دوره آموزشي طراحي ادوات فرآيندي

Sizing training course

تهيه كننده : محمد بهزادي Mohammad Behzadi

دوره طراحی (Sizing)

تهیه کننده: محمد بهزادی

Design Criteria

Pressure Design Criteria

$$DP=OP*(1+A/100)+B$$

DT=design Pressure
OT=Operating Pressure

	Lower Limit (PSIA)	Upper Limit (PSIA)	Param. A	Param. B (PSIA)
Range 1	0.000	15.000	-100.000	15.000
Range 2	15.000	50.000	-100.000	50.000
Range 3	50.000	265.000	0.000	25.000
Range 4	265.000	1015.000	0.000	50.000
Range 5	1015.000		5.000	0.000

Temperature Design Criteria

$$DT=OT*(1+A/100)+B$$

DT=design temperature

OT=Operating temperature

	Lower Limit (DEG. F)	Upper Limit (DEG. F)	Param. A	Par (D
Range 1	-459.670	32.000	0.000	-5
Range 2	32.000	70.000	-100.000	7(
Range 3	70.000	200.000	-100.000	25
Range 4	200.000	600.00	0.000	5(
Range 5	600.00	1000.00	0.000	5(

- PFD ماهیت فرآیند
- P&ID چیدمان تجهیزات،ابزار دقیق،لوله کشي،شیرها و اتصالات
  - ENGINNERING FLOWSHEET
  - ENGINEERING LINE DIAGRAM

Separators/Accumulators

مخازن

- درام جريان برگشتي(بين كندانسور برج و تجهيزات پايين دست)
- درام قبل از كمپرسور(براي جمع آوري مايعات)
- مخزن روي كوره ها(تيوبهاي داخل كوره را در مقابل خشك شدن محافظت مي كند)
- مخزن روي خط خروجي كمپرسورهاي رفت و برگشتي(جهت يكنواخت كردن فشار خروجي)

- مخازن   چند دقیقه زمان ماند
- تانکها   چند ساعت یا روز زمان ماند

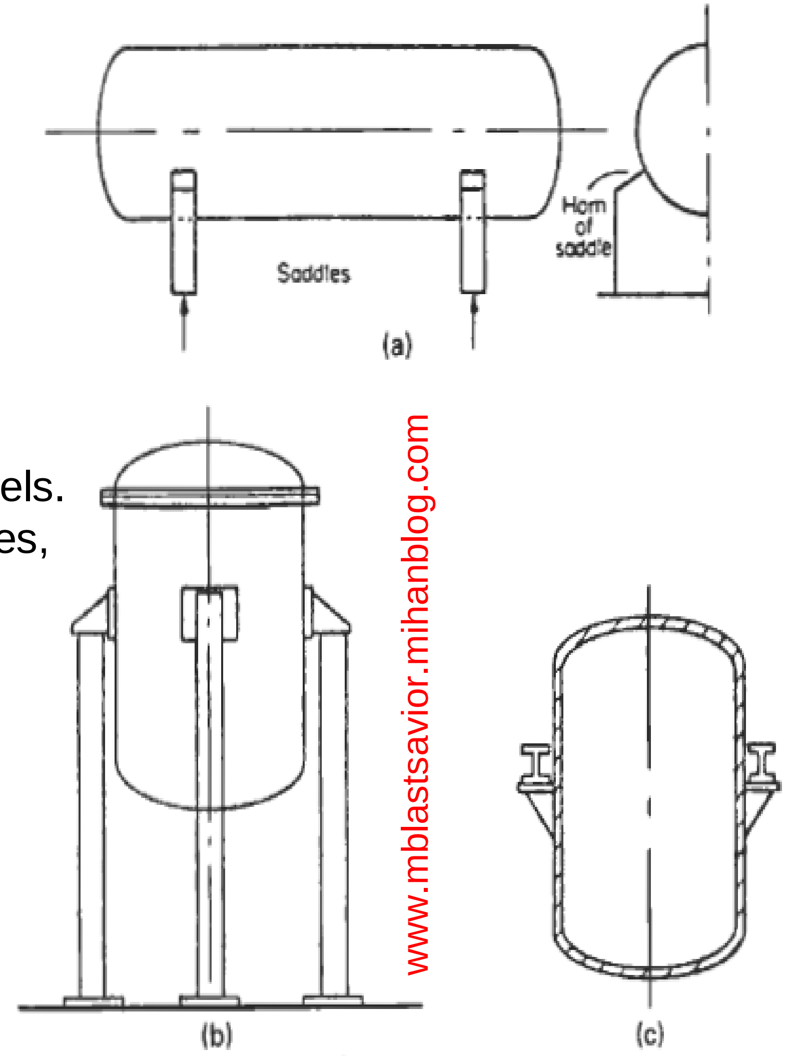
تانکها

- تانک خوراک برج تقطير ناپيوسته
- تانکهاي تجمعي Rundown بين تجهيزات

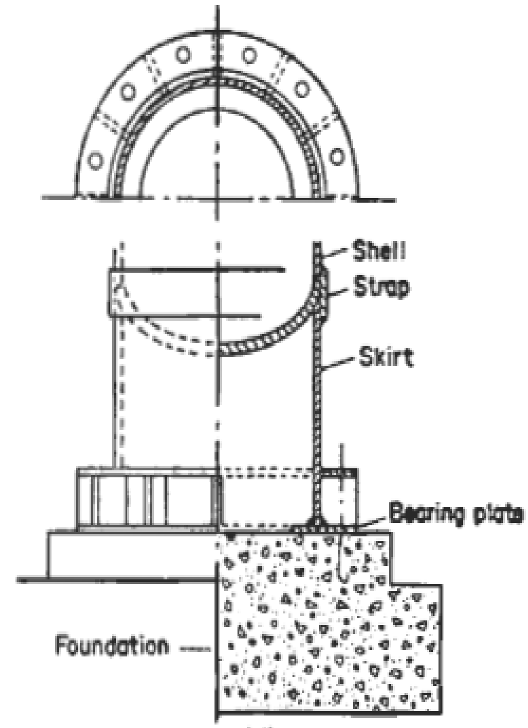
- مخازن مايع عموما افقي
- جداكننده هاي گاز-مايع عموما عمودي

P (psig)	0–250	251–500	501+
L/*D*	3	4	5

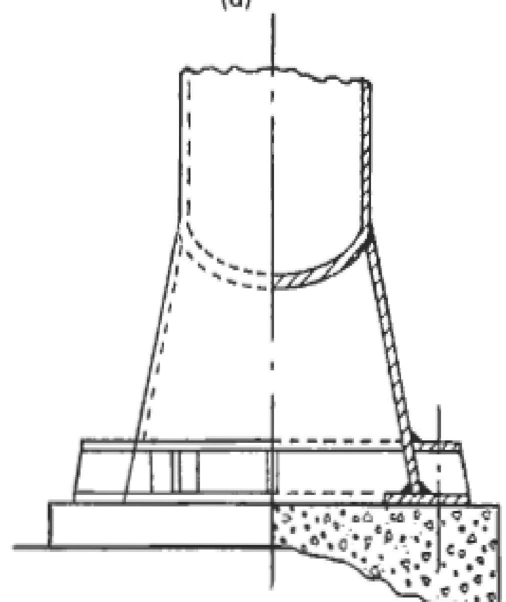
Methods of supporting vessels.
(a) Saddle supports for
horizontal vessels, usually of concrete.
(b) Bracket or lug supports
resting on legs, for either vertical or horizontal vessels.
(c) Bracket or lug supports resting on steel structures,
for either vertical or
horizontal vessels.

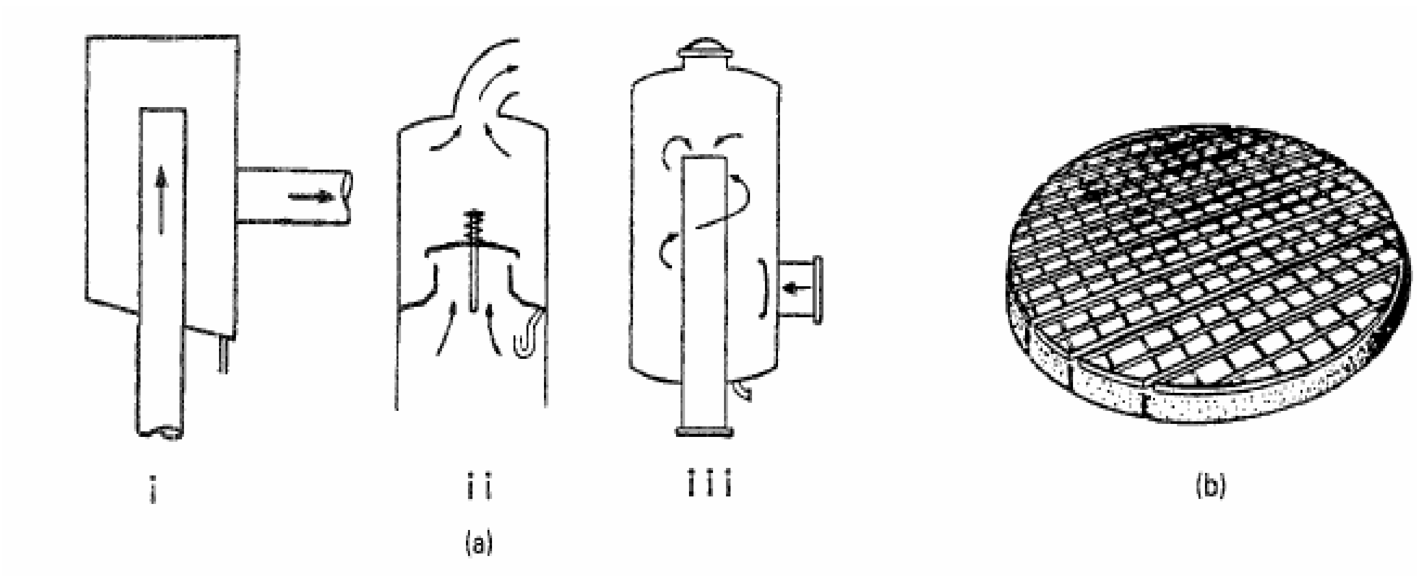


(d) Straight skirt support for towers and other tall vessels; the bearing plate **is** bolted to the foundation.
(e) Flared skirt for towers and other tall vessels, used when the required
number of bolts is such that the bolt spacing becomes less than the
desirable **2** ft.

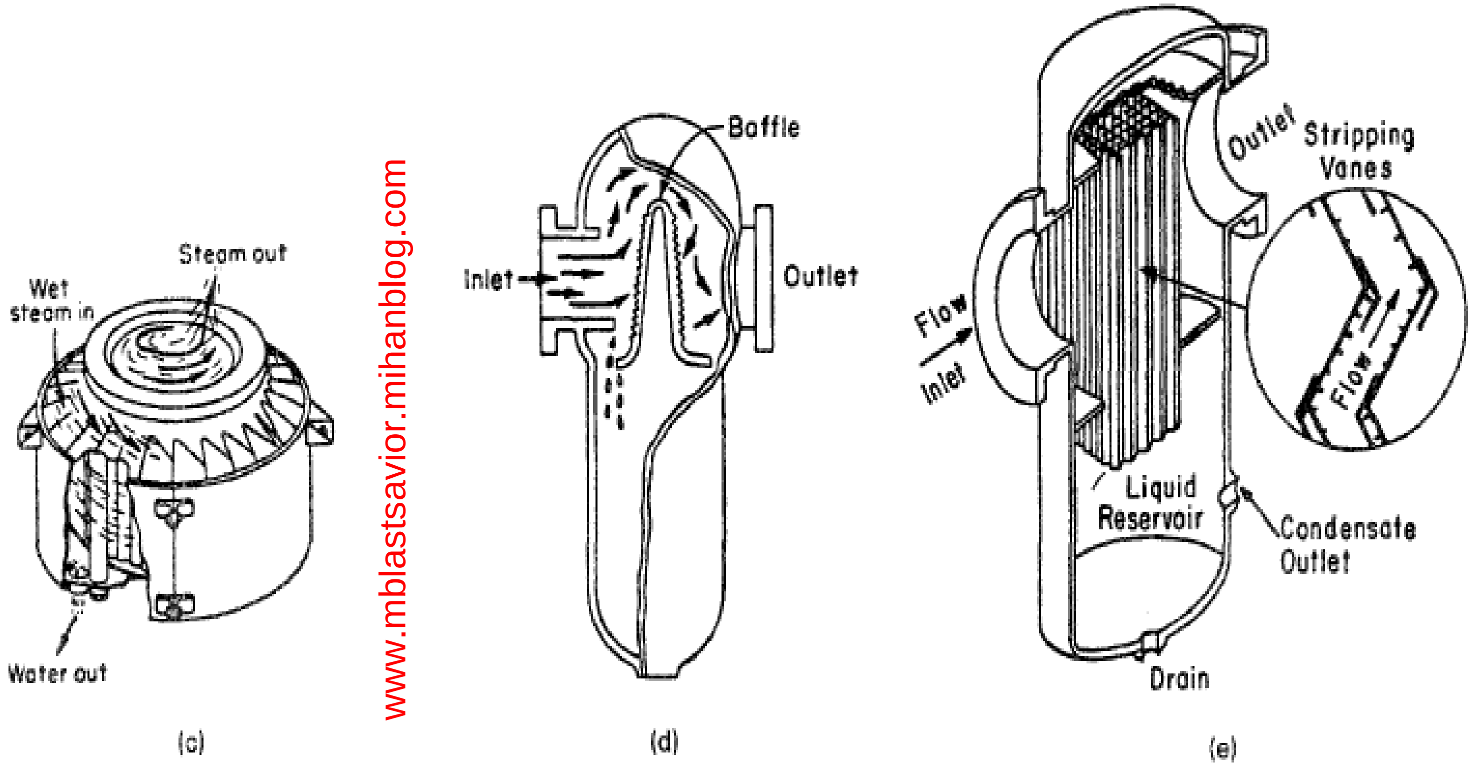


(d)


(e)



Principles of entrainment separation and some commercial types of equipment.
(a) Basic principles of entrainment separating
equipment: (i) change of direction; (ii) impingement on a baffle; (iii) tangential inlet resulting in centrifugal force.
(b) Wire or fiber mesh pad, typical installations as in Figure **B.7.**



(c) A separator combining impingement and centrifugal force
(d)Equipment with impingement and change of direction
(e) Multiple zig-zag baffle arrangement

FRACTIONATOR REFLUX DRUMS

Commonly their orientation is horizontal.

A method of sizing reflux drums proposed by Watkins (1967) is based on several factors itemized in Table 18.1. A factor F_3 is applied to the net overhead product going downstream, then instrument factors F_1 and labor factors F_2 which are added together and applied to the weighted overhead stream, and finally a factor F_4 is applied, which depends on the kind and location of level indicators. When L is the reflux flow rate and D the overhead net product rate, both in gpm, the volume of the drum (gal) is given by

$$V_d = 2F_4(F_1 + F_2)(L + F_3 D) \text{ gal}, \quad \text{full.} \qquad (18.1)$$

or, 6.25 min half-full. With the best of everything, $F_1 = 0.5$, $F_2 = 1$, $F_3 = 2$, $F_4 = 1$, and

$$V_d = 2(0.5 + 1)(400 + 2(200)) = 2400 \text{ gal,} \quad \text{full}$$

TABLE 18.1 Factors for Sizing Reflux Accumulators

a. Factors F_1 and F_2 on the Reflux Flow Rate

	Instrument Factor F_1		Labor Factor F_2		
Operation	w/ Alarm	w/o Alarm	Good	Fair	Poor
FRC	$\frac{1}{2}$	1	1	1.5	2
LRC	1	$1\frac{1}{2}$	1	1.5	2
TRC	$1\frac{1}{2}$	2	1	1.5	2

b. Factor F_3 on the Net Overhead Product Flow to External Equipment

Operating Characteristics	F_3
Under good control	2.0
Under fair control	3.0
Under poor control	4.0
Feed to or from storage	1.25

c. Factor F_4 for Level Control

	F_4
Board-mounted level recorder	1.0
Level indicator on board	1.5
Gage glass at equipment only	2.0

For example, with $L = 400$ gpm and $D = 200$ gpm, at average conditions $F_1 = 1$, $F_2 = 1.5$, $F_3 = 3$, $F_4 = 1.5$, and

$$V_d = 2(1.5)(1 + 1.5)(400 + 3(200)) = 7500 \text{ gal}, \quad \text{full}$$

Vapor Residence Time

For vapor/liquid separators, this is usually expressed in terms of maximum velocity which is related to the difference in liquid and vapor densities. The standard equation is

$$U_{vapor\ max} = K[(\rho_L - \rho_v)/\rho_v]^{0.5}$$

where

U = Velocity, ft/sec
ρ = Density of liquid or vapor, lbs/ft³
K = System constant

Figure 1 relates the K factor for a vertical vessel (K_v) to:

$$W_L/W_v(\rho_v/\rho_L)^{0.5}$$

where

W = Liquid or vapor flow rate, lb/sec

For a horizontal vessel $K_H = 1.25\,K_v$.

Figure 1 is based upon 5% of the liquid entrained in the vapor. This is adequate for normal design. A mist eliminator can get entrainment down to 1%.

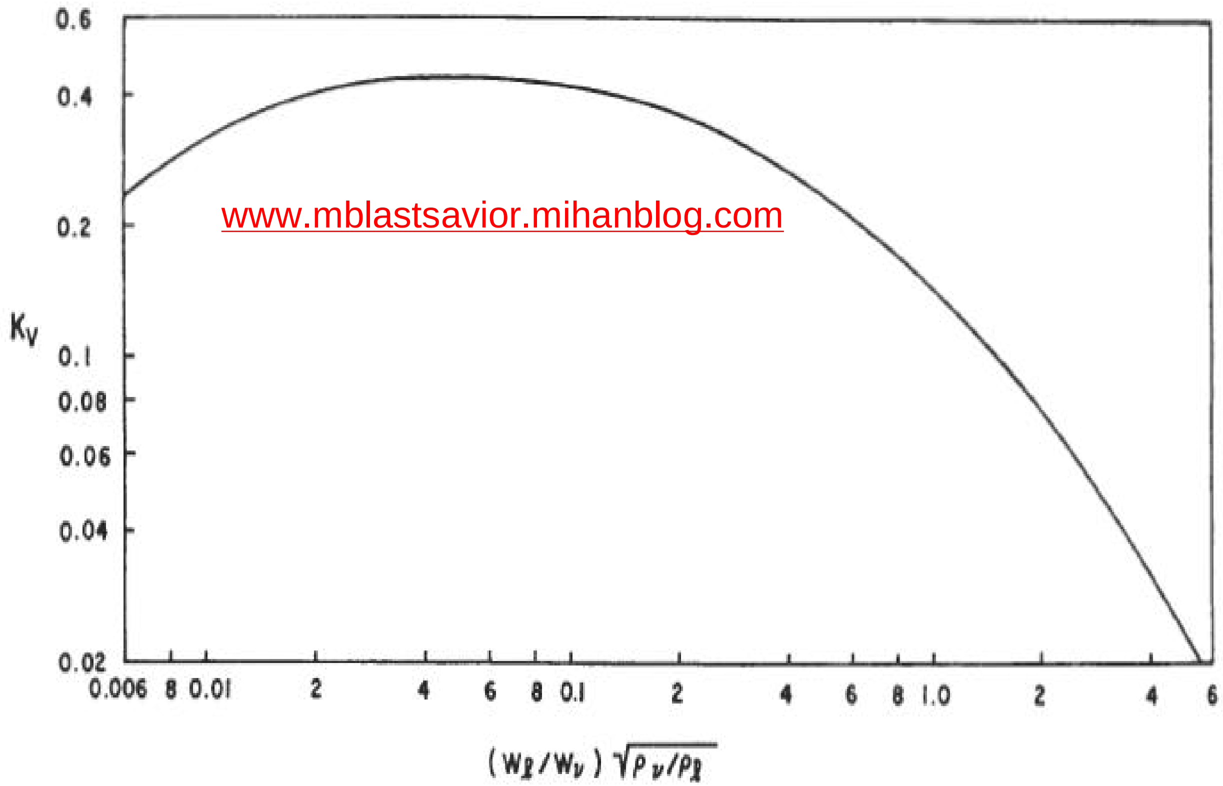


Figure 1. Design vapor velocity factor for vertical vapor-liquid separators at 85% of flooding.

An equation has been developed for Figure 1 as follows:

$X = \ln(W_l/W_v(\rho_v/\rho_L)^{0.5})$

please note that "X" in the equation is the natural logarithm of "X" in the graph

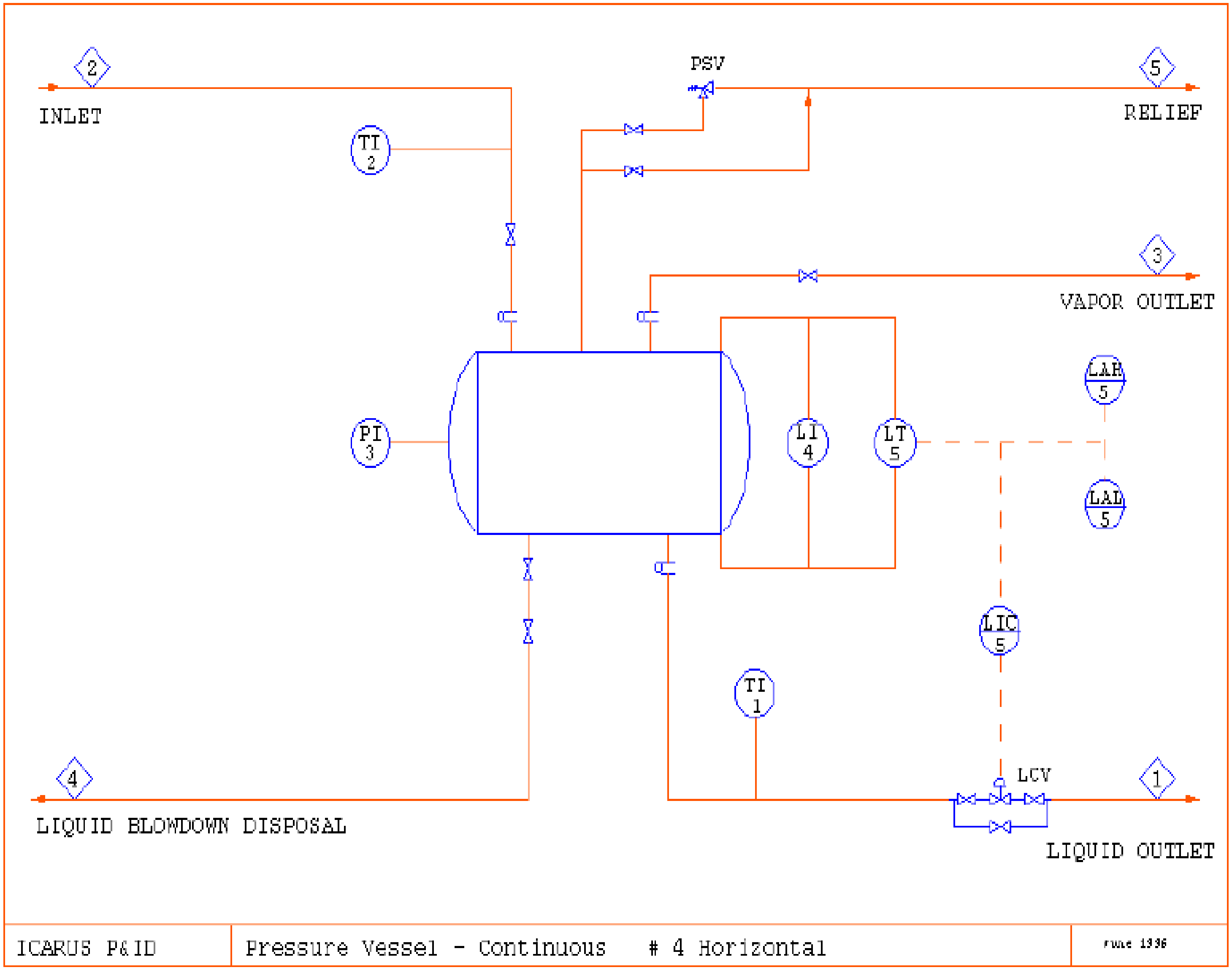
$Y = K_v$ (Remember $K_H = 1.25K_v$)

Y = EXP(A + BX + CX^2 + DX^3 + EX^4 + FX^5)
A = −1.942936
B = −0.814894
C = −0.179390
D = −0.0123790
E = 0.000386235
F = 0.000259550

Sources

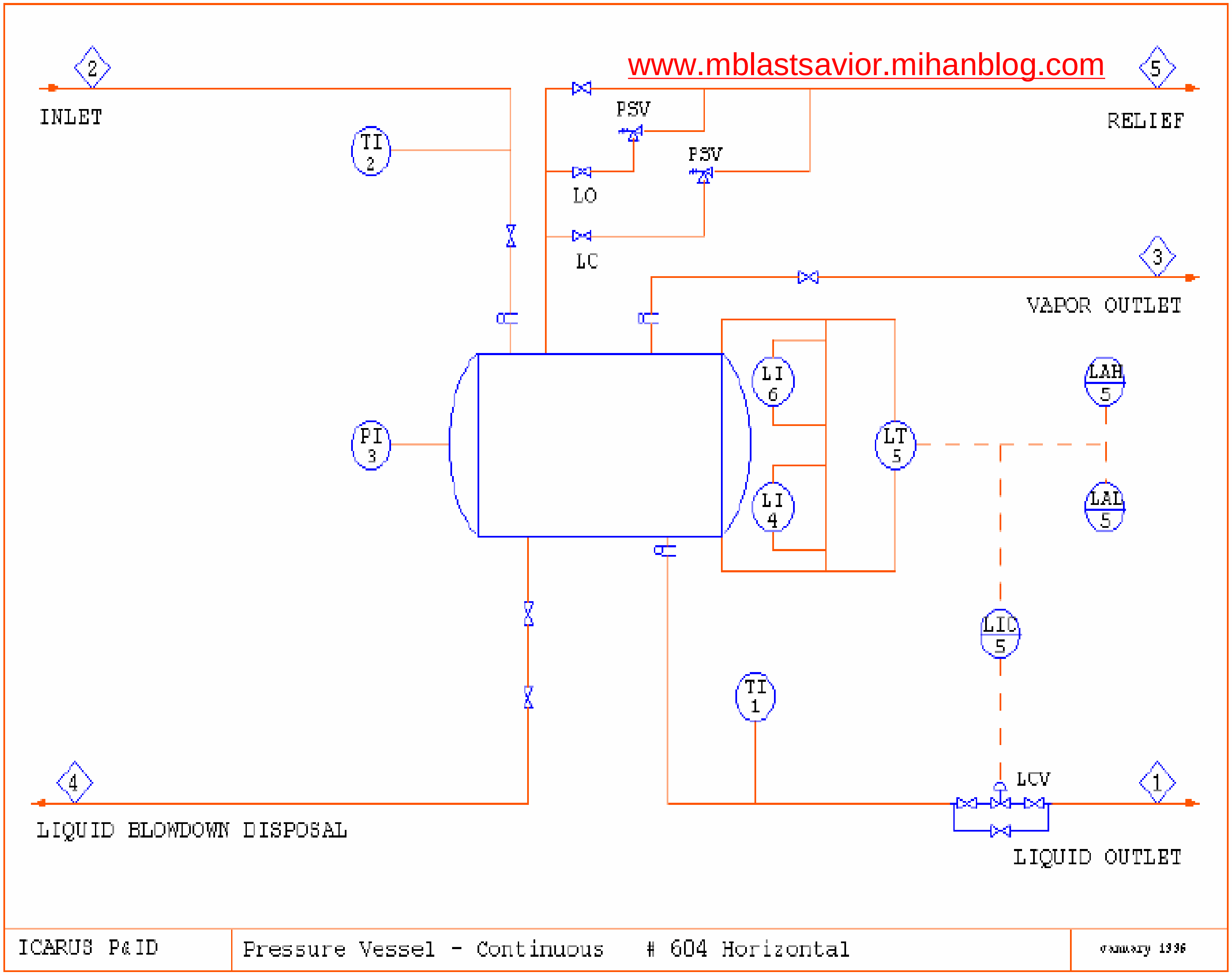
1. Watkins, R. N., "Sizing Separators and Accumulators," *Hydrocarbon Processing*, November 1967.
2. The equation was generated using FLEXCURV V. 2.0, Gulf Publishing Co.

4 Horizontal Pressure Vessel – Continuous

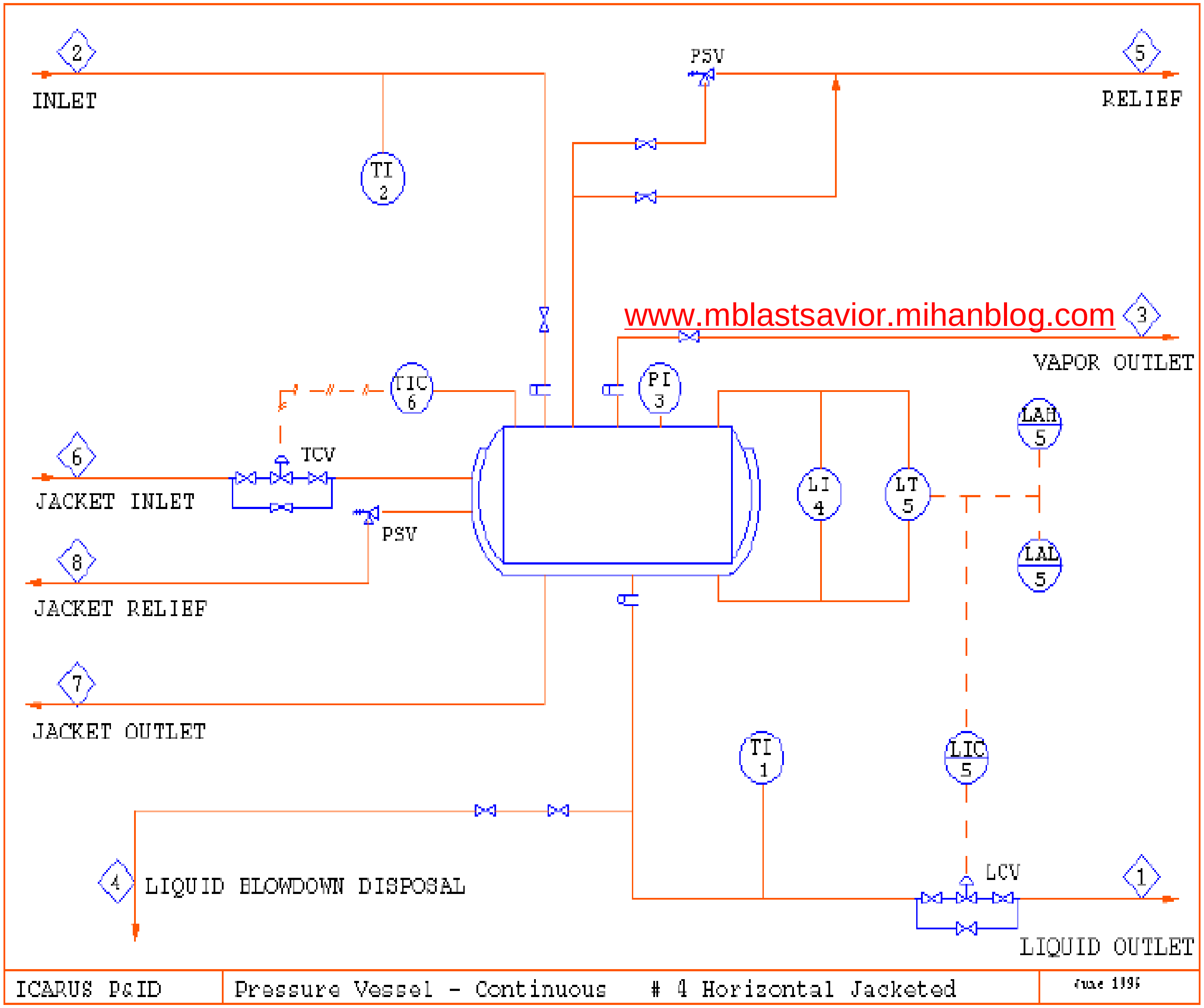


تهیه کننده:محمد بهزادی

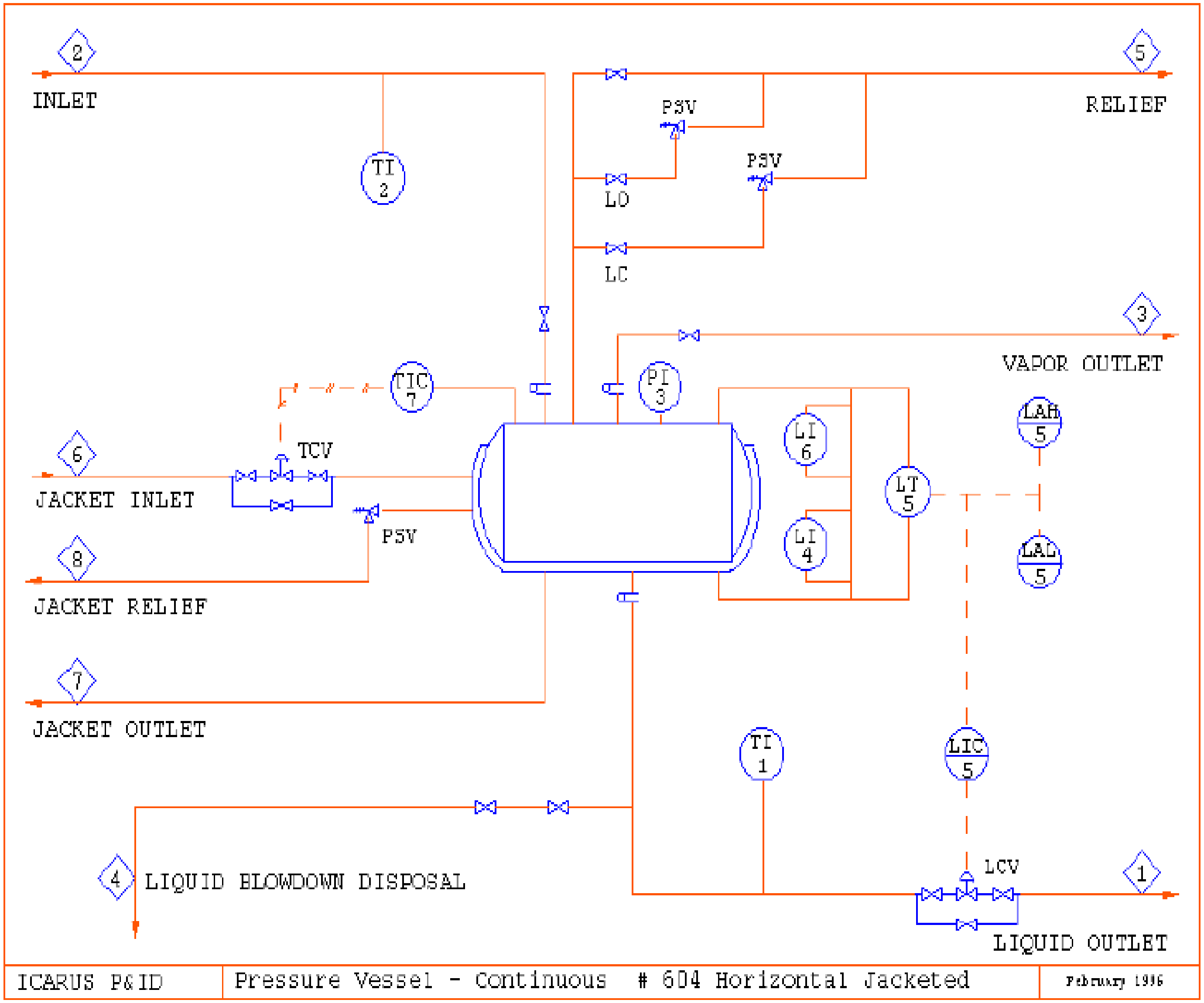
604 Horizontal Pressure Vessel – Continuous



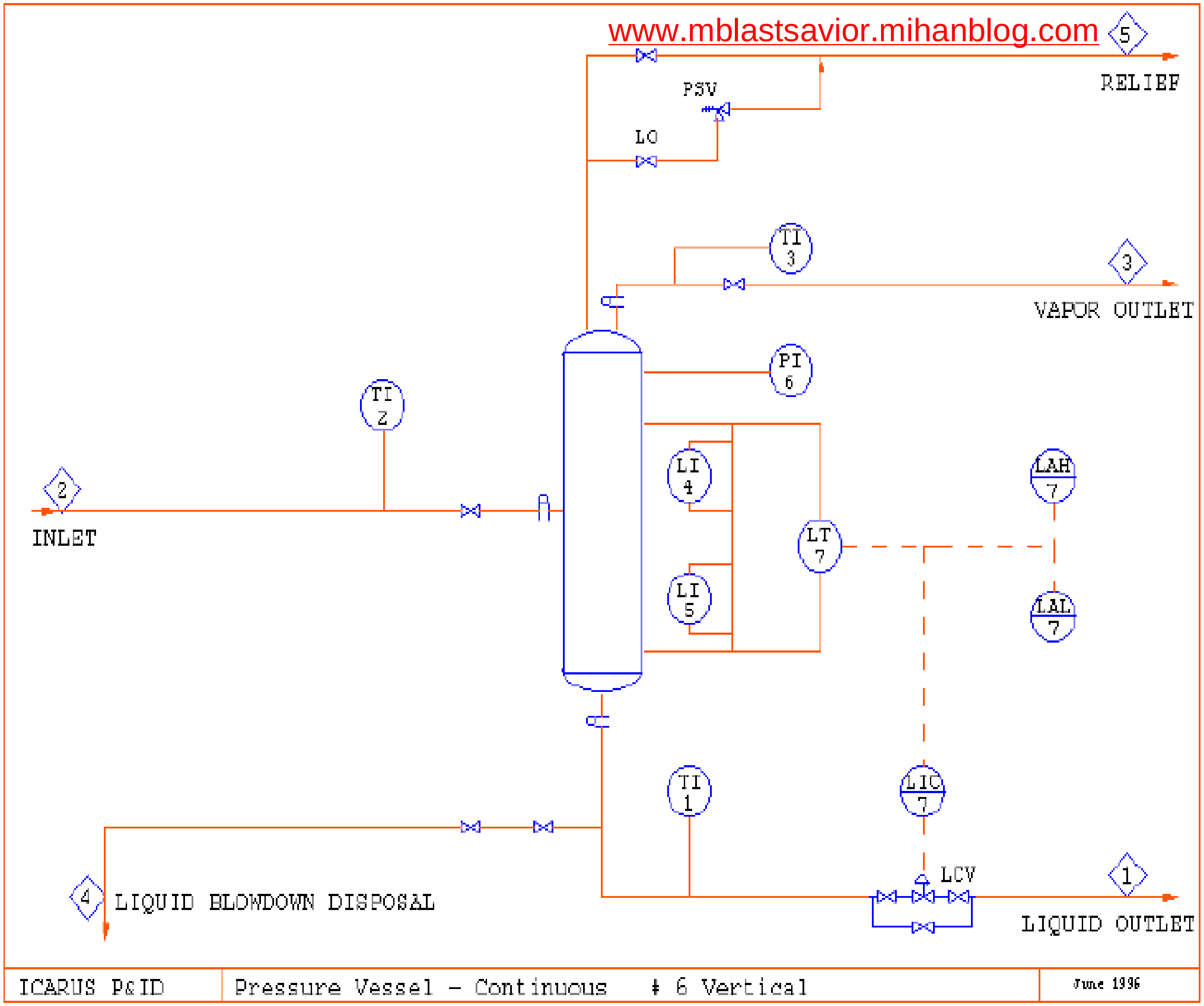
4 Horizontal Jacketed Pressure Vessel - Continuous



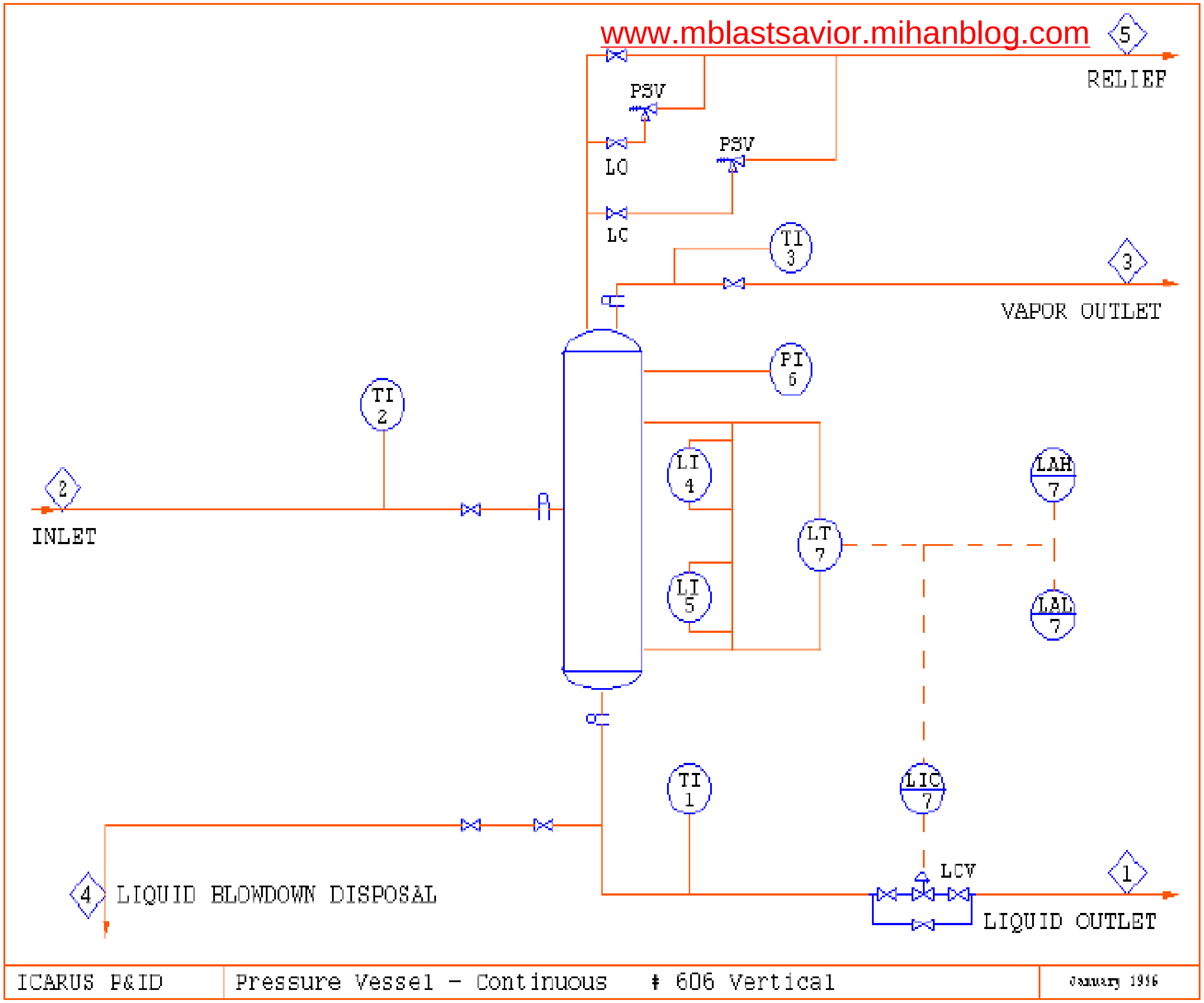
604 Horizontal Jacketed Pressure Vessel – Continuous



6 Vertical Pressure Vessel – Continuous



606 Vertical Pressure Vessel – Continuous



WO. No. ____________
PAGE No. ____________
REVISION No. ____________
PREPARED BY ____________
APPROVED BY ____________
DATE ____________

VESSEL DATA SHEET

PLANT	LOCATION		ITEM Nos.
SERVICE			
SIZE Dia X	S.-S. X	(SKIRT) (LEGS)	
CAPACITY	SPECIFIC GRAVITY-CONTENTS	No. REQ'D	
STANDARD REFERENCE DRAWINGS	DESIGN DATA		
STD.C.3. Ladders, Platforms & Handrail	CODE	STAMP REQ'D (Yes) (No)	
STD.C/4.5/Col. Davits & M.H. Hinge & Davit	DESIGN PRESS	psig. DESIGN TEMP.	
STD.C/4.6. Pipe Guides & Supports	OPER. PRES.	psig. OPER. TEMP.	
STD.C/4.7. Vessel Skirt Openings	CORROSION ALLOWANCE		
	WIND LOAD.	mph. SEISMIC FACTOR	
	No. & TYPE OF TRAYS	Furn. By	
REMARKS:	STRESS RELIEVE (Yes) (No)		
	TESTS	X-Ray (Yes) (No)	

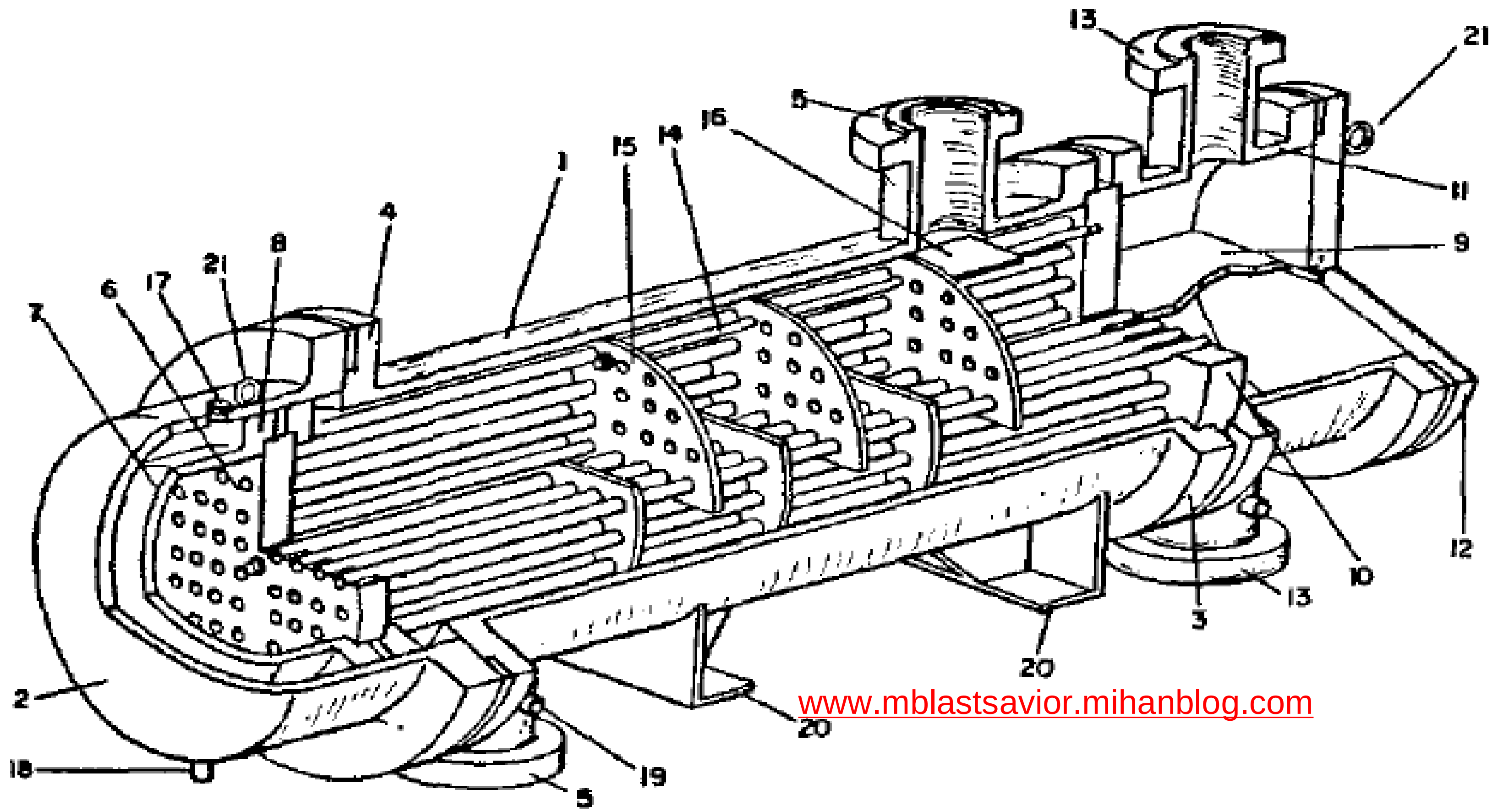
ITEM	THK.	MAT'L	COMMENTS
SHELL			
HEADS			TYPE
CLADDING, LINER			
SUPPORT			(Skirt) (Saddles) (legs)
TRAY SUP. RINGS			
GASKETS			
NUTS & BOLTS	—		
LADDER (CAGED)	—		
PLATFORMS #1			Ang. or Len X Wid.
PAINT	—	None	
INSULATION			
INSUL. SUP. RGS.			@ 10' Spacing (Nom)

NOZZLE SCHEDULE

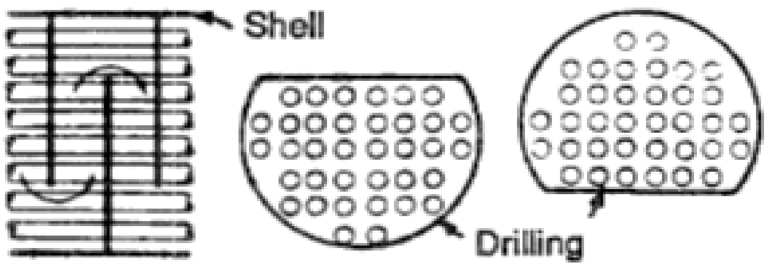
MK.	SERVICE	No.	SIZE	RATING	FACING	PROJECTION
N-1						
N-2						
N-3						
N-4						
N-5						
N-6						
N-7						
N-8						

No.	REVISION	APP'D	DATE

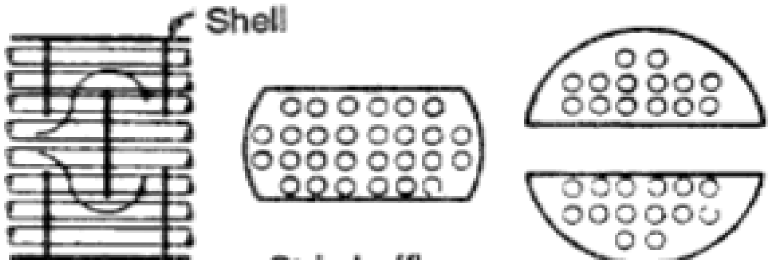
Heat Exchangers



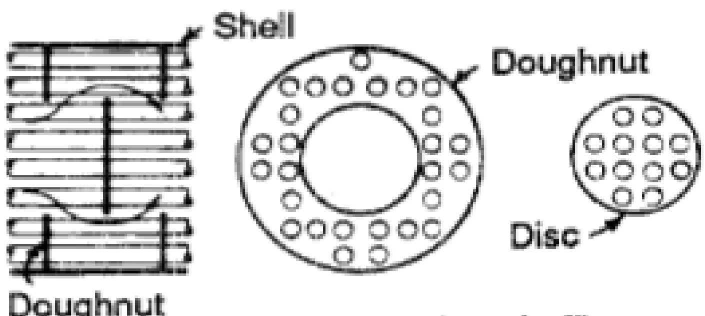
1. SHELL
2. SHELL COVER
3. SHELL CHANNEL
4. SHELL COVER END FLANGE
5. SHELL NOZZLE
6. FLOATING TUBESHEET
7. FLOATING HEAD
8. FLOATING HEAD FLANGE
9. CHANNEL PARTITION
10. STATIONARY TUBESHEET
11. CHANNEL
12. CHANNEL COVER
13. CHANNEL NOZZLE
14. TIE RODS AND SPACERS
15. TRANSVERSE BAFFLES OR SUPPORT PLATES
16. IMPINGEMENT BAFFLE
17. VENT CONNECTION
18. DRAIN CONNECTION
19. TEST CONNECTION
20. SUPPORT SADDLES
21. LIFTING RING



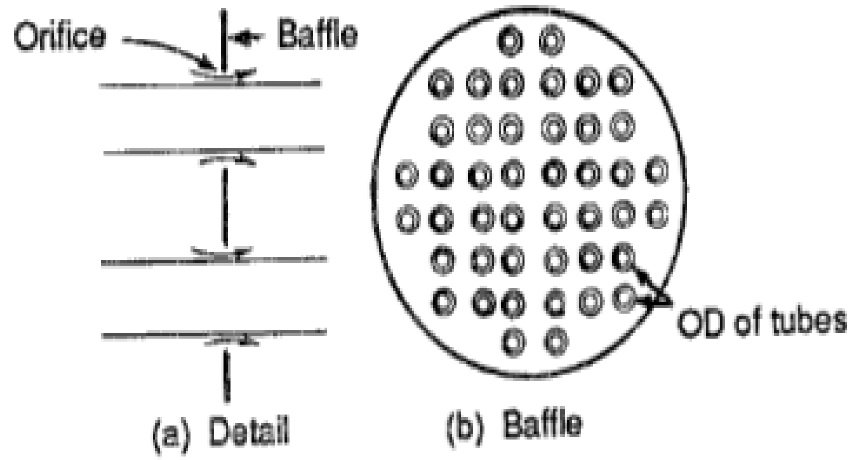
Segmental baffle detail



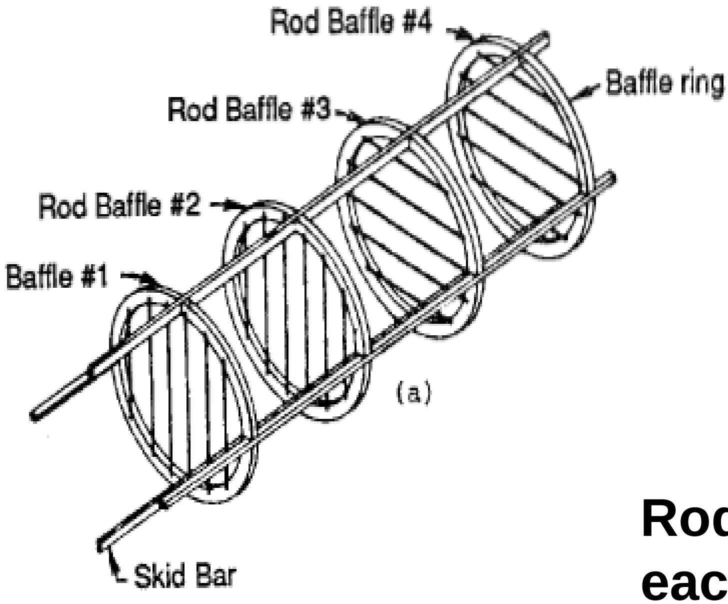
Strip baffle



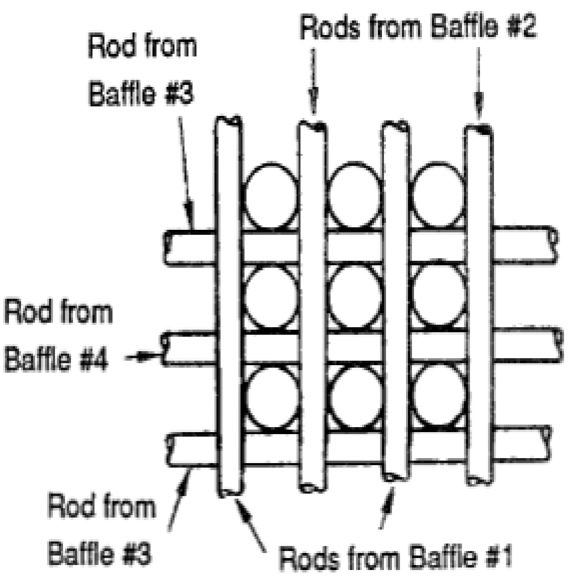
Disc and doughnut baffle



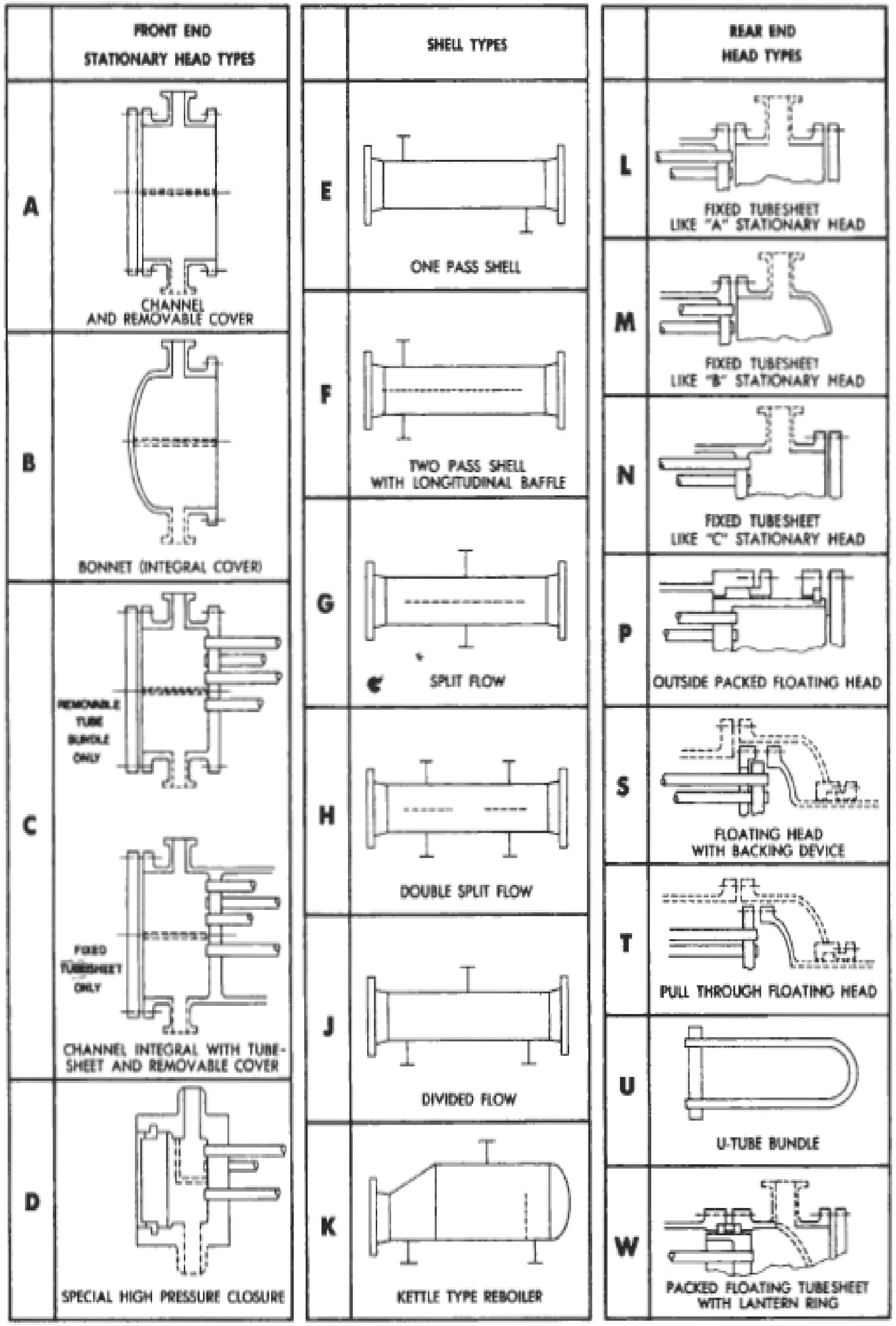
Orifice baffle



Rod baffles for minimizing tube vibrations; each tube is supported by four rods.



Standards of Tubular Exchanger Manufacturers Association (TEMA).



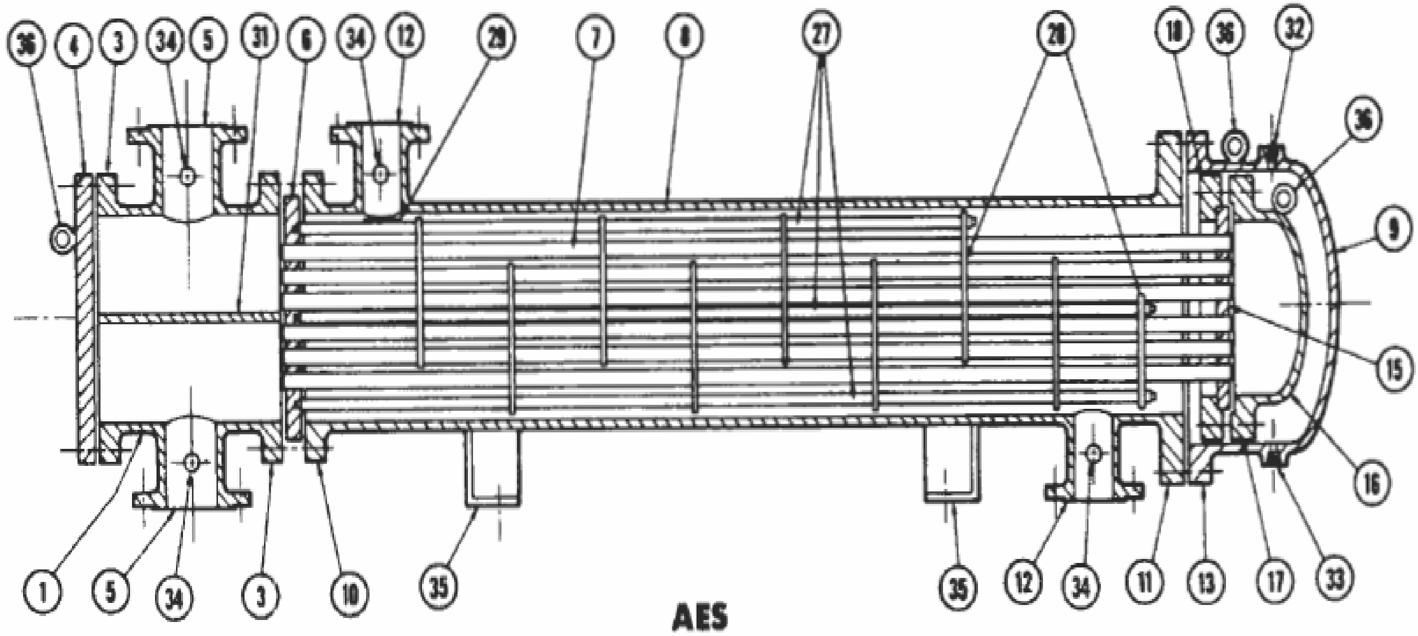
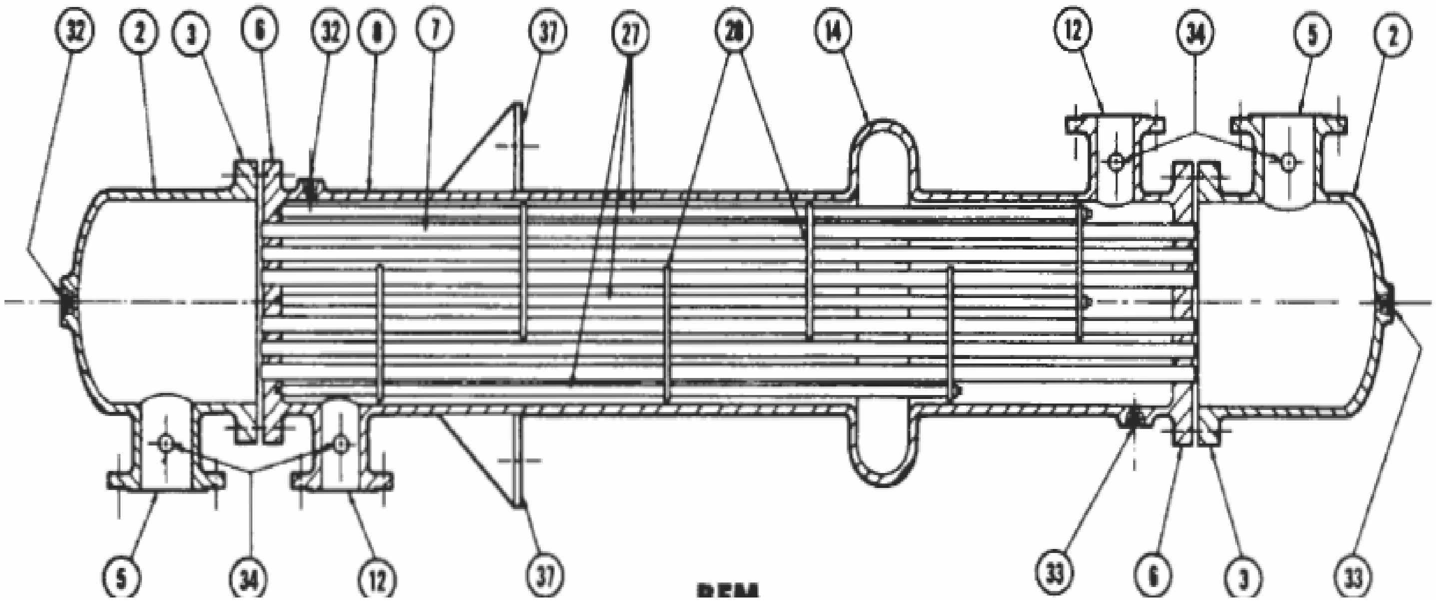


Figure 2. Type AES.



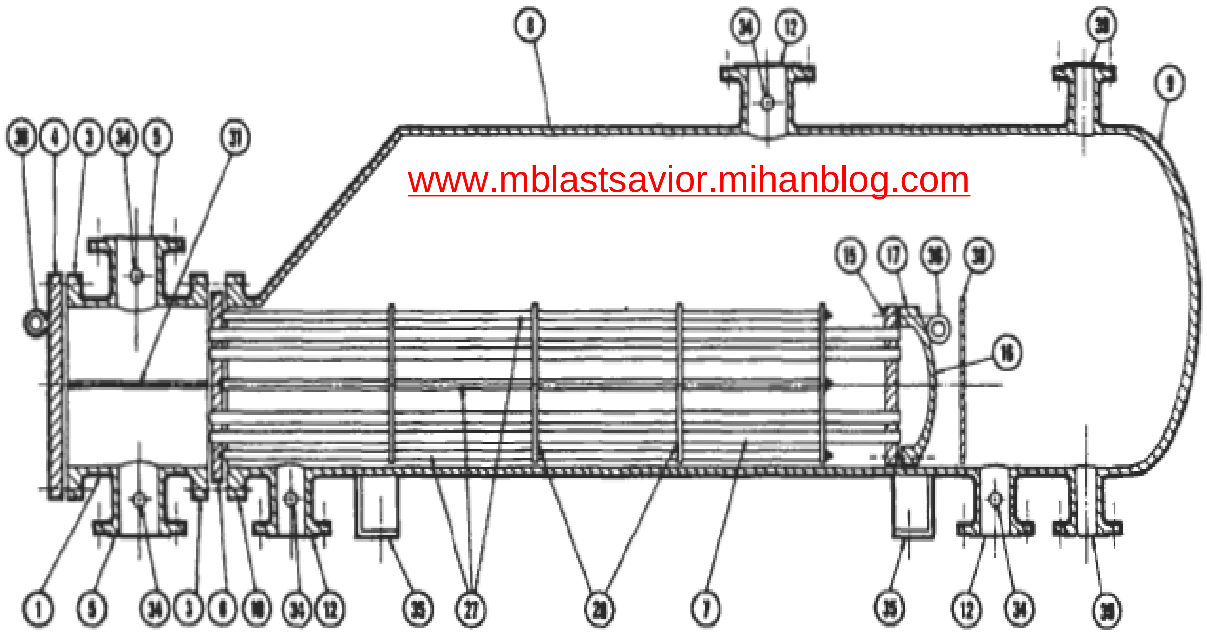
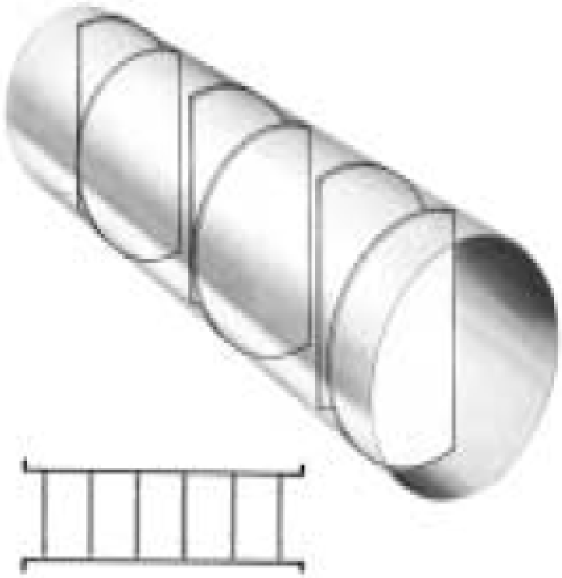


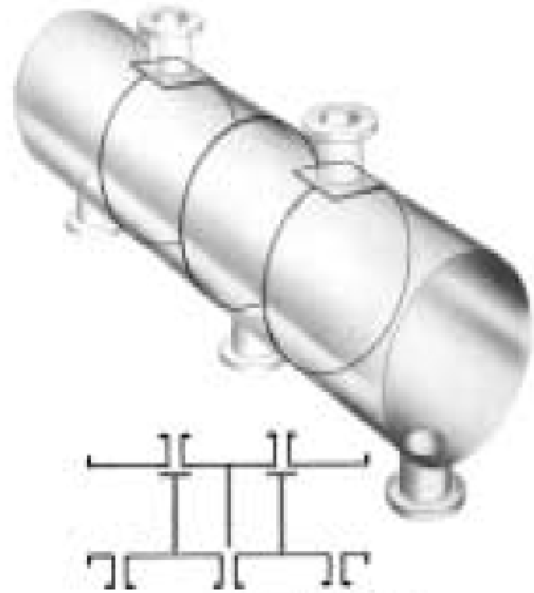
Table 1
Typical Heat Exchanger Parts and Connections

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

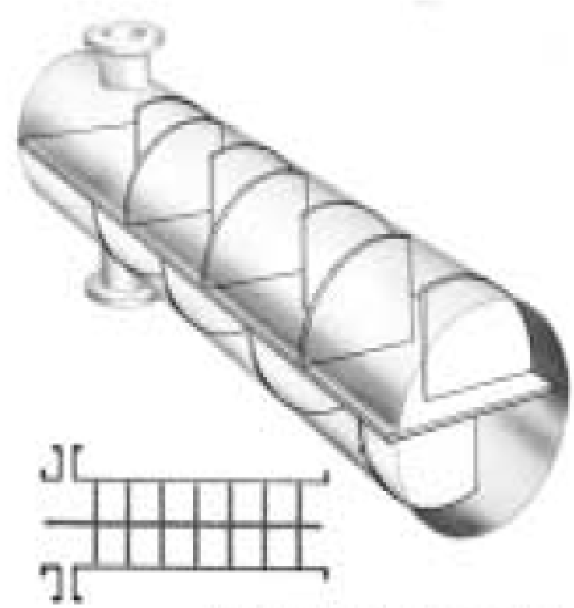
تهیه کننده:محمد بهزادی



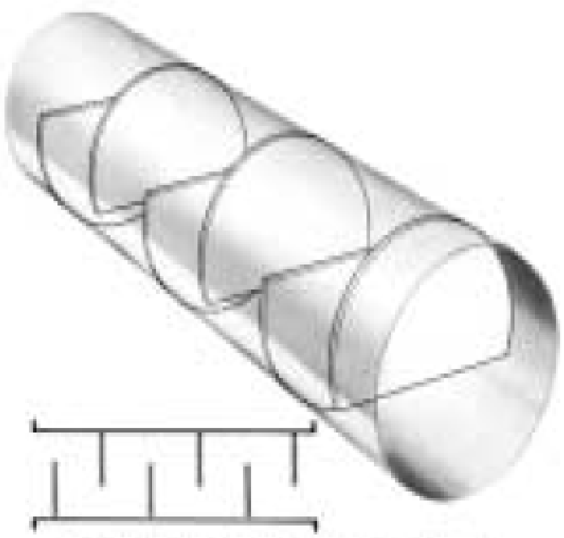
standard segmental baffle designed for side to side flow



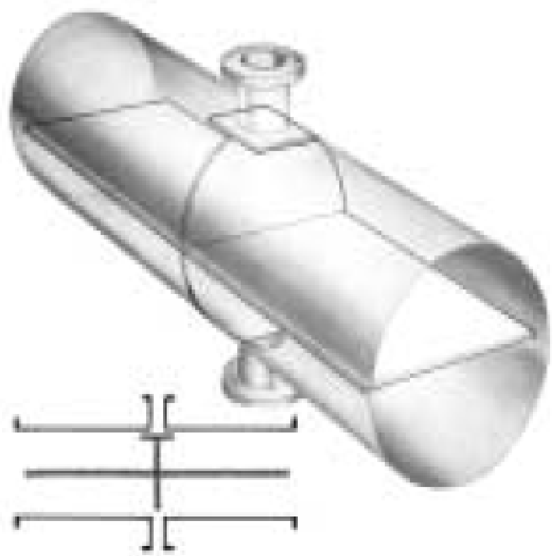
standard double split flow design



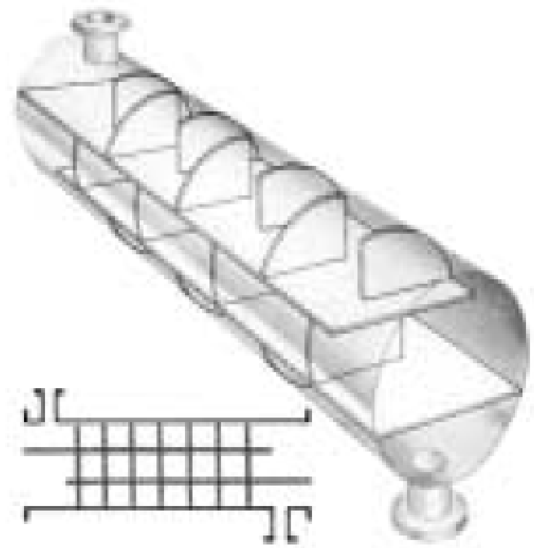
standard segmental two shell baffle design



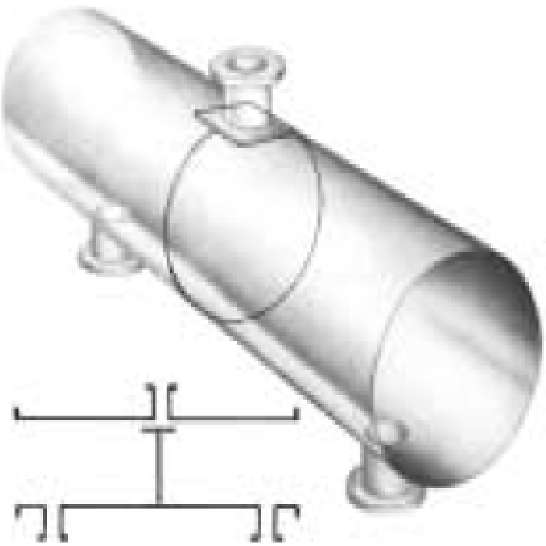
standard segmental baffle designed for up and down flow



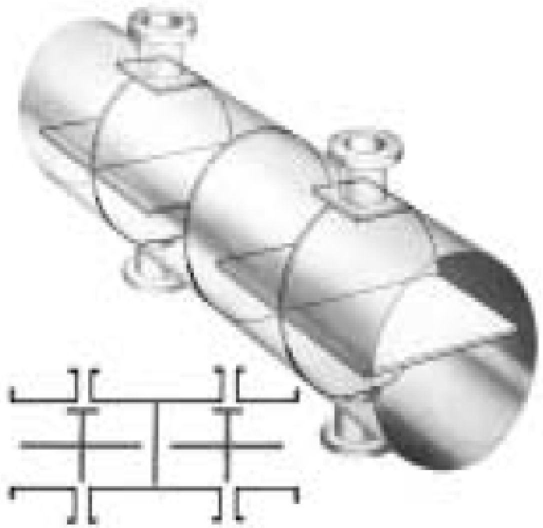
standard split flow design with horizontal baffle



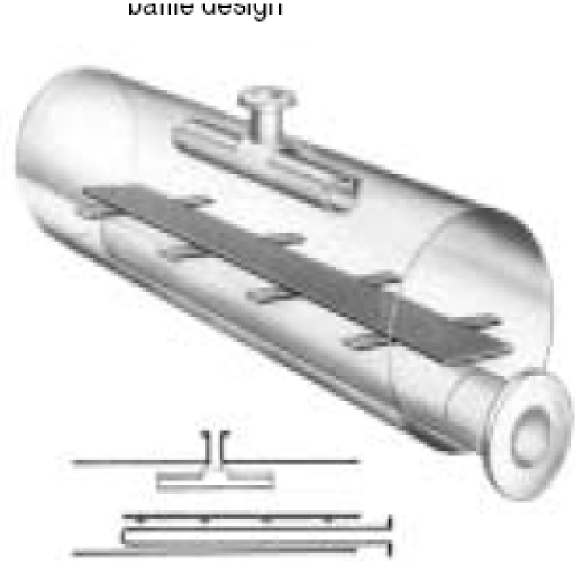
standard segmental three shell pass baffle design



standard single flow design



standard double split flow design with horizontal beffles



P-K standard splash baffle and vapor liquid separator designs. Used for vapor generation.

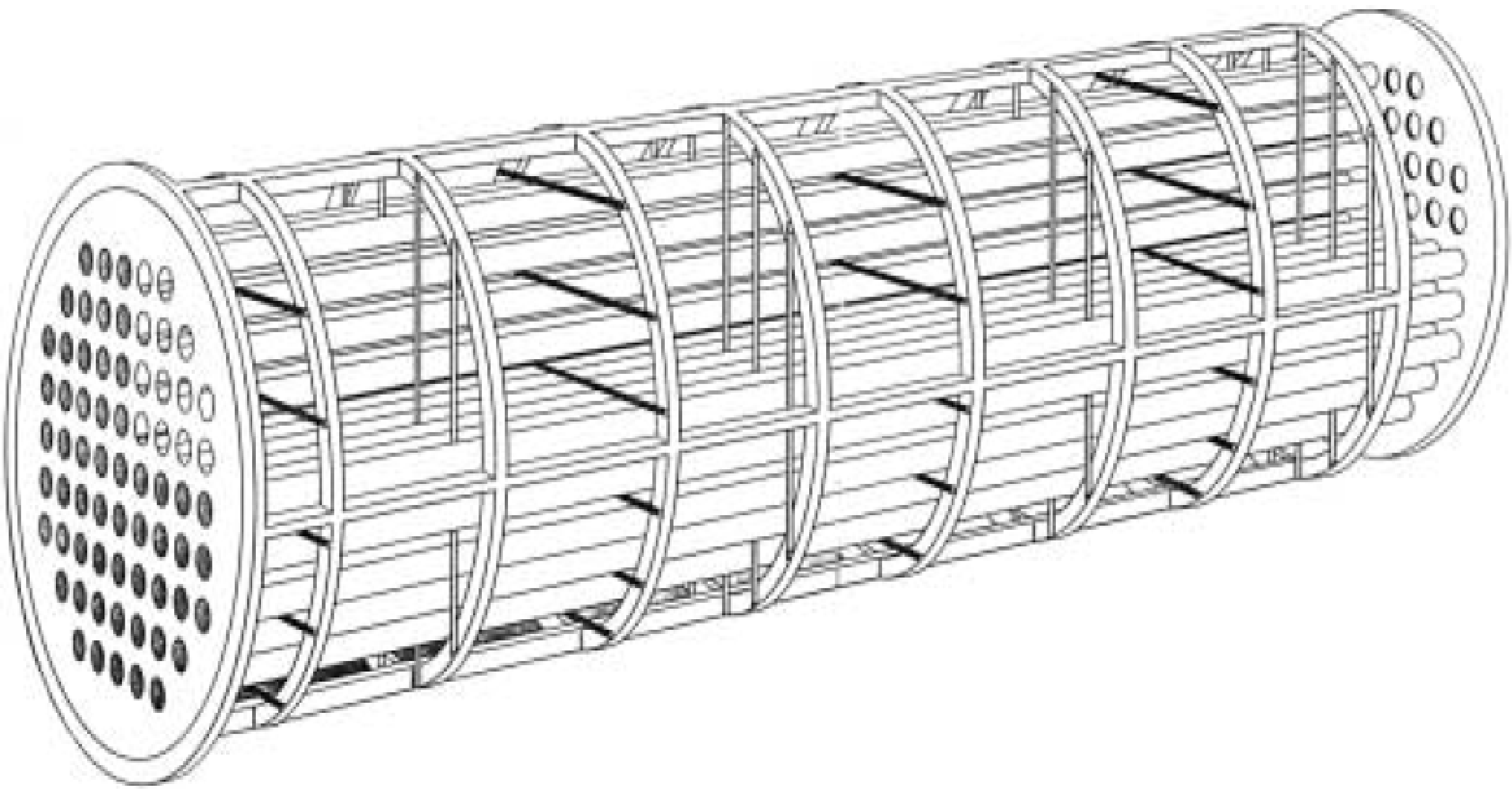
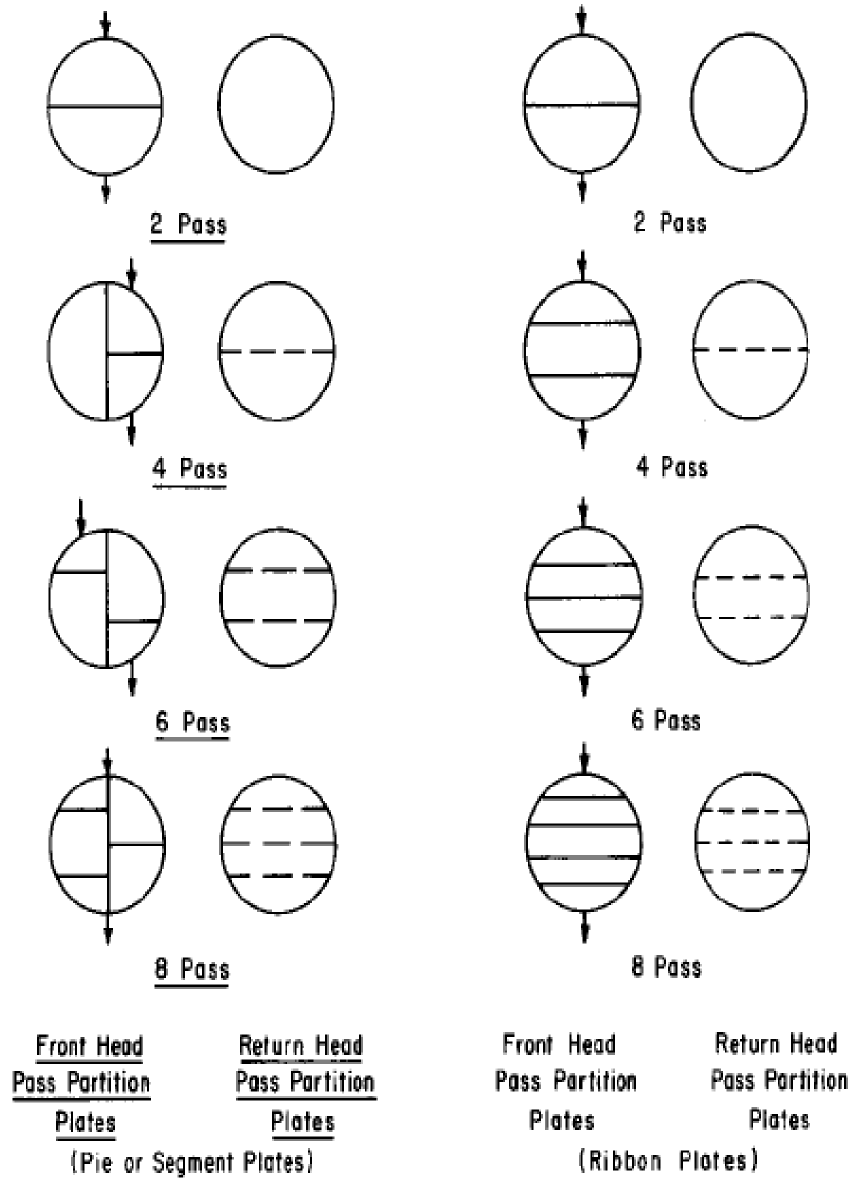
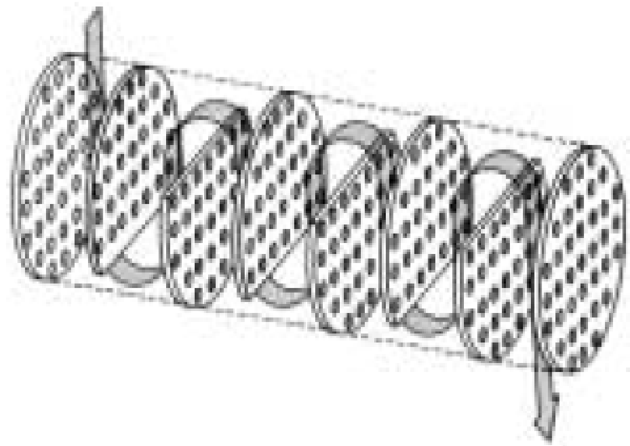


Figure 10-20A. RODbaffle® exchanger cross-section showing assembly, using TEMA E, F, H, J, K, and X shells. (Used by permission: © Phillips Petroleum Company, Licensing Div., Bul. 1114–94-A–01.)


2 Pass
4 Pass
6 Pass
8 Pass
Front Head Pass Partition Plates
Return Head Pass Partition Plates
(Pie or Segment Plates)
2 Pass
4 Pass
6 Pass
8 Pass
Front Head Pass Partition Plates
Return Head Pass Partition Plates
(Ribbon Plates)



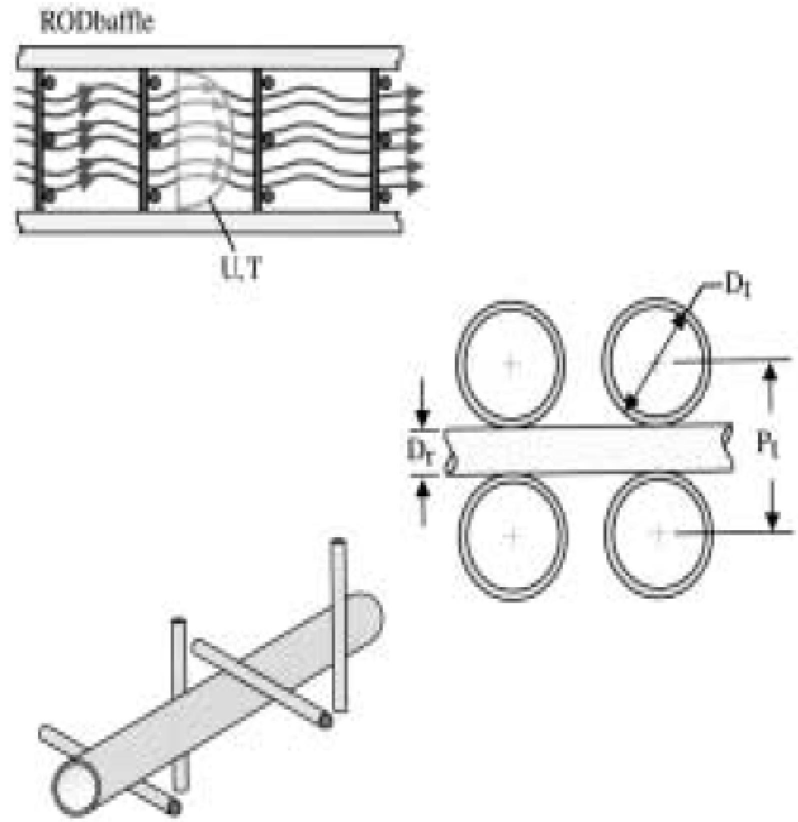


Figure 10-20C. RODbaffle® tube-baffle details. (Used by permission: © Phillips Petroleum Company, Licensing Div., Bul. 1114–94-A–01.)

Piping

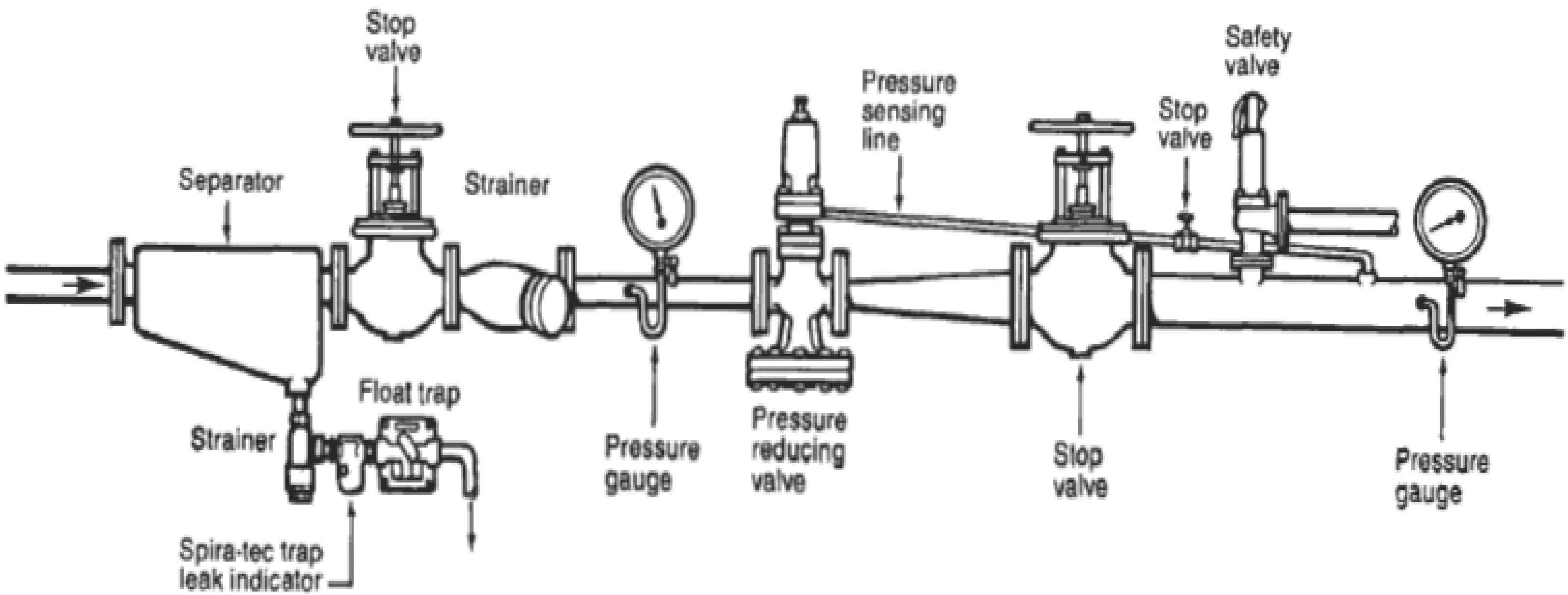


Figure 2-2. Portion of a plant piping system. By permission, Spirax-Sarco, Inc., 1991.

Schedule number(SN)

کد BS 3351

$T=Pd/(20\ s_d+P)$

P(bar) d(mm) $s=N/mm^2$ تنش طراحي در دماي عملياتي

Schedule number = 1000 P/S,

where

P = internal pressure, psig

S = allowable working stress in psi.

عموما sch40

مقدار ضخامت لوله بر اساس مقاومت در برابر فشار داخلي و ميزان خوردگي

PIPE SUPPORT

- PIPERACK
- PIPESLIPPER

- تنش در لوله ها:

۱-انبساط حرارتي دستگاه ها و لوله ها(مهمترين)==> انعطاف پذيري بسيار مهم

۲-وزن حاصل از لوله ، اتصالات،عايق كاري و تجهيزات جانبي(قابل جبران از طريق ساپورتها)

۳-تنش حاصل از عملكرد متقابل در برابر افت فشار(قابل صرفنظر)

۴-بارهاي ناشي از عملكرد تجهيزات فرعي از قبيل شيرهاي اطمينان

۵-لرزه

Velocity Head

Two of the most useful and basic equations are

$$\Delta h = \frac{u^2}{2g} \qquad (1)$$

افت فشار با سرعت نسبت مجذور دارد

$$\Delta P(V) + \frac{\Delta u^2}{2g} + \Delta Z + E = 0 \qquad (2)$$

where

Δh = Head loss in feet of flowing fluid
u = Velocity in ft/sec
$g = 32.2\ ft/sec^2$
P = Pressure in lb/ft^2
V = Specific volume in ft^3/lb
Z = Elevation in feet
E = Head loss due to friction in feet of flowing fluid

when using it with Equation 2, which is the famous Bernoulli equation. The terms are

1. The PV change
2. The kinetic energy change or "velocity head"
3. The elevation change
4. The friction loss

These contribute to the flowing head loss in a pipe.

In Equation 1 Δh is called the "velocity head." This expression has a wide range of utility not appreciated by many. It is used "as is" for

1. Sizing the holes in a sparger
2. Calculating leakage through a small hole
3. Sizing a restriction orifice پاشنده
4. Calculating the flow with a pitot tube

With a coefficient it is used for

1. Orifice calculations
2. Relating fitting losses, etc.

For a sparger consisting of a large pipe having small holes drilled along its length Equation 1 applies directly. This is because the hole diameter and the length of fluid travel passing through the hole are similar dimensions. An orifice on the other hand needs a coefficient in Equation 1 because hole diameter is a much larger dimension than length of travel (say ⅛ in. for many orifices).

Example: heat exchanger tube pressure loss(water)

W=10 kg/s

L=3.2 m

Id=.75 in

(lb=453.6 gr)

Piping Pressure Drop

A handy relationship for turbulent flow in commercial steel pipes is:

$$\Delta P_F = W^{1.8}\mu^{0.2}/20{,}000d^{4.8}\rho$$

where:

ΔP_F = Frictional pressure loss, psi/100 equivalent ft of pipe
W = Flow rate, lb/hr
μ = Viscosity, cp
ρ = Density, lb/ft^3
d = Internal pipe diameter, in.

This relationship holds for a Reynolds number range of 2,100 to 10^6. For smooth tubes (assumed for heat exchanger tubeside pressure drop calculations), a constant of 23,000 should be used instead of 20,000.

Source

Branan, Carl R. "Estimating Pressure Drop," *Chemical Engineering*, August 28, 1978.

Table 1
Equivalent Length of Valves and Fittings in Feet

Nominal Pipe size in.	Globe valve or ball check valve	Angle valve	Swing check valve	Plug cock	Gate or ball valve	45° ell	Short rad. ell	Long rad. ell	Hard T.	Soft T.	90° miter bends			Enlargement					Contraction				
														Sudden			Std. red.		Sudden			Std. red.	
														Equiv. L in terms of small d									
						Weld thrd	Weld thrd	Weld thrd	Weld thrd	Weld thrd	2 miter	3 miter	4 miter	d/D = ¼	d/D = ½	d/D = ¾	d/D = ½	d/D = ¾	d/D = ¼	d/D = ½	d/D = ¾	d/D = ½	d/D = ¾
1½	55	26	13	7	1	1 2	3 5	2 3	8 9	2 3				5	3	1	4	1	3	2	1	1	—
2	70	33	17	14	2	2 3	4 5	3 4	10 11	3 4				7	4	1	5	1	3	3	1	1	—
2½	80	40	20	11	2	2 ..	5 ..	3 ..	12	3 ..				8	5	2	6	2	4	3	2	2	—
3	100	50	25	17	2	2	6	4	14	4				10	6	2	8	2	5	4	2	2	—
4	130	65	32	30	3	3	7	5	19	5				12	8	3	10	3	6	5	3	3	—
6	200	100	48	70	4	4	11	8	28	8				18	12	4	14	4	9	7	4	4	1
8	260	125	64	120	6	6	15	9	37	9				25	16	5	19	5	12	9	5	5	2
10	330	160	80	170	7	7	18	12	47	12				31	20	7	24	7	15	12	6	6	2
12	400	190	95	170	9	9	22	14	55	14	28	21	20	37	24	8	28	8	18	14	7	7	2
14	450	210	105	80	10	10	26	16	62	16	32	24	22	42	26	9	—	—	20	16	8	—	—
16	500	240	120	145	11	11	29	18	72	18	38	27	24	47	30	10	—	—	24	18	9	—	—
18	550	280	140	160	12	12	33	20	82	20	42	30	28	53	35	11	—	—	26	20	10	—	—
20	650	300	155	210	14	14	36	23	90	23	46	33	32	60	38	13	—	—	30	23	11	—	—
22	688	335	170	225	15	15	40	25	100	25	52	36	34	65	42	14	—	—	32	25	12	—	—
24	750	370	185	254	16	16	44	27	110	27	56	39	36	70	46	15	—	—	35	27	13	—	—
30	—	—	—	312	21	21	55	40	140	40	70	51	44										
36	—	—	—		25	25	66	47	170	47	84	60	52										
42	—	—	—		30	30	77	55	200	55	98	69	64										
48	—	—	—		35	35	88	65	220	65	112	81	72										
54	—	—	—		40	40	99	70	250	70	126	90	80										
60	—	—	—		45	45	110	80	260	80	190	99	92										

Sizing Cooling Water Piping in New Plants Maximum Allowable Flow, Velocity and Pressure Drop

	LATERALS			MAINS		
Pipe Size in.	Flow GPM	Vel. ft/sec.	ΔP ft/100′	Flow GPM	Vel. ft/sec.	ΔP ft/100′
3	100	4.34	4.47	70	3.04	2.31
4	200	5.05	4.29	140	3.53	2.22
6	500	5.56	3.19	380	4.22	1.92
8	900	5.77	2.48	650	4.17	1.36
10	1.500	6.10	2.11	1,100	4.48	1.19
12	2,400	6.81	2.10	1,800	5.11	1.23
14	3,100	7.20	2.10	2,200	5.13	1.14
16	4,500	7.91	2.09	3.300	5.90	1.16
18	6,000	8.31	1.99	4.500	6.23	1.17
20	....	....	....	6,000	6.67	1.17
24	....	....	....	11.000	7.82	1.19
30	....	....	....	19.000	8.67	1.11

Sizing Piping for Miscellaneous Fluids

Dry Gas	100 ft/sec
Wet Gas	60 ft/sec
High Pressure Steam	150 ft/sec
Low Pressure Steam	100 ft/sec
Air	100 ft/sec
Vapor Lines General	Max. velocity 0.3 mach 0.5 psi/100 ft
Light Volatile Liquid Near Bubble Pt. Pump Suction	0.5 ft head total suction line
Pump Discharge, Tower Reflux	3–5 psi/100 ft
Hot Oil Headers	1.5 psi/100 ft

Suggested Fluid Velocities in Pipe and Tubing
(Liquids, Gases, and Vapors at Low Pressures to 50 psig and 50°F–100°F)

The velocities are suggestive only and are to be used to approximate line size as a starting point for pressure drop calculations.

The final line size should be such as to give an economical balance between pressure drop and reasonable velocity.

Fluid	Suggested Trial Velocity	Pipe Material
Acetylene (Observe pressure limitations)	4000 fpm	Steel
Air, 0 to 30 psig	4000 fpm	Steel
Ammonia		
Liquid	6 fps	Steel
Gas	6000 fpm	Steel
Benzene	6 fps	Steel
Bromine		
Liquid	4 fps	Glass
Gas	2000 fpm	Glass
Calcium Chloride	4 fps	Steel
Carbon Tetrachloride	6 fps	Steel
Chlorine (Dry)		
Liquid	5 fps	Steel, Sch. 80
Gas	2000–5000 fpm	Steel, Sch. 80
Chloroform		
Liquid	6 fps	Copper & Steel
Gas	2000 fpm	Copper & Steel
Ethylene Gas	6000 fpm	Steel
Ethylene Dibromide	4 fps	Glass
Ethylene Dichloride	6 fps	Steel
Ethylene Glycol	6 fps	Steel
Hydrogen	4000 fpm	Steel
Hydrochloric Acid		
Liquid	5 fps	Rubber Lined
Gas	4000 fpm	R. L., Saran, Haveg
Methyl Chloride		
Liquid	6 fps	Steel
Gas	4000 fpm	Steel
Natural Gas	6000 fpm	Steel
Oils, lubricating	6 fps	Steel
Oxygen	1800 fpm Max.	Steel (300 psig Max.)
(ambient temp.)	4000 fpm	Type 304 SS
(Low temp.)		
Propylene Glycol	5 fps	Steel

Fluid	Suggested Trial Velocity	Pipe Material
Sodium Hydroxide		
0–30 Percent	6 fps	Steel
30–50 Percent	5 fps	and
50–73 Percent	4	Nickel
Sodium Chloride Sol'n.		
No Solids	5 fps	Steel
With Solids	(6 Min.– 15 Max.) 7.5 fps	Monel or nickel
Perchlorethylene	6 fps	Steel
Steam		
0–30 psi Saturated*	4000–6000 fpm	Steel
30–150 psi Saturated or superheated*	6000–10000 fpm	
150 psi up superheated	6500–15000 fpm	
*Short lines	15,000 fpm (max.)	
Sulfuric Acid		
88–93 Percent	4 fps	S. S.-316, Lead
93–100 Percent	4 fps	Cast Iron & Steel, Sch. 80
Sulfur Dioxide	4000 fpm	Steel
Styrene	6 fps	Steel
Trichlorethylene	6 fps	Steel
Vinyl Chloride	6 fps	Steel
Vinylidene Chloride	6 fps	Steel
Water		
Average service	3–8 (avg. 6) fps	Steel
Boiler feed	4–12 fps	Steel
Pump suction lines	1–5 fps	Steel
Maximum economical (usual)	7–10 fps	Steel
Sea and brackish water, lined pipe	5–8 fps } 3 (Min.)	R. L., concrete, asphalt-line, saran-lined, transite
Concrete	5–12 fps } 3 (Min.)	

آلیاژی از نیکل و کبالت که در برابر
خوردگی مقاوم است

Note: R. L. = Rubber-lined steel.

Typical Design Vapor Velocities* (ft./sec.)

Fluid	Line Sizes ≤6"	8"–12"	≥14"
Saturated Vapor			
0 to 50 psig	30–115	50–125	60–145
Gas or Superheated Vapor			
0 to 10 psig	50–140	90–190	110–250
11 to 100 psig	40–115	75–165	95–225
101 to 900 psig	30–85	60–150	85–165

**Values listed are guides, and final line sizes and flow velocities must be determined by appropriate calculations to suit circumstances. Vacuum lines are not included in the table, but usually tolerate higher velocities. High vacuum conditions require careful pressure drop evaluation.*

Typical Design* Velocities for Process System Applications

Service	Velocity, ft./sec.
Average liquid process	4–6.5
Pump suction (except boiling)	1–5
Pump suction (boiling)	0.5–3
Boiler feed water (disch., pressure)	4–8
Drain lines	1.5–4
Liquid to reboiler (no pump)	2–7
Vapor-liquid mixture out reboiler	15–30
Vapor to condenser	15–80
Gravity separator flows	0.5–1.5

**To be used as guide, pressure drop and system environment govern final selection of pipe size.*
For heavy and viscous fluids, velocities should be reduced to about ½ values shown.
Fluids not to contain suspended solid particles.

Suggested Steam Pipe Velocities in Pipe Connecting to Steam Turbines

Service—Steam	Typical range, ft./sec.
Inlet to turbine	100–150
Exhaust, non-condensing	175–200
Exhaust, condensing	400–500

Sources

1. Branan, C. R., *The Process Engineer's Pocket Handbook*, Vol. 1, Gulf Publishing Co., 1976.
2. Ludwig, E. E., *Applied Process Design for Chemical and Petrochemical Plants*, 2nd Ed., Gulf Publishing Co.
3. Perry, R. H., *Chemical Engineer's Handbook*, 3rd Ed., p. 1642, McGraw-Hill Book Co.

GENERAL INFORMATION/EQUIPMENT DESIGN

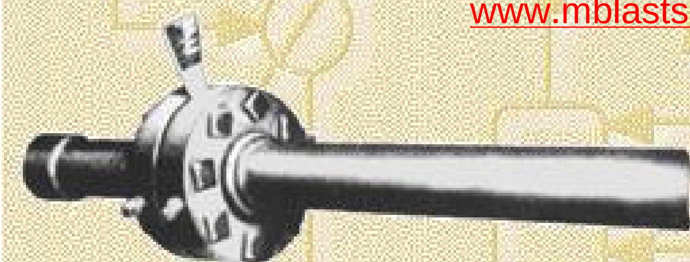
(Pictures courtesy of Badger Meter, Inc., Tulsa, OK)

Orifices, also called orifice plates, constrict fluid flow using a flat metal disc with a circular hole in the center, such as the one to the left. This constriction causes a pressure drop across the plate. Pressure taps on both sides of the orifice measure the differential.

The bottom left picture shows an orifice plate installed between flanges in a pipe.

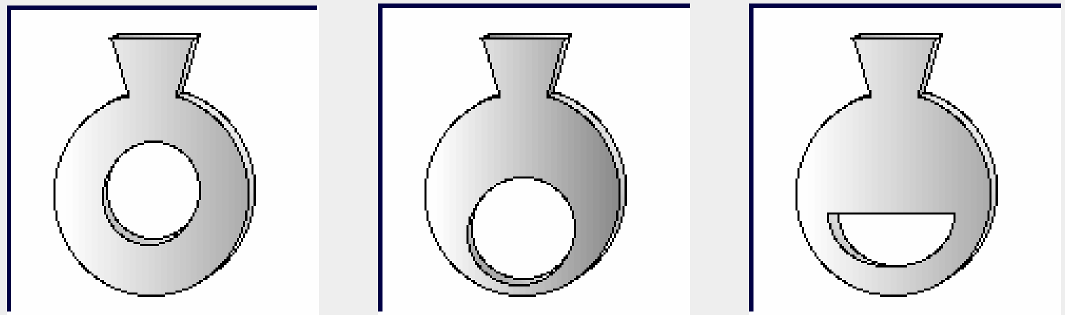
Different flow conditions are accommodated by changing the location of the orifice in the plate and the way the edge is bored.

www.mblastsavior.mihanblog.com



(Courtesy of KOBOLD Instruments Inc., Pittsburgh, PA)

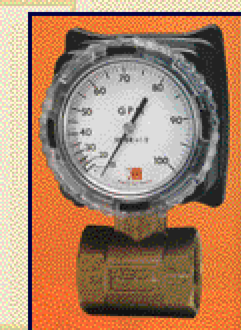
Concentric orifices are the most common. **Eccentric** and **segmental** orifices are used to prevent entrained liquids or gases from building up at the plate. The hole is placed at the bottom of the plate for gas flows (to allow passage of heavier liquid particles) and at the top of the plate for liquid flows (to allow passage of lighter gas particles).



Concentric **Eccentric** **Segmental**

Click to Continue

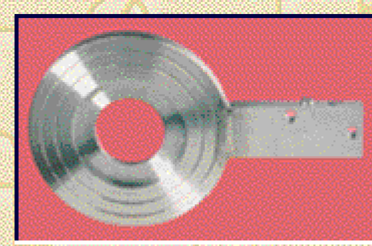
USAGE EXAMPLES

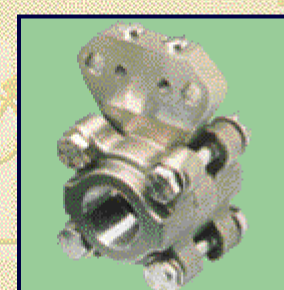


Most gas, water, steam, and air applications are easily metered by orifice plates.

Orifices such as the one above left, made of bronze, and below left, made of bronze and cast iron, can be used to meter lube oil, cooling water systems, and compressed air flow.

The two orifice meters below are made of stainless steel and are specially designed to handle corrosive materials, such as strong acids and bases.





(Pictures courtesy of KOBOLD Instruments Inc., Pittsburgh, PA)

Condition I.

A single pipe line which consists of two or more different diameter lines.

Let L_E = equivalent length

$L_1, L_2, \ldots L_n$ = length of each diameter

$D_1, D_2, \ldots D_n$ = internal diameter of each separate line corresponding to $L_1, L_2, \ldots L_n$

D_E = equivalent internal diameter

$$L_e = L_1\left[\frac{D_E}{D_1}\right]^{4.8539} + L_2\left[\frac{D_E}{D_2}\right]^{4.8539} + \ldots L_n\left[\frac{D_E}{D_n}\right]^{4.8539}$$

مثال

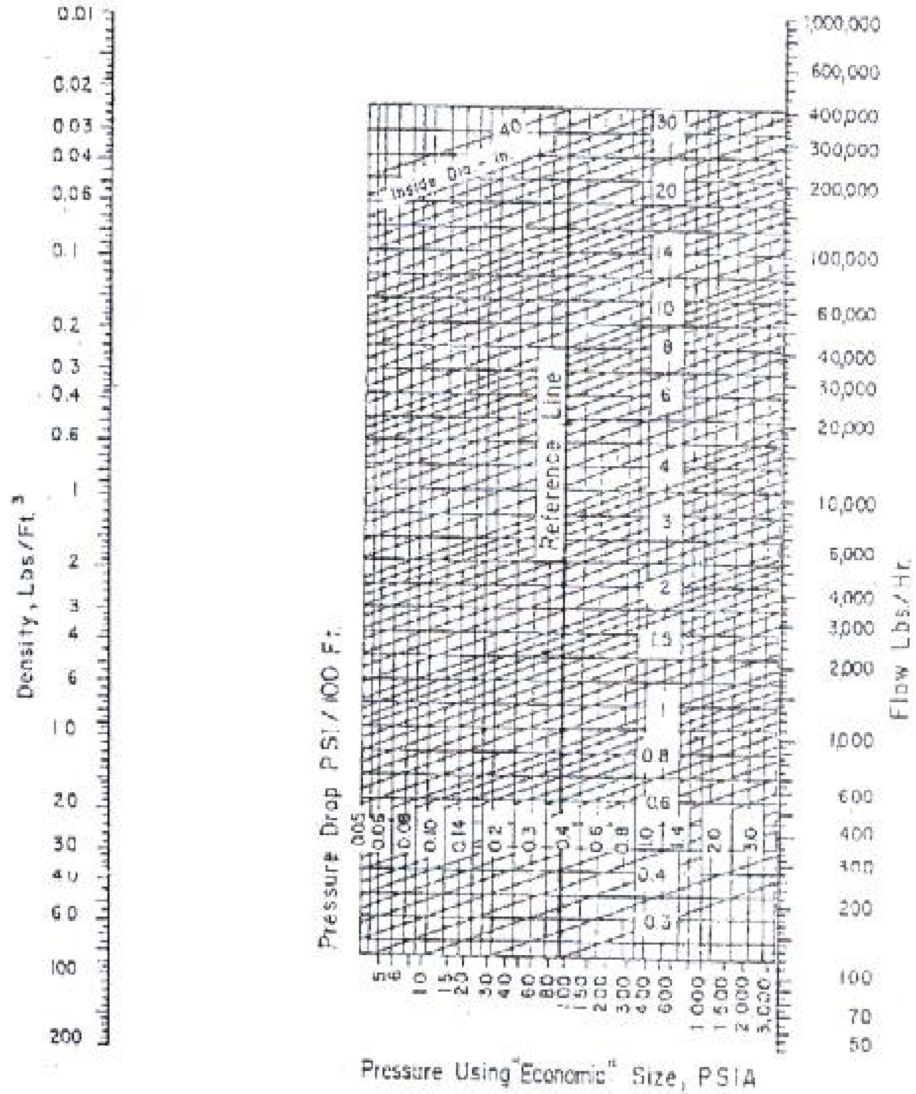
Example. A single pipe line, 100 miles in length consists of 10 miles 10¾-in. OD; 40 miles 12¾-in. OD and 50 miles of 22-in. OD lines.

Find equivalent length (L_E) in terms of 22-in. OD pipe.

$$L_E = 50 + 40\left[\frac{21.5}{12.25}\right]^{4.8539} + 10\left[\frac{21.5}{10.25}\right]^{4.8539}$$

$= 50 + 614 + 364$

$= 1{,}028$ miles equivalent length of 22-in. OD



روش کار با نمودار: یک خط از دانسیته سیال مورد نظر به دبی وصل کنید سپس از محل تقاطع این خط با خط مبنا یک خط رسم کنید. حال یا بر اساس افت فشار، قطر و فشار عملیاتی را بدست آورید و یا بر اساس قطر، افت فشار و فشار عملیاتی و اساس فشار عملیاتی، قطر و افت فشار را بخوانید (خطوط عمودی) - "قابل توجه است که این نمودار برای زبری 0.004 تهیه شده است"

نمودار تعیین اندازه خط لوله و تخمین افت فشار و فشار عملیاتی

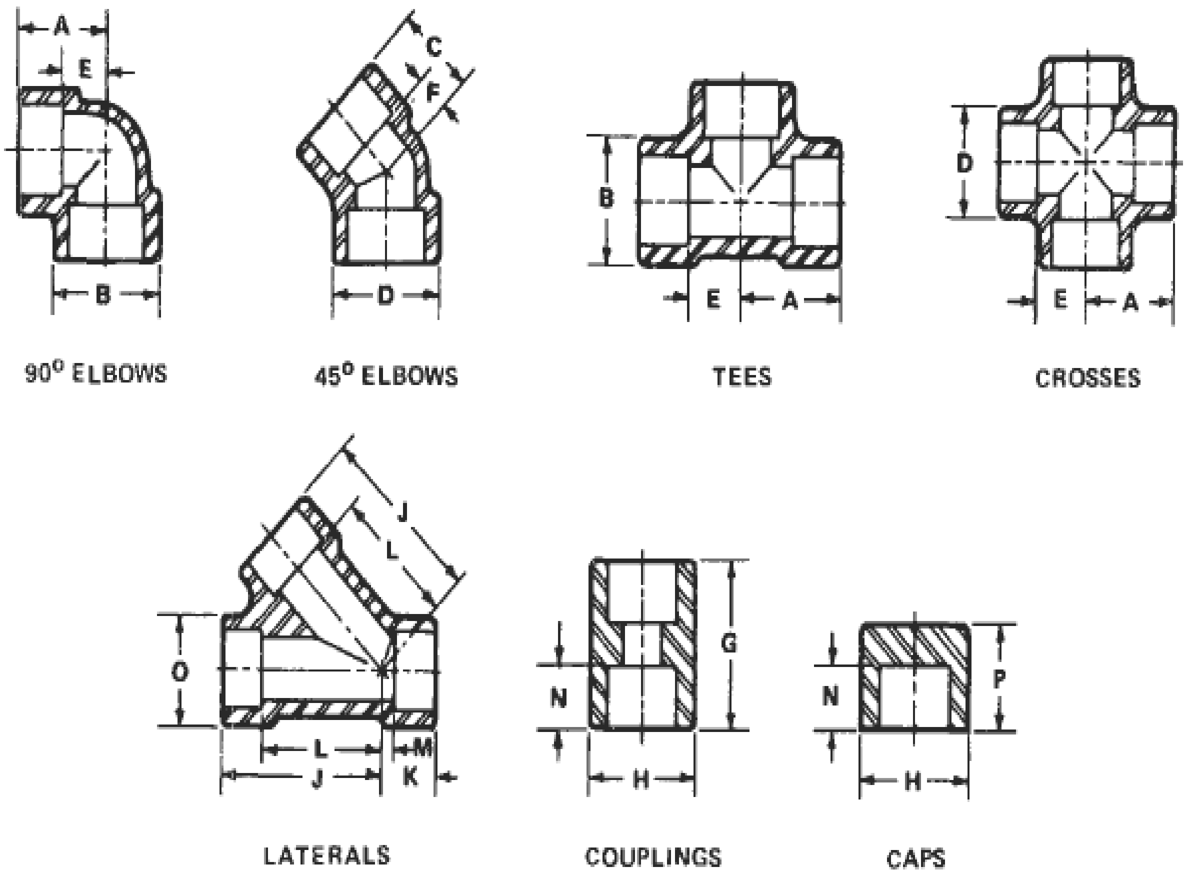


Figure 2-4B. Forged steel socket weld fittings, WOG (water, oil or gas service). Note: the working pressures are always well above actual plant operating levels and are heavy to allow for welding. Pressure classes 3000 psi and 6000 psi, sizes ⅛ in. through 4 in. nominal. Do not weld on malleable iron or cast iron fittings. (By permission, Ladish Co., Inc.)

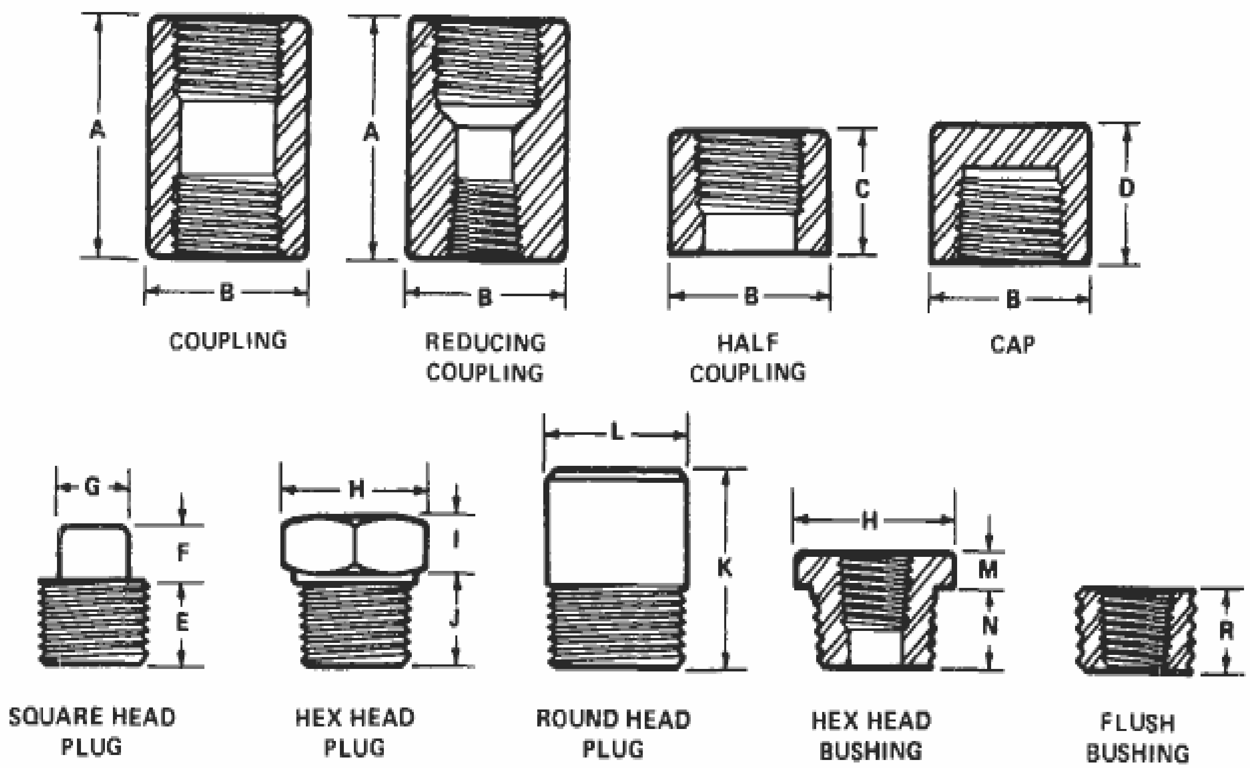


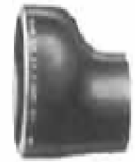
Figure 2-4A. Forged steel threaded pipe fittings, WOG (water, oil or gas service). Note: the working pressures are always well above actual plant operating levels. Pressure classes 3000 psi and 6000 psi, sizes ⅛ in. through 4 in. nominal. By permission, Ladish Co., Inc.

Nominal Pipe Size	O.D. Inches		I.D. Inches	
Inches	Schedule 40	80	40	80
¾	1.050	1.050	0.824	0.742
1	1.315	1.315	1.049	0.957
1½	1.900	1.900	1.610	1.500
2	2.375	2.375	2.067	1.939
3	3.500	3.500	3.068	2.900
4	4.500	4.500	4.026	3.826

American Standards Association piping pressure classes are:

ASA Pressure Class	Schedule No. of Pipe
≤ 250 lbs./sq. in.	40
300–600	80
900	120
1500	160
2500 (½ in.–6 in.)	XX (double extra strong)
2500 (8 in. and larger)	160

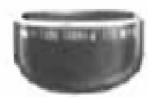
90° ELBOWS
Long Radius
Pages 12 - 17



ECCENTRIC REDUCERS
Pages 63 - 70

PIPELINE and WELDING NECK FLANGES
Pages 100 - 115

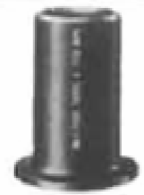
90° ELBOWS
Long Tangent
One End
Page 16



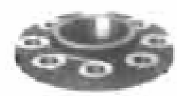
CAPS
Pages 71 - 75

SLIP-ON FLANGES
Pages 101 - 115

90° REDUCING ELBOWS
Long Radius
Pages 18 - 21



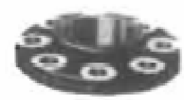
LAP JOINT STUB ENDS
Pages 76 - 77



LAP JOINT FLANGES
Pages 102 - 115

3R ELBOWS
45° and 90°
Page 22

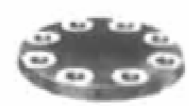
LATERALS
Straight and Reducing Outlet
Page 78



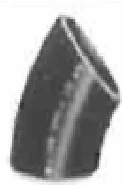
THREADED FLANGES
Pages 102 - 115

90° ELBOWS
Short Radius
Pages 23 - 25

SHAPED NIPPLES
Page 79



BLIND FLANGES
Pages 102 - 115



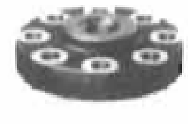
45° ELBOWS
Long Radius
Pages 26 - 30

SLEEVES
Page 80

SOCKET TYPE WELDING FLANGES
Pages 102 - 105
108 - 109
112 - 113

180° RETURNS
Long Radius
Pages 31 - 35

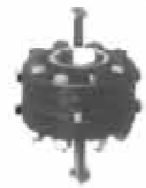
SADDLES
Page 80



REDUCING FLANGES
Pages 102 - 115

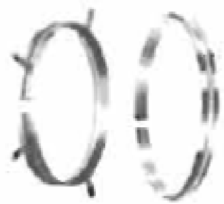
180° RETURNS
Short Radius
Pages 37 - 39

FULL ENCIRCLEMENT SADDLES
Page 81



ORIFICE FLANGES
Pages 116 - 123

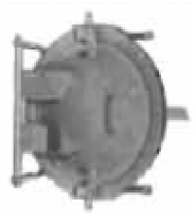
TEES
Straight and Reducing Outlet
Pages 40 - 57



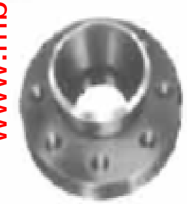
WELDING RINGS
Pages 82 - 83

LARGE DIAMETER FLANGES
Pages 130 - 142

CROSSES
Straight and Reducing Outlet
Pages 58 - 62



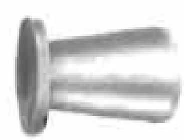
HINGED CLOSURES
Pages 84 - 87



EXPANDER FLANGES
Page 143

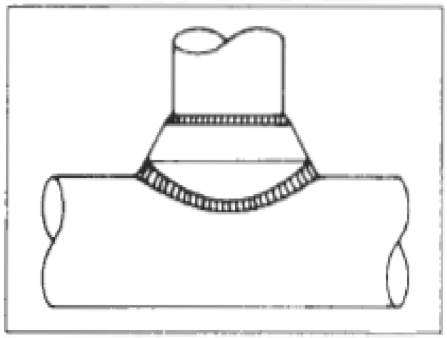
CONCENTRIC REDUCERS
Pages 63 - 70

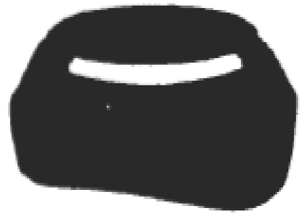
T-BOLT CLOSURES
Pages 88 - 89



VENTURI EXPANDER FLANGES
Page 144

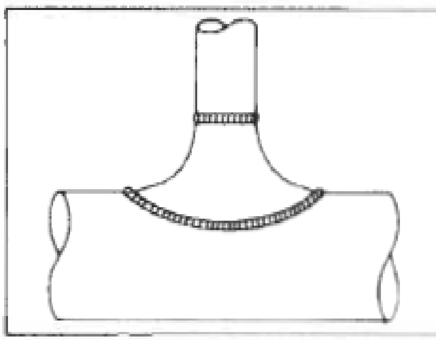
Weldolet





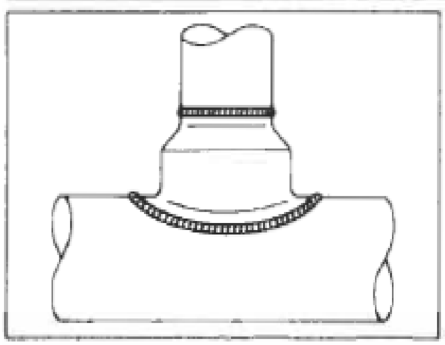
Weldolet®, an economical butt-weld branch connection, is designed to minimize stress concentrations and provide integral reinforcement.

Sweepolet



Sweepolet® is a contoured, integrally reinforced, butt-weld branch connection with a low stress intensification factor for low stresses and long fatigue life. The attachment weld is easily examined by radiography, ultrasound and other standard non-destructive techniques.

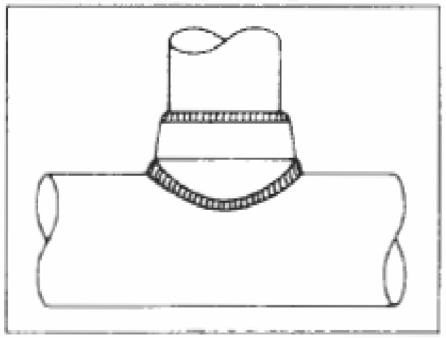
Insert Weldolet



Insert Weldolet® is another contoured butt-weld branch connection used in less critical applications. Like the Sweepolet, the attachment welds are easily examined by radiography, ultrasound and other standard non-destructive techniques.

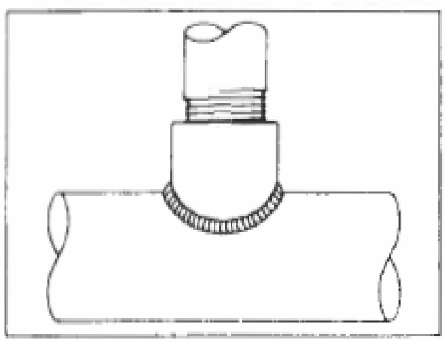
www.mblastsavior.parsiblog.com

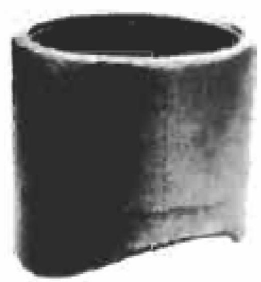
Sockolet



Sockolet® utilizes the basic Weldolet design configuration and incorporates a socket-weld outlet.

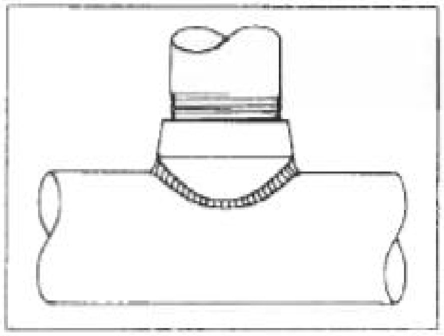
Coupolet





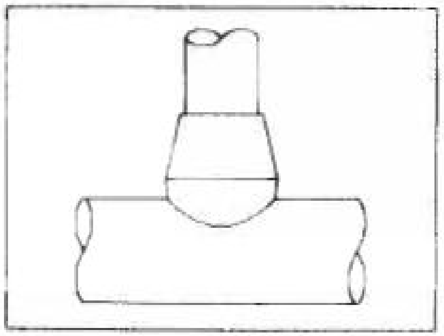
Coupolet® fittings are designed for use in fire protection sprinkler systems and other low pressure piping applications.

Thredolet



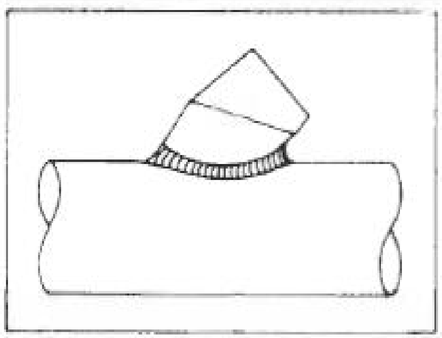
Thredolet® utilizes the basic Weldolet configuration, provides a threaded outlet branch connection.

Brazolet

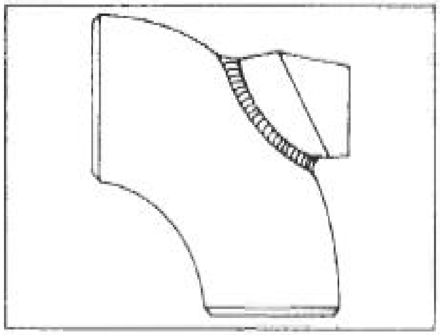


Brazolet® is designed for use with KLM and IPS brass or copper piping or copper tubing.

Latrolet

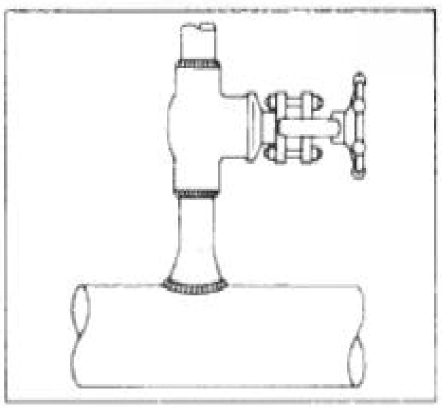


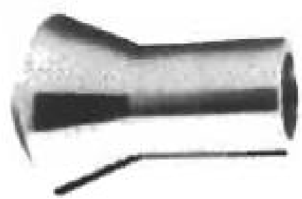
Latrolet® used for 45° lateral connections, is available butt-weld to meet your specific reinforcement requirements, and 3000# or 6000# classes for socket weld and threaded applications.



Elbolet

Elbolet® is used on **90° Long Radius** Elbows (can be manufactured for Short **Radius** Elbows) for thermowell and instrumentation connections. Available butt-weld to meet your specific reinforcement requirements, and **3000#** and 6000# classes for socket weld and threaded applications.

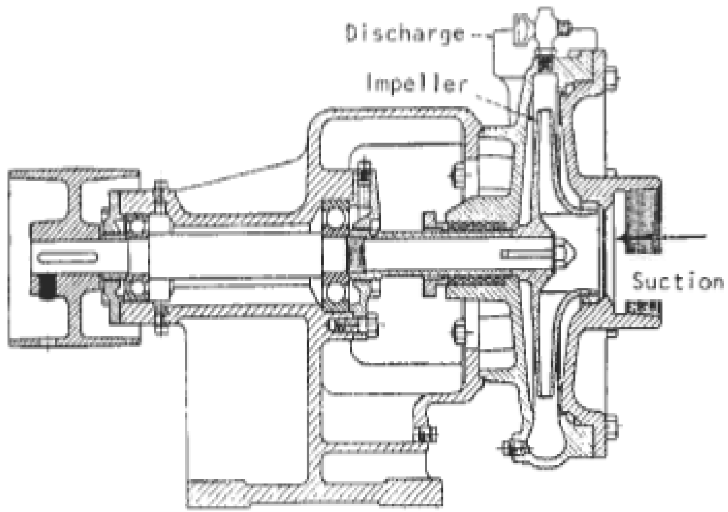




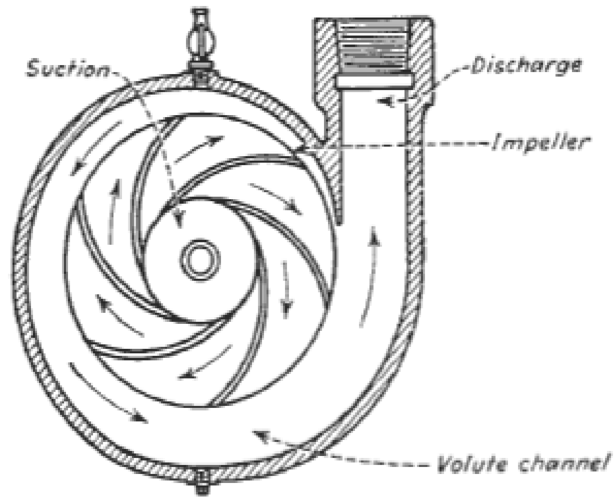
Nipolet

Nipolet® is a one piece fitting for valve take-offs, drains and vents. Available with male socket-weld or male threaded outlets.

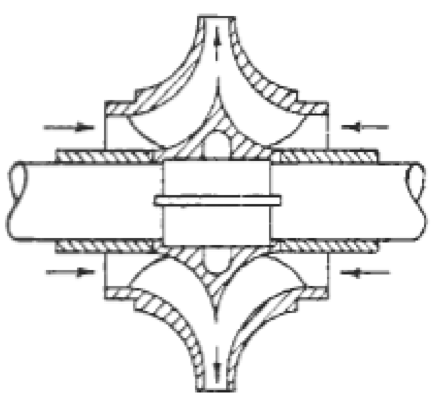
PUMP & Compressor



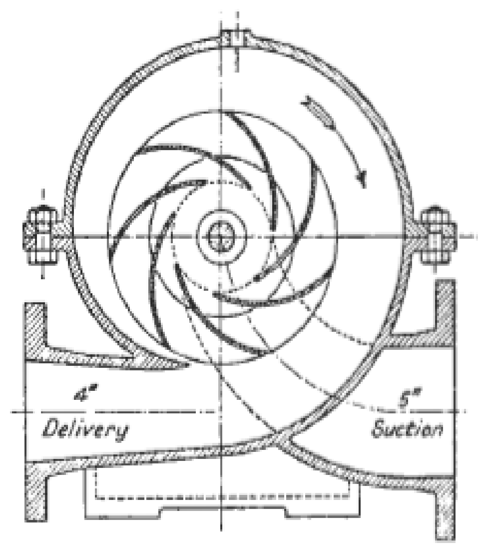
(a)



(b)



(c)



(d)

Some types of centrifugal pumps. (a) Single-stage, single suction volute pump. (b) Flow path in a volute pump. (c) Double suction for minimizing axial thrust. (d) Horizontally split casing for ease of maintenance.

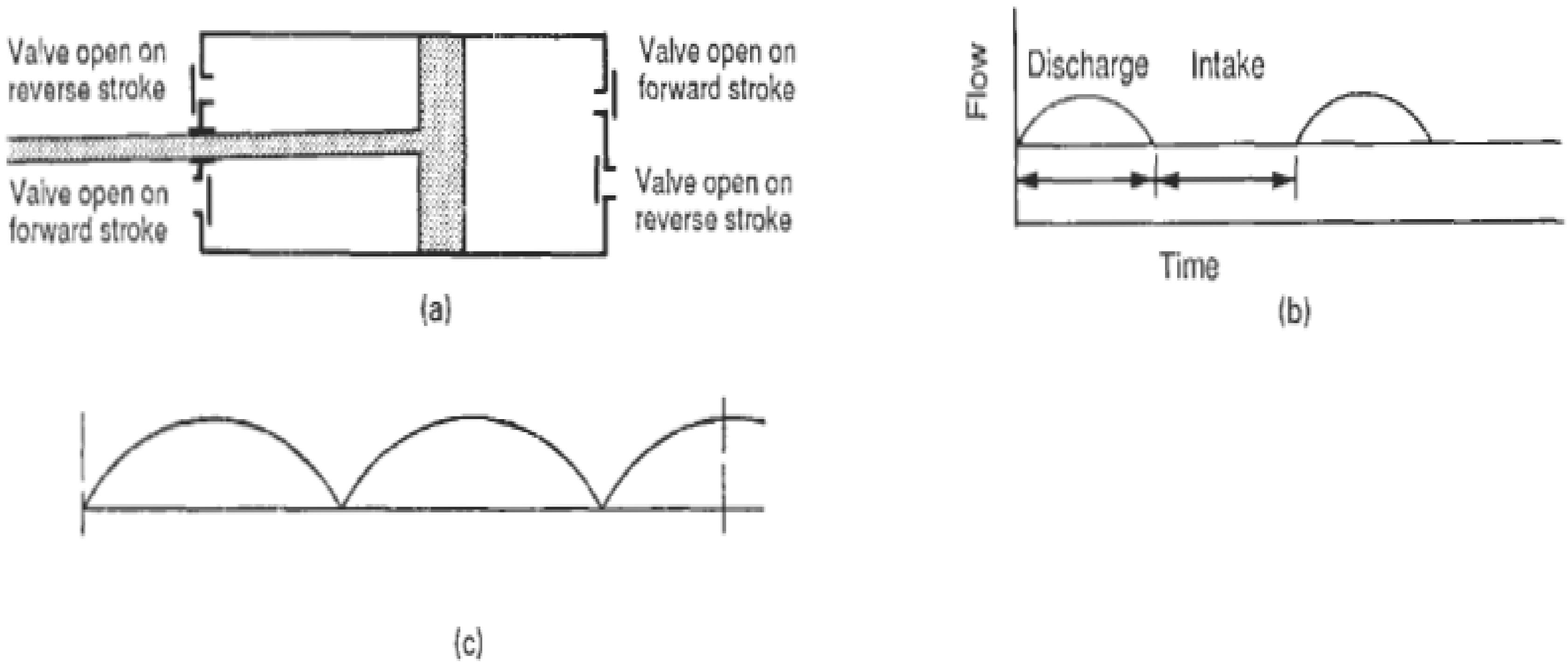
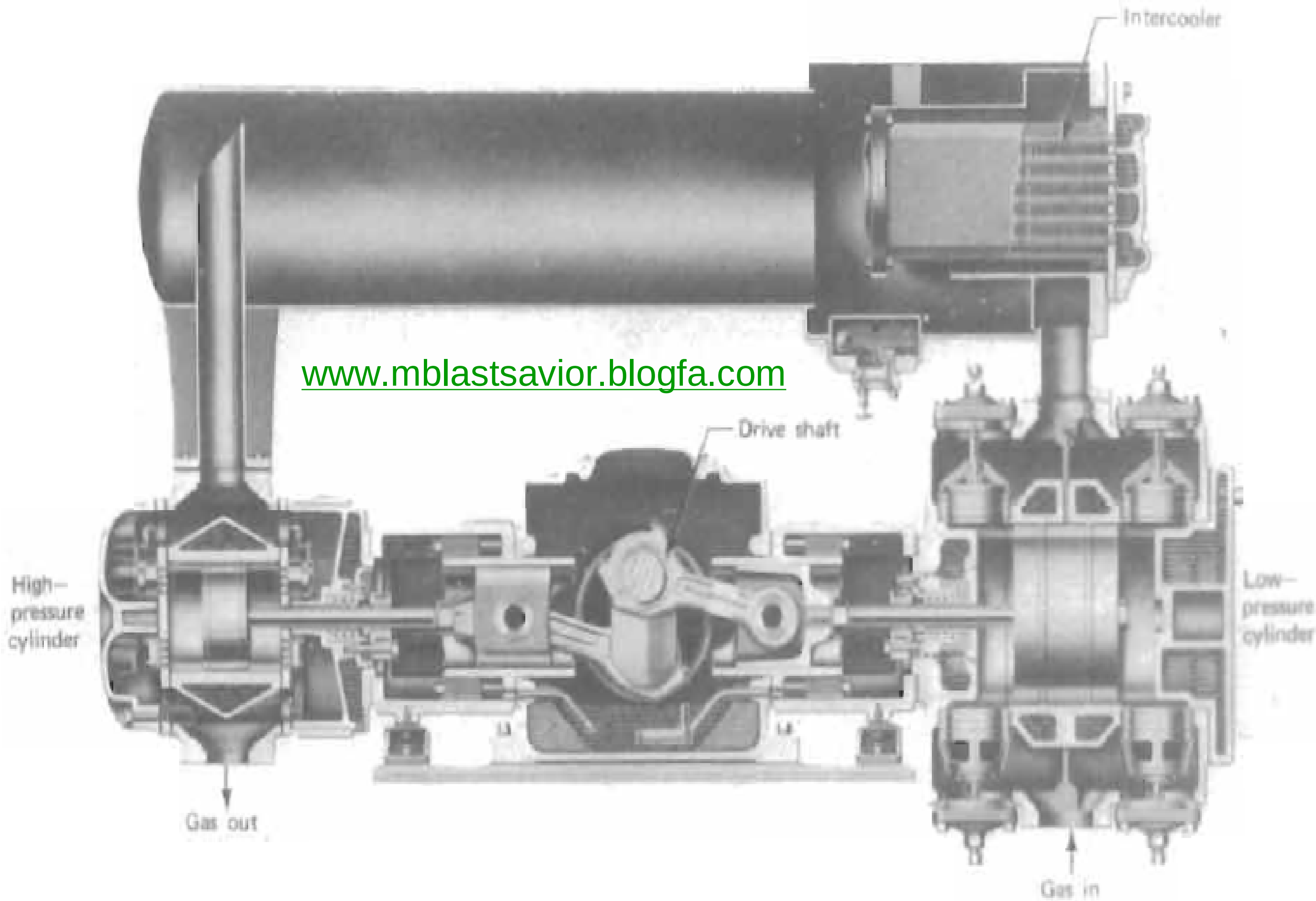


Figure 7.12. Some types of positive displacement pumps. (a) Valve action of a double acting reciprocating piston pump. (b) Discharge curve of a single acting piston pump operated by a crank; half-sine wave. (c) Discharge curve of a simplex double acting pump as in (a). (d)



Double-acting, two-stage reciprocating compressor with water-cooled jacket and intercooler

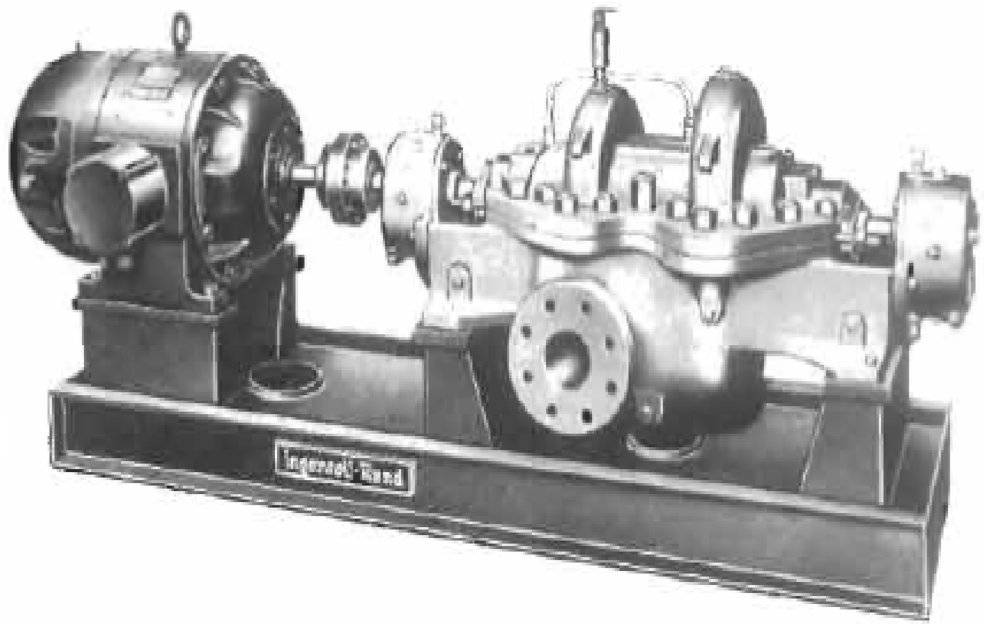


Figure 3-7. Exterior view of horizontal two-stage split case centrifugal pump. (Courtesy Ingersoll-Rand Co.)

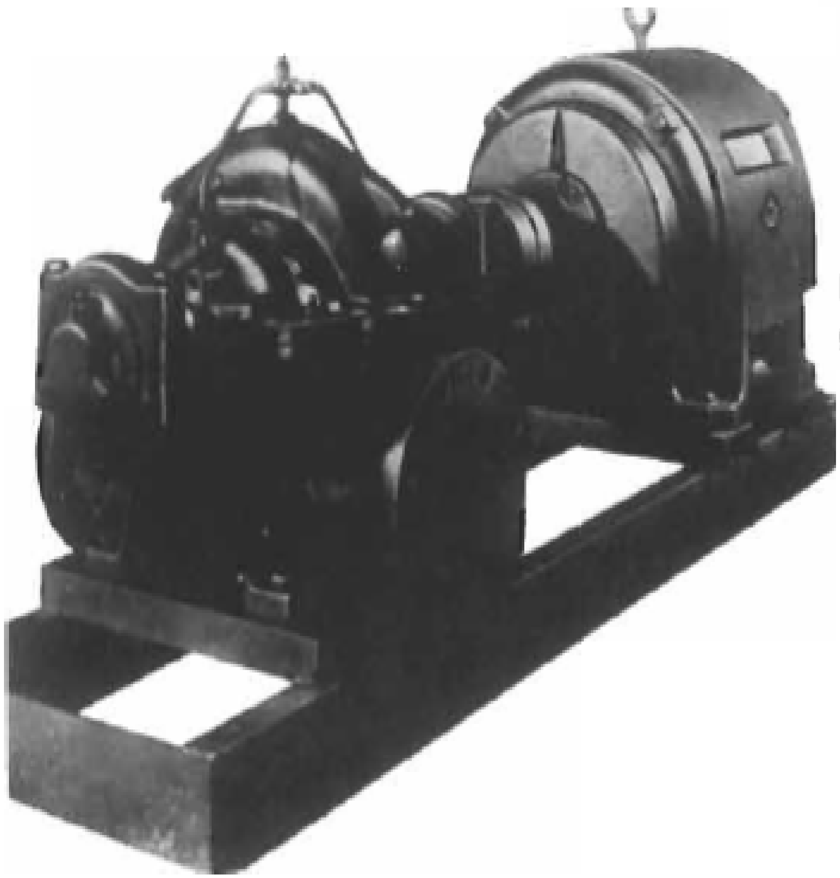
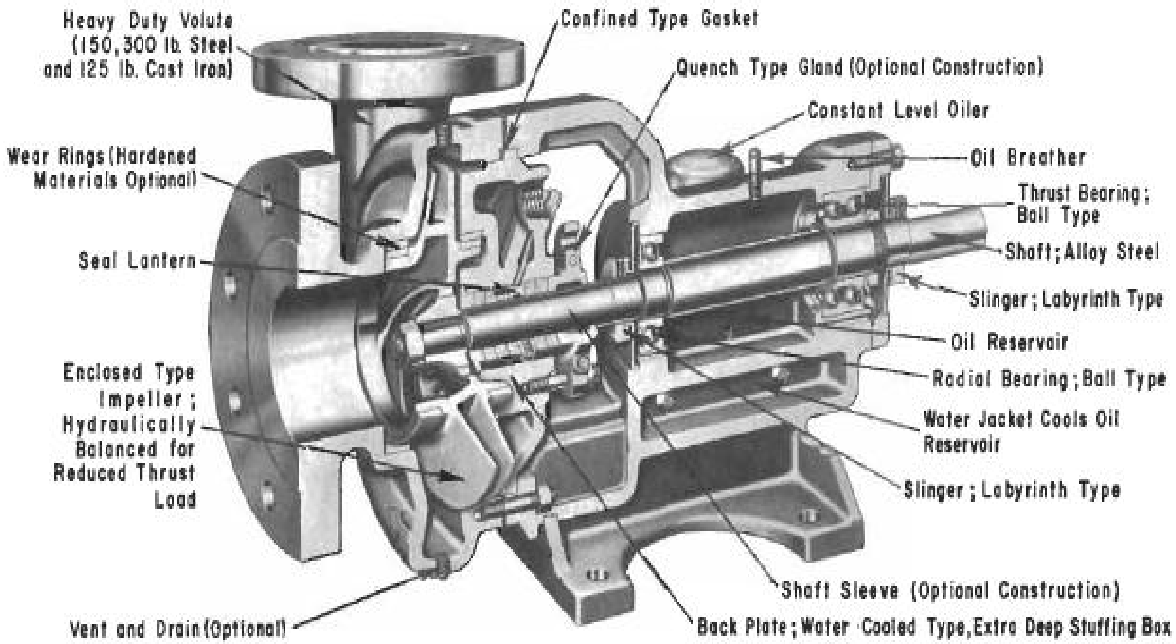


Figure 3-5. External view double suction single-stage pump. (Courtesy Allis-Chalmers Mfg. Co.)



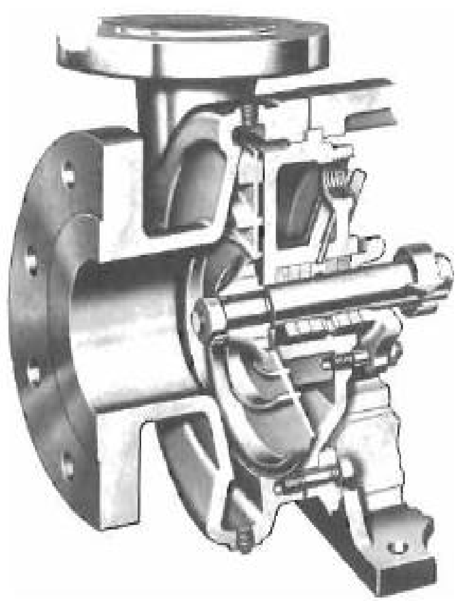
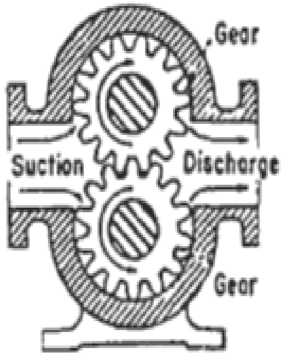
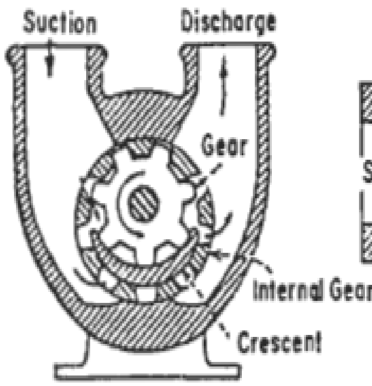


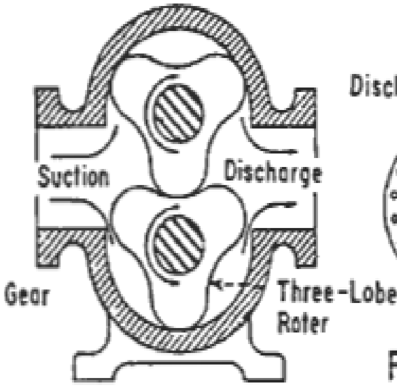
Figure 3-2. Cut-a-way section of single-stage pump. Part 1 (above) enclosed type impeller, Part 2 (lower left) open type impeller. (Courtesy Peerless Pump Div. FMC Corp.)



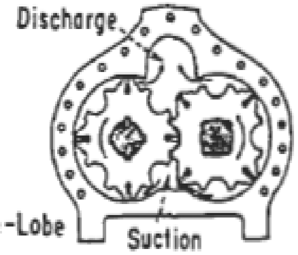
External Gear Pump



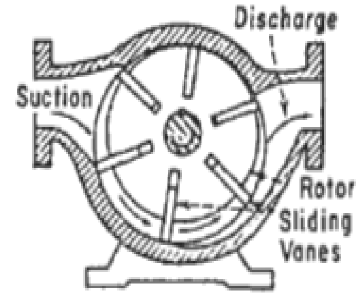
Internal Gear Pump



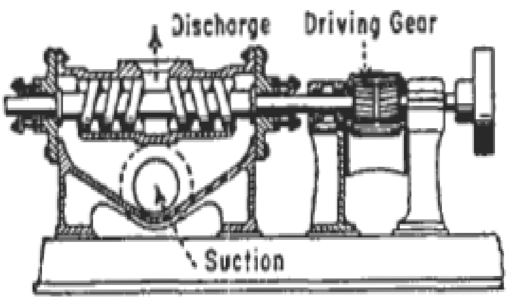
Three-Lobe Pump



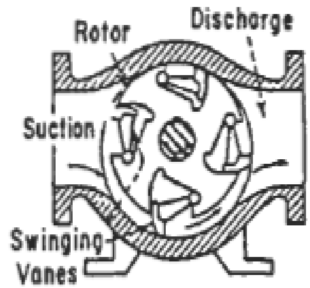
Four-Lobe Pump



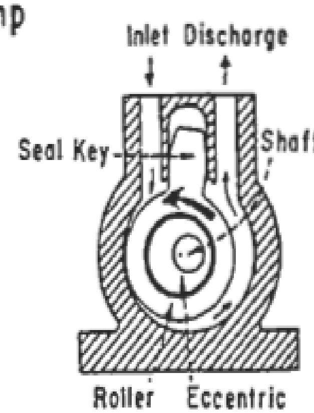
Sliding Vane Pump



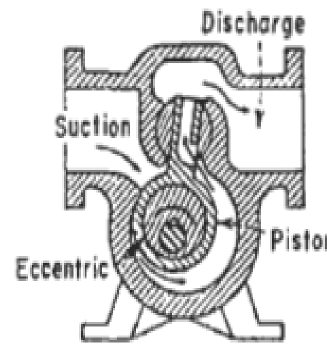
Single Screw Pump



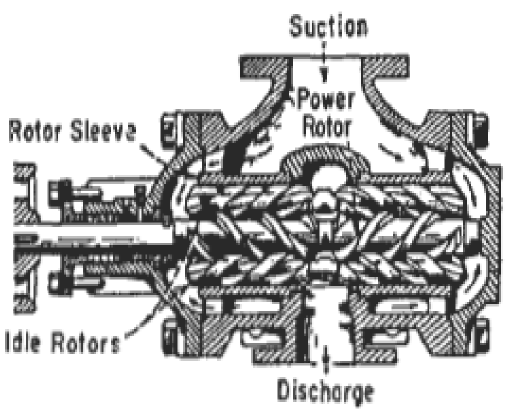
Swinging Vane Pump



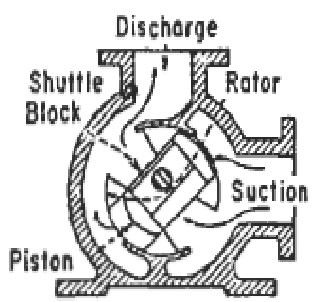
Cam or Roller Pump



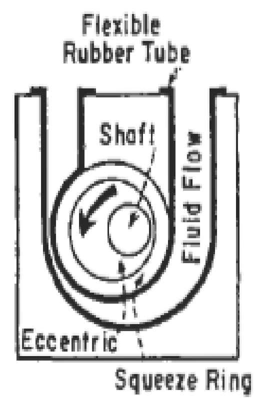
Cam-and-Piston Pump



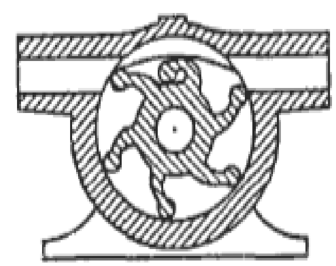
Three-Screw Pump



Shuttle Block Pump



Squeegee Pump



Flexible Vane

ی

Impellers

- The three common types of impellers that impart the
- 1. Fully enclosed-used for high head, high pressure applications.
- 2. Semi-enclosed-used for general purpose applications, has open vane tips at entrance to break up suspended particles and prevent clogging.
- 3. Open-used for low heads, suspended solids applications,
- very small flows.

Table 3-3
Basic Parts of a Centrifugal Pump

Part	Purpose
Impeller	Imparts velocity to the liquid, resulting from centrifugal force as the impeller is rotated.
Casing	Gives direction to the flow from the impeller and converts this velocity energy into pressure energy which is usually measured in feet of head.
Shaft	Transmits power from the driver to the impeller.
Stuffing box	This is a means of throttling the leakage which would otherwise occur at the point of entry of the shaft into the casing. Usually not a separate part, but rather made up of a group of small details, as "A" to "D".
(A) Packing	This is the most common means of throttling the leakage between the inside and outside of the casing.
(B) Gland	To position and adjust the packing pressure.
(C) Seal gage (also called water-seal or lantern ring	Provides passage to distribute the sealing medium uniformly around the portion of the shaft that passes through the stuffing box. This is very essential when suction lift conditions prevail to seal against in-leakage of air.
(D) Mechanical seal	Provides a mechanical sealing arrangement that takes the place of the packing. Basically it has one surface rotating with the shaft and one stationary face. The minutely close clearance between these two faces prevents leakage of liquid out or air in.
Shaft sleeve	Protects the shaft where it passes through the stuffing box. Usually used in pumps with packing but often eliminated if mechanical seals are employed.
Wearing rings	Keeps internal recirculation down to a minimum. Having these rings as replaceable wearing surfaces permits renewal of clearances to keep pump efficiencies high. On small types only one ring is used in the casing and on larger sizes, companion rings are used in the casing and on the impeller.
Wearing plates	With open type impellers or end clearance wearing fits, these perform the same purpose as wearing rings do with radial clearances.
Bearings	Accurately locate shaft and carry radial and thrust loads.
Frame	To mount unit rigidly and support bearings. In most single suction pumps this is a separate piece. In many double suction pumps, the support is through feet cast as part of the casing. In some special suction pumps, the feet are also part of the casing and the bearing assembly is overhung. With close coupled single suction types, this support is provided by the motor or by special supporting adapters.
Coupling	Connects the pump to the driver.

Minimum Flow

Most pumps need minimum flow protection to protect them against shutoff. At shutoff, practically all of a pump's horsepower turns into heat, which can vaporize the liquid and damage the pump. Such minimum flow protection is particularly important for boiler feedwater pumps that handle water near its boiling point and are multistaged for high head. The minimum flow is a relatively constant flow going from discharge to suction. In the case of boiler feedwater pumps, the minimum flow is preferably piped back to the deaerator.

The process engineer must plan for minimum flow provisions when making design calculations. For preliminary work, approximate the required minimum flow by assuming all the horsepower at blocked-in conditions turns into heat. Then, provide enough minimum flow to carry away this heat at a 15°F rise in the minimum flow stream's temperature.

This approach will provide a number accurate enough for initial planning. For detailed design, the process engineer should work closely with the mechanical engineer and/or vendor representative involved to set exact requirements, including orifice type and size for the minimum flow line. Also, a cooler may be required in the minimum flow line or it may need to be routed to a vessel. For boiler feedwater pumps, a special stepped type orifice is often used to control flashing.

Source

Branan, C. R., *The Process Engineer's Pocket Handbook*, Vol. 2, Gulf Publishing Co., 1983.

pressure and any pressure losses in the entire suction system such as:

1. Friction losses in straight pipe, valves, and fittings
2. Loss from vessel to suction line
3. Loss through equipment in the suction line (such as a heat exchanger)

Suction System NPSH for Studies

For studies or initial design it is good to have quick estimates of pump NPSH. Evans discusses the general formula

$$n(Q)^{0.5} / (NPSH)^{3/4} = C$$

where

n = Speed, rpm
Q = Capacity, gpm
C = A constant between 7,000 and 10,000

Evans plotted the relationship with C = 9,000 resulting in the following graph for initial estimates of minimum NPSH required.

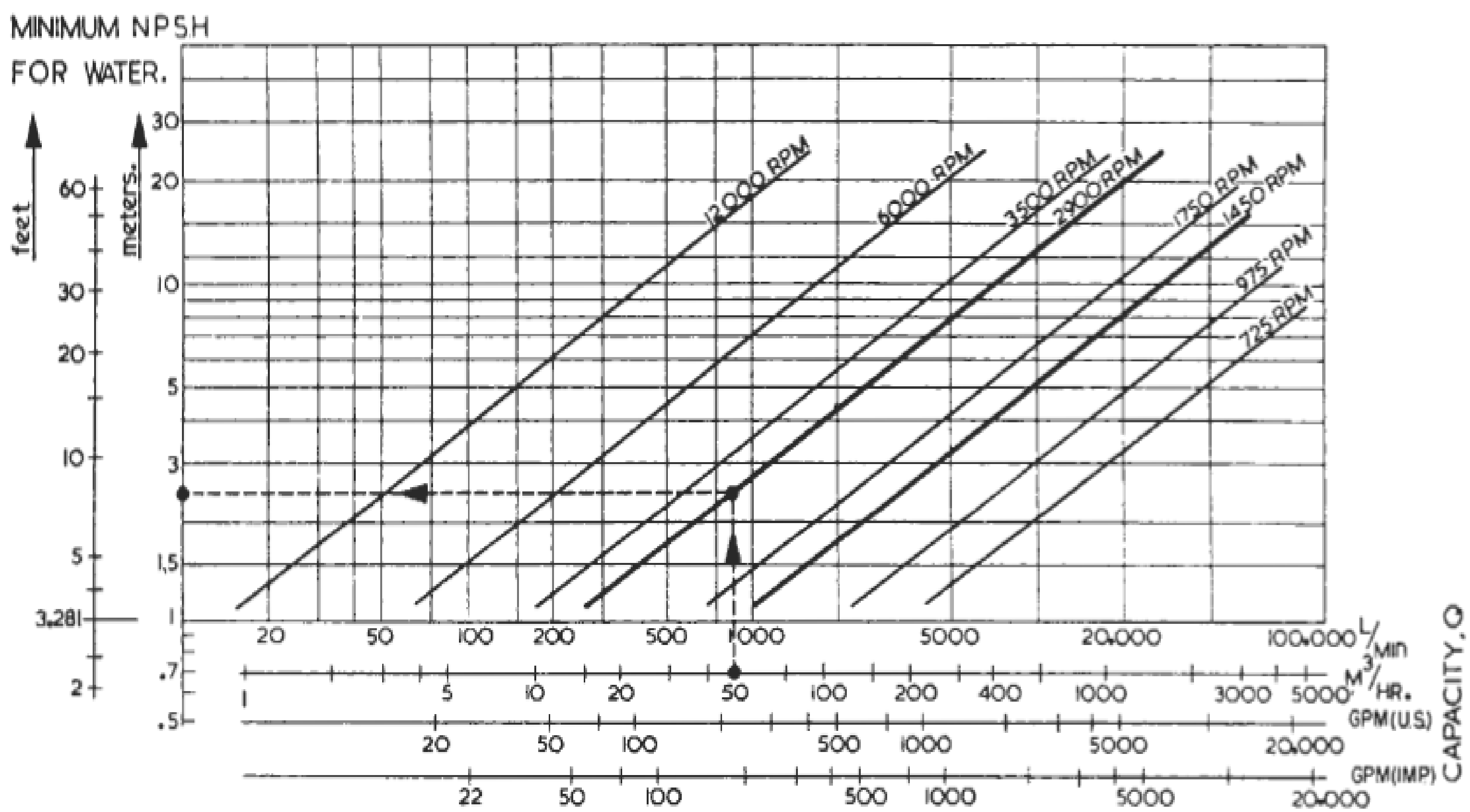
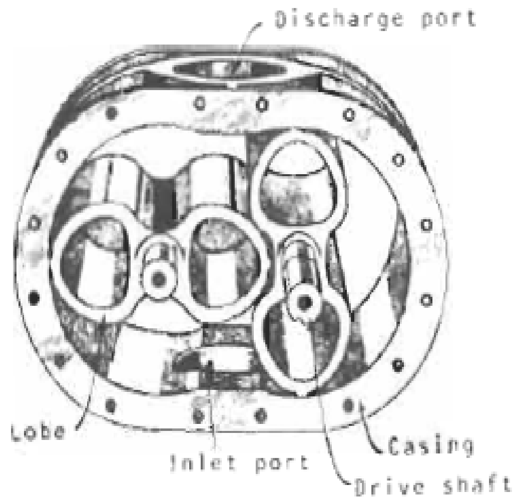
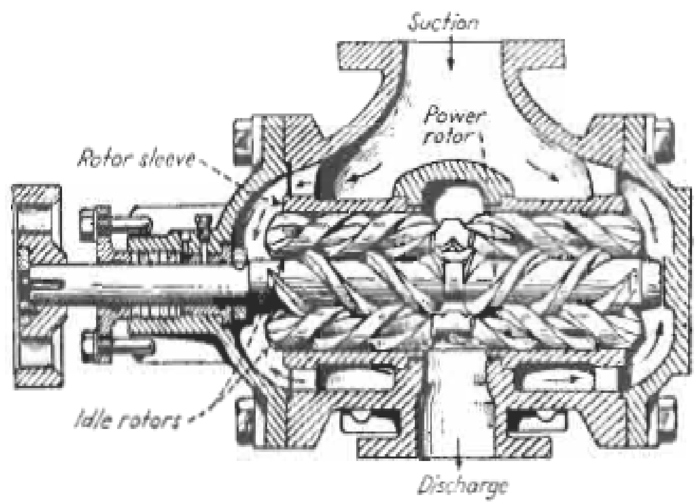
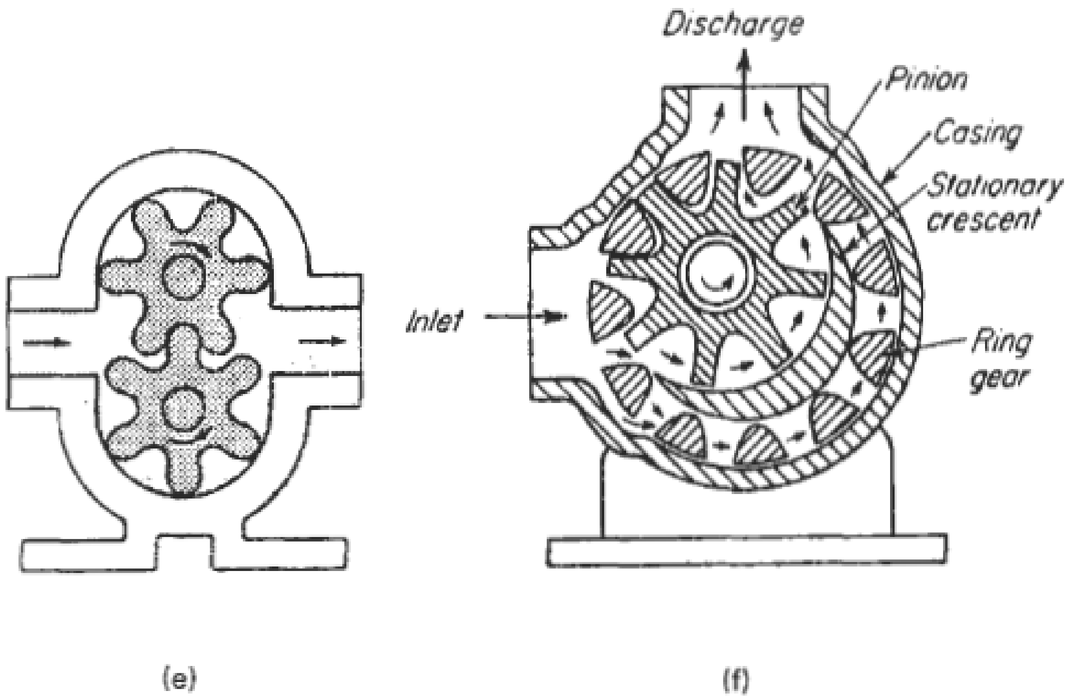


Figure 1. Use these curves to find minimum NPSH required.


Discharge port
Lobe
Inlet port
Casing
Drive shaft

(a)


Suction
Power rotor
Rotor sleeve
Idle rotors
Discharge



e) An external gear pump; characteristics are in Figure 7.8(c). (f) Internal gear pump; the outer gear is driven, the inner one follows

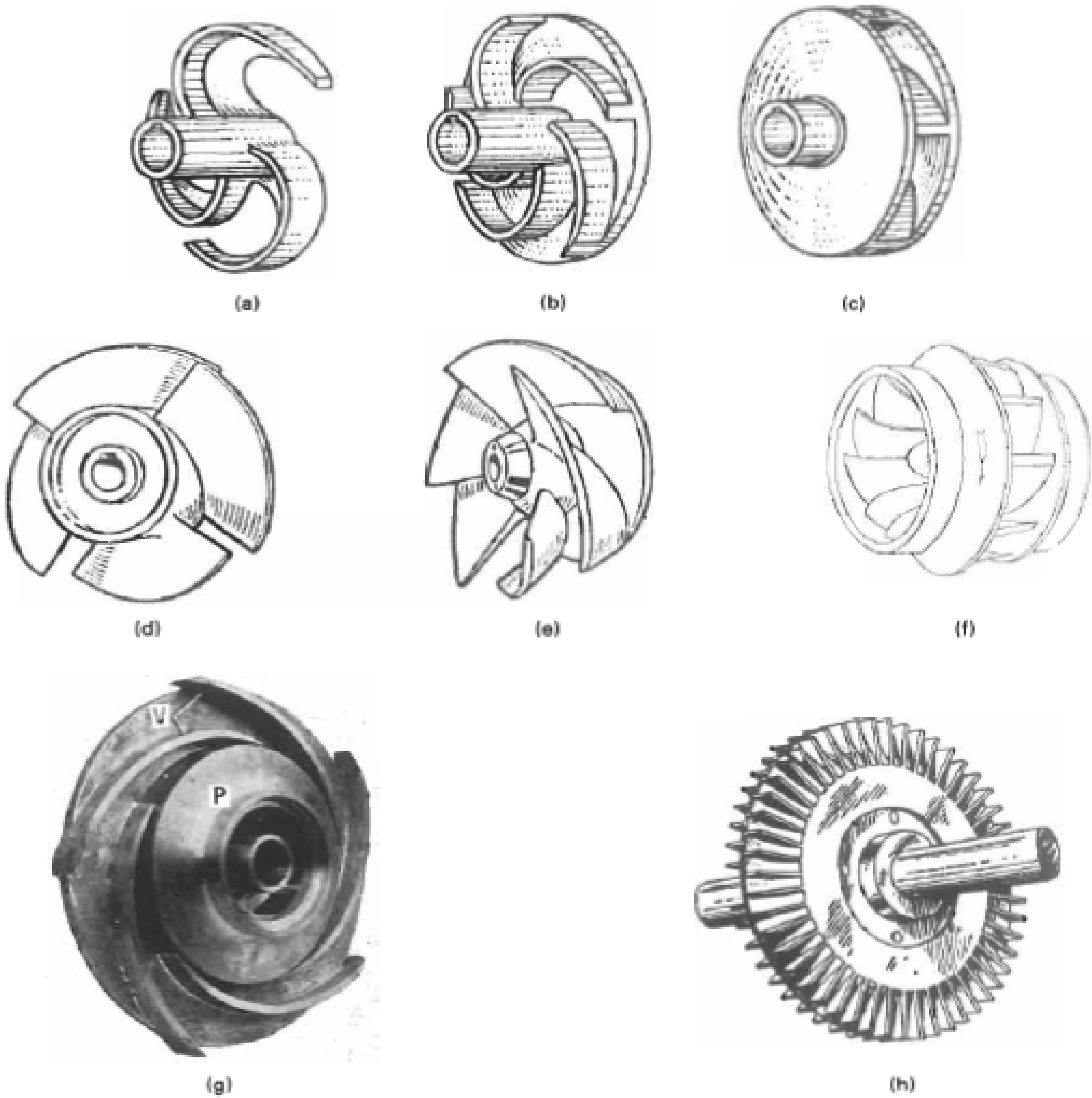


Figure 7.10. Some types of impellers for centrifugal pumps. (a) Open impeller. (b) Semiopen impeller. (c) Shrouded impeller. (d) Axial flow (propeller) type. (e) Combined axial and radial flow, open type. (f) Shrouded mixed-flow impeller. (g) Shrouded impeller (P) in a case with diffuser vanes (V). (h) Turbine impeller.

محمد بهزادی

PUMP Horsepower

Horsepower

The handiest pump horsepower formula for a process engineer is:

$$HP = GPM(\Delta P)/1715(Eff)$$

where:

HP = Pump horsepower
GPM = Gallons per minute
ΔP = Delivered pressure (discharge minus suction), psi
Eff = Pump efficiency, fraction

PUMP Efficiency

$$\text{Eff.} = 80 - 0.2855F + 3.78 \times 10^{-4}FG - 2.38 \times 10^{-7}FG^2 + 5.39 \times 10^{-4}F^2 - 6.39 \times 10^{-7}F^2G + 4 \times 10^{-10}F^2G^2$$

where

Eff. = Pump percentage efficiency
F = Developed head, ft
G = Flow, GPM

Ranges of applicability:

F = 50–300 ft
G = 100–1,000 GPM

PUMP NPSHA

The Net Positive Suction Head (NPSH) available for a pump is defined as:

$$NPSHA = P_{in} - P_{vapor} + H_v + H_s$$

Where:

$NPSHA$	=	Net Positive Suction Head Available
P_{in}	=	Inlet pressure
P_{vapor}	=	Vapor pressure of the liquid at inlet conditions
H_v	=	Velocity head (= $u^2 / 2g$ *u* is the velocity and *g* is gravitation constant)
H_s	=	Hydraulic static head corrected to the pump centerline

The NPSH available has to be greater than the NPSH required (NPSHR) to avoid cavitation. NPSH required is a function of pump design.

PUMP NPSHR

$$NPSHR = \left[\frac{N\,Q^{0.5}}{N_{ss}} \right]^{4/3}$$

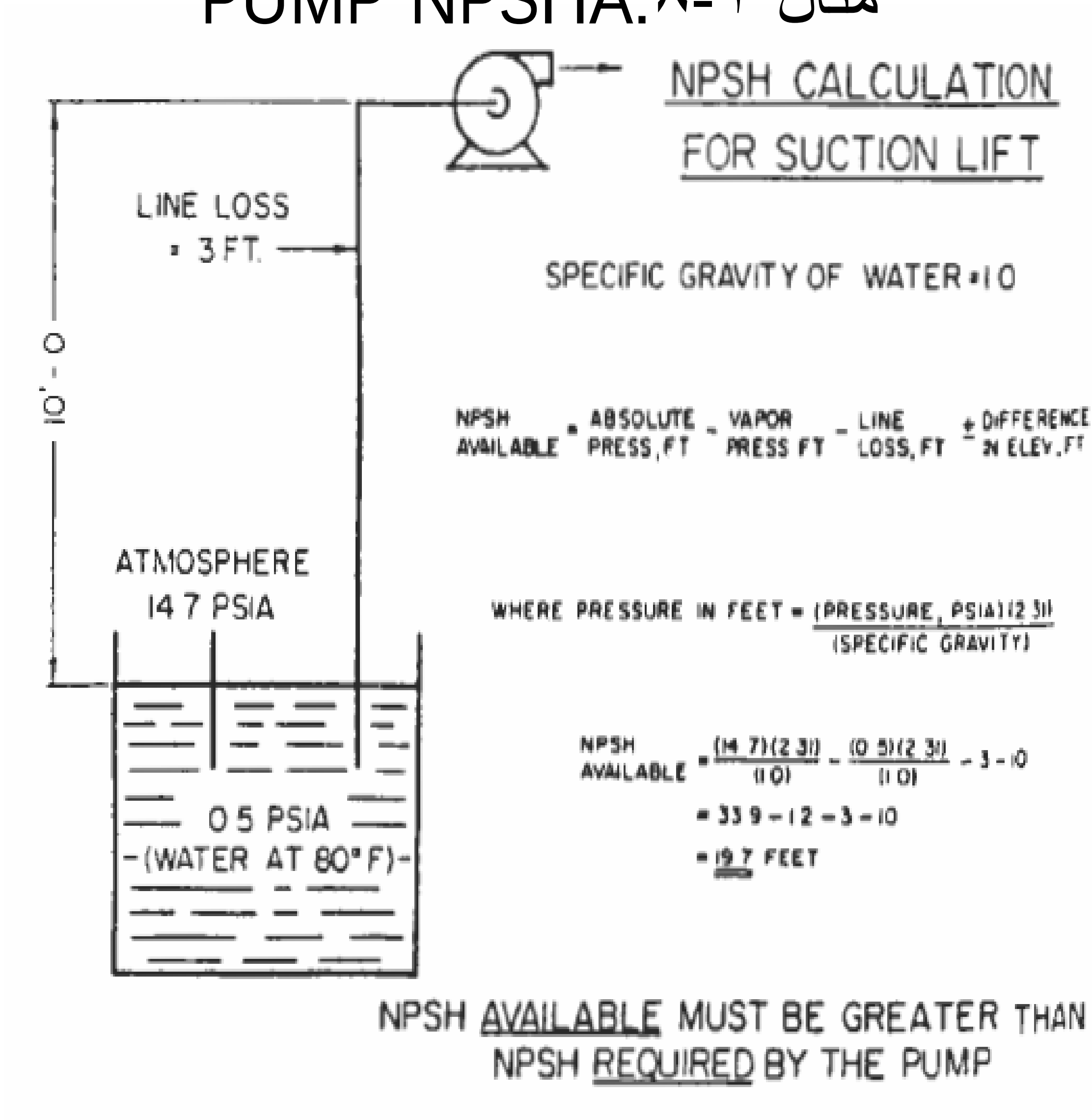
Where:

$NPSHR$	=	Net Positive Suction Head Required
N	=	Pump shaft speed (rpm)
Q	=	Volumetric flow rate at the suction conditions
N_{ss}	=	Suction specific speed

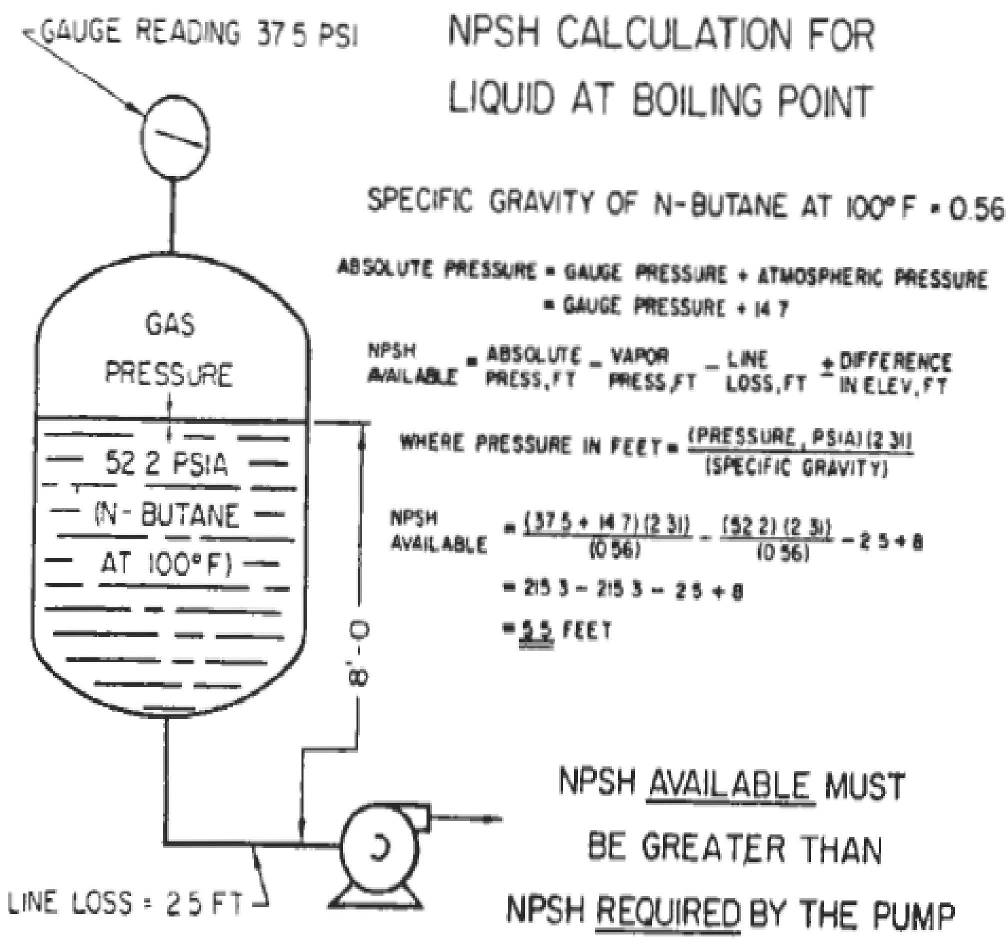
The units for Q and $NPSHR$ are:

US:	Q in gal/min and NPSHR in feet
Metric:	Q in cum/hr and NPSHR in meters

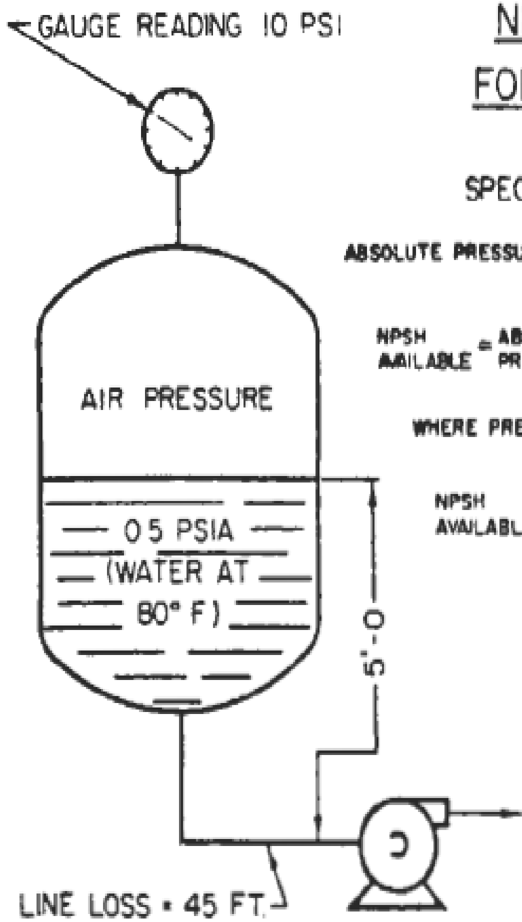
PUMP NPSHA:۸-۱ مثال



PUMP NPSHA:مثال ۲-۸



PUMP NPSHA For Pressured Drum:مثال ۳-۸



NPSH CALCULATION FOR PRESSURED DRUM

SPECIFIC GRAVITY OF WATER = 1.0

ABSOLUTE PRESSURE = GAUGE PRESSURE + ATMOSPHERIC PRESSUR
= GAUGE PRESSURE + 14.7

$$\text{NPSH AVAILABLE} = \text{ABSOLUTE PRESS, FT} - \text{VAPOR PRESS, FT} - \text{LINE LOSS, FT} \pm \text{DIFFERENCE IN ELEV, FT}$$

$$\text{WHERE PRESSURE IN FEET} = \frac{(\text{PRESSURE, PSIA})(2.31)}{(\text{SPECIFIC GRAVITY})}$$

$$\text{NPSH AVAILABLE} = \frac{(10+14.7)(2.31)}{(1.0)} - \frac{(0.5)(2.31)}{(1.0)} - 45 + 5$$

$$= 57.1 - 12 - 45 + 5$$

$$= \underline{15.9}\ \text{FEET}$$

NPSH AVAILABLE MUST BE GREATER THAN NPSH REQUIRED BY THE PUMP

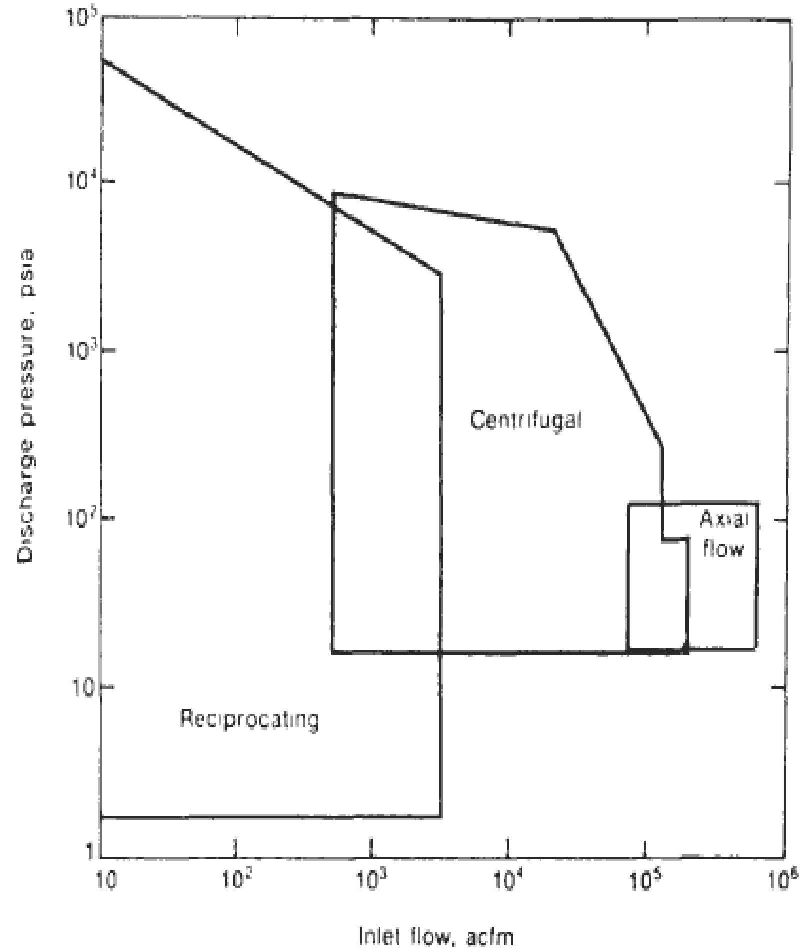
Centrifugal pump impeller

$Q_2 = Q_1(d_2/d_1)$ flow rate

$h_2 = h_1(d_2/d_1)^2$ head delivered

$A_2 = A_1(d_2/d_1)^3$ amperage drawn by motor

Compressor selection



Approximate ranges of application for reciprocating, centrifugal, and axial-flow compressors.

Generalized Z

A quick estimate of the compressibility factor Z can be made from the nomograph[1,2] shown as Figure 1.

where

T = Temperature in consistent absolute units
T_c = Critical temperature in consistent absolute units
$T_R = T/T_c$
P = Pressure in consistent absolute units
P_c = Critical pressure in consistent absolute units
$P_R = P/P_c$

An accuracy of one percent is claimed, but the following gases are excluded: helium, hydrogen, water, and ammonia.

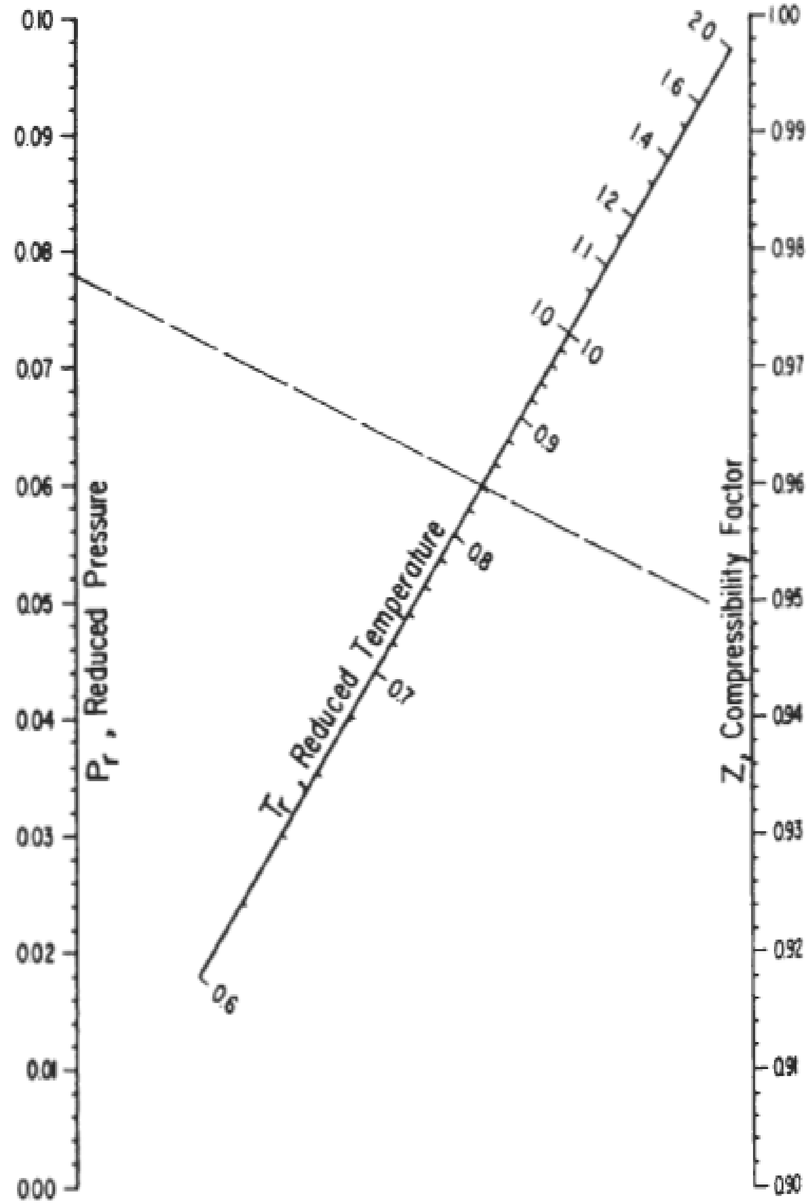


Figure 1. Generalized compressibility factor. (Reproduced by permission *Petroleum Refiner*, Vol. 37, No. 11, copyright 1961, Gulf Publishing Co., Houston.)

Generalized K

The following handy graph from the *GPSA Engineering Data Book* allows quick estimation of a gas's heat-capacity ratio ($K = C_p/C_v$) knowing only the gas's molecular weight.

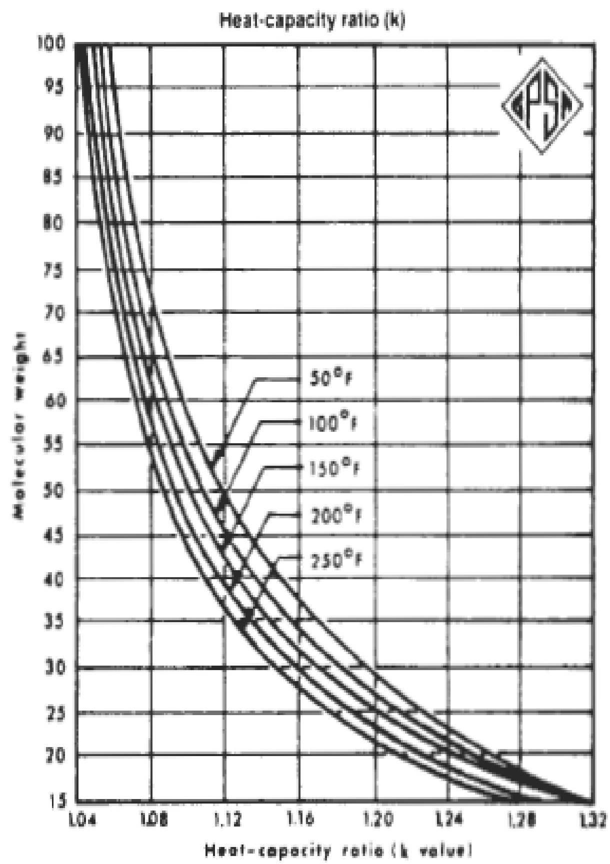


Figure 1. Approximate heat-capacity ratios of hydrocarbon gases.

where

C_p = Heat capacity at constant pressure, Btu/lb°F
C_v = Heat capacity at constant volume, Btu/lb°F

Source

GPSA Engineering Data Book, Gas Processors Suppliers Association, Vol. 1, 10th Ed., 1987.

Horsepower Calculation

For centrifugal compressors the following method is normally used.

First, the required head is calculated. Either the polytropic or adiabatic head can be used to calculate horsepower so long as the polytropic or adiabatic efficiency is used with the companion head.

Polytropic Head

$$H_{poly} = \frac{ZRT_1}{(N-1)/N}\left[\left(\frac{P_2}{P_1}\right)^{(N-1)/N} - 1\right]$$

Adiabatic Head

$$H_{AD} = \frac{ZRT_1}{(K-1)/K}\left[\left(\frac{P_2}{P_1}\right)^{(K-1)/K} - 1\right]$$

where

Z = Average compressibility factor; using 1.0 will yield conservative results

R = 1,544/mol. wt.

T_1 = Suction temperature, °R

P_1, P_2 = Suction, discharge pressures, psia

K = Adiabatic exponent, C_p/C_v

N = Polytropic exponent, $\frac{N-1}{N} = \frac{K-1}{KE_p}$

E_p = Polytropic efficiency

E_A = Adiabatic efficiency

The polytropic and adiabatic efficiencies are related as follows:

$$E_A = \left[\frac{\left(\frac{P_2}{P_1}\right)^{(K-1)/K} - 1}{\left(\frac{P_2}{P_1}\right)^{(N-1)/N} - 1}\right] = \left[\frac{\left(\frac{P_2}{P_1}\right)^{(K-1)/K} - 1}{\left(\frac{P_2}{P_1}\right)^{(K-1)/KE_P} - 1}\right]$$

The gas horsepower is calculated using the companion head and efficiency.

From Polytropic Head.

$$HP = \frac{WH_{poly}}{E_p 33{,}000}$$

From Adiabatic Head.

$$HP = \frac{WH_{AD}}{E_A 33{,}000}$$

where

HP = Gas horsepower
W = Flow, lb/min

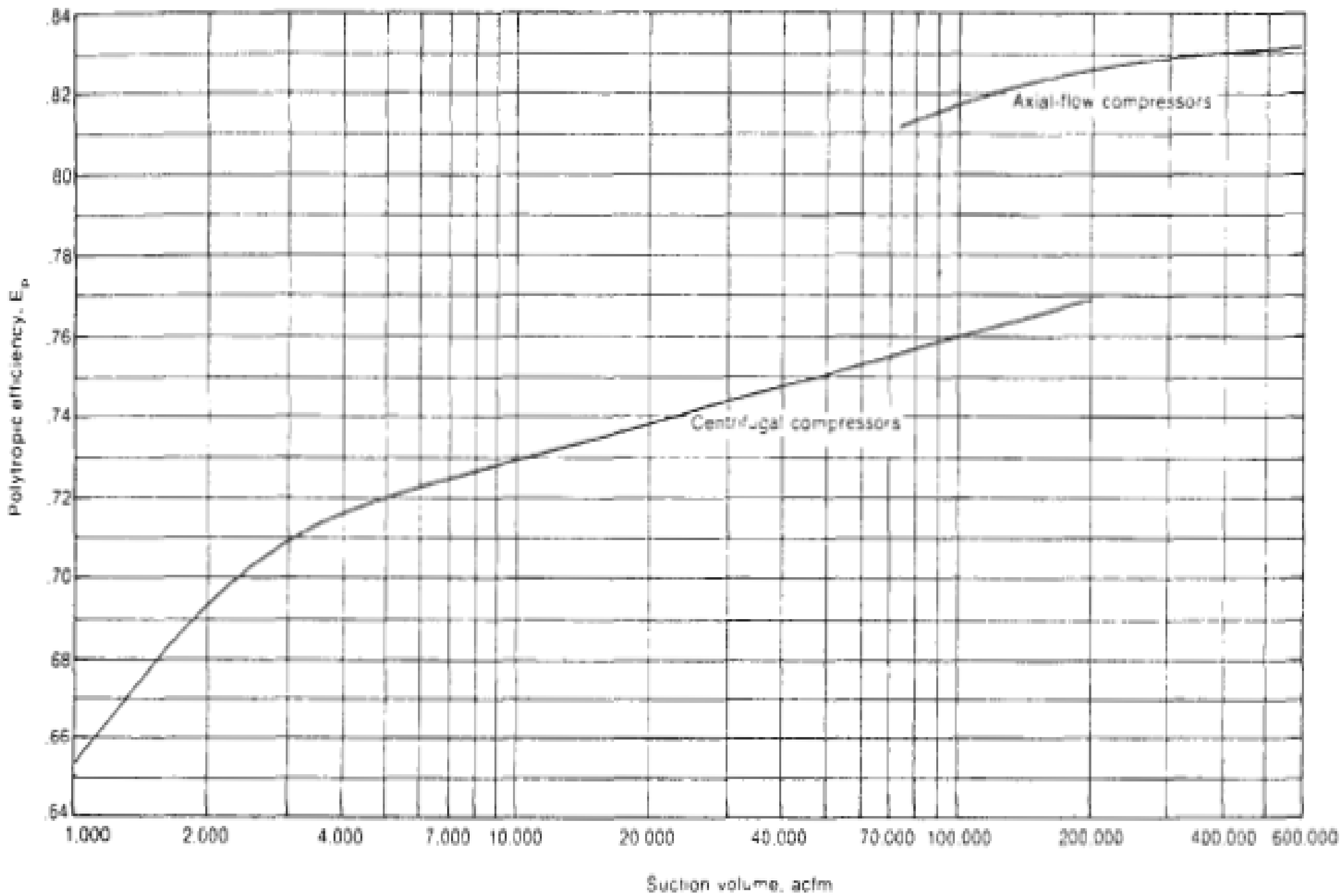
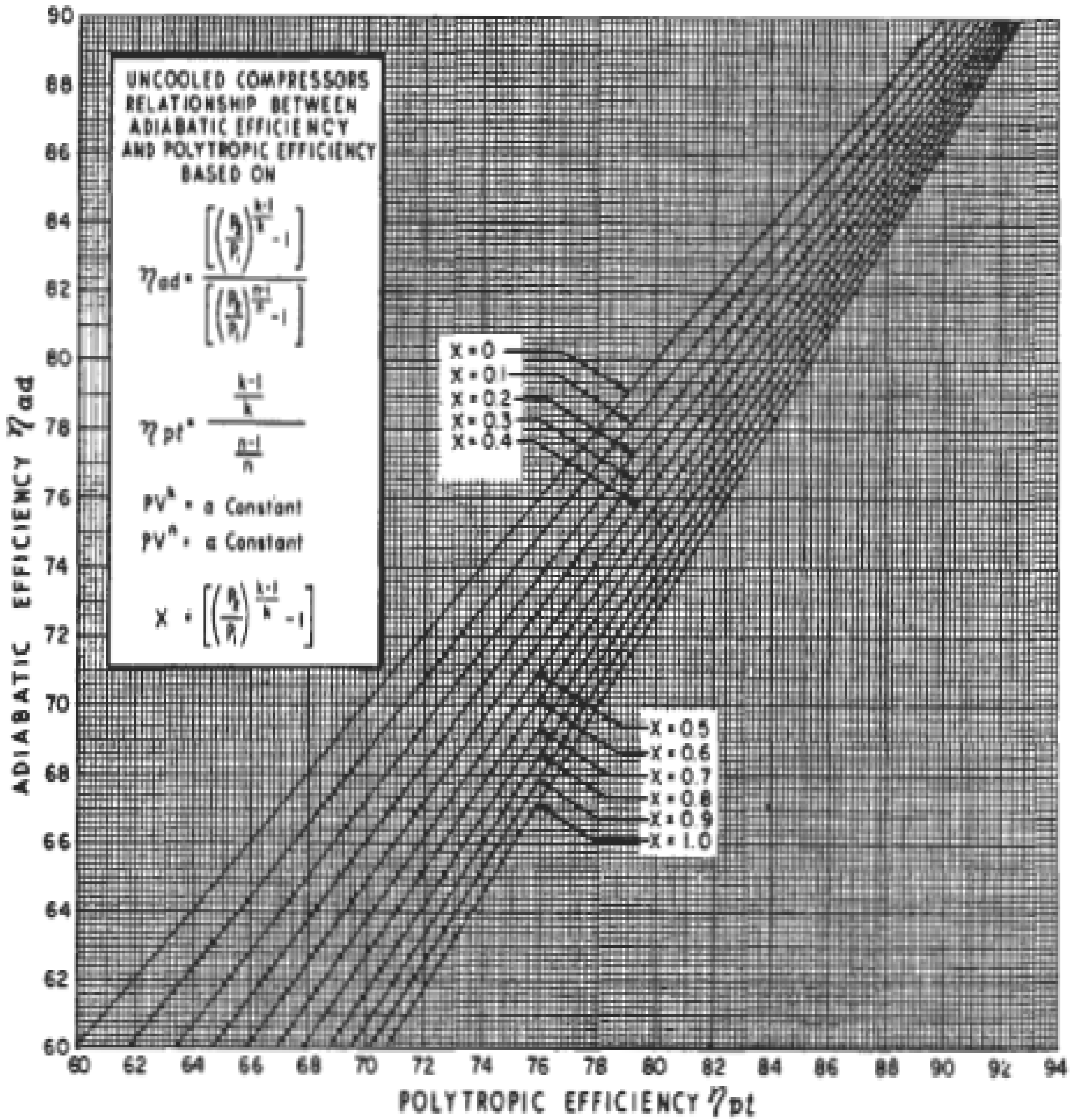


Figure 1. Approximate polytropic efficiencies for centrifugal and axial flow compressors.



$$\eta_{ad} = \frac{\left[\left(\frac{P_2}{P_1}\right)^{\frac{k-1}{k}} - 1\right]}{\left[\left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}} - 1\right]}$$

$$\eta_{pt} = \frac{\frac{k-1}{k}}{\frac{n-1}{n}}$$

$$X = \left[\left(\frac{P_2}{P_1}\right)^{\frac{k-1}{k}} - 1\right]$$

Uncooled compressor relationship between adiabatic efficiency and polytropic efficiency.

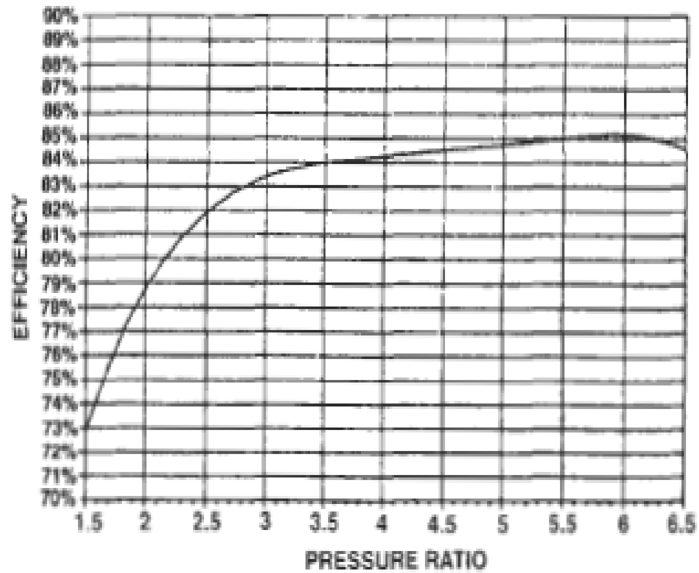


Figure 3. Reciprocating compressor efficiencies.

FHP

The fluid horsepower (FHP) is defined as follows:

$$FHP = w \times g \times dH$$

$$dH = \frac{dP}{\rho g}$$

Where:

dH	=	head generated
w	=	mass flow rate
g	=	gravitational acceleration
dP	=	the pressure difference across the pump
ρ	=	fluid mass density

- Brake Power

The brake horsepower is considered to be the pump power input

$$BHP = FHP / Eff_{pump}$$

- Electricity

The electric horsepower

$$(EHP) = BHP / Eff_{motor}$$

$$FHP = EHP * Eff_{pump} * Eff_{motor}$$

valve

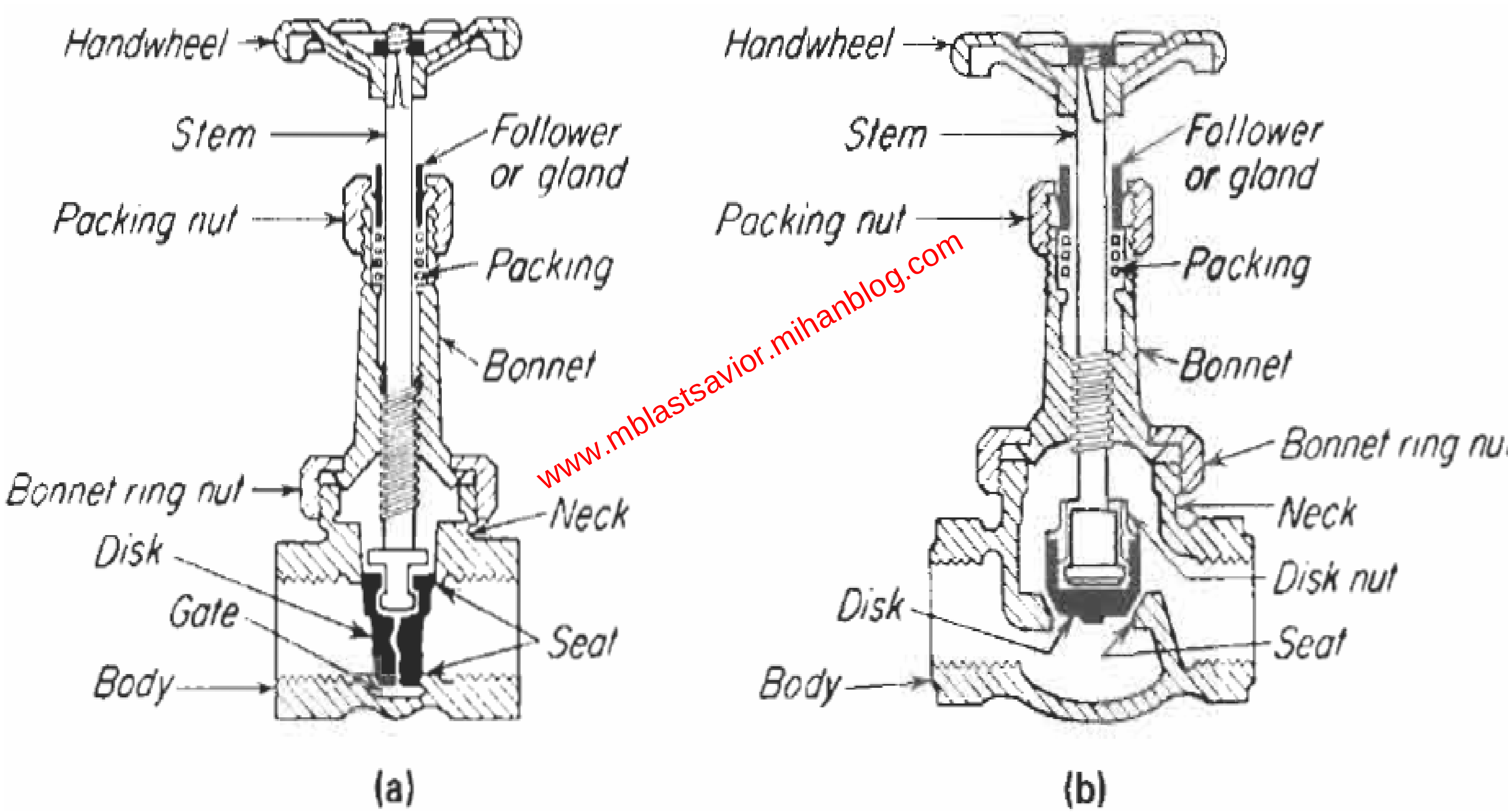
valve

- Block(shut-off) (ball,plug,gate,butterfly)
  - بدون نشتي در حالت بسته
  - در حالت باز حداقل مقاومت در برابر عبور جريان
  - Butterfly عموما براي گازها و بخارها

- (globe) Control
  - قابليت كنترل جريان از حالت كاملا باز تا كاملا بسته

Ball Valve

- Full Bore
  - بالا و پايين PSV
  - پايين piglaucher و بالاي pig receiver
  - Vent-Drain
  - شيرهاي ابزار دقيق
  - قطع كننده جريان در خطوط هيدرو كربني كه افت فشار در حالت بحراني است
  - Utility بزرگتر از ۲ اينچ
- Reduce Bore
- جريان بدون ذرات جامد



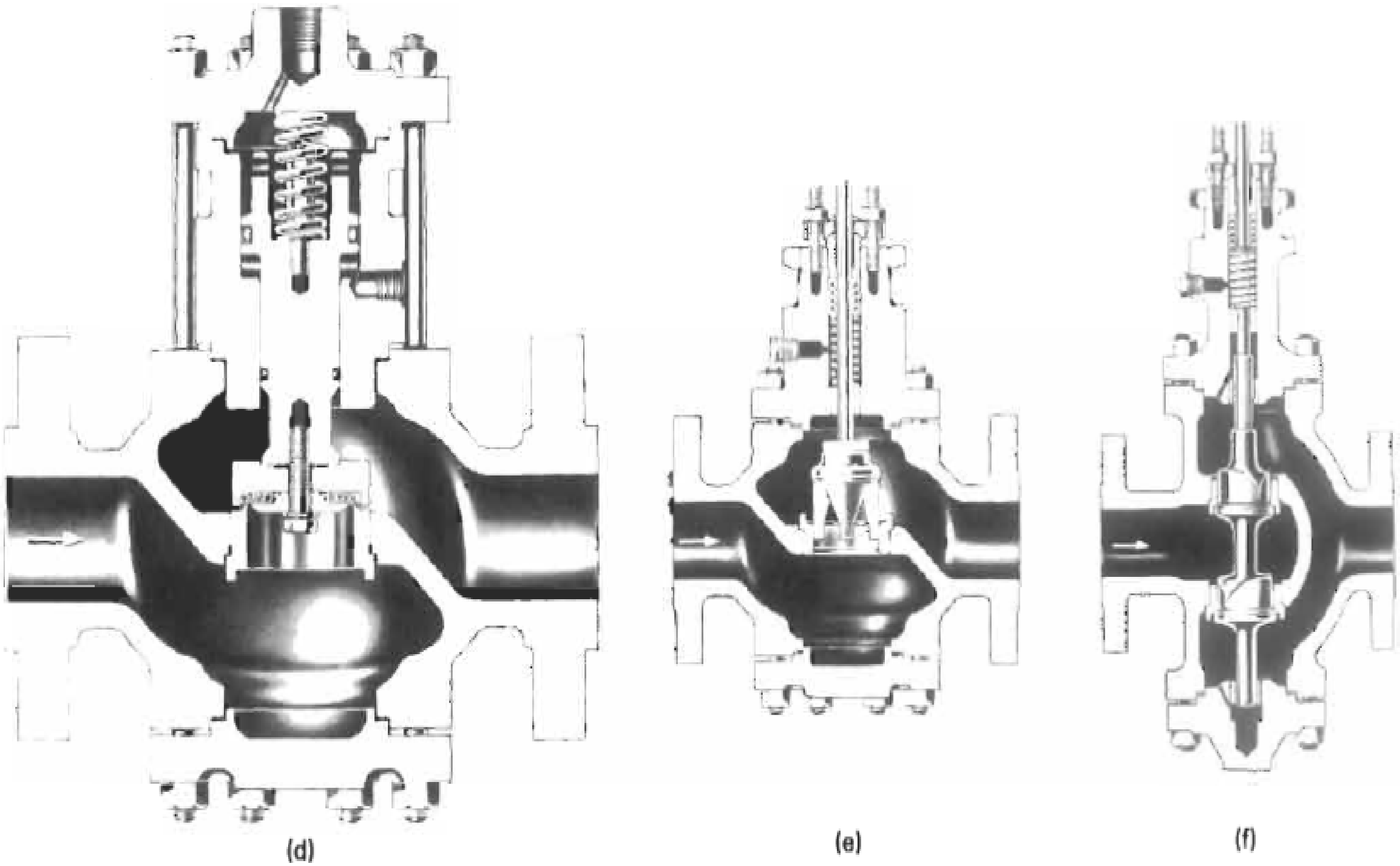
بزرگتر

سرعت قطع جریان بالاتر

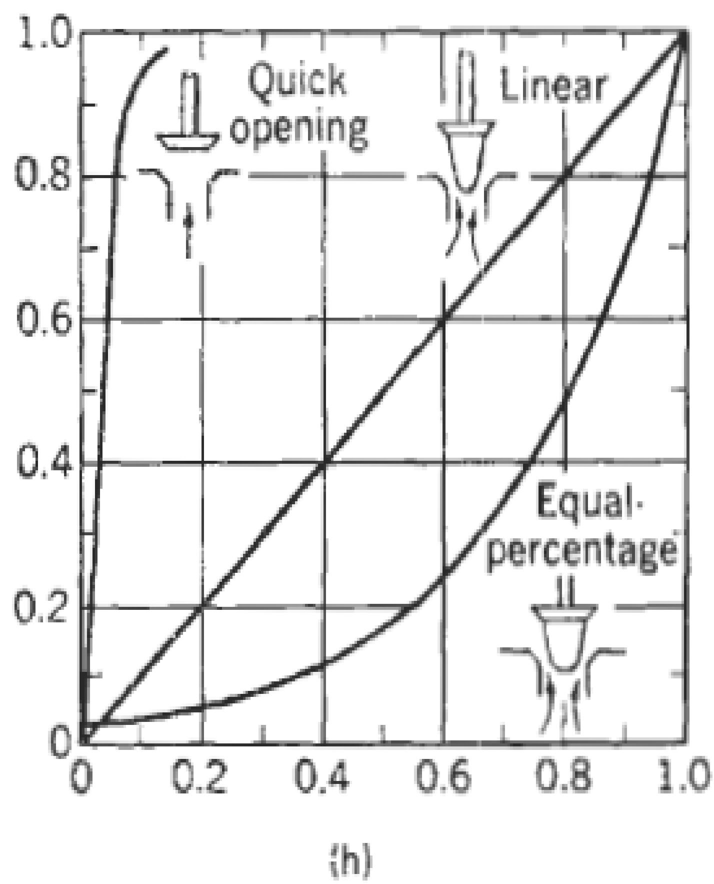
Utility کوچکتر از ۲ اینچ

سبکتر

(a) Gate valve, for the majority of applications. (b) Globe valve, when tight shutoff is needed.



(d) A pressure relief valve, in which the plug is raised on overpressure. (e) A control valve with a single port. ***(f)*** A double-port, reverse-acting control valve.

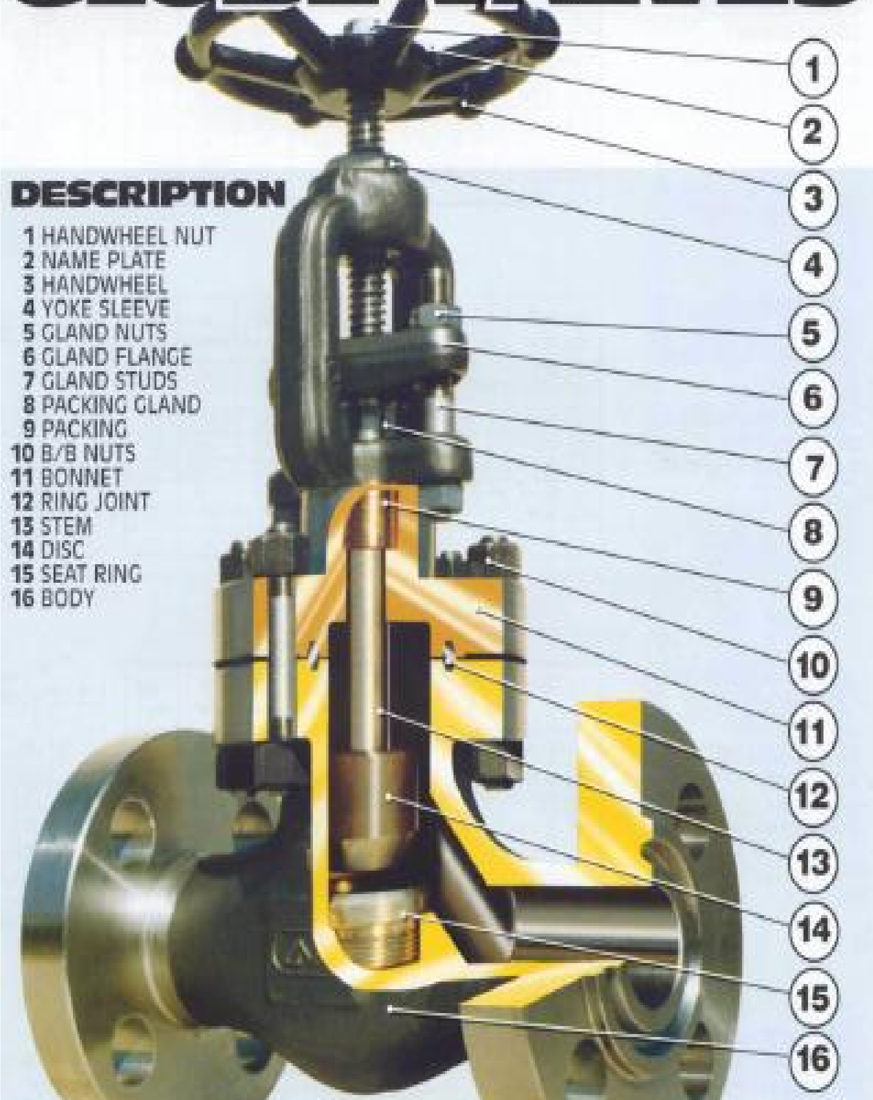


(h) Relation between fractional opening and fractional flow of three modes of valve openings.

GLOBE VALVES

DESCRIPTION

1 HANDWHEEL NUT
2 NAME PLATE
3 HANDWHEEL
4 YOKE SLEEVE
5 GLAND NUTS
6 GLAND FLANGE
7 GLAND STUDS
8 PACKING GLAND
9 PACKING
10 B/B NUTS
11 BONNET
12 RING JOINT
13 STEM
14 DISC
15 SEAT RING
16 BODY



Disc type | Ball type | Parabolic type | Needle type

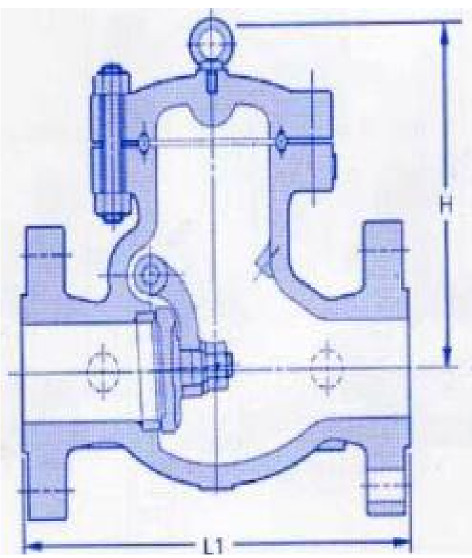
GATE VALVES

DESCRIPTION

1 HANDWHEEL NUT
2 NAME PLATE
3 HANDWHEEL
4 YOKE SLEEVE
5 GLAND NUTS
6 GLAND FLANGE
7 GLAND STUDS
8 PACKING GLAND
9 B/B NUTS
10 PACKING
11 BONNET
12 GASKET
13 STEM
14 WEDGE
15 SEAT RINGS
16 BODY

Standard wedge | Flexible wedge | Split wedge

Check valve



Control Valve

- Globe
- Butterfly(مسير گاز و ورودي كمپرسور)

Distillation Columns

Towers

Fractionators

Sources

1. Branan, C. R., Development of Short-cut Equipment Design Methods, ASEE Annual Conference Proceedings, Computer Aided Engineering, American Society for Engineering Education, 1985.
2. Lieberman, N. P., *Process Design For Reliable Operations*, 2nd Ed., Gulf Publishing Co., 1989.

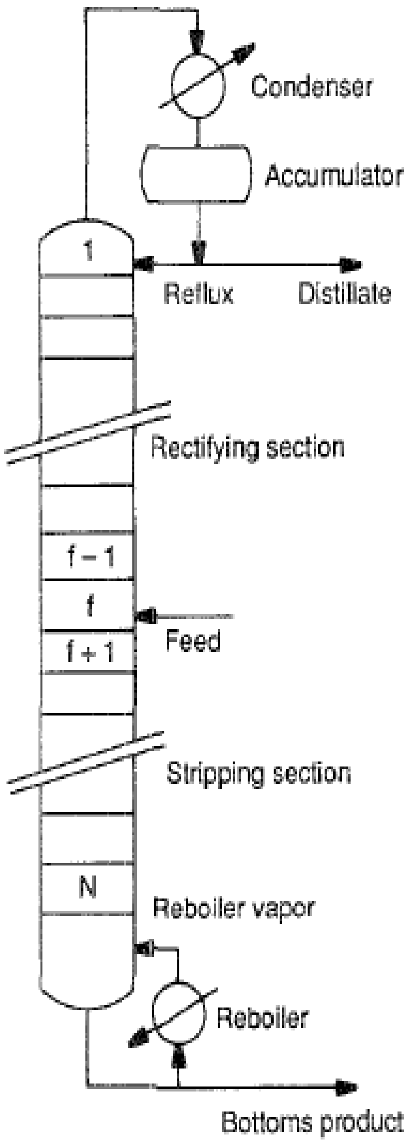


Figure 13.1. Distillation column assembly.

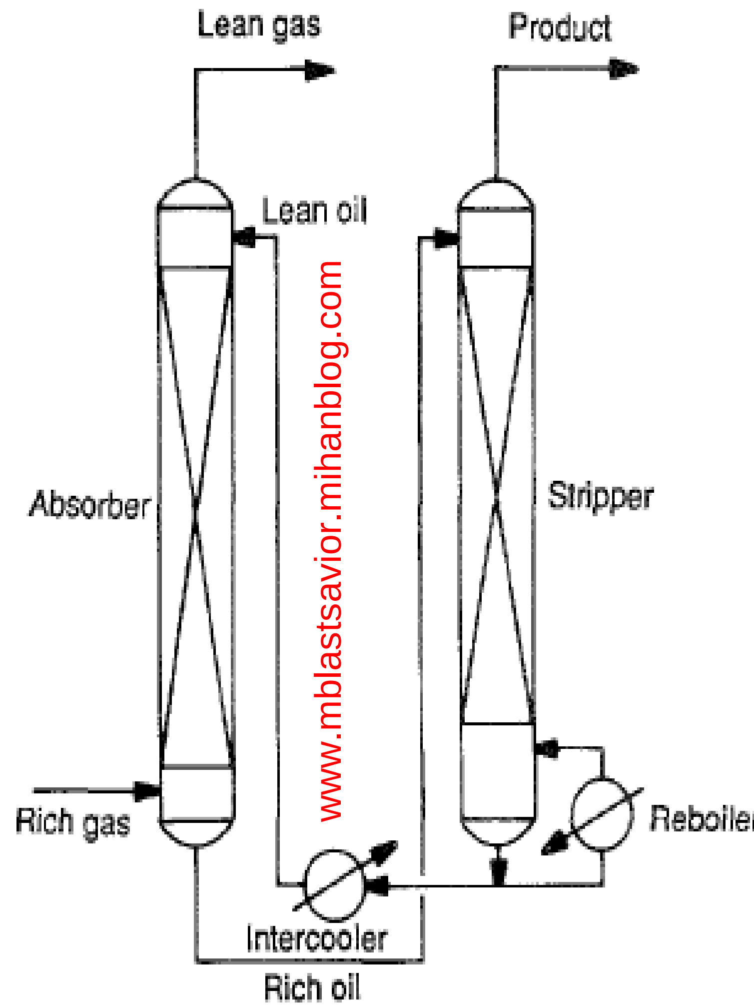


Figure 13.2. Absorber–stripper assembly.

Relative Volatility

For quick estimates, a relative volatility can be estimated as follows:

The equilibrium vaporization constant K is defined for a compound by

$$K_i = \frac{Y_i}{X_i}$$

where

Y_i = Mole fraction of component i in the vapor phase
X_i = Mole fraction of component i in the liquid phase

To calculate a distillation, the relative volatility α is needed, it is defined as

$$\alpha = \frac{K_i}{K_j}$$

where i and j represent two components to be separated.

Raoult's Law for ideal systems is

$$p_i = P_i X_i$$

where

p_i = Partial pressure of i
P_i = Vapor pressure of pure component i

By definition

$$p_i = \Pi Y_i$$

where

Π = Total pressure of the system

so

$$P_i X_i = \Pi Y_i$$

and

$$\frac{P_i}{\Pi} = \frac{Y_i}{X_i} = K_i$$

Therefore for systems obeying Raoult's Law

$$\alpha = \frac{P_i}{P_j}$$

Source

Branan, C. R., *The Process Engineer's Pocket Handbook*, Vol. 1, Gulf Publishing Co., 1976.

Minimum Reflux Multicomponent

The Underwood Method will provide a quick estimate of minimum reflux requirements. It is a good method to use when distillate and bottoms compositions are specified. Although the Underwood Method will be detailed here, other good methods exist such as the Brown-Martin[3] and Colburn[4] methods. These and other methods are discussed and compared in Van Winkle's book.[5] A method to use for column analysis when distillate and bottoms compositions are not specified is discussed by Smith.[6]

The Underwood Method involves finding a value for a constant, θ, that satisfies the equation

$$\sum_{1}^{n} \frac{X_{iF}\alpha_i}{\alpha_i - \theta} = 1 - q = \frac{X_{1F}\alpha_1}{\alpha_1 - \theta} + \frac{X_{2F}\alpha_2}{\alpha_2 - \theta} + \cdots$$

The value of θ will lie between the relative volatilities of the light and heavy key components, which must be adjacent.

After finding θ, the minimum reflux ratio is determined from

$$R_m + 1 = \sum_{1}^{n} \frac{\alpha_i X_{iD}}{\alpha_i - \theta}$$

Nomenclature

α_i = Relative volatility of component i verses the heavy key component

θ = Underwood minimum reflux constant

X_{iF} = Mol fraction of component i in the feed

X_{iD} = Mol fraction of component i in the distillate

q = Thermal condition of the feed

- Bubble point liquid q = 1.0
- Dew point vapor q = 0
- General feed q = $(L_S - L_R)/F$

where:

L_S = Liquid molar rate in the stripping section

L_R = Liquid molar rate in the rectification section

F = Feed molar rate

R_m = Minimum reflux ratio

Minimum Stages

The Fenske Method gives a quick estimate for the minimum theoretical stages at total reflux.

$$N_m + 1 = \frac{\ln[(X_{LK}/X_{HK})_D (X_{HK}/X_{LK})_B]}{\ln(\alpha_{LK/HK})_{AVG}}$$

Nomenclature

B = subscript for bottoms
D = subscript for distillate
HK = subscript for heavy key
LK = subscript for light key
N_m = minimum theoretical stages at total reflux
X_{HK} = mol fraction of heavy key component
X_{LK} = mol fraction of the light key component
$\alpha_{LK/HK}$ = relative volatility of component vs the heavy key component

Source

Fenske, M., *Ind. Eng. Chem. 24*, 482, (1932).

Actual Reflux and Actual Theoretical Stages

The recommended[1] method to use to determine the actual theoretical stages at an actual reflux ratio is the Erbar/Maddox[2] relationship. In the graph, N is the theoretical stages and R is the actual reflux ratio L/D, where L/D is the molar ratio of reflux to distillate. N_m is the minimum theoretical stages and R_m is the minimum reflux ratio.

The actual reflux ratio that one picks should be optimized from economics data. For a ballpark estimate use

1.1–1.2 R_m for a refrigerated system, and 1.2–1.35 R_m for a hot system.

The author has curve-fit the Erbar/Maddox curves since readability for the graph is limited. For simplicity, let:

$x = N_m/N$
$y = R/R(R + 1)$
$z = R_m/(R_m + 1)$

For $y = A + Bx + Cx^2 + Dx^3 + Ex^4 + Fx^5$, the following table is presented:

Z	A	B	C	D	E	F
0	.00035	.16287	-.23193	5.09032	-8.50815	4.48718
.1	.09881	.32725	-2.57575	10.20104	-12.82050	5.76923
.2	.19970	.14236	-.58646	2.60561	-3.12499	1.76282
.3	.29984	.09393	-.23913	1.49008	-2.43880	1.79486
.4	.40026	.12494	-.49585	2.15836	-3.27068	2.08333
.5	.50049	-.03058	.81585	-2.61655	3.61305	-1.28205
.6	.60063	-.00792	.60063	-2.06912	3.39816	-1.52243
.7	.70023	-.01109	.45388	-1.25263	1.94348	-.83334
.8	.80013	-.01248	.76154	-2.72399	3.85707	-1.68269
.9	.89947	.00420	.38713	-1.14962	1.40297	-.54487
1.0	1.0	-0-	-0-	-0-	-0-	-0-

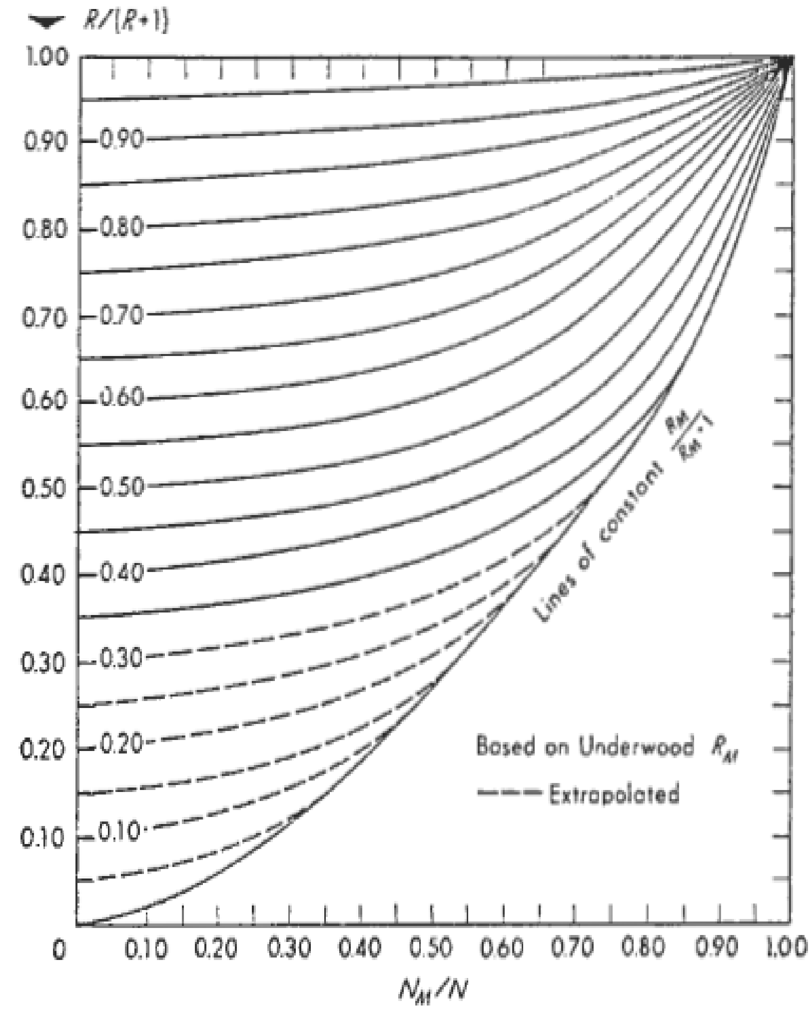


Figure 1. Plates-reflux correlation of Erbar and Madd

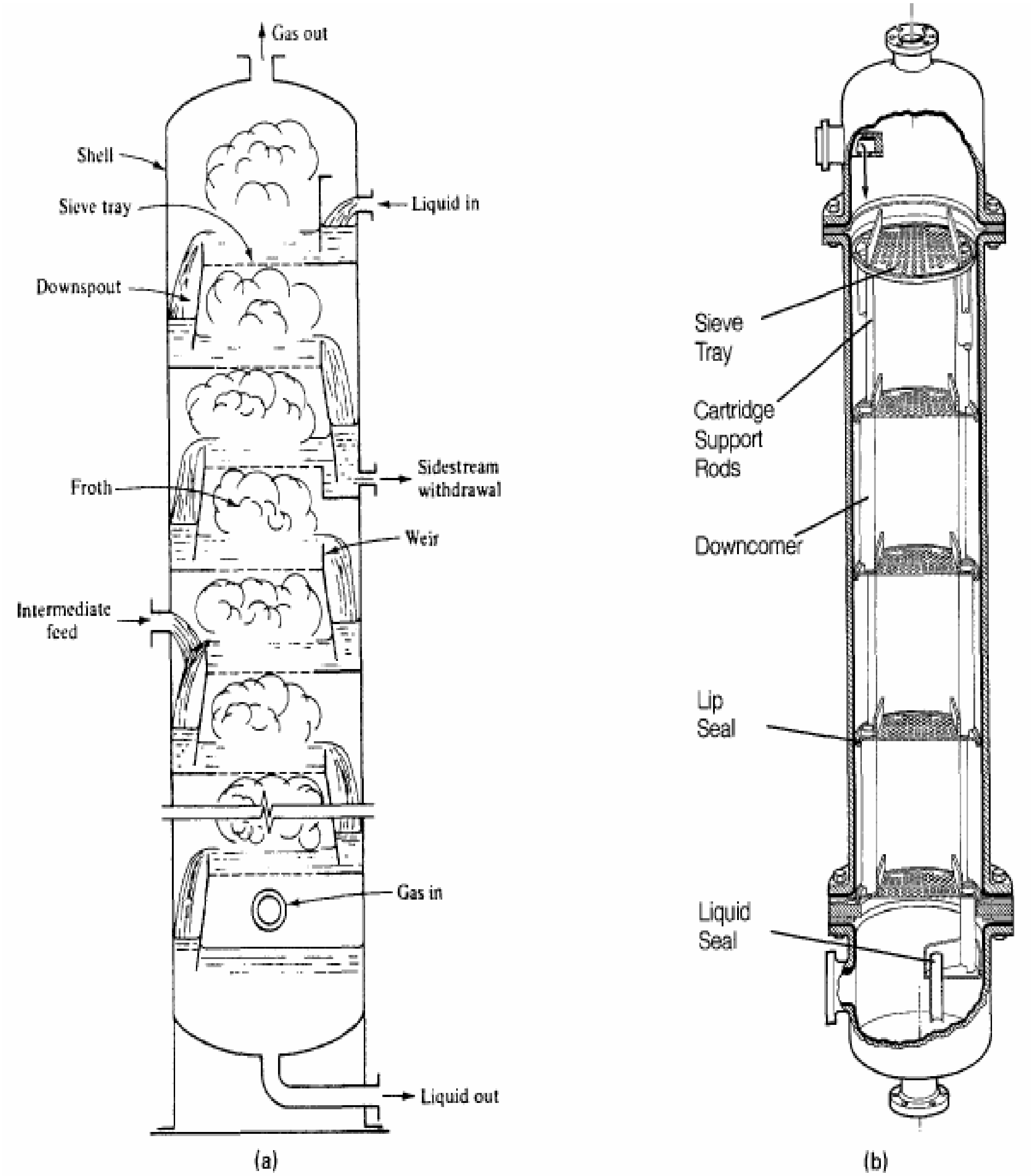


Figure 13.31. Assembled sieve tray towers. (a) Flowsketch of a sieve tray tower (*Treybal, 1980*). (b) Cartridge type sieve tray tower in small diameters (*Pfaudler Co.*).

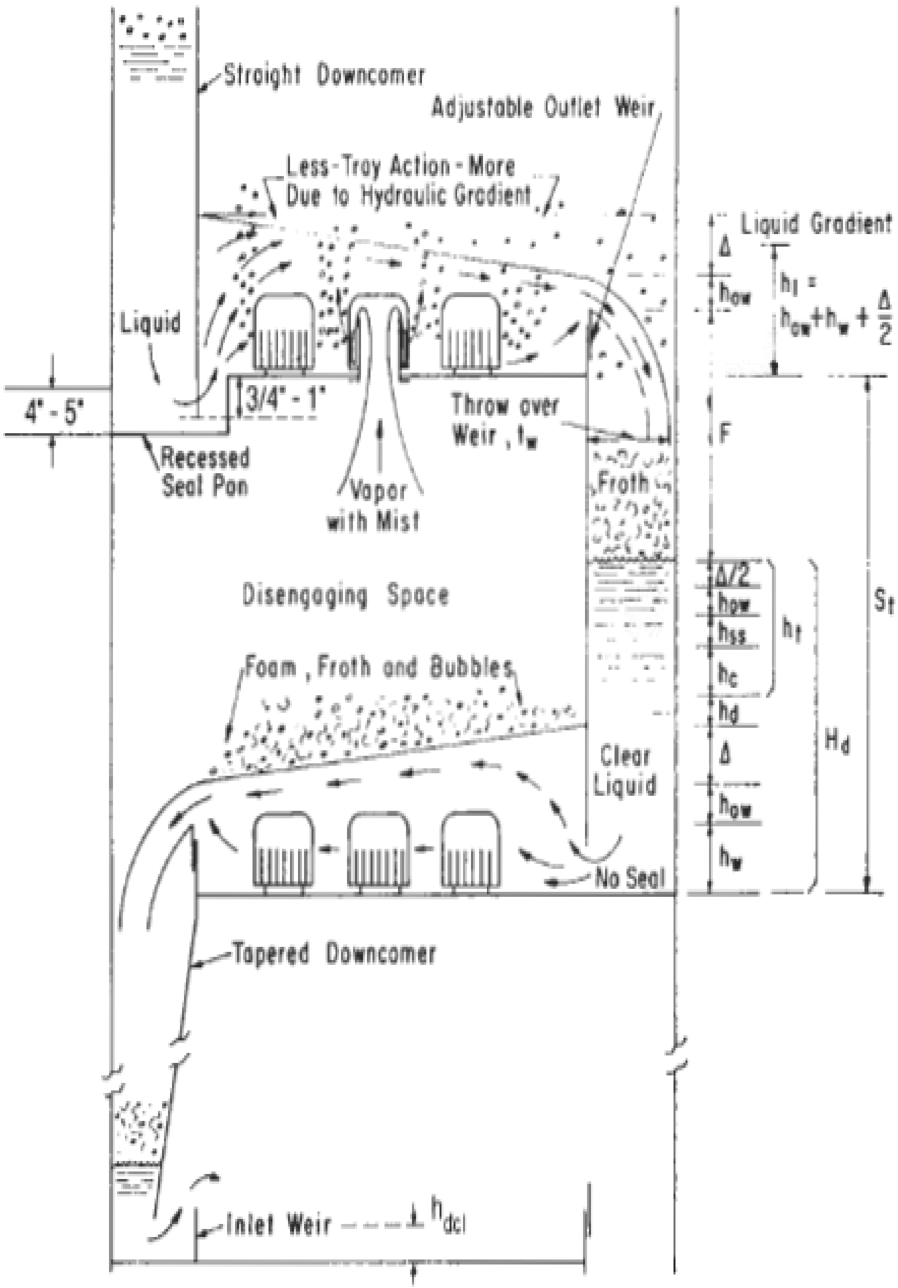
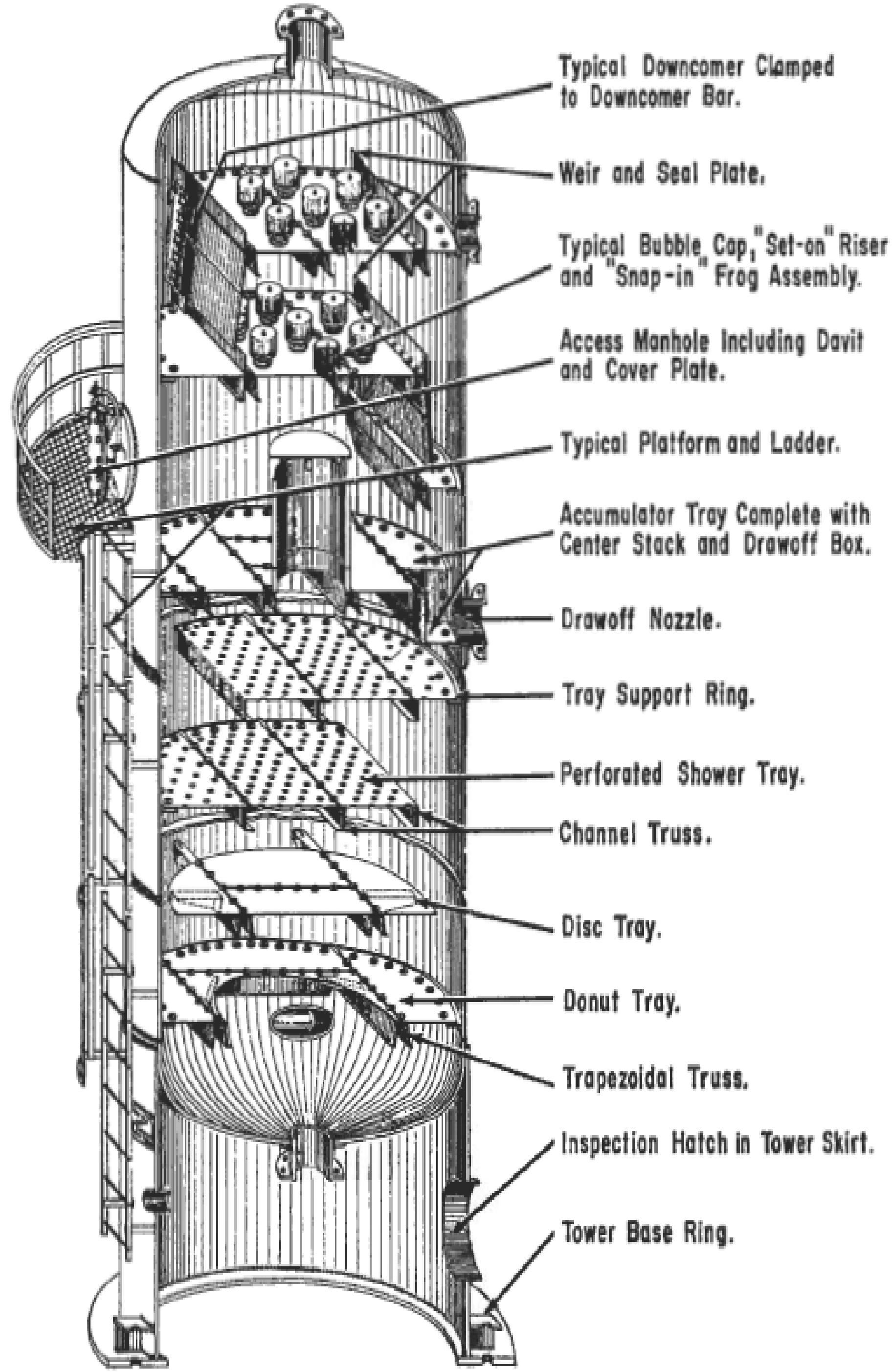
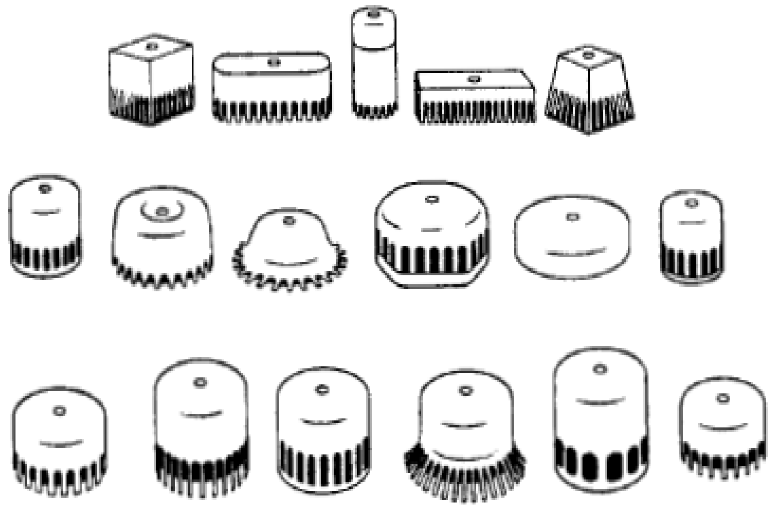
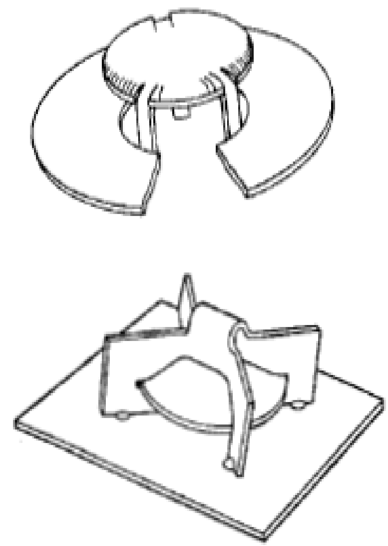


Figure 8-63. Bubble cap tray schematic--dynamic operation.

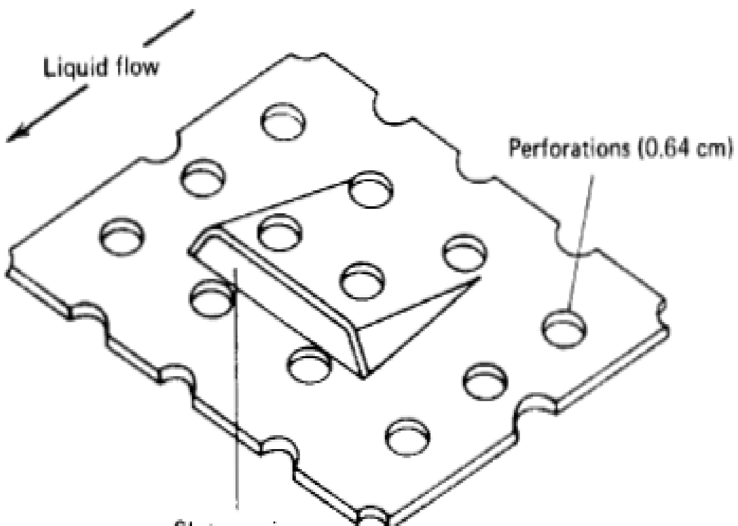




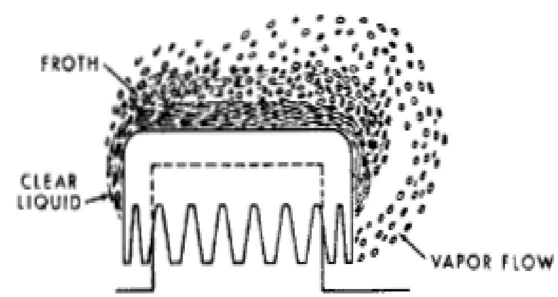
(a)



(b)



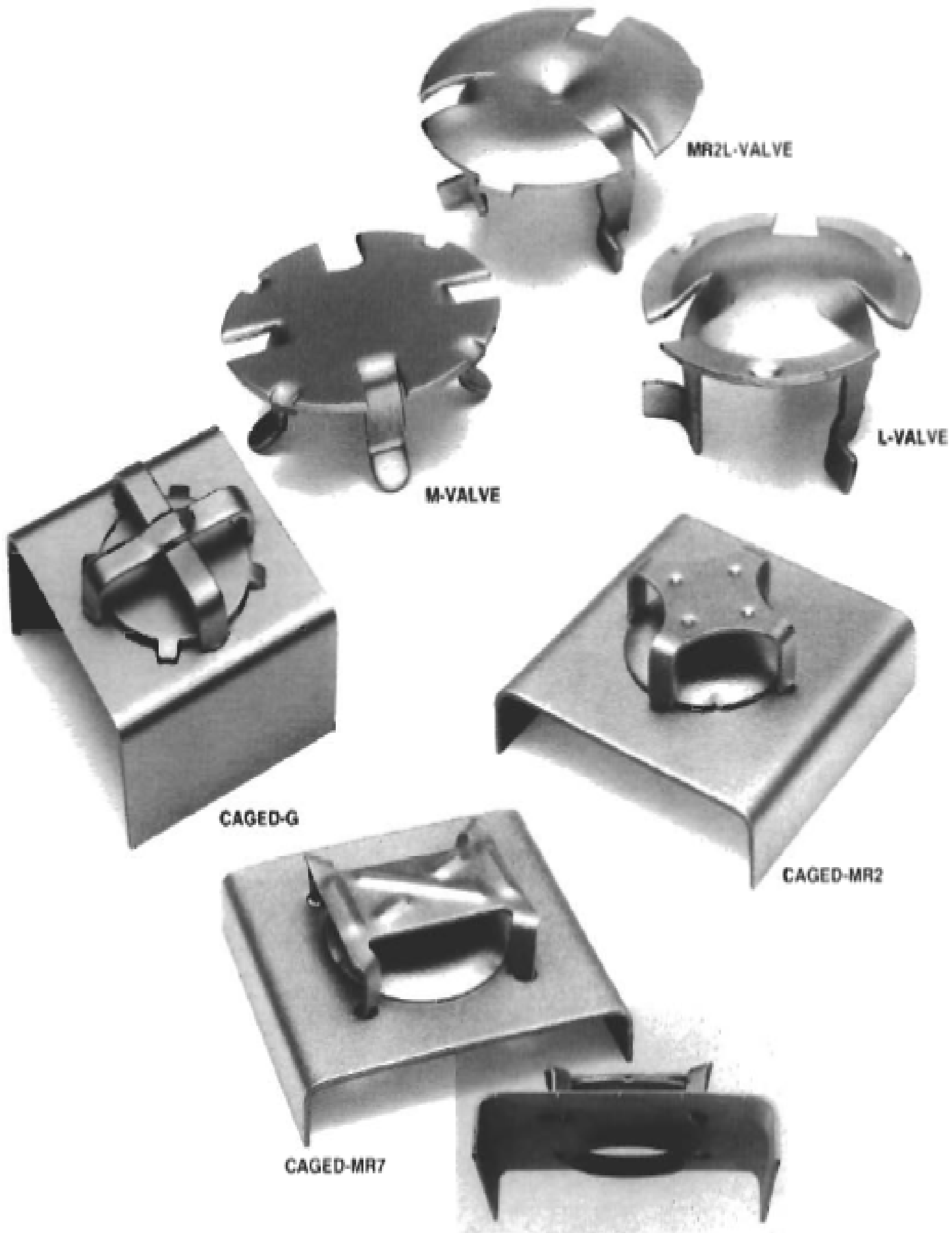
(c)

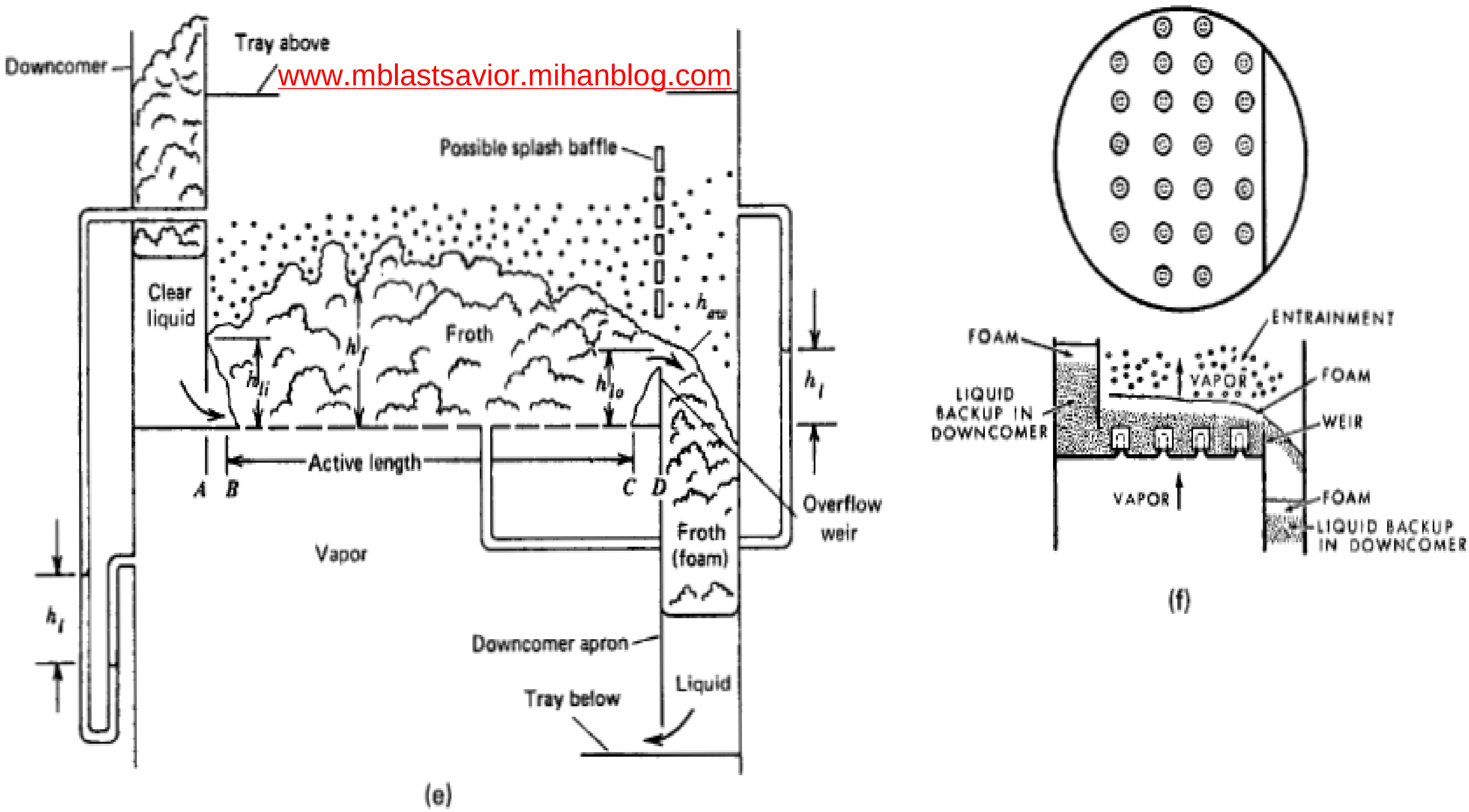


(d)

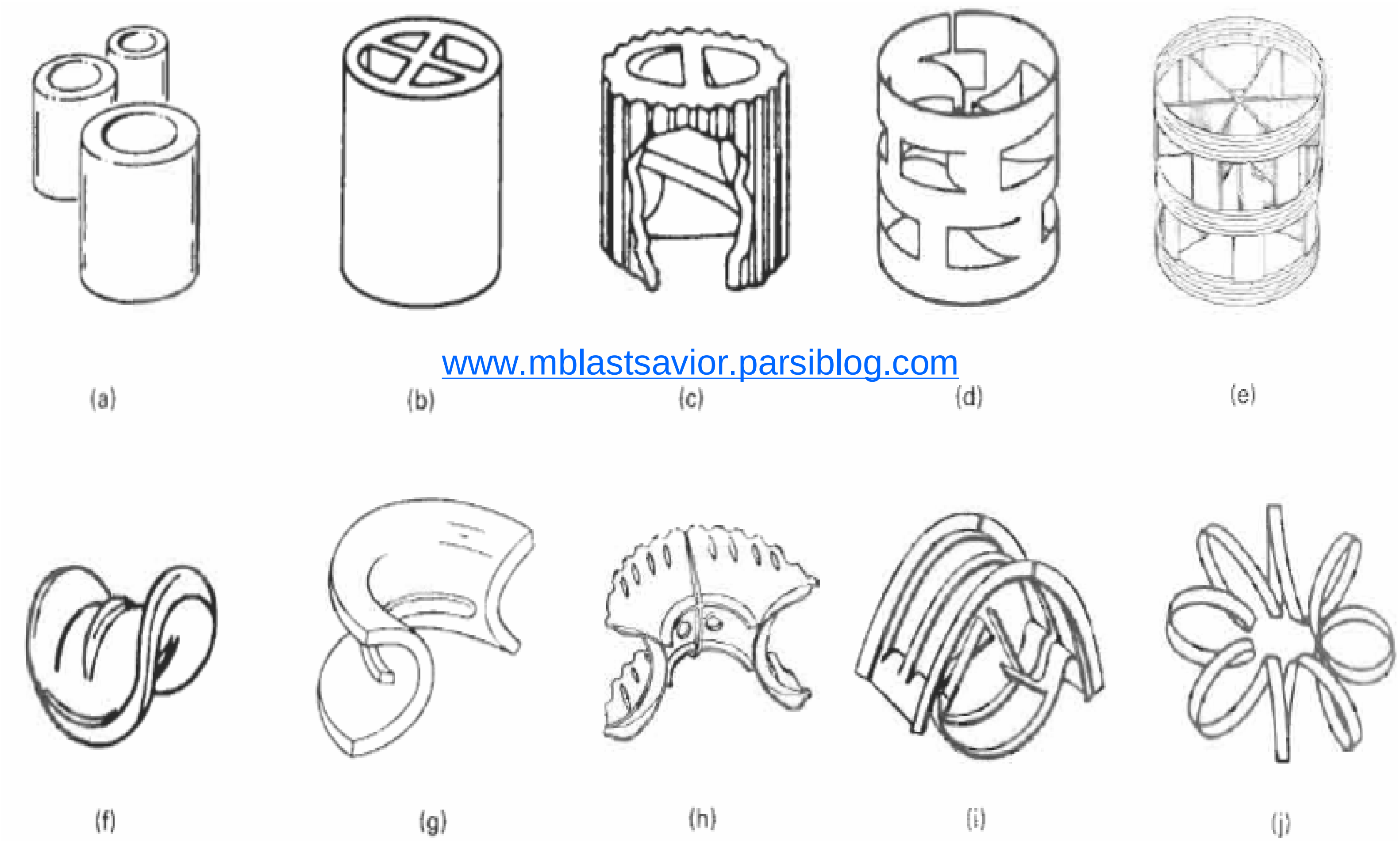
(a) Some kinds of bubblecaps
(c) Vapor directing slot on a Linde sieve tray

(b) Two kinds of valves for trays.
(d) Vapor flow through a bubblecap.

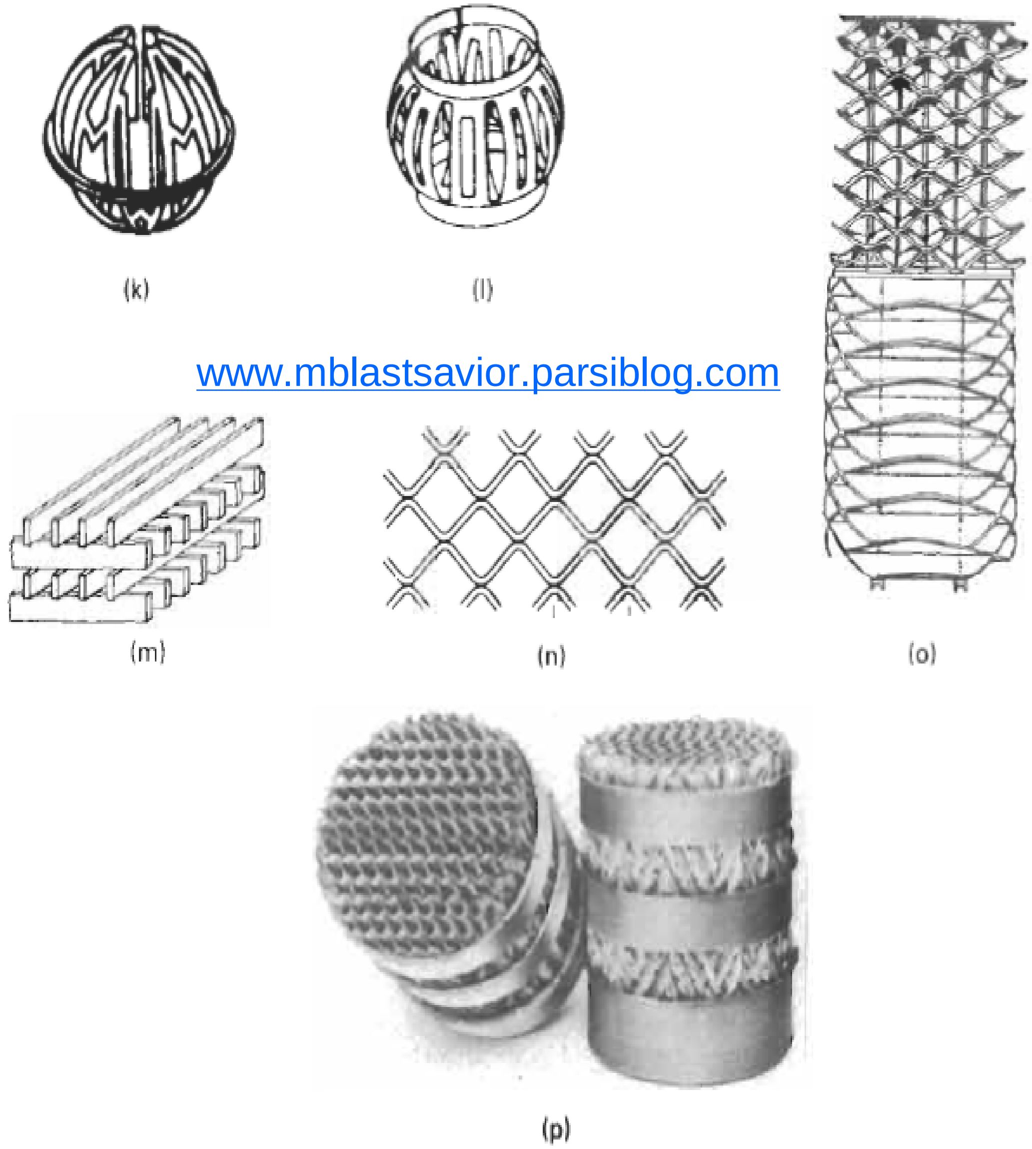

MR2L-VALVE
M-VALVE
L-VALVE
CAGED-G
CAGED-MR2
CAGED-MR7



(e) Sieve tray phenomena and pressure relations; h, is the head in the downcomer, h_l is the equivalent head of clear liquid on the tray, hf is the visible height of froth on the tray, and h_t is the pressure drop across the tray
(f) Assembly of and action of vapor and liquid on a bubblecap tray.



a) Raschig ring; (b) partition or Lessing ring; (c) double spiral ring; (d) metal pall ring; (e)plastic pall ring; (f) ceramic Berl saddle (g) ceramic intalox saddle (h) plastic intalox saddle (i) metal intalox saddle (j) Tellerette



(k) plastic tripak (l) metal tripak (m) wood grid; (n) section through expanded metal packing; (0) sections of expanded metal packings placed alternatively at right angles (p) GEM structured packing

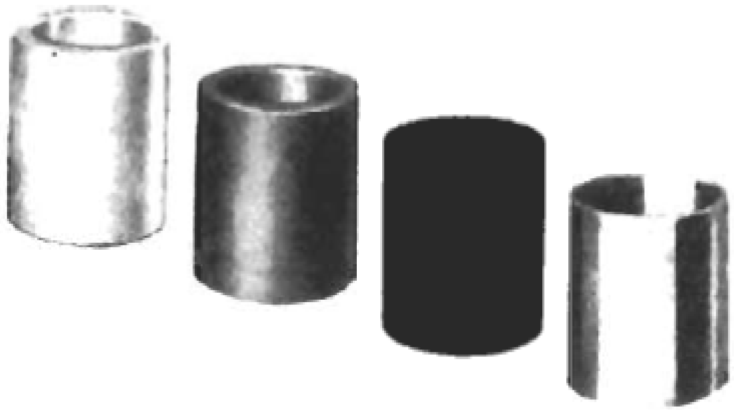


Figure 9-6B. Raschig rings (ceramic, carbon, metal).

Figure 9-6D. Berl saddles (ceramic), dumped.

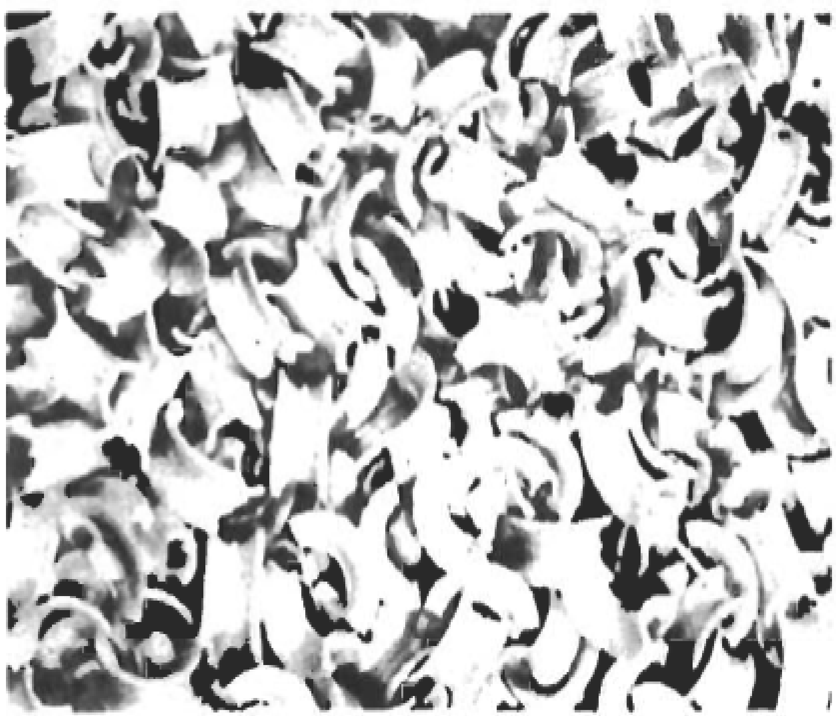


Figure 9-6C. Intalox® saddles (ceramic), dumped. Used by permission of Norton Chemical Process Products Corp.

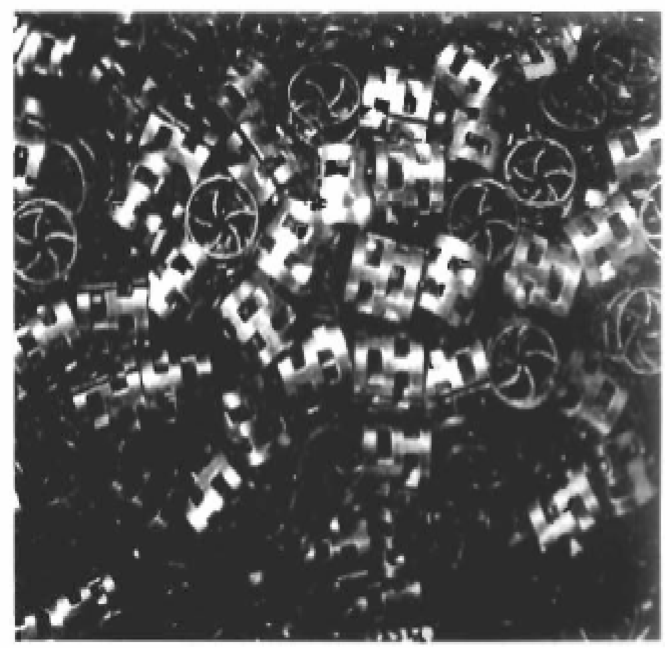


Figure 9-6E. Pall rings (metal), dumped.

Figure 9-6K. Nutter Ring™ (metal random packing). Used by permission of Nutter Engineering, Harsco Corp., Bull. NR-2.

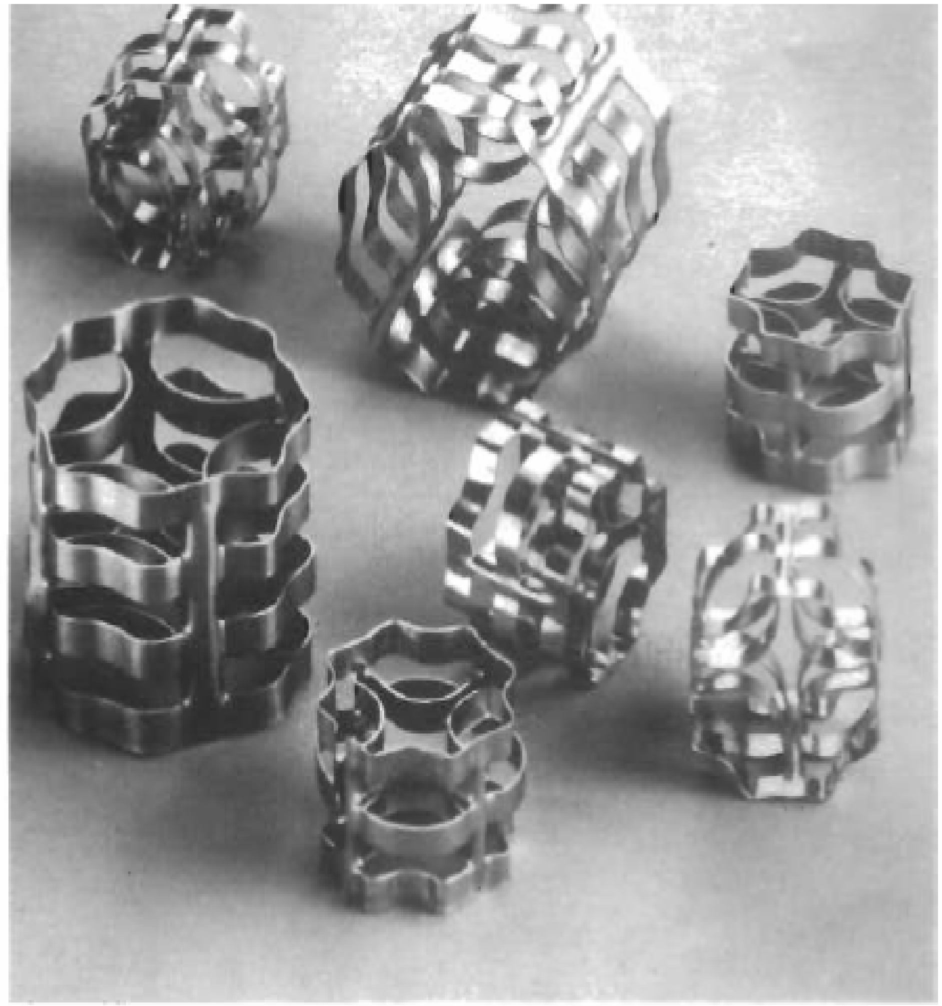


Figure 9-6M. Metal VSP® high capacity packing. Used by permission of Vereinigte Füllkörper-Fabriken GmBH & Co. Ransbach Baumbach, Germany.

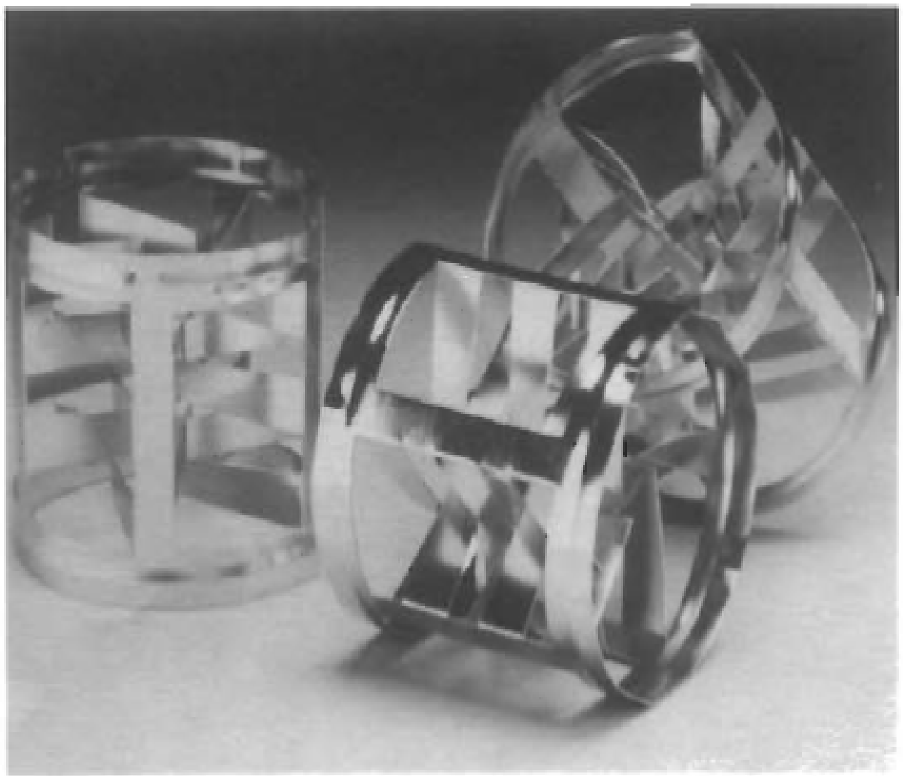


Figure 9-6N(a). Koch Metal HcKp™ random packing. Used by permission of Koch Engineering Co., Inc., Bull. KRP-2.

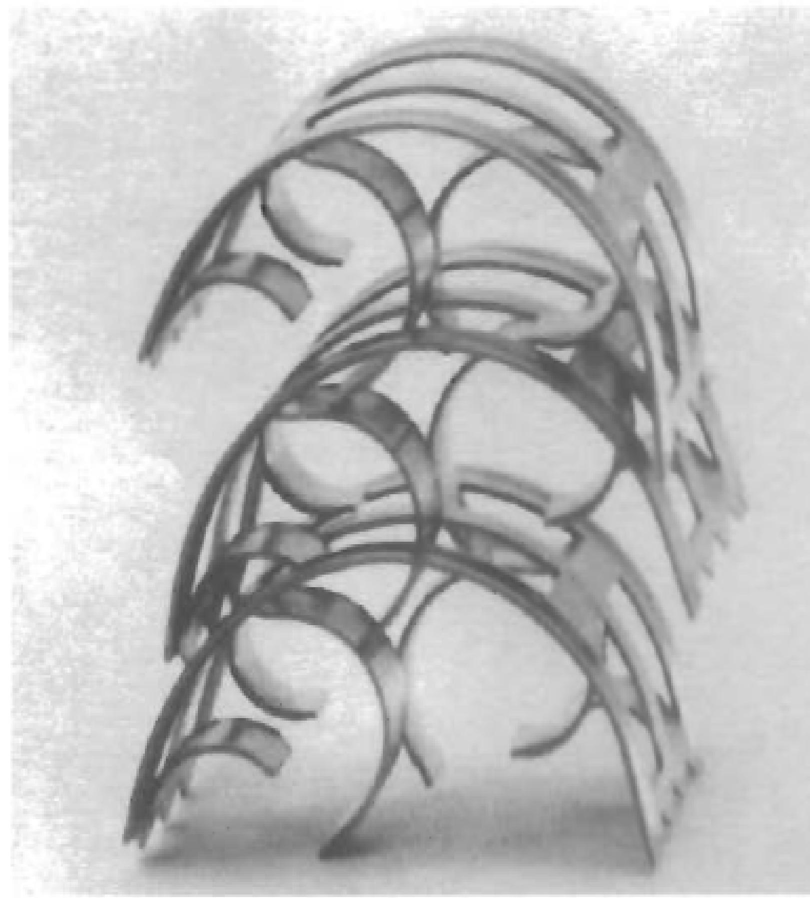


Figure 9-6P. Metal Chempak® packing. Used by permission of Chem-Pro Equipment Corp., licensed from Dr. Max Leva.

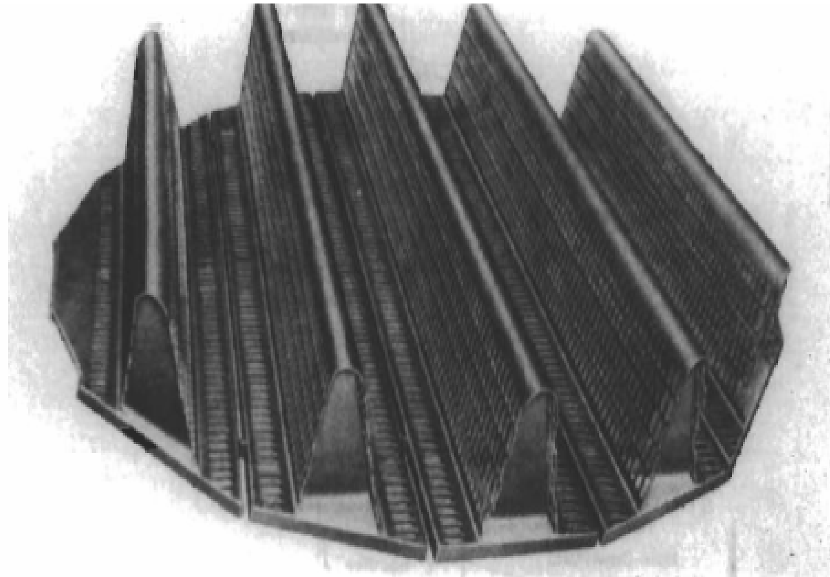


Figure 2. Multibeam packing support plate. (Courtesy of Norton Chemical Process Products Corporation.)

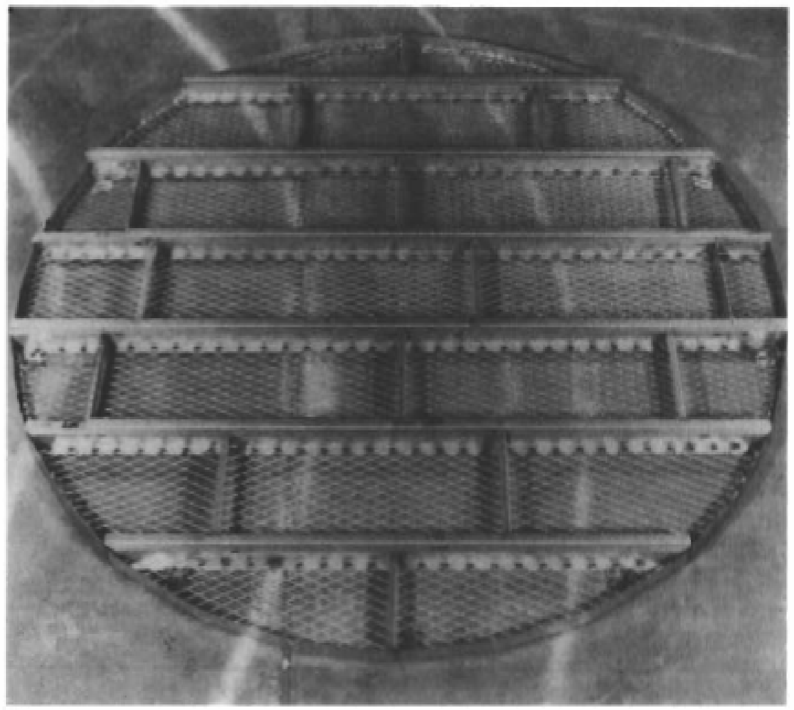


Figure 3. Bed limiter, Model 823. (Courtesy of Norton Chemical Process Products Corporation.)

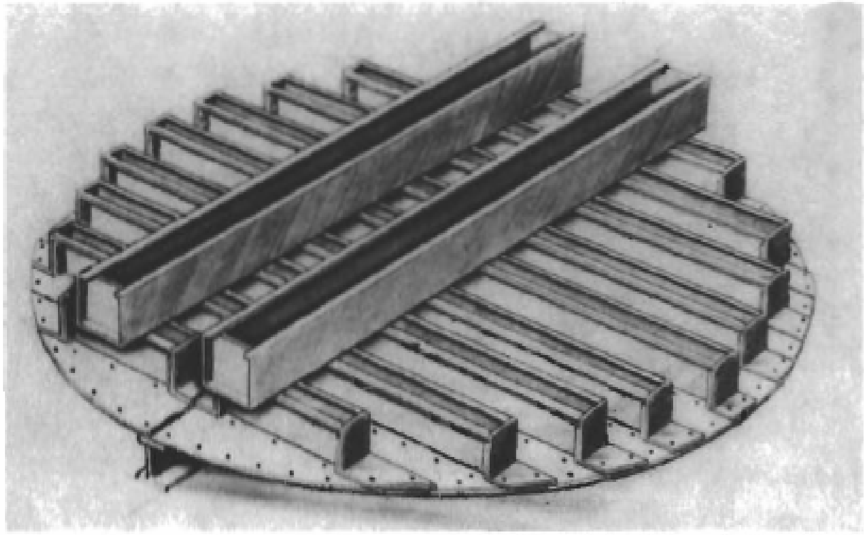


Figure 4. Orifice deck liquid distributor. (Courtesy of Norton Chemical Process Products Corporation.)

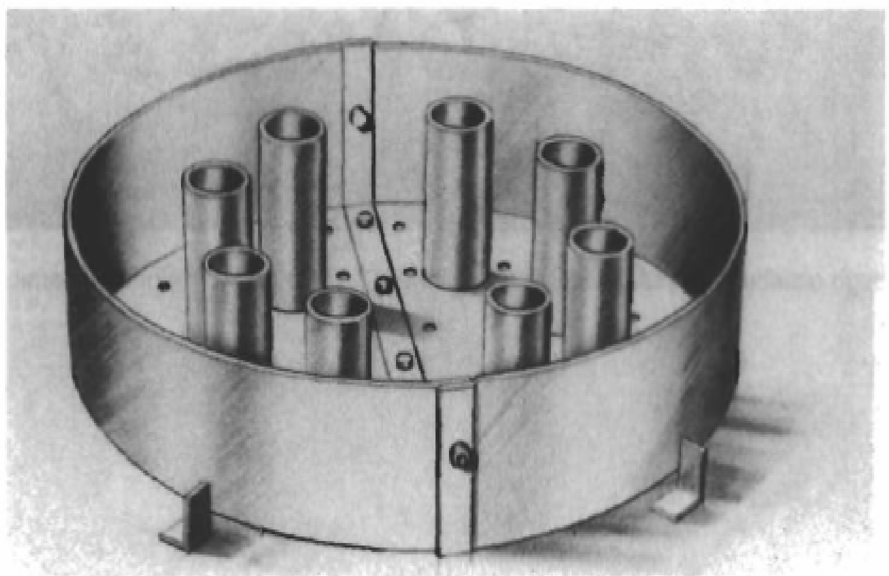


Figure 5. Orifice pan liquid distributor. (Courtesy of Norton Chemical Process Products Corporation.)

محمد بهزادی:ه

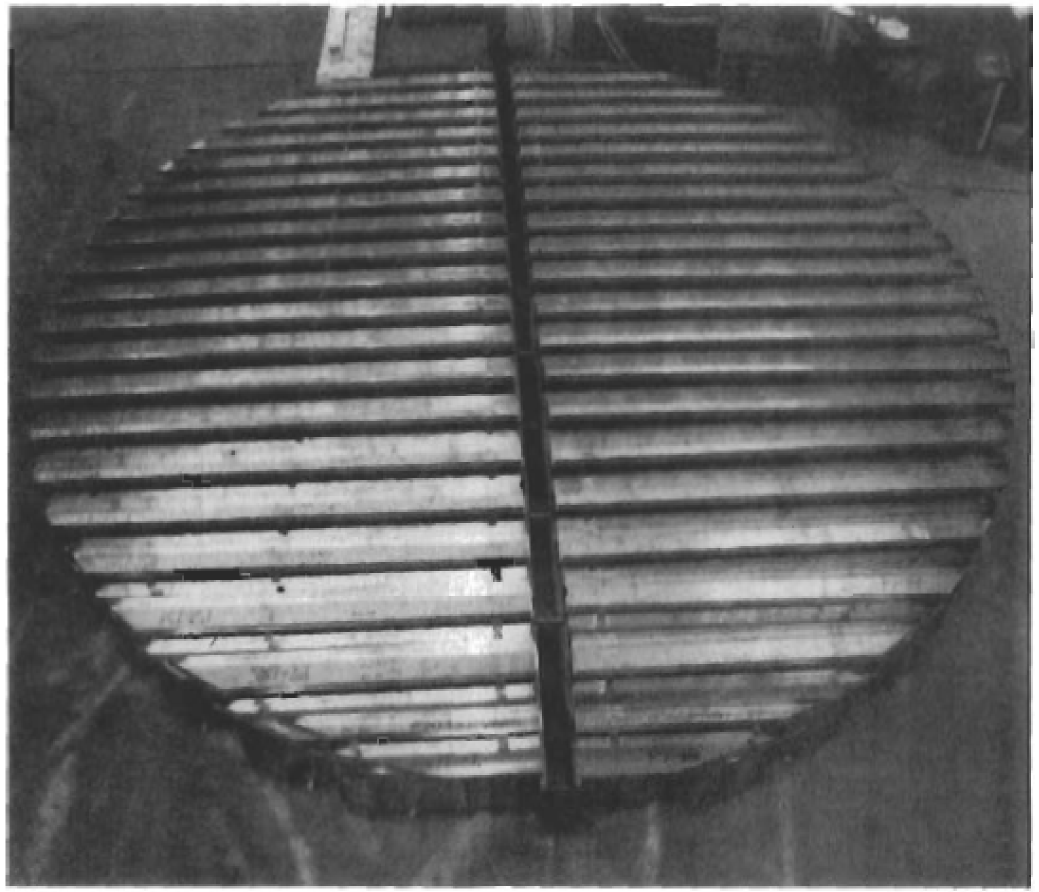


Figure 6. Orifice trough distributor with side-wall orifice, Model 137. (Courtesy of Norton Chemical Process Products Corporation.)

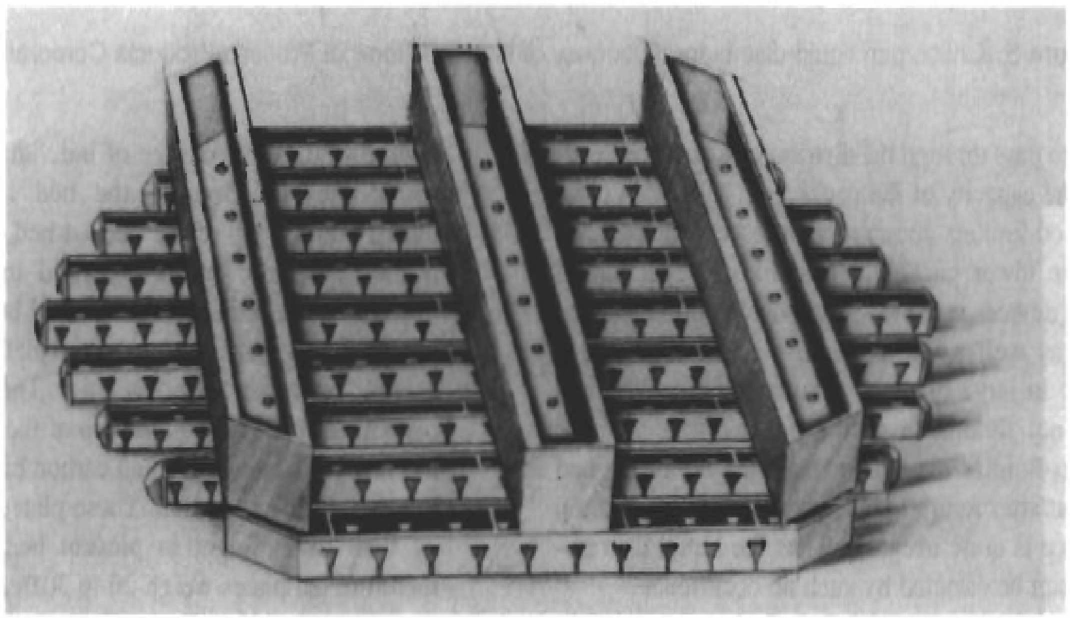


Figure 7. Weir trough liquid distributor. (Courtesy of Norton Chemical Process Products Corporation.)

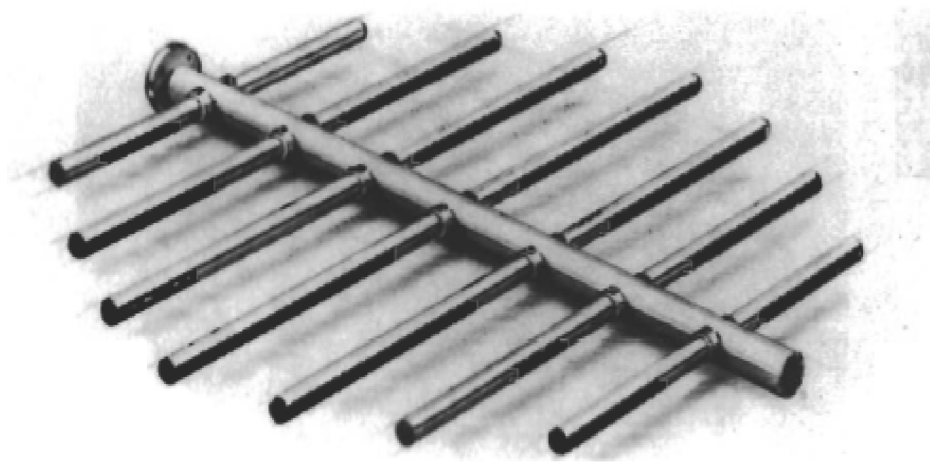


Figure 8. Orifice ladder liquid distributor. (Courtesy of Norton Chemical Process Products Corporation.)

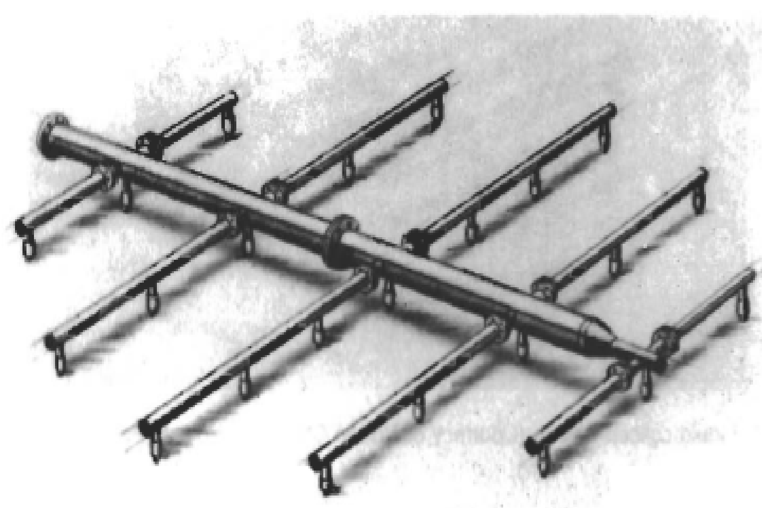


Figure 9. Spray nozzle liquid distributor. (Courtesy of Norton Chemical Process Products Corporation.)

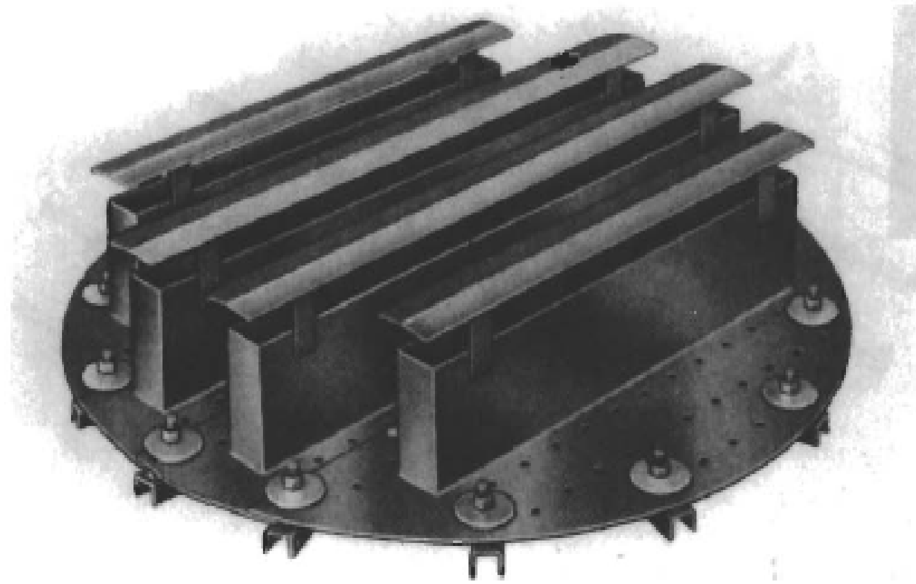


Figure 10. Orifice deck-liquid redistributor. (Courtesy of Norton Chemical Process Products Corporation.)

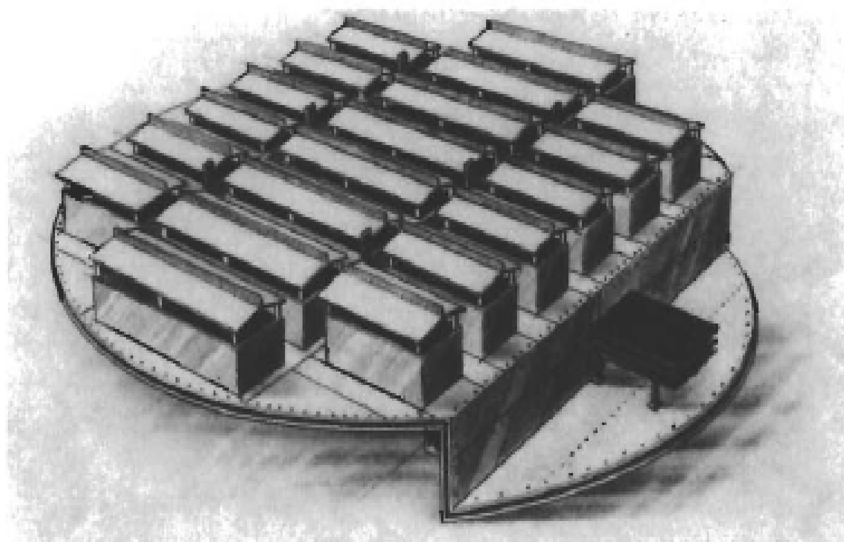


Figure 11. Liquid collector plate. (Courtesy of Norton Chemical Process Products Corporation.)

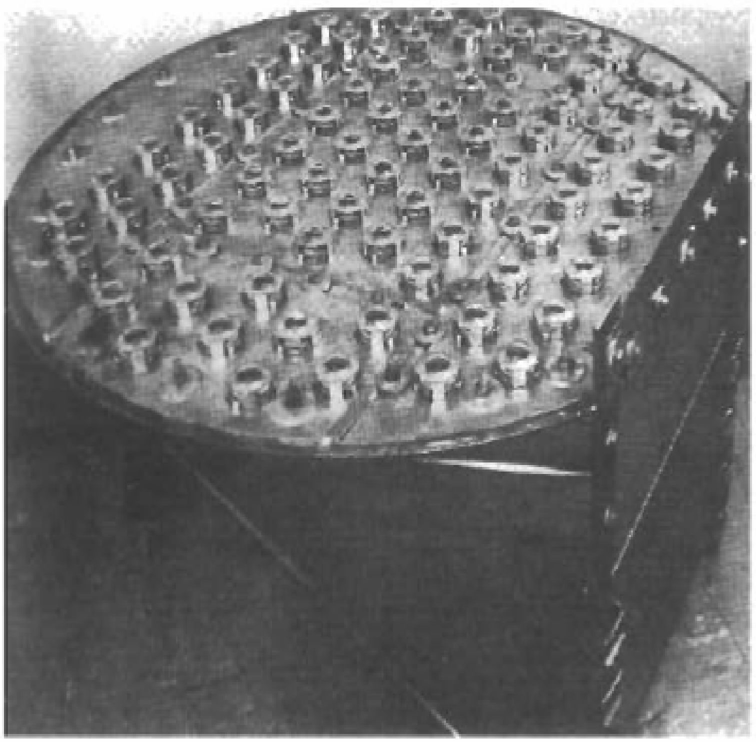
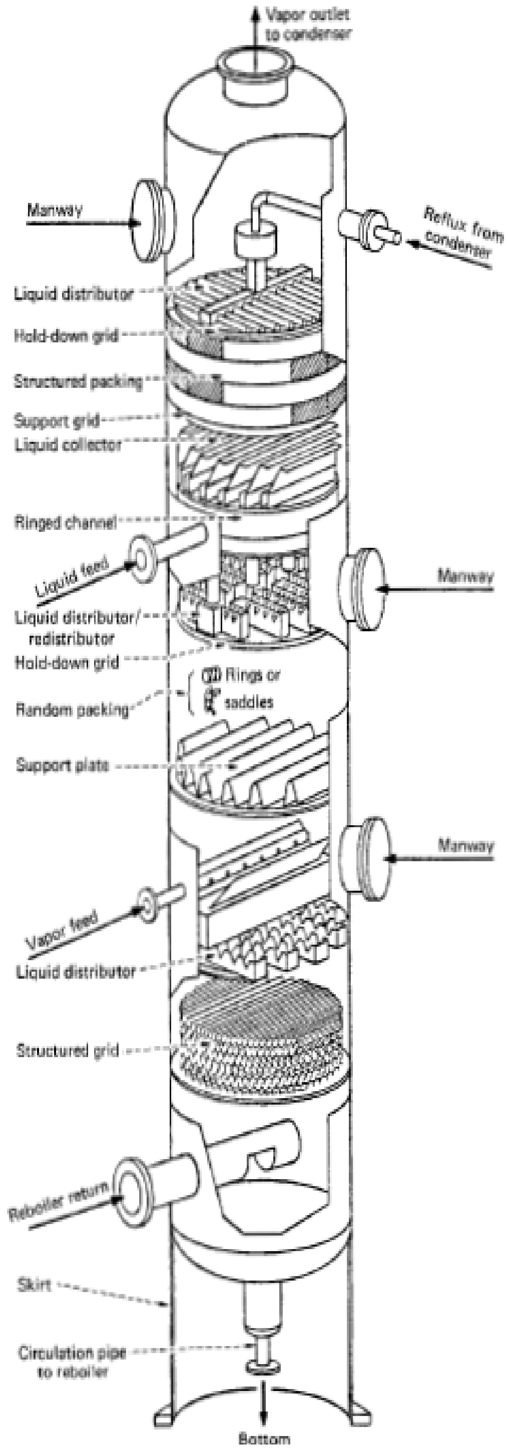
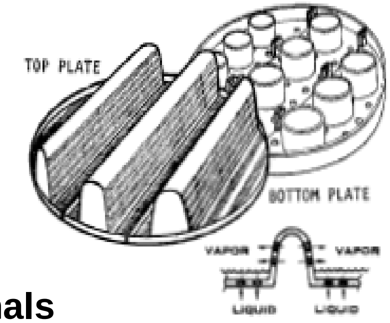


Figure 8-76. Type A-1 Ballast® Tray. Used by permission, Glitsch, Inc.

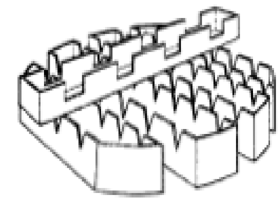
Figure 8-77. Type V-1 Ballast® Tray. Used by permission, Glitsch, Inc.



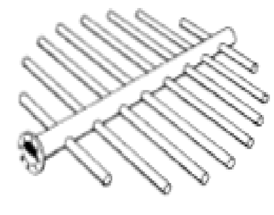
(a) Example packed column with a variety of internals
(b) Packing support and redistributor assembly.
(c) Trough-type liquid distributor.
(d) Perforated pipe distributor.
(e)Rosette redistributor for small towers.
(f) Hold-down plate, particularly for low density packing.



(b)

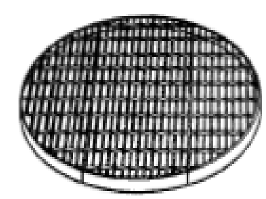


(c)



(d)

(e)



(f)

سخن پایانی

به نظر می رسد در عصری که آن را عصرانفجار اطلاعات نامیده اند ومن آن را عصر روشن ایران می نامم، مهمترین دغدغه برای پیشرفت و ترقی پیدا کردن منابع درست مطالعاتی می باشد.در جزوات اخیر سعی شده است بر اساس تجربه و مطالعه چندین منبع مختلف بهترین سیستم آموزشی برای سریعترین نتیجه گیری ارائه شود.

مطمئن باشید که با بخشش علمی به اطرافیان درهای پنهان و ناگشوده علم را بر روی خود گشوده خواهید دید! این درسی است که از طبیعت گرفتم .قدرتمندی و ویران کنندگی یک گردباد به میزان خلا درون آن بستگی دارد.انتقال دانش به دیگران همان منشا خلا علمی شماست.

این جزوه تقدیم می شود به پدر و مادرم که پشتوانه ای بی بدیل برای این حقیر بودند.

و با تشکر از تمام کسانی که صمیمانه در این راه یاورم بودند

به طور قطع این جزوه خالی از اشکال نمی باشد. خواهشمند است در تصحیح و بهتر نمودن آن اینجانب را یاری نمایید.

Email: lastsavior_b@yahoo.com
Weblog: www.mblastsavior.mihanblog.com
www.mblastsavior.blogfa.com