

**REMOVAL EFFICIENCY OF SPIRAL SHEET CYCLONE FOR
SAND DUST**

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OF THE REQUIRMENTS FOR THE DEGREE OF
MASTER OF SCIENCE (INDUSTRIAL HYGIENE AND SAFETY)
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Thesis
entitled
**REMOVAL EFFICIENCY OF SPIRAL SHEET CYCLONE FOR
SAND DUST**

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REMOVAL EFFICIENCY OF SPIRAL SHEET CYCLONE FOR SAND DUST

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ABSTRACT

A removal efficiency test of a spiral sheet cyclone for sand dust was done by design and fabrication of a cyclone shape spiral sheet. The sheet was rolled into a helix shape and installed internally to control air mixed with sand dust that is sucked in a tangential direction and touches the spiral sheet surface to create a vortex effect that separates sand dust, which then drops to the bottom of the spiral sheet cyclone.

Design of the spiral sheet cyclone dimension and shape is based on the Stairmann's hypothesis size of spiral sheets and calculated by using the Stroke's equation. Final dimensions were a diameter of 500 mm., cylindrical length of 800 mm., cone length of 1,000 mm., and total length of spiral sheet at 2,900 mm..

To determine the size of experimental sand dust, it was separated by sieve into 5 ranges: 1-53, 57-75, 75-106, 106-150, and 150-212 micron. In the experiment, sand dust had 4 different flow rates: 19.5, 23.4, 27.41, and 32.72 cubic-meter/min. Determination of the efficiency found that removal efficiency of the spiral sheet cyclone for sand dust has a statistically significant efficiency of 90% (p -Value <0.05) and has an average sand dust removal of 96.69%, with standard deviation of 5.97 – 13.42.

KEY WORDS: CYCLONE/SPIRAL SHEET

60 pages

การศึกษาประสิทธิภาพของสไปรอลชีทไซโคลนในการขจัดฝุ่นทราย

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บทคัดย่อ

การทดสอบประสิทธิภาพของสไปรอลชีทไซโคลนในการขจัดฝุ่นทราย โดยการออกแบบสร้างสไปรอลชีทไซโคลนมีรูปร่างคล้ายกับไซโคลน ออกแบบให้มีแผ่นโลหะม้วนกลมแบบก้นหอยติดตั้งประกอบอยู่ภายในเพื่อบังคับให้ลำอากาศที่มีฝุ่นทรายปนเปื้อนที่ส่งเข้ามาในทิศทางแนวสัมผัส ไหลสัมผัสกับแผ่นก้นภายในเกิดกระบวนการแบบวอร์เท็กซ์แยกฝุ่นทรายให้ตกลงด้านล่างของสไปรอลชีทไซโคลน

การออกแบบกำหนดสัดส่วนและรูปร่างของสไปรอลชีทไซโคลนใช้สมมติฐานของสเตแมนด์ส่วนความยาวของแผ่นก้นวอร์เท็กซ์ประยุกต์ใช้สมการของสโตรคซึ่งได้ขนาดเส้นผ่าศูนย์กลาง 500 มิลลิเมตร ความยาวทรงกระบอก 800 มิลลิเมตร ความยาวกรวย 1000 มิลลิเมตร ความยาวของแผ่นสไปรอลชีท 2900 มิลลิเมตร

ฝุ่นทรายที่ใช้ในการทดลองได้จากการคัดขนาดโดยเครื่องร่อนเลือกมาทดลอง 5 ช่วงขนาดได้แก่ช่วงขนาดระหว่าง 1-53, 57-75, 75-106, 106-150, และ 150-212 ไมครอน นำฝุ่นทรายมาปล่อยด้วยอัตราการไหลที่แตกต่างกัน 4 ระดับคือ 19.5, 23.4, 27.41, และ 32.72 ลูกบาศก์เมตรต่ออนาที และคำนวณหาประสิทธิภาพในการขจัดฝุ่นทรายพบว่ามีประสิทธิภาพในการขจัดฝุ่นทรายของสไปรอลชีทไซโคลนสูงกว่าร้อยละ 90 อย่างมีนัยสำคัญทางสถิติ ($p\text{-Value} < 0.05$) โดยมีค่าเฉลี่ยในการขจัดฝุ่นทรายทุกขนาดร้อยละ 96.69 มีส่วนเบี่ยงเบนมาตรฐานระหว่างร้อยละ 5.97 – 13.42

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LIST OF SYMBOLS

Symbol		
F_d	Drag Force	N/m^2
D	Particle Diameter	$\mu(\text{micron})$
ρ_a	Air Density	Kg/ m^3
ρ_f	Fluid Density	Kg/ m^3
ρ_p	Particle Density	Kg/ m^3
V	Velocity	m/sec
V_o	the speed is initial	m/sec
V_{avg}	Average Velocity	m/sec
V_t	Terminal velocity	m/sec
μ_a	Air Viscosity	$Kg/ m.s$
g	Gravity	m/ sec^2
C_d	Drag Coefficient	
Re	Renold number	
C	Cunningham correction factor	
A	An experimentally determined constant	
λ	Mean Free path	
$X_{\text{stokes stopping}}$	fall distance of the particle	μ
D_a	Aerodynamic Particle Diameter	μ
L	Lenght	m
W_i	Wide of cyclone inlet	m
H	Height	m
r	radius	m
f	Dracy Friction Factor	
D_i	Inlet Diameter	m

LIST OF SYMBOLS(cont.)**Symbol**

η_i	Grade of Efficiency	%
η	Total Efficiency	%

CHAPTER I

INTRODUCTION

1.1 Background and significant of problem

Air pollution means the atmosphere that contains high degree of contamination for long time which can cause unhealthy of human, animals, plants and other materials. The major poisonous substance is dust, lead, carbon monoxide and sulfur dioxide.

Air pollution system consist of three related parts as follows :

1. Emission Sources
2. Atmosphere
3. Receptors

As per table of relations in figure 1. (8)

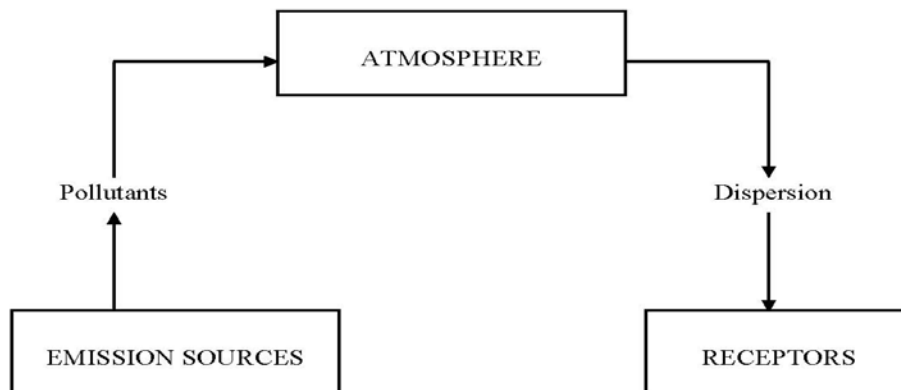


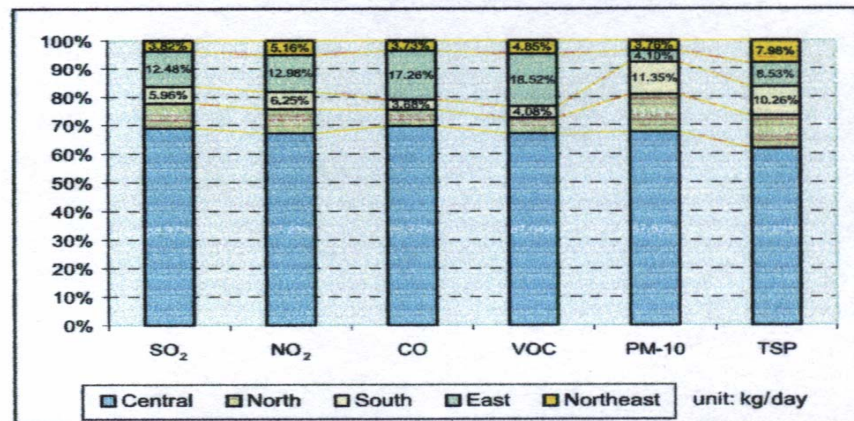
Figure 1.1 Air pollution system.

There are two types of air contaminant things: gas and aerosol that sources from (1,8)

1. Human: from industrial manufacturing process and agricultural etc.

2. Natural: volcano burst, wild fires etc.

Fuel combustion process, industrial manufacturing process and transportation were sources of air contaminant things as particulate matters; fume, mist and smoke especially within urban region and industrial zone toxicity dust were found in very high level. Total amount of pollution is released from fuel combustion process, industrial manufacturing process all over the world has volume of 0.1 -0.3 million-ton per day (1). Source of air pollution in Thailand divided into four major sources which are industrial factory, electricity power plant, land vehicle and local area source. Among all these four sources, the industrial factory releases the highest amount of air pollution which is equal to 60-70%. The industry that release the highest degree of dust is cement industry, gasoline and paraffin, non-metal, steel, sugar plant and refinery plant consecutively (8).



Source: *Environmental Institutions Development Technical Assistance, The World Bank, Estimate of Industrial Emissions Thailand, 2000.*

Note: Total industrial emission of SO₂ is 1,352,126. NO₂ is 830,273. CO is 817,475. VOC is 526,125. PM₁₀ is 468,929. TSP is 600,572.

Figure 1.2 Industrial Emissions in Thailand, 2000

Dust condition in urban region found that amount of micro particle dust (PM10) is exceed limit of 50 micro-gram/cubic-meters e.g. in Bangkok by the record since 2538 to 2550.(2)

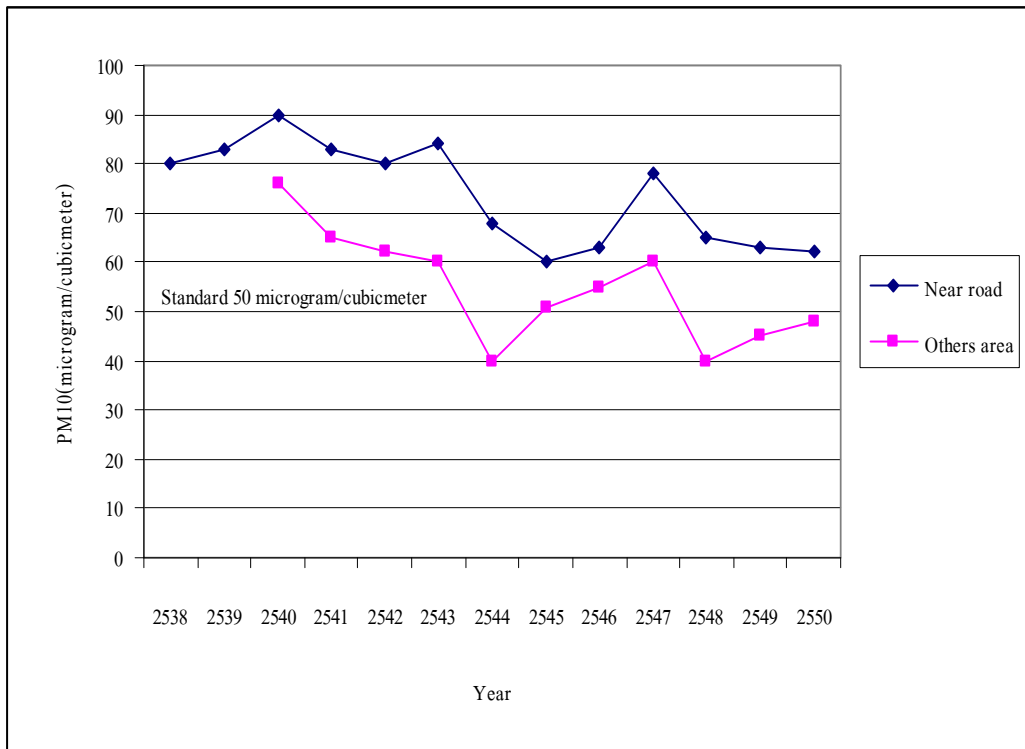


Figure 1.3 Illustrate amount of micro dust within Bangkok

Air pollution relating to dust is continue build up annoying trouble to communities supported by complaints via the Pollution Control Department e.g. during 2549 – 2551 there are dust trouble complaint as 22 -24% of all pollution trouble.(2)

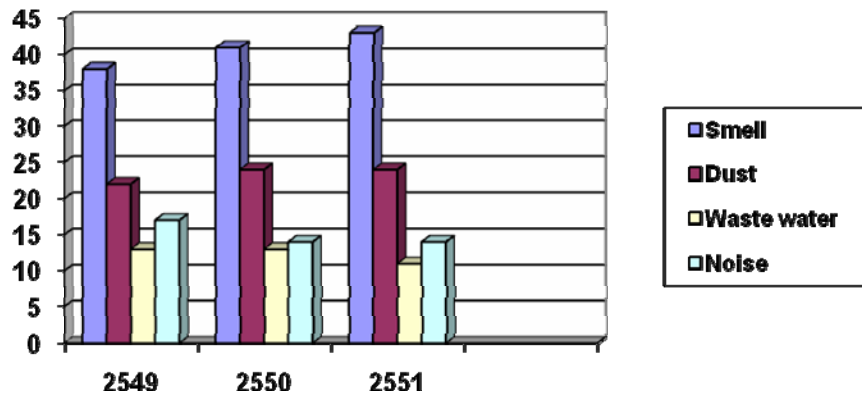


Figure1. 4 Illustration amount of pollution complaint via the Pollution Control Department

Micro dust harm to human by enter into breathe system and infiltrate to interstium and imphatic system create asthma, chronic trachea disease eye and throat irritation and reduce efficiency of lung (3). In 2541, the World Bank has financially supported a study about an impact of dust towards the healthiness of people in Bangkok. The study found that the degree of dust in Bangkok has impact towards the healthiness in a high level close to the findings of the other study in big city around the world. The degree of micro dust can cause an early death of Bangkok people around 4,000 – 5,500 cases in a year. Further more, the findings presented the relations of hospital admission and micro dust, the economical appraisal presented that if the micro dust (PM_{10}) in the air can be reduced by 10 microgram per cubic metre then it can reduce healthiness impact in terms of medical expenses for 35,000 – 88,000 million baht per year.

Pollution has effected to manufacturing industrial since the International Organization for Standardization: ISO has established the requirement of the Environmental Management Standard: ISO-14000 requires the organization to maintain, control, and improve the quality of environment. Hence, dust pollution that formed one of factor to determine whether organization have certified according to ISO14000 and was on of factor prescribed within sell contract with customer. (4)

Law requirement relating to air pollution control within industrial sector in Thailand announced by the Department of Industrial Works, Ministry of Industry on “Definition of released air contaminant things B.E. 2548” Illustrate as following table: (6)

Type of adulterated thing	Source	Amount mixing in air	
		Non-fuel combustion	Fuel -combustion
1. Total Suspended Particulates (mg/cu-m)	Heat source that use		
	Fuel oil		240
	Coal		320
	Bio-mass		320
	Other fuel		320
	Smelting, casting, press and/or		
	Produce		
aluminum	300	240	
general	400	320	

Table 1.1 Illustration air contaminant things releasing form industry defined by the Department of Industrial Works

Purpose of dust collection (11)

Dust collection is concerned with the removal or collection of solid dispersoins in gases for purpose of

1. Nuisance elimination as in cleaning of ventilation air or fly-ash removal from power-plant combustion gases.
2. Equipment maintenance reduction as in filtration of engine-intake air or pyrites furnace-gas treatment prior to its entry to a chamber sulfuric acid system.
3. Safety- or health-hazard elimination as in collection of siliceous and metallic dusts around grinding and drilling equipment and insome metallurgical operations and flour dusts from milling or bagging operations.
4. Product-quality improvement as in air cleaning in the product of pharmaceutical products and photo-graphic film.
5. Recovery of a valuable product as in collection of dusts from dryers and smelters.

6. Powdered-product collection as in pneumatic conveying; the spray drying of milk, eggs and soap; and the manufacture of high-purity zinc oxide and carbon black.

Control of pollution contaminated with air to environment is considered upon following criteria (5) :

1. Concentration that harm to human
2. Require by law
3. Reduce pollution create better living, environment
4. Pollution that cause reduce or disappear of responsibility latency

Conceptual for control produced pollution within manufacturing process can be set into two types (1,7):

1. Improve productivity and reduce use of hazard material.
2. Eliminate pollution occur during process before release out to environment.

Therefore, concept of control dust before release air to environment, is to separate dust from air. There are five type of equipments for dust separation from air are including: (3,8)

- 2.1 Setting chamber
- 2.2 Centrifugal separators e.g. cyclone
- 2.3 Wet scrubber
- 2.4 Filters
- 2.5 Electrostatic precipitators

The most prevalent type of mechanical collector is cyclone. Although more complicated in design than simple gravity systems. cyclons still provide a relatively low – cost method of removing particulate matter form exhaust gas streams. Hence their removal efficiency is accordingly much beeter than that of settling chambers. However, cyclones are not efficiency as baghouses, ventury scrubbers, and electrostatic precipitators, but are often installed as precleaners before these more effective devices.

Cyclones have no moving parts and come many sizes and shapes. Regardless of this fact, the basic separation principle remains the same. Particle enter the cyclone with the flowing gas; the gas stream is forced to turn, but the larger

particles have too much momentum and cannot make the turn. These particles collide with the cyclone wall, slide down the wall, and are collected in hopper. Much like the funnel of a tornado, the gas stream actually turns a number of times in a helical pattern. This provides many opportunities for particles to break through the streamline, thus hitting the cyclone wall.(5)

Due to its relative simplicity to fabricate, low cost to operate and well adaptability to extremely harsh conditions, cyclone separators have become one of the most important particle removal devices that preferably is utilized in both engineering and process operations. However, the increasing emphasis on environmental protection and gas-solid separation is indicating that finer and finer particles must be removed. To meet this challenge, the improvement of cyclone geometry and performance is required rather than having to resort to alternative units. Many researchers have contributed to a large volume of work on improving the cyclone performance, by introducing new inlet designs and operation variables. These include studies of testing a cyclonic fractionator for sampling that used multiple inlet vanes by Wedding et al.(18), developing a mathematical model to predict the collection efficiency of small multiport cyclones by DeOtte(19), testing multiple inlet cyclones based on Lapple's type geometry by Moore and McFarland(20),

The Lapple research has found that the efficiency to separate dust by the cyclone is based on the hypothesis that the outside air twisted must have the number of turns enough for the dust to separate away from the center. By calling the number of air twisters that "the number of effective turns" or N_e , which is the non-unit variable.(21) that conform to the study of Zhao Jialin and Gao Qinyou who study the efficiency of spiral sheet cyclones and conventional cyclones found that the spiral sheet cyclone has lower pressure loss, higher collection efficiency and more sampling flow rate than conventional cyclones(16)

The concept of particle separation with a spiral sheet cyclone in this study is using centrifugal separation e.g. by installing a spiral sheet inner cylindrical controlling air stream helical flow to remove dust from air and fall down to bottom, releasing only fresh air to the environment through an outlet located at the top of the cylindrical.

1.2 Objectives

1.2.1 To study, design and fabricate spiral sheet cyclone equipment.

1.2.2 To determine the removal efficiency of spiral sheet cyclone equipment eliminating dust in the air.

1.3 Hypothesis

1.3.1 Efficiency of spiral sheet cyclone equipment is over than 90%.

1.3.2 Changing of inlet air flow rate to spiral sheet cyclone is effect to its efficiency.

1.4 Variables

1.4.1 Independent variable

1.4.1.1 Inlet air flow rate to spiral sheet cyclone equipment

1.4.1.2 Size of sand dust

1.4.2 Dependent variable

1.4.2.1 Removal efficiency of spiral sheet cyclone for sand dust

1.5 Scope of study

1.5.1 Design, fabricate and examine removal efficiency of spiral sheet cyclone for sand dust.

1.5.2 Use dust particle size 1.1-212 micron for removal efficiency examination.

1.6 Limitation of study

This research is conducted by design and fabrication spiral sheet cyclone to experiment by fix dimension of all components of spiral sheet cyclone and vary inlet air flow rate, air velocity and sand dust particle size during of test and determine removal efficiency of spiral sheet cyclone. Experimental is conducted in the open air unable control factor such as temperature, humidity and atmospheric wind velocity.

1.7 Outcomes and benefit

1.7.1 Clearly know removal efficiency of built spiral sheet cyclone for sand dust.

1.7.2 Acquire prototype and final concept for design and fabricate air dust separator.

1.7.3 Gathering results of study as guideline for further research and development.

1.8 Definition of this research

1.8.1 Particle matter that are suspend in the air both in solid and liquid form has single molecule and size up to 100 micron that solid particle e.g. dust, fume, smoke, ashes and fibre and liquid e.g. mist etc.

1.8.2 Dust was solid particle diffused into air causing form work such as cutting, press, grind, crash, explode etc. that dust has uncertain shape, different size bigger particle will immediately fall to ground except small dust particle will suspend in the air for long time dust that have particle size less than 10 micron will be breathed into deep breathing system and accumulated at by dust particle over than 10 micron will be breathed to upper breathing system all these dust may be call total dust.

1.8.3 Smoke composing of fine particle that the diameter less than 1 micron with complexity structure. Smoke usually is causing from imperfection burning of main carbon composition substance e.g. fuel, coal etc.

1.8.4 Gases maintain its state at ambient temperature and normal atmospheric pressure e.g. Co₂ and its state can become fluid or solid when pressure is applied and reduce temperature.

1.8.5 Spiral sheet cyclone capacity mean capacity of spiral sheet cyclone on dust entrapping within device that is calculated by concentration of input dust minus with output dust divide by concentration of input dust and multiply by 100 as percent removal capacity of spiral sheet cyclone for dust.

CHAPTER II

LITERATURE REVIEW

2.1 Gas – Particle interaction

2.1.1 Terminal velocity means during particle dropped down in fluid stream will generated acceleration causing by particle mass. During move of particle will have drag force act with the opposite moving direction particle increase its velocity till equal to drag force that interact to that particle create zero velocity while particle speed is stable drop down when characteristic of fluid interacted with particle is not changed the maximum drop down speed of particle is called Terminal velocity as figure 2.1. (9)

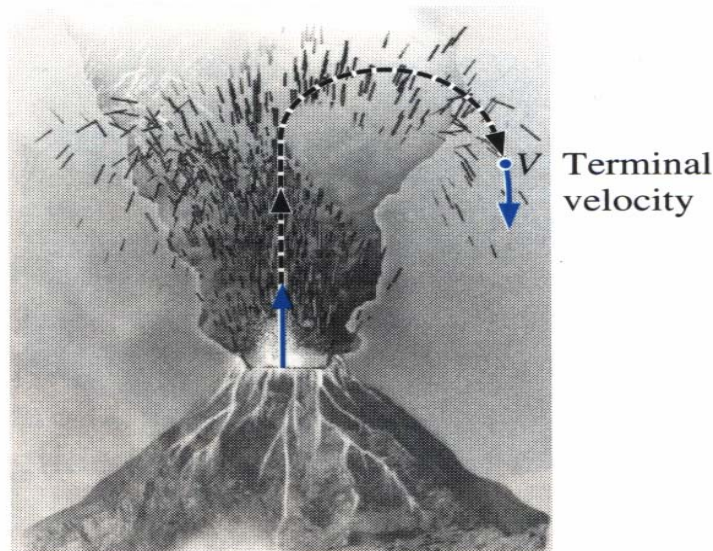


Figure 2.1 Showing the moving speed of Terminal velocity

In the state of particles has high Terminal velocity is mean that particles is floating in the fluid in short period and fall down near the origin with this principle can be employed to separate particle from atmosphere by decrease particle speed than Terminal velocity (10) therefore particles is separated from the air. The terminal velocity as shown in Figure 2.2 (11)

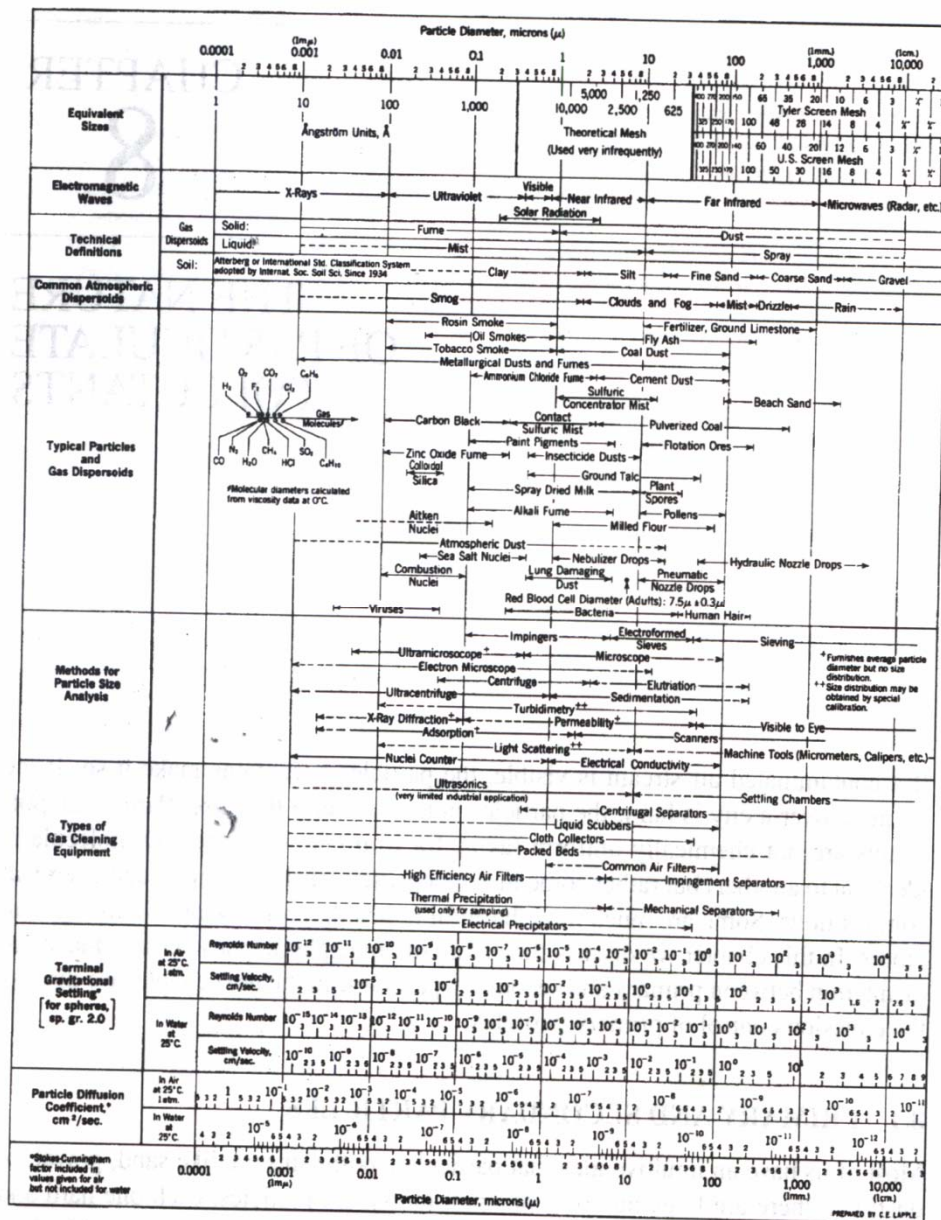


Figure 2.2 shows Terminal velocity of each particles type

2.1.2 Drag Force and Drag Coefficient

Drag Force (F_d) is fluid force react to shape of particle in the opposite direction of movement amount of drag force depend on particle shape can calculate drag force value by Newton's law (10)

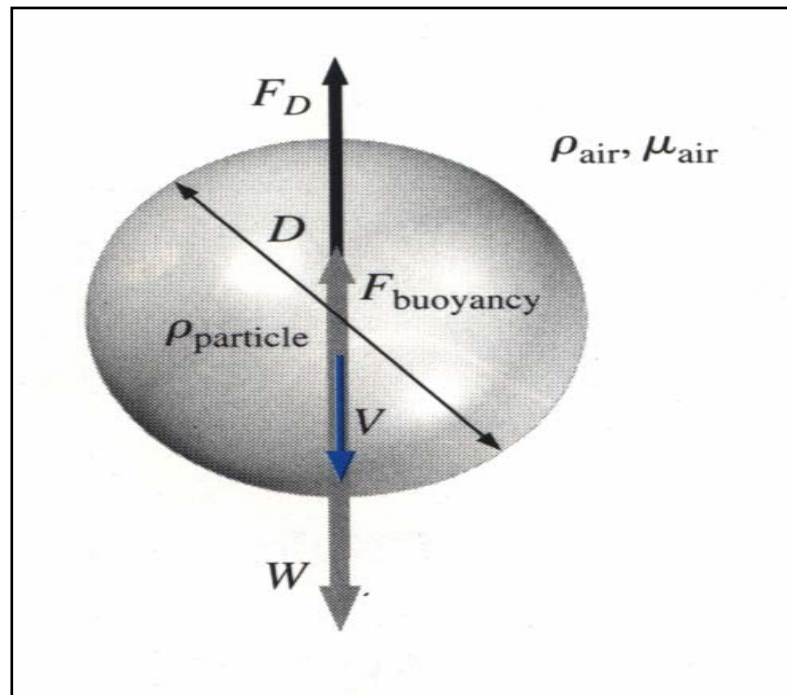


Figure 2.3 Illustration of force balance during Terminal velocity moving

$$m a = \rho_p \left(\frac{\pi}{6} \right) D^3 g - \rho_f \left(\frac{\pi}{6} \right) D^3 g - F_d$$

During particle move in Terminal velocity mode acceleration rate will be zero

Therefore

$$F_d = \rho_p \left(\frac{\pi}{6} \right) D^3 g - \rho_g \left(\frac{\pi}{6} \right) D^3 g$$

$$F_d = \left(\frac{\pi}{6} \right) D^3 g (\rho_p - \rho_g) \tag{1}$$

Amplitude of drag force (F_d) is depending on particle shape, fluid density, fluid velocity, position of particle in fluid which is hard to find actual drag force (F_d) then calculation is made in form of drag coefficient (C_d) by the following equation:(9)

$$C_d = 2 F_d / \rho V^2 A$$

For spherical particle:

$$C_d = 8 F_d / \rho V^2 \pi D^2 \tag{2}$$

Drag coefficient (C_d) value has different value between creeping flow and turbulent flow inertia value have less effect for flow with low Renold number (Re). If $Re < 1$ called creeping flow by flowing pass spherical shape object along the surface of spherical and Drag coefficient for spherical object is

$$C_d = 24/ Re \quad (Re \leq 1) \text{ there for } Re = \rho V D/\mu$$

Or known as Stokes Law

Fill drag coefficient (C_d) value into equation (2)

$$F_d = 3 \pi V D \mu \quad (3)$$

Fill $F_d = 3 \pi V D \mu$ from equation(3) into equation(2) will get Terminal velocity (V_t)

$$V_t = \frac{(\pi/6) D^3 g (\rho_p - \rho_g)}{3\pi D \mu}$$

$$V_t = \frac{D^2 g (\rho_p - \rho_g)}{18\mu}$$

However Stokes law is accurate and good for $Re \leq 0.3$ but Re value is $0.3 \leq Re \leq 1000$ then drag coefficient value calculate by (10)

$$C_d = 24/ Re(1 + 0.14 Re^{0.7})$$

Drag coefficient value is dependent to Renold number(Re) for flow of each type have value as following table(3):

Flow regime	Re	Cd
Laminar regime	$10^{-4} < Re > 2$	$C_d = 24/Re$
Transution regime	$2 < Re > 10^4$	$C_d = 0.4 + (40/ Re)$
Turbulent regime	$10^4 < Re$	$C_d = 0.44$

Table 2.1 Illustration of drag coefficient (C_d) value at different Renold number (Re)

In case of extremely small particle size according to gas molecule mean free path that particle will move pass through gas molecule effecting to particle itself increase speed of moving. (3) Drag force value maybe calculate by (10):

$(1 + A\lambda/D)$ is term called Cunningham correction factor (C)

2.1.3 Stokes stopping distance (10)

Mean distance that particle moving into fluid at certain speed and stand still by drag force which this distance is calculated by

$$X_{\text{stokes stopping}} = \frac{V_o D^2 \rho_p C}{18 \mu}$$

2.1.4 Aerodynamic particle diameter (12)

Mean diameter of ideal spherical object that have particle density of 1000 kg/cu.m. and has moving speed equal to Terminal velocity that equal to moving speed of particle by has any size, shape and density and assume diameter of particle equal to diameter of ideal spherical calculating by (10):

$$Da = D (\rho_p C)^{1/2}$$

2.2 Spiral sheet cyclone

2.2.1 General particle Particle Collection Mechanism

In every dust collection there must be input force to the particle for separate the particle from gas flow and control the particle moves to collide with collector. It might be the surface collector, mechanism or force to separate the particle composed of six forces. (8) Gravity, the easiest mechanism. Macro particle with gas moves in with low speed, so that can separate macro particle from gas such as in the Gravity Settling Chamber (8,13)

2.2.1.1 Centrifugal Force, separate centrifugal force, gas and particle that moves in with curve-shaped mechanism such as cyclone, that makes internal twist and particle centrifugal force to the wall of mechanic due to particle momentum has lost its kinetic energy and separate from gas. Particle will fall into the hopper because of the gravity so that the centrifugal force and the gravity are the important factors in cyclone dust collection (8).

2.2.1.2 Inertial Impaction will be happened when mass particle cannot move along the gas line which encircle the target object due to the

inertial impaction. So the particle will hit the object. The big size and mass particle can be collected easily (8, 13).

2.1.1.3 Direct Interception, micro particle which moves along the gas flow encircle the object may contact with object if the central of particle is far from the target object in less than the radius of the particle (8).

2.1.1.4 Diffusion of micro particle that has the Brownian Motion. So the particle may hit the target due to its random moving. This mechanic presents that the diffusion is important to the micro particle with size less than 0.1 micron (8, 13).

2.1.1.5 Electrostatic Attraction happen when electro particle move to containing surface of target object with anti-electrometer which cause the collection of dust (8).

2.2.2 Spiral sheet cyclone particle separation mechanism

In dust or particle collection may use one or many forces or mechanism to force the particle. Force or mechanic used in separate the particle of spiral sheet cyclone consists of two forces as follows : (8)

2.2.2.1 Gravity that happen during the particle is losing its kinetic energy due to the centrifugal forces makes the particle fall down by gravity and store at the bottom of spiral sheet cyclone.

2.2.2.2 Centrifugal Force of gas and particle which move into the spiral sheet cyclone will be forced by spiral sheet to flow encircle the spiral sheet from outside to inside. This will cause the internal twisting and particle centrifugal force to both side of partition of spiral sheet. Because of the particle momentum has lost its kinetic energy and separate out from gas, particle will fall down to the hopper due to the gravity. So the gravity and the centrifugal force are the important factors in separating dust (8).

2.2.3 Spiral sheet cyclone structure

Major structure of spiral sheet cyclone composing of major component as following:

1. Housing (Cylindrical)
2. Spiral sheet

3. Cone
4. Dust outlet
5. Gas-particle Inlet
6. Clean gas outlet
7. Buffer Plate

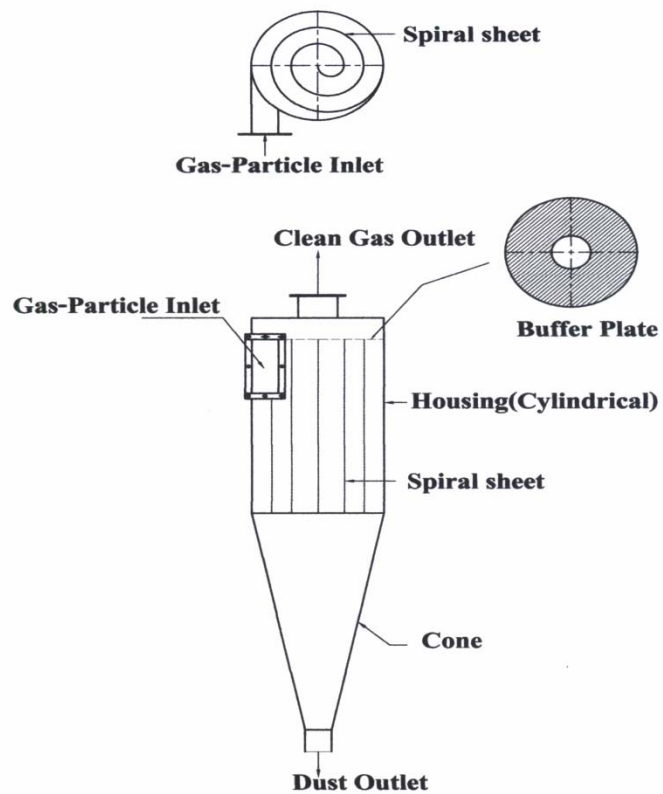


Figure 2.4 Structure of spiral sheet cyclone

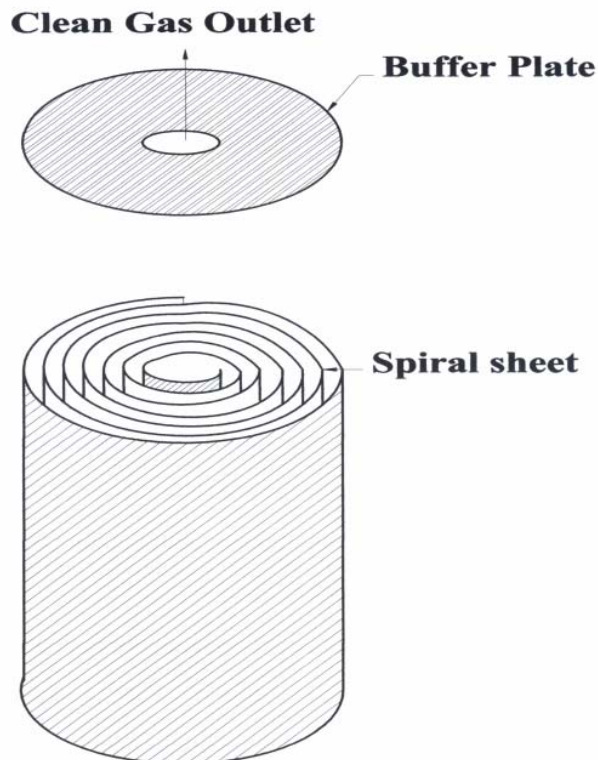


Figure 2.5 Inner structure of spiral sheet cyclone

2.2.4 Principle of spiral sheet separator

Air with particle will passing through spiral sheet cyclone reach out layer of spiral sheet and forced to vortex flow along spiral sheet surface path to inner layer centrifugal force occurred during migration and friction of both surface of spiral sheet created inertia to particle and separated from air dropped down to dust bin. Principle as described above was similar to cyclone operation by increasing of cyclone operation is being made with various concept and one of them is improving surface area of cyclone body, therefore, **H.T. Kim** study has compared 5 different type of cyclone body including: 1.) 4 rounds spiral structure 2.) 6 rounds spiral structure 3.) Circumferential groove body 4.) Vertical groove body and 5.) Conventional cyclone with flow rate 15 – 80 Liters/min, using particle size between 0.63 – 0.8 micron to determine efficiency of all type found spiral structures have more efficiency especially at low flow rate. However, at high flow rates, the guide no longer plays an important role in cyclone collection efficiency. Both groove and conventional cyclone has

similar efficiency at low flow rate and groove type will exhibit much lower efficiency than conventional cyclone in higher flow rate. 50% cut diameter of groove type is higher than conventional cyclone type while groove type will has lowest pressure drop among all types. (14). **K.S. Lim** and cohort study by using different vortex finder cylinder shape and cone shape, cylinder shape have 4 size 7, 11, 15 and combind of 11 and 15mm.Cone shape have 4 size, 6 characteristic of vortex finder lenght. Conclusion from empirical study concludes that highest efficiency of vortex finder was cylindrical shape and has size of 7 mm and Cut off diameter at 50% will be decreased when reduce vortex finder size.Cone length of vortex finder are not an important factor in affecting the particle collection efficiency. (15) **Zhao Jialin** and **Gao Qinyou** study analysis on the structure characteristic of continuous spiral cyclone found spiral cyclone have the significant advantages, such as lower pressure loss, higher collection efficiency and more sampling flow rate than conventional cyclones.(16) **WANG Can-xing** and **YI Lin** study on numerical simulation of three dimensional Gas-Particle flow in a spiral cyclone found there is a steady fluid flow in the spiral channel,which is advantageous for particle separation. In the centre of cyclone body, the tangential velocity profile show a combined vortex structure, and the highly rotation flow results in a large pressure loss. An increase in the flow rate lead to an increase in collection efficiency, while the pressure loss increase. Pressure loss is smaller than the conventional cyclones.(17)

2.2.5 Praticle terminal velocity on centrifugal force

Centrifugal force of particle can calculated by (10)

$$\text{Centrifugal force} = (m/r) V_c^2 \quad \text{Or} \quad m\omega^2 r$$

During air with particle migration through spiral sheet cyclone velocity will occurred into 2 directions including: Terminal velocity (V_t) or radius path and perimeter path (V_c) relative of these velocity as shown at Figure 2.6 (10)

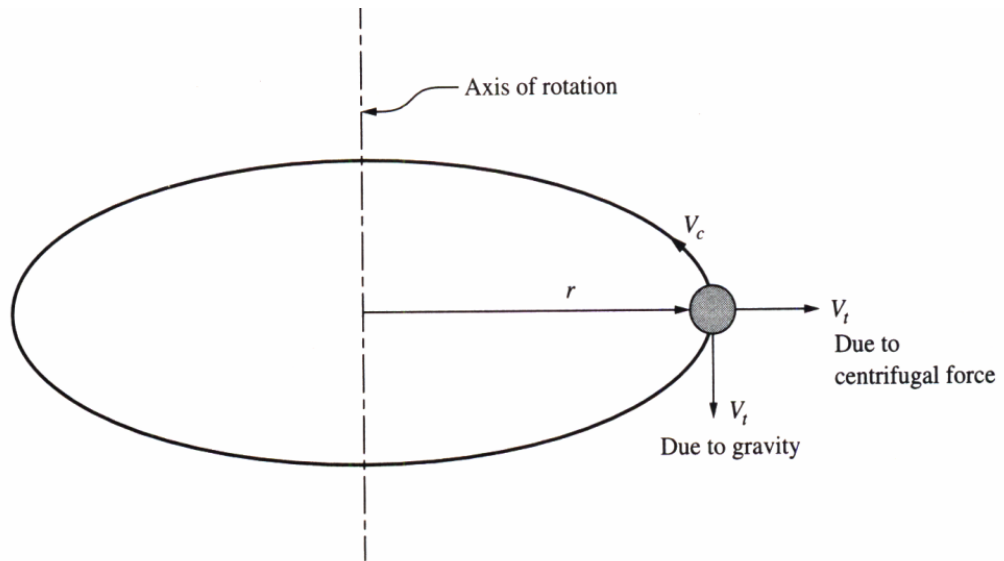


Figure 2.6 Illustrate relation of velocity while spiral migration

As figure 2.6 will see that the term of V_t will composing of two terms, however, V_{tg} Gravity term has less than V_{tr} Terminal velocity along the radius path as many as 100 times relation of V_t and V_c can be estimated by (10)

The radius path Terminal velocity is fill by $g = V_c^2 / r$ into equation calculation for V_t

$$V_{tr} = \frac{V_c^2 D^2 (\rho_p - \rho_g)}{18\mu r}$$

V_t = terminal velocity

V_c = velocity along the circular path

D = diameter of particle

ρ_p = density of particle

μ = gas viscosity

r = radius

Terminal velocity cause by gravity

$$V_{tg} = \frac{D^2 (\rho_p - \rho_g)}{18\mu}$$

V_{tg} = terminal velocity

- D = diameter of particle
- ρ_g = density of gas
- ρ_p = density of particle
- μ = gas viscosity

2.2.6 Size and dimension of spiral sheet cyclone

This research has built spiral sheet cyclone by apply the Stairmann hypothesis that has dimension of spiral sheet cyclone as Figure 2.7

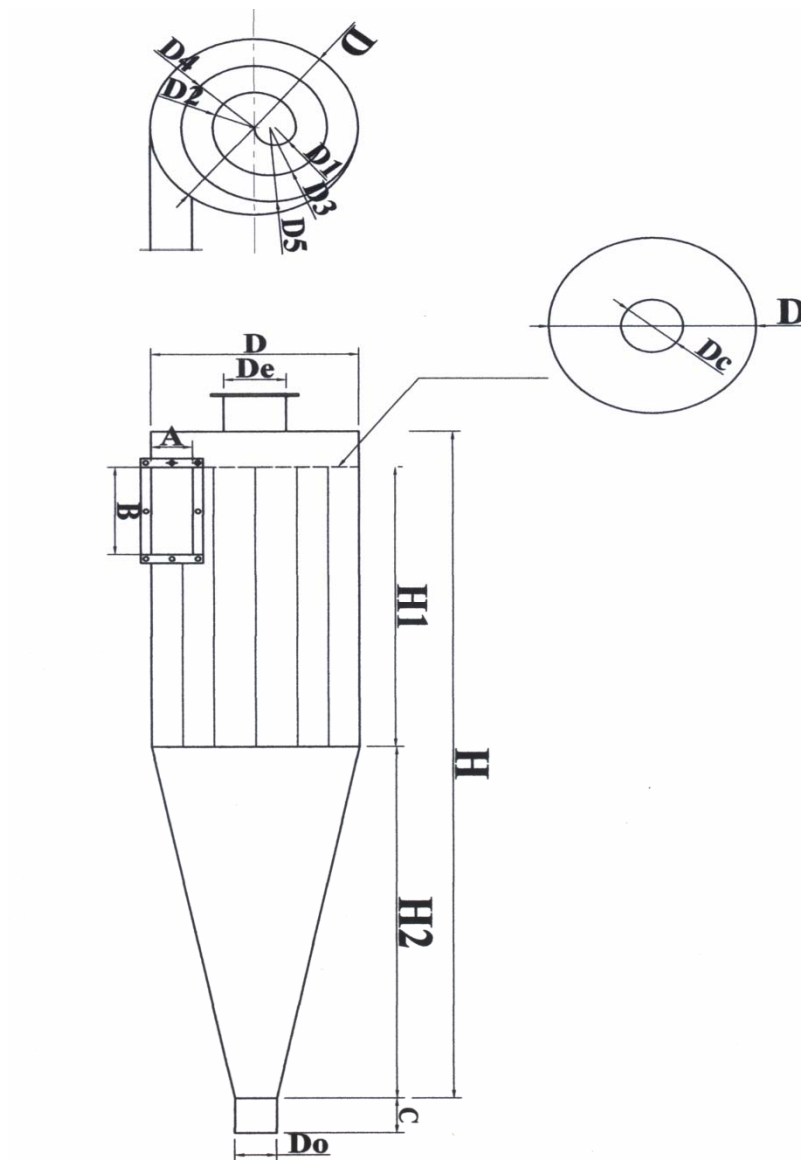


Figure 2.7 Proportion of spiral sheet cyclone

Part name	symbol	proportion
Diameter of SSC.	D	1D
Inlet wide	A	0.2D
Inlet height	B	0.5D
Outlet Diameter	De	0.3D
Spiral sheet height	H1	1.6D
Cone height	H2	2D
Dust Outlet Diameter	Do	0.2D
Dust Outlet height	C	0.2D
Total height of SSC.	H	3.8D
Dia. Spiral sheet 1.	D1	0.2D
Dia. Spiral sheet 2.	D2	0.4D
Dia. Spiral sheet 3.	D3	0.55D
Dia. Spiral sheet 4.	D4	0.7D
Dia. Spiral sheet 5.	D5	0.85D
Buffer Plate Diameter	Dc	0.3D

Table 2.2 Proportion of spiral sheet cyclone

2.2.7 Spiral sheet cyclone efficiency

Grad efficiency of spiral sheet cyclone can be estimated by Gravity settler efficiency calculation and cyclone efficiency is (10):

$$\text{Vertical settling distance} = V_t L / V_{\text{avg}}$$

Efficiency calculation can be made by use fractional of particle divide vertical settling distance

$$\eta_i = \frac{V_t L}{H V_{\text{avg}}} \quad \text{For Gravity settler}$$

$$\eta_i = \frac{V_t DN}{W_i V_c} \quad \text{For Cyclone}$$

Grad efficiency of spiral sheet cyclone can be calculated by

$$\eta_i = \frac{V_t L}{W_i V_c}$$

Fill V_t into grad efficiency of spiral sheet cyclone

$$\eta_i = \frac{L V_c D^2 (\rho_p - \rho_g)}{18 W_i \mu r}$$

- η_i = grad efficiency of Spiral Sheet cyclone
- L = total length of spiral sheet
- W_i = wide inlet port
- V_c = Inlet velocity
- D = diameter of particle
- ρ_p = density of particle
- ρ_g = density of gas
- r = radius of Spiral Sheet cyclone
- μ = gas viscosity

Total efficiency of spiral sheet cyclone can be calculated by

$$\eta = \sum \eta_i W_i$$

η = total efficiency of spiral sheet cyclone

η_i = grad efficiency of spiral sheet cyclone

W_i = percentage of particle weight of grad

2.2.8 Cut diameter (10)

Mean particle size that machine can separate at efficiency of 50% and also was efficiency index of spiral sheet cyclone can be calculated by application of Lapple equation (1951):

$$d_{\text{pcut}} = \left| \frac{9 \mu W_i r}{L V_c (\rho_p - \rho_g)} \right|^{1/2}$$

2.2.9 Pressure drop (9)

Means indication of power consumed for separate particle if spiral sheet cyclone has much power loss it shall use more power to create sufficient flow for particle separation and can be calculated by: (8)

$$\Delta P = \rho g V_p^2 N_H / 2$$

ΔP = pressure drop

ρg = density of gas

V_p = gas velocity

N_H = the number of inlet head

$$N_H = KHW / D_e^2$$

K = 16 for tangential cyclone, 7.5 for vane cyclone

H = height of inlet port

W = wide of inlet port

D_e = diameter of gas outlet

Or calculate as static head of water as centimeter unit by:

$$\Delta P(\text{cm.wg}) = 5.12 \rho g V_p^2 N_H$$

ρg = air density

V_p = air velocity

N_H = KHW / D_e^2

CHAPTER III

MATERIALS AND METHODS

3.1 Study desing

This empirical study is conducted to determine removal efficiency of spiral sheet cyclone for sand dust by using river sand that pass heating process and sort out size with grating machine into five categories including: 1-53, 53-75, 75-106, 106-150 and 150-212 micron. Spiral sheet cyclone is tested by feed such mixed air and sand with four level flow rate including: 19.5, 23.4, 27.41, and 32.72 cubic-meter per minute and determine efficiency by collect sample both input and output of spiral sheet cyclone with Isokinetic sampling technique and calculate and present efficiency as percent.

3.2 Methods

3.2.1 Sand dust size analytical

Sand dust that passed heating process first sifted with sieve No. 60 will get sand dust which have particle size between 1 to 250 micron then is sifted with individual 5 sieve size No. 270, 200,140,100 and 70 to get sand dust particle of 1-53, 53-75, 75-106, 106-150 and 150-212 micron respectively.

3.2.2 Spiral sheet cyclone construction

Spiral sheet cyclone is constructed of metal rolled sheet and weld with electric welding which compose of five major components including:

3.2.2.1 Gas outlet

3.2.2.2 Buffer plate between cylindrical and gas outlet

3.2.2.3 Cylindrical and spiral sheet

3.2.2.4 Cone

3.2.2.5 Dust bin

Spiral sheet cyclone dimension is based on the Stamann's hypothesis: diameter 500 mm., cylindrical length 800 mm., cone length and spiral sheet length 2900 mm. shape and dimension of each part is illustrated at figure 3.1 and Table 3.1

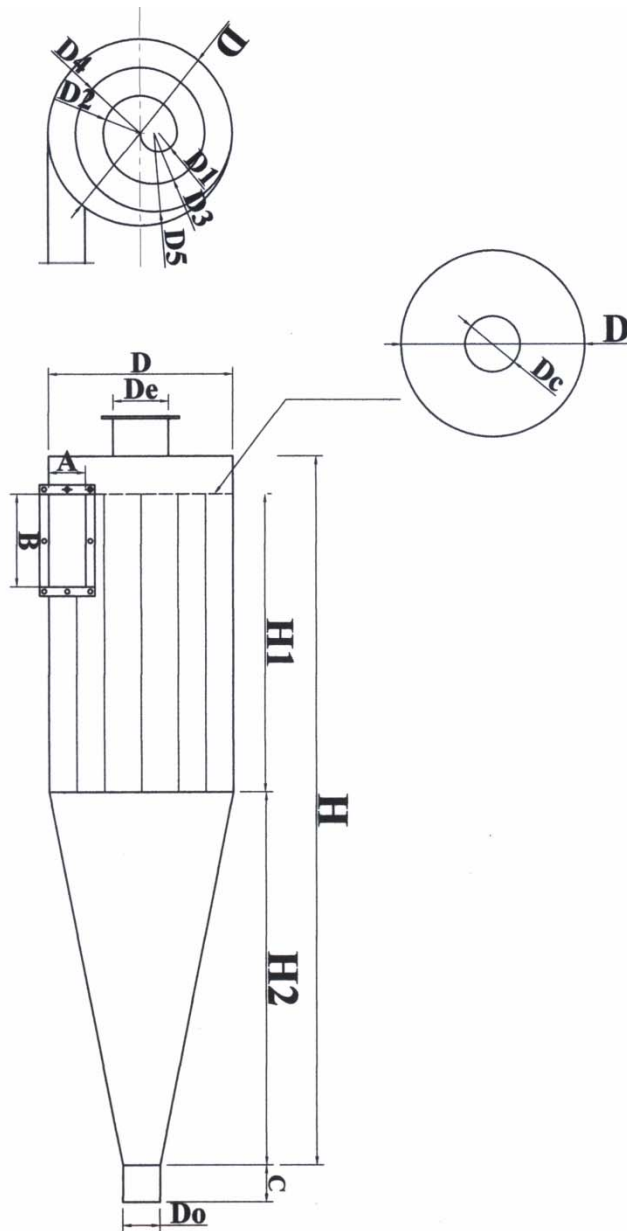


Figure 3.1 Proportion of Spiral Sheet cyclone

Part name	symbol	proportion	Dimension(mm.)
Diameter of SSC.	D	1D	500
Inlet wide	A	0.2D	100
Inlet height	B	0.5D	250
Outlet Diameter	De	0.3D	150
Spiral sheet height	H1	1.6D	800
Cone height	H2	2D	1000
Dust Outlet Diameter	Do	0.2D	100
Dust Outlet height	C	0.2D	100
Total height of SSC.	H	3.8D	1900
Dia. Spiral sheet 1.	D1	0.2D	100
Dia. Spiral sheet 2.	D2	0.4D	200
Dia. Spiral sheet 3.	D3	0.55D	275
Dia. Spiral sheet 4.	D4	0.7D	350
Dia. Spiral sheet 5.	D5	0.85D	425
Buffer Plate Diameter	Dc	0.3D	150

Table 3.1 Dimension of spiral sheet cyclone

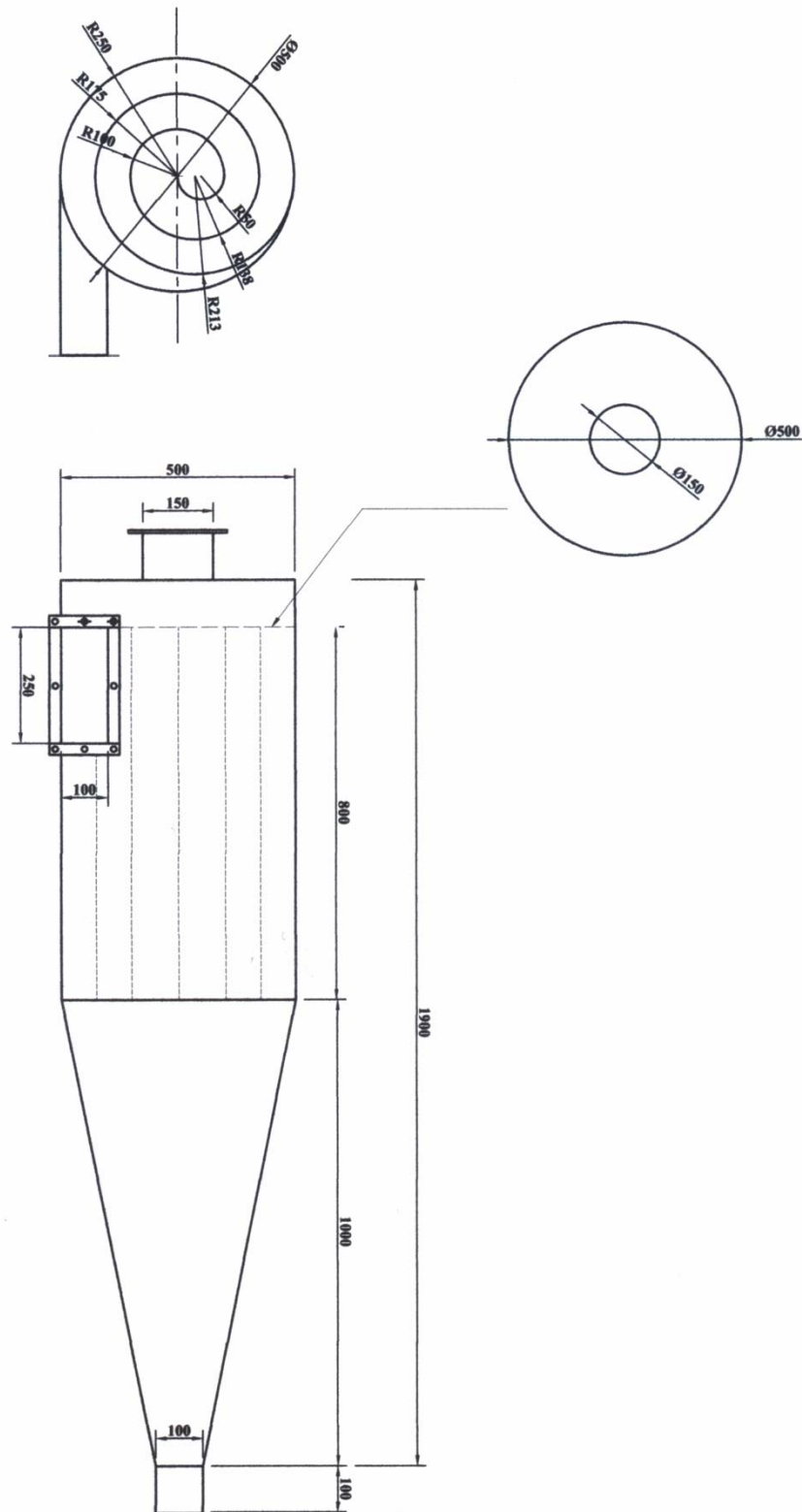


Figure 3.2 Dimension of Spiral Sheet cyclone

3.2.3 Dust concentration

Spiral sheet cyclone's efficiency is determined by collect sample of dust both inlet and outlet and measure concentration with Isokinetic sampling technique by using fiberglass filter paper diameter 37 mm., filter holder and pumps. Instruction for filter preparation and post sampling measurement are as following:

1. Keep filter paper within a desiccator for 12 hours.
2. Weight filter and record mounted to holder
3. Mounted to holder and close both holder's end
4. After used keep filtered paper within desiccator for 12 hours.

Weight filtered paper and record

3.2.4 Testing condition and Parameters

1. Temperature
2. Humidity
3. Dust velocity
4. Air flowrate
5. Weight of sand dust of each particle size is 30.1 g.

3.2.5 Testing Methods

1. Install sampling device including sampling probe, filter, and pump both input and output of spiral sheet cyclone.

2. Switch on fan motor.
3. Switch on sampling pump both.
4. Feed sand dust by using cone cup.
5. Switch off input sampling device when time passes 1.5 minute.
6. Switch off output sampling device when time passes 2.0 minutes.
7. Switch off fan.
8. Detached filter and keep in closed box.
9. Clean sampling probe and rubber tube.
- 10 Open dust bin at bottom and clean.

11. Switch on fan for 5 minutes as cleaning method before conduct another sampling to ensure have not former testing sand dust left over.

11 Repeat step 1 – 10 by changing sand dust particle size and air flow rate.

3.3 Experimental design

Air duct is installed diameter 200 mm. Cone cup size 5 mm is mounted at the inlet of spiral sheet cyclone for feed sand dust and far from inlet sampling device for 1500 mm. Sampling device is installed both inlet and outlet of spiral sheet cyclone. Outlet end duct is attached with power electric fan 3 HP with inverter to control fan speed for adjustment of air flow rate.

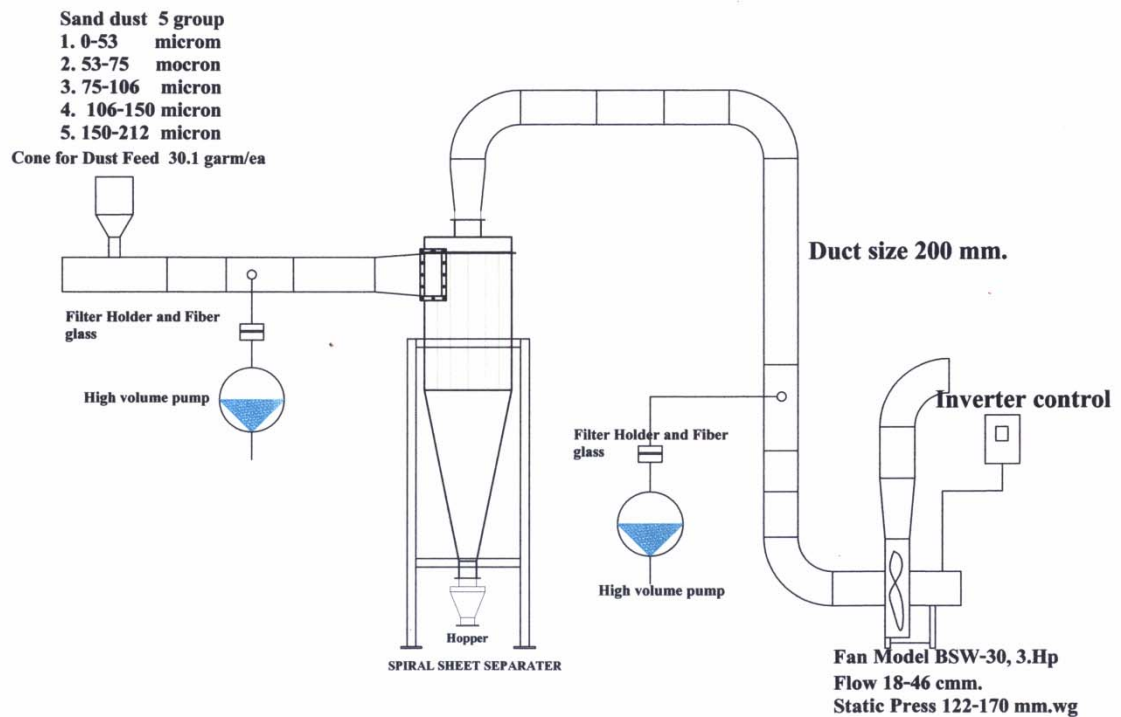


Figure 3.3 Experimental design

3.4 The test instrument

The test instruments used in this experiment consisted of

1. Air velocity

To measure the duct velocity, hot wire anemometer (vellocalc plus, model: 8386A-m-GB, sn: 03120366 rev. P) was sued in this study.

2. Air Temperature

To measure Air temperature, hot wire anemometer (vellocalc plus, model: 8386A-m-GB,sn: 03120366 rev. P) was used in this study.

3. Humidity

To measure Air humidity, hot wire anemometer (vellocalc plus, model: 8386A-m-GB,sn: 03120366 rev. P) was used in this study.

4. Atmospheric pressure

Barometer was used to measure the Atmospheric pressure

5. Particle concentration

1. Fiber glass filter

2. Filter Holder

3. Sampling Probes

4. Sampling pumps

5. Weigh scales

6. Fan speed control

To adjusted Fan speed and air flow rate, Fuji inverter model. FVR-E11S-4 En series. 380 V/3Hp/50 Hz power supply.

7. Fan

Centrifugal fan (Venz model BSW-30) 380v/3ph/50Hz, 2 pole, 2950 rpm. Air flowrate 18-46 cmm. Static pressure 122-170 mm.w.g.

8. Rotameter

To calibrate sampling pump flow rate, (SIBATA model: SV-30) was used in this study.

9. Sieve analytical

To separated sand dust size, (Gilson model: ss-3 r1, serial no.:1357, USA.)

10. Inclined manometer

To measure pressure drop of experimental study Inclined manometer was used in this study.

11. Balance

To weigh filter of experimental study METTLER TOLEDO model: AX-205 was used in this study.

3.5 Data analysis

3.5.1 Descriptive statistic

To explain the efficiency of the collection, the pressure drop and the particle concentration at the inlet and the outlet duct, the mean and standard deviation were applied.

3.5.2 Inferential statistic

To compare the mean of spiral sheet cyclone efficiencies between hypothesis and the experimental results was determined by one sample t-test

CHAPTER IV

RESULT

This study is to determine efficiency of spiral sheet cyclone for sand dust testing is performed by using sand dust that passed sieving into five ranges size including 1-53, 53-75, 75-106, 106-150, and 150-212 micron and feed sand dust through spiral sheet cyclone with four velocity rate including: 19.5, 23.4, 27.41, and 32.72 cubic-meter per minute and calculate efficiency by using measured data both input and output of spiral sheet cyclone result of study can be described into three parts as following:

- 4.1 Spiral sheet cyclone performance prediction
- 4.2 The experimental results
- 4.3 Statistic analysis of data

4.1 Spiral sheet cyclone performance prediction

Spiral sheet cyclone used in this study has its size 500 mm, height 1,800 mm and size of other parts as shown in Table 4.1. The material used to produce is steel sheet rolled and welded as per the designing process and effectiveness prediction of spiral sheet cyclone. Details are as follows:

Part name	symbolt	proportion	Dimension(mm.)
Diameter fo ssc.	D	1D	500
Inlet weight	A	0.2D	100
Inlet height	B	0.5D	250
Outlet Diameter	De	0.3D	150
Spiral sheet height	H1	1.6D	800
Cone height	H2	2D	1000
Dust Outlet	Do	0.2D	100

Diameter			
Dust Outlet height	C	0.2D	100
Total height of ssc.	H	3.8D	1900
Dia. Spiral sheet 1.	D1	0.2D	100
Dia. Spiral sheet 2.	D2	0.4D	200
Dia. Spiral sheet 3.	D3	0.55D	275
Dia. Spiral sheet 4.	D4	0.7D	350
Dia. Spiral sheet 5.	D5	0.85D	425
Buffer Plate Diameter	Dc	0.3D	150

Table 4.1 Illustrating dimension of spiral sheet cyclone

Concept designed and spiral sheet cyclone performance prediction

4.1.1 Testing condition

1.1 Air temperature	31 C
1.2 Air density	1.16 Kg/m ³
1.3 Air viscosity	1.8 x 10 ⁻⁵ Kg/ m.s
1.4 Atmosphere pressure	760 mm.Hg
1.5 Particle density	1500 Kg/m ³
1.6 Air flow rate	15-40 cmm.

4.1.2 Calculation procedure

4.1.2.1 Determination of sand dust particle for experiment

Sand dust size(micron)	1-5	5-10	10-15	15-20	20-30
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4.1.2.2 Determination of flow rate for experiment

Air flow rate (cmm.)	19.5	23.4	27	32.72	40
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Average of air flow rate = 28.52 cmm.

4.1.2.3 Determination for dust removing efficiency at each particle size

Sand dust size	Average dust size	Efficiency requirement
1-5	3	90
5-10	7.5	92
10-15	12.5	97
15-20	17.5	98
20-30	25	100
Average	13.1	95.4

Table 4.2 Illustrating average sand dust and efficiency requirement

4.1.2.4 Determination diameter size of spiral sheet cyclone = 500 mm.

4.1.2.5 Calculation of flow rate at spiral sheet cyclone inlet

By the Stairman’s hypothesis ratio between width of inlet and diameter of cylindrical duct is 0.2D and ratio between length of inlet and diameter of cylindrical duct is 0.5D

Therefore width of inlet = 0.2 x 500
= 100 mm.

Length of inlet = 0.5 x 500
= 250 mm.

Cross sectional area of inlet = 100 x 250
= 25000 mm²
= 0.025 m²

Calculate flow rate at inlet by:

$$Q = AV$$

Q = Average of air flow rate 28.52 cmm.

$$A = \text{Area of inlet port} = 0.025 \text{ m}^2$$

$$V = 28.52 / 0.025 \\ = 1,140.8 \text{ m/min}$$

$$\text{Air velocity at inlet of spiral sheet cyclone} = 19.01 \text{ m/sec}$$

4.1.2.6 Calculate length of spiral sheet by:

$$\eta_i = \frac{L V_c D^2 (\rho_p - \rho_g)}{18 W_i \mu r}$$

$$L = \frac{0.954 \times 18 \times 0.1 \times 0.25 \times 1.8 \times 10^{-5}}{19.01 \times (13.1 \times 10^{-6})^2 \times (1500 - 1.16)}$$

Minimum spiral sheet length = 1.6 meter

4.1.2.7 Calculate efficiency at each particle size with inlet flow rate of 19.01 m/sec

$$\text{By } \eta_i = \frac{L V_c D^2 (\rho_p - \rho_g)}{18 W_i \mu r}$$

Result of spiral sheet cyclone prediction:

Sand dust size(micron)	Efficiency (%)
1	0.56
2	2.25
4	9.00
6	20.26
8	36.02
10	56.28
12	81.05
13	95.12
14	100

Table 4.3 Illustrating calculation for prediction spiral sheet cyclone efficiency

4.1.2.8 Cut Diameter calculation

By

$$d_{\text{pcut}} = \left| \frac{9 \mu W_i r}{L V_c (\rho_p - \rho_g)} \right|^{1/2}$$

$$d_{\text{pcut}} = \left| \frac{9 \times 1.8 \times 10^{-5} \times 0.1 \times 0.25}{1.6 \times 19.01 \times (1500 - 1.16)} \right|^{1/2}$$

$$d_{\text{pcut}} \text{ prediction of spiral sheet cyclone} = 9.43 \text{ micron}$$

4.1.2.9 Pressure Drop calculation

By

$$\Delta P = \rho_g V_p^2 N_H / 2$$

Or

$$\Delta P(\text{cm.wg}) = 5.12 \rho_g V_p^2 N_H$$

$$N_H = KHW / D_e^2$$

$$N_H = (16 \times 5 \times 10) / (15^2)$$

$$= 17.78$$

Calculate pressure drop at flow rate of 19.5 cmm.

$$\Delta P(\text{cm.wg}) = 5.12 \times 0.00116 \times 13^2 \times 17.78$$

Prediction pressure drop at flow rate of 19.5 cmm. = 17.85 cm.

Prediction of pressure drop for each flow rate as illustrated in following table 4.4

Air flow rate (cmm.)	Air Inlet velocity(m/sec)	Pressure drop(cm.wg.)	
		cm.wg.	mm.wg
19.5	13	8.36	83.6
23.4	15.6	12.04	120.4
27.41	18.25	16.48	164.8
32.72	21.8	23.51	235.1
40	26.8	75.85	758.5

Table 4.4 Prediction of pressure drop for each flow rate

4.2 Experimental result

Effectiveness in eliminating sand dust of spiral sheet cyclone, from the experiments of five different sand dust with four levels of flow rate as shown in Table 4.5, found that at flow rate 19.5, 23.4, 27.41 and 32.72 cmm can cause the average effectiveness of Spiral sheet cyclone at 96.78, 95.79, 97.35 and 96.76 % consecutively. Average effectiveness of spiral sheet cyclone at every interval of sand dust and at every flow rates is equal to 96.69 %. Pressure Drop of spiral sheet cyclone at flow rate 19.5, 23.4, 27.41 and 32.72 cmm. will be 20.32, 29.21, 39.37 and 57.15 consecutively.

Air flow rate (cmm)	Sand dust size					Efficiency average	Pressure drop mm.Wg.
	1-53 micron	53-75 micron	75-106 micron	106-150 micron	150-212 micron		
19.5	93.9	97.38	99.33	99.35	94.38	96.87	20.32
23.4	91.73	94.85	97.89	97.22	97.24	95.79	29.21
27.41	91.13	98.3	99.53	98.72	99.08	97.35	39.37
32.72	90.43	95.94	99.81	98.86	98.76	96.76	57.15

Table 4.5 Collection efficiency and pressure drop of Spiral sheet cyclone

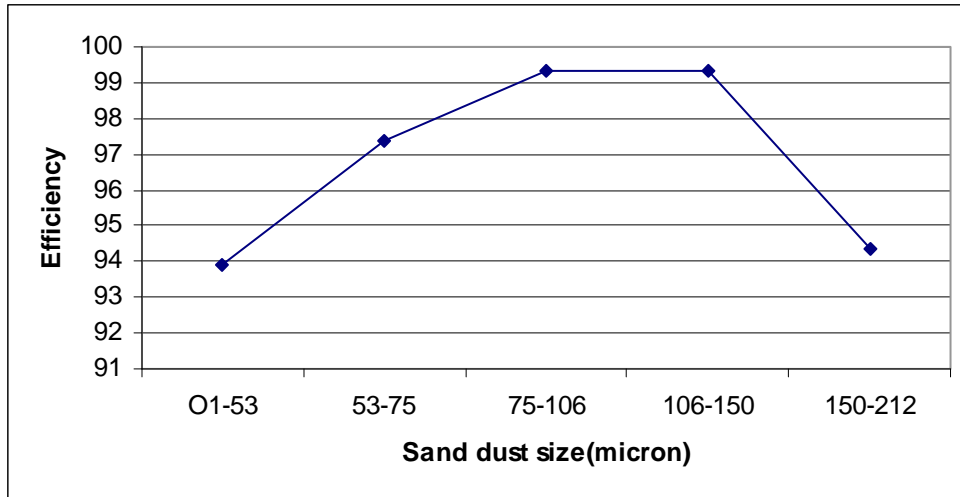


Figure 4.1 Illustration of spiral sheet cyclone efficiency for 19.5 cm. Flow rate.

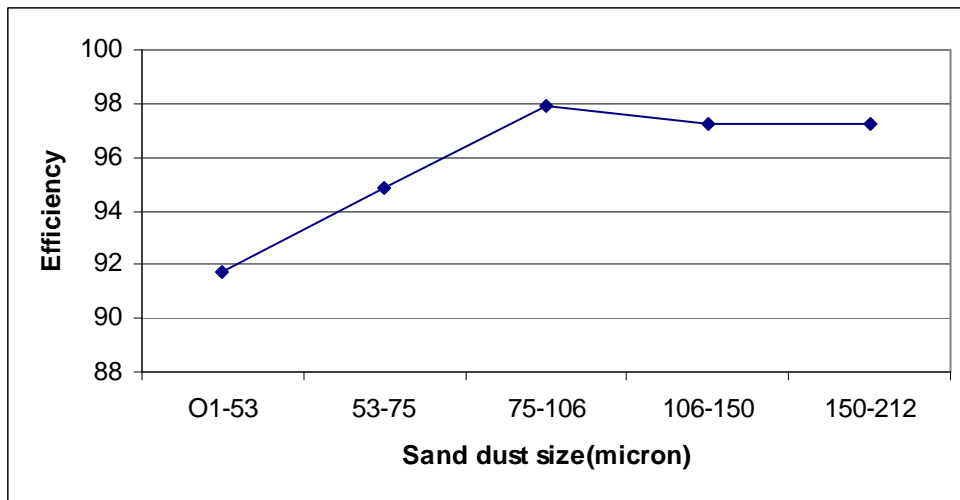


Figure 4.2 Illustration of spiral sheet cyclone efficiency for 23.4 cm. Flow rate.

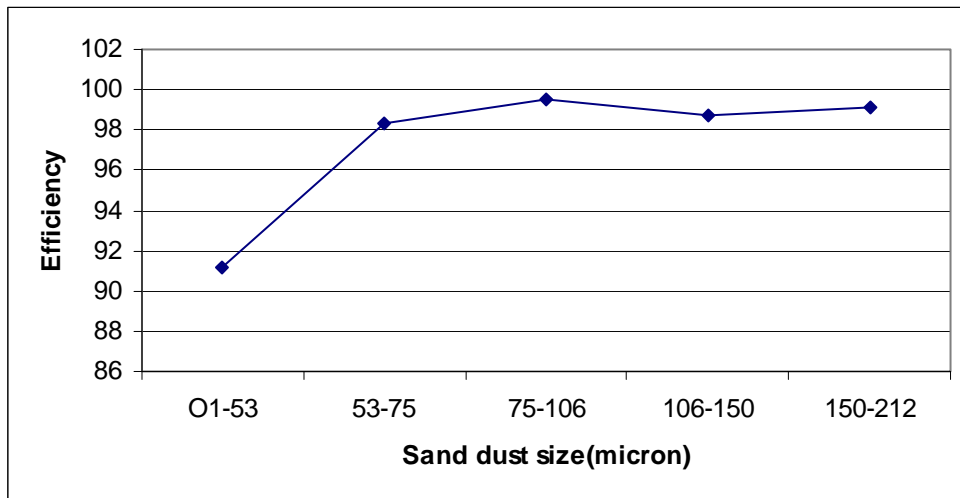


Figure 4.3 Illustration of spiral sheet cyclone efficiency for 27.41 cm. Flow rate.

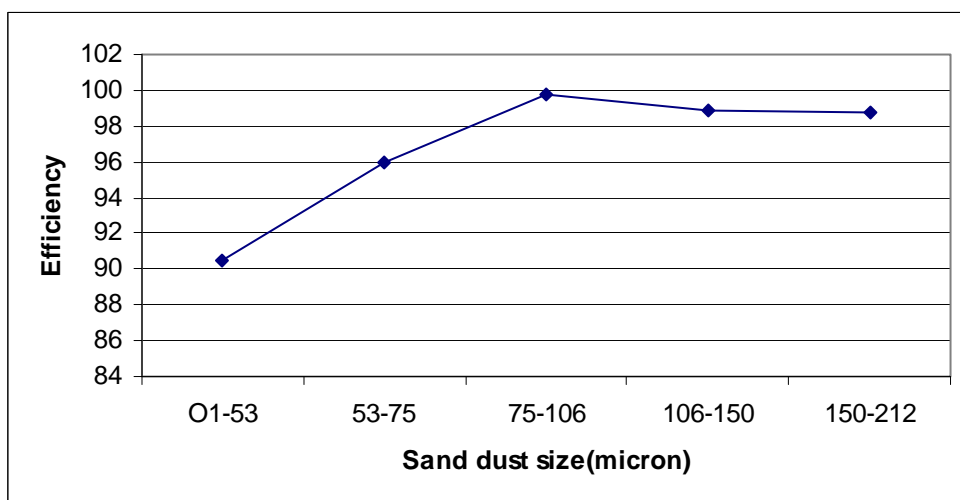


Figure 4.4 Illustration of spiral sheet cyclone efficiency for 32.72 cm. Flow rate.

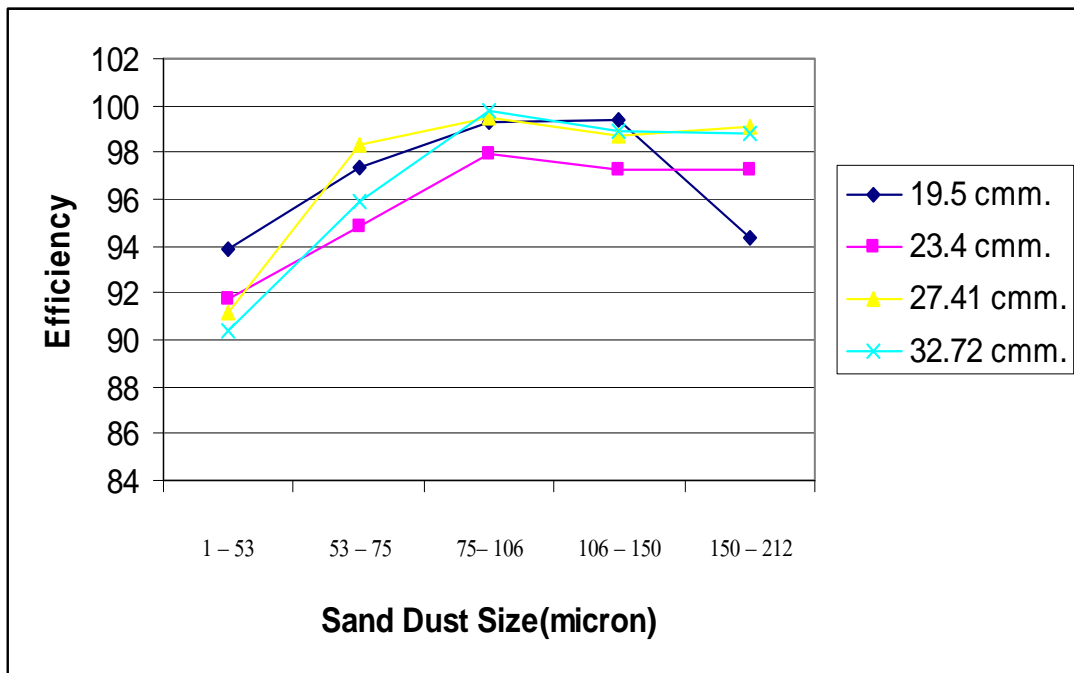


Figure 4.5 Illustration of spiral sheet cyclone efficiency for each air flow rate.

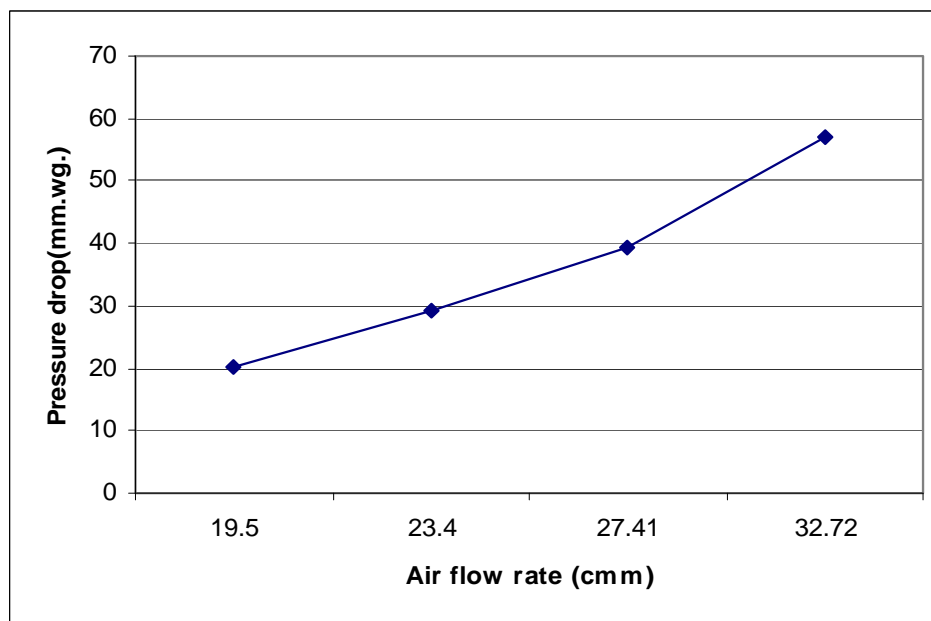


Figure 4.6 Illustration pressure drop of spiral sheet cyclone for each flow rate

From figure 4.1-4.5 found that maximum effectiveness of spiral sheet cyclone at every flow rates is at the interval of 75-106 micron sand dust.

From figure 4.6 found that pressure drop of spiral sheet cyclone has relations with the flow rate. It means that if the flow rate is rising up then the pressure drop will be higher.

4.3. Statistic Analysis of Data

One sample t- test was used to analyze the hypothesis as present:

4.3.1 The collection efficiency of Spiral Sheet cyclone was more than 90 % Mean efficiency of spiral sheet cyclone for dust comparison with all dust range size to assumption by using one sample t- test result as Table 4.6

Condition	Mean	SD	μ	df	t-test	p-value
- At air flow rate 19.5cmm.	96.87	5.97	90	14	2	<0.0005
- At air flow rate 23.40cmm.	95.79	6.85	90	14	3.27	<0.001
- At air flow rate 27.41cmm.	97.35	10.87	90	14	2.62	0.0101
- At air flow rate 32.72cmm.	96.76	13.42	90	14	1.95	0.0442

Table 4.6 t-test statistic analysis

From table 4.6 can be concluded that efficiency of spiral sheet cyclone for 90% which has statistical significant (p-Value<0.05) by has efficiency for all particle size of 96.69 % with standard deviation between 5.97 and 13.42.

CHAPTER V

DISCUSSION

This study was the empirical study by experimental kits is installed on the building No. 5 of the department of occupational health and safety, Faculty of Public Health , Mahidol university.

This chapter will discuss in four parts including:

5.1 Sizing of sand

5.2 Design concept and fabricating of spiral sheet cyclone.

5.3 Samples collection

5.4 Result of study

5.1 Sizing of sand

Sand river for general construction is used in this study that is dried with temperature 150 degree Celsius and passes screen size into five groups including: 1-53, 57-75, 75-106, 106-150, and 150-212 micron with sieve no. 325, 270, 200, 140 and 70 respectively. Factor which has impact towards filtration to separate the size of sand dust is the duration of filtration, quantity of sand dust in filtration and humidity of sand dust. These three factors have caused the incomplete of filtration and separation the size of sand dust. When take the sand dust to experiment result of the effectiveness of spiral sheet cyclone will be incorrect.

5.2 Design concept and fabricating of spiral sheet cyclone

Design of spiral sheet cyclone has shape like cyclone with rolled sheet to helix shape installed internally to control air mixed with sand dust that are sucked and tangential direction and touch with spiral sheet create vortex effect separate sand dust

drop to the bottom of spiral sheet cyclone which spiral sheet cyclone dimension is based on the Stamann's hypothesis and size of spiral sheet is calculated by Stroke's equation: diameter 500 mm., cylindrical length 800 mm., cone length 1000 mm. and spiral sheet length 2900 mm.

Spiral sheet cyclone is constructed of metal rolled sheet and weld with electric welding which compose of five major components including:

5.2.1 Air Outlet

5.2.2 Buffer plate between cylindrical and Air Outlet

5.2.3 Cylindrical and spiral sheet

5.2.4 Cone

5.2.5 Dust bin

All five parts is assembling together with flange and tighten with bolt and nut, rolling of spiral sheet is difficulty to made completely round, seam of joint after electrical welding and not grind as smoothest as possible which is effected to the spiral sheet cyclone performance.

5.3 Samples collection

Sample collection is done according to Isokinetic technique that is speed of sampling is equal to inlet flow by using two sets of sample collector installed both input and output time spending for sampling for input and output are 1 and 1.5 minute respectively by using free of moist filter paper with passing absorbed moisture within desiccator for 12 hours weighting and record weight before use feeding of sand dust into spiral sheet cyclone by using 30.1 mg. of sand dust. Some factors are found during sample collection and potentially error of this study including:

5.3.1 Changes of atmosphere around the experiment place e.g. wind speed etc. may effect to sample collection process.

5.3.2 Different size of sand dust particle is affected by sampling method causing of bigger sand dust particle will fall down and is not vacuumed in to sample collector.

5.3.3 Missing of sample dust may be occurred during taking filter form collector to weighting.

5.3.4 Found some residues sand dust within internal collector surface.

5.4 Result of study

Result of this study found that spiral sheet cyclone has significant variation by has mean efficiency of dust removal by all sand dust particle size at 96.69 % and has standard deviation between 5.97 to 13.42% which has possible cause as following:

5.4.1 Only one position of sample probe installed in the center of duct may not represent as sample as a whole.

5.4.2 Pressure drop found from the experiments is much lower than the prediction which conform to the study of Zhao jialin and Gao Qinyou who study about the comparison of Spiral sheet cyclone and Conventional cyclone (16). Also, the study of Wang Can-xing and YI Lin which study about the Simulation of three dimension Gas-Particle flow in a spiral cyclone (17).

5.4.4 Actual efficiency of spiral sheet cyclone is less than designed potentially causing of rolling and welding process affecting to the surface.

CHAPTER VI

CONCLUSION AND RECOMMENDATION

This empirical study is conducted to determine removal efficiency of spiral sheet cyclone for sand dust. Design of spiral sheet is based on Starman's hypothesis and apply Stoke's equation for designing of spiral sheet install inside to control sand dust contaminated air flow inside at the surface plane from outer end to inside and created centrifugal force during move and cause of decrease velocity of dust and dropped into dust bin at the bottom of spiral sheet cyclone. Dimension of spiral sheet cyclone have diameter 500 mm., cylindrical length 800 mm., cone length 1000 mm. and spiral sheet length 2900 mm. and attach with air duct diameter 200 mm. with electric fan 3 HP.

6.1 CONCLUSION

Result of study can be concluded as following:

6.1.1 Removal efficiency of spiral sheet cyclone for sand dust is more than 90% by has statistical significant ($P\text{-value} < 0.05$) by has mean removal efficiency of all sand dust particle size at 96.69% with standard deviation between 5.97 and 13.42.

6.1.2 Variation of size of sand dust and air flow rate is effect to the removal efficiency of spiral sheet cyclone.

6.2 RECOMMENDATION

Constraint of this study that effect to measurement of spiral sheet cyclone efficiency including: atmospheric condition during test and mixture between air and sand dust.

Recommendations for further study of removal efficiency of spiral sheet cyclone for dust are as following:

6.2.1 Area for test should indoor place to reduce effect from atmospheric condition variation.

6.2.2 Appropriate mixing room between sand dust and air shall provide to ensure homogenously.

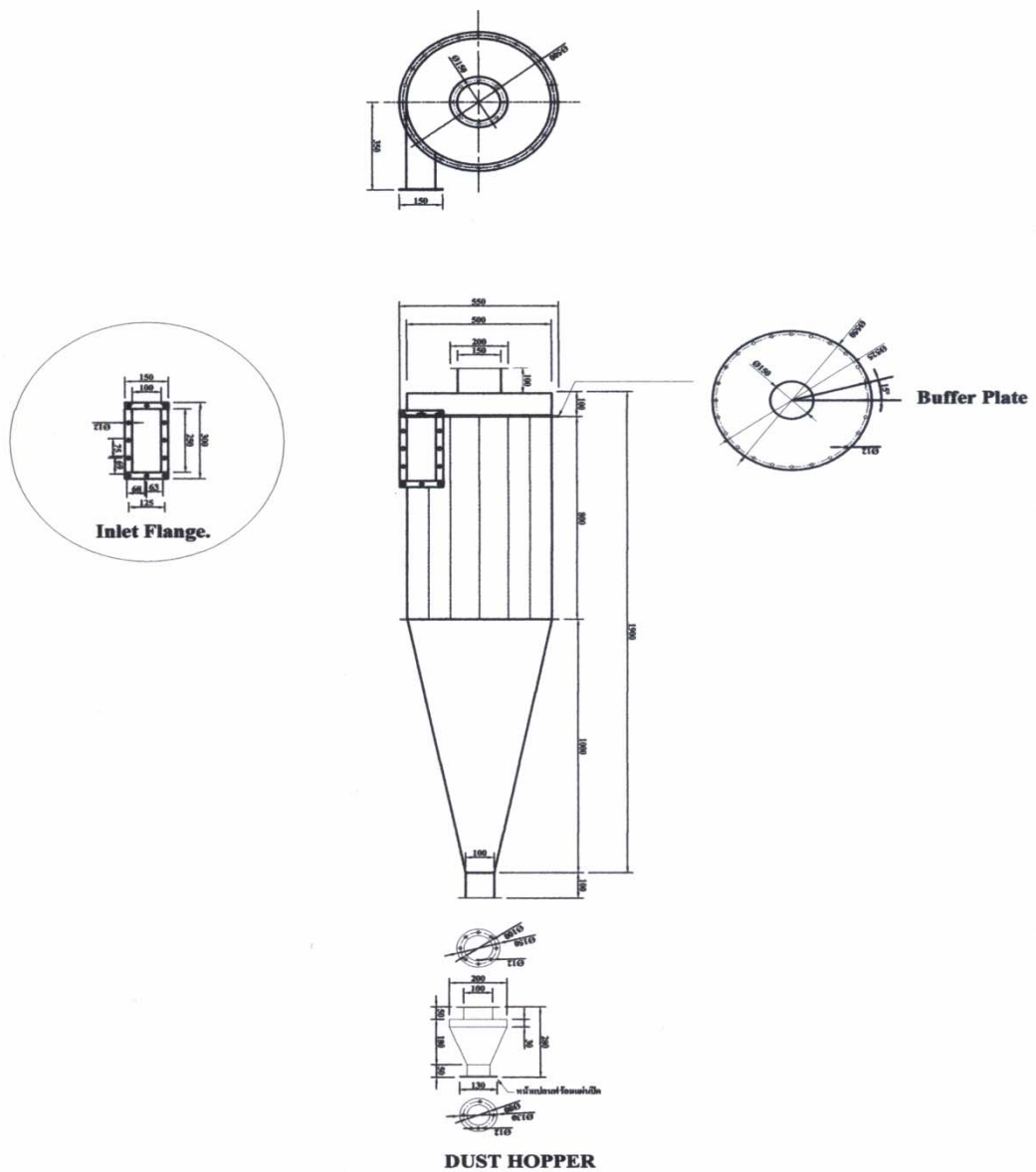
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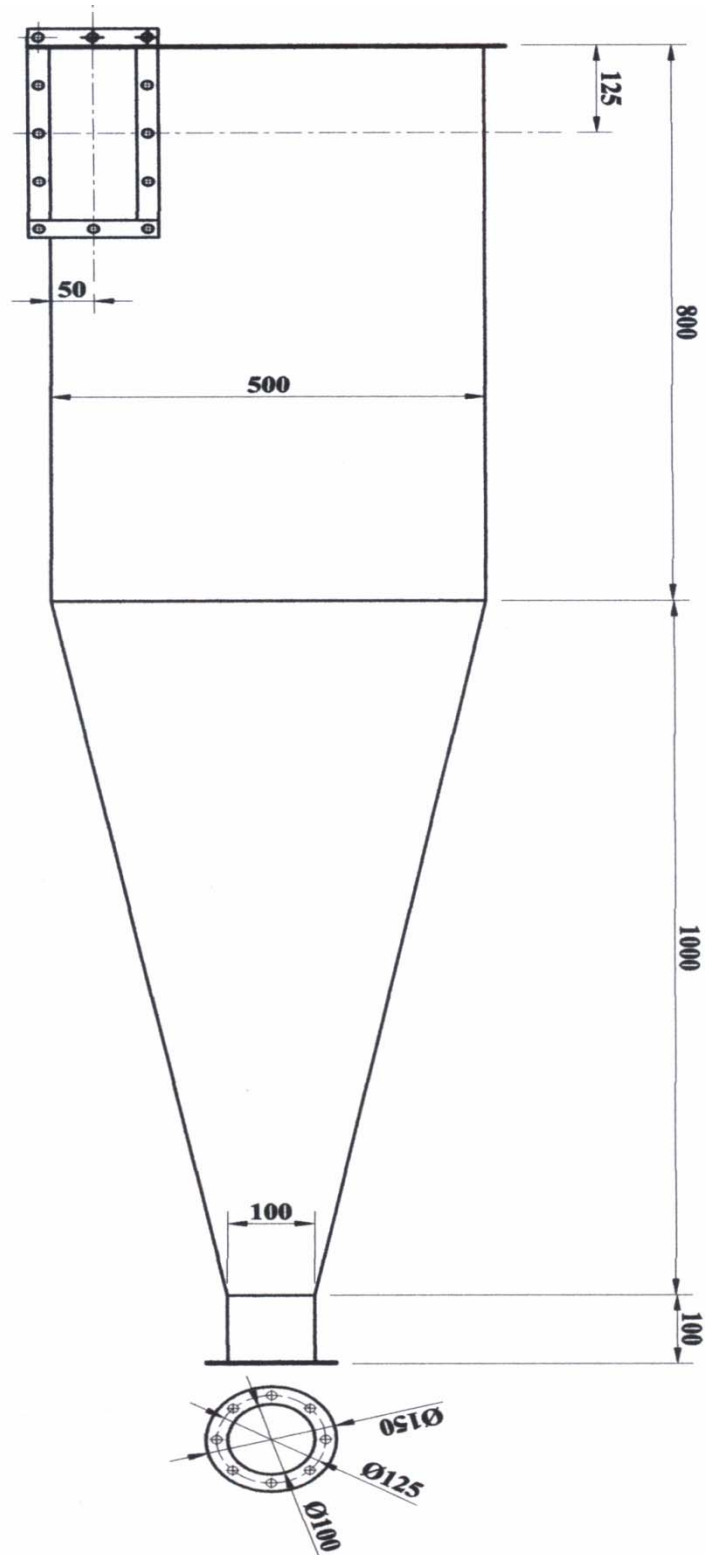
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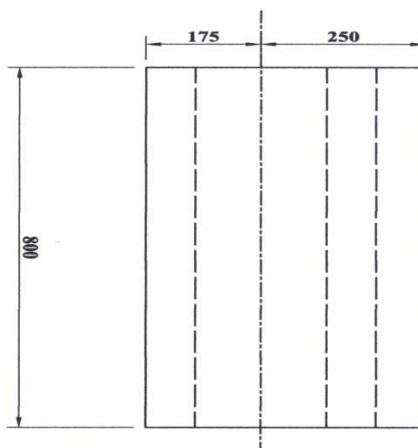
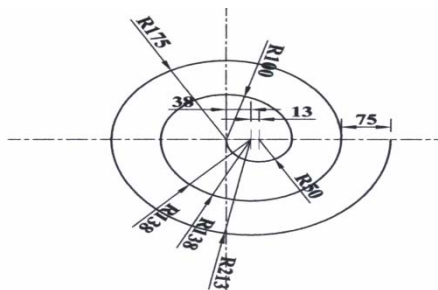
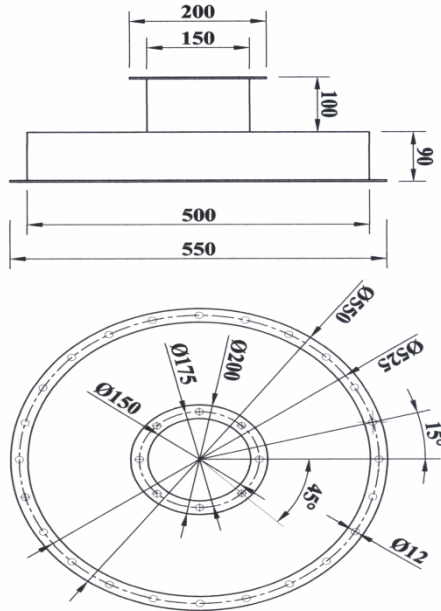
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APPENDICES

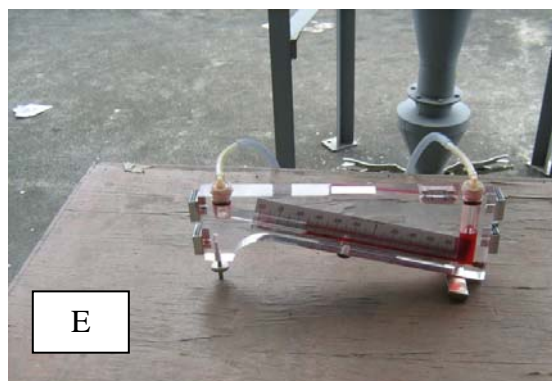
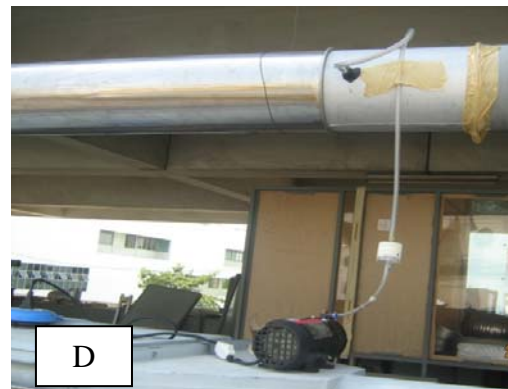
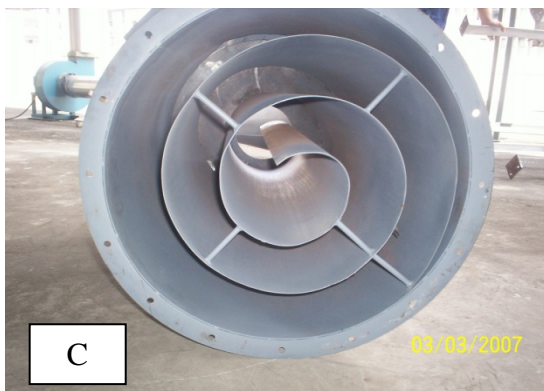
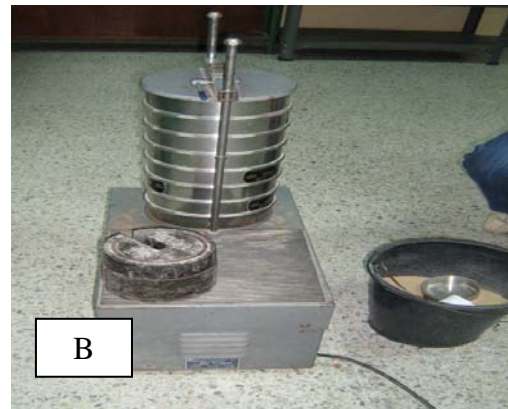
APPENDIX A. DIMENSIONS OF SPIRAL SHEET CYCLONE







APPENDIX C. PHOTOGRAPH OF EXPERIMENT



A).Experimental model,
D).Air Sampling.

B).Sand analytical,
E).Pressure drop measurement.

C).Spiral sheet,

APPENDIX D. EXPERIMENTAL RESULT

Experimental result

Date : 22/03/2552 time : 12.00-15.00

Relative Humidity : 49.4 %

Temperature : 33.6 °C

Air flow rate 19.5 m³/minute

Dust size (micron)	No. of sampling	Inlet				Outlet				Conc. Diff.	Eff (%)	Avg. eff (%)
		Filter weigh(mg)		Weigh diff.	Conc. (mg/m ³)	Filter weigh(mg)		Weigh diff.	Conc. (mg/m ³)			
		Pre	Post			Pre	Post					
1 to 53	1	77.537	95.177	17.640	1445.90	77.253	79.343	2.09	114.21	1331.69	92.10	93.90
	2	79.877	93.727	13.850	819.53	78.403	79.947	1.54	36.54	782.98	95.54	
	3	78.337	92.277	13.940	824.85	78.603	80.6700	2.07	48.92	775.93	94.07	
53 to 75	1	77.957	94.437	16.48	1350.82	76.78	77.31	0.53	28.96	1321.86	97.86	97.38
	2	79.903	94.31	14.407	1180.90	78.467	79.08	0.613	33.50	1147.40	97.16	
	3	75.857	88.94	13.083	1072.38	76.843	77.407	0.564	30.82	1041.56	97.13	
75 to 106	1	78.51	85.55	7.04	577.05	80.383	80.463	0.08	4.37	572.68	99.24	99.33
	2	78.813	84.36	5.547	454.67	76.673	76.73	0.057	3.11	451.56	99.31	
	3	76.45	86.327	9.877	809.59	78.193	78.277	0.084	4.59	805	99.43	
106 to 150	1	76.317	79.607	3.29	269.67	76.423	76.443	0.02	1.09	268.58	99.59	99.34
	2	75.21	81.1	5.89	482.79	77.86	77.987	0.127	6.94	475.85	98.56	
	3	74.35	85.803	11.453	938.77	77.477	77.503	0.026	1.42	937.35	99.85	
150 to 212	1	75.607	76.873	1.266	103.77	76.477	76.58	0.103	5.63	98.14	94.58	94.38
	2	78.587	82.02	3.433	281.39	77.287	77.577	0.29	15.85	265.55	94.37	
	3	73.313	76.49	3.177	260.41	76.223	76.5	0.277	15.14	245.27	94.19	

Experimental result

Date : 15/03/2552 time : 13.00-16.00

Relative Humidity : 44.9 %

Temperature : 29.8 °C

Air flow rate 27.41 m³/minute

Dust size (micron)	No. of sampling	Inlet				Outlet				Conc. Diff	Eff (%)	Avg eff (%)
		Filter weigh(mg)		Weigh diff	Conc. (mg/m ³)	Filter weigh(mg)		Weigh diff	Conc. (mg/m ³)			
		Pre	Post			Pre	Post					
1 to 53	1	77.33	92.253	14.92	898.80	76.86	78.79	1.924	77.269	821.53	91.40	91.13
	2	75.78	91.163	15.38	926.51	79.94	82.63	2.687	107.912	818.59	88.35	
	3	77.75	89.563	11.813	711.63	77.12	78.25	1.13	45.382	666.24	93.62	
53 to 75	1	76.19	90.007	13.82	832.53	74.41	74.70	0.293	11.767	820.76	98.59	98.30
	2	78.02	91.783	13.766	829.28	78.70	78.96	0.263	10.562	818.71	98.73	
	3	76.87	91.263	14.39	866.87	75.39	75.91	0.523	21.004	845.86	97.58	
75 to 106	1	74.95	89.027	14.077	848.01	75.19	75.35	0.16	6.426	841.59	99.24	99.53
	2	73.38	89.253	15.87	956.02	73.75	73.82	0.073	2.932	953.09	99.69	
	3	72.32	80.36	8.04	484.34	73.85	73.89	0.04	1.606	482.73	99.67	
106 to 150	1	71.19	90.49	19.3	1162.65	70.19	70.60	0.413	16.586	1146.06	98.57	98.72
	2	74.23	88.207	13.977	841.99	70.70	70.99	0.284	11.406	830.58	98.65	
	3	73.36	92.29	18.927	1140.18	72.31	72.61	0.303	12.169	1128.01	98.93	
150 to 212	1	71.01	84.603	13.596	819.04	67.62	67.87	0.247	5.846	813.19	99.29	99.08
	2	71.54	82.567	11.027	664.28	70.53	70.73	0.2	4.734	659.54	99.29	
	3	67.91	83.927	16.017	964.880	73.77	74.313	0.543	12.8521	952.03	98.67	

Experimental result

Date : 15/03/2552 time : 9.20-12.00

Relative Humidity : 54.4 %

Temperature : 27.1 °C

Air flow rate 32.72 m³/minute

Dust size (micron)	No. of sampling	Inlet				Outlet				Conc. Diff	Eff (%)	Avg eff (%)
		Filter weigh(mg)		Weigh diff	Conc. (mg/m ³)	Filter weigh(mg)		Weigh diff	Conc. (mg/m ³)			
		Pre	Post			Pre	Post					
1 to 53	1	70.01	84.30	14.29	708.48	71.28	73.647	2.367	78.24	630.24	88.96	90.43
	2	70.24	84.93	14.693	728.46	71.947	73.217	1.27	41.98	686.48	94.24	
	3	70.80	86.74	15.943	790.43	75.343	78.19	2.847	94.10	696.33	88.10	
53 to 75	1	74.40	88.21	13.81	684.68	71.533	72.517	0.984	32.52	652.16	95.25	95.94
	2	72.20	87.79	15.584	772.63	70.173	71.04	0.867	28.66	743.98	96.29	
	3	71.66	83.49	11.836	586.81	73.287	73.95	0.663	21.91	564.90	96.27	
75 to 106	1	74.90	87.56	12.66	627.66	74.01	74.0967	0.087	1.80	625.86	99.71	99.81
	2	73.93	86.32	12.39	614.28	74.573	74.6233	0.050	1.05	613.23	99.83	
	3	73.69	88.92	15.23	755.08	72.953	72.993	0.040	0.83	754.25	99.89	
106 to 150	1	77.68	91.08	13.397	664.20	77.55	78.067	0.517	17.09	647.12	97.43	98.86
	2	77.19	86.07	8.883	440.41	79.577	79.657	0.08	2.64	437.76	99.40	
	3	74.77	91.40	16.624	824.19	76.583	76.647	0.064	2.12	822.08	99.74	
150 to 212	1	77.06	88.50	11.44	567.18	80.353	80.56	0.21	6.84	560.34	98.79	98.76
	2	76.60	84.31	7.716	382.55	79.313	79.537	0.22	4.66	377.89	98.78	
	3	80.72	92.17	11.456	567.97	76.977	77.33	0.35	7.34	560.63	98.71	

BIOGRAPHY

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