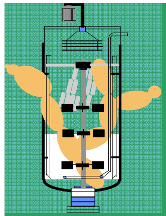


Aeration 2

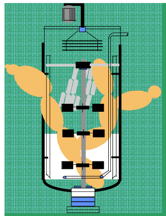
$$\frac{dC}{dt} = \ldots - C\big) - xQ$$

On what and how saturation oxygen koncentration C* depends ?

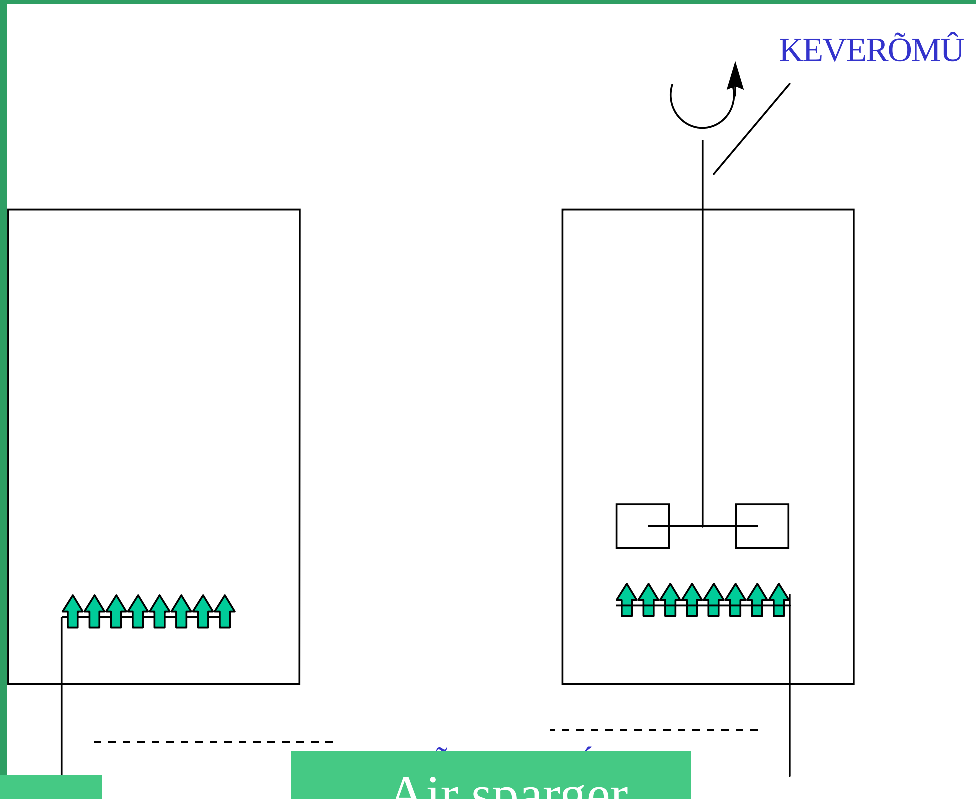
On what and how … K_L ?

On what and how… a ?

On what and how …. $K_l a$?

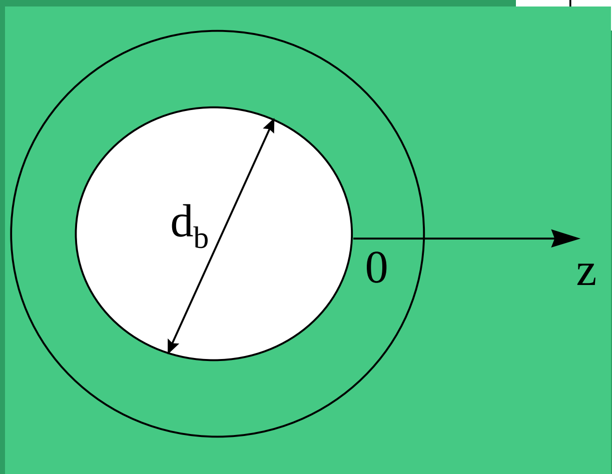


Aeration 3



Air sparger

Not mixed reactors
Only aeration

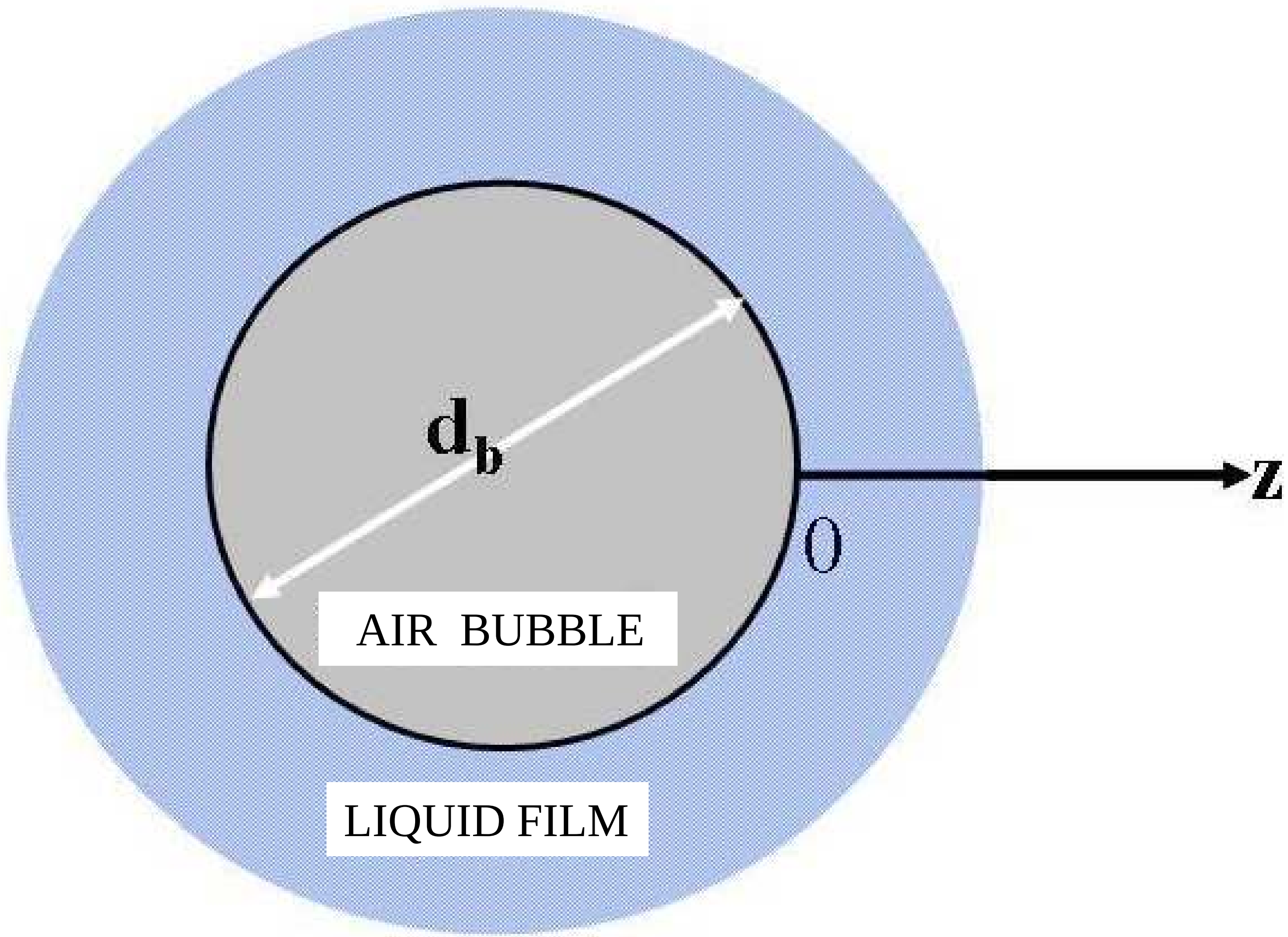


$$\frac{dC}{dt} = -D_{O_2}\left(\frac{\partial C}{\partial z}\right)_{z=0}$$

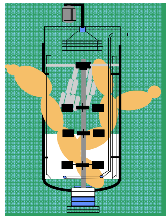
Fick-law of diffusion

$$dC/dt = k_L\,(C^* - C).$$

Oxygen flux through unit surface erea



d_b
z
0
AIR BUBBLE
LIQUID FILM



Aeration 3

Dimensionless form

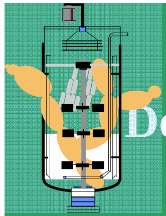
$$\overline{C} = f\left(\overline{z}, Sh, Sc, Gr\right)$$

Sh = g(Sc,Gr)

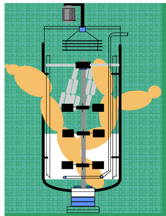
Dimensionless mass transfer coefficient: Sherwood-number

There are numerous correlations describing K_l (Sh) as a function of hydrodymanic Behaviour and liquid characteristics

Aeration 3



Definition, explanation		general form	form used for oxygen m.tr.
REYNOLDS No	$\mathrm{Re} = \dfrac{\text{inertial forces}}{\text{viscous forces}}$	$\dfrac{\mathrm{d}v\rho}{\mu}$	$\dfrac{\mathrm{d_b} v_b \rho_l}{\mu_l}$
PECLET No	$\mathrm{Pe} = \dfrac{\text{konvective component stream}}{\text{konductive component stream}}$	$\dfrac{\mathrm{d}v}{D}$	$\dfrac{\mathrm{d_b} v_b}{D_{O_2}}$
SCHMIDT No	$\mathrm{Sc} = \dfrac{\text{momentum diffusivity}}{\text{mass dffusivity}}$	$\dfrac{\mu}{\rho D}$	$\dfrac{\mu_l}{\rho_l D_{O_2}}$
FROUDE No	$\mathrm{Fr} = \dfrac{\text{centrifugal force}}{\text{gravitational force}}$	$\dfrac{v^2}{gL}$	–
GRASHOF No (Archimédes-No)	$Gr = \dfrac{\text{buoyant force}}{\text{viscous force}}$	$\dfrac{d^3 \rho g \Delta\rho}{\mu^2}$	$\dfrac{d_b^3 \rho_l g (\rho_l - \rho_g)}{\mu_l^2}$
SHERWOOD No (dimensionless Mass tr. coeff.)	$\mathrm{Sh} = \dfrac{\text{bubble diameter}}{\text{film thickness}}$	$\dfrac{kd}{D}$	$\dfrac{k_l d_b}{D_{O_2}}$



Aeration 3

Example for estimating k_l

2. **CALDERBANK and MOO-YOUNG** in most lab and industrial aerated reactors bubbles move up and/or down in groups, clusters , they are in interaction with each other (influence each other's movement) ((single, independently moving bubbles are rare in real situations))

d_b < 2,5 mm

$$Sh = \frac{k_L d_b}{D_{O_2}} = 0{,}31 Gr^{\frac{1}{3}} Sc^{\frac{1}{3}}$$

hidrofil materials

Small holes

(sintered plates, bubble columns)

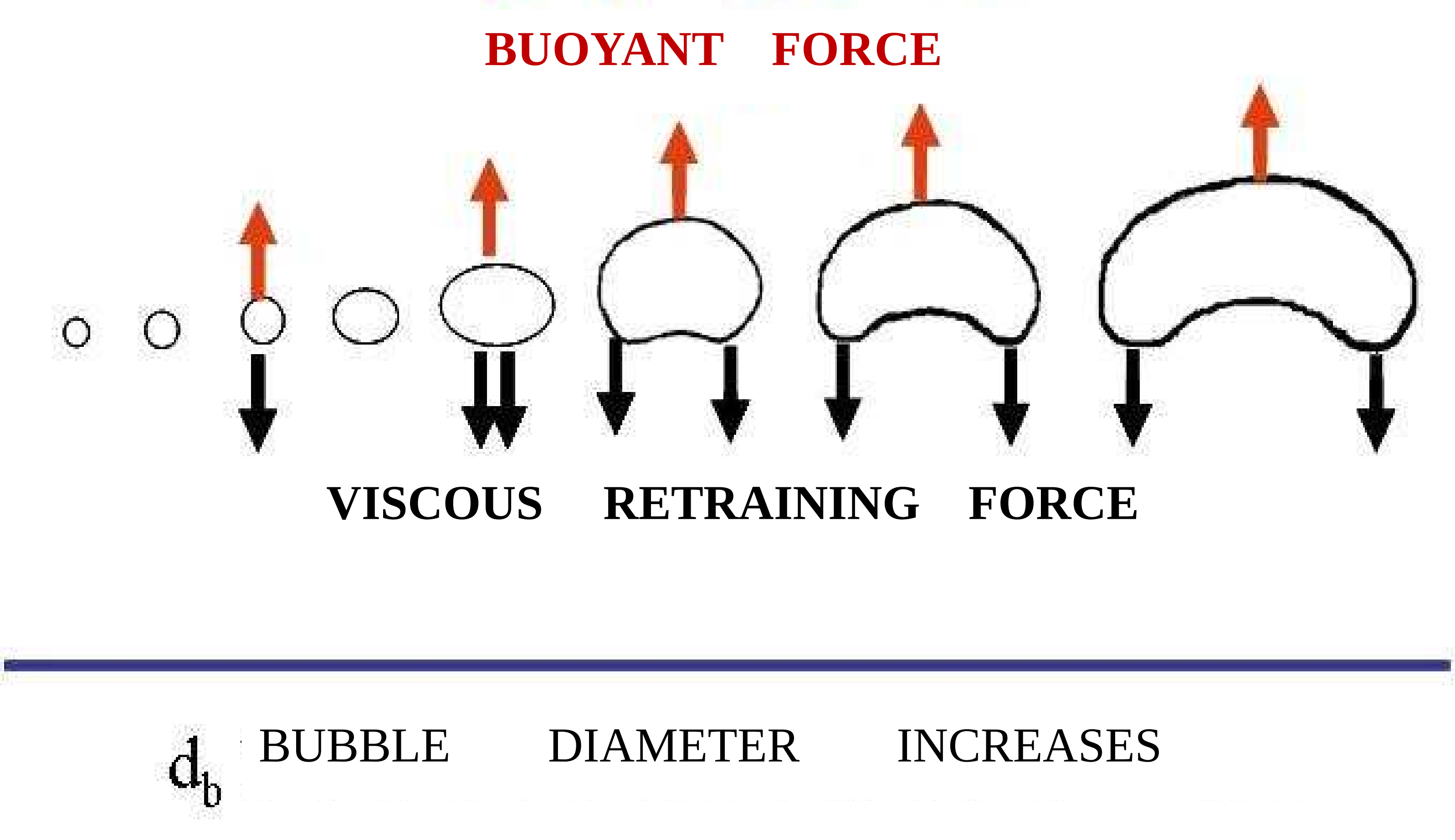
d_b>2,5 mm

$$Sh = \frac{k_L d_b}{D_{O_2}} = 0{,}42 Gr^{\frac{1}{3}} Sc^{\frac{1}{2}}$$

Pure water

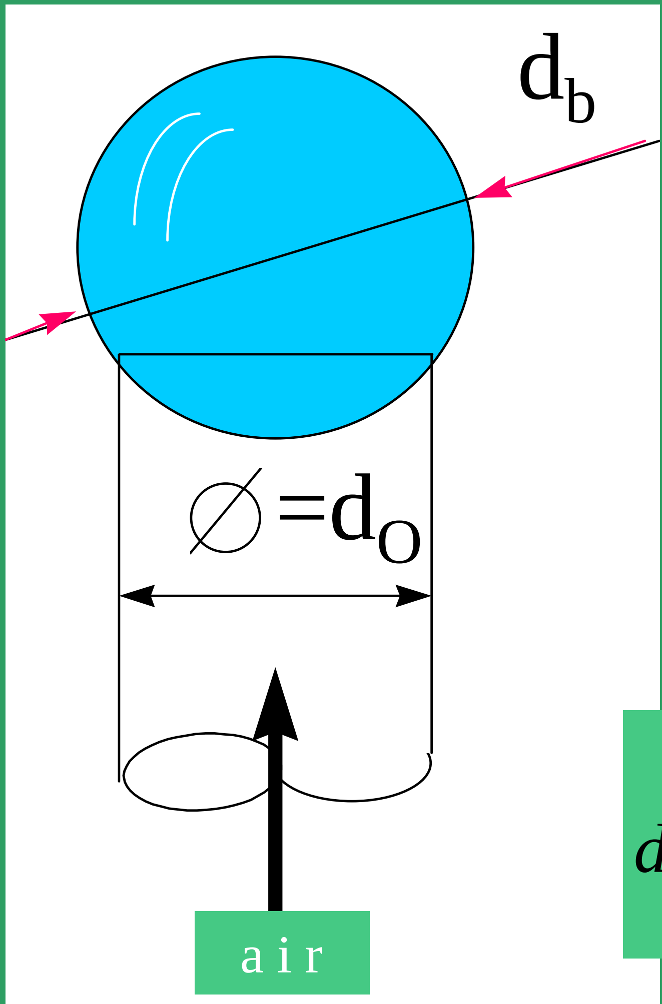
Sieve tray

Aeration 3


BUOYANT FORCE
VISCOUS RETRAINING FORCE
db
BUBBLE DIAMETER INCREASES

Aeration 3

ESTIMATION OF a



At birth of a bubble there is an equilibrium between buoyant force and restraining force (surface tension on the circumference of the hole.

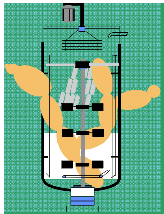
$$\frac{d_b^3 \pi \Delta \rho g}{6} = \pi d_o \sigma$$

σ surface tension

$$d_b = \left(\frac{6 \sigma d_o}{g \Delta \rho} \right)^{\frac{1}{3}}$$

$$f_{\text{one bubble}} = \pi d_b^2$$

How many bubbles are present in the system at a given time?



Aeration 3

How many bubbles are present in the system at a given time?

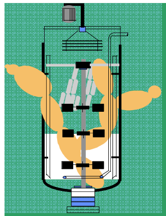
It depends on residence time.

$$t_b = \frac{H_L}{v_b}$$

H_L - liquid heights
v_b - bubble velocity.

v_b is not constant, it varies while moves upward from the hole to the surface.

Bubble velocity: usually terminal v. at the surface (when explodes into the gas phase above.



Aeration 3

$$a = \frac{1}{V} nqt_b \frac{\pi d_b^2}{\frac{\pi d_b^3}{6}} = \frac{nqt_b}{V} \frac{6}{d_b}$$

Surface of one bubble

Total bubble volume
In the reactor

Volume of one bubble

Specific surface of one bubble

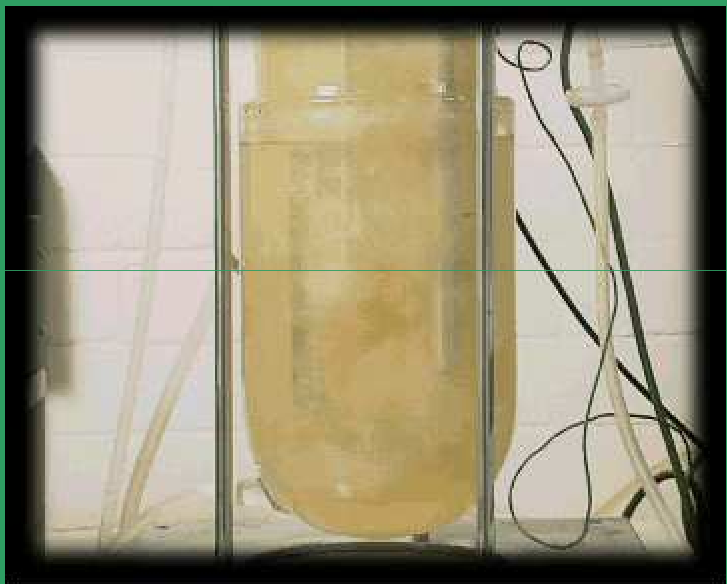
$$a = H_0 \frac{6}{d_b}$$

Hold up = $\dfrac{\text{GAS VOLUME}}{\text{TOTAL VOLUME}}$

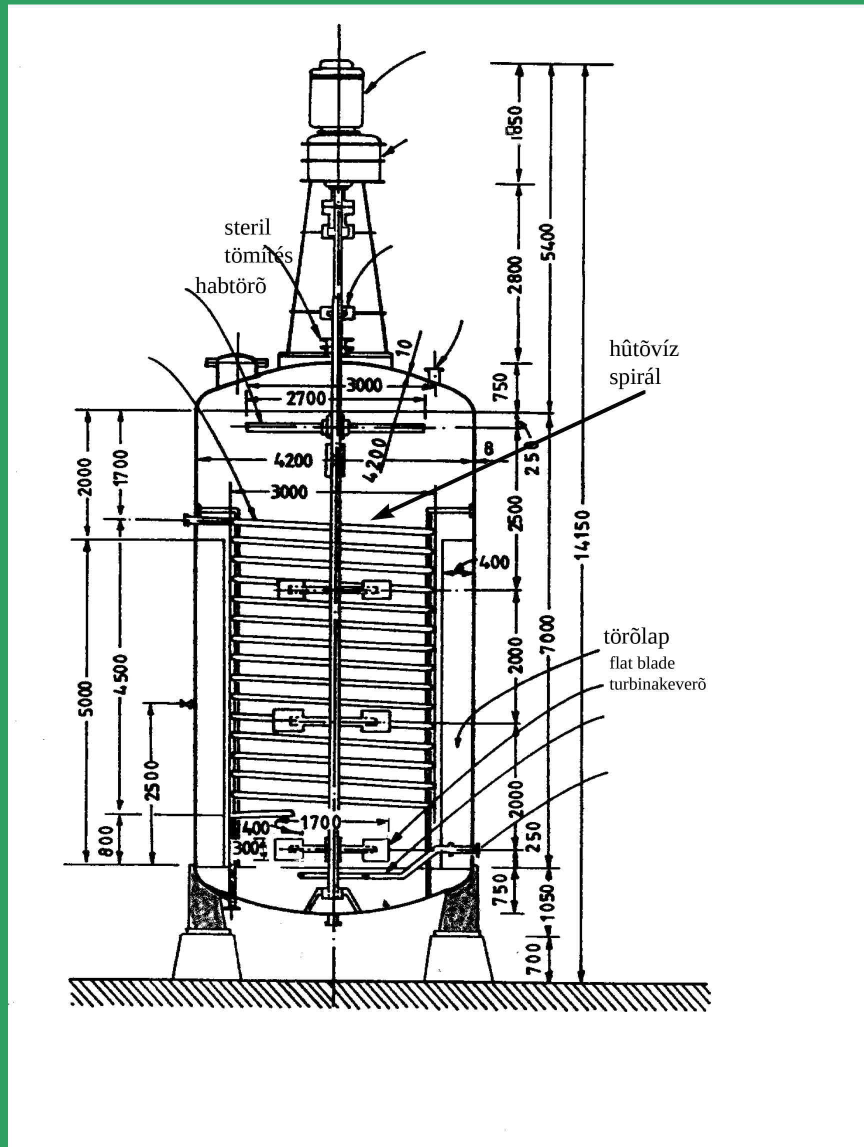
HOW CAN WE INREASE?

Aeration 3

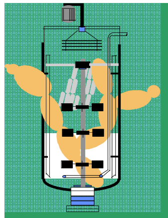
OXYGEN MASS TRANSFER IN MIXED REACTOR

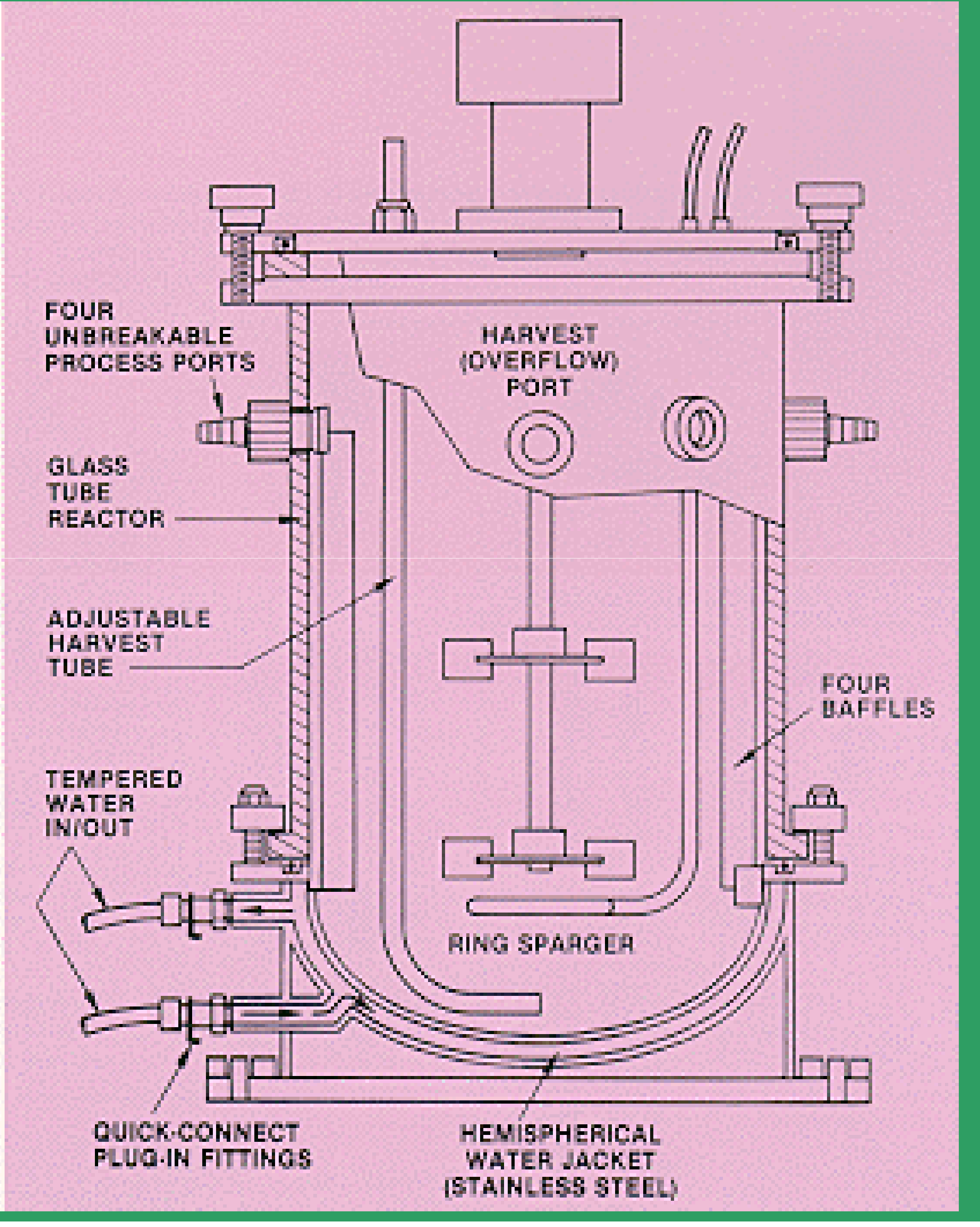


A5342



Aeration 3




FOUR
UNBREAKABLE
PROCESS PORTS
HARVEST
(OVERFLOW)
PORT
GLASS
TUBE
REACTOR
ADJUSTABLE
HARVEST
TUBE
FOUR
BAFFLES
TEMPERED
WATER
IN/OUT
RING SPARGER
QUICK-CONNECT
PLUG-IN FITTINGS
HEMISPHERICAL
WATER JACKET
(STAINLESS STEEL)

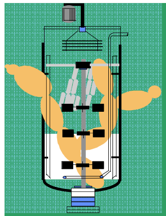
Aeration 3


FILTERED GAS/AIR LINE
ALPHA-NUMERIC DISPLAY SCREEN
DETACHABLE DRIVE MOTOR
GAS/AIR REGULATOR
2 or 4 GAS CONTROLLER
EXHAUST GAS CONDENSER
STERILE SAMPLER
DATA COMMAND CENTER
DEDICATED CELL CULTURE VESSEL (Optional)
FIVE PROGRAM-MABLE, ASSIGNABLE PUMPS
PACKED BED BASKET IMPELLER
WATER IN/OUT
FERMENTOR VESSEL WITH STAINLESS STEEL JACKET

Aeration 3

MSG, JAPAN
HOFU

63420 GALLON
100 FEET



Aeration 3

ROLE OFMIXING:

-Energy input to the liquid

moving

heat

P/V → K_La

-Dispersion of bubbling gas in the liquid

BUBLE FORMATION, MASS TRANSFER

-Separation of gas from liquid

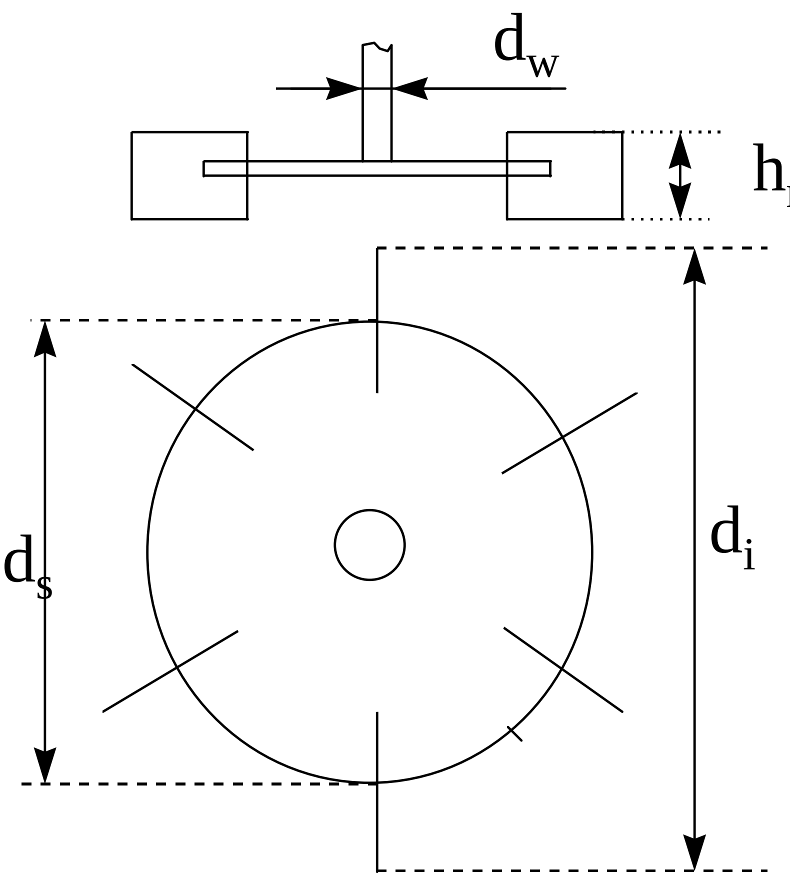
REVERSE MASS TRANSFER CO_2

-good mixing of the dissolved and suspended materials in the liquid

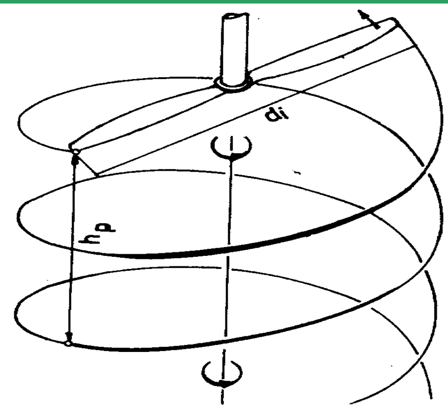
GENERAL MIXING FUNCTION

substrates, products...

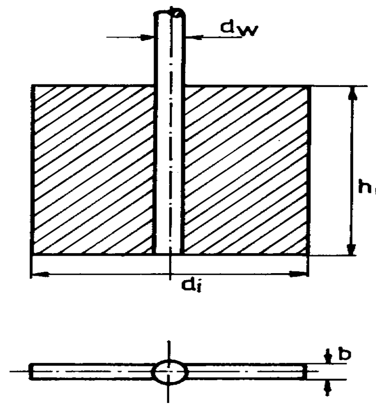
Aeration 3



egyenes lapátú nyitott turbinakeverõ (flat blade)

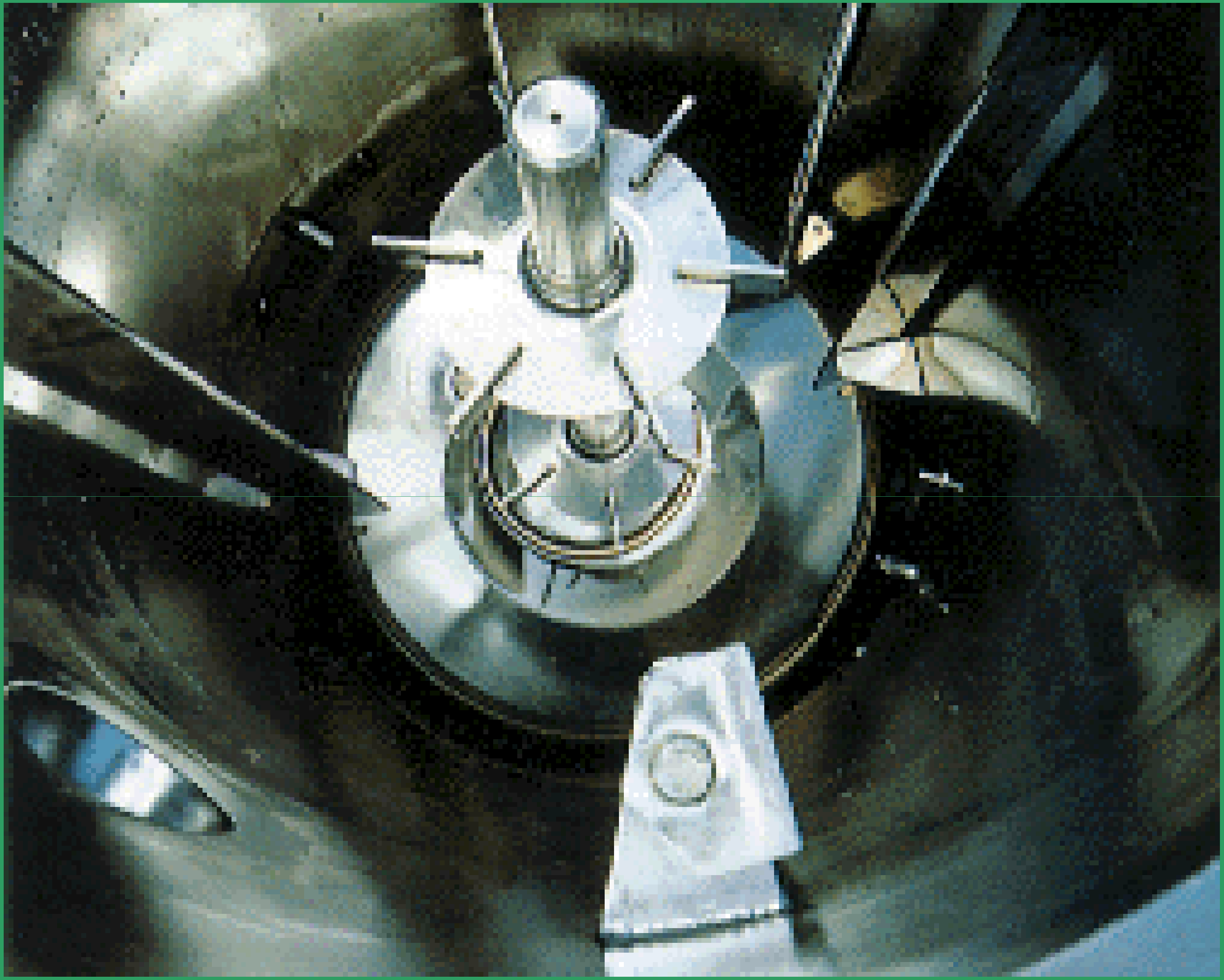


propellerkeverõ

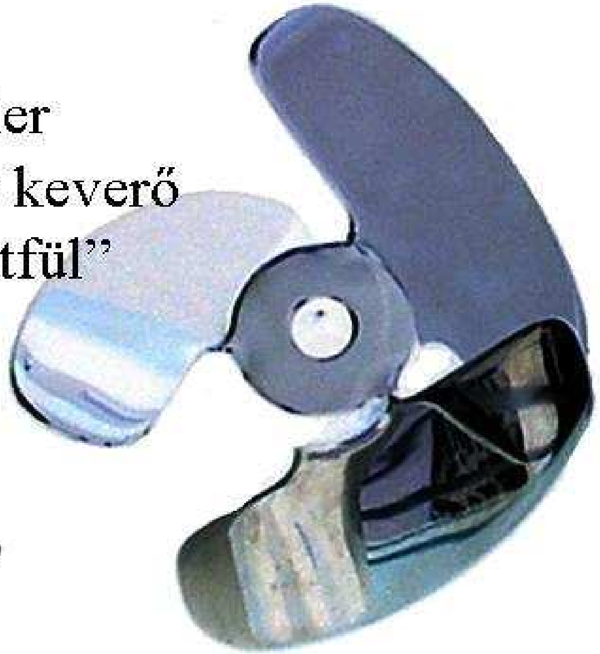


paddle

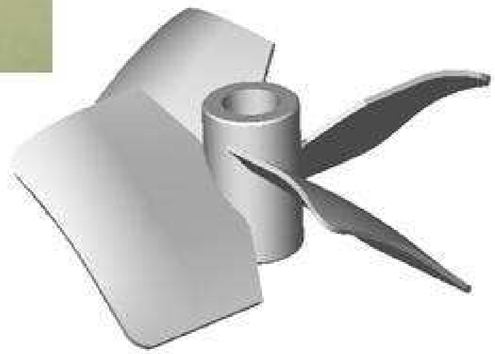
Aeration 3



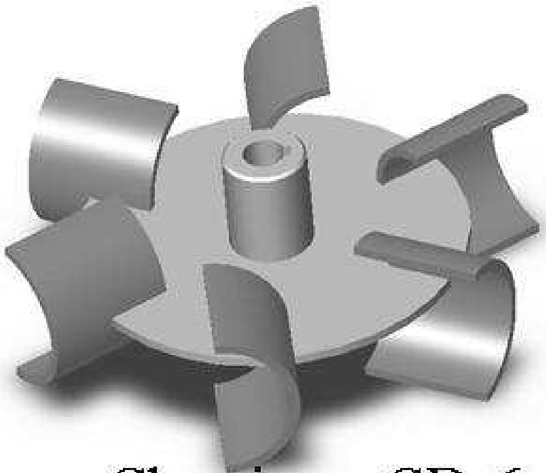
Rushton-turbina



Propeller
axiális keverő
„ elefántfül”



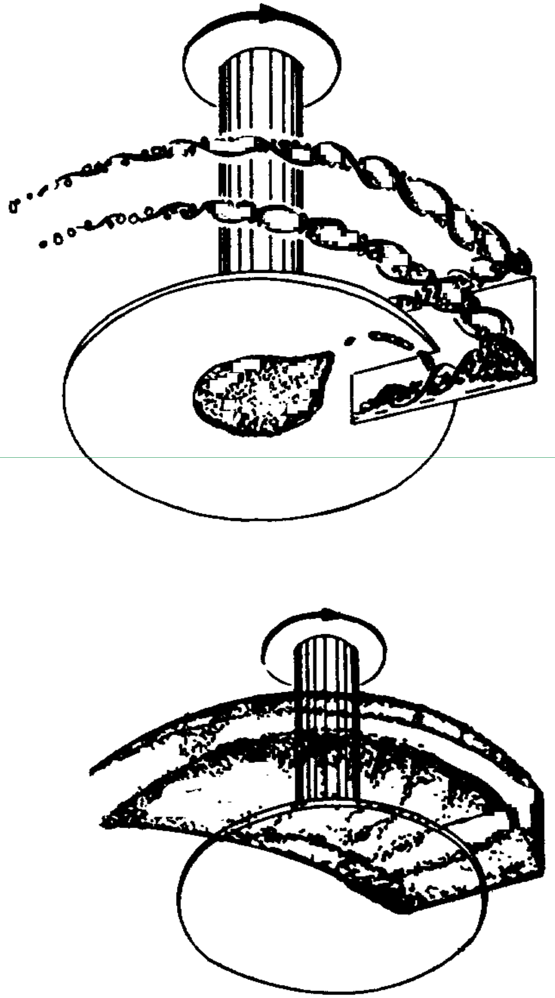
Maxflo és Lightning
axiális keverők

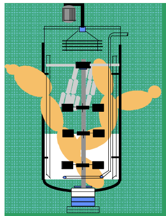


Chemineer CD-6

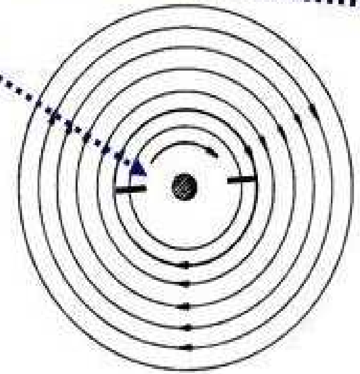
Chemineer BT-6

Aeration 3

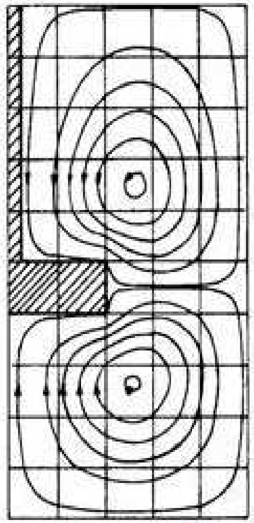




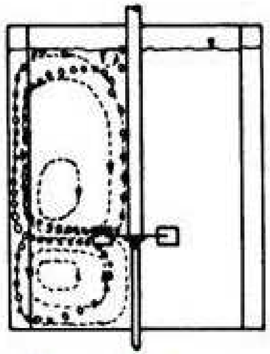
agitator



primary
liquid stream

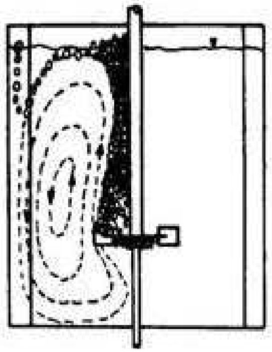


secondary
liquid stream



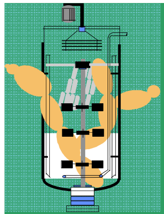
Bubble motion
at small gas velocity

good g/f dispersion



Bubble motion
at large gas velocity

flooding



Aeration 3

Power uptake of the mixing device

$$P = A D_i^5 N^3 \rho \, Re^m \, Fr^n \left(\frac{W_i}{D_i}\right)^{\alpha} \left(\frac{D_T}{D_i}\right)^{\beta} \left(\frac{H_L}{D_i}\right)^{\gamma} \ldots$$

ρ - specific density
N – revolution rate of mixer.

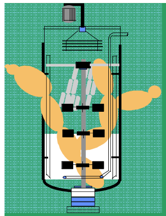
mixing Re

$$Re = \frac{D_i . N D_i \rho}{\mu} = \frac{N D_i^2 \rho}{\mu} \quad \left(\text{ált.}: Re = \frac{d v \rho}{\mu} \right)$$

$$N D \pi = \text{kerületi sebesség}$$

Mixing Fr

$$Fr = \frac{(D_i N)^2}{g D_i} = \frac{D_i N^2}{g} \qquad \left(\text{see.}: \; Fr = \frac{v^2}{g L} \right)$$



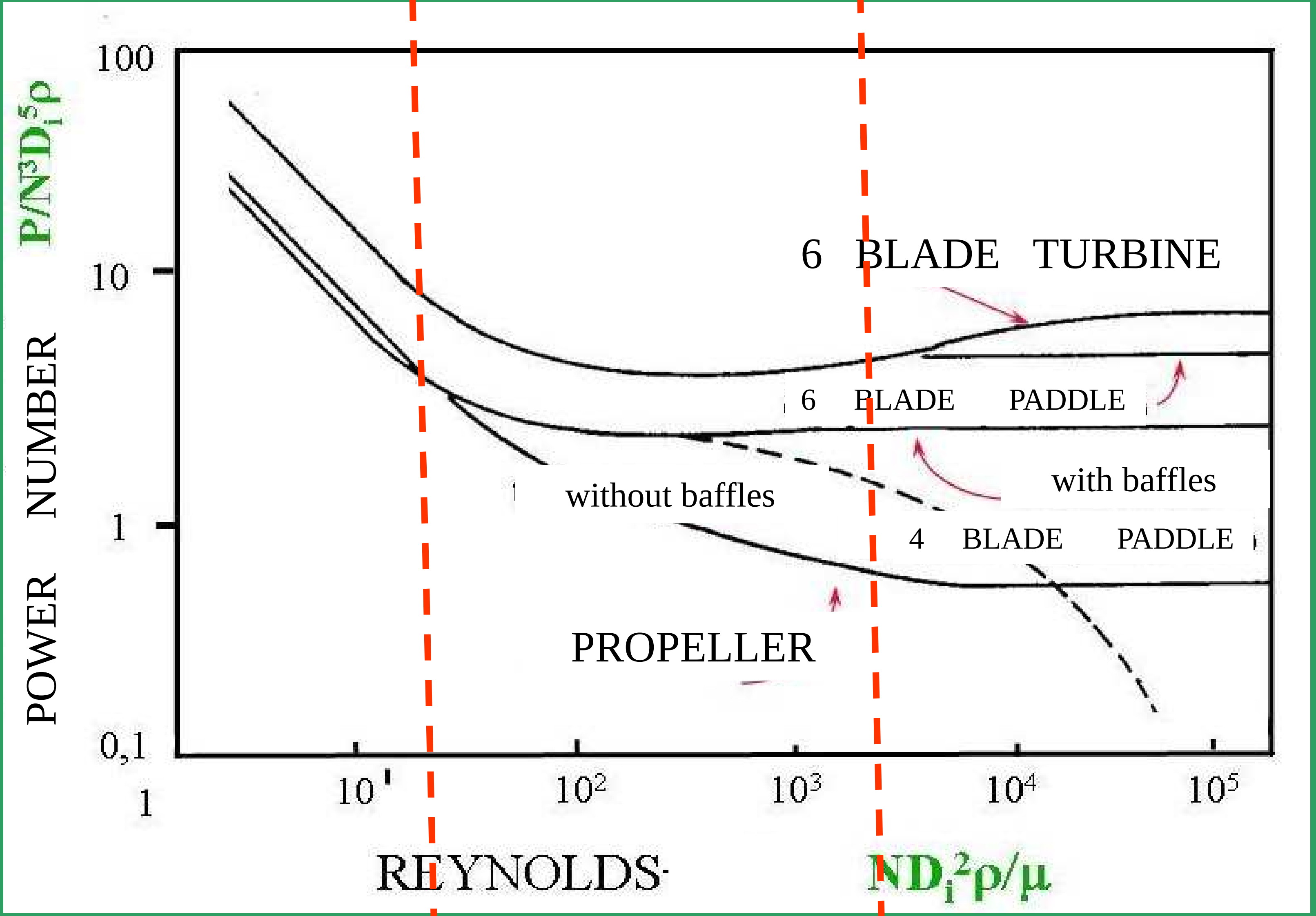
Aeration 3

For a bioreactor of a given geometry

$$P = A' D_i^5 N^3 \rho \, Re^m \, Fr^n$$

Power number (Ne=Newton-szám vagy Eu=Euler-szám) :

$$N_P = \frac{P}{D_i^5 N^3 \rho} = A' \, Re^m \, Fr^n$$

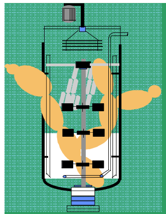


$N_P = A' Re^{-1}$

$P = A' \mu D_i^3 N^2$

$N_P = A'$

$P = A' D_i^5 N^3 \rho$



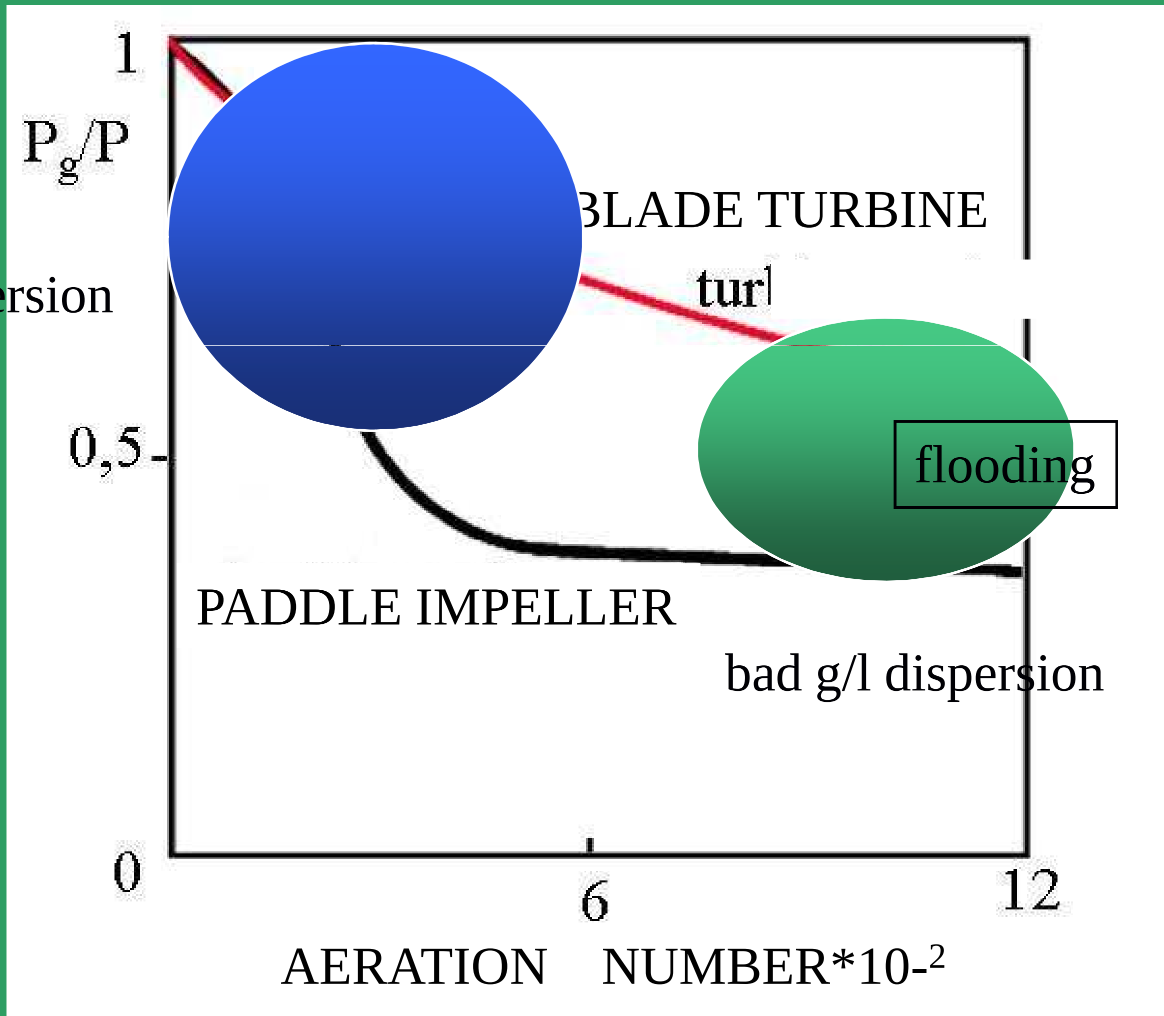
Aeration 3

P decrease when aerating

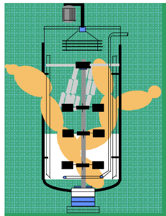
$$Na = \frac{\text{apparent superficial aeration rate}}{\textit{keverő kerületi sebessége}} = \frac{\dfrac{F\ \mathrm{m}^3/s}{\dfrac{D_i^2\pi}{4}\ m^2}}{ND_i\pi\ m/s} = \frac{F}{ND_i^3}$$

$$\frac{P_g}{P} = f(Na)$$

good g/l dispersion



0,25-0,4



Aeration 3

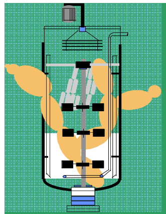
$$K_L a \propto \left(\frac{P_g}{V}\right)^{0,4} v_s^{0,4} N^{0,5}$$

For lab fermentors

$$K_L a \propto \left(\frac{P_g}{V}\right)^{\alpha} v_s^{\beta} N^{0,5}$$

generally

α 0,3 — 0,95 β 0,50—67 scale dependent constants,



Aeration 3

$$\frac{dC}{dt} = \ldots - C) - xQ$$

In aerated/agitated reactor

On what and how depends C* ?

pO_2

On what and how depends $K_l a$?

$$K_L a \propto \left(\frac{P_g}{V}\right)^{\alpha} v_s^{\beta} N^{0,5}$$

$$a = H_0 \frac{6}{d_b}$$

Air sparger

N

N **F(=Q)**