

CH402 Chemical Engineering Process Design

Class Notes L4

Agitators

Part I

Agitator Design – General Features

Tank/Vessel Mixers

PTW, p. 628

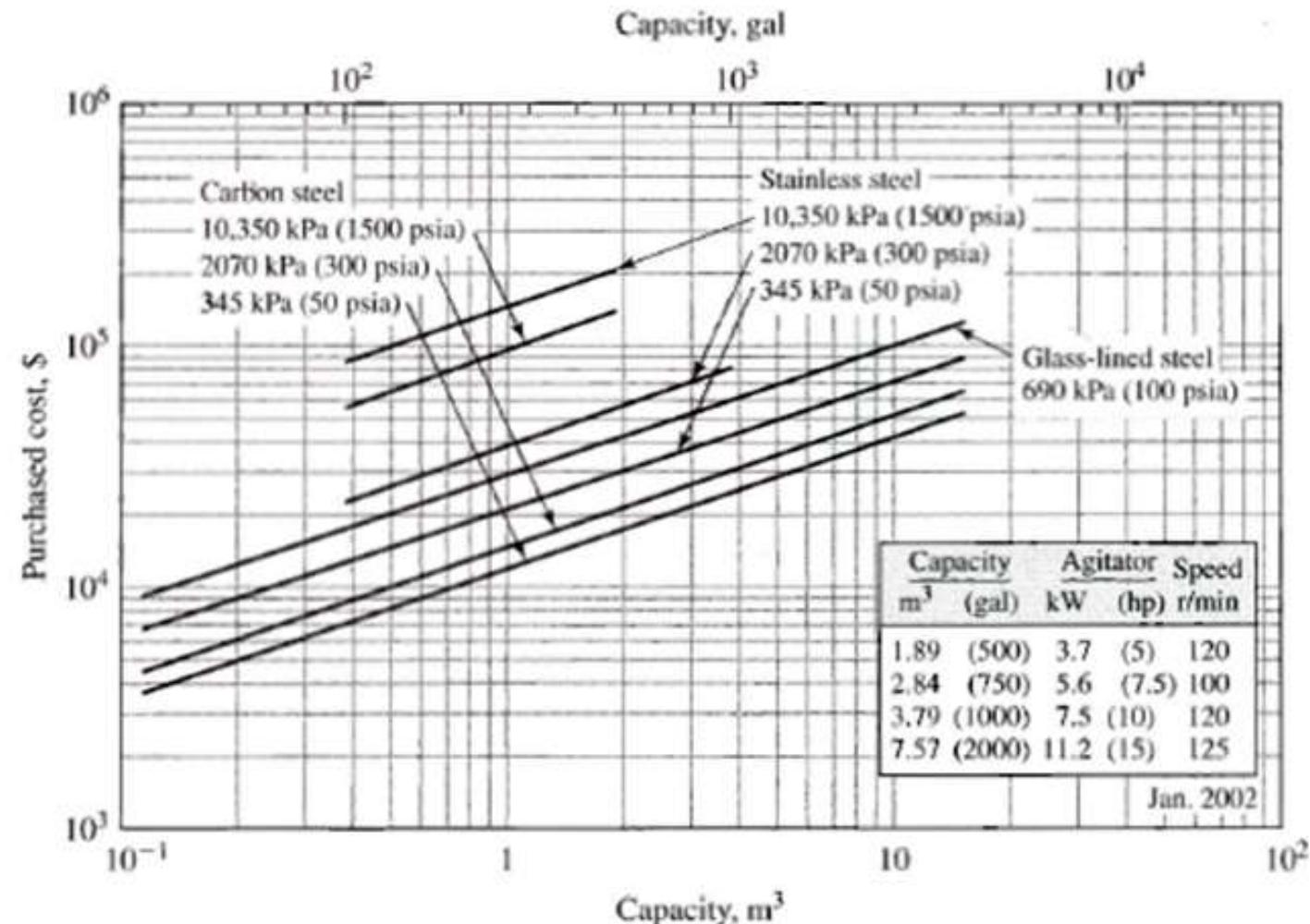
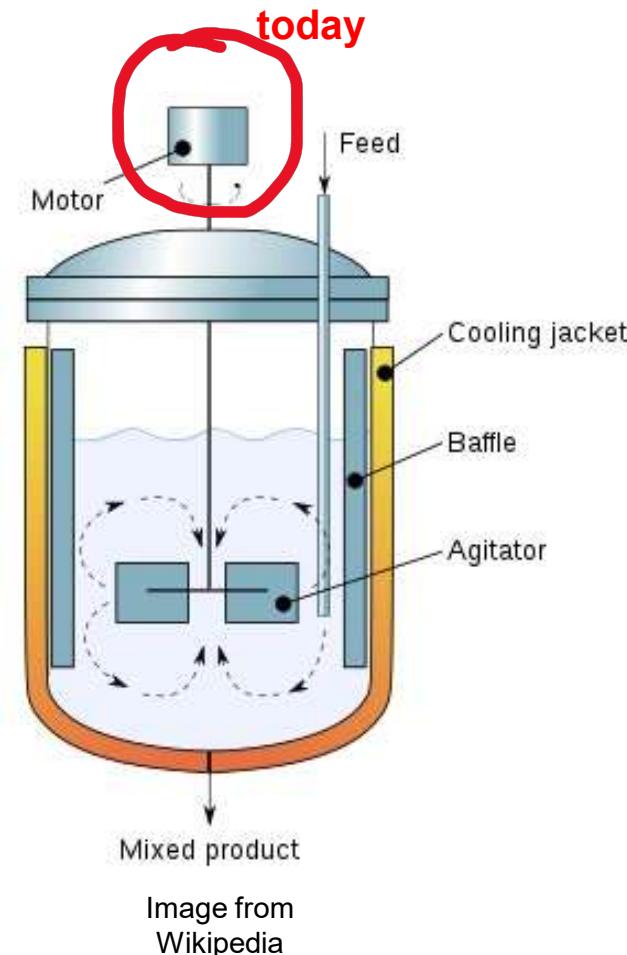


Figure 13-15
Purchased cost of jacketed and stirred reactors

Volume of a CSTR:
(CH364)

$$V = F_{A_0} \frac{x_A}{-r_A}$$

$$-r_A = k \cdot C_{A_0} x_A$$

x_A = fractional conversion of A
 F_{A_0} = molar flow rate of A in feed
 C_{A_0} = molar concentration of A in feed

For stirred tanks, also need power...

... to size and price motors and mixers.
... predict electricity requirement.



<http://www.gmmpfaudler.com>

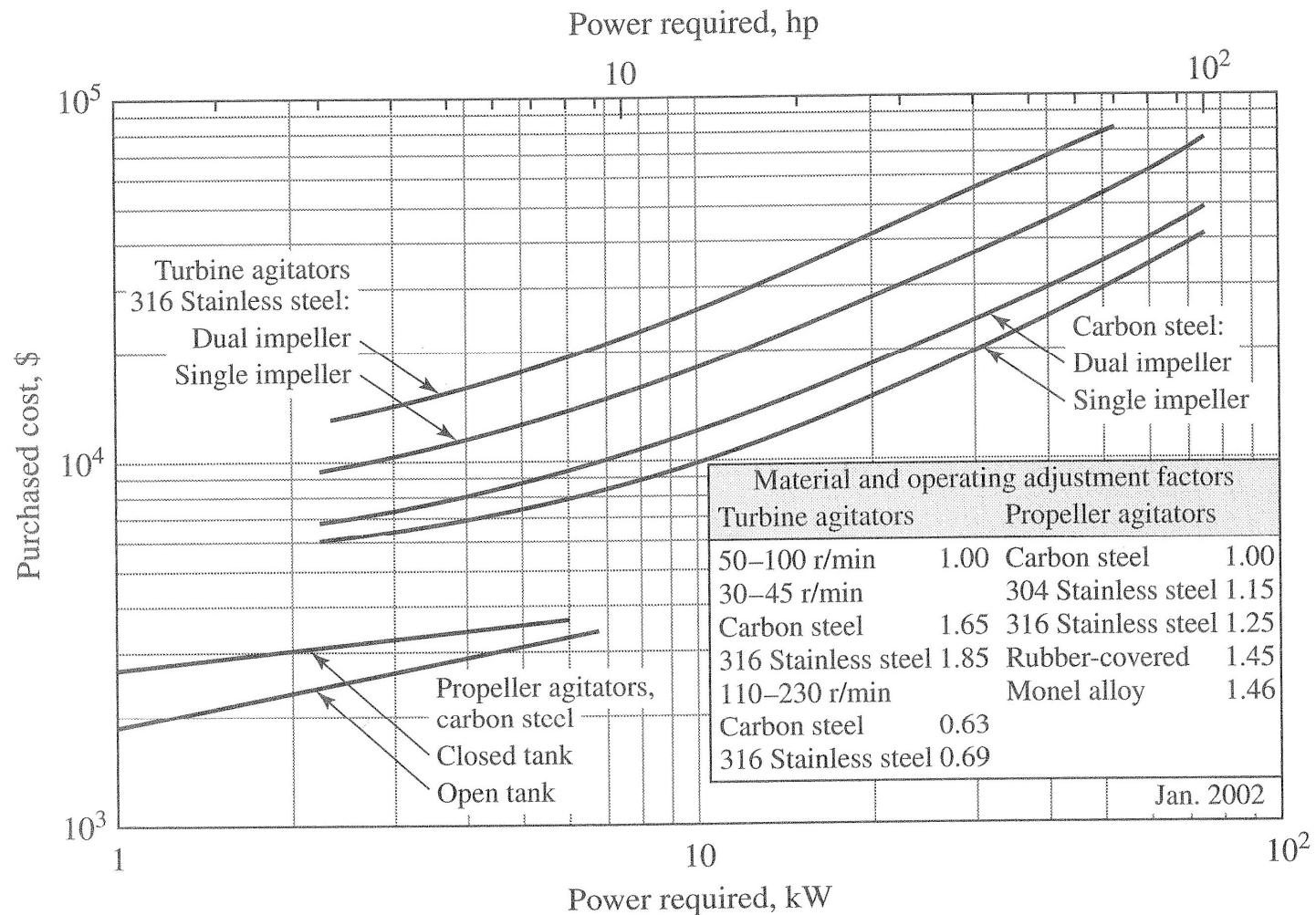


Figure 12-42

Purchased cost of turbine and propeller agitators

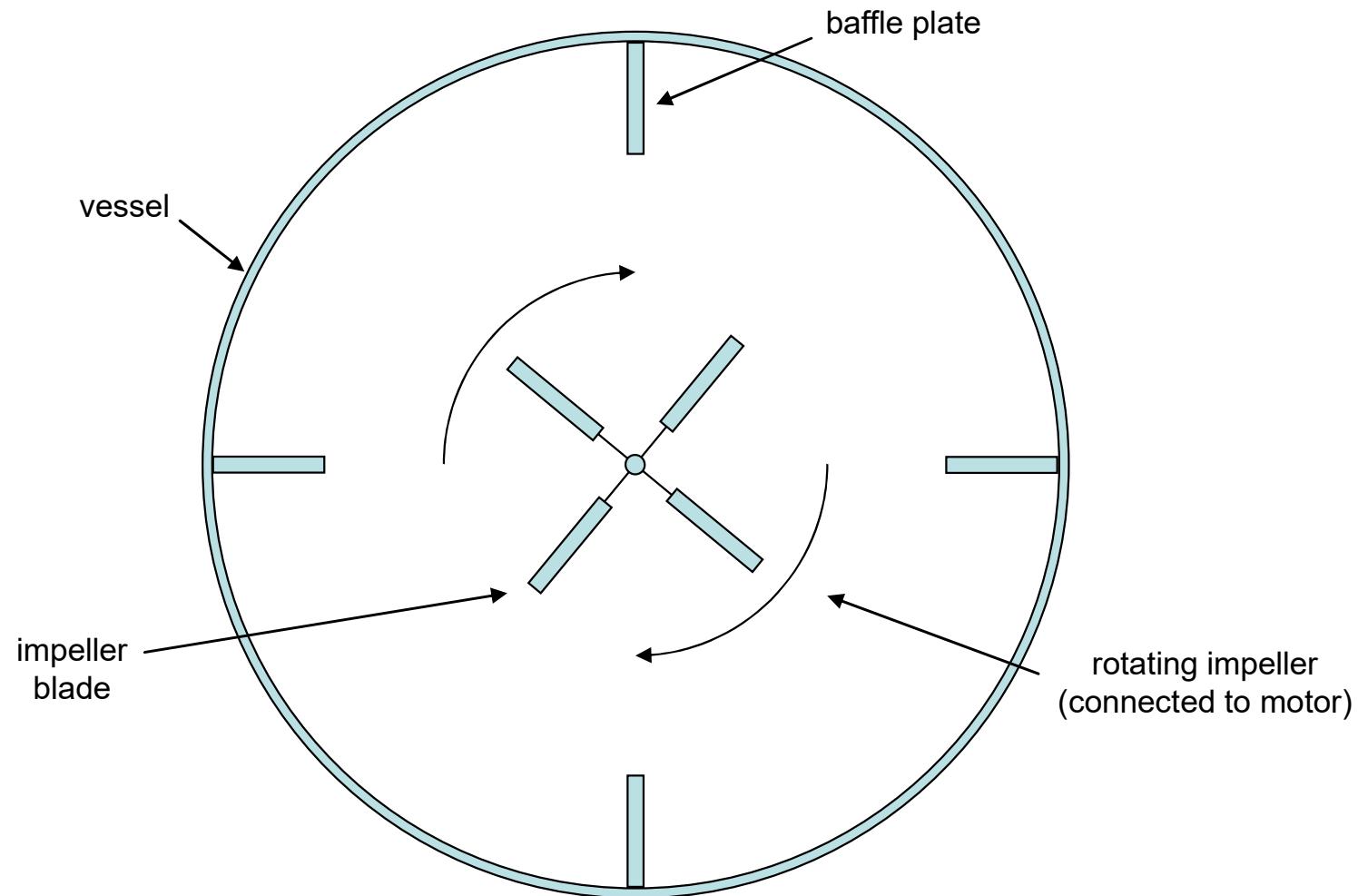
Other designs - Figs. 12-41 through 12-49, pages 545-549

Part II

Agitator Design – Method 1

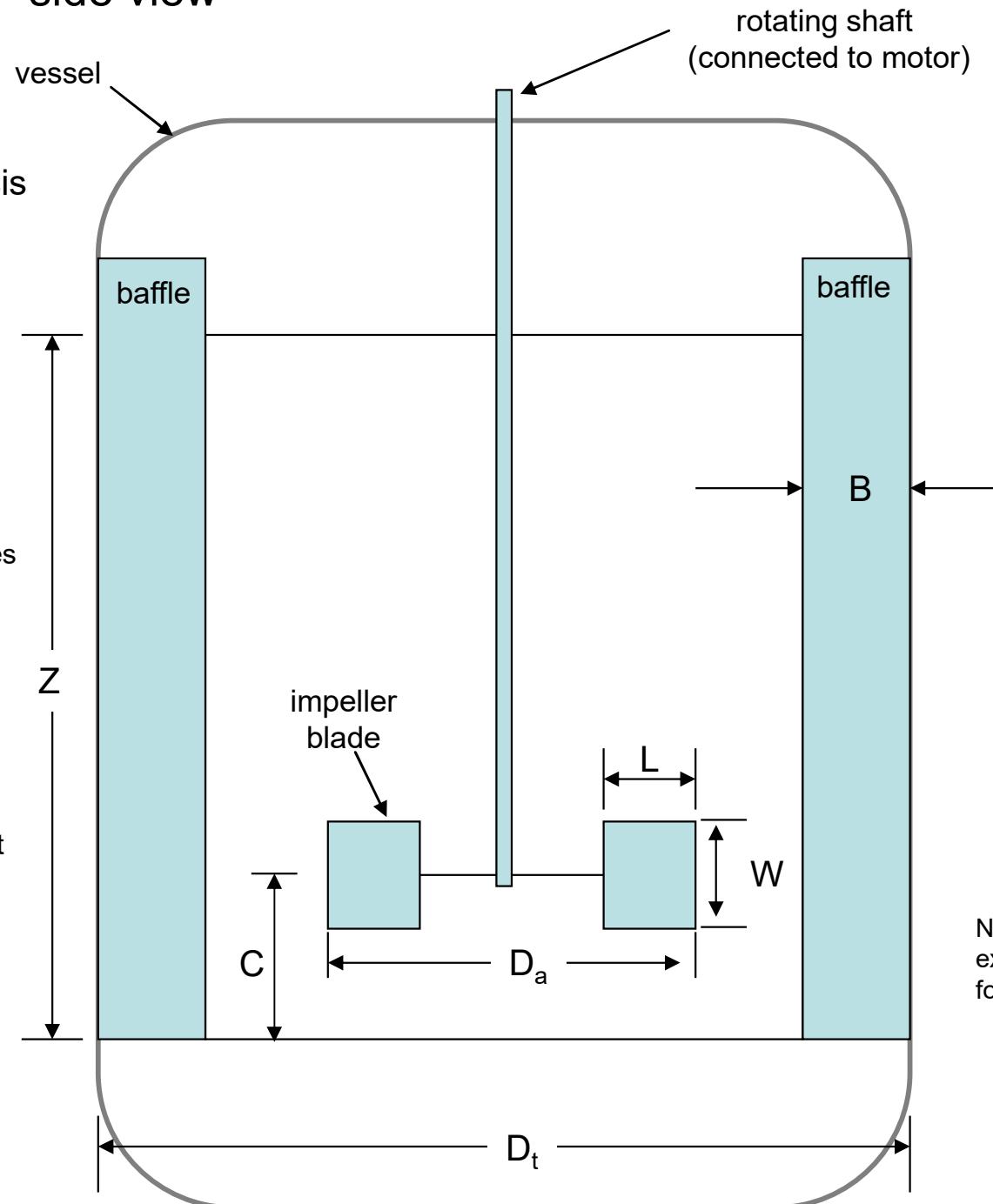
(Stirred Tank Impeller Agitators)

Basic Design - top view



Basic Design - side view

Slide 7



From dimensional analysis

Rayleigh's Method, a.k.a.
Buckingham's Pi method

Reynolds Number

$$Re = \frac{D_a^2 \cdot N_r \cdot \rho}{\mu}$$

defined in Fig. 12-40, p. 540
ratio of inertial to frictional forces

Froude Number

$$Fr = \frac{D_a \cdot N_r^2}{g}$$

defined in para. 3, p. 540
ratio of inertial forces to weight

Power Number

$$N_{Po} = \frac{P}{N_r^3 \cdot D_a^5 \cdot \rho}$$

defined in para. 3, p. 540
dimensionless power

$$N_{Po} = f(Re, Fr, S_1, S_2, S_3, S_4, S_5, S_6)$$



$$N_{Po} = \phi \cdot Fr^m$$

$$\phi = f(Re, S_i)$$

$$m = \frac{a - \log_{10} Re}{b} \quad (\text{eq 12-41})$$

(p. 540)

shape parameters:

$$S_1 = D_t/D_a$$

$$S_2 = C/D_a$$

$$S_3 = L/D_a$$

$$S_4 = W/D_a$$

$$S_5 = B/D_t$$

$$S_6 = Z/D_t$$

Note typo in Re and Fr formulas in example 12-6. Calculation is OK but formulas have D_t instead of D_a .

$$Re = \frac{D_a^2 N_r \rho}{\mu}$$

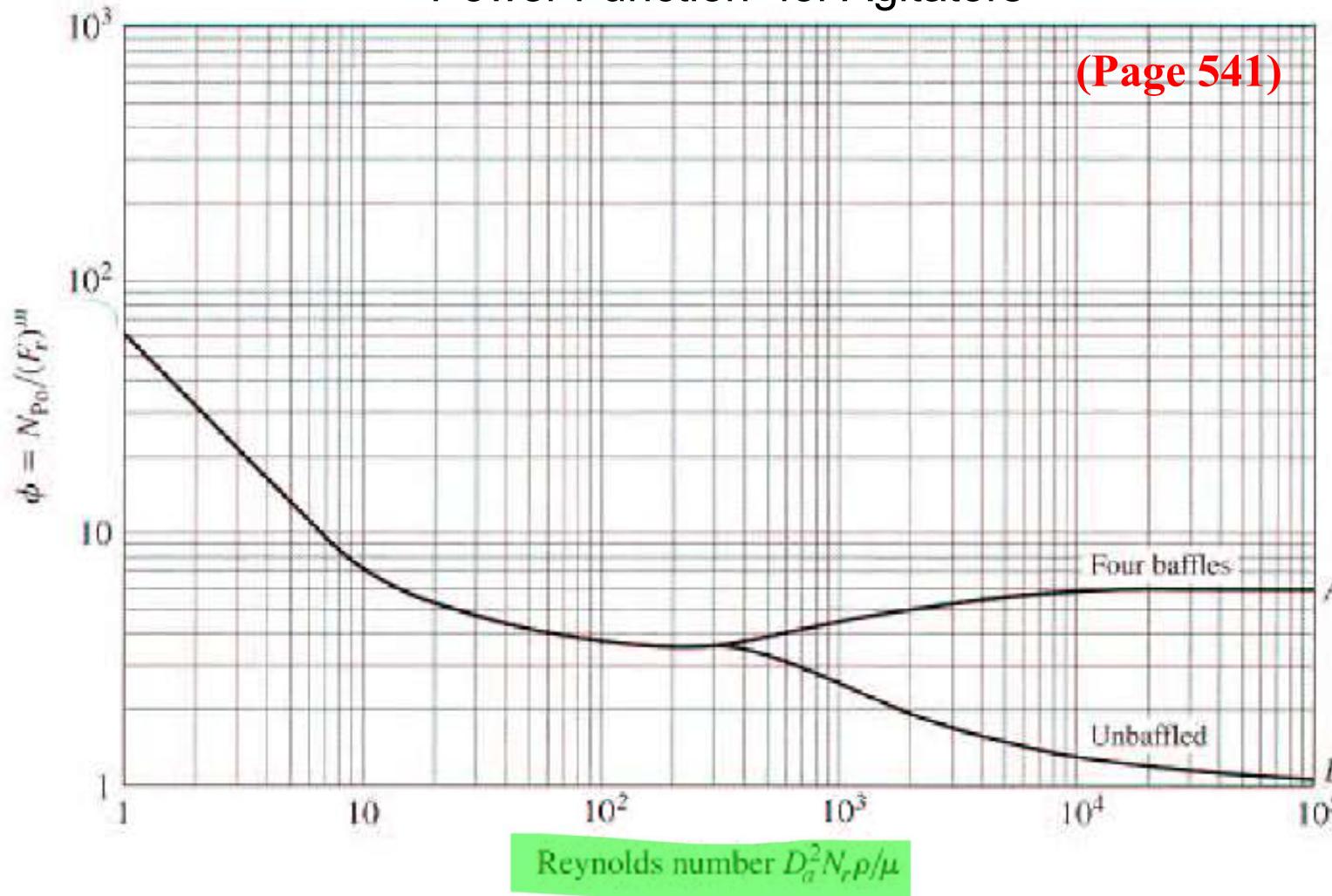
$$Fr = \frac{D_a \cdot N_r^2}{g}$$

$$m = \frac{1 - \log_{10} Re}{40}$$

$$N_{Po} = \phi \cdot Fr^m$$

$$N_{Po} = \frac{P}{N_r^3 \cdot D_a^5 \cdot \rho}$$

“Power Function” for Agitators



shape parameters:

$$S_1 = D_t/D_a = 3.0$$

$$S_2 = C/D_a = 1.0$$

$$S_3 = L/D_a = .25$$

$$S_4 = W/D_a = .20$$

$$S_5 = B/D_t = 0 (= 0.1)$$

$$S_6 = Z/D_t = 1.0$$

(these shape factors go with this chart)

Figure 12-40

Relation between the power function ϕ and the Reynolds number for a six-blade turbine mixer. Constants a and b in Eq. (12-41) for this mixer have been evaluated as 1.0 and 40.0, respectively.

$$Re = \frac{D_a^2 N_r \rho}{\mu}$$

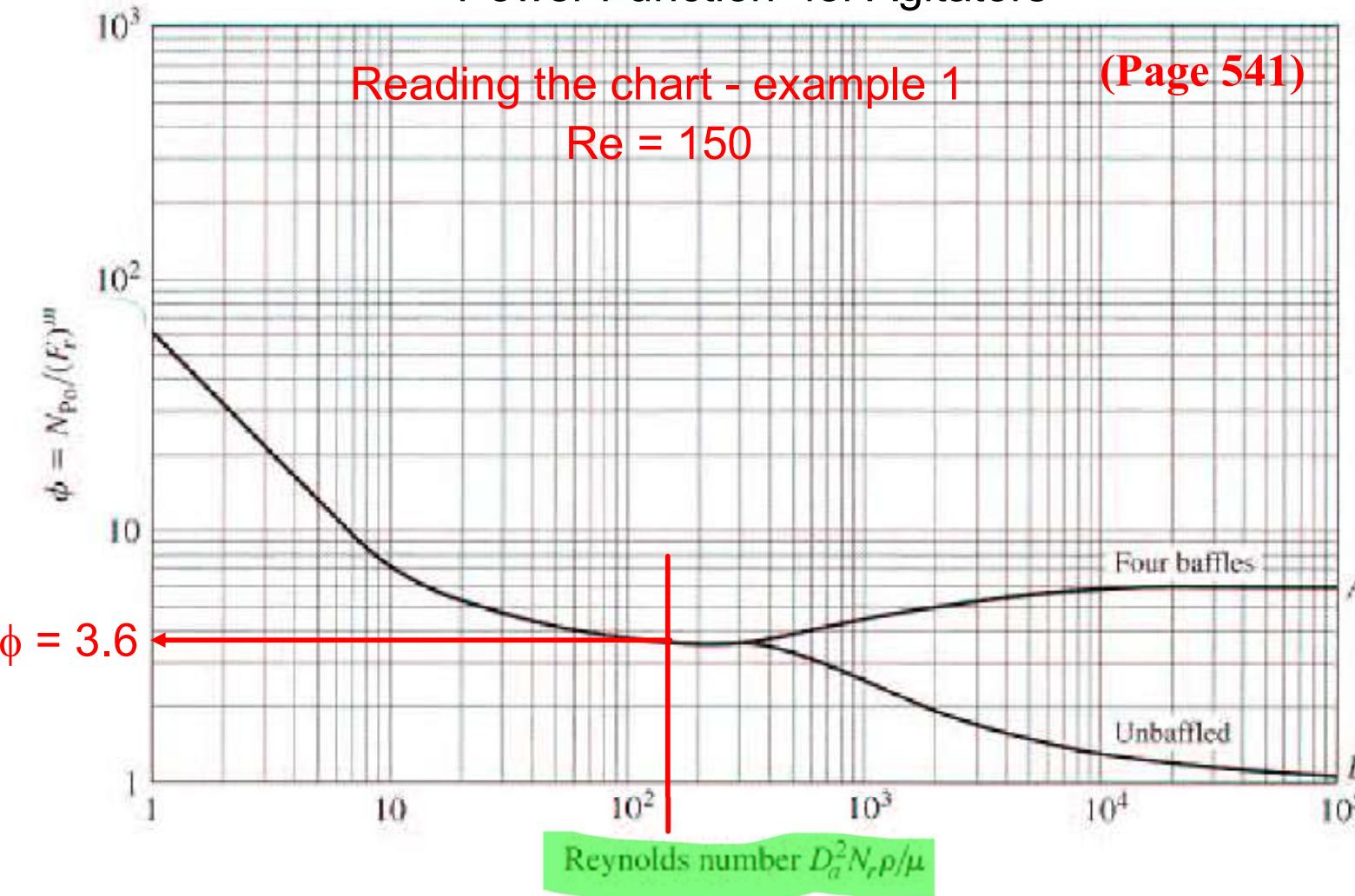
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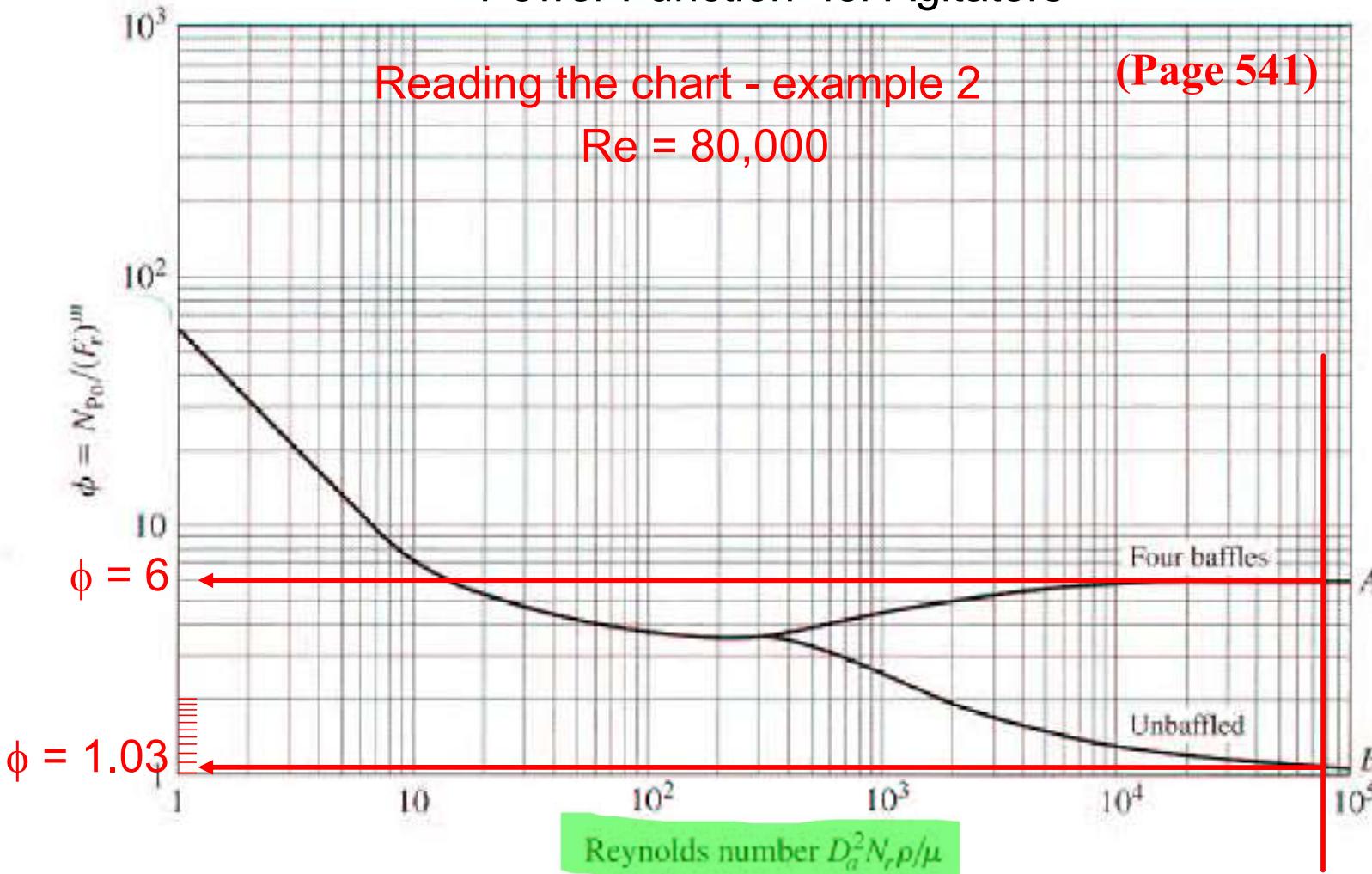
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Relation between the power function ϕ and the Reynolds number for a six-blade turbine mixer. Constants a and b in Eq. (12-41) for this mixer have been evaluated as 1.0 and 40.0, respectively.

Mixing Time (θ) for a Stirred Tank:

$$\theta = 12000 \cdot \left(\frac{\mu \cdot V}{P} \right)^{0.5} \cdot (V)^{0.2}$$

Mixing time in seconds

Equation 12-45, page 542

V = tank volume in m^3

P = power in watts

μ = viscosity in $kg/(m \cdot s)$

Important for CSTR design:

Compare θ to τ (space-time)

Generally, $\theta \ll \tau$

Calculating Power Requirement – Method 1

1. Determine Fluid Properties

density, viscosity

2. Determine Mechanical Properties

dimensions, propeller speed

3. Calculate dimensionless groups

Reynolds #, Froude #

4. Determine m

5. Determine ϕ

6. Calculate Power Number (N_{P_0}) and then Power (P)

7. Calculate Mixing Time (Slide 12)

Part III

Agitator Design – Method 2

(Method used on the FE Exam Method)

Calculating Power Requirement – FEE Method

Turbulent Flow Impeller Mixer

$$P = K_T(n)^3(D_i)^5\rho_f$$

where

K_T = impeller constant (see table)

n = rotational speed (rev/sec)

D_i = impeller diameter (m)

Turbulent
mixing

$Re > 10,000$

$$N_{Po} = K_T$$

$$N_{Po} = \frac{P}{N_r^3 \cdot D_a^5 \cdot \rho}$$

Values of the Impeller Constant K_T
(Assume Turbulent Flow)

Type of Impeller	K_T
Propeller, pitch of 1, 3 blades	0.32
Propeller, pitch of 2, 3 blades	1.00
Turbine, 6 flat blades, vaned disc	6.30
Turbine, 6 curved blades	4.80
Fan turbine, 6 blades at 45°	1.65
Shrouded turbine, 6 curved blades	1.08
Shrouded turbine, with stator, no baffles	1.12

Note: Constant assumes baffled tanks having four baffles at the tank wall with a width equal to 10% of the tank diameter.

Source: Reprinted with permission from *Industrial & Engineering Chemistry*, "Mixing of Liquids in Chemical Processing," J. Henry Rushton, 1952, v. 44, no. 12. p. 2934, American Chemical Society.

Viscous mixing
(not in FEE)

$$Re < 10$$

$$N_{Po} \cdot Re = K_L$$

$$Re = \frac{D_a^2 \cdot N_r \cdot \rho}{\mu}$$

K_L is in Table 12-9
on page 542

This method is for
baffled tanks only.

Calculating Power Requirement – Method 2

(Table 12-9 Method)

1. Determine Fluid Properties

density, viscosity

2. Determine Mechanical Properties

dimensions, propeller speed, type of impeller

3. Use Table 12-9 to determine K_L and K_T . FEE will not have viscous mix

4. Calculate Reynolds Number

5. Calculate Power Number (N_{Po}) and then Power (P)

5a. Laminar (Reynolds <10)

$$N_{Po} Re = K_L$$

5b. Turbulent ($Re>10,000$) with baffles:

$$N_{Po} = K_T$$

6. Calculate Mixing Time (Slide 12)

Questions?