Mechanical Design of Chemical Process Equipments

Pressure Vessel Design

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Pressure Vessel Design

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

- IS 2825 – Indian standard code

Materials of Construction

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

- Pipe Materials – A106,

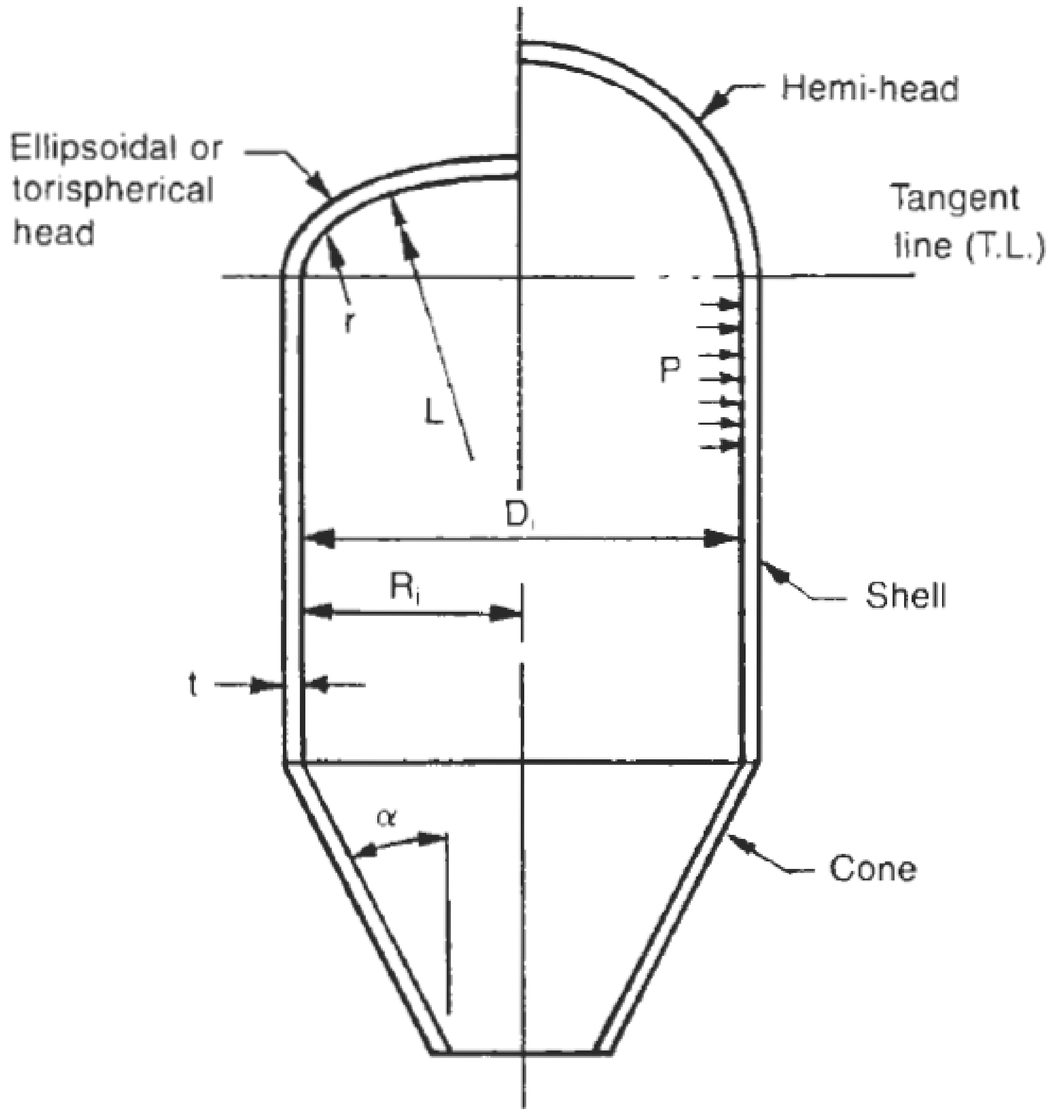
- Forgings – A105,

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
P
L
D_i
R_i
Shell
t
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

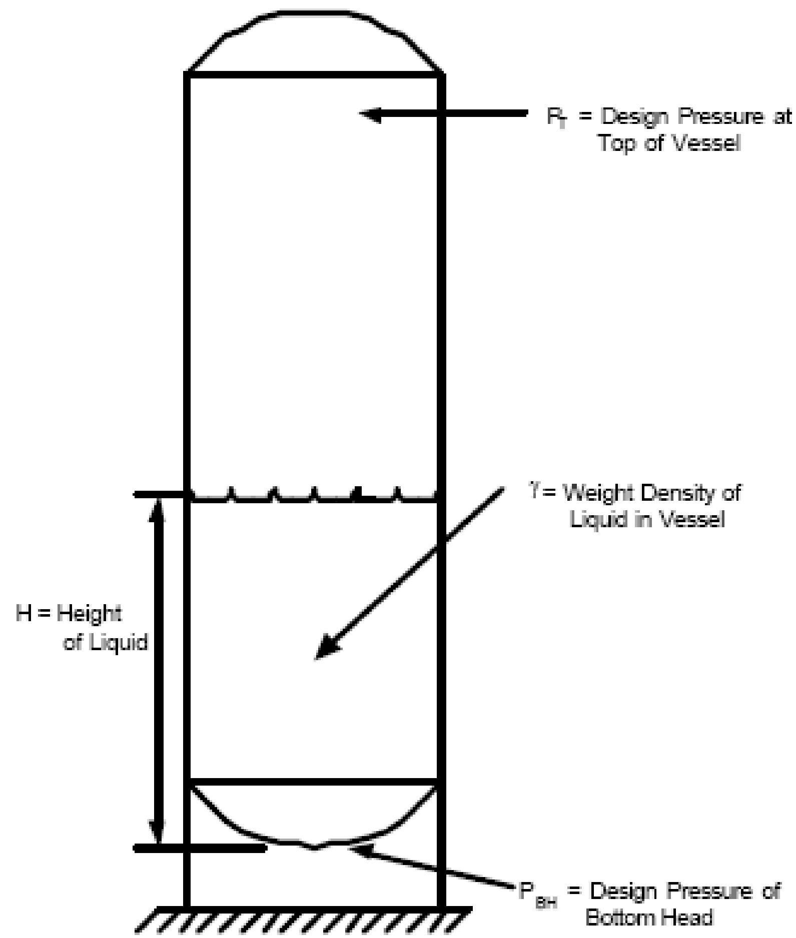
Circumferential stress is the controlling stress; and cylindrical shell is designed based on the circumferential stress formula.

- **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.

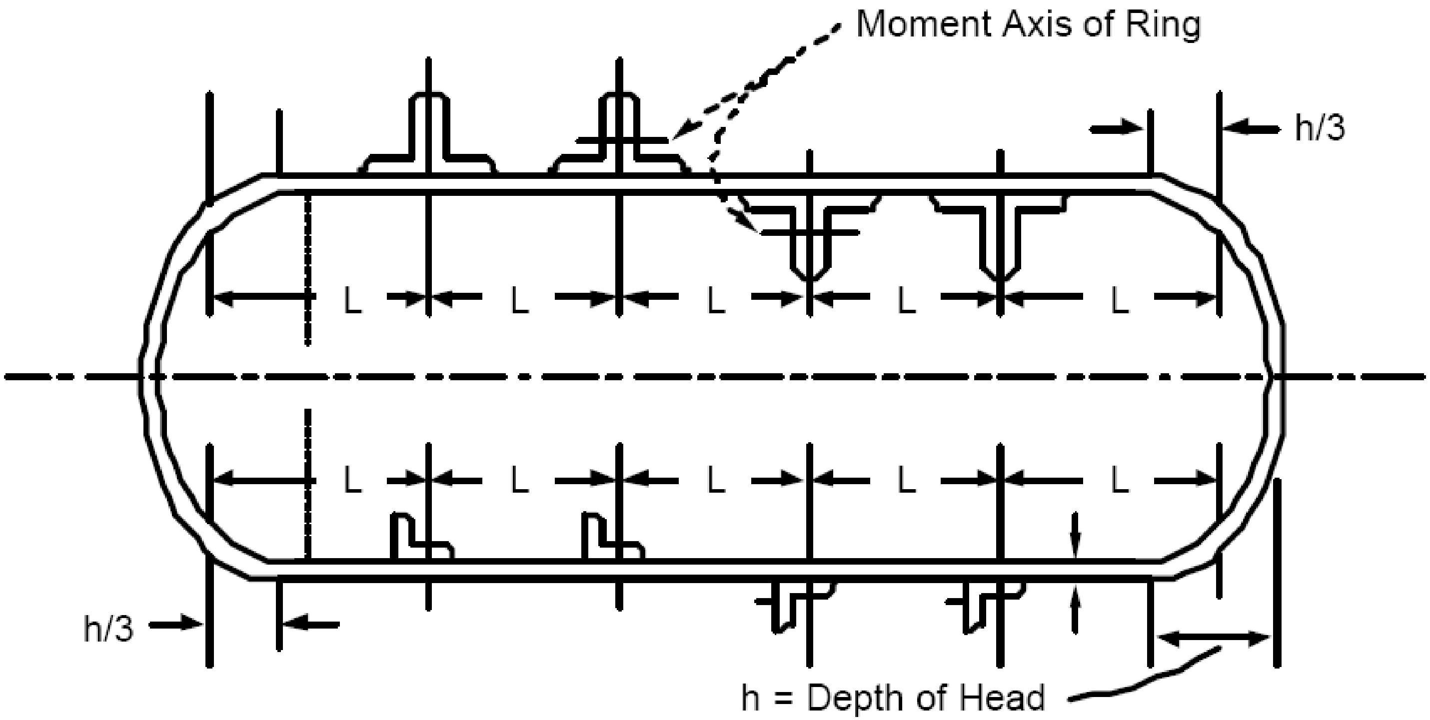
Corrosion Allowance

- 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 $t_p = \frac{Pr}{SE_1 - 0.6P}$

  P = 650 psig

  r = $0.5 \times D + CA$

  = $(0.5 \times 126) + 0.125 = 63.125$ 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

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

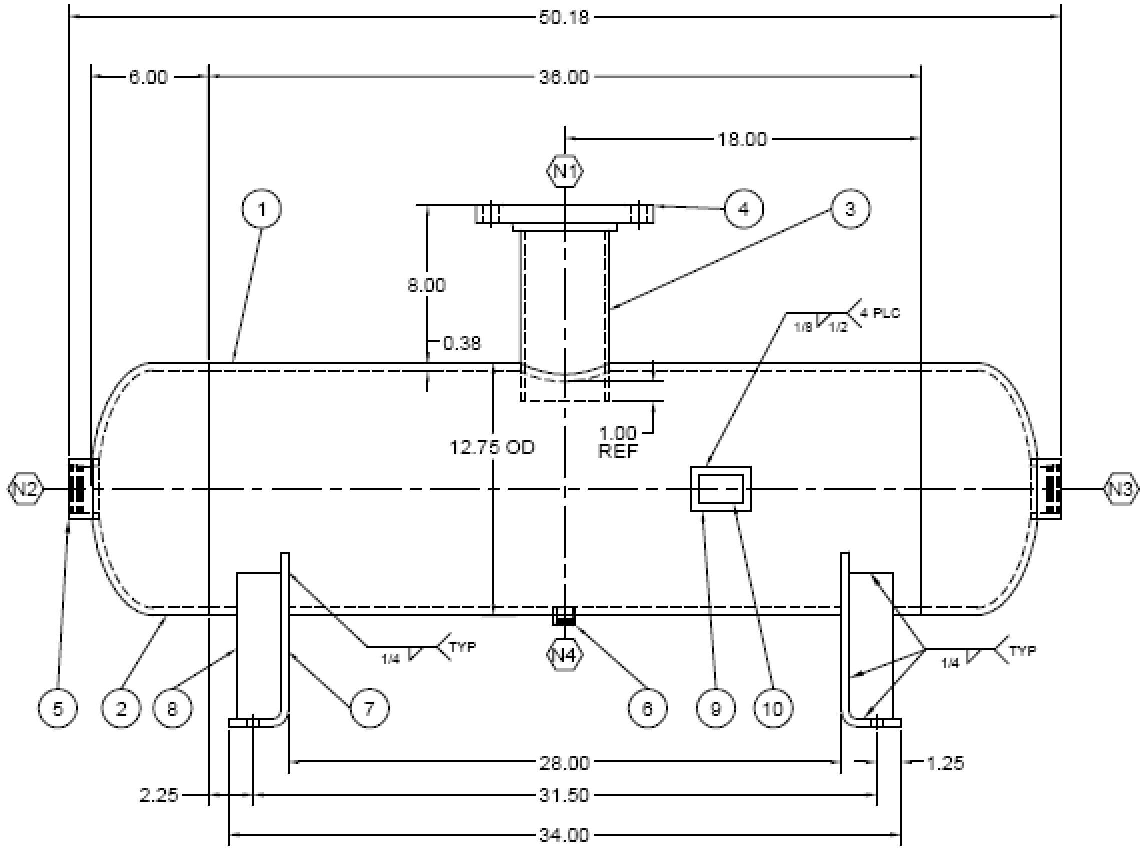
$$t_p = \frac{650(126 \times 0.9) + 0.250}{(2 \times 16{,}600) - (0.2 \times 650)} = 2.23 \text{in.}$$

Add corrosion allowance

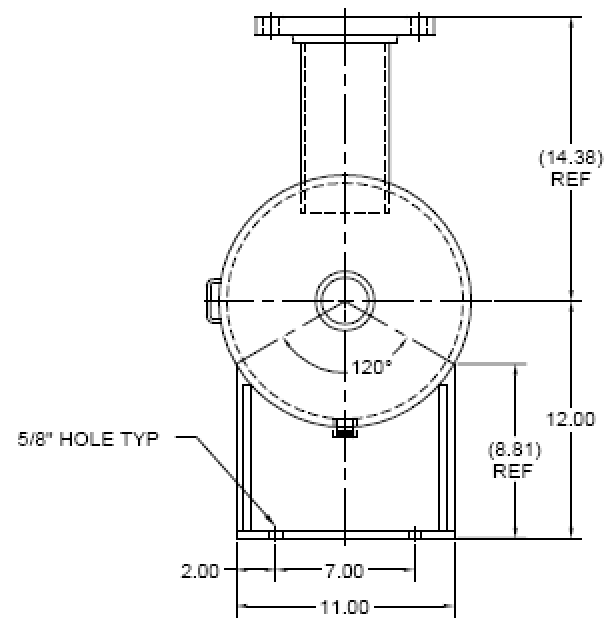
$$t_p = 2.23 + 0.125 = 2.355 \text{ in.}$$

Design Codes

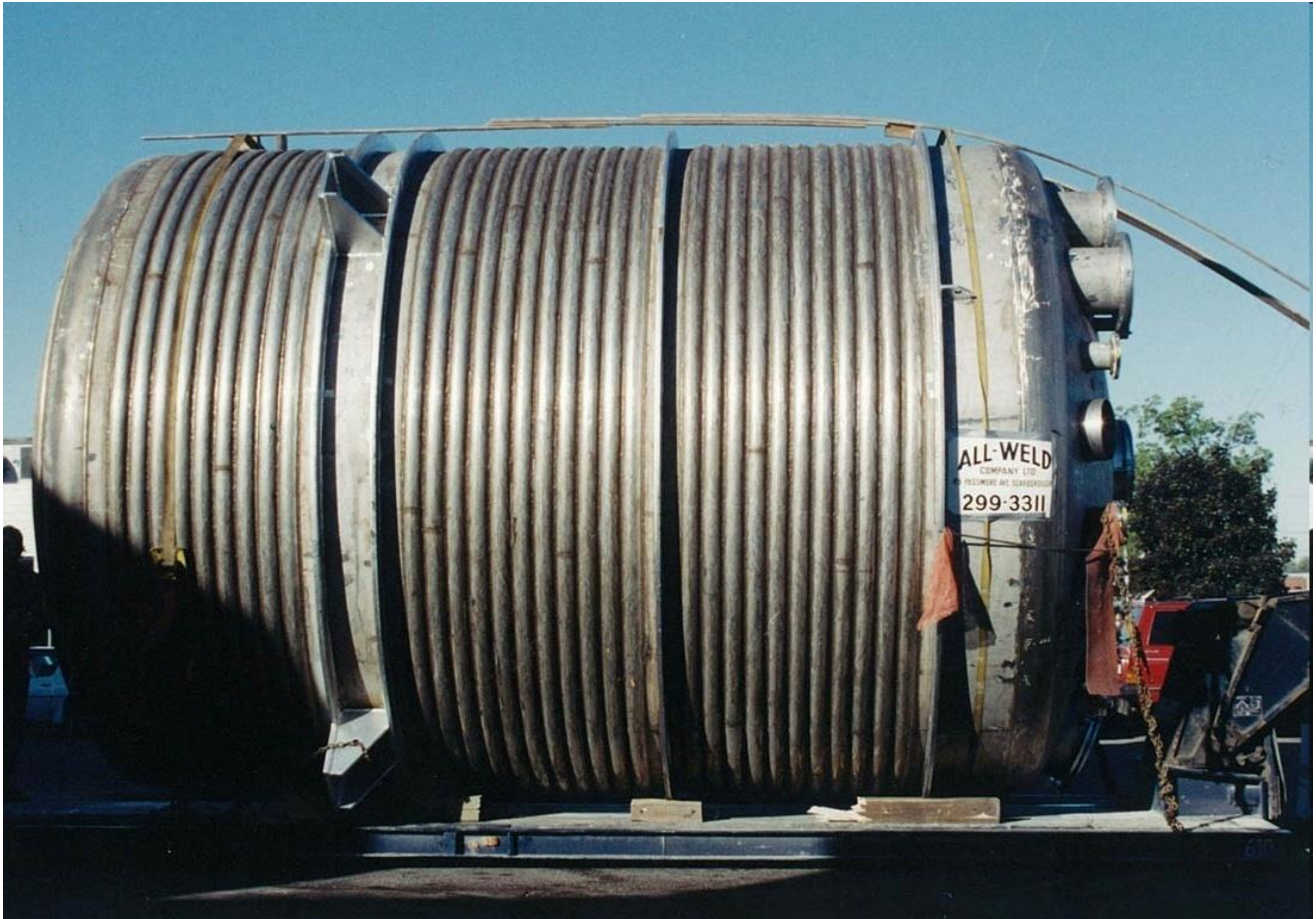
- Pressure Vessels: ASME Sec VIII, IS 2825
- Storage Tank: API 650, IS 803



SIDE ELEVATION



END VIEW


ALL-WELD
COMPANY LTD
299-3311

Storage Tanks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