# Design of Particulate Matter Emission Control Equipment for Khandsari Industry

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***Abstract:** In the ongoing past, the rising Indian economy is principally reliant on ordinary and in addition sustainable power source to satisfy its vitality need. Keeping the capability of biomass and its ample accessibility, the India government has been urging different enterprises to produce their own particular power. The Indian sugar industry has received and made amazing development in bagasse based heating to satisfy their vitality need and heating of liquid sugar. Out of total sugarcane annually produced in India, around 2/3rd is used to produce sugar; 1/5th used to produce jaggery and remaining is used for other commercial purposes [1]. The preparation of jaggery is considered as a small-scale industry, giving employment to many formers in rural India. Jaggery contains 65–85% of sucrose, 10–15% of reducing sugar, 3–10% of moisture, and the remaining is insoluble matter [2] The Khandsari udyog involves manufacturing of jaggery through the process of crushing sugarcane which produce sugar juice and bagasse, heating of sugar juice, crystallization of heated sugar and extraction of sugar and drying. The bagasse, which is generated by crushing of sugarcane, has enough heat content and is burned in closed chamber to create heat, which is utilized for heating up the juice. The air contamination starts with the consuming of bagasse. Heaters are described by inadequate ignition, less warmth recuperation and exorbitant utilization of bagasse, which brings about outflow of particulate issue, including smoke, carbon monoxide, oxides of nitrogen, and so forth. These gases which emit from this industry has low gas velocity which results in their breathing problems, also cause fair amount of air pollution and particulate matter starts gathering in the nearby area. This paper presents analytical calculations to design the air pollution control equipment to control emission of gases and particulate matter from Khandsari udyog.***

***Keywords:** Air Pollution, Khandsari, Bagasse, Jaggery, Particulate Matter*

## INTRODUCTION

Khandsari Udyog is a small-scale village level cottage industry for the production of sugar and jaggery. In India around 45% of total sugarcane production is crushed in Khandsari udyog. There are various standards, which are declared by Central Pollution Control Board (CPCB) for the control of pollution in this industry. But due to some negligence from the industry owners or due to high cost of pollution control equipment no standard were carried out in the industry. There are around 5500 functioning Khandsari industry in Uttar Pradesh itself, which works about 6 months in a season. In one season around 900 lakh quintal of cane is crushed in Khandsari industry which burns around 225 lakh quintal of fuel at a temperature of $180^0$C, generating around 787 Lakh quintal of fuel gas (mass) this in turn generates 3.82 lakh quintal of ash per season. Improper utilization of Khandsari industry have cause degradation of nearby area air quality which results in the occurrence of breathing problems to the people who are working in the industry and living in the nearby area. Process of production of jaggery begins with the crushing of sugarcane in the roller mills, which produce juice and bagasse as byproducts. Rollers are driven by diesel engine or by electric motor, use of diesel engine also cause air pollution and also not economic way to extract juice as diesel is also costly fuel. Juice produced is then filtered by the use of fine mesh where the heavy suspended particles or impurities are washed away from the juice. Then juice is transferred to a pan, which is heated by the use of bagasse heat upto $85^0$C. Use of bagasse for heating of juice is the second point where air pollution is occurs during the production. Since diesel engines are now upto BS-VI generation, which causes very little harm to, the environment but use of bagasse, causes a very high level of air pollution. Bagasse, which generated from crushing, has 45% moisture content, 53% volatile impurities and 2% ash content. When the wet bagasse is burned inside the furnace it consume air and results in the emission of polluted air. When the wet bagasse is burned inside the furnace it consume air and results in the emission of polluted air and component of polluted air is shown in the Table 1.

| | |
|---|---|
| C | 40%(w/w) |
| $O_2$ | 36% (w/w) |
| $H_2$ | 5% (w/w) |
| Moisture | 10% (w/w) |
| Ash | 8% (w/w) |
| Si | 0.08% (w/w) |
| $N_2$ | 0.51% (w/w) |

**Table 1:** %(W/W) of various components in bagasse

### Emission Monitoring

Table 2 shows the results of proximate analysis of bagasse sampling. Samples are collected by the use of vacuum sampling pump and followed standard method for collection of samples and analysis. The composition of flue gas components is as per Table 3.

| | |
|---|---|
| Carbon dioxide | 06.20% |
| Oxygen | 12.6% |
| Carbon-monoxide | 00.38% |

**Table 2:** Proximate Analysis of Bagasse

**Design of Equipment**

The measurement of various data such as ambient temperature, stack gas temperature, flue gas velocity, flue gas sampling rate, particulate matter emission were taken at the firing point, in the main combustion chamber at different points. Figure shows a temperature profile for the furnace from the point of stack to the chimney. The estimation of different information, like measuring temperature, stack gas temperature, vent gas speed, flue gas testing rate, particulate issue discharge were taken at the terminating point, in the primary ignition chamber at various points. Figure demonstrates a temperature profile for the heater from the purpose of stack to the smokestack.

| **Parameter** | **M/s Vidur Khandsari Udyog, Bijnor** |
|---|---|
| Ambient temperature ($^0$C) | 25 |
| Stack gas temperature ($^0$C) | 400 |
| Flue gas velocity (m/s) | 5.93 |
| Flue gas sampling rate (LPM) | 13 |
| Particulate matter emission (mg/Nm$^3$) | 690 |

**Table 3:** Flue gas analysis of stack gas

It is apparent from figure 1 that temperature is peak at the firing point and then temperature drops very rapidly along the flow path. Temperature measurements were also done for the hot juice in the pans and the temperature of the hot juice as shown in figure 1.

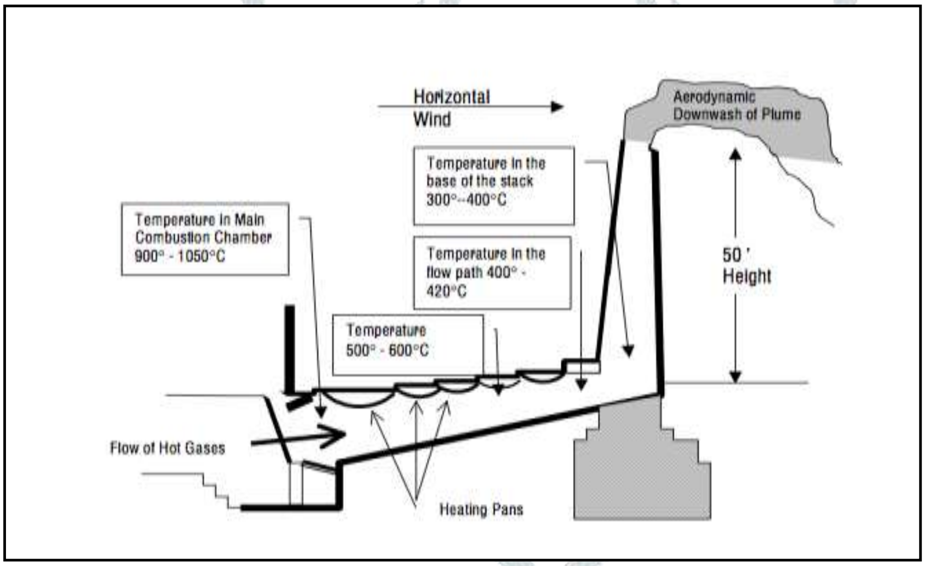


**Figure 1:** Temperature measurements at different points [3]

In summary, our problem is the release of various harmful gases and the fly ash (particulate matter), which generates due to burning of bagasse. So our main target or project is to control the emission of particulate matter and release of gases as per standard given by CPCB.

For the design of pollution control equipment we are assuming some technical data for the proper design and effective result.

Assumptions:

Sugarcane crushing capacity of mill = 100000kg/day
Juice extracted after crushing of sugarcane = 70% of weight
= 70000 kg
Solids generated (Bagasse) = Weight of sugar cane - Juice extracted
= 100000-70000 = 30000kg
Air required for burning of bagasse = 3.5 times of solid
= 3.5 x 30000kg
= 105000kg
Volume of air to be cleaned = 105000/1.29 m$^3$
= 81395.33m$^3$ /day

= 10174.41$m^3$/hour

Assume 1 day is equal to 8 working hours

Therefore, Generated effluent gas different has different gases and volatile contents which can be calculated as per table 1.

So, our project is to control the emission of particulate matter, which is generated by burning of bagasse. There are various options, which can be used to control pollution in Khandsari Udyog. But cost of these equipment's plays a important role in selection and design of equipment as small-scale industry are not in the condition that they can afford very high cost equipment's. Equipments available in the market to control air pollution are:

1. Electrostatic Precipitators
2. Baghouse Filter
3. Particulate Scrubber
4. Cyclones

**Selection of device:**

1. Electrostatic Precipitators:

ESP is very high cost equipment.

Required a lot of electricity for working.

Skilled manpower is required for their working.

Needs a lot of space.

ESP's are mainly used for some product recovery

2. Cyclones:

Cyclones are low cost equipment used to separate particulate from air, gas, and liquid stream without use of filter.

Cyclones can't be used for removal of gases from air stream

High operating costs

Low efficiencies

3. Particulate Scrubber:

Particulate Scrubber is high cost equipment used to separate particulates and gases from the air flow. Provide cooling of hot gases.

Collection efficiencies can be varied

Corrosive gas and dusts can be neutralized.

Need a lot of water which again cause water pollution and small-scale industry can't afford such requirement of water.

4. Baghouse filter:

Baghouse filter are extremely high collection efficiencies even for very small particles.

They can operate in wide range of dusts types.

They required reasonably low-pressure drops.

Can collect acid gases.

Can be easily designed and modules can be preassembled at the factory. They can operate over an extremely wide range of volumetric flow rates.

So, on the basis of above points we easily select Baghouse filter for the pollution prevention device for Khandsari industry.

**Design of Baghouse Filter for Khandsari Industry:**

Available data for designing of filter:

| | | |
|---|---|---|
| Air flow | = | 10174.41 $m^3$/h |
| | = | 5988.43 cfm (generated from burning of bagasse) |

= 169.57$m^3$/min

SPM Concentration in exhaust air stream = 800mg/$m^3$

Density of emitted particles = 550kg/$m^3$

Velocity of airstream when flowing through 5 inch diameter circular pipe = 55.78m/s

Temperature of exhaust gas from furnace = $400^0$C

Required temperature of air stream at baghouse filter equipment = $150^0$C

Fabric Filter Material for this temperature range = Teflon or Glass

Since Temperature is too high, which may result in early deterioration of baghouse filter and also there is very less variety of filters for this temperature range. So we need to cool down the temperature.

**Cooling of Exhaust Gas:**

Air Dilution can do cooling of exhaust gas. Air Dilution is one of the easiest way to cool the hot exhaust airstream. In Air dilution if the temperature of the incoming hot airstream is too high then quantity of air required for dilution is substantially very high. Air required for dilution can be written as

$$Q_d=Q_e\left(\frac{T_e-T_f}{T_f-T_d}\right)\left|\frac{T_d}{T_e}\right| \quad [4]$$

Where

$Q_d$ = dilution airflow rate needed
$Q_e$ = exhaust airflow rate to be cooled
$T_e$ = temperature of the exhaust air
$T_d$ = temperature of the dilution air
$T_f$ = final temperature of the mixed stream

The absolute value signs | | in eq () serve as a reminder that, at this point, $T_d$ and $T_e$ must be expressed as absolute temperatures.

Therefore, Airflow rate required of fresh air for the dilution can be written as

$$Q_d=Q_e\left(\frac{T_e-T_f}{T_f-T_d}\right)\left|\frac{T_d}{T_e}\right|$$

$$Q_d = 10174.41\left(\frac{400-150}{150-30}\right)\left|\frac{30}{400}\right|$$

$Q_d$ = 1587.21 $m^3$/hr

Total Volume of air which will get filtered though baghouse filter equipment = Volume of air stream which is release from furnace + Volume of air stream which is added during dilution

= 10174.41 + 1587.21 $m^3$/hr
= 11761.62 $m^3$/hr
= 6922.62 cfm

Now, A Mild Steel Pipeline will be used which carry air stream from point of air dilution to baghouse filter whose diameter is 10 inch. Therefore, velocity of airstream through this pipeline is 64.47m/s

Maximum Filtering velocity V = 3.50 cfm/$ft^2$ for Fly-ash [5]

Net Cloth Area = Q/V
= 6922.62/3.50
= 1977.89 $ft^2$.
= 183.75 $m^2$.

No. of compartments = 2 [6]

Net cloth area = 91.87 $m^2$.

Assume, Diameter of each bag = 0.2 m
Length of each bag = 3 m
Filtering area of each bag = $\pi$dl
= 3.14 x 0.2 x 3
= 1.884 $m^2$

No of bags required = 91.87/1.884
= 48.76 bags or 50 bags

Therefore, Each Compartment will have 25 bags (5 x 5 bags).
Assume, Gap of 0.05m between each bag and 0.34m between outer bag edge and compartment wall.
Thus, Inside Length and Breadth of compartment is 1.88 m.
Floor Area of compartment= 1.88 x 1.88 $m^2$
= 3.53 $m^2$
Let Efficiency of baghouse filter ($\eta$) = 99.5% for PM<2.5
Therefore, SPM Concentration after filtration = 800 x 0.005
= 4mg/$m^3$
Collection of particulate matter per $m^3$ of airstream in baghouse = 800-4= 796mg/$m^3$

**Conclusion:**
In the paper we design the baghouse filter for Khandsari industry with Teflon filter whose life is very long as compare to other filter's to control particulate matter, which are release during the jaggery production. Use of baghouse filter in Khandsari industry will be boon, as it requires very less electricity and very low maintenance during operating period.

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