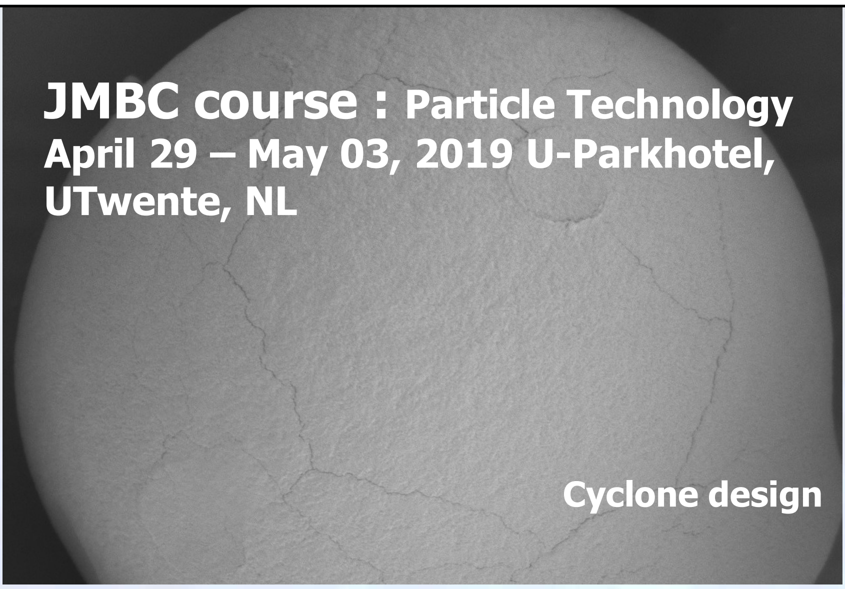

JMBC course : Particle Technology

April 29 – May 03, 2019 U-Parkhotel,
UTwente, NL

Cyclone design

JMBC course 2019
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What is a cyclone?

- A device that separates particulate from gas (fluid) by centrifugal force.
- Works simply by the kinetic energy of the incoming mixture (flow stream) and the geometry of the cyclone.

How a cyclone works?

- **Two main factors affect cyclone efficiency**

– velocity particle moves towards the wall or collection area of the cyclone where it is theoretically collected

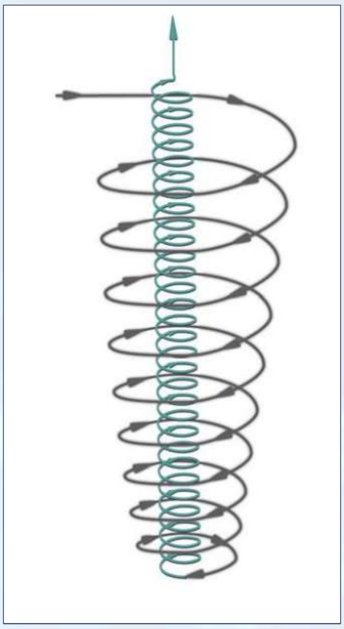
– length of time available for collection: Residence Time

- **Two main metrics describe cyclone performance**

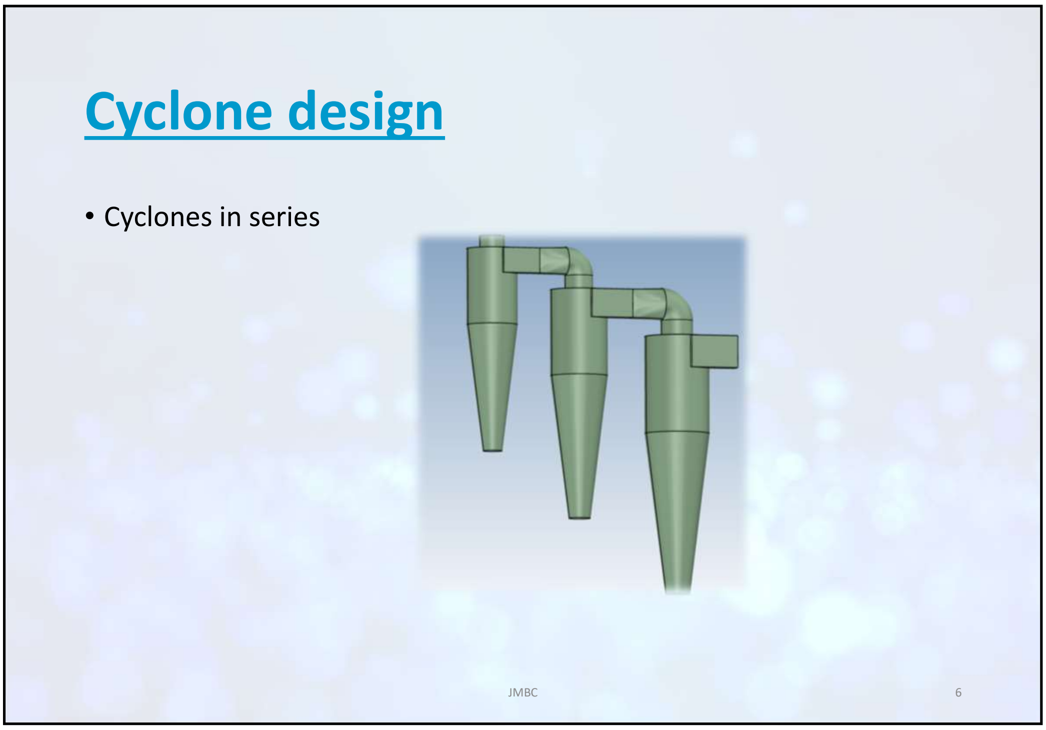
– Pressure drop

– Fractional efficiency curve

Basic flow patterns



Industrial use



Cyclone design

- Cyclones in series

Cyclone design

Cyclone design

- The rate of settling of suspended particles in a gas stream may be greatly increased if **centrifugal** rather than gravitational forces are employed.
- The gas mixture is introduced tangentially into a cylindrical vessel at a velocity of about 20-30 m/s and the clean gas is taken off through a central outlet at the top.
- The solids are thrown outwards against the cylindrical wall of the vessel, and then move away from the gas inlet and are collected in the conical base of the plant.

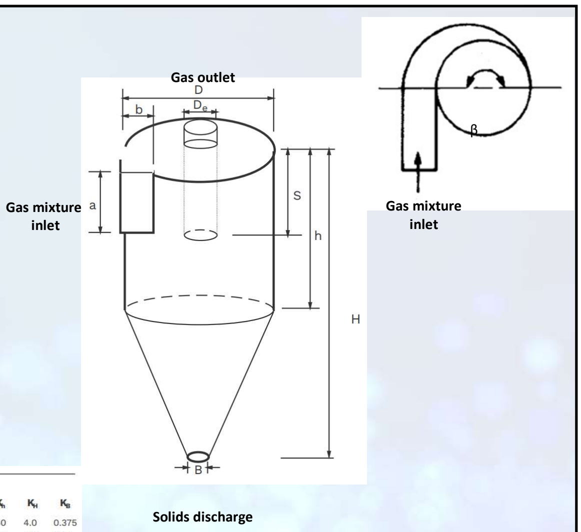
Cyclone design

$$D = \sqrt{\frac{IA}{0.1}} \qquad K_s = \frac{S}{D}$$

$$K_a = \frac{a}{D} \qquad K_h = \frac{h}{D}$$

$$K_b = \frac{b}{D} \qquad K_B = \frac{B}{D}$$

$$K_e = \frac{D_e}{D} \qquad K_H = \frac{H}{D}$$



Cyclone Design Configurations

Source	Recommended Duty	D	K_a	K_b	K_e	K_s	K_h	K_H	K_B
Stairmand	High efficiency	1.0	0.50	0.20	0.50	0.50	1.50	4.0	0.375
Swift	High efficiency	1.0	0.44	0.21	0.40	0.50	1.40	3.9	0.40
Lapple	General purpose	1.0	0.50	0.25	0.50	0.625	2.00	4.0	0.25
Swift	General purpose	1.0	0.50	0.25	0.50	0.60	1.75	3.75	0.40
Peterson and Whitby	Experimental	1.0	0.583	0.208	0.50	0.583	1.333	3.17	0.50

Cyclone design

High efficiency

High throughput

Cyclone design

High efficiency

High throughput

Cyclone design

High efficiency

High throughput

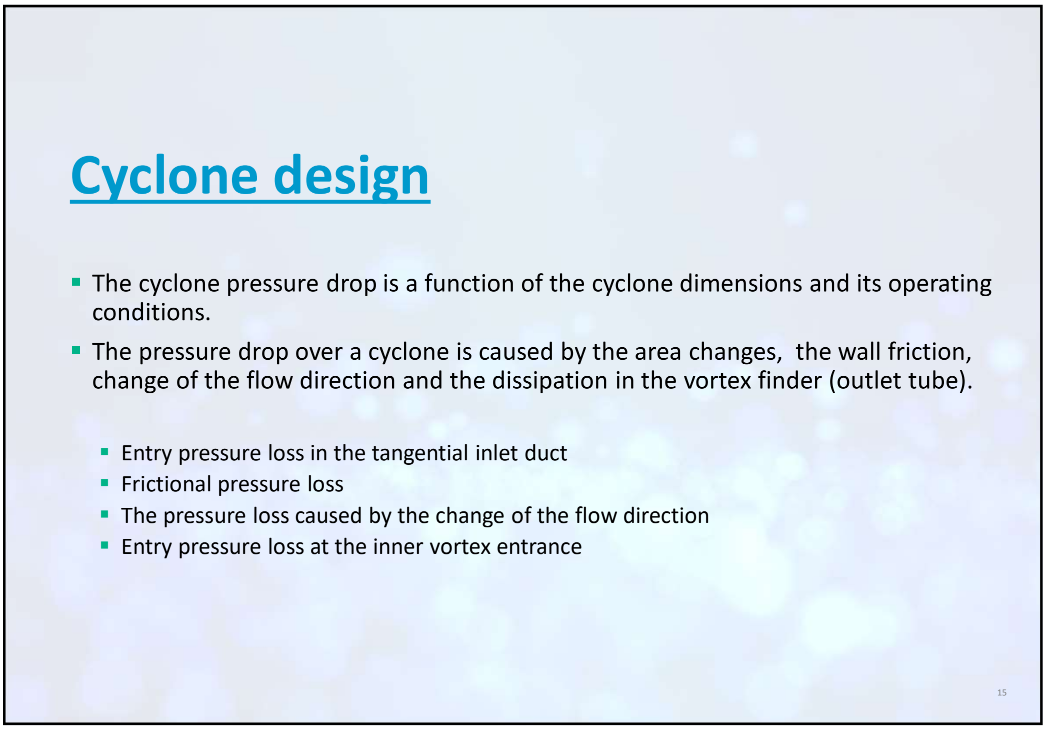
Cyclone design

High efficiency

High throughput

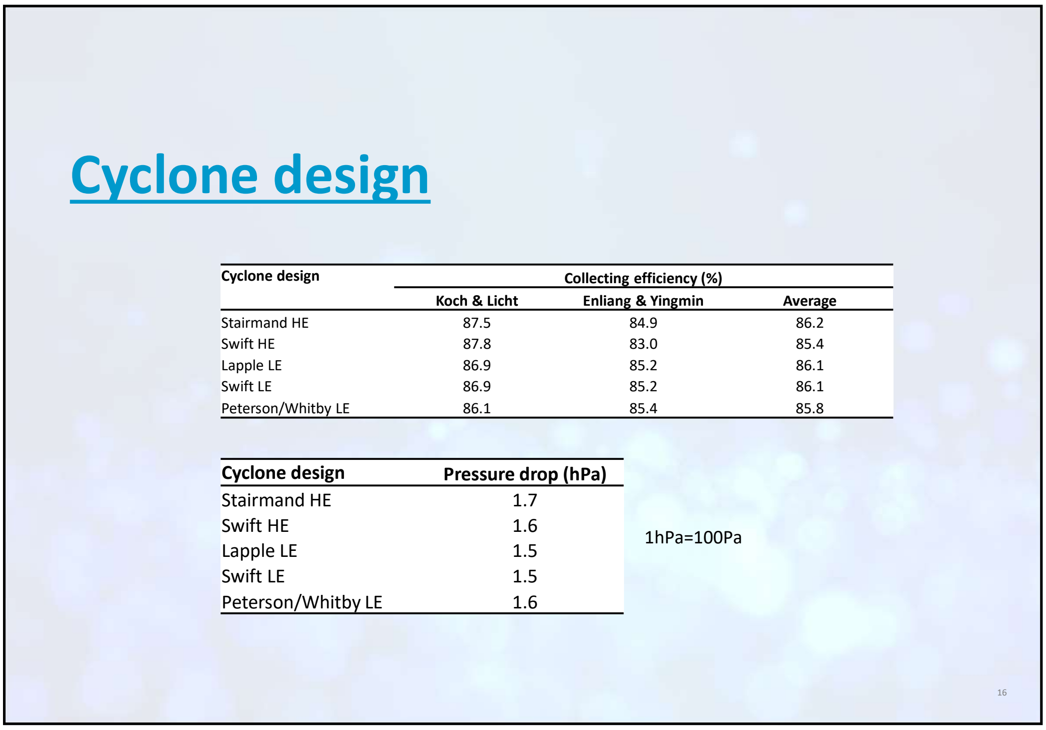
Cyclone design

Cyclone design	Collecting efficiency (%)		
	Koch & Licht	Enliang & Yingmin	Average
Stairmand HE	87.5	84.9	86.2
Swift HE	87.8	83.0	85.4
Lapple LE	86.9	85.2	86.1
Swift LE	86.9	85.2	86.1
Peterson/Whitby LE	86.1	85.4	85.8



Cyclone design

- The cyclone pressure drop is a function of the cyclone dimensions and its operating conditions.
- The pressure drop over a cyclone is caused by the area changes, the wall friction, change of the flow direction and the dissipation in the vortex finder (outlet tube).
    - Entry pressure loss in the tangential inlet duct
    - Frictional pressure loss
    - The pressure loss caused by the change of the flow direction
    - Entry pressure loss at the inner vortex entrance



Cyclone design

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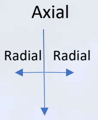
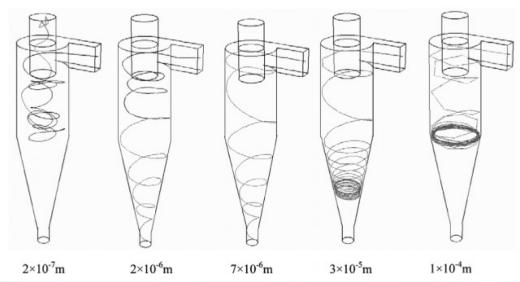
Cyclone design	Pressure drop (hPa)
Stairmand HE	1.7
Swift HE	1.6
Lapple LE	1.5
Swift LE	1.5
Peterson/Whitby LE	1.6

1hPa=100Pa

Cyclone design

- This separator is very effective unless the gas contains a large proportion of particles less than about 10 µm in diameter.
- Trajectories of particles with different diameters (an example)





The Dietz model

$$\eta = 1 - \left[K_0 - \left(K_1^2 + K_2 \right)^{0.5} \right] \times \exp\left[\frac{-\pi(2S-a)\rho_p d^2 v_i}{18\mu ab} \right]$$

$$K_0 = \frac{1}{2}\left[1 + \left(\frac{D_e}{D}\right)^{2n} \left(1 + \frac{9\mu ab}{\pi\rho_p l d^2 v_i} \right) \right]$$

$$K_1 = \frac{1}{2}\left[1 - \left(\frac{D_e}{D}\right)^{2n} \left(1 + \frac{9\mu ab}{\pi\rho_p l d^2 v_i} \right) \right]$$

$$K_2 = \left(\frac{D_e}{D}\right)^{2n}$$

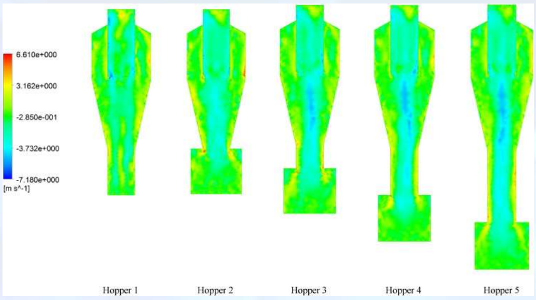
η	fractional collection efficiency for particles of one size (dimensionless)
μ	gas viscosity, Pa · s
a	cyclone inlet height, m
b	cyclone inlet width, m
l	natural length of cyclone, m
S	cyclone gas outlet duct length, m
d	particle diameter, m
v_i	gas inlet velocity, m/s
D	cyclone body diameter, m
D_e	cyclone gas outlet diameter, m
n	cyclone vortex exponent

Cyclone design

- Trajectories of tracing particles entering from different inlet regions

Cyclone design

- There have been several studies in which the flow patterns within the body of the cyclone separator have been modelled using a computational Fluid Dynamics (CFD) technique.



Axial velocity contours along the vertical axis of cyclone separators with different dust outlet geometries

See also
https://youtu.be/Le9UJXJvKpM

(Some references)

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