CFD analysis for investigation of design parameter of cyclone separator

[1]Chine Shweta C., [2]Dr. J.H.Bhangale, [3]Prof. K.R. Sonawne
[1]PG Student, ME Heat power, [2]Head of Department, [3]Ass. Professor
Matoshree College of Engineering and Reaserch Center Nashik

Abstract - **The study aimed toward improvement of performance of gas solid separator operating at pressure at 1 Mpa and at high flux density in the cyclone body. Here we are going to study various parameter affective the cyclone process and calculating various changes because of it. The receiver consisting of cone shaped converging channel and an externally fined circular pipe is found in the middle of cylindrical cyclone body. A fine and tube flow conditioner is mounted upstream of converging channel inlet. Experimental result show that optimal cyclone design velocity which are for 1D3D cyclone should be determine based on standard air density. It is important to consider the air density effect on cyclone performance in design of cyclone abatment system. By using this system pressure drop was tested against the measured data at different inlet velocity. This result show cyclone pressure drop varies with inlet velocity but not with diameter. Simulation results are going to be involved in estimation of the main performance characteristics of the separator. Experimental research on a 1;2 separator model allowed estimation of pressure drop.**

keywords - **cyclone separator, CFD, design, pressure drop, velocity.**

I. Introduction

Cyclones are widely used for removing industrial dust from air or process gases. They are the most frequently encountered type of gas-solid separator in industry. The primary advantages of cyclones are economy, simplicity in construction and ability to operate at high temperature and pressures. The principle of cyclone separation is simple, where the gas–dust mixture enters from the inlet section. Then, the cylindrical body induces a spinning (swirl), vertical flow pattern to the gas--dust mixture. Centrifugal force separates the dust from gas stream, the dust travels to the walls of the cylinder and down the conical section to the dust outlet and the gas exits through the vortex finder from the top. In order to describe the cyclone performance (pressure drop and collection efficiency) experimental Investigation, and computational fluid dynamics (CFD) approach are used. The cyclone performance is affected by several parameters, inlet height *a,* the inlet width *b,* the vortex finder diameter *Dx,* the vortex finder length *s*, the dust outlet diameter *Bc,* the cylindrical part height *h,* the total cyclone height *Ht* . [7]

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 configurations of 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 cyclone.[3]

In this paper , after the simulation result of 1D2D, 1D3D, and 2D2D cyclone we consider only 1D3D cyclone for experimentation on the basis of pressure result of cyclone separator. Whereas the 1D3D cyclone has a barrel length equal to the barrel diameter and a cone length of three times the barrel diameter. The configuration of 1D3D cyclone shows in figure 1.

II. Literature review

In this cyclone study Kashan Bashir study the new theoretical method for computing travel distance, numbers of turns, and cyclone pressure drop have been developed. The flow pattern and cyclone dimension determine the travel distances. The new theoretical analysis of cyclone pressure drop was tested against measured data at different inlet velocities and gave excellent agreement. The result show that cyclone pressure drop varies with the inlet velocity but not with cyclone diameter. Cyclone cut-point for different dust were traced were traced from measured cyclone overall collection efficiency and the theoretical model for calculating cyclone overall efficiencies. The cut-point correction model 2D2D cyclone were developed through regressions fit from traced and theoretical cut-point diameter. Experimental result show that optimal cyclone design velocity, which are for 2D2D cyclone should be determined based on standard air density. It is very important to consider the air density effect on cyclone performance in the design of cyclone abatement systems. The tangential inlet generate the swirling motion of the gas stram, which force particles toward the outer wall where the spiral in the downward direction. Eventually the particle are collected in the dustbin located t the bottom of the conical section of the cyclone body. The cleaned gas leaves through the exit pipe at the top.[3]

"Cyclone Separator for Gas-Liquid Mixture with High flux Density". In this paper Nikolay Mikheev, Ilya Saushin studies the Cyclone separator for gas-liquid mixture with high flux density. The study is aimed at improvement of efficiency of a gas-liquid separator operating at the pressure of 2.5 MPa and high flux density in the cyclone body. The construction of the separator provides the reduced dynamic head of gas in the zones with increased liquid phase concentration and prevents the entrainment of separated liquid to the outlet receiver. The receiver consisting of a conical converging channel and an externally finned circular pipe is located in the middle of cylindrical cyclone body. A fin-and-tube flow conditioner is mounted upstream of the converging channel inlet. Detailed flow structure in the separator has been obtained from numerical study based on Reynolds-averaged Navier–Stokes equations with anisotropic Reynolds stress turbulence model. Result show that the construction of a gas-liquid high-pressure cyclone separator provides high separation efficiency at the K-value that was at least one order higher than the limitations recommended in literature. The effect is achieved due to very effective damping of the high-velocity head in outlet duct of separator. It is established from numerical simulation of flow in the separator that there are no conditions for drop entrainment from the liquid film surface at the maximum flow rate of the mixture, and the near-wall dynamic head of upward flows does not exceed 30 Pa. Such values of the dynamic head prevent conditions that trigger upward film flows from the[1]

Design of Cyclone and Study of Performance parameter" in this paper Mahesh R. Jadhav studies Design of cyclone and study of performance parameter. This paper present the development of cyclone based on CFD along with experimental trials. This study is based on the performance of flour mill cyclone for different flow rates. In the present investigation the characteristics of flour mill cyclone are studied for various flow rates (inlet velocities) and its effect on performance parameters like pressure drop and efficiency are Studied Therefore in this paper two cyclones are evaluated with same dimensions only difference in their inlet geometry. One cyclone model is having single tangential inlet with same size inlet and outlet pipe and another is having two symmetrical tangential inlets and one outlet. Simulation of flow will be done with the help of CFD software and verification will be done with the help of experimental work. Results showed that these new designs can improve the cyclone performance parameters significantly and very interesting details were found on cyclone fluid dynamics properties. Experimental trial is completed successfully also CFD simulation is also done. A small scale cyclone designed for flour mill is evaluated and following results are obtained. The test was performed on both cyclones at different velocities. Graph shows the comparison of results of single and symmetrical inlet cyclone.[6]

III. Design of cyclone

The cyclone geometry is constructed by using reffrences of Classical cyclone design method The CCD process (the Lapple model) is perceived as a standard method and has been considered by some engineers to be acceptable. First of all, the CCD process does not consider the cyclone inlet velocity in developing cyclone dimensions. By considering this geometric ratio's the modelling of the cyclone done in catia V5.

Consider, diameter Dc cyclone body diameter = 200mm For 1D3D type of Cyclone Separator,
Bc = cyclone inlet width =Dc/4 = 200/4 = 50mm
De = cyclone gas outlet diameter= Dc/2 = 200/2 = 100mm
Hc = cyclone inlet height =Dc/2 = 200/2 = 100mm
Jc =cyclone dust outlet diameter Dc/4 = 200/4 = 50mm
Sc = length of gas outlet duct =Dc/8 = 200/8 = 25mm
Lc = cyclone cylinder height = 1*Dc = 1*200 = 200mm
Zc = height of cyclone cone 3*Dc = 3*200 = 600mm

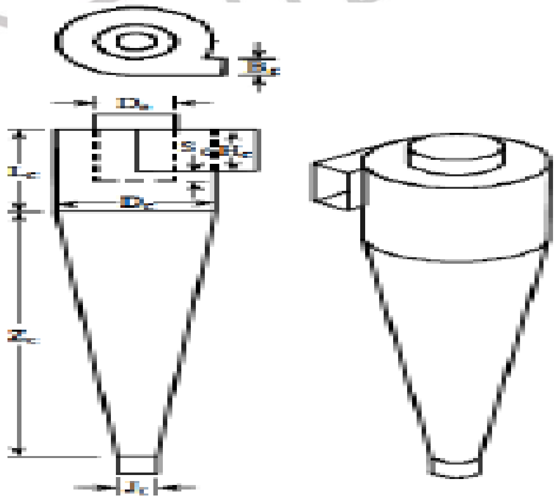


Fig.1 1D3D cyclone configuration

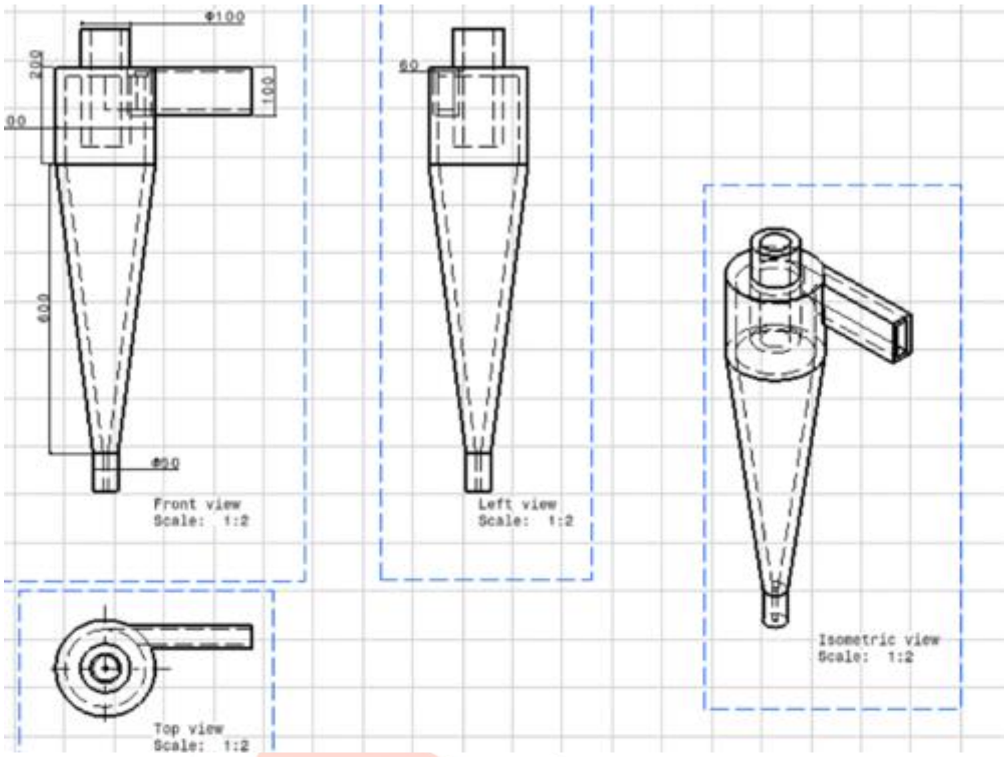


Fig.2 Drafting of 1D3D cyclone Separator

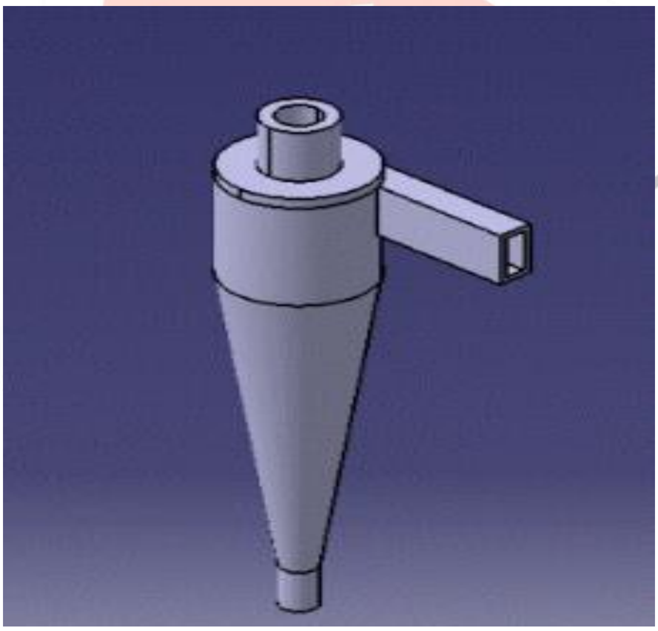


Fig.3 3D Model of 1D3D cyclone separator

IV. CFD ANALYSIS

Import the cyclone design from the solid works. Open the design modeler. Click on generate the imported geometry appears. Select the part body in the tree outline .select the body click on the screen. Change the solid body into the fluid body. Close the design modular and save the project.

Open mesh.>create named sections

1. Select the inlet face.name it as velocity inlet
2. Select the outlet face and name it as pressure outlet.
3. Select the rest of the faces and name them as wall.

Select mesh in tree outline. In mesh details default conditions are set to be CFD and FLUENT solver as shown in the fig and fig . Give high smoothing condition and fine relevance. And change the transition slow to fast to reduce the no. of elements. Select mesh and click generate mesh to obtain mesh.

Mesh

Open mesh.>create named sections

1. Select the inlet face.name it as velocity inlet
2. Select the outlet face and name it as pressure outlet.
3. Select the rest of the faces and name them as wall.

Select mesh in tree outline. In mesh details default conditions are set to be CFD and FLUENT solver as shown in the fig and fig . Give high smoothing condition and fine relevance. And change the transition slow to fast to reduce the no. of elements. Select mesh and click generate mesh to obtain mesh.

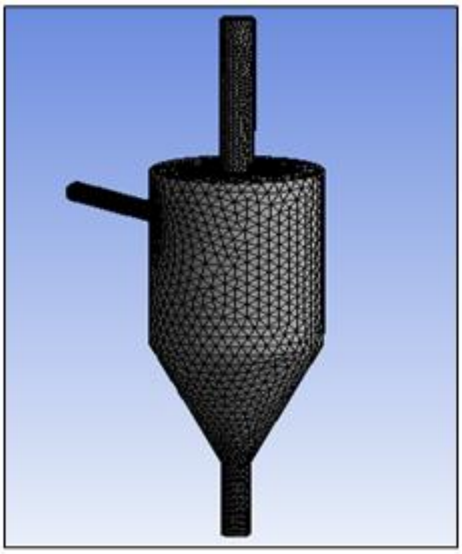


Fig.4 Meshing of Cyclone Separator

Input and settings

Double click on the fluent set up to set the

Simulation conditions. The software automatically recognizes the 3d dimension. The display mesh after reading, embed graphics windows and work bench color scheme must be enabled. Enable the double precision and serial processing options. Then click ok to open the fluent.

STEP 1: General > check mesh (To verify the mesh is correct or not) Enable pressure based type)

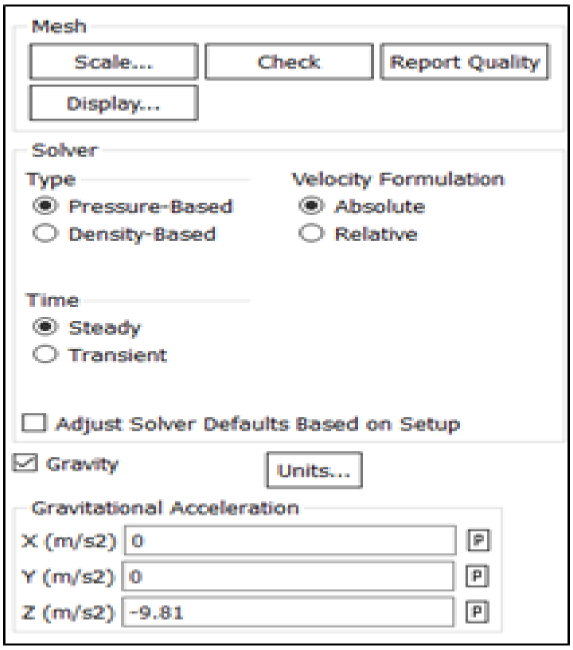


Fig.5 Input settings for meshing

Step 2 – DPM is set to on and create new injection for the cyclones. The particles will enter from the inlet surface with 10m/s.

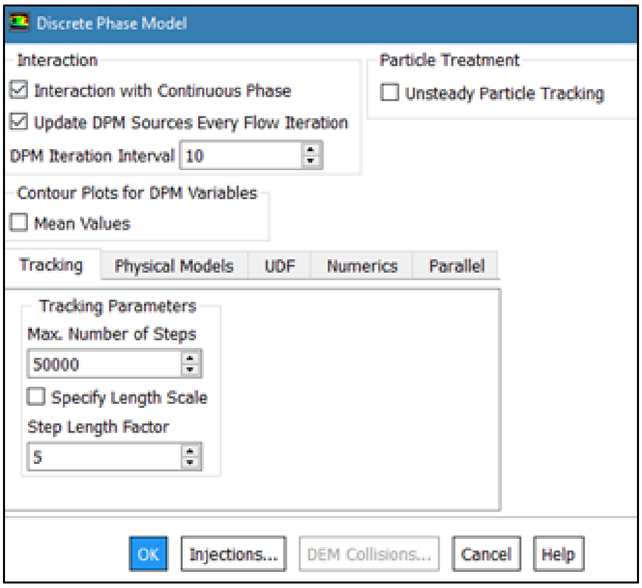


Fig.6 Input settings for DPM

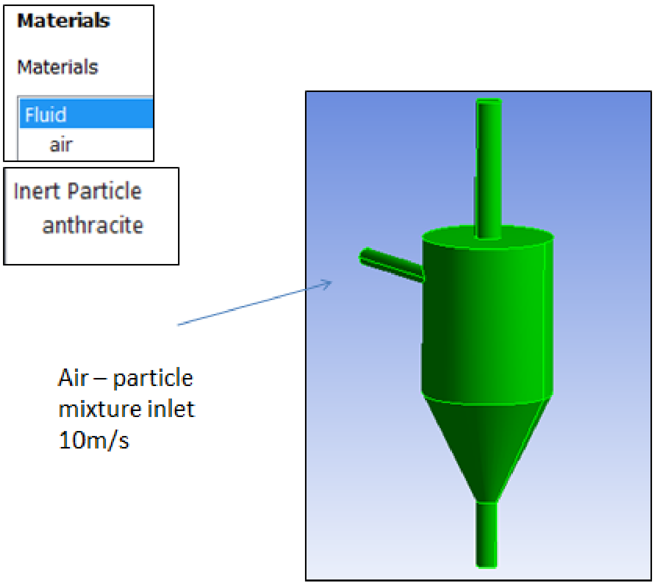


Fig.7 Discrete phase model of cyclone separator

V. Experimental Testing

The experimental set up of Cyclone separator is made as shown in the fig.7 there are total 3 Types of cyclone separator out of which 1D3D type of cyclone separator is made. Firstly, the blower is started and flow rate is measured with the help Anemometer. After that the flow rate at the upper end and lower end is measured with the help of Anemometer. The velocity at the down ward end is 1.1m/sec & velocity at upward is 2.4 m/sec. after this experimentation pressure drop is calculate by using velocity reading.

Fig.8 1D3D Cyclone separator

Cyclone pressure drop is one of the major parameter to be considered in the process of designing a cyclone system. Two steps are involved in the lapple approach to estimate of cyclone pressure drop. The first step in this approach to calculate the pressure drop in the number of inlet velocity heads (Hv) by equation. The second step in this approach is to convert the number of inlet velocity heads to static pressure drop (ΔP) by equation. [1]
Velocity at the down ward = 1.1m/sec
Velocity at the upward = 2.4m/sec
Height at the inlet = 100mm
Width = 50mm
Diameter = De = 100mm
Density of Air = ρ = 1.225 kg/m3

Pressure Drop = Hv = $\frac{K*H*W}{De2}$
Where, K = constant between 12 to 18 = 15

By Putting all the values in above equation, Hv = $\frac{15*0.1*0.05}{0.12}$

Hv = 7.5

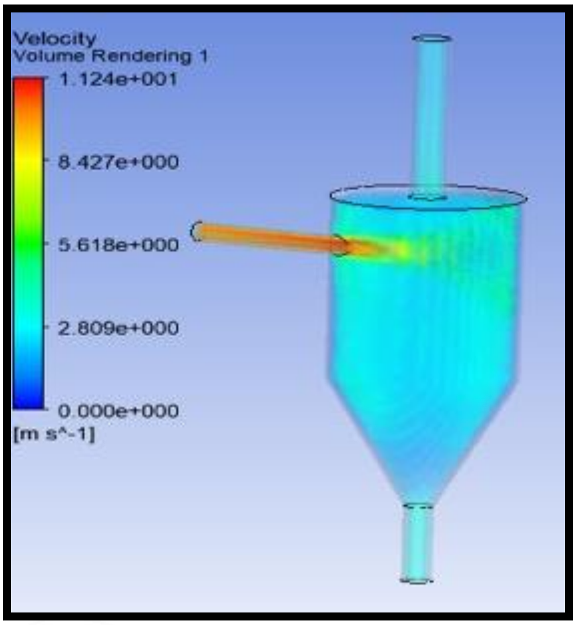
Pressure at the downward = P = $\frac{\rho*v2*Hv}{2}$ = 5.56 Pa

Pressure at the upward = P = $\frac{\rho*v2*Hv}{2}$ = 26.46 Pa

VI. RESULT AND DISCUSSION

Velocity Counter

As we can see from the fig. the velocity magnitude is increase from center to the wall of the cyclone geometry. But velocity is decrease from top to bottom of the cyclone. As we know that the tangential velocity of of the gas flow which relates to the pressure drop must be increased cyclone efficiency.



Pressure Counter

Pressure contours are plotted and it is observing that non-Dimensional pressures are in the range of -6.413 to 3.116 respectively for cyclone. Pressure is increasing from center to wall surface but along the vertical section pressure is not uniform, it is decreasing at the bottom of the cone section of the cyclone as in case of cyclone separator

VII. CONCLUSION

After studying the exiting literature and performing analysis and experimental testing following conclusion is drawn.

1. From the Experimental results & from the analysis results it is clear that the pressure values are nearly equal. Pressure at the downward = 5.56Pa from the testing & from the analysis it is 6.41 Pa. The pressure at the upward = 26.46Pa from the testing & from the analysis it is 31.16Pa. So, the validation is done.
2. In operating condition and cyclone types FLUENT CFD was found to be much closer to the experimental measurement.

VIII. ACKNOWLEDGMENT

First and foremost I am very much thankful to my respected Co-guide Prof.K.R.Sownawne and Guide Dr.J.H.Bhangale for their leading guidance in this topic. Also they have been persistent source of inspiration to me. I would like to express my sincere thanks and appreciation to M.E. coordinator Prof V.S.Daund, again H.O.D. of Mechanical Engineering Department Dr. J. H. Bhangale , Principal of M.C.O.E. & R.C.Dr. G.K. Kharate for their valuable support

REFERENCES

[1] Nikole Mikheev, Ilyan Saushin " Cyclone Separator for gas-liquid mixture with high flux density" Power Tech. Vol. 8, No. 40 , Aug. 2018
[2] Abhijit Gaikwad and Dr. Shivarudraiah " CFD Analysis of Symmetrical Tangential inlet Cyclone Separator" IRJET Vol. 04 ,No- 08 , Aug. 2017
[3] Kashan Bashir "Designe and Fabrication of cyclone Separetor" Reserchgate ,August 2015.
[4] Khaire Elsayed, Cheris Lacor , The Effect of Cyclone Dimension on the flow Pattern and Performance , Applied mathematics modlling 35 ,2011 .1952- 1968
[5] Raj Reddy Dere ,A. Divya Sree ,S. Rajiv Rav and G. Mahesh Babu "Design and Analysis of Cyclone Separator" IJERT Vol. 3, No 08, Aug. 2014
[6] Mahesh R. Jadhav , "Design of Cyclone and its Performance Parameter" IJMERR, Vol. 3 No.04 Oct. 2014
[7] Kh. Elsayed and C. Lacer " Invistigation of Geometriacl Parameter and Flow Parameter Effect on Performance and Flow Fild of Cyclone Separetor Using Mathematical Model and Eddy Simulation" 13thconfference of aerosapce Science and Aviation Technology, 13, May-26-28, 2009J.
[8] Kaspar, P., K.D. Mihalski and C.B. Parnell, Jr. 1993. Evaluation and development of cyclone design theory. In *Proc. 1993 Beltwide Cotton Production Conferences*. New Orleans, La. National Cotton Council
[9] Lapple, C. E. 1951. Processes use many collector types. *Chemical Engineering* 58 (5):144-151