FALSE AIR IN THE CEMENT MANUFACTURING PROCESS

Information on the importance of false air in the kiln and raw mill process in cement plants.

False air calculation and measurement.

Comparison between different sealing solutions to reduce false air in kilns.

The importance of equipment maintenance to reduce false air.

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November 2019 Rev. May 2022

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1. INTRODUCTION

In the last 30 years, the cement industry has greatly improved their production facilities and reduced heat consumption and electricity, contributing to reduce their carbon footprint.

The kilns increased their capacity from 1,000 to 2,000 t/d to 3,000 to 6,000 t/d.

The 5-stage cyclone preheaters and pre-calciner not only improved operating conditions, but also allowed the use of low-cost alternative fuels.

False air in the kiln, preheater, pre-calciner and in the main fan remains a major problem that negatively influences production and operation costs, CO_2 emissions and, in some cases, clinker quality.

In this paper we will discuss kilns in general and, as an example, a 3,000 t/d kiln with a 5-stage preheater and pre-calciner as this is a common size today.

2. PROCESS DATA FOR A 3,000 T/D KILN Z

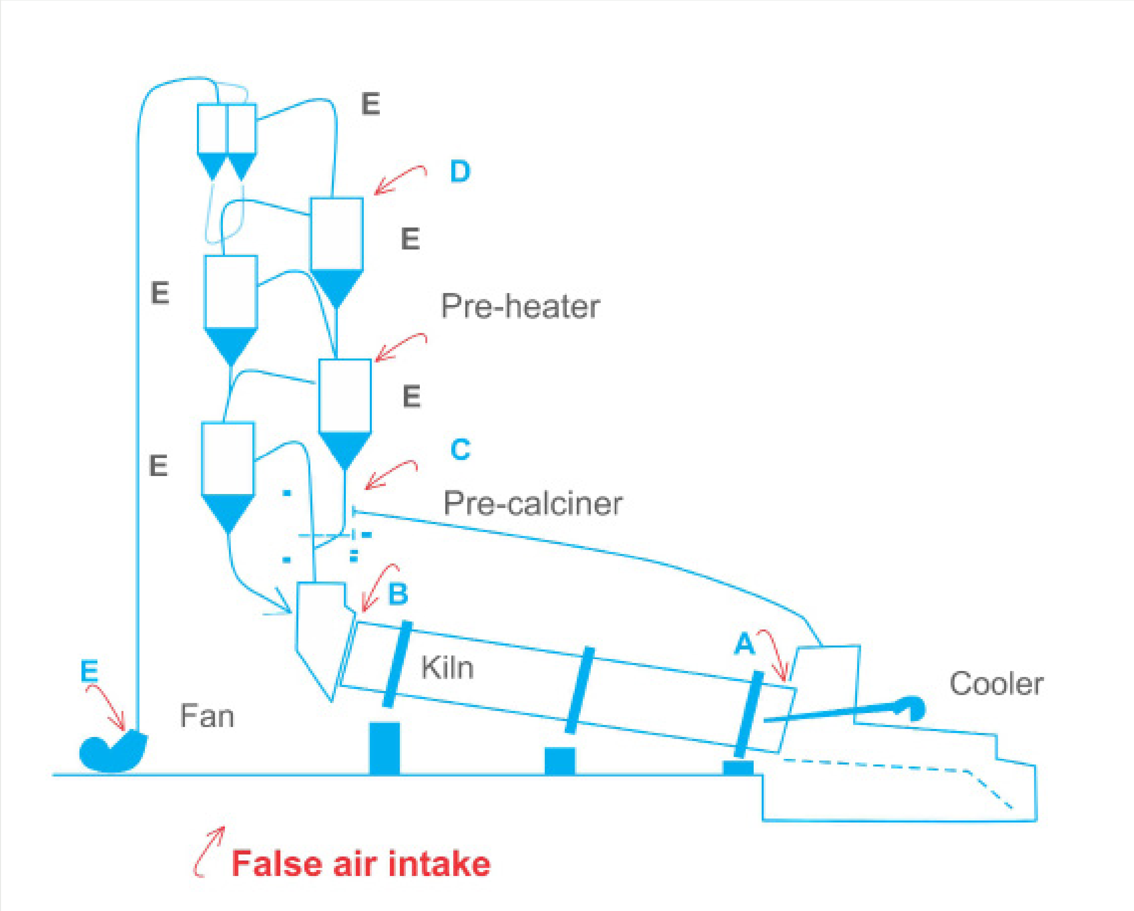
	Temperature °C	Density kg/m3	Gases volume Nm3/kg clinker	Gases volume m3/kg clinker
Preheater Stage 1	320	0,530	1,390	3,650
Preheater Stage 2	520	0,420	1,350	4,600
Preheater Stage 3	650	0,349	1,310	5,386
Preheater Stage 4	810	0,302	1,296	6,090
Preheater Stage 5	890	0,284	1,280	6,448

Gas temperature at the preheater outlet: 320 to 340 °C

Heat consumption: 770 Kcal/kg clinker

Main fan pressure: approx. 520mmAC

3. FALSE AIR INTAKE IN THE KILN SYSTEM



False Air Intake
A. Kiln outlet (discharge) seal.
B. Kiln inlet (feed) seal.
C. Fuel feed pre-calciner.
D. Cyclone preheater. Cleaning doors.
E. Fan. Seal on rotor shaft.

A significant amount of false air can also enter through the inlet seal, in the case of the raw mill installed to use kiln gases to dry the raw material.

The largest false air intake takes place through the kiln inlet B and outlet A seals, due to the large diameter of the seal and the continuous kiln rotary motion.

4. FALSE AIR CONSEQUENCES IN THE KILN SYSTEM

False air intake can cause the following issues:

1. Increased heat consumption which may increase CO2 emissions (the incoming cold air reduces the temperature of the process gases),

2. Increased electrical energy consumption in the draft fan due to a larger volume of gases,

3. Reduced kiln production, if the draft fan does not have a backup,

4. Flame out of control in the main burner at the main kiln due to pressure and temperature variations caused by false air,

5. Impact on the protective layer and on the refractory life cycle,

6. In some kilns there was a C35, C4AF, C3A crystals variation due to alterations in the cooling area,

7. Ring formation at the kiln inlet,

8. Avalanches at the kiln inlet,

9. Loss of fine material that must be removed,

10. Cleaning and maintenance problems,

11. Accidents risks due to the material high temperature,

12. Flame out of control during pre-calcination,

13. Obstruction in the preheater cyclones,

14. Capacity loss on the draft fan (shaft),

15. Affects the stability of the process in general.

5. FALSE AIR QUANTIFICATION

With the rising cost of thermal and electrical energy in recent years, reducing the amount of false air entering the process has become increasingly important to reduce production costs, improve operation and help reduce the carbon footprint.

Measuring studies were carried out in Germany and other EU countries in several kiln systems with a capacity near to 3,000 t/d. These were the results:

PERCENTAGE OF FALSE AIR %		
	Before sealing improvement	**After sealing improvement**
Kiln inlet side	7 to 6	3 to 2
Kiln outlet side	6 to 5	2 to 1
Pre-calciner	6 to 5	3 to 2
Pre-heater	3 to 2	1
TOTAL FALSE AIR	22 to 18	9 to 6

False air intake through the main fan shaft seal has not been measured.

As displayed in the table above, in the best-case scenario, false air reduction can reach 16% (from 22% to 6%) and in the worst-case scenario can reach 9% (from 18% to 9%), all this with proper seals on both ends and good overall maintenance in the preheater and pre-calciner.

The highest volumes of false air occur at the kiln inlet and outlet. There are extreme cases, where the numbers reach 10% at the inlet and 8% at the outlet, depending on the condition of the seals and maintenance quality.

In a specific case, before the seals improvement, a kiln of 3,000 t/d with 5 stages presented 18% of false air of the total volume of gases, of which 11% corresponded to the kiln inlet and outlet, 5% to the pre-calciner and 2% to the preheater.

After modifying the kiln seals and maintenance of the preheater and pre-calciner, the false air was reduced by 8%. This represented a 3.5% reduction in fuel consumption and a 12% reduction in fan power consumption, contributing proportionally to reduce the carbon footprint. As a result, the annual cost was reduced by 340,000 euros (depending on local costs).

Considering that each seal replacement can cost 180,000 euros, the return on investment took less than a year.

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6. FALSE AIR CALCULATIONS

6.1 Calculation based on false air inlet gap

This calculation is based on the negative pressure inside the process equipment (kiln, cyclones, etc.).

This method is not very accurate because the area where there is false air intake is difficult to measure due to the large diameter of the kiln (seal) and the variations during rotation; and especially in the case of a kiln with run-out.

The air intake speed is easy to calculate with the negative pressure calculation, but to calculate false air volume it is necessary to know the size of the intake area, which as already indicated above is difficult to determine. The most difficult calculation is the pressure loss, because in this case it is necessary to apply a coefficient that represents the complexity of the air intake, which is different for each type of gap.

6.2 Calculation based on process data

As an example, the calculation will be carried out for a 3,000 t/d kiln using the process data indicated in item 2 and the volume of false air indicated in item 5. A case study of a seal installed in Brazil.

With a new seal or modification of the existing one, the false air reduction would be 4% at the kiln inlet (letter B in the image of item 3).

At the kiln inlet, the measured temperature is 870°C and the gas flow is 6.360 m3/kg clinker and 4% is 0.254 m3/kg clinker and the gas density 0.279 kg/m3 (values very close to those of the preheater cyclones stage 5).

The thermal energy loss due to the false air intake with a room temperature of 25°C is:

$Eq = V \times d \times Ca \times \Delta T$

V = Volume of false air 0.254 m3/kg clinker
d = Gases density 0.279 kg/m3
Ca = Air specific heat 0.24 Kal/kg °C
ΔT = Temperature difference 870 - 25 = 845 °C

Eq = 0.254 x 0.279 x 0.24 x 845
= 14.37 Kcal/kg clinker

Since the kiln production is 3,000 t/d, i.e., 3,000,000 kg clinker/day x 14.37 Kcal/kg clinker = 43,110,000 Kc

Assuming an average fuel heat value of 7,600 Kcal/kg, a fuel price of R$ 500/t and 320 days of kiln production, we reach a:

R$ 907,200.00 reduction / year.

The main fan would have to exhaust, in addition to the process gases, another 4% of false air.

The ratio between the power consumed and the flow rate is:

$$\frac{P}{P1} = \left(\frac{V}{V1}\right)^3$$

For a fan flow rate of 3,650 at 320 °C, the amount of false air would be 0.146 m3/kg clinker and if the current fan consumption is 1,100 kW.

$$P1 = \frac{P}{\left(\frac{V}{V1}\right)^3} = 937{,}3KW$$

With an estimated cost of R$ 0.22 per kWh, the reduction in electricity cost would be:

Ce = 0.22 x (1100-937.3) x 24 x 320 = R$ 274,898 / year.

And the total cost reduction due to 4% less false air at the kiln inlet is:
R$ 1,182,098 / year.

Also considering false air reduction at the kiln outlet, in the preheater and in the pre-calciner, it can reach a reduction of R$ 2,500,000 to R$ 2,800,000 / year.

As the installation cost of an efficient seal is approximately R$ 1,000,000 to R$ 1,300,000, the return on investment is very fast.

These values are from a kiln in Brazil in November 2019, it is possible to calculate them for any kiln taking into consideration the existing local costs.

6.3 Calculation based on o2 and co2 in the gases

O_2 and CO_2 values are measured by gas analyzers installed in the flow circuits.

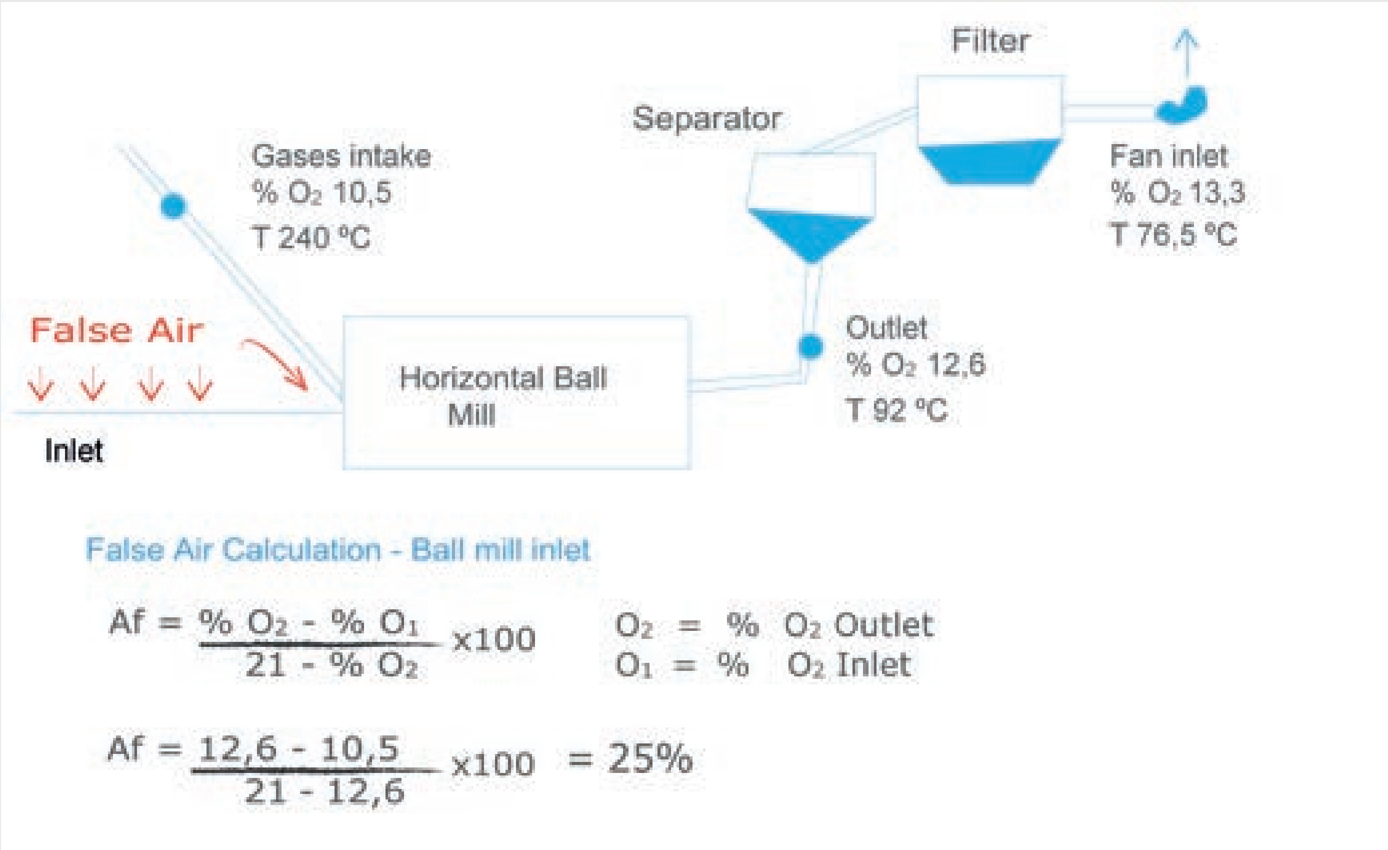
In a kiln, it is very important that combustion is complete. The amount of air must be sufficient for all the carbon to be transformed into CO_2.

A well-controlled excess of air in combustion allows normal operation, avoids fuel waste, and therefore, it helps to reduce the carbon footprint.

In the operation of cement kilns, the excess of air varies between 5% and 15%, which represents a percentage in the preheater exhaust gases of 1.5% to 3.5% O_2.

CO is produced when O2 is missing. To avoid an increase in fuel consumption, CO should be kept below 0.2% at the preheater outlet (0.1% depending on the fuel).

As an example, below is the false air calculation of a raw meal milling plant using drying hot process gases.



Calculation at the inlet fan:

$$Afv= \frac{13,3 - 10,5}{21 - 13,3} \times 100 = 36\%$$

False air calculation in Nm3/h:

$$Aq= Q_1 \frac{\% Af}{100}$$

Q1 = Volume of process gases at the mill inlet in Nm3/h (Q1 is known for each mill and is different in each case).

$$An= \frac{Aq}{Q_1 + Aq} \times 100$$

And the quantity of gases at the mill outlet:

$$Q_2 = Q_1 + An \text{ em } Nm^3/h$$

Knowing the quantity of gases at the mill inlet, the fuel and electrical energy costs calculation in the fan is carried out as in item 6,2.

In this ball mill, an improvement would be necessary by replacing the inlet seal with an external leaf seal, as well as to improve maintenance of the whole installation.

In a 2,500 mm diameter, 12,400 mm long FLS mill at an Argos Cement plant in Colombia, a SEAL PLUS external leaf seal was installed.

The results were very positive:

The mill production had an average improvement of 4%, with a 20% reduction in false air at the inlet and 7% reduction in fan energy consumption.

6.4 Gas flow calculation

This is a very direct method to evaluate the process gas volume and its variation over time.

The flow calculation is carried out through a Venturi system or with modern flow meters that give an accuracy of 2%, which is enough to check the evolution of false air in the process.

To obtain more accurate values and to calibrate the flow meters, the flow calculations should be carried out along with process calculations through one of the methods described above.

7. PREVENTING FALSE AIR INTAKE

7.1 Kiln seals

The solution to reduce false air intake in the kiln is to install a good quality seal between the mobile section and the fixed section on both ends. This will improve the issues mentioned above.

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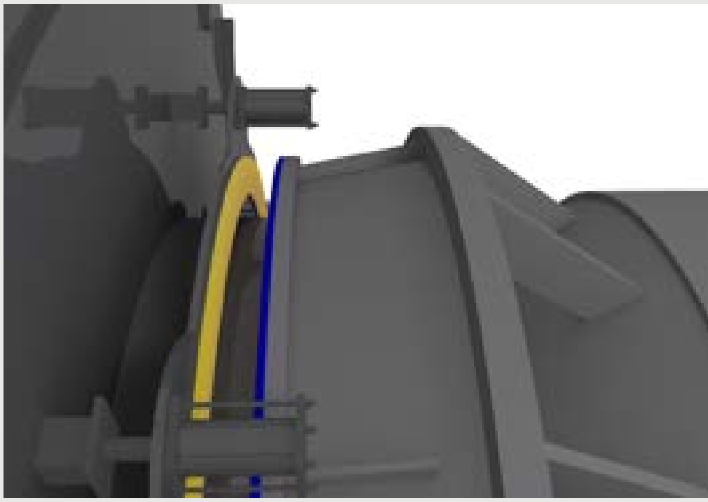
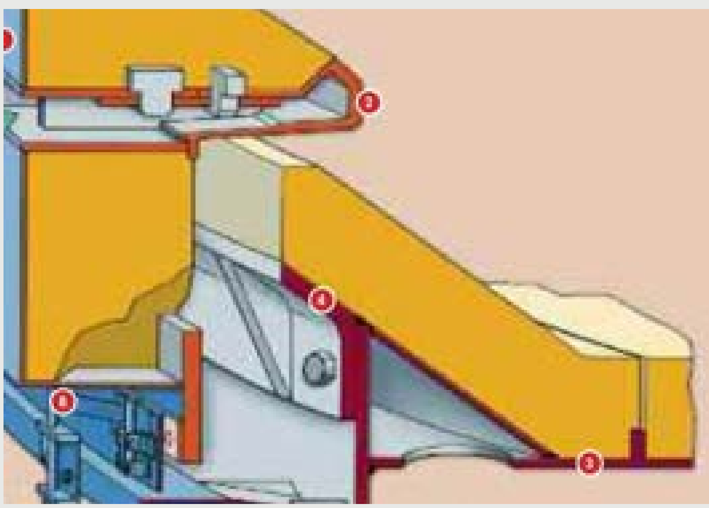
7.2 Kiln seal types

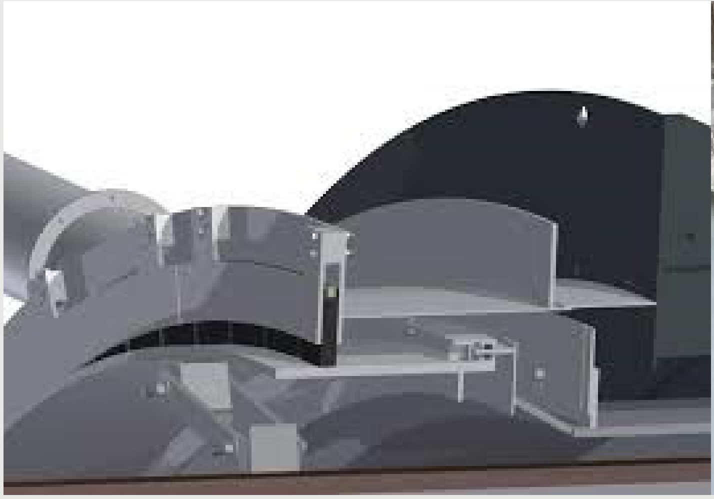
A. Axial pressure seals with pneumatic cylinders



B. Axial pressure seals with springs

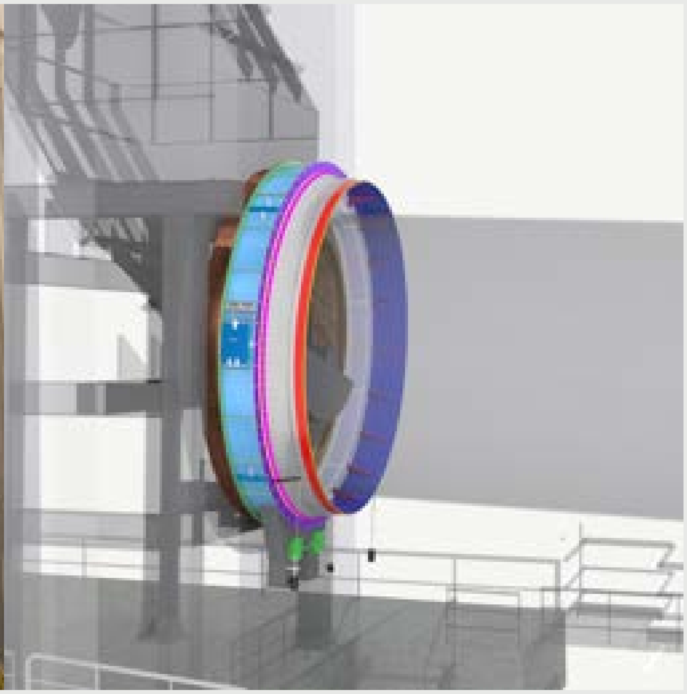


C. Graphite seals with counterweight pressure



D. Flexible leaf seals with counterweight pressure

D1. Inlet



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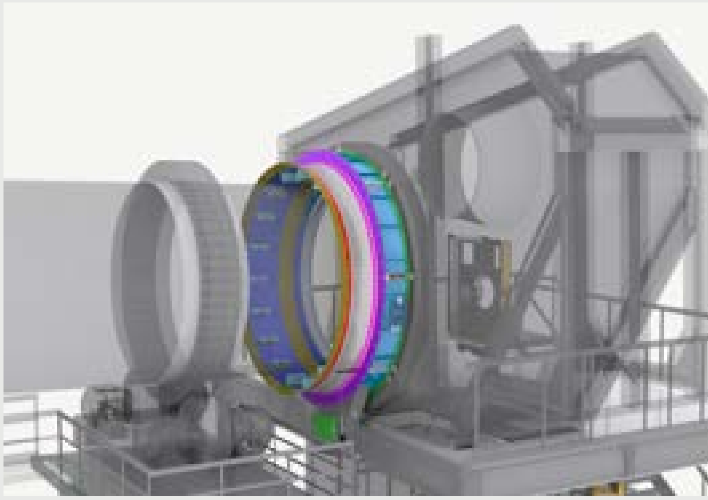
D2. Outlet



7.3 Seal types comparison

	Cylinder Seal	Springs Seal	Graphite Seal	Leaf Seal
Installation time	8	9	9	10
Maintenance	7	8	9	9
Availability	7	8	8	10
Seal parts wear	8	8	8	9
Axial and radial variations	7	7	8	10
Replacement for a different seal	7	8	9	10
TOTAL	44	48	51	58

The price of the seals was not compared because it depends on the manufacturing, installation, and import and taxes costs, which are different in each case.

Comparison explanation:

Installation time

A new leaf seal has an installation time of 12 days. In case of an improvement of an existing leaf seal, the time is less. Both graphite and cylinder seals have additional items, such as the cooling fan for the graphite seal and the compressed air system for the cylinder seal, that can cause difficulties during installation.

Maintenance

For the leaf seal, as the leaves are external, they are very easy to replace. The replacement is performed only with bolts. In the graphite seal it is a bit more challenging due to the cooling fan. With cylinder seals, the pneumatic system with valves and pipes is more complex. With spring seals, the pressing force gradually decreases until it is insufficient.

Availability

The best seal is the leaf seal, as it is self-adjusting with flexible leaves and counterweights that are always active without any other external elements. The graphite seal relies on a fan, meaning that its dependent on an engine that can stop working anytime, increasing the wear of the sealing elements. The cylinder seal relies on the operation of the compressed air and the spring seal relies on the wearing condition of the springs.

Seal parts wear

The cylinder seal shows increasing wear over time due to the difficulty of maintaining the block under the same constant pressure. The spring seal is similar. On the graphite, the sealing property can wear out faster when the fan air cooling is not working regularly. The leaves have a uniform controlled wear due to their design and counterweight.

Kiln axial and radial variations

In the case of cylinder or spring seals, as they are more rigid systems, the variations are poorly absorbed, causing deformation of the construction elements. With graphite seals, wear increases because the radial stress goes directly to the sealing element. In the case of leaf seals, both axial and radial stress are compensated by the flexibility of the leaf.

Replacement for a different type of seal

The leaf seal is the easiest to apply to replace different types of seals due to the easy installation and the flexibility of the system, sometimes even using existing parts of the previous seal. Other seals are more difficult to adapt because they have very specific designs.

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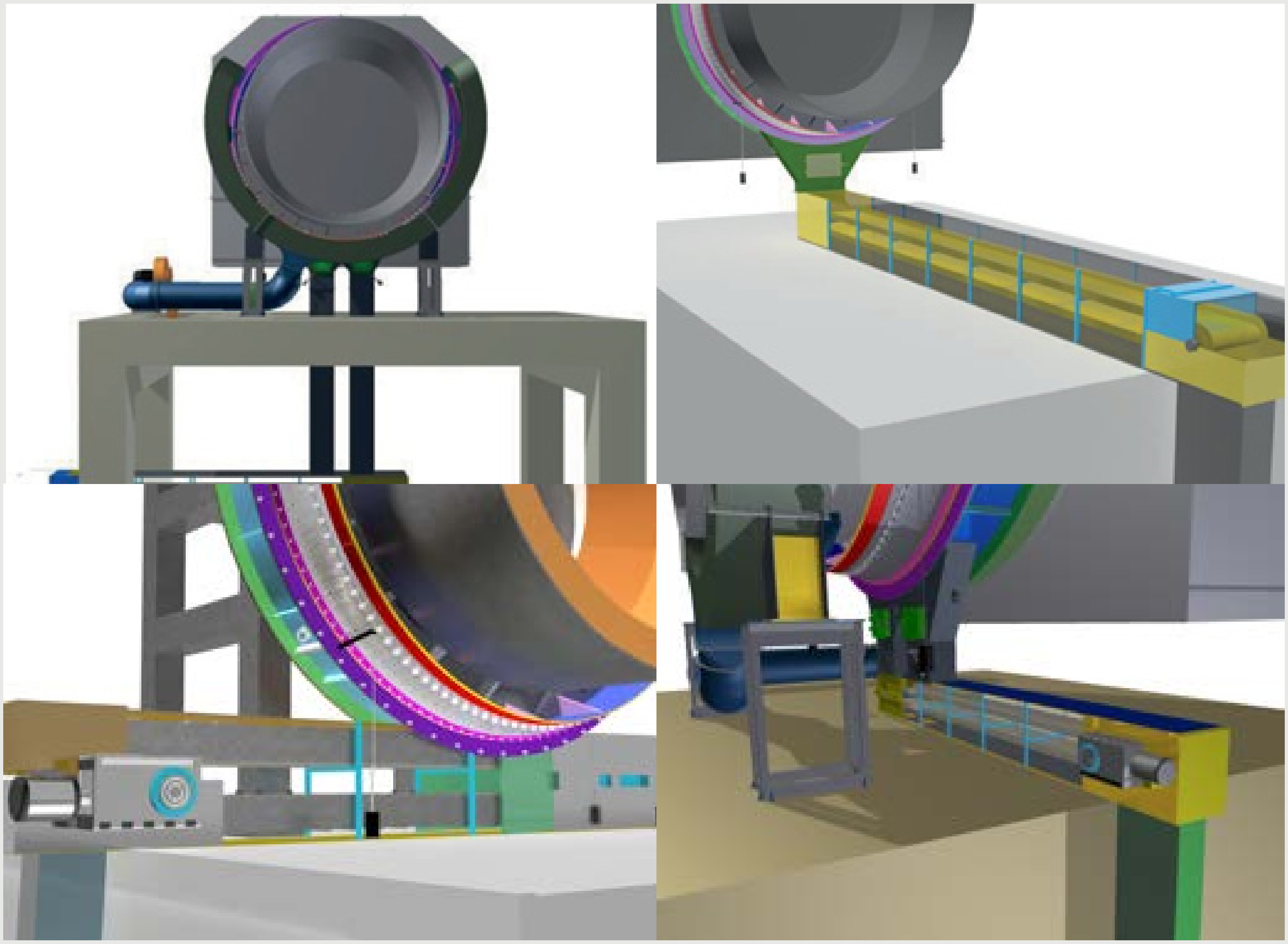
7.4 Material evacuation transport

Kiln seals are not airtight, given that one section is fixed and the other is mobile (rotating). As mentioned before, the sealing force is provided by counterweights, springs, or pneumatic cylinders. Under normal operating conditions, no material should come out of the seals, but when the rings of material break or there are avalanches, a momentary overpressure occurs at the seal and small amounts of fine material escape.

To prevent material from accumulating under the kiln, which is often dangerous due to the high temperatures, a small metal heat resistant conveyor must be installed to dispose the material into a hopper located on the side of the kiln



8. SEALING AT THE PRE-HEATER CYCLONES

The preheater cyclones and ducts have doors for monitoring and cleaning the equipment. Also, in the exhaust chamber (kiln inlet).

The doors must be monitored and adjusted to avoid false air intake, which, in addition to increasing energy costs, can increase the formation of blockages due to the material cooling that recirculates in the gas flow.

Loss of fine material at high temperatures through door openings has caused in the past, dangerous accidents for operation and maintenance personnel.

The raw material feeding should also be monitored.

9. SEALING AT THE PRE-CALCINER

There are several pre-calcination systems, always adapted to the process and the type of fuel.
Given the increasing use of fuels different from the classic oil, gas, and coal, which have other characteristics (such as viscosity, granulometry, etc.), the way of adding them into the process has to be the most appropriate.

In some cases, multiple gates are used, in others, partially or fully enclosed feeders.

All this equipment requires good maintenance, continuous monitoring and performing the necessary adjustments.

10. MAIN FAN

There are two causes that can decrease the main fan efficiency. First is the wear of the rotor blades after a long period of use and second is false air intake through the rotor shaft seal.

In both cases, the result is an increase in electrical energy consumption and sometimes a decrease in kiln output when there is no capacity reserve in the fan.

In the case of the rotor blades, it is possible to carry out an improvement, which is quite difficult, since with small modifications the characteristic curves of the fan can change significantly.

In the case of shaft sealing, a change of the sealing elements can solve the problem.

In both cases, since is a very relevant equipment in the operation, it is advisable to consult the manufacturer of the fan and, depending on its condition, replace it with a new one.

11. RAW MILL SEAL

As discussed in item 6.3, in a raw material ball mill that uses hot gases from the process or from an auxiliary burner, false air is a problem because it increases energy consumption, can reduce production, and may increase CO_2 emissions.

The leaf seal has been used successfully and the principle is the same as the kiln seal.

It can only be installed when there is enough space at the mill inlet. Therefore, it must be verified in detail for each case.

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THE FOLLOWING IMAGE DISPLAYS A SEAL INSTALLATION IN A RAW MILL

12. OPERATION AFTER FALSE AIR REDUCTION

After a reduction of false air, the gases flow will be lower in both the kiln and the raw mill and two opportunities for the process arise:

- Maintain production, reduce energy costs, and help reduce the carbon footprint.
- Increase production, reduce energy costs, and help reduce the carbon footprint.

To increase production, it is necessary to review the set of equipment involved, such as feeding, transport, etc.

In the kiln it will be necessary to adapt the operating parameters to the new conditions; O2, CO, temperatures and pressures in the preheater and the outlet and verify the quality of the clinker produced. Especially when performing a full upgrade (2 seals, cyclones, etc.).

In the case of the raw mill, it is also necessary to adapt to the new conditions, being much simpler than in the case of the kiln.