SEPARATION PROCESS

PARTICLE HANDLING & PROCESSING

Part 1

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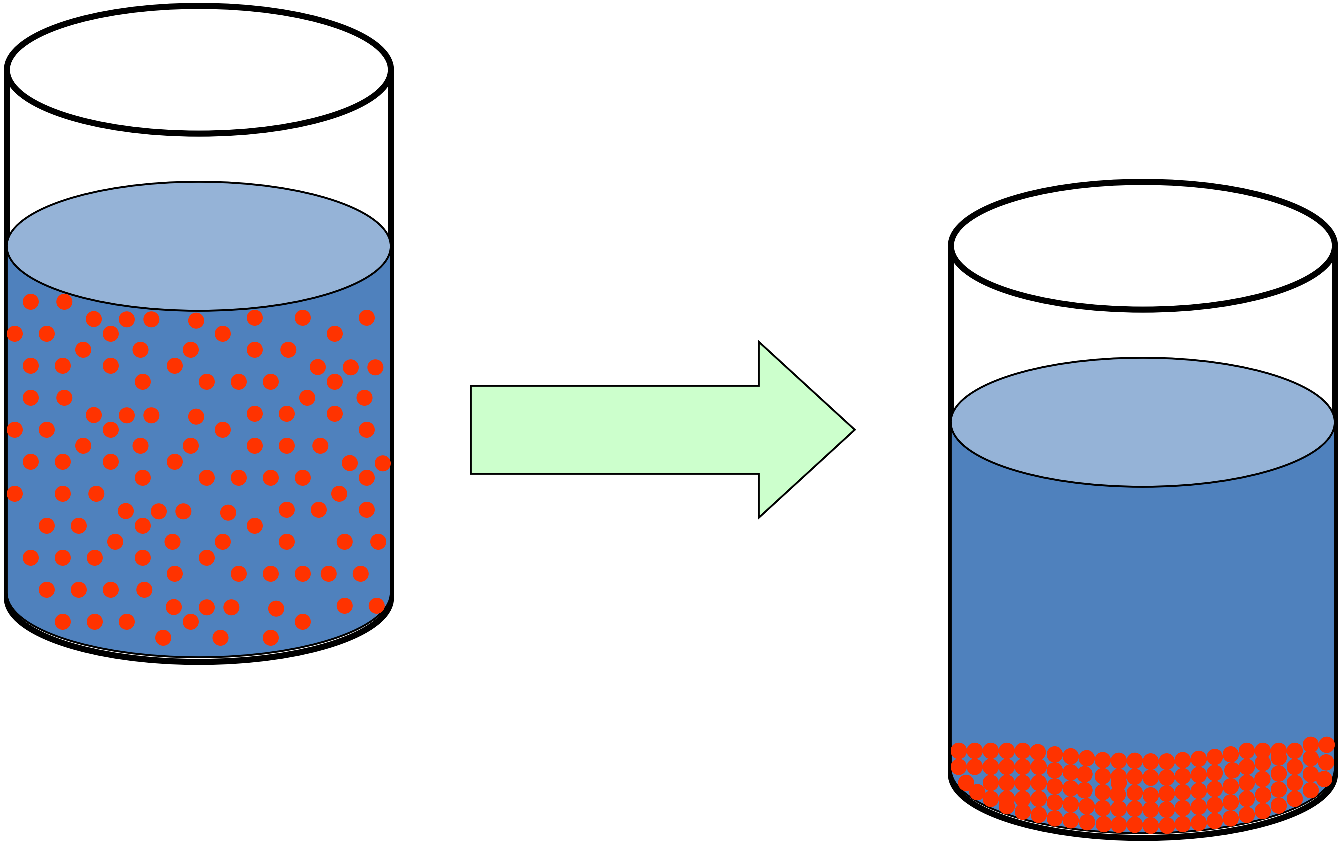
Sedimentation in particle fluid separation



Sedimentation theory

Buoyant force, F_b

$$F_b = \frac{m\rho g}{\rho_p} = V_p \rho g$$

Gravitation force, F_g

$$F_g = mg$$

Drag force, F_D

$$F_D = C_D \frac{v^2}{2} \rho A$$

Resultant force, F

$$F = F_g - F_b - F_D = m\frac{dv}{dt}$$

At terminal velocity (free settling v_t) $\frac{dv}{dt} = 0$

$$v_t = \sqrt{\frac{2g(\rho_p - \rho)m}{A\rho_p C_D \rho}}$$

Spherical particle in laminar flow

$$C_D = \frac{24}{\mathrm{Re}} = \frac{24}{D_p v \rho / \mu}$$

$$v_t = \frac{g D_p^2 (\rho_p - \rho)}{18\mu}$$

Hindered settling – large number of particle present

Effective viscosity

$$\mu_m = \frac{\mu}{\psi_p}$$

$$\psi_p = \frac{1}{10^{1.82(1-\varepsilon)}}$$

Effective fluid phase density

$$\rho_m = \varepsilon\rho + (1-\varepsilon)\rho_p$$

Density different

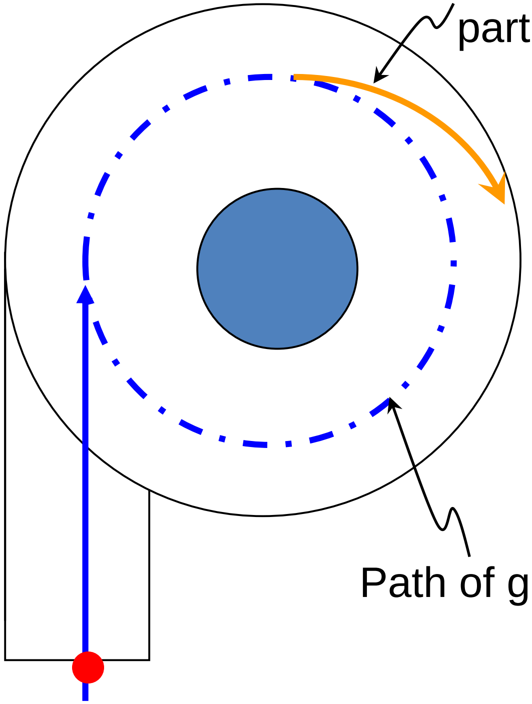
$$\rho_p - \rho_m = \varepsilon(\rho_p - \rho)$$

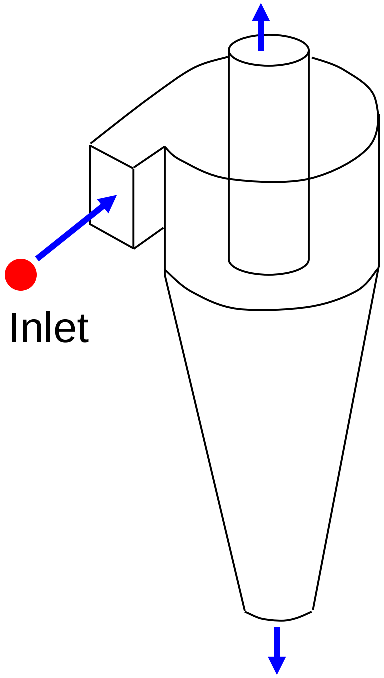
Free settling velocity

$$v_t = \frac{gD_p^2(\rho_p - \rho)}{18\mu}(\varepsilon^2\psi_p)$$

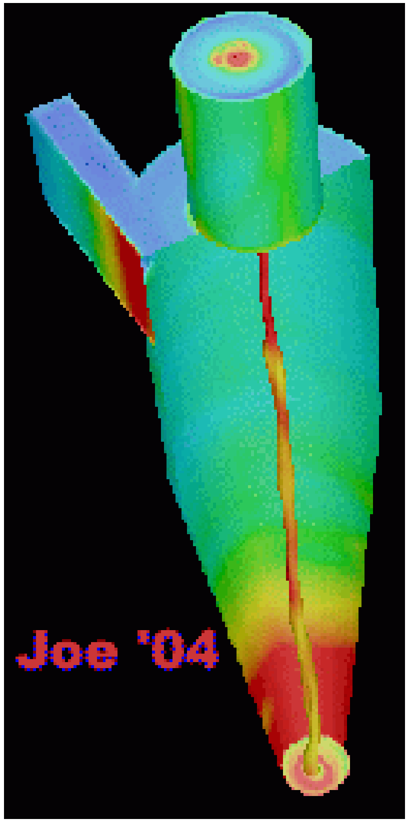
Cyclone

Operating Principles

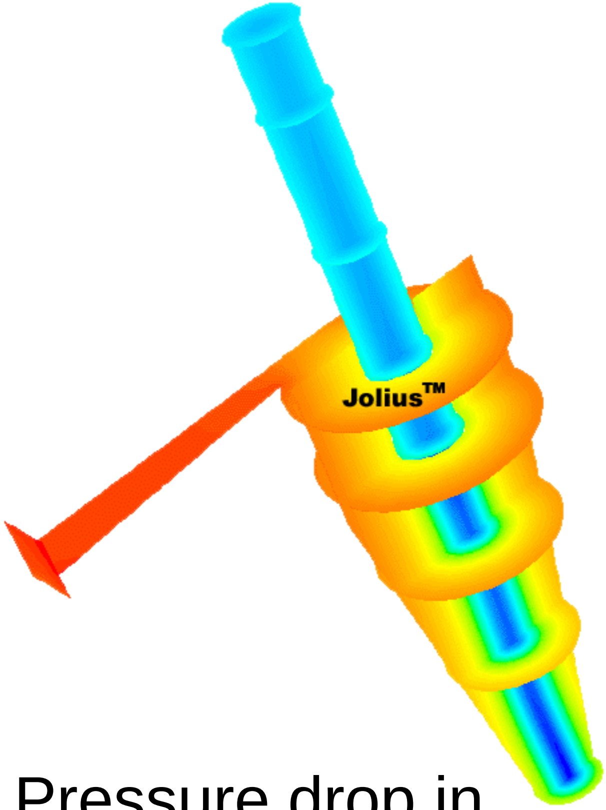




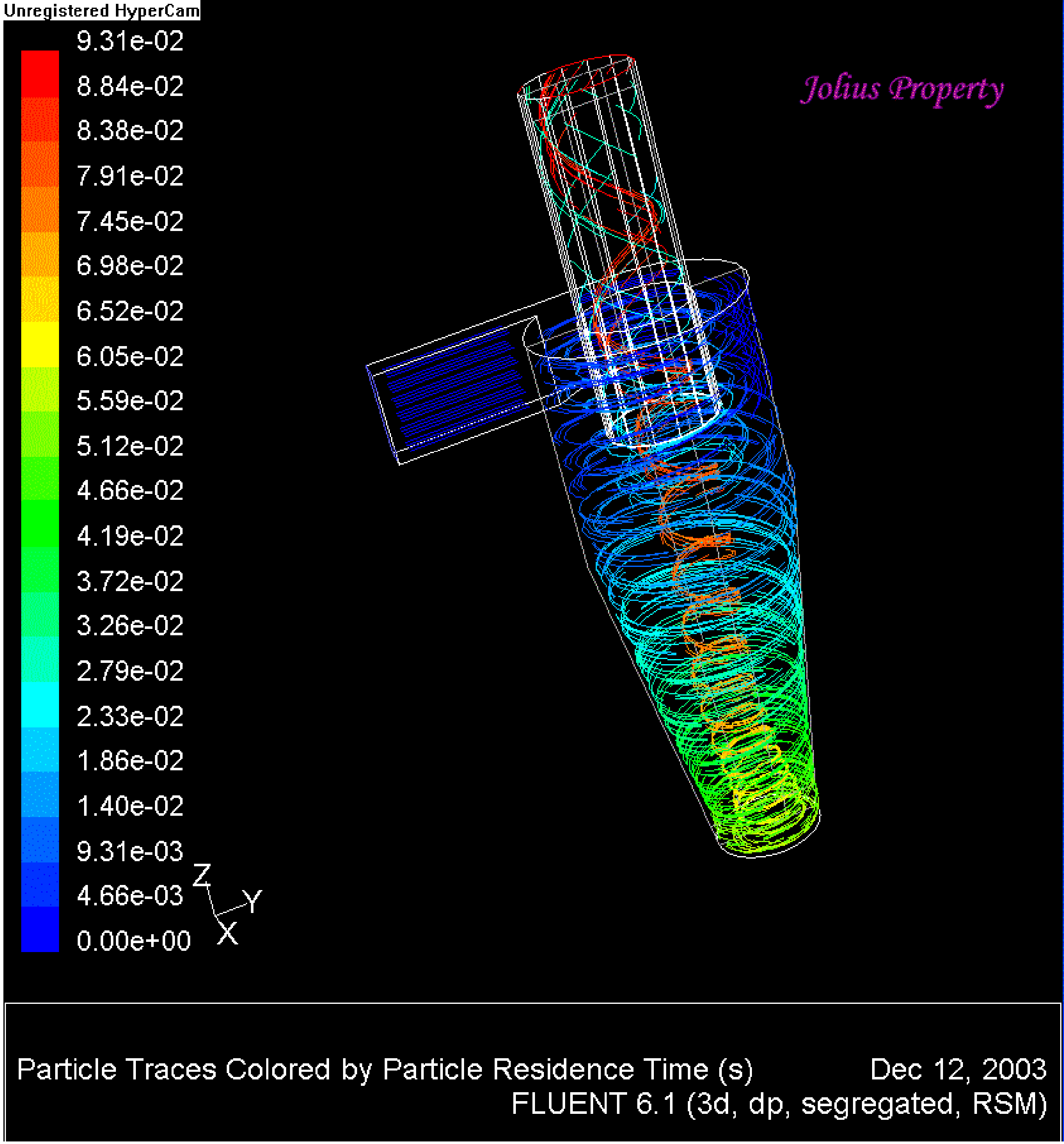
Flow in cyclone (CFD simulation)



Particle removed by centrifugal force



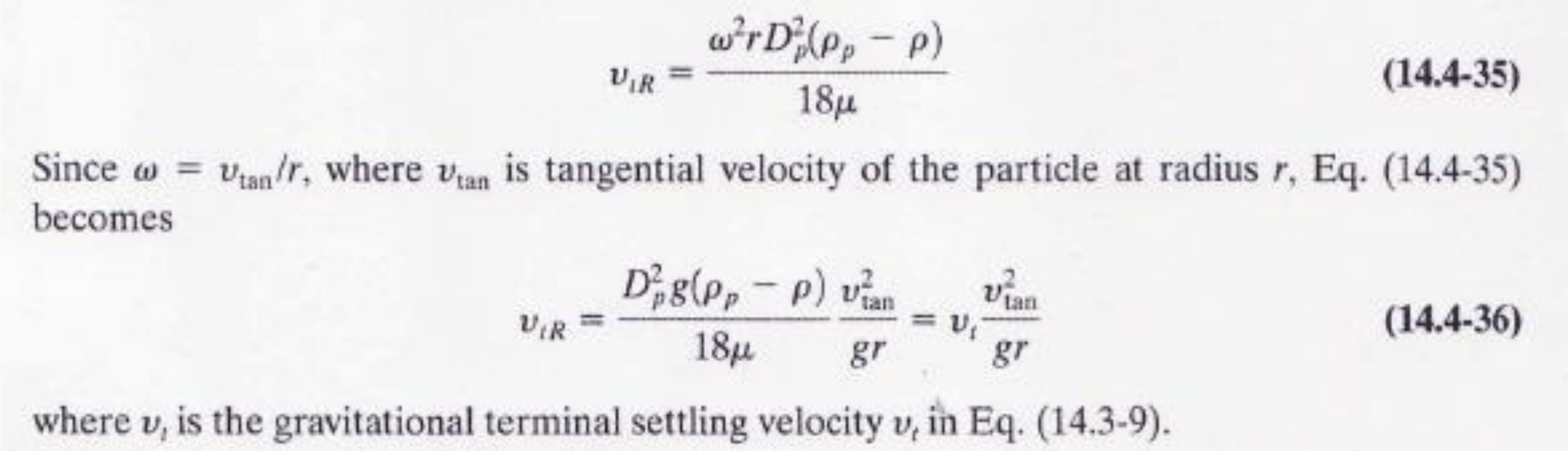
Pressure drop in cyclone



Particle Traces Colored by Particle Residence Time (s) Dec 12, 2003
FLUENT 6.1 (3d, dp, segregated, RSM)

Theory for cyclone separators.

It is assumed that particles on entering a cyclone quickly reach their terminal settling velocities. Particle sizes are usually so small that Stokes' law is considered valid. For centrifugal motion, the terminal radial velocity u_{tR} is given by Eq.(14.4-8),with u_{tR}, being used for u_t,:

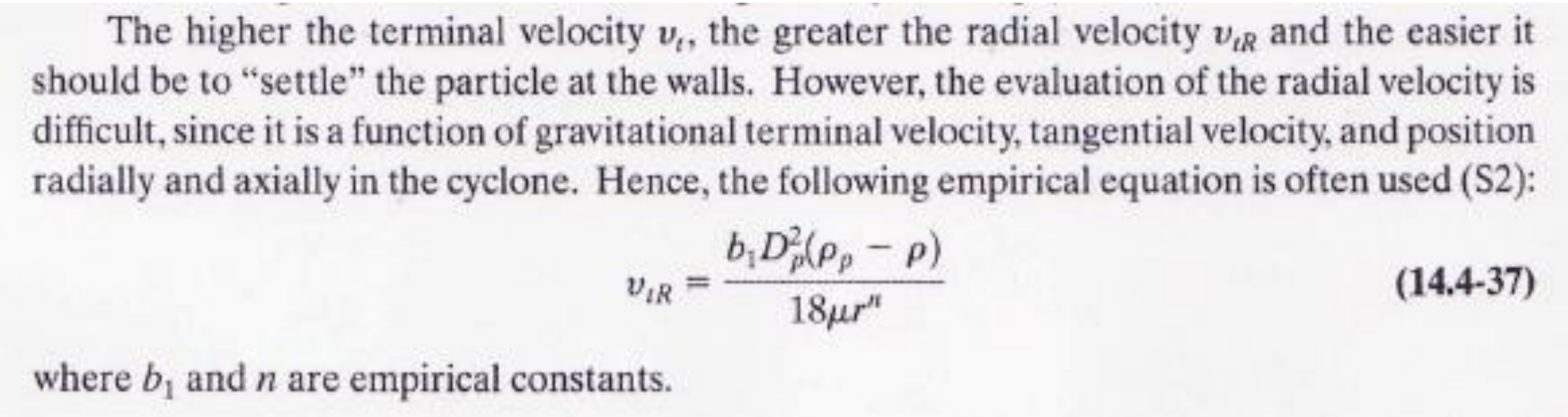


$$v_{tR} = \frac{\omega^2 r D_p^2(\rho_p - \rho)}{18\mu} \tag{14.4-35}$$

Since $\omega = v_{\tan}/r$, where $v_{\tan}$ is tangential velocity of the particle at radius r, Eq. (14.4-35) becomes

$$v_{tR} = \frac{D_p^2 g(\rho_p - \rho)}{18\mu}\frac{v_{\tan}^2}{gr} = v_t\frac{v_{\tan}^2}{gr} \tag{14.4-36}$$

where v_t is the gravitational terminal settling velocity v_t in Eq. (14.3-9).



The higher the terminal velocity v_t, the greater the radial velocity v_{tR} and the easier it should be to "settle" the particle at the walls. However, the evaluation of the radial velocity is difficult, since it is a function of gravitational terminal velocity, tangential velocity, and position radially and axially in the cyclone. Hence, the following empirical equation is often used (S2):

$$v_{tR} = \frac{b_1 D_p^2 (\rho_p - \rho)}{18 \mu r^n} \tag{14.4-37}$$

where b_1 and n are empirical constants.

Cyclone configuration

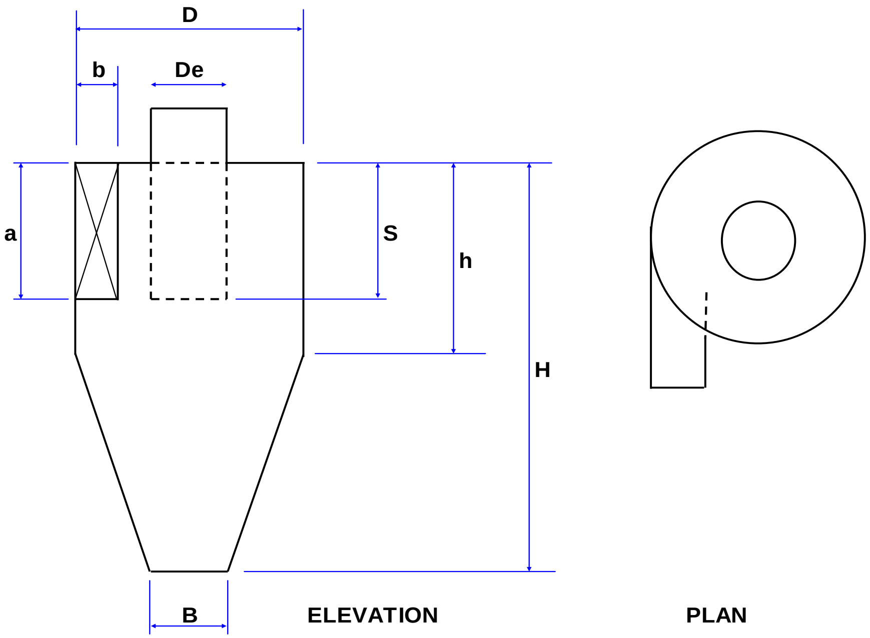


Fig. 1: Tangential cyclone configuration

Table 1 Standard cyclone configuration

Geometry	*a/D*	*b/D*	D_e/D	*S/D*	*h/D*	*H/D*	*B/D*
Stairmand high efficiency	0.5	0.2	0.5	0.5	1.5	4	0.375
Swift High Efficiency	0.44	0.21	0.4	0.5	1.4	3.9	0.4
Swift Low Efficiency	0.5	0.25	0.5	0.6	1.75	3.75	0.4
Lapple Low Efficiency	0.5	0.25	0.5	0.625	2	4	0.25

Cyclone collection efficiency *(Lapple model)*

Number of revolutions, N_e

$$N_e = \frac{1}{a}\left[h + \frac{H-h}{2}\right]$$

Cut diameter, d_{pc}

$$d_{pc} = \left[\frac{9\mu b}{2\pi N_e v_i(\rho_p - \rho_g)}\right]^{\frac{1}{2}}$$

The collection efficiency of particle of any size is given by

$$\eta_i = \frac{1}{1+\left(d_{pc} / \bar{d}_{pi}\right)^2}$$

Cyclone Pressure drop

Dirgo model – Static pressure different and cyclone configuration.

Cyclone pressure drop model can be rearrange in a function of velocity head as follow

Coker model – Velocity head.

$$\Delta P = \alpha \frac{\rho_g v_i^2}{2}$$

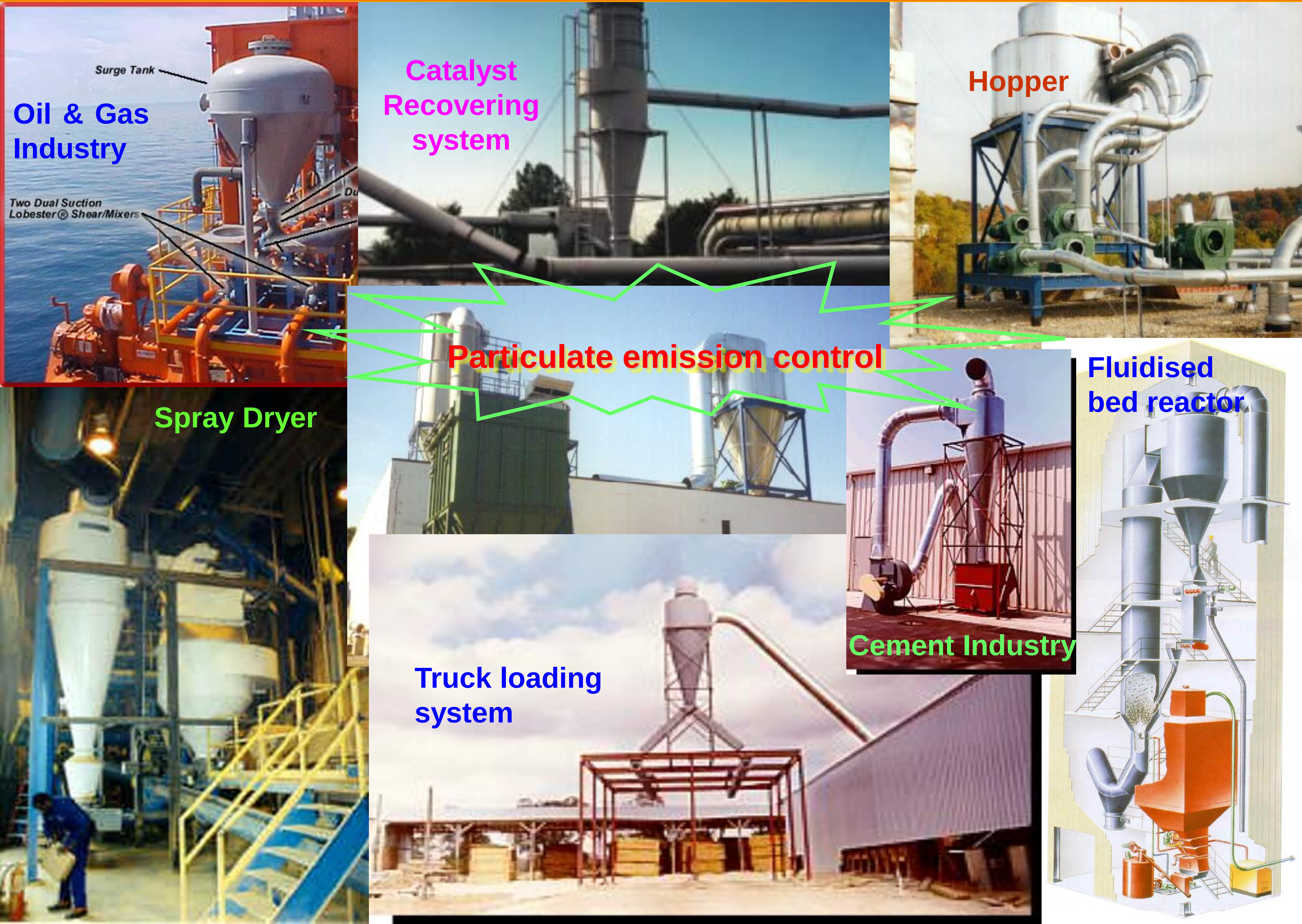
Shepherd & Lapple model – Static pressure difference.

$$\alpha = 16 \frac{ab}{D_e^2}$$

Casal & Martinez model – Statistical analysis of experimental data.

$$\alpha = 11.3 \left(\frac{ab}{D_e^2} \right)^2 + 3.33$$

AREA OF APPLICATION



Oil & Gas Industry

Catalyst Recovering system

Hopper

Particulate emission control

Fluidised bed reactor

Spray Dryer

Cement Industry

Truck loading system

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