HEUMANN ENVIRONMENTAL

Basic Cyclone Design

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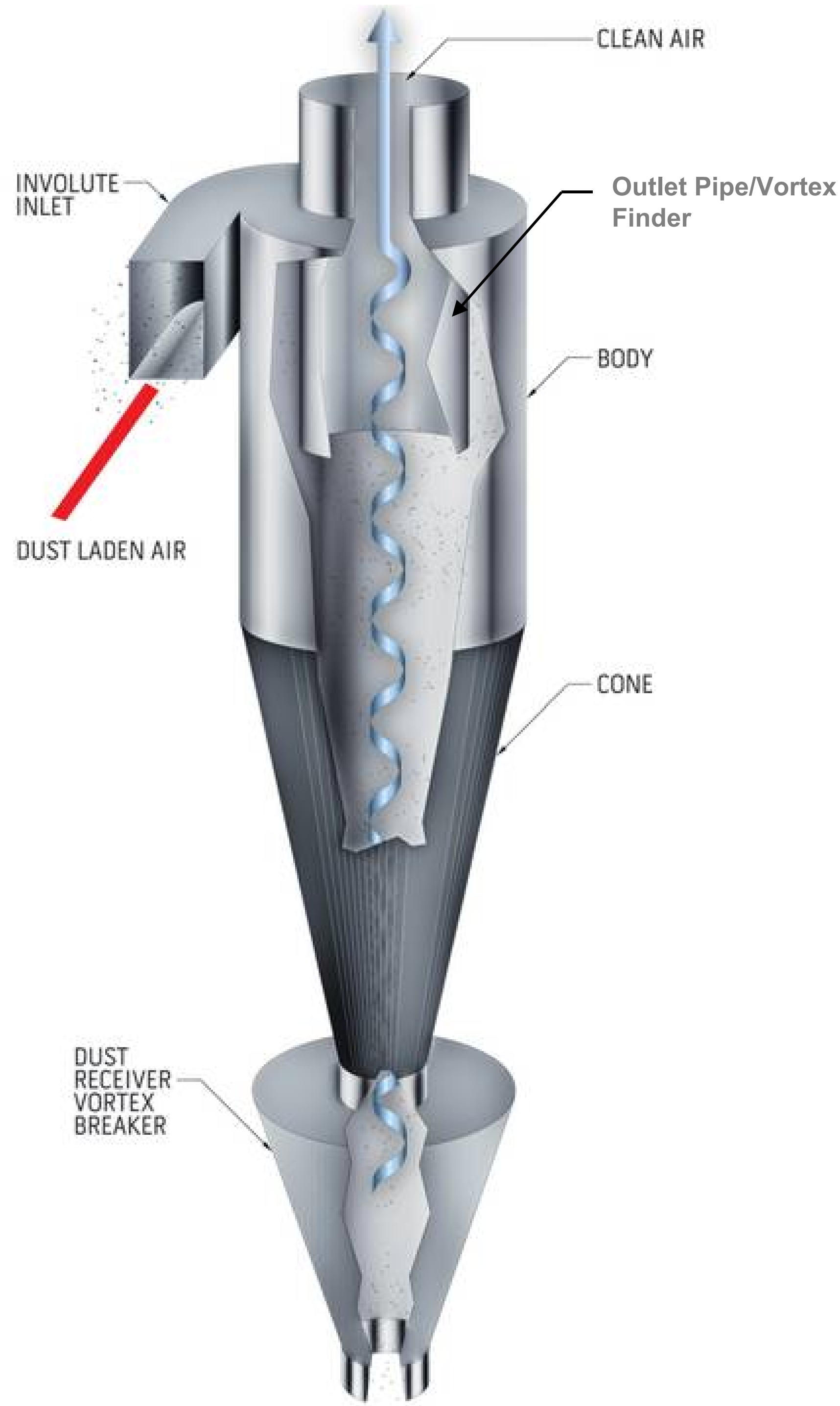
Introduction

- Brief history
- 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

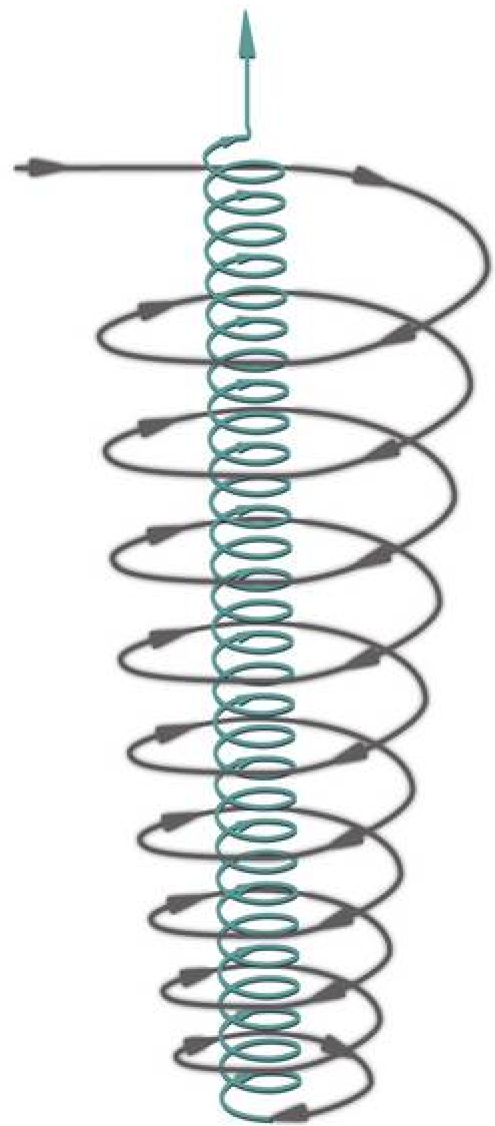
How Cyclones Work: Nomenclature

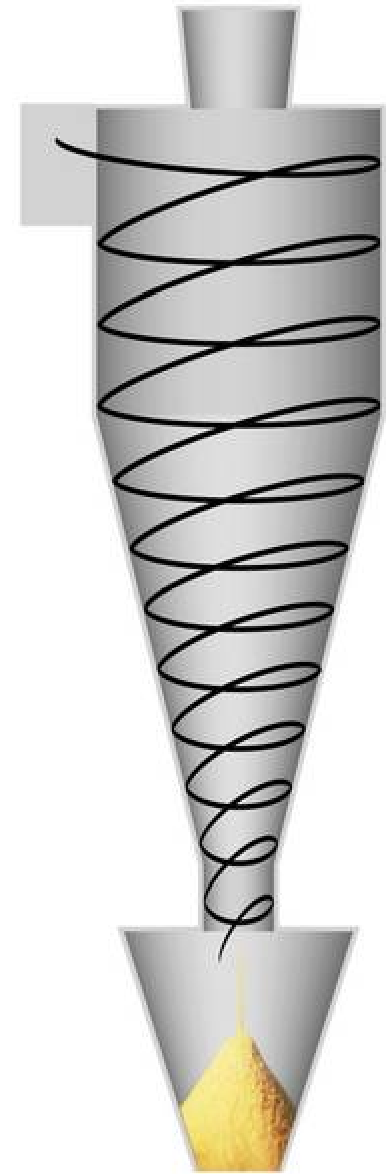


How cyclones work

- All cyclones work by *centrifugal* force
- 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 (FEC)

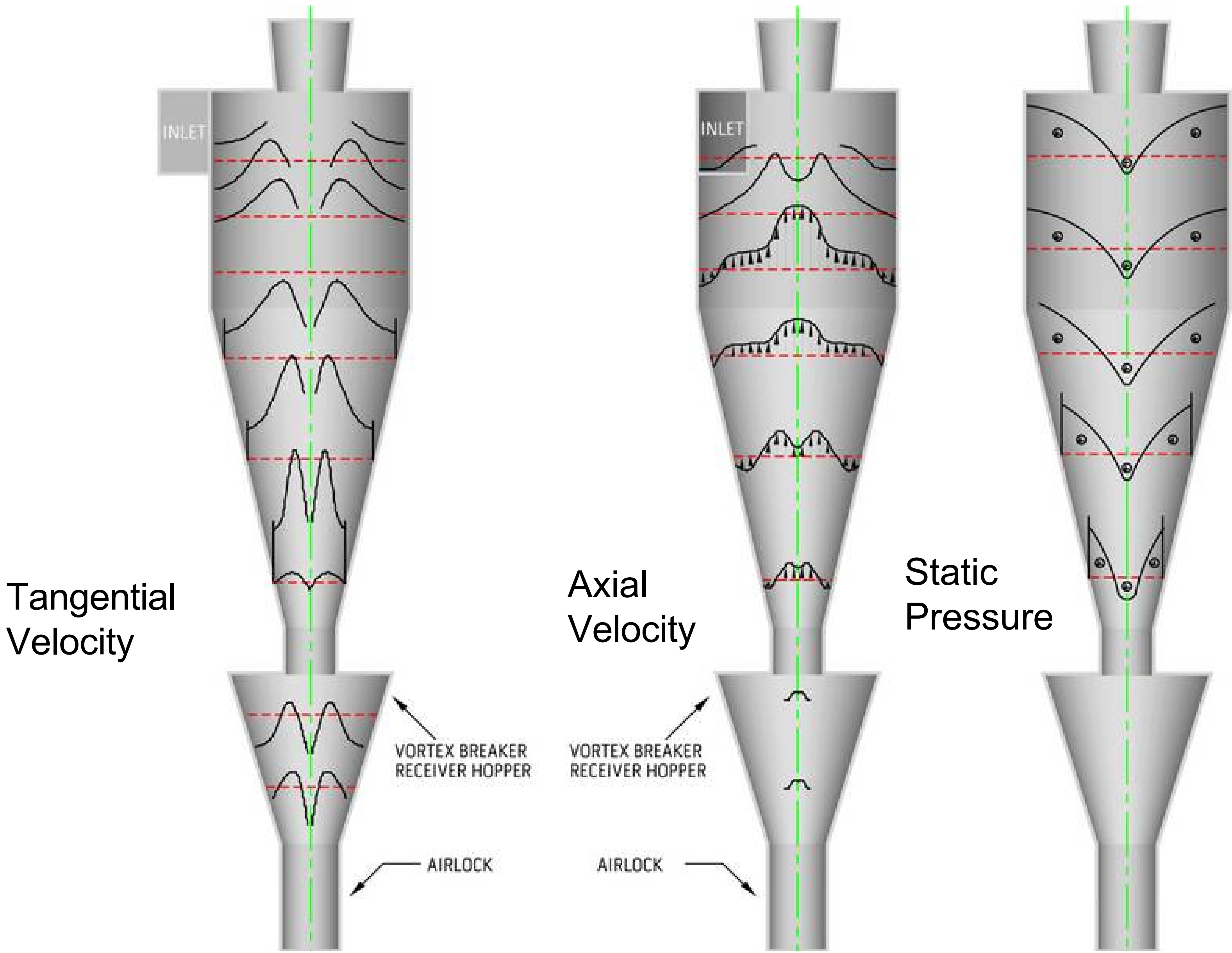
How Cyclones Work: Basic Flow Patterns (Reverse Flow Cyclone)



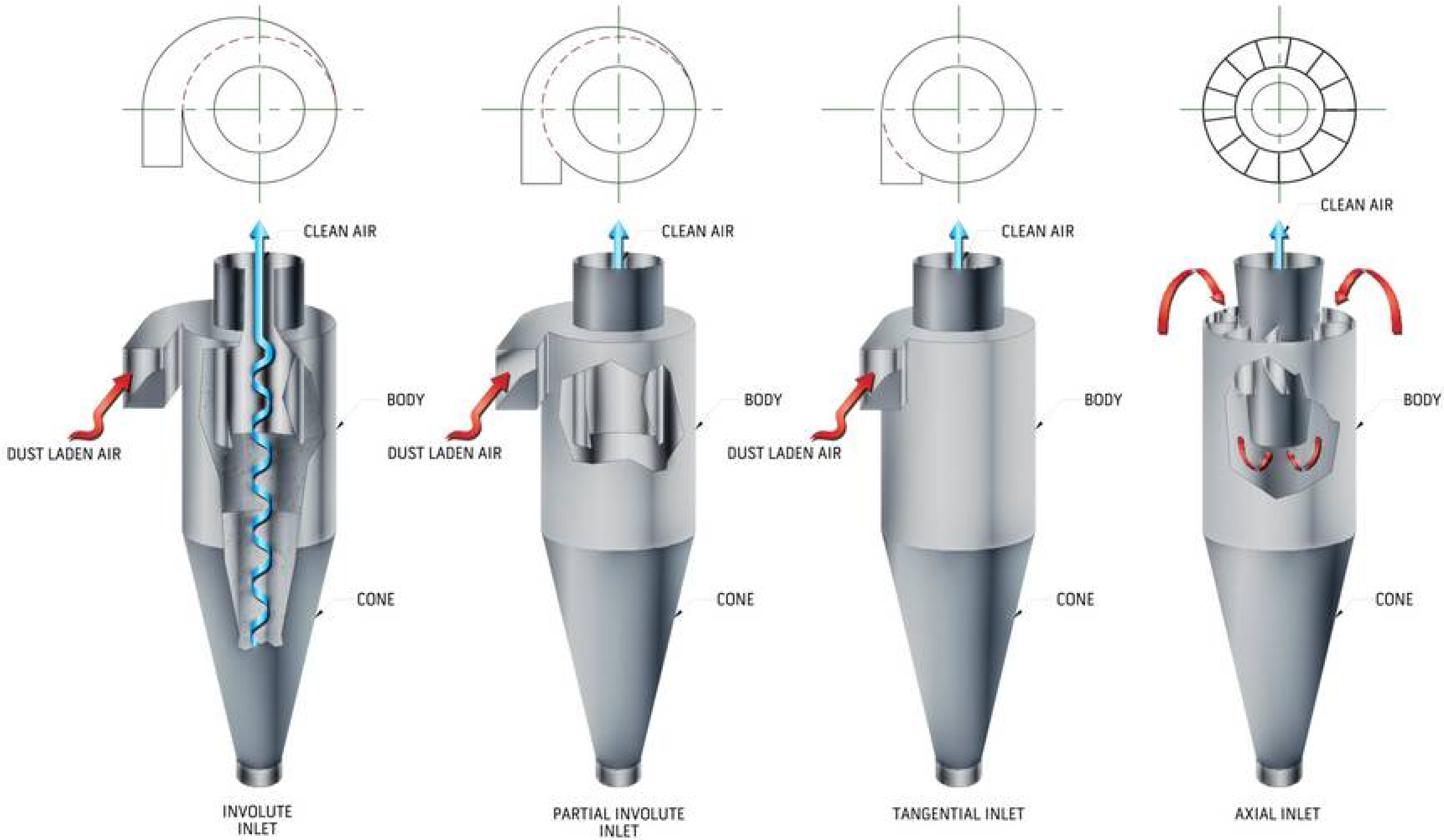


Another Kind of Cyclone

How Cyclones Work: Basic Flow/Pressure Patterns

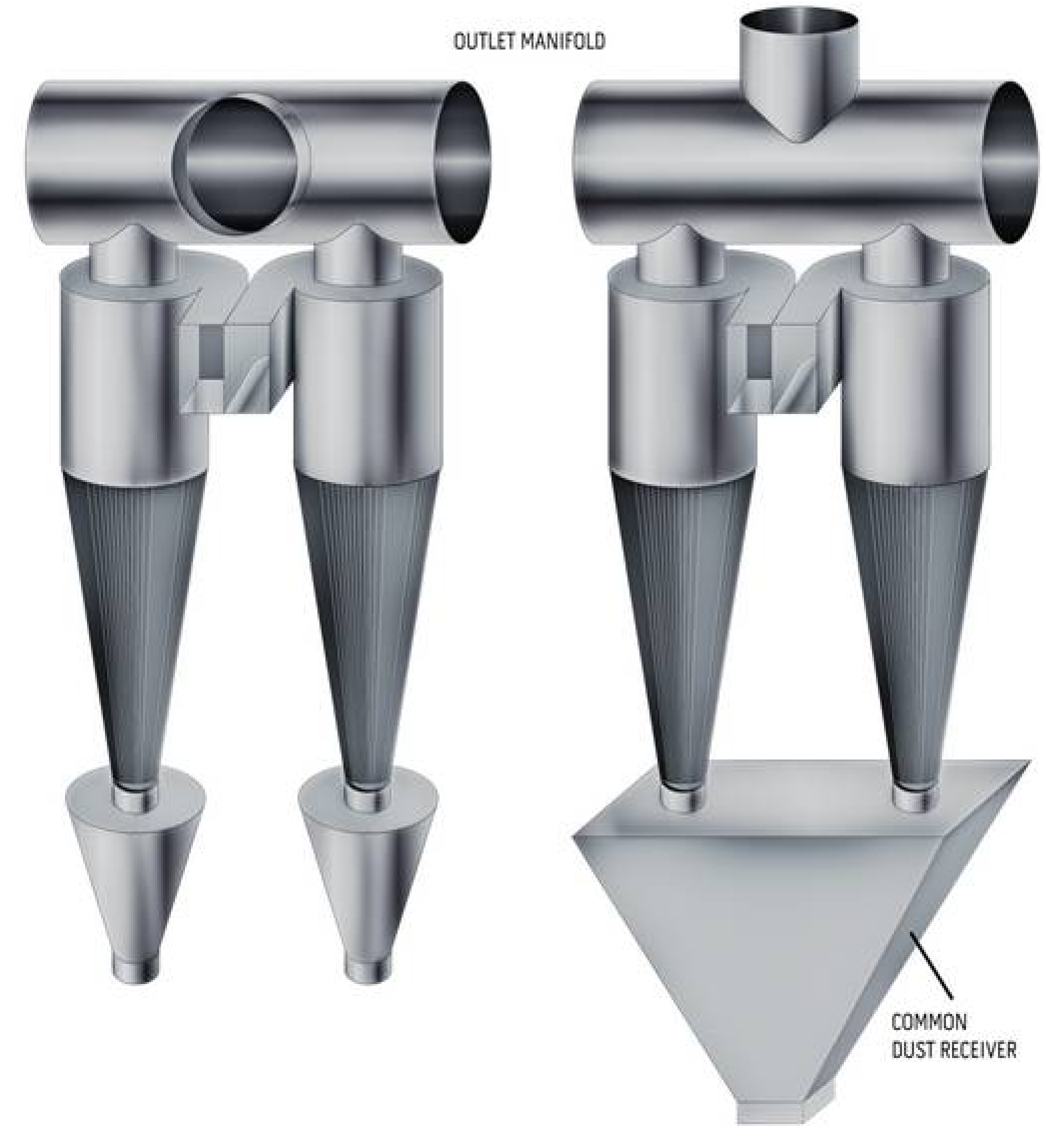


Different styles of Cyclones: Inlet Designs

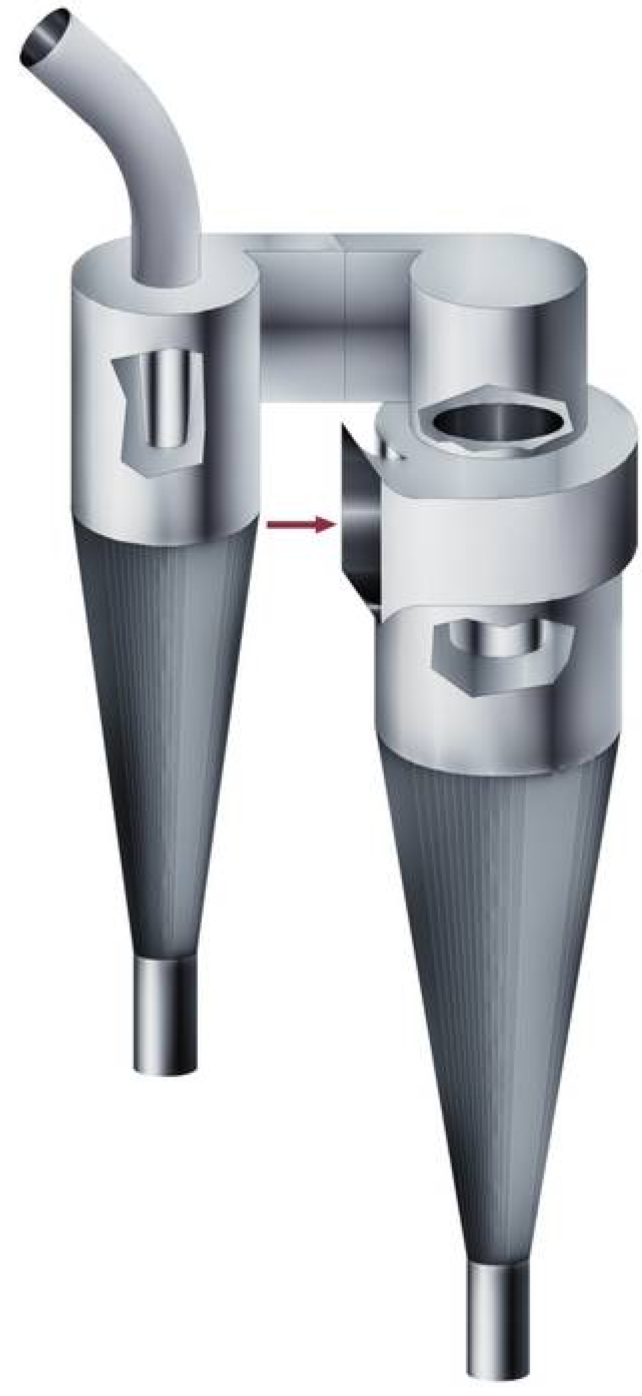


Different Arrangements of Cyclones

Parallel Arrangement



Different Arrangements of Cyclones: Series Arrangement



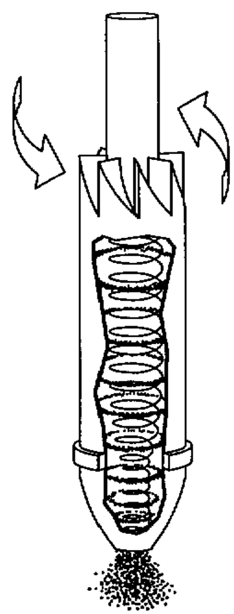
Parallel Cyclones

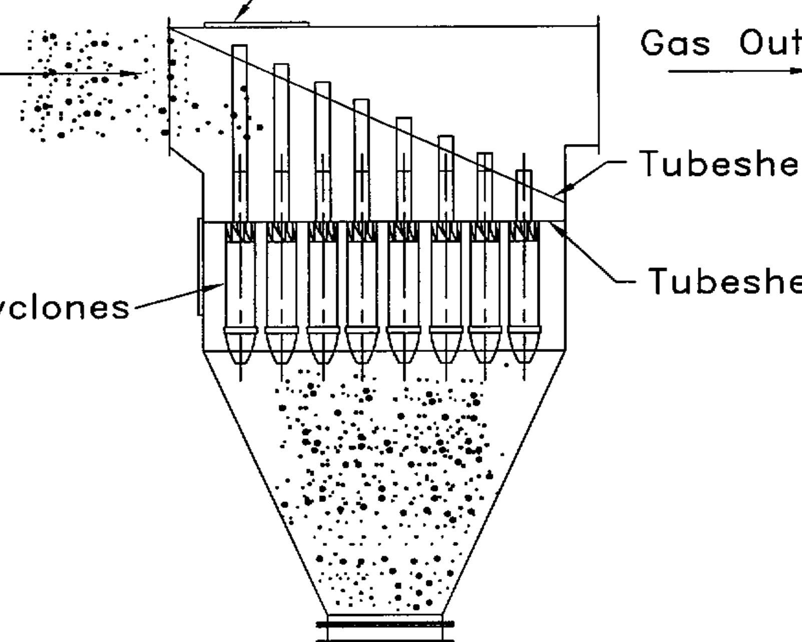
Parallel Cyclones

Different styles of cyclonic devices

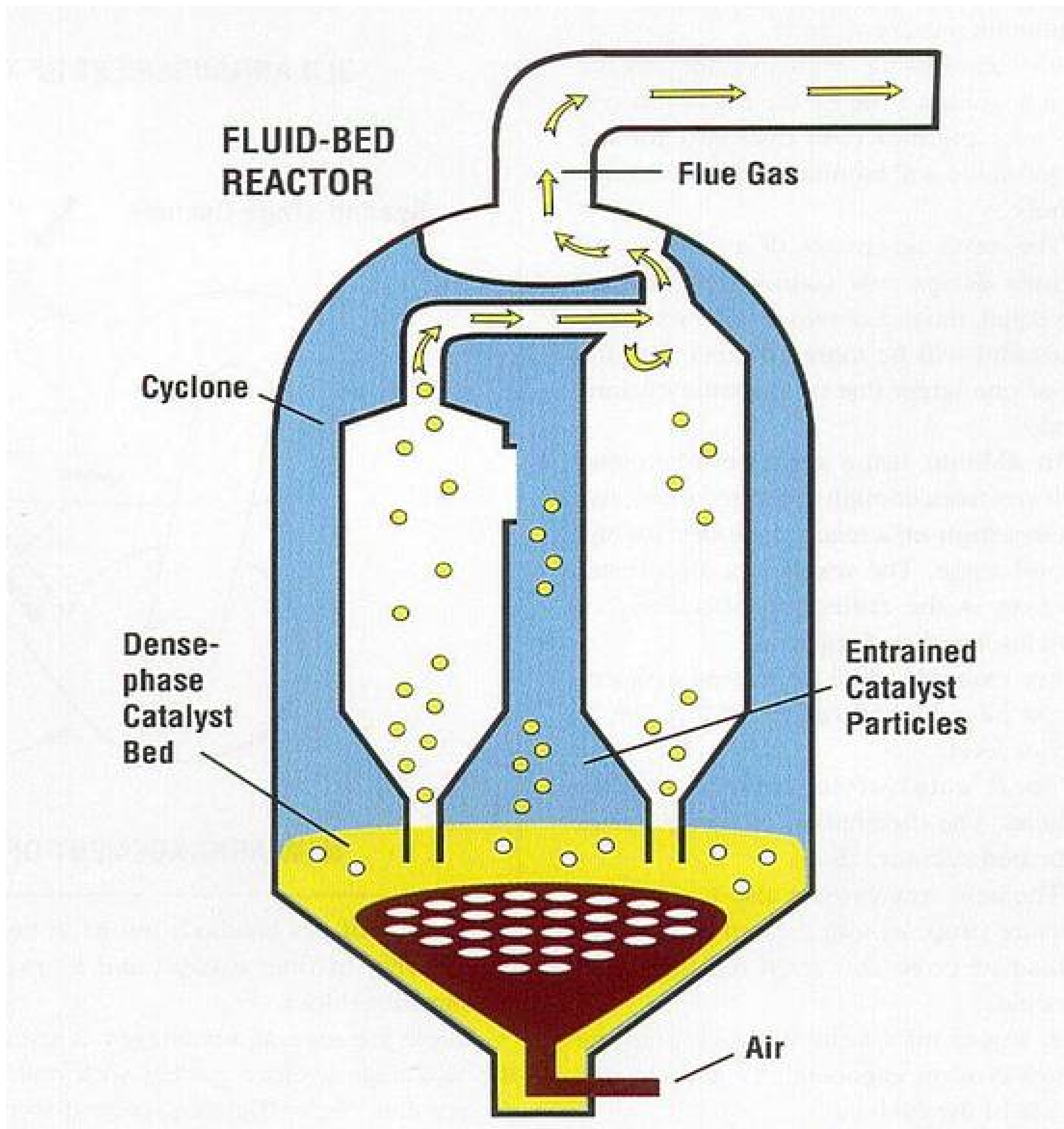
Parallel Cyclones

Reverse Flow-
Axial Inlet

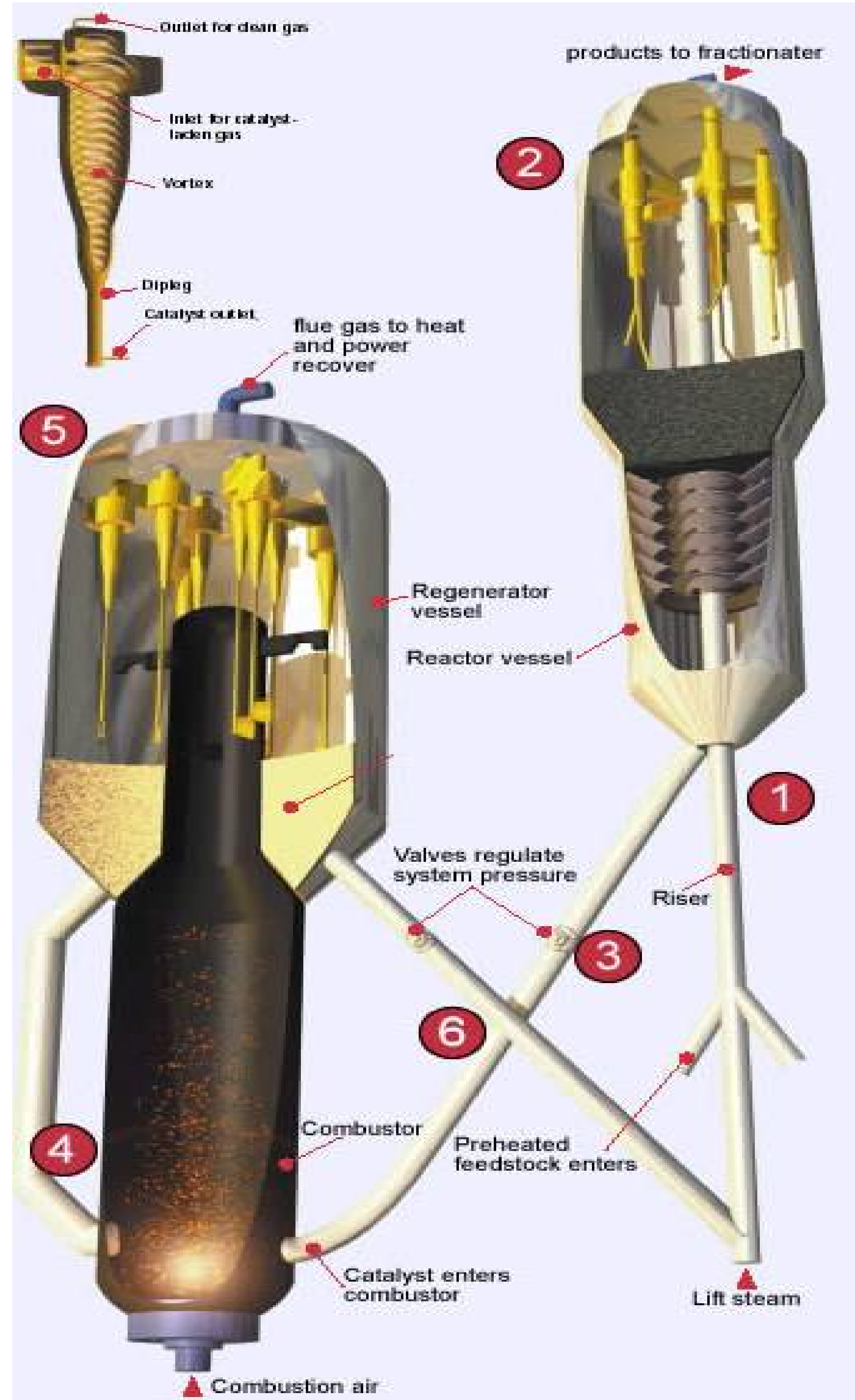




Series Cyclone Arrangement

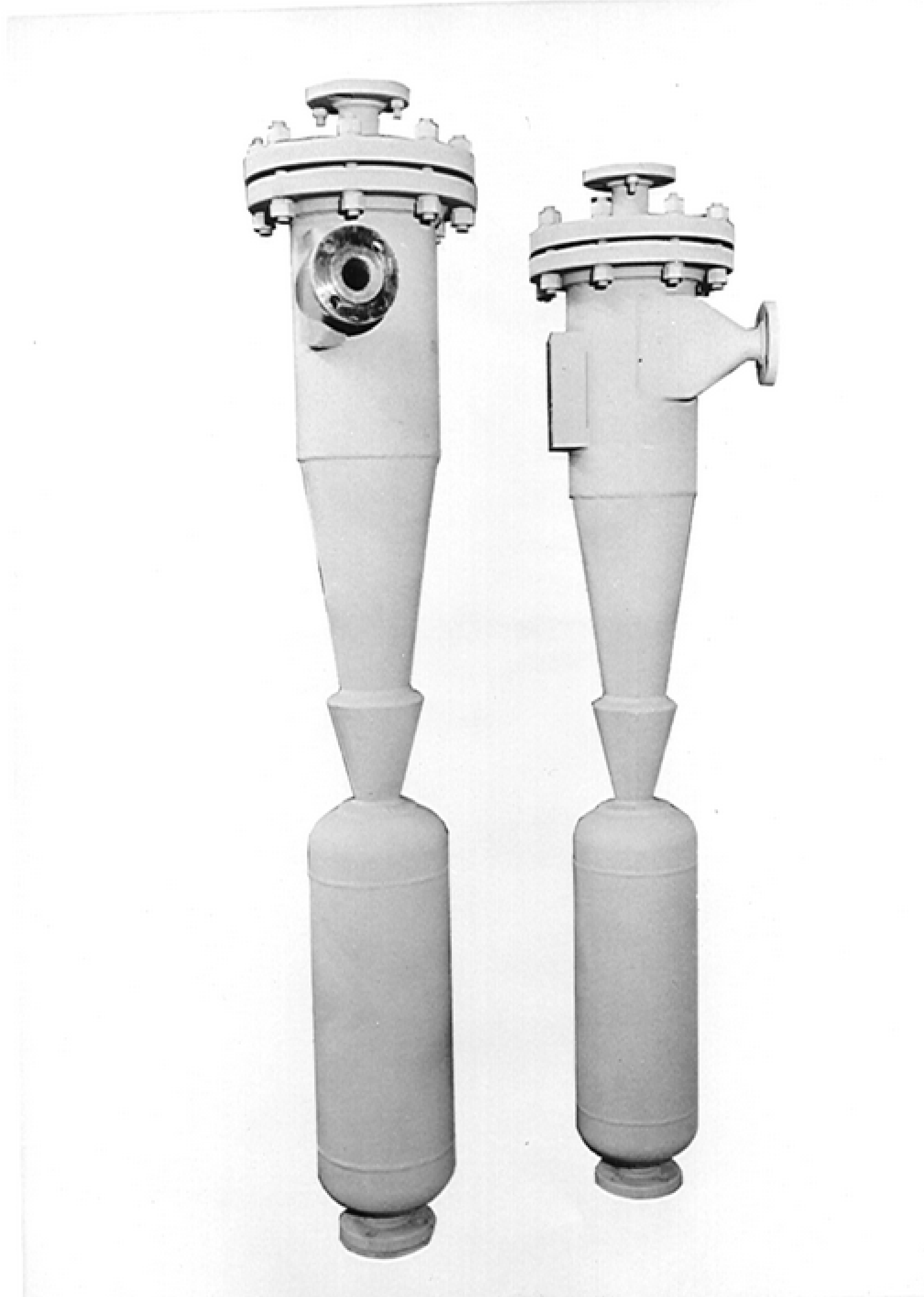


FCC Process: The heart of the system



FCC Regenerator Cyclones

Pressure Vessel Cyclones



A cyclone picture of another sort..

Why Use Cyclones?

- Dry
- No moving parts
- Robust Construction
- Can be easily designed for very severe duty (examples)
- Low cost (sometimes)
- Safety

When do you use a cyclone?

- When it is the most economical solution!
  - Capital Costs
  - Installation Costs
  - Operating Expenses
  - Maintenance Expense
  - Depreciation (life expectancy)
  - Safety and liability issue
  - Product recovery
  - System operability
  - Effects on downstream equipment and process

Cyclone Performance Metrics: Pressure drop

- Pressure drop = power consumption
- Pressure drop measurement

$$\Delta P = P_{a\ inlet} - P_{a\ outlet}$$

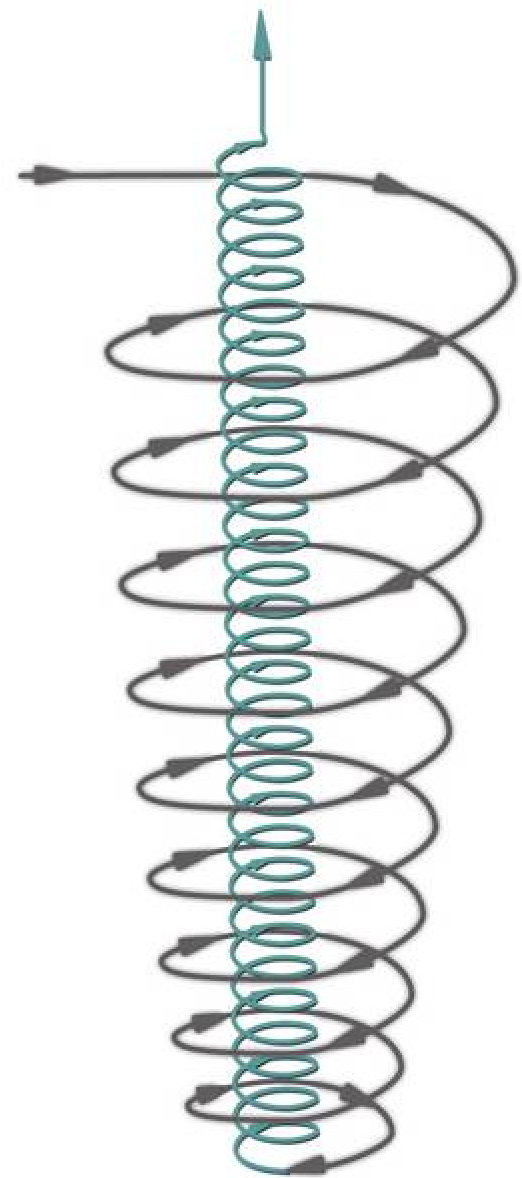
where;

$\Delta P =$ **cyclone pressure drop**

$P_a =$ **absolute pressure**

Where Does Pressure Drop Come From?

- Frictional and entrance losses usually = 10%-30% of total
- The rest is the pressure gradient generated by the vortex



Pressure drop @ no load

- Basic pressure drop equation

$$\Delta P_2 = \Delta P_1 \bullet (Q_2/Q_1)^E \bullet (\rho_2/\rho_1)$$

where;

Q = gas flow rate
E = geometry exponent (1.9-2.3)
ρ = gas density

Pressure drop @ load

- Pressure drop goes down with increased dust load
- Pressure drop dust loading equation

$$\Delta P_L = C \bullet \Delta P_0$$

$$C = 2.095 \bullet W^{-.02} - 1.09$$

where;

ΔP_L = pressure drop @ load

ΔP_0 = pressure drop @ no load

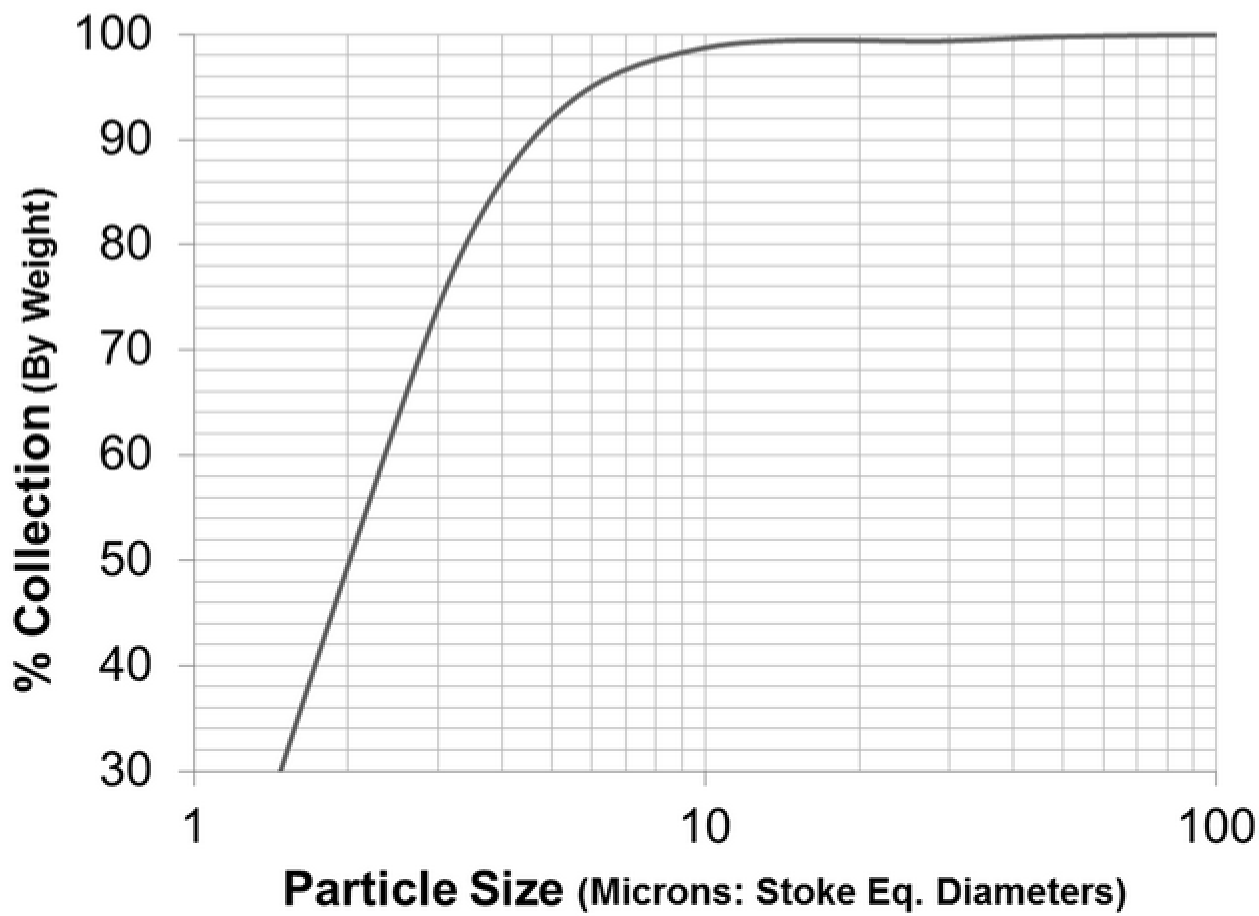
W = dust load (grains/acf)

Fractional efficiencies

- collection efficiency @ various particle sizes
- fractional *or* size efficiency curve
- may be graphical or tabular

Example Size Efficiency Curve

Particle Diameter (microns)	% collection (B.W)
1	5
3	74
5	92
10	98.74
30	99.4
50	99.8
100	99.99



FEC Variables

- Cyclone Geometry
- Cyclone Velocities
- Particle Density
- Gas Viscosity
- Dust Load

Cyclone Total Collection Efficiency

- Function of the cyclone FEC and incoming Particle Size Distribution (PSD)
- Cyclone Total Collection Efficiency can vary greatly but it may be doing exactly the same thing!

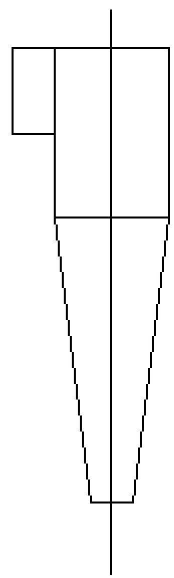
Total collection efficiency sample calculation

particle size range (microns) min	max	particle size distribution (% by weight)	d50 (microns)	fractional efficiencies collection (% by weight)	collected particulate (% by weight)
0	5	3	2.5	25.96	0.78
5	10	5	7.5	94.83	4.74
10	20	12	15	98.79	11.85
20	30	19	25	99.28	18.86
30	40	13	35	99.87	12.98
40	50	12	45	99.94	11.99
50	70	11	60	99.99	11.00
70	90	10	80	100.00	10.00
90	110	7	100	100.00	7.00
110	130	6	120	100.00	6.00
130	150	2	140	100.00	2.00
Totals		100			97.21

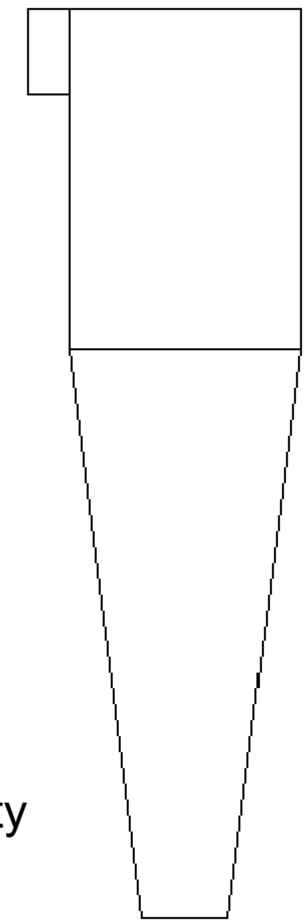
Tools for Increased Cyclone Efficiency: Cyclone Geometry Variables

- Inlet configuration and ratio
- Cyclone L/D Ratio
- Outlet pipe penetration
- Dust receiver
- Residence time

Tools for Increased Cyclone Efficiency: High Residence Time



High Capacity/Low Residence Time

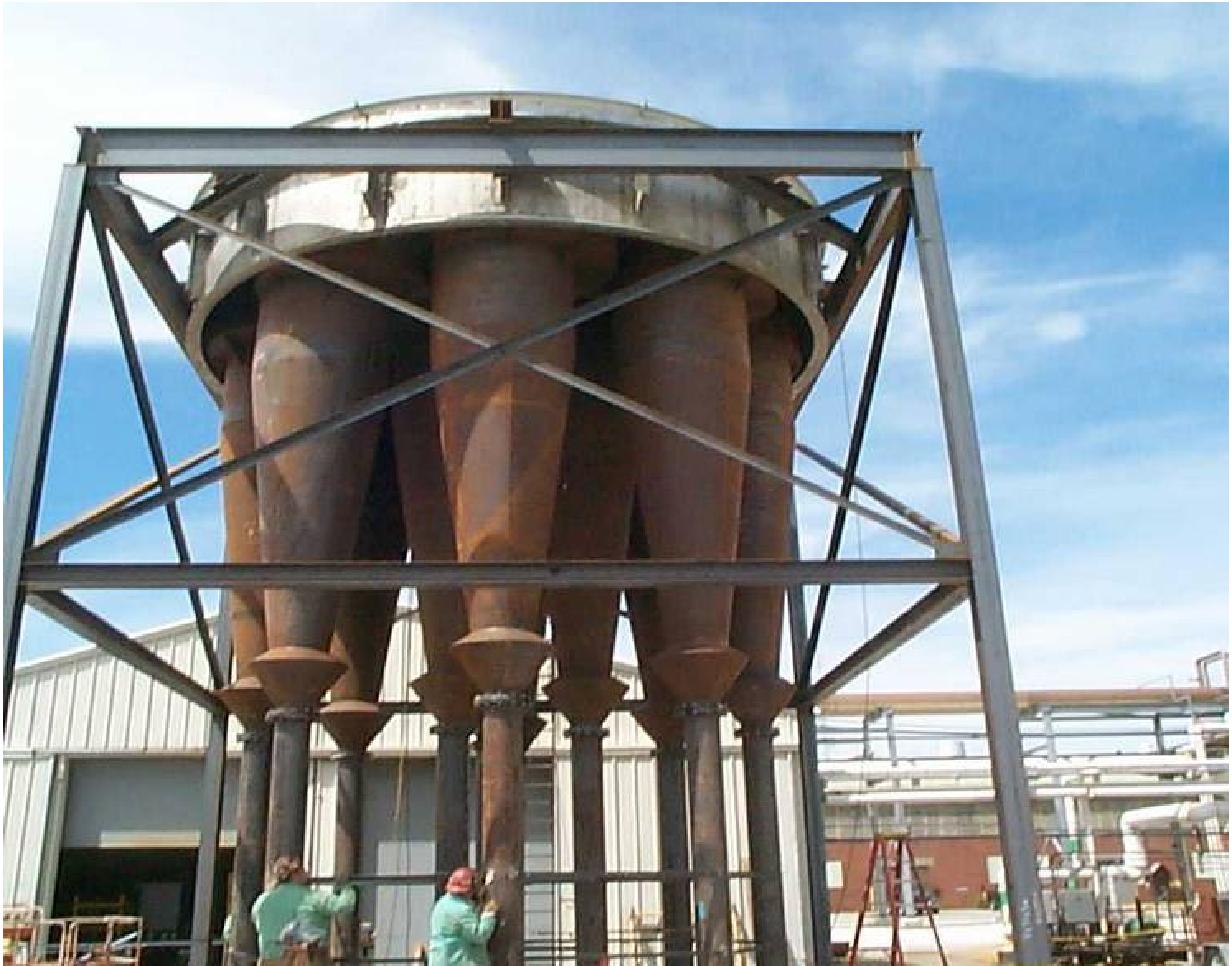


High Residence Time/Low Capacity

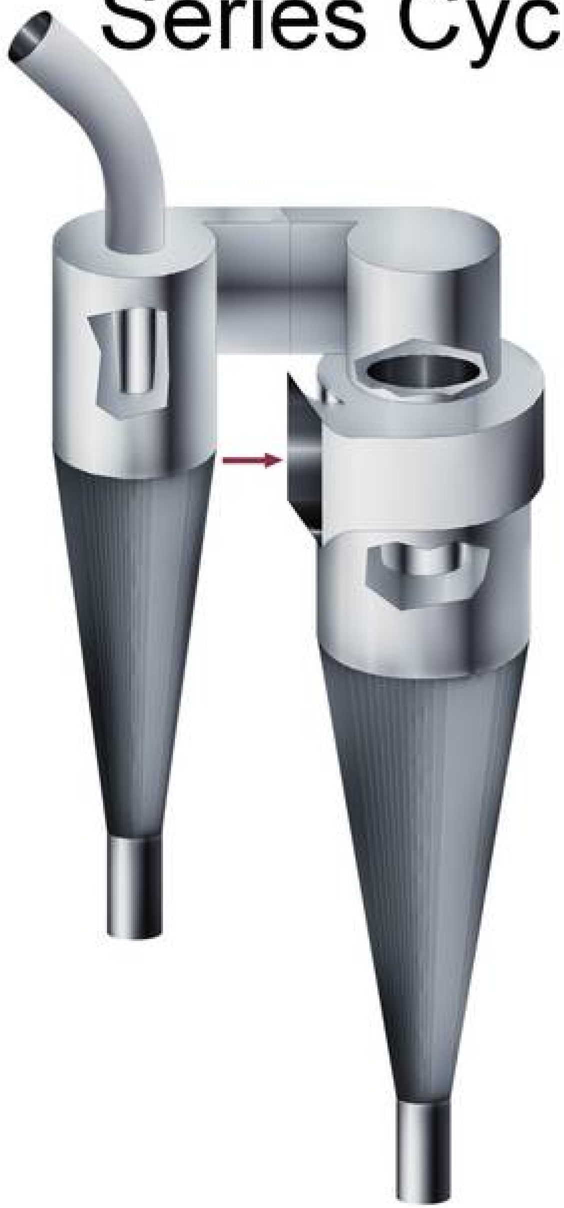
Tools for Increased Cyclone Efficiency: Parallel Cyclone Arrangements

- One of best tools for getting higher collection efficiency: For a given power consumption and family of cyclones, splitting the flow into parallel streams allows the use of more efficient, smaller cyclones: “Small Cyclones are more efficient than large ones.”
- Parallel arrangements may provide the best solution when headroom is limited

Tools for Increased Cyclone Efficiency: Parallel Cyclone Arrangements



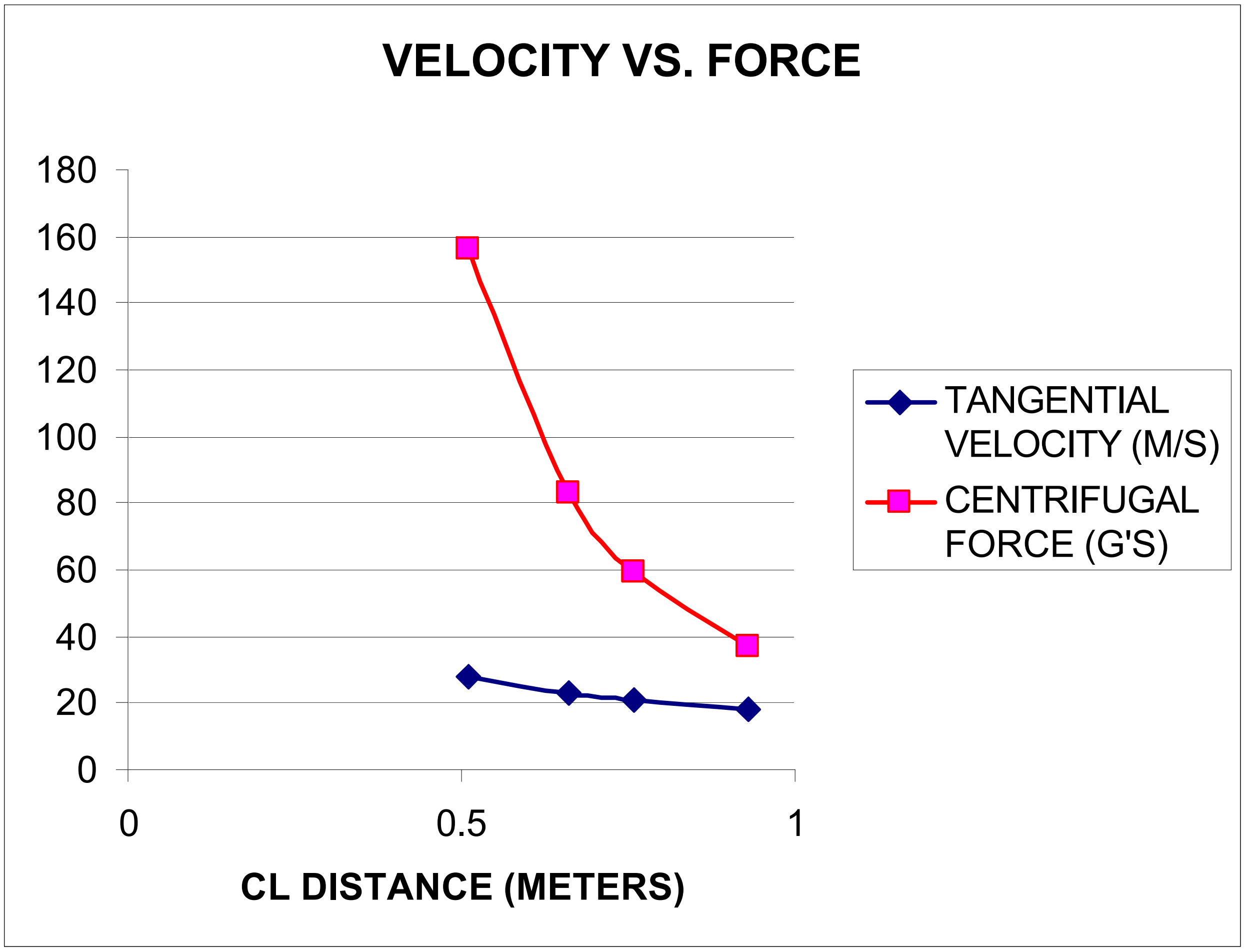
Tools for Increased Cyclone Efficiency: Series Cyclone Arrangements

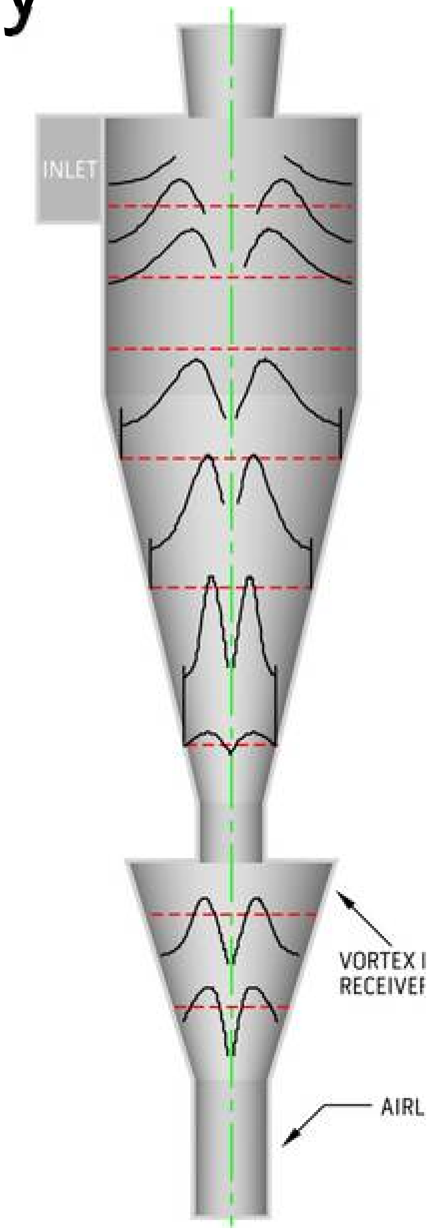


- Can provide higher collection efficiency for a limited inlet velocity because of the cumulative efficiency: 90% @ 5 micron + 90% @ 5 micron= 99% @ 5 micron
- May provide for redundancy in the event of system upsets

Tools for Increased Cyclone Efficiency: Tangential (Radial) Velocity

$$F_c = m \bullet V_t^2 / r$$





Tools for Increased Cyclone Efficiency: Tangential Velocity and/or Centrifugal Force

- How do we increase Tangential Velocity?
  - Increase Inlet Velocity
  - Increase Outlet Velocity
- What else can we do to increase Centrifugal Force?
  - Smaller radius flow path: Use parallel cyclones
  - Decrease outlet pipe diameter

Other Tools for Increased Efficiency: Geometry

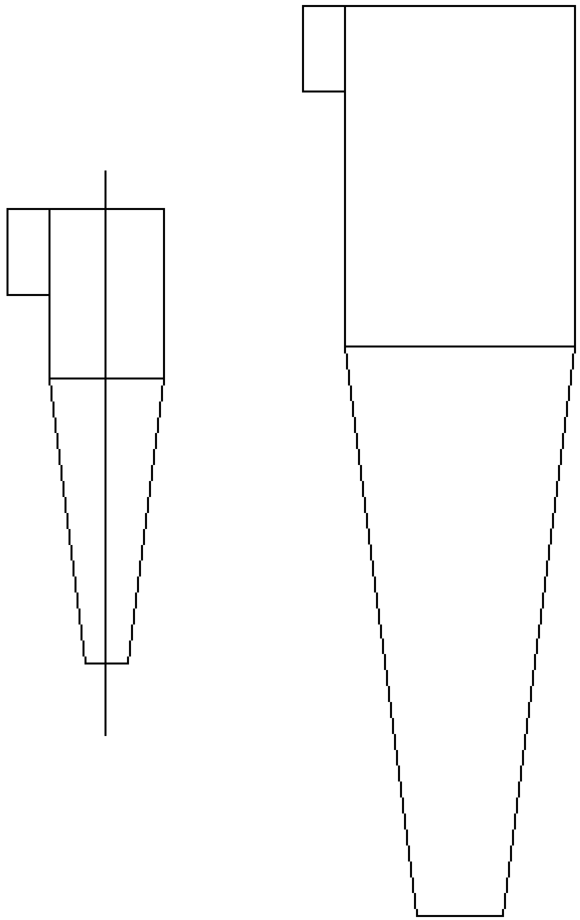
- L/D Ratio
- Inlet Design
- Optimum Outlet Pipe Length
- Dust Receivers

Other Tools for Increased Efficiency: Arrangement

- Cyclones in Parallel
  - Takes advantage of rule that says “for cyclones of the same family (geometrically proportional) at the same operating conditions, smaller cyclones are more efficient than larger ones
- Cyclones in Series
  - Redundant chances for particle collection

The Costs of Increased Efficiency: High Residence Time Cyclones

- Capital Cost
- Headroom
- May not be possible or viable with some processes



The Costs of Increased Efficiency: Parallel Cyclones

- Capital Costs
- Manifolding can be expensive and difficult
- Pneumatic isolation can be difficult or cost prohibitive
- More horizontal space required

The Costs of Increased Efficiency: Series Cyclones

- Capital Costs
- Manifolding can be expensive and difficult
- More horizontal space required
- Pressure Drop is Cumulative
- Diminished benefit as PSD gets smaller

The Costs of Increased Efficiency: Increased Velocity

- Pressure Drop (Power Consumption)
- Erosion
- Particle Attrition
- Re-entrainment
- At very high velocities may have acoustical and/or Ranque-Hilsch effects

How Cyclones Fail

- Improperly Designed
  - Incorrect or inaccurate design data
  - Lack of know how by cyclone designer- after all, "anyone can build a cyclone"
- Leakage into the cyclone
- Plugged cyclones
- Cyclones wear out too quickly

How Cyclones Fail: Design/ Fabrication Errors

- No dust receiver
- Short outlet pipes
- Dished heads
- Poor or non existent airlocks
- Instruments or access ports installed into cyclonic flow streams
- Related equipment not designed for cyclonic flow
- Inlet elbows, transitions, or other obstructions

- For More Information Visit www.heumannenviro.com
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