Terminology in Power Calculation

(i) Flow Number

$q \alpha n D_a^3$

$$N_Q = \frac{q}{nD_a^3}$$

- Where q is the volumetric flow rate, measured at the tip of the blades, n is the rotational speed (rpm), Da is the impeller diameter
- Total flow was shown to be→ $q_T = 0.92nD_a^3\left(\frac{D_t}{D_a}\right)$
- N_Q is constant for each type of impeller. For flat-blade turbine (FBT), in a baffled vessel, N_Q may be taken as 1.3; For marine propellers (Square pitch), N_Q = 0.5; For four blade 45° turbine, N_Q = 0.87;
- For HE impeller- N_Q=0.47

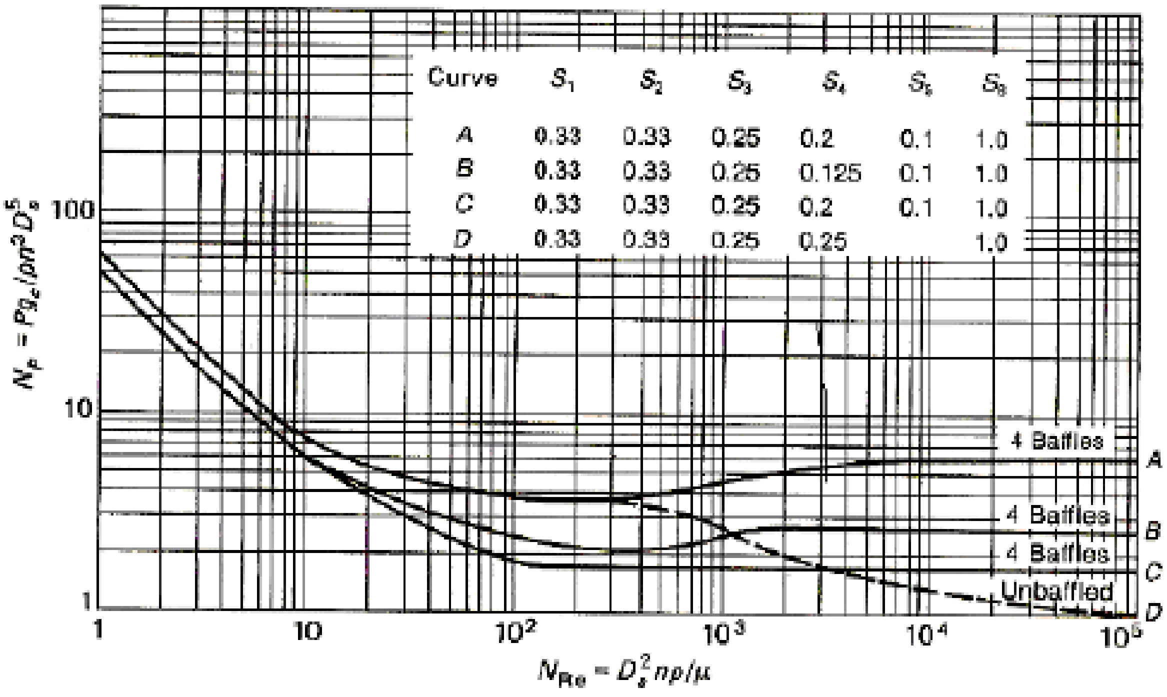
(ii) The Reynolds number, N_{Re}

$$N_{RE} = \frac{D_a^2 n\rho}{\mu}$$

(iii) The Froude number, N_{Fr}

$$N_{Fr} = \frac{n^2 D_a}{g}$$

- Froude No. is a measure of the ratio of the inertial stress to the gravitational force per unit area acting on the fluid. It appears in the dynamic situations where there is significant wave motion on a liquid surface. Important in ship design. Unimportant when baffles are not used or Re< 300



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

Fig. 18. Power Curve for Turbine Type agitator

Curve A = vertical blades, $W/D_a = 0.2$

Curve B = vertical blades, $W/D_a = 0.125$

Curve C = pitched blade

Curve D = unbaffled tank

The power number is calculated as:

$$\phi = N_p = \frac{P}{\rho N^3 D_a^5} \quad \text{and} \quad N_{Re} = \frac{\rho N D_a^2}{\mu}$$

where N_p = power number

P = power requirement, kg.m

g_c = gravitational acceleration, m/sec^2

ρ = density of the fluid, kg/m^3

μ = viscosity of the fluid, kg/m sec

D_a = Diameter of the vessel

For unbaffled vessel:

$$\phi = N_p = \frac{Pg_c}{\rho N^3 D_a^5}$$ for $N_{Re} <= 300$

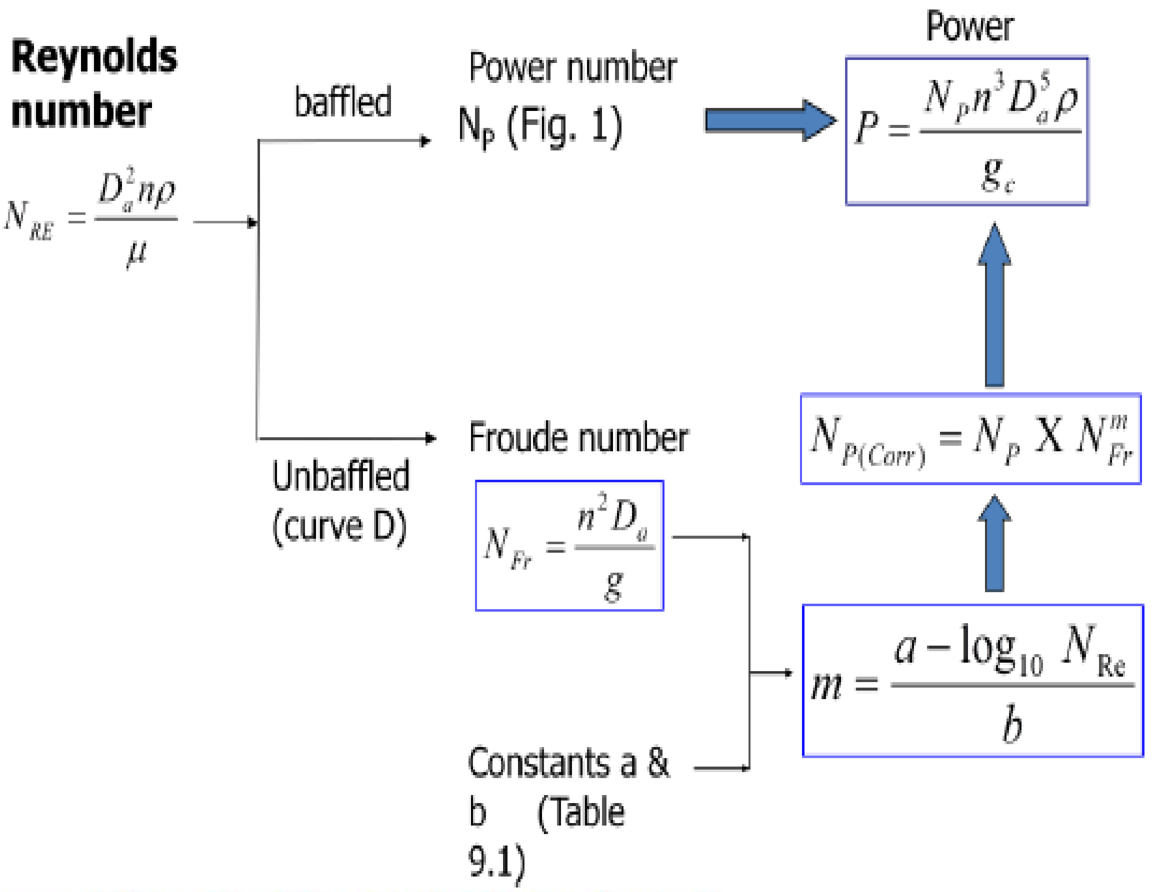
$$\phi = N_p = \frac{\alpha - \log_{10} N_{Re}}{N_{Fr}\,\beta}$$ For $N_{Re} > 300$

$$N_{Fr} = \frac{N^2 D_a}{g}$$ Fraud Number

Here the values of α & β are given as the function of Diameter of the agitator:

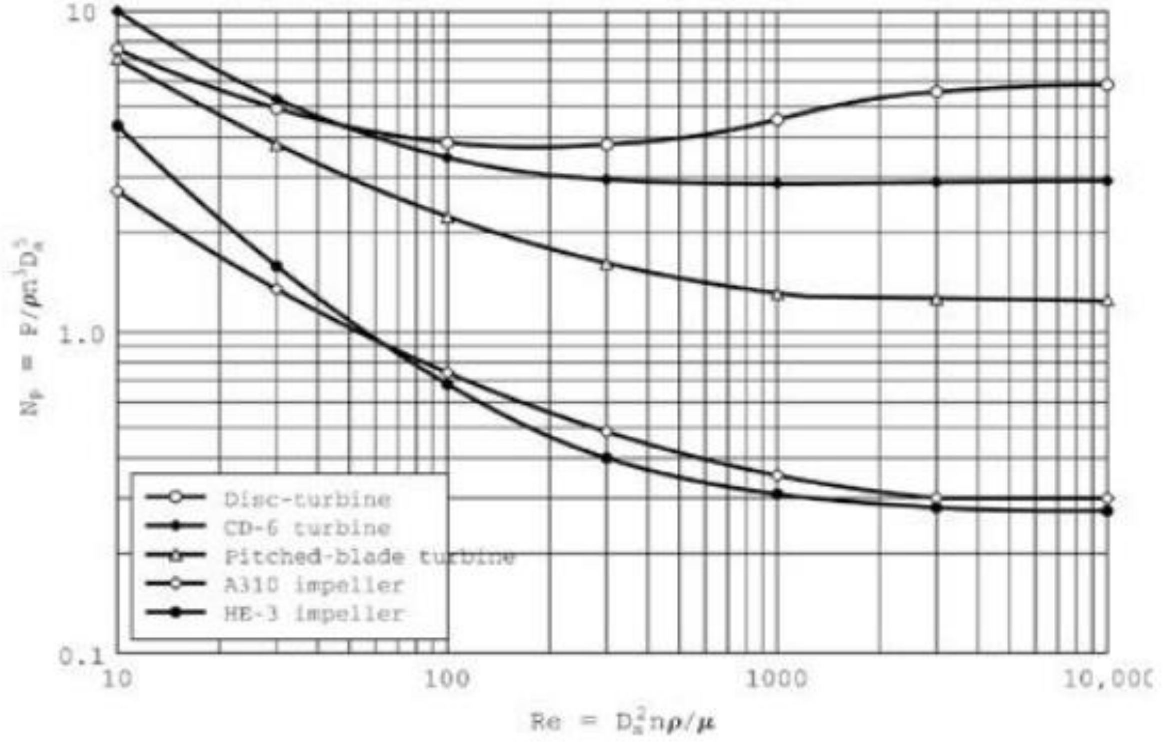
Diameter Da	Da/D	α	β
10	0.3	1.0	4.0
15	0.33	1.0	4.0

If the configuration changes the graph will be changed and the also the values.

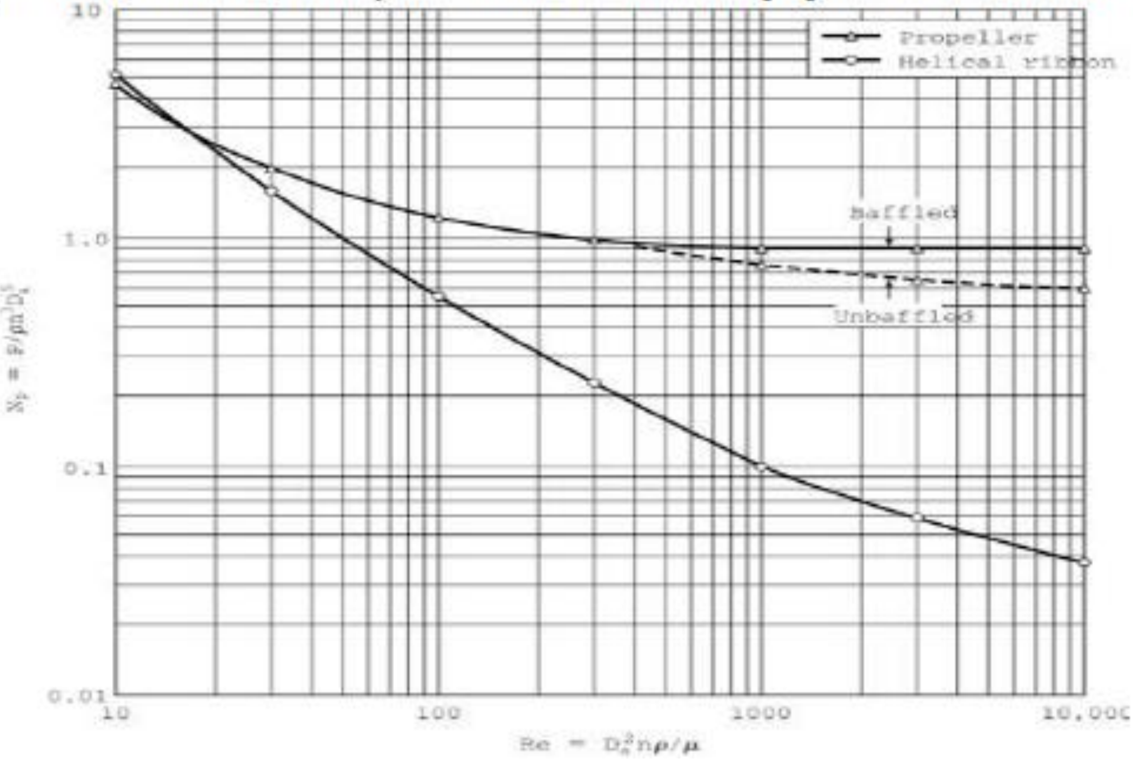


Power Number Curves for Various Type of Impeller

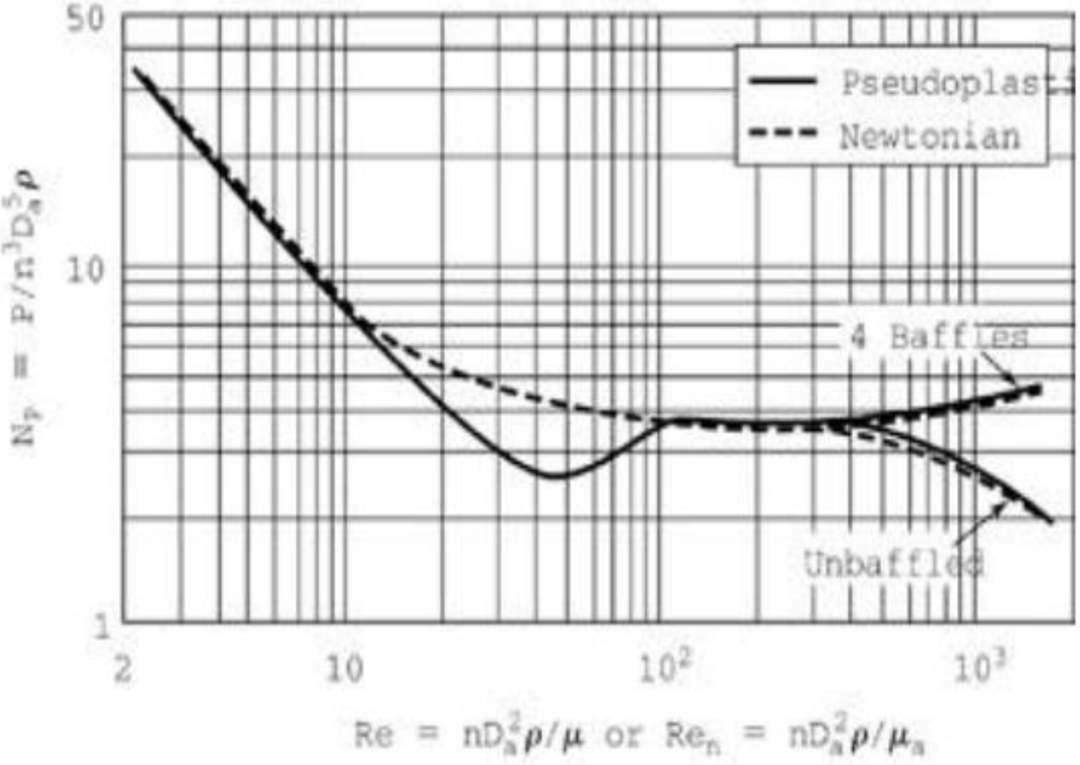
(i) Power number N_p vs. Reynolds number Re for turbines and impellers



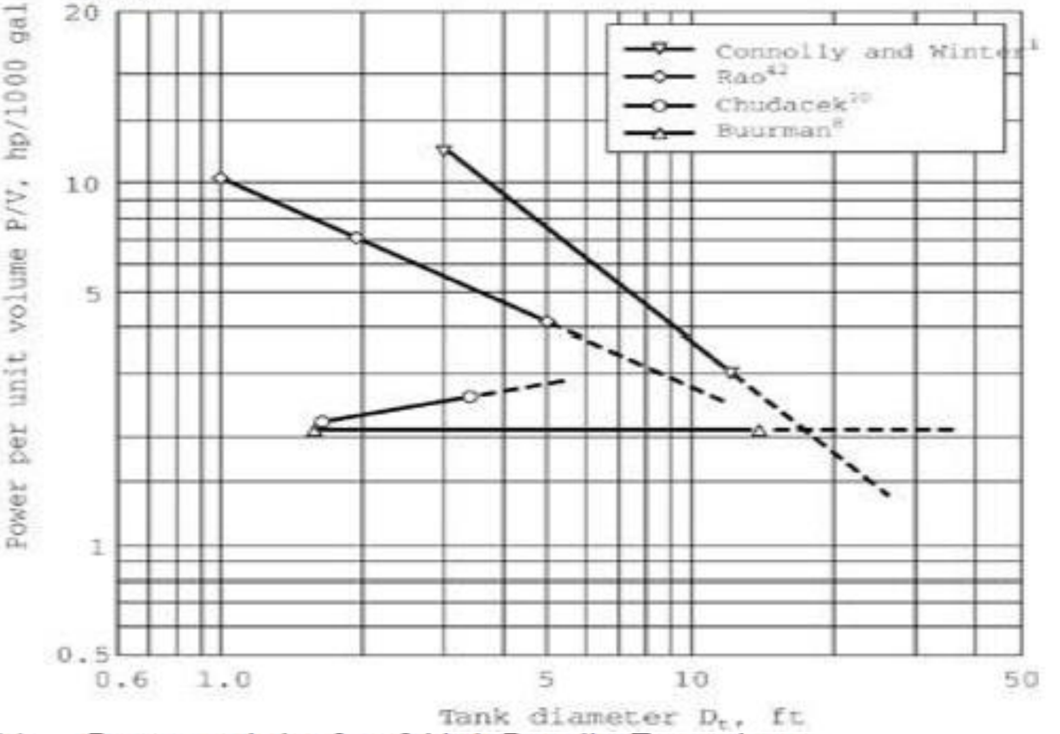
(ii) Power number N_p vs. Reynolds number Re for marine propellers and helical ribbons



(iii) Power correlation for a 6-blade turbine in pseudo plastic liquids



(iv) Power required for complete suspension of solids in agitated tanks using pitched-blade turbines



(v) Power correlation for a 3-blade Propeller Type agitator

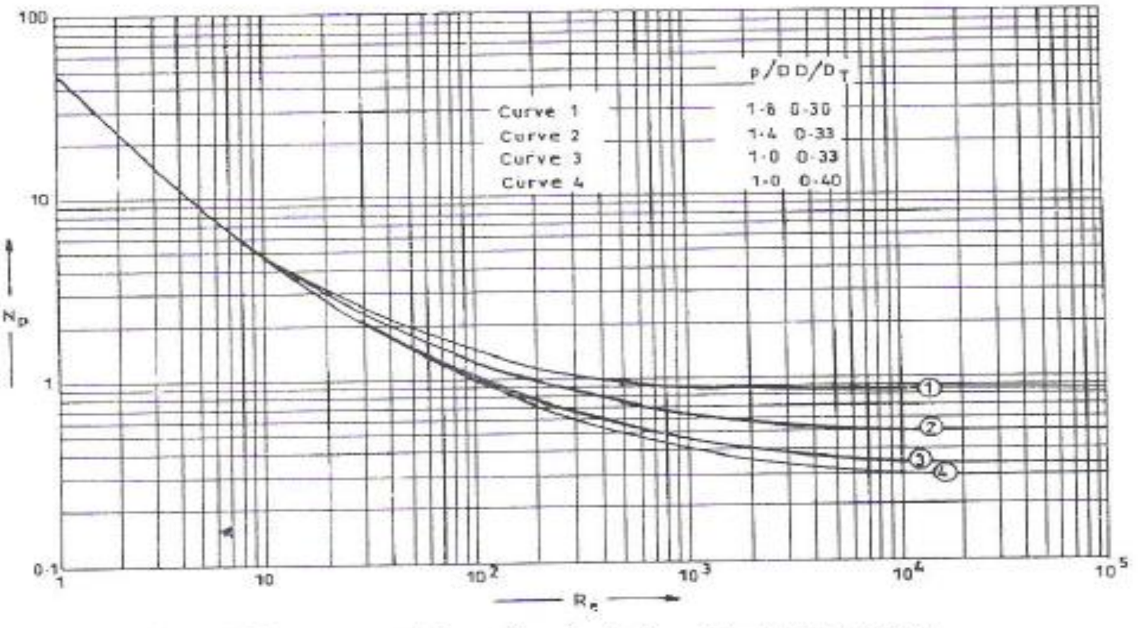


Fig. 4.6 Power correlations for single three bladed propellers

(vi) for turbine type agitator with 6 flat blades liquid height equal to vessel height and 4 baffles are installed

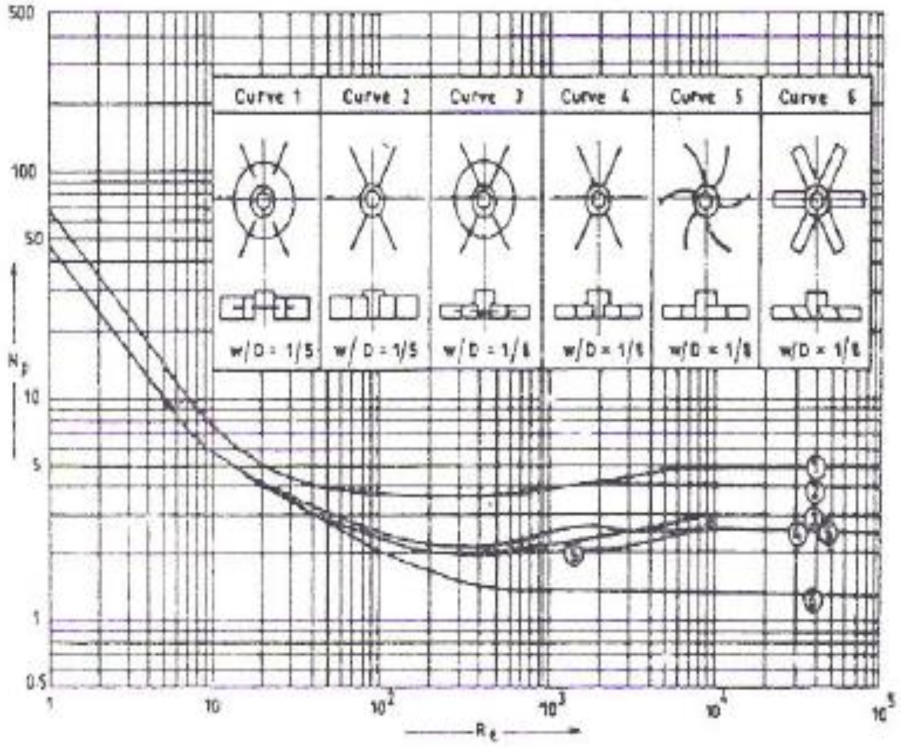


Fig. 4.9 Power correlations for baffled turbine impellers

Power Consumption

- Power Requirement $$P = \frac{N_P n^3 D_a^5 \rho}{g_c}$$
- At low N_{Re} (<10), density is no longer a factor $$N_P = \frac{K_L}{N_{Re}}$$ $$P = \frac{K_L n^2 D_a^3 \mu}{g_c}$$
- At N_{Re}>10,000 in baffled tanks, P is independent of N_{Re} and viscosity is not a factor $$N_P = K_T$$ $$P = \frac{K_T n^3 D_a^5 \rho}{g_c}$$

- K_L and K_T are constants for various types of impellers and tanks

Type of Impeller	K_L	K_T
Propeller, 3 blades Pitch 1.0 Pitch 1.5	41 55	0.32 0.87
Turbine 6-blade disk (S_3=0.25 S_4=0.2) 6 curved blades (S_4=0.2) 6 pitched blades (45°, S_4=0.2) 4 pitched blades (45°, S_4=0.2)	65 70 - 44.5	5.75 4.80 1.63 1.27
Flat paddle, 2 blades (45°, S_4=0.2)	36.5	1.70
Anchor	300	0.35

Example

A flat-blade turbine with six blades is installed centrally in a vertical tank. The tank is **1.83 m** in diameter, the turbine is **0.61 m** in diameter & is positioned **0.61 m** from the bottom of the tank. The turbine blades are **127mm** wide. The tank is filled to a depth of **1.83m** with a solution of 50% caustic soda at 65.6°C, which has a viscosity of **12cP** and a density of **1498 kg/m³**. The turbine is operated at **90 rpm**. What power will be required to operate the mixer if the tank was baffled?

Solution:

Solution (a) baffled

n = 90rpm / 60 s = 1.5 r/s

D_a = 0.61m

μ = 12cP = 12×10^{-3} kg/ms

$$N_{RE} = \frac{D_a^2 n \rho}{\mu} = \frac{(0.61)^2 (1.5)(1498)}{12 \ X 10^{-3}} = 69600$$

For Re > 10000, Np = K_T = 5.8 from curve A for baffle (NRe = 69600),
NP = 5.8 (or from table 2 given before)

$$P = \frac{N_P n^3 D_a^5 \rho}{g_c}$$

$$= (5.8)(1.5)^3 (0.61)^5 (1498) = 2476.6\ mN/s = 2476.6W$$

Solution (b) unbaffled

From Fig 1, curve D (N_{Re} = 69600), N_p = 1.07

Froude number,

n = 90rpm / 60 s = 1.5 r/s

D_a = 0.61m

μ = 12cP = 12x10^{-3} kg/ms

$N_{RE} = 69600$

$$N_{Fr} = \frac{n^2 D_a}{g} = \frac{(1.5)^2(0.61)}{9.81} = 0.14$$

$$m = \frac{a - \log 10\ N_{Re}}{b} = \frac{1.0 - \log_{10} 69600}{40} = -0.096$$

$$N_{P(Corrected)} = N_p \text{ X } N_{Fr}^m = 1.07\text{X}0.14^{-0.096} = 1.29$$

Thus power,

$$P = \frac{N_p n^3 D_a^5 \rho}{g_c} = (1.29)(1.5)^3(0.61)^5(1498)$$

$$= 550 mN/s = 550\ W$$

Newtonian and non-Newtonian Fluids

- Newtonian fluids:
  Fluids which obey the Newton's law of viscosity are called as Newtonian fluids. Newton's law of viscosity is given by
- Non-Newtonian fluids:
  Fluids which do not obey the Newton's law of viscosity are called as non-Newtonian fluids. Generally non-Newtonian fluids are complex mixtures: slurries, pastes, gels, polymer solutions etc.

$$\tau_{xy} = \mu \frac{\partial v_x}{\partial y}$$

There is also one more - which is not real, it does not exist - known as the ideal fluid. This is a fluid which is assumed to have no viscosity. This is a useful concept when theoretical solutions are being considered - it does help achieve some practically useful solutions.

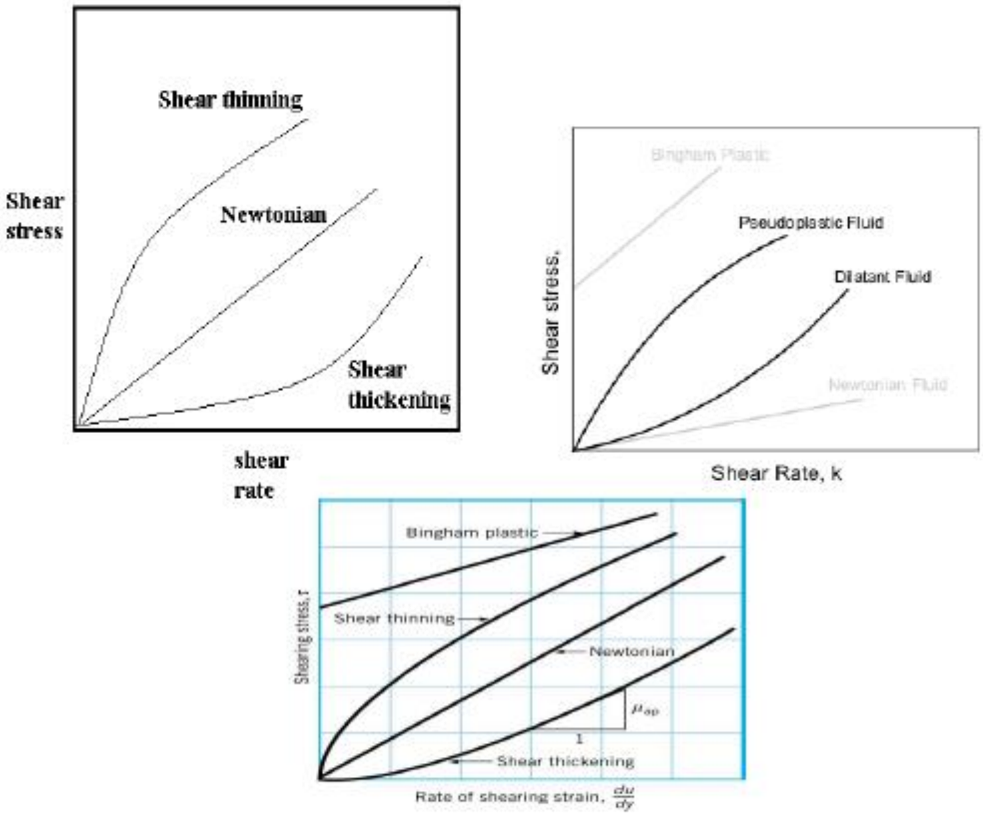


Fig. 19. Various Non-Newtonian Fluids