	MODIFIED STARCH FLASH DRYER PROJECT						
	CYCLONE CALCULATION						
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FLASH DRYER CYCLONE CALCULATION

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REV.	**ISSUE**	**PURPOSE OF ISSUE**	**PREPARED**	**CHECKED**	**APPROVED**

TABLE OF CONTENT

1. Introduction

There are different processes for collecting the dried powder in a gas stream, among them, cyclones are probably one of the most widespread solutions, in any industry. Cyclone dried powder collectors are simple from a mechanical point of view and therefore generally provide a cost-effective solution.

The system utilizes a battery of **6 parallel cyclones** (2 rows of 3) to process the total exhaust flow. This analysis evaluates the performance of six cyclones operating in parallel, using geometric specifications from Chinese manufacturing data.

The cyclone battery operates under the following conditions:

- **Total airflow:** 67000 m^3/h at 160°C
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- **Gas density:** 1.029 kg/m^3
- **Gas viscosity:** 2.04×10^{-5} Pa·s
- **Particle density:** 1,500 kg/m^3 (starch)
- **Starch mass flow:** 6,986 kg/h (12% moisture)

1.1. Cyclone Diameter Calculation

$$Dc = \sqrt{\frac{(8-10)Qa}{Vi}}$$

Where:
Dc: Cyclone Diameter, (m)
Qa : Air volume at each cyclone, (m^3/s)
Vi: Inlet air speed, (m/s)

$$Qa = \frac{Qt}{n}$$

Where:
Qt : Total air volume, (m^3/s)
n : Cyclone quantity

$$Qa = \frac{67000}{6} = 11{,}167\, m^3/h$$

$$Qa = \frac{11{,}167}{3600} = 3.1\, m^3/s$$

To achieve the high-efficiency separation required for starch, the inlet velocity (V(in) is optimized between 15–20 m/s

$$Vi = 15\, m/s$$

$$Dc = \sqrt{\frac{(8-10)Qa}{Vi}}$$

$$Dc = \sqrt{\frac{(8-10)4.16}{15}} = 1.49\, m - 1.67\, m$$

$$1.49m < Dc < 1.67m$$

$$Dc = 1.6\, m$$

1.2. Cyclone Dimension

Cyclone's efficiency is directly related to their geometry, which has been the object of various research. a set of STANDARD dimensions have been defined. Those dimensions, or rather proportions, constitute the basis of most of the design across the industry. It is recommended to keep those standard configurations, or some adaptation by reputable suppliers, and not modify it. Specific design can still be developed for specific high value applications.

The table -1 is due to Koch and Licht (1977) and is summarizing the work of different authors (Lapple, Stairmand, etc), dimensions are selected based on high efficiency (Swift or Stairmand) however these dimensions are first estimate and final geometry selected based on previous similar experiences.

$a = 0.5Dc$
$b = 0.2Dc$
$S = 0.5Dc$
$De = 0.5Dc$
$h = 1.5Dc$
$H - h = 2.5Dc$
$B = 0.375Dc$

Table-1

Dimensions	Standard Geometries for cyclones with tangential inlet				
	Standard			High efficiency	
	Lapple	Swift	Peterson Whitby	Stairmand	Swift
a/D	0.5	0.5	0.583	0.5	0.44
b/D	0.25	0.25	0.208	0.2	0.21
S/D	0.625	0.6	0.583	0.5	0.5
D_e/D	0.5	0.5	0.5	0.5	0.4
h/D	2	1.75	1.333	1.5	1.4
(H-h)/D	2	2	1.84	2.5	2.5
B/D	0.25	0.4	0.5	0.375	0.4

$a = 0.5 \times 1.6 = 0.8\ m$
$b = 0.2 \times 1.6 = 0.32\ m$
$S = 0.5 \times 1.6 = 0.8\ m$
$De = 0.5 \times 1.6 = 0.8\ m$
$h = 1.5 \times 1.6 = 2.4\ m$
$H = 2.5 \times 1.6 + 2.4 = 6.4\ m$
$B = 0.375 \times 1.6 = 0.6\ m$

Selected Dimension:

$D = 1.604\ m$
$a' = 0.6\ m$
$b' = 0.306\ m$
$S = 0.8\ m$
$De = 0.8\ m$
$h' = 2.527\ m$
$H' - h' = 3.015\ m$
$H' = 5.542\ m$
$B = 0.564\ m$

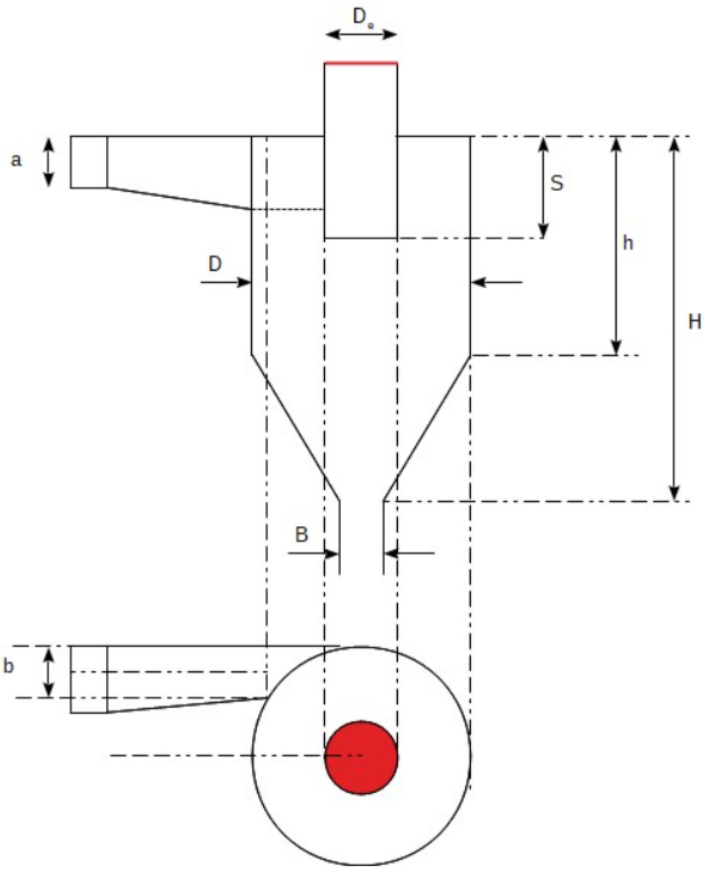

Figure -1

1.3. Pressure Drop

The pressure drop in the cyclone is given, according to ESCO Engineering calculation by the following formula:

$$\Delta P = 98.PD\left(11.3\left(a\frac{b}{s^2}\right)^2 + 3.33\right)$$

$$PD = 0.0052\rho(Vin)^2$$

Where:

ΔP: Pressure Drop (Pa)
PD : Pressure differential parameter
a : Inlet height (m)
b : Inlet width (m)
s : Outlet height (m)
Vin : Air inlet velocity (m/s)
ρ: Density of inlet gas (kg/m^3)

Actual Velocity at Inlet:

$$Vi = \frac{Qa}{A} = \frac{3.1}{0.306 \times 0.6} = 16.88$$

$$PD = 0.0052 \times 1.05 \times (16.88)^2 = 1.56$$

$$\Delta P = 98 \times 1.56\left(11.3\left(0.6\frac{0.306}{0.8^2}\right)^{0.5} + 3.33\right) = 1433\ Pa$$

1.4. Cut off size of particle (100%)

Particles having a diameter equal to the cut off diameter are captured with an efficiency of 100%. It means that the cyclone will capture 100% of the particles having this diameter in the gas stream and will let through the other 100%.

$$dc = 10^6 \times \sqrt{\frac{9\mu a \times a}{2\pi . Nt . Vin . (\rho s - \rho g)}}$$

$$Nt = \frac{1}{a}\left[h' + \left(\frac{H' - h'}{2}\right)\right]$$

Where:

dc: Cut off size of particle 100% (micron)
μa: Viscosity of air at temp. (Kg/m. s)
Nt: number of turns in cyclone
Vin: Air inlet velocity (m/s)
ρs: Density of material (kg/m^3)
ρg: Density of gas (kg/m^3)
H': Height of cyclone (m)
h': Height of Cylindrical
a: Inlet height (m)

$$Nt = (\frac{1}{0.6})[2.527 + \left(\frac{3.015}{2}\right)] = 6.72$$

$$dc = 10^6 \times \sqrt{\frac{9 \times 0.0000204 \times 0.6}{2\pi \times 6.72 \times 16.88 \times (1500 - 1.029)^{0.5}}} = 7.25\ \mu m$$

1.5. Efficiency of Collection

The efficiencies are calculated relatively to the cut off diameter. Bigger particles will lead better efficiencies. Smaller particles to lower efficiencies.

First, the size and amount of starch particles are determined by testing the output dry starch sample and then the average size of each range is calculated.

$$Mean\ Size = \frac{Min.Size + Max.Size}{2}\ (microns)$$

$$E = \frac{1}{1 + ({}^{dc}/_{Ms})^2}$$

$$CE = E \times percent\ of\ retained$$

$$EOC = \sum CE$$

Where:

E: Efficiency for each range of particles

CE: Cumulative efficiency for each range

EOC: Efficiency of Collection

dc: Cut off size of particles (microns)

Ms: Mean Size

Based on realistic agglomeration conditions in the flash dryer, the particle size distribution at the cyclone inlet is as follows:

Table-2

Minimum sieve (microns)	maximum sieve (microns)	mean size	% of retained
700	800	750	15.00
600	700	650	25.00
500	600	550	34.30
400	500	450	20.00
300	400	350	5.65
200	300	250	0.05
			100

Table -3 (Cyclone Efficiency Calculation)

Minimum sieve (microns)	maximum sieve (microns)	mean size	% of retained	efficiency %	cummulative efficiency %
700	800	750	15.00	1.00	15.00
600	700	650	25.00	1.00	25.00
500	600	550	34.30	1.00	34.29
400	500	450	20.00	1.00	19.99
300	400	350	5.65	1.00	5.65
200	300	250	0.05	1.00	0.05
			100	Efficiancy:	99.982%

Cyclones Efficiency of Collection is 99.982 %

$$EOC = 99.982\%$$

1.6. Outlet Concentration

We know that we have about 6986 kg of starch with 12% moisture at the outlet. To calculate the maximum amount of starch that is introduced into the ambient air by the fan, first we calculate the total amount of dry starch by subtracting 12% moisture. Then, considering the calculated total efficiency of 99.982%, we calculate the amount of starch losses and divide it by the inlet air flow rate of the dryer section to obtain the maximum amount of starch input per cubic meter. It should be noted that as the amount of inlet air increases according to the conditions, the air speed in the cyclone increases and consequently the efficiency increases, And as the efficiency increases, the amount of starch output to the air decreases.

Allowable outlet concentration is 23 mg per cubic meter of air so calculated outlet concentration shall be smaller than it.

$$Dried\ Starth\ at\ Outlet = 6986 \times 0.88 = 6148\ kg/h$$

$$Waste\ Starch\ per\ hour = 6148 \times (100 - 99.98)\% = 1.11\ kg/h$$

$$waste\ \ Starth\ per\ qubic\ meter\ of\ inlet\ air = 1.11/67000 = 0.000017\ kg/m^3$$

$$Maximun\ waste\ \ Starth\ per\ qubic\ meter\ of\ inlet\ air = 17\ mg/m^3$$

1.7. Summary

- The cyclone achieves cut diameter of 7.25 micron, providing excellent separation efficiency for starch particle.
- Pressure drop is 1432 pa, which is well within acceptable limits.
- With realistic particle size distribution (d50=465 micron after agglomeration), the system achieves 17 mg per cubic meter, outlet concentration, meeting the target 23 mg per cubic meter.
- Final collection efficiency is 99.982%, ensuring minimal product loss.
- Starch loss is 1.11 kg/h from the inlet mass flow of 6985 kg/h, representing a loss rate of 0.016%.