SPECIAL NOTES FOR NEW USERS OF EZZE CYCLONE 2.0

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WARRANTY

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TERMINOLOGY

In the EZZE CYCLONE program there is some terminology used which may not be familiar to you. Definitions and significance of calculated parameters can be found in the references listed below or the tutorial.

TECHNOLOGY

This program is a utility program to assist in the design and evaluation of the performance of Cyclones It is based on a series of equations which have been developed from theory and confirmed experimentally. The results derived from the equations can be used in discussions with manufacturers or inhouse experts during the evaluation/ design process.

In addition to generic cyclones the program can be adapted to use with Manufacturer's data and get reasonable agreement with efficiencies and other parameters published IN THEIR PRODUCT LITERATURE. A sample evaluation of a cyclone using Manufacturer's data is included with a brief description of the procedure.

REFERENCES

AIR POLLUTION CONTROL	CD COOPER KO ALLEY 1996	
AIR POLLUTION CONTROL SYSTEMS FOR BOILERS AND INCINERATORS	US ARMY COE -TM 5-815-1	
MODERN MATERIALS HANDLING	CHEMICAL ENGINEERING 1989	
PRINCIPLES OF POWDER TECHNOLOGY	MARTIN RHODES = WILLEY 1990	
PROCESS DRYING PRACTISE	EDMUND COOK, HARMON DUMONT-McGRAWHILL 1991	
DESIGN-AIR POLLUTION CONTROL FOR BOILERS AND INCINERATORS	US ARMY CORPS OF ENGINEERS UFC-3-430-03	
FISHER-KLOSTERMAN XQ SERIES HIGH PERFORMANCE CYCLONES	FISHER-KLOSTERMAN	BULLETIN 218 C

SUPPORT

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USER GUIDE

1.1 This template has 5 worksheets. READMEFIRST contains instructions and data for the operation of the program

CALCULATION is the user's interface to enter data required for cyclone design
REPORT is a preformatted page linked to CALCULATION for your design report
To complete just add comments in DESIGN CONDITIONS & CONCLUSIONS
EQUATIONS is where main design equations are located
REFERENCE contains reference material (cyclone dimensions, sample problem data, cyclone performance data) which may be useful in your investigation.

1.2 Before using the program please check the REFERENCE, REPORT and CALCULATION sheets to familiarize yourself with their layout and contents. Make a special note of the instructions in green font in the CALCULATION sheet before you use it for the first time.

1.3 The Calculation sheet contains 6 generic, 2 manufacturer, and 1 user defined cyclones to select for your design investigation. Select a cyclone enter its size (D) and its dimensions are calculated. Note that manual data entry cells are sand colour and auto calculated data cells are green (input data) or no colour (cyclone parameters). This template can be used for single or multi cyclones - the procedure for this follows in 4.0 below and is briefly described in the Calculation Sheet .

2.1 There are two modes for using this template - a Cyclone has been selected and you are checking its capabilities or no Cyclone has been selected and you are selecting one using the cyclone presizer to determine a best guess Collector for the initial calculations. To use the presizer enter gas flow rate Q plus H/D & W/D for cyclone selected and the presizer calculates the cyclone diameter D (size) for the cyclone you wish to evaluate. The presizer provides the D factor to use calculate cyclone dimensions to use with process properties for the full test.

2.2 Included in the CYCLONE DATA TABLE are two FISHER KLOSTERMAN CYCLONEs which were evaluated a SIZE 21 MODEL XQ120 & a MODEL XQ340. The first one was checked as follows:
The collection efficiency and pressure drop was calculated using the equations developed for this template. The pressure drop - velocity relationship showed good agreement with that calculated using the Manufacturers equipment specific methodology'. The efficiency was lower then the Manufacturers', howvever, by using a collector factor resulted in a reasonable agreement (95% collection efficiency vs 91%). Why use a factor? Per EPA (see below), efficiency varies greatly with cyclone design and increases with the number of turns (revolutions) the gas makes in the cyclone. Revolutions that the gas makes is a theoretical number(Ne) which has been calculated for generic collectors, and is a significant impactor upon efficiency. Adding a factor is reasonable based on using the factor with a second F-K cyclone (model XQ340) and evaluating it on the same basis. In both instances there was good agreement wiith MANUFACTURERS site data. for the calculation of Dpc which is tabulated below

F-K CYCLONE		Vi	Dpc	Dpc
SIZE	MODEL	fps	EZZE	F-K
21	XQ120	57	2.33	2.177
21	XQ340	57	3.91	3.697

The F-K CYCLONE FACTOR is 2.0 . The CYCLONE FACTOR for generic and other cyclones is 1.0.

2.3 This method may be valid for fitting the generic theory to other Manufacturer's published performance claims. The ultimate test is confirming the equations with plant data. Until confirmed with field data this technique is only theoretical fitting equations to manufacturer performance claims. It does however provide a basis to do a preliminary evaluation of how his equipment(compare sizes, models, options) might perform in your process.

3 If you know the particle size distribution in the feed to the cyclone the program can estimate the efficiency for each of the fractions. This is done automatically just enter your data in the same format as the example.

4 In some cases, due to capacity and/or space constraints it may be more practical to use a 'multi cyclone. The method for doing this is as follows. Consider the multiunit as a single unit for the exhaust from and inlet to the multiclone. Internally it is split up into a set of equal gas flows equal to the number of cyclones in the multiclone. Each of the cyclones work as if it were a single cyclone (gas+dust in, cyclonic forces=dust out dust exit and gas + less dust out the exhaust into the common exhaust. Each cyclone operates independently but additive in the overrall system

5 The results of your Cyclone investigation are automatically summarized on a report page which is setup for printing. Just add your comments and your report is ready to print!

6 The Reference sheet contains Cyclone dimensional data for common cyclone types, Sample problems to learn how the template works and background data for use in your investigation. It may prove useful for you to put your personal reference data here as well.

COMMENTS ON EFFICIENCY

1 Efficiency varies greatly with particle size and cyclone design
2 Manufacturers cyclones with efficiencies>98% for particles >5 microns and 90% for >15-20 micron are common
3 According to Kalen and James ratio of Saltation to inlet velocity falls between 1.25 and 1.36 for maximum efficiency
Velocity greater then this result in solids not settling out and or reintrained after they settle out, Saltation relationship assumes inlet dust loading > 0.014 lb/cuft.

4 The Texas A&M Cyclone Design (TCD) process specifies the "ideal" cyclone inlet velocities (design velocities) for the different cyclone designs to optimize cyclone performance. The design inlet velocities for the 1D3D, 2D2D and 1D2D cyclones are 975 m/min ± 122 m/min (3200fpm ± 400 fpm), 914 m/min ± 122 m/min (3000fpm ± 400 fpm) and 732 m/min ± 122 m/min (2400fpm ± 400 fpm), respectively. USE 1200m/min FOR GENERIC OTHER AND F-K PRESIZER (first try values)

5 In an Air Pollution Technology Factsheet EPA made the following comments concerning cyclones:
   1 collector efficiency varies as a function of particle size and cyclone design
   2 cyclone efficiency increases with particle size and/or density, inlet duct velocity, cyclone body length, number of gas revolutions in the cyclone, ratio of cyclone diameter to gas exit diameter, dustloading and smoothness of cylinder wall
   3 A cyclone's efficiency will decrease with an increase in gas viscosity, body diameter, and gas inlet duct area
   4 In general, 18.3 m/sec (60 fps) is considered the best operating velocity.

DESIGN GUIDELINES

In a typical cyclone separator, the gas-dust mixture enters the top cylindrical section of the cyclone through a tangential opening. As particles must reach the wall of the cyclone before they can be recovered from the gas stream, it is best if the inlet shape is rectangular instead of circular.
A circular inlet would have only one point tangential to the wall, but a rectangular inlet should have at least a quarter of the perimeter tangent.

When a rectangular inlet is used, it is recommended that the height of the inlet duct be greater than the width, to increase the tangential inlet surface. In order to reduce erosion and the migratory loss of particles it is best to place the inlet duct flush with the cyclone roof.

For best efficiency the penetration of the outlet duct should be 1 to 1.2 times the height of the inlet duct to prevent the inlet particles from going directly out of the cyclone with the exiting gas stream. Increasing the penetration of the outlet duct beyond 1.2 is not economically feasible as the entire length of the cyclone would also have to be increased

The contraction of the outlet gas stream represents a pressure loss which should be minimized by maximizing the area of the outlet gas duct.

The main areas of pressure loss in a cyclone are due to the contraction of the inlet and outlet ducts. If the ratio of outlet area to inlet area is less than one, an increased pressure drop is experienced and the cyclone must be lengthened to avoid dust reentrainment in the spiraling gas stream
Typical pressure drop efficiency data (see reference page)

STOKES , REYNOLDS AND EULER COMMENTS

Experience and theory have shown that there are certain relationships among cyclone dimensions that should be observed for efficient cyclone performance, and which are generally related to the cyclone diameter. There are several different standard cyclone “designs” and using standard geometries of cyclones is much easier to predict effects on variables changes and scale-up calculations are greatly reduced. Such calculations may be carried out by means of dimensionless relationships. Selection and operation of cyclones can be described by the relationship between the pressure drop and the flow rate, and the relationship between separation efficiency and flow rate

The Euler number is a pressure loss factor, easily defined as the limit on the maximum characteristic velocity v

$$Eu = \frac{2\Delta P}{\rho_g v^2}$$

The Reynolds number defines flow characteristics of the system and, in the case of cyclones, the characteristic dimension may be taken as the cyclone body diameter Dc.

$$Re = \frac{D_c v \rho_g}{\mu_g}$$

The relationship between separation efficiency and flow rate is not significantly influenced by operational variables, so it is commonly expressed in terms of cut size x_{50}. The use of cut size to define efficiency of cyclones is of utmost importance since their performance is highly dependent on particle size. Considering that cut size implies the size of particles to be separated it follows that such particles must be influenced by forces exercised on the suspension. The forces developed in a cyclone can be analyzed by sedimentation theory, and a dimensionless group thus derived, the Stokes number *Stk* , will include the cut size. The Stokes number is a very useful theoretical tool

$$Stk_{50} = \frac{x_{50}^2 \rho_s v}{18 \mu_g D_c}$$

The cyclone inside diameter D_c, has all geometrical proportions related to it. In the case of scale-up procedures, proportions must be maintained. The cyclone body velocity *v* is the characteristic velocity which can be defined in various ways, but the simplest one is based on the cross section of the cylindrical body so that:

$$v = \frac{4Q}{\pi D_c^2}$$

EZZE CYCLONE

TYPICAL CYCLONE DIMENSIONAL PROPERTIES

DIMENSIONAL PROPERTIES	GENERIC CYCLONE TYPE						FISHER - KLOSTERMAN actual dimensions		USER DEFINED CYCLONE	
	HIGH EFFICIENCY		CONVENTIONAL		HIGH THROUGHPUT		SIZE21MODELS120&340		Peterson - Whitley	
	TYPE 1	TYPE 2	TYPE 3	TYPE 4	TYPE 5	TYPE 6	M(model120)	M(340)	ratio""/Dc	METRIC
BODY DIAMETER D/D	1.14	1	1	1	1	1	1.79	0.91	1	1.00
HEIGHT OF INLET H/D	0.57	0.44	0.5	0.5	0.75	0.8	0.53	0.53	0.583	0.58
WIDTH OF INLET W/D	0.228	0.21	0.25	0.25	0.375	0.35	0.27	0.27	0.208	0.21
DIAMETER OF GAS EXIT De/D	0.57	0.4	0.5	0.5	0.75	0.75	0.85	0.51	0.5	0.50
LENGTH OF VORTEX IN S/D	0.57	0.5	0.625	0.6	0.875	0.85	0.53	0.53	0.583	0.58
LEGTH OF BODYLb/D	1.71	1.4	2	1.75	1.5	1.7	2.16	1.30	1.33	1.33
LENGTH OF CCONE Lc/D	2.85	2.5	2	2	2.5	2	3.63	2.18	1.84	1.84
DIAMETER DUST OUTLETDo/D	0.4275	0.4	0.25	0.4	0.375	0.4	0.58	0.33	0.5	0.50
COLLECTION FACTOR	1	1	1	1	1	1	2	2		
VALUE OF Dc	1.14	1	1	1	1	1	xxxxxxxxxxxxx	xxxxxxxxx	1	xxxxxxxxx

ENTER THE VALUE FOR Dc
CYCLONEDIMENSIONS ARE
AUTOMATICALLY CALCULATED

PROBLEM DEFINITION AND PROCESS PROPERTIES

CYCLONE PROPERTIES - METRIC

FACTOR: 1

CYCLONE ID.: STAIRMAN HE

D	H	W	De	S	Lb	Lc	Do
1.14	0.57	0.228	0.57	0.57	1.71	2.85	0.4275

PROCESS CONDITIONS

1 ENTER TOTAL GAS FLOW & # OF CYCLONES INDIVIDUAL FLOW CALCULATED
2 ENTER AIR TEMP & PRESS - DENSITY AND VISCOSITY CALCULATED
3 ENTER PARTICLE DENSITY, DUST LOAD AND PARTICLE SIZE DISTRIBUTION

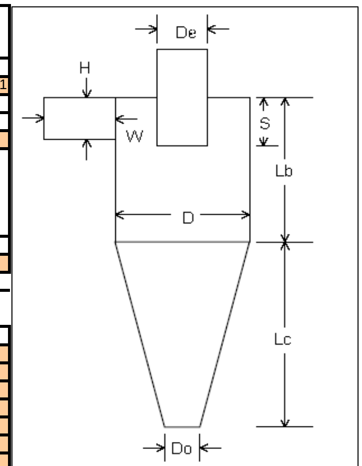
AIR TEMP C	AIR DENSITY kg/m&3	AIR VISCOSITY kg/mhr	AIR PRESSURE ATMS
80	0.999963979	0.0753	1
TOTAL GAS FLOW m^3/min	# OF CYCLONES	DUST LOAD kg/m^3	
570	4		
PARTICLE DENS. kg/m^3	GAS FLOW m^3/min PER CYCLONE		
2100	142.5		

MEAN SIZE RANGE = MICRON FROM	TO	PARTICULATE MASS % RANGE
0	2	1
2	4	1
4	6	6
6	10	10
10	18	30
18	30	30
30	40	16
40	100	6

PRESIZER INSTRUCTIONS
1. ENTER GAS FLOW (Q) BELOW
2. SELECT CYCLONE TYPE

Q m^3/min	H/D	W/D	D
142.5	0.5	0.2	1.15

3. ENTER H/D & W/D FOR CYCLONE SELECTED. PRESIZER CALCULATES D CYCLONE SIZE TO EVALUATE



CYCLONE DESIGN PARAMETERS

DESIGN EQUATION RESULTS | **COLLECTION EFFICIENCY OF DUST DISTRIBUTION RANGE**

			Davg	Davg/Dpc	Ej	mj/M	MASS%
59.94152047	vi	ft/sec INLET VELOCITY					
42.5602289	Vs	SALTATION VELOCITY ft/sec	Davg	Davg/Dpc	Ej	mj/M	MASS%
4.276323707	Pd	PRESSURE DROP INCHES WATER	1	0.175699	0.029945602	1	0.029946
470.2771215	EU	Euler Number	3	0.527096	0.217423415	1	0.217423
5.691562686	Dpc	DIAMETER(micron) PARTICLE 50% EFF,	5	0.878493	0.435586468	6	2.613519
8.049085142	Dpj	DIAMETER(micron) jth PARTICLE	8	1.405589	0.663942526	10	6.639425
0.00036899	ST	Stokes Number	14	2.459781	0.858166581	30	25.745
1.077316416	Td	GAS RESIDENCE TIME (sec)	24	4.216768	0.946755077	30	28.40265
5.5	Ne	# OF EFFECTIVE TURNS IN VORTEX	35	6.149453	0.974237281	16	15.5878
6.4	Nh	#OF INLETVELOCITY HEADS	70	12.29891	0.993432421	6	5.960595
126881.7268	RE	Reynolds Number	AVERAGE EFFICIENCY IS				85.19635

CORRECTIONS

PROCESS CONDITIONS				PRESSURE DROP @ STANDARD AIR			
AIR TEMP F	176	STANDARD AIR 70F					
DENSITY lb/cu.ft.	0.062343	DENSITY lb/cu.ft.	0.075	5.144537422	" WG	1286.134	Pascal
PRESSURE DROP	4.276324						

THIS COLLECTOR IS 90 % EFFICIENT ABOVE 17.07468806 MICRON

DISCUSSION OF RESULTS

1 SALTATION AND INLET VELOCITIES

According to theory the maximum efficiency occurs when inlet velocity is between 1.25 and 1.36 times the Saltation velocity.

2 PRESSURE DROP AND INLET VELOCITY

3 CYCLONE SELECTION - CHANGE?

4 COLLECTION EFFICIENCY - PARTICLE?

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CONCLUSIONS

1
2
3

PREPARED BY BILBO J. BAGGINS ESQ. 6/2/2006 18:52

EZZE CYCLONE DESIGN REPORT

PROBLEM DEFINITION AND PROCESS PROPERTIES

DESIGN CONDITIONS

1 Require 85%+ efficiency with Stairmand cyclone
2 Particulate collected is detergent from a Spray Dryer
3 Powder is collected and recycled to Spray Dryer

PROCESS CONDITIONS

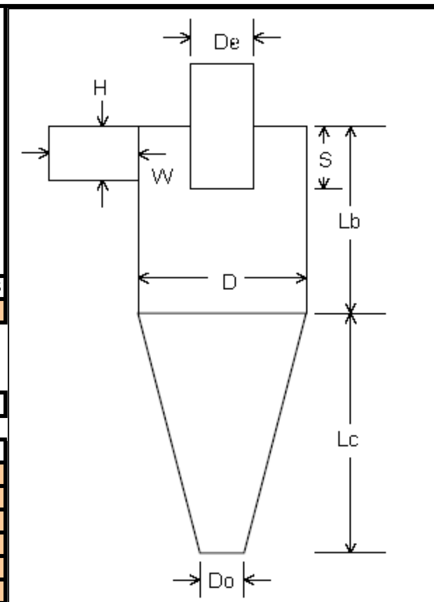
AIR TEMP C	AIR DENSITY kg/m&3	AIR VISCOSITY kg/mhr	AIR PRESSURE ATMS
80	0.999963979	0.0753	1
	# CYCLONES	TOTAL GAS FLOW m^3/min	
	4	570	
PARTICLE DENS. kg/m^3	GAS FLOW PER CYCLONE m^3/min	PARTICULATE SIZE DISTRIBUTION	
2100	142.5	MEAN SIZE RANGE = MICRON	MASS % RANGE

PRESIZER INSTRUCTIONS
1. ENTER GAS FLOW (Q) BELOW
2. SELECT CYCLONE TYPE

Q m^3/min	H/D	W/D	D
142.5	0.5	0.2	1.15

3. ENTER H/D & W/D FOR CYCLONE SELECTED. PRESIZER CALCULATES D CYCLONE SIZE TO EVALUATE

FROM	TO	MASS % RANGE
0	2	1
2	4	1
4	6	6
6	10	10
10	18	30
18	30	30
30	40	16
40	100	6



STAIRMAN HE

CYCLONE DESIGN RESULTS

CYCLONE DIMENSIONS	D	H	W	De	S	Lb	Lc	Do
	1.14	0.57	0.228	0.57	0.57	1.71	2.85	0.4275

DESIGN EQUATION RESULTS			DUST COLLECTION EFFICIENCY				
59.94152	vi	ft/sec INLET VELOCITY					
42.56023	Vs	SALTATION VELOCITY ft/sec	Davg	Davg/Dpc	Ej	mj/M	MASS%
4.276324	Pd	PRESSURE DROP INCHES WATER	1	0.175699	0.029946	1	0.029946
470.2771	EU	Euler Number	3	0.527096	0.217423	1	0.217423
5.691563	Dpc	DIAMETER(micron) PARTICLE 50% EFF,	5	0.878493	0.435586	6	2.613519
8.049085	Dpj	DIAMETER(micron) jth PARTICLE	8	1.405589	0.663943	10	6.639425
0.000369	ST	Stokes Number	14	2.459781	0.858167	30	25.745
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5.5	Ne	# OF EFFECTIVE TURNS IN VORTEX	35	6.149453	0.974237	16	15.5878
6.4	Nh	#OF INLETVELOCITY HEADS	70	12.29891	0.993432	6	5.960595
126881.7	RE	Reynolds Number	AVERAGE EFFICIENCY IS				85.19635

CORRECTIONS

PROCESS CONDITIONS				PRESSURE DROP @ STANDARD AIR			
AIR TEMP F	176	STANDARD AIR 70F					
DENSITY lb/cu.ft.	0.062343	DENSITY lb/cu.ft.	0.075	5.144537	" WG	1286.134	Pascal
PRESSURE DROP	4.276324						

THIS COLLECTOR IS 90 % EFFICIENT ABOVE 17.07469 MICRON

CONCLUSIONS

1 The detergent particulate from the Spray Dryer can be collected at an efficiency of 85.19% using 4 x 1.14 m diameter Stairmand style cyclones operating in parallel.
2 The 50% 'cut (Dpc50) is 5.69 micron collected at a pressure drop of 5.14 inches W.G. (1286pascals).
3

PREPARED BY ____________ 6/2/2006 18:52