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CASE STUDY: DEDUSTING SYSTEM FROM LIME KILN EXHAUSTING GASES IN A PULP AND PAPER INDUSTRY USING A FLOODED DISK VENTURI SCRUBBER

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ABSTRACT

This article presents a technical solution to reduce dust emissions from lime kiln exhausting gases in a pulp and paper industry, aiming to decrease environmental impacts. These emissions are regulated at the federal level by Brazil's National Environmental Council (CONAMA), through Resolution 436 of 2011, and by state environmental entities, for which said emissions must not exceed 180mg/scm. In the cases studied, the amount of flue gas particulate material emitted from the lime kiln after primary treatment was 700mg/scm, well above the value permitted by law. Several technologies relate equipment and systems to the solid-gas separation processes in the gaseous emission sources. Each one of them has its own advantages and applications. In analyzing different dedusting mechanisms, the main and most common unit operations are the electrostatic precipitator and the Venturi scrubber. In this context, the flooded disk Venturi scrubber was the option chosen for the solid-gas separation process, given its implementation costs, dedusting efficiency and operability of the system. This solution was assembled in 2 lime kilns at the same pulp mill (1040 ADTPD, air-dried ton per day), where the maximum dry basis concentration obtained was 59.49 (lime kiln A) and 31.04 (lime kiln B) mg/scm at 8% O_2. These results show that the system chosen is an effective solution, staying at least 66% below the limit of CONAMA Resolution 436/11.

Keywords: *Gaseous emissions, lime kiln, pulp and paper, venturi scrubber, environmental legislation*

INTRODUCTION

This paper aims to present an alternative to treat lime kiln flue gases in a pulp and paper industry, with the objective of reducing particulate emissions to below legal limits.

A lime kiln is used to convert lime mud into lime for reuse in the causticizing plant of the kraft recovery process (Tran, 2008). Lime mud is fed into a rotary kiln where it is dried and heated in counter flow with the combustion gases from the burner as shown in the Figure 1.

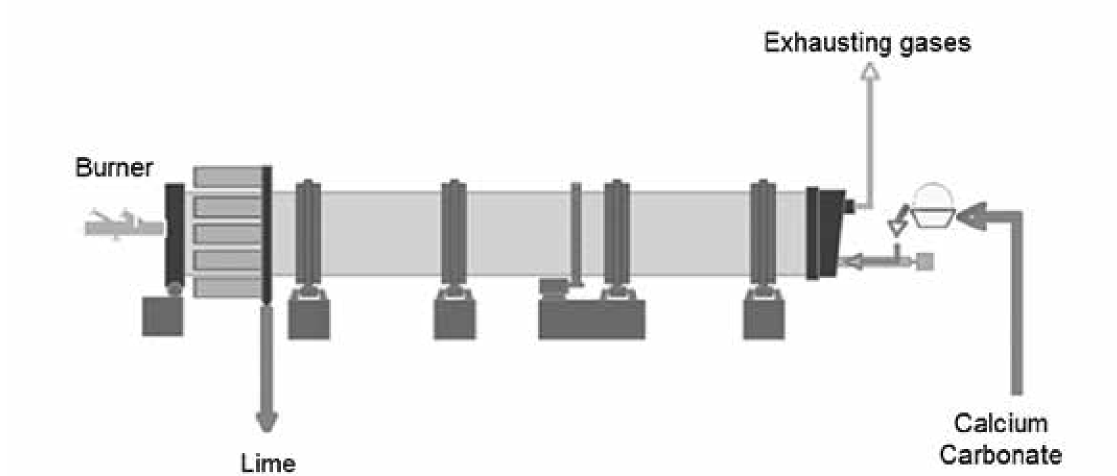

Figure 1. Lime kiln basic flow

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O PAPEL vol. 83, N.o 3, pp. 67 - 71 - MAR 2022

As the mud reaches the temperature of about 800°C (1470°F), the calcination zone, the calcium carbonate decomposes into lime, as indicated in the following reaction (1)

$$CaCO_{3\ (aq)} \rightarrow CaO_{(s)} + CO_{2\ (g)} \qquad \text{Reaction}(1)$$

As lime mud moves through the kiln, the composition changes as the mud begins to decompose. The decomposition temperature of lime mud depends greatly on the local CO_2 partial pressure and impurity content in the mud. Since the CO_2 concentration in the kiln gas varies from 12% CO_2 near the burner to about 25% in the back end, the decomposition temperature varies from 800 to 820°C (1470 to 1510°F). During decomposition, temperature of the solids remains constant due to heat absorption. It increases only when most of the $CaCO_3$ in the solids has been calcined. (Tran, 2008).

As lime mud slides through the kiln, solid particles, dust, are entrained in the exhausting gas flow. Most of this dust is captured by precipitators, scrubbers or filters and returned to the kiln, the most common system for this are the electrostatic precipitator and venturi scrubbers.

The generation of an electrical field for particle ionization is the driving force for dust and smoke separation from an exhausting gas flow in the electrostatic precipitation process. White (1963) claimed in the mentioned date that propelling spaceships into space using ion propulsion engines would be a theoretical possibility only in space. Today, we have ion thruster engines. An electrostatic precipitator (EP) works under the same concept of ion generation, however, here the objective is to manage the electrical field to keep supplying electrons and accelerating the electrically charged particles and/or smokes to a collecting wall, known as the corona effect, removing the undesiring pollutants from the gaseous current.

EPs have several considerable configurations: dry and wet precipitators, plate precipitators and tubular ones, to name a few. They work by generating a high differential potential between electrodes, ranging from 30,000 to 100,000 V (White, 1963). Respecting the required electrode distance, the induction of an electrical field turns neutrally inlet gas mixture into a negatively charged (ionized) cloud. Inside the equipment, the ionized particle matter or/end smoke is attracted to the opposite charged electrode, normally a grounded metallic object. Once it touches the collecting surface it loses its charge, which creates a powder-like layer that is latter cleaned by several different methods, dry and wet. The intensity of this differential potential is directly dependent on the application, hence, average bulk resistivity (conductivity), which is a function of the composition of emitted gaseous effluent (Parker, 2003). Figure 2 shows a representative flow pattern in a plate precipitator and its electrode disposition, it also shows the control unit and the particulate continuous emission monitoring system (CEMS).

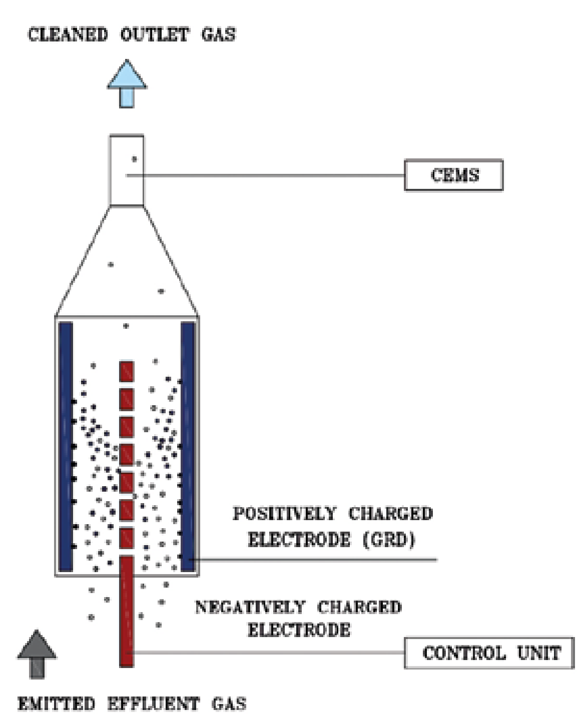

Figure 2. Representative flow pattern and electrode disposition

O PAPEL vol. 83, N.o 3, pp. 67 - 71 - MAR 2022

Table 1. Range of Precipitator Operating Conditions (White, 1963 – adapted)

Gas Flow	**1.7 – 5,000,000 m³/h**
Gas Temperature	**Up to 650 °C**
Gas Pressure	**Up to 10 bar**
Gas Velocity	**1 – 4.5 m/s**
Draft Loss	**2.5 – 12.7 mm H2O**
Particle Size	**0.1 – 200+ µm**
Particle Concentration	**2.25 – 230,000 mg/m³**
Particle Composition	**No basic limit; Solid, liquid, corrosive chemicals**
Treatment Time	**1 – 10 sec for most applications**
Efficiency	**80% to 99%; some 99.9%**

Table 1 shows some important variable ranges related to design, operation and performance of electrostatic precipitators.

The gas flow indicated confirms that EPs are eligible options for the study case presented in this paper. We see that this equipment is capable of reaching high efficiency levels. Nevertheless, they have an expensive capital cost and do not work in variable composition systems.

On the other hand, the main mechanism to capture particles in a wet scrubber is impaction, where the particles shock with the droplet and are then collected. Therefore, when impacts are promoted, they enhance the capture; the higher the velocity of the gases and liquid flow, the higher the capture.

Another mechanism is interception, which occurs when the particle passes sufficiently close to a water droplet and is captured due to the surface tension of the water droplet. Increasing the density of droplets in a spray increases interception (Mussatti & Hemmer, 2002).

The liquid injection system design promotes mixing of the waste gas and scrubbing liquid in the venturi scrubber. There are basically two types for injecting liquid into a venturi scrubber: open pipe and spray nozzles. The liquid is injected in the same side of the venturi that the waste gas comes in. Both systems inject the liquid in the same direction of the gas stream.

In this case, a specific type of venturi was used, a flooded disc scrubber, a variable throat venturi, The venturi throat area is increased or decreased by the dampers when the waste gas inlet conditions change (Mussatti & Hemmer, 2002). Walker & Hall (1968) describe the function of the flooded disc, the section cited by them is shown in Figure 3.

"Hot, dirty gases enter the contractor section at A, pass down to impact on the flooded disc at B, and are forced through the annular orifice where they are accelerated to velocities in the order of 100 to 400 fps. Scrubber liquor enters at point C, passes upward through the center disc support column, impinges on the liquor distribution cone, and is distributed radially across the face of the disc. The scrubbing liquor, as it passes off the periphery of the disc, is atomized by the shearing action of the high velocity gas stream passing through the annular orifice. Because of the large gas-liquid interface formed by the atomization of the liquor, the gases are quickly saturated." (Walker & Hall, 1968)

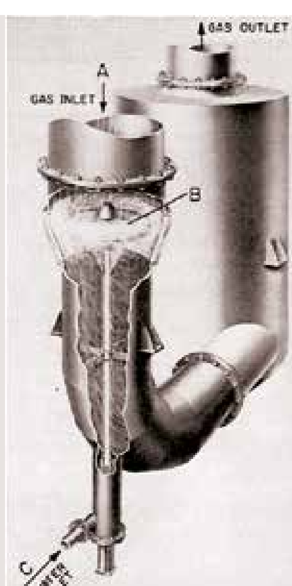

Figure 3. General configuration of flooded disc scrubber (Walker & Hall, 1968)

O PAPEL vol. 83, N.o 3, pp. 67 - 71 - MAR 2022

After the venturi, the gas passes through a collection chamber and mist eliminator, this collection chamber may be a simple tower, baffled tower or a cyclone (Mussatti & Hemmer, 2002); in this particular case a cyclone was used.

CONTEXT

CONAMA Resolution 436, dated December 22, 2011, establishes the higher limits of atmosphere pollutants by pollutant and font type. For this case, gaseous emissions from the pulp production process (attachment VII) in the lime kiln. This limits the emission of particulate material to 180mg/scm, dry base 8% of oxygen.

The systems assayed in this paper, were assembled in two lime kilns at the same pulp mill (1040 ADTPD, divided in two production lines) in 2018. After the lime kiln, in each production line, had a primary treatment that did not comply with legal limits. Table 2 shows the maximum emission measured in local stack of each system, before 2018.

Table 2. Maximum emission measured

System	Particle emission (mg/scm)
System A	444.40
System B	619.45

At that time, waste gases were suctioned from the lime kiln by a fan and sent to a venturi scrubber, and then to the separator cyclone and local stack. From the local stack these gases were directed to the main stack by a second fan, as illustrated in the Figure 4, both systems (A and B) were similar.

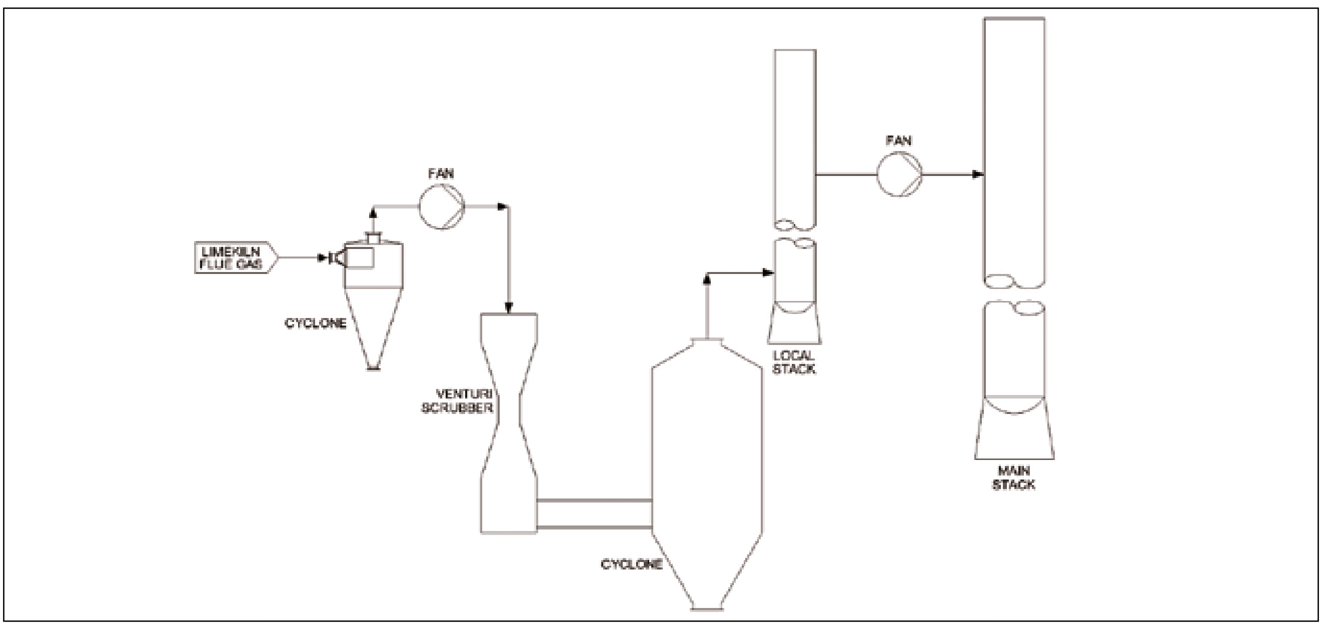

Figure 4. Basic gas flowsheet before 2018

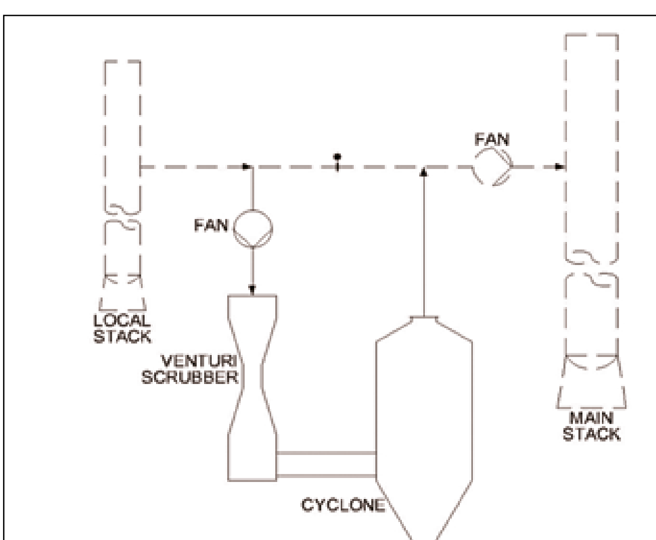

Figure 5. Basic gas flowsheet system A

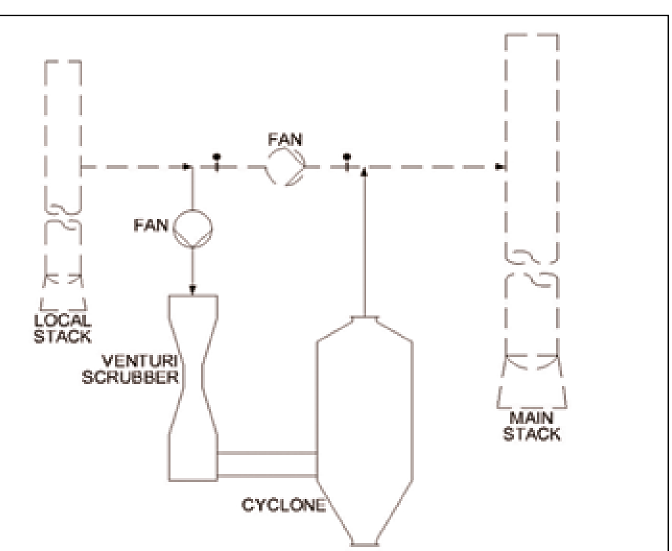

Figure 6. Basic gas flowsheet system B

O PAPEL vol. 83, N.o 3, pp. 67 - 71 - MAR 2022

Table 3. Particulate material in lime kiln A sample

Sample	Gas flow (scm/h)	Concentration as sampled (mg/scm)	Concentration 8% O_2 (mg/scm)
Sample1	13,918.55	24.71	59.49
Sample2	14,077.36	21.88	50.79
Sample3	13,982.56	23.94	57.63

Table 4. Particulate material in lime kiln B sample

Sample	Gas flow (scm/h)	Concentration as sampled (mg/scm)	Concentration 8% O_2 (mg/scm)
Sample1	25,559.23	31.04	31.04
Sample2	25,568.58	24.89	25.28
Sample3	25,553.17	24.51	24.89

The systems were assembled after the local stack of each line. In A, the second fan was deactivated, while in B, it was maintained. The clean gases from new systems were sent to the main stack. With this, these new systems were installed to operate in series with the existent. The new system contains a fan, scrubber and separator.

METHODS

To measure emissions, samples were collected following CETESB (State Environmental Company of São Paulo) specifications. Samples of the particulate material were collected using an isokinetic sampler and, simultaneously, the gas velocity was measured using a pitot. The mass of the material collected was quantified by a gravimetric analysis, while the particulate material mass and the sampled volume of gas ratio obtained the concentration. The samples were collected three times.

RESULTS

Table 3 and Table 4 present the sampling results obtained in lime kiln A and B, respectively.

CONCLUSION

Nowadays, an EP is a much more common choice for this application, but when the subject is environment, it is not the only choice. Environmental legislation in Brazil states that particulate emissions in the lime kiln of a pulp and paper industry needs to be under 180mg/scm dry basis at 8% oxygen, and the treatment system studied reached a maximum particle emission under 60mg/scm. This shows that the venturi scrubber is an excellent choice to reduce particulate emissions in the lime kiln of a pulp and paper industry. ■

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