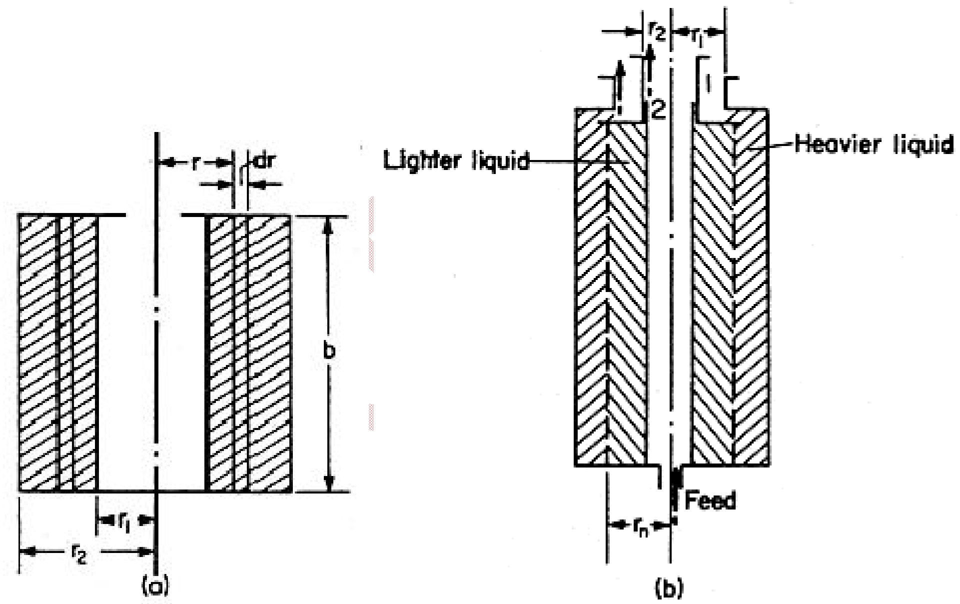
LIQUID SEPARATION BY CENTRIFUGAL

The separation of one component of a liquid-liquid mixture , where the liquids are immiscible but finely dispersed , as in an emulsion , It is particularly common in the dairy industry in which the emulsion , milk , is separated by a centrifuge into skim milk and cream . It seems worthwhile, on this account, to examine the position of the two phases in the centrifuge as it operates. The milk is fed continuously into the machine , which is generally a bowl rotating about a vertical axis , and cream and skim milk come from the respective discharges . At some point within the bowl there must be a surface of separation between cream and the skim milk .



Liquid centrifuge (a) pressure difference (b) neutral zone

Consider a thin differential cylinder, of thickness d_r the differential centrifugal force across the thickness d_r is given by ;

$$dF_c = (dm)\, r\omega^2 = (\rho\, dV)\, r\omega^2$$
$$dF_c = (2\pi\rho r b dr)\, r\omega^2$$

where dF_c is the differential force across the cylinder wall,
dm is the mass of the differential cylinder,
ρ is the density of the liquid
b is the height of the cylinder .
The area over which the force dF_c acts is $2\pi rb$, so that , the differential pressure dP across the wall of the differential cylinder is ;

$$dP = dF_c / A = dF_c / 2\pi\, r\, b = \rho\, \omega^2\, r\, dr$$

$$P_2 - P_1 = \rho\omega^2 (r_2^2 - r_1^2)/2$$

Last Equation shows the radial variation in pressure across the centrifuge. Consider now Fig. 2(b) , which represents the bowl of a vertical continuous liquid centrifuge. The feed enters the centrifuge near to the axis , the heavier liquid A discharges through the top opening 1 and the lighter liquid B through the opening 2 .

Let r_1 be the radius at the discharge pipe for the heavier liquid
r_2 that for the lighter liquid .
r_n (neutral zone) radius of interface between the two liquids , the heavier and the lighter at hydrostatic balance .
For the system to be in hydrostatic balance , the pressures of each component at radius r_n must be equal , so
$P_A = P_B$

$$\rho_A\omega^2(r_n^2 - r_1^2)/2 = \rho_B\omega^2(r_n^2 - r_2^2)/2$$

$$r_n^2 = (\rho_A r_1^2 - \rho_B r_2^2) / (\rho_A - \rho_B) \qquad (*)$$

where
ρ_A is the density of the heavier liquid
ρ_B is the density of the lighter liquid .

Equation (*) shows that as the discharge radius for the heavier liquid is made smaller , then the radius of the neutral zone must also decrease . When the neutral zone is nearer to the central axis, the lighter component is exposed only to a relatively small centrifugal force compared with the heavier liquid. The feed to a centrifuge of this type should be as nearly as possible into the neutral zone so that it will enter with the least disturbance of the system. This relationship can , therefore , be used to place the feed inlet and the product outlets in the centrifuge to get maximum separation .

Ex. :
If a cream separator has discharge radii of 5 cm and 7.5 cm and if the density of skim milk is 1032 kg/m^3 and that of cream is 915 kg/m^3, calculate the radius of the neutral zone so that the feed inlet can be designed.

Solution
For skim milk , $r_1 = 0.075m$, $\rho_A=1032\ kg/m^3$,
cream $r_2 = 0.05\ m$, $\rho_B= 915\ kg/m^3$

$r_n^2 = [1032 \times (0.075)^2 - 915 \times (0.05)^2] / (1032 - 915)$
$= 0.03\ m^2$
$r_n = 0.17\ m = 17\ cm$