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Dust Control in Phosphatic Fertilizer Plants

presented by

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About the IFA Technical Committee

The IFA Technical Committee encourages the development and adoption of technology improvements that can lead to greater production efficiencies and reduced emissions, as well as better health and safety standards throughout the fertilizer industry. Our mission is to actively promote the sustainable development of efficient and responsible production, storage and transportation of all plant nutrients. The Technical Committee accomplishes these objectives through a variety of channels, including:

- Technical and policy-oriented information materials. The committee regularly conducts surveys and produces reports on key industry metrics, including the IFA Energy Efficiency and CO_2 Emissions Report, the IFA Safety Report, and the IFA Emissions Report. This work enables member companies to assess their operations over time, make comparisons with similar facilities on an established level of performance, determine the need for technology improvements and identify good industrial and management practices.

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Dust Control in Phosphatic Fertilizer Plants

Abstract

The aim of the work is intended to design and apply a proposed system to control dust emission from super phosphate fertilizer industry. Dimensions and engineering parameters of the system components are investigated and designed with optimal dimensions to perform and achieve maximum efficiency.

The environmental problem is one of the major problems facing industrial development. In this work, design and application of dust control systems are conducted. Cyclone is designed with optimal dimensions to handle the existed air flow. It used as a pre collector before the designed bag filter. It is found that the designed cyclone and bag filter achieve an efficiency of 99%. Therefore, the studied system is considered successful and worked at high efficiency for removing dust emissions in the fertilizer industry.

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Revamp of CO$_2$ Removal Section in MW Kellogg Ammonia Plant to 2-Stage GV Process using existing Lo-Heat Benfield Solution

Introduction

Phosphorus (P), is an essential nutrient for plant growth plays a major role in existence of all living creature. Among other things, it ensures the transfer and storage of energy and permits the conservation and transmission of genetic characteristics in plants, human and animals. All living creatures need phosphorus, and plants are the primary providers of this indispensable element. Therefore it is imperative to develop and promote agriculture practices that enhance phosphate fertilizer use efficiency and minimize its potential unwanted effects on the environment.

Phosphorus for improvement in crop yields

Crops species and their cultivars/varieties vary in (P) requirements for optimum production. Long-term field experience under the conditions of Egyptian land and crops showed significant crop yield responses to (P) fertilizer application in combination with other major plant nutrients. Most of the winter crops responded consistently to (P) application.

Single super phosphate fertilizer

Single super phosphate (SSP), has been the principle phosphate fertilizer for more than a century and has supplied over 60% of the world's phosphate needs as late as 1955. Since then its relative importance has declined steadily: In 1965 it supplied only 20% of the fertilizer phosphate. Thus (SSP) was and still an important fertilizer and will remain so, even though its relative importance has decreased.

- (SSP) will still be a logical choice in many situations;
- Where both P$_2$O$_5$ and sulphur are deficient, (SSP) may be the most economical way to meet these needs.

Chemistry of (SSP)

The main overall chemical reaction that occurs when finely ground phosphate rock is mixed with sulphuric acid in the manufacture of SSP may be represented by the following equation:

$$Ca_{10}F_2(PO_4)_6 + 7H_2SO_4 + 3H_2O \rightarrow 3Ca(H_2PO_4)_2 \cdot H_2O \ + \ 7CaSO_4 \ + \ 2HF$$
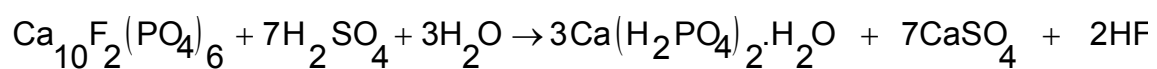
| Fluor Apatite | Sulphuric Acid | Mono calcium Phosphate | Calcium Sulphate | Hydrofluoric Acid |

It is generally, agreed that the reaction proceeds in two stages:

1. Sulphuric acid reacts with part of the rock, forming phosphoric acid and calcium sulphate;
2. Phosphoric acid, which formed in the first step, reacts with more phosphate rock forming mono calcium phosphate.

The two reactions take place concurrently, but the first stage is completed rapidly, while the second stage continues for several day or weeks.
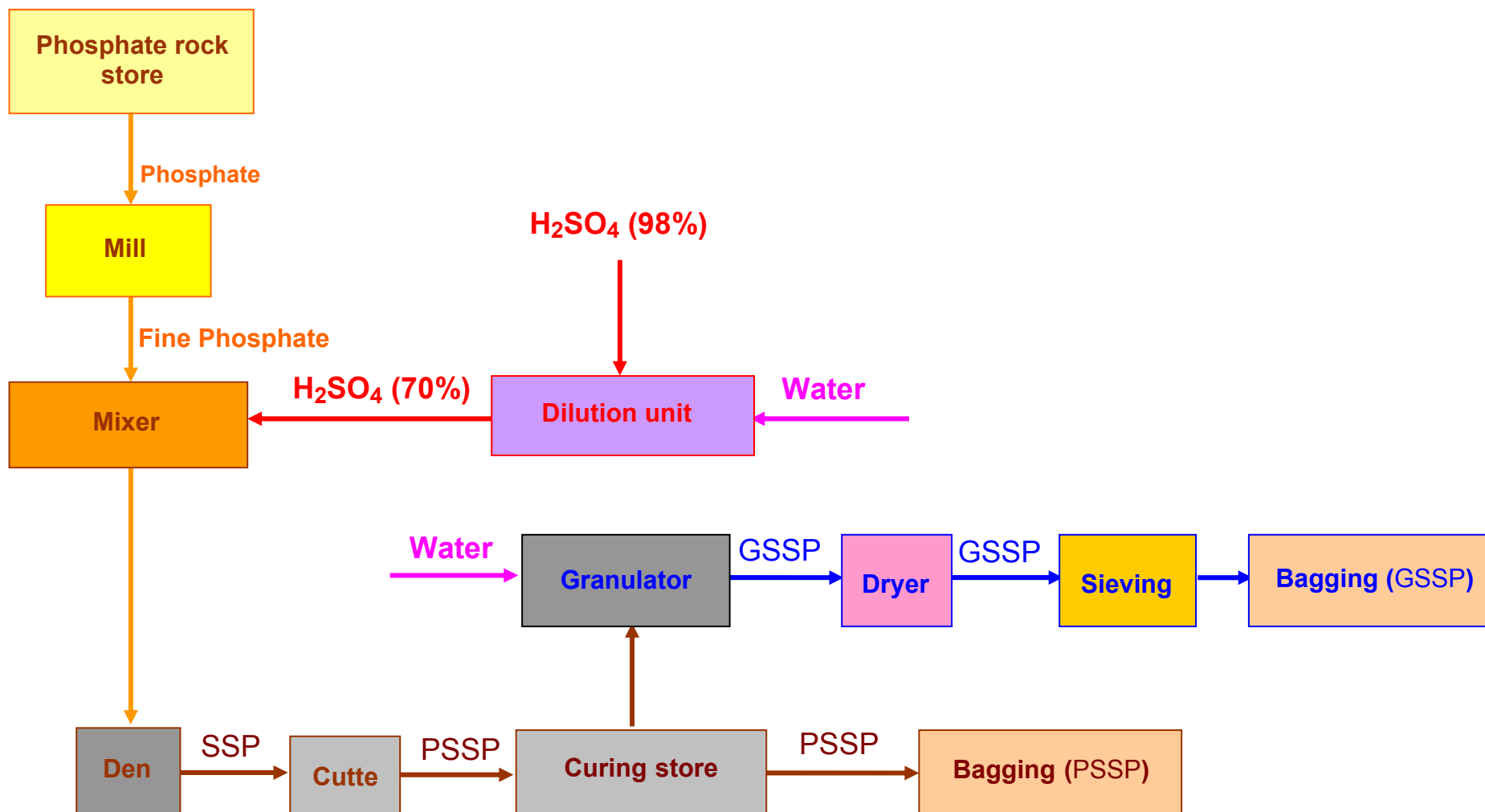
Production method

The manufacture of super phosphate involves the following four operations:

1. Finely ground phosphate rock (90% < 100 mesh) is mixed with sulphuric acid. Phosphate rock with 32% P_2O_5 content and about 0.58 Kg of sulphuric acid 100% basis is required per one Kg of rock;
2. The fluid materials from the mixer go to a den where it solidifies. Solidification results from continued reaction and crystallization of mono calcium phosphate. The super phosphate is excavated from the den after (0.4 – 0.5) hr, its temperature $\cong$ 100 °C;
3. The removed product from the den is conveyed to storage piles for final curing, which requires (2 – 6) weeks, depending on the nature and properties of the raw materials and the condition of manufacture. During curing, the reaction approaches completion. In the free acid, moisture, unreacted rock contents decrease, and the available and water soluble P_2O_5 contents increase. The material hardens and cools. The product from storage is fed to a disintegrator, usually of the hammer-mill or cage mill type. The product from the mill is discharged onto an inclined screen of about (6) mesh size, the material that fails to pass the screen is returned back to the mill for further grinding;
4. If granular super phosphate (GSSP) is desired, the product (PSSP) is granulated either before or after it is cured. Granulation before curing has the advantage that less water or steam is required, after granulation, the product is dried in a fuel - fired dryer and screened; the fines are returned to the granulation unit.

The operation requirements for one ton

	PSSP	GSSP	
Phosphate rock	626	626	kg
Sulphuric acid	380	380	kg
Electricity	30	34	kw
Fuel	0	62	kg
Steam	0	55	kg
Water	100	85	kg
Supervision	0.02	0	mh
Labour	0.15	0.21	mh

Process of Single Super Phosphate (S S P)

Process of Single Super Phosphate (SSP)

- Phosphate rock store → (Phosphate) → Mill → (Fine Phosphate) → Mixer → Den → (SSP) → Cutter → (PSSP) → Curing store → (PSSP) → Bagging (PSSP)
- H_2SO_4 (98%) → Dilution unit; Water → Dilution unit; Dilution unit → (H_2SO_4 (70%)) → Mixer
- Water → Granulator; Curing store → Granulator → (GSSP) → Dryer → (GSSP) → Sieving → Bagging (GSSP)

Air pollution control

Since the beginning of time, nature has evolved and perfected a method dealing with naturally suspended impurities in air and soil, thereby maintaining a delicate balance.

The introduction of artificial impurities into an industrial society has seriously interfered with nature and continues to do so. The problems have reached critical limits in some areas. The possible solutions have continued to inspire the development and growth of a technology whose products are vital to our existence.

Most industrial progress, e.g. cement, stevedoring, flour, storage silos, aluminum, fertilizers, detergents, fodder, flour mills, bakeries, iron, steel, textile, wood works, food, fly ash, ceramics, sugar, chemicals, painting materials etc., emit dust-laden exhaust during the following process:

- Material handling, crushing, sieving and screening;
- Milling, calcinations, packing and transportation.

Air pollution is still one of the big engineering challenges of our time. It requires a professional trained in such disciplines as material and energy balances; thermo-dynamics, fluid dynamics, heat and mass transfer, reaction kinetics, process design and economics.

The governments of all industrialized countries recognize the urgency of this predicament and have developed legislation aimed at reducing emissions of air pollutants while maintaining healthy economic progress.

Large phosphate fertilizer production plants produce many types and configurations of fertilizers in the form of "powders and grains". The grains must comply with the customer needs, so there may be a big sieving and screening system, which generates very fine dust and noise in a big way.

The study reinforces the fact that the environmental performance of the phosphate fertilizer industry has improved over the recent decade, although challenges remain. Our sincere hope is that fertilizer companies will continue striving to achieve cleaner and safer production as a part of their efforts to contribute to sustainable development.

Dust emission control system

This paper explores the techniques used to minimize dust emissions to comply with the Egyptian environmental law n<u>o</u> 4 / 1994 (dust emission ≤ 50 mg/m^3).

Today, separation and filtration equipments are universally used for dust removal in industrial atmosphere and are present in almost every field of industrial activity. Some dust emission control systems have been specially designed to achieve maximum performance that yields less than (3 mg/m^3) outlet dust emission.

The system is based on the collection of gas with a high concentration of suspended dust particles. Such flow of gas is made to pass through cyclones and bag filters.

The following are the main objectives of dust emission control systems designed by our engineers and fabricated in our factories:

- Very advanced, new design, completely sealed screens (7,500mm x 2,500 mm), 200 TPH;
- High efficiency cyclones;
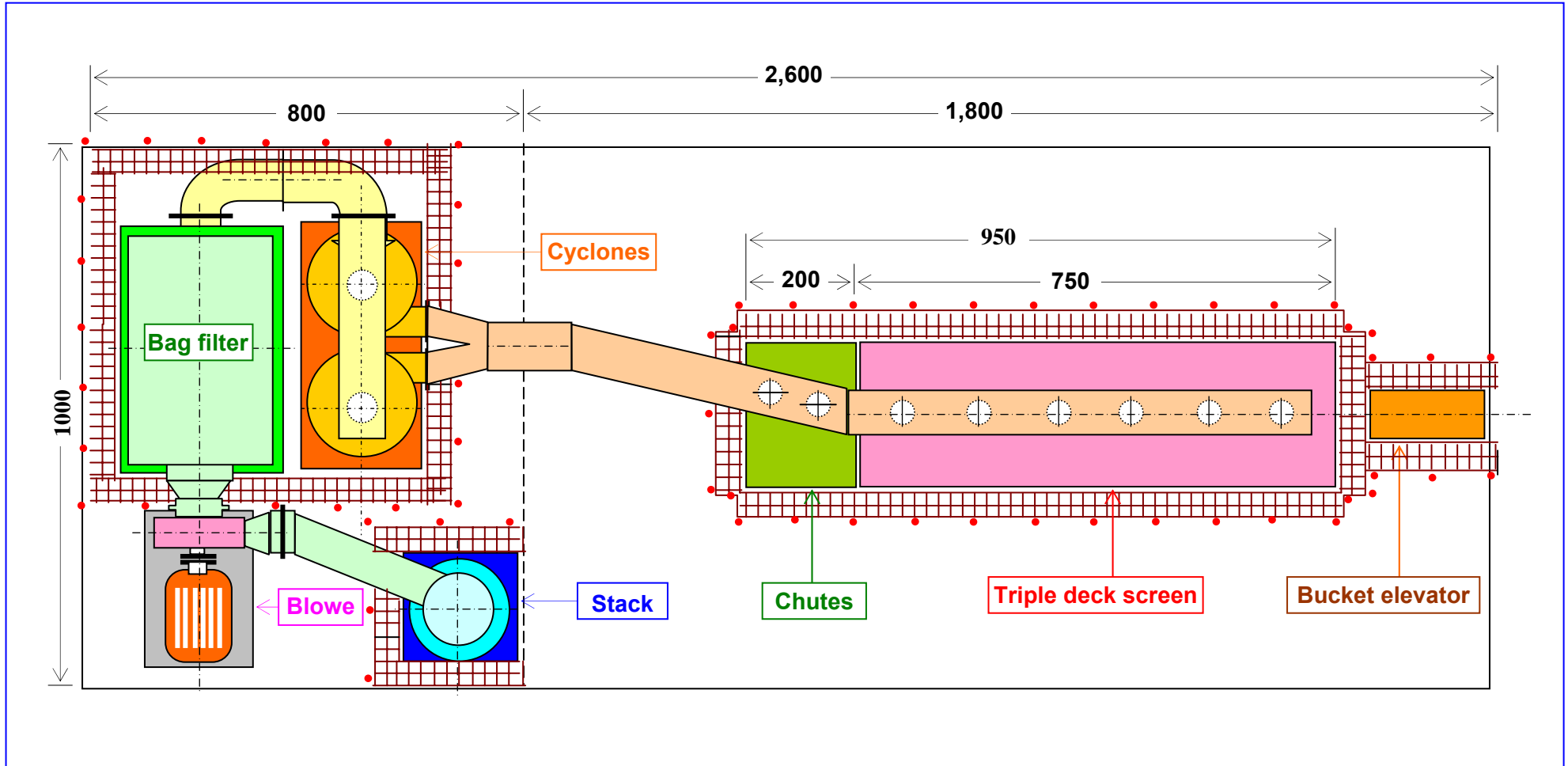- High efficiency filtration system depend on;

- High filtration speed;
- Optimum A / C (air to cloth ratio);
- Convenient design for filter bags with its cage and venture;
- Suitable type of cleaning mechanism (pulse jet);
- Equal gas distribution through the collector;
- Suitable centrifugal fan (type – pressure);
- Extracting material devices (screw, air lock and flaps);
- Ducting system.

The designed control system as arranged is shown in Figure 1.

Figure 1. Dust control system.

Dimension: cm
Scale: 1:100

Labels in figure: Cyclones, Bag filter, Blowe, Stack, Chutes, Triple deck screen, Bucket elevator

Dimensions: 2,600; 800; 1,800; 1000; 950; 200; 750

Cyclone

Devices for particular control include a gravity settling chamber, inertial separators (cyclones), bag house, single and multistage electrical precipitators. In (cyclones), dust- laden gases after entering a cyclone, passes in a circular path, when gases travel 180°, creates a centrifugal force, this force imparted to particulates and drive the heavier dust particles toward the cyclone walls and concentrated near the wall. Carrier gases in which dust particulates are suspended undergoes two confined vortices, one ascending and another descending, whereby the dust particles are separated from the carrier gas.

The primary advantages of cyclone separators are simplicity in construction, design and economy and requiring low initial capital, operational, and maintenance costs. Since there are no moving parts, cyclones are relatively maintenance free. Pressure drops are low and are able to handle large dust loading. The separated dust can easily be removed and smaller area is required. Although cyclones do not have very high collection efficiencies in relation to particle size, they can be used effectively for relatively coarse particles, generally larger than 10 µ.

Classification

There are two main classifications of cyclones based on efficiency:

1. High efficiency cyclones where the inlet gas velocity is higher thereby imparting higher centrifugal force; they are generally < 30 cm diameter and have long cone;

2. High throughput cyclones, where diameters are generally larger, efficiencies moderate and they can handle larger flow rate.

Cyclones can be further classified (based on the positions of three components: the dust – laden gas inlet, clean gas outlet and separated particles outlet) into two categories:

1. Tangential gas inlet with axial/peripheral particulate discharge;

2. Axial gas inlet with axial/peripheral particulate discharge.

Cyclones can be built as either single units or in multiples. Also they can be arranged in series or in parallel, having manifold to give uniform distribution of gas flow as well as particulate concentration. However, only one inlet and one outlet are used.

The two distinct vortexes present in the cyclone are:

1. <u>The descending vortex</u>. It is the helical stream of gases that carry down the dust particles of large diameters which separated along the walls of the cyclone body and cone; these dust particles are ultimately discharged in the dustbin. The gases reverse direction and enter the ascending vortex. Near the apex of the cone, dust is discharged, which consists of particles concentrated near the walls and away from the ascending vortex; they are carried out downwards.

2. <u>The ascending vortex</u>. Somewhere near the dust outlet, the gas from the descending vortex reverses its direction and goes up from the bottom to the top. The ascending vortex carries the clean gas out as centrifugal forces drive the heavier particulates toward the cyclone wall. The length of the ascending vortex is from the dust outlet to the inlet of the gas exhaust duct. This gas may contain particles smaller than the cut size.
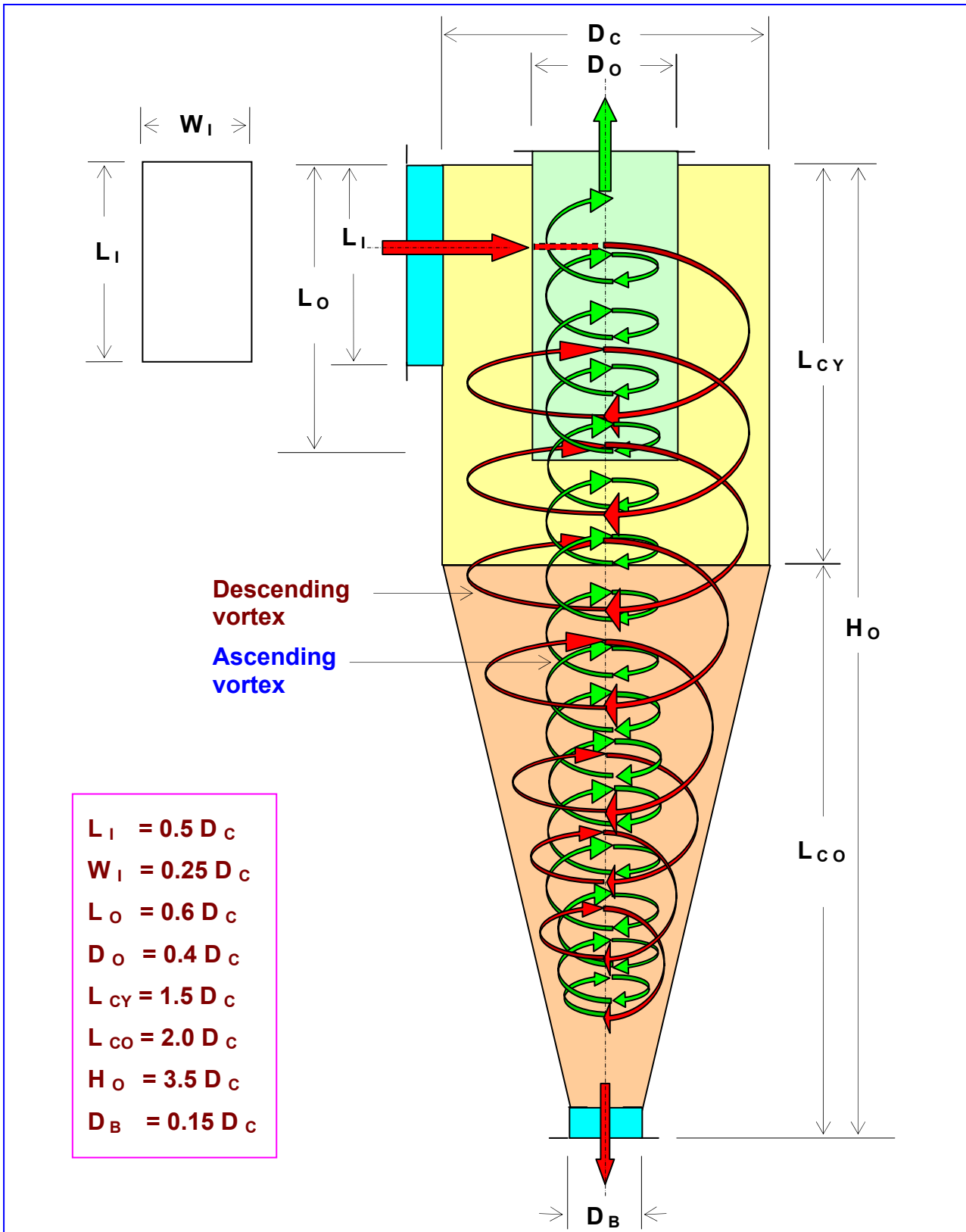
Design Factors

In the cyclone design the following factors must be considered:

1. Dust size distribution, particulate density and shape, physical, chemical properties, such as agglomeration, hygroscopic, stickiness;
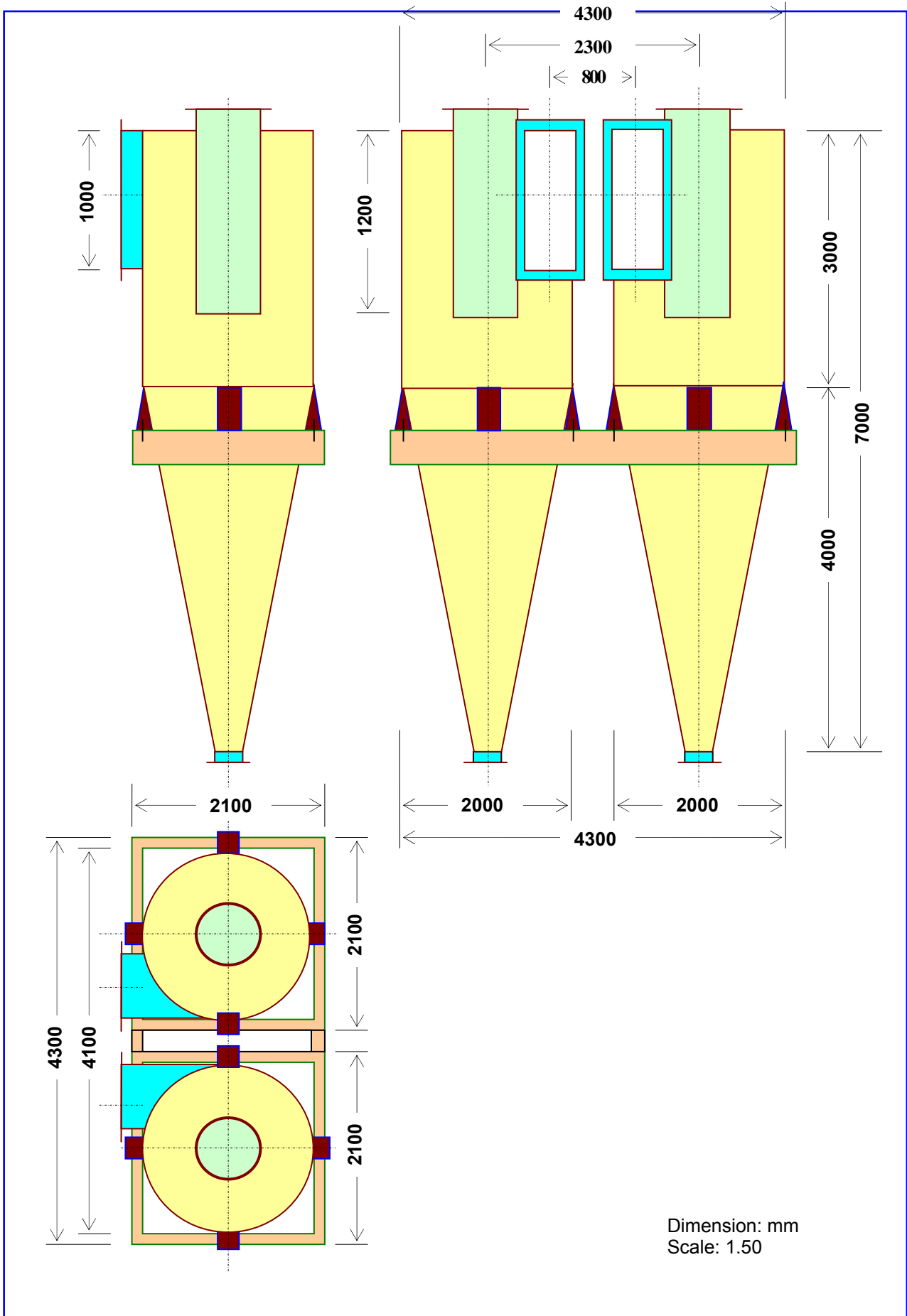
2. Contaminated gas stream; its temperature, pressure, humidity, condensable components, density;
3. Process variables such as dust concentration, gas flow rate, allowable pressure drop, and size top separated;
4. Structure limits, temperature, pressure rating, material of construction and space limits.

Cyclone dimension and parameters are illustrated in Figures 2 & 3.

Figure 2. Cyclone proportional dimensions.

Descending vortex

Ascending vortex

$L_I = 0.5 D_C$

$W_I = 0.25 D_C$

$L_O = 0.6 D_C$

$D_O = 0.4 D_C$

$L_{CY} = 1.5 D_C$

$L_{CO} = 2.0 D_C$

$H_O = 3.5 D_C$

$D_B = 0.15 D_C$

Figure 3. Cyclone arrangements.

Dimension: mm
Scale: 1.50

Cut size

Theoretically, there is a "Cut Size" for cyclones. Gas laden with larger particles that will be removed efficiently, where smaller particles than the cut size will go out with "clean" gases. The following equation can be used to estimate the cut size: (1)

$$d_{Pc} = \left(\frac{9 \, \mu_f \cdot w_i}{2\pi \, N_e \, V_i (\rho_s - \rho_f)} \right)^{0.5}$$

Rosen derived the following equation for the minimum particle diameter, that be completely separated from the gas stream: (3)

$$d_{pn} = \left(\frac{9 \, \mu_f w_i}{\pi \, N_e \, V_i \, (\rho_s - \rho_f)} \right)^{0.5}$$

Where:

d_{pc} : Cut size particle diameter collected at 50% efficiency, cm.

d_{pn} : The diameter of smallest size theoretically completely collected, cm.

μ_f : Fluid viscosity (air), gm/cm.sc.

W_i : Cyclone inlet width, cm.

N_e : Effective number of turns within cyclone, dimensionless.

V_i : Inlet velocity, cm/sc.

g : Acceleration, cm/sc^2.

ρ_s : Density of solid particles, gm/cm^3.

ρ_f : Density of fluid (air), gm/cm^3.

The effective number of turns made by gas (N_e) can be calculated from the formula: (3)

$$N_e = \frac{\left(V/Q \right) V_i}{\pi D_C}$$

The effective volume, V, of the cyclone is: (3)

$$V = \frac{\pi}{4} \left[\left(\frac{L_{co}}{D_C - D_B} \right) \left(\frac{D_C^3 - D_B^3}{3} \right) + D_C^2 \cdot L_{cy} - D_o^2 \cdot L_o \right]$$

$$= 0.7854 \left[\left(\frac{2.0 D_C}{D_C - 0.15 D_C} \right) \left(\frac{D_C^3 - \overline{0.15 D_C^3}}{3} \right) + D_C^2 \cdot 1.5 D_C - 0.4 D_C^2 \cdot 0.6 D_C \right] = 1.717 D_C^3$$

$$Q = V_i \left(L_i * w_i \right) = 0.125 \, D_C^2 \cdot V_i$$

$$N_e = \frac{\left(1.717 D_C^3 / 0.125 D_C^2 \cdot V_i \right) V_i}{\pi D_C} = 4.37 \text{ turn.}$$

The reason d_{pc} particle size is measured at 50% efficiency is due to the fact that the practical efficiency curve meets the theoretical cut size curve at approximately 50% efficiency.

Pressure drop

Cyclone pressure drop, ΔP, is dependent mainly on the velocity. There are several equations provided to describe pressure drop in cyclone. The most often used is Shepherd-Lapple equation as modified by Briggs for dust loading: (4)

$$\Delta\rho = 8.19 \times 10^{-3} \rho_f \ V_i^2 \left(\frac{LiWi}{D_o^2} \right) \left(\frac{1}{0.0057Ci+1} \right)$$

Where:

ΔP : Pressure drop, cmw.
V_i : Inlet velocity, cm/sc.
ρ_f : Density of fluid (air), gm/cm^3.
L_i : Inlet length, cm.
W_i : Inlet width, cm.
D_O : Outlet diameter, cm.
C_i : Inlet dust loading, gm/m^3.

Notes:

-   Excessive pressure drop can affect collection efficiency.
-   Pressure drop decrease as dust loading increase.

Overall efficiency

Industrial efficiencies can be calculated using particle cut diameter $d_{PC,}$ and particle mass mean diameter d_m, Theodore shows that overall fractional efficiency $\left(E_o \right)$ is: (4)

$$\text{Efficiency} \ \left(E_o \right) = \frac{1}{1 + \left(\dfrac{dpc}{dm} \right)}$$

$\left(E_a \right)$ Actual efficiency = theoretical efficiency $\left(E_o \right)$ - (10 – 15) %. (Practical)

Where:

d_{pc} : The particle cut diameter, cm.
d_m : The particulate mass mean diameter, cm.

Cyclone Proportional Dimensions (4)

D_C	: Body (cylinder diameter)	= 1Dc	= 2,000 mm
L_I	: Inlet length (height)	= 0.5 Dc	= 1,000 mm
W_I	: Inlet width	= 0.25 Dc	= 500 mm
LO	: Outlet length	= 0.6 Dc	= 1,200 mm
DO	: Outlet diameter	= 0.4 Dc	= 800 mm
Lcy	: Cylinder length	=1.5 Dc	= 3,000 mm
Lco	: Cone length	=2.0 Dc	= 4,000 mm
HO	: Over all length	= 3.5 Dc	= 7,000 mm
DB	: Bottom diameter	= 0.15 Dc	= 300 mm
L	: Natural length	= 2.04 Dc	≥ 3,680 mm
G	: Configuration factor (depends upon design)	= 600	

Natural length (L) of a cyclone is considered to be the length required for a complete gas vortex configuration, and should be less than the overall cyclone height (minus) the gas outlet (L_O) to maintain the full gas vortex. This is given by Leith and Licht as: (4)

$$L = 2.3 D_O \left(D_C^2 / L_i w_i \right)^{\frac{1}{3}} = 2.3 * 800 \left[\frac{2000^2}{1000 * 500} \right]^{\frac{1}{3}} = 3,680 \text{ mm}$$

Volumetric flow rate (Q) is roughly approximated by: (4)

	High efficiency	**Conventional**	**Low efficiency**
Q (m³/h)	5,480 D_C^2	6,850 D_C^2	15,350 D_C^2

Q = 50,000 m³/h = (6.945 m³/sc)   (For two conventional cyclones arranged in parallel)

<u>For one cyclone</u>:

Q = 25,000 m³/h = 6850 D_C^2 (I.e.) D_C = 1.91 m ≅ 2 m

$$V_i = \frac{6.945}{0.5} = 13.89 \text{ m/sc} = 1389 \text{ cm/sc}$$

Cut size $$\left(d_{pc} \right) = \left[\frac{9 \, \mu_f \, w_i}{2 \pi N_e V_i (\rho_s - \rho_f)} \right]^{0.5}$$

$$= \left(\frac{9 * 1.84 * 10^{-4} * 50}{2 \pi * 4.4 * 1389 \left(1.05 - 1.22 * 10^{-3} \right)} \right)^{0.5}$$

$$= 1.434 . 10^{-3} \text{ cm} = 14.34 \mu m$$

The reason d_{pc} particle size is measured at (50% efficiency), is due to the fact that the practical efficiency curve meet the theoretical cut size curve at approximately 50% efficiency

$$d_{pn} = 1.414 \ d_{pc}$$
$$= 1.414 * 14.34 = 20.27 \mu m \qquad \cong 20 \ \mu m$$

Efficiency $(E_{th}) = \dfrac{1}{1 + \dfrac{d_{pc}}{d_m}}$ & (dm = 65 μm)

$$(E_{th}) = \dfrac{1}{1 + \left(\dfrac{14.34}{65}\right)} = 0.82$$

Actual efficiency (E_{ac}) = 82% - 12% = 70%

Pressure drop

$$\Delta P = 8.19 * 10^{-3} * \rho_f V_i^2 \left(\dfrac{L_i w_i}{D_o^2}\right)\left(\dfrac{1}{0.0057 C_i + 1}\right)$$

$$= 8.19 * 10^{-3} * 1.22 * 10^{-3} * \overline{1389}^2\left(\dfrac{100 \cdot 50}{80^2}\right)\left(\dfrac{1}{0.0057 \cdot 50 + 1}\right) = 11.72 \ \text{cmw}$$

Practical application of the proposed cyclone

It is found that:
- Dust load before cyclone = 50 g/m^3
- Dust load after cyclone = 15 g/m^3
- Pressure drop through cyclone = 11.7 cmw
- Efficiency of cyclone = 70%

Bag filter

Fabric filtration is a widely accepted method for particulate emissions control. In fabric filtration the particles laden gas flow through a number of filter bags placed in parallel, leaving the dust retained by the fabric.

Extended operation of a fabric filter requires that the dust be periodically cleaned off the cloth surface and removed from the bag house. After a new fabric goes through a few cycles of use and cleaning, it retains a residual cake of dust that becomes the filter medium. This phenomenon is responsible for the highly efficient filtering of small particles.

Most of energy requirement of the system are to overcome the gas pressure drop across the bags, dust cake, and associated ductwork.

The most important distinction between fabric filters design, is the method used to clean the dust from the bags between filtration cycles, there are three methods for cleaning.

Shaker cleaning

Used with inside to outside gas flow, the bags are suspended from a motor-driven hook or frame that oscillates and the motion creates a sine wave along the fabric, which dislodges the previously collected dust and falls into a hopper below the compartment.

1. Reverse air cleaning. Used with fiber glass fabric, a gentler means of cleaning the bags is needed to prevent bag failure. Gas flow to the bags is stopped in the compartment being cleaned and a reverse flow of air is directed through the bags. This reversal of flow gently collapses the bags and the shear forces developed remove the dust from the surface of the bags.

2. Pulse – Jet cleaning. Used with gas flow from outside to inside, this process forces a bust of compressed air down through the bags, expanding it violently. When the fabric reaches its extension limit, the dust separates from bags. Bags are mounted on wire cages to prevent collapse while the dusty gas flows through them. The top of the bag and cage assembly is attached to the bag house structure; the bottom end is loose and tends to move in turbulent gas flow. Bags are cleaned by rows when a timer initiates the bust of cleaning through a quick opening valves usually 10% of the bags is pulsed at zones. A pipe above each row of bags carries the compressed air and the pipe is pierced above each bag so the cleaning air exits directly downward into the bag via a special designed venture that allows the compressed air to expand to a lower pressure to avoid the bag failure. The pulse opposes and interrupts forward gas flow for only a fraction of second. However, the quick resumption of forward flow re deposits some of the dust back on the clean bags or on adjacent bags.

Some particles pass through the bag house and reduce the overall efficiency of the dust collector; this called "penetration". There are two basic mechanisms for penetration:

1. Particles can escape collection through leaks in, ducting, tube sheet, or bag clamps, or through holes, tears, or improperly sewn seams in the bags themselves;
2. Particles movement through the dust cake and fabric, also known as "bleed through" Bleed through is primarily a function of bag house design and particle morphology.

Design of bag filter

The most important design parameter is the ratio of the gas volumetric flow rate to fabric area, known as gas to cloth ratio (for pulse jet **ACR ≤** 4.07 cm/sc), that produces the optimum balance between pressure drop and baghouse size. Other important parameters include the operation pressure drop, cloth area, cleaning mechanism, fabric type, life and other properties, bag house configuration and cost, beside process variables include particle characteristics; size distribution and stickiness, gas characteristics; temperature and corrosively.

Pressure drop

There are several contributions to the total pressure drop across bag house including the pressure drop from flow through the inlet and outlet ducts, from flow through the hopper regions, and from flow through the bags.

The most often used equation to describe pressure drop in a fabric filter system is: (5)

$$\Delta P = K_1(V_f) + K_2 (c) (V^2_f)t$$

Where:

ΔP	:	Pressure drop	cmw
V_f	:	Filtration velocity	= 2.08 mpm
K_1	:	Friction coefficient of bag	= 1.9
K_2	:	Friction coefficient of cake	= 8.3
C	:	Dust concentration (kg/m^3)	= 0.015 kg/ m^3
t	:	Filtration time	= 12 mn
		Bag diameter / length	= 125 / 2500 mm
		No of bags / type	= 400 / (felt fabric)
		Fluid flow rate	= 50,000 m^3 / h
		Fluid density (ρ_f)	= 1.225 x 10^{-3} gm / m^3
		Dust load	= 15 gm / m^3

$$\Delta P = 1.9 \times 2.08 + 8.3 \times 0.015 \times 2.08 \times 12 \cong 11.2 \quad cmw$$

However, the use of high velocity filtration felt fabrics, or the presence of sticky or low porosity cake often develop pressure drop on the order of (15 – 25) cmw.

Filter design and dimensions are presented in Figures 4 & 5.

Practical application of the proposed bag filter

It is found that:
- Dust load before bag house   = 15 gm / m^3
- Dust load after bag house   = 3 mg / m^3
- Pressure drop through bag house = 11.2 cmw
- Efficiency of bag house   = 99 %
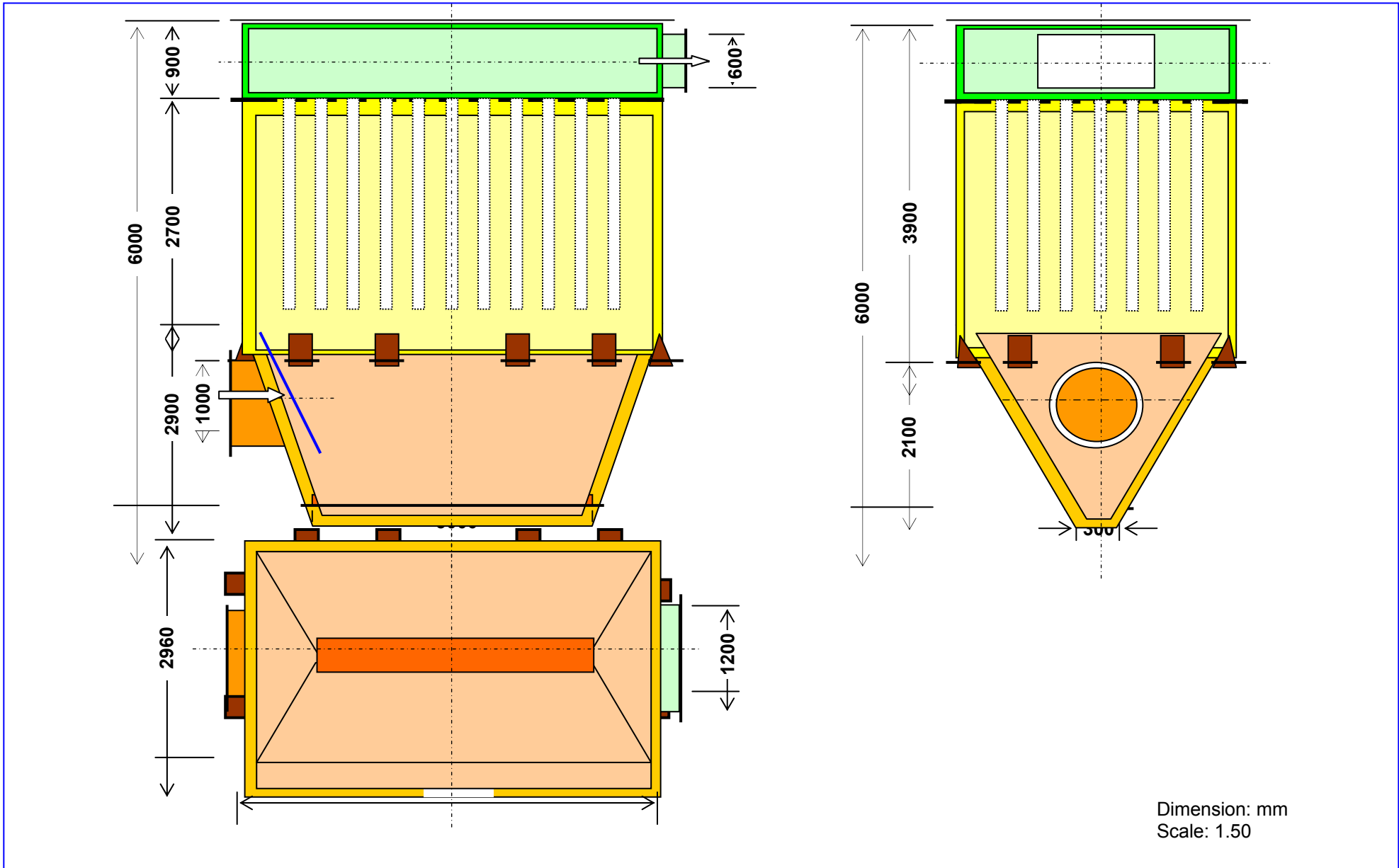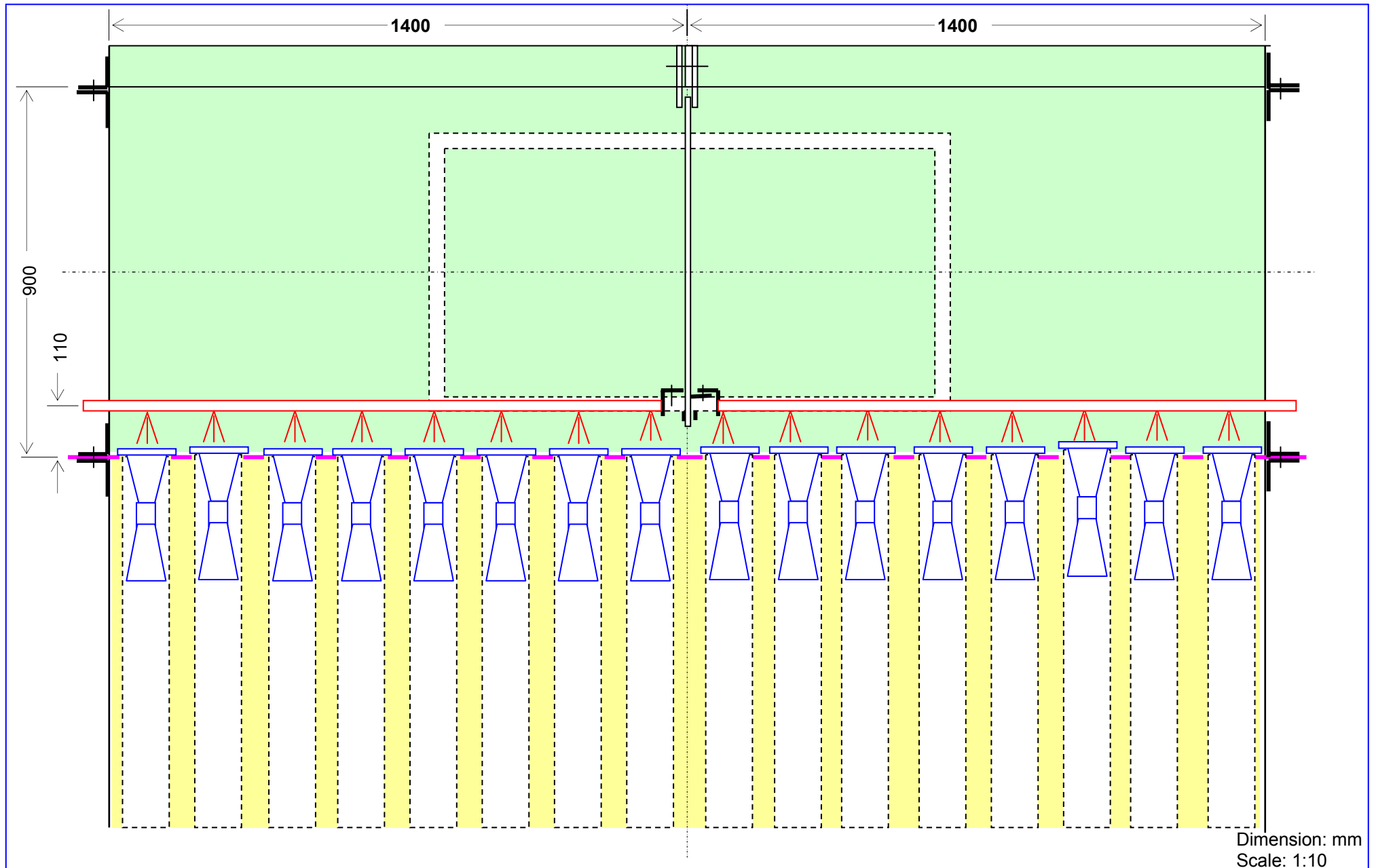
Figure 4. Bag filter.

Dimension: mm
Scale: 1.50

Figure 5. Air pulse system.

Dimension: mm
Scale: 1:10

Conclusions

From the above study, the following conclusions can be drawn:

1. - Dust load before cyclone   = 50 g /m^3
   - Dust load after cyclone   = 15 g / m^3
   - Pressure drop through cyclone   = 11.7 cmw
   - Efficiency of cyclone   = 70 %

2. - Dust load before bag filter   = 15 g /m^3
   - Dust load after bag filter   = 3 mg / m3
   - Pressure drop   = 11.2 cmw
   - Efficiency of bag filter   = 99 %

3. - Dust load before de dust system   = 50 gm /m^3
   - Stack dust emission   = 3 mg / m3
   - Pressure drop through the system   = 22.9 cmw
   - Efficiency of de dust system   = 99 %

Similar design approaches can be applied in other industrial plants to remove dust particles from the air stream.

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