

CH402 Chemical Engineering Process Design

Class Notes L5

Flow Measurement
Storage of Fluids

Lesson 5 Agenda

Orifice Demo, CHEMCAD

Flow Measurement – Orifice

Vessel design considerations

Homework – Problem 12-14

Lab this week

DS (1245 Friday) and next week (1245 Tuesday)

Design Problem 2

Files will be posted in CANVAS

Due end of lab hour (1445)

Make sure Adobe is working

Demo – Orifice Plate Design

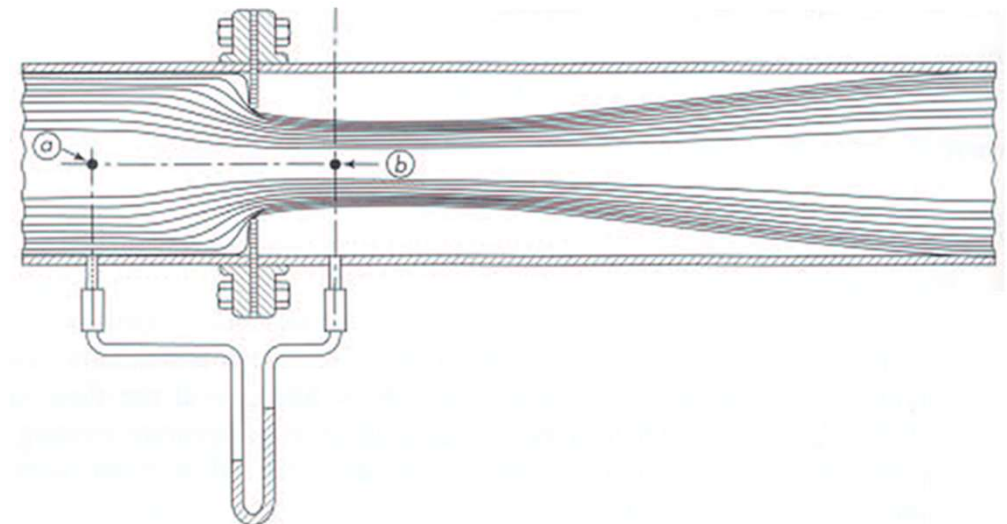
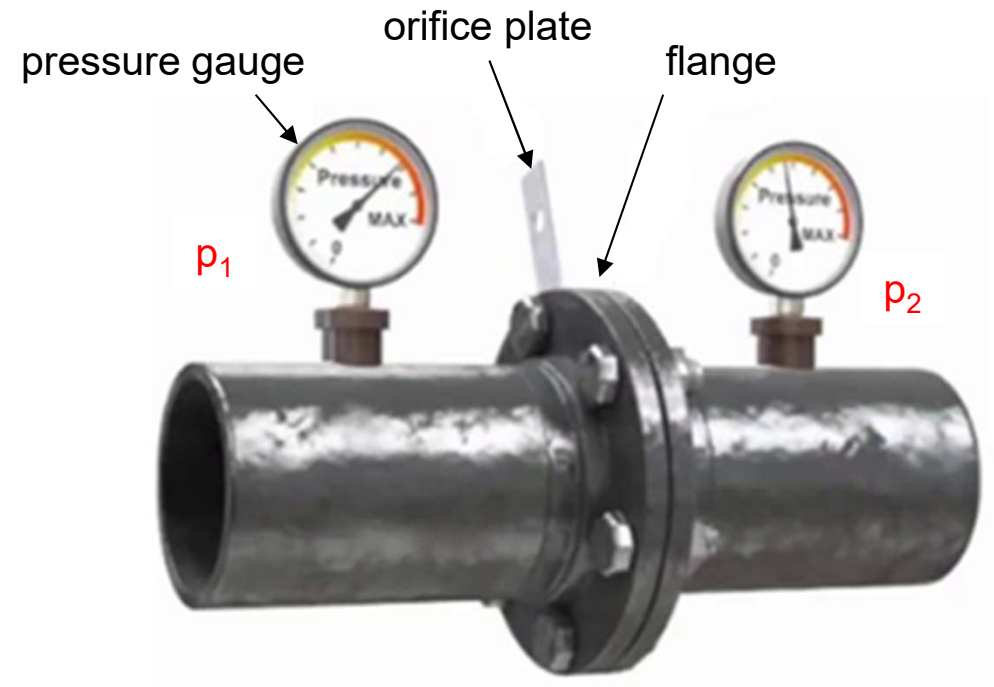
Cadets have separate slide deck with instructions in CANVAS

Flow Measurement – Orifice Plates

Flow Measurement with Orifice Meters

A constriction is added to the pipe – Bernoulli's equation

ΔV induces ΔP across orifice - gives flow rate



Flow Measurement with Orifice Plates

$$\dot{m}_v = Y \cdot C_d \cdot A_c \cdot \left[\frac{2 \cdot (p_1 - p_2)}{\rho \cdot (1 - \beta^4)} \right]^{1/2} \quad \text{Eq. 12-47, p. 550}$$

Rotameters,
Eq. 12-46, p. 550

\dot{m}_v = volumetric flow rate, m³ / s

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

A_c = cross-sectional area at minimum, m²

ρ = fluid density, kg/m³

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, dimensionless

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

Tanks and Vessels – Design Thickness

Storage Tanks and Vessels

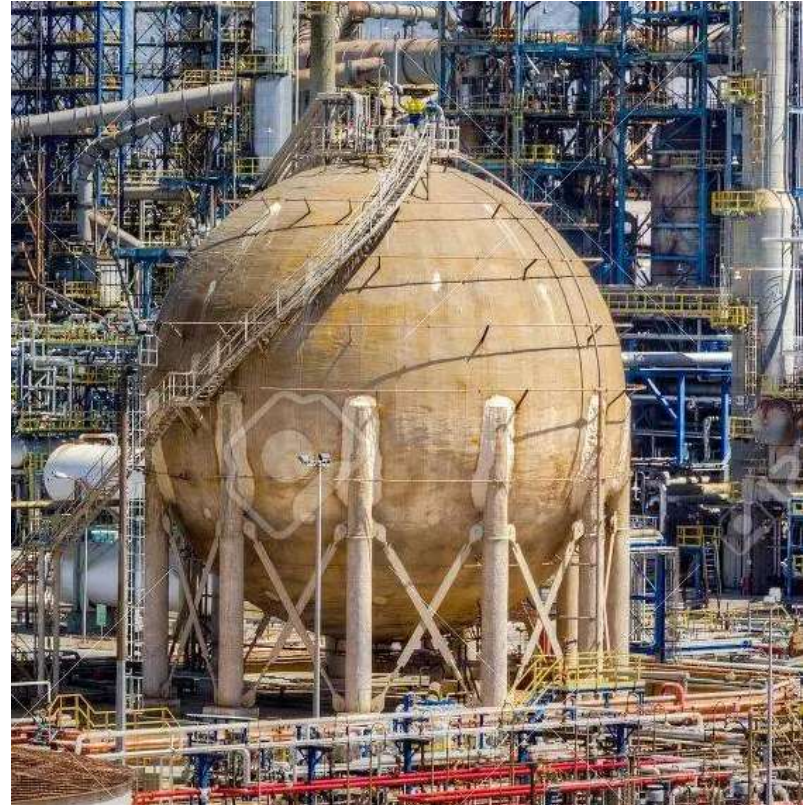
Vertical cylindrical storage tank fabricated on-site from flat plates



Small vertical cylindrical storage tanks with elliptical endcaps.



Large spherical storage tank in a refinery.



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

$$t = \frac{P \cdot L_a}{S \cdot E_j - .2 \cdot P} + C_c$$

Table 12-10, pages 554-555

Check your “limiting conditions”

spherically dished (torispherical) caps

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

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

C_c = corrosion allowance, m

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

L_a = inside radius of spherical head

next
slide

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.

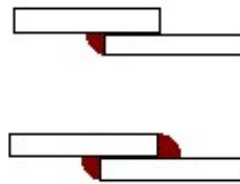
If all welds pass radiography test, then $E_J = 1.0$

butt-weld



spot examined double butt weld $E_J = 0.85$
unradiographed double butt weld $E_J = 0.70$
spot examined single butt weld $E_J = 0.60$

lap-weld



spot examined lap weld $E_J = 0.80$

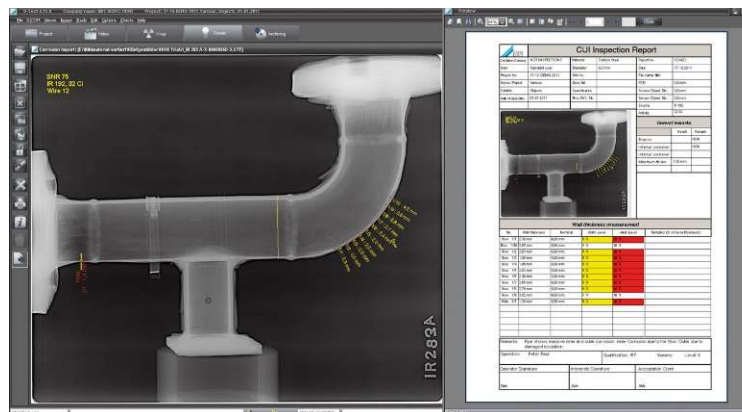
Butt-weld with backing plate



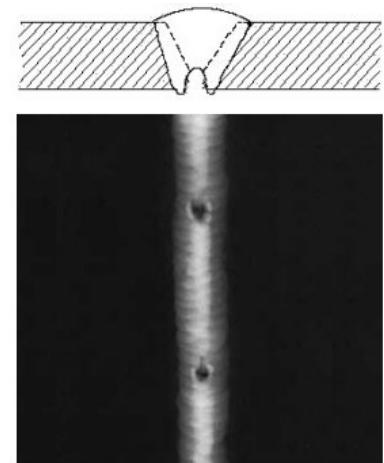
spot examined $E_J = 0.90$



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://sawyerimg.com/>

Questions?