CH2357 Process Equipment Design I

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Mechanical Design of Process Equipments

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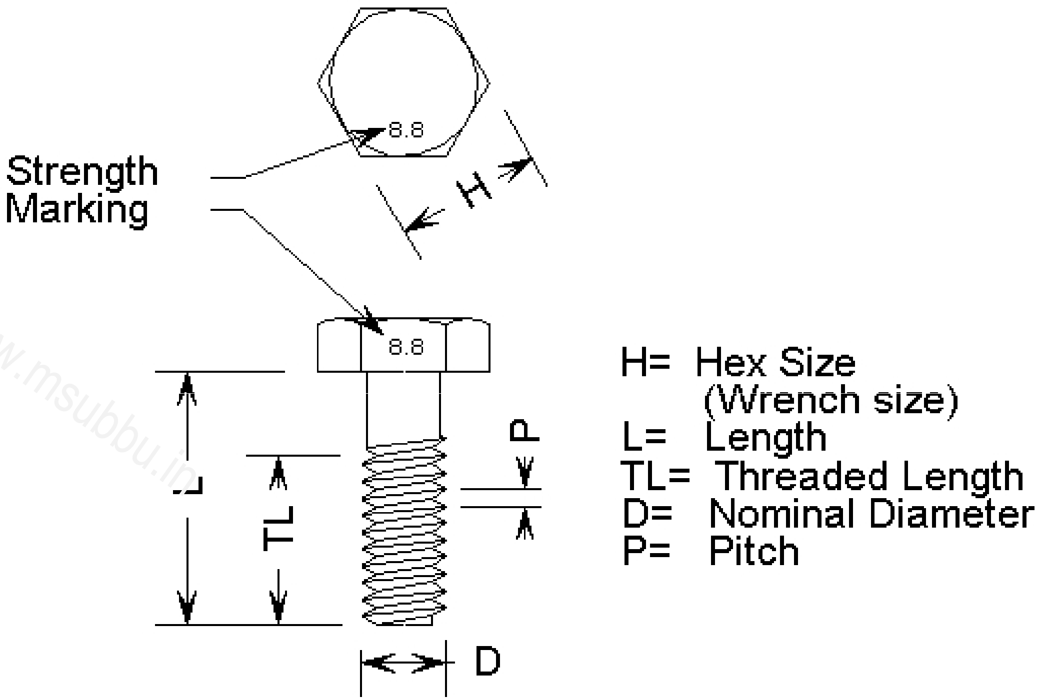
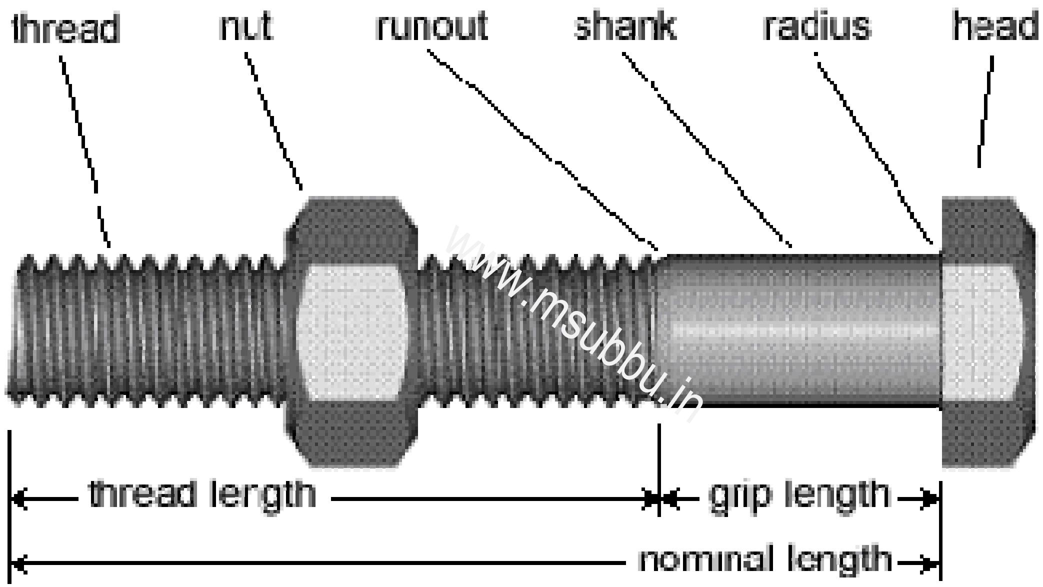
Syllabus Contents

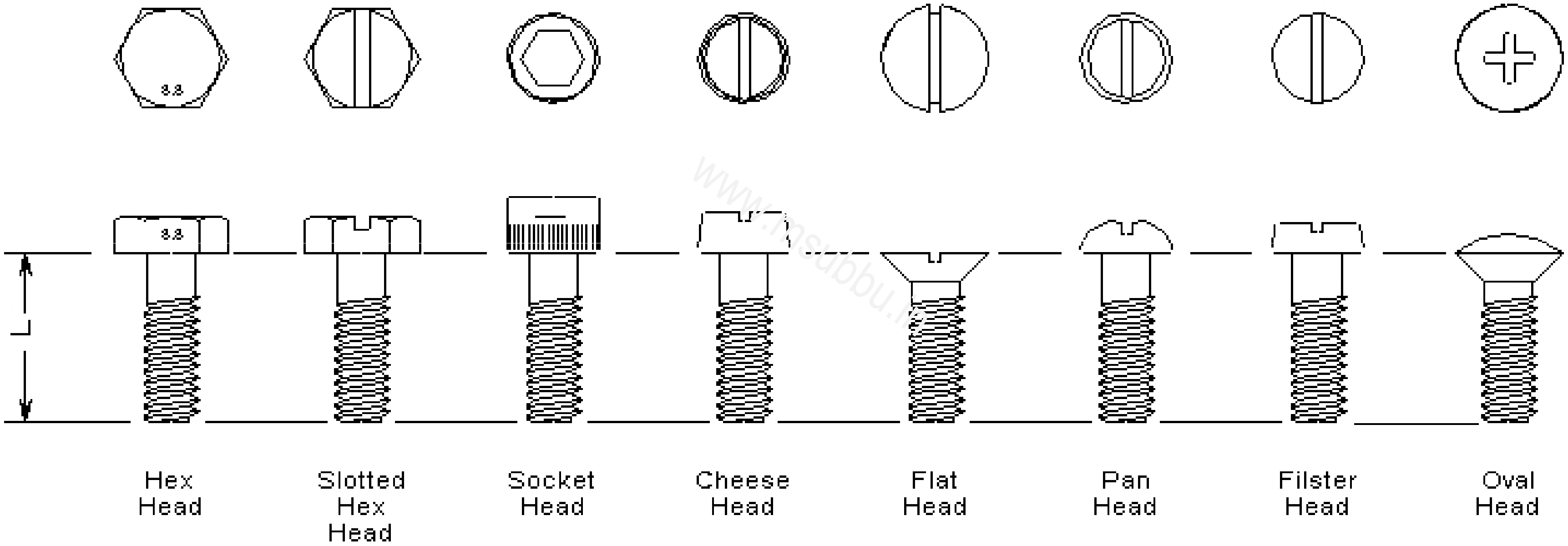
1. Design and drawing considerations of bolt, nut and screws, welded and riveted joints, **flanged joints**, **nozzles and reinforcements**. Pipe fittings.
2. Design and drawing considerations of **vessel supports** such as bracket, saddle, skirt, etc. Storage **Tanks** for solids, liquids and gases.
3. General **design** and drawing consideration **of vessels subjected to internal pressure, and external pressure**. High pressure vessels.
4. Fundamental principles, equations, general design and drawing considerations of cyclone separators centrifuges, thickeners and filtration equipments.
5. General design and drawing considerations of crystallizers, **agitated vessel**, **jacketed and coil heated vessels**.

Bolts & Nuts

- Specification: Mx (in units of millimeters)
- Preferred sizes: M2 2.5 3 4 5 6 8 10 12 16 20 24 30 36 42

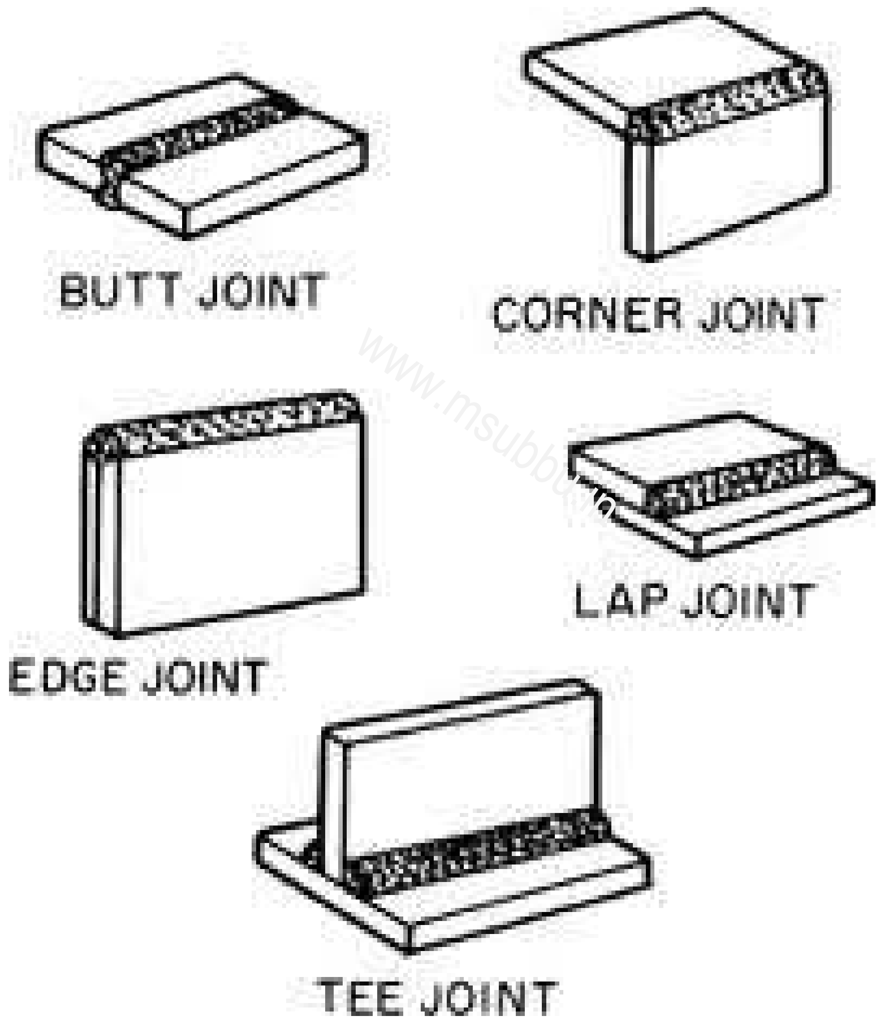


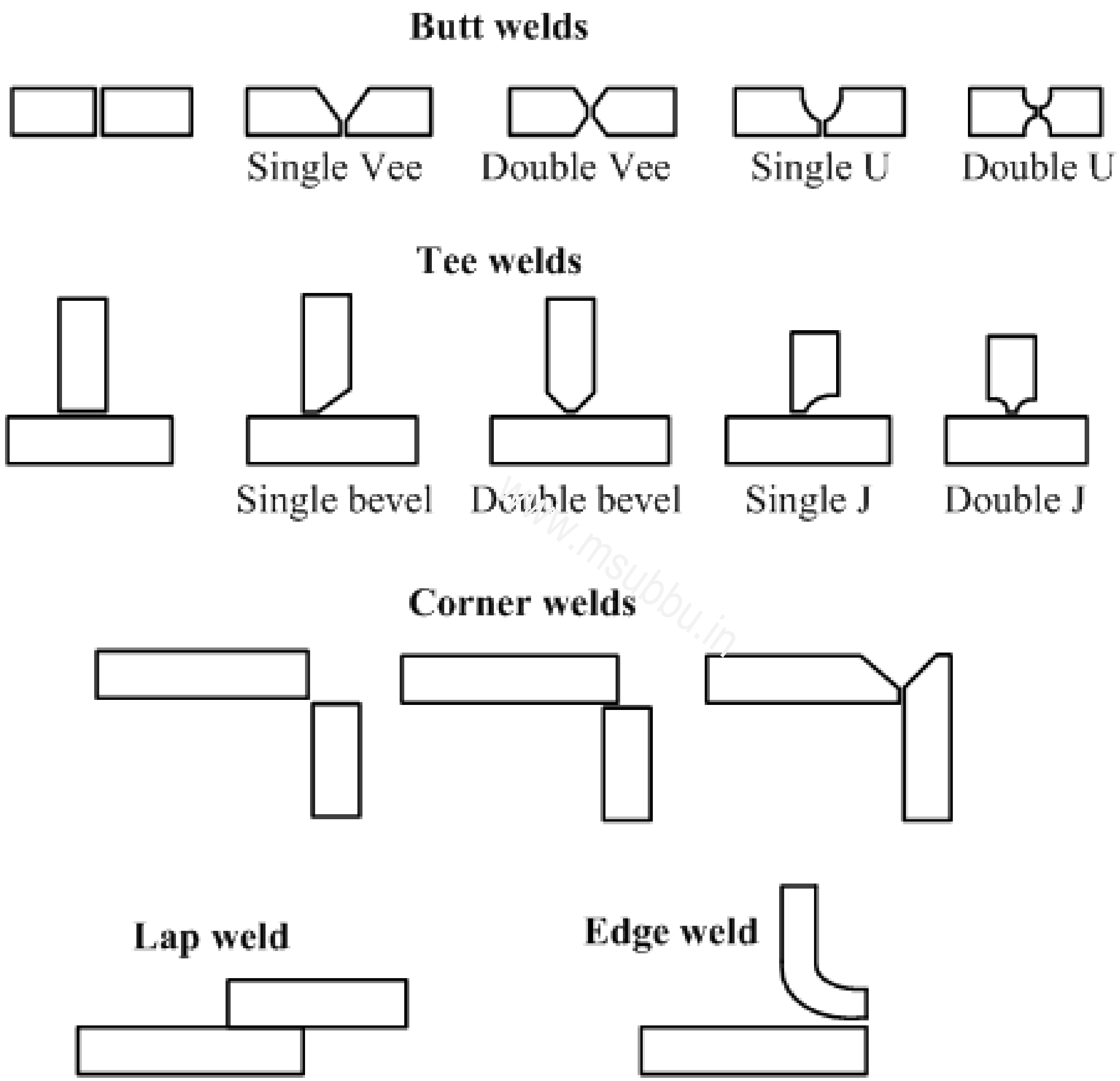

thread
nut
runout
shank
radius
head
thread length
grip length
nominal length

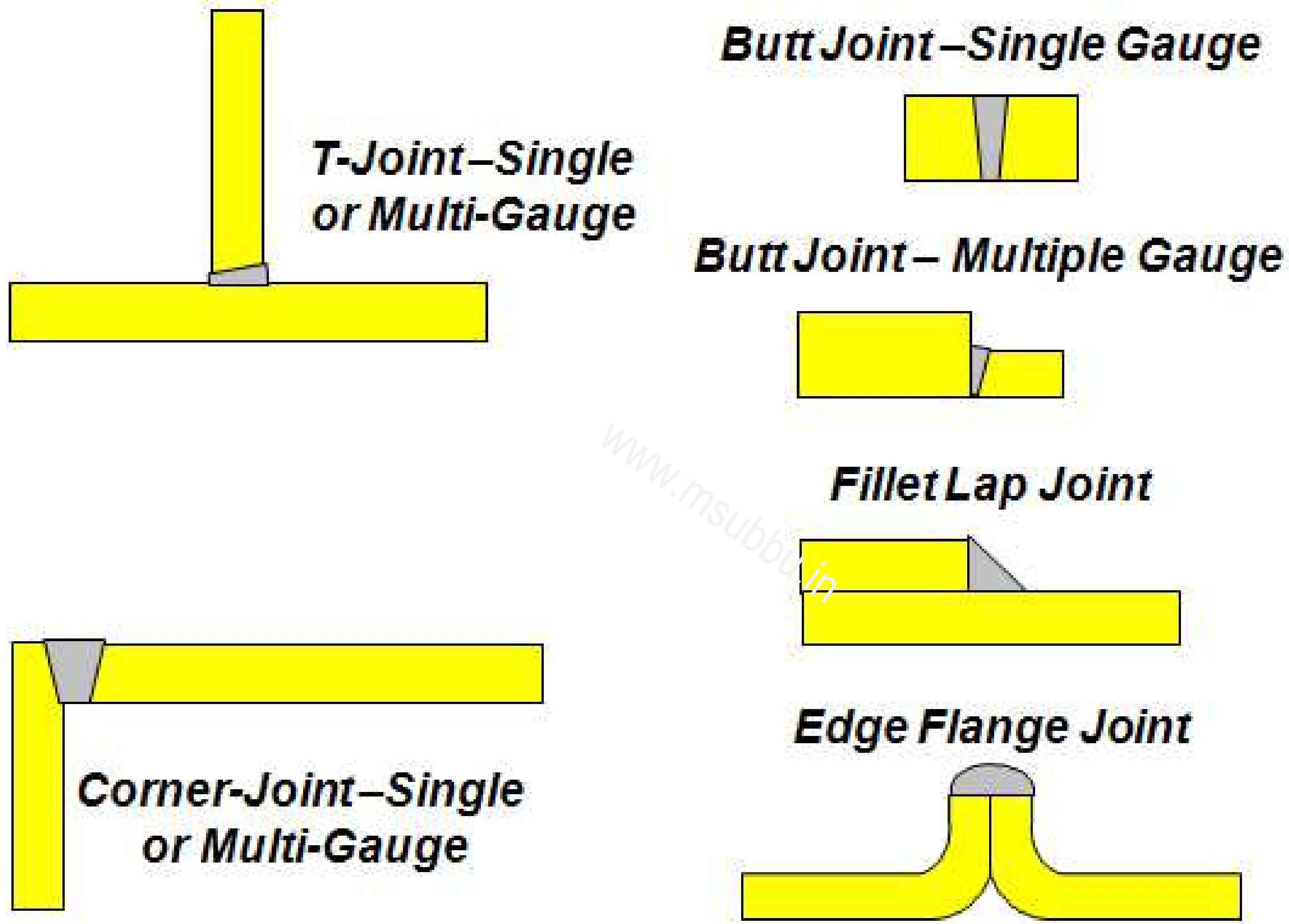


8.8
8.8
L
Hex
Head
Slotted
Hex
Head
Socket
Head
Cheese
Head
Flat
Head
Pan
Head
Filster
Head
Oval
Head

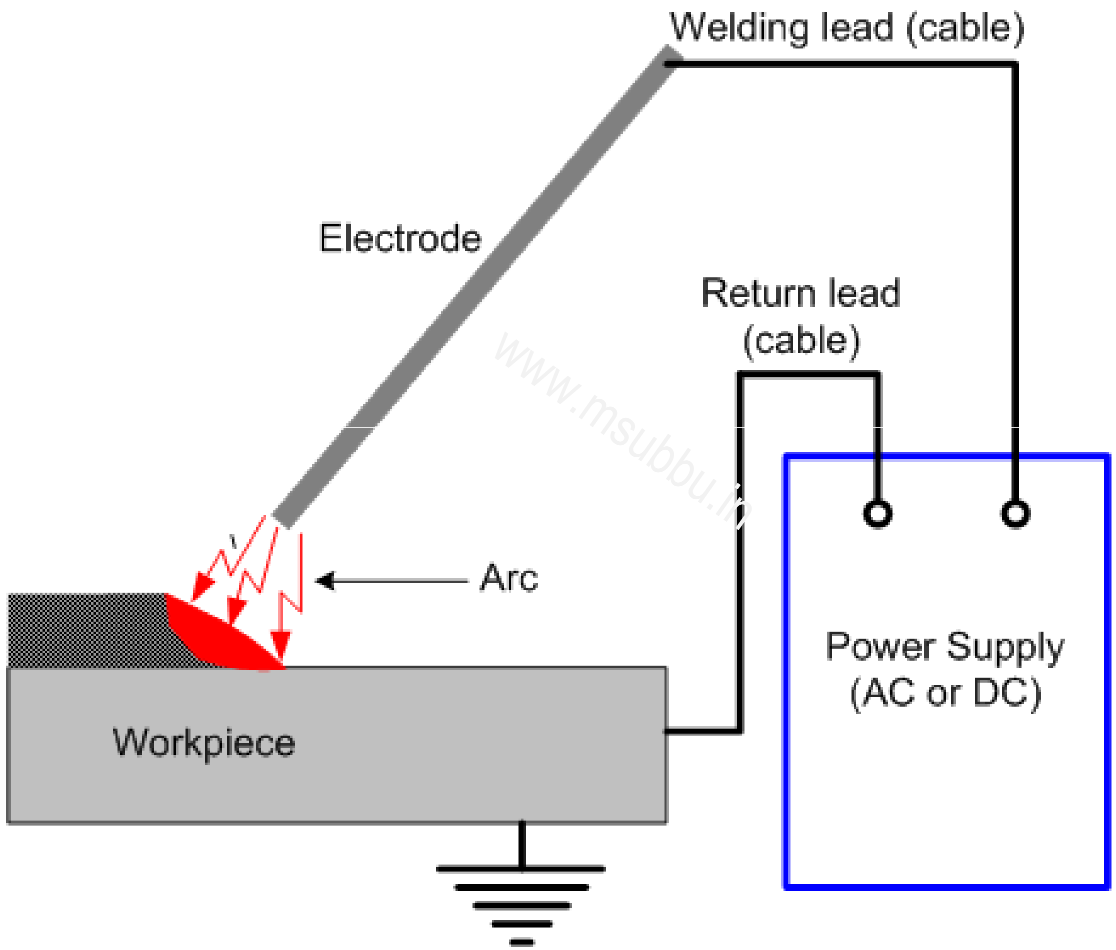
Welded Joints




Butt welds
Single Vee
Double Vee
Single U
Double U
Tee welds
Single bevel
Double bevel
Single J
Double J
Corner welds
Lap weld
Edge weld

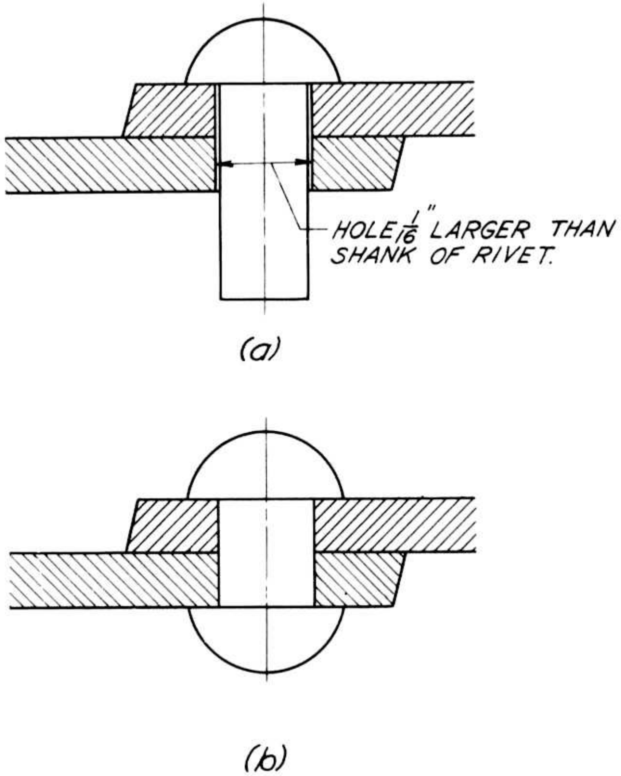

T-Joint–Single
or Multi-Gauge
Butt Joint–Single Gauge
Butt Joint– Multiple Gauge
Fillet Lap Joint
Edge Flange Joint
Corner-Joint–Single
or Multi-Gauge

Arc Welding

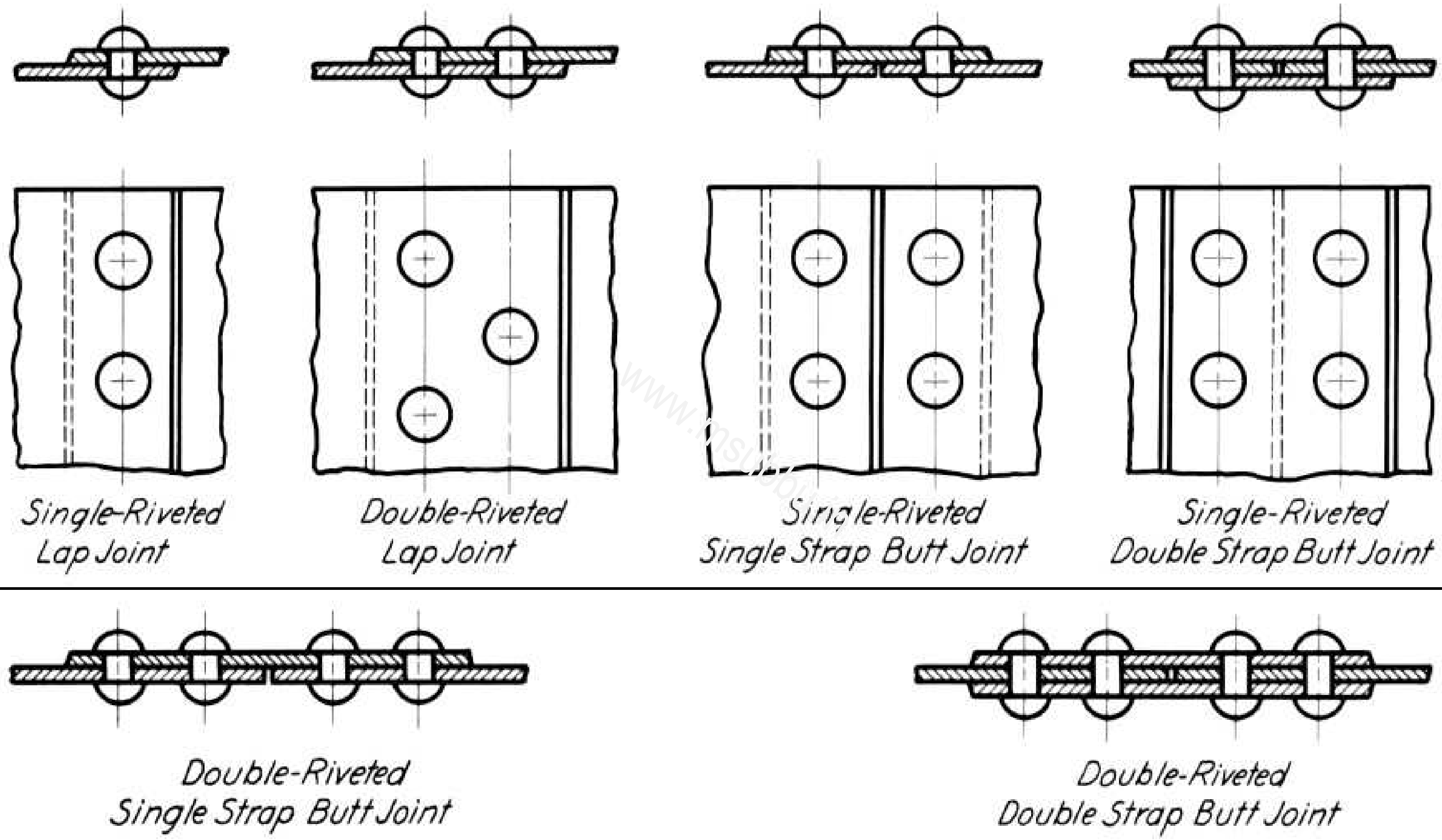


Welding lead (cable)
Electrode
Return lead
(cable)
Arc
Power Supply
(AC or DC)
Workpiece

Riveted Joints

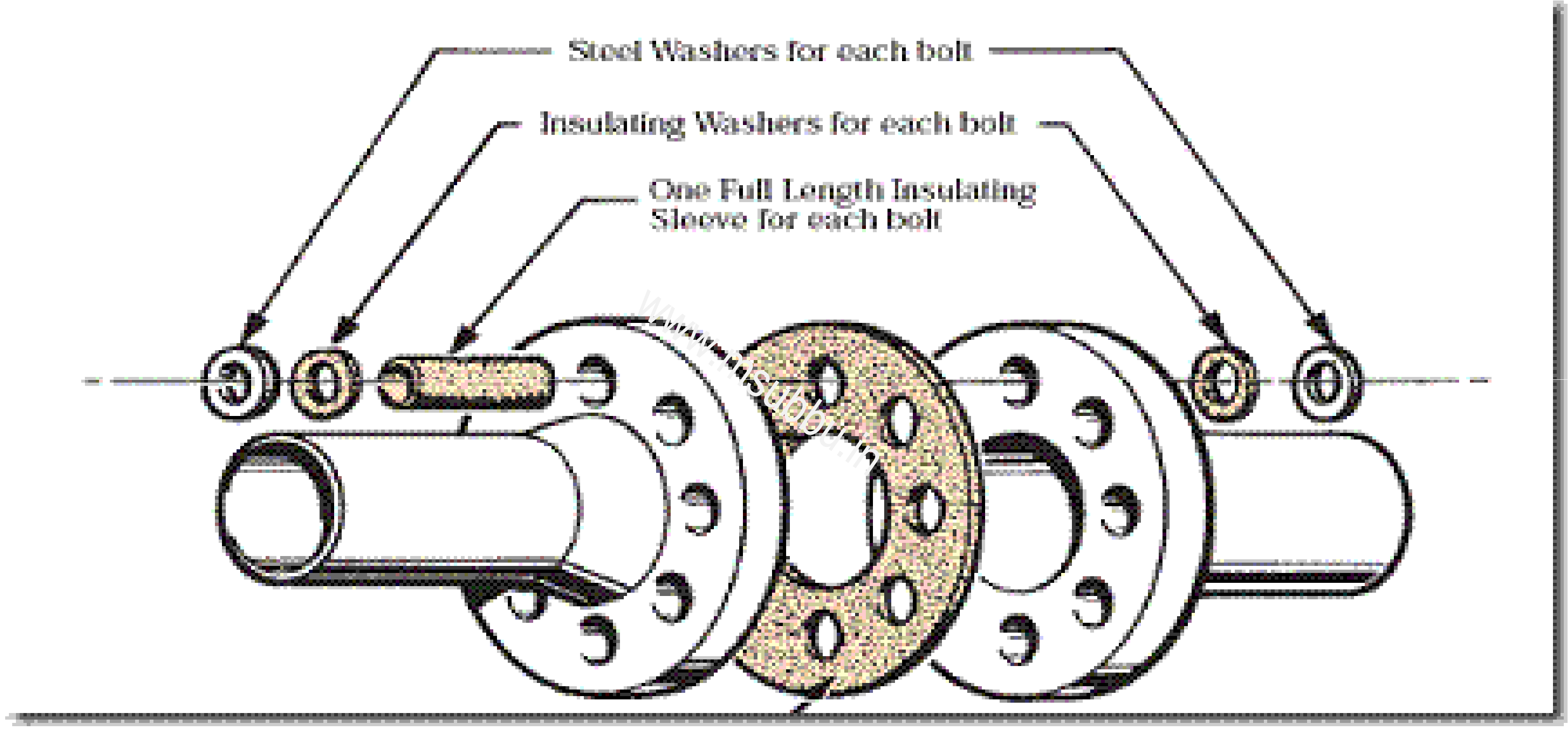


Riveting procedure.



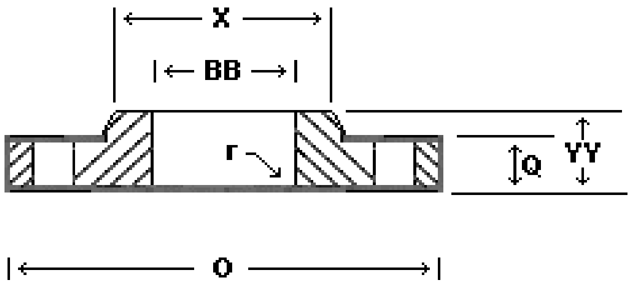
Forms of riveted joints.

Flanged Joints

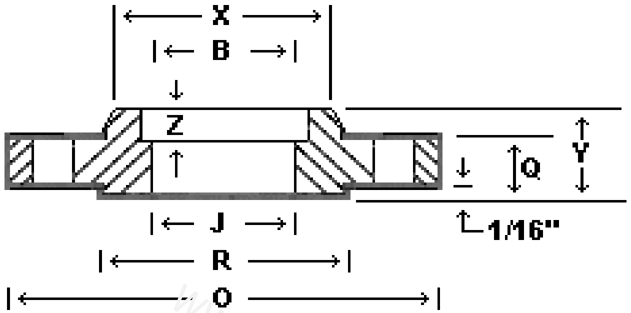

Steel Washers for each bolt
Insulating Washers for each bolt
One Full Length Insulating
Sleeve for each bolt

Types of Flanges

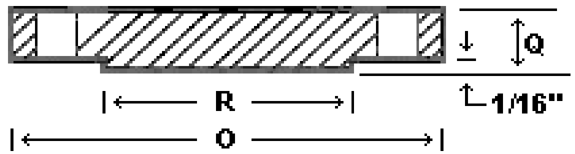
- Slip-on raised face
- Welding neck
- Lap-joint
- Stub-end
- Screwed



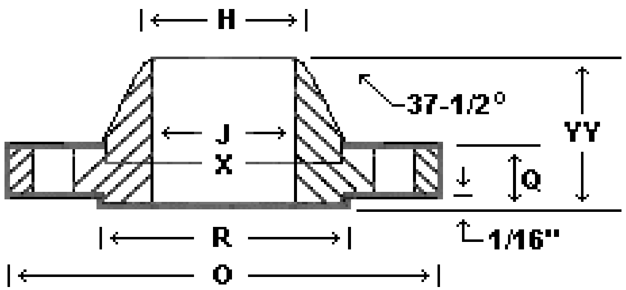
LAP JOINT



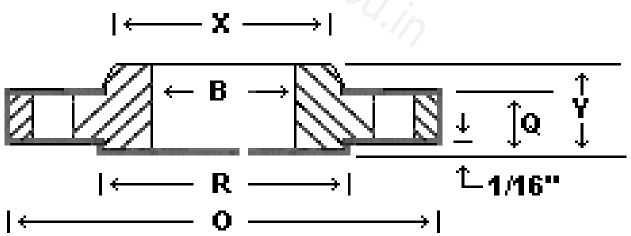
SOCKET



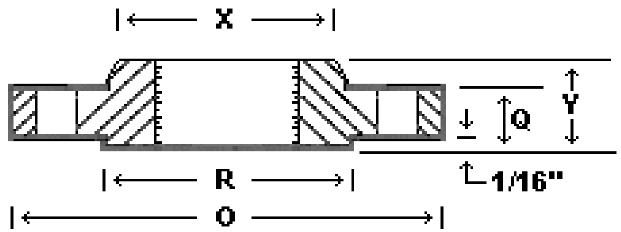
BLIND



WELDING NECK



SLIP ON

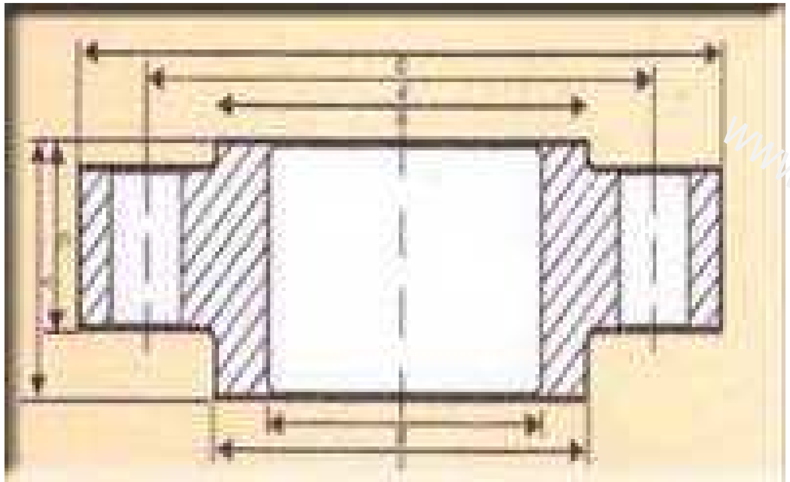


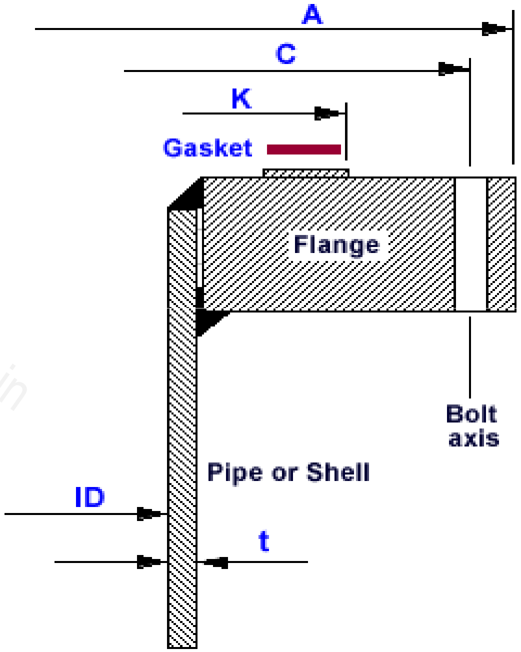
THREADED

Material of Construction

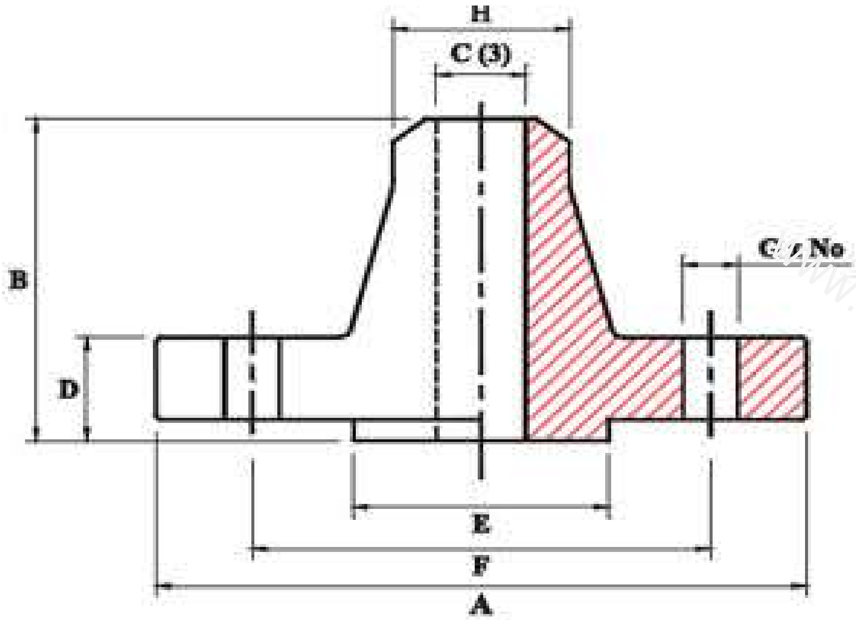
- Forgings, castings, plates
- Forged Steel such as ASTM A 105

Slip-on Raised Face Flange

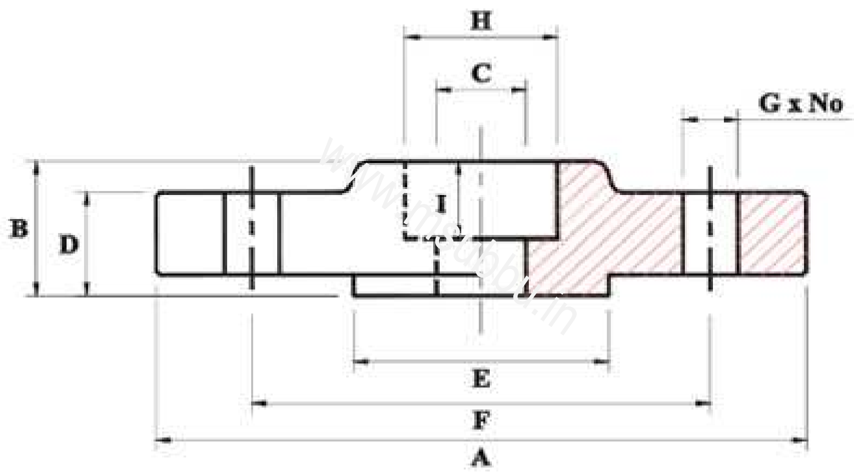




Welding Neck Flange

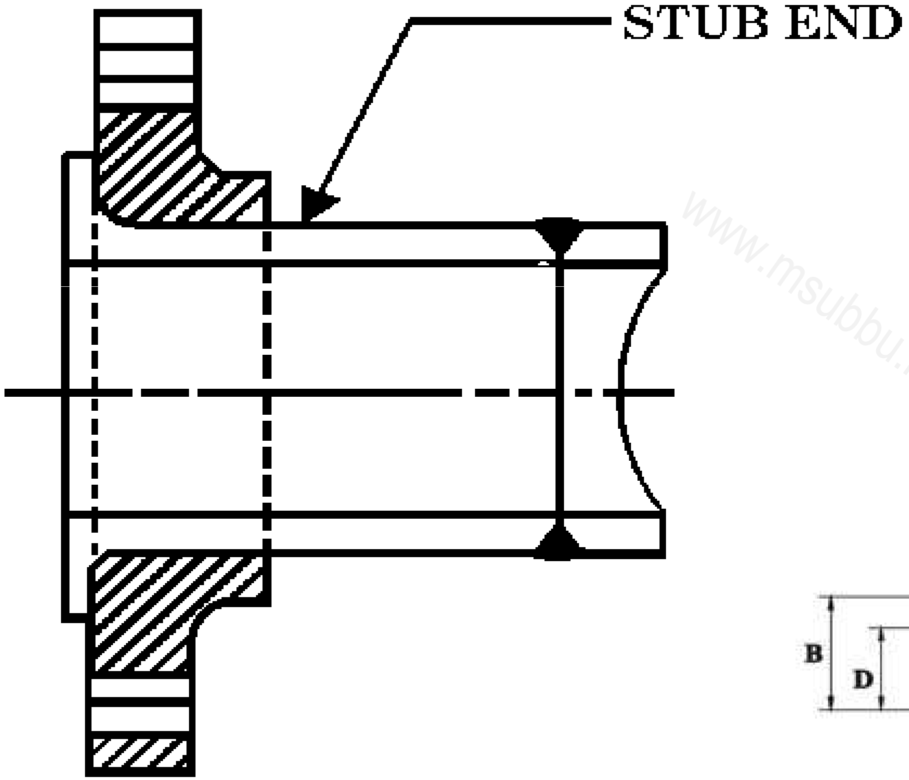


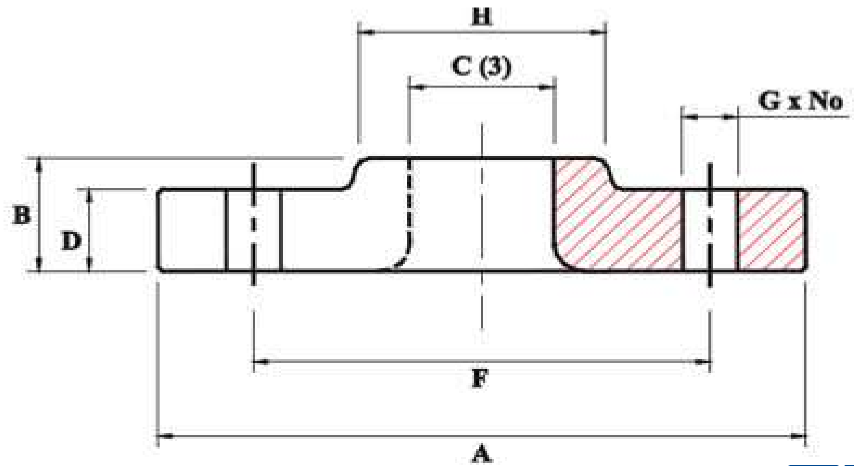
Socket Weld Flange



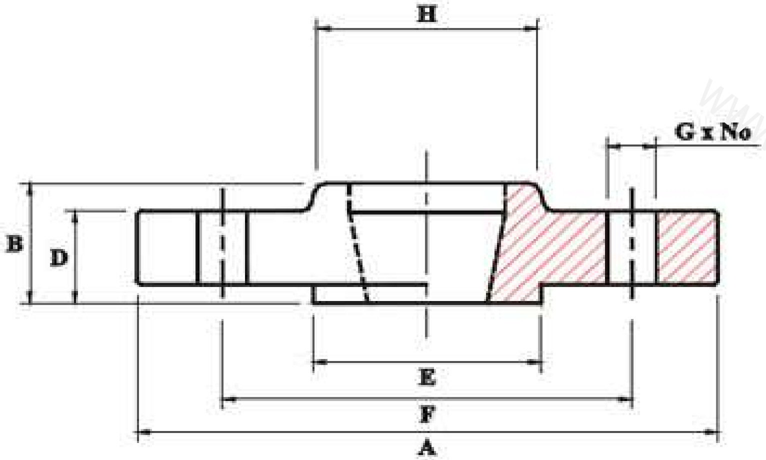
Lap joint

LAP-JOINT FLANGE (with Stub-end)





Screwed Flange



Blind flange

Standards Evolution

- ASA B16e, 1932
- ASA B16.5, 1953,
- ANSI B16.5, 1973
- ASME/ANSI B16.5, 1988
- ASME B16.5, 1996

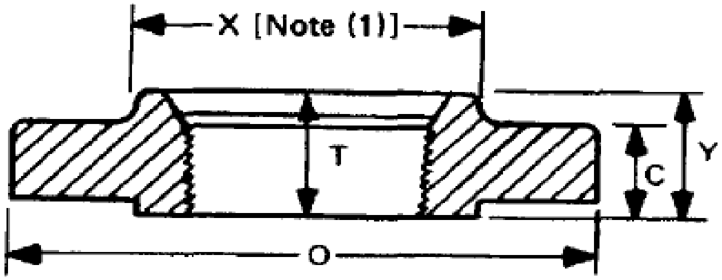
ASME B16.5-1996

(Revision of ASME/ANSI B16.5-1988)

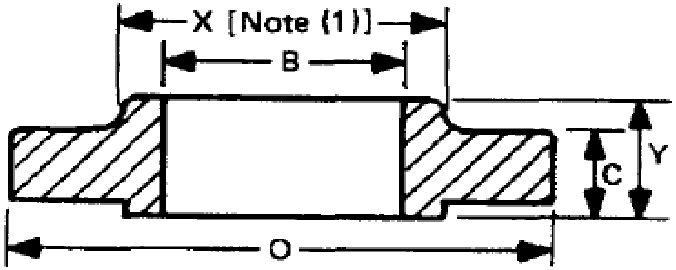
Rating of Flanges

- 150, 300, 600, 900, 1500, 2500 psig

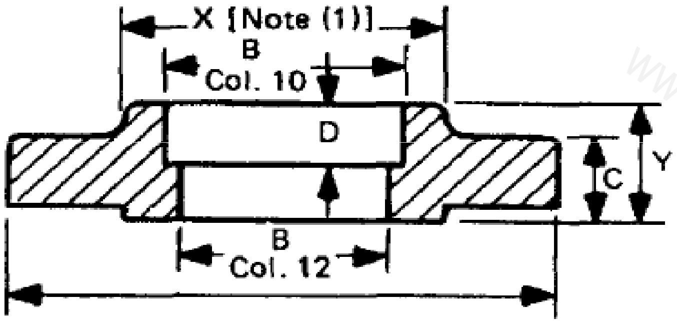
- Pipe flanges and flanged fittings: NPS ½ through NPS 24.



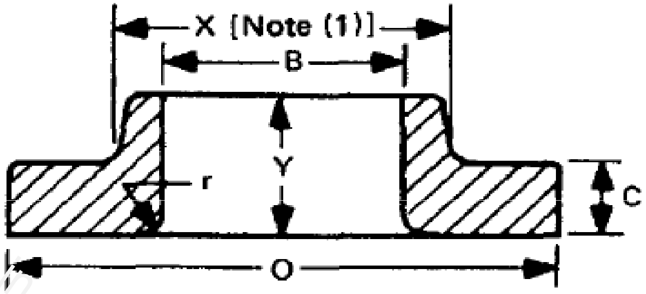
Threaded



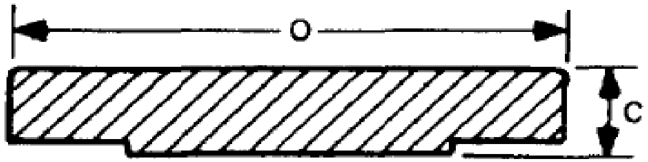
Slip-On Welding



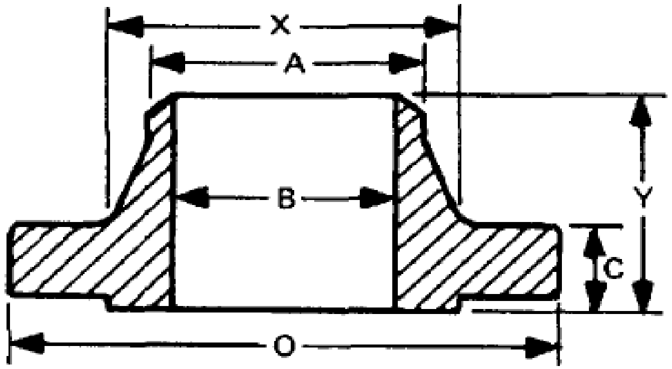
Socket Welding (1/2 to 3 Only)



Lapped



Blind



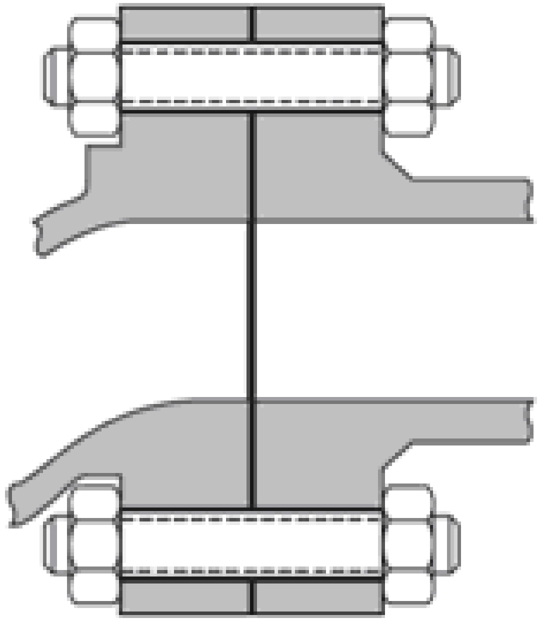
Welding Neck

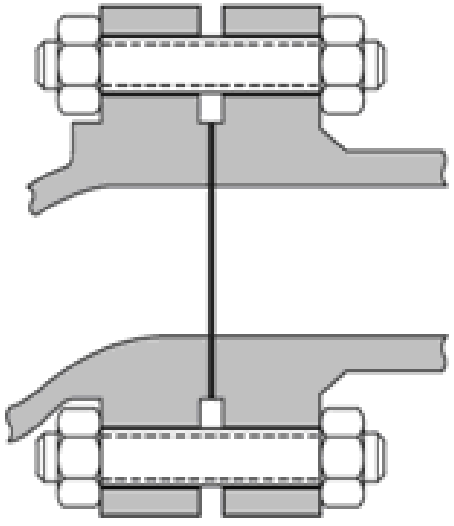
TABLE 9 DIMENSIONS OF CLASS 150 FLANGES[2–8]

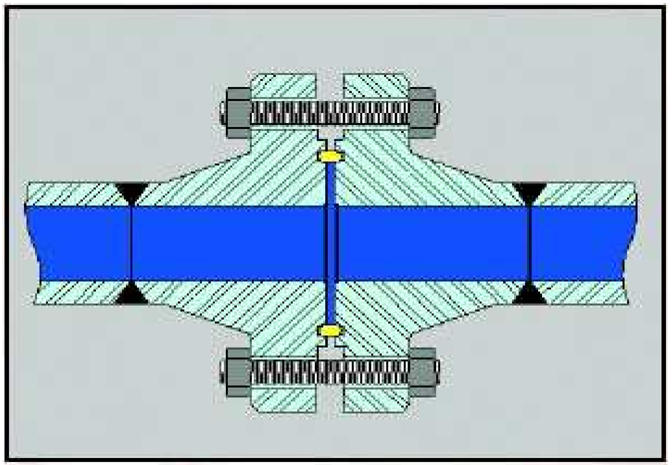
1	2	3	4	5	6	7	8	9	10	11	12	13	14
					Length Through Hub				Bore				
Nominal Pipe Size	Outside Diameter of Flange O	Thickness of Flange [(9)–(11)], Min. C	Diameter of Hub X	Hub Diameter Beginning of Chamfer Welding Neck (12) A	Threaded Slip-On Socket Welding Y	Lapped Y	Welding Neck Y	Thread Length Threaded Flange (13), Min. T	Slip-On Socket Welding, Min. B	Lapped, Min. B	Welding Neck Socket Welding (14) B	Corner Radius of Bore of Lapped Flange and Pipe r	Depth of Socket D
½	3.50	0.44	1.19	0.84	0.62	0.62	1.88	0.62	0.88	0.90	0.62	0.12	0.38
¾	3.88	0.50	1.50	1.05	0.62	0.62	2.06	0.62	1.09	1.11	0.82	0.12	0.44
1	4.25	0.56	1.94	1.32	0.69	0.69	2.19	0.69	1.36	1.38	1.05	0.12	0.50
1¼	4.62	0.62	2.31	1.66	0.81	0.81	2.25	0.81	1.70	1.72	1.38	0.19	0.56
1½	5.00	0.69	2.56	1.90	0.88	0.88	2.44	0.88	1.95	1.97	1.61	0.25	0.62
2	6.00	0.75	3.06	2.38	1.00	1.00	2.50	1.00	2.44	2.46	2.07	0.31	0.69
2½	7.00	0.88	3.56	2.88	1.12	1.12	2.75	1.12	2.94	2.97	2.47	0.31	0.75
3	7.50	0.94	4.25	3.50	1.19	1.19	2.75	1.19	3.57	3.60	3.07	0.38	0.81
3½	8.50	0.94	4.81	4.00	1.25	1.25	2.81	1.25	4.07	4.10	3.55	0.38	. . .
4	9.00	0.94	5.31	4.50	1.31	1.31	3.00	1.31	4.57	4.60	4.03	0.44	. . .
5	10.00	0.94	6.44	5.56	1.44	1.44	3.50	1.44	5.66	5.69	5.05	0.44	. . .
6	11.00	1.00	7.56	6.63	1.56	1.56	3.50	1.56	6.72	6.75	6.07	0.50	. . .
8	13.50	1.12	9.69	8.63	1.75	1.75	4.00	1.75	8.72	8.75	7.98	0.50	. . .
10	16.00	1.19	12.00	10.75	1.94	1.94	4.00	1.94	10.88	10.92	10.02	0.50	. . .
12	19.00	1.25	14.38	12.75	2.19	2.19	4.50	2.19	12.88	12.92	12.00	0.50	. . .
14	21.00	1.38	15.75	14.00	2.25	3.12	5.00	2.25	14.14	14.18	To be specified by purchaser	0.50	. . .
16	23.50	1.44	18.00	16.00	2.50	3.44	5.00	2.50	16.16	16.19		0.50	. . .
18	25.00	1.56	19.88	18.00	2.69	3.81	5.50	2.69	18.18	18.20		0.50	. . .
20	27.50	1.69	22.00	20.00	2.88	4.06	5.69	2.88	20.20	20.25		0.50	. . .
24	32.00	1.88	26.12	24.00	3.25	4.38	6.00	3.25	24.25	24.25		0.50	. . .

Flange Facings

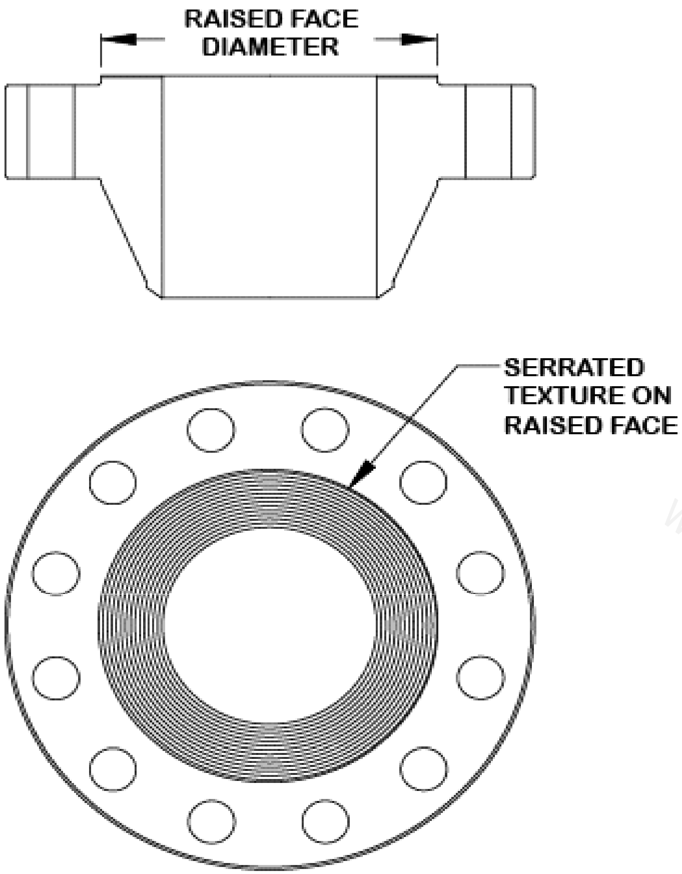
- Flat Facing (FF):
- Raised Facing (RF): The Raised face is the most common of all flange faces. The Raised face is named like this because the gasket surfaces are raised above the bolting circle face (the raised face is only a slight step). Raised face flanges are therefore not full contact flanges. As such, some flange stress may be created when the bolting is tightened. The raised face is finished with a series of concentric circular grooves for keeping the gasket in place and providing a better seal. Raised face flanges are specified for low, medium and high pressure-temperature applications.
- Ring type Joint Facing (RTJ)

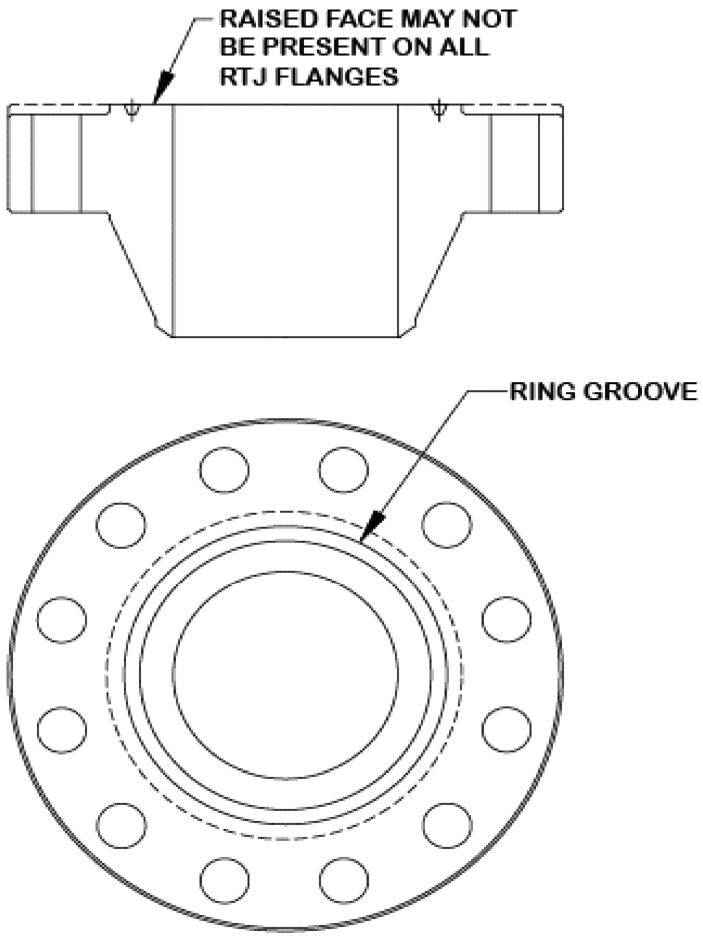


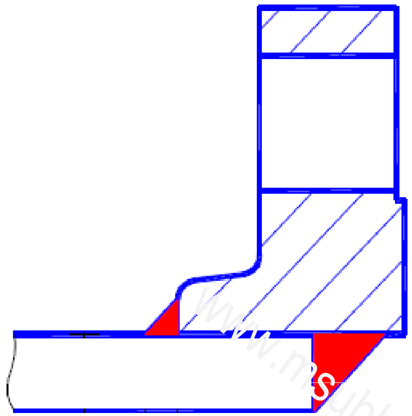


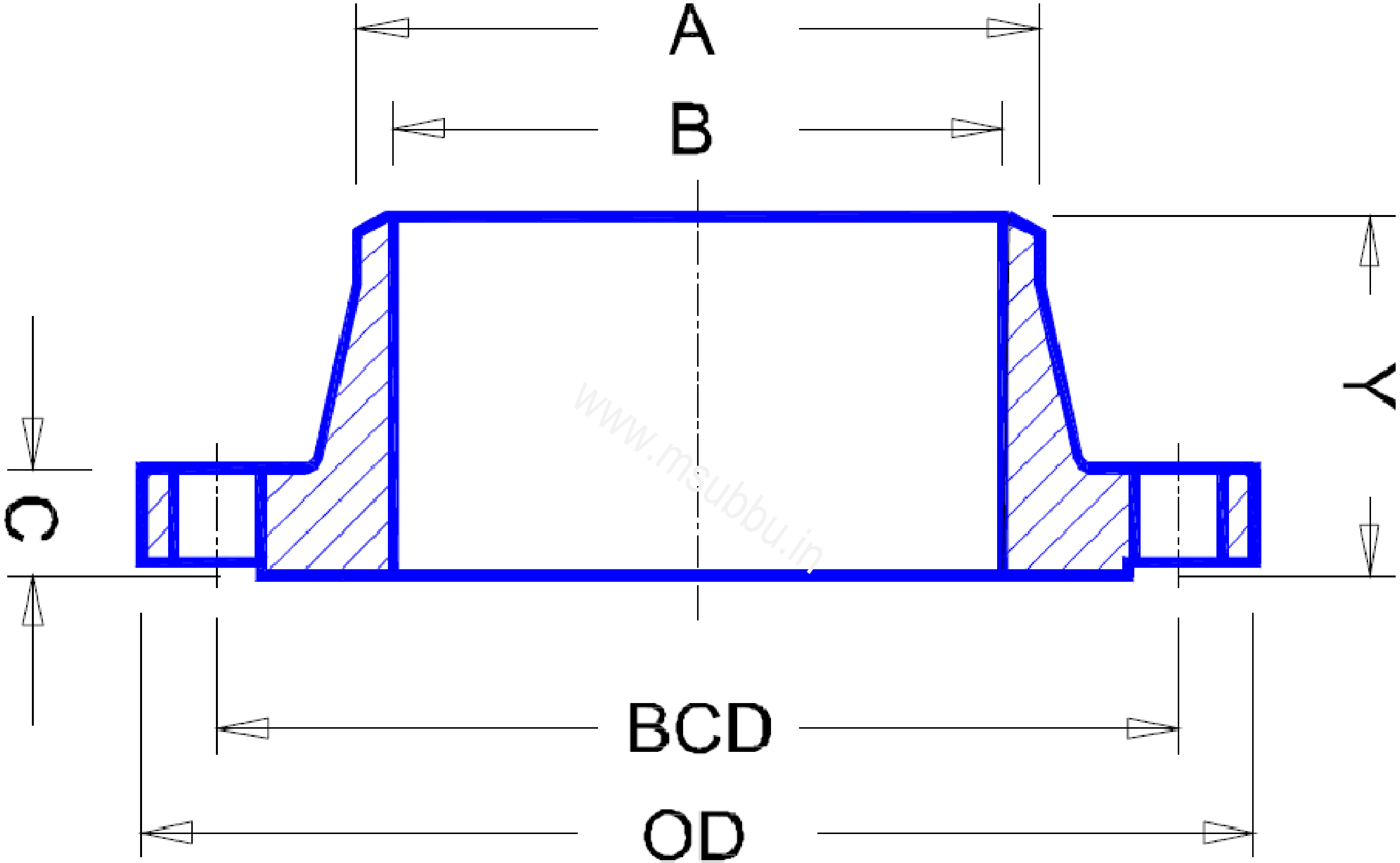


R & RX ring standard


RAISED FACE
DIAMETER
SERRATED
TEXTURE ON
RAISED FACE


RAISED FACE MAY NOT
BE PRESENT ON ALL
RTJ FLANGES
RING GROOVE




A
B
Y
C
BCD
OD
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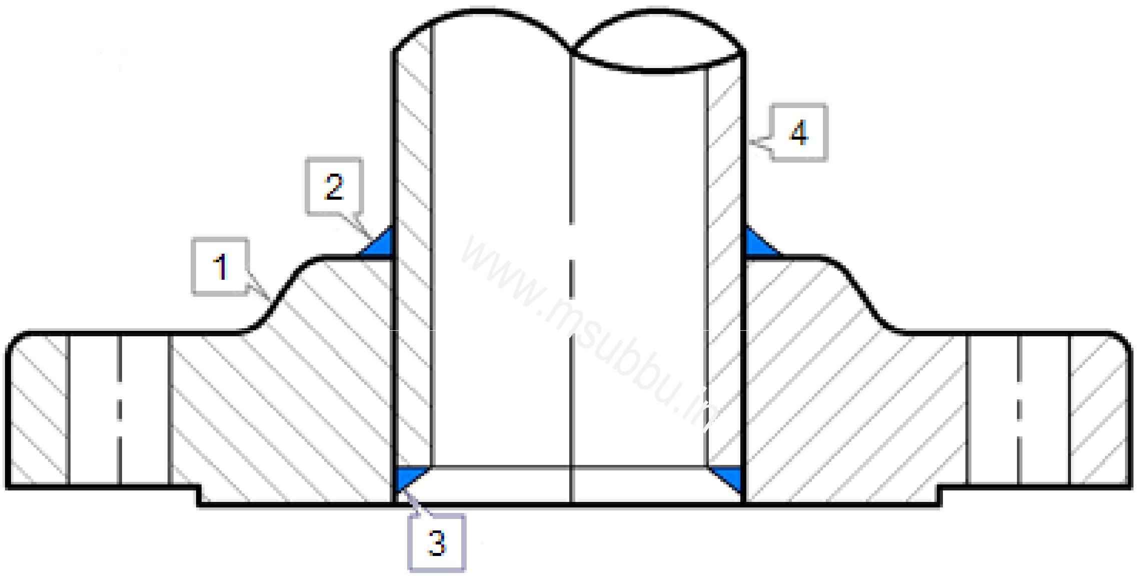
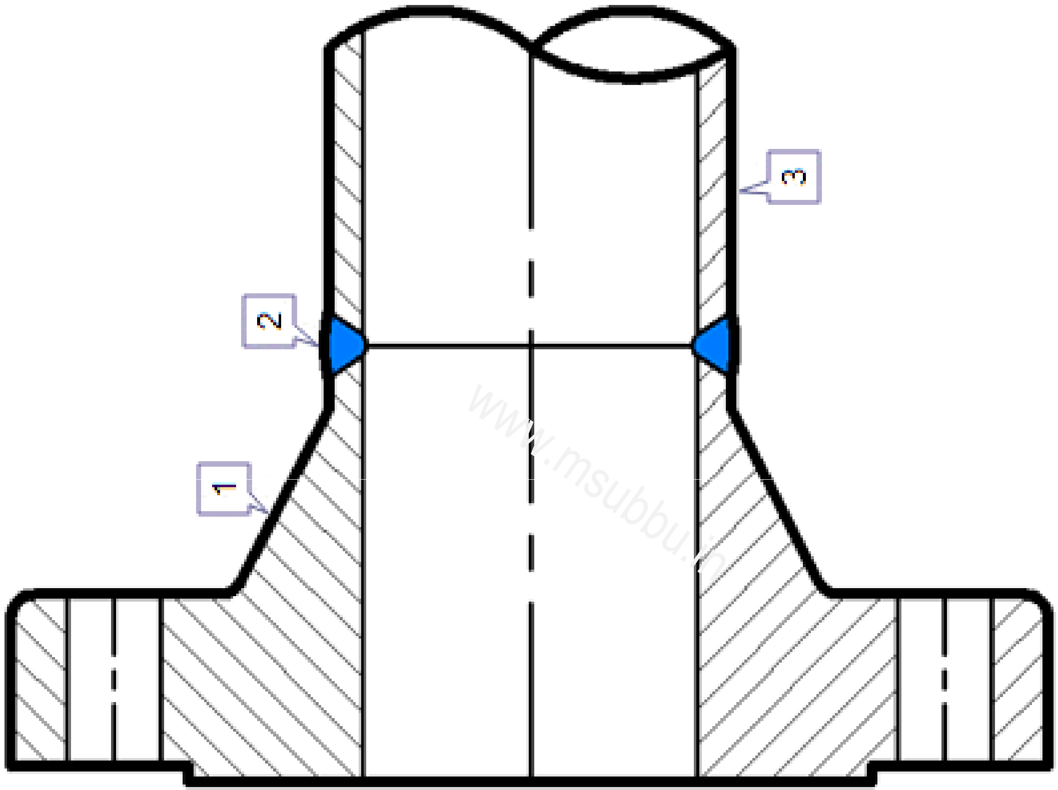
How to Order a Flange

½" - 24" – covered by ANSI B16.5

Quantity
Size (nominal pipe size)
Pressure Class (150-2500)
Facing (RF, FF, RTJ, ect.)
Type (WN, SO, Threaded, Blind, SW, LJ)
Bore (if SW or WN)
Material
e.g. 2 – 4" 300# RFWN STD 304



1
2
3
4
www.msubbu.in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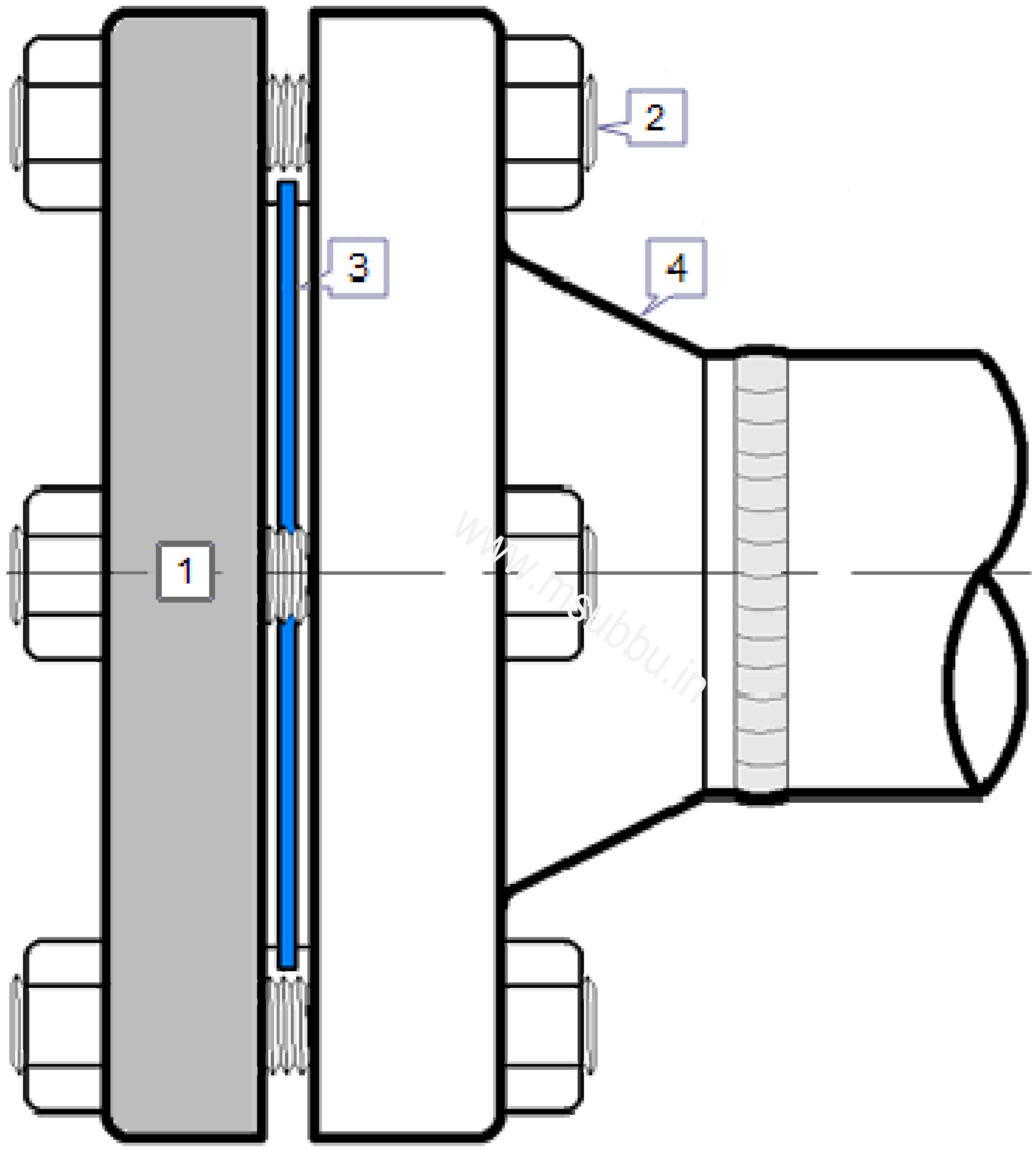

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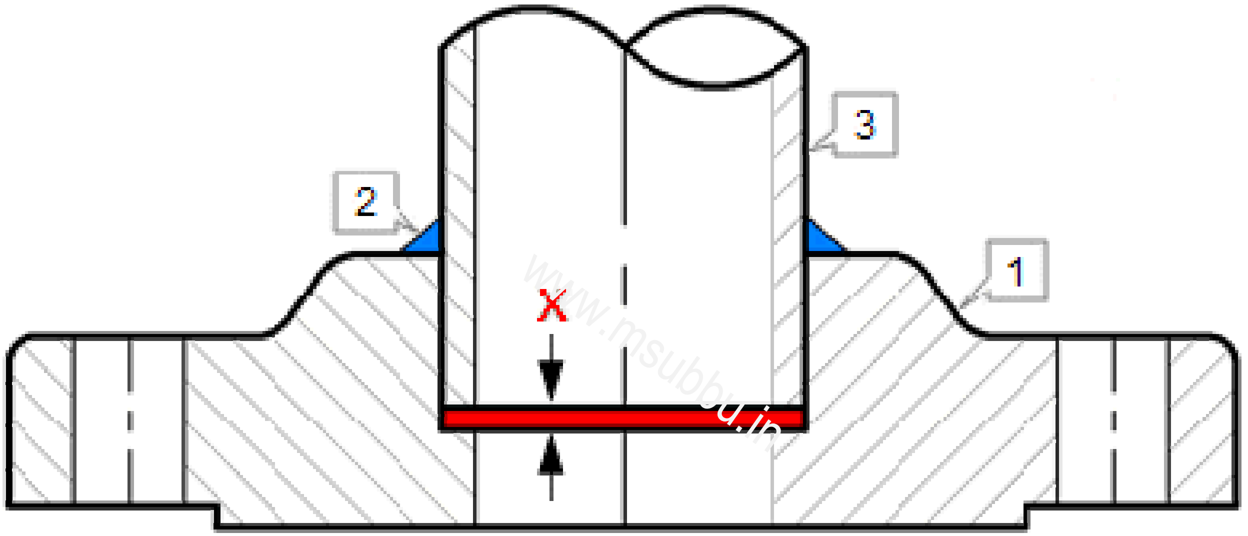
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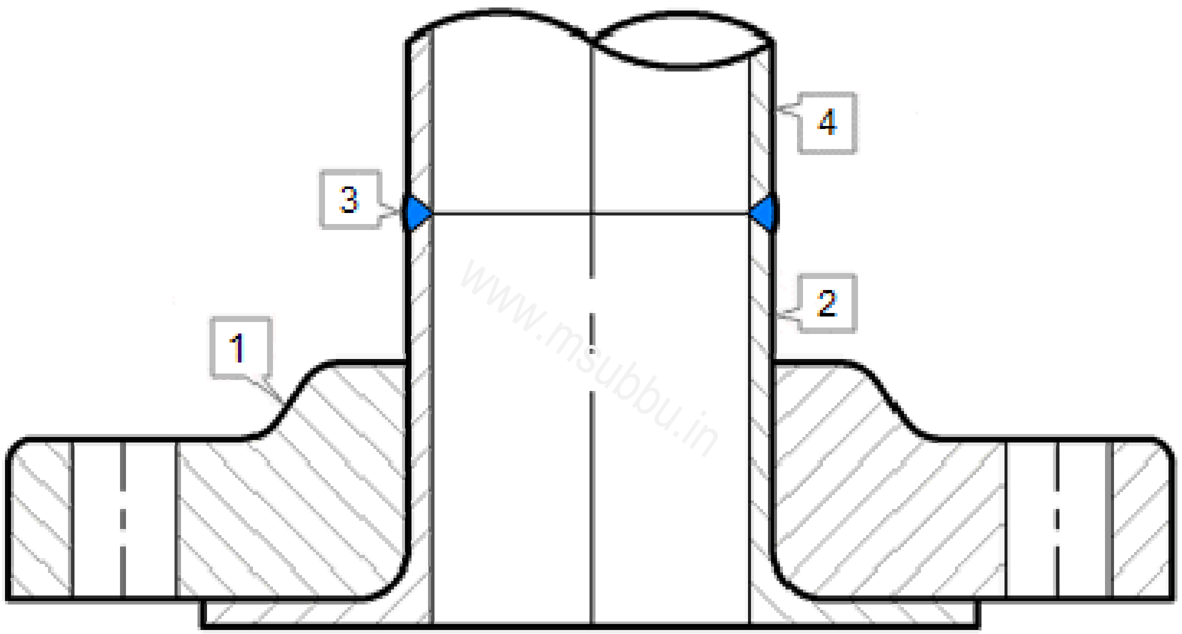
X
www.msubbu.in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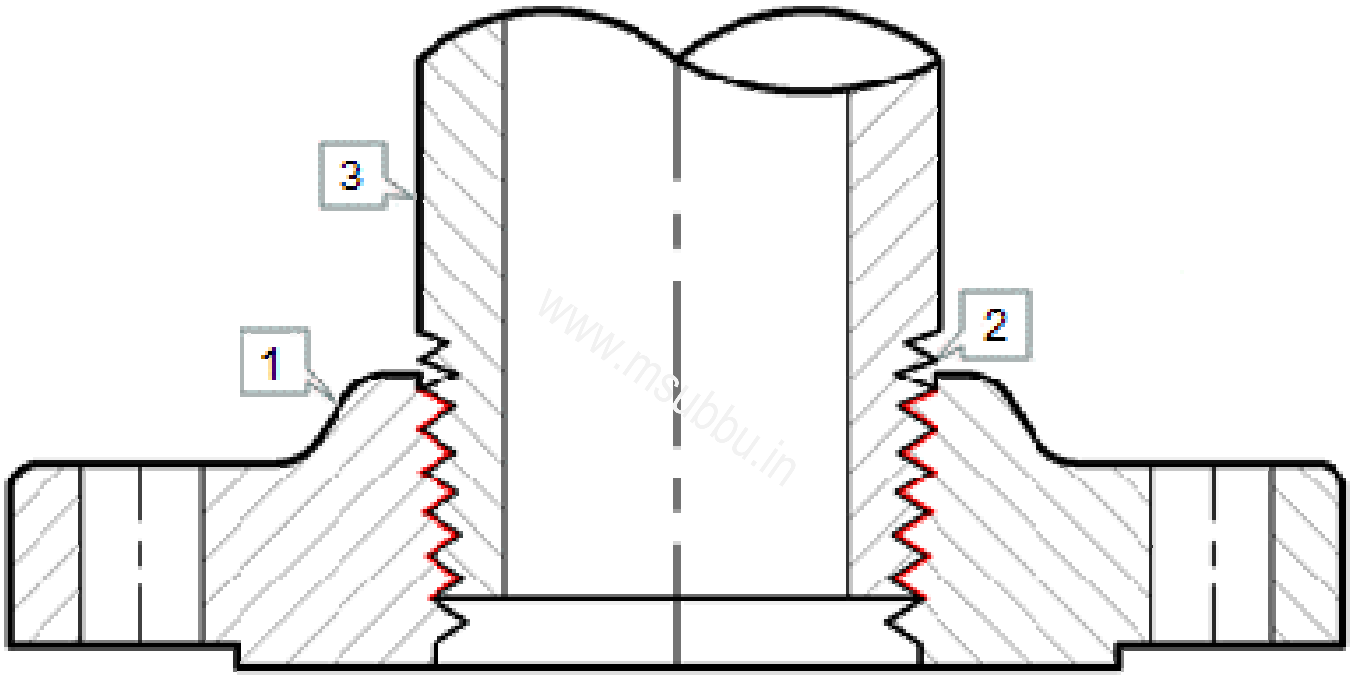
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2
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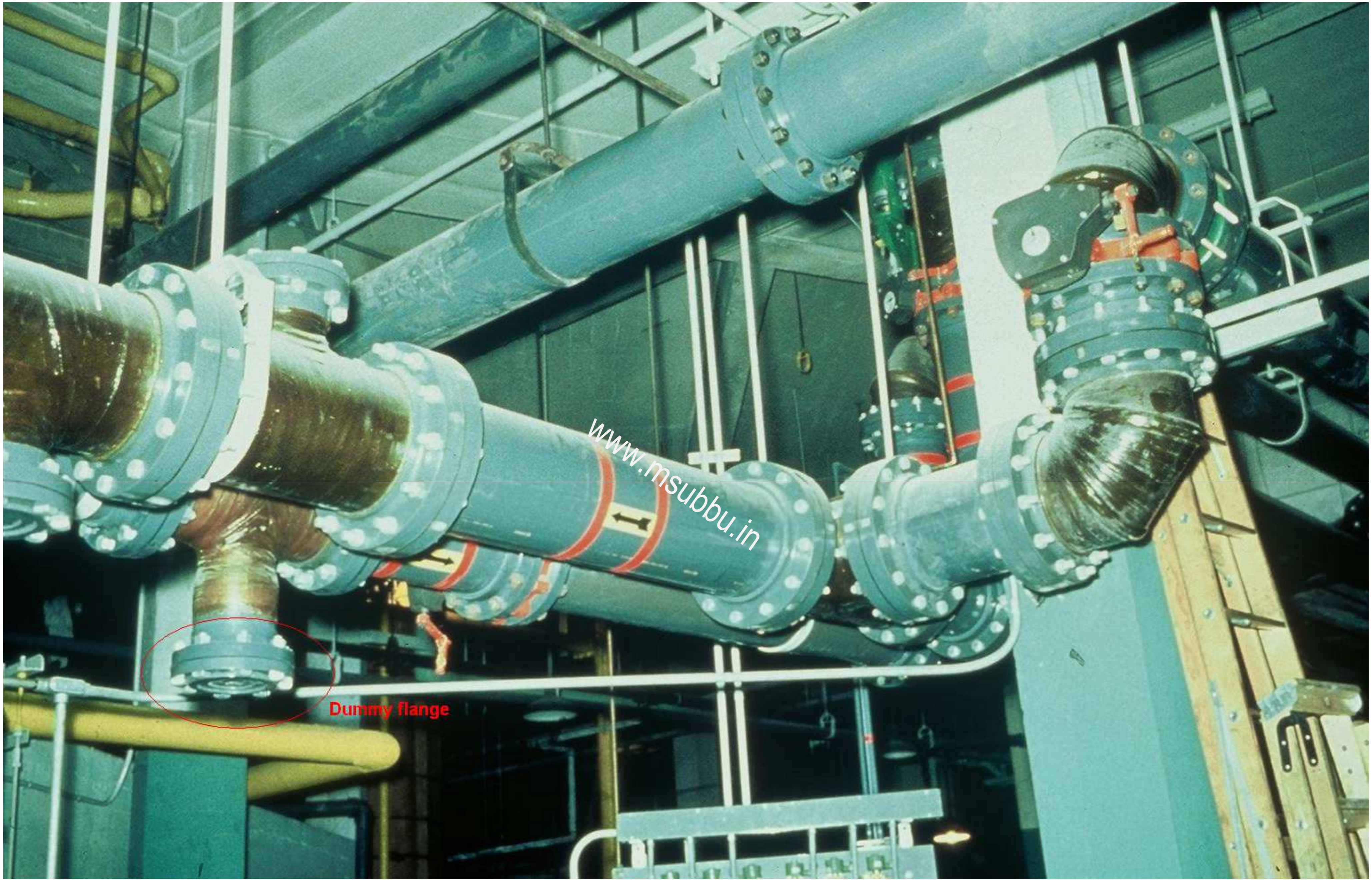
www.msubbu.in


B
L
G
K
D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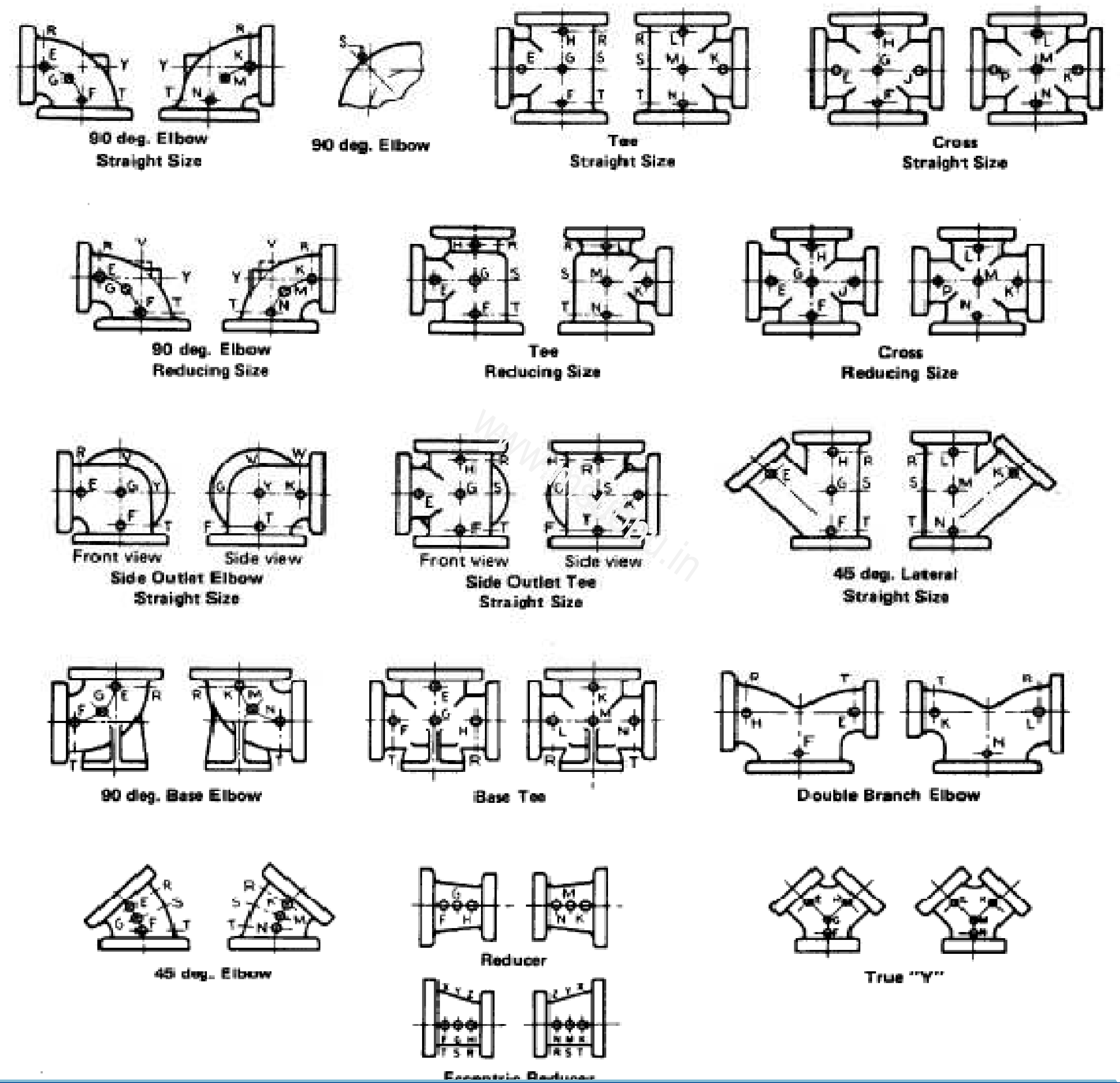
Dummy flange

FLANGED FITTINGS



Dished Ends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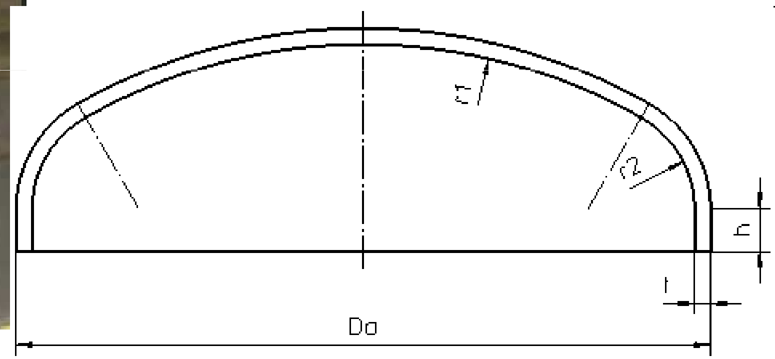
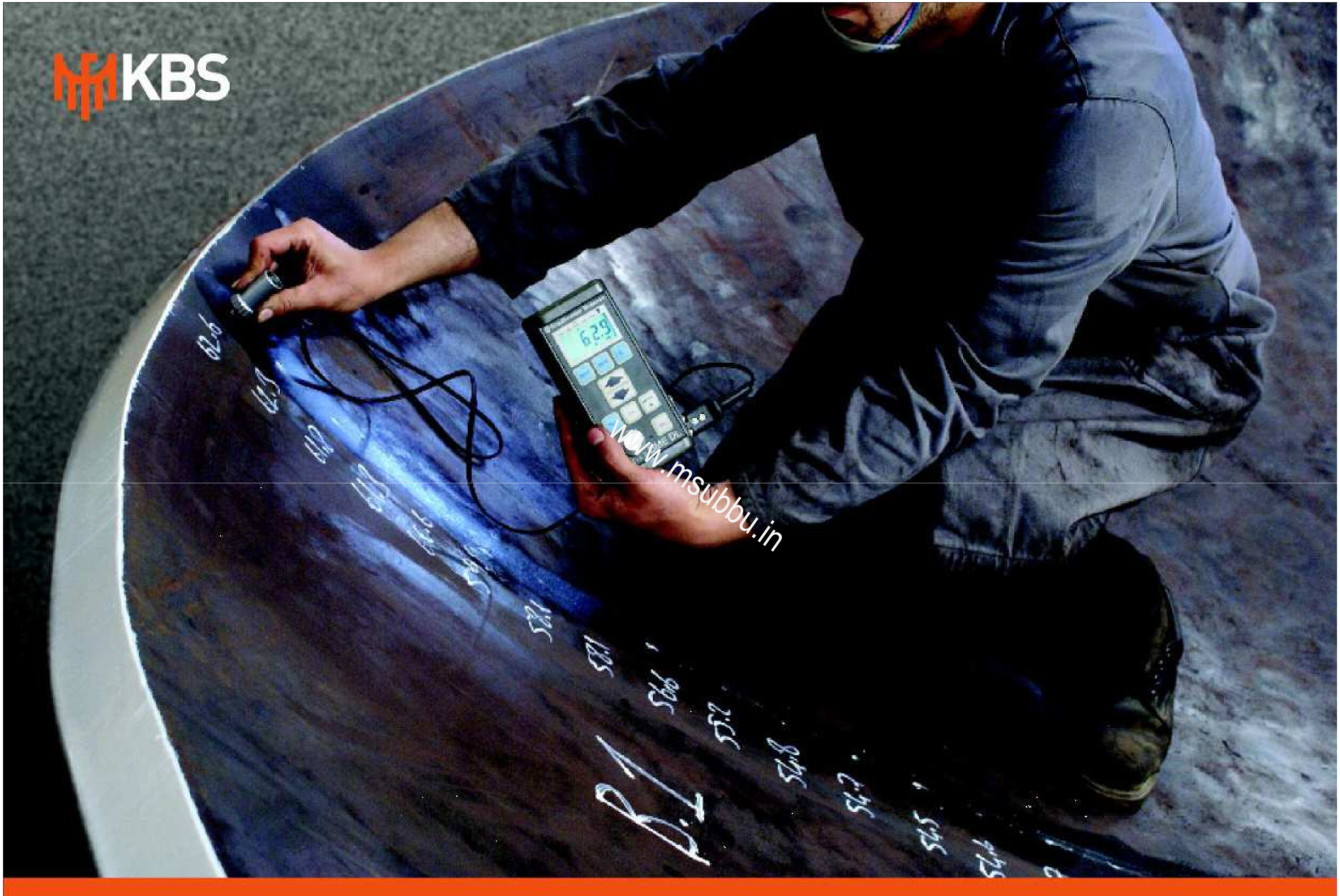
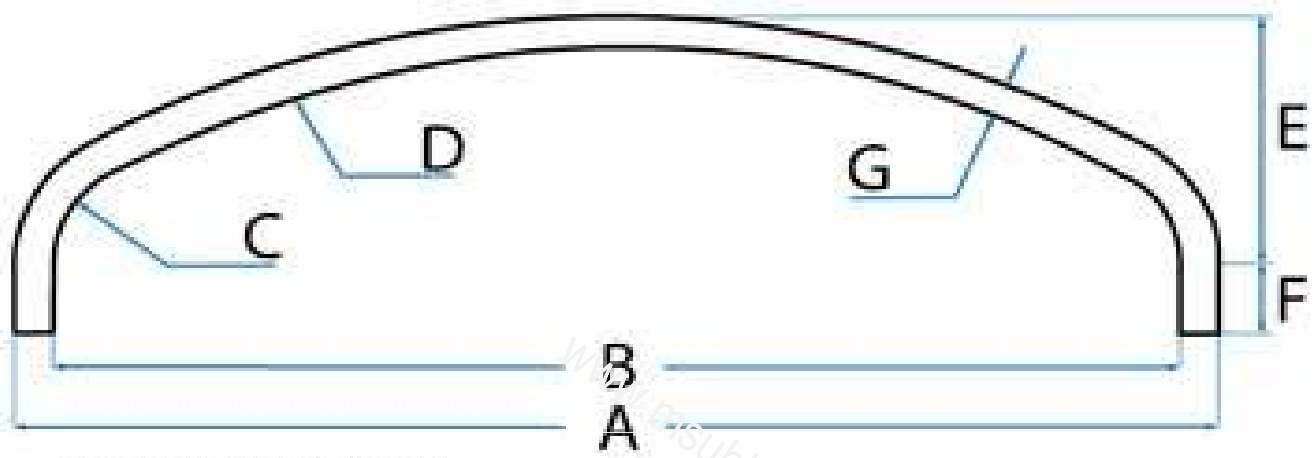
11 7:57PM



The manufacturing of such an end is easier than that of a hemisphere. The starting material is first pressed to a radius r1 and then curled at the edge creating the second radius r2. Vessel dished ends can also be welded together from smaller pieces.

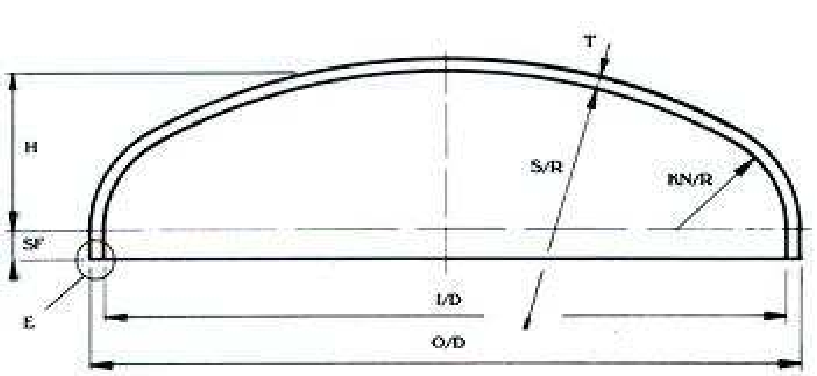




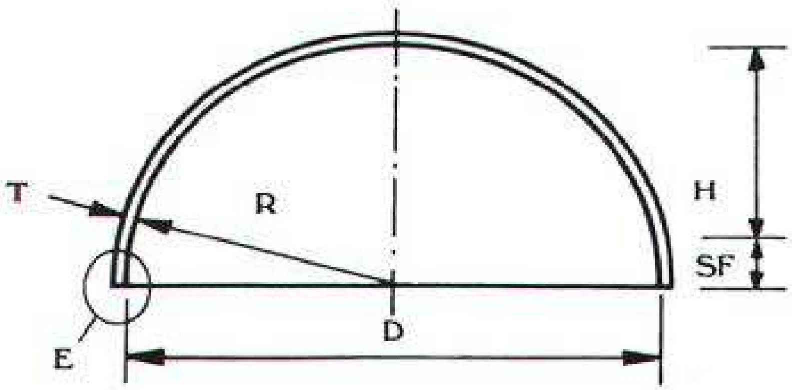
A OUTSIDE DIAMETER
B INSIDE DIAMETER
C KNUCKLE REDIUS
D INSIDE CROWN RADIUS OR SPHERICAL RADIUS
E INTERNAL TANGENTIAL HEIGHT
F STRAIGHT FLANGE
G MATERIAL THICKNESS FORMED FROM

Types of Ends

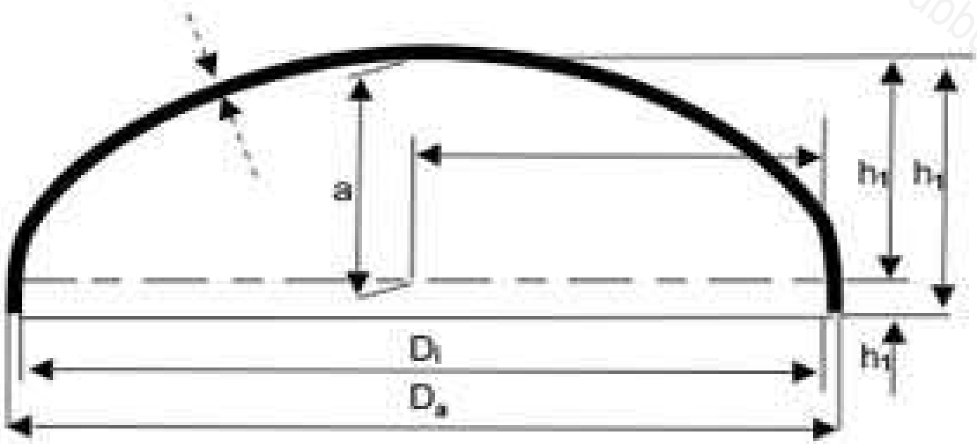
- Flanged
- Ellipsoidal
- Torispherical
- Hemispherical
- Conical
- Toriconical



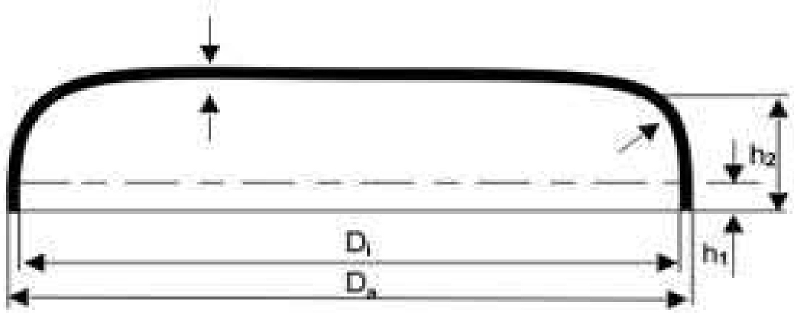
Torispherical



Hemispherical



Ellipsoidal



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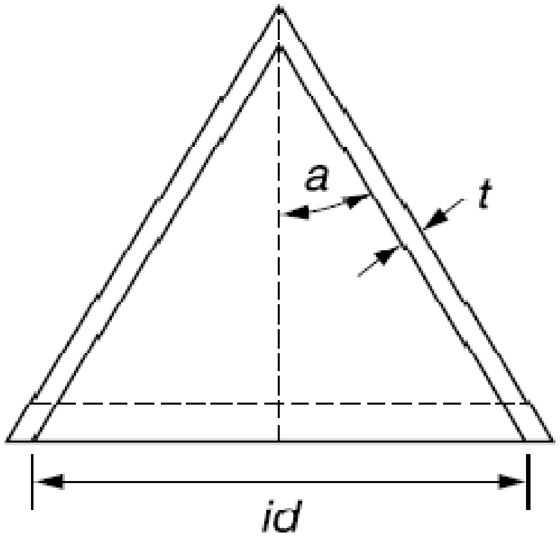
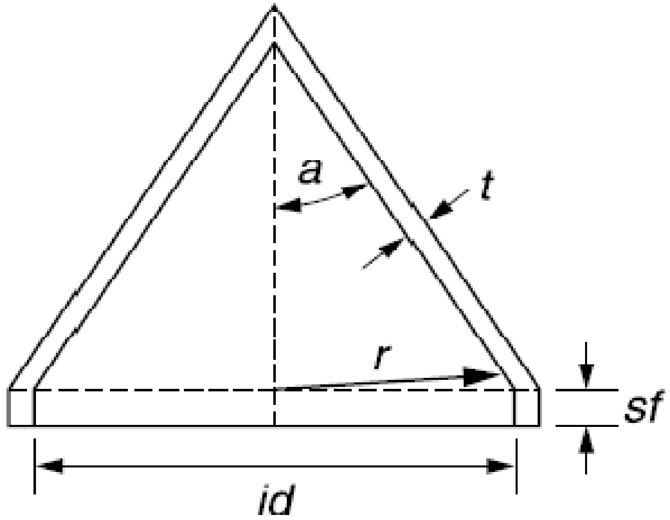
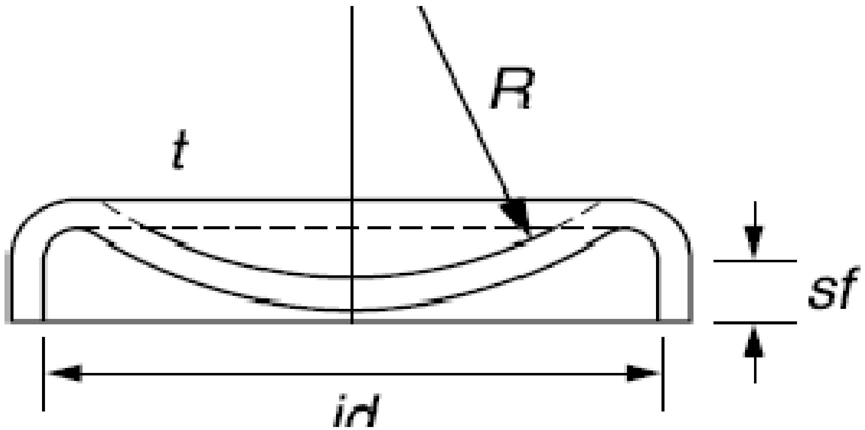


Conical

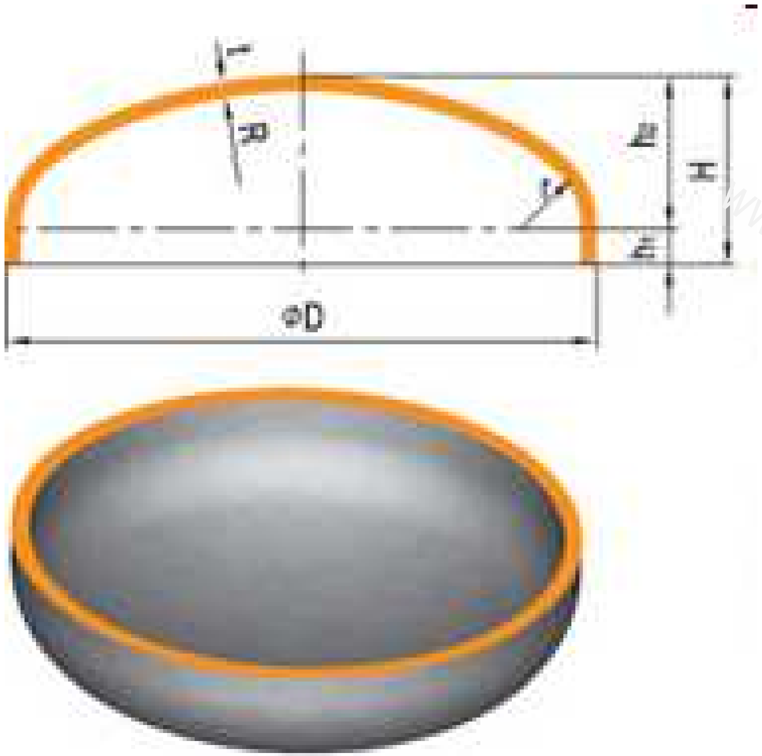


Toriconical

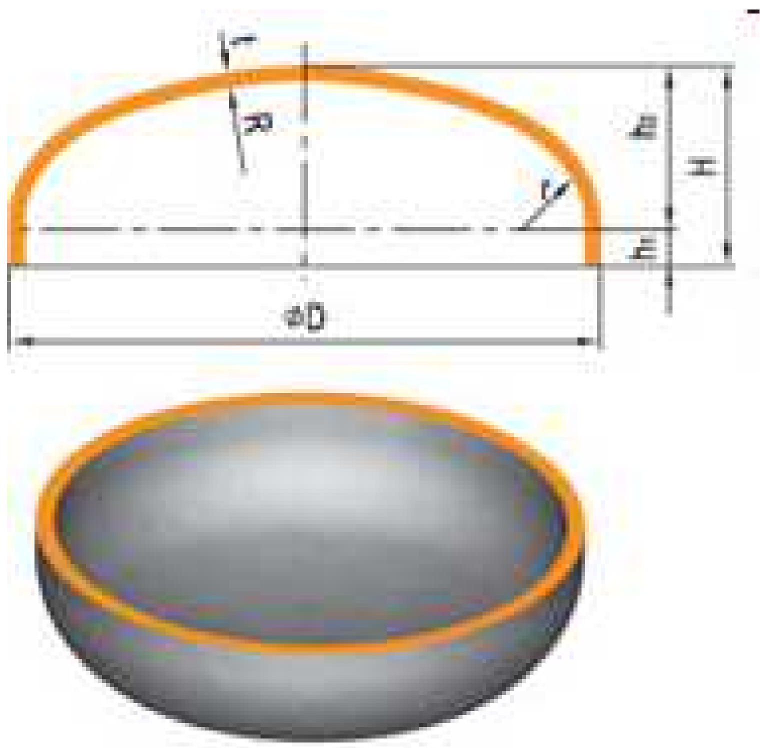


Reverse dished

Tori-spherical

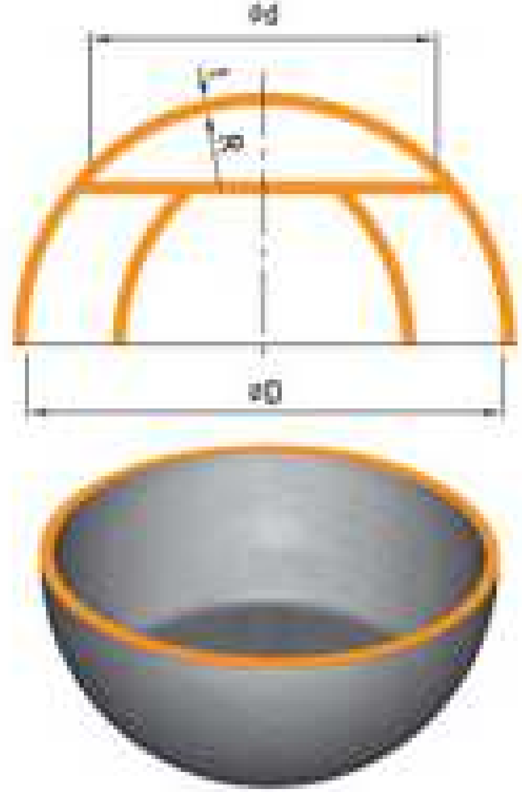


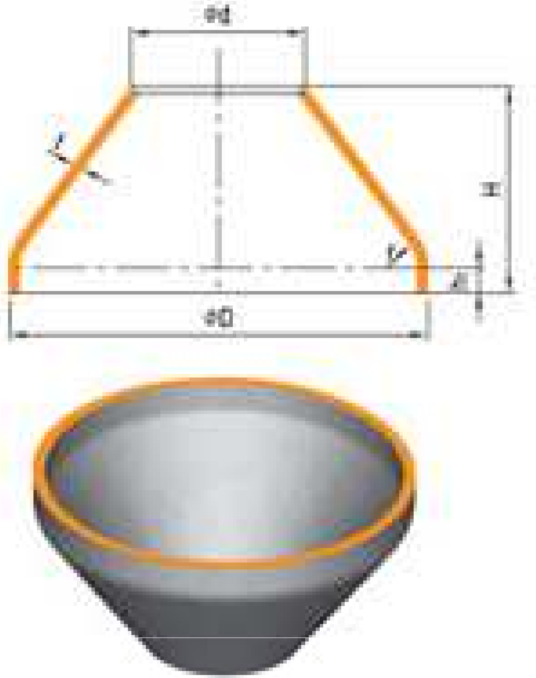
Ellipsoidal



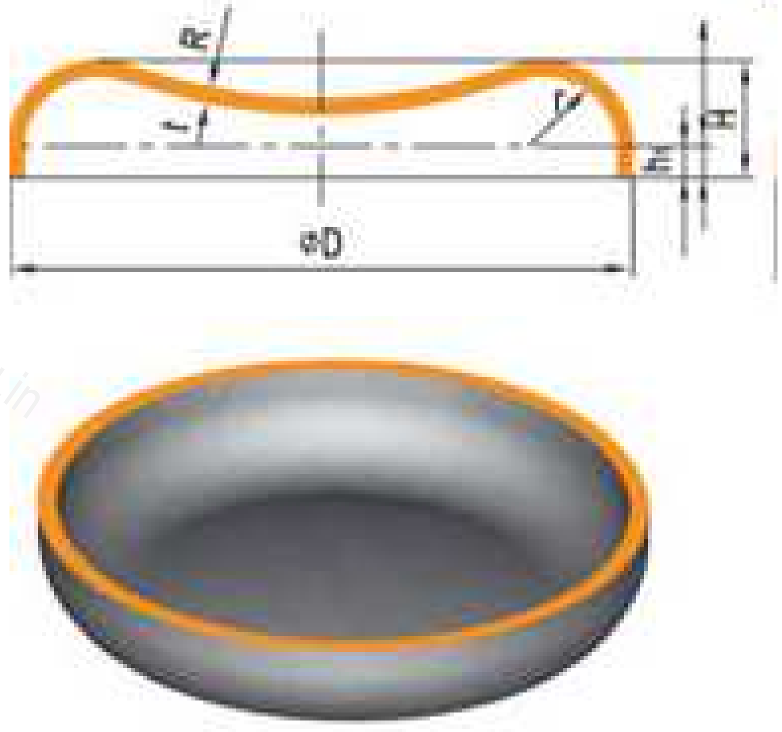
Hemi-Spherical (Deep Drawn)

Hemi-spherical (Segmental)

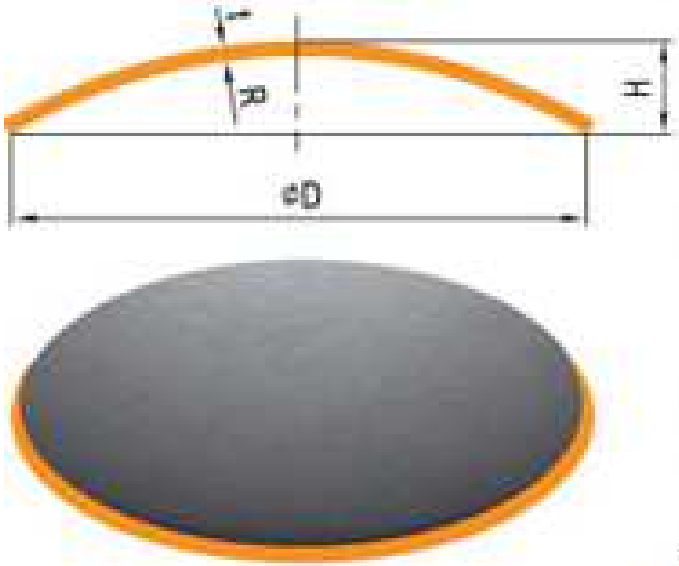




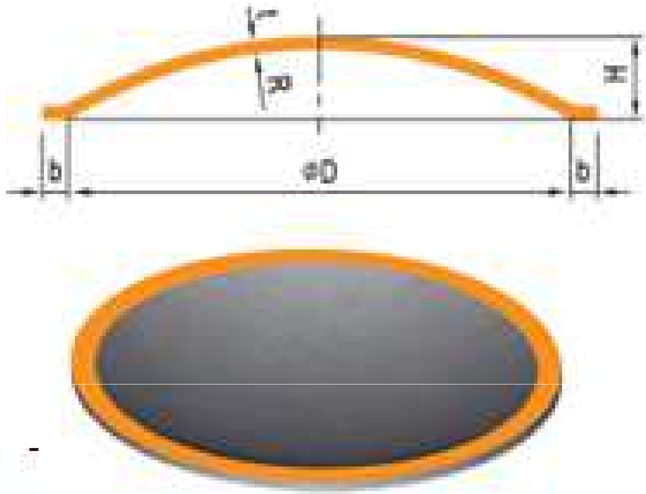
Diffuser Head



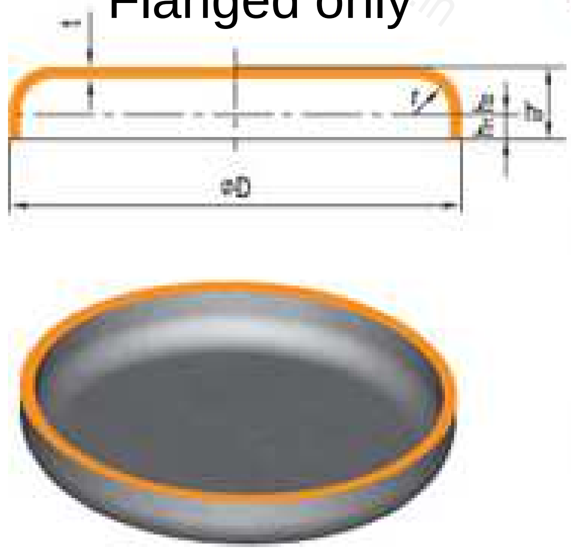
Dished Only Head

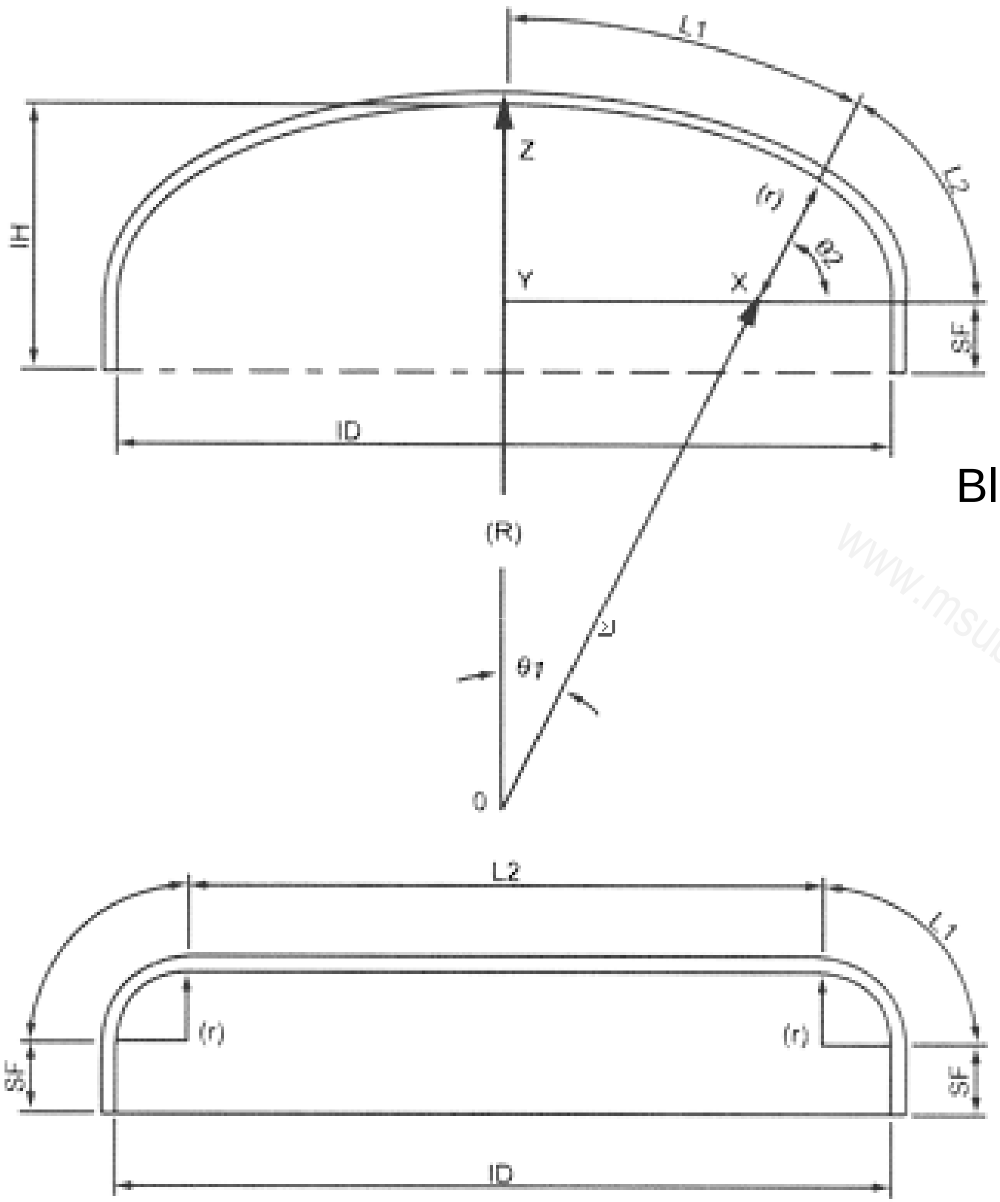


Dished & Flared Head



Flanged only





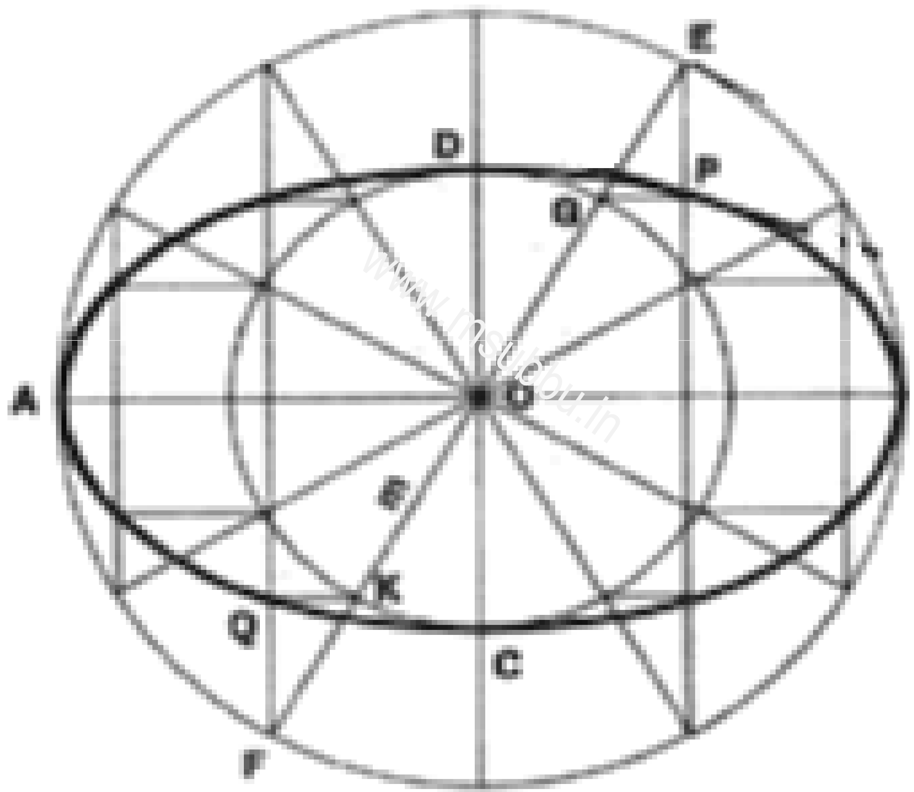
XY = ID/2 - r, OX = R - r

Ø1 = Sin XY / OX , Ø2 = 90° - Ø1

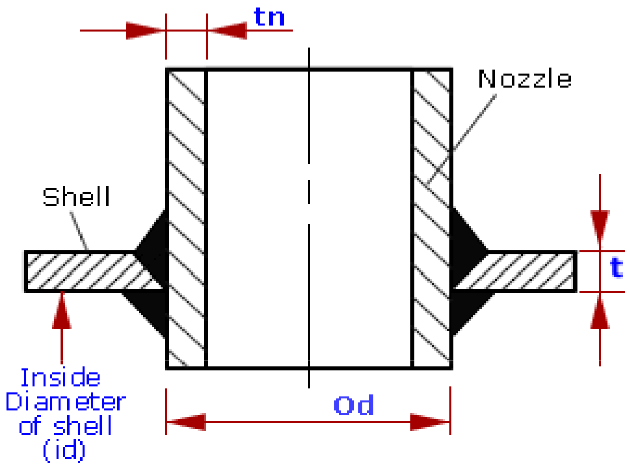
Blank Plate Diameter (BPD) = 2 (L1+ L2+L1)

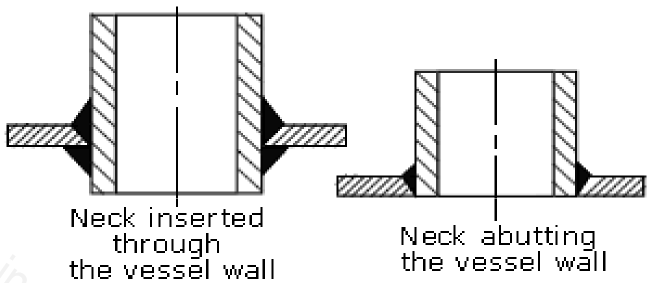
OD = outside diameter	ID = inside diameter
R = crown radius	r = knuckle radius
t = wall thickness	h = height of dished portion (straight flange not incl.)
SF = straight flange	IH = total inside height

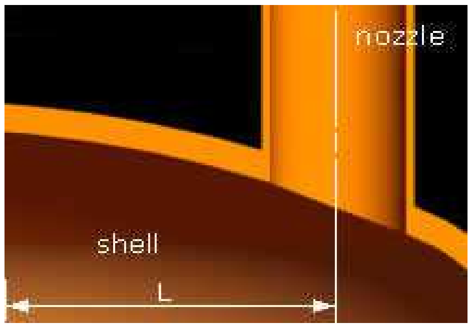
Drawing an Ellipse

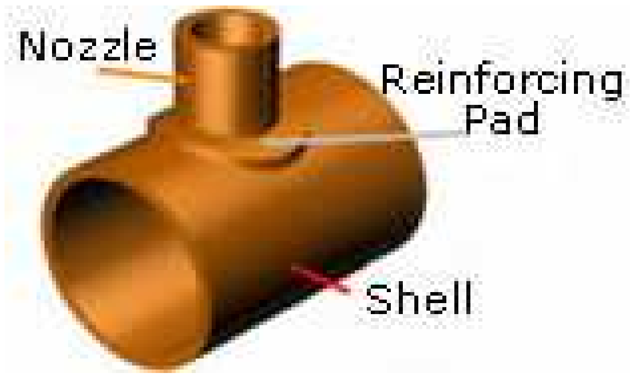


Nozzles attachment to shell

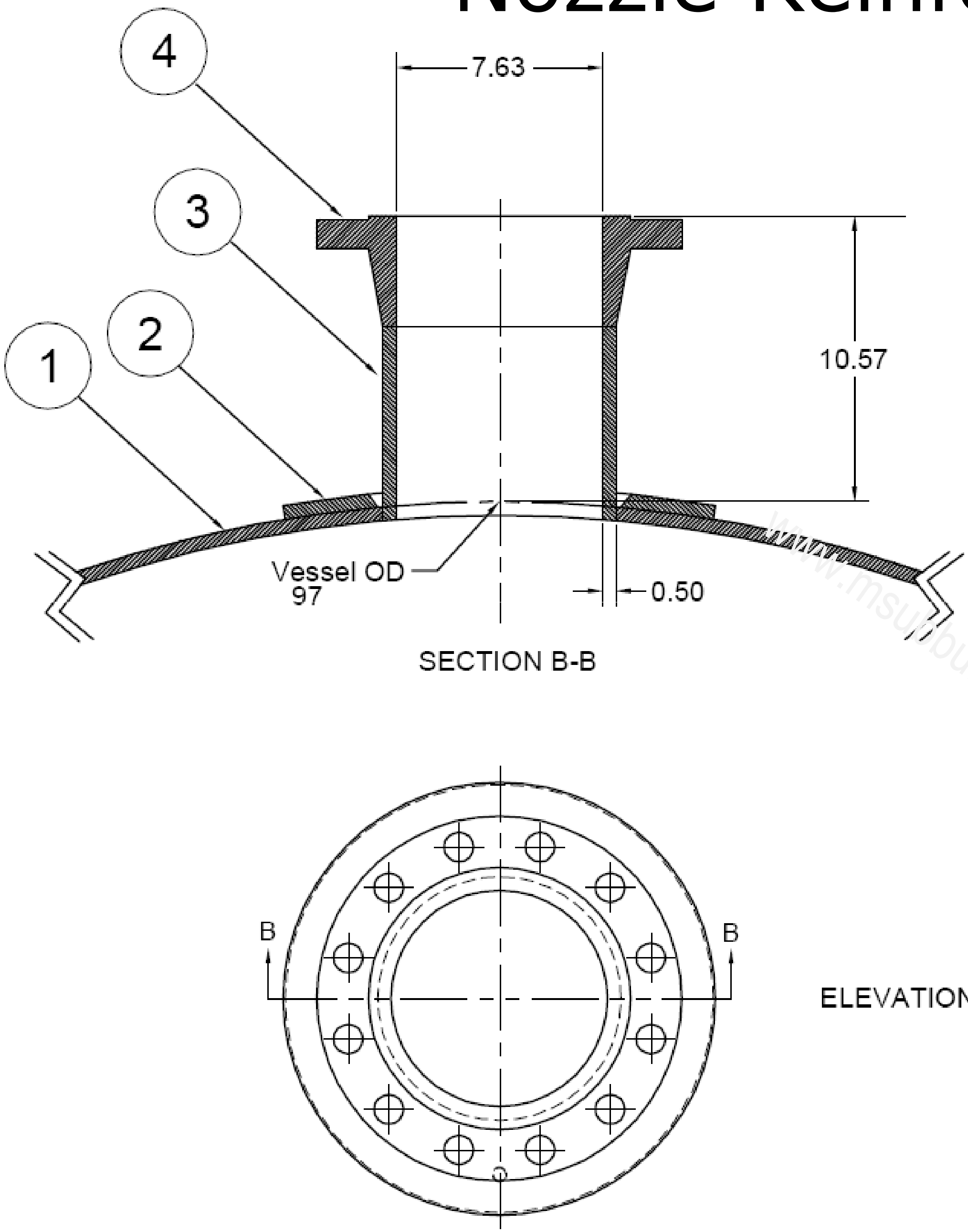




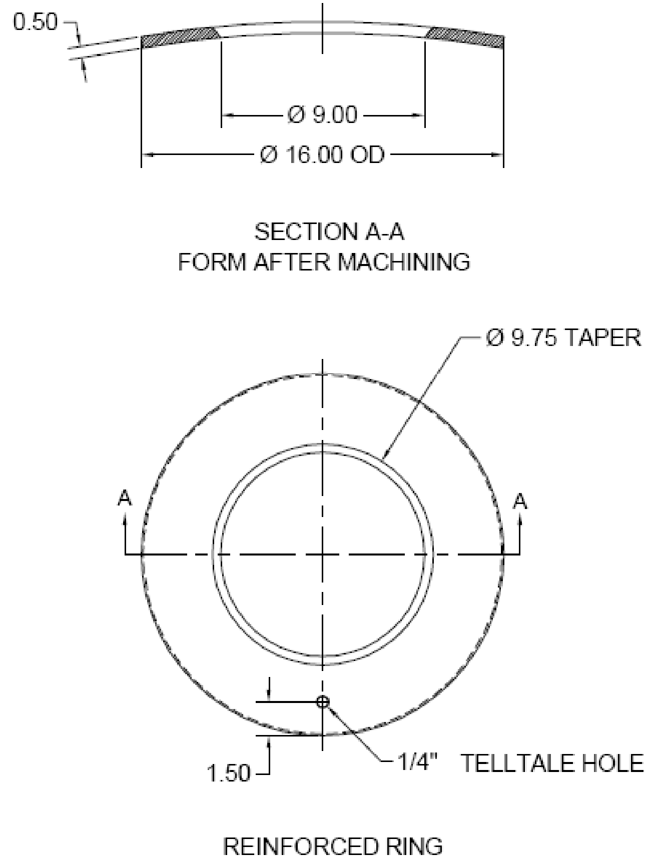


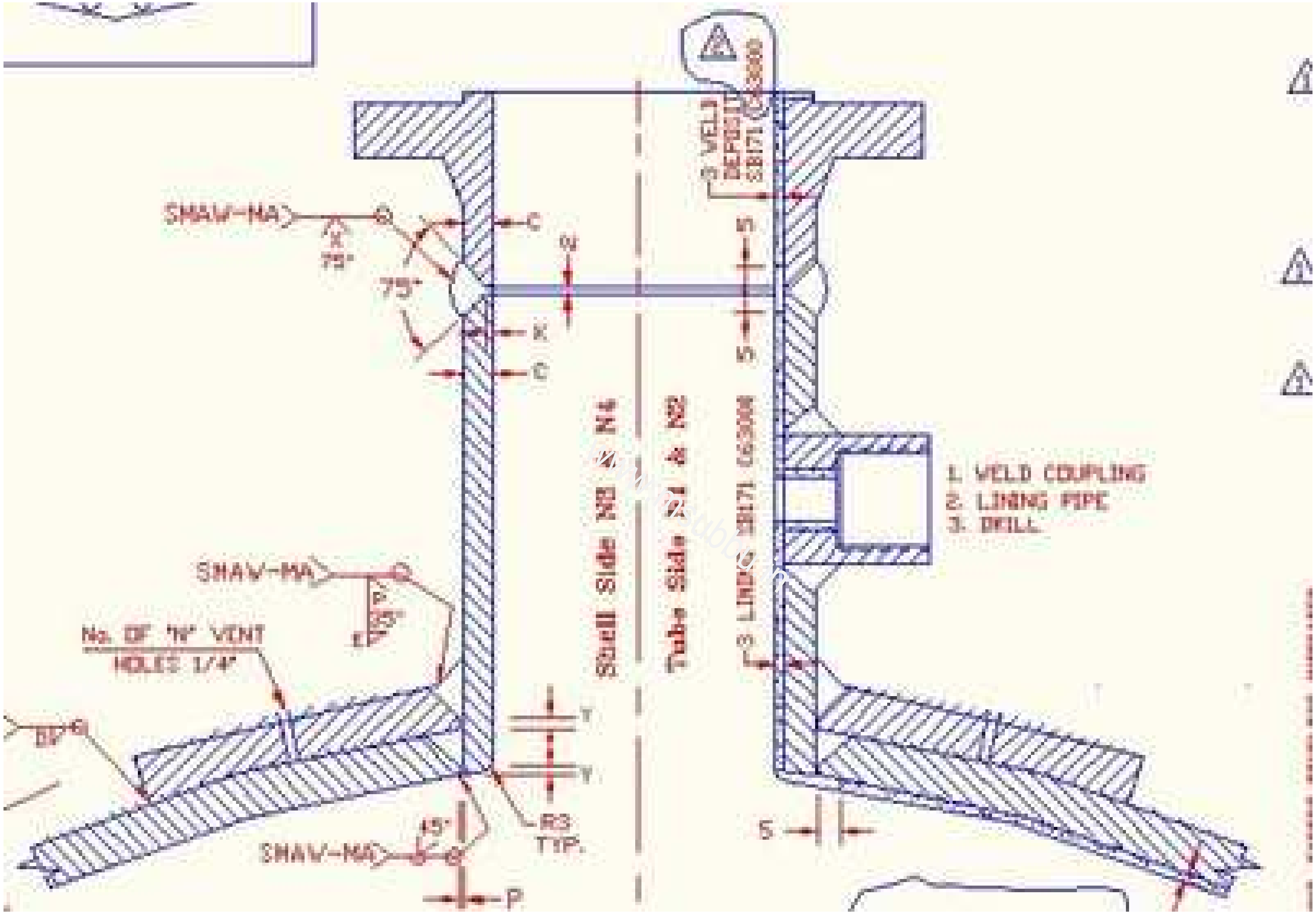


Nozzle Reinforcement



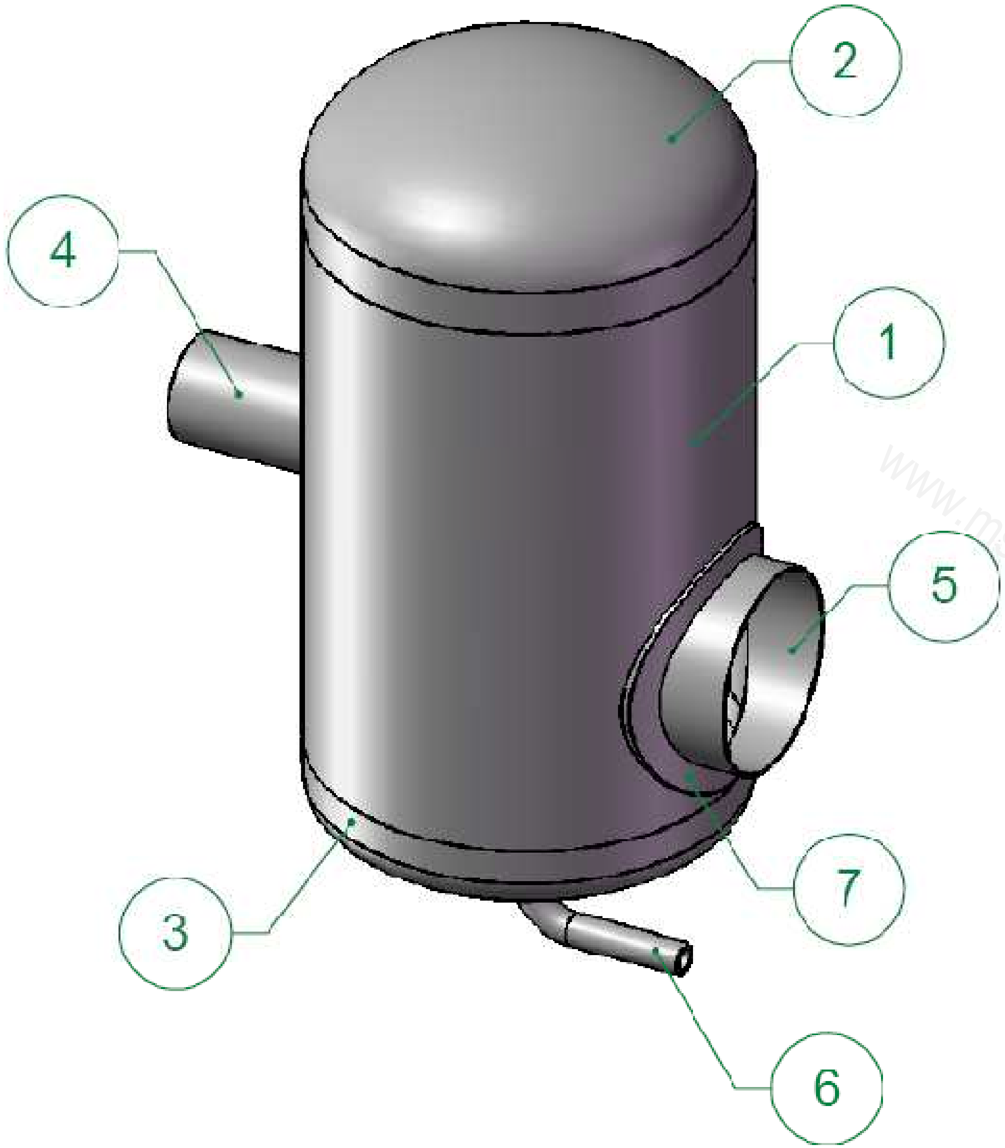
ELEVATION

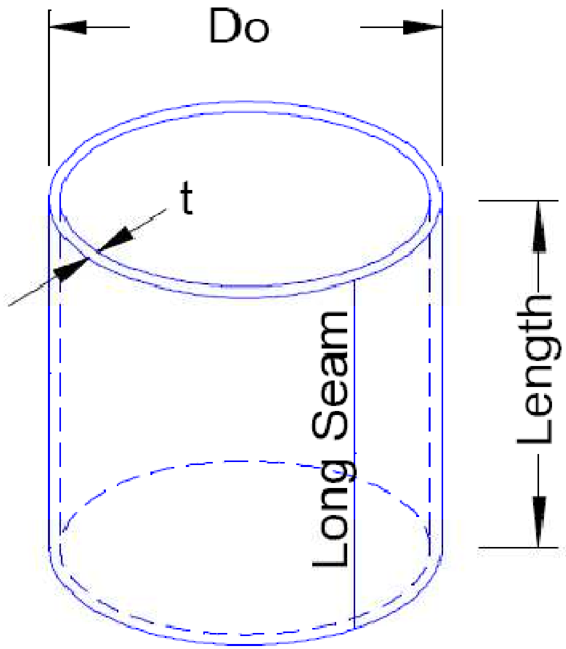


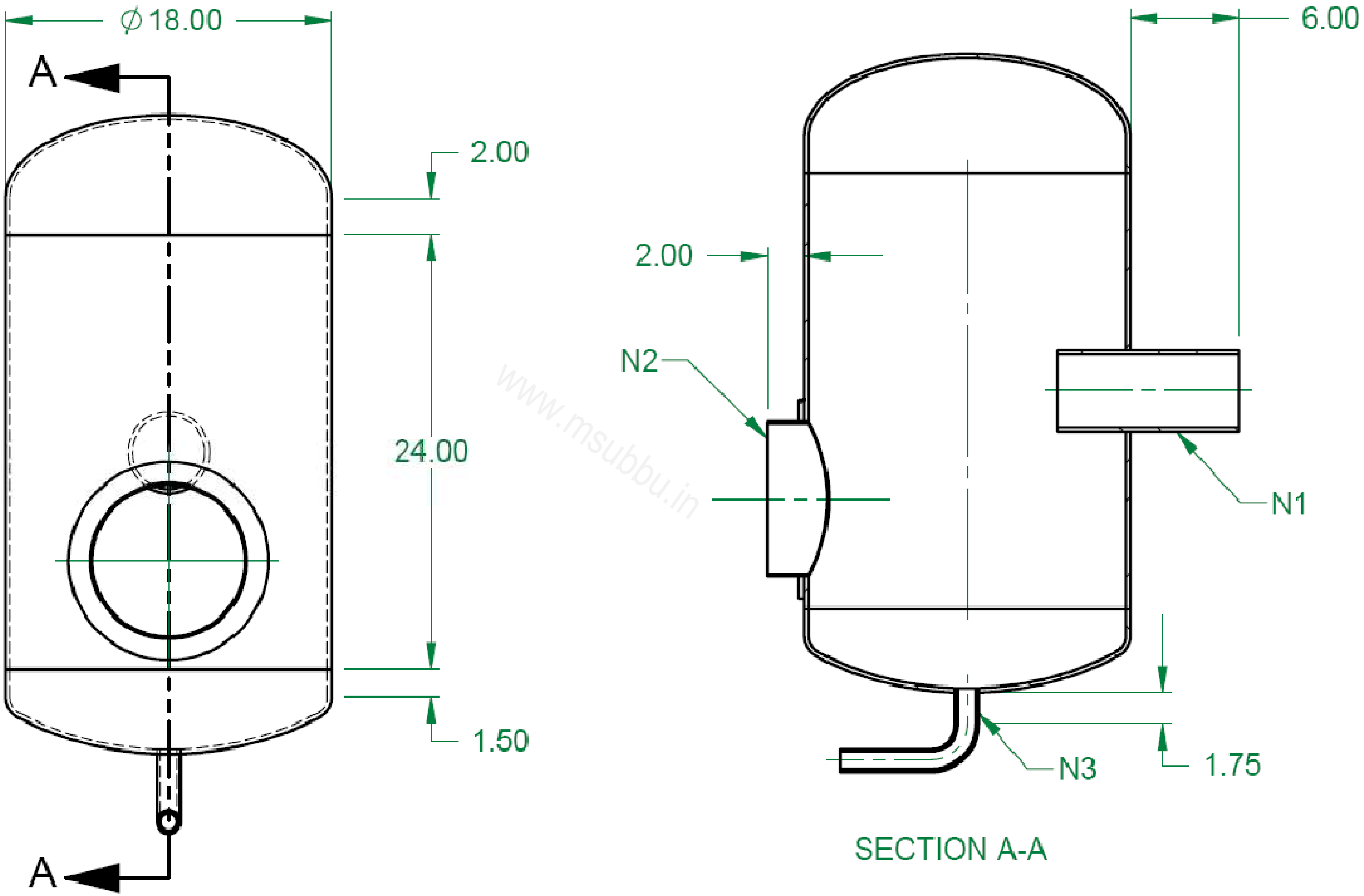

SMAW-MA
75°
C
K
SMAW-MA
No. OF "N" VENT
HOLES 1/4"
R3
TYP.
P
Y
5
Shell Side N3 & N4
Tube Side N1 & N2
1. WELD COUPLING
2. LINING PIPE
3. DRILL

Reinforcement of Openings

- Openings must be reinforced to account for metal removed.
- Metal used to replace that removed must be equivalent in metal area


2
4
1
5
3
7
6


Do
t
Long Seam
Length



∅ 18.00
A
A
2.00
24.00
1.50
6.00
2.00
N2
N1
N3
1.75
SECTION A-A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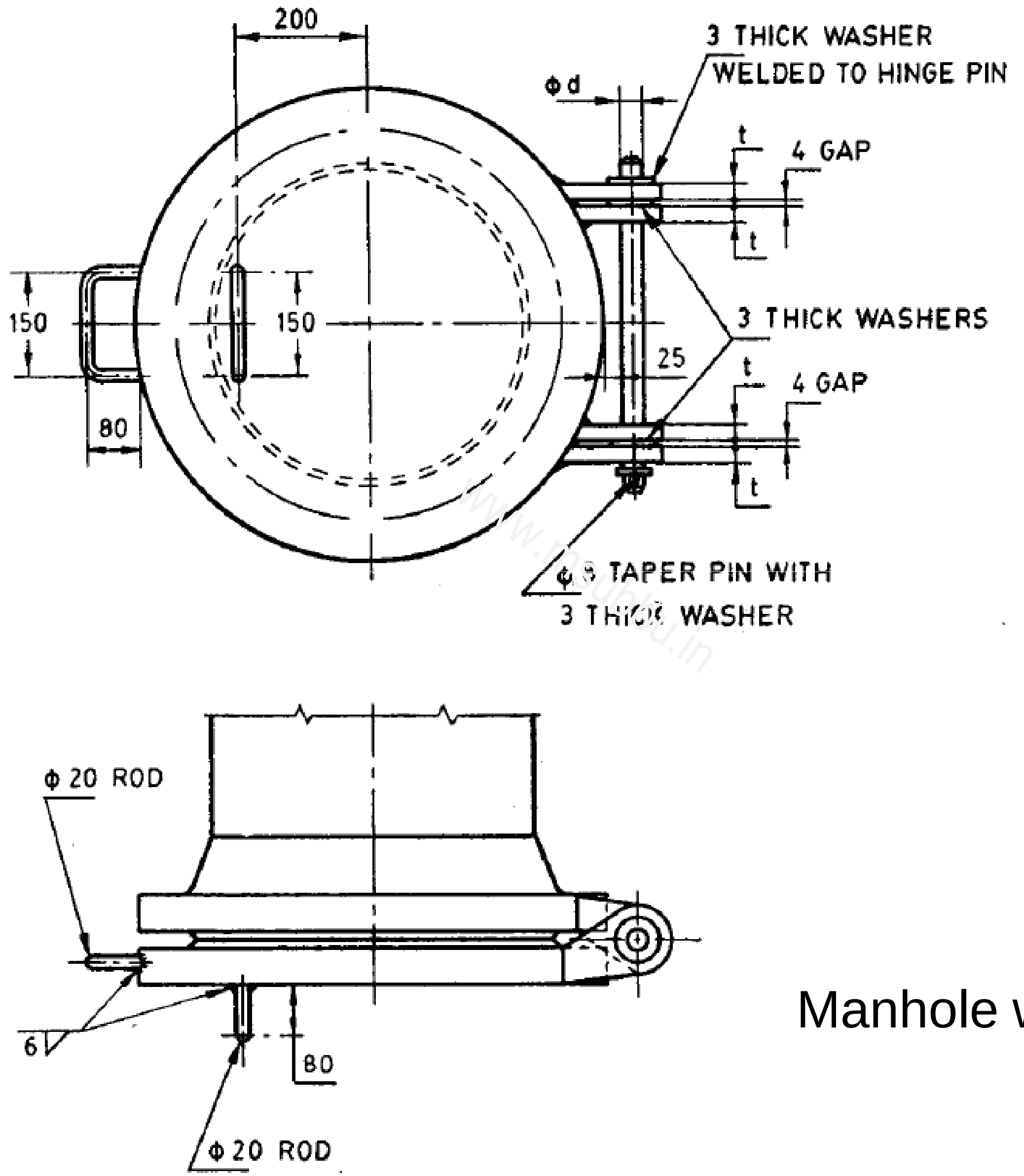
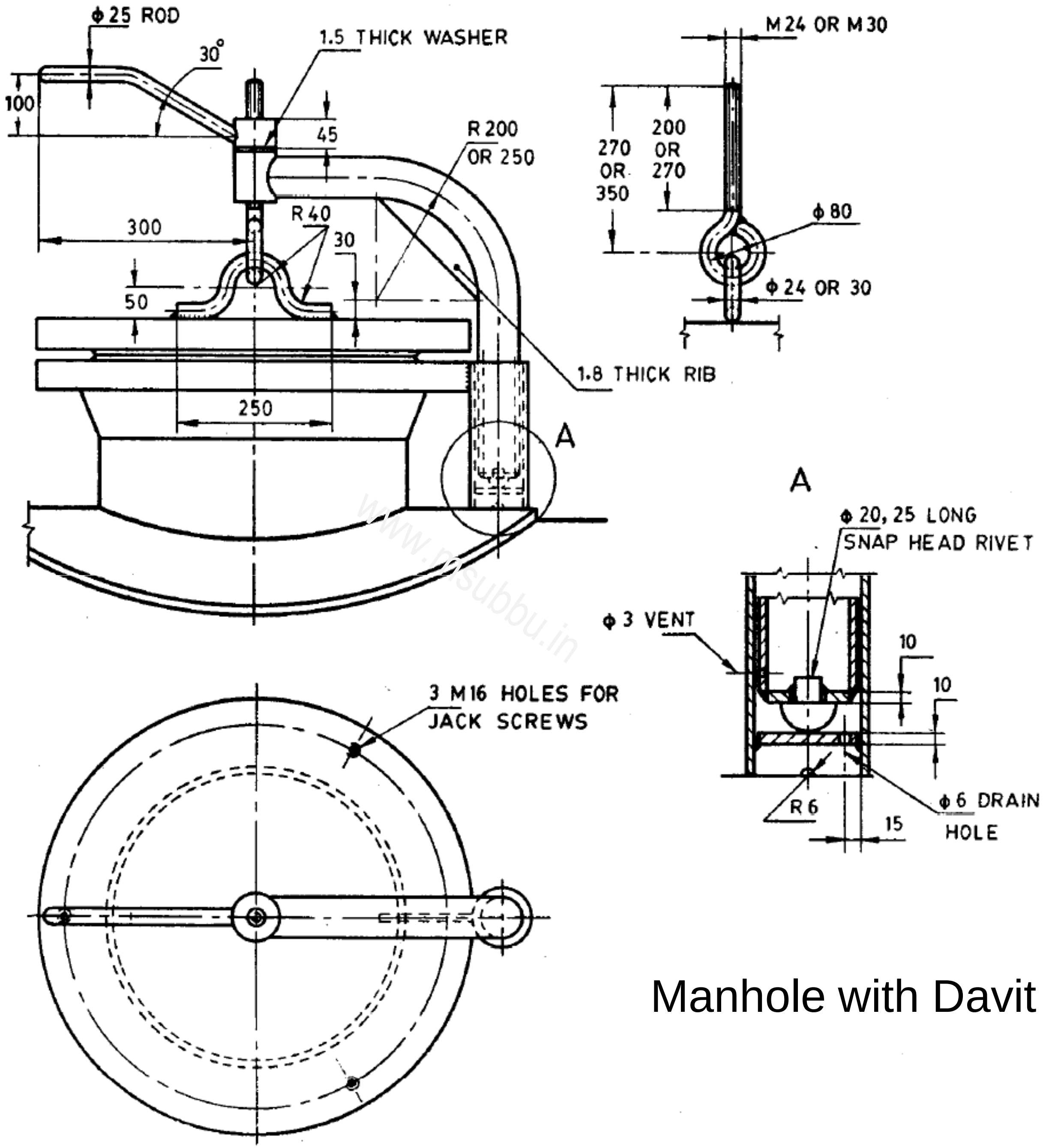


Manhole with hinge support



Manhole with Davit

巴西
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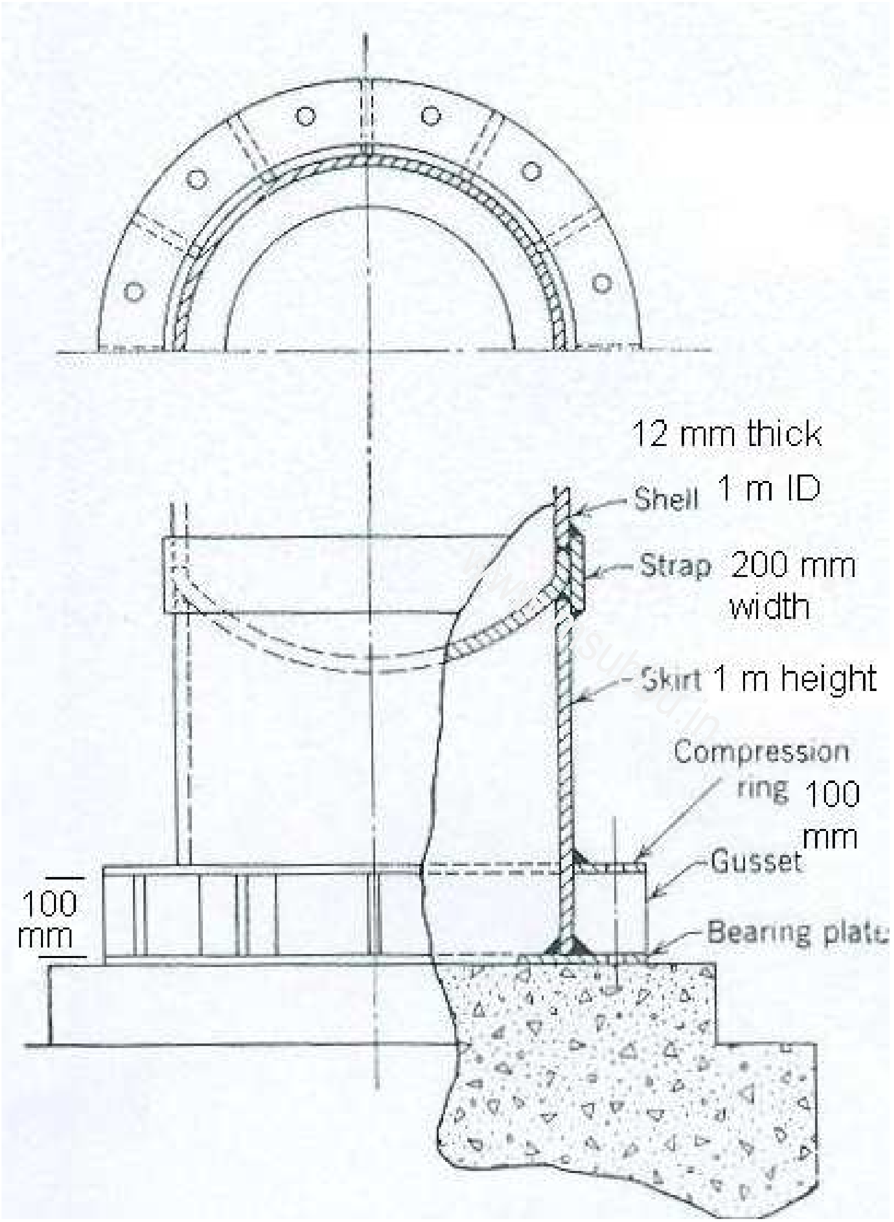
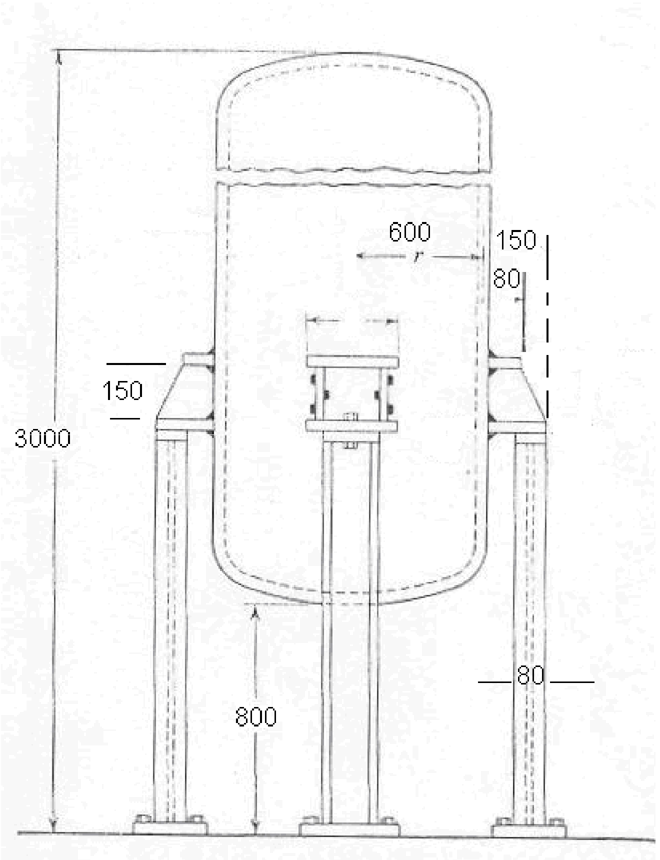
Supports to Process Vessels

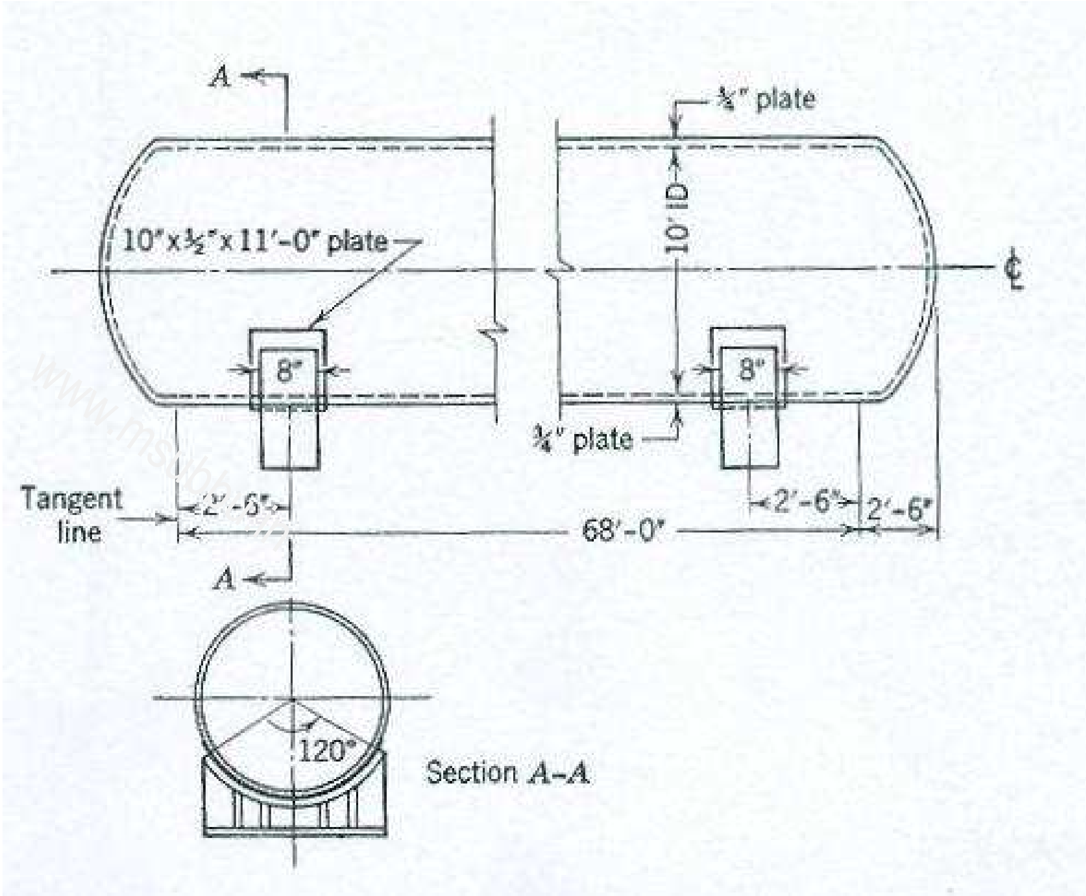
Types of Supports

- Leg support
- Lug support
- Saddle support
- Skirt support


12 mm thick
Shell 1 m ID
Strap 200 mm width
Skirt 1 m height
Compression ring 100 mm
Gusset
Bearing plate
100 mm

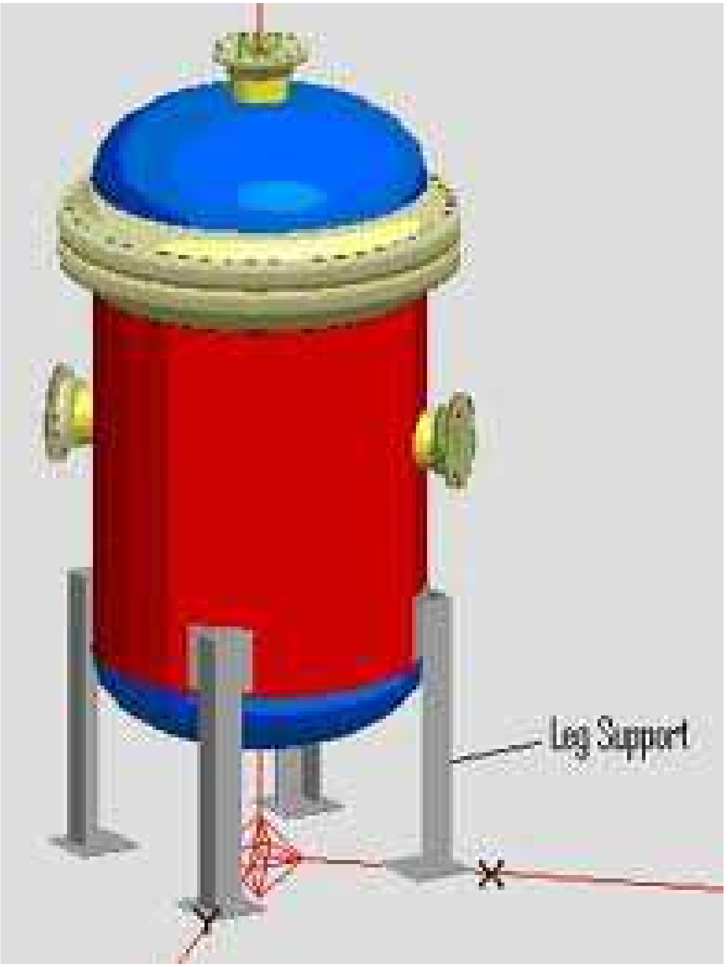


600
r
150
80
150
3000
800
80



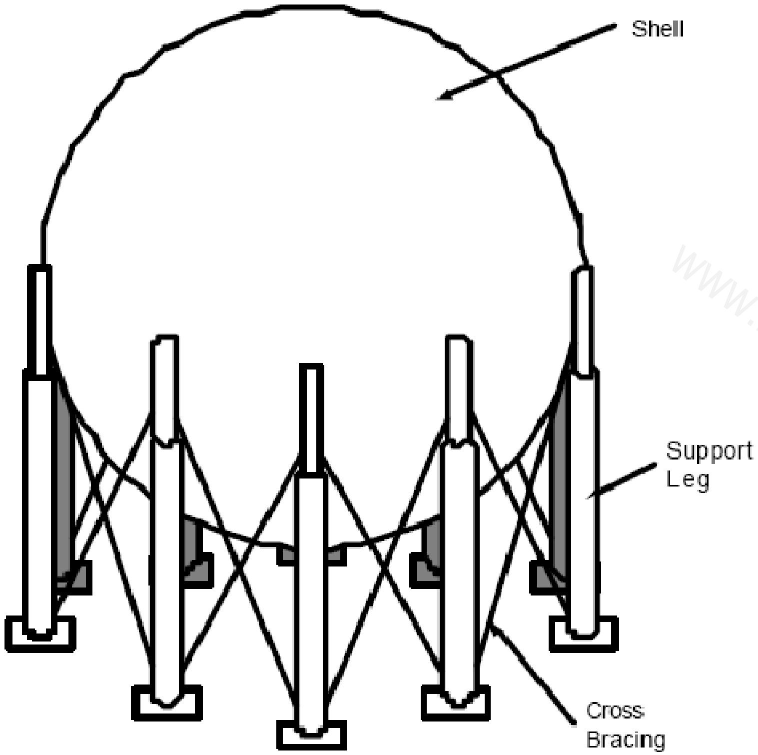
A
¾" plate
10' ID
10"x½"x11'-0" plate
℄
8"
8"
¾" plate
Tangent line
2'-6"
2'-6"
2'-6"
68'-0"
A
120°
Section A–A

Leg support



- Small vertical pressure vessel leg at the bottom of the shell.
- Ring reinforcement pad to provide additional reinforcement of local and load distribution, where the local stresses that occur
- The sum of the leg is needed depends on size and weight received vessel.
- Support leg is also commonly used in pressurized spherical storage vessels.


MUELLER



- Spherical storage vessels typically supported on legs.
- Cross-bracing typically used to absorb wind and earthquake loads.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Lug Support

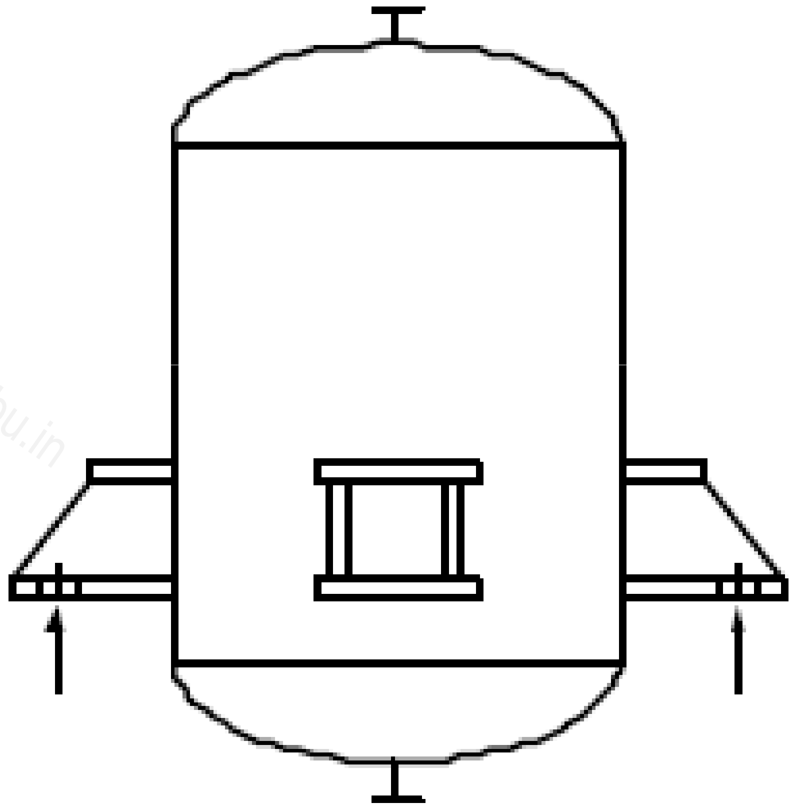
- Vessel size limits for lug supports:

  1 – 10 ft diameter

  2:1 to 5:1 height/diameter ratio

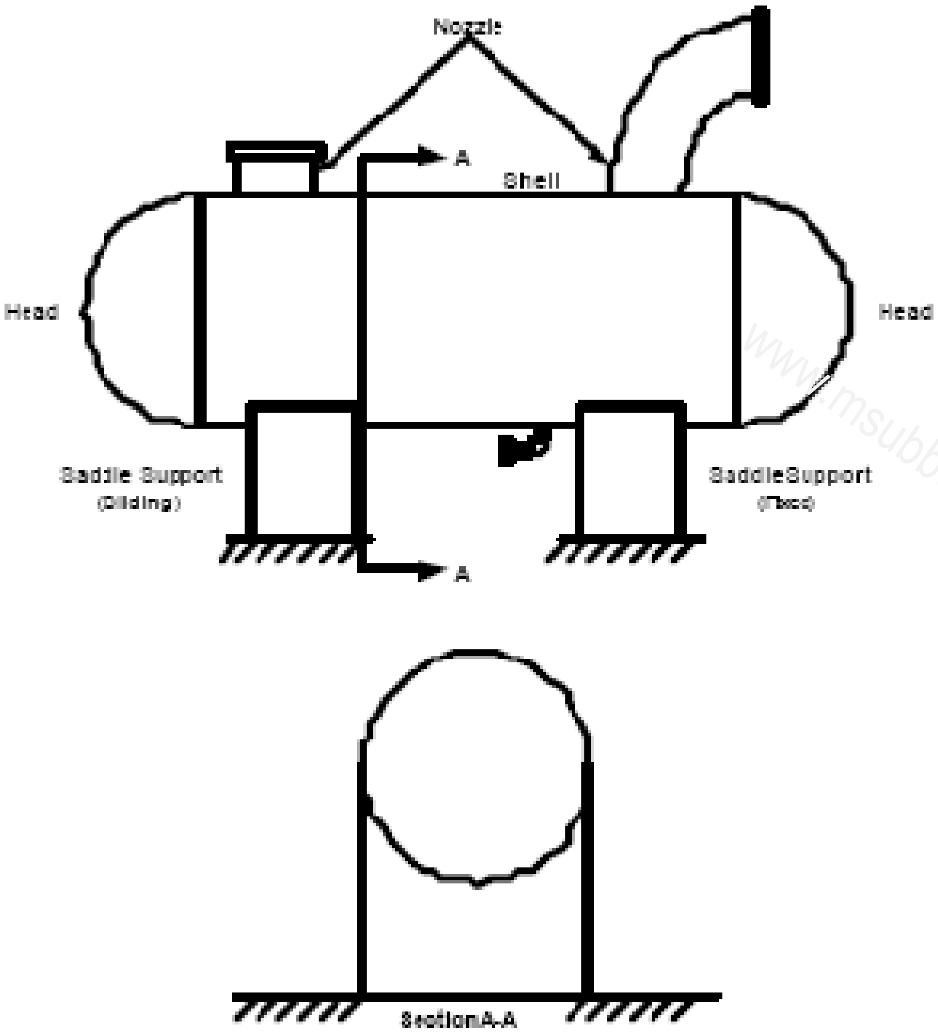
- Lugs bolted to horizontal structure.

- Bolt holes are often given the gap to provide radial thermal expansion of freedom in the vessel.



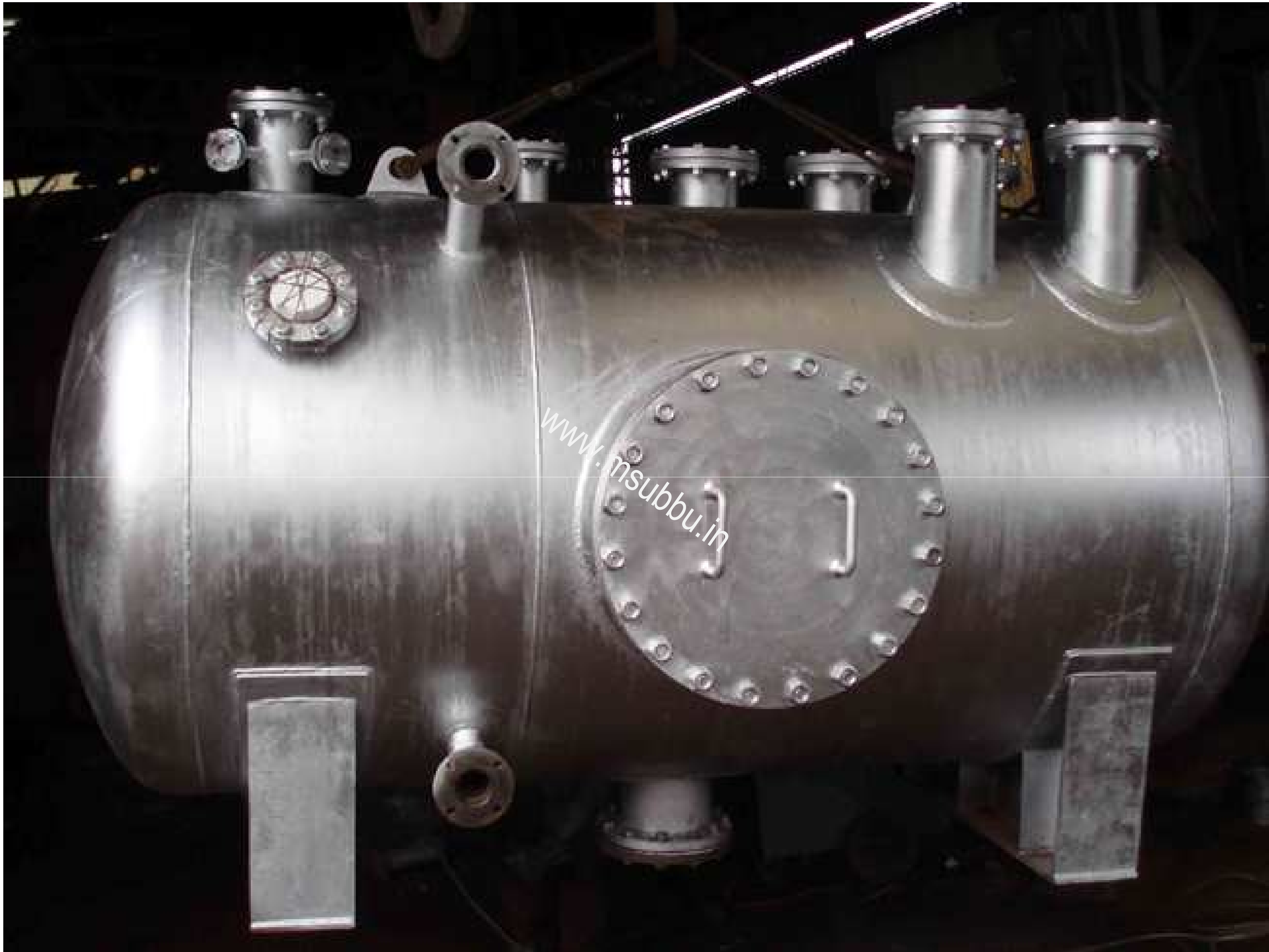

客户至上 质量为本

Saddle Support

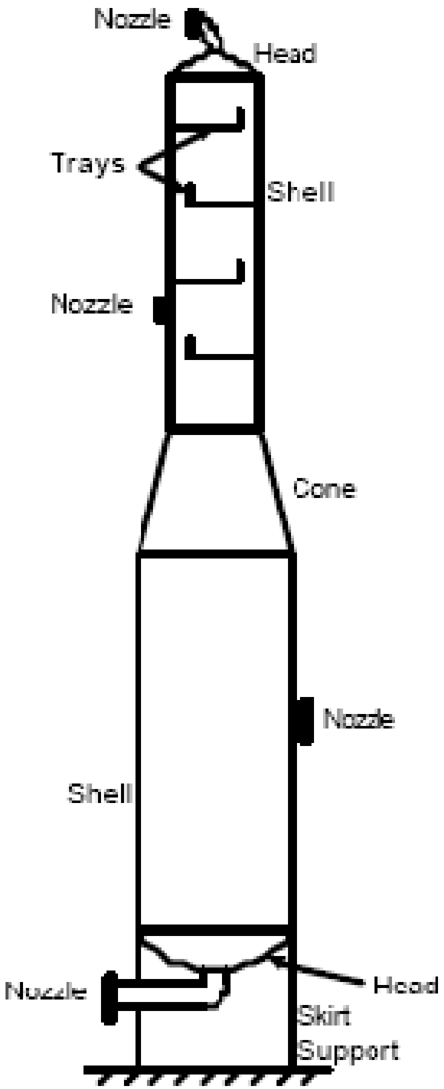


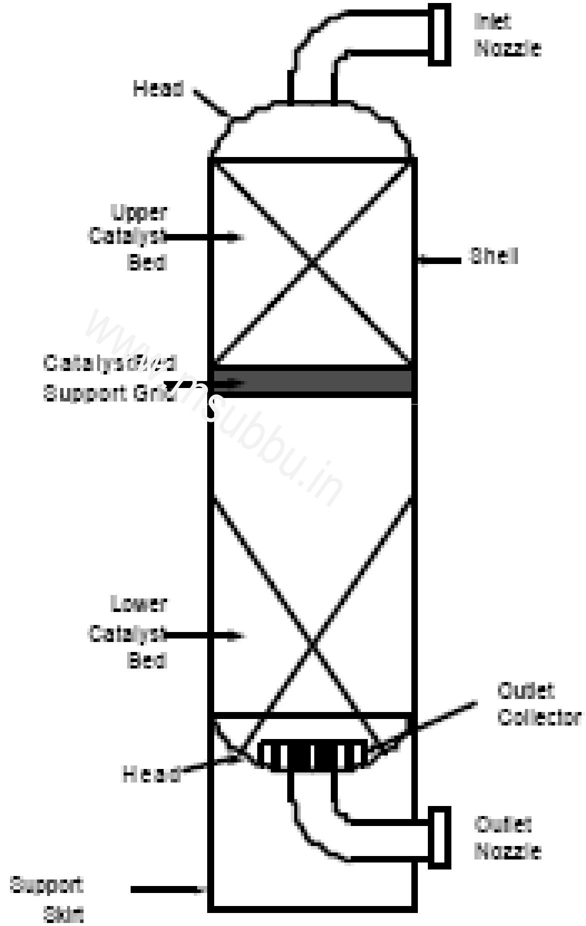
Saddle Support

- Saddle supports used for horizontal drums.
  - Spreads load over shell.
  - One support fixed, other slides.



Skirt Support



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Skirt Support

- Skirt supports typically used for tall vertical vessels
- Designed for weight, wind, earthquake. Pressure not a factor.

Pressure Vessel Design

- ASME Section VIII is most widely used Code.
- Assures safe design.

Materials of Construction

- Plate Materials:
  - Mild Steel: A-36, A-516 Gr 60, 70,
  - Stainless Steel: 304, 316, 304L, 316L

- Pipe Materials – A106,

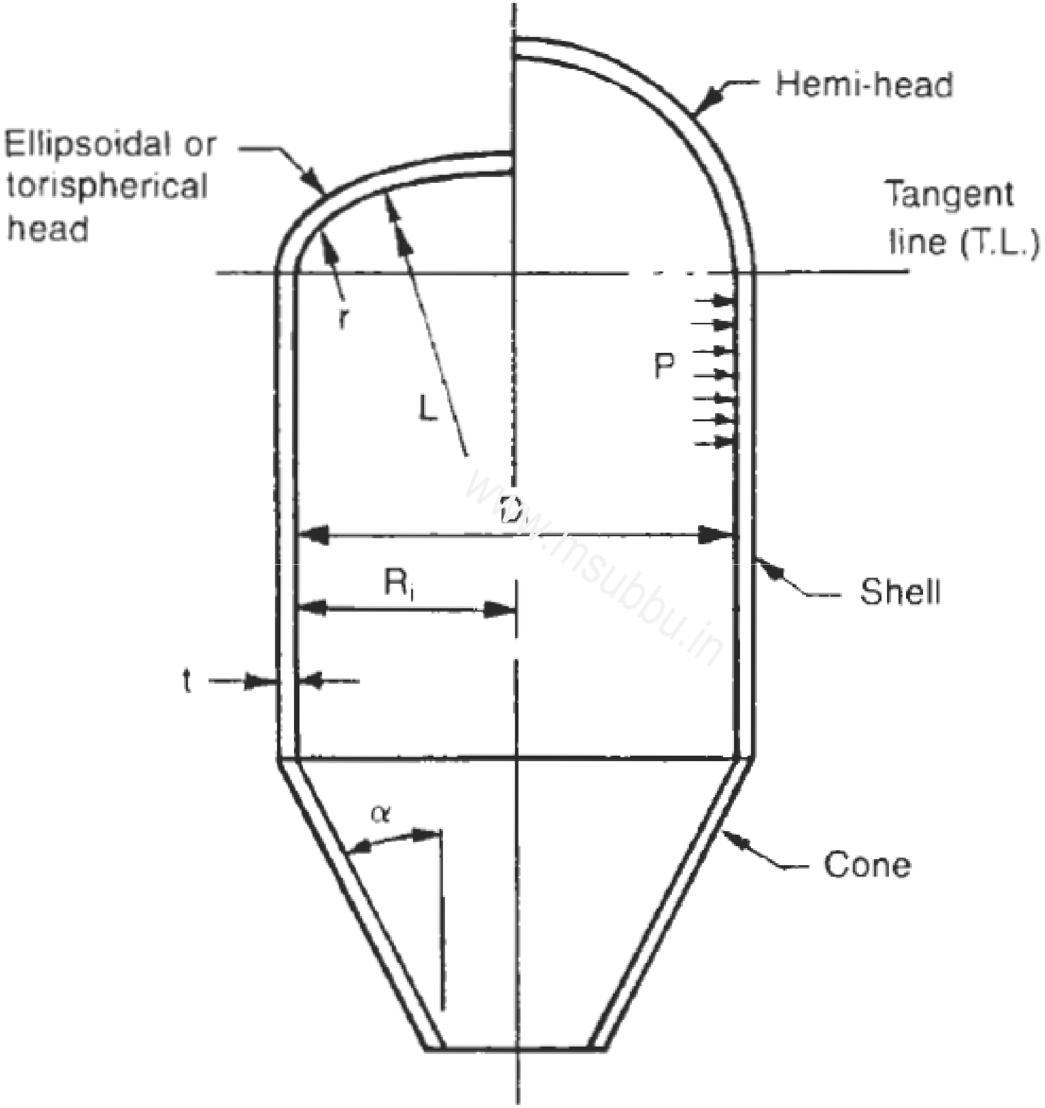
- Forgings – A105,

SS 304	18 - 20 % Cr, 8 - 12 % Ni, 0.08% (max) C	18-8 stainless steel, most commonly used material for process equipments
SS 304L	18 - 20 % Cr, 8 - 12 % Ni, 0.03% (max) C	Low carbon version of SS 304
SS 316	16 - 18 % Cr, 10 - 14% Ni, 2 - 3 % Mo, 0.1% (max) C	Addition of molybdenum improves resistance to chloride environments.
SS 316L	16 - 18 % Cr, 10 - 14% Ni, 2 - 3 % Mo, 0.03% (max) C	Low carbon version of SS 316
SS 430	14 - 18 % Cr, 0.5% Ni	Tableware. The first chemical plant application of stainless steel was SS 430 tank-car for shipping nitric acid.

Titanium - wet chlorine: The industries like paper, textile, plastics and detergents, which use wet chlorine and bleaching agents have started using titanium equipment for extended life of their plant and equipment.

– Should not be used with dry chlorine

Nickel: Most tough corrosion problems involving caustic and caustic solutions are handled with nickel. Corrosion resistance to caustic is almost directly proportional to the nickel content of an alloy.



Hemi-head
Ellipsoidal or torispherical head
Tangent line (T.L.)
r
L
P
D
R
t
Shell
α
Cone

Thickness of Pressure Vessels

- Cylindrical vessel
  - Longitudinal stress:

$$t = \frac{pd}{4fJ}$$

  - Circumferential stress:

$$t = \frac{pd}{2fJ}$$

where t = thickness of shell
d = diameter of cylinder
p = design pressure
f = allowable stress
J = joint efficiency

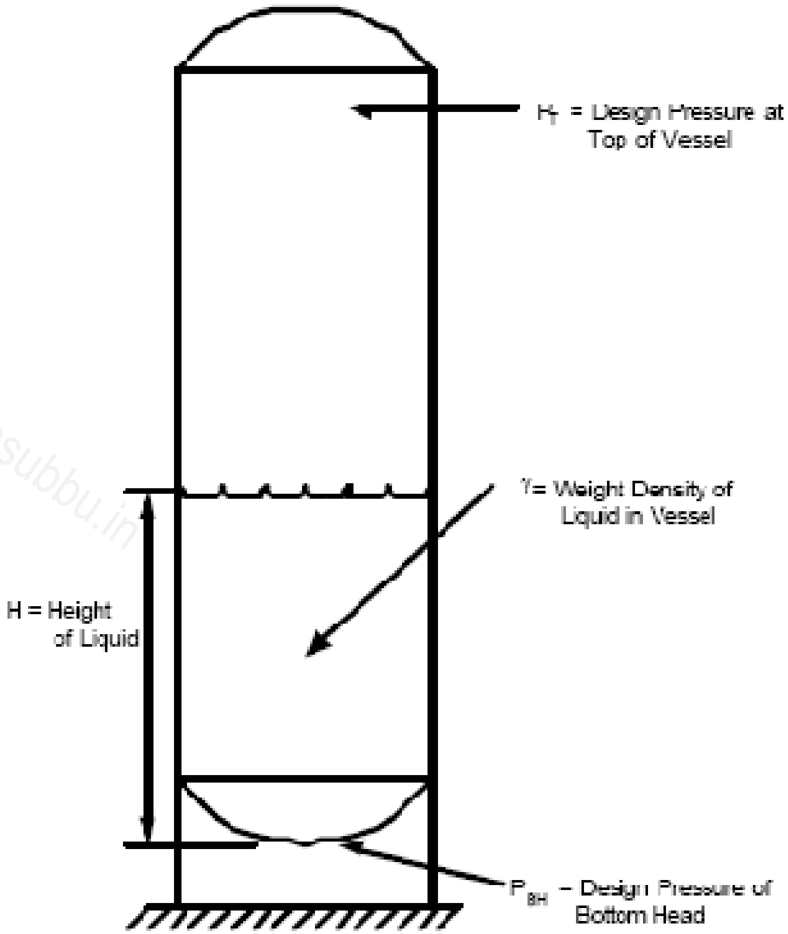
Circumferential stress is the controlling stress; and cylindrical shell is designed based on the circumferential stress formula.

- Spherical vessel

$$t = \frac{pd}{4fJ}$$

Design Pressure

- May have internal of external pressure, or both at different times.
- Must have margin between maximum operating pressure at top of vessel and design pressure.
- Hydrostatic pressure of operating liquid (if present) must be considered at corresponding vessel elevation.



Design Pressure

- For vessels under internal pressure, the design pressure is normally taken as the pressure at which the relief device is set. This will normally be 5 to 10 per cent above the normal working pressure, to avoid spurious operation during minor process upsets.
- Vessels subject to external pressure should be designed to resist the maximum differential pressure that is likely to occur in service.

Additional Loadings

Loadings other than pressure and temperature:

- Weight of vessel and normal contents under operating or test conditions
- Superimposed static reactions from weight of attached items (e.g., motors, machinery, other vessels, piping, linings, insulation)
- Loads at attached internal components or vessel supports
- Wind, snow, seismic reactions

Joint Efficiency

- 1, 0.85, 0.7

- **Joint Efficiency**

No radiography	:	70%
Spot radiography	:	85%
100% radiography	:	100%

Joint efficiency is 100% for seamless heads.

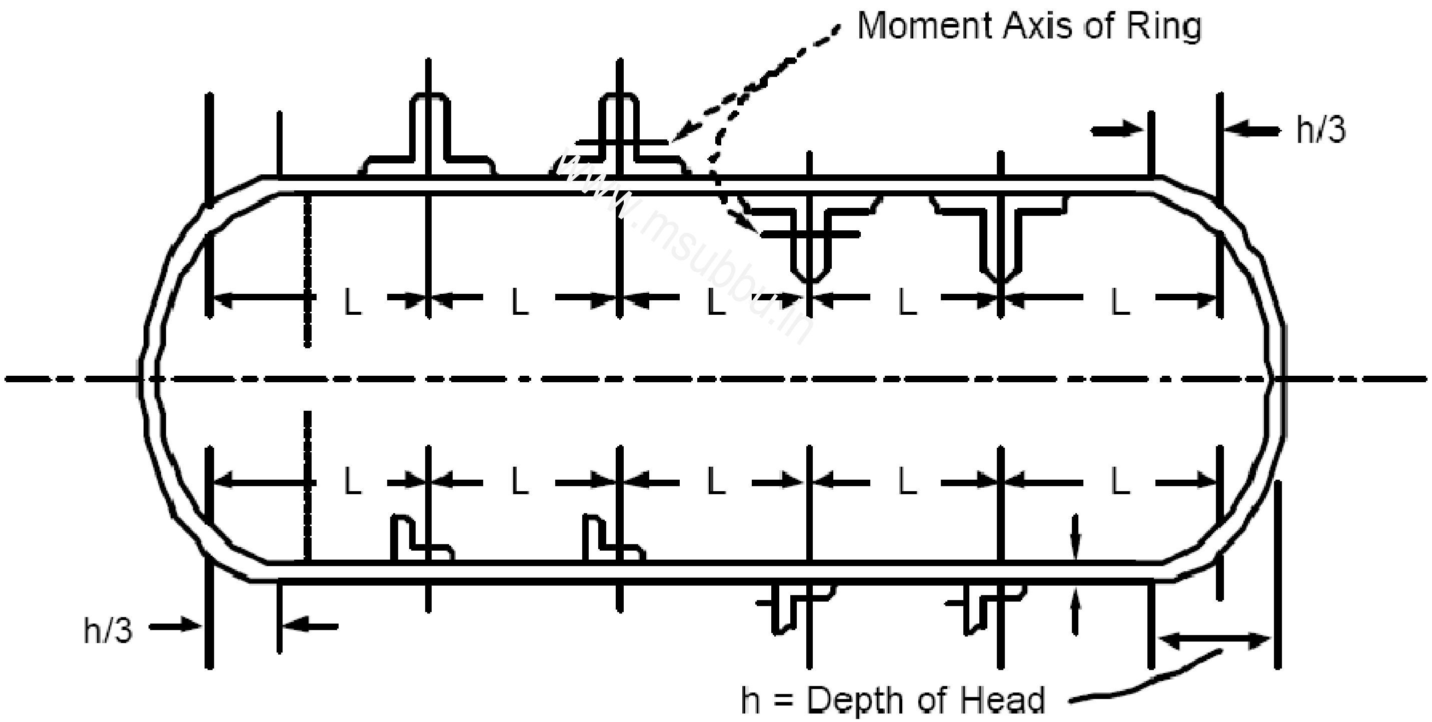
Corrosion Allowance

- The corrosion allowance must be added to the calculated thickness.

Design for External Pressure and Compressive Stresses

- Compressive forces caused by dead weight, wind, earthquake, internal vacuum
- Can cause elastic instability (buckling)
- Vessel must have adequate stiffness
  - Extra thickness
  - Circumferential stiffening rings

Stiffener Rings



Design for Internal Pressure

- Inside Diameter - 10′ - 6″
- Design Pressure - 650 psig
- Design Temperature - 750°F
- Shell & Head Material - SA-516 Gr. 70
- Corrosion Allowance - 0.125 in.
- 2:1 Semi-Elliptical heads, seamless
- 100% radiography
- Vessel in vapor service

Design – as per codes

- For shell $t_p = \dfrac{Pr}{SE_1 - 0.6P}$

  P = 650 psig

  r = 0.5 × D + CA

  = (0.5 × 126) + 0.125 = 63.125 in.
- S = 16,600 psi, Figure 3.3 for SA-516 Gr. 70
- E = 1.0, Figure 4.8 for 100% radiography

$$t_p = \frac{650 \times 63.125}{(16{,}600 \times 1.0) - (0.6 \times 650)} = 2.53\,\text{in.}$$

Add corrosion allowance

$$t_p = 2.53 + 0.125 = 2.655 \text{ in.}$$

- For the heads

$$t_p = \frac{PD}{2SE - 0.2P}$$

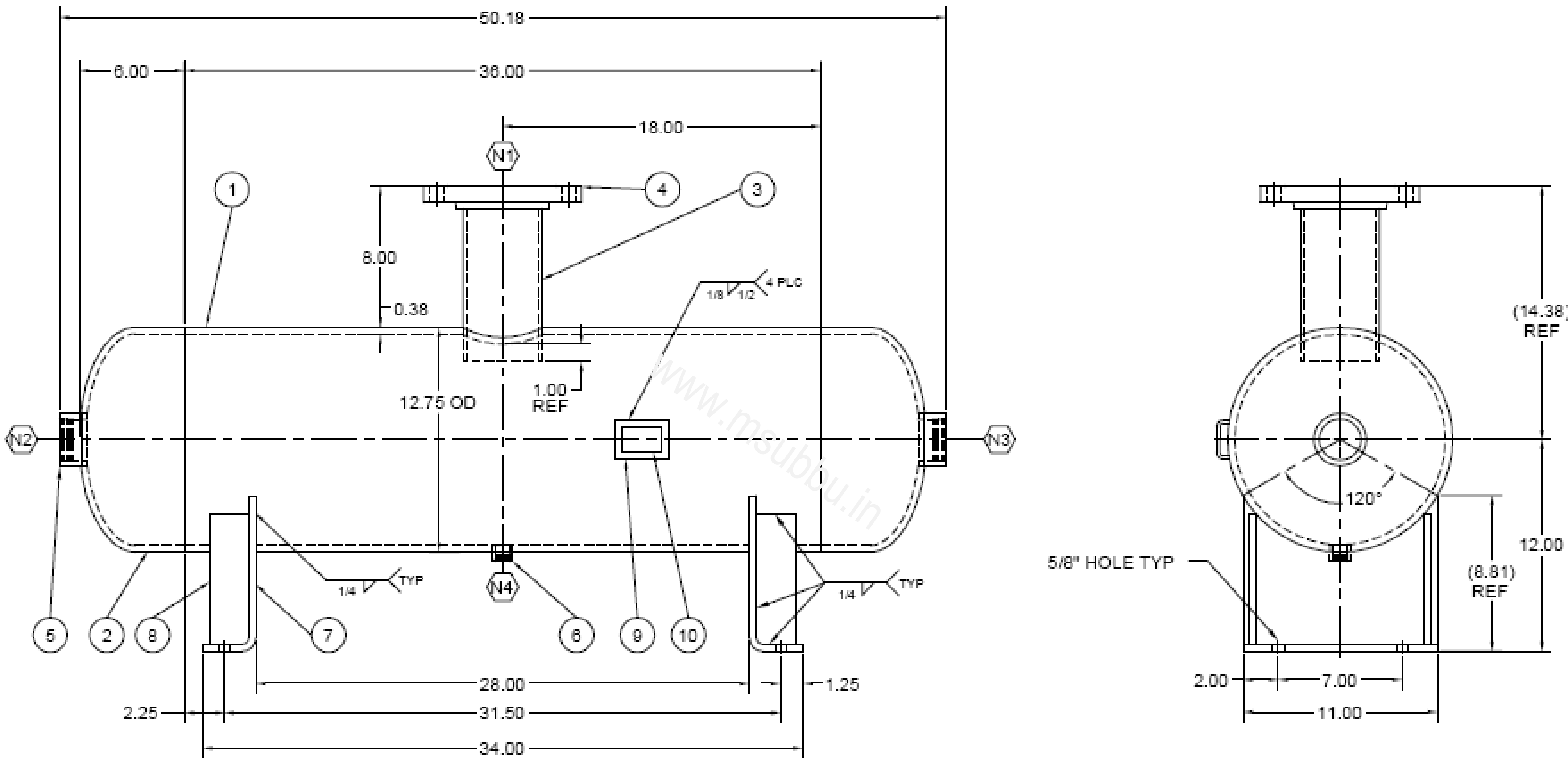
$$t_p = \frac{650(126 \times 0.9) + 0.250}{(2 \times 16{,}600) - (0.2 \times 650)} = 2.23 \text{in.}$$

Add corrosion allowance

$$t_p = 2.23 + 0.125 = 2.355 \text{ in.}$$

Design Codes

- Pressure Vessels: ASME Sec VIII, IS 2825
- Storage Tank: API 650, IS 803



SIDE ELEVATION

END VIEW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2
1


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