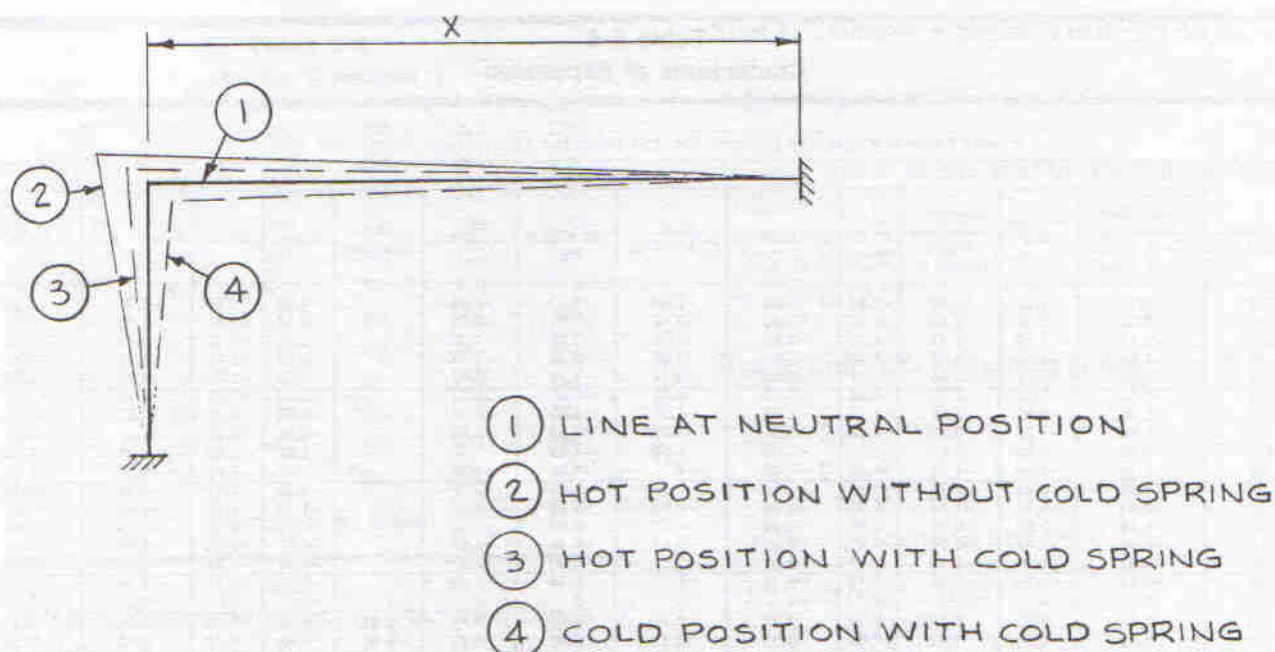


Figure 5-10. Cold spring in piping.

Cold Spring in Piping

Cold spring is the term used for springing pipe in the cold position a per cent of the calculated expansion. Figure 5-10 shows an L-shaped configuration with solid lines indicating the neutral position. As the long leg gets hot the line would expand 3" away from the anchor, forcing the elbow out 3". By using 50% cold spring, cutting 1½" out of leg X, the line will be sprung in the cold position. This reduces forces considerably, applying reduction in both the cold and hot positions since the elbow now only moves 1½" beyond the neutral position.

Cold spring is often abused by inexperienced piping designers who specify small amounts of cold spring on their drawings. The designer must remember that pipe fabrication tolerances normally are between 1/16" and 1/8". A cold spring of 1/8", or even 1/4", is ignored unless a special *hold to no tolerance* note is added to the drawing – and the designer must be aware that this will be a costly note. This type of cold spring is rarely justified.

Cold spring is applied to piping systems for these four basic reasons:

1. When required by detailed stress analysis
2. To improve resultant forces and moments although not required by stress analysis
3. To maintain adequate pipe spacing
4. Misalignment correction

Any small amount of cold spring may be dictated by detailed stress analysis. When necessary, drawings must show the specified amount to the closest 1/16". Cold spring may be specified when not mandatory to improve resultant forces and moments such as hot lines connecting to rotating equipment. Less than 1/4" is not specified.

To maintain adequate pipe spacing and clearances in pipe racks and pipe groups, cold spring of 1" or more is specified. Normal pipe spacing will allow for more than 2" expansion so cold spring of less than 1" is seldom justified.

Misalignment correction cold spring is used only for physical appearance and should never be specified for less than 3/4". Normally this is used when a perfectly flexible line would grow as much as 4"-6" and might appear to be out of line with a parallel line. Small amounts of growth here would not be visually recognized.

Definition of Terms

When working with metals certain terms are used. To avoid any possible communication problem, a glossary is presented at the end of this chapter. Some of the terms included will be used in the text. The others are presented as a ready reference.

aging The term originally applied to the process or sometimes to the effects of allowing a metal to remain at ordinary temperatures. Heat treatment at temperatures above room temperature for the purpose of accelerating changes of the type that might take place during aging at ordinary temperature is called *artificial aging*. When the changes taking place during artificial aging are due to the precipitation of some substance from solid solution, the heat treatment may be called *precipitation treatment*. Aging is an approach to the attainment of equilibrium from an unstable condition induced by a prior operation. The fundamental reaction involved is generally one of precipitation, sometimes submicroscopic. The method employed to bring about aging consists of exposure to a favorable temperature subsequent to (a) a relatively rapid cooling from some elevated temperature (quench aging) or (b) a limited degree of cold work (strain aging).

alclad The common name for a type of clad wrought aluminum product with coatings of high purity aluminum; or an aluminum alloy different from the core alloy in composition

alloy A metallic substance consisting of two or more elements, of which at least one is a metal, and in which all elements are miscible in the molten state, and which do not separate when solid

alloying elements Chemical elements constituting an alloy. In steel, usually the elements added to modify the properties of the steel

annealing A heating and controlled cooling operation to impart specific desirable

properties generally concerned with subsequent fabrication of the alloy, such as softness and ductility. When annealing follows cold working for the purpose of stress removal, it is called stress annealing.

arc welding Welding accomplished by using an electric arc formed between a metallic or carbon electrode and the metal being welded, between two separate electrodes, or between two separate pieces being welded, also called fusion welding

austenite A solid solution in which gamma iron is the solvent, having a face-centered cubic crystal structure

austenitic steel Steel, which due to its composition has a stable structure at normal (room) temperatures; as for example: the 18-8 types. It is not hardened by thermal treatment.

bend test A test commonly used to determine relative ductility of a sample by bending it over a given radius and through a given angle

billet A semi-finished rolled ingot of rectangular or nearly rectangular cross section

brass A copper-base alloy in which zinc is the principle added element

brazing Joining metals by fusion of nonferrous alloys with melting points above 800°F but below the melting point of the metals being joined

brinell hardness A hardness number determined by applying a known load to the surface of the material to be tested through a hardened steel ball of known diameter. Note: Not suitable for measuring the hardness of strip and sheet because of insufficient thickness.

brittleness A tendency to fracture without appreciable deformation

carbon steel Steel in which carbon provides the properties without substantial amounts of other alloying elements

carburizing Diffusing carbon into the surface of iron-base alloys by heating in the presence of carbonaceous materials

case hardening Carburizing, nitriding, or cyaniding and subsequent hardening by suitable heat treatment, if necessary, all or part of the surface portions of a section of iron-base alloy

casting Pouring molten metal into a mold or a metal object so produced

cementite An iron-carbon compound with the chemical formula Fe_3C often called iron carbide

charpy test A pendulum type of impact test in which a notched specimen, supported at both ends as a simple beam, is broken by the impact of the falling pendulum. The energy absorbed in breaking the specimen, as determined by the decreased rise of the pendulum, is a measure of the impact strength of the metal.

chemical analysis Separating an alloy into its component elements and identifying them. In quantitative analysis, the proportion of each element is determined.

chromium A hard crystalline metal used as an alloying element to give resistance to heat, corrosion, and wear and increase strength and hardenability

cold working Permanent deformation of a metal below its recrystallization temperature. Also defined as plastic deformation of a metal at a temperature low enough to insure strain hardening. Mechanical properties, such as tensile strength, hardness, and ductility are also altered.

compressive strength The ability to withstand compressive stresses

compressive stress Stress caused by a compressive load or in fibers compressed by a bending

cooling stresses Stresses caused by uneven

contraction, external restraint or localized plastic deformation during cooling

corrosion Gradual chemical or electrochemical attack on a metal by atmosphere, moisture or other elements

corrosion embrittlement Embrittlement in certain alloys caused by exposure to a corrosive environment

corrosion fatigue Combined action of corrosion and fatigue in which local corroded areas act as stress concentrators, causing failure at the point of stress concentration and exposing new metal surfaces to corrosion. The failure is progressive and rapid.

creep Plastic flow of metal, usually occurring at high temperatures, subject to stress appreciably less than its yield strength. Progresses through first, second, and third stages to fracture or results in stress relaxation.

cyaniding A process of case hardening a ferrous alloy by heating in a molten cyanide salt bath, thus causing the alloy to absorb carbon and nitrogen simultaneously. Cyaniding is usually followed by quenching to produce a hard case

ductility That property of metal which allows the metal to be permanently deformed before final rupture.

elastic limit (limit of elasticity) Maximum stress to which a metal can be subjected without permanent deformation at the point of stress

electrochemical corrosion Localized corrosion that results from exposure of an assembly of dissimilar metals in contact with or coupled with one another; or of a metal containing microscopic areas dissimilar in composition or structure. The dissimilar elements form short-circuited electrodes. The corrosive medium is the electrolyte, and an electric current is induced, which results in the dissolution of the electrode that has the

more anodic solution potential, while the other is unattacked.

elongation The amount of permanent extension in the tensile test, usually expressed as a percentage of the original gage length, as "25 per cent in 2 inches." It may also refer to the amount of extension at any stage in any process which continuously elongates a body, as in rolling.

endurance limit A limit of stress below which metal will withstand stress without fracture; a specified large number of applications of such stress

eutectoid steel A carbon steel containing 0.80% carbon becomes a solid solution at any temperature in the austenite temperature range between 1333 F and 2500 F

fatigue The tendency of a metal to fracture under conditions of repeated cyclic stressing below the ultimate tensile strength but above the yield strength

ferrite A solid solution in which alpha iron is the solvent and having a body-centered cubic crystal structure

ferritic steel Steel which, due to its composition, is not hardenable by heat treatment. Such stainless types as 405, 430 and 448 are essentially ferritic steels.

free machining That property of steel imparted by additions of sulphur, selenium or phosphorous which promote chip breakage and permit increased machining speeds. Additions of sulphur or selenium also help to decrease friction between the chips and the tool face.

galling The damaging of one or both metallic surfaces by removal of particles from localized areas during sliding friction

galvanic corrosion Corrosive action occurring when two dissimilar metals are in contact and are joined by a solution capable of conducting an electric current, a condition which causes

a flow of electric current and corrosion of the more anodic of the two metals. (also see *electrochemical corrosion*)

gas welding Welding in which heat is supplied by a manually or automatically controlled torch flame of oxyacetylene or oxyhydrogen, also called *fusion welding*

grains Individual crystals in metal

hardenability In a ferrous alloy, the property that determines the depth and distribution of hardness induced by heat treating and quenching

hardness Resistance to indentation by standard balls, diamonds, etc., under standard loads. Also, the degree of cold working.

heading An upsetting process used to form rivet, screw, and bolt heads in making these products from wire or rod

heat treatable Refers to an alloy which may be hardened by heat treatment

heat treatment A combination of heating and cooling operations timed and applied to metal or alloy to produce desired properties

homogenizing A process of heat treatment at high temperature to eliminate or decrease chemical segregation by diffusion. Attainment of austenite that has a uniform distribution of carbon.

Hooke's Law Stress is proportional to strain in the elastic region

hot forming Working operations performed on metals heated to temperatures above room temperature

hot working Hot forming above the recrystallization temperature

hydrogen embrittlement A brittleness sometimes engendered by contact with plating and pickling solution acid due to absorption of hydrogen by the metal. The embrittlement

is more evident in hardened parts, and can be removed by aging or heating the steel for prescribed period.

hypereutectoid steels Steels containing from 0.80% to above 2.0% carbon

hypoeutectoid steels Carbon steels containing less than 0.80% carbon

impact test A test designed to determine the energy absorbed in fracturing a test bar at high velocity. The usual impact test specimen is a standard size square bar with a *V* or keyhole-type notch. (see charpy test and *izod test*)

intergranular corrosion Corrosion which tends to localize at grain boundaries, usually under conditions of prolonged stress and certain environments and in association with poor heat treating or welding practice which has caused the precipitation of a more easily attacked constituent at these boundaries

izod test A pendulum type of notched bar impact test in which the specimen is supported at one end as a cantilever beam and the energy required to break off the free end is used as a measure of impact strength

machinability The rate and ease with which a metal can be machined

magnetic particle testing This method of inspection consists in suitably magnetizing the material and applying a prepared magnetic powder which adheres along lines of flux leakage. On properly magnetized material, flux leakage develops along surface nonuniformities. This method is not applicable to high manganese or austenitic stainless steels and nonferrous alloys which are nonmagnetic.

martensite An unstable constituent in quenched steel, the hardest of the transformation products of austenite

martensitic steel Steel which, due to its composi-

tion, has martensite as its chief constituent after cooling. The hardenable stainless types are all martensite steels.

mechanical properties Those properties that reveal the reaction, elastic or plastic, of a material to an applied stress, or that involving the relationship between stress and strain; for example, Young's modulus, tensile strength, fatigue limit. These properties have often been designated as physical properties, but the term *mechanical properties* is technically more accurate and therefore preferred.

modulus of rigidity The ratio of the unit shear stress to the unit angular strain in the elastic range

nitriding A process of surface hardening in which a ferrous alloy is heated in an atmosphere of cracked ammonia gas or other suitable nitrogenous material thus allowing nitrogen to diffuse into the surface metal. Nitriding is conducted at temperatures below the critical temperature range and produces surface hardening of the metal without quenching.

normalizing A process in which a steel is heated to a suitable temperature above the transformation range and is subsequently cooled in still air at room temperature. This operation is used for grain refining or to develop specified mechanical properties.

notch sensitivity The reduction caused in nominal strength, impact or static, by the presence of a stress concentration, usually expressed as the ratio of the notched to the un-notched strength

permeability Magnetic permeability is the ratio of the magnetic induction to the intensity of the magnetizing field

physical properties Those properties familiarly discussed in physics, exclusive of those described under Mechanical Properties; for example, density, electrical conductivity; coefficient of thermal expansion. The term has often been used to describe mechanical

properties, but such usage is not recommended.

pickling Immersion in dilute acid or other suitable media for the removal of oxide scale from hot-rolled or otherwise sealed surfaces

plasticity The ability of a metal to be deformed extensively without rupture

plating Deposition of a thin film of a metal or alloy on a different base metal from a solution containing ions of the plating metal

Poisson's Ratio Ratio expressing the relation of strain normal to the applied load as a proportion of direct strain within the elastic limit. Also relates *moduli of elasticity and rigidity*.

precipitation hardening Hardening of metallic alloys, by aging, which results from the precipitation of a constituent from a super-saturated solid solution usually nonferrous alloys. Also termed *age hardening*. (see *aging*)

process annealing An annealing operation carried out at a constant temperature just below the critical transformation temperature. Also referred to as subcritical annealing.

proof stress In a test, stress that will cause a specified permanent set in a material, usually 1% or less

proportional limit The highest stress at which the material still follows Hooke's Law. Similar to *elastic limit*.

quenching A process of rapid cooling from an elevated temperature

radiography The use of X-rays or gamma radiation to detect internal structural defects in metal objects

reduction of area In a tensile test, the difference between the original cross-sectional area and that of the smallest area at the point of rupture. It is usually stated as a percentage

of the original area. Also called *contraction of area*. Not applicable to the mechanical testing of sheet and strip. Also a measure of cold work.

refractory metals Metals such as tungsten, columbium, tantalum, molybdenum, which have relatively high melting temperatures

residual stress Stresses locked in a metal after the completion of nonuniform heating or cooling, working, etc. due to expansion, contraction, phase changes and other phenomena

resistance welding A welding process in which the work pieces are heated by the passage of an electric current through the contact area, combined with pressure causing joining by fusion

Rockwell Hardness test This test consists of forcing a cone-shaped diamond or hardened steel ball into a metal specimen to determine the degree of penetration and, hence, the hardness

rupture stress The true stress given by dividing the load at the moment of incipient fracture by the area supporting that load

salt spray test An accelerated corrosion test in which the metal specimens are exposed to a fine mist of salt water solution

scaling Surface oxidation caused by heating in an oxidizing atmosphere

seam welding Resistance welding which consists of a series of overlapping spots forming a continuous weld

shear Plastic deformation in which parallel planes in metal crystals slide so as to retain their parallel relationship. Also, *angular elastic strain*.

shear stress Stress acting on a shear plane

solution treating A condition of complete solubility resulting in a single phase for

compositions of two or more alloying elements at temperatures lower than the solidus. Solid solutions may be limited in extent with respect to range of alloy composition or can be continuous, extending throughout an alloy series.

specific gravity A numerical value representing the weight of a given substance compared with the weight of an equal volume of water

spot welding A resistance welding process in which the fusion is limited to a small circular or oval area

stabilization Prevention of the formation of carbides at the grain boundaries of austenitic stainless steels. Dimensional control of nonferrous castings.

strain Deformation expressed in units per unit of length produced by strain

strain aging Aging induced by cold working

stress Load per unit of area

stress concentrator or stress raiser Any notch, scratch, sharp change of contour, slot, groove, hole, defect or other discontinuity in an engineering material which has the effect of concentrating the stresses applied to the material or generated in it by heating or cooling

stress corrosion Corrosive action induced and accelerated by the presence of stresses

stress rupture A test to destruction at elevated temperature, by which it is possible to determine the stress which causes failure at a given temperature and with the lapse of a given period of time

temper A condition produced in a metal or alloy by mechanical or thermal treatment and having characteristic structure and mechanical properties

temper brittleness Brittleness that results when certain steels are held within or slowly cooled through a certain range of

temperature below the transformation range. The brittleness is revealed by notched bar impact tests at room temperature or lower temperatures.

tempering The process of reheating quench hardened or normalized steel to a temperature below the transformation range and then cooling at any rate desired. This operation is frequently called stress relieving. *Drawing* is synonymous with tempering but the latter is the preferred usage.

tensile strength The maximum load in pounds per square inch, based on the original cross section, which may be developed in tensile testing (see also *ultimate strength*)

thermal stresses Stresses in metal, resulting from nonuniform temperature distribution

through-hardening Term descriptive of alloys which harden completely, so the center of a hardened section exhibits hardness similar to the surface

torsion Strain created in an object by a twisting action or the stresses created by such an action

toughness Ability to absorb considerable energy before fracture, usually represented by the area under a stress-strain curve and therefore involving both ductility and strength

ultimate strength The maximum strength or stress before complete failure or fracture occurs

vacuum melting A process by which alloys are melted in a near-perfect vacuum to prevent contamination by atmospheric elements

vickers hardness test An indentation hardness test utilizing a diamond pyramid and useful over the entire range of common metals

welding A process of joining metals whereby partial melting of the parent metals occurs except in the case of pressure welding when heating is only sufficient to cause recrystallization across the interface

yield point The load per unit of original cross section at which a marked increase in deformation occurs without increase in load. In stainless and heat-resisting steels, this occurs only in the martensitic and ferritic chromium types. In the austenitic stainless and heat-resisting steels, the yield point is the stress corresponding to some

definite and arbitrary total deformation, permanent deformation or slope of the load deformation curve; this is more properly termed the *yield strength*.

yield strength Stress corresponding to some fixed permanent deformation such as 0.1 or 0.2 per cent offset from the modulus slope

Index

- Allowable forces,
 - aluminum pumps, 144;
 - aluminum turbines, 146;
 - cast iron pumps, 144;
 - cast iron turbines, 146;
 - compressors, 146;
 - exchangers, 147;
 - steel pumps, 143;
 - steel turbines, 145
- Adjustable wedges, 72
- Air coolers, 134, 139
- Air filter, 60
- Atomizing steam, 85

- Barrell pumps, 22
- Bolt studs, 60
- Bottle wedges, 72
- Box heater, 78
- Break-out flanges, 58
- Buckstay, 86
- Burner piping, 82

- Can type pumps, 22
- Case support, pumps, 21
- Cavitation at pumps, 2
- Common spare pumps, 20
- Compressor,
 - case design, 42;
 - case types, 44;
 - centrifugal, 42;
 - cylinders, 53;
 - definition, 42, 51;
 - drivers, 44, 53;
 - engine utilities, 60;
 - location, 43;
 - lube and seal oil, 43;
 - maintenance, 43, 63;
 - piping flexibility, 51;
 - plot arrangements, 47;
 - seal oil overhead tank, 49;
 - suction and discharge nozzles, 44, 65;
 - surface condensers, 46;
 - traveling crane, 43;
 - turbine details, 46;
 - wedges, 72
- Cold spring, 156
- Coupling guard, 21

- Decoking, 111
- Double acting cylinders, 53
- Double pipe exchangers, 116
- Drain funnels at pumps, 22
- Drop area, 44, 64

- Exchanger,
 - air cooler, 134;
 - air cooler cell, 134;
 - air cooler piping, 139;
 - basic parts, 117;
 - coil shed, 137;
 - double pipe, 116;
 - horizontal, 125;
 - humidified air cooler, 137;
 - induced vs. forced draft, 135;
 - nozzle, 125;
 - nozzle reinforcement, 134;
 - odd vs. even pass, 135;
 - outline drawings, 120;
 - part definitions, 123;
 - pipe-rack mounted, 135;
 - piping expansion at air coolers, 139;
 - piping rule, 116;
 - shell and tube, 117;
 - thermosiphon reboilers, 123;
 - vertical, 124
- Exhaust silencer, 60
- Explosion doors, 81

- Fin tube exchanger, 116
- Fired heaters, 78
- Flame scanner, 110
- Flare headers, 66

- Flexibility of piping, 147-154
- Flue gas, 82
- Flywheel, 53
- Foundations, 47, 63
- Fuel gas, 89

- Gas, wet, 65, 89
- Glycol jacket, 60
- Grating, floor type, 63

- Hairpin, 116
- Head at pumps, 2
- Heaters,
 - arrangements, 98;
 - burners, 82;
 - decoking tubes, 111;
 - dual purpose, 82;
 - flow through, 82;
 - instrumentation, 109;
 - locations, 90;
 - maintenance, 90;
 - parts, 78;
 - passes, 81;
 - piping, 101;
 - soot blowers, 111;
 - symmetrical piping, 105;
 - two-phase flow, 105;
 - types, 78
- Hold-downs, 72
- Hook height, crane, 44
- Horizontal pumps, 20
- Hydrogen separator, 66

- Inline pumps, 4, 16
- Internal line design, 66
- Instrumentation, 60

- Jacket water, 62

- Laterals, 66
- Lube oil console, 43

Manifolded piping, 101
Mezzanine installations, 44

Observation doors, 81, 95
Oil gun, 90
Outline drawings, pumps, 16
Overhead tank, 49

Peep holes, 81
Pilot gas, 81
Pipe support spacing, 68
Pump,

cavitation, 2;
close nozzles, 6;
curve, 2;
definition, 1;
discharges, 8;
end suction, 6;
head, 2;
horizontal, 20;
hot piping, 6;
inline, 16;
nozzle rating, 10;
performance, 2;
side suction, 8;
stations, 1;
strainers, 4;

suction valves, 4, 14;
types, 1;
vertical, 22
Pup, definition, 8

Quick check method, 148

Reactor-heater piping, 90, 97
Reciprocating compressor, 51
Reducers,

at compressors, 43;
at pump discharge, 6;
at pump suction, 4

Regeneration, 51
Reverse flow, 116
Ring headers, 85-86, 104

Seal oil,
console, 43;
overhead tank, 49
Sentinel valves, 23
Side suction pumps, 8, 20
Snuffing steam, 89
Soot blowers, 111
Starting air, 62
Strainers,
basket, 4, 7-8;

conical, 4, 9-10;
flat, 4, 11;
turbine,, 35
Surface condenser, 47

Tandem drive, 42
Taper boring, 101
Thermosiphon reboilers, 123
Thermowell details, 110
Tube pulling, 90, 96, 120
Turbine,
inlet piping, 35;
outlet piping, 39
Two-phase flow, 105

Valves, pump suction, 4
Vertical heaters, 78
Vertical pumps, 22
Volume bottles, 60
Volume tank, 62

Washer installation, 74
Wedge braces, 72
Wedges and hold-downs, 72
Weight, concrete, 53, 63
Wet gas, 65, 89

Process Piping Design Volume 2

Piping designers, engineers, students and college instructors—this book is for you.

In the two volumes of *Process Piping Design*, Rip Weaver systematically presents a complete course in the design of piping systems for processing plants.

Weaver has drawn on his own extensive experience to explain each phase of piping design and its attendant problems. He writes in the simple descriptive language of field personnel about standards of the industry published here for the first time.

Process Piping Design can be used as a text for schools or businesses. It takes up where *Process Piping Drafting*, already a text in hundreds of schools and used in more than 50 countries, ends.

Easy-to-understand and absolutely complete, this book includes review questions at the end of each chapter and dozens of illustrations by the author as well as many from industrial publications.

This is *the* reference book on the design of piping systems. It deals in depth with problems and solutions of vital interest to all those involved in the design or installation of industrial piping. No one in the process industries can afford to be without it.

About the Author

Rip Weaver, has more than 35 years of experience in drafting, design, and engineering for such firms as M.W. Kellogg, Fluor, and SMC McEver. During his career, he has trained hundreds of drafting technicians and has had numerous articles published in trade and technical magazines. His books are used as textbooks in hundreds of schools in the United States and Canada, and in companies throughout the world. Mr. Weaver is presently a consultant in Houston, Texas.

Piping Videos Are Also Available From Gulf Publishing Company—

Piping Fundamentals

This 10-part series is packed with proven techniques of piping drafting, design, and engineering. The tapes cover Piping Codes and Equipment; Flanges, Fittings, and Valves; Symbolology and Orthographic Projections; Flow Diagrams; Plant Coordinate Systems, Elevations, and Math; Detail Dimensions; Piping Details; Piping Specifications and Plans; Isometric Configurations; and Dimensioned Isometrics.

Piping Familiarization

This 13-part video series provides a clear, thorough understanding of process plant terminology, components, and functions. The tapes describe flanges, valves, utility systems, fractionating towers, pressure vessels, pump, compressors, instrumentation, heat exchangers, and much more.

Piping Pointers

Aimed at designers and supervisors, this 5-part series reveals time-saving, cost-cutting tips for doing better, more efficient piping drafting.

Preview tapes are available. Call (713) 520-4444.

Process Piping Design

Volume 1

1. General Piping
2. Process Terms
3. Plant Arrangement and Storage Tanks
4. Process Unit Plot Plans
5. Piping Systems and Details
6. Pipe Fabrication
7. Vessels
8. Instrumentation
9. Appendix on Conversions

Volume 2

1. Pumps and Turbines
2. Compressors
3. Fired Heaters
4. Exchangers
5. Piping Flexibility



Gulf Publishing Company
Book Division
P.O. Box 2608
Houston, Texas 77252-2608

PRODUCT #1994

ISBN 0-87201-994-2



9 780872 019942

(Series) ISBN 0-87201-995-0