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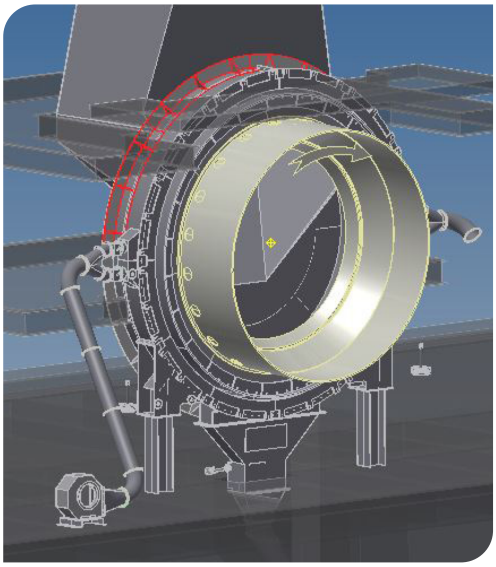
SEALS FOR CEMENT KILNS

With so much attention paid to more striking decarbonisation solutions like CO_2 capture, solar-powered clinker production and calcined clay, it is easy to miss the key role that will be played by seemingly unassuming parts of the plant, including the vital role of effective kiln seals.

Each rotary kiln needs two kiln seals, one at the inlet and one at the outlet, to keep the kiln under slight negative pressure, controlling both the process and emissions. Kiln seals are certainly not particularly 'glamorous' compared to other projects, but are nevertheless crucial.

Why? Good kiln seals greatly reduce - or even eliminate - the entry of false air into the system. This lowers the mass of flue gas, which, in turn, reduces the electrical power consumption of the plant, especially for the induced draft (ID) fan. The amount of fuel needed is also reduced. Although similar, there are differences between the kiln inlet and outlet seals. In contrast to an inlet seal, on an outlet seal, the turning ring is attached to the cowl shell as well as the kiln shell, with some specific tie rods so as to leave room for the nose ring cooling air. On an outlet seal, there is an additional positive pressure protection system, i.e.: a small fan, to create a counter pressure into the seal casing whenever necessary.



3D render of ITECA leakless graphite-based kiln seal.

If hot meal or clinker can be seen, the seal is not performing effectively.

Types of kiln seals

Traditional kiln seal technologies include ones with overlapping leaves. Spring steel is used to keep a constant connection with the kiln shell. However, the steel gradually deforms due to high operating temperatures, kiln movements and/or process instability, allowing false air to enter. Frequent repairs must be undertaken to avoid large gaps. Variations include seals with two layers of leaves and those with inverted leaves, with or without tensioning cables.

Hydraulic or pneumatic pressure type seals push plates together in line with the axis of the kiln. The contact surfaces can be metal-to-metal or, sometimes, wear plates against metal surfaces. It can be difficult to keep continuous contact between the large, rotating, circular surface and the stationary one. There is also the risk of the hydraulic/pneumatic pistons wearing out due to high temperatures. Again, gaps can occur and frequent maintenance is required to prevent excessive false air.

Some kiln seals, including those made from graphite by ITECA, are entirely leakless. The history of this design dates back to the origin of the company, originally a spin-off from the Lafarge Research & Development and Mechanical Division in 1985. Graphite blocks are positioned inside a channel and distributed around the circumference of the kiln between the rotating sliding ring, which is attached to the kiln, and the fixed seal casing. This provides an effective seal against rotational and axial movement. The graphite plates are able to move perpendicularly to the kiln axis in order to absorb any kiln rotation defects. The width of the sliding track allows the axial movement of the kiln.

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Table 1 - Example calculation for kiln inlet seal

Savings on Fuel	Value
Kiln diameter (mm)	4800
Fume box pressure (mm WG)	-25.4
Mean existing seal gap (mm)	6.0
Fume box gas temperature (°C)	1100
Clinker production rate (t/day)	3300
Ambient temperature (°C)	30
Production (days/yr)	320
Cost of fuel (US$/t)	70
Calorific value of fuel (kCal/kg)	6000
Results	
Calorific cost (US$/1000 kCal)	0.011667
Air speed (m/s)	12.76
Air volume (m^3/s)	1.22
Fuel savings (kCal/s)	384.26
Fuel cost savings (US$/yr)	**123,947**
Fuel savings (kCal/kg clinker)	10.06
Air needed for combustion (Nm^3/1000kCal)	1.1
Excess air (%)	10
Kiln efficiency (kCal/kg clinker)	800
Combustion air (Nm^3/kg clinker)	0.968
Production (kg clinker/s)	38
Combustion air (Nm^3/s)	36.97
False air leakage (%)	3.30
Savings on Power Supply	
Existing ID fan (kW)	4000
Power of seal cooling fan (kW)	3
Cost (US$/kWh)	0.06
Results	
Hourly savings (kWh)	381
Power savings (US$/yr)	**175,337**
TOTAL ENERGY SAVINGS (US$/yr)	**299,284**

Energy savings

Unlike many projects that aim to save money and energy in cement plants, it is easy to calculate and verify the gain that results from replacing a gappy seal with a leakless one. Savings from ID fans and reduced fuel demand are the main benefits. However, due to the interrelation of the elements of the cement manufacturing process, other fans in the system may also be favourably impacted.

To calculate the savings, the amount of false air must be calculated. This can be done either by the stoichiometric approach, which uses oxygen concentration measurements, or the Bernoulli equation-based calculations, which makes use of the fact that the velocity of a fluid being forced through a constriction is proportional to the square root of the pressure drop of that fluid.

Table 1 shows an example calculation to estimate the expected savings of installing a leakless graphite-based kiln seal from ITECA. The example shows typical values, with payback generally well below two years.

Other benefits

Leakless kiln seals also bring benefits beyond those related to reduced false air. The most obvious is a reduction in the need for repairs and maintenance. The wear parts *are* the graphite blocks, which, once they have adopted the shape of the steel riding ring, experience very little wear. Indeed, the average life of the graphite blocks is four to seven years. The only scheduled work is the annual replacement of the pair of steel cables that keep the blocks in place.

On top of this, the avoidance of false air may modify some of the thermodynamics, reaction kinetics and chemical-equilibria within the kiln, which can lead to positive changes to the average crystal sizes and other properties of the clinker. Also, if a plant were to add a CO_2 capture system at a later date, effective kiln seals will minimise the load on that system, while maximising the CO_2 concentration in the gas stream.

Case studies

ITECA's graphite-based leakless seals have been installed extensively in cement plants around the world. These include at the La Salle, Illinois, plant operated by Illinois Cement, part of Eagle Materials. The project was initiated in April 2022 and overseen by Illinios Cement's Michael Swingel. The installation of such a kiln seal was realised during a main shutdown, with careful scheduling and coordination to ensure that the work took place in parallel with kiln rebricking.

"The successful installation of the ITECA inlet seal on our kiln has yielded impressive results and reinforced our dedication to efficiency and sustainability," commented Swingel. "The advanced features of this seal have significantly minimised false air, resulting in reduced ID fan power consumption, fuel savings and less build-up in the riser duct. The exceptional support we received from ITECA and our installation contractor, Kiln Technology, resulted in a flawless upgrade for our plant."

Mike Schweinert, Project Manager at Kiln Technology, the Wisconsin-based kiln maintenance contractor that carried out the installation, was already familiar with ITECA's graphite seals from previous projects. He said, "Over the years we have installed many different seal types. Regardless of seal type, we have found that the most difficult portion of the installation is mating up to the existing feed end structure, which is often distorted due to the poor performance of past seals, overheating and/or thin refractory and other types of wear. ITECA provides several pre-cut plates to help overcome this. They are sized to make material handling easier and are easy to modify to assist with fitting."

The 4.2m-diameter ITECA leakless graphite kiln inlet seal installed at the Illinois Cement – Eagle Materials Group plant.

"Due to the forward-thinking design of these seals, there are additional features that aid installation," continues Schweinert. "The wrapper plates have an innovative V-block joint that helps self-align the joints. The run-out ring has ample room for alignment hardware, which makes final ring and wrapper alignment much more efficient."

"The graphite blocks are also well thought-out. Prior to running the cable, there are set screws that hold the blocks in. All the blocks can be installed, before the tensioner cable is aligned and tensioned, without fear of the blocks shifting. This also means that if something were to happen to the cable, the blocks don't fall out."

In 2016, the Tehachapi plant in California, then owned by Lehigh Southwest, saved US$290,000/yr by installing ITECA graphite-based leakless kiln seals, in part due to the financial incentives offered by its utility supplier SoCalEdison. This was calculated based on peak power savings of >390kW, electricity savings of 3,200,000kWh per year and a blended rate for electricity of US$0.09/kWh. The payback time was far less than one year.

Another satisfied plant is Mitsubishi Cement in Lucerne Valley, California. With prices of electricity being among the highest in the US, return on investment periods tend to be shorter than average. In 2014 the plant decided to replace its existing inlet seal with one from ITECA. Pleased with the result, the plant ordered an outlet seal in 2018. Unfortunately, a substantial delay due to Covid-19 meant that this could only be installed in 2022.

Steve Tyrrell, Maintenance Director at the plant, said "The result of changing the inlet and outlet seals contributed to a substantial reduction in false air into the process. The most significant reduction occurred with the inlet seal. The maintenance has also been significantly reduced as the graphite blocks wear was less than expected. The annual cable change is really the only activity that is required. The graphite elements are expected to be replaced in five to seven years."

Conclusions

Leakless graphite inlet and outlet seals provide major benefits to cement plants in terms of reduced electrical power use and lower operating costs, with quick payback times. Reaching carbon neutrality by 2050 requires that cement plants undertake projects that reduce their specific energy consumption. Small projects with good payback, such as leakless graphite seals, have a lot to contribute.