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POWER CONSUMPTION

1. INTRODUCTION

In the chemical and other processing industries, many operations are dependent to a great extent on effective agitation and mixing of fluids. Though often confused, agitation and mixing are not synonymous. Generally, agitation refers to forcing a fluid by mechanical means to flow in a circulatory or other pattern inside a vessel. Mixing usually implies the taking of two or more separate phases, such as a fluid and a powdered solid, or two fluids, and causing them to be randomly distributed through one another. A single homogeneous material, such as a tankfull of cold water, can be agitated, but it cannot be mixed until some other material, such as a quantity of hot water or some powdered solid, is added to it.

The term mixing is applied to a variety of operations, different widely in the degree of homogeneity of the mixed material. Consider, in one case, two gases which are brought together and thoroughly blended, and, in a second case, sand, gravel, cement, and water which are tumbled in a rotating drum for a long time. In both cases the final product is said to be mixed. Yet the products are obviously not equally homogeneous. Samples of the mixed gases; even very small samples; all have the same composition. Small samples of the mixed concrete, on the other hand, obviously differ widely in composition.

2. THEORY

2.1. AGITATION OF LIQUIDS

Liquids are agitated for a number of purposes, depending on the objectives of the processing step. These purposes include:

1. Blending of two miscible liquids, such as ethyl alcohol and water.

2. Dissolving solids in liquids, such as salt in water.

3. Dispersing a gas in a liquid as fine bubbles, such as oxygen from air in a suspension of microorganisms for fermentation or for activated sludge process in waste treatment.

4. Suspending of fine solid particles in a liquid, such as in the catalytic hydrogenation of a liquid where solid catalyst particles are dispersed in the liquid.

5. Agitation of the fluid to increase heat transfer between the fluid and a coil or jacket in the vessel wall.

2.1.1. Agitation Equipment

Liquids are most often agitated in some kind of tank or vessel, usually cylindrical in form and with a vertical axis. The top of the vessel, may be open to the air, or it may be closed. A standardized design as that shown in Fig.1, however, is applicable in many situations. The tank bottom is rounded, not fiat, to eliminate sharp corners or regions into which the fluid currents would not penetrate. An impeller is mounted on an overhung shaft, i.e., a shaft supported from above. The shaft is driven by a motor, sometimes directly connected to the shaft but more often connected to it through a speed-reducing gearbox. Accessories such as inlet and outlet lines, coils, jackets, and wells for temperature-measuring devices are usually included. The impeller creates a flow pattern in system, causing the liquid to circulate through the vessel and return eventually to the impeller.

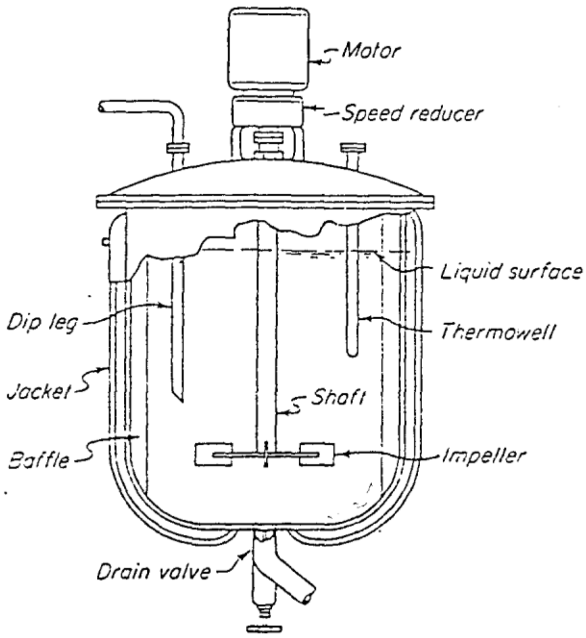

Figure 1. Typical agitation process vessel

2.1.2. Impellers

Impellers may be roughly divided into two broad classes: axial-flow impellers and radial-flow impellers. The classification depends on the angle that the blade makes with the plane of impeller rotation.

Axial-flow impellers include all impellers in which the blade makes an angle of less than 90° with the plane of rotation. Propellers and pitched-blade turbines or paddles are representative axial-flow impellers.

Radial-flow impellers have b1ades which parallel to the axis of the drive shaft. The smaller multiplade ones are known as turbines; larger, slower - speed impellers, with two or four blades are often called paddles.

2.1.2.1. Propellers

Propellers are often used for agitation in tanks smaller than 3.8 m^3 of reactor volume or less than 1.8 m in diameter when less than 2.2 kW is satisfactory for obtaining the desired process results. Two basic speed ranges are available: 1150 or 1750 rpm with direct drive and 350 or 420 rpm with a gear drive. The high-speed units produce higher velocities and shear rates in the propeller discharge stream and a lower circulation rate throughout the vessel than the low-speed units.

The propeller blades vigorously cut or shear the liquid. Because of the persistence of the flow currents, propeller agitators are effective in very large vessels. A revolving propeller traces out a helix in the fluid, and, if there were no shop between liquid and propeller, one full revolution would move the liquid longitudinally a fixed distance depending on the angle of inclination of the propeller blades. The ratio of this distance to the propeller diameter is known as the pitch of the propeller. A typical propeller is illustrated in Fig 2.a. standard three-bladed marine propellers with square pitch are most common; four-bladed, toothed, and other designs are employed for special purposes.

2.1.2.2. Paddles

For the simpler problems an effective agitator consists of a fiat paddle turning on a vertical shaft. Two-bladed and four-bladed paddles are common. Sometimes the blades are pitched; more often they are vertical. Some typical paddles are illustrated in Fig.2.b. Paddles turn at slow to moderate speeds in the center of a vessel; they push the liquid radially and tangentially with almost no vertical motion at the impeller unless the blades are pitched. The currents they generate travel outward to the vessel wail and then either upward or downward:

Industrial paddle agitators turn at speeds between 20 and 150 rpm. The total length of a paddle impeller is typically 50 to 80 percent of the inside diameter of the vessel. The width of the blade is one-sixth to one tenth its length. At very slow speeds a paddle gives mild agitation in an unbaffled vessel; at higher speeds baffles become necessary. Otherwise the liquid is swirled around the vessel at high speed but with little mixing.

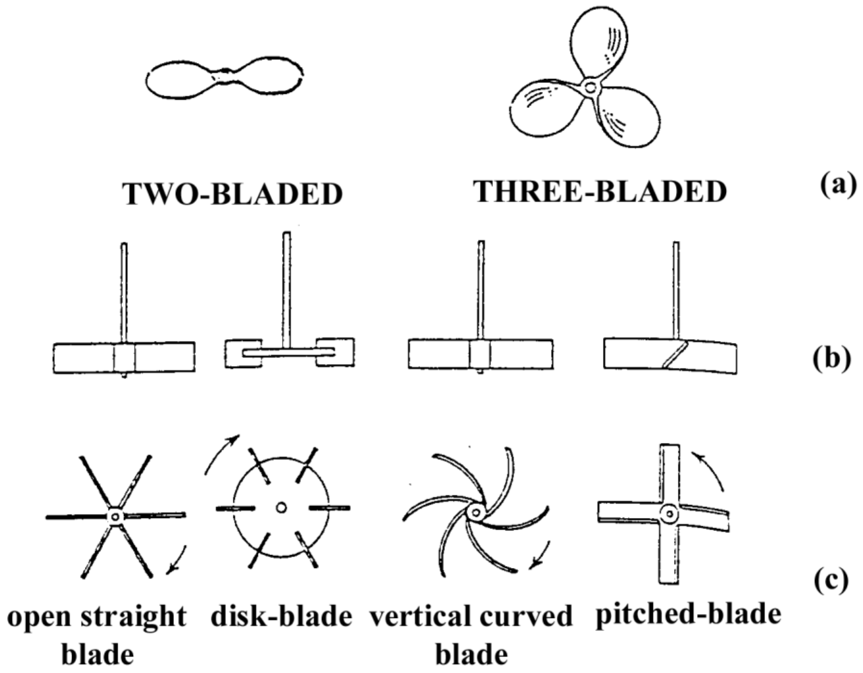

Figure 2. Mixing Impellers: a) Propellers, b) Paddles, c) Turbines

2.1.2.3. Turbines

Most of turbines resemble multibladed paddle agitators with short blades, turning at high speeds on a shaft mounted centrally in the vessel. The diameter of a turbine is normally ranging from 30 to 50 percent of the diameter of the vessel. Turbine impellers come in a variety of types, such as curved-blade, pitched-blade and flat-blade, as illustrated in Fig.2.c.

Turbines are effective over a very wide range of viscosities. In low viscosity liquids turbines generate strong currents which persist throughout the vessel, seeking out and destroying stagnant pockets. Near the impeller is a zone of rapid currents, high turbulence, and intense shear. The principal currents are radial and tangential. The tangential components induce vortexing and swirling, which must be stopped by baffles or by a diffuser ring if the impeller is to be most effective.

2.1.3. Flow Patterns in Agitated Vessels

The type of flow in an agitated vessel depends on the type of impeller; the characteristics of the fluid and size and proportions of the tank, baffles, and agitator. The velocity of the fluid at any point in the tank has three components, and the overall flow pattern in the tank depends on the variations in these three velocity components from point to point. The first velocity component is radial and acts in a direction perpendicular to the shaft of the impeller. The second component is axial and acts in a direction parallel with the shaft. The third component is tangential, or rotational, and acts in a direction tangent to a circular path around the shaft.

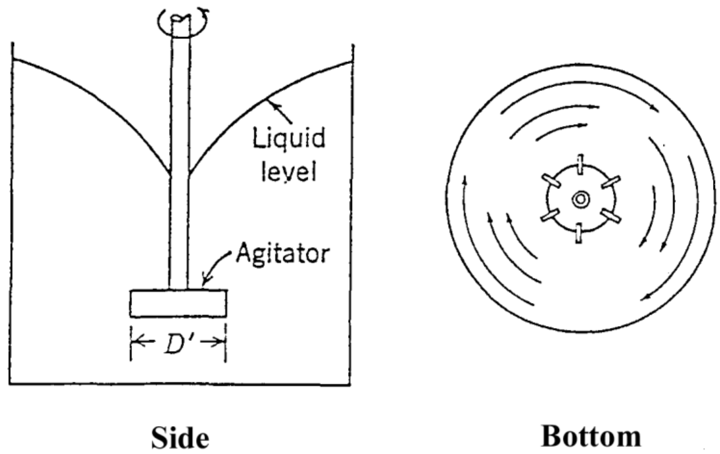

Figure 3. Typical flow pattern for either axial or radial-flow impellers in an unbaffled tank

The radial and axial components are useful and provide the flow necessary for the mixing action. When the shaft is vertical and centrally located in the tank, the tangential component is generally disadvantageous. The tangential flow follows a circular path around the shaft and creates a vortex in the liquid, as shown in Fig. 3 for a fiat-bladed turbine. Exactly the same flow pattern would be observed with a pitched blade turbine or a propeller. At high impeller speeds the vortex may be so deep that it reaches the impeller, and gas from above the liquid is drawn into the charge. Generally this is undesirable.

Circulatory flow and swirling can be prevented by any of three methods. In small tanks, the impeller can be mounted off center. The shaft is moved away from the centerline of the tank, then tilted in a plane perpendicular to the direction of the move. in larger tanks, the agitator may be mounted in the side of the tank, with the shaft in horizontal plane but an angle with a radius. In large tanks with vertical agitators, the preferable method of reducing swirling is to install baffles, which impede rotational flow without interfering with radial or axial flow.

2.2. POWER CONSUMPTION IN AGITATED VESSELS

An important consideration in the design of an agitated vessel is the power required to drive the impeller. This power requirement can not be estimated theoretically, even in the simplest agitated system, but it can be studied by the same type of quantitative experiment, guided by dimensional analysis, that has been successfully applied to other problems in fluid mechanics. Thus, consider the fiat-blade turbine agitator shown in Fig.4; assume that the tank is filled to a definite level (unagitated) with a liquid of known density and viscosity and that the impeller is driven at a speed of n times revolutions per unit time. Assume also that all important measurements of the apparatus are known. It is desired to find by dimensional analysis a relationship for the power required to maintain the speed of the impeller in terms of the above variables.

The power should be dependent on the flow pattern in the mixer and on the geometrical proportions of the equipment. The mechanism of flow is a complicated combination of laminar flow, turbulent flow, and boundary-layer separation. The controlling variables that must enter the analysis can be listed as follows:

The important measurements of tank and impeller, the viscosity μ and density ρ of the fluid, the speed n, because of the Newton's law applies, the dimensional constant g_c. Also unless is to eliminate swirling, a vortex will appear at the surface of the liquid. Some of the liquid must be lifted above the average, or unagitated, level of the liquid surface and this lift overcome the force of gravity. Accordingly, the acceleration of gravity g must be considered as a factor in the analysis.

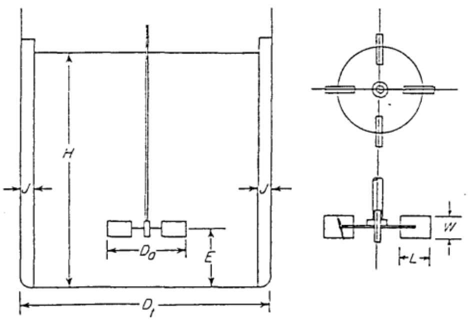

Figure 4. Measurements of a standard agitation tank and a turbine

2.2.1. The Shape Factors of the System

The various linear measurements of the impeller can all be converted to dimensionless ratios, called shape factors, by dividing each of them by one of their number which is arbitrarily chosen as a basis. The diameter of the impeller D_a is a suitable choice for this base measurement, and the shape-factors are calculated by dividing each of the remaining measurements by the magnitude of D_a.

The important measurements of the apparatus are tank diameter, D_t the distance of the impeller from the bottom of the tank, E; length of impeller blades L, width of impeller blades, W; width of baffles, J; and liquid depth, H. Also the number and arrangement of the baffles and the number of impeller blades must be specified. If a propeller is used, the pitch and number of blades are important. The shape factors for the mixer in Fig.4 are

$S_1=D_a/D_t$, $S_2=E/D_a$, $S_3= L/D_a$, $S_5=W/D_a$, $S_6=J/D_t$ and $S_7=H/D_t$

The effects on power of the shape factors S_1, S_2,…S_n are sometimes small and sometimes very large. Sometimes two or more of the factors are interrelated, i.e., the effect of changing S_1, say, may depend on the magnitude of S_2 or S_3.

2.2.2. Fluid Mechanics of Agitation

The agitation of fluids in vessels is an operation based on the principles of fluid mechanics and consequently should be resolvable using these principles. An agitation in a baffled tank as shown in Fig.4 will maintain a uniform fluid level irrespective of the speed of rotation of the agitator. However, if the tank is not baffled, as shown in Fig.3, at a high enough speed of rotation a vortex will form. The vortex occurs when the fluid level increases along the radius at higher agitator speeds. The liquid level pattern shown in Fig.3 is that of a typical vortex. Vortex formation is a phenomenon that can occur at an unbounded, or free, surface. It is related to wave motion on bodies of water, which can only occur at an unbounded surface.

The analysis of agitation can be approached in terms of the energy equation. For unit mass of fluid

$$\Delta\left(\frac{\upsilon^2}{2g_c\alpha}\right)+\Delta z\frac{g}{g_c}+\Delta(PV)-\int_{V_2}^{V_1}PdV-\sum F=-W_f' \qquad (1)$$

In the usual sense, the energy equation relates changes between points in a flowing system. In the over-all sense, the agitator does not constitute a flowing system; therefore, all position-dependent terms go to zero, and the equation becomes

$$\sum F = W_f^{'} \tag{2}$$

and therefore only the friction or work need be known.

Baffled Tank: The moving blades are resisted by a drag force distributed over the area of the impeller. Imagine that the distributed drag force may be replaced by a concentrated force F acting on the impeller blades. By definition of the drag force in Eq.3, F_D in terms of the drag coefficient C_D is

$$F_D = C_D \frac{A_p \upsilon^2 \rho}{2g_c} \tag{3}$$

F_D : the force applied to the solid surface by the fluid motion, N or lb_f

C_D : the drag coefficient

A_p : the projected area of the solid normal to the fluid motion, m^2 or ft^2.

υ : a characteristic velocity of the fluid, m/s or ft/s

ρ : the density of the fluid, kg/m^3 or lb/ft^3

The motion of the fluid over the agitator blade and the consequent motion of the fluid past the stationary baffles must have associated with them skin friction and form drag, depending upon the speed and design. Therefore, for a geometrically similar system of agitator, tank, and baffles, the drag coefficient-Reynolds number relationship may be written

$$C_D = \Phi N_{\mathrm{Re}} \tag{4}$$

These terms may be expanded into groups of variables for further consideration.

$$\frac{2F_D g_c}{A_p \upsilon^2 \rho} = \Phi \frac{L^{'} \upsilon \rho}{\mu} \tag{5}$$

The variables in Eq.5 with the exception of fluid properties are not in a form that is easily measurable for agitation; therefore, before Eq.5 can be applied, some modification is in order. In a geometrically similar system, all length dimensions bear a constant ratio; therefore, any measurable dimension may be used to replace L’. The agitator diameter D_a will be used in any instance in which a characteristic length is required.

The term F/A, the force applied to the fluid per unit area, can be used more conveniently if the term is converted to power input. Recall that power is the product of force and velocity of application; then,

$$\frac{\upsilon F}{A_p} = \frac{P}{A_p} \tag{6}$$

where P defined as power. The area term may be written in terms of the characteristic length; that is, the area is proportional to D_a^2.

$$\frac{F_D}{A_p} \propto \frac{P}{\upsilon D_a^2} \tag{7}$$

The velocity (υ) is a linear velocity. In this system, the tangential tip velocity of the agitator is proportional to linear tip velocity so that

$$\upsilon \propto \pi n D_a \propto n D_a \tag{8}$$

Equations 7 and 8 may be substituted into Eq. 9

$$\frac{P g_c}{n^3 D_a^5 \rho} = \Phi \frac{D_a^2 n \rho}{\mu} \tag{9}$$

or

$$N_{Po} = \Phi N_{\mathrm{Re}} \tag{10}$$

where $N_{Po} = P g_c / n^3 D_a^5 \rho$, the drag coefficient for agitation systems referred to as the "power number" and represents the ratio

$$N_{Po} = \frac{\text{drag stress}}{\text{inertial stress}}$$

$N_{\mathrm{Re}} = D_a^2 n \rho / \mu$, the Reynolds number expressed in variables convenient for agitation and represents the ratio

$$N_{\mathrm{Re}} = \frac{\text{inertial stress}}{\text{shear stress}}$$

This equation is written expressly for geometrically similar tank systems in which the tanks are baffled.

Unbaffled Tanks: In unbaffled tanks, the formation of vortex introduces an additional mechanism, namely, the fluid forces associated with gravity. In the vortex a part of the tank contents is supported against the gravitational acceleration of the earth, and therefore fluid forces in the system must supply the force to maintain the head of the fluid that constitutes the vortex. The nature of the forces can be analyzed if an element of fluid is examined in the vortex, as shown in Fig.5 The fluid element is taken at z the lowest point of the vortex, and therefore, at any radial position, a "head" of fluid will exist above the element. At steady state, the pressure on any element in the fluid must be such that the forces on every face of unit area of the element are the same. As elements are examined at z_o from r=0 to $r=r_1$ the pressure must be increasing because an increasing head of fluid is present. The force associated with the head is represented by F_b, the body force, and the radial force is represented by F_c and surely.

$$F_b = F_c \tag{11}$$

The force F then is obviously a centrifugal force resulting from the motion of the fluid trough the volume element. Therefore, each of the forces can be related to system variables. The body force on the element $\Delta x \Delta y \Delta z$ is

$$F_b = \Delta x \Delta y (z - z_o) \rho \frac{g}{g_c} \tag{12}$$

and the centrifugal force on the element is

$$F_c = \frac{\Delta x \Delta y \Delta z r \omega^2 \rho}{g_c} \tag{13}$$

where Δx, Δy, Δz : the element dimensions, m or ft.

$(z\text{-}z_o)$: the height of fluid above the element, m or ft.

r : the radial position, m or ft.

ω : angular velocity, rad/s

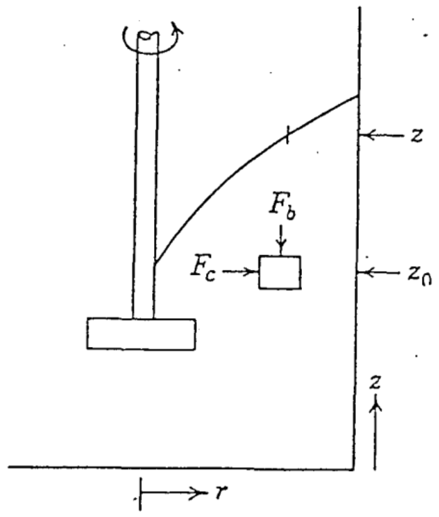

Figure 5. Forces associated with an element of fluid in a vortex.

These forces can be equated.

$$\Delta x \Delta y (z - z_o) \rho \frac{g}{g_c} = \frac{\Delta x \Delta y \Delta z r \omega^2 \rho}{g_c} \tag{14}$$

ρ , Δx , Δy and g_c cancel from the equation so that

$$(z - z_o) g = \Delta z r \omega^2 \tag{15}$$

The right-hand term of the equation is related to the kinetic energy of the fluid, and the left-hand side is related to forces associated with gravity. This equation may be written

$$\frac{\Delta z r \omega^2}{(z - z_o) g} = 1 \tag{16}$$

The exact numerical value of each term is not known, but, in a similar system, all length dimensions can be taken proportional, so that

$$\Delta z \propto (z - z_o) \approx r \approx D_a \tag{17}$$

and in a dynamically similar system

$$\omega \propto n \tag{18}$$

Therefore, Eq. 16 may be written as

$$\frac{D_a n^2}{g} = \text{constant} \tag{19}$$

for a dynamically similar system. The group $D_a n^2 / g$ is called the Froude number, (N_{Fr}) and represented the ratio

$$N_{Fr} = \frac{\text{Forces associated with kinetic energy}}{\text{Forces associated with gravity}}, \text{ or, } \frac{\text{inertial stress}}{\text{gravitional stress}}$$

and the group is dimensionless. The Froude number appears in fluid-dynamic situations where there is significant wave motion on the surface of a liquid. It is especially important in the design of ships.

The additional gravitational effects in an unbaffled agitator system can be included in a correlation equation in terms of the Froude number so that

$$N_{Po} = \Phi(N_{\text{Re}})(N_{Fr}) \tag{20}$$

Equation.20 may be expanded into system variables as

$$\left(\frac{Pg_c}{n^3 D_a^5 \rho}\right) = \Phi\left(\frac{D_a^2 n \rho}{\mu}\right)\left(\frac{D_a n^2}{g}\right) \tag{21}$$

2.2.3. Calculation of Power Consumption

In the baffled tank, N_{Po} is a function of the N_{Re} only, as shown in Eq.10, and the definition of N_{Po} to give

$$P = \frac{N_{Po} n^3 D_a^5 \rho}{g_c} \tag{22}$$

There are several typical plots of N_{Po} as a function of N_{Re}. At low Reynolds numbers, these lines for both baffled and unbaffled tanks coincide, and the slope of the line on logarithmic coordinates is -1 (Figs. 6 and 7). The flow becomes laminar in this range, density is no longer a factor and Eq. 10 becomes

$$N_{Po} N_{\text{Re}} = K_L \tag{23}$$

Then from Eq.24,

$$P = \frac{K_L n^2 D_a^3 \mu}{g_c} \qquad (24)$$

Eq.23 and 24 can be used when N_{Re} less than 10. In baffled tanks at N_{Re} larger than about 10.000, the N_{Po} is independent of the N_{Re} and viscosity is not a factor. Changes in N_{Fr} have no effect. In this range the flow is fully turbulent, and Eq.10 becomes

$$N_{Po} = K_T \qquad (25)$$

from which

$$P = \frac{K_T n^3 D_a^5 \rho}{g_c} \qquad (26)$$

The region between that defined by Eq.23 and 25 represents transition of the boundary layer and development of significance of the accelerative effects associated with form drag (Figs. 6 and 7).

Magnitudes of the constands K_T and K_L for various types of impellers and tanks are shown in Table 1.

Table 1. Values of canstants K_T and K_L for baffeled tanks having four baffles at tank wall.

Type of Impeller	K_L	K_T
Propeller, three blades		
Pitch 1.0	41	0.32
Pitch 1.5	55	0.87
Turbine		
Six-blade disk (S_3 = 0.25, S_4 = 0.2)	65	5.75
Six curved disk (S_4 = 0.2)	70	4.80
Six pitched blades (45^0, S_4 = 0.2)	-	1.63
Four pitched blades (45^0, S_4 = 0.2)	44.5	1.27
Flat paddle, two blades (S_4 = 0.2)	36.5	1.70
Anchor	300	0.35

The effect of the Froude number on power, appears when there is vortex formation, and then only if the Reynolds number is greater than 300. The Froude number is taken into account when it is a factor, consequently, N is given by following equation:

$$N_{Po(cor)} = N_{Po} N_{Fr}^{m} \quad (27)$$

The exponent *m* in Eq.27 is, for a given set of shape factors, empirically related to the Reynolds number by the equation

$$m = \frac{a - \log N_{\mathrm{Re}}}{b} \quad (28)$$

where *a* and *b* are constants. The magnitudes of a and b for the curves of Figs.6 and 7 are given in Table 2. So that, Eq.22 may be written as

$$P = \frac{N_{Po(Cor)} n^3 D_a^5 \rho}{g_c} \quad (29)$$

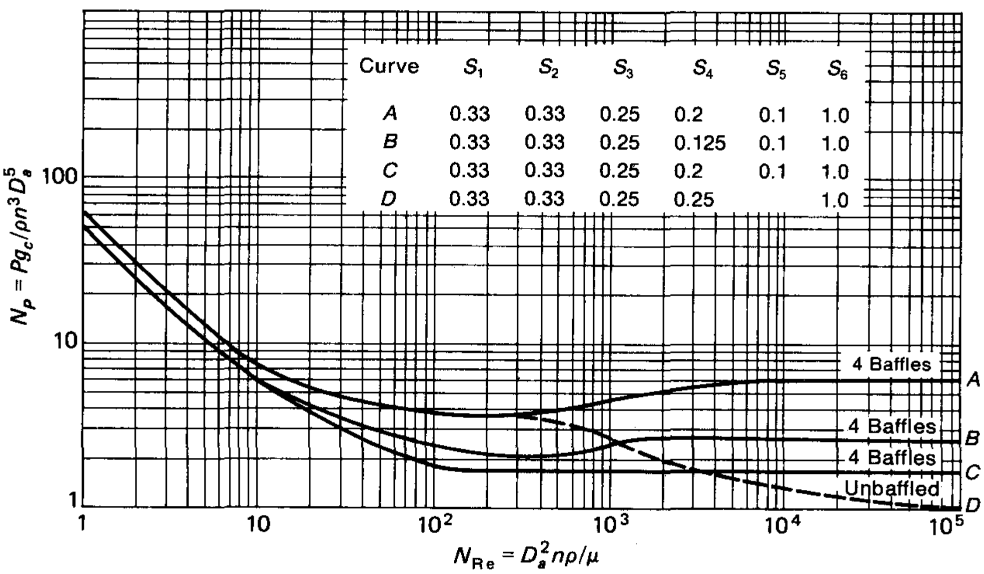

Figure 6. Power number N_P versus N_{Re} for six-blade turbine. With the dashed portion of curve D, the value of N_P read from the figure must be multiplied by N_{Fr}^{m}

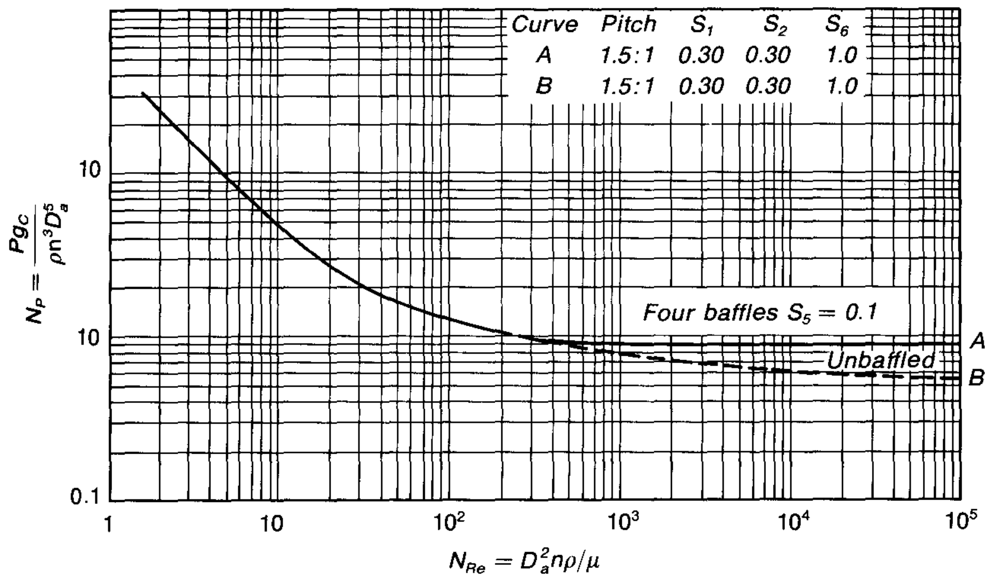

Figure 7. Power number N_P versus N_{Re} for three-blade propeller. With the dashed portion of curve B, the value of N_P read from the figure must be multiplied by N_{Fr}^m

Table 2.Constants a and b of eq.28

Figure	Line	a	b
6	D	1.0	40.0
7	B	1.7	18.0

3. EXPERIMENTAL SECTION

3.1. EXPERIMENTAL SET-UP

The aim of the experiment is to observe the various flow pattern that can be achieved by the use of different impellers with and without the use of baffles, to show the power consumed by a mixer varies with speed, type of impeller, and with the inclusion of baffles and to predict the power absorbed by a large mixer using the fluid mixing apparatus provided as a model.

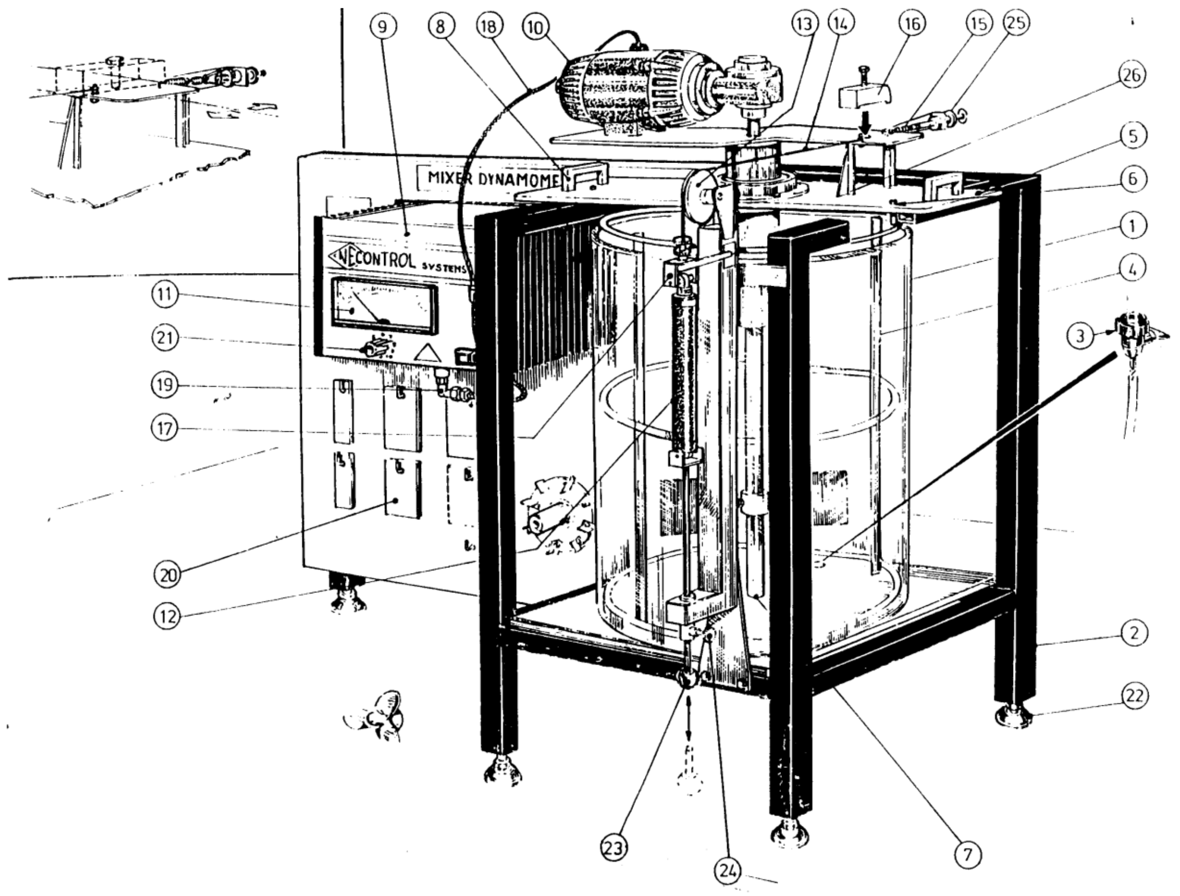

Figure 8. Fluid Mixing Apparatus

1. Acrylic cylindrical mixing vessel
2. Steel framework
3. Dram tap
4. Removable baffles
5. Dynamometer support plate
6. Support dowels
7. Drive shaft
8. Lifting handles
9. Electronic speed controller
10. Motor
11. Tachometer

12. Dynamometer
13. Pulley
14. Cord
15. Tensioning spring
16. Setting block
17. Indicator
18. Power cable
19. Power supply
20. Paddle
21. Speed controller switch
22. Base
23. Calibration rod
24. Setting screw
25. Setting screw
26. Assembly

The apparatus consists of an acrylic cylindrical mixing vessel mounted on a mild steel framework and backboard. The mixing vessel incorporates a drain tap, depth scale and a removable set of baffles. Mounted directly above the mixing vessel is the dynamometer support plate which locates on two support dowels ensuring that the drive shaft is positioned centrally in the mixing vessel. An electronic speed controller is used to vary the speed of a D.C. shunt wound, geared motor. A tachometer, gives a direct reading of the drive shaft speed in rpm. Torque transmitted to the dynamometer is obtained using a direct reading force balance mounted on the frame. A pulley and cord arrangement transfers the horizontal force on the motor to a vertical force. A tensioning spring and locking arrangement permit the dynamometer arm to be positioned in a neutral position, which is determined by the setting block. An indicator above the force balance can be set to align with a datum line on the frame by adjustment of the cord length. The range of impellers supplied is attached to the backboard. These impellers can be easily fitted to the drive shaft by clamping them to the locking collar which itself can be positioned at any distance along the drive shaft.

3.2. EXPERIMENTAL PROCEDURE

Flow Patterns

- Attach flat paddle impeller with base of bush level with the end of the shaft.
- Add a small quantity of plastic pellets and make sure that the torque arm clamp is fixed.
- Turn up the speed of the impeller in small increments, say 25 rpm., until the pellets are seen to swirl around in the water. A vortex will be seen to form on the surface of the water. As the speed is increased air is entrained and bubbles become dispersed through the water.
- Care should be taken to make sure that water does not spill over the sides of the tank by increasing the speed too much.
- Repeat the procedure with each impeller and again with the four baffles in position with each impeller. Observe the movement of pellets in each case.

Power Consumption

- Fill the tank up to a depth of 0.3m with water, and attach the flat paddle impeller with the base of the bush level with the end of the shaft.
- Release the balance adjustment clamp, and allow the dynamometer arm to move freely (length of torque arm, r, 0.11m) To set the dynamometer to a neutral position use the setting bar and adjust the tension spring as necessary.
- Adjust the length of the cord so that the indicator aligns with the mark on the datum plate in the neutral position.
- Increase the speed control knob in gradual increments and record the speed on the speed indicator and the force on the balance at each speed of the mixer.
- Repeat using the turbine impeller and other flat bladed paddles.
- Repeat with the baffles fitted with each flat paddle and the turbine impeller.

4. CALCULATIONS

4.1. Experimental Calculations

- Calculate the angular velocity and torque values by using experimental data of each impellers.

- Calculate the power absorbed by a mixer for each data by using following equation

$$P = \tau \times \omega$$

  And prepare the table which include n, ω, F, τ and P values for each different impellers with and without the use of baffles.
- Plot the power against the angular velocity for different impellers to discuss the difference between the baffled and unbaffled systems.

4.2. Theoretical Calculations

Baffled Tank

- Calculate the N_{Re} and read the N_{Po} from typical plots of N_{Po} as a function of N_{Re}.
- Calculate the theoretical power by using Eq.23.
- If N_{Re} is less than 10 or larger than 10.000, calculate the power as expressed in page 10.
- Prepare the table which include n, N_{Re}, N_{Po} and P values for each impeller with the use of baffle.

Unbaffled Tank

- Calculate the N_{Re} and read the N_{Po} from typical plots of N_{Po} as a function of N_{Re}.
- If N_{Re} is greater than 300, calculate the N_{Fr} and m by using Eq.19 and Eq. 29 respectively and calculate the $N_{Po(cor)}$ from Eq.28 by using N_{Po}, N_{Fr} and m values.
- Finally, calculate the power by using Eq.30.
- Prepare the table which include n, N_{Re}, N_{Po}, N_{Fr}, m, $N_{Po(cor)}$ and P values for each impeller without the use of baffles.

SYMBOLS

A_P	The projected area of the solid normal to the fluid motion, m^2 or ft^2
a	Constant in Eq.29
b	Constant in Eq.29
C_D	Drag coefficient
D	Diameter of impeller, D_a; diameter of tank, D_t; m or ft
E	Height of impeller above vessel floor, m or ft
F	Force, N or lb_f; F_D, drag force; F_b, body force; F_c, centrifugal force
g	Gravitational acceleration, m/s^2 or ft/s^2
g_c	Newton's-law proportionality factor, 32.174 ft-lb/ lb_f-s^2
H	Depth of liquid in vessel, m or ft
J	Width of baffles, m or ft
K_L	Constant in Eq.24
K_T	Constant in Eq.26
L	Length of impeller blades, m or ft
L′	A characteristic dimensions, m or ft
m	Exponent in Eq.29
N_{Fr}	Froude number
N_{Po}	Power number
N_{Re}	Reynolds number
n	Rotational speed, r/s
P	Power, W or ft-lb_f/s
r	The radial position, m or ft
S	Shape factor; S_1, S_2, S_3, S_4, S_5 and S_6
υ	A characteristic velocity of the fluid, m/s or ft/s
W	Impeller width, m or ft
ρ	The density of the fluid,kg/m^3 or lb/ft^3
μ	The absolute viscosity of the fluid, P or lb/ft-s
ω	Angular velocity, rad/s
Φ	Function

REFERENCES

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3. Perry, Robert. H., Green, D., "Perry's Chemical Engineers' Handbook", sixth edition, pp 19-5,19-10, McGraw Hill, USA, 1986.
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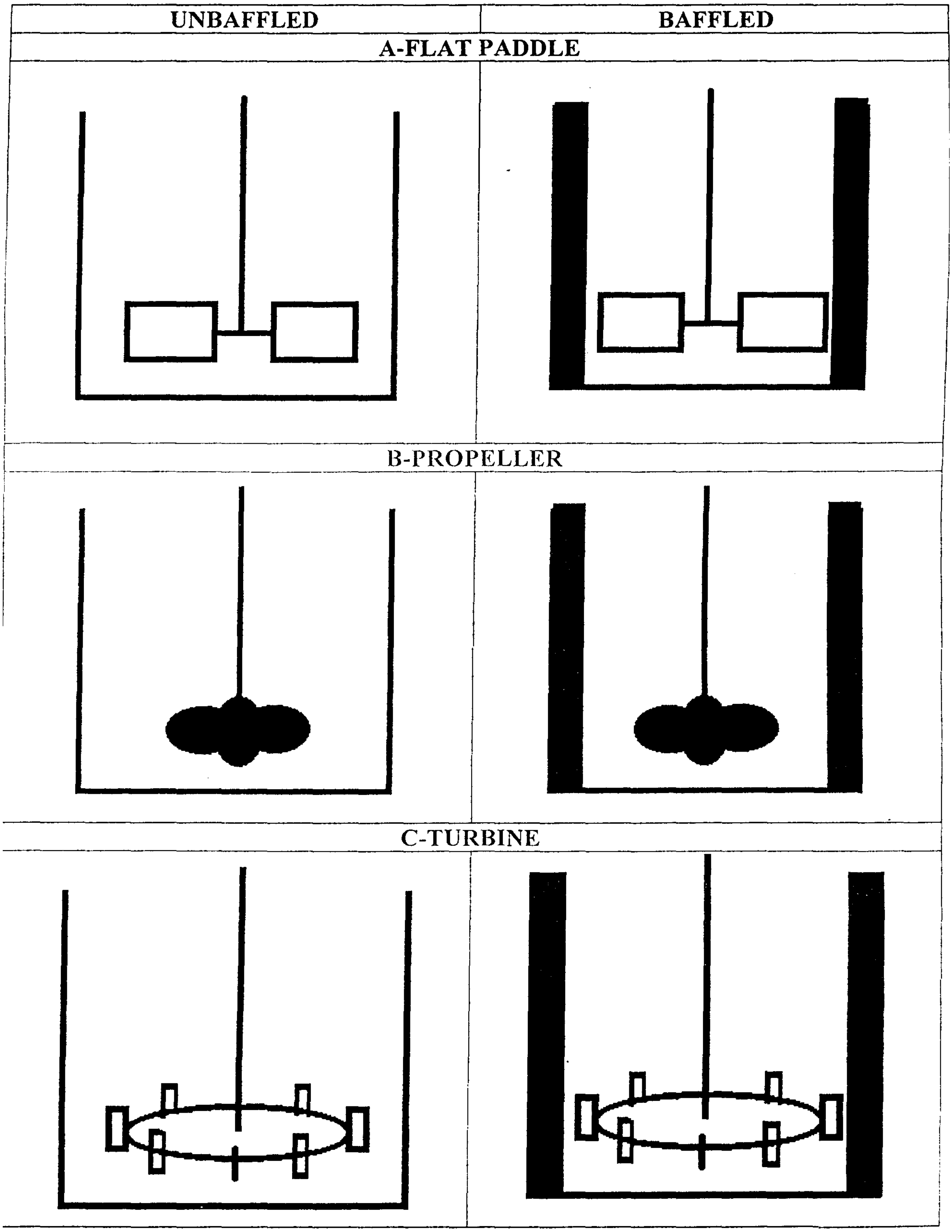
DATA SHEET

1. FLOW PATTERN



2. POWER CONSUMPTION

D_t= **H=** **J=**

Impeller type:

D_a= **L=** **W=** **E=**

BAFFLED **UNBAFFLED**

Impeller speed (rpm)	F (N)	Impeller speed (rpm)	F (N)	h_{vortex} (mm)

Impeller type:

D_a= **L=** **W=** **E=**

BAFFLED **UNBAFFLED**

Impeller speed (rpm)	F (N)	Impeller speed (rpm)	F (N)	h_{vortex} (mm)

Impeller type:

D_a= **L=** **W=** **E=**

BAFFLED **UNBAFFLED**

Impeller speed (rpm)	**F (N)**	**Impeller speed (rpm)**	**F (N)**	**h_{vortex} (mm)**

Impeller type:

D_a= **L=** **W=** **E=**

BAFFLED **UNBAFFLED**

Impeller speed (rpm)	**F (N)**	**Impeller speed (rpm)**	**F (N)**	**h_{vortex} (mm)**