CH402 Chemical Engineering Process Design

Class Notes L5

Flow Measurement

Storage of Fluids

Lesson 5 Agenda

Vessel design considerations

Homework – Problem 12-14

Flow Measurement – Orifice

Orifice Demo, CHEMCAD

Lab this week, DS (1245 Tuesday)

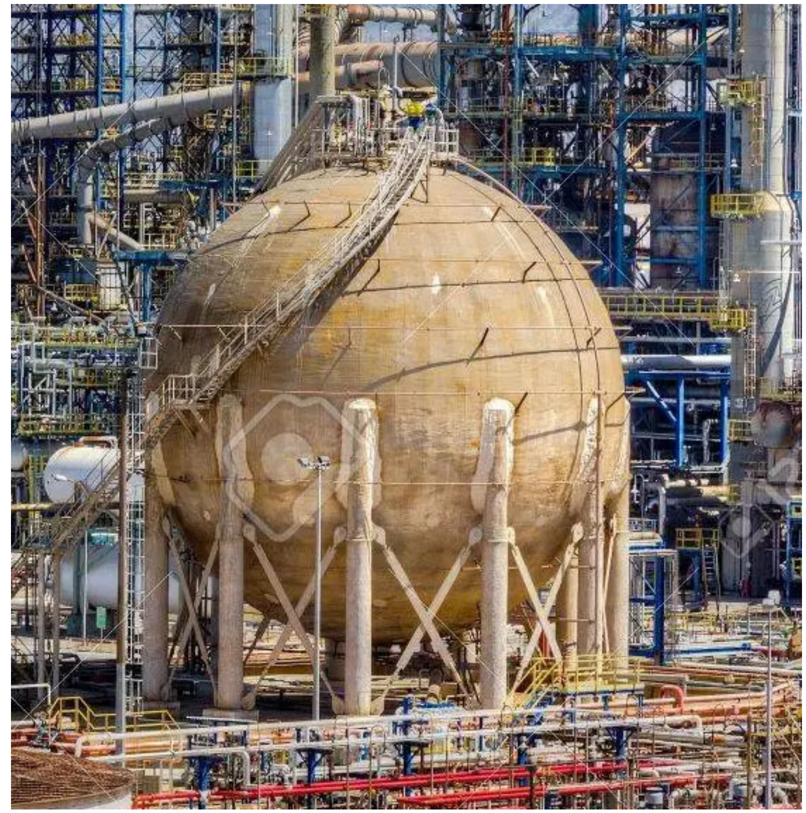
- Design Problem 2
- Files in Canvas
- Due end of lab hour

Tanks and Vessels – Design Thickness

Storage Tanks and Vessels

Vertical cylindrical storage tank fabricated on-site from flat plates

Large spherical storage tank in a refinery.



Small vertical cylindrical storage tanks with elliptical endcaps.

Cost determined by volume and material:

Spherical	Fig. 12-52, p. 557
Horizontal	Fig. 12-54, p. 558
Small field-erected	Fig. 12-55, p. 559
Large field-erected	Fig. 12-56, p. 559
Small containers	Table 12-13, p. 560

Vessel Design Calculations

Thickness must be calculated for safe design and cost

spherical tank

$$t = \frac{P \cdot r_i}{S \cdot E_J - .2 \cdot P} + C_C$$

cylindrical tank

$$t = \frac{P \cdot r_i}{S \cdot E_J - .6 \cdot P} + C_C$$

ellipsoidal end caps

$$t = \frac{P \cdot D_a}{2 \cdot S \cdot E_J - .2 \cdot P} + C_C$$

spherical end caps

$$t = \frac{P \cdot L_a}{S \cdot E_J - .2 \cdot P} + C_C$$

spherically dished (torispherical) caps

$$t = \frac{.885 \cdot P \cdot L_a}{S \cdot E_J - .1 \cdot P} + C_C$$

Table 12-10, pages 554-555

Check your "limiting conditions"

$t =$ shell thickness, m

$P =$ maximum allowable working pressure, kPa

$r_i =$ inside radius of shell, without corrosion allowance, m

$S =$ maximum allowable working stress, kPa, Table 12-10

$E_J =$ joint efficiency (for welds), dimensionless, Table 12-10 page 555; depends on weld

next slide

$C_C =$ corrosion allowance, m

$D_a =$ major axis of ellipsoidal head, without corrosion allowance, m

$L_a =$ inside radius of spherical head

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pressure vessel

$\text{Cost} = 73 \cdot W_v^{-.34}$

Cost figures for vessels

Figures 12-52 to 12-57, Table 12-13

PTW website

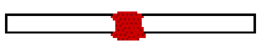
Types of Welds

Needed to understand Table 12-10 formulas

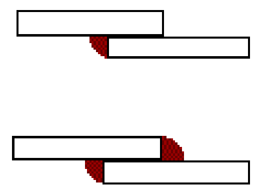
A weld is a joining of two materials, normally metals or plastics, with or without the use of a filler. Welding is a highly specialized field and there are about 30 different types.

If all welds pass radiography test, then $E_J = 1.0$.
If spot-examined, $E_J = 1.0$.
If not radiographed, $E_J = 1.0$.

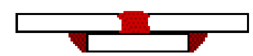
butt-weld



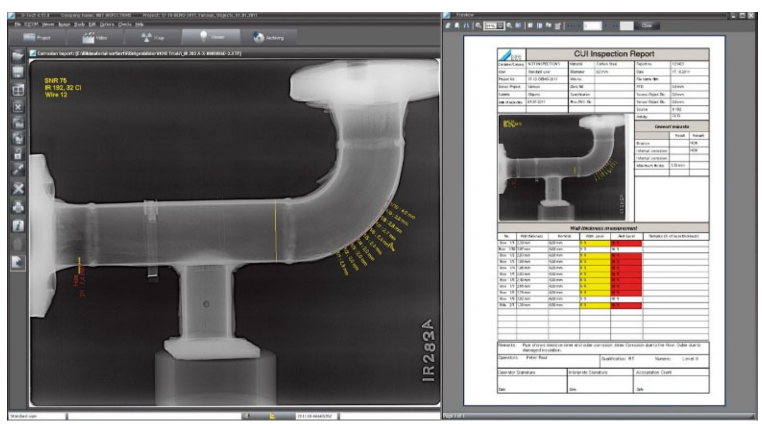
lap-weld



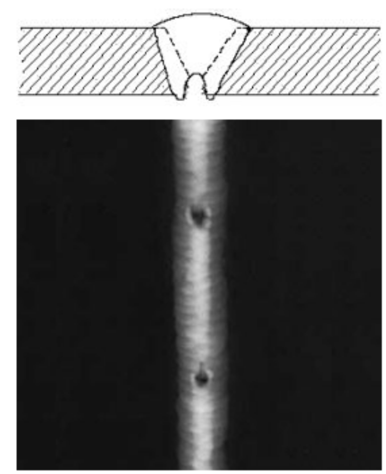
Butt-weld with backing plate



Shielded-metal arc welding is popular for heavy steel structures and industrial fabrication. Flux on electrode disintegrates forming a vapor barrier. http://welderstation.com/



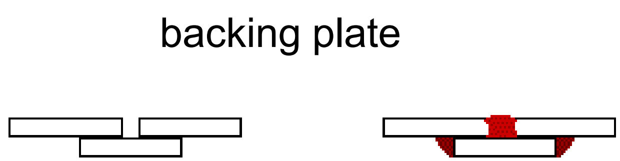
Radiographic testing of welds and weld testing are necessary steps in any pipeline construction process to detect flaws and defects within welded materials. One common method of non-destructive testing is radiographic testing, whereby radiographic images, or x-rays, of the weld are produced.



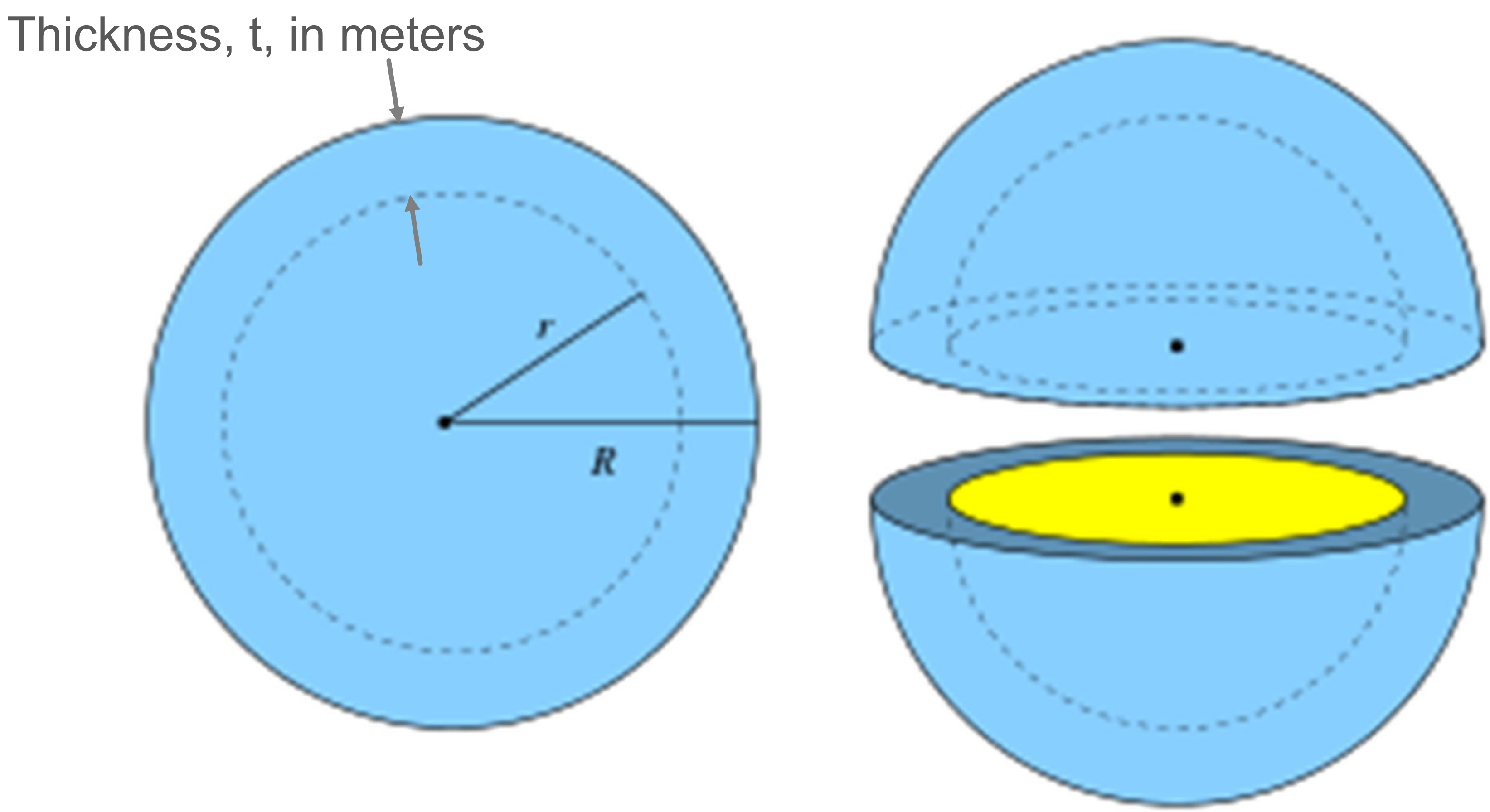
Radiographers identify typical welding defects in the image image. The localized dark area is “burn-through.” https://sawyermfg.com/

Problem 12-14 (Problem Set 3)

A spherical carbon-steel tank with an inside diameter of 9 m will be subjected to a working absolute pressure of 310 kPa and a temperature of 27 ºC. All of the welds on the tank are butt-welded with a backing strip. Assuming no corrosion allowance is required, what is the required wall thickness of the tank? Estimate the cost of steel for this tank if the cost of steel sheet is $1.10 per kilogram. On the bases of the data in Figure 12-52, determine the fraction of the purchased cost of the tank that is due to the cost for the steel.



Sketch of Spherical Shell for Problem 12-14



https://en.wikipedia.org/wiki/Spherical_shell

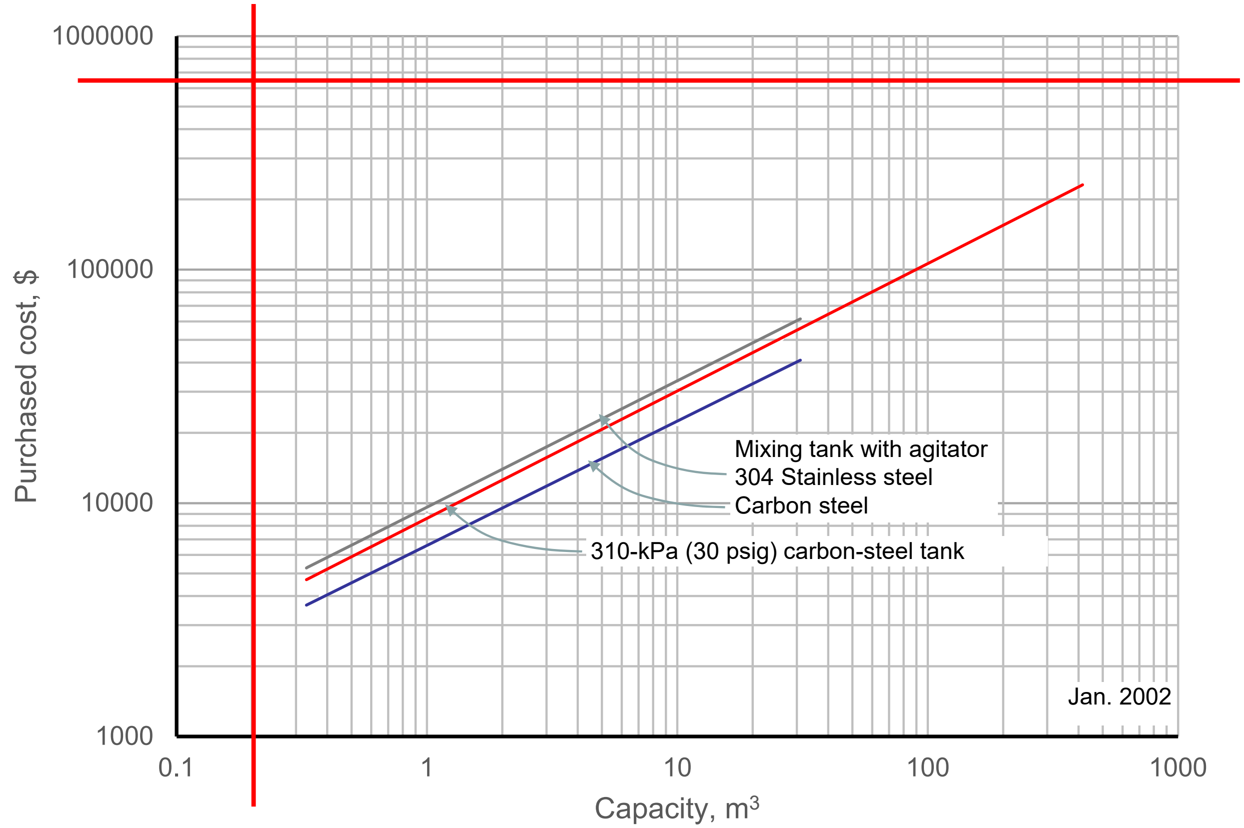


Figure 12-52. Purchased cost of mixing and storage tanks. Price for mixing tank includes the cost of the driving unit.

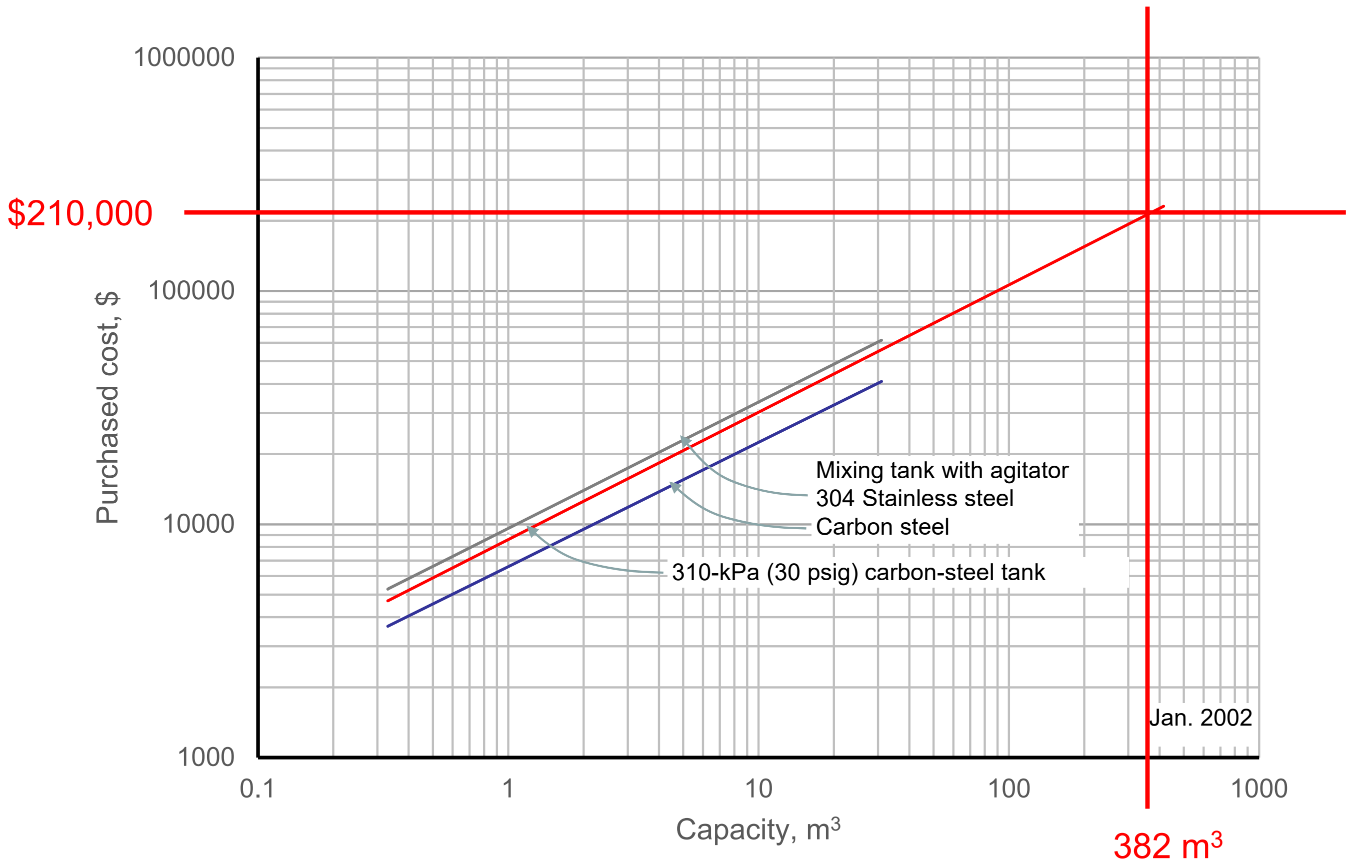


Figure 12-52. Purchased cost of mixing and storage tanks. Price for mixing tank includes the cost of the driving unit.

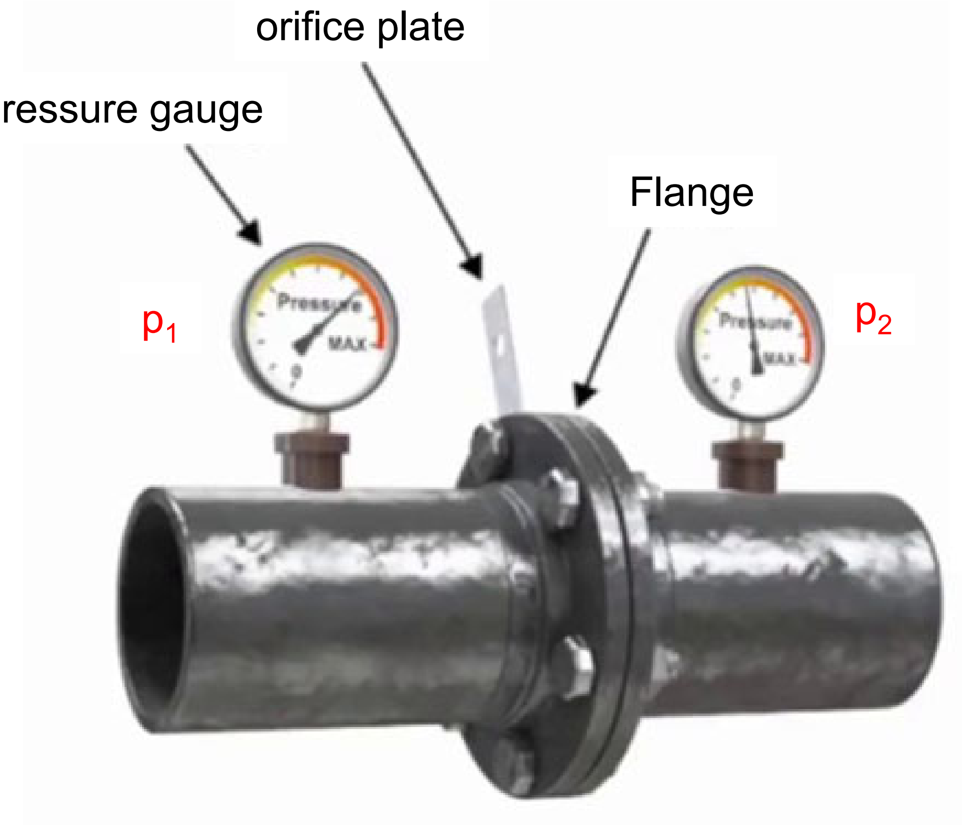
Flow Measurement – Orifice Plates

Flow Measurement with Orifice Meters

A constriction is added to the pipe

Measurement of ΔP across orifice gives flow rate

orifice plate



Textbook:

$$\dot{m}_V = Y \cdot C_d \cdot A_C \cdot \left[\frac{2 \cdot (p_1 - p_2)}{\rho \cdot (1 - \beta^4)} \right]^{1/2}$$

PTW, Eq. 12-46, p. 550

Liquids, Y=1

$$\dot{m}_V = C_0 \cdot A_C \cdot \left[\frac{2 \cdot (p_1 - p_2)}{\rho \cdot (1 - \beta^4)} \right]^{1/2}$$

McCabe, Smith, & Harriott, Eq. 8-28, p. 229

Symbols defined in slides 6-8

Flow Measurement with Orifice Plates

$$\dot{m}_V = Y \cdot C_d \cdot A_C \cdot \left[\frac{2 \cdot (p_1 - p_2)}{\rho \cdot \left(1 - \beta^4\right)} \right]^{1/2}$$

Eq. 12-47, p. 550

Rotameters,
Eq. 12-46, p. 550

$\dot{m}_V$ = volumetric flow rate, m^3 / s

C_d = discharge coefficient, dimensionless, Fig. 12 – 51

A_C = cross-sectional area at minimum, m^2

ρ = fluid density, kg/m^3

β = ratio of throat diameter to pipe diameter

p_1 = static pressure upstream before constriction, kPa

p_2 = static pressure at minimum flow area, kPa

Y = expansion factor, dimensionlless

liquids: $Y = 1$ (for liquids)

gasses:

$$Y = \left[r^{2/k} \cdot \left(\frac{k}{k-1} \right) \cdot \left(\frac{1 - r^{(k-1)/k}}{1 - r} \right) \cdot \left(\frac{1 - \beta^4}{1 - \beta^4 \cdot r^{2/k}} \right) \right]^{1/2}$$

Eq. 12-48, p. 550

$r = p_2 / p_1$

$k = C_p / C_V$

Plot, Fig. 12-50, page 551

Demo – Orifice Plate

Cadets have separate slide deck with instructions