Agricultural and Food Engineering Department
Indian Institute of Technology, Kharagpur

**End Autumn Semester Examination 2009-10** **Full Marks: 50**
**Date of Examination: 23-11-2009 (FN)** **Time: 3 hr**
**Course: IV Year B.Tech. (Hons.) Agril. & Food Engineering** **No. of Students: 15**
**Subject No.: AG 40005** **Sub. Name: Mechanical Operations in Food Processing -**

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**Instructions:** Answer all questions. Make reasonable assumptions wherever necessary.

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1. **(a)** Derive expressions for pressure drop and minimum fluidization velocity in a packed bed. [4]

   **(b)** Solid particles having a size of 0.16 mm, a shape factor of 0.89, and a density of 890 $kg/m^3$ are to be fluidized with using air at 2 atm abs and 25°C. The voidage at min. fluidization conditions is 0.45. The air properties at 1 atm and 25°C are given as $\mu = 1.2$ x10-5 Pa.s, $\rho = 1.187$ $kg/m^3$ $p = 1.0132 \times 10^5$ Pa. (i) If the cross section of the empty bed is 0.45 $m^2$ and bed contains 500 kg of solid, calculate the minimum height of the fluidized bed.(ii) Calculate the pressure drop at minimum fluidizing conditions. (iii) Calculate the minimum velocity for fluidization. (iv) Estimate the voidage of the bed, if the operating velocity is 3 times the minimum fluidizing velocity. [6]

2. **(a)** Enumerate different equipment used for agitation with various configurations drawn neatly. [2.5]

   **(b)** Explain the procedure for agitator scale-up and derive an expression for scale-up rule exponent under different turbulent agitation conditions. [2.5]

   **(c)** A flat blade turbine agitator with disk having six blades is installed in a tank with a diameter $D_t$ of 1.83 m, the turbine diameter $D_a$ of 0.61 m, $D_t = H$ and the width W is 0.122 m. The tank contains four baffles each having a width J of 0.15 m. The turbine is operated at 90 rpm and the liquid in the tank has viscosity of 10 cp and a density of 929 $kg/m^3$ .(i) Calculate the required power of the mixer. (ii) For the same conditions if the solution viscosity changes to 50000 cp, calculate the percent change in power requirement. [5]

3. **(a)** What are the criteria considered in selection of the proper conveying systems? Explain the working of screw conveyor with a diagram? [5]

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**(b)** Design a horizontal screw conveyer for conveying wheat with bulk density of 850 $kg/m^3$ with a required capacity of 5 ton/h & for conveying length of 6 metre. Assume the avg. size of grain as 5.6 mm and the screw diameter and pitch as 15 cm mounted on a shaft of 5 cm and operated at 120 rpm.

If the same screw conveyer is operated at minimum and maximum permissible speed for a grain with 720 $kg/m^3$ bulk density, calculate variation in capacity and power requirement [3+2=5]

**4.(a)** It is desired to agitate a liquid having a viscosity of $1.75 \times 10^{-3}$ Pa-s and a density of 1065 $kg/m^3$ in a tank having dimensions of 0.95 m diameter and 1.2 m height. The agitator will be a propeller having dia 0.295 m and pitch = Da, operating at 180 rpm. The tank has four baffles each with Dt/J = 10. (i) Calculate the required power in kW. (ii) If the velocity in increased by 4 folds, what will be change in power per unit volume of liquid? **[5]**

**(b)** A viscous solution containing solid particles with density $\rho_p = 1460$ $kg/m^3$ is to be clarified by centrifugation. The solution density $\rho = 900$ $kg/m^3$, and its viscosity is 100 cp. The centrifuge has a bowl with $r_2 = 0.02225$ m, $r_1 = 0.00716$ m, and height b = 0.1970 m. Calculate the critical particle diameter of the largest particles in exit stream if N =22000 rpm and the flow rate q = 0.002832 $m^3/h$. [5]

**5. (a)** Oil droplets having diameter of 200 μm are to be settling from still air at 38°C and 101.32 kPa pressure. The density of oil is 900 $kg/m^3$. A settling chamber is 0.45 m high. Calculate the terminal settling velocity. How long will it take the droplets to settle? Take properties of air at 38°C as $\rho = 1.137$ $kg/m^3$, $\mu = 1.90 \times 10^{-5}$ Pa.s. Assume laminar flow for settling of the oil droplets. **[2+2=4]**

**(b)** A liquid is being filtered at pressure of 200 kPa through 0.2 $m^2$ of filter. Initial results indicate that 5 min is required to filter 0.3 $m^3$ of liquid. Determine the time which will be elapsed until the rate of filtration drops to $0.5 \times 10^{-4}$ $m^3/s$. Assume the filter medium resistance is negligible. **[3 ]**

**(c)** Write short notes on the following:

(i)Disk bowl centrifuge

(ii) Two stage milk homogenization **[1.5+1.5=3]**

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**Tab. 1 Correction factor (C) for inclined position of screw conveyer**

| Inclination, deg | 0 | 5 | 10 | 15 | 20 | 25 |
|---|---|---|---|---|---|---|
| Value of correction factor (C) | 1.0 | 0.9 | 0.8 | 0.7 | 0.6 | 0.5 |

**Tab. 2 Recommended speeds of screw conveyers**

| Screw diameter, mm | Screw speed, rpm | |
|---|---|---|
| | Minimum | Maximum |
| 150 | 23.6 | 150 |
| 20 | 23.6 | 150 |
| 250 | 23.6 | 118 |
| 300 | 19.0 | 118 |
| 400 | 19.0 | 95 |
| 500 | 19.0 | 95 |

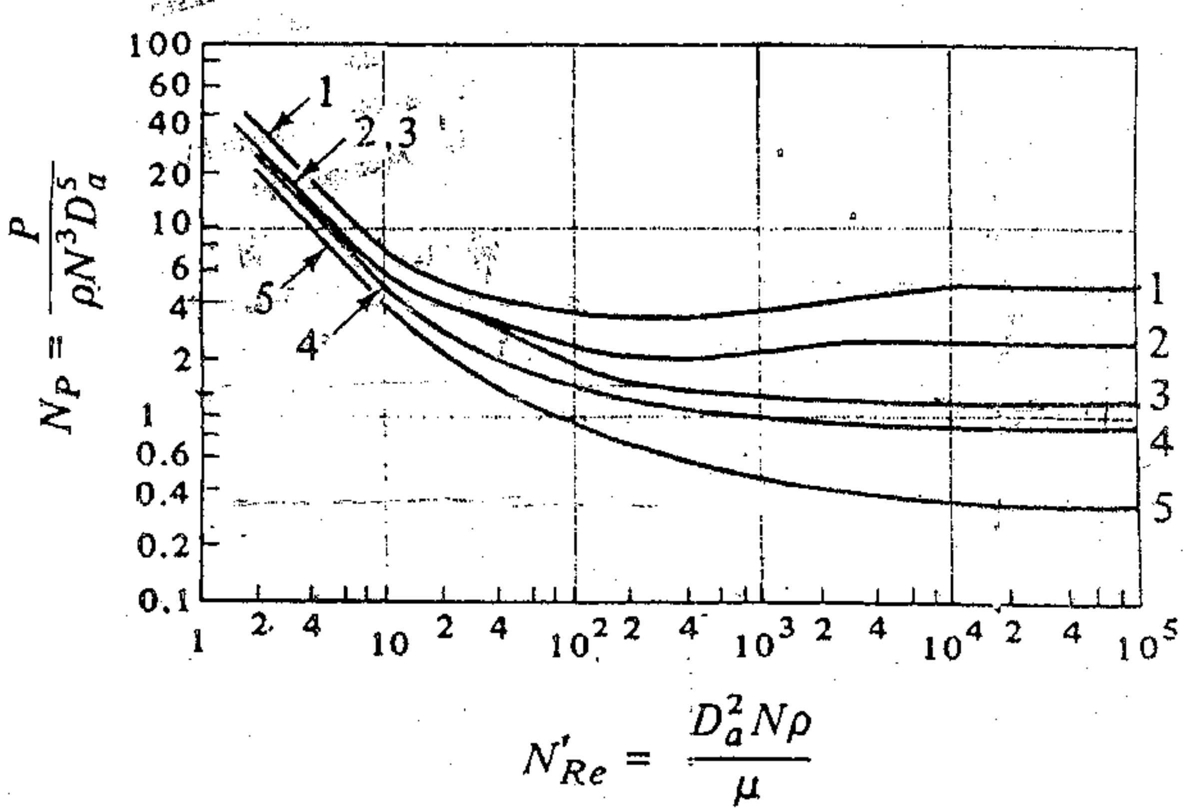


FIGURE 3.4-4. *Power correlations for various impellers and baffles (see Fig. 3.4-3c for dimensions $D_a$, $D_t$, $J$, and $W$).*

*Curve 1. Flat six-blade turbine with disk (like Fig. 3.4-3 but six blades); $D_a/W = 5$; four baffles each $D_t/J = 12$.* ( upto)

*Curve 2. Flat six-blade open turbine (like Fig. 3.4-2c); $D_a/W = 8$; four baffles each $D_t/J = 12$.*

*Curve 3. Six-blade open turbine but blades at 45° (like Fig. 3.4-2d); $D_a/W = 8$; four baffles each $D_t/J = 12$.*

*Curve 4. Propeller (like Fig. 3.4-1); pitch = $2D_a$; four baffles each $D_t/J = 10$; also holds for same propeller in angular off-center position with no baffles.*

*Curve 5. Propeller; pitch = $D_a$; four baffles each $D_t/J = 10$; also holds for same propeller in angular off-center position with no baffles.*