Design and fabrication of cyclone separator

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Acknowledgement

I have only the pearls of my eyes to admire the blessings of the Compassionate and Omnipotent because the words are bound, knowledge is limited and the time is short to express HIS dignity. We are immeasurably grateful to Almighty Allah, the Propitious, the Benevolent and Sovereign, who has endowed our brain and instable instinct contraction of knowledge and body to accomplish our work in the form of this dissertation, whose blessing and glory flourished our thoughts, thrived our ambitions, granted us talented teachers, affectionate parents, loving brothers and exceptional friends.

Trembling lips and wet eyes praise for The Last Prophet Hazrat Muhammad (PBUH) for enlightening our conscience with the essence of faith in ALMIGHTY ALLAH, enabling us to recognize the Oneness of our creator, and showed us the right path for the success. Faithfulness in the performance of small duties gives us strength to adhere to difficult determinations that life will someday force us to make.

"The ink of the scholar is more holy than the blood of the martyr."

The work presented in this design was accomplished under the sympathetic attitude, fatherly behavior, animate direction, observant pursuit, scholarly criticism, sheering perspective and enlightened supervision of **Engr. Hafiz Muhammad Amir**, Department of Chemical Engineering, University of Gujarat. We are very grateful to his ever inspiring guidance, keen interest, scholarly comments and constructive suggestions during the course of our studies.

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Kashan Bashir

Abstract

To design a cyclone abatement system for particulate control, it is necessary to accurately estimate cyclone performance. In this cyclone study, new theoretical methods for computing travel distance, numbers of turns and cyclone pressure drop have been developed. The flow pattern and cyclone dimensions determine the travel distance in a cyclone. The number of turns was calculated based on this travel distance. The new theoretical analysis of cyclone pressure drop was tested against measured data at different inlet velocities and gave excellent agreement. The results show that cyclone pressure drop varies with the inlet velocity, but not with cyclone diameter.

Cyclone cut-points for different dusts were traced from measured cyclone overall collection efficiencies and the theoretical model for calculating cyclone overall efficiency. The cut-point correction models 2D2D cyclones were developed through regression fit from traced and theoretical cut-points Diameter.

Experimental results indicate that optimal cyclone design velocities, which are for 2D2D cyclones, should be determined based on standard air density. It is important to consider the air density effect on cyclone performance in the design of cyclone abatement systems. The tangential inlet generates the swirling motion of the gas stream, which forces particles toward the outer wall where they spiral in the downward direction. Eventually the particles are collected in the dustbin located at the bottom of the conical section of the cyclone body. The cleaned gas leaves through the exit pipe at the top.

In Pakistan it has been installed in many industries its Main modes of operation is similar to collect the particles but the collection of particles and method of collection are Distinguish. Cement Sector is one of advance sector application for Cyclone Separator. DG cement in one of those Cement Manufacturing Plant where Cyclone working Efficiently .

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CHAPTER #1

INTRODUCTION

CYCLONE SEPERATOR

This chapter gives introduction to cyclone separators, reasons for its popularity and objective of using cyclone separator at micro level.

Introduction

Chemical processes consist of reaction stages and/or separation stages in which the process streams are separated and purified. Such separations involve physical principles based on differences in the properties of the constituents in the stream. Heterogeneous mixtures consist of two or more phases which have different composition. These mixtures consist of components that do not react chemically and have clearly visible boundaries of separation between the different phases. Components of such mixture can be separated using one or more appropriate techniques. These separation processes includes Gas-Liquid (vapor-liquid) separation, Gas-Solid separation (vapor-solid), Liquid-Liquid separation (immiscible), Liquid-Solid, and Solid-Solid separation etc. This separation can be done by exploiting the differences in density between the phases. Gravitational force or centrifugal force can be used to enhance the separation. The separation units can be either horizontal or vertical. The main techniques used to separate the phases, and the components within the phases, are discussed in details.

The principle methods for the separation of such mixtures could be classified as:

1. Cyclone separator, 2. Gas-Liquid separator, 3. Liquid-Liquid separator

4. Gravity separator, 5. Centrifugal separator, 6. High speed tubular centrifuge 7. Scrubbers 8. Electrostatic precipitator, 9. Hydro cyclone

Cyclone Separator

Cyclone separators provide a method of removing particulate matter from air or other gas streams at low cost and low maintenance. Cyclones are somewhat more complicated in design than simple gravity settling systems, and their removal efficiency is much better than that of settling chamber. Cyclones are basically centrifugal separators, consists of an upper cylindrical part referred to as the barrel and a lower conical part referred to as cone (figure 5.1). They simply transform the inertia force of gas particle flows to a centrifugal force by means of a vortex generated in the cyclone body. The particle laden air stream enters tangentially at the top of the barrel and travels downward into the cone forming an outer vortex. The increasing air velocity in the outer vortex results in a centrifugal force on the particles separating them from the air stream. When the air reaches the bottom of the cone, it begins to flow radially inwards and out the top as clean air/gas while the particulates fall into the dust collection chamber attached to the bottom of the cyclone.

Figure. 1

Types of Cyclone

Three different types of cyclone are shown in figure 2. First figure i.e. 2a shows a cyclone with a tangential entry. These types of cyclones have a distinctive and easily recognized form and widely used in power and cement plants, feed mills and many other process industries.

Figure 2b shows the axial entry cyclones, the gas enter parallel to the axis of the cyclone body. In this case the dust laden gases enter from the top and are directed into a vortex pattern by the vanes attached to the central tube. Axial entry units are commonly used in multi cyclone configuration, as these units provide higher efficiencies. Another type of larger cyclonic separator shown in figure 2c is often used after wet scrubbers to trap particulate matter entrained in water droplets. In this type, the air enters tangentially at the bottom, forming vertex. Large water droplets are forced against the walls and are removed the air stream.

Cyclone collectors can be designed for many applications, and they are typically categorized as high efficiency, conventional (medium efficiency), or high throughput (low efficiency). High efficiency cyclones are likely to have the highest-pressure drops of the three cyclone types, while high throughput cyclones are designed to treat large volumes of gas with a low-pressure drop. Each of these three cyclone types have the same basic design. Different levels of collection efficiency and operation are achieved by varying the standard cyclone dimensions.

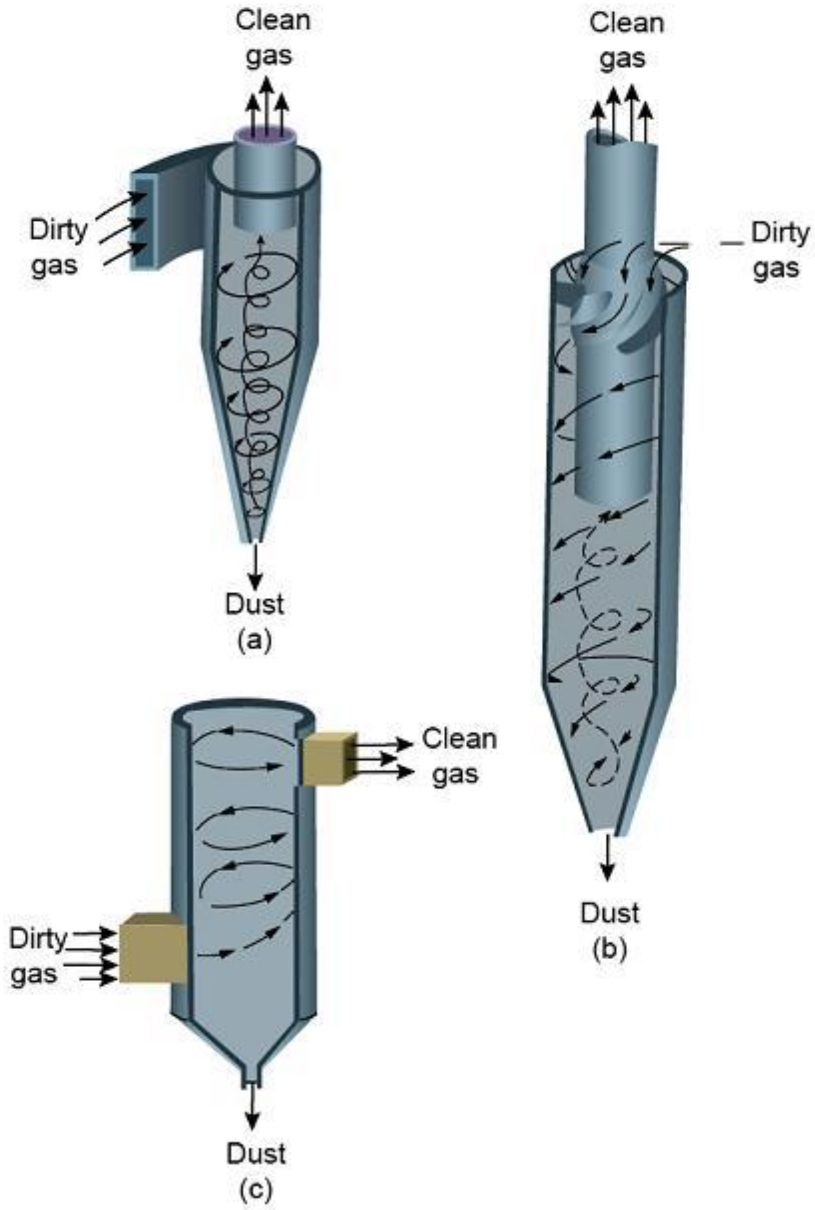
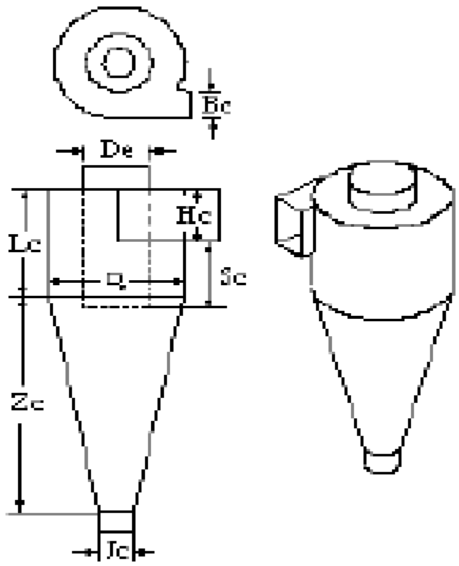


Figure 2

Different Cyclone Model

In the agricultural processing industry, 2D2D (Shepherd and Lapple, 1939) and 1D3D (Parnell and Davis, 1979) cyclone designs are the most commonly used abatement devices for particulate matter control. The D’s in the 2D2D designation refer to the barrel diameter of the cyclone. The numbers preceding the D’s relate to the length of the barrel and cone sections, respectively. A 2D2D cyclone has barrel and cone lengths of two times the barrel diameter, whereas the 1D3D cyclone has a barrel length equal to the barrel diameter and a cone length of three times the barrel diameter. The configurationsof these two cyclone designs are shown in figure 2. Previous research (Wang, 2000) indicated that, compared to other cyclone designs, 1D3D and 2D2D are the most efficient cyclone collectors for fine dust (particle diameters less than 100 µm). Mihalski et al (1993) reported “cycling lint” near the trash exit for the 1D3D and 2D2D cyclone designs when the PM in the inlet air stream contained lint fiber. Mihalski reported a significant increase in the exit PM concentration for these high efficiency cyclone designs and attributed this to small balls of lint fiber “cycling” near the trash exit causing the fine PM that would normally be collected to be diverted to the clean air exit stream. Simpson and Parnell (1995) introduced a new low-pressure cyclone, called the 1D2D cyclone, for the cotton ginning industry to solve the cycling-lint problem. The 1D2D cyclone is a better design for high-lint content trash compared with 1D3D and 2D2D cyclones (Wang et al., 1999). Figure 3 illustrates the configuration of 1D2D cyclone design.



1D2D

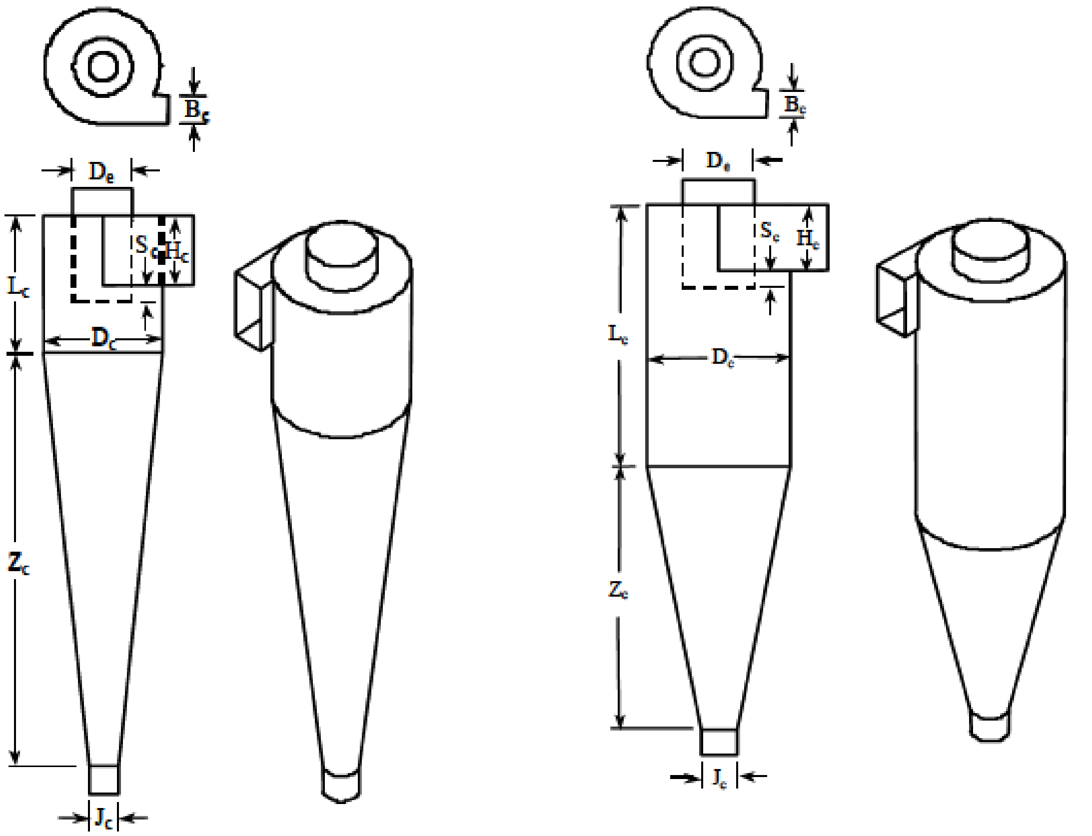
$B_c = D_c/4$ $J_c = D_c/2$

$D_e = D_c/1.6$ $S_c = 5D_c/8$

$H_c = D_c/2$ $L_c = 1 \times D_c$

$Z_c = 2 \times D_c$

Figure 3. 1D2D cyclone configuration.



1D3D

$B_c = D_c/4$ $J_c = D_c/4$

$D_e = D_c/2$ $S_c = D_c/8$

$H_c = D_c/2$ $L_c = 1 \times D_c$

$Z_c = 3 \times D_c$

2D2D

$B_c = D_c/4$ $J_c = D_c/4$

$D_e = D_c/2$ $S_c = D_c/8$

$H_c = D_c/2$ $L_c = 2 \times D_c$

$Z_c = 2 \times D_c$

Figure 2. 1D3D and 2D2D cyclone configurations.

Similarly, cyclone efficiency will decrease with increases in the parameters such as gas viscosity; cyclone body diameter; gas exit diameter; gas inlet duct area; gas density; leakage of air into the dust outlet. The efficiency of a cyclone collector is related to the pressure drop across the collector. This is an indirect measure of the energy required to move the gas through the system. The pressure drop is a function of the inlet velocity and cyclone diameter. Form the above discussion it is clear that small cyclones are more efficient than large cyclones. Small cyclones, however, have a higher pressure drop and are limited with respect to volumetric flow rates. Another option is arrange smaller cyclones in series and/or in parallel to substantially increase efficiency at lower pressure drops. These gains are somewhat compensated, however, by the increased cost and maintenance problems. Also these types of arrangements tend to plug more easily. When common hoppers are used in such arrangements, different flows through cyclones can lead to reentrainment problems. A typical series arrangement is shown in figure In such arrangements large particle can be arrested in the first cyclone and a smaller, more efficient cyclone can collect smaller particles. Due to that it reduces dust loading in the second cyclone and avoids problems of abrasion and plugging. Also, if the first cyclone is plugged, still there will be some collection occurring in the second cyclone. The additional pressure drop produced by the second cyclone adds to the overall pressure drop of the system and higher pressure can be a disadvantage in such series system design. Cyclone efficiency can also be improved if a portion of the flue gas is drawn through the hopper. An additional vane or lower pressure duct can provide this flow. However, it may then become necessary to recirculate or otherwise treat this as purge exhaust to remove uncollected particulate matter.

CHAPTER #2
EQUIPMENT DESIGN
Shepherd and Lapple Model

CLASSICAL CYCLONE DESIGN (CCD)

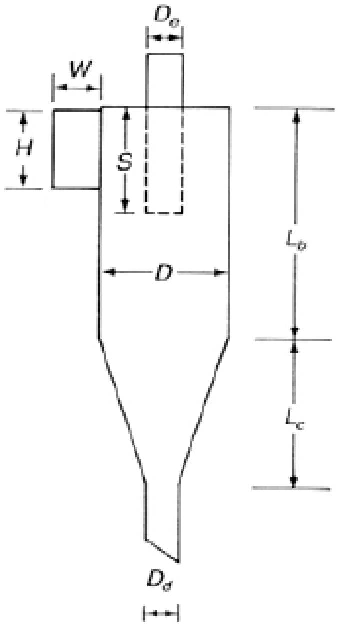
The cyclone design procedure outlined in Cooper and Alley (1994), hereafter referred to as the classical cyclone design (CCD) process, was developed by Lapple in the early 1950s. The CCD process (the Lapple model) is perceived as a standard method and has been considered by some engineers to be acceptable. However, there are several problems associated with this design procedure. First of all, the CCD process does not consider the cyclone inlet velocity in developing cyclone dimensions. It was reported (Parnell, 1996) that there is an “ideal” inlet velocity for the different cyclone designs for optimum cyclone performance. Secondly, the CCD does not predict the correct number of turns for different type cyclones. The overall efficiency predicted by the CCD process In order to use the CCD process, it is assumed that the design engineer will have knowledge of (1) flow conditions, (2) particulate matter (PM) concentrations and particle size distribution (PSD) and (3) the type of cyclone to be designed (high efficiency, conventional, or high throughput). The PSD must be in the form of mass fraction versus aerodynamic equivalent diameter of the PM. The cyclone type will provide all principle dimensions as a function of the cyclone barrel diameter (D). With these given data, the CCD process is as follows:

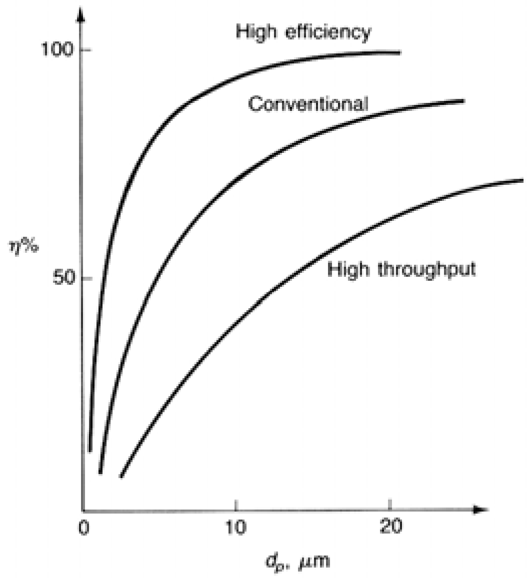
Standard Cyclone Dimensions

Extensive work has been done to determine in what manner dimensions of cyclones affect performance. In some classic work that is still used today, Shepherd and Lapple (1939, 1940) determined “optimal” dimensions for cyclones. Subsequent investigators reported similar work, and the so-called “standard” cyclones were born. All dimensions are related to the body diameter of the cyclone so that the results can be applied generally. The table on the next slide summarizes the dimensions of standard cyclones of the three types mentioned in the previous figure. The side figure illustrates the various dimensions used in the table.

Standard cyclone dimensions

	Cyclone Type					
	High Efficiency		Conventional		High Throughput	
	(1)	(2)	(3)	(4)	(5)	(6)
Body Diameter, D/D	1.0	1.0	1.0	1.0	1.0	1.0
Height of Inlet, H/D	0.5	0.44	0.5	0.5	0.75	0.8
Width of Inlet, W/D	0.2	0.21	0.25	0.25	0.375	0.35
Diameter of Gas Exit, D_e/D	0.5	0.4	0.5	0.5	0.75	0.75
Length of Vortex Finder, S/D	0.5	0.5	0.625	0.6	0.875	0.85
Length of Body, L_b/D	1.5	1.4	2.0	1.75	1.5	1.7
Length of Cone, L_c/D	2.5	2.5	2.0	2.0	2.5	2.0
Diameter of Dust Outlet, D_d/D	0.375	0.4	0.25	0.4	0.375	0.4





The Number of Effective Turns (N_e)

The first step of CCD process is to calculate the number of effective turns. The number of effective turns in a cyclone is the number of revolutions the gas spins while passing through the cyclone outer vortex. A higher number of turns of the air stream result in a higher collection efficiency. The Lapple model for N_e calculation is as follows:

$$N = \frac{1}{H}\left(L_b + \frac{L_c}{2}\right)$$

where

N = number of turns inside the device (no units)

H = height of inlet duct (m or ft)

Lb = length of cyclone body (m or ft)

Lc = length (vertical) of cyclone cone (m or ft).

Based on equation the predicted numbers of turns for 4 cyclone designs were calculated . 1D2D, 2D2D, and 1D3D cyclones are the cyclone designs shown in figures 2 and 3. These three cyclone designs have the same inlet dimensions (H_c and B_c), referred to as the 2D2D inlet. The 1D3D cyclone is a traditional 1D3Dt cyclone design, which has the same design dimensions as 1D3D .

. It has been observed that the Lapple model for Nproduces an excellent estimation of the number of turns for the 2D2D cyclone designs. However, this model cyclones in figure 2 except the inlet dimensions. The 1D3Dt cyclone has an inlet height equal to the barrel diameter (H_c = D_c) and an inlet width of one eighth of the barrel diameter (B_c = D_c/8). Table 1 gives the comparison of the predicted N_e vs. the observed N_e fails to give an accurate estimation of Ne for the cyclone design other than 2D2D design. This observation indicates a limitation for the Lapple model to accurately predict the number of effective turns. The N_e model is valid only for 2D2D cyclone designs, which was originally developed by Shepherd and Lapple (1939).

Table 1. Number of effective turns (N_e)

Cyclone	Lapple	Observed
1D2D	4	N/A
2D2D	6	6
1D3D	5	6
1D3Dt	2.5	6

Cut point Diameter

The second step of the CCD process is the calculation of the cut-point diameter. The cut-point of a cyclone is the aerodynamic equivalent diameter (AED) of the particle collected with 50% efficiency. As the cut-point diameter increases, the collection efficiency decreases.

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

Where, d_p = diameter of the smallest particle that will be collected by the cyclone

μ = gas viscosity (kg/m. s)

W = width of inlet duct (m)

$\mathrm{Ne} = \frac{1}{\mathrm{H}}\left[\mathrm{Lb} + \frac{\mathrm{Lc}}{2}\right] = \text{number of turns}$

Vi = inlet gas velocity (m/s)

$\rho_p = \text{particle density } (\frac{kg}{m^3})$

p_a = Density of fluid

It is worth noting that in this expression, *dp* is the size of the smallest particle that will be collected if it starts at the inside edge of the inlet duct. Thus, in theory, all particles of size *dp* or larger should be collected with 100% efficiency. The preceding equation shows that, in theory, the smallest diameter of particles collected with 100% efficiency is directly related to gas viscosity and inlet duct width, and inversely related to the number of effective turns, inlet gas velocity, and density difference between the particles and the gas.

Gas Residence time

To be collected, particles must strike the wall within the amount of time that the gas travels in the outer vortex. The *gas residence time* in the outer vortex is

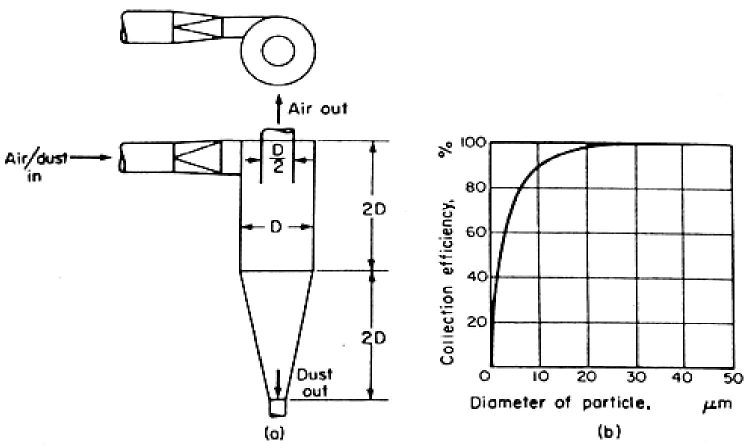
$$\Delta t = \text{path length} / \text{speed} = \pi D N / V_i$$

Δt = time spent by gas during spiraling descent (sec)
D = cyclone body diameter (m or ft)
V_i = gas inlet velocity (m/s or ft/s) = Q/WH
Q = volumetric inflow (m^3/s or ft^3/s)
H = height of inlet (m or ft)
W = width of inlet (m or ft).

The maximum radial distance traveled by any particle is the width of the inlet duct *W*. The centrifugal force quickly accelerates the particle to its terminal velocity in the outward (radial) direction, with the opposing drag force equaling the centrifugal force. The terminal velocity that will just allow a particle initially at distance *W* away from thewall to be collected in time is

$$V_t = W / \Delta t$$

where Vt = particle drift velocity in the radial direction (m/s or ft/s).



The particle drift velocity is a function of particle size.

Assuming Stokes regime flow (drag force = $3\pi\mu d_p V_t$) and spherical particles subjected to a centrifugal force mv^2/r , with m = mass of particle in excess of mass of air displaced, $v = V_i$ of inlet flow, and $r = D/2$, we obtain

$$V_t = \frac{(\rho_p - \rho_a)\, d_p^2\, V_i^2}{9\,\mu\, D}$$

where

V_t = terminal drift transverse velocity (m/s or ft/s)
d_p = diameter of the particle (m or ft)
ρ_p = density of the particle (kg/m^3)
ρ_a = air density (kg/m^3)
μ = air viscosity (kg/m.s).

Fractional Efficiency Curve

The third step of CCD process is to determine the fractional efficiency. Based upon the cut-point, Lapple then developed an empirical model for the prediction of the collection efficiency for any particle size, which is also known as fractional efficiency curve:

$$\eta_j = \frac{1}{1 + \left(d_{pc} / d_{pj}\right)^2}$$

dp*j*= collection efficiency of particles in the *j*th size range (0 < n*j* < 1)

dpj = characteristic diameter of the *j*th particle size range (in microns).

Pressure Drop (ΔP)

Cyclone pressure drop is another major parameter to be considered in the process of designing a cyclone system. Two steps are involved in the Lapple approach to estimation of cyclone pressure drop. The first step in this approach is to calculate the pressure drop in the number of inlet velocity heads (H_v) by equation The second step in this approach is to convert the number of inlet velocity heads to a static pressure drop (ΔP) by equation

There is one problem associated with this approach. “The Lapple pressure drop equation does not consider any vertical dimensions as contributing to pressure drop” (Leith and Mehta, 1973). This is a misleading in that a tall cyclone would have the same pressure drop as a short one as long as cyclone inlets and outlets dimensions and inlet velocities are the same. It has been considered that cyclone efficiency increases with an increase of the vertical dimensions. With the misleading by Lapple pressure drop model.

one could conclude that the cyclone should be as long as possible since it would increase cyclone efficiency at no cost in pressure drop (Leith and Mehta, 1973). A new scientific approach is needed to predict cyclone pressure drop associated with the dimensions of a cyclone.

$$H_v = K \frac{HW}{D_e^2}$$

$$\Delta P = \frac{1}{2} \rho_g V_i^2 H_v$$

Where

Hv = pressure drop, expressed in number of inlet velocity Heads

K = constant that depends on cyclone configurations and

Operating conditions (K = 12 to 18 for a standard tangential-entry cyclone)

.Cyclone Efficiency

Overall separation efficiency

The overall efficiency is usually the most important consideration in industrial process. Let’s us consider the mass balance of solid particle in cyclone. As explained by Hoffmann and Stein in their book on gas cyclones, Mf, Mc and Me are the mass flow rate of the feed, mass flow rate of particle collected and mass flow rate of escaped particles respectively. Then force balance of solid particle over the cyclone can be denoted by eq. 6.

$$M_f = M_c + M_e$$

The overall separation efficiency can be calculated directly as the mass fraction of feed that is successfully collected.

$$\eta = \frac{M_c}{M_f} = 1 - \frac{M_e}{M_f} = \frac{M_c}{M_c + M_e}$$

Factors affecting the cyclone collection efficiency

Various factors are observed to affect the cyclone efficiency. An account of some important factors as presented by Schnell and Brown in Air pollution control technology Handbook is presented here.

Inlet velocity is prime factor effecting the pressure drop and hence the cyclone efficiency. Efficiency increases with increase in velocity as centrifugal force increases but this also increases the pressure drop which is not favorable. Also, decreasing the cyclone diameter increases centrifugal force and hence efficiency. Another factor affecting the cyclone efficiency is gas viscosity. With decrease in viscosity, efficiency increases. This is due to reduction in drag force with reduction in viscosity. Decrease in temperature will increase the gas density. One may be tempted to conclude that this will increase efficiency as viscosity decreases. But increase in temperature also decreases the volumetric flow rate and thereby decreasing efficiency. Another important factor affecting the efficiency is particle loading. With high loading the particles collide with each other more and results into pushing of particle towards wall. This in turn increases efficiency.

Figure 10 shows relationship between efficiency and particle size for high efficiency cyclone which slender and long, high throughput cyclone which are broad and create less pressure drop and a conventional standard cyclone.

Material of Construction

Material used for fabrication of cyclone separator is iron 26 Gauge of thickness. Material is available on market easily .

CHAPTER #3
EQUIPMENT DESIGN CALCULATIONS

Standard Cyclone Dimension (Lapple Dimesion)

Conventional Dimensions

Cyclone Separator Dimesions			
	Dimensions	**Ratio**	**Value (m)**
Diameter od cyclone Body (Barrel)	D	D	0.3048
Length of the Body	Lb	2D	0.6090
Length of the Cone	Lc	2D	0.6090
Height of the Inlet	H	D/2	0.1524
Width of the Inlet	W	D/4	0.0762
Diameter of inlet Pipe	d	$A = \pi r^2$	0.1180
Diameter of Gas Exit	D_e	D/2	0.1524
Diameter of Dust outlet	D_d	D/4	0.0762
Length of vortex Finder	S	0.625	0.1905
Length of S_c	S_c	D/8	0.0381
Total length of cyclone	Lb+Lc	4D	1.2192

Blower Calculations

Volumetric flow rate of Blower=0.058 m3/s

Velocity of Air inlet Duct = Vi= Q/WH

= 0.058/0.0762 x 0.1524

= 5.272 m/s

Dynamic Pressure = 1/2 ρV^2

= 1/2x1.22x2.77

P = 16941 pa

Number of Effective turn

$$N_e = \frac{1}{H}\left[L_b + \frac{Lc}{2}\right]$$

Ne = 1/0.1524[0.609+0.609/2]

Ne = 6

Gas Residence time

$\Delta t = \pi DN/Vi$

$= 3.14 x 0.3048 x 6/5.27$

$= 1.08$ Sec

Particle Drift Velocity

$Vt = W/\Delta t$

$= 0.0762/1.08 = 0.07055$ m/sec

Terminal Drift Transverse Velocity

$Vt = (\rho p - pa)dp\text{^}2Vi\text{^}2/9\mu D$

$= (1602-1.22)x(0.0004)^2 x(5.27)^2/9x0.0000183x0.3048$

$= 226830.16$ m/sec

Cut point Diameter

$d_{pc} = [9\mu W/2\pi NVi(\rho p - pa)]\ ½$

$=[9x0.0000183x0.0762/2x3.14x6x5.27x(1602-1.22)]1/2$

$d_{pc} = 6.28\ \mu m$

Pressure Drop

$\Delta P = \alpha\rho Vi^2/2$

$\alpha = 16\ HW/De^2 = 16x0.1524x0.0762/0.0232 = 9.29$

$\Delta P = 9.29\ x1.22x27.772/2 = 157.38$ Pa

Power Requirement

$W_f = Q\Delta P$

$= 0.058x157.38$

$W = 9.12$ J/sec

Outlet Gas Velocity

$V_o = Q/\pi r_i^2$

$= 0.05806/3.14x0.005806$

$= 3.184$m/sec

Collection Efficiency

$$\eta j = 1/1+(d_{pc}/d_{pj})^2$$

Particle Size Range µm	
0	2
2	4
4	6
6	10
10	18
18	30
30	50
50	100

Average Size Range dj µm
1
2
3
5
9
15
25
50

$\eta j = 1/1+(d_{pc}/d_{pj})^2$

$= 1/1+(6.28\ \mu m/1\ \mu m)^2$

$= 0.02$

$\eta j = 1/1+(d_{pc}/d_{pj})^2$

$= 1/1+(6.28\ \mu m/2\ \mu m)^2$

$= 0.09$

$\eta j = 1/1+(d_{pc}/d_{pj})^2$

$= 1/1+(6.28\ \mu m/3\mu m)^2$

$= 0.1$

$\eta j = 1/1+(d_{pc}/d_{pj})^2$

$= 1/1+(6.28\ \mu m/5\mu m)^2$

$= 0.38$

$\eta j = 1/1+(d_{pc}/d_{pj})^2$

$= 1/1+(6.28\ \mu m/9\mu m)^2$

$= 0.67$

$\eta j = 1/1+(d_{pc}/d_{pj})^2$

$= 1/1+(6.28\ \mu m/15\mu m)^2$

$= 0.850$

$\eta j = 1/1+(d_{pc}/d_{pj})^2$

$= 1/1+(6.28\ \mu m/25\mu m)^2$

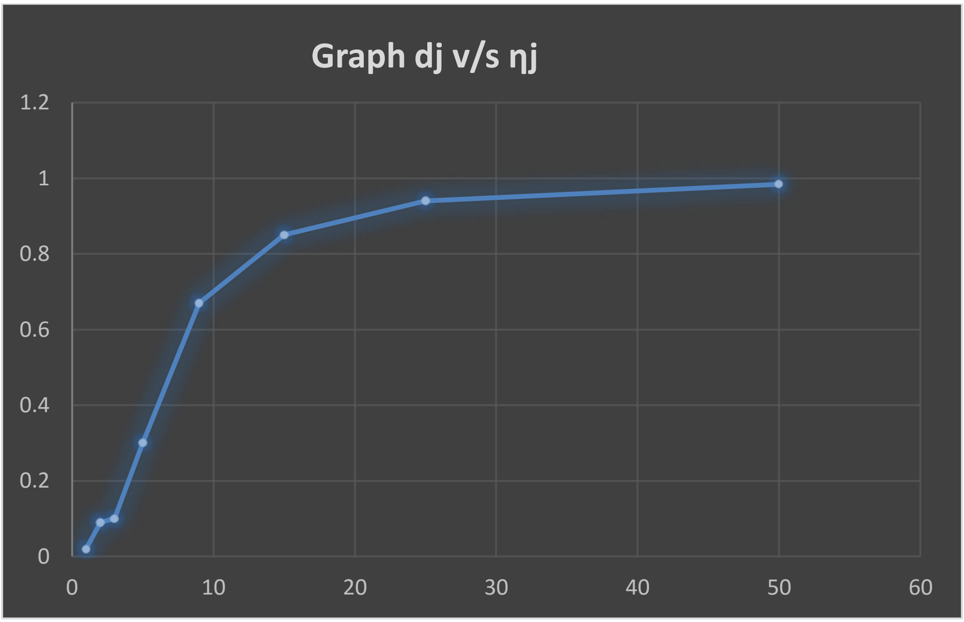
$= 0.940$

$\eta j = 1/1+(d_{pc}/d_{pj})^2$

$= 1/1+(6.28\ \mu m/50\mu m)^2$

$= 0.984$

dj	ηj
1	0.02
2	0.09
3	0.1
5	0.3
9	0.67
15	0.850
25	0.940
50	0.984



Cyclone Efficiency

Overall separation efficiency

$$M_f = M_c + M_e$$

$$\eta = \frac{M_c}{M_f} = 1 - \frac{M_e}{M_f} = \frac{M_c}{M_c + M_e}$$

Mf=92+10

η = 92/100=1-8/100=92/92+80

=0.92x100

=92%

Cost Estimation

Cost of cyclone Body=150$

Cost of Stand = 10 $

Cost of Labor = 50 $

Cost of Blower = 50 $

Cost of construction expenses=50$

Cost of Maintenance = 10$

Testing Cost = 5$

Total Cost = 325$=32500 Rs

CHAPTER #4
SAFETY PRECATUONS

Cyclone Safety Precautions

1.The unit must be lifted by a means with sufficient lifting capacity.

2. When installed, the unit must be separately grounded.

3. Do not manually override or electrically bypass any protective device.

4. Special care must be exercised to insure all such personnel are fully informed of the potential hazards and follow rules – with special emphasis on explosion proof electrical tools and cutting or welding in unsafe environments.

5. Keep the workplace cleaned up and free of dirt and dust at all times. Do not attempt to work on slippery or unsafe ladders or work platforms when maintenance or repair work is being performed on the Cyclone.

6. Do not exceed maximum load ratings when installing or servicing the Cyclone.

7. Never allow any kind of metal or other foreign objects to enter a Cyclone while in operation, unless the system is specifically designed as a wire or metal reclaim system.

8. The Cyclone has no moving parts. Therefore, access into the machine is not restricted. However, in some installations, there is a machine discharging material from the Cyclone. The accessory machinery feeding and discharging the material may be dangerous to personnel working on or around the Cyclone.

9. Operate safely at all times. Use personal protective equipment when and where appropriate, such as hard hats, helmets, gloves, earplugs, and eye protection devices. Keep personal protective equipment in good repair and convenient to the operator.

10. When carrying out cleaning, service or maintenance activities a dust mask should be worn.

11. The operator of the cyclone must ensure that adequate lightning conditions are provided at the set-up location.

12. It is ultimately the operator’s responsibility to implement the above listed precautions and insure proper equipment use, maintenance and lubrication. Keep these instructions and list of warnings with your machine at all times.

13.Keep away all metallic instrument for secure the outer surface of cyclone Body.

14.While working on the Cyclone it is mandatory not touch the other part of Blower except Speed variable .

15.Do not touch the any electric part of the instrument .

16. Keep a safe Distance from Cyclone.

17. Don’t try to move the instrument while its in working position .

18. We should not add any liquid in the cyclone otherwise liquid may harm the surface of material as well it may cause corrosion and it will produce Rust in it

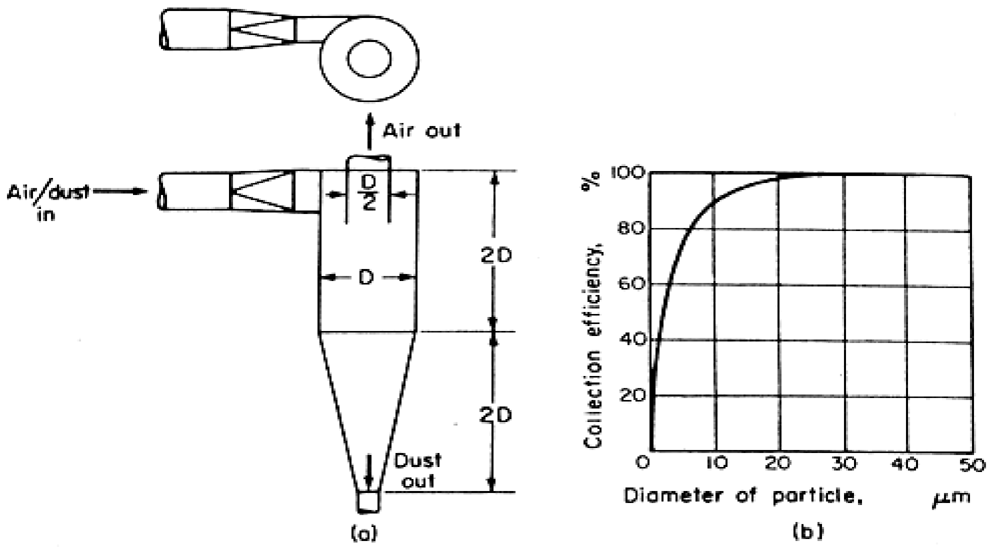
19.We should not add any thick liquid it because it may be form of sludge and damage the cyclone .

20. Keep away cyclone from water and any other liquid.

21. Cyclones are designed and built in a manner such that all wall thicknesses
are sufficient to the point that danger due to wear and tear can be excluded. However, elbows, fans and separators in the system are subject to the normal wear expected in any system handling comparable stocks, so equipment must be examined regularly for signs of wear and damage.

Conclusion

A prominent problem in calculating the efficiency of cyclone is the effect of flow characters in cyclone. In big cyclones the flow is turbulent and friction factors assumed give good results. This is not true for small cyclones. The flow in small cyclones can be laminar or even transitional. In such case the operational conditions, like velocity, temperature, pressure, viscosity and cyclone diameter, may be of significant importance and their effect changes from cyclone to cyclone. In laminar flow, operating parameters influence cyclone efficiency more than turbulent case. This makes the prediction of efficiency and pressure drop very difficult especially in small cyclone. Most of the models depend on empirical or semi-empirical equations. The models calculate efficiency and predict the cutoff size which corresponds to 50% efficiency. According to Wang et al. cyclone performance is function of geometry and operating parameters of cyclone, as well as particle size distribution of the entrained particulate matter. Several models have been proposed to predict the efficiency of cyclone. It is widely agreed amongst the scientists that cyclone performance is definitely affected by operating parameters and hence they should be included in the modeling. Many theories account for density, gas velocity, viscosity and particle diameter. As far as effect of geometry is considered there is difference in approach for various scientists. Some consider all the geometric parameters where as some consider only few important parameters like inlet and outlet diameter and height in their models. As mentioned, most of the theories consider cut size “d50”, which corresponds to diameter of particle where 50% of particles smaller and 50% of particles greater that that size will be collected. Two most common approaches for calculating efficiency are Force Balance Theory [Lapple] which assumes that terminal velocity is achieved when drag fore and centrifugal force equal each other and the Static Particle Approach [Barth] which considers simple force balance where forces acting on particle are balanced. Various other complicated theories have been proposed but the essentially have their base in one of the two theories.



CHAPTER #4
APPLICATIONS

Cyclone separator Applications

Gas cyclone separator is widely used in industries to separate dust from gas or for product recovery because of its geometrical simplicity, relative economy in power and flexibility.

Major applications include:

- oil refineries to separate oils and gases
- cement industry
- vacuum cleaners

CHEMICAL AND PETROCHEMICAL PROCESSES

Dust collector for dryer and cooler processes hot gas cleaning and product recovery separation in spray dryers cyclone dust collector for dust recovery of 5 microns [and below] recovery of particulate in maleic anhydride process reactors ultra fine gas cleaning of fluid catalytic cracking (FCCU) regenerator gases

INDUSTRIAL, METALLURGICAL AND POWER GENERATION

Cyclone dust collector for metallurgical process mills, smelters and kilns fine particulate recovery cyclone in fluidised bed combustors hot gas cleaning in coal gasifier and activated carbon plants particulate recovery in abrasive and hot gas streams cyclone separator for npk & lan fertilizer dust in coolers & dryers dust collector cyclone for reducing emissions in fluidised bed boilers zinc dust recovery and extraction in galvanizing plants

FOOD & PHARMACEUTICAL

powder recovery cyclone filter in pharmaceutical sterile processes cyclone separator for product recovery in milk powder, coffee and cereal plants

Cement Industry

In cement manufacturing industries, large-sized cyclone separators are used as main process equipments in significant numbers for handling high volumetric flow rates of dust-laden gases. The cyclone is a simple mechanical device commonly used in the grinding circuits to remove relatively large particles from gas streams. Cyclones are often used as precleaners to remove more than 80% of the particles greater than 20µm in diameter. Smaller particles that escape the cyclones can then be collected by more efficient control equipment like bag filters and electro precipitators Cyclones are relatively inexpensive since they have no moving parts and they are easy to operate

The most common type of cyclone is known as reverse flow cyclone separator

Others:

cyclones are used in sawmills to remove sawdust from extracted air

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