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

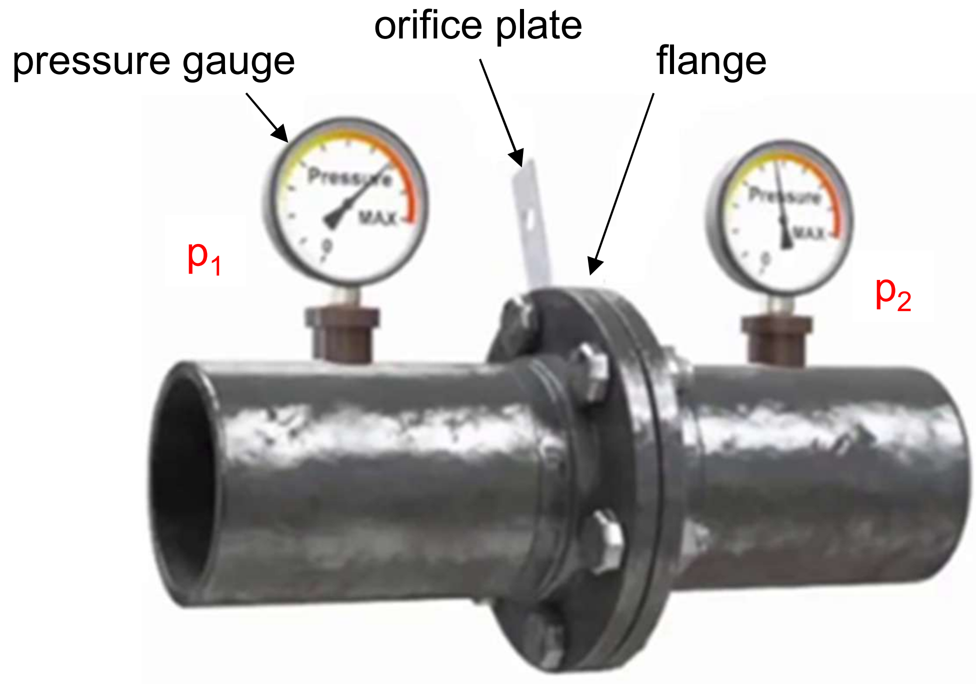
Flow Measurement – Orifice Plates

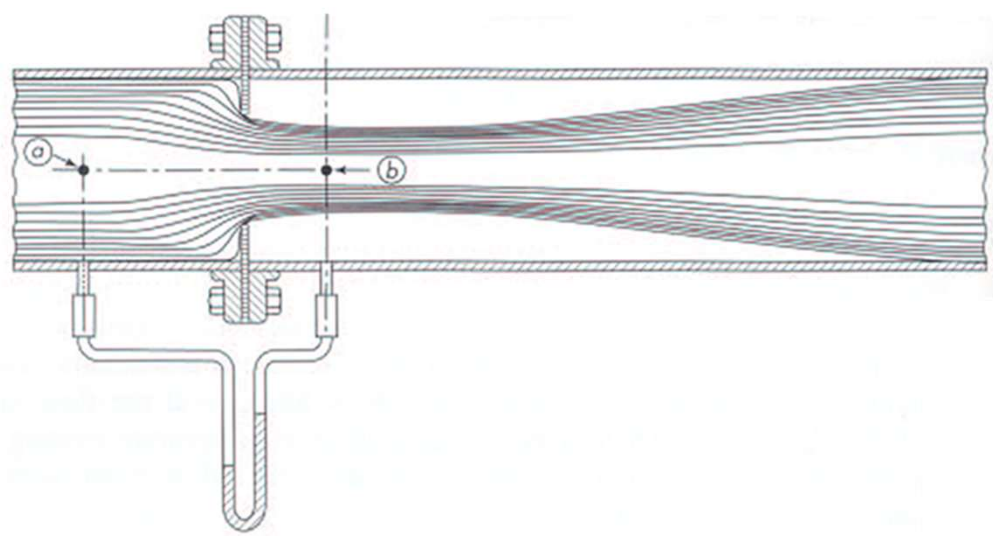
Flow Measurement with Orifice Meters

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

ΔV induces ΔP across orifice - gives flow rate

orifice plate





Flow Measurement with Orifice Plates

$$Q = CA_0\sqrt{2g\left(\frac{P_1}{\gamma}+z_1-\frac{P_2}{\gamma}-z_2\right)}$$

$\gamma = \rho g$

$$C = \frac{C_v C_c}{\sqrt{1 - C_c^2\left(A_0/A_1\right)^2}}$$

FEE, pages 194-196
C, C_v, C_c in table on p. 196

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

Textbook:
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, 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

$r = p_2/p_1$

$k = C_p/C_V$

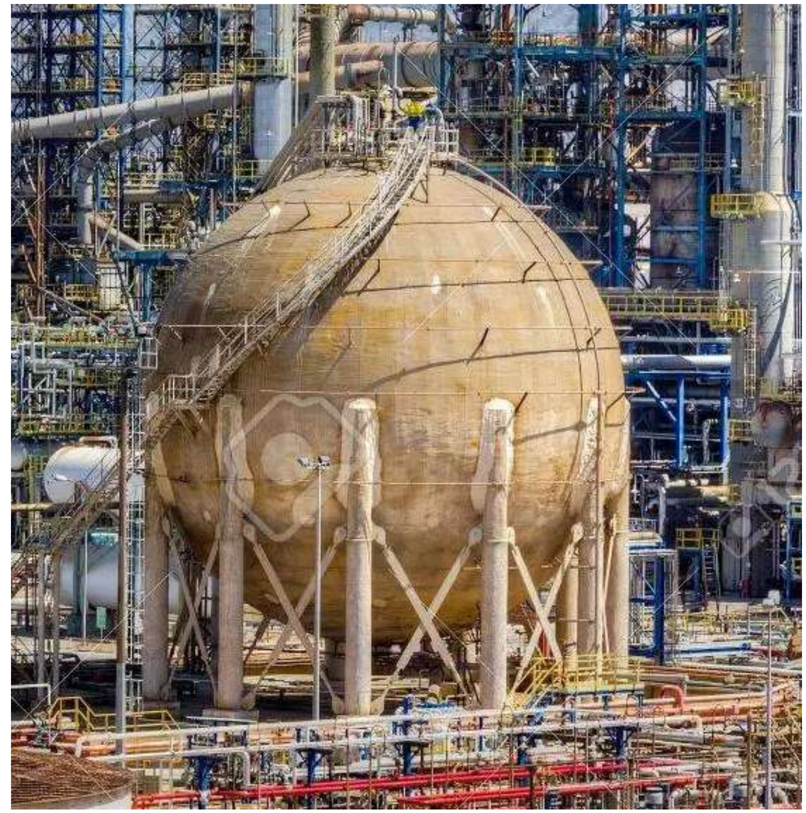
Plot, Fig. 12-50, page 551

Tanks and Vessels – Design Thickness

Storage Tanks and Vessels

Vertical cylindrical storage tank fabricated on-site from flat plates

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

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

Cost figures for vessels

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

PTW website

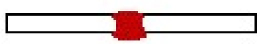
Types of Welds

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.

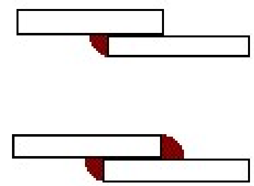
If all welds pass radiography test, then $E_J = 1.0$

butt-weld



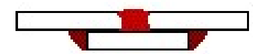
spot examined double butt weld $E_J = 0.85$
unradiographed double butt weld $E_J = 0.70$
spot examined single butt weld $E_J = 0.60$

lap-weld



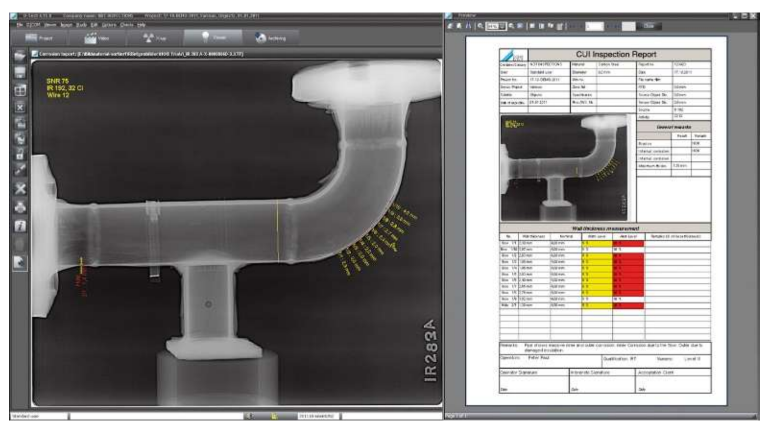
spot examined lap weld $E_J = 0.80$

Butt-weld with backing plate

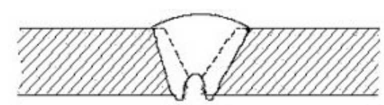


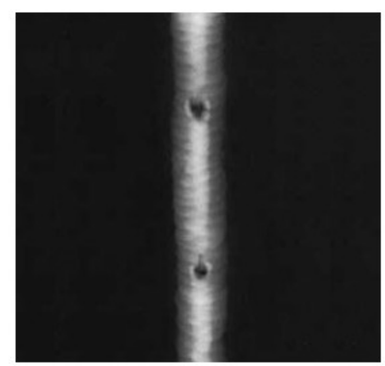
spot examined $E_J = 0.90$

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://sawyermfg.com/

<u>Questions?</u>