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A New Theoretical Approach for Predicting Number of Turns and Cyclone Pressure Drop

by

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Abstract. *A new theoretical method for computing travel distance, number of turns and cyclone pressure drop has been developed and presented in this paper. The flow pattern and cyclone dimensions determine the travel distance in a cyclone. The effective number of turns was calculated based on the travel distance. Cyclone pressure drop is assumed to be composed of five pressure loss components. The frictional pressure loss is the primary pressure loss in a cyclone. This new theoretical analyses of cyclone pressure drop for 1D2D, 2D2D, and 1D3D cyclones were tested against measured data at different inlet velocities and gave excellent agreement. The results show that cyclone pressure drop varies with the inlet velocities, but not with cyclone diameter.*

Keywords. Cyclone, number of turns, pressure drop

Introduction

Cyclone separators provide a method of removing particulate matter from air streams at low cost and low maintenance. The pressure drop of cyclones is an important parameter to be considered in the design of a cyclone abatement system since it relates directly to the energy consumption and operating cost.

Many models have been developed to determine the cyclone pressure drop. Shepherd and Lapple (1939) determined that a cyclone pressure drop was composed of the following components:

(1) Loss due to expansion of gas when it enters the cyclone chamber.
(2) Loss as kinetic energy of rotation in the cyclone chamber.
(3) Loss due to wall friction in the cyclone chamber.
(4) Any additional friction losses in the exit duct, resulting from the swirling flow above and beyond those incurred by straight flow.
(5) Any regain of the rotational kinetic energy as pressure energy.

Analysis of the cyclone pressure drop and separation performance requires knowledge of the characteristics of the internal flow. This knowledge of the flow pattern in a cyclone is useful in coordinating theoretical considerations and actual results for the prediction of both pressure drop and dust collection efficiency. Many investigations have been made to determine the flow pattern (velocity profile) in a cyclone rotational field. Shepherd and Lapple (1939) reported that the primary flow pattern consisted of an outer spiral moving downward from the cyclone inlet and an inner spiral of smaller radius moving upward into exit pipe. They are known as outer vortex and inner vortex. The transfer of fluid from outer vortex to inner vortex apparently began below the bottom of the exit tube and continued down into the cone to a point near the dust outlet at the bottom of the cyclone. They concluded from streamer and Pitot tube determinations that the radius marking the outer limit of the inner vortex and the inner limit of the outer vortex was roughly equal to the exit duct radius. Ter Linden (1949) measured the details of the flow field in a 14 in cyclone. He reported that the interface of inner vortex and outer vortex occurred as a radius somewhat less than that of the exit duct in the cylindrical section of the cyclone and approached the center line in the conical section.

The velocity profile in a cyclone can be characterized by three velocity components (tangential, axial and radial). The tangential velocity is the dominant velocity component. It also determines the centrifugal force applied to the air stream. Research results of Shepherd, Lapple (1939), Ter Linden (1949) and Ma (1983) indicated that tangential velocity in the annular section (at the same cross-sectional area) of the cyclone could be determined by the equation (1).

$$V_t * r^n = C_1 \quad \text{……………………………………(1)}$$

where:

V_t = tangential velocity,
r = air stream rotational radius,

n = 0.5 (in outer spiral) (Shepherd and Lapple, 1939), and
C_1 = a numerical constant.

As the outer spiral moving downward, the tangential velocity is inversely proportional to the radius (First, 1950).

$$V_t = \frac{C_2}{r} \quad \text{..(2)}$$

where:

V_t = tangential velocity,
r = radius, and
C_2 = a numerical constant.

A New Theoretical Method

One hypothesis is that the air stream travel distance in the outer vortex and the cyclone dimensions determine the number of turns. The travel distance can be calculated mathematically by the velocity and traveling time. A cyclone consists of a cylinder upper body (barrel) with a conical lower section (cone, Figure1). In the barrel, there are two velocity components: tangential velocity (V_t) and axial velocity (V_z). Airflow rate is constant in the barrel. Then, the tangential velocity and the axial velocity can be considered as constant too. In the cone, the air stream is squeezed. As a result, air leaks from outer vortex to inner vortex through their interface. It is assumed that the air leak (airflow rate) follows a linear model from the top of the cone part to the intersection of vortexes interface and the cone walls. There are three velocity components in the cone part: tangential velocity (V_t), axial velocity (V_z) and radial velocity (V_r).

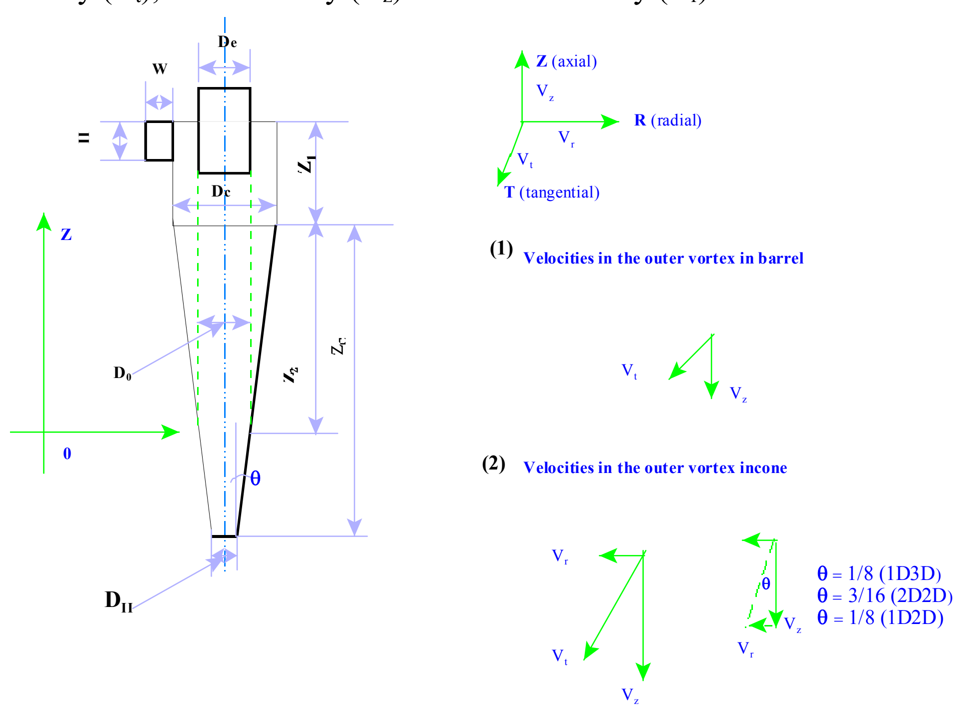

Figure 1. Cyclone dimensions and velocity vectors

Travel distance (L) and number of turn (N):

In the barrel (L_1 & N_1):

As it is shown in the Figure 1, there are two velocity components in the barrel. They are the tangential velocity (V_{t1}) and axial velocity (V_{z1}). It is assumed that tangential velocity is equal to the inlet velocity for the tangential inlet design ($V_{t1} = V_{in}$). The axial velocity can be calculated based on the constant airflow rate.

$$V_{z1}\left(\frac{\pi * D_c^2}{4} - \frac{\pi * D_e^2}{4}\right) = V_{in} * \frac{D_c^2}{8} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

where:

V_{z1} = axial velocity in the barrel,
V_{in} = inlet velocity,
D_c = cyclone diameter, and
D_e = air exit tube diameter.

Then,

$$V_{z1} = \frac{2V_{in}}{3\pi} \text{ (for 1D3D and 2D2D design)}$$

$$V_{z1} = \frac{8V_{in}}{13\pi} \text{ (for 1D2D design)}$$

The total average velocity and travel distance in the barrel can be obtained by the following equations.

$$V_1 = \sqrt{V_{t1}^2 + V_{z1}^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(4)$$

$$L_1 = \int_0^{t_1} V_1 * dt = \int_0^{z_1} V_1 * \frac{dz}{V_{z1}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(5)$$

where:

L_1 = travel distance in the barrel,
V_1 = total average velocity in the barrel at time t,
Z_1 = length of the barrel, and
dz = axial component of travel distance during the time dt.

Then,

$$L_1 = 1.53 * \pi * Z_1 \text{ (for 1D3D and 2D2D design)}$$

$$L_1 = 1.656 * \pi * Z_1 \text{ (for 1D2D design)}$$

The following equation can be used to calculate number of turns in the barrel.

$$N_1 = \frac{L_1}{\pi * D_c} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(6)$$

where:

N_1 = number of turns in the barrel,
L_1 = travel distance in the barrel, and
D_c = cyclone diameter.

Then,

$N_1 = 1.53$ (for 1D3D)
$N_1 = 3.06$ (for 2D2D)
$N_1 = 1.66$ (for 1D2D)

In the cone (L_2 & N_2):

In the cone, the flow pattern becomes more complex. There are three velocity components involved in the total velocity calculation. They are tangential velocity (V_{t2}), axial velocity (V_{z2}) and radial velocity (V_{r2}). The tangential velocity in the cone can be determined by the equation (2). In the developing the equations for the velocity components, the following assumptions are made:

(1) The diameter (D_o) of the interface of the inner vortex and outer vortex is equal to the exit tube diameter (De) (see Figure 1).
(2) The airflow leaks from outer vortex to inner vortex along the travel path in the cone because the air stream is squeezed.
(3) The air leaking follows a linear model from the top of the cone to the intersection of the interface and the cone walls. On the top of the cone, airflow rate in the outer vortex is equal to the total inlet airflow rate. At the intersection area, all the air has leaked to the inner vortex and the airflow rate is equal to zero. At the any other cross-section between top and intersection (in Z_2 range), the outer vortex airflow rate can be quantified by the equation (7).

$$Q_z = Q_{in} * \frac{Z}{Z_2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(7)$$

where:

Q_z = airflow rate at Z cross-section (at time t),
Q_{in} = inlet air-flow rate,

$$(Q_{in} = V_{in} * \frac{D_c^2}{8})$$

Z = axial component of air stream travel distance at time t, and
Z_2 = axial length of total travel distance in the cone.

$Z_2 = 2D_c$ (for 1D3D)
$Z_2 = 1.33D_c$ (for 2D2D)
$Z_2 = 1.5D_c$ (for 1D2D)

Based on the assumptions described above, the three velocity components in the cone can be determined by the equations (8, 9 and 10).

$$V_{t2} = \frac{C}{r} = \frac{R * V_{in}}{r} = \frac{R * V_{in}}{r_o + z * tg\theta} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots(8)$$

where:

V_{t2} = tangential velocity at time t in the cone,

V_{in} = inlet velocity,
R = exit tube radius,
r_o = inner vortex and outer vortex interface radius,
Z = axial component of travel distance at time t, and
θ = cyclone cone angle.

$$tg\theta = \frac{1}{8} \text{ (1D3D)}, \quad tg\theta = \frac{3}{16} \text{ (2D2D)}, \quad tg\theta = \frac{1}{8} \text{ (1D2D)},$$

Then,

$$V_{t2} = \frac{4D_c * V_{in}}{Z + 2D_c} \quad \text{(1D3D)}$$

$$V_{t2} = \frac{8D_c * V_{in}}{3Z + 4D_c} \quad \text{(2D2D)}$$

$$V_{t2} = \frac{8D_c * V_{in}}{2Z + 5D_c} \quad \text{(1D2D)}$$

$$V_{z2} = -\frac{Q_z}{A_z} = \frac{-Q_{in}}{\pi * (R - r_o)} * \frac{1}{\frac{R - r_o}{Z_2} * Z + 2r_o} \text{ ....(9)}$$

where:

V_{z2} = axial velocity at time t in the cone part,
Q_z = airflow rate at Z cross-section (at time t),
A_z = outer vortex cross-section area at z (annular area),
Q_{in} = inlet airflow rate,
R = exit tube radius,
r_o = inner vortex and outer vortex interface radius, and
Z = axial component of travel distance at time t.

Then,

$$V_{z2} = -\frac{4D_c * V_{in}}{(Z + 4D_c) * \pi} \quad \text{(1D3D)}$$

$$V_{z2} = -\frac{8D_c * V_{in}}{(3Z + 8D_c) * \pi} \quad \text{(2D2D)}$$

$$V_{z2} = -\frac{16D_c * V_{in}}{(3Z + 15D_c) * \pi} \quad \text{(1D2D)}$$

$$V_r = V_{z2} * tg\theta \text{ .... (10)}$$

The total average velocity and travel distance in the cone can be obtained by the following equations.

$$V_2 = \sqrt{V_{t2}^2 + V_{z2}^2 + V_r^2} \text{ ....(11)}$$

$$L_2 = \int_0^{t_2} V_2 dt = \int_{z_2}^{0} V_2 * \frac{dz}{V_z} \text{ .... (12)}$$

where:

L_2 = travel distance in the barrel,
V_2 = total average velocity in the barrel at time t,
Z_2 = axial length of total travel distance, and
dz = axial component of travel distance during time dt.

Then,

$L_2 = 10.83D_c$ (mathcad solution for 1D3D)
$L_2 = 7.22D_c$ (mathcad solution for 2D2D)
$L_2 = 2.565D_c$ (mathcad solution for 1D2D)

The number of turns in the cone can be obtained by the equation (13).

$$N_2 = \frac{L_2}{\pi * (\frac{D_c + D_o}{2})} \quad \text{..................................(13)}$$

where:

N_2 = number of turns in the cone,
L_2 = travel distance in the cone,
D_c = cyclone diameter, and
D_o = inner vortex and outer vortex interface diameter ($D_o = D_e$).

Then,

$N_2 = 4.6$ (for 1D3D)
$N_2 = 3.07$ (for 2D2D)
$N_2 = 1.01$ (for 1D2D)

Total travel distance (L) and number of turns (N):

As a result of the above calculation, the total travel distance and number of turns for the 1D3D, 2D2D and 1D2D are listed in the Table 1.

Table 1. Air stream travel distance and number of turns in the cyclone

Cyclone Design	Barrel Part		Cone Part		Total	
	L_1	N_1	L_2	N_2	L	N
1D3D	$4.8D_c$	1.53	$10.83D_c$	4.6	$15.63D_c$	6.13
2D2D	$9.6D_c$	3.06	$7.22D_c$	3.07	$16.82D_c$	6.13
1D2D	$5.2D_c$	1.66	$2.57D_c$	1.01	$7.77D_c$	2.67

L --- travel distance; N--- number of turns; D_c --- cyclone diameter.

Analysis of cyclone pressure drop:

In the evaluation of a cyclone design, pressure drop is a primary consideration. Under any circumstance, a knowledge of pressure drop through the cyclone is essential in designing the fan system. In general, a cyclone pressure loss can be obtained by summing all of individual pressure loss components. Following five pressure loss components involve in the analysis of cyclone pressure loss:

(1) Cyclone entry loss (ΔP_e).

(2) Kinetic energy loss (ΔP_k).
(3) Frictional loss in the outer vortex (ΔP_f).
(4) Kinetic energy loss caused by the rotational field (ΔP_r).
(5) Pressure loss in the inner vortex and exit tube (ΔP_o).

Cyclone entry loss (ΔP_e)

The cyclone entry loss is caused by the inlet tube area change and can be determined as follow:

$$\Delta P_e = C^* \, VP_i \quad \text{……………………………..(14)}$$

where:

ΔP_e = cyclone entry loss (dynamic pressure loss in the inlet duct),
C = dynamic loss constant ($C \approx 1$), and
VP_i = inlet velocity pressure (in. H_2O)

$$VP_i = \left(\frac{V_{in}}{4005}\right)^2 \text{ (for standard air) ……………(15)}$$

Kinetic energy loss (ΔP_k):

This part of energy loss is caused by the area change (velocity change) from the inlet tube to exit tube. It can be calculated by the following equation.

$$\Delta P_k = VP_{in} - VP_o = \left(\frac{V_{in}}{4005}\right)^2 - \left(\frac{V_o}{4005}\right)^2 \quad \text{……….(16)}$$

where:

ΔP_k = kinetic energy loss,
VP_i = inlet velocity pressure (in. H_2O),
VP_o = outlet velocity pressure (in. H_2O),
V_i = inlet velocity, and
V_o= outlet velocity.

$$V_o = \frac{2}{\pi} * V_{in} \quad \text{(for 1D3D, 2D2D design)}$$

$$V_o = \frac{1.28}{\pi} * V_{in} \quad \text{(for 1D2Ddesign)}$$

Frictional loss in the outer vortex (ΔP_f):

The frictional pressure loss is the pressure loss in the cyclone outer vortex caused by the friction of air/surface wall. In the outer vortex, air stream flows in a downward spiral through the cyclone. It may be considered that the air stream travels in an imaginary spiral tube with diameter D_s and length L (the air stream travel distance in the outer vortex). The frictional pressure loss can be determined by the Darcy's equation:

$$d\Delta P_f = f * \frac{VP_s}{D_s} * dL \text{ ....(17)}$$

where:

$d\Delta P_f$ = frictional pressure loss at travel distance dL,
f = friction factor, dimensionless ($f \approx 0.011$),
dL = air stream travel distance in the outer vortex during the time dt,
D_s = equivalent stream diameter at time t, and
VP_s = stream velocity pressure at time t.

The equivalent stream diameter was used to quantify the size of oval-shape stream. The flow rate and total velocity of the stream determine this equivalent diameter as shown in the equations (18 and 19).

$$V_{s1} * \frac{\pi * D_{s1}^2}{4} = V_{in} * \frac{D_c^2}{8} \quad \text{(in the barrel) ....(18)}$$

where:

V_{s1} = air stream velocity in the barrel part ($V_{s1} = V_1$ determined by equation (4)),
D_{s1} = equivalent stream diameter in the barrel,
D_c = cyclone diameter, and
V_{in} = inlet velocity

and,

$$V_{s2} * \frac{\pi * D_{s2}^2}{4} = V_{in} * \frac{D_c^2}{8} * \frac{Z}{Z_2} \quad \text{(in the cone).........(19)}$$

where:

V_{s2} = air stream velocity in the cone ($V_{s2} = V_2$ determined by equation (11)),
D_{s2} = equivalent stream diameter in the cone,
D_c = cyclone diameter,
V_{in} = inlet velocity,
Z = axial component of air stream travel distance at time t in the cone, and
Z_2 = axial length of total travel distance in the cone.

The frictional pressure loss can be determined as follow by combining equations (4, 11, 17, 18 and 19) and integrating equation (17):

$$\Delta P_f = \Delta P_{f1} + \Delta P_{f2} = \int_0^{L_1} f * \frac{VP_{s1}}{D_{s1}} dL + \int_0^{L_2} f * \frac{VP_{s2}}{D_{s2}} dL$$
$$\text{.......} = \int_0^{z_1} f * \frac{VP_{s1}}{D_{s1}} * V_1 * \frac{dz}{V_{z_1}} + \int_{z_2}^{0} f * \frac{VP_{s2}}{D_{s2}} * V_2 * \frac{dz}{V_{z2}} \quad \text{..................(20)}$$

where:

ΔP_f = total frictional loss,
ΔP_{f1} = frictional loss in the barrel,
ΔP_{f2} = frictional loss in the cone,
L_1 = travel distance in the barrel,

L_2 = travel distance in the cone,
f = friction factor,
VP_{s1} = stream velocity pressure at time t in the barrel,
VP_{s2} = stream velocity pressure at time t in the cone,
D_{s1} = stream diameter at time t in the barrel,
D_{s2} = stream diameter at time t in the cone,
dL = air stream travel distance in the outer vortex at time dt,
V_1 = air stream total velocity at time t in the barrel,
V_2 = air stream total velocity at time t in the cone,
V_{z1} = axial velocity component in the barrel at time t,
V_{z2} = axial velocity component in the cone,
Z_1 = length of the barrel,
Z_2 = axial component of travel distance in cone, and
dz = axial component of travel distance during the time dt.

Rotational kinetic energy loss (ΔP_r):

In the cyclone cone, the rotation of the airflow in a cyclone establishes a pressure field because of radial acceleration. The rotational energy loss is the energy that is used to overcome centrifugal force and let the stream move from outer vortex to inner vortex. To develop an equation for the rotational kinetic energy loss, it is assumed that the direction of rotation in both inner vortex and outer vortex are the same so that little friction is to be expected at their interface (the junction point).

The rotational loss can be quantified as the pressure change in the pressure field from cyclone cone walls to the vortex interface.

$$dP = \rho * \frac{V_t^2}{r} dr \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(21)$$

where:

dP = pressure gradient from outer vortex to inner vortex at the radius r,
ρ = air density,
r = radius, and
V_t = tangential velocity at the radius r.

In the equation (21), the tangential velocity distribution in a cyclone may be expressed by the equation (1). Solving the equation (21), the rotational loss can be obtained as the follow:

$$\Delta P_r = \rho * V_{in} * \left(\frac{R}{r_o} - 1 \right) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(22)$$

Then, $\Delta P_r = 2*VP_{in}$ (for 1D3D and 2D2D design)
$\Delta P_r = 1.22*VP_{in}$ (for 1D2D design)

where:

ΔP_r = rotational pressure loss,
ρ = air density,
V_{in} = inlet velocity,
R = cyclone radius,

r_o = radius of the vortexes interface, and
VP_{in} = inlet velocity pressure.

Pressure loss in the inner vortex and the exit tube (ΔP_o):

The inner vortex is assumed to have a constant height of spiral and constant angle of inclination to the horizontal, and to have the same rotational velocity at the same radius at any vertical position. The method of calculation on this part of pressure component will be to determine the average pressure loss in the inner vortex and exit tube. It can be determined as follow:

$$\Delta P_o = C*VP_o \quad \text{.............................(23)}$$

where:

ΔP_o = pressure loss in the inner vortex and exit tube.
C = dynamic loss constant ($C \approx 1.8$), and
VP_o = outlet velocity pressure.

Prediction of cyclone pressure drop:

Based on the five pressure loss components analyzed above, the predictions of cyclone pressure drop for 1D3D, 2D2D and 1D2D are listed in the Tables 2, 3, and 4, respectively.

Table 2. 1D3D Pressure Drop Components @ V_{in} = 3200 (fpm)

Size	ΔP_e	ΔP_k	ΔP_f		ΔP_r	ΔP_o	Cyclone
D (in.)	[1]	[2]	ΔP_{f1}	ΔP_{f2}	[4]	[5]	ΔP
4	0.64	0.38	0.09	1.44	1.28	0.468	4.3
6	0.64	0.38	0.09	1.44	1.28	0.468	4.3
12	0.64	0.38	0.09	1.44	1.28	0.468	4.3
24	0.64	0.38	0.09	1.44	1.28	0.468	4.3
36	0.64	0.38	0.09	1.44	1.28	0.468	4.3

Note: pressure is in inch water gauge (in. H_2O).

Table 3. 2D2D Pressure Drop Components @ V_{in} = 3000 (fpm)

Size	ΔP_e	ΔP_k	ΔP_f		ΔP_r	ΔP_o	Cyclone
D (in.)	[1]	[2]	ΔP_{f2}	ΔP_{f2}	[4]	[5]	ΔP
4	0.561	0.33	0.16	0.85	1.12	0.41	3.44
6	0.561	0.33	0.16	0.85	1.12	0.41	3.44
12	0.561	0.33	0.16	0.85	1.12	0.41	3.44
24	0.561	0.33	0.16	0.85	1.12	0.41	3.44
36	0.561	0.33	0.16	0.85	1.12	0.41	3.44

Note: pressure is in inch water gauge (in. H_2O).

Table 4. 1D2D Pressure Drop Components @ V_{in} = 2400 (fpm)

Size D (in.)	ΔP_e [1]	ΔP_k [2]	ΔP_f ΔP_{f2}	ΔP_{f2}	ΔP_r [4]	ΔP_o [5]	Cyclone ΔP
4	0.36	0.3	0.05	0.323	0.43	0.11	1.57
6	0.36	0.3	0.05	0.323	0.43	0.11	1.57
12	0.36	0.3	0.05	0.323	0.43	0.11	1.57
24	0.36	0.3	0.05	0.323	0.43	0.11	1.57
36	0.36	0.3	0.05	0.323	0.43	0.11	1.57

Note: pressure is in inch water gauge (in. H_2O).

Testing of the New Method

System setup:

To test the prediction of cyclone pressure drop by new method, an experiment was conducted to measure the cyclone pressure drop at different inlet velocities. The experimental setup is shown in Figure 2. The tested cyclones' diameters are 6 inch. The pressure transducers and data loggers (HOBO) were used to obtain differential pressure from cyclone inlet and outlet and the orifice pressure drop. The orifice pressure drop was used to monitor the system airflow rate.

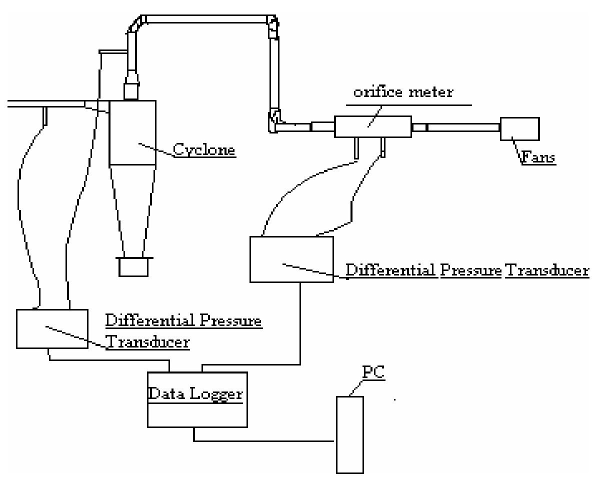

Figure 2. Cyclone pressure drop measurement system setup

There was a problem observed during the tests. In order to measure the static pressure drop through cyclones, the static pressure taps (Figure 3) were inserted into air stream such that the static pressure sensing position was in the direction of air flow. In the outlet tube, air stream is spiraling upward. This spiral path caused some difficulties in measuring static pressure in the outlet tube if the static pressure taps were not placed properly in the exit tube.

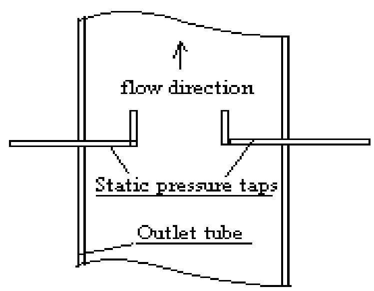

Figure 3. Static pressure taps in the cyclone outlet tube

Comparison of the theoretical prediction to the testing results:

Three measurements were made on each cyclone design at different inlet velocities. At the same time, the new theoretical method was used to predict the cyclone pressure drop at the different inlet velocities. The calculated pressure drops and the measured pressure drops vs. inlet velocities were shown in the Figures 4, 5 and 6.

For the 1D3D cyclone, measurement #1, 2, 3 were run on 6-inch cyclone and measurement #4 was run on 4-inch cyclone. The testing results show that there was no significant pressure drop difference between these two cyclones.

The calculated pressure drops were obtained by using the new theoretical method. The special software Mathcad was used to integrate the travel distance and the frictional pressure loss in the cyclone cone part. For the same cyclone design, the same calculated pressure drops were obtained for 4, 6, 12, 24 and 36-inch cyclone diameters. The theoretical analysis results show that cyclone pressure drop is independent of cyclone diameter.

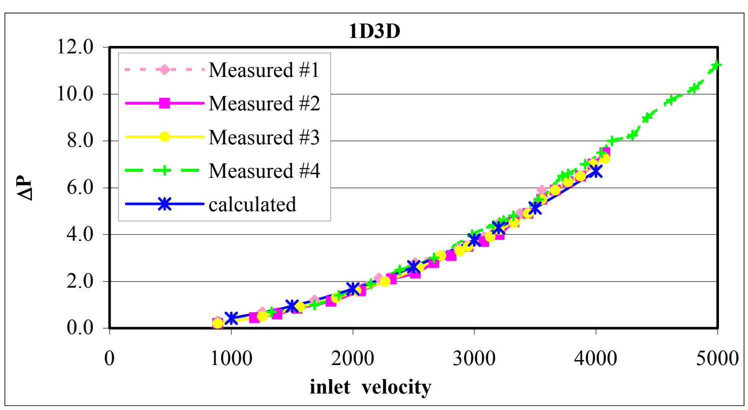

Figure 4. Measured pressure drop and theoretically calculated pressure drop vs. inlet velocities for 1D3D

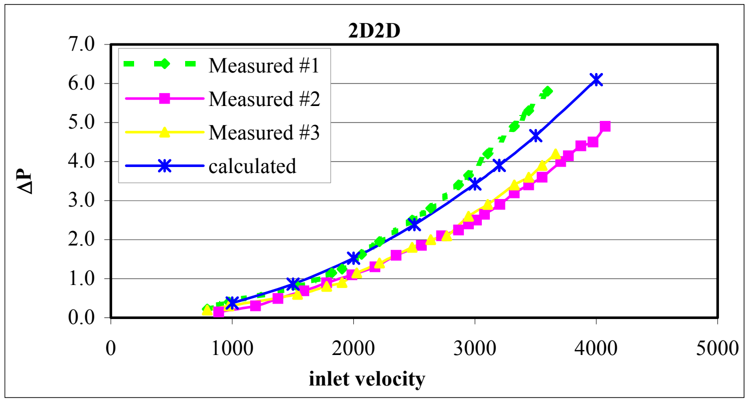

Figure 5. Measured pressure drop and theoretically calculated pressure drop vs. inlet velocities for 2D2D

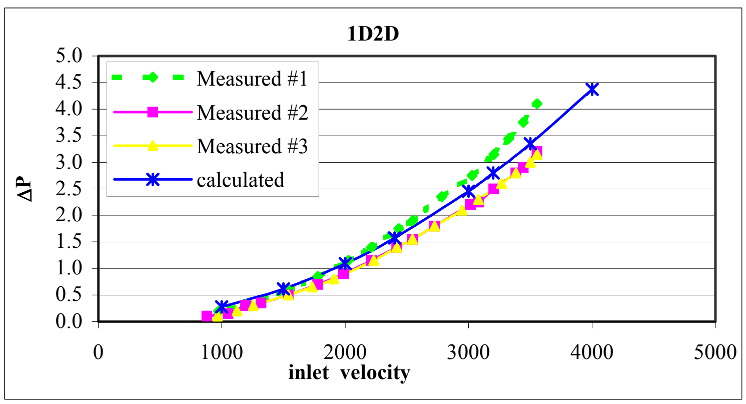

Figure 6. Measured pressure drop and theoretically calculated pressure drop vs. inlet velocities for 1D2D

Conclusion

Air stream travel distance and effective number of turns can be determined based upon the velocity profile in a cyclone. Theoretical analysis shows that number of turns is determined by the cyclone design. It is independent of cyclone diameter and inlet velocity. There are 6.13 turns in both 1D3D and 2D2D cyclones and 2.67 turns in 1D2D cyclone. Cyclone pressure drop consists of five individual pressure drop components. The frictional loss in the outer vortex and the rotational energy loss in the cyclone are the major pressure loss components. The theoretical analyses of the pressure drop for five different size cyclones (4, 6, 12, 24 and 36 inch) show that cyclone pressure is independent of its diameter. Experiments were conducted to verify the theoretical analysis results and gave excellent agreement. It shows that the new theoretical method can be used to predict the air stream travel distance, number of turns and cyclone pressure drop. For the 1D3D, 2D2D and 1D2D cyclone designs, the prediction of pressure drop are 4.3, 3.43 and 1.57 H_2O respectively at their own design inlet velocity (3200fpm, 3000fpm and 2400fpm respectively).

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