دوره آموزشي طراحي ادوات فرآيندي

Sizing training course

تهيه كننده : محمد بهزادي Mohammad Behzadi

وبلاگ آموزشي: www.mblastsavior.mihanblog.com
پست الكترونيكي: Lastsavior_b@yahoo.com

تقديم به برادرم سعيد رادپور كه با بخشش علمي بيدريغ خود استاد و قطب نماي علمي در مسير زندگيم بود

تذكر: براي ديدن راهنماي مطالب لازم است تا از آكروبات7 يا بالاتر استفاده شود

Acrobat 7.0 or higher is needed for view commenting!

دوره طراحی (Sizing)

تهیه کننده: محمد بهزادی

Design Criteria

خواسته های کارفرما و ضوابط کدها

Pressure Design Criteria

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

DP=design Pressure
OP=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	Pa (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 کشی،شیرها و اتصالات
  - ENGINNERING FLOWSHEET
  - ENGINEERING LINE DIAGRAM

Separators/Accumulators

انواع مخازن

- درام جریان برگشتی(بین کندانسور برج و تجهیزات پایین دست)
- درام قبل از کمپرسور(برای جمع آوری مایعات)
- درام قبل و بعد از کمپرسور رفت و برگشتی (جهت یکنواخت کردن فشار خروجی)
- مخزن روی کوره ها(تیوبهای داخل کوره را در مقابل خشک شدن محافظت می کند)

تفاوت مخازن و تانکها

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

تانکها

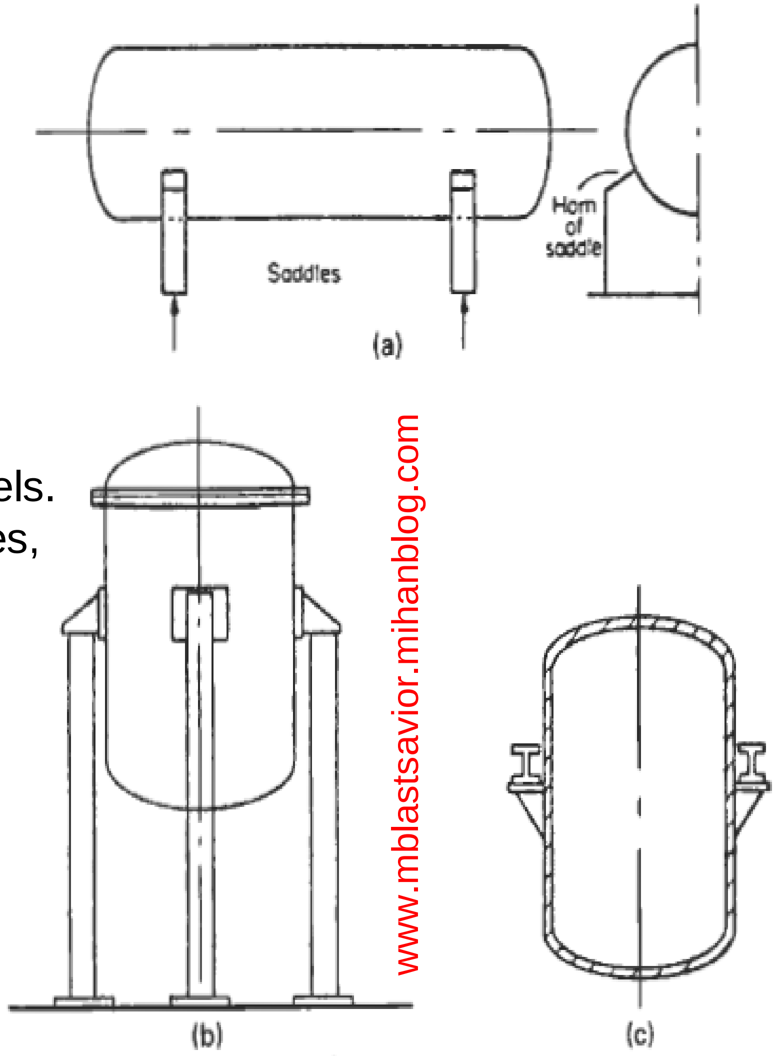
- تانک خوراك برج تقطير ناپيوسته
- تانکهای تجمعی Rundown بين تجهيزات

- مخازن مایع عموما افقی
- جداکننده های گاز-مایع عموما عمودی

P (psig)	0–250	251–500	501+
L/D	3	4	5

انواع ساپورت مخازن

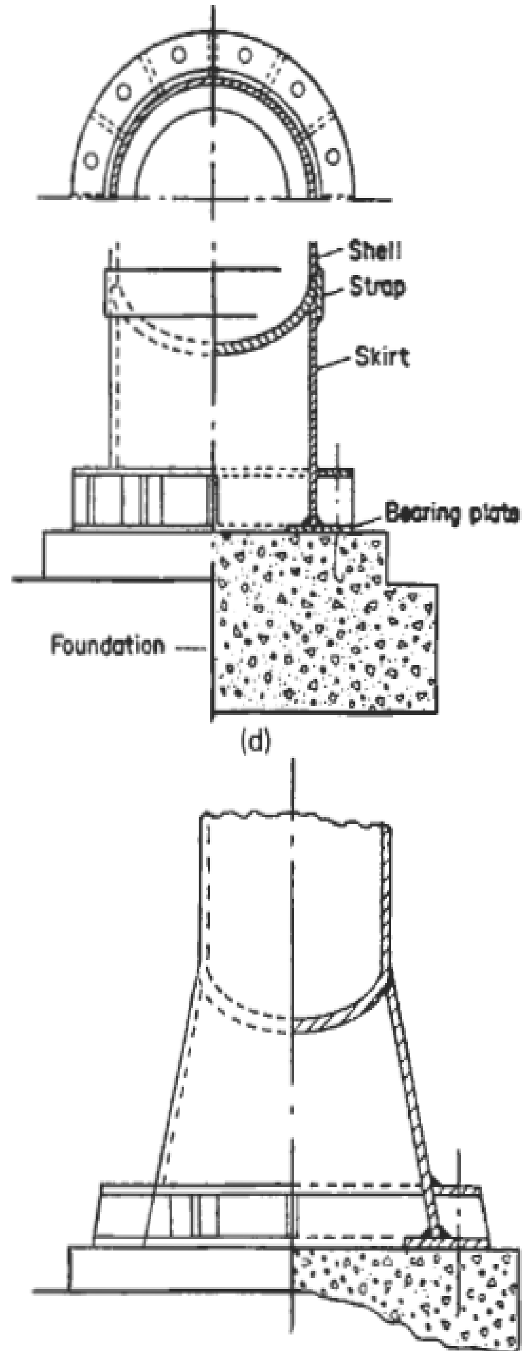
Methods of supporting vessels.
(a) Saddle supports for
horizontal vessels, usually of concrete.
(b) Bracket or lug supports
resting on legs, for either vertical or horizontal vessels.
(c) Bracket or lug supports resting on steel structures,
for either vertical or
horizontal vessels.



تهیه کننده:محمد بهزادی

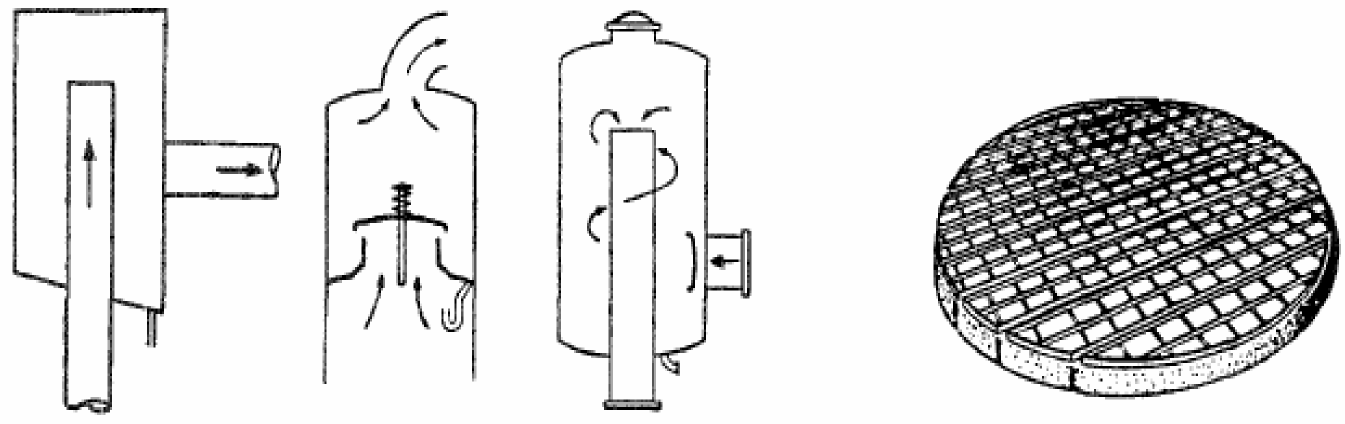
انواع ساپورت مخازن

(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.



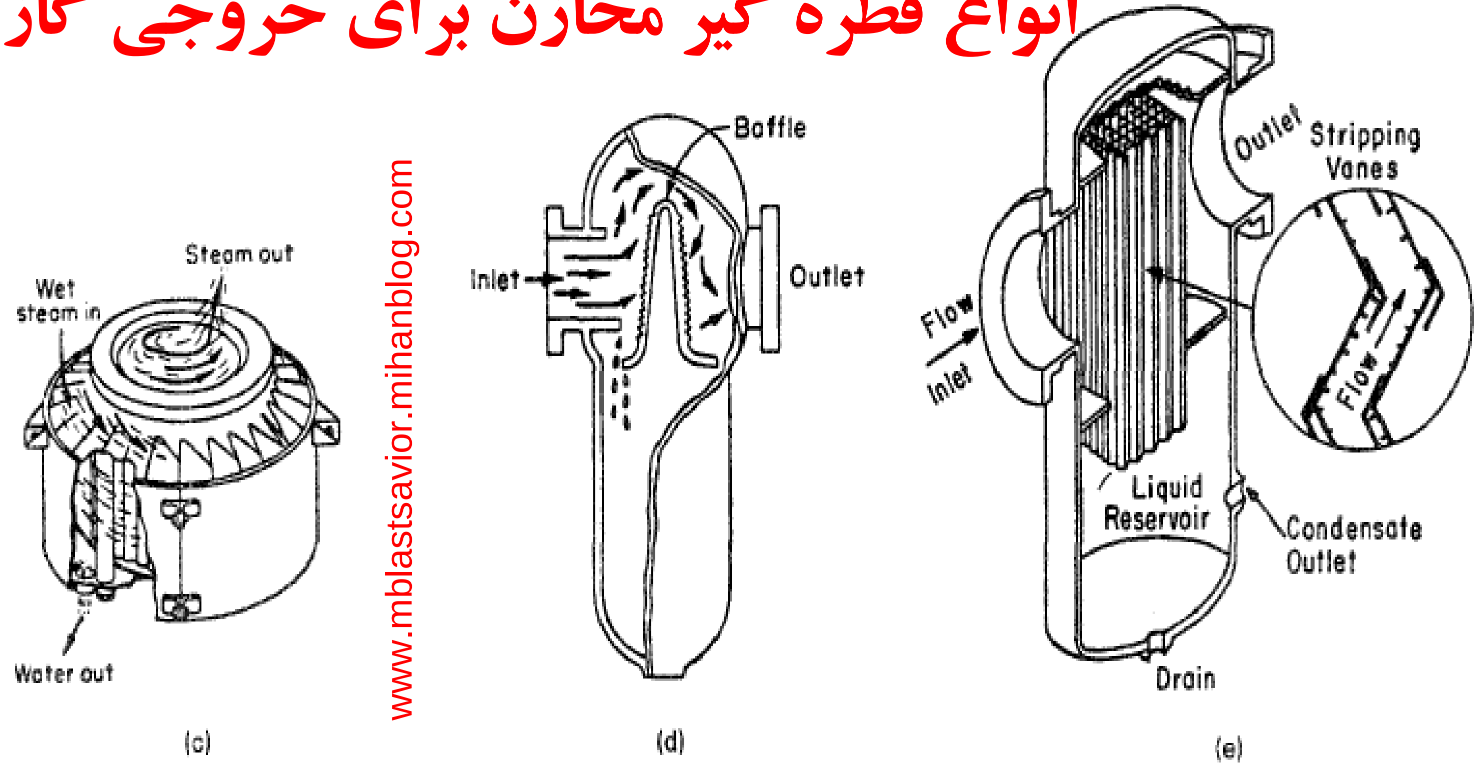
تهیه کننده:محمد بهزادی

انواع قطره گیر مخازن برای خروجی گاز



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.**

انواع قطره گیر مخازن برای خروجی گاز



(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.

سایزینگ درام

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

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

تهیه کننده:محمد بهزادی

سایزینگ درام

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

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

سایزینگ درام

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

www.mblastsavior.mihanblog.com	F_4
Board-mounted level recorder	1.0
Level indicator on board	1.5
Gage glass at equipment only	2.0

تهیه کننده:محمد بهزادی

سایزینگ درام

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/ft^3
K = System constant

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

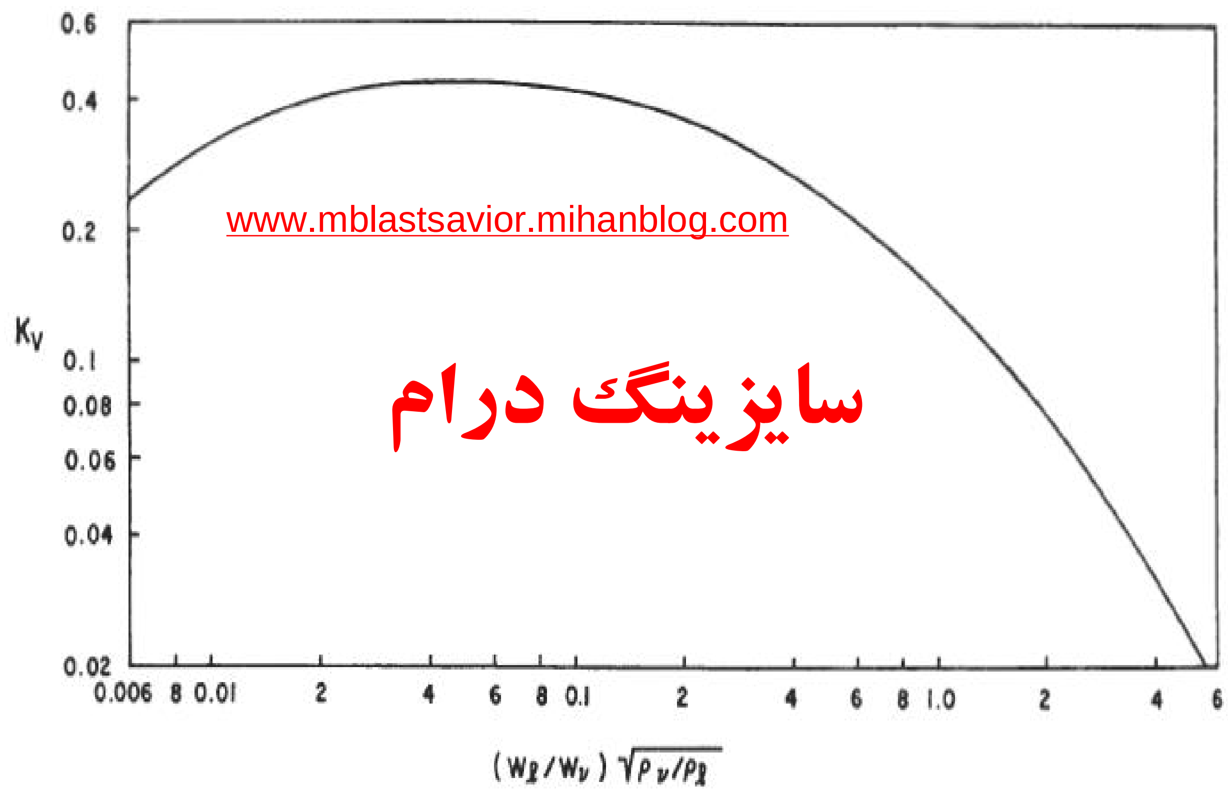
$$W_L/W_v(\rho_v/\rho_L)^{0.5}$$

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%.



سایزینگ درام

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

سایزینگ درام:مثال

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 $K_H = 1.25K_v$)

$Y = EXP(A + BX + CX\char`^2 + DX\char`^3 + EX\char`^4 + FX\char`^5)$

$A = -1.942936$

$B = -0.814894$

$C = -0.179390$

$D = -0.0123790$

$E = 0.000386235$

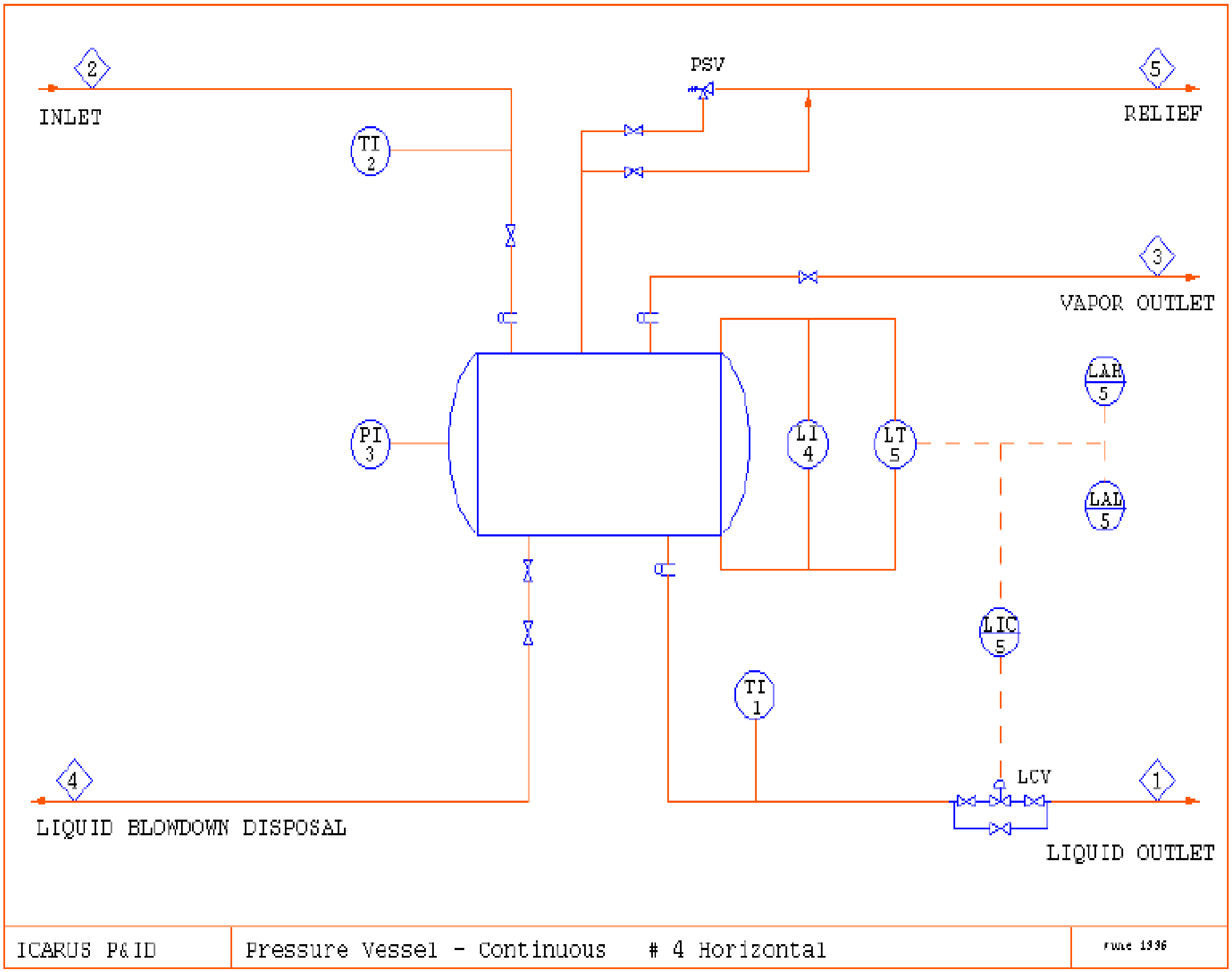
$F = 0.000259550$

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.

کنترل درام

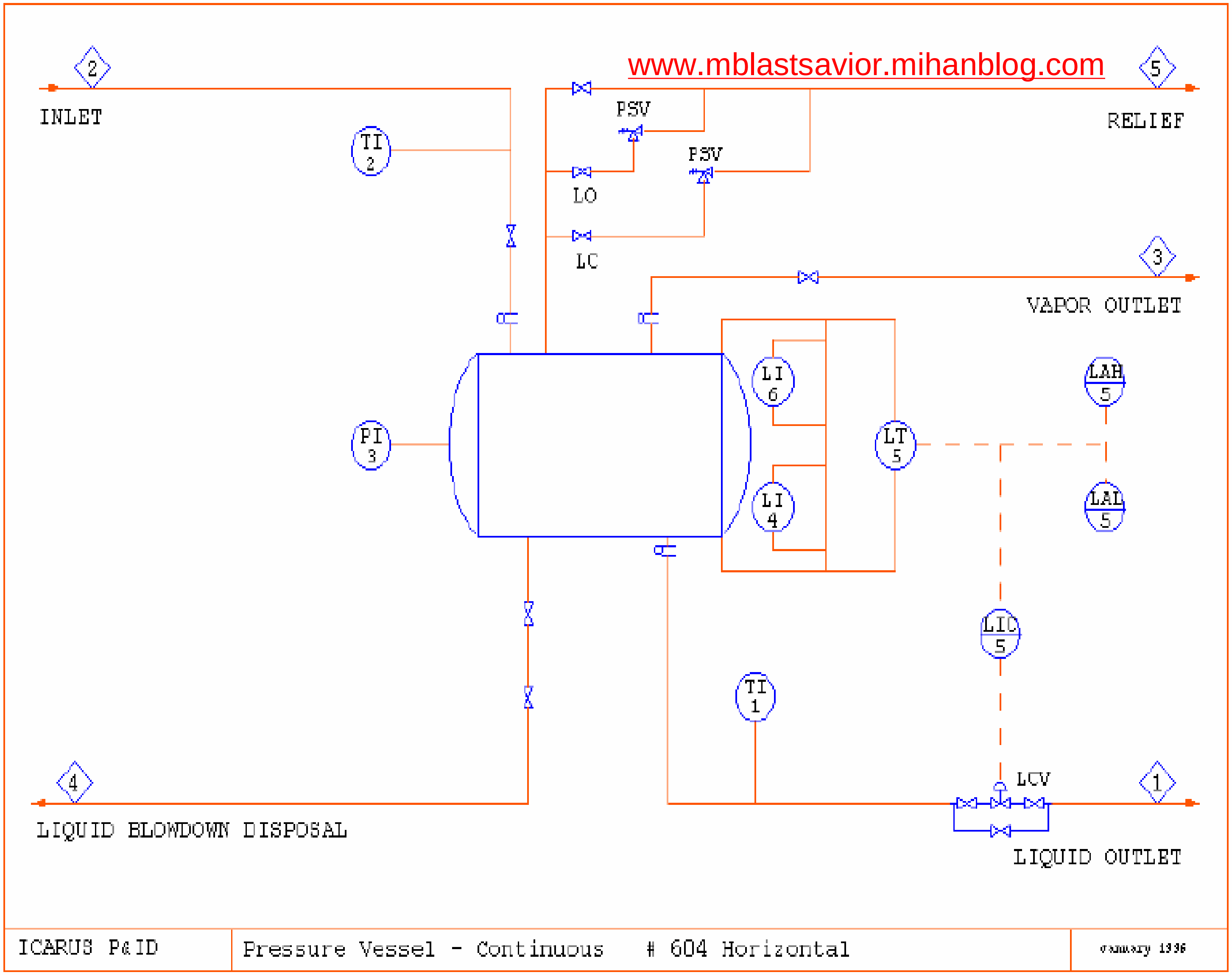
4 Horizontal Pressure Vessel – Continuous



تهیه کننده:محمد بهزادی

604 Horizontal Pressure Vessel – Continuous

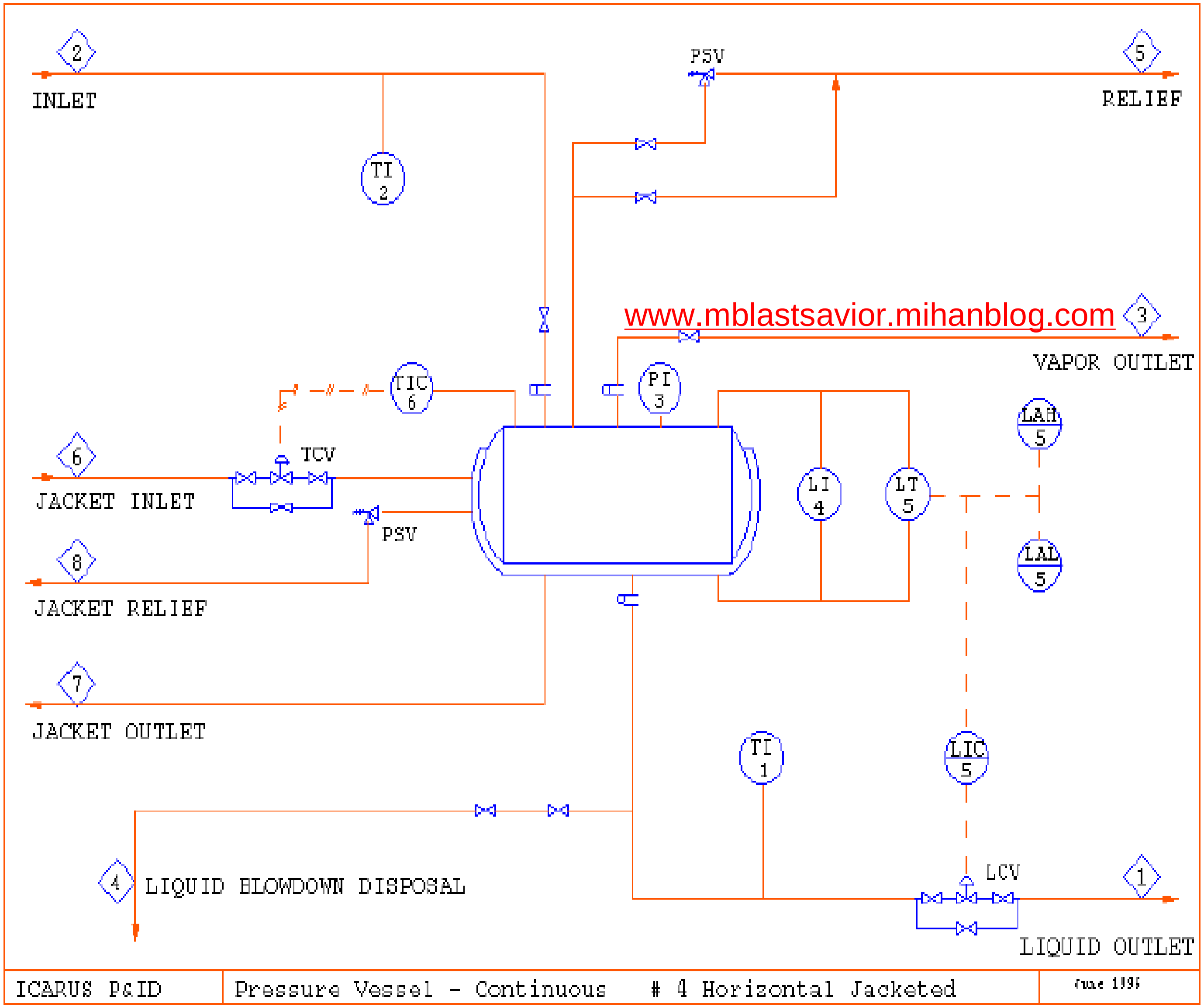
کنترل درام



تهیه کننده:محمد بهزادی

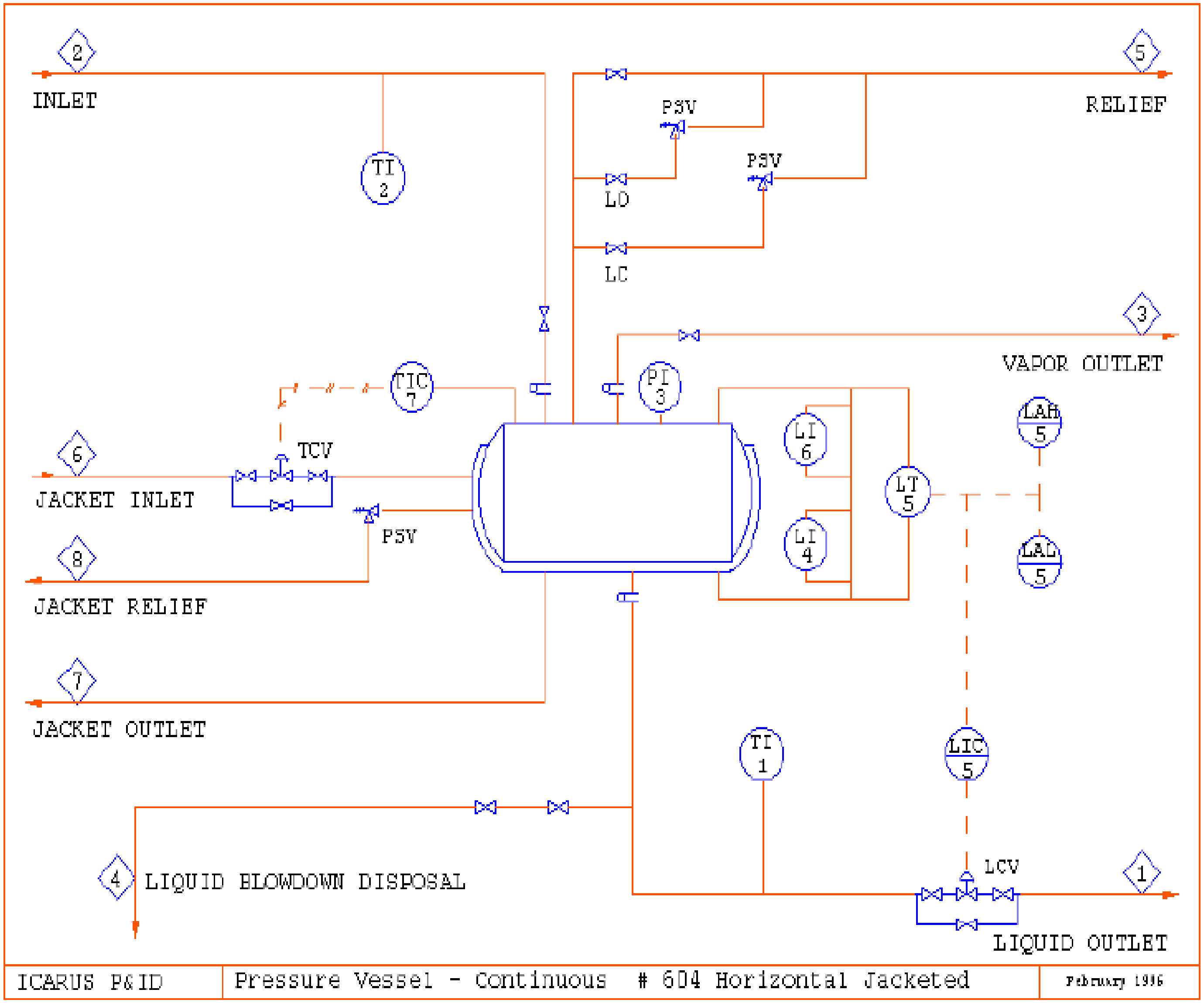
کنترل درام

4 Horizontal Jacketed Pressure Vessel - Continuous



تهیه کننده:محمد بهزادی

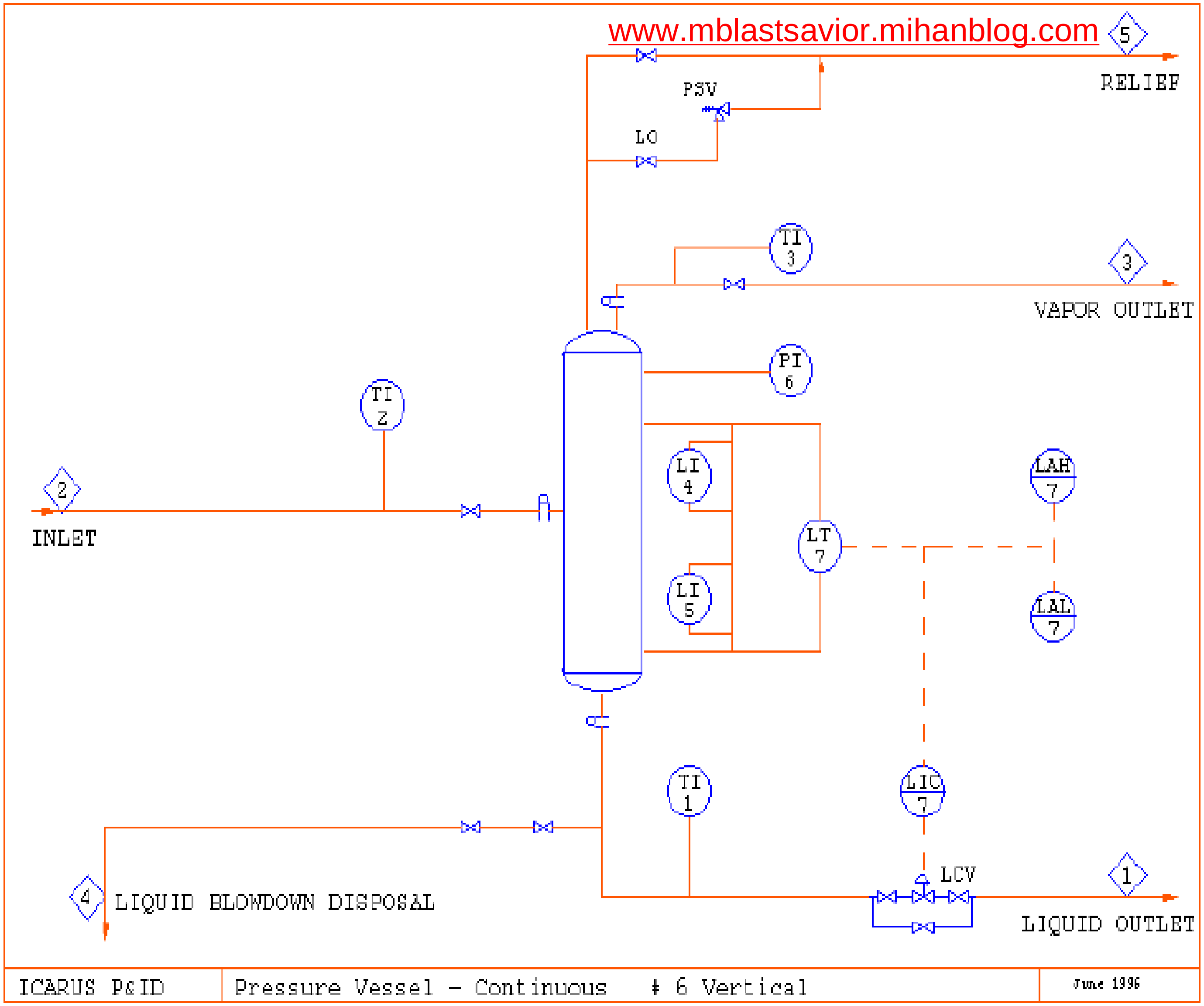
604 Horizontal Jacketed Pressure Vessel – Continuous کنترل درام



تهیه کننده:محمد بهزادی

کنترل درام

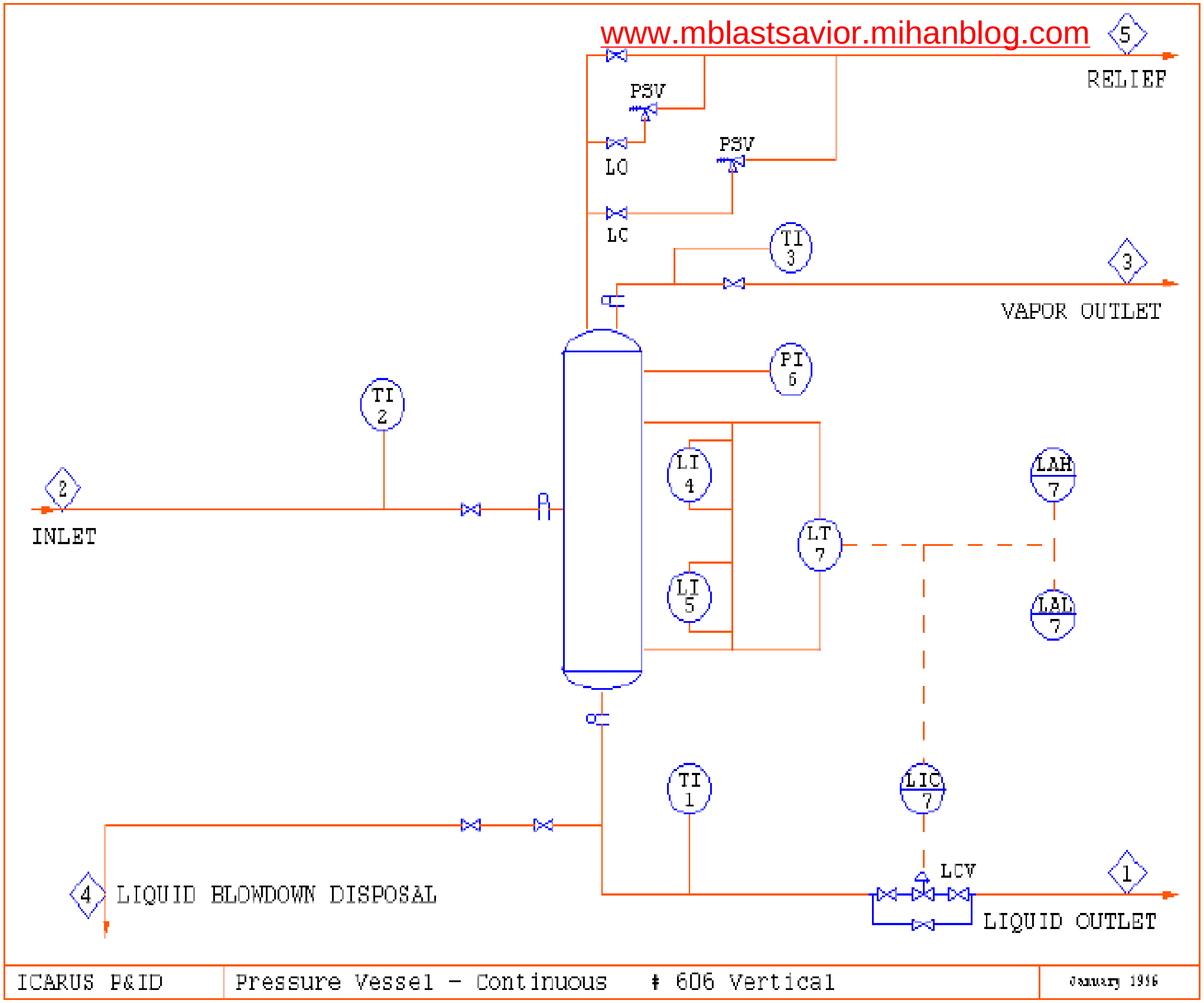
6 Vertical Pressure Vessel – Continuous



تهیه کننده:محمد بهزادی

606 Vertical Pressure Vessel – Continuous

کنترل درام



تهیه کننده:محمد بهزادی

Datasheet درام

VESSEL DATA SHEET

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

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)

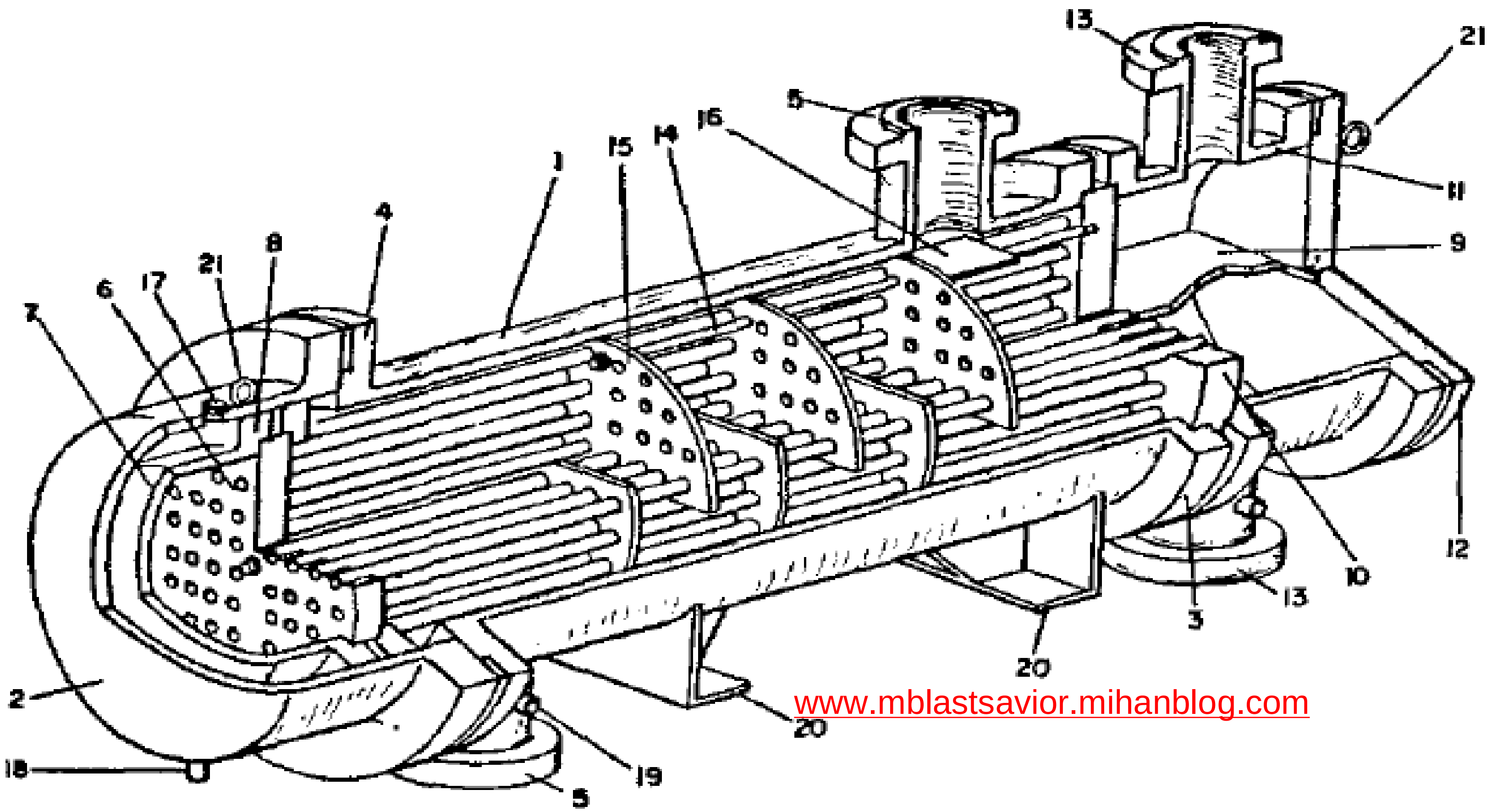
NOZZLE SCHEDULE

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

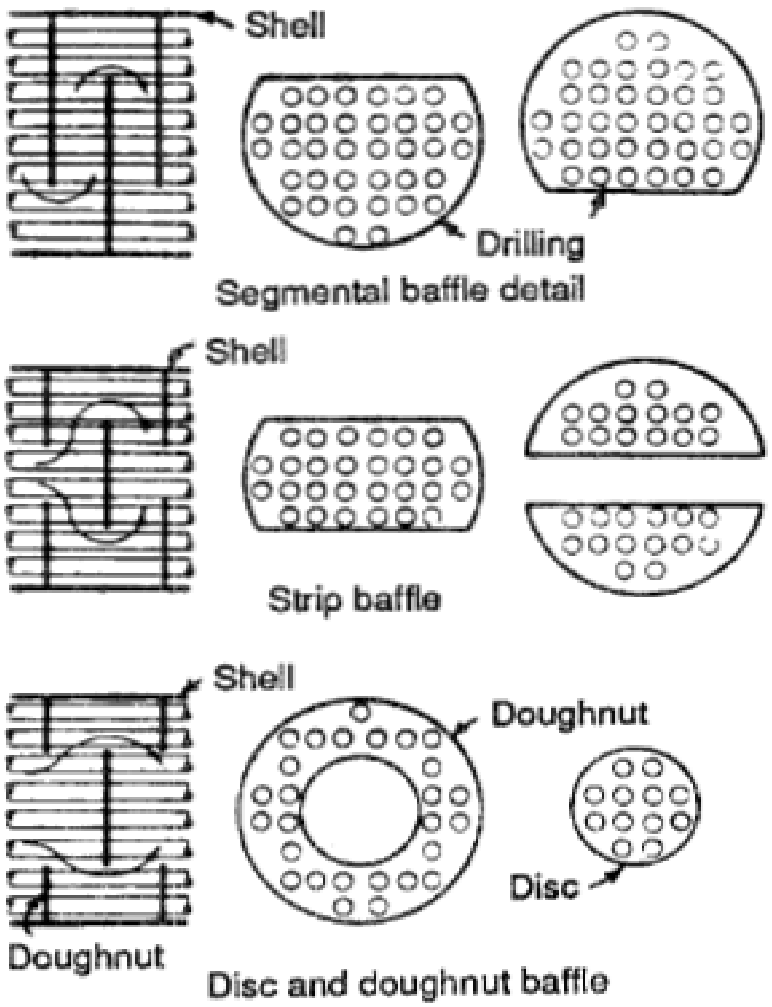
تهیه کننده:محمد بهزادی

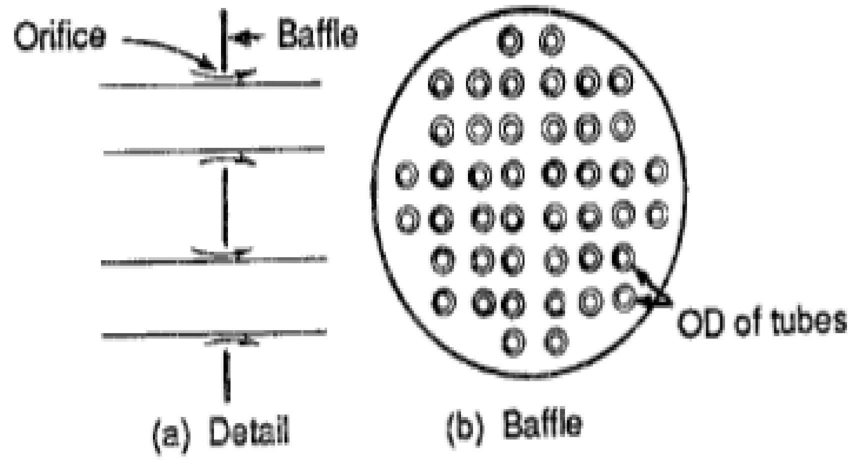
Heat Exchangers



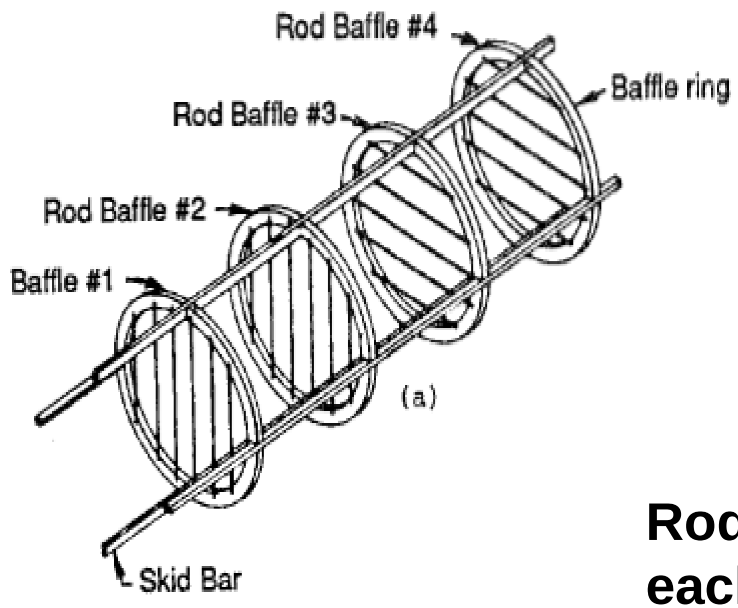
1. SHELL
2. SHELL COVER
3. SHELL CHANNEL
4. SHELL COVER END FLANGE
5. SHELL NOZZLE
6. FLOATING TUBESHEET
7. FLOATING HEAD
8. FLOATING HEAD FLANGE
9. CHANNEL PARTITION
10. STATIONARY TUBESHEET
11. CHANNEL
12. CHANNEL COVER
13. CHANNEL NOZZLE
14. TIE RODS AND SPACERS
15. TRANSVERSE BAFFLES OR SUPPORT PLATES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

انواع بفل متقاطع



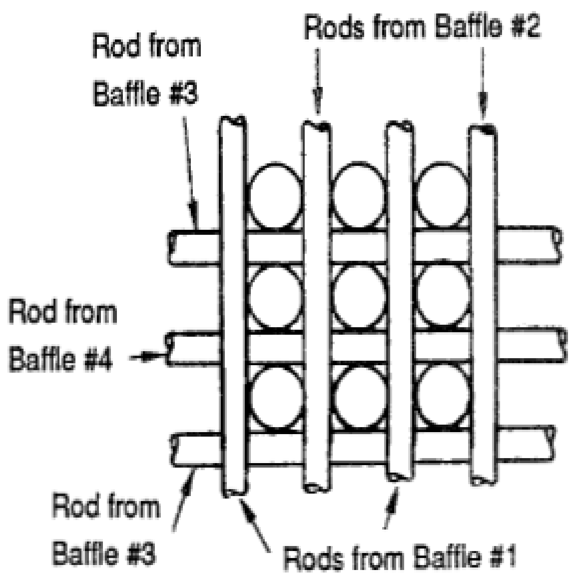


Orifice baffle



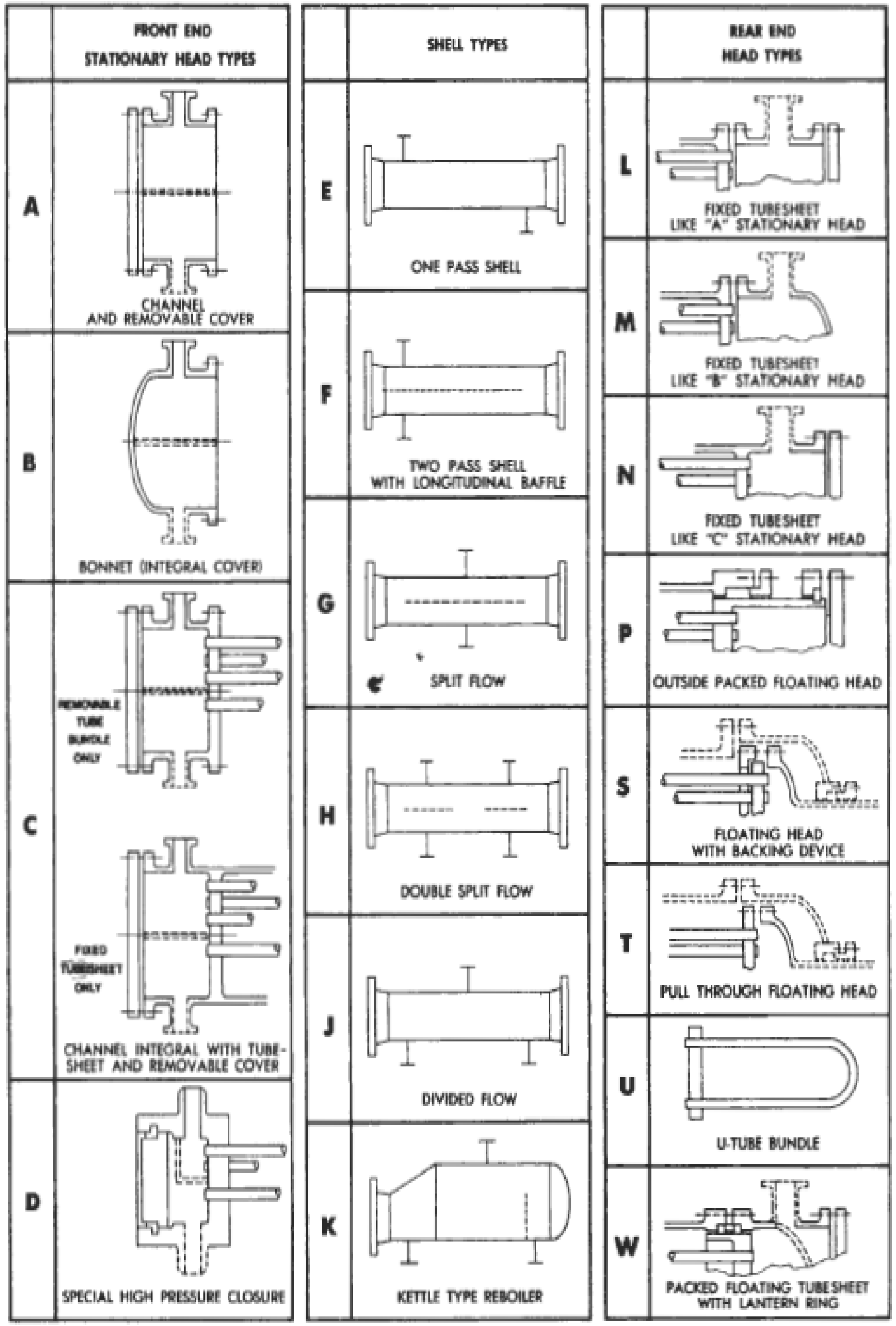
Rod Baffle

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



کدهای TEMA

Standards of Tubular Exchanger Manufacturers Association (TEMA).



تهیه کننده:محمد بهزادی

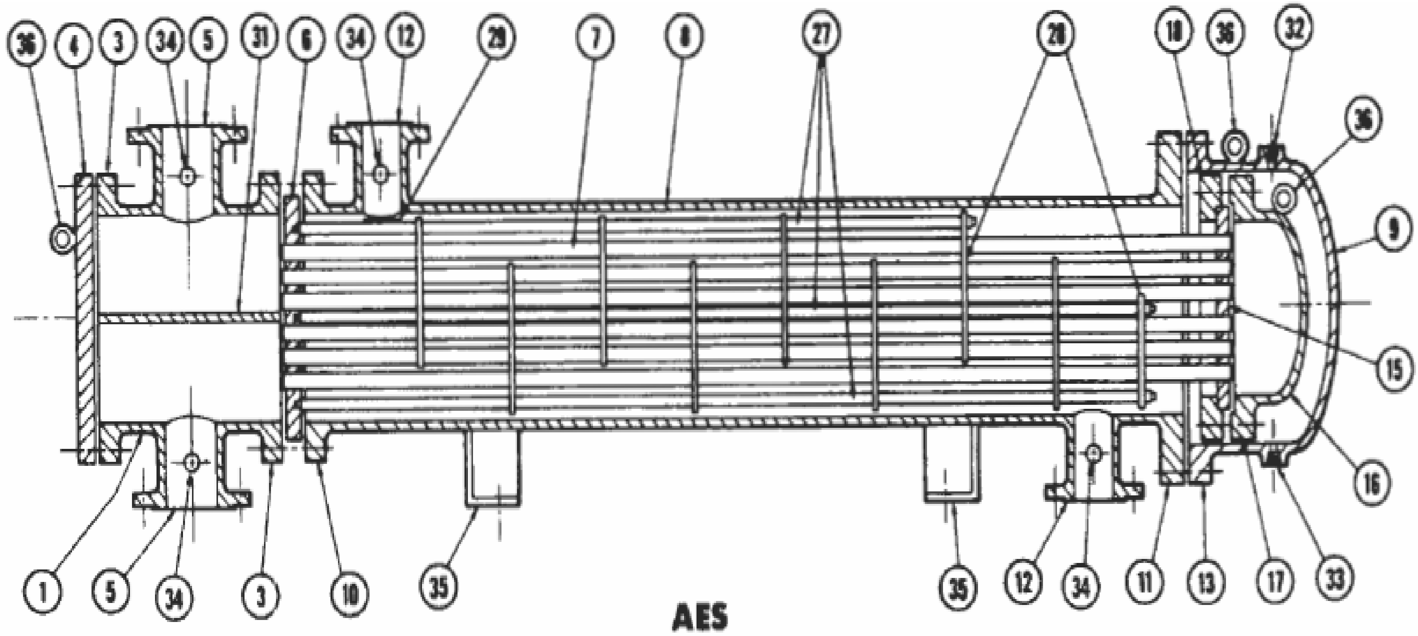
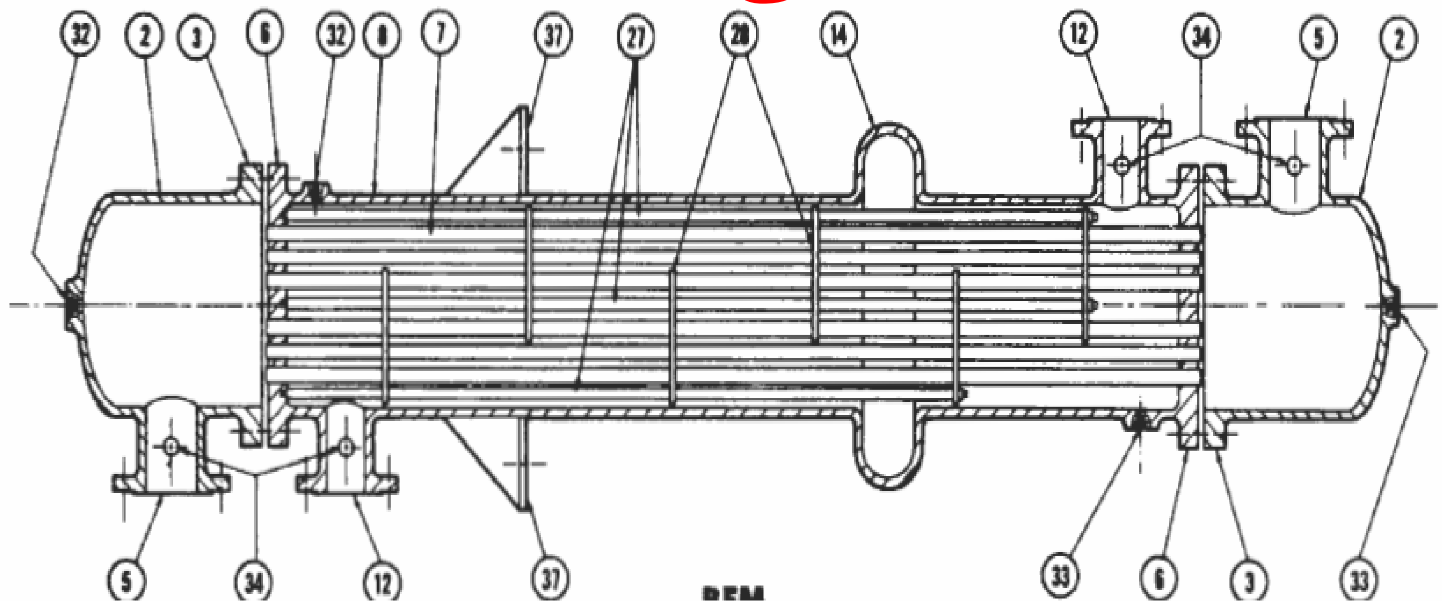


Figure 2. Type AES.

کدهای TEMA



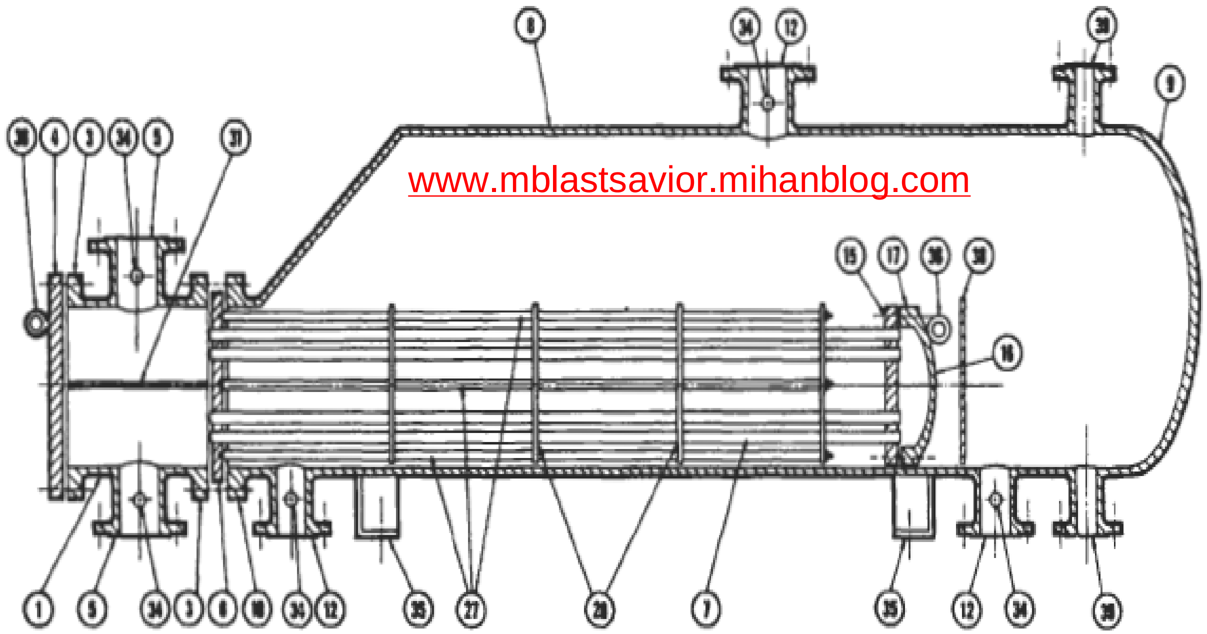


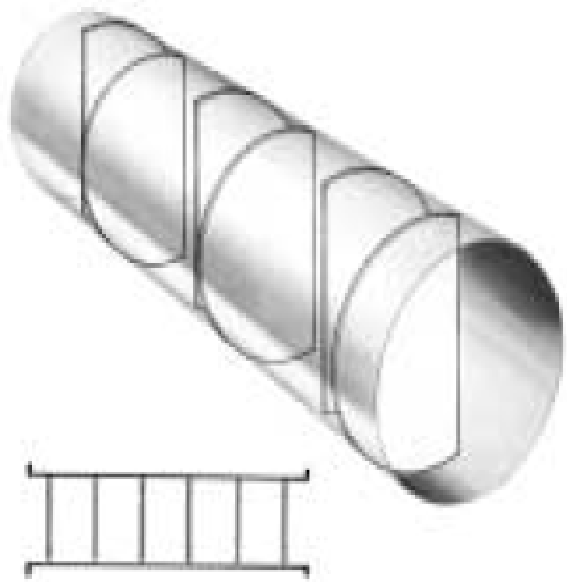
Table 1
Typical Heat Exchanger Parts and Connections

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

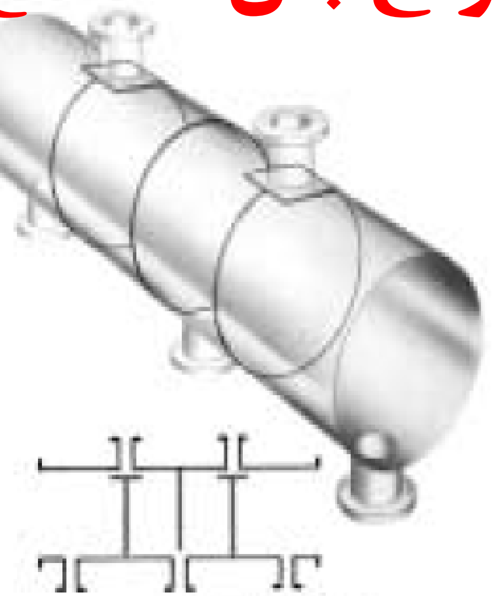
کدهای TEMA

تهیه کننده:محمد بهزادی

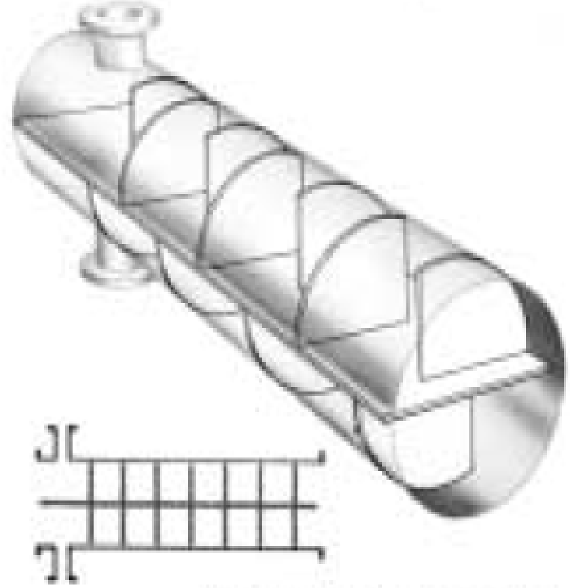
انواع بفل متقاطع



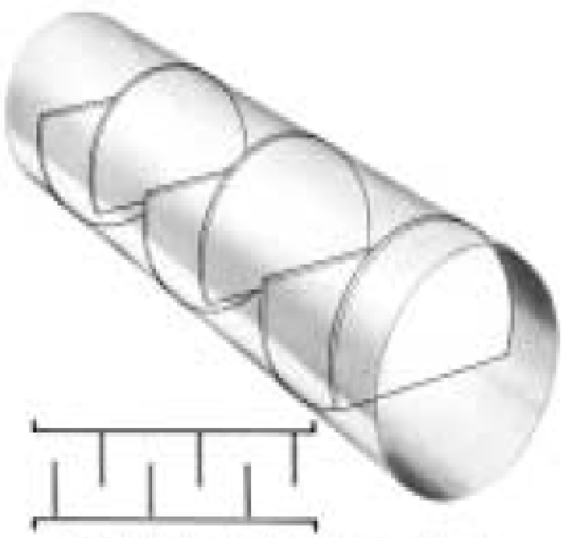
standard segmental baffle designed for side to side flow



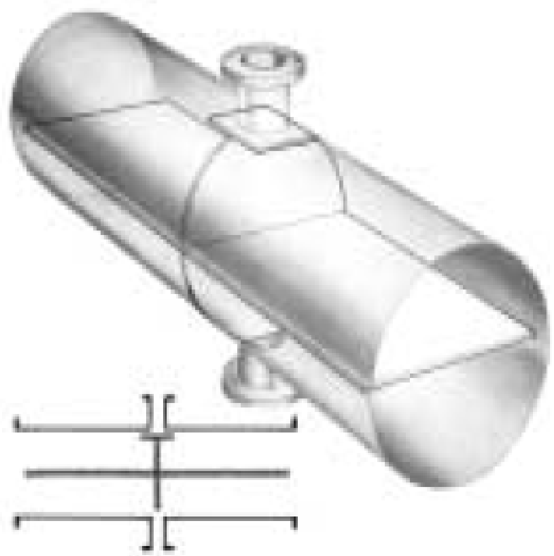
standard double split flow design



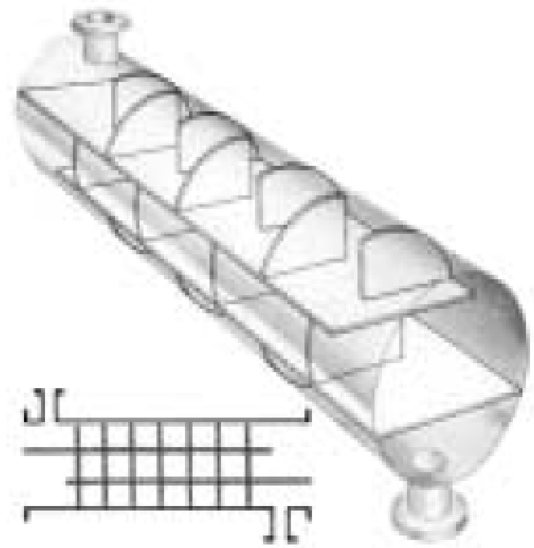
standard segmental two shell baffle design



standard segmental baffle designed for up and down flow

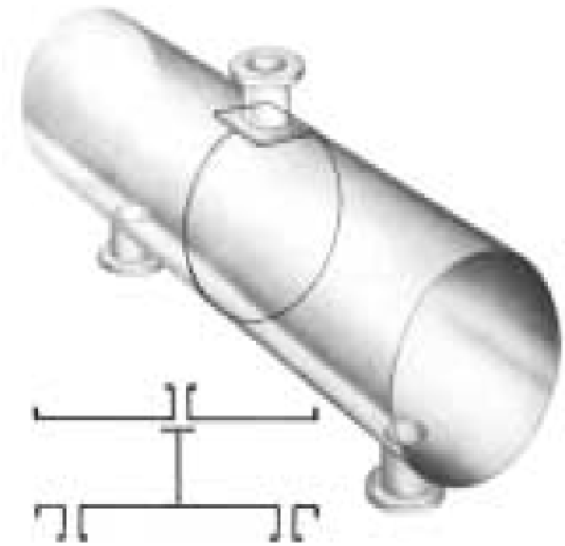


standard split flow design with horizontal baffle

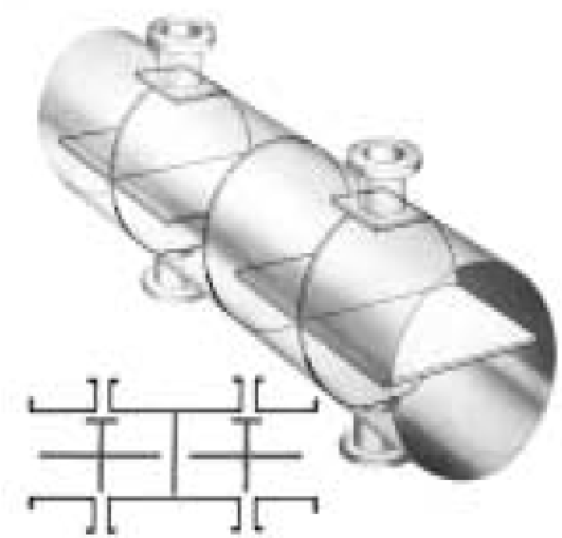


standard segmental three shell pass baffle design

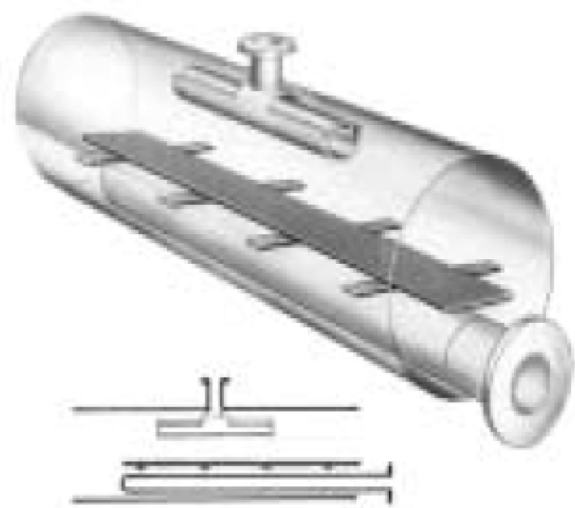
انواع بفل متقاطع



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.

Rod Baffle

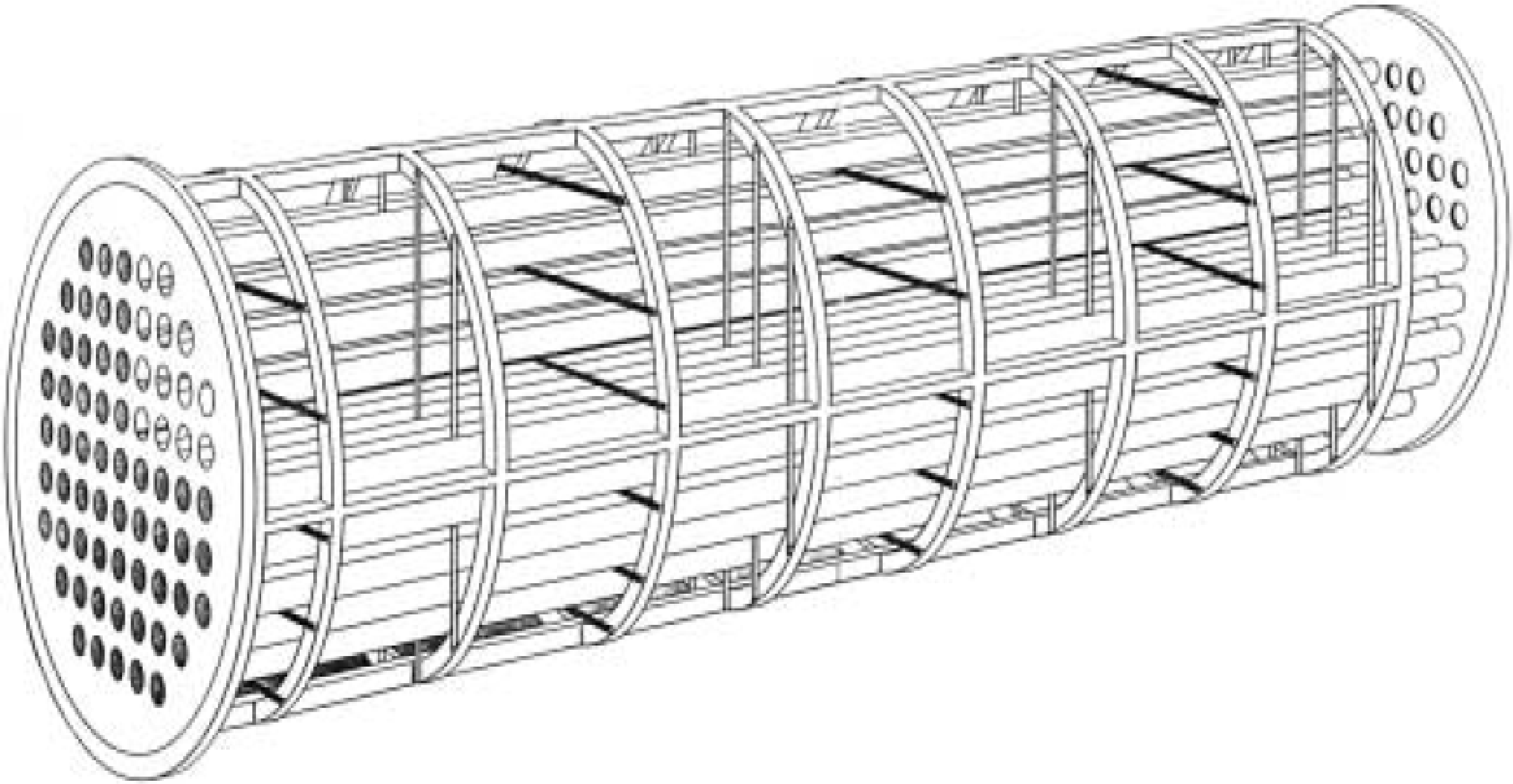
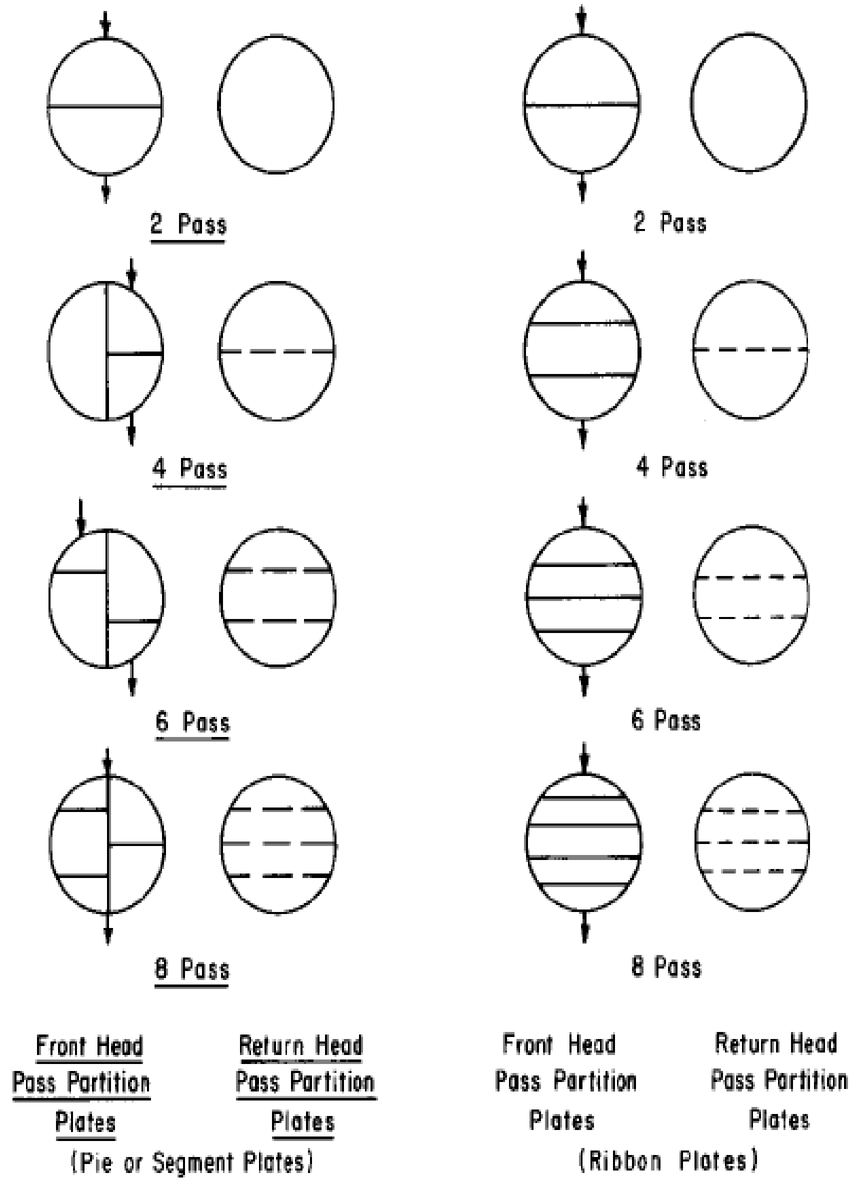
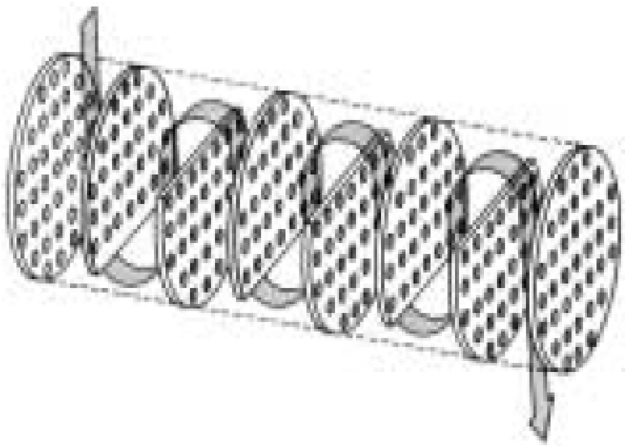


Figure 10-20A. RODbaffle® exchanger cross-section showing assembly, using TEMA E, F, H, J, K, and X shells. (Used by permission: © Phillips Petroleum Company, Licensing Div., Bul. 1114–94-A–01.)


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



Rod Baffle

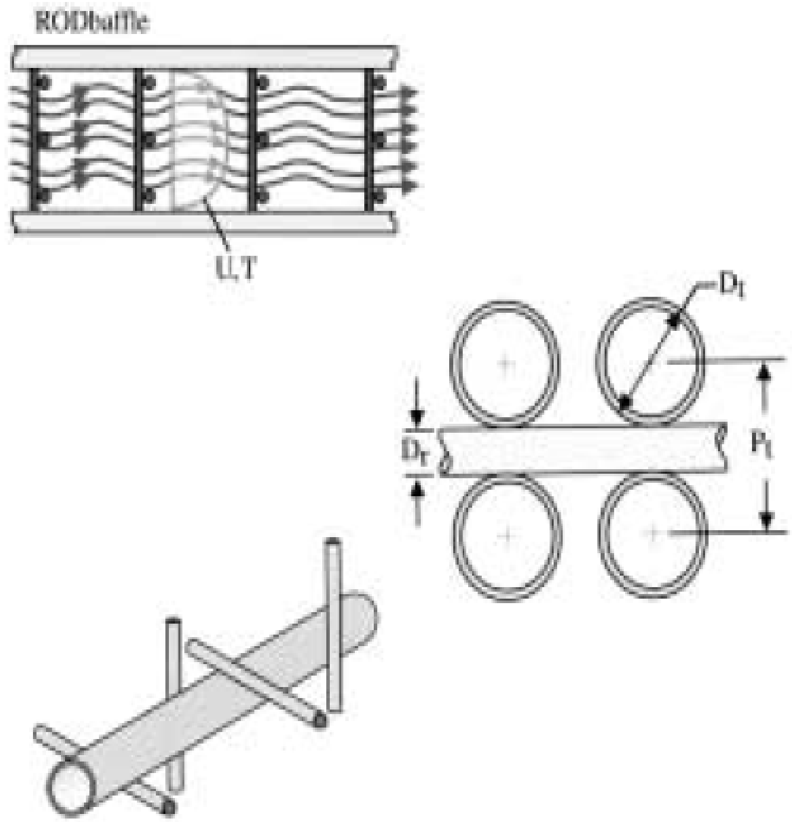


Figure 10-20C. RODbaffle® tube-baffle details. (Used by permission: © Phillips Petroleum Company, Licensing Div., Bul. 1114–94-A–01.)

Piping

انواع ادوات پایپینگ

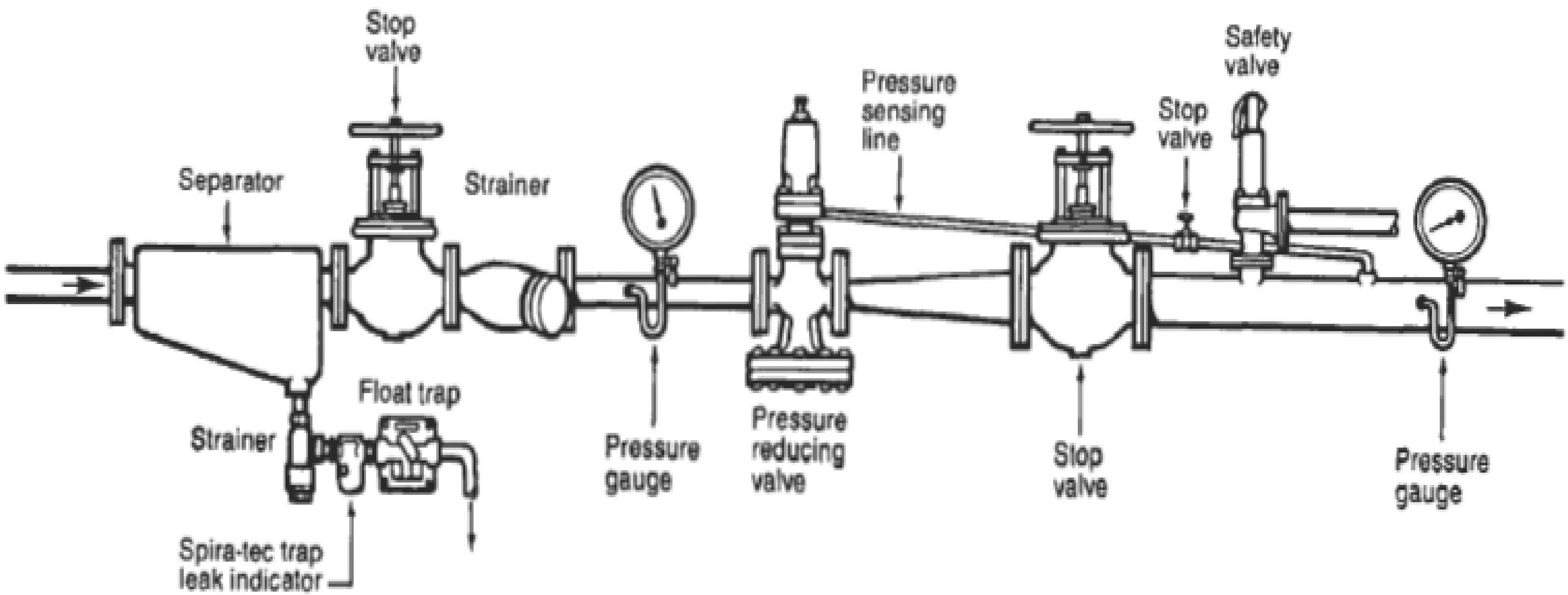


Figure 2-2. Portion of a plant piping system. By permission, Spirax-Sarco, Inc., 1991.

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(PR)**
- **PIPESLIPPER(PS)**

- **تنش در لوله ها:**

1-انبساط حرارتی دستگاه ها و لوله ها(مهمترین)==> انعطاف پذیری بسیار مهم
2-وزن حاصل از لوله ، اتصالات،عایق کاری و تجهیزات جانبی(قابل جبران از طریق ساپورتها)
3-تنش حاصل از عملکرد متقابل در برابر افت فشار(قابل صرفنظر)
4-بارهای ناشی از عملکرد تجهیزات فرعی از قبیل شیرهای اطمینان
5-لرزه(SEISIMIC)

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
$g = 32.2\ \text{ft/sec}^2$
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 پاشنده
2. Calculating leakage through a small hole
3. Sizing a restriction orifice
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.

تهیه کننده:محمد بهزادی

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 Weld	45° ell thrd	Short rad. ell Weld	Short rad. ell thrd	Long rad. ell Weld	Long rad. ell thrd	Hard T. Weld	Hard T. thrd	Soft T. Weld	Soft T. thrd	90° miter bends 2 miter	90° miter bends 3 miter	90° miter bends 4 miter	Enlargement Sudden d/D = ¼	Enlargement Sudden d/D = ½	Enlargement Sudden d/D = ¾	Enlargement Std. red. d/D = ½	Enlargement Std. red. d/D = ¾	Contraction Sudden d/D = ¼	Contraction Sudden d/D = ½	Contraction Sudden d/D = ¾	Contraction Std. red. d/D = ½	Contraction Std. red. d/D = ¾
																			Equiv. L in terms of small d									
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

Pipe Size in.	LATERALS Flow GPM	LATERALS Vel. ft/sec.	LATERALS ΔP ft/100′	MAINS Flow GPM	MAINS Vel. ft/sec.	MAINS 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	

الیاژی 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.

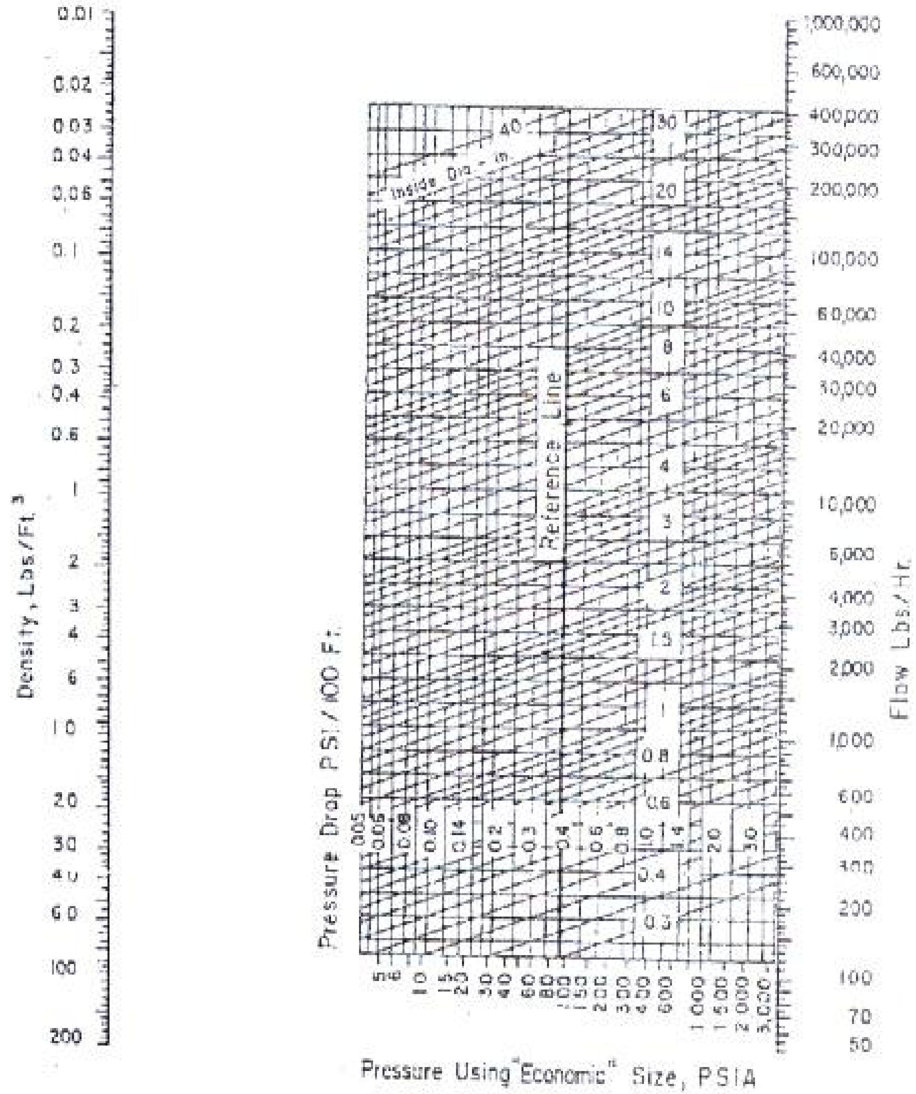
Pipe optimum diameter

- Power=Volumetric flow-rate*pressure drop

Conversion between fluid head loss in feet and pressure drop in psi, any fluid:

Pressure drop, pounds/sq in., $\Delta P = h_L \rho / 144$ (2-7)

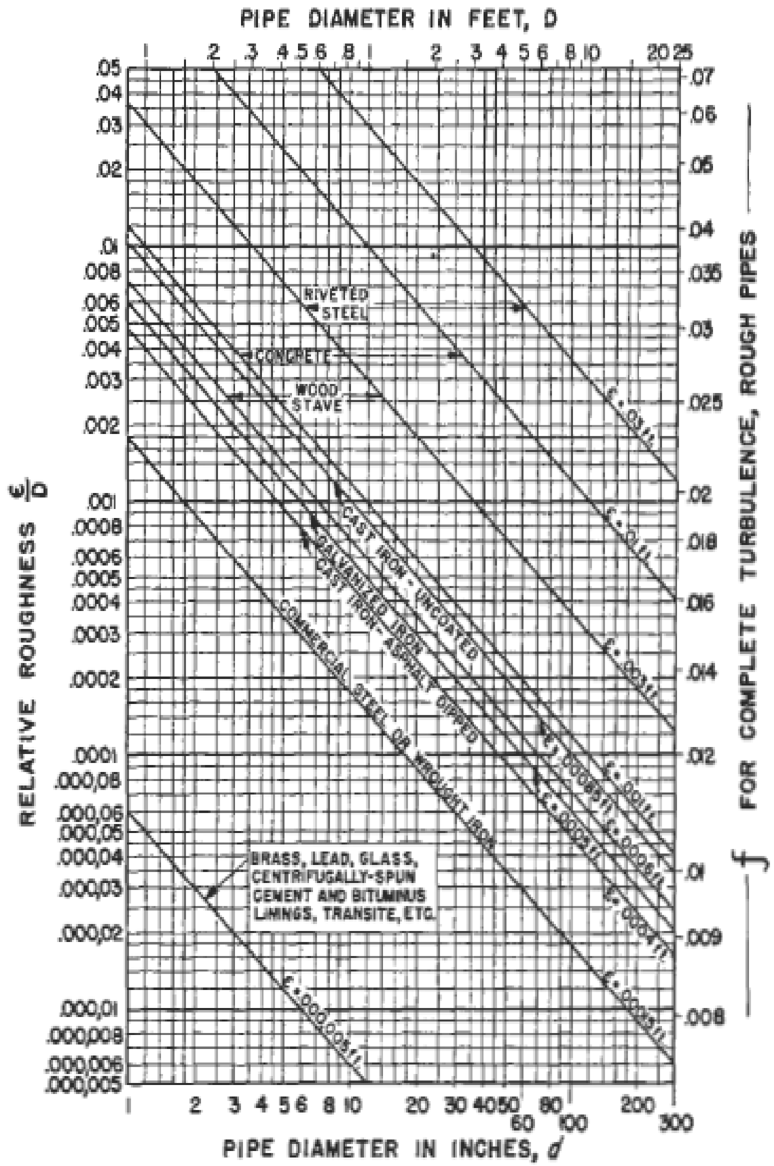
For water, $\Delta P = h_L / 2.31$, psi (2-8)



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

تهیه کننده:محمد بهزادی



RELATIVE ROUGHNESS FACTORS FOR NEW CLEAN PIPES

Example

Density of a Nonideal Gas from Its Equation of State

The Redlich–Kwong equation of carbon dioxide is

$$(P + 63.72(10^6)/\sqrt{T}\,V^2)(V - 29.664) = 82.05T$$

with P in atm, V in mL/g mol and T in K. The density will be found at $P = 20$ and $T = 400$. Rearrange the equation to

$$V = 29.664 + (82.05)(400)/(20 + 63.72(10^6)/\sqrt{400}\,V^2).$$

Substitute the ideal gas volume on the right, $V = 1641$; then find V on the left; substitute that value on the right, and continue. The successive values of V are

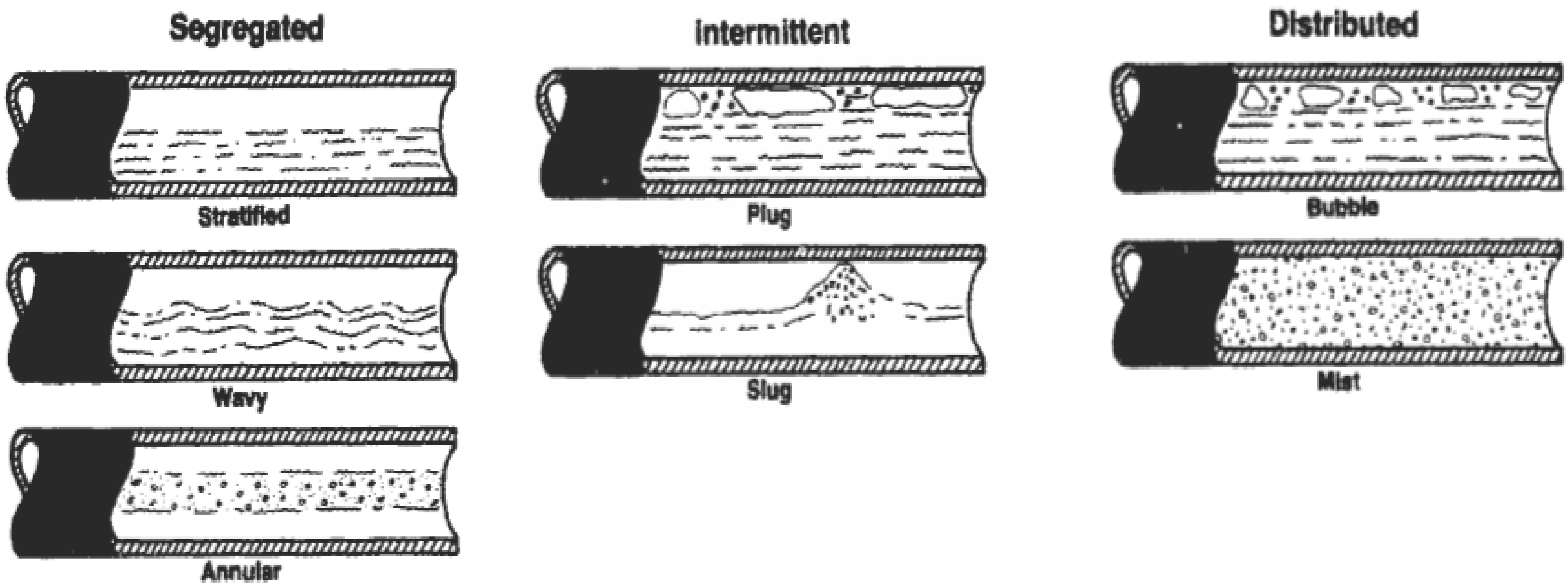
$$V = 1641,\ 1579,\ 1572.1,\ 1571.3,\ 1571.2,\ \cdots \quad \text{mL/g mol}$$

and converge at 1571.2. Therefore, the density is

$$\rho = 1/V = 1/1571.2, \quad \text{or} \quad 0.6365\ \text{g mol/L} \quad \text{or} \quad 28.00\ \text{g/L}.$$

انواع رژیم جریان دو فازی

Representative forms of horizontal two-phase flow



annular
حلقه مانند، حلقوی،

Segregated
جدا شده

intermittent
متناوب، نوبت دار، نوبه‌ای، نوبتی

Stratified
لایه ای ، طبقه ای

تهیه کننده:محمد بهزادی

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 $10\frac{3}{4}$-in. OD; 40 miles $12\frac{3}{4}$-in. OD and 50 miles of 22-in. OD lines.

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

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

$$= 50 + 614 + 364$$

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

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

ارتباط بین کلاس فشاری و Scedule

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

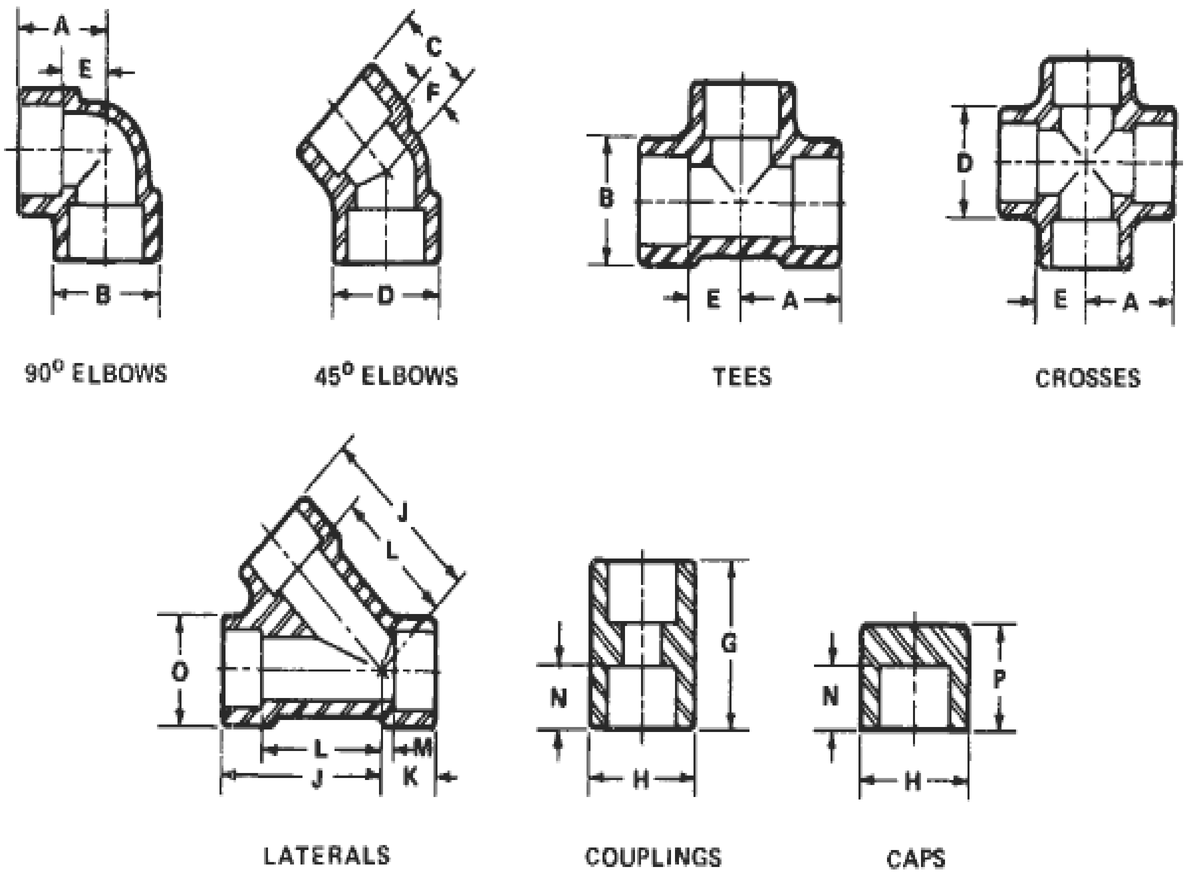


Figure 2-4B. Forged steel socket weld fittings, WOG (water, oil or gas service). Note: the working pressures are always well above actual plant operating levels and are heavy to allow for welding. Pressure classes 3000 psi and 6000 psi, sizes ⅛ in. through 4 in. nominal. Do not weld on malleable iron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

تهیه کننده:محمد بهزادی

انواع ادوات پایپینگ

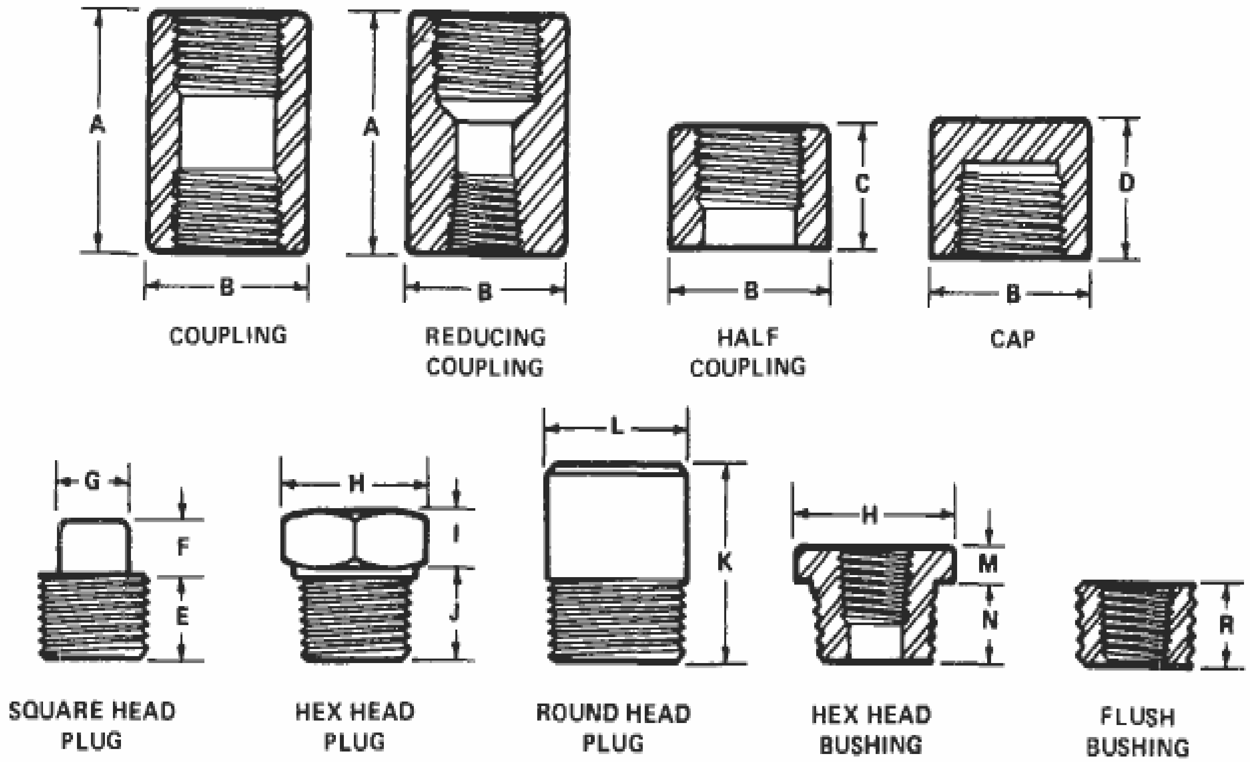
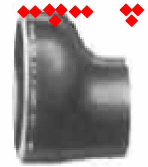


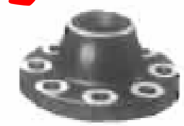
Figure 2-4A. Forged steel threaded pipe fittings, WOG (water, oil or gas service). Note: the working pressures are always well above actual plant operating levels. Pressure classes 3000 psi and 6000 psi, sizes ⅛ in. through 4 in. nominal. By permission, Ladish Co., Inc.

انواع ادوات پایپینگ

90° ELBOWS
Long Radius
Pages 12 - 17

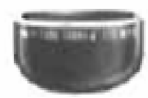


ECCENTRIC
REDUCERS
Pages 63 - 70



PIPELINE and
WELDING NECK
FLANGES
Pages 100 - 115

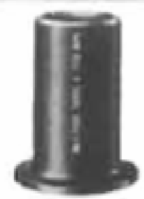
90° ELBOWS
Long Tangent
One End
Page 16



CAPS
Pages 71 - 75

SLIP-ON FLANGES
Pages 101 - 115

90° REDUCING ELBOWS
Long Radius
Pages 18 - 21

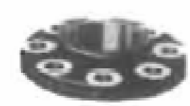


LAP JOINT
STUB ENDS
Pages 76 - 77

LAP JOINT FLANGES
Pages 102 - 115

3R ELBOWS
45° and 90°
Page 22

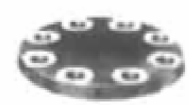
LATERALS
Straight and
Reducing Outlet
Page 78



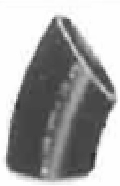
THREADED FLANGES
Pages 102 - 115

90° ELBOWS
Short Radius
Pages 23 - 25

SHAPED NIPPLES
Page 79



BLIND FLANGES
Pages 102 - 115



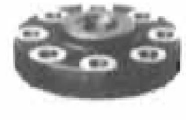
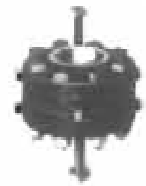
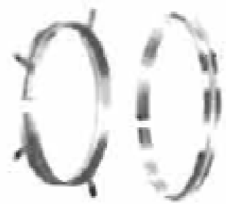
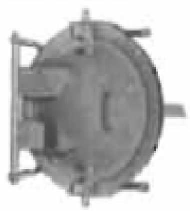
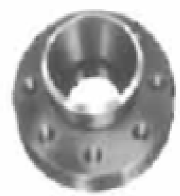
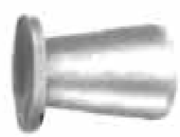
45° ELBOWS
Long Radius
Pages 26 - 30

SLEEVES
Page 80

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

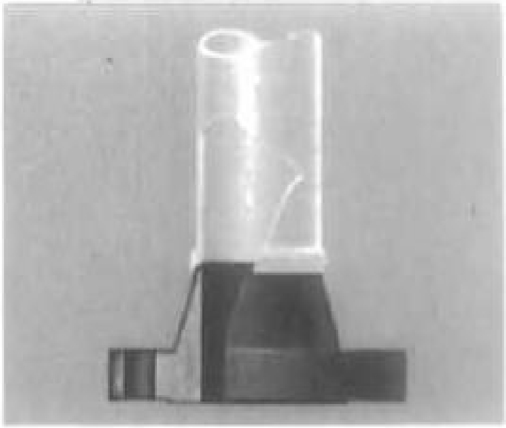
زادی

انواع ادوات پایپینگ

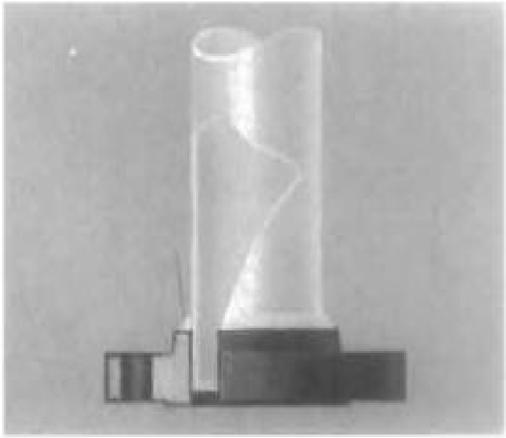
 180° RETURNS Long Radius Pages 31 - 35	 SADDLES Page 80	 REDUCING FLANGES Pages 102 - 115
 180° RETURNS Short Radius Pages 37 - 39	 FULL ENCIRCLEMENT SADDLES Page 81	 ORIFICE FLANGES Pages 116 - 123
 TEES Straight and Reducing Outlet Pages 40 - 57	 WELDING RINGS Pages 82 - 83	 LARGE DIAMETER FLANGES 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

انواع فلنج

Welding neck flanges are distinguished from other types by their long tapered hub and gentle transition of thickness in the region of the butt weld joining them to the pipe. Thus this type of flange is preferred for every severe service condition, whether this results from high pressure or from sub-zero or elevated temperature, and whether loading conditions are substantially constant or fluctuate between wide limits.

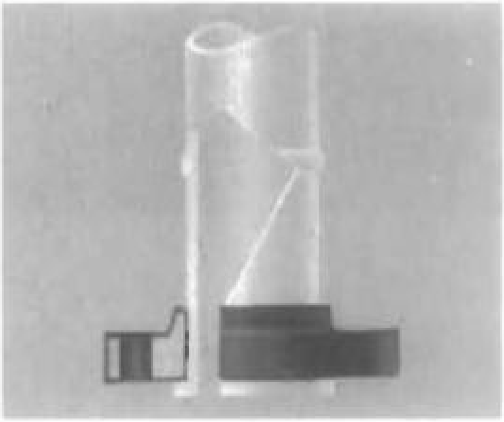


Slip-on flanges continue to be preferred to welding neck flanges by many users on account of their initially lower cost, the reduced accuracy required in cutting the pipe to length, and the somewhat greater ease of alignment of the assembly; however, their final installed cost is probably not much, if any, less than that of welding neck flanges. Their calculated strength under internal pressure is of the order of two-thirds that of welding neck flanges, and their life under fatigue is about one-third that of the latter.

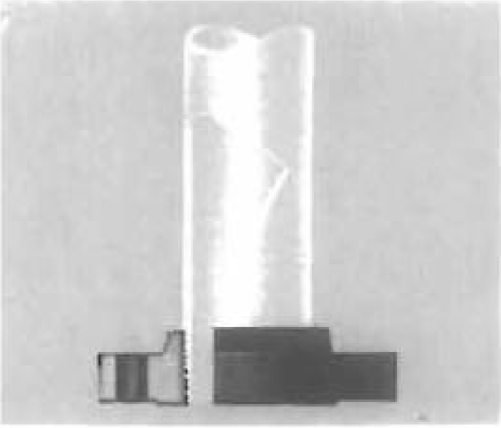


انواع فلنج

Lap joint flanges are primarily employed with lap joint stubs, the combined initial cost of the two items being approximately one-third higher than that of comparable welding neck flanges. Their pressure-holding ability is little, if any, better than that of slip-on flanges and the fatigue life of the assembly is only one-tenth that of welding neck flanges. The chief use of lap joint flanges in carbon or low alloy steel piping systems is in services necessitating frequent dismantling for inspection and cleaning and where the ability to swivel flanges and to align bolt holes materially simplifies the erection of large diameter or unusually stiff piping. Their use at points where severe bending stress occurs should be avoided.



Threaded flanges made of steel, are confined to special applications. Their chief merit lies in the fact that they can be assembled without welding; this explains their use in extremely high pressure services, particularly at or near atmospheric temperature, where alloy steel is essential for strength and where the necessary post-weld heat treatment is impractical. Threaded flanges are unsuited for conditions involving temperature or bending stresses of any magnitude, particularly under cyclic conditions, where leakage through the threads may occur in relatively few cycles of heating or stress; seal welding is sometimes employed to overcome this, but cannot be considered as entirely satisfactory.



انواع فلنج

Socket welding flanges were initially developed for use on small-size high pressure piping. Their initial cost is about 10% greater than that of slip-on flanges; when provided with an internal weld as illustrated, their static strength is equal to, but their fatigue strength 50% greater than double-welded slip-on flanges. Smooth, pocketless bore conditions can readily be attained (by grinding the internal weld) without having to bevel the flange face and, after welding, to reface the flange as would be required with slip-on flanges.

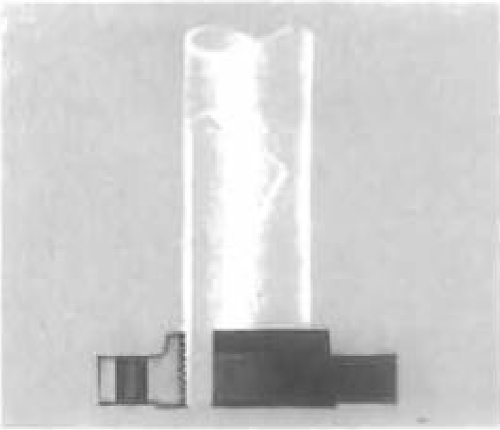
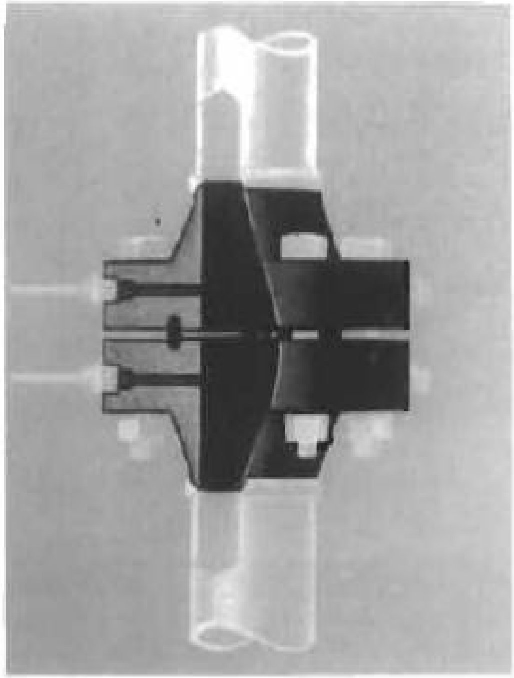
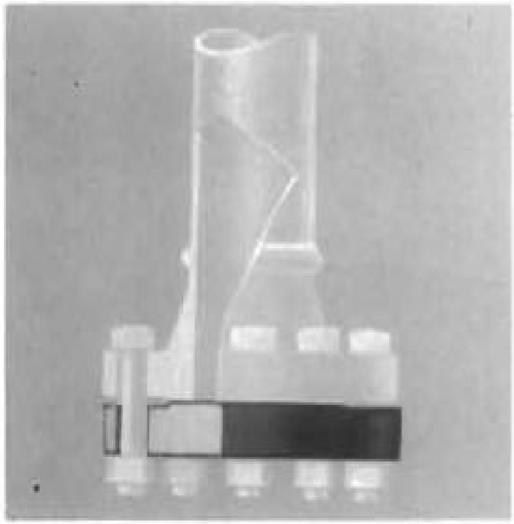


Figure 2-6. (continued on next page)

انواع فلنج

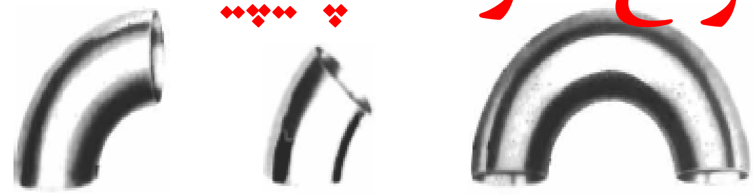


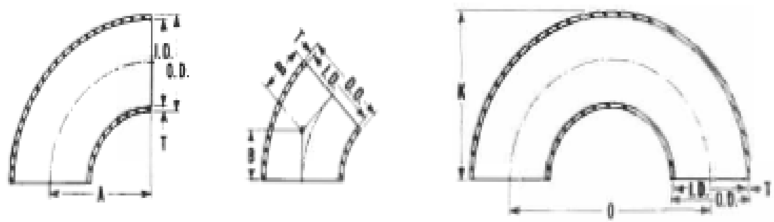
Orifice flanges are widely used in conjunction with orifice meters for measuring the rate of flow of liquids and gases. They are basically the same as standard welding neck, slip-on and screwed flanges except for the provision of radial, tapped holes in the flange ring for meter connections and additional bolts to act as jack screws to facilitate separating the flanges for inspection or replacement of the orifice plate.



Blind flanges are used to blank off the ends of piping, valves and pressure vessel openings. From the standpoint of internal pressure and bolt loading, blind flanges, particularly in the larger sizes, are the most highly stressed of all American Standard flange types; however, since the maximum stresses in a blind flange are bending stresses at the center, they can safely be permitted to be higher than in other types of flanges.

انواع ادوات پایپینگ





90° ELBOW
long radius
2WCL

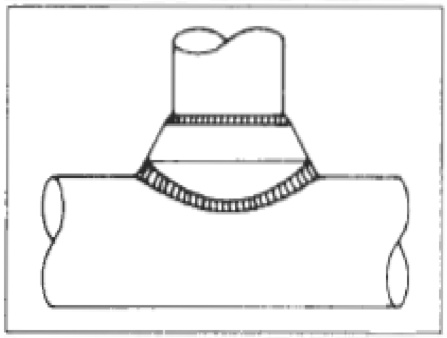
45° ELBOW
long radius
2WK

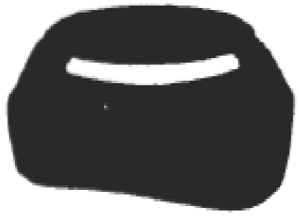
180° RETURN
long radius
2WUL
(304 S/S only)

TUBE O.D. SIZE	OUTSIDE DIAMETER	INSIDE DIAMETER	WALL THICKNESS	GAUGE NUMBER	90° ELBOW LONG RADIUS	45° ELBOW LONG RADIUS	180° RETURN LONG RADIUS	
	O.D.	I.D.	T		A	B	K	O
¾	.750	.625	.065	18	1⅛	⅝	1⅛	2¼
1	1.000	.870	.065	16	1½	⅝	2	3
1½	1.500	1.370	.065	16	2¼	¹⁵⁄₁₆	3	4½
2	2.000	1.870	.065	16	3	1¼	4	6
2½	2.500	2.370	.065	16	3¾	1⁹⁄₁₆	5	7½
3	3.000	2.870	.065	16	4½	1⅞	6	9
4	4.000	3.834	.083	14	6	2½	8	12
6	6.000	5.782	.109	12	9	3¾	12⁹⁄₁₆	18
8	8.000	7.782	.109	12	12	5	16⁹⁄₁₆	24
10	10.000	9.732	.134	10	15	6¼	20⅝	30
12	12.000	11.732	.134	10	18	7½	24⅝	36

تهیه کننده:محمد بهزادی

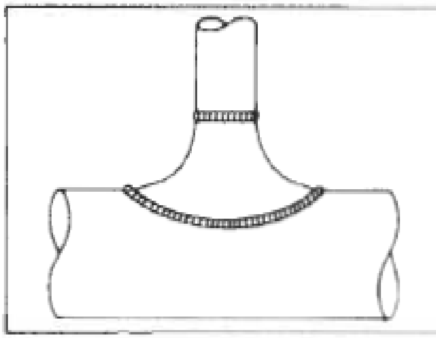
انواع اتصالات فرعی





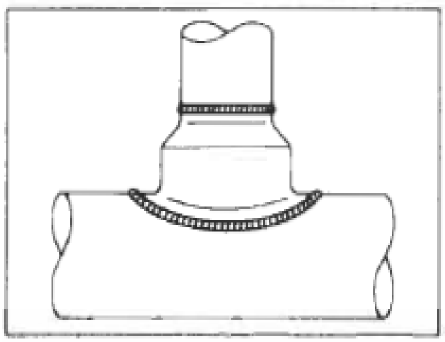
Weldolet

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.

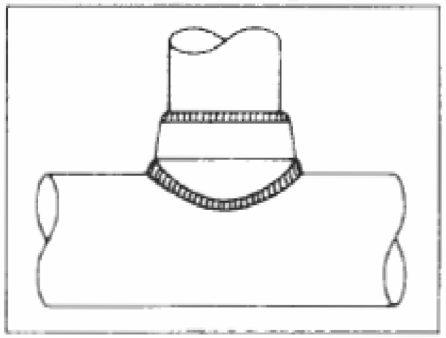


Insert Weldolet

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.

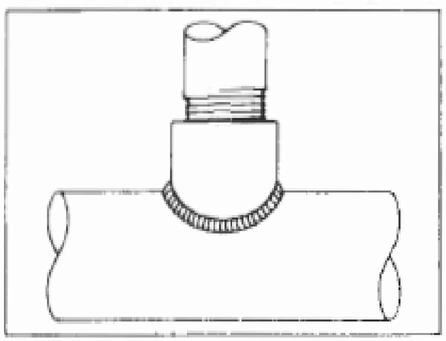
انواع اتصالات فرعی

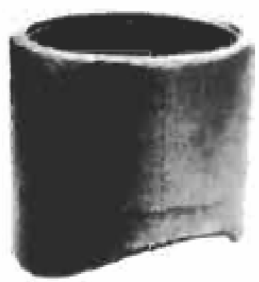
Sockolet



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

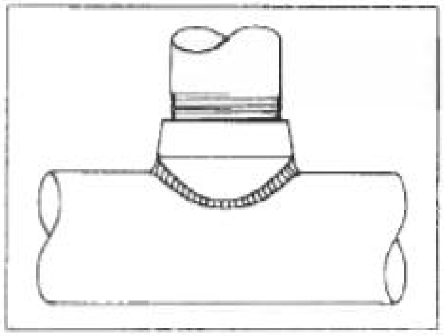
Coupolet





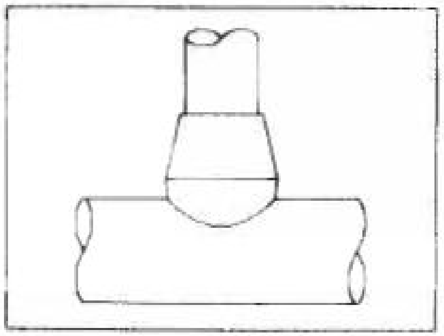
Coupolet® fittings are designed for use in fire protection sprinkler systems and other low pressure piping applications.

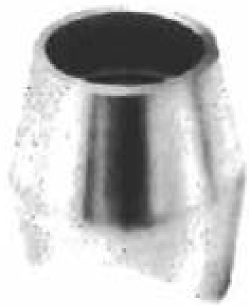
انواع اتصالات فرعی



Thredolet

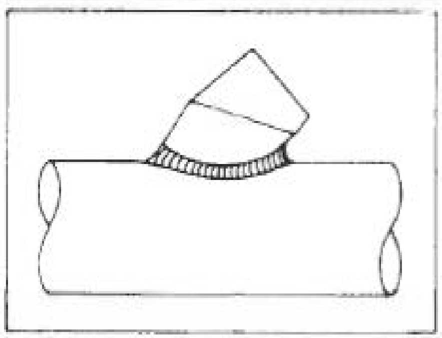
Thredolet® utilizes the basic Weldolet configuration, provides a threaded outlet branch connection.





Brazolet

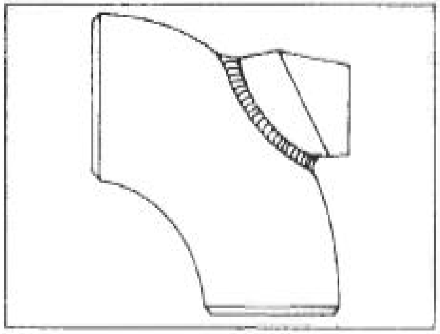
Brazolet® is designed for use with KLM and IPS brass or copper piping or copper tubing.



Latrolet

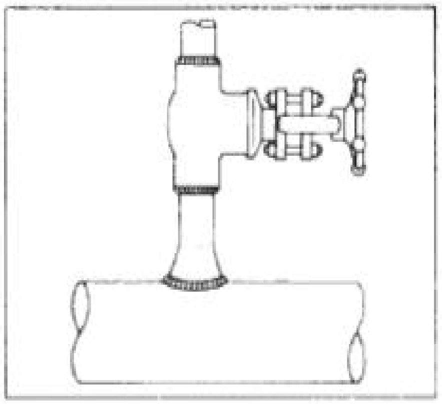
Latrolet® used for 45° lateral connections, is available butt-weld to meet your specific reinforcement requirements, and 3000# or 6000# classes for socket weld and threaded applications.

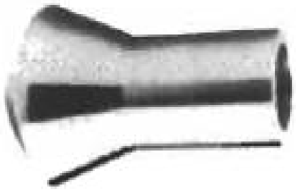
انواع اتصالات فرعی



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.

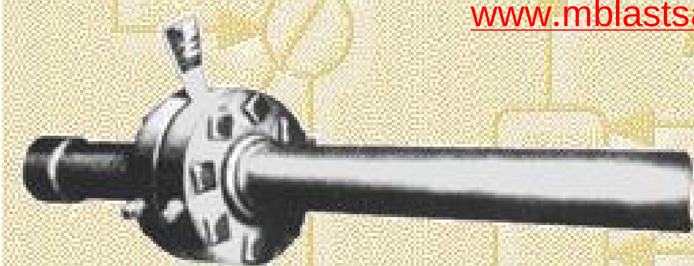
GENERAL INFORMATION/EQUIPMENT DESIGN

(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.

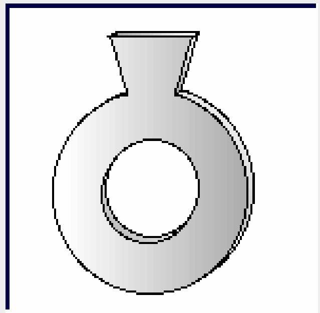
The bottom left picture shows an orifice plate installed between flanges in a pipe.

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

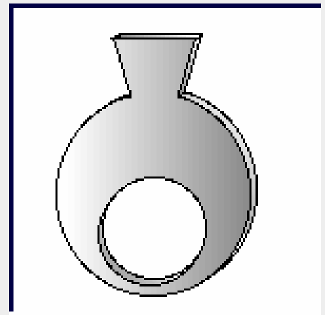


(Courtesy of KOBOLD Instruments Inc., Pittsburgh, PA)

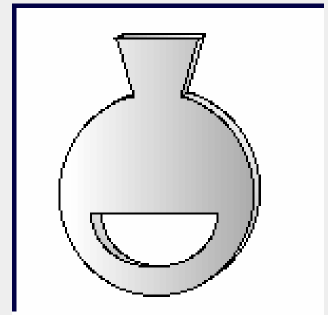
Concentric orifices are the most common. **Eccentric** and **segmental** orifices are used to prevent entrained liquids or gases from building up at the plate. The hole is placed at the bottom of the plate for gas flows (to allow passage of heavier liquid particles) and at the top of the plate for liquid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



Concentric



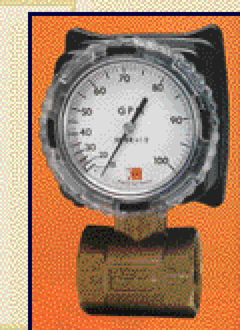
Eccentric



Segmental

Click to Continue

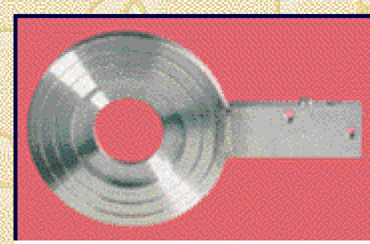
USAGE EXAMPLES

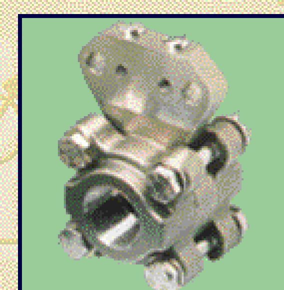


Most gas, water, steam, and air applications are easily metered by orifice plates.

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.





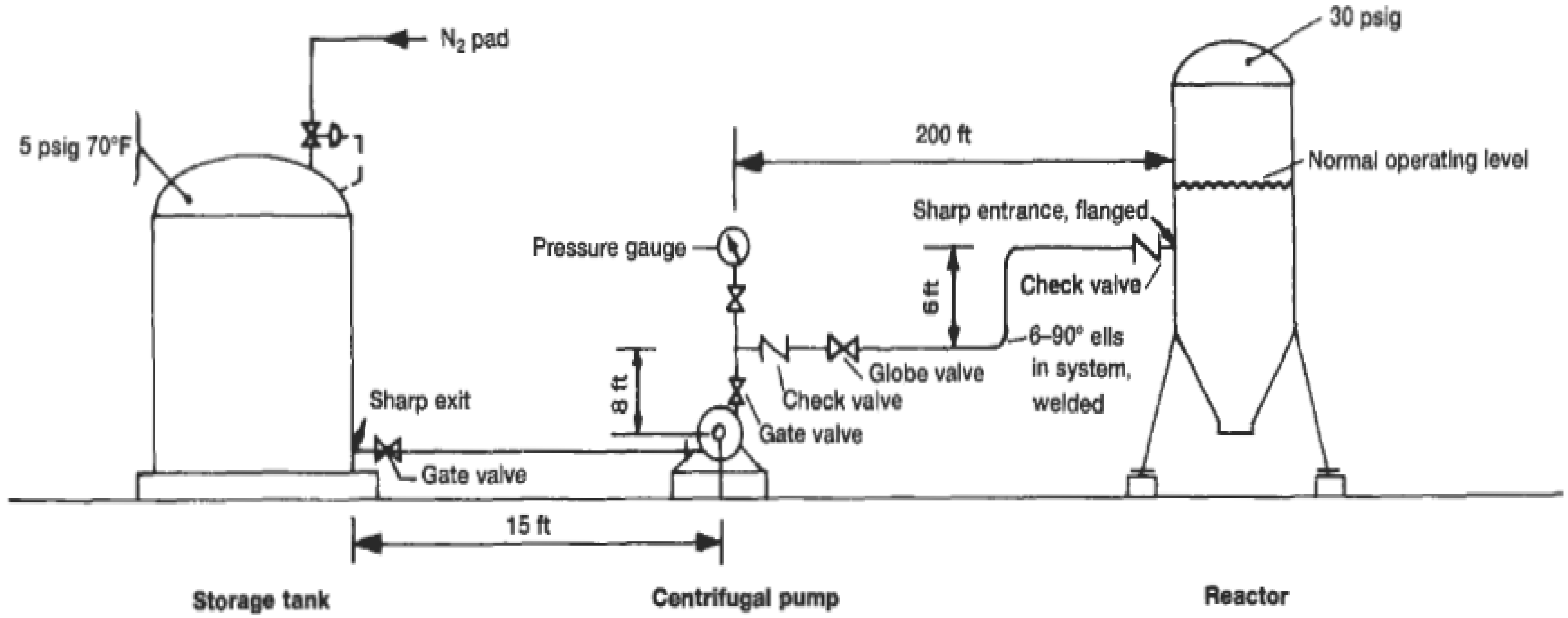
(Pictures courtesy of KOBOLD Instruments Inc., Pittsburgh, PA)

Example

Pipe Sizing Using Resistance Coefficients, K

A plant decides to add a nitrogen blanket (at 5 psig) to a storage tank holding up to 25,000 gallons of a hydrocarbon mixture having kerosene-like properties and pumps this material into a process reactor operating at 30 psig. (See Figure 2-19)

The flow rate needs to be 20 gpm. Connections of pipe and valve are flanged, with the 6°–90° elbows added in the line.



Pump suction velocity = 2 ft/sec (Selected low in accordance with good pump suction practice,

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.

تهیه کننده:محمد بهزادی

Table 2-4

Suggested Fluid Velocities in Pipe and Tubing: Liquids, Gases, and Vapors at low/moderate pressure to 50 psig and 50° to 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 Concrete	5-8 fps / 5-12 fps (3 Min.)	R. L., concrete, asphalt-line, saran-lined, transite

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

Sizes and thicknesses listed herein are covered by the following Standards:—

1) American National Standard Institute B36.10
2) American National Standard Institute B36.19
3) American Petroleum Institute Standard API 5L
4) American Petroleum Institute Standard API 5LX
5) New United States Legal Standard for Steel Plate Gauges.

ANSI American National Standards Institute

All data is computed from the *nominal* dimensions listed and the effect of tolerances is not taken into account. Values are computed by application of the following formulas:

Radius of Gyration: $R = \frac{\sqrt{D^2 + d^2}}{4}$

Moment of Inertia: $I = R^2 A$

Section Modulus: $Z = \frac{I}{0.5\ D}$

Nominal Pipe Size	Nominal Outside Diam. D	Designation	Wall Thickness	Inside Diam. d	Weight per Foot	Wt. of Water per Ft. of Pipe	Sq. Ft. Outside Surface per Ft.	Sq. Ft. Inside Surface per Ft.	Transverse Area in.² a	Area of Metal in.² A	Moment of Inertia in.⁴ I	Section Modulus in.³ Z	Radius of Gyration in. R
⅛	.405	10S	.049	.307	.186	.0320	.106	.0804	.0740	.0548	.00090	.00440	.1270
		Std.	.068	.269	.244	.0246	.106	.0705	.0568	.0720	.00106	.00530	.1215
		X-Stg.	.095	.215	.314	.0157	.106	.0563	.0364	.0925	.00122	.00600	.1146
¼	.540	10S	.065	.410	.330	.0570	.141	.1073	.1320	.0970	.00280	.01030	.1695
		Std.	.088	.364	.424	.0451	.141	.0955	.1041	.1250	.00331	.01230	.1628
		X-Stg.	.119	.302	.535	.0310	.141	.0794	.0716	.1574	.00378	.01395	.1547
⅜	.675	10S	.065	.545	.423	.1010	.177	.1427	.2333	.1245	.00590	.01740	.2160
		Std.	.091	.493	.567	.0827	.177	.1295	.1910	.1670	.00730	.02160	.2090
		X-Stg.	.126	.423	.738	.0609	.177	.1106	.1405	.2173	.00862	.02554	.1991
½	.840	10S	.083	.670	.671	.1550	.220	.1764	.3568	.1974	.01430	.03410	.2692
		Std.	.109	.622	.850	.1316	.220	.1637	.3040	.2503	.01710	.04070	.2613
		X-Stg.	.147	.546	1.087	.1013	.220	.1433	.2340	.3200	.02010	.04780	.2505
		160	.138	.464	1.310	.0740	.220	.1220	.1706	.3836	.02213	.05269	.2402
		XX-Stg.	.294	.252	1.714	.0216	.220	.0660	.0499	.5043	.02424	.05772	.2192
¾	1.050	10S	.083	.884	.857	.2660	.275	.2314	.6138	.2522	.02970	.05660	.3430
		Std.	.113	.824	1.130	.2301	.275	.2168	.5330	.3326	.03704	.07055	.3337
		X-Stg.	.154	.742	1.473	.1875	.275	.1948	.4330	.4335	.04479	.08531	.3214
		160	.219	.612	1.940	.1280	.275	.1607	.2961	.5698	.05270	.10038	.3041
		XX-Stg.	.308	.434	2.440	.0633	.275	.1137	.1479	.7180	.05792	.11030	.2840
1	1.315	10S	.109	1.097	1.404	.4090	.344	.2872	.9448	.4129	.07560	.1150	.4282
		Std.	.133	1.049	1.678	.3740	.344	.2740	.8640	.4939	.08734	.1328	.4205
		X-Stg.	.179	.957	2.171	.3112	.344	.2520	.7190	.6388	.10560	.1606	.4066
		160	.250	.815	2.850	.2261	.344	.2134	.5217	.8364	.12516	.1903	.3868
		XX-Stg.	.358	.599	3.659	.1221	.344	.1570	.2818	1.0760	.14050	.2136	.3613
1¼	1.660	10S	.109	1.442	1.806	.7080	.434	.3775	1.633	.5314	.1606	.1934	.5499
		Std.	.140	1.380	2.272	.6471	.434	.3620	1.495	.6685	.1947	.2346	.5397
			.191	1.278	2.996	.5553	.434	.3356	1.283	.8815	.2418	.2913	.5237
			.250	1.160	3.764	.4575	.434	.3029	1.057	1.1070	.2833	.3421	.5063
			.382	.896	5.214	.2732	.434	.2331	.6305	1.5340	.3411	.4110	.4716

(Continued). Properties of Pipe

Nominal Pipe Size	Nominal Outside Diam. D	Designation	Wall Thickness	Inside Diam. d	Weight per Foot	Wt. of Water per Ft. of Pipe	Sq. Ft. Outside Surface per Ft.	Sq. Ft. Inside Surface per Ft.	Transverse Area in.² a	Area of Metal in.² A	Moment of Inertia in.⁴ I	Section Modulus in.³ Z	Radius of Gyration in. R
1½	1.900	10S	.109	1.682	2.085	.9630	.497	.4403	2.221	.613	.2469	.2599	.6344
		Std.	.145	1.610	2.717	.8820	.497	.4213	2.036	.800	.3099	.3262	.6226
		X-Stg.	.200	1.500	3.631	.7648	.497	.3927	1.767	1.068	.3912	.4118	.6052
		160	.281	1.337	4.862	.6082	.497	.3519	1.405	1.430	.4826	.5080	.5809
		XX-Stg.	.400	1.100	6.408	.4117	.497	.2903	.950	1.885	.5678	.5977	.5489
2	2.375	10S	.109	2.157	2.638	1.583	.622	.5647	3.654	.775	.5003	.4213	.8034
		Std.	.154	2.067	3.652	1.452	.622	.5401	3.355	1.075	.6657	.5606	.7871
		X-Stg.	.218	1.939	5.022	1.279	.622	.5074	2.953	1.477	.8679	.7309	.7665
		- -	.250	1.875	5.673	1.196	.622	.4920	2.761	1.669	.9555	.8046	.7565
		160	.344	1.687	7.450	.970	.622	.4422	2.240	2.190	1.162	.9790	.7286
		XX-Stg.	.436	1.503	9.029	.769	.622	.3929	1.774	2.656	1.311	1.1040	.7027
2½	2.875	10S	.120	2.635	3.53	2.360	.753	.6900	5.453	1.038	.9878	.6872	.9755
		Std.	.203	2.469	5.79	2.072	.753	.6462	4.788	1.704	1.530	1.064	.9474
		X-Stg.	.276	2.323	7.66	1.834	.753	.6095	4.238	2.254	1.924	1.339	.9241
		160	.375	2.125	10.01	1.535	.753	.5564	3.547	2.945	2.353	1.638	.8938
		XX-Stg.	.552	1.771	13.69	1.067	.753	.4627	2.464	4.028	2.871	1.997	.8442
3	3.500	10S	.120	3.260	4.33	3.62	.916	.853	8.346	1.272	1.821	1.041	1.196
		API	.125	3.250	4.52	3.60	.916	.851	8.300	1.329	1.900	1.086	1.195
		API	.156	3.188	5.58	3.46	.916	.835	7.982	1.639	2.298	1.313	1.184
		API	.188	3.125	6.65	3.34	.916	.819	7.700	1.958	2.700	1.545	1.175
		Std.	.216	3.068	7.57	3.20	.916	.802	7.393	2.228	3.017	1.724	1.164
		API	.250	3.000	8.68	3.06	.916	.785	7.184	2.553	3.388	1.936	1.152
		API	.281	2.938	9.65	2.94	.916	.769	6.780	2.842	3.819	2.182	1.142
		X-Stg.	.300	2.900	10.25	2.86	.916	.761	6.605	3.016	3.892	2.225	1.136
		160	.438	2.624	14.32	2.34	.916	.687	5.407	4.214	5.044	2.882	1.094
		XX-Stg.	.600	2.300	18.58	1.80	.916	.601	4.155	5.466	5.993	3.424	1.047
3½	4.000	10S	.120	3.760	4.97	4.81	1.047	.984	11.10	1.46	2.754	1.377	1.372
		API	.125	3.750	5.18	4.79	1.047	.982	11.04	1.52	2.859	1.430	1.371
		API	.156	3.688	6.41	4.63	1.047	.966	10.68	1.88	3.485	1.743	1.360
		API	.188	3.624	7.71	4.48	1.047	.950	10.32	2.27	4.130	2.065	1.350
		Std.	.226	3.548	9.11	4.28	1.047	.929	9.89	2.68	4.788	2.394	1.337
		API	.250	3.500	10.02	4.17	1.047	.916	9.62	2.94	5.201	2.601	1.329
		API	.281	3.438	11.17	4.02	1.047	.900	9.28	3.29	5.715	2.858	1.319
		X-Stg.	.318	3.364	12.51	3.85	1.047	.880	8.89	3.68	6.280	3.140	1.307
		XX-Stg.	.636	2.728	22.85	2.53	1.047	.716	5.84	6.72	9.848	4.924	1.210
4	4.500	10S	.120	4.260	5.61	6.18	1.178	1.115	14.25	1.65	3.97	1.761	1.550
		API	.125	4.250	5.84	6.15	1.178	1.113	14.19	1.72	4.12	1.829	1.548
		API	.156	4.188	7.24	5.97	1.178	1.096	13.77	2.13	5.03	2.235	1.537
		API	.188	4.124	8.56	5.80	1.178	1.082	13.39	2.52	5.86	2.600	1.525
		API	.219	4.062	10.02	5.62	1.178	1.063	12.96	2.94	6.77	3.867	1.516
		Std.	.237	4.026	10.79	5.51	1.178	1.055	12.73	3.17	7.23	3.214	1.510
		API	.250	4.000	11.35	5.45	1.178	1.049	12.57	3.34	7.56	3.360	1.505
		API	.281	3.938	12.67	5.27	1.178	1.031	12.17	3.73	8.33	3.703	1.495
		API	.312	3.876	14.00	5.12	1.178	1.013	11.80	4.11	9.05	4.020	1.482
		X-Stg.	.337	3.826	14.98	4.98	1.178	1.002	11.50	4.41	9.61	4.271	1.477
		120	.438	3.624	19.00	4.47	1.178	.949	10.32	5.59	11.65	5.177	1.444
		- -	.500	3.500	21.36	4.16	1.178	.916	9.62	6.28	12.77	5.676	1.425
		160	.531	3.438	22.60	4.02	1.178	.900	9.28	6.62	13.27	5.900	1.416
		XX-Stg.	.674	3.152	27.54	3.38	1.178	.826	7.80	8.10	15.28	6.793	1.374

(Continued). Properties of Pipe

Nominal Pipe Size	Nominal Outside Diam. D	Designation	Wall Thickness	Inside Diam. d	Weight per Foot	Wt. of Water per Ft. of Pipe	Sq. Ft. Outside Surface per Ft.	Sq. Ft. Inside Surface per Ft.	Transverse Area in.² a	Area of Metal in.² A	Moment of Inertia in.⁴ I	Section Modulus in.³ Z	Radius of Gyration in. R
5	5.563	10S	.134	5.295	7.77	9.54	1.456	1.386	22.02	2.29	8.42	3.028	1.920
		API	.156	5.251	9.02	9.39	1.456	1.375	21.66	2.65	9.70	3.487	1.913
		API	.188	5.187	10.80	9.16	1.456	1.358	21.13	3.17	11.49	4.129	1.902
		API	.219	5.125	12.51	8.94	1.456	1.342	20.63	3.68	13.14	4.726	1.891
		Std.	.258	5.047	14.62	8.66	1.456	1.321	20.01	4.30	15.16	5.451	1.878
		API	.281	5.001	15.86	8.52	1.456	1.309	19.64	4.66	16.31	5.862	1.870
		API	.312	4.939	17.51	8.31	1.456	1.293	19.16	5.15	17.81	6.402	1.860
		API	.344	4.875	19.19	8.09	1.456	1.276	18.67	5.64	19.28	6.932	1.849
		X-Stg.	.375	4.813	20.78	7.87	1.456	1.260	18.19	6.11	20.67	7.431	1.839
		120	.500	4.563	27.10	7.08	1.456	1.195	16.35	7.95	25.74	9.253	1.799
		160	.625	4.313	32.96	6.32	1.456	1.129	14.61	9.70	30.03	10.800	1.760
		XX-Stg.	.750	4.063	38.55	5.62	1.456	1.064	12.97	11.34	33.63	12.090	1.722
6	6.625	12 Ga.	.104	6.417	7.25	14.02	1.734	1.680	32.34	2.13	11.33	3.42	2.31
		10S	.134	6.357	9.29	13.70	1.734	1.660	31.75	2.73	14.38	4.34	2.29
		8 Ga.	.164	6.297	11.33	13.50	1.734	1.649	31.14	3.33	17.38	5.25	2.28
		API	.188	6.249	12.93	13.31	1.734	1.639	30.70	3.80	19.71	5.95	2.28
		6 Ga.	.194	6.237	13.34	13.25	1.734	1.633	30.55	3.92	20.29	6.12	2.27
		API	.219	6.187	15.02	13.05	1.734	1.620	30.10	4.41	22.66	6.84	2.27
		API	.250	6.125	17.02	12.80	1.734	1.606	29.50	5.01	25.55	7.71	2.26
		API	.277	6.071	18.86	12.55	1.734	1.591	28.95	5.54	28.00	8.46	2.25
		Std.	.280	6.065	18.97	12.51	1.734	1.587	28.90	5.58	28.14	8.50	2.24
		API	.312	6.001	21.05	12.26	1.734	1.571	28.28	6.19	30.91	9.33	2.23
		API	.344	5.937	23.09	12.00	1.734	1.554	27.68	6.79	33.51	10.14	2.22
		API	.375	5.875	25.10	11.75	1.734	1.540	27.10	7.37	36.20	10.90	2.21
		X-Stg.	.432	5.761	28.57	11.29	1.734	1.510	26.07	8.40	40.49	12.22	2.19
		- -	.500	5.625	32.79	10.85	1.734	1.475	24.85	9.63	45.60	13.78	2.16
		120	.562	5.501	36.40	10.30	1.734	1.470	23.77	10.74	49.91	15.07	2.15
		160	.719	5.187	45.30	9.16	1.734	1.359	21.15	13.36	58.99	17.81	2.10
		XX-Stg.	.864	4.897	53.16	8.14	1.734	1.280	18.83	15.64	66.33	20.02	2.06
8	8.625	12 Ga.	.104	8.417	9.47	24.1	2.26	2.204	55.6	2.78	25.3	5.86	3.01
		10 Ga.	.134	8.357	12.16	23.8	2.26	2.188	54.8	3.57	32.2	7.46	3.00
		10S	.148	8.329	13.40	23.6	2.26	2.180	54.5	3.94	35.4	8.22	3.00
		8 Ga.	.164	8.297	14.83	23.4	2.26	2.172	54.1	4.36	39.1	9.06	2.99
		API	.188	8.249	16.90	23.2	2.26	2.161	53.5	5.00	44.5	10.30	2.98
		6 Ga.	.194	8.237	17.48	23.1	2.26	2.156	53.3	5.14	45.7	10.60	2.98
		API	.203	8.219	18.30	23.1	2.26	2.152	53.1	5.38	47.7	11.05	2.98
		API	.219	8.187	19.64	22.9	2.26	2.148	52.7	5.80	51.3	11.90	2.97
		3 Ga.	.239	8.147	21.42	22.6	2.26	2.133	52.1	6.30	55.4	12.84	2.96
		20	.250	8.125	22.40	22.5	2.26	2.127	51.8	6.58	57.7	13.39	2.96
		30	.277	8.071	24.70	22.2	2.26	2.115	51.2	7.26	63.3	14.69	2.95
		API	.312	8.001	27.72	21.8	2.26	2.095	50.3	8.15	70.6	16.37	2.94
		Std.	.322	7.981	28.55	21.6	2.26	2.090	50.0	8.40	72.5	16.81	2.94
		API	.344	7.937	30.40	21.4	2.26	2.078	49.5	8.94	76.8	17.81	2.93
		API	.375	7.875	33.10	21.1	2.26	2.062	48.7	9.74	83.1	19.27	2.92
		60	.406	7.813	35.70	20.8	2.26	2.045	47.9	10.48	88.8	20.58	2.91
		API	.438	7.749	38.33	20.4	2.26	2.029	47.2	11.27	94.7	21.97	2.90
		X-Stg.	.500	7.625	43.39	19.8	2.26	2.006	45.6	12.76	105.7	24.51	2.88
		100	.594	7.437	50.90	18.8	2.26	1.947	43.5	14.96	121.4	28.14	2.85
		- -	.625	7.375	53.40	18.5	2.26	1.931	42.7	15.71	126.5	29.33	2.84
		120	.719	7.187	60.70	17.6	2.26	1.882	40.6	17.84	140.6	32.61	2.81
		140	.812	7.001	67.80	16.7	2.26	1.833	38.5	19.93	153.8	35.65	2.78
		XX-Stg.	.875	6.875	72.42	16.1	2.26	1.800	37.1	21.30	162.0	37.56	2.76
		160	.906	6.813	74.70	15.8	2.26	1.784	36.4	21.97	165.9	38.48	2.76

تهیه کننده:محمد بهزادی

(Continued). Properties of Pipe

Nominal Pipe Size	Nominal Outside Diam. D	Designation	Wall Thickness	Inside Diam. d	Weight per Foot	Wt. of Water per Ft. of Pipe	Sq. Ft. Outside Surface per Ft.	Sq. Ft. Inside Surface per Ft.	Transverse Area in.² a	Area of Metal in.² A	Moment of Inertia in.⁴ I	Section Modulus in.³ Z	Radius of Gyration in. R
10	10.750	12 Ga.	.104	10.542	11.83	37.8	2.81	2.76	87.3	3.48	49.3	9.16	3.76
		10 Ga.	.134	10.482	15.21	37.4	2.81	2.74	86.3	4.47	63.0	11.71	3.75
		8 Ga.	.164	10.422	18.56	37.0	2.81	2.73	85.3	5.45	76.4	14.22	3.74
		10S	.165	10.420	18.65	36.9	2.81	2.73	85.3	5.50	76.8	14.29	3.74
		API	.188	10.374	21.12	36.7	2.81	2.72	84.5	6.20	86.5	16.10	3.74
		6 Ga.	.194	10.362	21.89	36.6	2.81	2.71	84.3	6.43	89.7	16.68	3.73
		API	.203	10.344	22.86	36.5	2.81	2.71	84.0	6.71	93.3	17.35	3.73
		API	.219	10.310	24.60	36.2	2.81	2.70	83.4	7.24	100.5	18.70	3.72
		3 Ga.	.239	10.272	28.05	35.9	2.81	2.69	82.9	7.89	109.2	20.32	3.72
		20	.250	10.250	28.03	35.9	2.81	2.68	82.6	8.26	113.6	21.12	3.71
		API	.279	10.192	31.20	35.3	2.81	2.66	81.6	9.18	125.9	23.42	3.70
		30	.307	10.136	34.24	35.0	2.81	2.65	80.7	10.07	137.4	25.57	3.69
		API	.344	10.062	38.26	34.5	2.81	2.63	79.5	11.25	152.3	28.33	3.68
		Std.	.365	10.020	40.48	34.1	2.81	2.62	78.9	11.91	160.7	29.90	3.67
		API	.438	9.874	48.28	33.2	2.81	2.58	76.6	14.19	188.8	35.13	3.65
		X-Stg.	.500	9.750	54.74	32.3	2.81	2.55	74.7	16.10	212.0	39.43	3.63
		80	.594	9.562	64.40	31.1	2.81	2.50	71.8	18.91	244.9	45.56	3.60
		100	.719	9.312	77.00	29.5	2.81	2.44	68.1	22.62	286.2	53.25	3.56
		- -	.750	9.250	80.10	29.1	2.81	2.42	67.2	23.56	296.2	55.10	3.54
		120	.844	9.062	89.20	27.9	2.81	2.37	64.5	26.23	324.3	60.34	3.51
		140	1.000	8.750	104.20	26.1	2.81	2.29	60.1	30.63	367.8	68.43	3.46
		160	1.125	8.500	116.00	24.6	2.81	2.22	56.7	34.01	399.4	74.31	3.43
12	12.750	12 Ga.	.104	12.542	14.1	53.6	3.34	3.28	123.5	4.13	82.6	12.9	4.47
		10 Ga.	.134	12.482	18.1	53.0	3.34	3.27	122.4	5.31	105.7	16.6	4.46
		8 Ga.	.164	12.422	22.1	52.5	3.34	3.25	121.2	6.48	128.4	20.1	4.45
		10S	.180	12.390	24.2	52.2	3.34	3.24	120.6	7.11	140.4	22.0	4.44
		6 Ga.	.194	12.362	26.0	52.0	3.34	3.23	120.0	7.65	150.9	23.7	4.44
		API	.203	12.344	27.2	52.0	3.34	3.23	119.9	7.99	157.2	24.7	4.43
		API	.219	12.312	29.3	51.7	3.34	3.22	119.1	8.52	167.6	26.3	4.43
		3 Ga.	.239	12.272	32.0	51.3	3.34	3.21	118.3	9.39	183.8	28.8	4.42
		20	.250	12.250	33.4	51.3	3.34	3.12	118.0	9.84	192.3	30.2	4.42
		API	.281	12.188	37.4	50.6	3.34	3.19	116.7	11.01	214.1	33.6	4.41
		API	.312	12.126	41.5	50.1	3.34	3.17	115.5	12.19	236.0	37.0	4.40
		30	.330	12.090	43.8	49.7	3.34	3.16	114.8	12.88	248.5	39.0	4.39
		API	.344	12.062	45.5	49.7	3.34	3.16	114.5	13.46	259.0	40.7	4.38
		Std.	.375	12.000	49.6	48.9	3.34	3.14	113.1	14.58	279.3	43.8	4.37
		40	.406	11.938	53.6	48.5	3.34	3.13	111.9	15.74	300.3	47.1	4.37
		API	.438	11.874	57.5	48.2	3.34	3.11	111.0	16.95	321.0	50.4	4.35
		X-Stg.	.500	11.750	65.4	46.9	3.34	3.08	108.4	19.24	361.5	56.7	4.33
		60	.562	11.626	73.2	46.0	3.34	3.04	106.2	21.52	400.5	62.8	4.31
		- -	.625	11.500	80.9	44.9	3.34	3.01	103.8	23.81	438.7	68.8	4.29
		80	.688	11.374	88.6	44.0	3.34	2.98	101.6	26.03	475.2	74.6	4.27
		- -	.750	11.250	96.2	43.1	3.34	2.94	99.4	28.27	510.7	80.1	4.25
		100	.844	11.062	108.0	41.6	3.34	2.90	96.1	31.53	561.8	88.1	4.22
		- -	.875	11.000	110.9	41.1	3.34	2.88	95.0	32.64	578.5	90.7	4.21
		120	1.000	10.750	125.5	39.3	3.34	2.81	90.8	36.91	641.7	100.7	4.17
		140	1.125	10.500	140.0	37.5	3.34	2.75	86.6	41.08	700.7	109.9	4.13
		- -	1.250	10.250	153.6	35.8	3.34	2.68	82.5	45.16	755.5	118.5	4.09
		160	1.312	10.126	161.0	34.9	3.34	2.65	80.5	47.14	781.3	122.6	4.07
		- -	1.375	10.000	167.2	34.0	3.34	2.62	78.5	49.14	807.2	126.6	4.05
		- -	1.500	9.750	180.4	32.4	3.34	2.55	74.7	53.01	853.8	133.9	4.01

تهیه کننده:محمد بهزادی

(Continued). Properties of Pipe

Nominal Pipe Size	Nominal Outside Diam. D	Designation	Wall Thickness	Inside Diam. d	Weight per Foot	Wt. of Water per Ft. of Pipe	Sq. Ft. Outside Surface per Ft.	Sq. Ft. Inside Surface per Ft.	Transverse Area in.² a	Area of Metal in.² A	Moment of Inertia in.⁴ I	Section Modulus in.³ Z	Radius of Gyration in. R
14	14.000	10 Ga.	.134	13.732	20	64.2	3.67	3.59	148.1	5.84	140.4	20.1	4.90
		8 Ga.	.164	13.672	24	63.6	3.67	3.58	146.8	7.13	170.7	24.4	4.89
		6 Ga.	.194	13.612	29	63.1	3.67	3.56	145.5	8.41	200.6	28.7	4.88
		API	.210	13.580	31	62.8	3.67	3.55	144.8	9.10	216.2	30.9	4.87
		API	.219	13.562	32	62.6	3.67	3.55	144.5	9.48	225.1	32.2	4.87
		3 Ga.	.239	13.522	35	62.3	3.67	3.54	143.6	10.33	244.9	35.0	4.87
		10	.250	13.500	37	62.1	3.67	3.54	143.0	10.82	256.0	36.6	4.86
		API	.281	13.438	41	61.5	3.67	3.52	141.8	12.11	285.2	40.7	4.85
		20	.312	13.375	46	60.8	3.67	3.50	140.5	13.44	314.9	45.0	4.84
		API	.344	13.312	50	60.3	3.67	3.48	139.2	14.76	344.3	49.2	4.83
		Std.	.375	13.250	55	59.7	3.67	3.47	137.9	16.05	372.8	53.2	4.82
		40	.438	13.124	63	58.5	3.67	3.44	135.3	18.66	429.6	61.4	4.80
		X-Stg.	.500	13.000	72	57.4	3.67	3.40	132.7	21.21	483.8	69.1	4.78
		60	.594	12.812	85	55.9	3.67	3.35	129.0	24.98	562.4	80.3	4.74
		- -	.625	12.750	89	55.3	3.67	3.34	127.7	26.26	588.5	84.1	4.73
		80	.750	12.500	107	51.2	3.67	3.27	122.7	31.22	687.5	98.2	4.69
		- -	.875	12.250	123	51.1	3.67	3.21	117.9	36.08	780.1	111.4	4.65
		100	.938	12.124	131	50.0	3.67	3.17	115.5	38.47	820.5	117.2	4.63
		- -	1.000	12.000	139	49.0	3.67	3.14	113.1	40.84	868.0	124.0	4.61
		120	1.094	11.812	151	47.5	3.67	3.09	109.6	44.32	929.8	132.8	4.58
		- -	1.125	11.750	155	47.0	3.67	3.08	108.4	45.50	950.3	135.8	4.57
		140	1.250	11.500	171	45.0	3.67	3.01	103.9	50.07	1027.5	146.8	4.53
		- -	1.375	11.250	186	43.1	3.67	2.94	99.4	54.54	1099.5	157.1	4.49
		160	1.406	11.188	190	42.6	3.67	2.93	98.3	55.63	1116.9	159.6	4.48
		- -	1.500	11.000	200	41.2	3.67	2.88	95.0	58.90	1166.5	166.6	4.45
16	16.000	10 Ga.	.134	15.732	23	84.3	4.19	4.12	194.4	6.68	210	26.3	5.61
		8 Ga.	.164	15.672	28	83.6	4.19	4.10	192.9	8.16	256	32.0	5.60
		- -	.188	15.624	32	83.3	4.19	4.09	192.0	9.39	294	36.7	5.59
		6 Ga.	.194	15.612	33	83.0	4.19	4.09	191.4	9.63	301	37.6	5.59
		API	.219	15.562	37	82.5	4.19	4.07	190.2	10.86	338	42.3	5.58
		3 Ga.	.239	15.522	40	82.0	4.19	4.06	189.2	11.83	368	45.9	5.57
		10	.250	15.500	42	82.1	4.19	4.06	189.0	12.40	385	48.1	5.57
		API	.281	15.438	47	81.2	4.19	4.04	187.0	13.90	430	53.8	5.56
		20	.312	15.375	52	80.1	4.19	4.03	185.6	15.40	474	59.2	5.55
		API	.344	15.312	57	80.0	4.19	4.01	184.1	16.94	519	64.9	5.54
		Std.	.375	15.250	63	79.1	4.19	4.00	182.6	18.41	562	70.3	5.53
		API	.438	15.124	73	78.2	4.19	3.96	180.0	21.42	650	81.2	5.51
		X-Stg.	.500	15.000	83	76.5	4.19	3.93	176.7	24.35	732	91.5	5.48
		- -	.625	14.750	103	74.1	4.19	3.86	170.9	30.19	893	111.7	5.44
		60	.656	14.688	108	73.4	4.19	3.85	169.4	31.62	933	116.6	5.43
		- -	.750	14.500	122	71.5	4.19	3.80	165.1	35.93	1047	130.9	5.40
		80	.844	14.312	137	69.7	4.19	3.75	160.9	40.14	1157	144.6	5.37
		- -	.875	14.250	141	69.1	4.19	3.73	159.5	41.58	1192	149.0	5.35
		- -	1.000	14.000	160	66.7	4.19	3.66	153.9	47.12	1331	166.4	5.31
		100	1.031	13.938	165	66.0	4.19	3.65	152.6	48.49	1366	170.7	5.30
		- -	1.125	13.750	179	64.4	4.19	3.60	148.5	52.57	1463	182.9	5.27
		120	1.219	13.562	193	62.6	4.19	3.55	144.5	56.56	1556	194.5	5.24
		- -	1.250	13.500	197	62.1	4.19	3.53	143.1	57.92	1586	198.3	5.23
		- -	1.375	13.250	215	59.8	4.19	3.47	137.9	63.17	1704	213.0	5.19
		140	1.438	13.124	224	58.6	4.19	3.44	135.3	65.79	1761	220.1	5.17
		- -	1.500	13.000	232	57.4	4.19	3.40	132.7	68.33	1816	227.0	5.15
		160	1.594	12.812	245	55.9	4.19	3.35	129.0	72.10	1893	236.6	5.12

Commercial Wrought Steel Pipe Data
(Based on ANSI B36.10 wall thicknesses)

Schedule 40

Nominal Pipe Size	Outside Diameter	Thickness	Inside Diameter		Inside Diameter Functions (In Inches)				Transverse Internal Area	
			d	D	d^2	d^3	d^4	d^5	a	A
Inches	Inches	Inches	Inches	Feet					Sq. In.	Sq. Ft.
1/8	0.405	0.068	0.269	0.0224	0.0724	0.0195	0.005242	0.00141	0.057	0.00040
1/4	0.540	0.088	0.364	0.0303	0.1325	0.0482	0.01756	0.00639	0.104	0.00072
3/8	0.675	0.091	0.493	0.0411	0.2430	0.1198	0.05905	0.02912	0.191	0.00133
1/2	0.840	0.109	0.622	0.0518	0.3869	0.2406	0.1497	0.09310	0.304	0.00211
3/4	1.050	0.113	0.824	0.0687	0.679	0.5595	0.4610	0.3799	0.533	0.00371
1	1.315	0.133	1.049	0.0874	1.100	1.154	1.210	1.270	0.864	0.00600
1 1/4	1.660	0.140	1.380	0.1150	1.904	2.628	3.625	5.005	1.495	0.01040
1 1/2	1.900	0.145	1.610	0.1342	2.592	4.173	6.718	10.82	2.036	0.01414
2	2.375	0.154	2.067	0.1722	4.272	8.831	18.250	37.72	3.355	0.02330
2 1/2	2.875	0.203	2.469	0.2057	6.096	15.051	37.161	91.75	4.788	0.03322
3	3.500	0.216	3.068	0.2557	9.413	28.878	88.605	271.8	7.393	0.05130
3 1/2	4.000	0.226	3.548	0.2957	12.59	44.663	158.51	562.2	9.886	0.06870
4	4.500	0.237	4.026	0.3355	16.21	65.256	262.76	1058.	12.730	0.08840
5	5.563	0.258	5.047	0.4206	25.47	128.56	648.72	3275.	20.006	0.1390
6	6.625	0.280	6.065	0.5054	36.78	223.10	1352.8	8206.	28.891	0.2006
8	8.625	0.322	7.981	0.6651	63.70	508.36	4057.7	32380.	50.027	0.3474
10	10.75	0.365	10.02	0.8350	100.4	1006.0	10080.	101000.	78.855	0.5475
12	12.75	0.406	11.938	0.9965	142.5	1701.3	20306.	242470.	111.93	0.7773
14	14.0	0.438	13.124	1.0937	172.24	2260.5	29666.	389340.	135.28	0.9394
16	16.0	0.500	15.000	1.250	225.0	3375.0	50625.	759375.	176.72	1.2272
18	18.0	0.562	16.876	1.4063	284.8	4806.3	81111.	1368820.	223.68	1.5533
20	20.0	0.593	18.814	1.5678	354.0	6659.5	125320.	2357244.	278.00	1.9305
24	24.0	0.687	22.626	1.8855	511.9	11583.	262040.	5929784.	402.07	2.7921

Density, Liquid ρ

Density liquid, ρ = (62.3 lb./cu. ft. water) (Sp. Gr. liquid), pounds /cu. ft.

Estimated flow velocity for assumed 2 in. Sch. 40 pipe (See Appendix A-16)

$$= \frac{(20\ \text{gpm})\ (8.33\ \text{lb}/\text{gal})\ (0.81\ \text{SpGr})}{(62.3 \times 0.81)\ (3.355\ \text{in}^2)\ (60\ \text{sec}/\text{min})/144}$$

$$= 1.91\ \text{ft}/\text{sec}$$

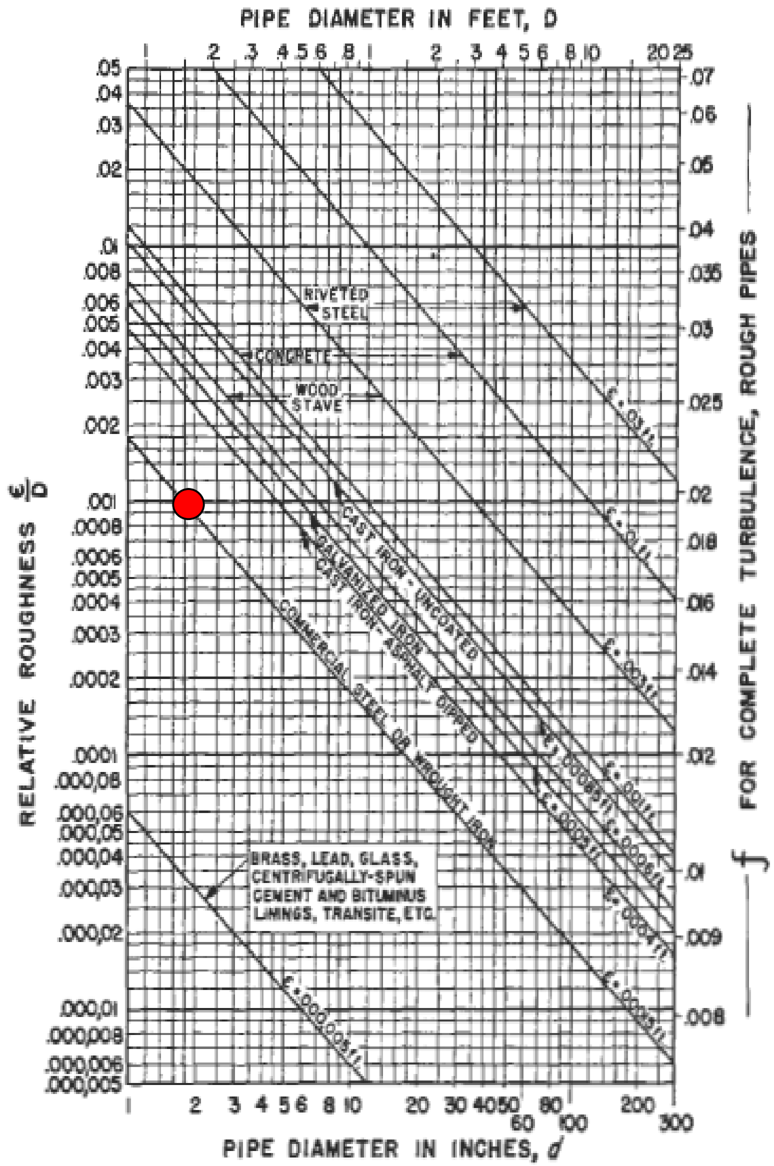
$$\text{Velocity head}\ \frac{v^2}{2g} = \frac{(1.91)^2}{2(32.2)} = 0.05664\ \text{ft of fluid}$$

$$\text{Reynolds number} = \frac{50.6\ Q\rho}{d\mu} \qquad (2\text{-}49)$$

$$= \frac{50.6\ (20)(0.81 \times 62.3)}{(2.06)(1.125\ \text{cp})}$$

$$R_e = 22{,}036\ (\text{turbulent})$$

$$\varepsilon/D = 0.00088,\ \text{Figure 2-11}$$



RELATIVE ROUGHNESS FACTORS FOR NEW CLEAN PIPES

تهیه کننده:محمد بهزادی

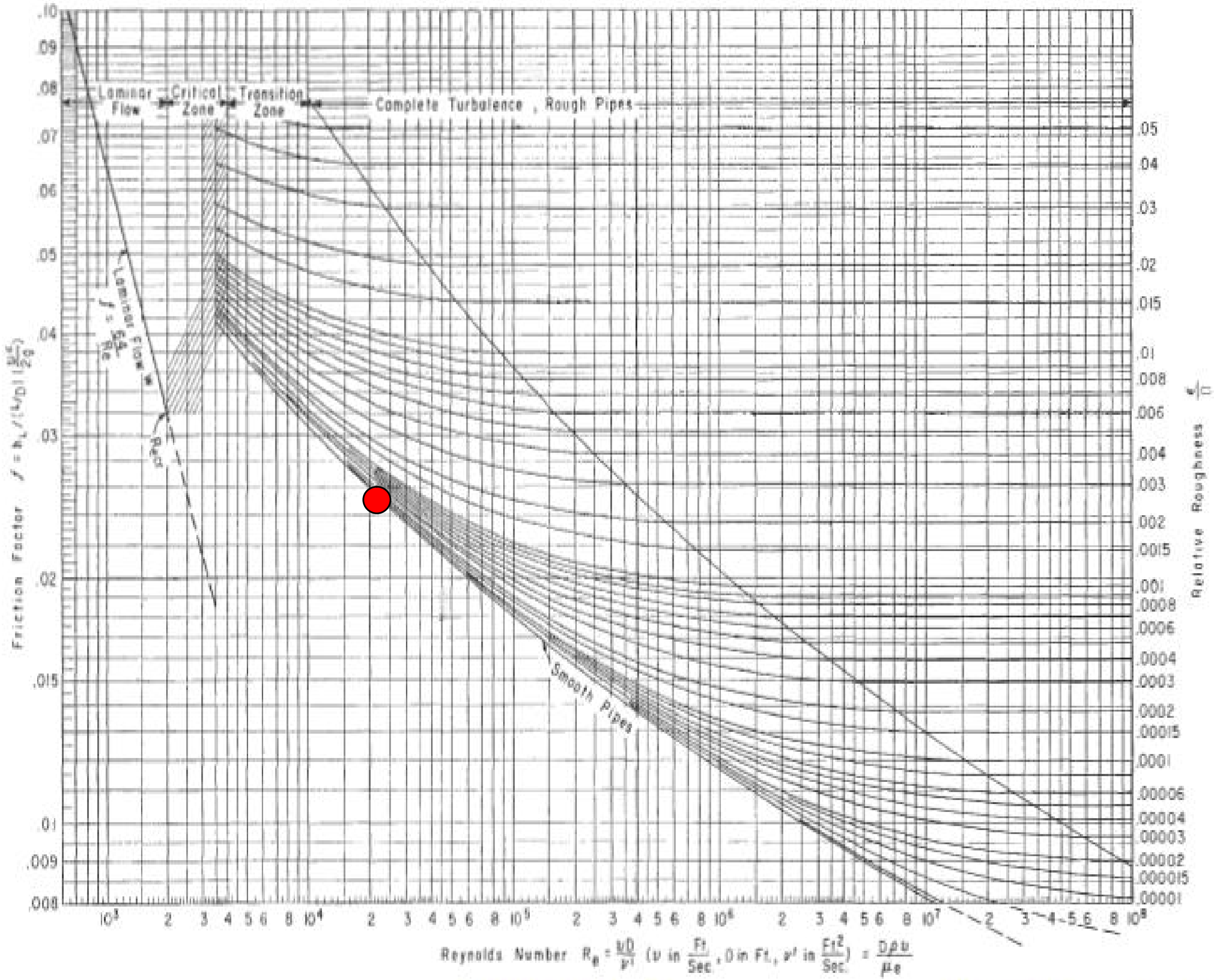


Figure 2-3. Moody or "regular" Fanning friction factors for any kind and size of pipe. Note: the friction factor read from this chart is four times the value of the f factor read from Perry's Handbook, 6th Ed. [5]. Reprinted by permission, *Pipe Friction Manual*, 1954 by The Hydraulic Institute. Also see *Engineering DataBook*, 1st Ed., The Hydraulic Institute, 1979 [2]. Data from L. F. Moody, "Friction Factors for Pipe Flow" by ASME [1].

تهیه کننده:محمد بهزادی

From Figure 2-3 (friction factor), $f_t = 0.0205$

$$h_f = \frac{fLv^2}{D(2g)} \qquad (2\text{-}2)$$

$$= \frac{0.0205\,(15)\,(1.91)^2}{\left(\frac{2.067\text{ in}}{12}\right) 2(32.2)}$$

$h_f = 0.101$ ft of kerosene fluid, pipe friction, for 15 ft

Loss through pump suction fittings:

a. Square edged inlet (tank to pipe), $K = 0.5$, Figure 2-12A

b. Gate valve flanged, open, in suction line, from Table 2-2, with $\beta = 1$, $K = 8\,f_T$

$K = 8\,(0.0205) = 0.164$

$h_f = Kv^2/2g = (0.5 + 0.164)\,(1.91)^2/2\,(32.2) = 0.0853$ ft fluid

Total suction pipe side friction *loss:*

$\Sigma h_f = 0.101 + 0.0853 = 0.1863$ ft kerosene

Note: when used for pump system balance, this Σh_f must be used as a negative number (-0.1863) because it is a pressure loss associated with the fluid flowing. For *pipe line sizing,* the pressure head on the tank of 5 psig and any elevation difference between tank outlet nozzle and pump suction centerline do not enter into the calculations.

Pump Discharge Line Sizing (only)

The pump discharge can flow at a higher velocity than the suction line, due in part to NPSH conditions on the suction side of any pump (which are not considered directly in these pipe sizing calculations).

From Table 2-4, select 6 ft/sec as design velocity for estimating pipe size.

For 20 gpm, cross-section area for flow required:

$$A = \frac{20}{7.48\text{ gal/cu ft }(60\text{ sec/min})\,(6\text{ ft/sec})}$$

$= 0.00742$ sq ft

$= (0.007427)(144) = 1.009$ sq in.

From Appendix A-16, Standard Schedule 40 pipe

For 1-in. pipe, $A = 0.8640$ sq in. (too small)

1½-in. pipe, $A = 1.495$ sq in. (too large)

Try 1¼-in. pipe, ID = 1.38 in.

(Note: Usually do not select this size. Could go to 1½-in. Velocity would be even slower.)

Actual velocity would be: (1½-in. pipe)

$v = 20\,(144)/[(60)\,(7.48)\,(1.495)] = 4.29$ ft/sec

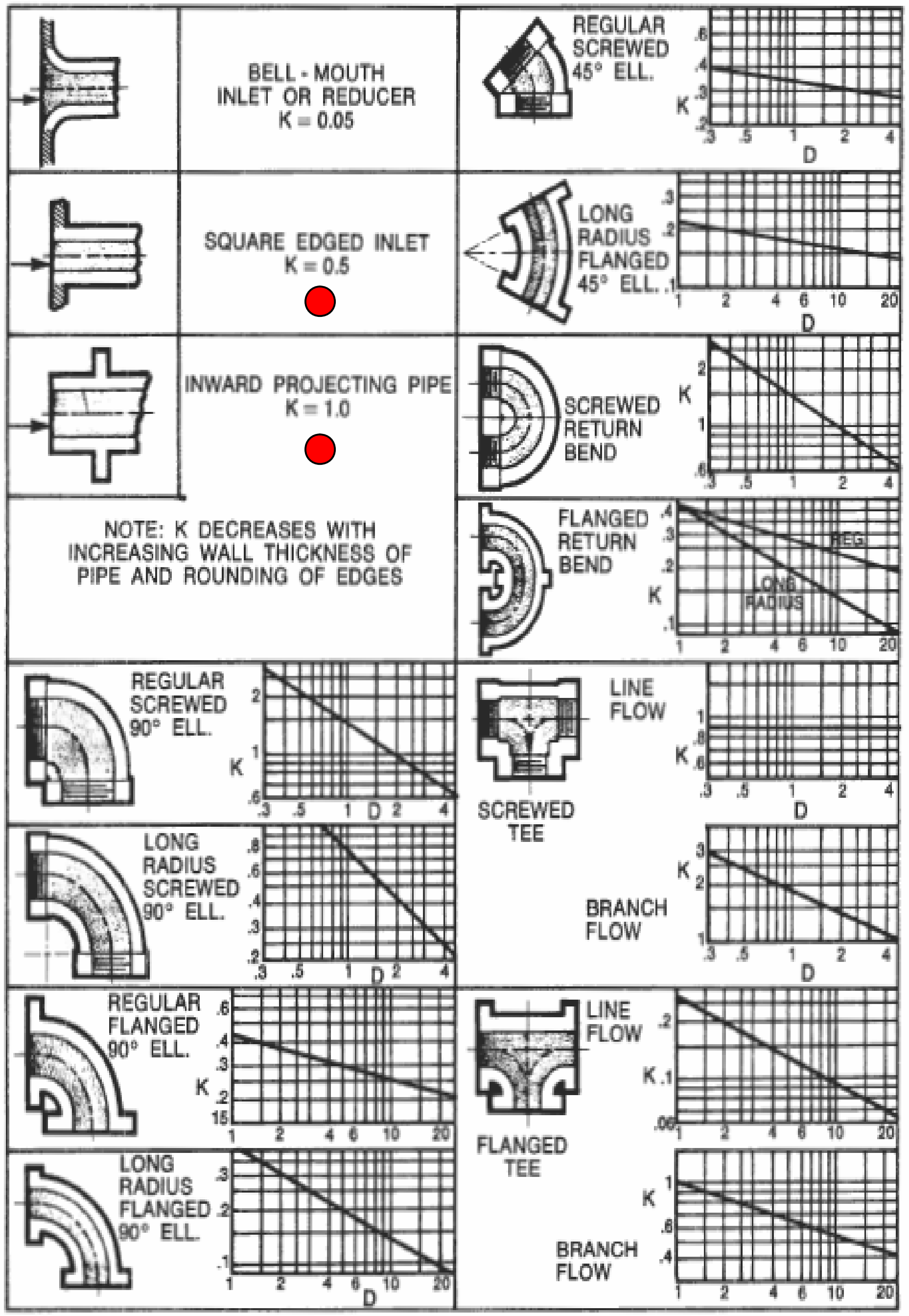
This is acceptable. Practical usage range is 3 ft/sec to 9 ft/sec, although 1½-in. pipe is not the best size for some plants.

Reynolds number, $R_e = 50.6Q\rho/d\mu$ (2-49)

$= 50.6\,(20)\,(0.81 \times 62.3)/1.38\,(1.125)$

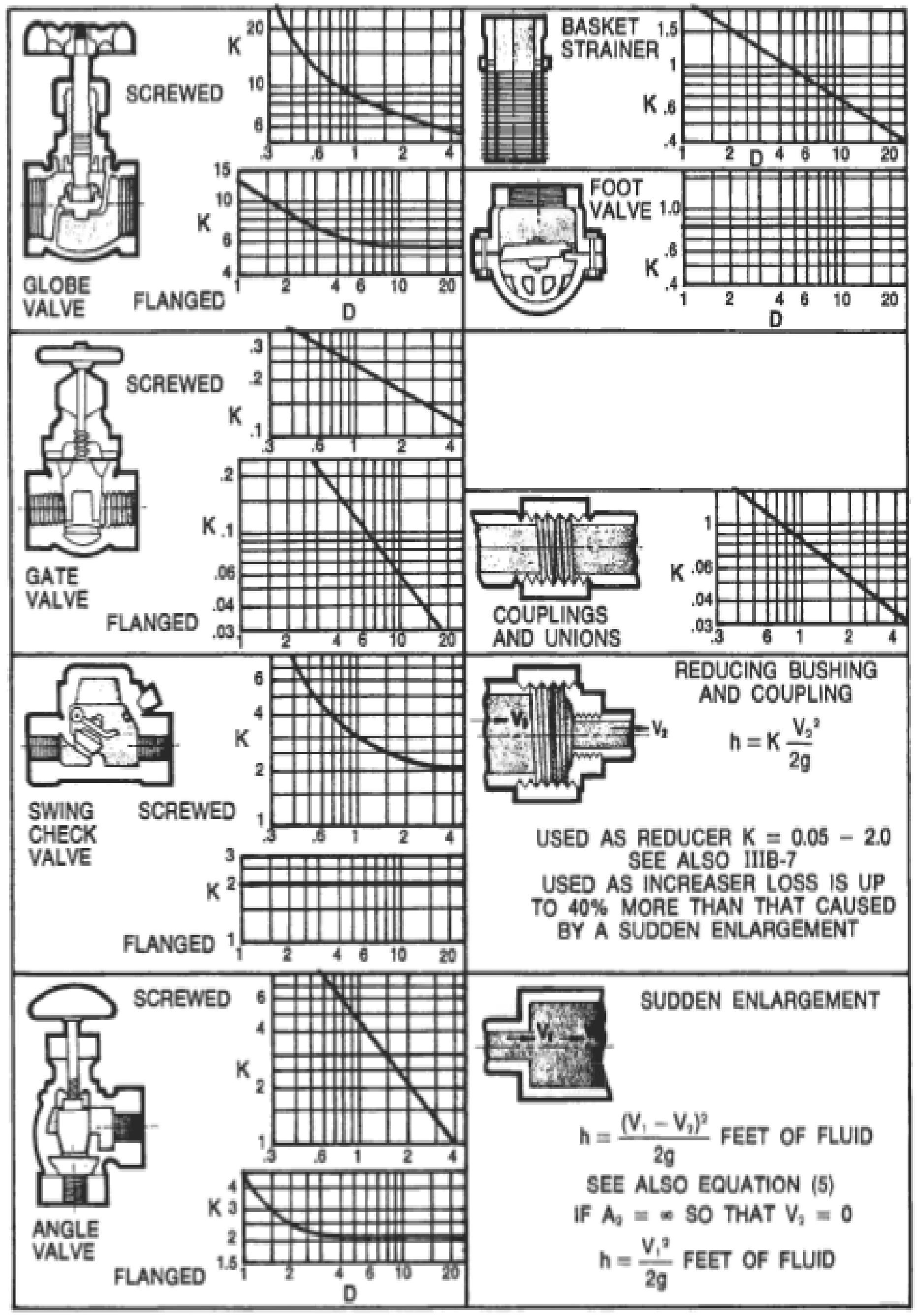
$= 32{,}894$ (turbulent)

For 1¼″ $\varepsilon/D = 0.0014$, Figure 2-11. (2-49A)



$$h = K \frac{V^2}{2g} \text{ FEET OF FLUID}$$

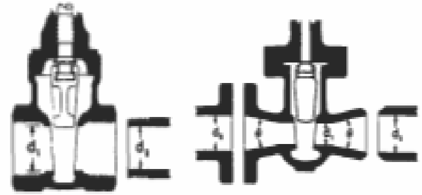
تهیه کننده:محمد بهزادی



$$h = K \frac{V^2}{2g} \text{ FEET OF FLUID}$$

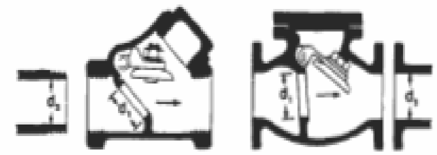
هیه کننده:محمد بهزادی

GATE VALVES
Wedge Disc, Double Disc, or Plug Type



If: $\beta = 1, \theta = 0$ .... $K_1 = 8 f_T$
$\beta < 1$ and $\theta \leqq 45°$ .... K_2 = Formula 5
$\beta < 1$ and $\theta > 45° \leqq 180°$ ... K_2 = Formula 6

SWING CHECK VALVES



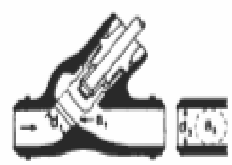
$K = 100 f_T$ — Minimum pipe velocity (fps) for full disc lift $= 35\sqrt{\bar{V}}$

$K = 50 f_T$ — Minimum pipe velocity (fps) for full disc lift $= 48\sqrt{\bar{V}}$

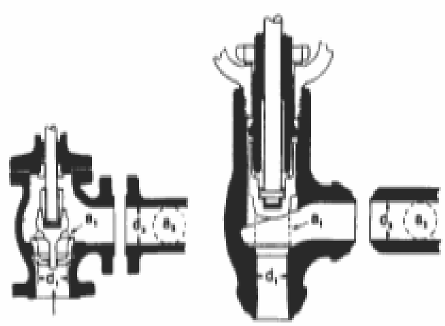
$$\beta = \frac{d_1}{d_2}$$

GLOBE AND ANGLE VALVES

If: $\beta = 1 \ldots K_1 = 340 f_T$



If: $\beta = 1 \ldots K_1 = 55 f_T$



If: $\beta = 1 \ldots K_1 = 150 f_T$ If: $\beta = 1 \ldots K_1 = 55 f_T$

All globe and angle valves, whether reduced seat or throttled,
If: $\beta < 1 \ldots K_2$ = Formula 7

LIFT CHECK VALVES

If: $\beta = 1 \ldots K_1 = 600 f_T$
$\beta < 1 \ldots K_2$ = Formula 7
Minimum pipe velocity (fps) for full disc lift $= 40\,\beta^2\sqrt{\bar{V}}$

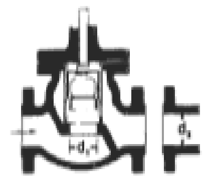
If: $\beta = 1 \ldots K_1 = 55 f_T$
$\beta < 1 \ldots K_2$ = Formula 7
Minimum pipe velocity (fps) for full disc lift $= 140\,\beta^2\sqrt{\bar{V}}$

TILTING DISC CHECK VALVES

	$\alpha = 5°$	$\alpha = 15°$
Sizes 2 to 8" ... K =	$40 f_T$	$120 f_T$
Sizes 10 to 14" ... K =	$30 f_T$	$90 f_T$
Sizes 16 to 48" ... K =	$20 f_T$	$60 f_T$
Minimum pipe velocity (fps) for full disc lift =	$80\sqrt{\bar{V}}$	$30\sqrt{\bar{V}}$

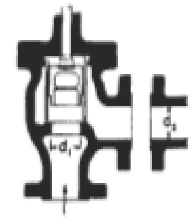
تهیه کننده:محمد بهزادی

STOP-CHECK VALVES
(Globe and Angle Types)



If:
$\beta = 1 \ldots K_1 = 400\, f_T$
$\beta < 1 \ldots K_2 =$ Formula 7

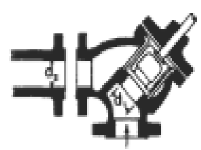
Minimum pipe velocity for full disc lift
$= 55\, \beta^2 \sqrt{\bar{V}}$



If:
$\beta = 1 \ldots K_1 = 200\, f_T$
$\beta < 1 \ldots K_2 =$ Formula 7

Minimum pipe velocity for full disc lift
$= 75\, \beta^2 \sqrt{\bar{V}}$

If:
$\beta = 1 \ldots K_1 = 350\, f_T$
$\beta < 1 \ldots K_2 =$ Formula 7



If:
$\beta = 1 \ldots K_1 = 300\, f_T$
$\beta < 1 \ldots K_2 =$ Formula 7

Minimum pipe velocity (fps) for full disc lift
$= 60\, \beta^2 \sqrt{\bar{V}}$

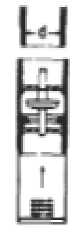
If:
$\beta = 1 \ldots K_1 = 55\, f_T$
$\beta < 1 \ldots K_2 =$ Formula 7

If:
$\beta = 1 \ldots K_1 = 55\, f_T$
$\beta < 1 \ldots K_2 =$ Formula 7

Minimum pipe velocity (fps) for full disc lift
$= 140\, \beta^2 \sqrt{\bar{V}}$

FOOT VALVES WITH STRAINER

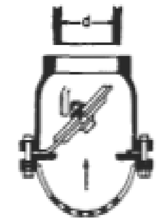
Poppet Disc



$K = 420 f_T$

Minimum pipe velocity (fps) for full disc lift
$= 15 \sqrt{\bar{V}}$

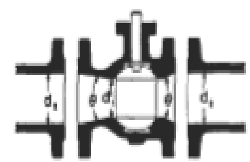
Hinged Disc



$K = 75 f_T$

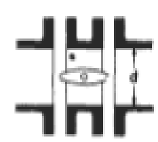
Minimum pipe velocity (fps) for full disc lift
$= 35 \sqrt{\bar{V}}$

BALL VALVES



If: $\beta = 1,\ \theta = 0 \ldots\ldots\ldots\ldots\ldots K_1 = 3\, f_T$
$\beta < 1$ and $\theta \leq 45° \ldots\ldots\ldots K_2 =$ Formula 5
$\beta < 1$ and $\theta > 45° \leq 180° \ldots K_2 =$ Formula 6

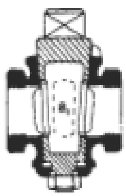
BUTTERFLY VALVES



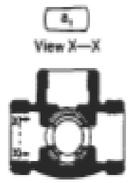
Sizes 2 to 8" ... $K = 45\, f_T$
Sizes 10 to 14" ... $K = 35\, f_T$
Sizes 16 to 24" ... $K = 25\, f_T$

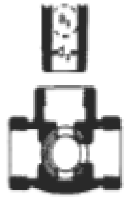
PLUG VALVES AND COCKS

Straight-Way



3-Way





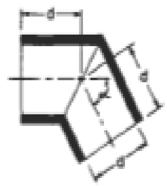
If: $\beta = 1$, $K_1 = 18\,f_T$

If: $\beta = 1$, $K_1 = 30\,f_T$

If: $\beta = 1$, $K_1 = 90\,f_T$

If: $\beta < 1 \ldots K_2$ = Formula 6

MITRE BENDS



α	K
0°	2 f_T
15°	4 f_T
30°	8 f_T
45°	15 f_T
60°	25 f_T
75°	40 f_T
90°	60 f_T

90° PIPE BENDS AND FLANGED OR BUTT-WELDING 90° ELBOWS

r/d	K	r/d	K
1	20 f_T	10	30 f_T
2	12 f_T	12	34 f_T
3	12 f_T	14	38 f_T
4	14 f_T	16	42 f_T
6	17 f_T	18	46 f_T
8	24 f_T	20	50 f_T

The resistance coefficient, K_B, for pipe bends other than 90° may be determined as follows:

$$K_B = (n-1)\left(0.25\,\pi f_T \frac{r}{d} + 0.5\,K\right) + K$$

n = number of 90° bends
K = resistance coefficient for one 90° bend (per table)

CLOSE PATTERN RETURN BENDS

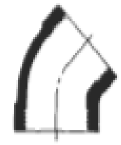
$K = 50\,f_T$

STANDARD ELBOWS

90°

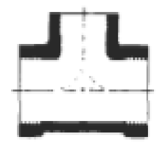
$K = 30\,f_T$

45°



$K = 16\,f_T$

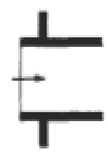
STANDARD TEES



Flow thru run. . . . . . . $K = 20\,f_T$
Flow thru branch. . . . $K = 60\,f_T$

PIPE ENTRANCE

Inward Projecting

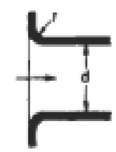


$K = 0.78$

r/d	K
0.00*	0.5
0.02	0.28
0.04	0.24
0.06	0.15
0.10	0.09
0.15 & up	0.04

*Sharp-edged

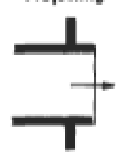
Flush



For K, see table

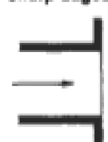
PIPE EXIT

Projecting



$K = 1.0$

Sharp-Edged



$K = 1.0$

Rounded

$K = 1.0$

تهیه کننده:محمد بهزادی

From Figure 2-3, read, $f = 0.0219 = f_T$
then, pipe only friction loss:

$$h_f = (f\,L/D)\,(v^2/2g) \qquad (2\text{-}2)$$

D = pipe, I.D., in ft $= 1.38/12 = 0.1150$ ft

$$h_f = 0.0219\,\frac{(8 + 6 + 200)}{0.1150}\,\frac{(4.29)^2}{(2)(32.2)}$$

h_f = 11.64 ft of kerosene flowing (pipe only)

Loss through discharge fittings, valves, connections, using K factors using Table 2-2:

2 check valves, swing, threaded, 100 f_T = 100 (0.0219) = 2.19 = 4.38 (for 2)

1 globe valve (open), $\beta = 1$: $K = 340\ f_T = 340\ (0.0219) = 7.446$

6 90° elbows, $r/d = 1.88/1.38 = 1.36$

$K = 30\ f_T = 30\ (0.0219) = 0.657$

For 6: $6 \times 0.657 = 3.94$

1 sharp edged entrance (sudden enlargement) = 1.0

1 gate valve, open, $\beta = 1.0$, $K = 8\ f_T$; $K = 8\ (0.0219) = 0.175$

$$K = [4.38 + 7.45^* + 3.94 + 0.175^* + 1.0] = 16.941$$

*Threaded, from Table 2-2.
For fittings:

$$\text{then, } h = Kv^2/2g = \frac{16.941\,(4.29^2)}{2(32.2)} = 4.84 \text{ ft kerosene}$$

Total friction loss for discharge side pump *due to friction:*

$$h = 11.64 + 4.84 = 16.48 \text{ ft fluid kerosene}$$

$$h_f = \Delta p = 16.48/[(2.31)/(0.81)] = 5.77 \text{ psi}$$

PUMP & Compressor

- اتصال پمپ به موتور:
- مستقیم
- از طریق پولی یا گیربکس

هد کل

- کار پمپ
- میزان توانایی پمپ برای بالا بردن سیال تا یک ارتفاع معین
- میزان توانایی پمپ برای ایجاد یک فشار تخلیه معین
- ارتفاع تخلیه منهای ارتفاع مکش
- هد تخلیه منهای هد مکش
- هد تخلیه بعلاوه لیفت(خیز) مکش
- فشار مطلق تخلیه منهای فشار مطلق مکش

NPSH

- مقدار انرژی موجود در مایع برای غلبه بر اتلاف اصطکاکی از نازل مکش به چشم پره بدون ایجاد تبخیر
- مکش پمپ + چشم پره
- ملاحظات:
- لوله مکش
- اتصالات
- ارتفاع
- فشار مطلق سیال در لوله مکش
- شرعت سیال
- دمای سیال
- بزرگتر بودن نازل مکش به ازل تخلیه برای جلوگیری از کمبود مایع

مکش هوا

- پمپ بالاکش(lift pump): برای رساندن و بالا بردن سیال به تراز خود پمپ

توربولنس

- بر اثر آشفتگی و اغتشاش در جریان
- تشکیل گردابه(Vortex) در جریان مکش
- کمبود و نارسایی لوله:زانوییهای تیز،موانع و اتصالات،فیلترها و صافی در جریان مکش
- عدم توجه به قوانین غوطه وری
- صدمات :روی پره به سمت چشم پره

کاربرد

- دبی بالا و پایین می شود(مثلا افت و خیز فصلی محصول)(بستنی و قرص سرماخوردگی) ولی
- هد و فشار ثابت(مثلا از بین رفتن باکتریها در دما و فشاری خاص)
- چرا اکثر پمپها را فقط با یک پره می فروشند؟؟!!
- پمپهای تعویض سریع(Back Pullout) برای تعویض سریع قطر
- نتیجه:اگر فرآیند به زمان بستگی ندارد می توان با کاهش سرعت به نصف، مصرف انرژی را 1/8 نمود!!

- انرژی جیمز وات:قابلیت انجام کار(نیرو در فاصله)
- توان:کار در زمان معین
- اسب بخار=550 lbs.ft/sec
- موتور تولید HPاسب بخار
- پمپ مصرف BHP اسب بخار ترمزی
- اختلاف این دو برابر اتلاف سیستم یعنی یاتاقانها، شفت و کوپلینگ بین موتور و پمپ

valve

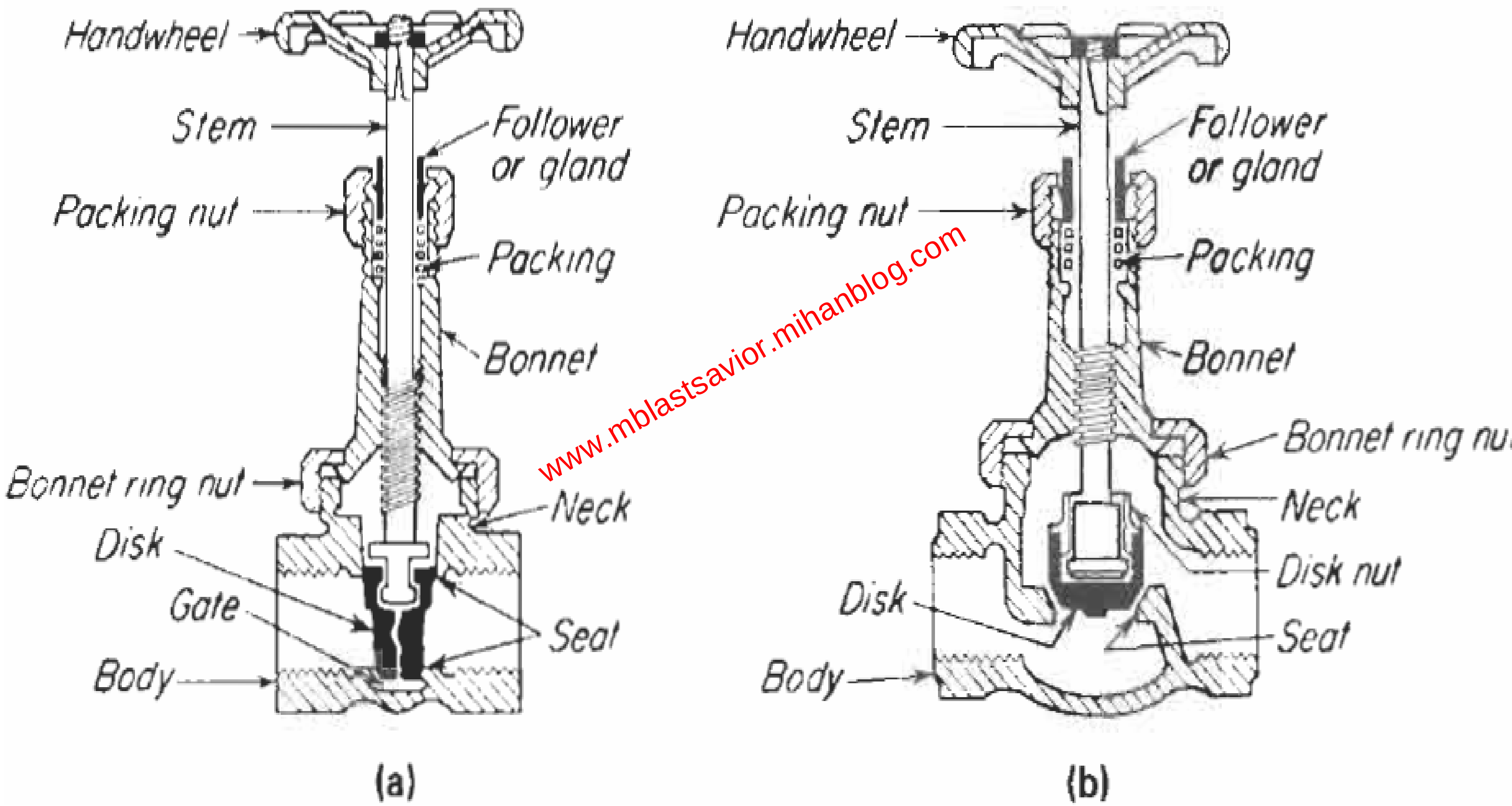
valve

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

- (globe) Control
  - قابلیت کنترل جریان از حالت کاملا باز تا کاملا بسته

Ball Valve

- Full Bore
  - بالا و پایین PSV
  - پایین piglaucher و بالای pig receiver
  - Vent-Drain
  - شیرهای ابزار دقیق
  - قطع کننده جریان در خطوط هیدرو کربنی که افت فشار در حالت بحرانی است
  - Utility بزرگتر از 2 اینچ
- Reduce Bore
- جریان بدون ذرات جامد



بزرگتر

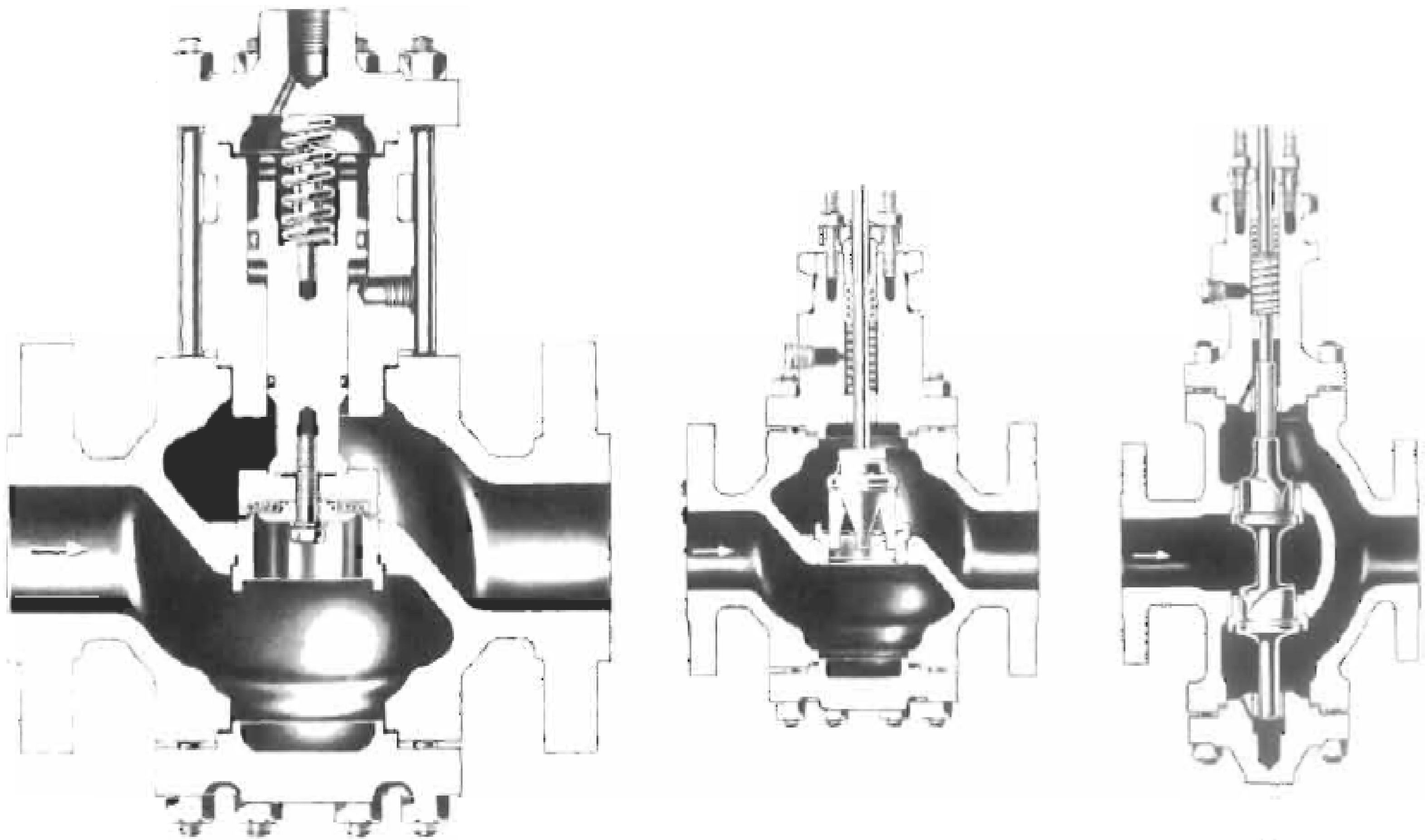
سرعت قطع جریان بالاتر

Utility کوچکتر از ۲ اینچ

سبکتر

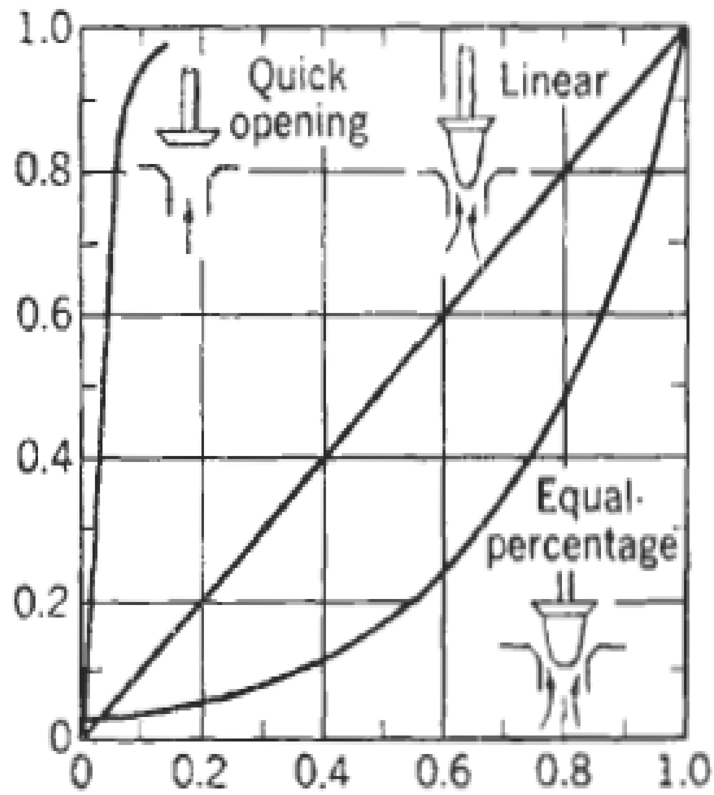
(a) Gate valve, for the majority of applications. (b) Globe valve, when tight shutoff is needed.

تهیه کننده:محمد بهزادی



(d) (e) (f)

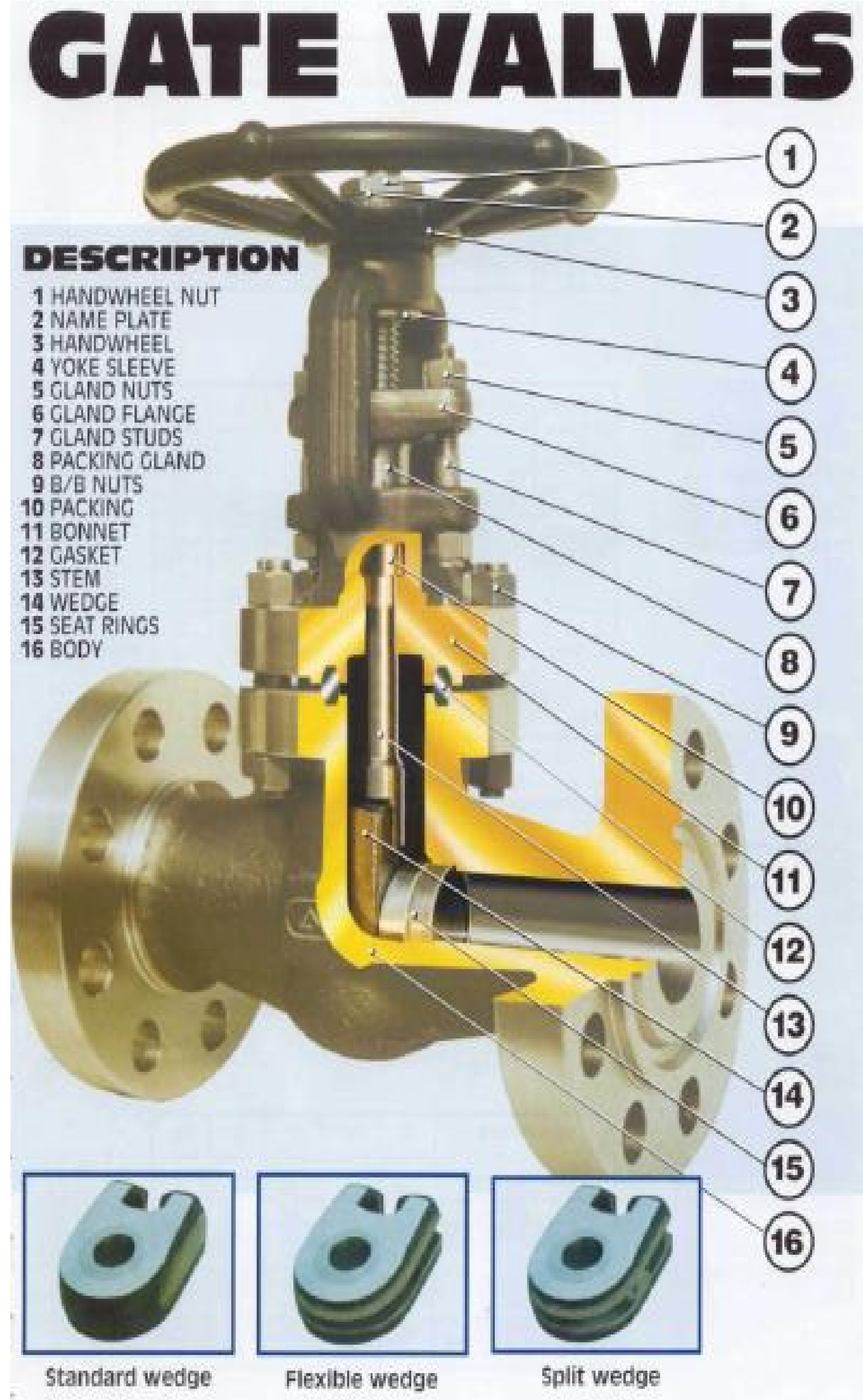
(d) A pressure relief valve, in which the plug is raised on overpressure. (e) A control valve with a single port. ***(f)*** A double-port, reverse-acting control valve.



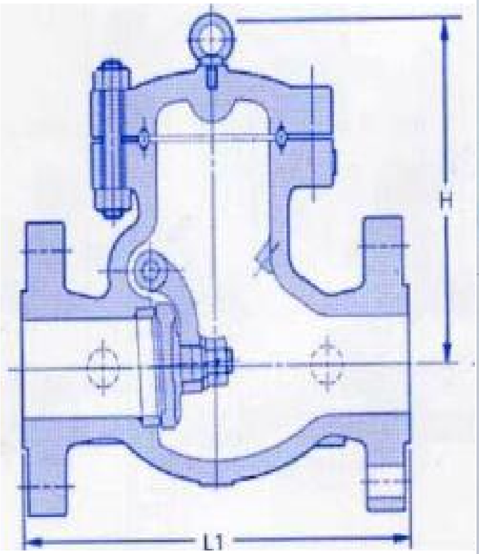
(h)

(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
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
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
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
Standard wedge
Flexible wedge
Split wedge

Check valve



تهیه کننده:محمد بهزادی

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.

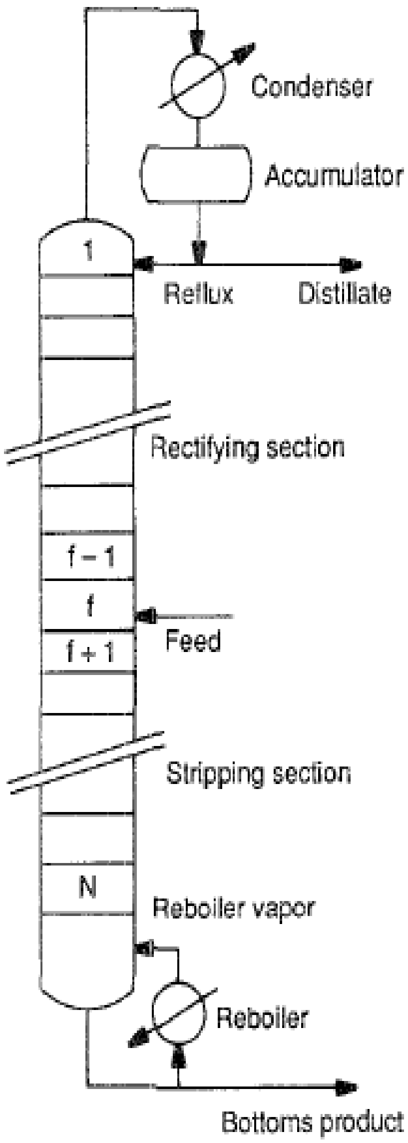


Figure 13.1. Distillation column assembly.

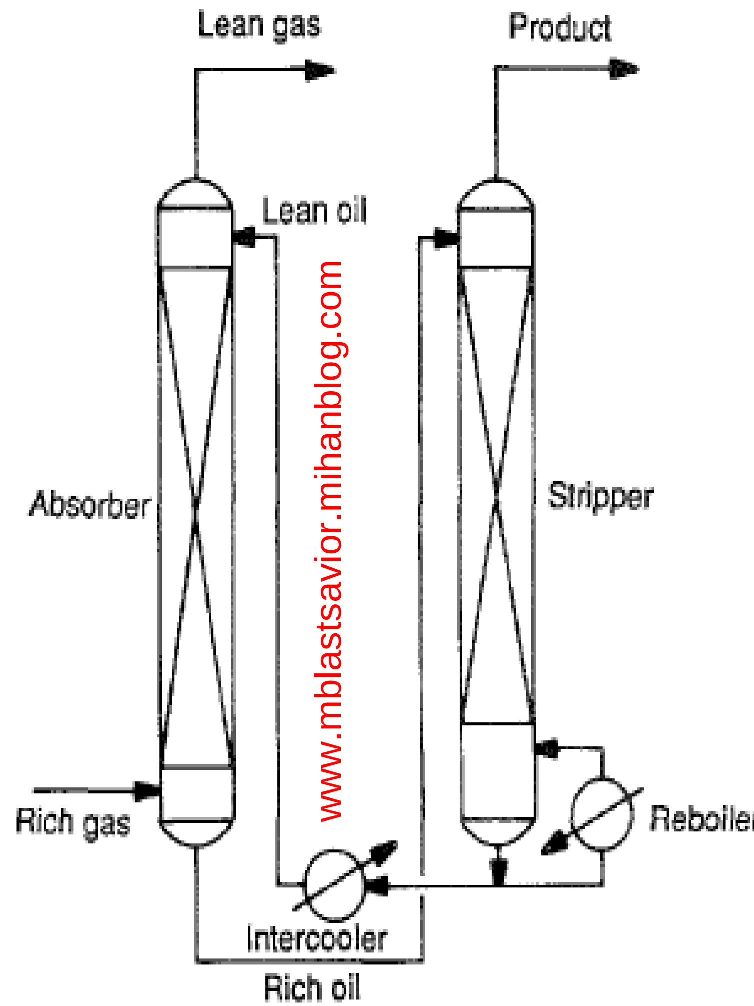


Figure 13.2. Absorber–stripper assembly.

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-

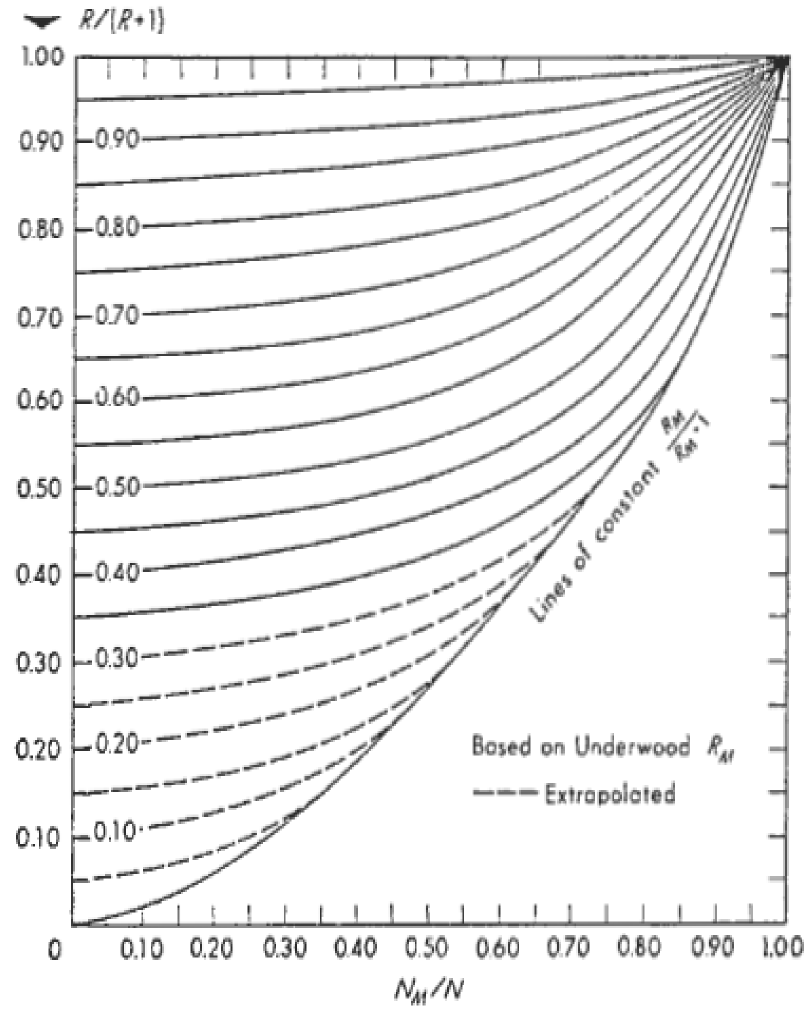
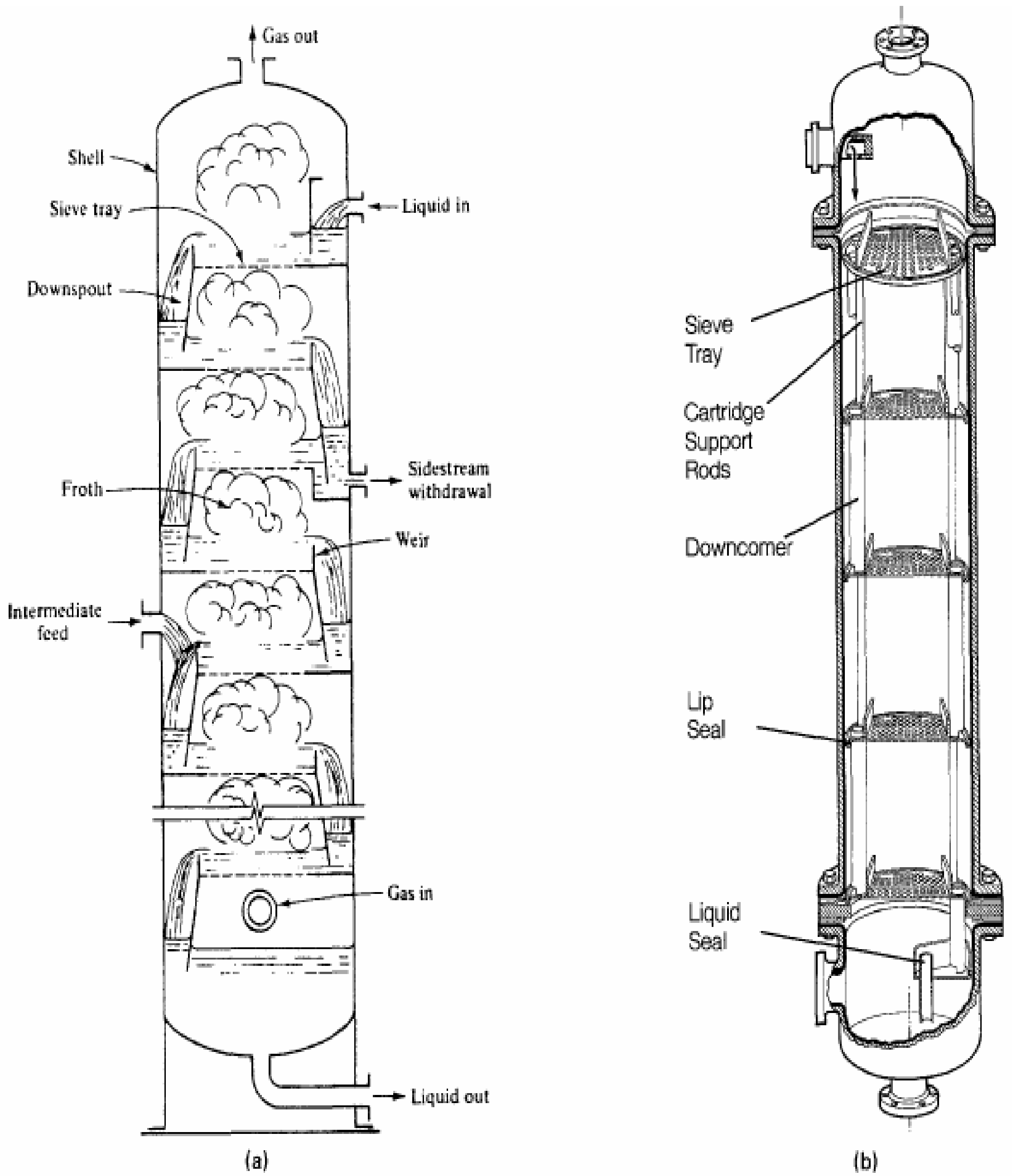


Figure 1. Plates-reflux correlation of Erbar and Madd



ه:محمد بهزادی

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.*).

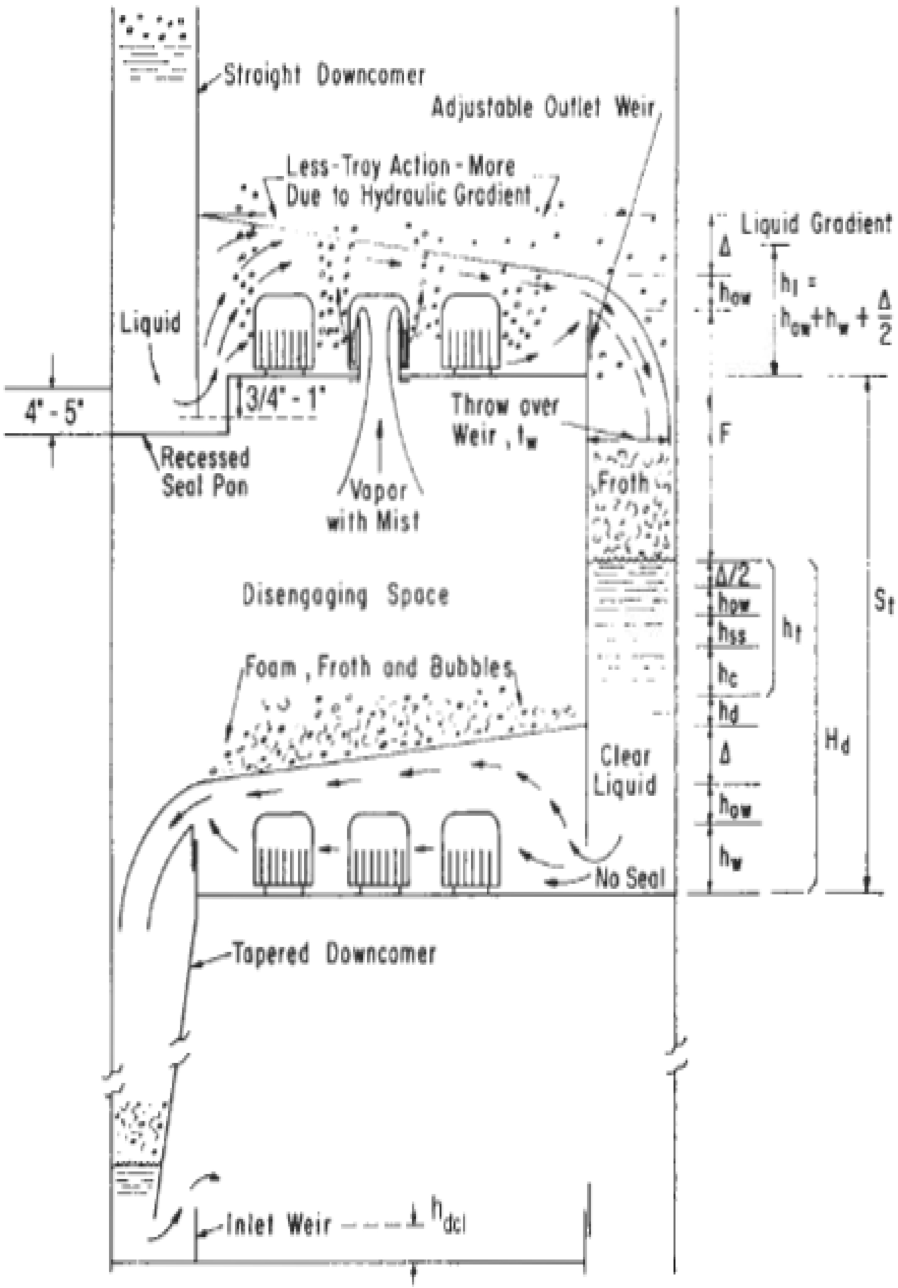
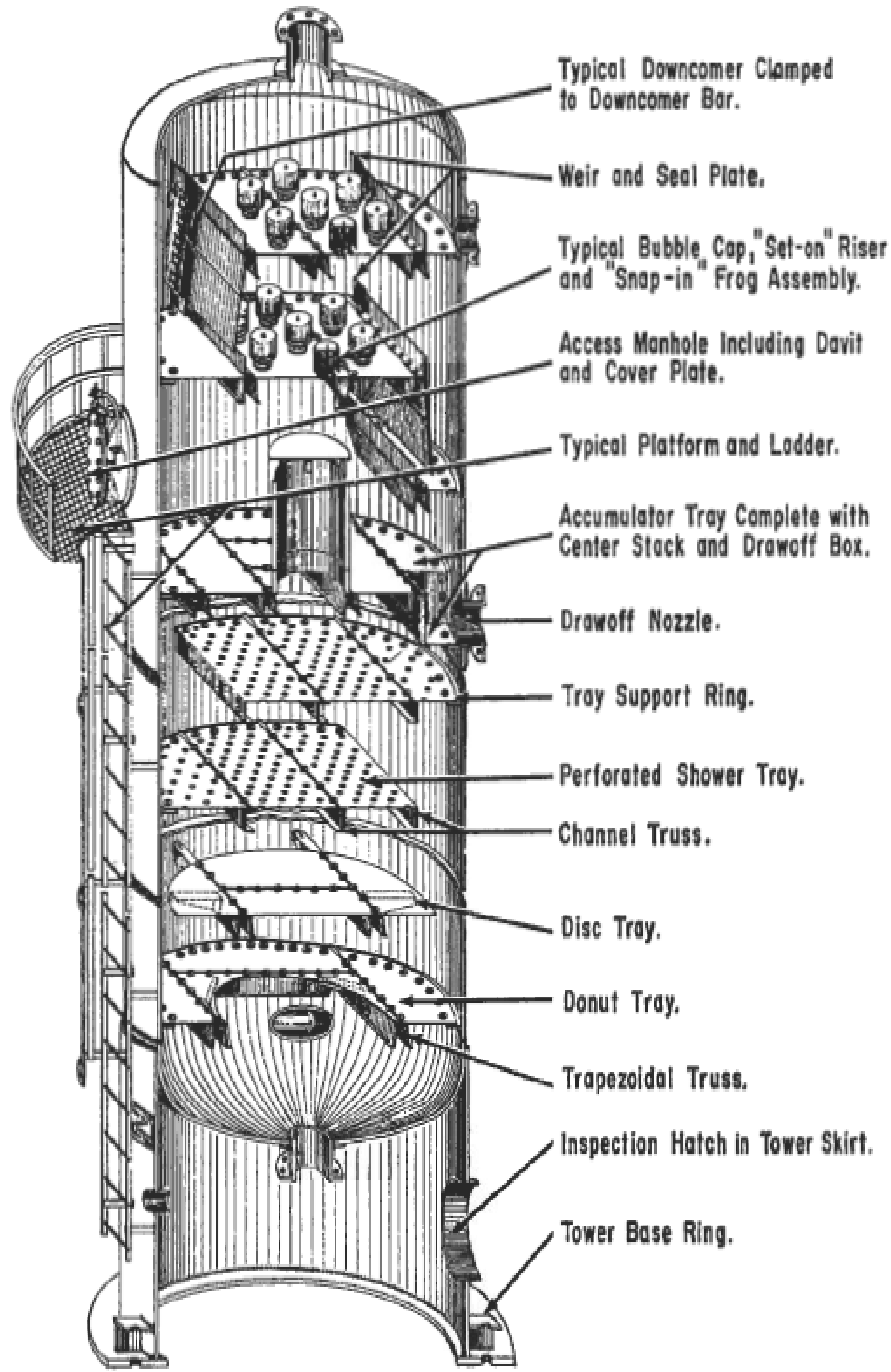
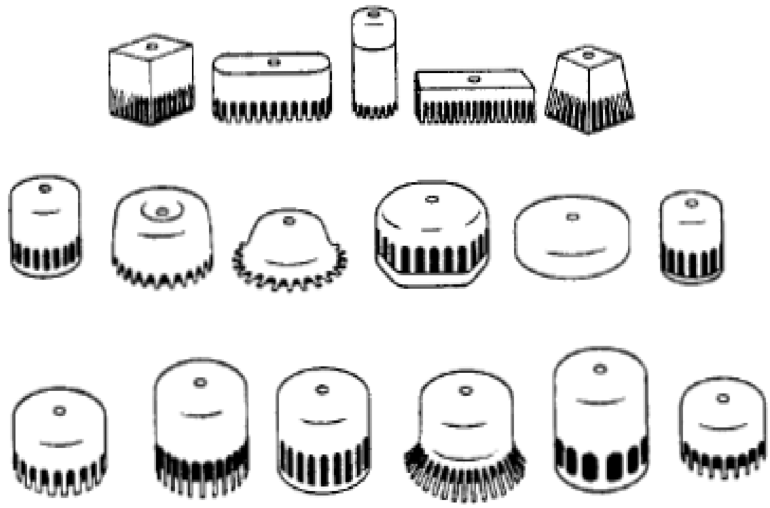
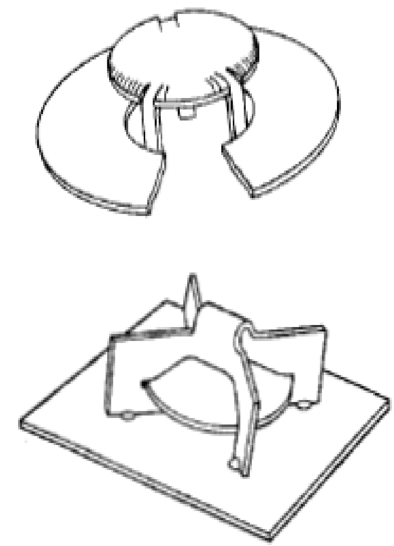


Figure 8-63. Bubble cap tray schematic—dynamic operation.

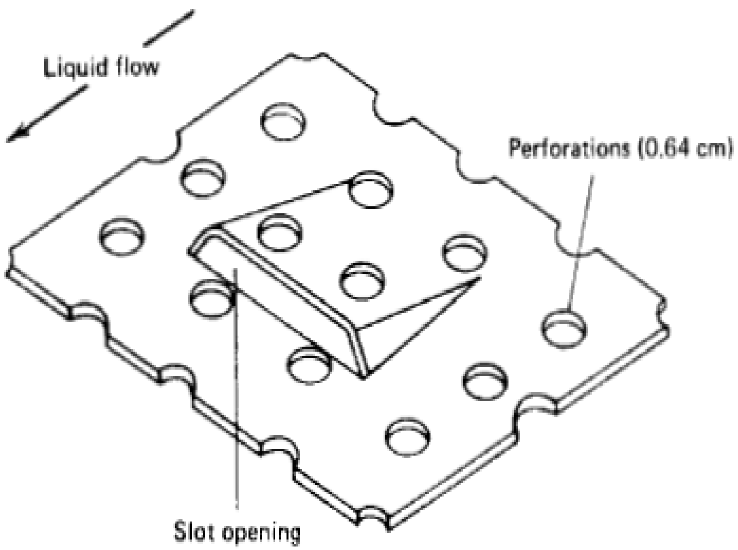




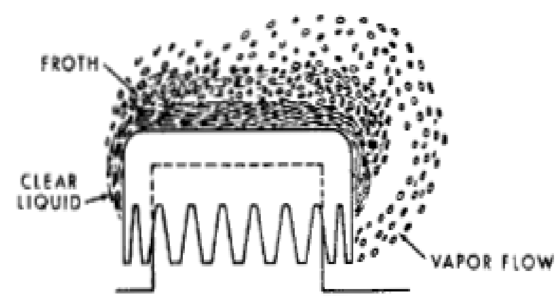
(a)



(b)



(c)

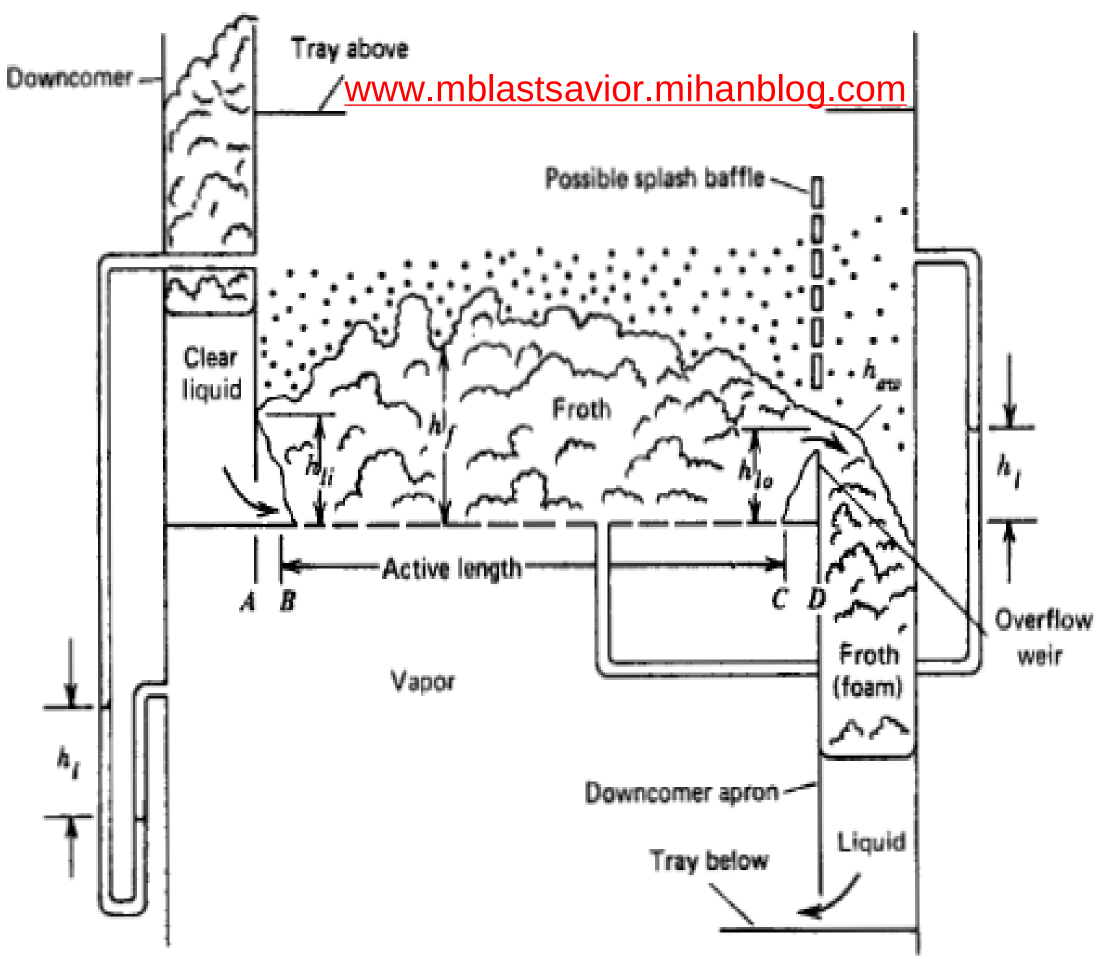


(d)

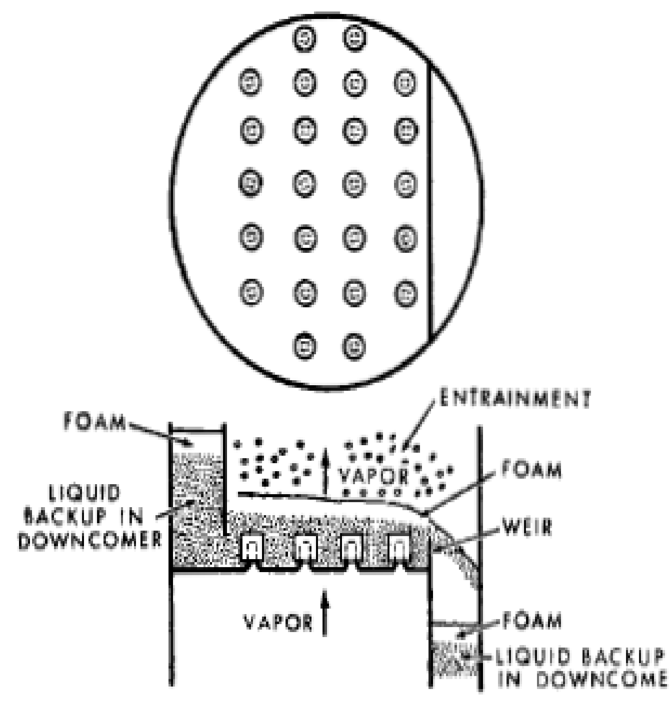
(a) Some kinds of bubblecaps
(c) Vapor directing slot on a Linde sieve tray

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


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



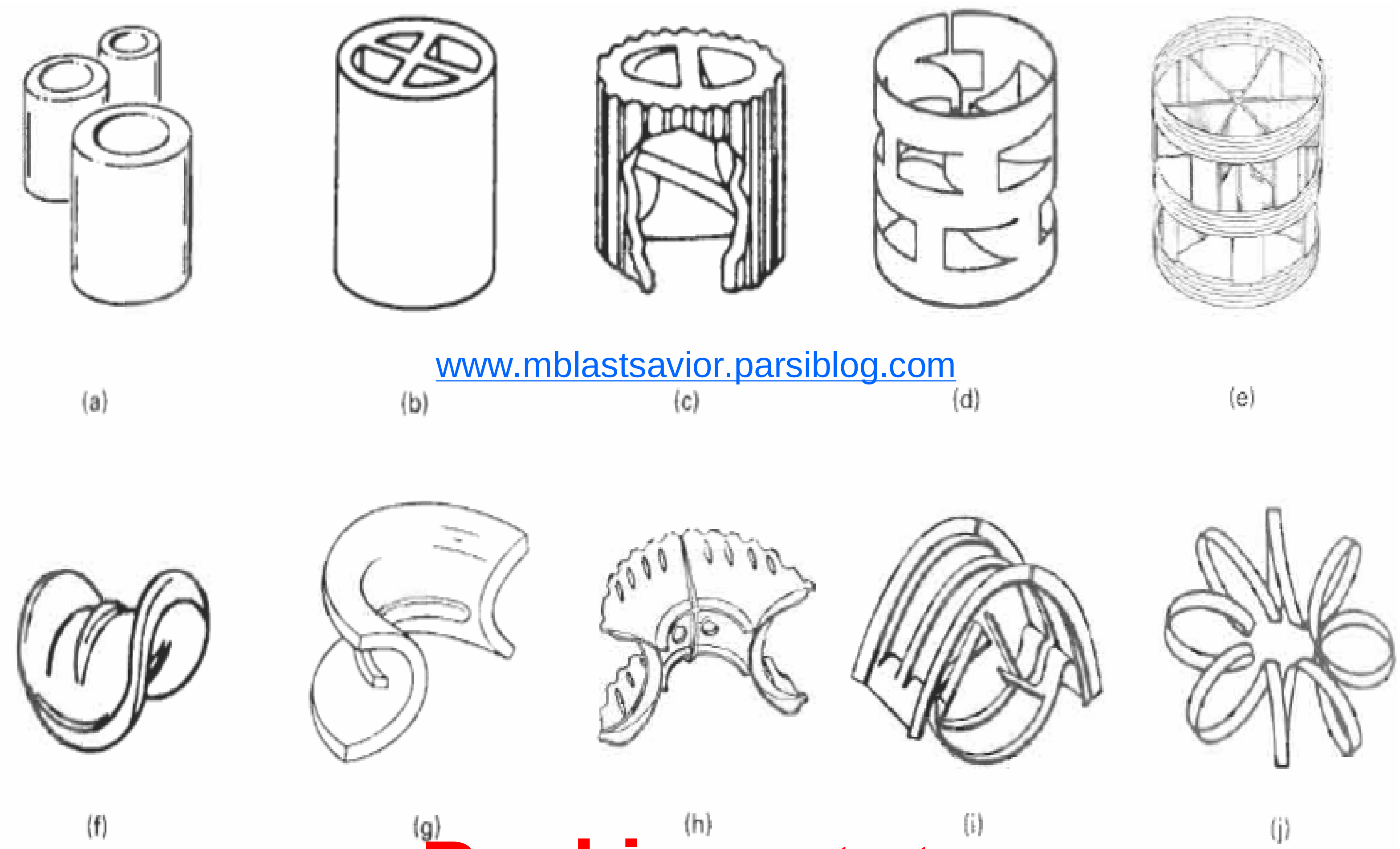
(e)



(f)

(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.

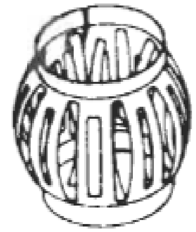
تهیه کننده:محمد بهزادی



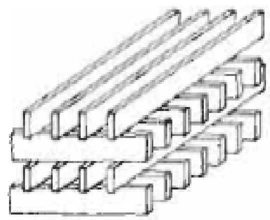
Packing انواع

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

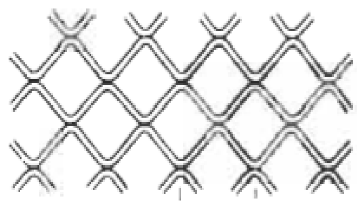
(k)



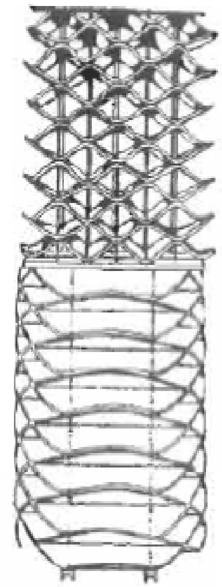
(l)



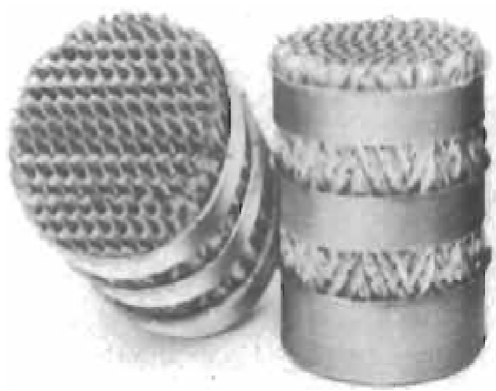
(m)



(n)



(o)



(p)

Packing انواع

(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

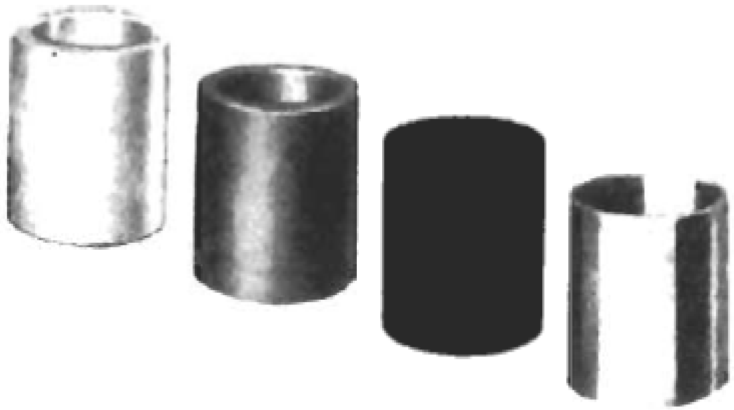


Figure 9-6B. Raschig rings (ceramic, carbon, metal).

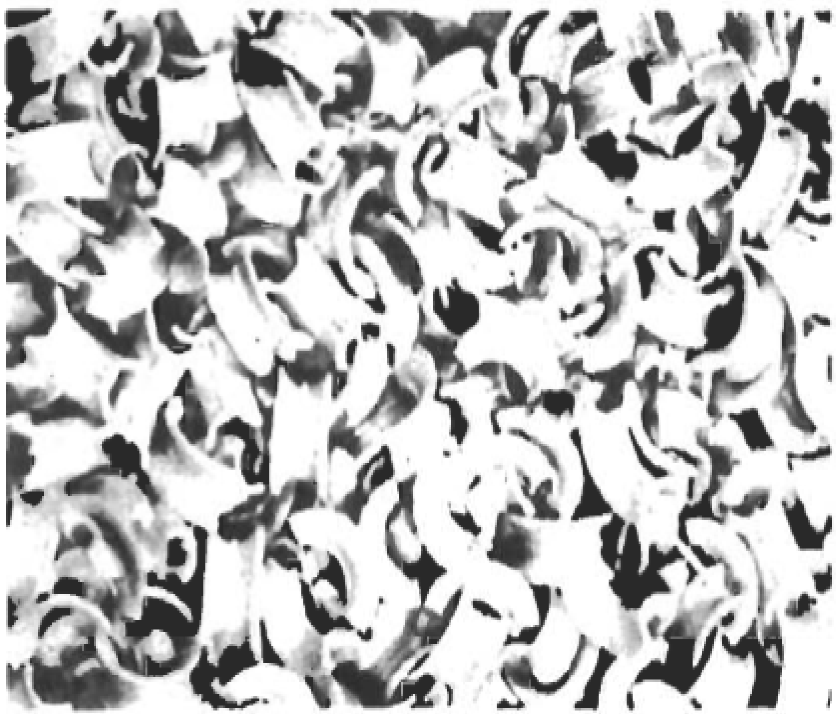


Figure 9-6C. Intalox® saddles (ceramic), dumped. Used by permission of Norton Chemical Process Products Corp.

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

Packing انواع

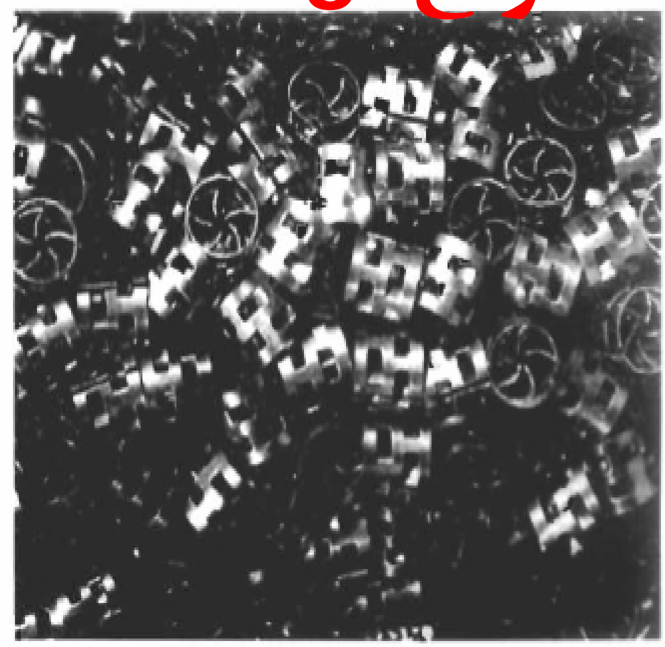


Figure 9-6E. Pall rings (metal), dumped.

Packing انواع

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

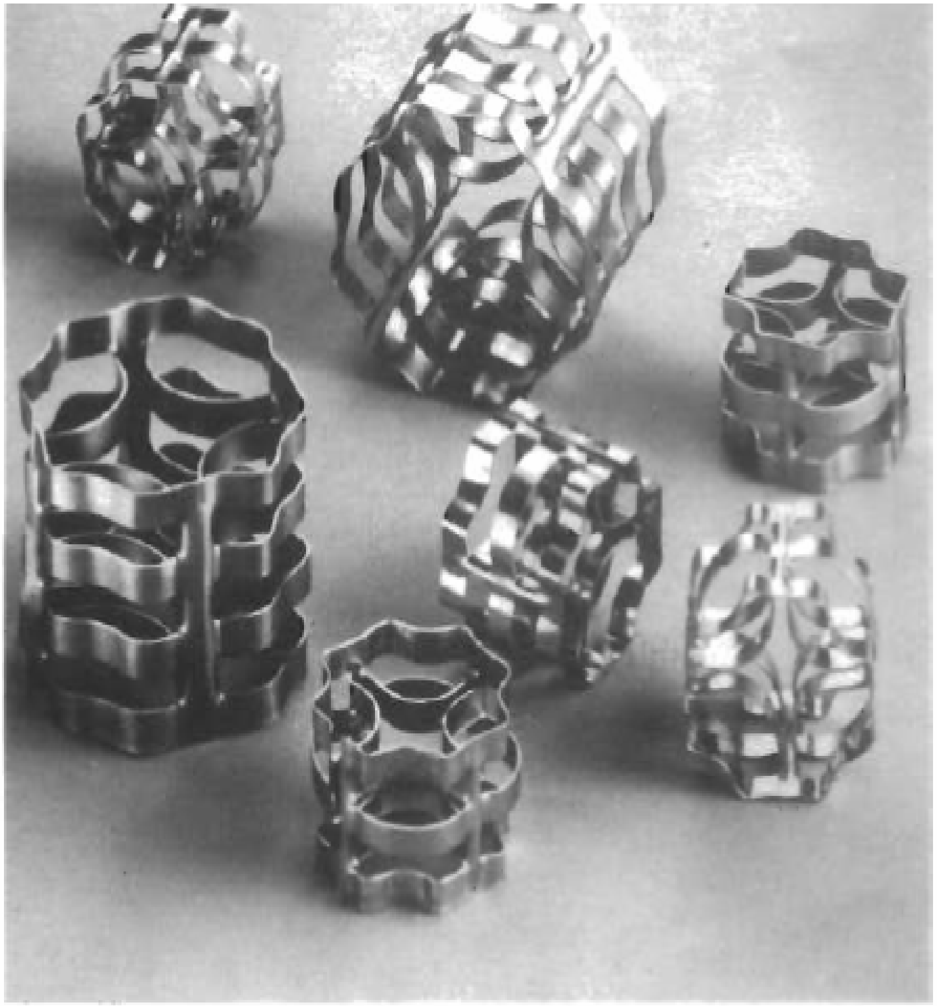


Figure 9-6M. Metal VSP® high capacity packing. Used by permission of Vereinigte Füllkörper-Fabriken GmbH & Co. Ransbach Baumbach, Germany.

تهیه کننده:محمد بهزادی

انواع Packing

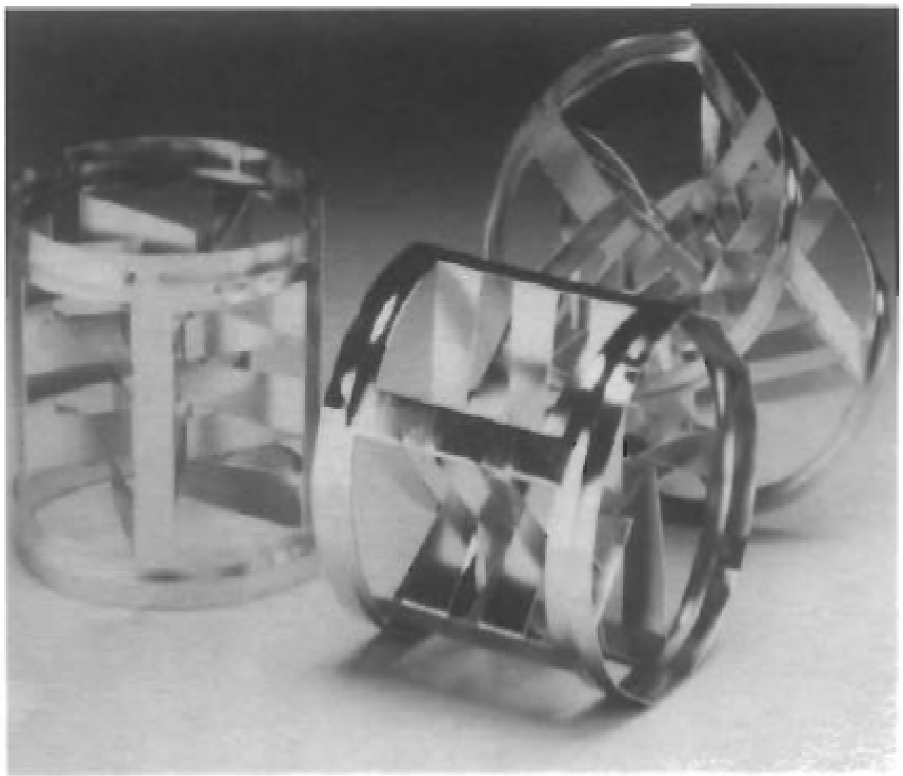


Figure 9-6N(a). Koch Metal HcKp™ random packing. Used by permission of Koch Engineering Co., Inc., Bull. KRP-2.

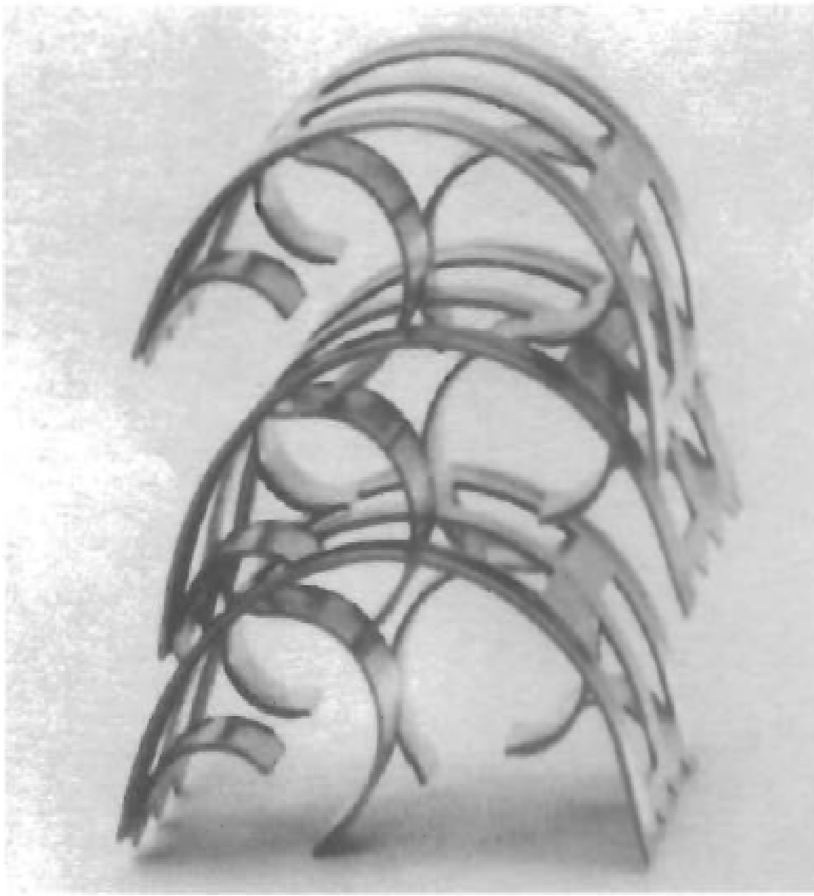


Figure 9-6P. Metal Chempak® packing. Used by permission of Chem-Pro Equipment Corp., licensed from Dr. Max Leva.

انواع پخش کننده مایع

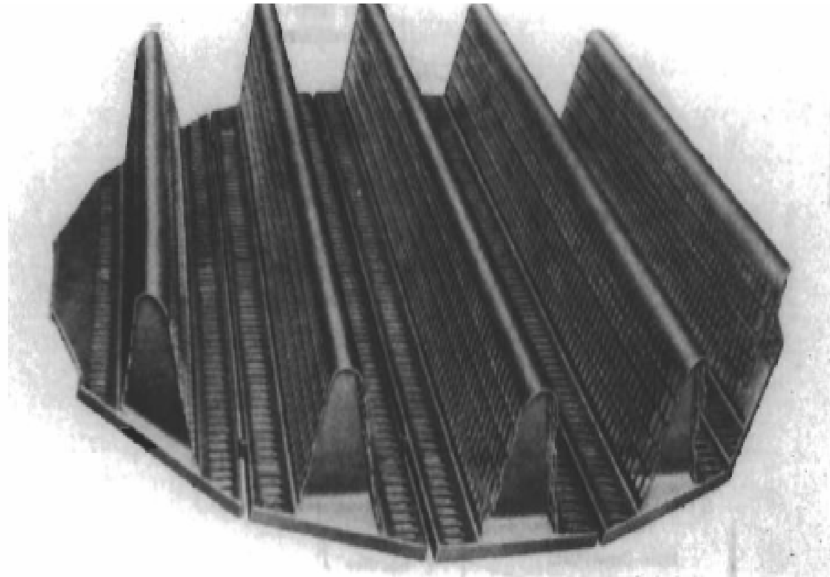


Figure 2. Multibeam packing support plate. (Courtesy of Norton Chemical Process Products Corporation.)

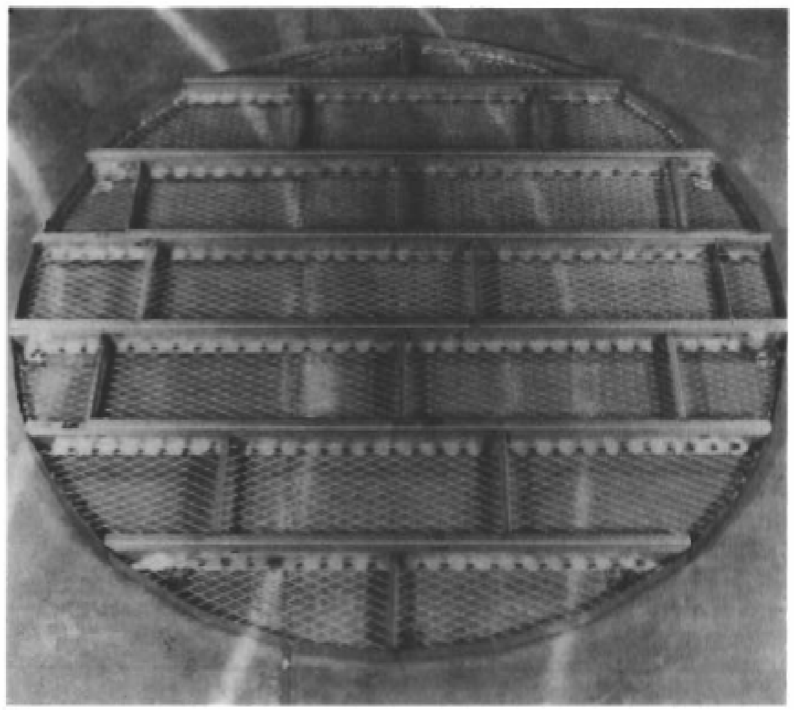


Figure 3. Bed limiter, Model 823. (Courtesy of Norton Chemical Process Products Corporation.)

انواع پخش کننده مایع

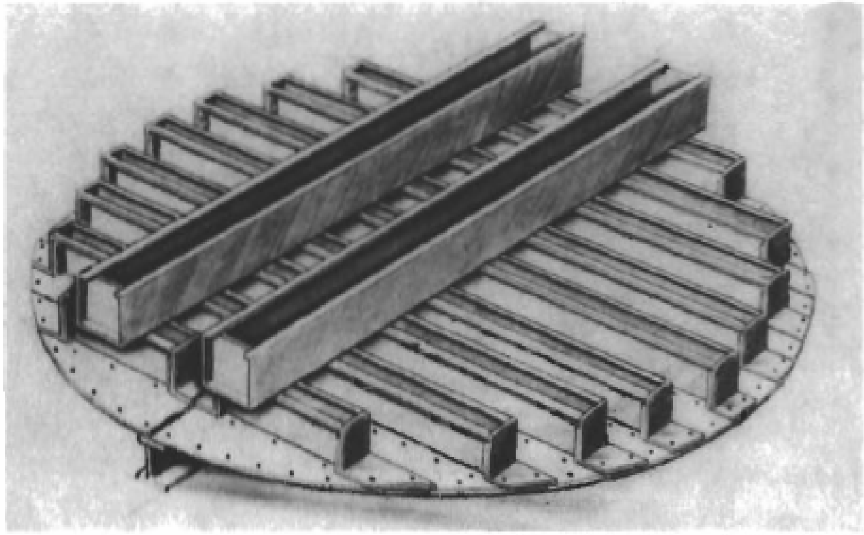


Figure 4. Orifice deck liquid distributor. (Courtesy of Norton Chemical Process Products Corporation.)

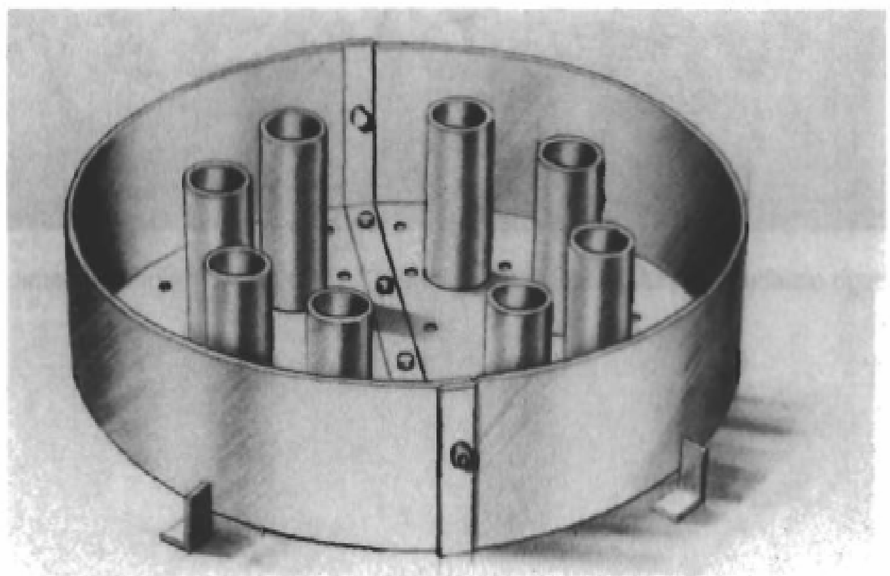


Figure 5. Orifice pan liquid distributor. (Courtesy of Norton Chemical Process Products Corporation.)

ه:محمد بهزادی

انواع پخش کننده مایع

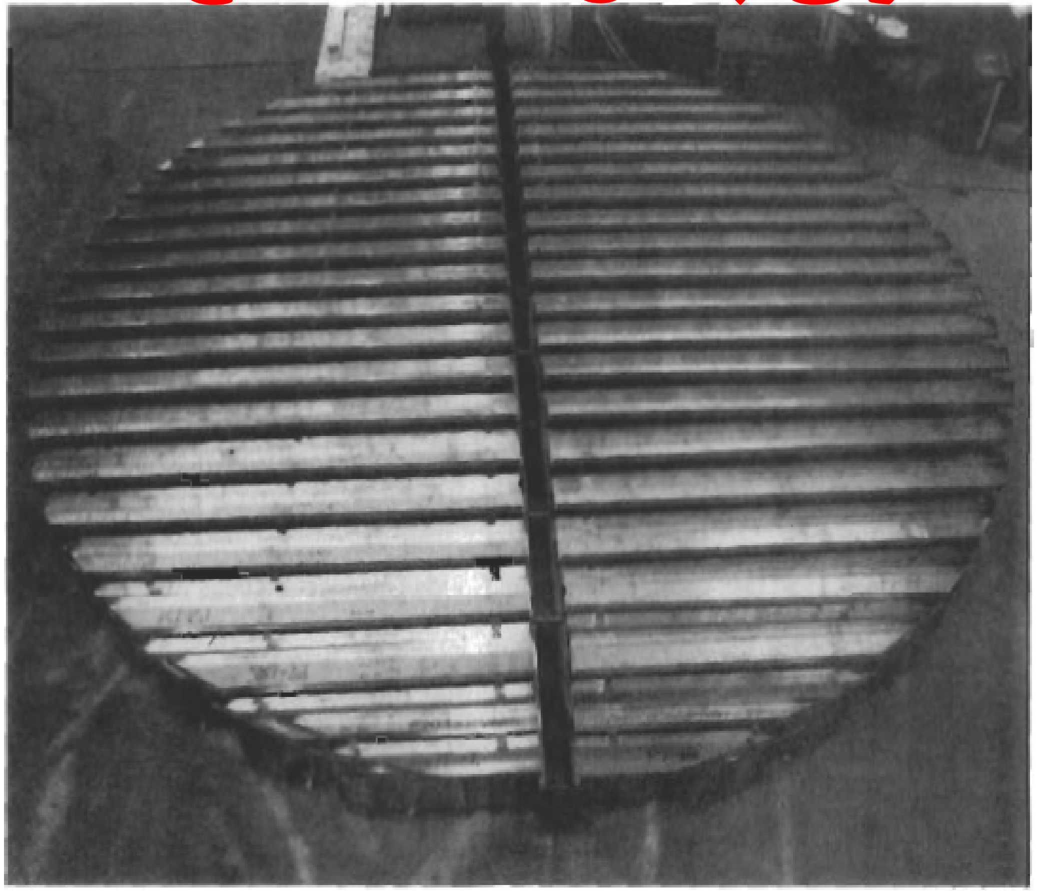


Figure 6. Orifice trough distributor with side-wall orifice, Model 137. (Courtesy of Norton Chemical Process Products Corporation.)

انواع پخش کننده مایع

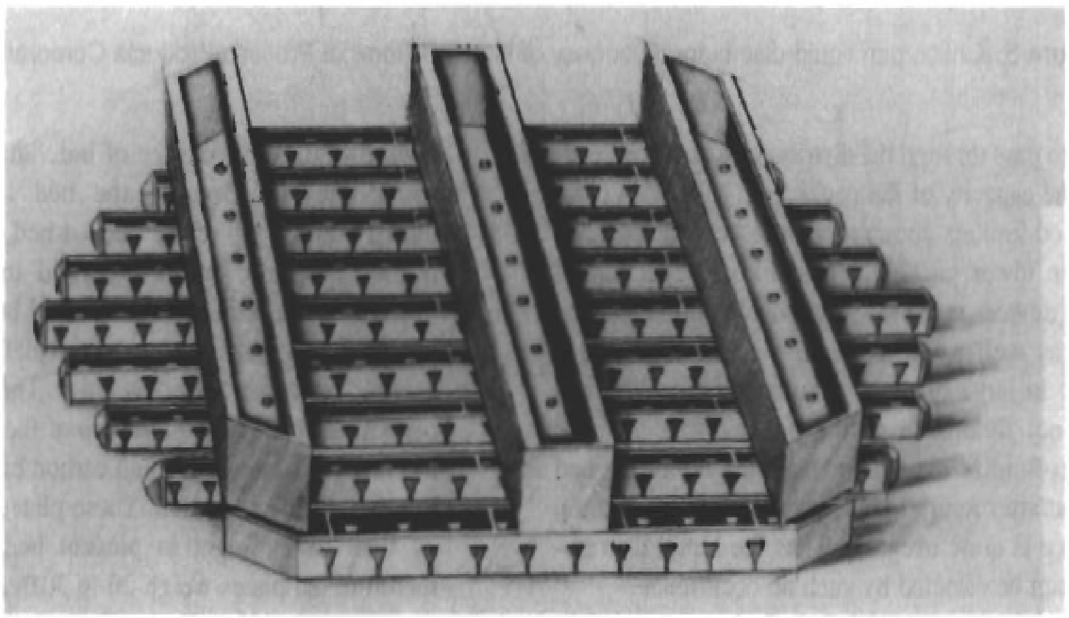


Figure 7. Weir trough liquid distributor. (Courtesy of Norton Chemical Process Products Corporation.)

انواع پخش کننده مایع

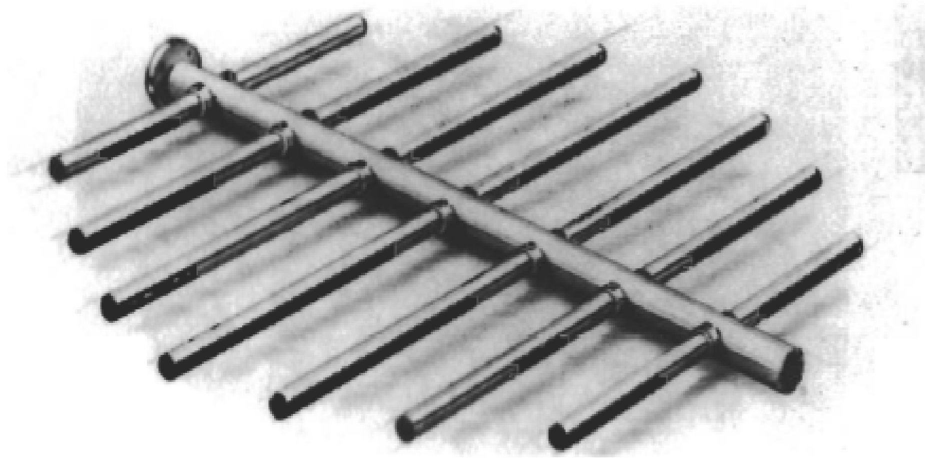


Figure 8. Orifice ladder liquid distributor. (Courtesy of Norton Chemical Process Products Corporation.)

www.mblastsavior.mihanblog.com

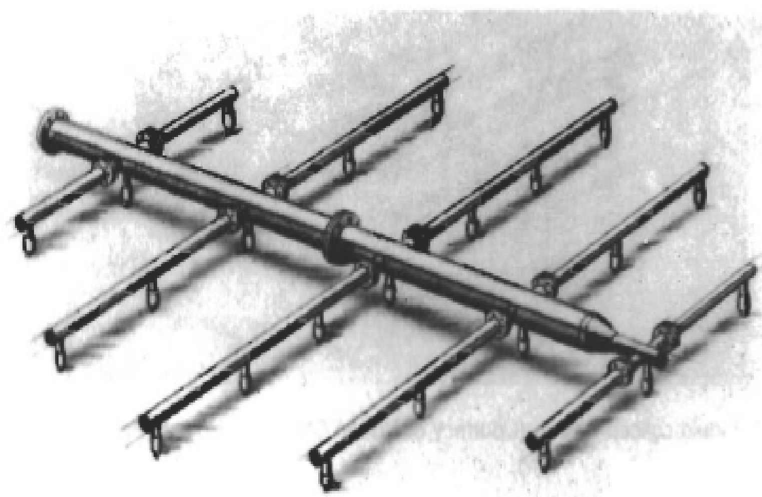


Figure 9. Spray nozzle liquid distributor. (Courtesy of Norton Chemical Process Products Corporation.)

کننده:محمد بهزادی

انواع پخش کننده مایع

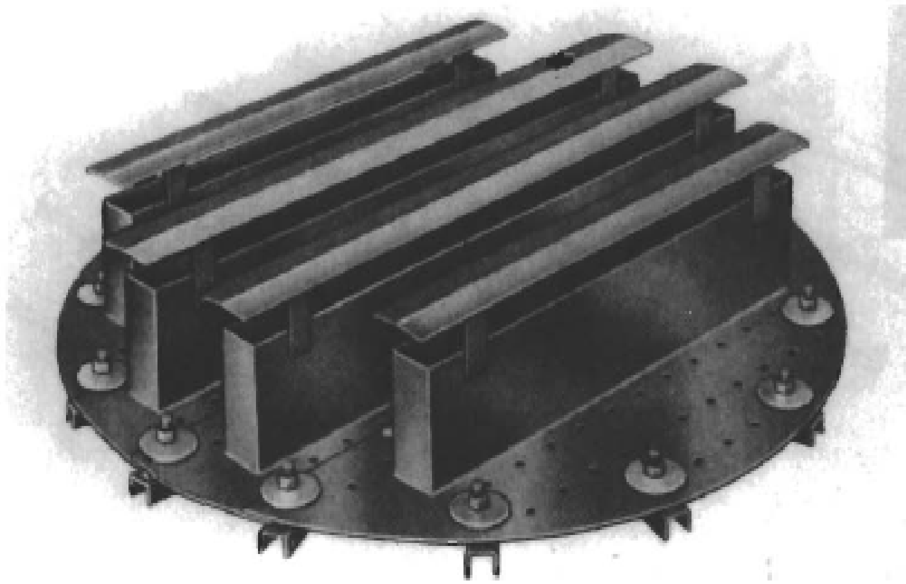


Figure 10. Orifice deck-liquid redistributor. (Courtesy of Norton Chemical Process Products Corporation.)

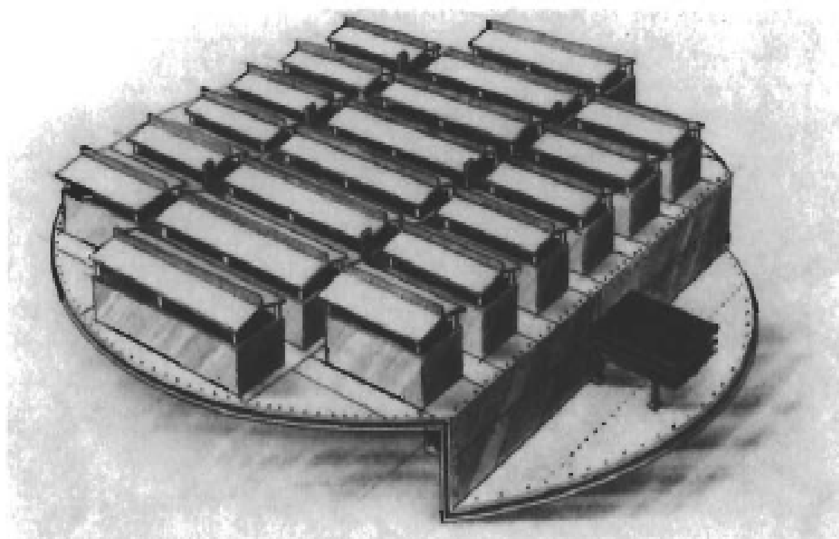


Figure 11. Liquid collector plate. (Courtesy of Norton Chemical Process Products Corporation.)

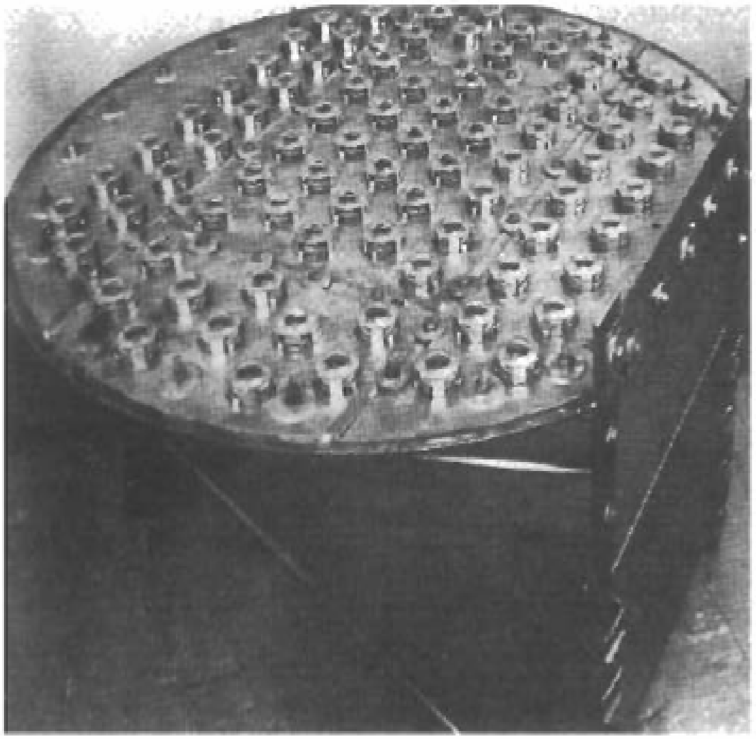
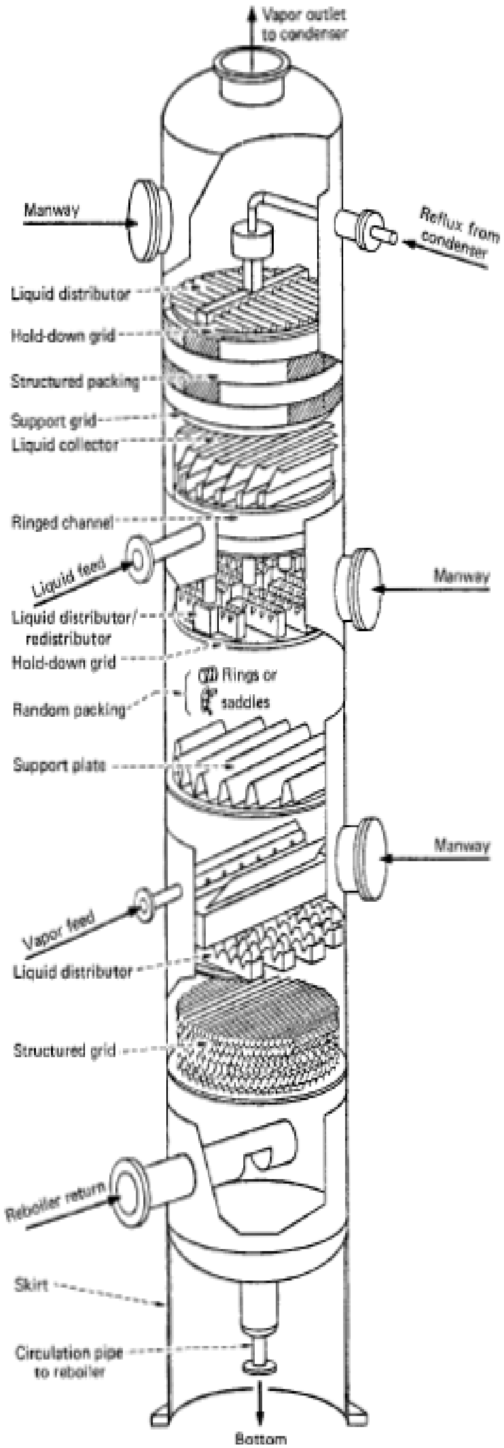


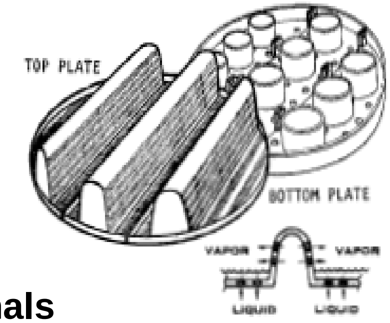
Figure 8-76. Type A-1 Ballast® Tray. Used by permission, Glitsch, Inc.

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

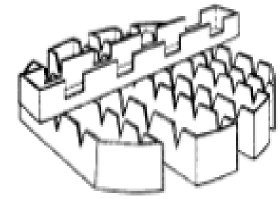


(a) Example packed column with a variety of internals
(b) Packing support and redistributor assembly.
(c) Trough-type liquid distributor.
(d) Perforated pipe distributor.
(e)Rosette redistributor for small towers.
(f) Hold-down plate, particularly for low density packing.

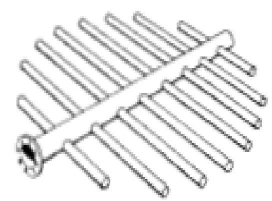
اجزای تشکیل دهنده یک برج



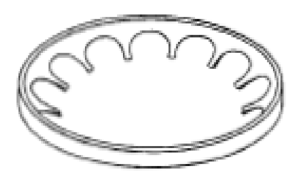
(b)



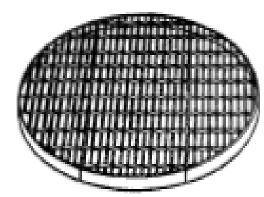
(c)



(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

از منابع دوستان با تشکر فراوان از زحمات این عزیزان در جزوات استفاده شده است:

اموزش Hysys نوشته رضا درستی-غلامرضا باغمیشه

اموزش Aspen Plus نوشته رضا درستی-غلامرضا باغمیشه

اموزش Aspen Plus نوشته محمد پوربافرانی

Rules of thumb for chemical engineers **Carl Branan**

Applied process design **ernest ludwig**

Chemical process equipment **Stanley walas**

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