REVIEW ON MULTICYCLONE DUST COLLECTOR

Shailesh Pansare[1], Sandesh Pokharkar[2], Kiran Pawar[3],
Tushar Khandve[4], Swapnil Patil[5]
[1,2,3,4] *B. E. Scholar, BVCOE & RI Nashik, Pune University, (India)*
[5]*Assistant Professor, Mechanical Dept. BVCOE & RI Nashik,Pune University, (India)*

ABTRACT

At present industries in India are growing rapidly. However this situation not only gain the economy but also created problems from production processes that might affect environment and human health. Especially the processes in which dust or micro particulates/pollutants are emitted to atmosphere. In coal fired boilers the flue gases have certain particles of solid matter in suspension, this is called smoke or dust. In case of pulverized coal furnaces the fly ash remains in suspension with flue gases. If the particle in suspension are of size ranging from 1-100 μm, it is called dust or smoke and for particle size more than 100 μm, it is called cinder. Any dust particles leaving into chimney exhaust are objectionable and harmful for the health of human being and for plant life. The production of smoke in chimney exhaust is also indicative of incomplete and improper combustion of fuel, in turn, it is indicative of low thermal efficiency of the thermal power plant. Nowadays rules and regulations regarding emissions and pollution control are getting strict. Therefore, it is always necessary to clean the gas from dust, smoke, or cinder particles before it is to be discharged from the chimney. Therefore to reduce the emission from steam producing industries we are willing to design and manufacture a multicyclone dust collector.

Keywords: - Cinder, Contaminants, Electrostatics, Fly-ash, Multicyclone, Particulates, Pulverized Coal, Stoker.

I. INTRODUCTION

The products of combustion of coal-fed fires contain particles of solid matter floating in suspension. This may be smoke or dust. If smoke, the indication is that combustion conditions are faulty, and the proper remedy is in the design and management of the furnace. If dust, the particle are finally fine ash particles called "Fly-ash" intermixed with some quantity of carbon-ash material called "Cinder". Pulverized coal and spreader stoker firing units are the principle types causing difficulty from this source. Other stokers may produce minor quantities of dust but generally not enough to demand special gas cleaning equipment. The two mentioned are troublesome because coal is burned in suspension-in a turbulent furnace atmosphere and every opportunity is offered for the gas to pick up the smaller particles and sweep them along with it.[7]
The size of the dust particles is measured in microns. The micron is one millionth of a meter. As an indication of the scale of this measure, the diameter of the human air is approximately 80 microns. Typical classification of particles by name is given in fig.1.1 but the limits shown are, for a most part, arbitrary. A critical characteristic

of dust is its "Settling Velocity" in still air. This proportional to the product of the square of micron size and mass density.[6]

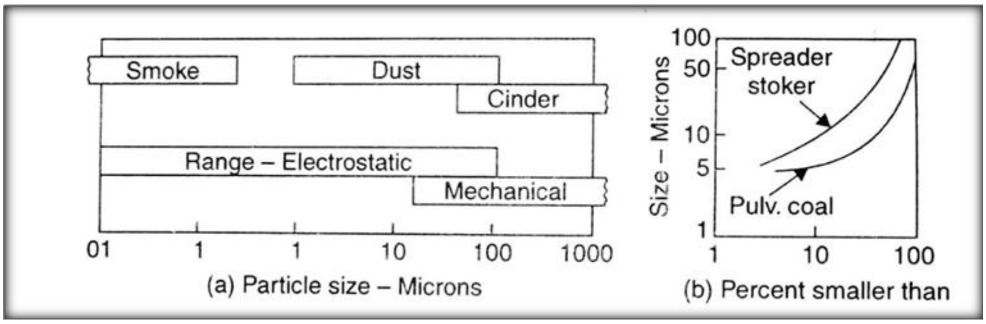

Fig1 Typical Particle Size

1.1 Purpose

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Nowadays rules and regulations regarding emissions and pollution control are getting strict. Therefore, it is always necessary to clean the gas from dust, smoke, or cinder particles before it is to be discharged from the chimney.Therefore to reduce the emission from steam producing industries we are willing to design and manufacture a multi-cyclone dust collector**.**

1.2 Objectives

1. To study dust characteristics from process.
2. To design and construct multi-cyclone for dust removal in process.
3. To determine collection efficiency of the constructed multi-cyclone.
4. To compare collection efficiency of the constructed multi-cyclone againstdifferent airflow rate**.**

II. LITERATURE REVIEW

2.1 Air Cleaning Devices

Air cleaning devices remove contaminants from an air or gas stream. They are available in a wide range of designs to meet variations in air cleaning requirements.[6] Degree of removal required, quantity and the characteristics of the contaminants to be removed, and conditions of the air or gas stream will have a bearing on the device selected for any given applications in addition, fire safety and explosion control must be considered in all selections.

For particulate contaminants, air cleaning devices are divided into two basic groups: air filters and dust collectors. Air filters are designed to remove low dust concentrations of the magnitude found in atmosphere air. They are typically used in ventilation, air-conditioning and heating system where dust concentration seldom exceeds 2mg/m^{3}of air and are usually well below 0.2 mg/m^3 dust collectors are usually designed for the much heavier loads from industrial processes where the air or gas effluents. Contaminants concentrations will vary from less than 230-2300 mg/m^3 or more for each cubic meter of air or gas. Therefore, dust collectors are, and must be, capable of handling concentrations 100 to 20,000 times greater than those for which air filters are designed.[3]

2.1.1 Existing Methods Of Dust Collection

The four major types of dust collectors for particulate contaminants are electrostatic precipitator, Mechanical dust collector.

2.1.1.1Electrostatic Precipitators

Electrostatic precipitators is also called as "Cottrell Precipitators", works effectively on the finer flue dusts. Fig.2 shows the basic elements of an electrostatic precipitator these are:

a) Source of high voltage.
b) Ionizing and collecting electrodes.
c) Dust-removal mechanism.
d) Shell to house the elements.

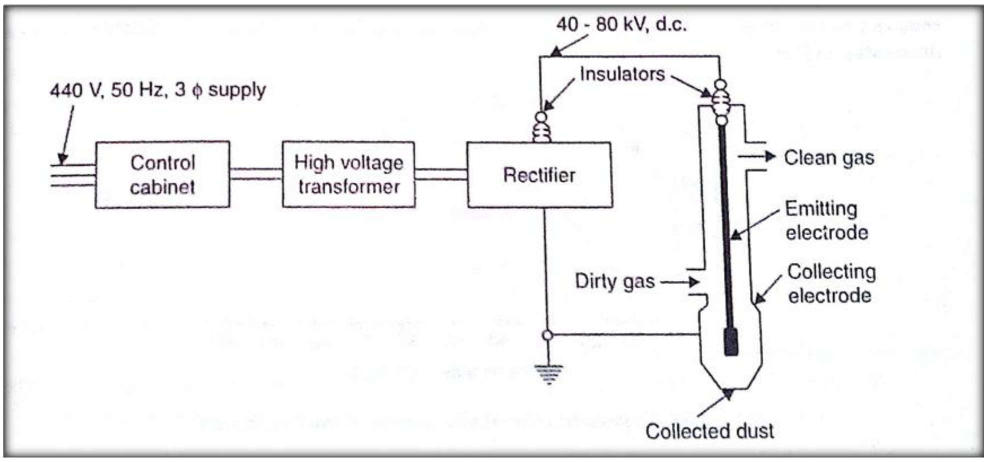

Fig 2 Basic Elements of Electrostatic Precipitators.

The precipitators has two set of electrodes, insulated from each other, that maintain an electrostatic field between them at high voltage. The field ionizes dust particles that pass through it, attracting them to the electrode of opposite charge. The high voltage system maintains a negatives potential of 30,000 to 60,000 volts with the collecting electrodes grounded. [7] The collecting electrodes have a large contact surface. Accumulated dust falls of the electrode when it is rapped mechanically.

A wet type of this unit removes dust by a water film flowing down on the inner side of the collecting electrode. These units have collection efficiency of the order of 90%.

2.1.1.2 Mechanical Dust Collector

The basic principles of mechanical dust collector is shown fig.

Fig. 2.1(a). Enlarging the dust cross sectional area to slow down the gas gives the heavier particles a chance to settle out.

Fig. 2.1(b). When a gas make a sharp change in flow direction, the heavier particles tend to keep going in the original direction and so settle out.

Fig. 2.1(c).Impingement baffles have more effect on the solid particles than the gas, helping them to settle out.

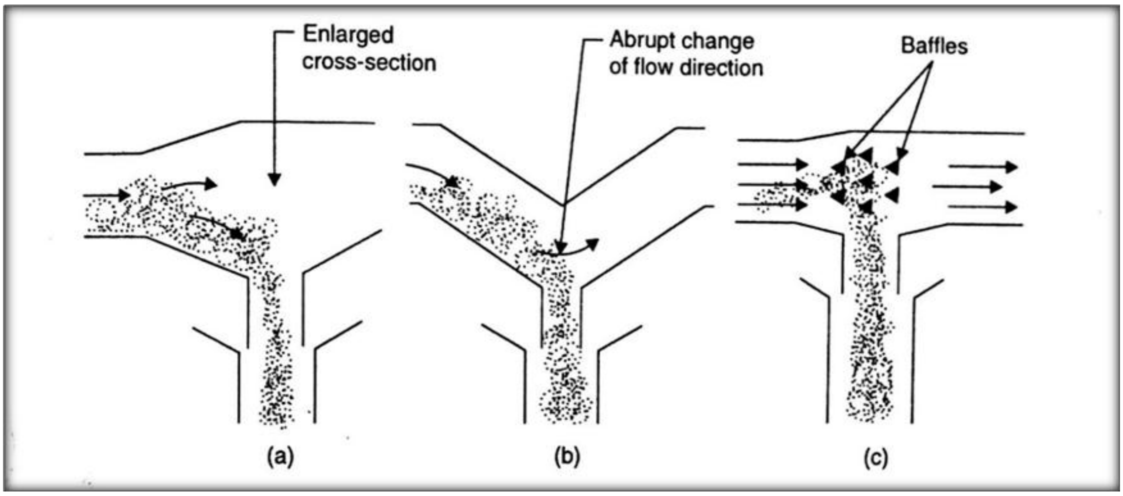

Fig 3 Principles Used In Dust Collection

2.1.1.3 Wet collectors

Wet collectors, or scrubbers, are commercially available in many different designs, with pressure drop from 375 pa to as much as 25kpa. [7] There is a corresponding variation in collector performance. It is generally accepted that, for will-designed equipment, efficiency is a function of total energy input per unit of volumetric flow rate whether the energy is supplied to the air or to the water. This means that well-designed collectors by different manufacturers will provide similar efficiency if equivalent power is utilized.

2.1.1.4 Dry Centrifugal collectors

Dry centrifugal collector, or cyclone, separate entrained particulate from an air stream by the use or combination of centrifugal, inertial, and gravitational force. It is commonly used for the removal of coarse dust from an air stream, as a pre cleaner to more efficient dust collectors. [6] Principal advantage are low cost, low maintenance, and relatively low drops. However, it is not suitable for the collection of the fine particles.

a) Gravitational Separators

These collectors act by slowing down gas flow so that particles remain in a chamber long enough to settle to the bottom. They are not very suitable because of large chamber volume needed.

b) Cyclone Separators

The cyclone is a separating chamber wherein high-speed gas rotation is generated for the purpose of "Centrifuging" the particle from the carrying gases. Usually, there is an outer downward flowing vertex which turn into an inward flowing vertex. Involute inlets and sufficient velocity head pressure are used to produce the vortices. As multiple, small diameter vortices with high pressure drop appear to high cleaning efficiency, that type is now being exploited. Skimming cyclones shave off the dust at the periphery of the vortex along with a small portion of the gas flow. This concentrated flow is then led to a secondary chamber for final separation.

The factors which affect the performance of this collectors are gas volume, particulate loading inlet velocity, and temperature, diameter to height ratio of cyclone and dust characteristics.

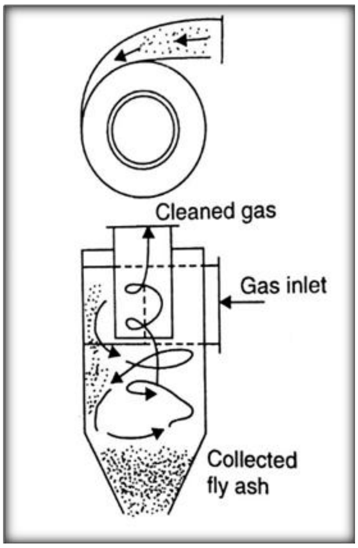

Fig 4 Cyclone Separators

2.1.2 Factors Affecting Selection Of Dust Collector

Dust collection equipment is available in numerous designs utilizing many different principles and featuring wide variations in effectiveness, first cost, operating and maintenance cost, space, arrangement, and materials of construction. Factors influencing equipment selection include following:

a) Contaminant concentration
b) Efficiency Required
c) Gas stream characteristic
d) Contaminant characteristic
e) Energy Consideration
f) Dust Disposal

2.1.2.1 Contaminant concentration

Contaminants in exhaust systems cover an extreme range in concentration and particle size. Concentrate can range from less than 230 kg of dust per cubic meter of air. In low pressure conveying systems, the dust ranges from 0.5 to 100 or more micrometers in size. [2] Deviation from means size (the range over and under the mean) will also vary with the material.

2.1.2.2 Efficiency Required

Currently, there is no accepted standards for testing and expressing the "efficiency" of a collector. It is virtually impossible to accurately compare the performance of two collectors by comparing efficiency claims. The only true measures of performance is the actual mass of emission rate, expressed in terms such as mg/m^3.evaluation will consider the need for high efficiency-high cost equipment requiring minimum energy such as high voltage electrostatic precipitation, high efficiency-moderate cost equipment such as fabric or wet collectors, or the lowers cost primary units such as the dry centrifugal pump. If either of the first two groups is selected, the combination with primary collectors should be considered. [4]

When the cleaned air is to be discharged outdoors, the required the degree of collection can depend on plant location; nature of contaminant (its salvage value and its potential as a health hazard, public nuisance, or ability to damage property); and the regulations of governmental agencies. Moreover, a safe recommendation in equipment selection is to choose the collector that will allow the least possible amount of containment to escape and is reasonable in first cost and maintenance while meeting all preventing air pollution regulations. For some application even the question of reasonable cost and the maintenance must be sacrificed to meet established standards for air pollution control or to prevent damage to health or property. [3]

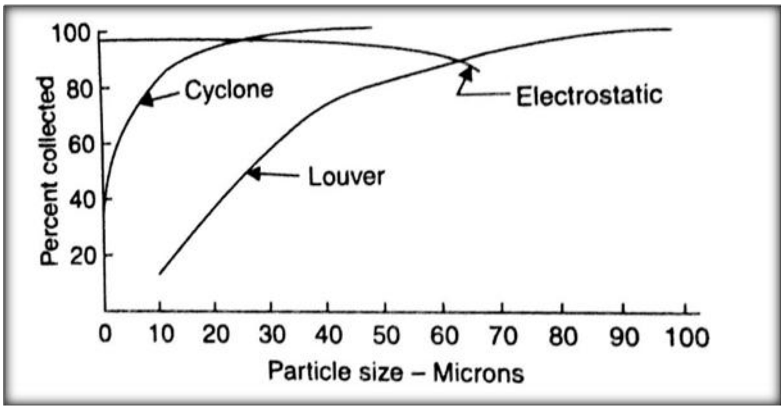

Fig 5 Typical Frictional Efficiencies of Dust Collectors

2.1.2.3 Gas stream characteristic

The characteristic of the carrier stream can have a marked bearing on equipment selection. Temperature of the gas stream may limit the material choices in fabric collectors. Condensation of water vapour will cause packing and plugging of air or dust passage in dry collectors. Corrosive chemicals can attack fabric or metal in dry collectors and when mixed with water in wet collectors can cause extreme damage.

2.1.2.4 Contaminant characteristic

The contaminants characteristic will also affect equipment selection. Chemicals emitted may attack collector elements or corrode wet type collectors. Sticky materials, such as metallic buffing dust impregnated with buffing compounds, can adhere to collector elements, fluffing collector passages. Linty materials will adhere to certain types of collector surface or elements. Abrasive materials in moderate to heavy concentrations will cause rapid wear on dry metal surfaces. particle size, and density will rule out certain design .for example, the parachute shape of particles like the "bees wings" from again will float through centrifugal collectors because their velocity of fall is less than the velocity of much smaller particles having the same specific gravity but a spherical shape.[5] The combustible nature of many finely divide materials will require specific collector designs to assume safe operation.

2.1.2.5 Energy Consideration

The cost and availability of energy makes essential careful consideration of total energy requirement for each collector type which can achieve the desired performance. An electrostatic precipitator for example, might be a better selection at a significant initial cost penalty because of energy savings through its inherently lower pressure drop.

2.1.2.6 Dust Disposal

Method of removal and disposal of collected materials will vary with the material, plant process, quantity involved and collector design. Dry collections can be unloaded continuously or in batches through dump gates, trickle values, and rotary locks to conveyors or containers. Dry materials can create a secondary dust problem if careful thought is not given to dust-free material disposal or to collector dust bin locations suited convenient material removal.

III. DESIGN ANALYSIS

- **Finding saltation velocity (V_s)**

$$V_s = 2.055\omega \left\{ \frac{(\frac{b}{D_c})^{0.4}}{1-(\frac{b}{D_c})^{1/3}} \right\} D_c^{\,0.067}.V_i^{\,2/3}$$

$$\omega = [4g\mu \frac{\rho_p - \rho_f}{3\rho_f^{\,2}}]^{1/3}$$

Where,

V_s= Saltation velocity, m/s ω = Omega, m/s b = Inlet width, m

D_c= Cyclone diameter, m V_i= Inlet velocity, m/s g= Gravity, 9.81 m/s^2

μ = Fluid viscosity, Kg/ms ρ_p = Particle density, Kg/m^3 ρ_f = Fluid viscosity, Kg/m^3

If $\frac{V_i}{V_s} \leq 1.25$, cyclone will be have maximum collection efficiency.

If $\frac{V_i}{V_s} \geq 1.36$, it will be caused the reentrainment.

- **Calculating volumetric flow rate**

$Q = abV_i$

Where,

Q = Total gas flow rate, m^3/s a = Inlet height, m

b = Inlet width, m V_i= Inlet velocity, m/s

- **Calculating Natural length, l**

$$l = 2.3D_e \left[\frac{{D_c}^2}{ab}\right]^{1/3}$$

Where,

l= Natural length, m D_e = Cyclone gas outlet diameter, m

D_c = Cyclone diameter, m   a = Inlet height, m   b = Inlet width, m

- **Calculating vortex exponent (n), Cyclone configuration factor (G), and Relaxation time (τ)**

$$n = 1 - [1 - (12D_C/2.5)^{0.14}][(T + 460)/530]^{0.3}$$

Where,

n = Vortex exponent D_C = Cyclone diameter, m T = Temperature, ^{0}C

$$G = 8K_c/{K_a}^2.{K_b}^2$$

$$K_a = \frac{a}{D_C}$$

$$K_b = \frac{b}{D_C}$$

$$K_c = \frac{2vs + (V_{nl} \text{ or } V_H)}{2{D_C}^3}$$

$$vs = \frac{\left\{\pi\left[S - \frac{a}{2}\right]\left[{D_C}^2 - {D_e}^2\right]\right\}}{4}$$

If l> (H-S), $V_H$is chosen for calculate K_c

$$V_H = \left[\frac{\pi {D_c}^2}{4}\right](h - s) + \left[\frac{\pi {D_c}^2}{4}\right]\left[\frac{H-h}{3}\right]\left[1 + \left(\frac{B}{D_c}\right) - \left(\frac{B^2}{{D_c}^2}\right)\right] - \left[\frac{\pi {D_e}^2}{4}\right](H - S)$$

If l< (H-S), V_{nl} is chosen for calculate K_c

$$V_{nl} = \left[\frac{\pi {D_c}^2}{4}\right](h - s) + \left[\frac{\pi {D_c}^2}{4}\right]\left[\frac{l+S-h}{3}\right]\left[1 + \left(\frac{d}{D_c}\right) - \left(\frac{d^2}{{D_c}^2}\right)\right] - \left[\frac{\pi {D_e}^2}{4}\right]l$$

$$d = D_c - (D_c - B)[\frac{(s + l - h)}{(H - h)}]$$

Where,

G = Cyclone configuration factor K_c = Cyclone volume constant

V_H = Volume below exit, m^3 V_{nl} = Volume at natural length, m^3

B = Cyclone dust outlet diameter, m H = Cyclone height, m

h = Cylindrical height of cyclone, m s = Gas outlet length, m

d = Diameter of central core at point where vertex turns, m

vs = Annular volume above exit duct to middle or entrance duct, m^3

$$\tau = \frac{\rho_p (d_{pi})^2}{18\mu}$$

Where,

τ = Relaxation time, sec ρ_p = Particle density, Kg/m^3

d_p = Particle size, m μ = Fluid viscosity, Kg/ms

i = Subscript denoted interval in particle size range

- **Calculating Grade or Fractional efficiency**

$$\eta_i = 1 - \exp\left\{-2\left[\left(\frac{G\tau Q}{{D_c}^3}\right)(n+1)\right]^{\frac{0.5}{n+1}}\right\}$$

Where,

η_i = Grade efficiency, % G = Cyclone configuration factor

τ = Relaxation time, sec n = Vortex exponent

Q = Total gas flow rate, m^3/s

- **Calculating overall collection efficiency**

$$\eta_T = \Sigma m_i \eta_i$$

Where,

η_T = Overall collection efficiency (%) m_i = Proportion of particle size range

η_i = Grade efficiency

- **Calculating pressure drop by using equation as follows:**

$$\Delta P = 0.003 \rho_f . {V_i}^2 . N_H$$

$$N_H = K(ab/D_e)$$

Where,

ΔP = Pressure drop, in N/m^2 ρ_f = Fluid density, Kg/m^3

V_i = Inlet velocity, m/s N_H = Number inlet velocity head

K = Empirical constant D_e = Cyclone gas outlet diameter, m

(K=7.5 for a cyclone with an inlet vane)

(K=16 for a normal tangential inlet)

After designing, dimensional proportion of cyclone have to be under the criteria

Conditions:•

$a \leq s$

• $b < ½ (D_c-D_e)$

• $s + l \leq H$

• $s < h$

• $h < H$

• $\Delta P < 10$ in w g

• $V_i / V_s \leq 1.35$

IV. INSTALLATION OF DUST COLLECTORS

Dust collector are installed between the boiler and the chimney, usually on the chimney side of the air heater, if there is one. There would be some advantages from the stand point of the heater cleanliness were the collector to be put ahead of it, however, the practice seems to be follow with the collector, and use blowers to keep the heater the surface clean. Where there is more than one boiler, the practice is to use an individual collector for each boiler. Generally the mechanical type is placed first in the gas flow. Another characteristic of interest in a combination is the variation of collection efficiency with the gas flow. As the flow increases, the electrostatic efficiency decreases, the cyclone efficiency increases.

V. GENERAL LAYOUT OF ASH HANDLING AND DUST COLLECTION SYSTEM

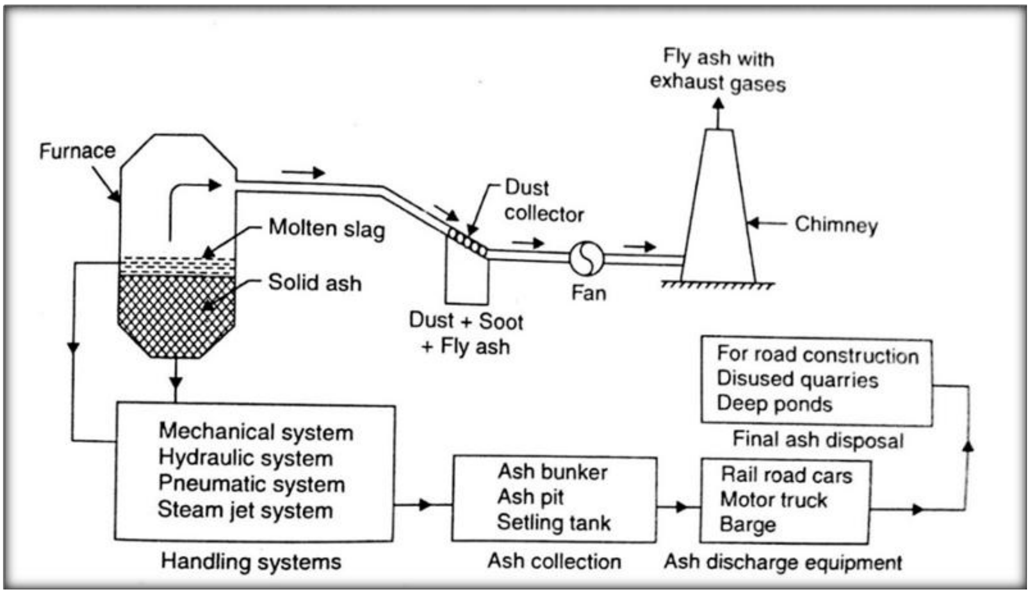

Fig 6 General Layout of Ash Handling and Dust Collection System

VI. CONCLUSION

The purpose of the research was to studies the collection efficiency of constructed multi-cyclone for dust removal in boilers. The multi-cyclone was composed of nine high-efficiency cyclones with axial inlet airflow which body diameter was 6 inches and arranged in parallel. Dimensions and shapes were calculated based on the hypothesis of Stairmand. The collection efficiency estimation was used theory of Leith and Licht. Then, it was setting up with local exhaust ventilation system that table hood and duct were designed by the recommended of the American Conference of Governmental Industrial Hygienists (ACGIH) Industrial Ventilation Manual.

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